# COLORADO DROUGHT MITIGATION AND RESPONSE PLAN

**August 2013**

Prepared Pursuant to
Disaster Mitigation Act 2000 & Section 409, PL 93-288

Prepared by
Colorado Water Conservation Board
Department of Natural Resources

In Cooperation with
The Department of Public Safety
Division of Homeland Security and Emergency Management
and the Drought Mitigation and Response Planning Committee

# The Colorado Drought Mitigation and Response Plan

## August 2013

## Drought Annex to the State All Hazards Mitigation Plan
## ANNEX VII to the State Emergency Operations Plan

Colorado Department of Natural Resources
Colorado Water Conservation Board

Updated in 2013 by the CWCB and AMEC Environment and Infrastructure in coordination with the Drought Mitigation and Response Planning Committee and the National Drought Mitigation Center

Drought Mitigation and Response Plan Comprehensive Revision by the CWCB and AMEC Environment and Infrastructure in 2010

Mitigation Plan Elements Revised by the CWCB and Leonard Rice Engineers in 2007

Revised by J. Brislawn, M. Gally, L. Boulas, J. Truby, T. Grier, P. White, and M. Koleis in 2001.

Revised by J Truby, L. Boulas, and R. Kistner in 1986 and 1990.

Original document developed by J. Truby, L. Boulas 1981
Colorado Department of Local Affairs
Division of Local Government
Office of Emergency Management

# Table of Contents


1 PREREQUISITE ..... 1

1.1 Adoption by the State ..... 1

1.1.1 Formal Adoption by the State ..... 1

1.1.2 Assurance of Continued Compliance with Federal Requirements ..... 1

2 PLANNING PROCESS ..... 2

2.1 Documentation of the Planning Process ..... 2

2.1.1 Description of Plan Preparation Process ..... 2

2.1.2 Involvement in Planning Process ..... 7

2.1.3 Agency Involvement in Plan Preparation Process ..... 9

2.1.4 Description of Plan Review and Analysis ..... 9

2.1.5 Indication of Section Revisions ..... 10

2.2 Coordination among Agencies ..... 11

2.2.1 Involvement of Federal and State Agencies ..... 11

2.2.2 Involvement of Interested Groups ..... 11

2.2.3 Changes in Coordination ..... 15

2.3 Program Integration ..... 16

2.3.1 Integration of Mitigation Planning with other State Planning Efforts ..... 16

2.3.2 Integration of Mitigation Planning with FEMA Mitigation Programs and Initiatives ..... 17

3 RISK ASSESSMENT ..... 18

3.1 Identifying the Drought Hazard ..... 18

3.2 Drought Hazard Profile ..... 20

3.2.1 Location of Drought Hazards in Colorado ..... 22

3.2.2 Monitoring Drought in Colorado ..... 24

3.2.3 Drought Indicators Modernization ..... 32

3.2.4 Drought History in Colorado ..... 33

3.2.5 Other Drought Implications in Colorado ..... 51

3.3 Assessing Vulnerability by Jurisdiction ..... 53

3.3.1 Vulnerability Based on Local and State Risk Assessment ..... 55

3.3.2 Jurisdictions Most Threatened and Most Vulnerable to Damage or Loss ...... 57
3.3.3 Process Used to Analyze Information from Local Mitigation Plans ............. 64
3.3.4 Changes in Development Patterns ................................................................ 66
3.4 Assessing Vulnerability of State Facilities ............................................................... 71
3.4.1 Types of State Owned/Operated Facilities .................................................... 71
3.5 Estimating Potential Losses by Jurisdiction .............................................................. 72
3.5.1 Overview and Analysis of Potential Losses................................................... 72
3.5.2 Potential Losses Based on Estimates in Local and State Risk Assessments .. 83
3.5.3 Impacts on Losses from Changes in Development........................................ 90
3.5.4 Estimating Potential Losses of State Facilities .............................................. 90
4 MITIGATION STRATEGY.............................................................................................. 96
4.1 Hazard Mitigation Goals............................................................................................ 96
4.1.1 Description of State Mitigation Goals ........................................................... 96
4.1.2 Reassessment of Goals for Validity or Need for Revision ............................. 96
4.2 State Drought Mitigation Capability Assessment...................................................... 98
4.2.1 Introduction.................................................................................................... 98
4.2.2 Pre-disaster Hazard Management Policies, Programs, Capabilities ............... 98
4.2.3 Post-disaster Hazard Management Policies, Programs, Capabilities............. 99
4.2.4 State Policies Related to Development in Drought Prone Areas.................. 102
4.2.5 State Funding Capabilities for Drought Hazard Mitigation Projects............ 102
4.2.6 Changes in Hazard Management Capabilities of the State ........................... 103
4.3 Local Capability Assessment.................................................................................... 104
4.3.1 Local Mitigation Policies, Programs, and Capabilities................................. 105
4.3.2 Effectiveness of Local Mitigation Policies, Programs, and Capabilities...... 107
4.4 Mitigation Actions .................................................................................................... 111
4.4.1 Identification of Actions under State Consideration.................................... 111
4.4.2 Progress in Statewide Mitigation Efforts..................................................... 127
4.4.3 Evaluation and Selection of Actions and Activities ..................................... 131
4.4.4 Prioritization of Actions and Activities ....................................................... 132
4.4.5 Contribution of Each Activity to Overall State Drought Mitigation Strategy ........................................................................................................ 134

4.4.6 Integration of Local Plans into Mitigation Strategy .................................... 134
4.5 Funding Sources.................................................................................... 137
4.5.1 Identification of Existing Federal, State, Local Funding Sources ................ 137
4.5.2 Identification of Potential Federal, State, Local Funding Sources ............... 145
4.5.3 Sources of Funding Used to Implement Previous Mitigation Activities ...... 146
5 COORDINATION OF LOCAL MITIGATION PLANNING .......................................... 149
5.1 Local Funding and Technical Assistance ............................................................... 149
5.1.1 Description of State Process to Support Local Plan Development............... 149
5.2 Local Plan Integration.................................................................................... 153
5.2.1 Process and Timeframe to Review Local Plans........................................... 153
5.2.2 Process and Timeframe to Coordinate and Link Local Plans to State Mitigation Plan...................................................................................... 154
5.3 Prioritizing Local Assistance ...................................................................... 154
5.3.1 Description of Criteria for Prioritizing Planning and Project Grants ........... 154
5.3.2 Cost-Benefit Review of Non-Planning Grants ............................................ 155
5.3.3 Criteria Regarding Areas of High Risk and Intense Development Pressures ...................................................................................... 155
6 PLAN MAINTENANCE PROCESS ...................................................................... 156
6.1 Monitoring, Evaluating and Updating the Plan ....................................................... 156
6.1.1 Method and Schedule for Monitoring Plan.................................................. 156
6.1.2 Method and Schedule for Evaluating Plan.................................................. 157
6.1.3 Method and Schedule for Updating Plan ..................................................... 158
6.1.4 Evaluation of Methods, Schedule, Elements, and Processes Identified in Previous Plan ...................................................................................... 158
6.2 Monitoring Progress of Mitigation Activities.......................................................... 159
6.2.1 Monitoring Mitigation Measures and Project Closeouts .............................. 159
6.2.2 Reviewing Progress on Achieving Goals in Mitigation Strategy ................. 159
6.2.3 Changes in System for Tracking Mitigation Activities ............................... 159
6.2.4 System for Reviewing Progress on Implementing Activities and Projects of Mitigation Strategy...................................................................... 160
6.2.5 Implementation of Previously Planned Mitigation Actions.......................... 160

## Annexes

***Annex A – Drought Response Plan***

***Annex B – Drought Vulnerability Assessment Technical Information***

***Annex C – Climate Change Implications***

***Annex D – Drought Monitoring Indices***

## Appendices

***Appendix A – Drought Mitigation and Response Planning Committee***

***Appendix B – Actions Taken to Reduce Drought Impacts in Previous Droughts***

***Appendix C – Drought Mitigation Capabilities Summary***

***Appendix D – References***

***Appendix E – Definitions and Acronyms***

# Executive Summary

The Colorado Drought Mitigation and Response Plan (Plan) was developed to provide an effective and systematic means for the State of Colorado to reduce the impacts of water shortages over the short and long term. The Plan outlines a mechanism for coordinated drought monitoring, impact assessment, response to emergency drought problems, and mitigation of long term drought impacts. There are three major components of the plan: mitigation, response and vulnerability assessment. The mitigation component of the Plan conforms to the Enhanced State Hazard Mitigation planning requirements of the Disaster Mitigation Act of 2000 and serves as the Base Plan. Included is a description of the process used to prepare the Plan and a profile of the drought hazard in Colorado, including the nature of impacts and probability of occurrence. A detailed vulnerability assessment discusses the past and potential impacts to Colorado's economy, environment, state assets, and water providers. The vulnerability assessment is covered in detail in Annex B, and summarized in Sections 3.4 and 3.5 of the Plan. The mitigation strategy outlines the goals of the Plan and specific action items intended to meet those goals. Many of these mitigation actions are ongoing and can occur during drought and non-drought times. A capability assessment describes the State's plans, policies, and procedures in place that already help manage and reduce drought impacts. The Plan describes funding sources that can be used to implement local mitigation projects and plans and a description of the process for implementation, monitoring and evaluating the Plan.

The response component of the Plan is detailed in Annex A and includes monitoring, assessment, and response. This Annex guides State and partner agency response actions during times of drought. Monitoring is ongoing and accomplished by regular meetings of the Water Availability Task Force (WATF). This task force is comprised of Colorado's water supply specialists from state, local, and federal governments, as well as experts in climatology and weather forecasting. This task force monitors snowpack, precipitation, reservoir storage, and streamflow and provides a forum for synthesizing and interpreting water availability information. When the WATF determines that drought conditions are reaching significant levels the Governor is notified and activation of the Plan is recommended.

When Annex A is activated, assessment begins with activation of the relevant Impact Task Forces (ITFs). These task forces convene on an as needed basis to determine existing or potential impacts within specific sectors. Impact Task Forces include Municipal Water, Agricultural Industry, Wildlife, and Energy. Assessment coordination is handled by the Drought Task Force. This task force is comprised of directors from the Departments of Natural Resources, Agriculture, Public Safety and Local Affairs, and chairpersons of the WATF and the Impact Task Forces. They review reports from the WATF and ITFs, aggregate impact assessments and projections, evaluate overall conditions, develop recommendations for drought response, and make timely reports to leadership, the media, the response agencies, and others. The response process consists of coordinated drought response activities amongst the lead state agencies under leadership of the Governor and recommendations of the ITFs.

# 1 PREREQUISITE

## 1.1 Adoption by the State

### 1.1.1 Formal Adoption by the State

Adoption by the Office of the Governor empowers the Colorado Water Conservation Board (CWCB) and the Colorado Division of Homeland Security and Emergency Management Office of Emergency Management (OEM) to execute their responsibilities with respect to disaster preparedness, response, recovery, and mitigation. The Drought Mitigation and Response Plan (hereto referred to as the Plan or Drought Plan; the mitigation component only is referred to as the Base Plan) was reviewed and formally approved by the board of the CWCB in September 2013. As an annex to the State of Colorado Natural Hazards Mitigation Plan (NHMP), this Plan is on a three year update cycle and will be re-adopted by the Governor each cycle.

### 1.1.2 Assurance of Continued Compliance with Federal Requirements

This Plan was prepared pursuant to the requirements of the Disaster Mitigation Act of 2000 (DMA or DMA 2000) (Public Law 106-390) and the implementing regulations set forth by the Interim Final Rule published in the Federal Register on February 26, 2002 (44 CFR §201.6) and finalized on October 31, 2007. (Hereafter, these requirements and regulations will be referred to collectively as the Disaster Mitigation Act.) While the act emphasized the need for mitigation plans and more coordinated mitigation planning and implementation efforts, the regulations established the requirements that local hazard mitigation plans must meet in order for a state jurisdiction to be eligible for certain federal disaster assistance and hazard mitigation funding under the Robert T. Stafford Disaster Relief and Emergency Act (Public Law 93-288).

The State of Colorado assures it will comply with all applicable federal statutes and regulations in effect with respect to the periods for which it receives grant funding in compliance with 44 CFR Part 13.11(c). The State will amend the NHMP whenever necessary to reflect changes in state or federal laws and statutes, as required in 44 CFR Part 13.11(d). The adoption of this NHMP demonstrates the State of Colorado's commitment to fulfilling the mitigation objectives in the NHMP and authorizes the agencies identified in the NHMP to execute their responsibilities. In addition, the Drought Mitigation Plan complies with and adheres to the Emergency Management Accreditation Program, or EMAP, standard. The EMAP is a voluntary review process for state and local emergency management programs. Accreditation is a means of demonstrating, through self-assessment, documentation and peer review, that a program meets national standards for emergency management programs. The Drought Response Plan Annex (Annex A) has been designed to comply with the National Response Framework (NRF) and National Incident Management System (NIMS) protocols.

# 2 PLANNING PROCESS

## 2.1 Documentation of the Planning Process

### 2.1.1 Description of Plan Preparation Process

The process established for this planning effort is based on the Disaster Mitigation Act of 2000 planning and update requirements and the Federal Emergency Management Agency's (FEMA) associated guidance for state hazard mitigation plans. The Drought Mitigation and Response Planning Committee (DMRPC) followed FEMA's recommended four-step mitigation planning process:

- Identify and organize available resources
- Identify hazards and assess risk
- Develop a mitigation strategy and mitigation plan
- Implement the Plan and monitor progress

The Colorado statewide mitigation planning program is designed to coordinate the efforts of many state agencies and organizations in mitigation planning and programming on an ongoing basis. It is also intended to actively promote and coordinate mitigation planning and programming by local jurisdictions. The OEM took the lead on the 2013 update of the State of Colorado 2013 NHMP umbrella document. The original umbrella document was created in 2001, was updated in 2007, 2010, and 2013 and was designed as a way to tie together various hazard-specific documents that had been developed over the previous years.

The OEM coordinated with other agencies on concurrent state planning and risk management efforts, including the extremely important natural hazard specific annexes to the state plan. The Department of Natural Resources (DNR), CWCB, Office of Water Conservation and Drought Planning took the lead on the 2007, 2010, and 2013 updates to the Drought Plan. A consulting firm (AMEC Environment and Infrastructure) was selected to coordinate and facilitate the 2010 update to the Plan as well as develop a detailed vulnerability assessment. Since the 2010 update was a comprehensive revision it will be referred to as such in the remainder of the Plan. AMEC also worked with the CWCB during the 2013 update process.

### Evolution of the Colorado Drought Mitigation and Response Plan

Drought planning has been evolving in Colorado since the late 1970s. During the 1976-1977 drought Colorado's government assumed a lead role in coordinating federal, state, and local government response and promoted statewide public conservation practices. Conclusions from that effort include:

- the diversity, complexity, and ambiguity of drought impacts blurred identification of alternative actions available to decision makers;

- a systematic definition of problem areas and potential solutions was essential to effective government response, so under and overreactions could be minimized;
- both physical and social impact data were needed;
- knowledge of the location, kind, and degree of water shortage provides better identification of impacts;
- timely and accurate data on impact development were crucial to effective response;
- impact identification provides the framework for governmental and public adjustments;
- integration of response by private, public, and governmental entities was needed;
- as the drought intensifies, the maintenance of established channels of responsibility, with emphasis on water conservation and planning, becomes increasingly important;
- as impact problems and local needs become more serious, better management and integration of effort also intensifies; and
- should drought intensify to the point where impacts exceed the State's response capabilities, an effective state program will help facilitate a request for federal assistance.

Governor Lamm took action in February 1981 to deal with potential drought situations. His memorandum of February 5 required the accomplishment of the following tasks:

1. Develop and activate a data collection and assessment system which will identify the potential impacts of a drought and track their occurrence and intensity. At some point, this assessment process may result in a recommendation that a drought emergency be proclaimed.
2. Develop a drought emergency response plan which would be activated by a drought emergency decision. This task includes cataloguing existing state and federal response and relief programs and authorities, and developing recommendations to meet additional needs.

The initial Colorado Drought Response Plan was completed in 1981, and revised in 1986, 1990, 2001, and 2002. In 1981, it was one of three state drought plans in the nation. Since that time, the Plan has been widely distributed and received interest both nationally and internationally and has served as a model for other states. Mitigation was first introduced into the Plan's 2001 update and since that time the Plan has been both a mitigation and response plan. Mitigation includes actions that could be taken pre-drought that would lessen impacts when a drought occurs. It also includes "incident" mitigation, which are short-term actions taken during a drought meant to reduce disasters losses or impacts. The mitigation component was further expanded in 2007 with the development of a companion document "Updated Information Provided in Support of the 2002 Colorado Drought Mitigation and Response Plan." This was developed to align the Plan's mitigation element with the standard state mitigation planning requirements of the DMA 2000, thus making it consistent with the NHMP and placing it on the same update cycle as that plan (required every three years).

The Colorado Drought Mitigation and Response Plan was developed to provide an effective and systematic means for the State of Colorado to reduce the impacts of water shortages over the short or long term. The Plan outlines a mechanism for coordinated drought monitoring, impact assessment, response to emergency drought problems, and mitigation of long-term drought impacts. The Plan does not create a new government entity to deal with drought, but provides a means for coordinating the efforts of public and private entities that would be called upon to deal with drought impacts.

There are four components of the Plan: monitoring, assessment, response, and mitigation. monitoring is ongoing and accomplished by regular meetings of the Water Availability Task Force (WATF). This task force is comprised of Colorado's water supply specialists from state, local, and federal governments, as well as experts in climatology and weather forecasting. This task force monitors snowpack, precipitation, reservoir storage, and streamflow and provides a forum for synthesizing and interpreting water availability information. When the WATF determines that drought conditions are reaching significant levels the Governor is notified and activation of the Plan is recommended. When the Plan is activated, the first step is impact assessment. Assessment begins with activation of the relevant Impact Task Forces (ITFs). These task forces convene to determine impacts within specific sectors which effect the environment and economy. The original Impact Task Forces included Municipal Water, Wildfire Protection, Agricultural Industry, Tourism, Wildlife, Economic Impacts, Energy Loss, and Health. These task forces have been activated as needed during times of drought, notably in 1989-1990, 1994, 1996, and 2002. The number and nature of the ITFs have changed over the years; the 2013 ITFs are listed and described in Annex A.

## 2010 Revision Planning Process

In 2010 the Plan underwent a significant revision and overhaul as part of the three year State Plan update cycle. The major objectives of this revision included:

- Updating the Plan to meet DMA 2000 and EMAP planning standards
- Merging the 2002 Response and Mitigation Plan with the 2007 companion document
- Developing a comprehensive drought hazard vulnerability assessment
- Revising and modernizing the response elements of the Plan
- Developing additional tools and resources to support local drought planning efforts
- Modernizing and evaluating the indices used for drought monitoring in the State

The results of this effort are captured in this Plan. A significant change in the 2010 document is that the response elements can be accessed in one location Annex A Drought Response Plan. This was done so that these elements could be referenced individually when a drought occurs. The Plan outline mirrors that of the FEMA standard mitigation plan update review crosswalk, as well as that of the Colorado Flood Hazard Mitigation Plan for consistency with DMA 2000 planning requirements. The remainder of this section details the planning process used to develop this Plan, with an emphasis on the 2010 revision process.

### *Drought Mitigation and Response Planning Committee*

The development, implementation, and maintenance of the Drought Plan are the responsibility of the DMRPC under the leadership of the CWCB. The DMRPC is made up of representatives of the principal state agencies and organizations with authorities, responsibilities, or expertise related to hazard mitigation programs. The committee was formed during the 2010 revision process based on membership of the existing WATF and ITF's. Specific membership is discussed in Section 2.1.2 and Appendix A Drought Mitigation and Response Planning Committee. The committee participated in three major planning meetings between December 2009 and April 2010, which are summarized in Table 1.

**Table 1 Key Planning Meetings of the 2010 Revision Process**

| Meeting | Date | Purpose |
|---|---|---|
| 1. Project Kickoff | 12/16/2009 | Review Disaster Mitigation Act planning requirements, scope of work, and schedule<br>Review role of DMRPC<br>Discuss data collection needs<br>Discuss stakeholder involvement |
| 2. Response Plan Revision & Capability Assessment | 02/26/2010 | Review and discuss improvements to response Plan elements<br>Discuss ITF model refinement<br>Introduce methodology for updating goals and objectives<br>Introduce methodology to record progress of mitigation actions from 2007 |
| 3. Risk Assessment and Mitigation Strategy | 04/30/2010 | Present and discuss updated risk assessment<br>Revisit and revise goals<br>Review and approve state mitigation criteria for evaluation and prioritization<br>Develop priority mitigation actions<br>Review and revise Plan maintenance and implementation strategy<br>Further discussion on Impact Task Force model refinement |

Sign in sheets and summaries of these meetings are included in a Planning Process Reference Notebook on file with the CWCB.

In addition to these meetings a core group of individuals including the CWCB, AMEC, National Drought Mitigation Center (NDMC), Natural Resource Conservation Service (NRCS), and Colorado Climate Center staff participated in monthly coordination meetings from January through May. The National Drought Mitigation Center staff provided a national and independent perspective into the planning process. Some of these meetings were also attended by staff from the University Corporation for Atmospheric Research (UCAR), who provided assistance with the vulnerability assessment revision.

Several other meetings took place to foster coordination and raise awareness of the planning effort. Significant events are noted here:

- May 7th – Meeting with CWCB, AMEC, and the Division of Water Resources (DWR)-State Engineer's Office (SEO) staff for input on mitigation strategy and capability assessment

- May 13 – Presentation on the drought vulnerability assessment at the meeting of the State Hazard Mitigation Team.
- May 20 – Internal CWCB coordination meeting with CWCB and AMEC to discuss methods of vulnerability assessment and how the Colorado River Water Availability Study results would be used to introduce climate change aspects in the Plan.
- May 21 – Presentation at the WATF on Plan revision status, including the path forward regarding the refinement of the Impact Task Force model.
- May 24 – Meeting to discuss the results of the drought triggers and indicators study and how to integrate it into the Drought Plan's response mechanism.

Additional meetings related to public and stakeholder outreach are discussed in Section 2.2.2. In addition to these meetings the process included individual phone conversations and emails between AMEC and CWCB staff with various entities and agencies on the DMRPC. AMEC staff also had phone or face to face meetings to interview DMRPC members for input on the vulnerability assessment.

### 2013 Update Planning Process

In 2013 the Plan was updated as part of the three year State Plan update cycle. The objectives of the update included:

- Reconvening and updating the DMRPC to provide input to the 2013 planning process
- Meeting DMA 2000 Enhanced State Plan update requirements and EMAP planning standards
- Review, revisit, and update all sections of the Plan, highlighting changes since 2010, notably progress in mitigation actions in Chapter 4.
- Update the Vulnerability Assessment in Annex B with recently available information
- Update the hazard profile to capture the 2013 assessment of Colorado's unique climatology, including a discussion of the 2011-2013 drought
- Update the Response Plan in Annex A to reflect current procedures and lessons learned from response to the 2011-2013 drought.
- Update changes in coordination and plan maintenance procedures.

The DMRPC followed the FEMA four phase planning process for the update. Similar to the 2010 revision process, the committee participated in three major planning meetings between February and June 2013, which are summarized in. Table 2

### Table 2 Key Planning Meetings of the 2013 Update Process

| Meeting | Date | Purpose |
|---|---|---|
| 1. Kickoff | 2/22/2013 | Review Disaster Mitigation Act planning requirements, scope of work, and schedule<br>Review role of DMRPC<br>Introduce methodology to record progress of mitigation actions from 2010<br>Discuss data collection needs<br>Discuss stakeholder involvement |
| 2. Risk Assessment & Capability Assessment | 05/16/2013 | Present and discuss updated risk assessment<br>Discuss improvements to response Plan elements<br>Introduce methodology for updating goals and objectives |
| 3. Mitigation Strategy | 06/04/2013 | Revisit and revise goals<br>Review and approve state mitigation criteria for evaluation and prioritization<br>Revisit status and priority of existing mitigation actions and develop new mitigation actions |

Sign in sheets and summaries of these meetings are included in a Planning Process Reference Notebook on file with the CWCB.

Several other meetings took place to foster coordination and raise awareness of the planning effort. Significant events are noted here:

- Discussion on Plan update progress at monthly WATF meetings March-August 2013.
- Discussion on proposed revisions to Annex A Response Plan through email and two Drought Task Force teleconferences (May 31 and June 14).

### 2.1.2 Involvement in Planning Process

During the revision to the Drought Plan, several individuals participated on the DMRPC and provided information and assistance to promote the development of the document. Appendix A identifies those that were involved or contacted for input in the update of this Plan.

The DMRPC consists of the following agencies/entities:

***State***

- Colorado State University – Colorado Climate Center
- Colorado State University – Water Resources Institute
- Department of Agriculture
- Department of Corrections
- Department of Local Affairs – Division of Local Government
- Department of Public Safety –

  - Division of Homeland Security and Emergency Management - Office of Emergency Management and Office of Preparedness
  - Division of Fire Prevention and Control
- Department of Local Affairs – Division of Local Government
- Department of Military and Veteran's Affairs
- Department of Natural Resources – Colorado Water Conservation Board (lead agency)
- Department of Natural Resources – Colorado State Forest Service
- Department of Natural Resources – Colorado Parks and Wildlife
- Department of Natural Resources – Division of Water Resources
- Department of Natural Resources – State Land Board
- Department of Public Health and Environment
- Department of Regulatory Affairs – Public Utilities Commission
- Colorado Energy Office
- Governor's Office of State Planning and Budgeting
- Governor's Office of Economic Development and International Trade – Tourism Office
- University of Colorado at Boulder

***Federal***

- U.S. Department of Agriculture - Natural Resources Conservation Service
- National Oceanic and Atmospheric Association – National Integrated Drought Information System
- U.S. Geological Survey

***Local***

- City of Aurora
- City of Thornton
- Northern Colorado Water Conservancy District
- Denver Water

***Other***

- Colorado School of Mines – Colorado Geological Survey
- National Drought Mitigation Center – University of Nebraska
- Vail Resorts
- Western Water Assessment
- Colorado River Outfitters Association
- National Center for Atmospheric Research
- University Corporation for Atmospheric Research

The DMRPC members were involved in the planning process through:

- Attending and participating in DMRPC meetings
- Providing available data requested
- Reviewing and commenting on Plan drafts and obtain agency buy-in for relevant sections
- Assist with public input/stakeholder process

### 2.1.3 Agency Involvement in Plan Preparation Process

During the update to the Drought Mitigation Plan, several agencies provided input and technical expertise. Several of the agencies listed previously provided data and information to support the Plan's vulnerability assessment. Documentation of their involvement in the 2010 revision and 2013 update process is included in Appendix A and in the Planning Process Reference Notebook on file with the CWCB. Agencies were provided a series of worksheets designed to capture information to revise the Plan. One worksheet was designed to collect suggestions for stakeholder and public involvement and outreach. Another was used to collect agency input on changes in capabilities and funding sources since 2010. This worksheet also solicited input on the status of existing mitigation actions outlined in the 2010 Plan to determine which items had been completed, deleted, deferred, or were ongoing. In 2010 another questionnaire was used to survey agencies on drought vulnerability from their perspective. DMRPC members filled out these questionnaires and worksheets, and the information directly contributed to the preparation of this Plan. During 2013 specific agencies and organizations with relevant data were contacted through email and phone to update the Vulnerability Assessment in Annex B.

Federal agencies play a key partnership role in drought monitoring and mitigation in Colorado. The NRCS modernized the Surface Water Supply Index (SWSI) for Colorado as part of the planning effort and developed a summary of this effort that is included in Annex D Drought Monitoring Indices. Parallel to this effort the Colorado Climate Center analyzed the validity of the Colorado Modified Palmer Drought Index as a drought indicator and prepared input for Annex D as part of the 2010 revision.

### 2.1.4 Description of Plan Review and Analysis

During the 2010 Plan revision and 2013 update, the DMRPC updated each of the sections of the previously approved plan to include new information and improve organization and formatting of the Plan's contents. The DMRPC analyzed each section using FEMA's state plan update guidance to ensure that the Plan met requirements. Table 3 briefly summarizes how each section of the Plan was reviewed and analyzed to capture changes that occurred since the previous plan was approved. More detailed documentation on revision methodology and process is provided at the beginning of each Plan section.

Additionally, the DMRPC reviewed and provided comment on the draft revised Plan. The document was shared electronically through email and posted on an FTP site for download. Comments were solicited during a two week period in June.

## 2.1.5 Indication of Section Revisions

As part of the 2013 update, every section was updated with new or revised information. Table 3 shows which sections of the Drought Mitigation Plan were revised with highlights of what is new.

**Table 3 Highlights of Changes in the 2013 Update**

| Plan Element | Highlights of Update |
|---|---|
| **Prerequisite**<br>Adoption by the State | • Language revised for 2013<br>• 2013 approval by CWCB Board |
| **Planning Process**<br>Documentation of the Planning Process<br>Coordination Among Agencies<br>Program Integration | • Extensive planning effort documented<br>• Multi-agency outreach and coordination and changes in coordination captured |
| **Risk Assessment**<br>Identifying Drought Hazards<br>Profiling Drought Hazards<br>Assessing Vulnerability by Jurisdiction<br>Assessing Vulnerability of State Facilities<br>Estimating Potential Losses by Jurisdiction | • Incorporated 2011-2013 drought info.<br>• Revised with latest climate science and incorporation of paleo hydrology analysis<br>• Detailed Vulnerability Assessment report in Annex B updated where available data permitted to assess drought vulnerability by various impact sectors. Includes EMAP consequence analysis updated to latest standards |
| **Mitigation Strategy**<br>Hazard Mitigation Goals<br>State Capability Assessment<br>Local Capability Assessment<br>Mitigation Actions<br>Funding Sources | • Goals reassessed and revised to reflect 2013 priorities<br>• Mitigation Action table updated with status and progress<br>• Actions revised and prioritized<br>• New actions developed<br>• Comprehensive capability assessment review<br>• Funding sources revision |
| **Coordination of Local Mitigation Planning**<br>Local Funding and Technical Assistance<br>Local Plan Integration<br>Prioritizing Local Assistance | • Information revised with changes and assistance provided in past three years |
| **Plan Maintenance Process**<br>Monitoring, Evaluating, and Updating the Plan<br>Monitoring Progress of Mitigation Activities | • Process more clearly defined and revised to reflect 2013 process |
| **Drought Response Plan Annex** | • Includes revisions to response and ITF framework to reflect lessons learned and methods employed in 2011-2013 drought response |

## 2.2 Coordination among Agencies

### 2.2.1 Involvement of Federal and State Agencies

Federal and state agencies were integrally involved in the development of the information provided in the revision to this Plan and the umbrella NHMP. The agencies are identified in the previous sections with specific contacts identified in Appendix A. Both federal and state agencies were represented on the DMRPC and participated in meetings previously listed. As indicated, these meetings served as a means to identify federal and state requirements, assign roles and responsibilities to obtain pertinent information, provide for the exchange or transmission of the information, and specifically provide insight and data pertinent to the risk assessment and mitigation strategies. In addition, the DMRPC provided a mechanism for federal and state agencies to review the draft Plan and provide comments that were incorporated into the final document.

### 2.2.2 Involvement of Interested Groups

During the 2010 and 2013 planning update process other groups and organizations were identified that may have an interest in the Plan or could participate as stakeholders in the process. Stakeholders could participate in various ways, either by contributing input at meetings, being aware of planning activities through an email group, providing information to support the effort, or reviewing and commenting on the draft Plan. Some of these groups participated in meetings of the DMRPC. These included:

- Vail Resorts
- Colorado River Outfitters Association

The following groups in the list that follows were identified as interested groups. Specific contacts were identified with each group to solicit input on the draft Plan. Those that provided feedback or comments are noted with an asterisk. Many of these agencies provided feedback that improved the accuracy and content of the final draft. Others may be considered for additional involvement or outreach in the future. During the comment period the Colorado Geological Survey (CGS) indicated their interest to be included on the DMRPC and involved in future updates to this plan and its implementation. The Department of Corrections also provided additional input regarding the vulnerability of their facilities to drought.

***Other Federal Agencies***

- U.S. Geological Survey (USGS)
- National Oceanic and Atmospheric Association (NOAA)
- National Renewable Energy Laboratory
- USDA – Farm Service Agency (FSA)
- USDA – Risk Management Agency (RMA)

- USDA – U.S. Forest Service (USFS)
- USDA – Natural Resource Conservation Service (NRCS)*
- FEMA
- US Army Corp of Engineers (USACE)
- US Department of the Interior (USDOI) – Bureau of Land Management (BLM)
- USDOI – National Park Service (NPS)
- USDOI – Fish and Wildlife Service (FWS)
- USDOI – Bureau of Indian Affairs (BIA)
- USDOI – Bureau of Reclamation (USBR)

#### *Other Agricultural Organizations*

- Co Farm Bureau Federation
- Co Cattlemen's Association*

#### *Wildland Fire/Forest Health*

- Colorado Fire Chiefs Association
- Front Range Fuels Treatment Partnership
- Colorado Bark Beetle Cooperative
- Northern Front Range Mountain Pine Beetle Working group
- Culebra Coalition (southern Front Range)

#### *Other Local and State Government*

- Colorado Geological Survey*
- Colorado Parks and Wildlife*
- Colorado Department of Corrections*
- Colorado Municipal League
- Colorado Counties Inc.
- Colorado Emergency Management Association
- Western Governors' Association*
- Dept of Labor and Employment

#### *Utility Providers*

- Xcel Energy
- Tri-State Energy
- Northern Colorado Water Conservation District
- Colorado River Water Conservation District
- Colorado Watershed Assembly
- Others on Local Drought Guidance Document Review committee

#### *Recreation/Tourism*

- Chambers of Commerce
- Colorado Ski Country USA

#### *Conservation Organizations*

- Colorado Wildlife Federation
- Colorado Audubon Society
- Colorado Trout Unlimited
- Defenders of Wildlife*
- Ducks Unlimited
- Playa Lakes Joint Venture
- Pheasants Forever
- The Nature Conservancy
- Western Resource Advocates*

#### *Other Organizations*

- National Drought Mitigation Center (NDMC)*
- Water Commissioners
- Western Water Assessment*
- Colorado Renewable Energy Society
- Associated General Contractors of Colorado
- Colorado Watershed Assembly
- Colorado Voluntary Organizations Active in Disasters
- Golf Course Superintendents Association of America*

### Outreach Efforts

Plan outreach was an important part of the 2010 revision, as well as continued outreach as part of implementation of the plan during 2011-2013 timeframe. A Stakeholder and Public Participation Plan was prepared to provide for a meaningful process through which Colorado's citizens, public officials, and stakeholder groups may effectively participate in the revision of the Colorado Drought Mitigation and Response Plan. The objectives of this document were three-fold:

- Recognizing that there are many levels of public and stakeholder participation, to provide for an effective mix of participation opportunities that meet the above bulleted purposes.
- Recognizing that not everyone participates in the same way or at the same time, to include a mix of participation strategies that provides for a broad and diverse set of participation opportunities across Colorado.
- To build public support for the revised Colorado Drought Mitigation and Response Plan.

The document synthesized input from the DMRPC on their recommendations, stakeholder recommendations, and public involvement and outreach opportunities. Stakeholder and outreach activities during the 2010 revision and 2013 update are summarized in Table 4.

**Table 4 Stakeholder and Public Participation Plan Implementation 2009-2013**

| Timeframe | Stakeholder and Public Participation Activities | Highlights/Outcome |
|---|---|---|
| October 2009 | Three "Dealing with Drought" workshops held by the CU-NOAA Western Water Assessment<br>Target audience local water providers<br>Oct 13 – Castle Rock<br>Oct 16 – Glenwood Springs<br>Oct 19 – Durango | Drought Plan Revision presentation on agenda<br>Summary report developed |
| Jan-Feb 2010 | Colorado Water Congress – presentation by AMEC on Vulnerability Assessment<br>Rural Water Association meetings<br>NDMC meetings in Nebraska and NE CO | Vail Resorts and Colorado River Outfitters Association participating on DMRPC |
| Mar-June 2010 | Advertise upcoming Plan public review period through press releases, newsletter articles, etc.<br>IBCC May meeting – presentation and/or exercise<br>Presentation to CWCB Board on May 19th<br>CML and CCI conferences (checked but no room in agendas) | Colorado Watershed assembly newsletter article on Plan planned for July/August edition<br>Board Meetings publicly broadcast |
| July 2010 | Revised Drought Mitigation and Response Plan stakeholder/public review and comment period<br>Post draft Plan on CWCB website and advertise through email blasts.<br>Web-based presentation on the draft Plan presented on August 16$^{t}$<br>Colorado Water Congress Meeting | Web-based meeting attended by 21 persons representing various local and state governments, University of Colorado, environmental organizations, local water providers, and the public.<br>Extensive outreach and comment period and revisions made to plan based on comments received. |
| September 2010 | Presentation to CWCB Board on September 15 | Board Meetings publicly broadcast |
| Spring 2011 | Five municipal drought planning workshops were held in various locations around the state by CWCB | Raised awareness of plan and planning guidance documents |
| September 2012 | 2012 Governors Drought Conference held, including presentations on the Drought Plan.<br>CWCB and NIDIS co-sponsored the first Colorado 'Drought Tournament' | Tournament enhanced multi-sector collaboration and creative response and mitigation in three simulated droughts. |
| July – August 2013 | Revised Drought Mitigation and Response Plan stakeholder/public review and comment period<br>Post draft Plan on CWCB website and advertise through email blasts. | Comment period open from July 20 – August 20$^{th}$. Nine separate public/stakeholder comments were received. Comments were logged in a matrix which was posted on the CWCB website with details on how the comment was addressed or plan revised, as appropriate. |
| September 2013 | Presentation to CWCB Board | Board Meetings publicly broadcast |

### 2.2.3 Changes in Coordination

Changes in coordination have occurred over the evolution of the Drought Plan. This Plan was originally developed and maintained by the Office of Emergency Management (formerly the Division of Emergency Management). |The Plan's lead agency became the DNR-CWCB in 2002. Changes in coordination occurred as a result of the 2010 Plan revision, most notably with the Plan's response functions as detailed in Annex A Drought Response Plan. A more simplified drought response framework was developed to replace an older, more complicated coordination and communication diagram. A formal Drought Task Force was defined, replacing the old Review and Reporting Task Force. The Department of Agriculture (CDA) was added as co lead, along with the Departments of Local Affairs (DOLA) and Natural Resources, to the Drought Task Force. In 2013 the Department of Public Safety was added as a co-lead. This was in response to the Division of Emergency Management being moved from DOLA into the DPS Division of Homeland Security and Emergency Management - Office of Emergency Management in 2012. The drought response framework was simplified even further based on lessons learned from the 2011-2013 drought and to reflect direct communication between the Governor's Office and the Drought Task Force. See Annex A for more details.

Other changes in coordination included the number, constituency, and makeup of the Impact Task Forces themselves. The original Impact Task Forces included Municipal Water, Wildfire Protection, Agricultural Industry, Tourism, Wildlife, Economic Impacts, Energy Loss, and Health. Various options to collapse and combine the Impact Task Forces into as few as four were presented and discussed at several planning meetings. The DMRPC discussions and emails on this topic validated that the model still worked but that some adjustments were needed. The group recommended combining the Health ITF with the Municipal Water ITF. The Economic ITF was dissolved as an individual Task Force but the component of tracking economic impacts was added as a responsibility of each ITF. The ITFs were again re-evaluated in 2013. The Tourism and Wildfire Impact Task Forces were removed since these historically had not been activated. Representatives from these sectors are included on the DTF and Municipal Water ITF. The revised ITFs are presented in Annex A, as well as more detailed roles and responsibilities and procedures.

One of the mitigation strategies identified in previous versions of this plan included 'Examine and improve role and relationship of public information and education efforts by the CWCB with the DNR, DWR–SEO, and the Governor's Office.' This examination was done as part of the 2010 Plan revision, and has resulted in improved coordination which has been tested and proven beneficial by the 2011-2013 drought.

The Colorado Climate Center has been part of the NIDIS (National Integrated Drought Information System) Upper Colorado River Basin Drought Early Warning System since 2009. Since that time, Colorado has experienced some level of drought across the state every year. This project allowed the state climate office to be much more involved in drought monitoring and communication efforts than what had been done previously. Prior to this NIDIS pilot project, updates had been done monthly through the Colorado Water Availability Task Force. Although these monthly meetings are key in the monitoring component of this Plan, the NIDIS project allowed for much more aggressive and timely weekly monitoring of conditions across the Upper Colorado River Basin and other basins in Colorado while contributing to the U.S. Drought Monitor as well. This intense monitoring proved to be much more effective in identifying drought early enough so that water managers had more information sooner to help support decision making. Response to exceptionally dry conditions in 2011-2012 in Colorado was much more coordinated than the 2002 drought in Colorado. The 2002 drought was proof that conditions could deteriorate rapidly and that is what happened again in 2012 (Ryan and Doesken, 2013).

Increased monitoring was the key to closely tracking drought conditions and getting accurate changes made to the U.S. Drought Monitor (USDM), which people rely on heavily for tracking national conditions. This increased monitoring allowed for a more localized depiction of conditions in Colorado which give users of the USDM more confidence in the product for their location (Ryan and Doesken, 2013). Coordination among state and federal agencies also increased with the 2010 revision with the inclusion of NOAA and USGS on the DMRPC. Additional coordination and collaboration occurred with the NRCS, who modernized the Surface Water Supply Index (SWSI) for Colorado as part of the planning effort. The State Land Board and Colorado Parks and Wildlife (CPW) were recognized as having assets potentially vulnerable to drought and became an active participant in the process. Other participants added into the planning process in 2013 included local water providers (Aurora, Denver, Thornton, Northern Colorado Water Conservancy District), additional state agencies (Department of Corrections and Department of Military and Veteran's Affairs, Colorado Geological Survey).

## 2.3 Program Integration

### 2.3.1 Integration of Mitigation Planning with other State Planning Efforts

This Plan has been an integral part of the Colorado Natural Hazards Mitigation Plan since 2007. The Colorado NHMP profiles drought as a separate hazard, but does not give the enhanced detail that the Drought Mitigation Plan does. Other plans that this Plan revises, complements, and integrates portions of include the CWCB's 2004 and 2007 Drought and Water Supply Assessments (DWSA). Annex A of this plan also complements and works in concert with the State Emergency Operations Plan. The CWCB has begun work on a draft Colorado Water Plan that is rooted in the grass-roots work of the Basin Roundtables and Interbasin Compact Committee to align state policy to Colorado's water values. The Water Plan will address a variety of issues to address existing and future gaps in water supply and demand, including how drought has the potential to magnify and affect water availability. The Drought Plan will be an integral reference as the Water Plan effort moves forward.

The State of Colorado is committed to the multi-agency mitigation strategy outlined in this Plan. Two goals listed in this Plan in Section 4.1 are related to this:

- Coordinate and provide technical assistance for state, local and watershed planning efforts
- Develop intergovernmental and interagency stakeholder coordination

Section 4.4 Mitigation Actions provides additional detail on actions designed to improve coordination and integration efforts. Details on related planning programs and initiatives are also discussed in Section 4.2 State Capability Assessment.

The following statewide planning efforts have included collaboration through the incorporation of the findings and recommendations from one plan to another:

- Colorado River Water Availability Study
- Colorado Inter Basin Compact Committee planning efforts
- Basin Needs Decision Support System
- Non-Consumptive Needs Toolbox (Draft 2013)
- Statewide Water Supply Initiative (various reports)
- Colorado Energy Assurance Emergency Plan
- Colorado Forest Resource Assessment Plan
- Local multi-hazard mitigation plans
- Local drought management plans
- Local water conservation plans

Specific action items related to future integration are noted in Section 4.4. This Plan is a related component of the Colorado River Water Availability Study phases and other water supply planning initiatives being spearheaded by the CWCB.

### 2.3.2 Integration of Mitigation Planning with FEMA Mitigation Programs and Initiatives

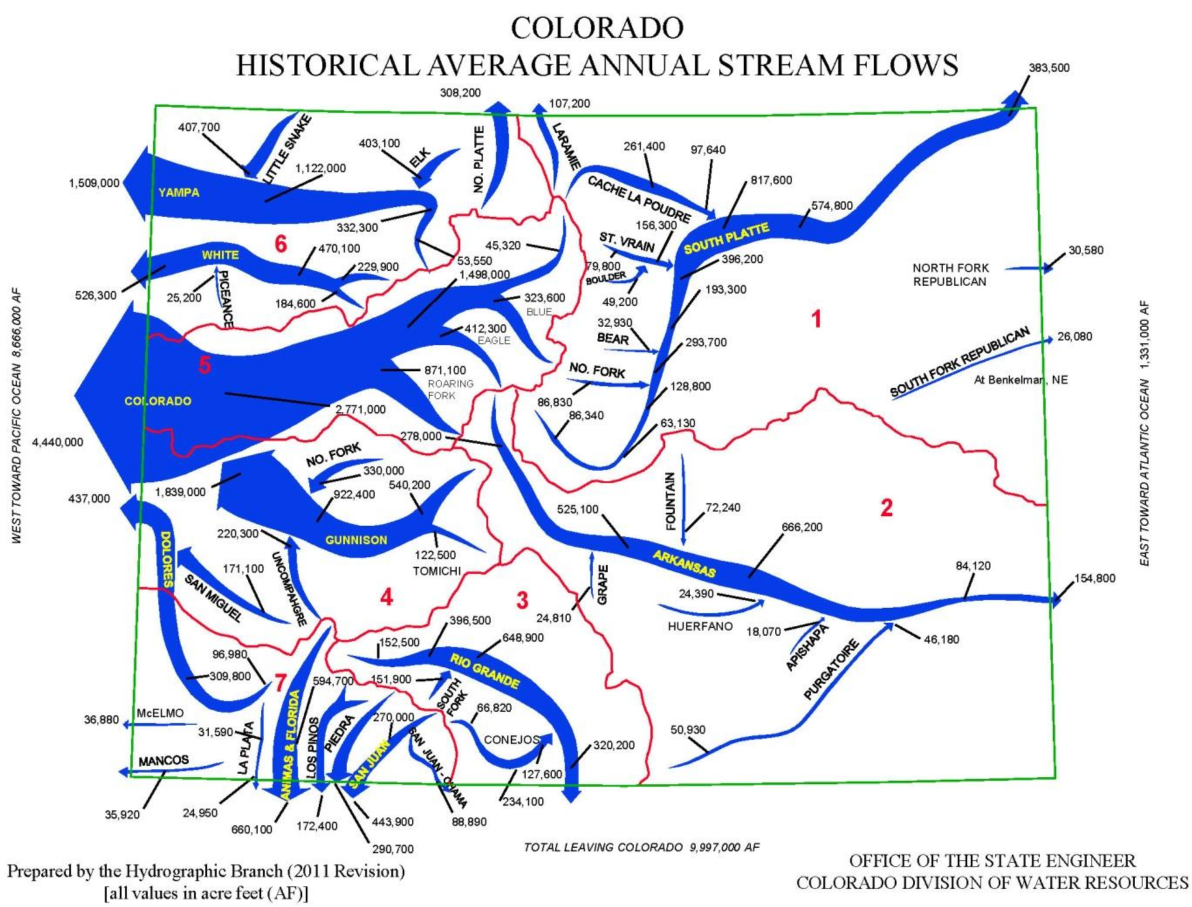
Mitigation planning associated with this document has strived to include the integration of other FEMA mitigation programs and initiatives. The mitigation component of the Plan conforms to the Standard State Hazard Mitigation planning requirements of the Disaster Mitigation Act of 2000 based on the FEMA Bluebook Multi-Hazard Mitigation Planning Guidance (2004, revised in 2008). FEMA does not have specific programs aimed at mitigating drought disasters. OEM is the primary state coordinating agency for all local emergency operation plans and hazard mitigation plans. The division has the primary responsibility of working with local governments in developing, reviewing, and updating local hazard mitigation plans. Refer to the umbrella 2013 Colorado NHMP for further description of the integration of FEMA mitigation programs and initiatives in Colorado.

# 3 RISK ASSESSMENT

## 3.1 Identifying the Drought Hazard

Colorado gets new water supplies from only one source: precipitation, in the form of rain, hail, or snow. Colorado gets all of its water from precipitation because there are no major rivers that flow INTO Colorado (McKee et al., 1999). There are several major river basins originating in the Colorado Rockies, which flow OUT of the State (see Figure 1), providing water to much of the southwestern United States, and contributing to the Missouri and Mississippi rivers as well. Thus, Colorado earns its title as "the Mother of Rivers."

**Figure 1. Colorado Historic Average Annual Streamflow (acre-feet)**




Source: Office of the State Engineer – Colorado Division of Water Resources

Although the source of Colorado's water supplies is precipitation, it is difficult to use directly in that form. Instead, water is often stored in one of five forms of usable water:

- snowpack (SN), used directly for recreation, although it also serves as a large storage of water supplies;

- streamflow (ST), used for recreation, habitat, irrigation and municipal water supplies, as well as meeting interstate compact obligations;
- reservoir water (RW), used similarly to streamflow;
- soil moisture (SM), used by natural vegetation and agriculture; and
- groundwater (GW) used for irrigation and municipal water supplies.

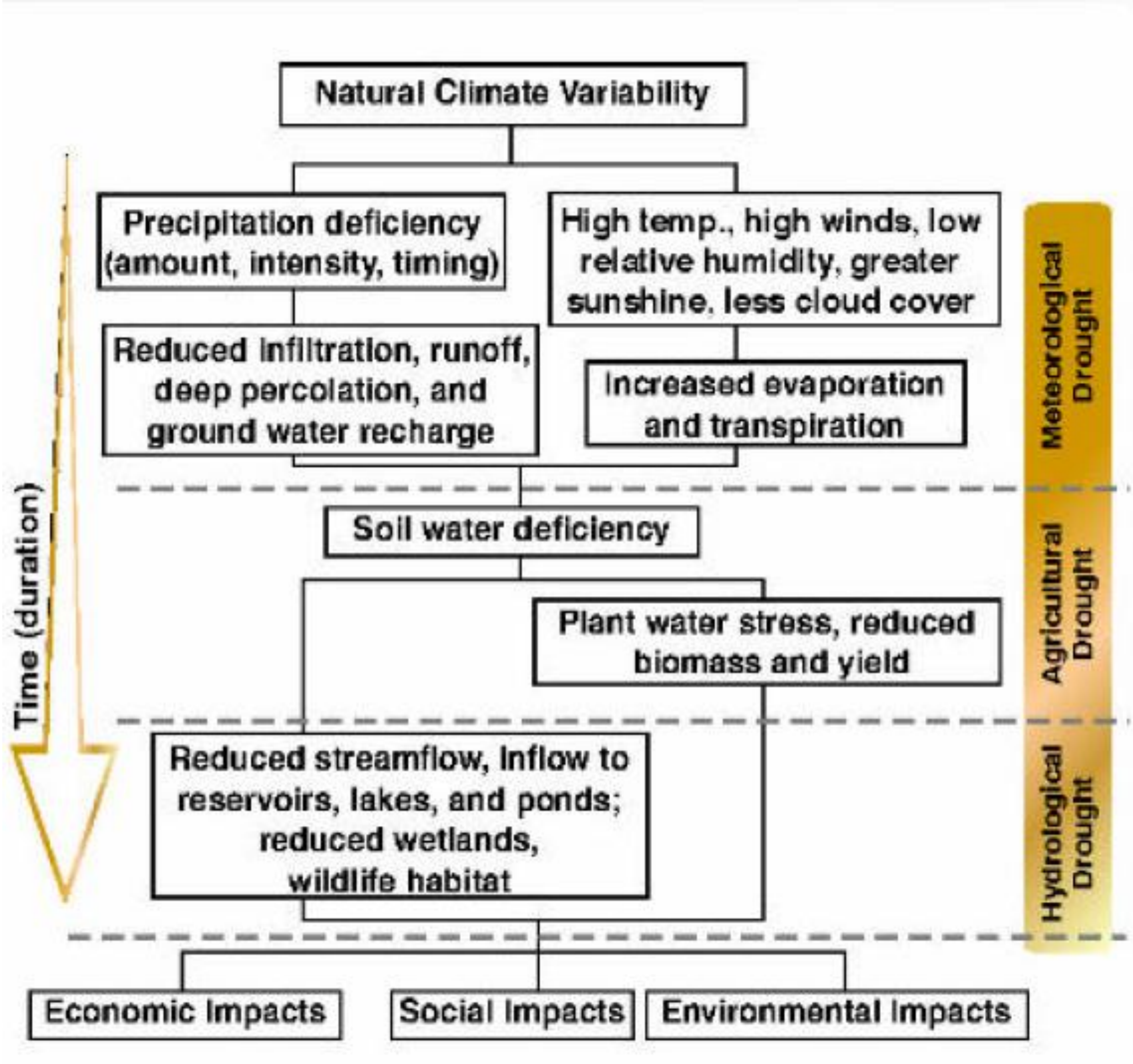
The amount of time it takes for precipitation to turn into a usable form of water can vary greatly. Precipitation can add to soil moisture or snowpack almost immediately. However, there can be delays of several days, weeks, or months before precipitation adds to the water levels in streams, reservoirs, or groundwater aquifers. During those periods, some precipitation is lost to evaporation as well as wind and dust-on-snow enhancing sublimation. Therefore, in warmer months with less precipitation, such as summer, brief rains that fall will add little or no water to the usable water supply.

Drought is a complex and a gradual phenomenon in Colorado. Although droughts can be characterized as emergencies, they differ from other emergency events in that most natural disasters, such as floods or forest fires, occur relatively rapidly and afford little time for preparing for disaster response. Droughts typically occur slowly, over a multi-year period, and it is often not obvious or easy to quantify when a drought begins and ends. Drought can often be defined regionally based on its effects:

- **Meteorological** drought is usually defined by a period of below average precipitation.
- **Agricultural** drought occurs when there is an inadequate water supply to meet the needs of the state's crops and other agricultural operations such as livestock.
- **Hydrological** drought is defined as deficiencies in surface and subsurface water supplies. It is generally measured as streamflow, snowpack, and as lake, reservoir, and groundwater levels.
- **Socioeconomic** drought occurs when a drought impacts health, well-being, and quality of life, or when a drought starts to have an adverse economic impact on a region.

Figure 2 relates these definitions to drought duration and potential impacts.

**Figure 2. Causes and Impacts of Drought**




Source: National Drought Mitigation Center

## 3.2 Drought Hazard Profile

With its semiarid conditions, drought is a natural part of the Colorado climate. Due to natural variations in climate and precipitation, it is rare for all of Colorado to be deficient in moisture at the same time. However, single season droughts over some portion of the State are quite common. Hydrologic conditions constituting a drought for water users in one location may not constitute a drought for water users elsewhere, or for water users that have a different water supply. Individual water suppliers may use different criteria, such as rainfall/runoff, amount of water in storage, or expected supply from a water wholesaler, to define their water supply conditions. The drought issue is further compounded by water rights specific to a state or region.

Water is a commodity possessed under a variety of legal doctrines. (See the Water Rights discussion in Section 3.2.5)

Drought impacts are wide-reaching and may come in different forms, such as economic, environmental, and/or societal. The most significant impacts associated with drought in Colorado are those related to water intensive activities such as agriculture, wildfire protection, municipal usage, commerce, tourism, recreation, and wildlife preservation. A reduction of electric power generation and water quality deterioration are also potential effects. Drought conditions can also cause soil to compact, decreasing its ability to absorb water, making an area more susceptible to flash flooding and erosion. A drought may also increase the speed at which dead and fallen trees dry out and become more potent fuel sources for wildfires. Drought may also weaken trees in areas already affected by mountain pine beetle infestations, causing more extensive damage to trees and increasing wildfire risk, at least temporarily. An ongoing drought which severely inhibits natural plant growth cycles may impact critical wildlife habitats. Drought impacts increase with the length of a drought, as carry-over supplies in reservoirs are depleted and water levels in groundwater basins decline.

Impacts from drought can also be exacerbated due to the affects of dust settling on snow, which causes increased solar energy absorption. As a result, snowmelt takes place earlier in the season and runoff magnitudes increase. Recent research has shown that dust deposition has increased throughout the western United States in the past 17 years, with the largest increases in western Colorado (Brahney et al., 2013). Rigorous sampling and analyses of dust by the Colorado Dust-on-Snow program (CODOS) and USGS show that most dust being deposited to the Colorado mountain snowpack is originating from source areas located outside of Colorado, scattered throughout the greater Colorado Plateau. Drought conditions in those dust source areas can increase the availability of dust for wind transport and, thereby, increase the dust-on-snow hazard in Colorado, even when the Colorado mountains are not experiencing drought conditions. In addition to earlier snowmelt due to dust-on-snow, runoff yields can be reduced, in some years, due to increased evapotranspiration by plants. This is caused by the plant community becoming active sooner than normal as a result of earlier snowmelt and loss of snowcover (Painter et al., 2010).

The impacts related to early runoff pose problems for many important sectors in Colorado including agriculture, recreation, tourism, and municipal water supplies. If runoff happens in a shorter timeframe, sometimes months early, it could mean a shorter season for the rafting industry and less water available for irrigation diversions in the summer. Reservoirs may also be filled to capacity during these constrained runoff periods, causing spills to be necessary. Ideally, to avoid releases of water downstream, water is captured over a longer timeframe with gradual melting of snowpack.

Alternatively, dust produced from the hardening and drying of bare soil can also be exposed as vegetative cover decreases due to extended periods of drought. The Eastern Plains of Colorado, where much of the agricultural economy exists, can suffer from dust storms originating from topsoil that is easily airborne. Entire crops can be damaged in one storm, affecting the livelihood of the farmers and ranchers. A more detailed discussion on drought impacts can be found in Section 3.2.5.

### 3.2.1 Location of Drought Hazards in Colorado

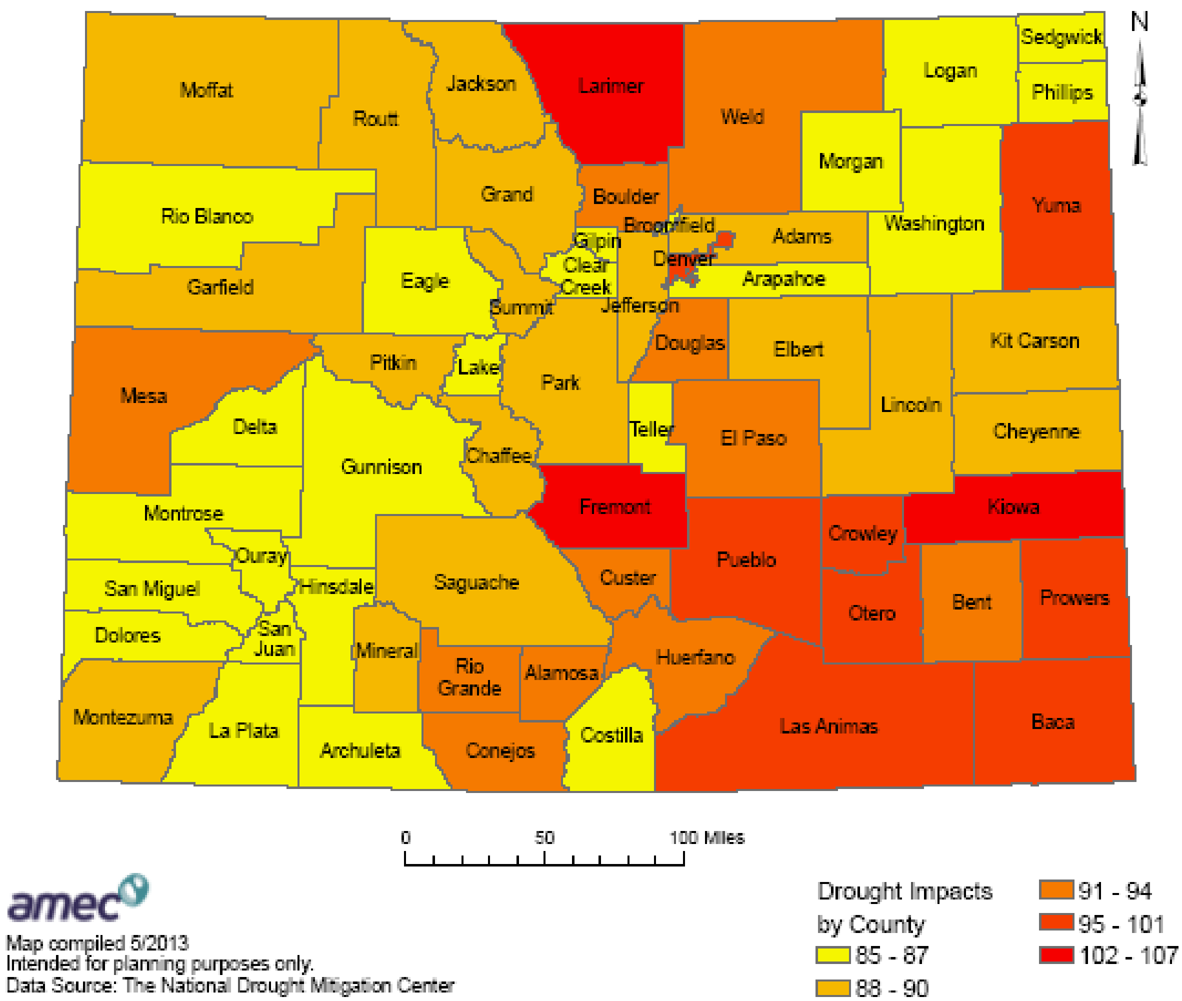
No portion of the State of Colorado is immune from drought conditions. The effects of drought vary based on where in the state it occurs, when it happens, and how long the drought persists. For example, a drought in the plains of the state can greatly affect agricultural crops. A long-term drought is not needed to affect agricultural yields. Droughts of just a few weeks during critical periods of plant development can have disastrous effects on agriculture production. Droughts that occur in the mountainous regions of the state during winter months may have great affects on the ski and tourism industry. However, drought in one area of the state may also impact other regions. Lack of winter snowfall in the mountains can eventually lead to agricultural impacts on the eastern plains due to decreased streamflows. Reduced reservoir storage from decreased runoff in the mountains leads to municipal and industrial water shortages on the Front Range. Droughts that occur in populated areas may not have direct affects to the residents, but may increase the threat of wildfire in the wildland urban interface areas. In summary, drought is one of the few hazards with the potential to directly or indirectly impact the entire population of the state, be it from water restrictions, higher water and food prices, reduced air or water quality, or restricted access to recreational areas (McKee and Doesken, 1999).

Tracking drought impacts can be difficult. The Drought Impact Reporter from the NDMC is a useful reference tool that compiles reported drought impacts nationwide. Figure 3 shows reported total drought impacts for all Colorado counties since the previous Plan update was approved in 2010 in the following impact categories:

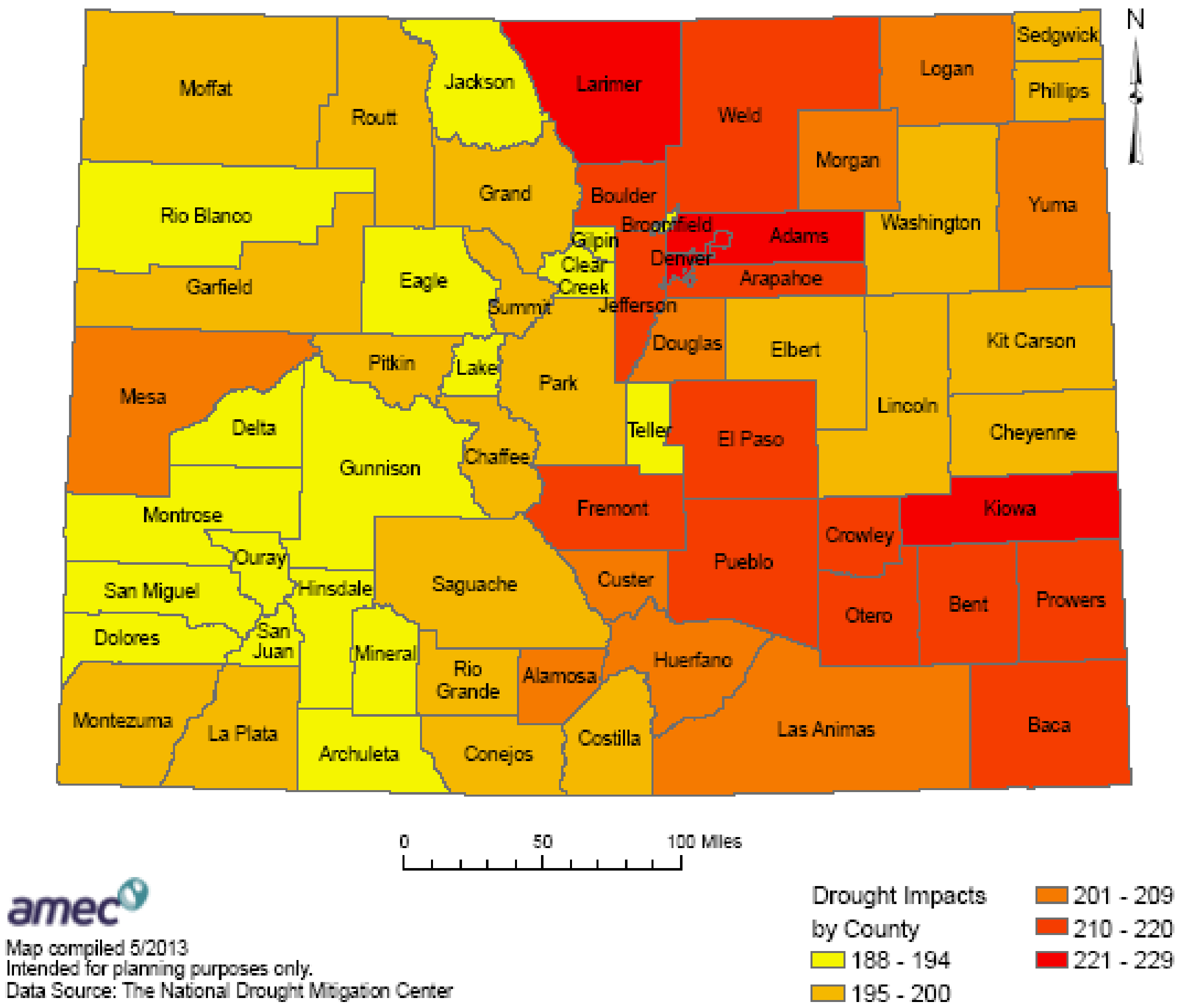
- Agriculture
- Business & Industry
- Energy
- Fire
- Plants & Wildlife
- Relief, Response & Restrictions
- Society & Public Health
- Tourism & Recreation
- Water Supply & Quality

Figure 4 shows total drought impacts for all Colorado counties from 1935 (earliest reported drought impact) to May 8, 2013 for the same impact categories. Based on reports to the NDMC, all counties recorded some impact from drought, and most counties recorded moderate to major amounts of impacts; illustrating that drought affects all regions of the state in all impact categories at one time or another. The data represented is skewed, with the majority of these impacts from records within the past 10 to 15 years.

**Figure 3. Drought Impact Reporter for Colorado (March 2010-May 8, 2013)**



## Figure 4. Drought Impact Reporter for Colorado (1935-May 8, 2013)




### 3.2.2 Monitoring Drought in Colorado

Because drought can be defined differently, based on the cause (lack of supply) and the effect (adverse impacts to water users), several methods have evolved to measure and assess drought. Severity, the most commonly used term for measuring drought, is a combination of the magnitude and duration of the drought. In order to assess the severity of a drought event it is necessary to monitor "normal" conditions as well as conditions during drought events. Individual indicators of drought conditions can be used in addition to indices that combine multiple indicators to give a more comprehensive set of information. Both traditional maps and graphs of precipitation, snowpack, and streamflow patterns and compilations provide valuable information for drought monitoring. Instrumental data are used extensively for monitoring precipitation, snowpack, streamflow, and reservoir levels, some of which are summarized below:

- Precipitation is measured daily at several hundred locations across Colorado. National Weather Service (NWS) stations have collected data for 100 years or more, and are used extensively by the Colorado Climate Center (CCC) at Colorado State University (CSU) for drought research.
- Snowpack data, critical for predicting runoff and surface water supplies, are collected at higher elevations by the NRCS at Snow Telemetry Network (SNOTEL) sites. A few of these sites date back more than 60 years. Precipitation and snowpack data have been analyzed to determine the patterns of wet and dry periods and their hydroclimatic impacts in Colorado over the last 100 years. Monitoring this data is very important to predict near-future drought potential.
- Streamflow is the net result of precipitation, snowmelt, evapotranspiration, infiltration, and groundwater recharge, as well as man-made influences such as irrigation diversions and reservoir storage and releases. The combination of streamflow readings and reservoir levels provides the best direct indication of available surface water supplies in each of Colorado's river basins.
- Dust and its impacts are being monitored by the CODOS program of the Center for Snow and Avalanche Studies (CSAS), based in Silverton, Colorado. CSAS's Senator Beck Basin Study Area at Red Mountain Pass is the primary sentry site for dust-on-snow events in Colorado, where rigorous monitoring began in 2002/2003. Ten additional locations throughout the Colorado mountains are also being monitored each spring by CODOS (CODOS, http://snowstudies.org/dust/index.html).

These climate observation networks provide important data necessary to analyze recent and historic droughts and relate water availability to observed impacts. Years of experience, along with common sense, have shown that drought impacts are directly related to the following drought characteristics:

- Magnitude – how large the water deficits are in comparison with historic averages
- Duration – how long the drought lasts
- Areal Extent – what area is impacted by the drought

A variety of drought indices are used to track precipitation and water supply, as well as classify droughts that have occurred in the past. These indices help simplify and synthesize complex data to provide actionable information for planners and decision makers. Paleoclimatic techniques, such as measurement of tree rings, ice cores, pollens, and ancient lake levels, are also employed to study drought patterns and frequencies over the past several centuries. The following set of indices are most commonly used in Colorado:

The **Colorado Modified Palmer Drought Index** (CMPDI) is a complex soil moisture calculation that has been used by federal agricultural agencies to determine when to provide drought assistance. It requires weekly or monthly precipitation and temperature data as inputs. Since this index was initially developed for areas of the country with more precipitation and more homogeneous climates, Colorado adapted the index by separating the state into 25 climatically similar regions. In recent years the CCC has added a 26th region -- the Sangre de Cristo Mountains which originally did not have adequate data. The Colorado Modified Palmer Index uses a +4 to -4 scale. It uses a 0 as normal, and drought is shown in terms of negative numbers; for example, -2 is moderate drought, -3 is severe drought, and -4 is extreme drought.

The **Surface Water Supply Index** (SWSI) was originally developed in Colorado in 1981 by the Soil Conservation Service (now the NRCS) and the Colorado Division of Water Resources (DWR). The purpose of the index was to describe drought severity where water availability is driven by winter snow accumulation and subsequent melt, typical in the Western US. The SWSI is comprised of four inputs: snowpack, streamflow, precipitation, and reservoir storage. During the winter months (December to May) the index uses snowpack, water year precipitation and reservoir storage. In summer and fall, (June to November) the index switches to streamflow, previous month's precipitation and reservoir storage. The index is computed by determining each variable's non-exeedance probability (the probability that subsequent sums of that component will not be greater than the current sum), then multiplying by a subjective weighting factor. The Index uses the following inputs depending on the time of year:

- For January-June: SWSI = Streamflow Forecast + Reservoir Storage
- For July-September*: SWSI = Reservoir Storage + Previous Month's Streamflow
- For October-December: SWSI = Reservoir Storage

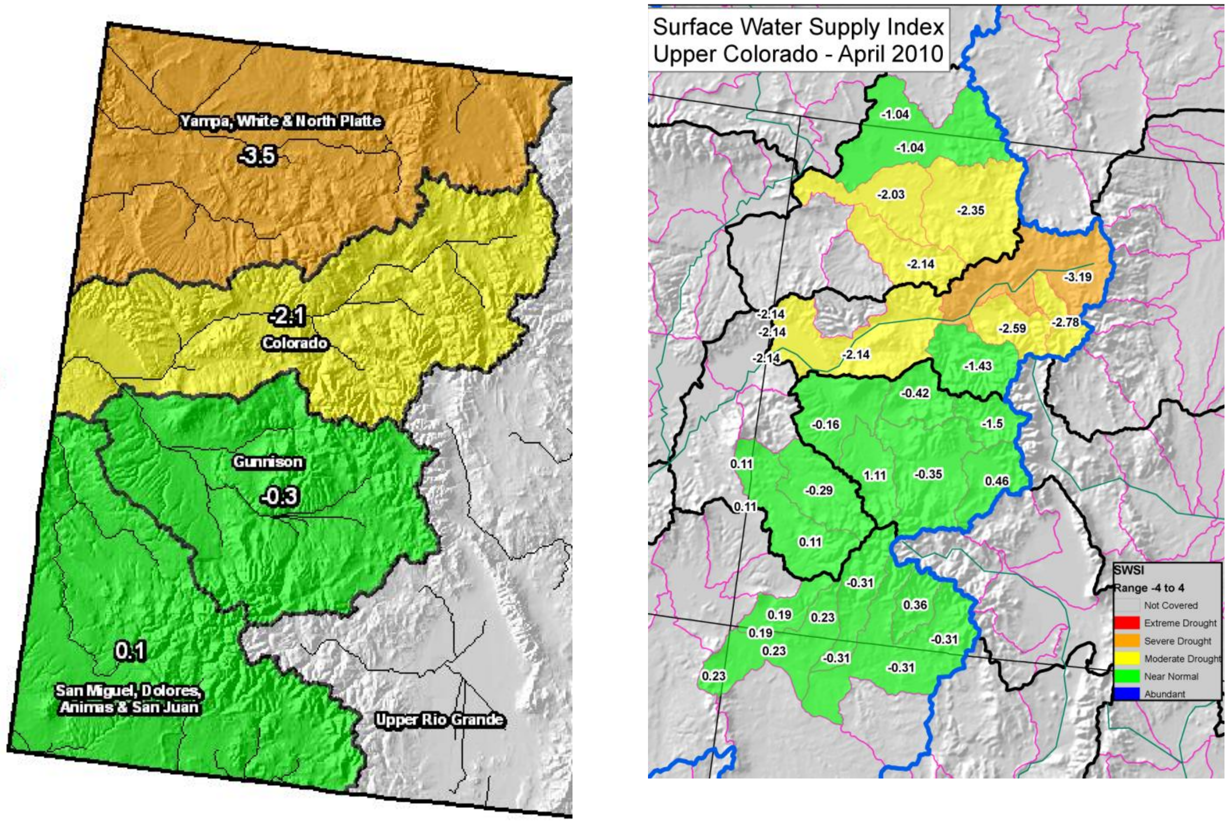
* Revised in 2010; formula was previously SWSI = Reservoir Storage + Observed Streamflow

The variables are summed and converted to an index of generally +4 (abundant supplies) to -4 (exceptional drought). The +4 to -4 range was used to mimic the widely accepted Palmer Drought Index. However, SWSI will likely be changed to a percentile-based index by late 2013. The SWSI is calculated independently for each basin due to differences in climate and reservoir capacities. One of the advantages to the SWSI is that it is simple to calculate and gives a representative measurement of surface water supplies across the state. It has been modified and applied in other western states as well.

As part of the 2010 Plan revision, the NRCS worked to revise the SWSI calculations for Colorado by implementing a method with a sounder theoretical and statistical basis, and to increase the spatial detail to approximately 30 watersheds instead of the seven major basins previously covered. The UCRB watersheds began using the revised SWSI in the spring of 2010. A comparison of the old and new SWSI is shown in Figure 5. The remaining basins in the State have been monitored using the revised SWSI since 2012. More information on the SWSI update and refinement can be found in Annex D.

## Figure 5. Comparison of Old and New Surface Water Supply Index – April 2010

| Old Method | New Method |
|---|---|




Source: USDA – Natural Resources Conservation Service

The **Standardized Precipitation Index** (SPI), also developed in Colorado, is fairly simple to compute but is often a robust index for describing drought patterns. The SPI values are based on the probability, calculated from the long-term precipitation record for a given location, of recording a given amount of precipitation over the stated time period, and these probabilities are standardized so that a value of zero always indicates the median precipitation amount. The SPI can be computed for different time scales, can provide early warning of drought and help assess drought severity, and is less complex than the CMPDI. The SPI identifies a beginning and end for each drought, as well as an intensity level for each month in which the drought occurs. Table 5 shows the values for the SPI index. The challenge of utilizing SPI objectively is understanding the appropriate time scale and vulnerability for various known and potential impacts.

## Table 5 SPI Index

| SPI Values | Description |
|---|---|
| 2.0 + | extremely wet |
| 1.5 to 1.99 | very wet |
| 1.0 to 1.49 | moderately wet |
| -.99 to .99 | near normal |
| -1.0 to -1.49 | moderately dry |
| -1.5 to -1.99 | severely dry |
| -2 and less | extremely dry |

Source: NOAA National Climatic Data Center

The **Crop Moisture Index** was developed from the Palmer Index, and was designed to evaluate short-term moisture conditions across major crop producing regions. It uses the average temperature and total precipitation for each week and compares the calculated index with the previous week. This is a better index to measure rapidly changing conditions and for comparing different locations. However, the gross scale of the climate divisions (only five for Colorado) makes it a less useful index for Colorado statewide.

In addition to the indices noted above the **U.S. Drought Portal**, which is a product of the National Integrated Drought Information System (NIDIS), is also used in Colorado.

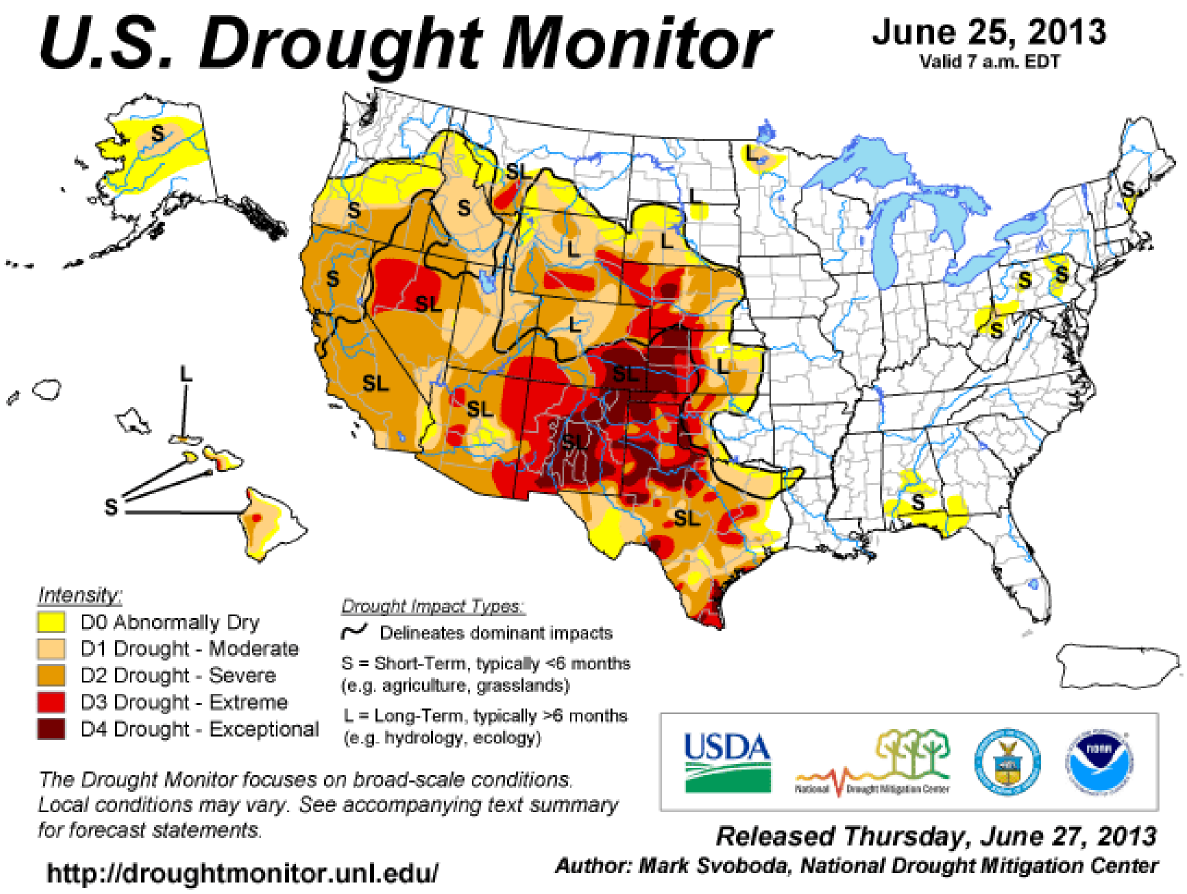
The U.S. Drought Portal is part of an interactive system to:

- Provide early warning about emerging and anticipated droughts
- Assimilate and quality control data about droughts and models
- Provide information about risk and impact of droughts to different agencies and stakeholders
- Provide information about past droughts for comparison and to understand 2013 conditions
- Explain how to plan for and manage the impacts of droughts
- Provide a forum for different stakeholders to discuss drought-related issues

A major component of this portal is the **U.S. Drought Monitor.** The Drought Monitor concept was developed jointly by the NOAA’s Climate Prediction Center, the NDMC, and the USDA's Joint Agricultural Weather Facility in the late 1990s as a process that synthesizes multiple indices, outlooks and local impacts into an assessment that best represents 2013 drought conditions. The final outcome of each Drought Monitor is a consensus of federal, state, and academic scientists who are intimately familiar with the conditions in their respective regions.

A snapshot of the drought conditions nationwide and specific to Colorado can be found in Figures 6 and 7. The figures indicate dry conditions that are evident throughout much of the central and western U.S. The southeastern portion of Colorado is experiencing exceptional to extreme drought conditions and the remainder of the state is ranked as severe to moderate, an indication that the situation has not improved much since the summer of 2012, when dry and warm conditions prevailed.

**Figure 6. June 2013 U.S. Drought Conditions**




Source: National Drought Mitigation Center

**Figure 7. June 2013 Colorado Drought Conditions**

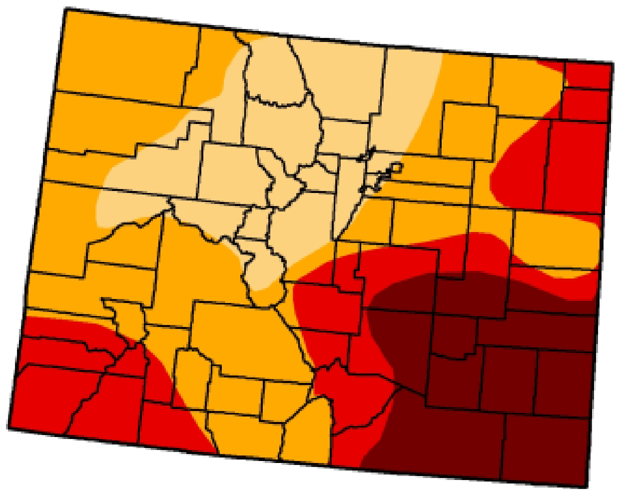
# U.S. Drought Monitor

**June 25, 2013**
Valid 7 a.m. EST

## Colorado

*Drought Conditions (Percent Area)*

| | None | D0-D4 | D1-D4 | D2-D4 | D3-D4 | D4 |
|---|---|---|---|---|---|---|
| Current | 0.00 | 100.00 | 100.00 | 79.46 | 39.21 | 17.54 |
| Last Week (06/18/2013 map) | 0.00 | 100.00 | 100.00 | 75.28 | 35.50 | 17.54 |
| 3 Months Ago (03/26/2013 map) | 0.00 | 100.00 | 100.00 | 88.97 | 45.98 | 13.83 |
| Start of Calendar Year (01/01/2013 map) | 0.00 | 100.00 | 100.00 | 95.06 | 53.47 | 13.48 |
| Start of Water Year (09/25/2012 map) | 0.00 | 100.00 | 100.00 | 100.00 | 61.75 | 16.89 |
| One Year Ago (06/19/2012 map) | 0.00 | 100.00 | 97.71 | 60.96 | 26.63 | 0.00 |



Intensity:

- D0 Abnormally Dry
- D1 Drought - Moderate
- D2 Drought - Severe
- D3 Drought - Extreme
- D4 Drought - Exceptional

*The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.*

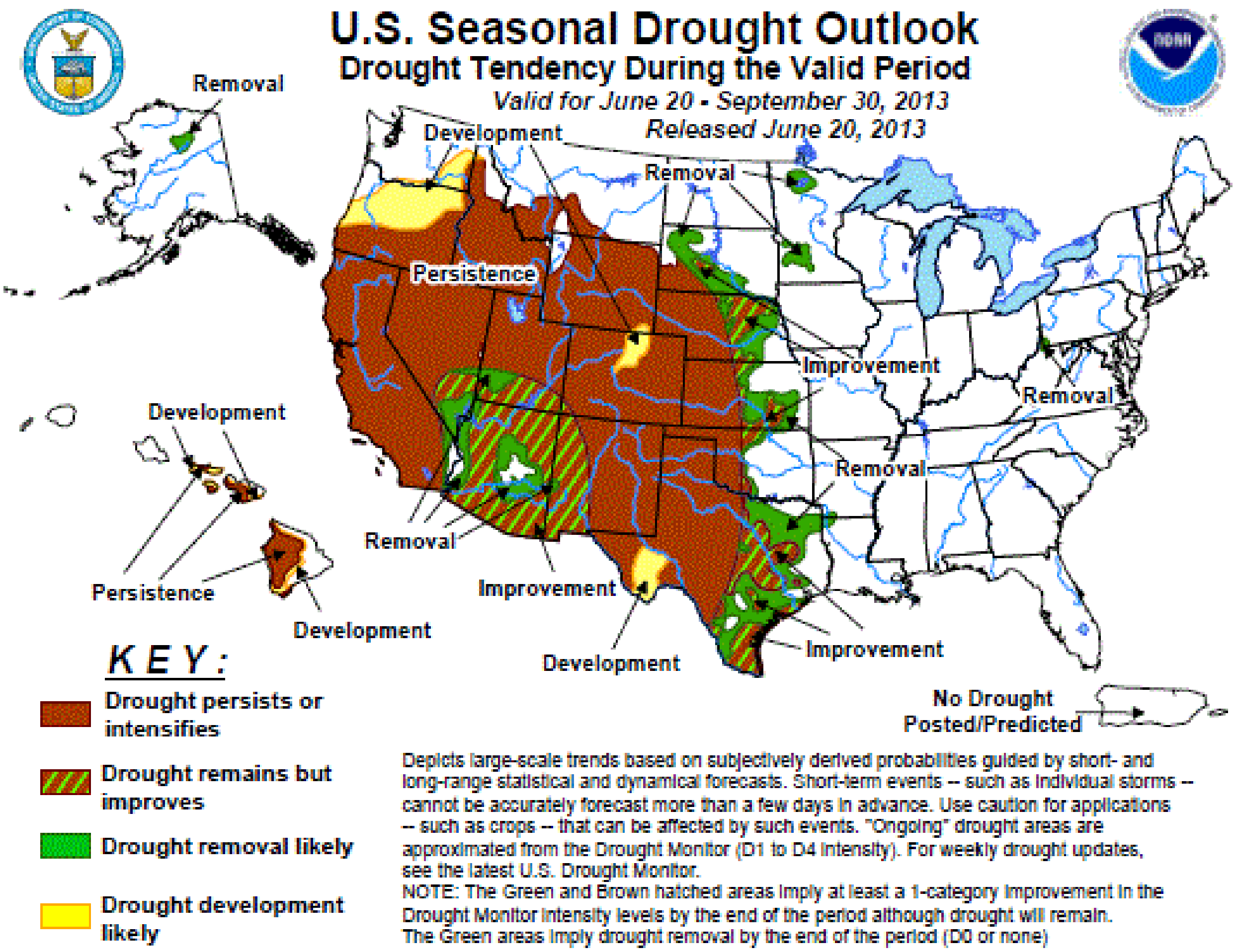
**http://droughtmonitor.unl.edu**

***Released Thursday, June 27, 2013***
***Mark Svoboda, National Drought Mitigation Center***

Source: National Drought Mitigation Center

The U.S. Seasonal Drought Outlook developed by NOAA synthesizes long-term forecasts to generalize drought tendencies across the nation. A sample of this product is shown in Figure 8 for June 2013, which shows that persistent drought is likely to continue throughout most of the western U.S., while a portion of the central and southwestern U.S., including a very small portion of southwestern Colorado near the Four Corners Region, may show some improvement in drought conditions.

**Figure 8. Seasonal Drought Outlook June 20, 2013-September 30, 2013**




Source: NOAA Climate Prediction Center

### *Upper Colorado River Basin NIDIS Pilot*

A pilot effort to develop a drought monitor type of product specific to the Upper Colorado River Basin (UCRB) began in 2009. This effort includes:

- Interviews with water providers and users to influence the design
- UCRB Community on the Drought Portal
- Web based snow model charting tool
- UCRB Weekly Climate, Water and Drought Assessment webinar series
- Monitoring gaps assessment
- Spatial analysis of water demand
- Reconciling estimates of 21st century flows
- Low flow impacts database
- Linkage of climate and river modeling

- Develop and test drought early warning activities

Results of this pilot project have the potential to be applied in other major river basins in Colorado. The pilot project has since morphed into the "Upper Colorado Drought Early Warning System." Current activities include weekly monitoring; drought assessment webinars; and weekly climate, water and drought assessments for Colorado and the Upper Colorado River Region. After a local consensus is reached, monitoring information is sent to the U.S. Drought Monitor along with recommendations.

### 3.2.3 Drought Indicators Modernization

The SWSI has been used, along with the Palmer Index and SPI, as the basis for making decisions for the activation and deactivation of the Colorado Drought Response Plan. While the use of the word "triggers" has been used in the past, the index values have been more appropriately used as guidelines that need to be evaluated with the professional judgment of the WATF before activation of the Response Plan. It had long been recognized that the SWSI methods were in need of modernization, and the validity of the Colorado Modified Palmer Index as a drought indicator had also been called into question. In 2009-2010 a significant effort was made, in coordination with the 2010 Drought Plan revision, to modernize the SWSI index for Colorado and to analyze the effectiveness of the Colorado Modified Palmer Index with respect to how it has performed indicating the severity of past droughts. The findings of these efforts are included in Annex D Drought Monitoring Indices and summarized here.

Careful evaluation and comparison of the CMPDI with SPI at several time scales has revealed some of the following characteristics:

- The 9 and 12 month SPI often behave similarly to the CMPDI.
- The CMPDI correlates well with certain impacts such as wheat yield and water year streamflow, but it does not perform equally well in all parts of the State. The CMPDI is sometimes the best leading indicator of these important impacts. However, the CMPDI has a very long "memory" and does not respond well to fairly rapid changes in hydrologic conditions.
- The 24 and 48 month SPIs are excellent for providing diagnostic documentation "after the fact" on the frequency, severity and areal extent of droughts that have occurred.
- The 3-9 month SPI values are more likely to provide predictive skills of some near future (next 1-9 month) drought impacts. The significance of these indices is highly seasonal and must be interpreted within the framework of seasonal climate cycles and seasonal and regional drought vulnerability.

Opportunities for further study may include the need to assess and evaluate what percent of Colorado is experiencing drought at any given time and for how long. Drought severity (duration, intensity, and area) all influence drought impacts. The CCC is able to produce ongoing time series of the percent of area within Colorado experiencing drought to graphically depict drought impacts.

### 3.2.4 Drought History in Colorado

Several times since the late 1800s Colorado has experienced widespread, severe drought. The most dramatic occurred in the 1930s and 1950s when many states, Colorado included, were affected for several years at a time. Table 6 shows seven multi-year droughts experienced in Colorado since 1893, based on McKee et al. 1999. The 2002 and 2011-2013 drought occurred after the study was published, but the table has been modified and updated to reflect Colorado's most recent and intense droughts based on input from the CCC. Following this section is a history of drought declarations. Details on the more significant droughts, particularly the droughts of 2002 and 2011-2013, conclude the discussion of drought history.

**Table 6 Historical Dry and Wet Periods in Colorado**

| Date | Dry | Wet | Duration (years) |
|---|---|---|---|
| 1893-1905 | X | | 12 |
| 1905-1931 | | X | 26 |
| 1931-1941 | X | | 10 |
| 1941-1951 | | X | 10 |
| 1951-1957 | X | | 6 |
| 1957-1959 | | X | 2 |
| 1963-1965 | X | | 2 |
| 1965-1975 | | X | 10 |
| 1975-1978 | X | | 3 |
| 1979-1999* | | X | 20 |
| 2000-2006* | X | | 6 |
| 2007-2010* | | X | 3 |
| 2010-2012* | X | | 2 |

Source: McKee, et al. 1999
*modified for 2010 Plan Revision and 2013 Plan Update based on input from the CCC

#### *USDA Disaster Declarations for Colorado*

In the past USDA Secretarial Disaster Declarations must have been requested by a governor's authorized representative or by an Indian Tribal Council leader. Damages and losses prompting disaster designation must be due to a natural disaster and a minimum of 30 % production loss in at least one crop in the county must have occurred. The Secretarial Disaster Declaration is widely used and makes low-interest loans and other emergency assistance available for those affected, e.g., to farmers and ranchers in the case of agricultural disasters due to drought. Under a new streamlined process by the Farm Services Agency (FSA), a nearly automatic USDA Disaster Declaration can be made if any portion of a county has experienced eight consecutive weeks of severe drought according to the U.S. Drought Monitor (Congressional Research

Service, 2013). Table 7 lists the disaster declarations related to drought for Colorado from 2003 to the present. The calendar year is listed, along with the type of hazard, the declaration number, and the primary affected counties. As can be seen in Table 7, numerous drought declarations were declared from 2011 through 2013. In early July 2012, 62 of the State's 64 counties were included in a Secretarial disaster designation due to drought. Farmers were then eligible to apply for FSA emergency loans for the next eight months.

**Table 7 USDA Secretarial Disasters 2003-Present**

| Year | Type | Declaration Number and Affected Counties |
|---|---|---|
| 2003 | Drought | **S1797** Baca, Bent, Elbert, Kiowa, Lincoln, Prowers |
| 2003 | Drought, Insects | **S1843** Alamosa, Archuleta, Chaffee, Conejos, Costilla, Crowley, Custer, Dolores, Fremont, Garfield, Hinsdale, Huerfano, La Plata, Lake, Las Animas, Mesa, Mineral, Moffat, Montezuma, Otero, Pueblo, Rio Blanco, Rio Grande, Routt, Saguache |
| 2003 | Drought | **S1890** Cheyenne, Phillips |
| 2004 | Drought, Freeze, Hail | **S1947** Baca, Chaffee, Cheyenne, Custer, Eagle, Fremont, Garfield, Grand, Jackson, Kiowa, Kit Carson, Lake, Lincoln, Phillips, Pitkin, Prowers, Pueblo, Routt, Summit, Yuma |
| 2004 | Drought | **S2009** Moffat |
| 2005 | Drought | **S2031** Huerfano, Las Animas, Rio Blanco |
| 2005 | Drought, Freezing Temperatures | **S2160** Delta, Kit Carson |
| 2005 | Drought, Wind, Heavy Rain, Hail | **S2188** Crowley, El Paso, Lincoln, Otero, Park, Phillips, Pueblo, Teller, Washington, Yuma |
| 2005 | Drought, Crop Diseases, Insect Infestation | **S2217** Logan |
| 2005-2006 | Drought, Crop Diseases, Insect Infestation | **S2287** Huerfano, Kiowa, Las Animas, Sedgwick |
| 2005-2006 | Drought, Fire, High Winds, Heat | **S2327** Adams, Alamosa, Baca, Broomfield, Chaffee, Cheyenne, Conejos, Costilla, Custer, Denver, Dolores, Douglas, Elbert, Fremont, Hinsdale, Huerfano, Kit Carson, Lake, Las Animas, Mineral, Montezuma, Morgan, Prowers, Pueblo, Rio Grande, Saguache, San Miguel, Weld |
| 2006 | Heat, High Winds, Insect pests, Late Freeze, Drought | **S2329** Arapahoe, Archuleta, Bent, Boulder, Crowley, Delta, El Paso, Gunnison, Jefferson, Kiowa, La Plata, Montrose, Ouray, Park, Phillips, Teller, Washington |
| 2006 | Heat, High Winds, Drought | **S2351** Eagle, Garfield, Larimer, Logan, Otero, Pitkin, Rio Blanco, Yuma |
| 2006 | Drought | **S2382** Jackson, Lincoln, Mesa, Moffat |
| 2006 | Drought | **S2480** Sedgwick |
| 2008 | Drought | **S2750** Adams, Arapahoe, Baca, Bent, Cheyenne, Crowley, Douglas, El Paso, Elbert, Huerfano, Kiowa, Kit Carson, Las Animas, Lincoln, Logan, Otero, Park, Prowers, Pueblo, Teller, Washington, Weld |
| 2008 | Drought | **S2802** Fremont |
| 2009 | Drought | **S2970** Dolores, Mesa, Montezuma, Montrose, San Miguel |
| 2010 | Drought, High Winds | **S2996** Costilla, Las Animas |

| Year | Type | Declaration Number and Affected Counties |
|---|---|---|
| 2011 | Drought | **S3080** Baca<br>**S3125** Baca, Bent, Crowley, El Paso, Kiowa, Las Animas, Lincoln, Otero, Prowers, Pueblo<br>**S3131** Archuleta, Baca, Conejos, Costilla, Las Animas<br>**S3133** Alamosa, Baca, Bent, Chaffee, Cheyenne, Costilla, Crowley, Custer, El Paso, Fremont, Gunnison, Huerfano, Kiowa, Lake, Las Animas, Lincoln, Otero, Park, Pitkin, Prowers, Pueblo, Saguache, Teller<br>**S3144** Alamosa, Archuleta, Chaffee, Conejos, Costilla, Custer, Fremont, Gunnison, Hinsdale, Huerfano, Las Animas, Mineral, Rio Grande, Saguache<br>**S3149** Montezuma<br>**S3172** Arapahoe, Douglas, El Paso, Elbert, Jefferson, Lincoln, Park, Teller |
| | Drought, Wildfires, High Winds | **S3117** Baca, Cheyenne, Kiowa, Kit Carson, Prowers |
| | Drought, Fire/Wildfire, Heat/Excessive Heat, Rain, Flooding, Tornadoes, Lightning, High Winds, Hail, Blizzard, Freeze | **S3139** Baca |
| | Drought, Excessive Heat/Rain, Flooding | **S3157** Cheyenne, Kit Carson |
| 2012 | Drought | **S3229** Arapahoe, Cheyenne, Crowley, Elbert, El Paso, Kiowa, Kit Carson, Lincoln, Pueblo, Washington |
| | Drought, Wind/High Winds, Heat/Excessive Heat | **S3260** Adams, Alamosa, Arapahoe, Archuleta, Baca, Bent, Boulder, Broomfield, Chaffee, Cheyenne, Clear Creek, Conejos, Costilla, Crowley, Custer, Delta, Denver, Dolores, Douglas, Eagle, Elbert, El Paso, Fremont, Garfield, Gilpin, Grand, Gunnison, Hinsdale, Huerfano, Jackson, Jefferson, Kiowa, Kit Carson, Lake, La Plata, Larimer, Las Animas, Lincoln, Logan, Mesa, Mineral, Moffat, Montezuma, Montrose, Morgan, Otero, Ouray, Park, Phillips, Pitkin, Prowers, Pueblo, Rio Blanco, Rio Grande, Routt, Saguache, San Juan, San Miguel, Sedgwick, Summit, Teller, Washington, Weld, Yuma |
| | Drought, Wind/High Winds, Fire/Wildfire, Heat/Excessive Heat, Insects | **S3267** Montezuma<br>**S3269** Delta, Gunnison, Mesa, Montrose<br>**S3276** Baca, Cheyenne, Kiowa, Kit Carson, Prowers, Yuma<br>**S3281** Yuma<br>**S3282** Archuleta, Baca, Conejos, Costilla, La Plata, Las Animas, Montezuma<br>**S3284** Baca<br>**S3289** Dolores, Garfield, Mesa, Moffat, Montezuma, Montrose, Rio Blanco, San Miguel<br>**S3290** Jackson, Larimer, Moffat, Routt, Weld<br>**S3315** Logan, Phillips, Sedgwick, Weld, Yuma<br>**S3319** Jackson, Larimer |

| Year | Type | Declaration Number and Affected Counties |
|---|---|---|
| 2013* | Drought, Wind/High Winds, Fire/Wildfire, Heat/Excessive Heat, Insects | **S3455** Montezuma<br>**S3456** Adams, Arapahoe, Baca, Bent, Boulder, Broomfield, Chaffee, Cheyenne, Clear Creek, Costilla, Crowley, Custer, Denver, Douglas, Eagle, Elbert , El Paso, Fremont, Gunnison, Huerfano, Jefferson, Kiowa, Kit Carson, Lake, Larimer, Las Animas, Lincoln, Logan, Morgan, Otero, Park, Phillips, Pitkin, Prowers, Pueblo, Saguache, Sedgwick, Teller, Washington, Weld, Yuma<br>**S3459** Baca, Cheyenne, Kiowa, Kit Carson, Prowers, Yuma<br>**S3461** Archuleta, Baca, Conejos, Costilla, La Plata, Las Animas, Montezuma<br>**S3463** Baca<br>**S3466** Dolores, Garfield, Mesa, Moffat, Montezuma, Montrose, Rio Blanco, San Miguel<br>**S3505** Phillips, Sedgwick, Weld, Yuma<br>**S3508** Larimer, Moffat, Routt, Weld<br>**S3518** Alamosa, Conejos, Costilla, Huerfano, Las Animas<br>**S3539** Archuleta, Dolores, Gunnison, Hinsdale, La Plata, Mineral, Montezuma, Montrose, Ouray, Saguache, San Juan, San Miguel<br>**S3545** Conejos, Hinsdale, La Plata, Mineral, Rio Grande, Saguache |

Source: USDA – Colorado Farm Services Agency
* Through June 26, 2013

### *Governor's Drought Emergency Declarations for Colorado*

In addition to USDA Drought Declarations, the following list shows a timeline for Governor Drought Emergency Declarations over the last 60 years. These differ from USDA declarations because they can provide emergency assistance beyond that targeted for agriculture.

- 8/3/1951 – Governor Dan Thornton declared a drought emergency in La Plata, Dolores, Montezuma, Rio Grande, Archuleta, Conejos, Alamosa, Saguache, Costilla, and Mineral counties due to a shortage of feed for livestock.
- 8/22/1952 – Governor Dan Thornton declared a drought emergency for Elbert, Douglas, Kit Carson, El Paso, and Cheyenne counties due to a shortage of feed for livestock.
- 2/10/1977 – Governor Richard Lamm issued a "Conserve Water! Month" proclamation. The Proclamation stated the snowpack was 30% of normal, and that the eastern plains had not received adequate precipitation for the second straight year. The intention of the proclamation was to encourage water conservation is order to lessen the impact of drought.
- 3/31/1977 – Governor Richard Lamm issued a "Conserve Water Year" proclamation, essentially extending the above proclamation out for the entire year. .
- 7/20/1977 – Governor Richard Lamm issued a proclamation for the formation of the Drought Council.
- 2/16/1978 – Governor Richard Lamm issued a proclamation to retain the Drought Council until the end of the drought.
- 8/1/1994 - In response to extremely arid conditions, Governor Roy Romer activated several Impact Task Forces to assess impacts.
- 7/29/1996 - Governor Roy Romer issued an Executive Order (D000996) proclaiming a Drought Disaster Emergency Declaration. Fifteen counties were included in a request for

USDA assistance. The Directive activated the Water Availability, Agriculture, Wildfire, Tourism, Municipal Water, and Review and Reporting Impact Task Forces.
2002 – Governor Bill Owens activated eight Impact Task Forces during the 2002 drought. (Colorado received a statewide Presidential Disaster Declaration for the wildfires)

- 2011 – Governor John Hickenlooper activated the Drought Mitigation and Response Plan and the Agricultural Impact Task Force due to drought conditions in southeast Colorado.
- 2012 - Governor John Hickenlooper requested and received a Presidential Disaster Declaration due to severe wildfires associated with ongoing drought conditions. The Governor also expanded activation of the Drought Mitigation and Response Plan from the southeast to statewide.
- May 2013 - Governor John Hickenlooper activated the Municipal Water Impact Task Force in response to growing water availability concerns due to ongoing and expanded drought conditions since 2011.

### *Major Droughts*

The following is a summary of information on major droughts that have affected Colorado.

**The 1930's Drought –** The Dust Bowl drought severely affected much of the United States during the 1930s. Figure 9 illustrates the extent of the Dust Bowl as defined by the Natural Resources Conservation Service.

## Figure 9. Extent of the Dust Bowl


Source: Public Broadcasting System American Experience "Surviving the Dust Bowl"
www.pbs.org/wgbh/amex/dustbowl/maps/index.html

The drought came in three waves, 1934, 1936, and 1939-1940, but some regions of the High Plains experienced drought conditions for as many as eight consecutive years. The soil, depleted of moisture, was lifted by the wind into great clouds of dust and sand which were so thick they concealed the sun for several days at a time. They were referred to as "black blizzards." The period itself is known as the dust bowl. The "black blizzards" were caused by sustained drought conditions compounded by years of land management practices that left topsoil susceptible to the forces of the wind.

The agricultural and economic damage devastated residents of the Great Plains. The Dust Bowl drought worsened the already severe economic crises that many Great Plains farmers faced. In the early 1930s, many farmers were trying to recover from economic losses suffered during the Great Depression. To compensate for these losses, they began to increase their crop yields. High production drove prices down, forcing farmers to keep increasing their production to pay for both their equipment and their land. When the drought hit, farmers could no longer produce enough crops to pay off loans or even pay for essential needs. Even with federal emergency aid, many Great Plains farmers could not withstand the economic impacts of the drought. Many farmers were forced off of their land. One in ten farms changed possession at the peak of the drought. The agricultural and economic damage devastated residents of the Great Plains.

Many factors contributed to the severe impact of this drought and in its aftermath a better understanding of the interactions between the natural elements (e.g., climate, plants, and soil) and human-related elements (e.g., agricultural practices, economics, and social conditions) of the Great Plains developed. As a result, farmers adopted new cultivation methods to help control soil erosion in dry land ecosystems; consequently, subsequent droughts in the region have not had the same impact.

**The 1950s Drought** – Fueled by post-war economic stability and technological advancement, the 1950s represented a time of growth and prosperity for some Americans. But while much of the country celebrated a resurgence of well-being, many residents of the Great Plains and southwestern United States were suffering. During the 1950s, the Great Plains and the southwestern U.S. withstood a five-year drought, and in three of these years, drought conditions stretched coast to coast. The 1950s drought was characterized by both decreased rainfall and excessively high temperatures. The first effects of the drought were felt in the southwestern U.S. in 1950 and by 1953 conditions had spread to Oklahoma, Kansas, and Nebraska. By 1954, the drought encompassed a ten-state area reaching from the mid-west to the Great Plains, and southward into New Mexico. The area from the Texas panhandle to central and eastern Colorado, western Kansas, and central Nebraska experienced severe drought conditions. The drought maintained a stronghold in the Great Plains, reaching a peak in 1956. The drought subsided in most areas with the spring rains of 1957. A disaster of this magnitude can create severe social and economic repercussions, as was the case in the southern Great Plains region. The drought devastated the region's agriculture, with crop yields in some areas decreased as much as 50%. Excessive temperatures and minimal rainfall scorched grasslands typically used for grazing. With grass scarce, hay prices rose, forcing some ranchers to feed their cattle a mixture of prickly pear cactus and molasses. By the time the drought subsided in 1957, many counties across the region were declared federal drought disaster areas (NCDC, 2003).

**The 1977 Drought** – During 1976 and 1977, the state experienced record-low streamflows at two-thirds of the major stream gages, records that held until the 2002 drought. In addition, the Colorado ski industry estimated revenue losses at $78.6 million; agriculture producers had to incur higher crop production costs due to short water supplies; and numerous municipalities were forced to impose water use restrictions on their customers. The state's agriculture producers and municipalities received over $110 million in federal drought aid as a result of the 1976-1977 drought.

**1980-1981 Drought** – Although short lived, beginning in the fall of 1980 and lasting until the summer of 1981, this drought generated costly impacts to the ski industry and initiated a huge investment in snow making equipment; it motivated the writing of the "Colorado Drought Response Plan" and the formation of the "Water Availability Task Force" described in Section 2.1.1.

**1994 Drought** – On August 1, in response to extremely arid conditions, the Governor activated, by memorandum, several Task Forces to assess impacts: Agriculture (blowing soils), Wildlife, Wildfire, Commerce/Tourism, and Review and Reporting. Significant impacts reported included an increase in wildfires statewide, loss to the winter wheat crops, difficulties with livestock feeding, and impacts to the State's fisheries.

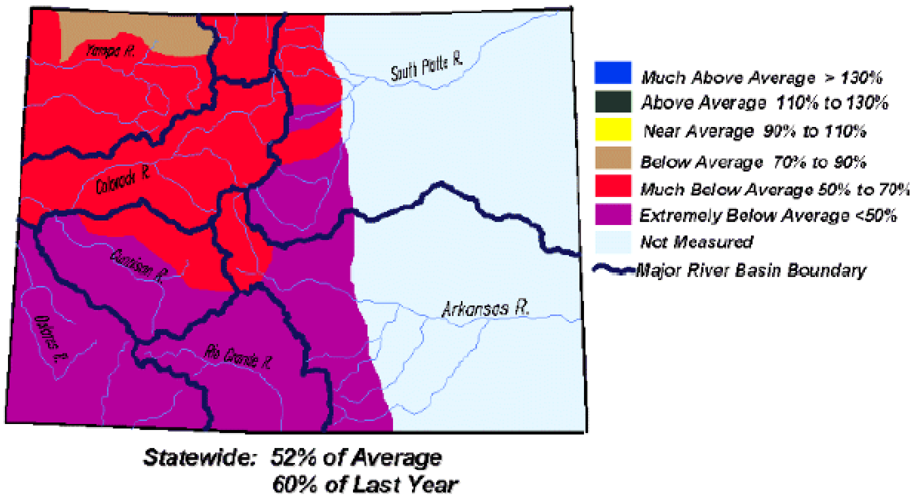
**1996 Drought** – July 29, the Governor issued an Executive Order (D000996) proclaiming a Drought Disaster Emergency Declaration. Fifteen counties were included in a request for USDA assistance. The directive activated the Water Availability, Agriculture, Wildfire, Tourism, Municipal Water, and Review and Reporting Task Forces to monitor the situation, and evaluate impacts to potable water supplies in the southwest and northwest portions of the State. The State Drought Review and Reporting Task Force provided a Drought Status Report to the Governor's Office. The situation called for continued monitoring by the WATF until fall and winter precipitation alleviated further concerns.

**2002 Drought** – On a statewide basis, 2002 was the most intense single year of drought in Colorado's history (Pielke and Doesken, 2003). This was an extremely dry year embedded in a longer dry period (2000-2006), similar to 1934 being an extremely dry year within a period of longer drought (1931-1939). Holders of senior water rights dated 1865 and 1881 placed calls on the South Platte River—the most senior calls placed on the river in over a generation. In the southern part of the State, the Rio Grande nearly ceased to flow (Hall, 2002). The magnitude of this drought cannot be overstated. These conditions were rated "exceptional" by the U.S. Drought Monitor and were the most severe drought experienced in the region since the Dust Bowl (Tronstad and Feuz, 2002). Indeed, based on studies of tree rings and archaeological evidence from aboriginal cultures, the 2002 drought was arguably the most severe in the recorded history of the State (Pielke and Doesken, 2003).

The drought of 2002 had its roots in the autumn of 1999. After a very wet spring and a soggy August, precipitation patterns reversed and the fall of 1999 was very dry across most of Colorado. The winter of 1999-2000 followed with below average snow fall and above average temperatures, dryness continued into spring and early summer over northeast Colorado and the South Platte watershed and drought conditions quickly emerged. A persistently hot summer with evapotranspiration rates higher than average deteriorated conditions. The 2001 water year, although less extreme, continued to trend on the dry side.

October 2001 weather patterns appeared more favorable as a variety of storm systems crossed the region. However the storms resulted in little moisture and when the month was over precipitation totaled again less than 50% of average over the majority of the state. November and December brought some snow accumulation but snow water content remained below average; and January's above average snowfall came down in the Front Range urban corridor and the southeastern plains, contributing very little to overall water supplies. February and March, despite cooler temperatures and numerous storm systems, did not see the copious wet snows that Colorado spring snowstorms typically produce. By the end of March 2002, the statewide snow water equivalent was a mere 52% of average and portions of Colorado's mountains were even further below average (see Figure 10).

**Figure 10. April 1, 2002 snowpack for the State of Colorado**

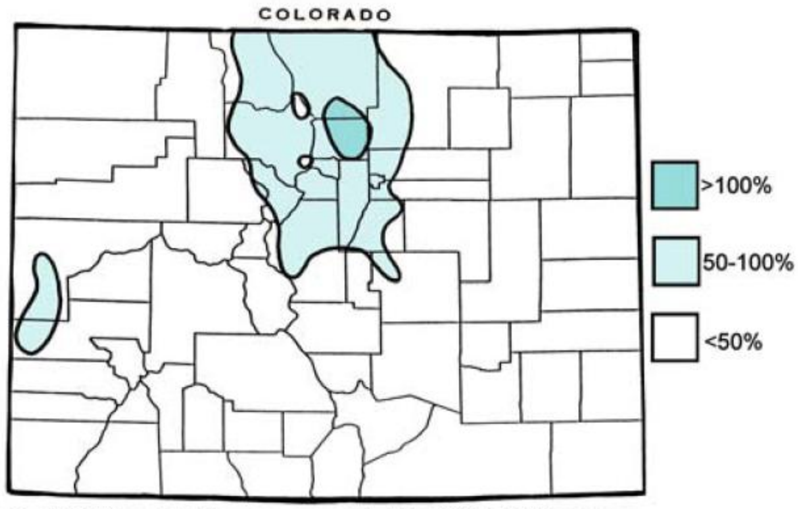



Source: National Resources Conservation Service

The spring storms that sometimes dump heavy and widespread precipitation were nonexistent in April and temperatures soared to record highs. In the mountains snow melted or evaporated at an alarming rate. Relative humidity on several afternoons fell to below 10%. Fire danger, which typically stays low to moderate through early June, was already high by mid April, and the first severe forest fire of the season ignited near Bailey on April 23 (Snaking Fire).

May was even drier (see Figure 11). At a time of year when Colorado's rivers and streams are normally churning with snowmelt runoff, there were only mere glimpses of snowmelt flows. Irrigation water demand was high, and it was soon obvious that supplies would not last through the growing season. Municipalities began to face the possibility that available water supplies might not be sufficient to meet typical summertime demand. Many areas implemented strict water conservation restrictions. Other forest fires erupted and each new blaze seemed to spread faster than the one before.

**Figure 11. May 2002 Precipitation as a Percent of 1960-1991 Average**

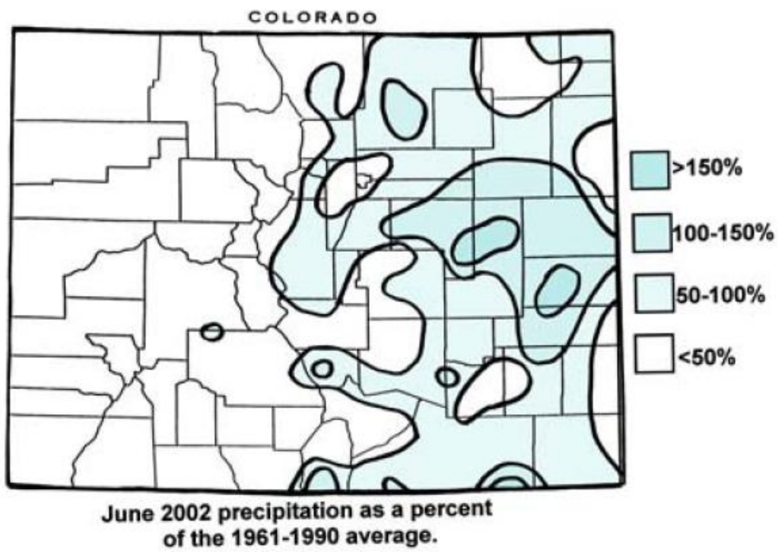


May 2002 precipitation as a percent of the 1961-1990 average.

Source: *The Drought of 2002 in Colorado*. Nolan Doesken and Roger Pielke, Sr.

June arrived accompanied by relentless summer heat, temperatures routinely climbed above 90 degrees Fahrenheit at lower elevations east and west of the mountains. Vegetation that normally grows lush and tall with spring moisture barely greened up. Relative humidity often dropped to less than 10%, and bans on outside burning were enforced statewide. Little or no precipitation fell for the entire month over western Colorado (see Figure 12). Winter wheat crop conditions continued rapid deterioration, and ranchers quickly sold or relocated their herds in response to the poor range conditions and high cost of feed. The most severe fires of the season erupted in June, including the Hayman fire southwest of Denver which quickly grew to be the largest documented forest fire in Colorado (217 $mi^2$) on record .

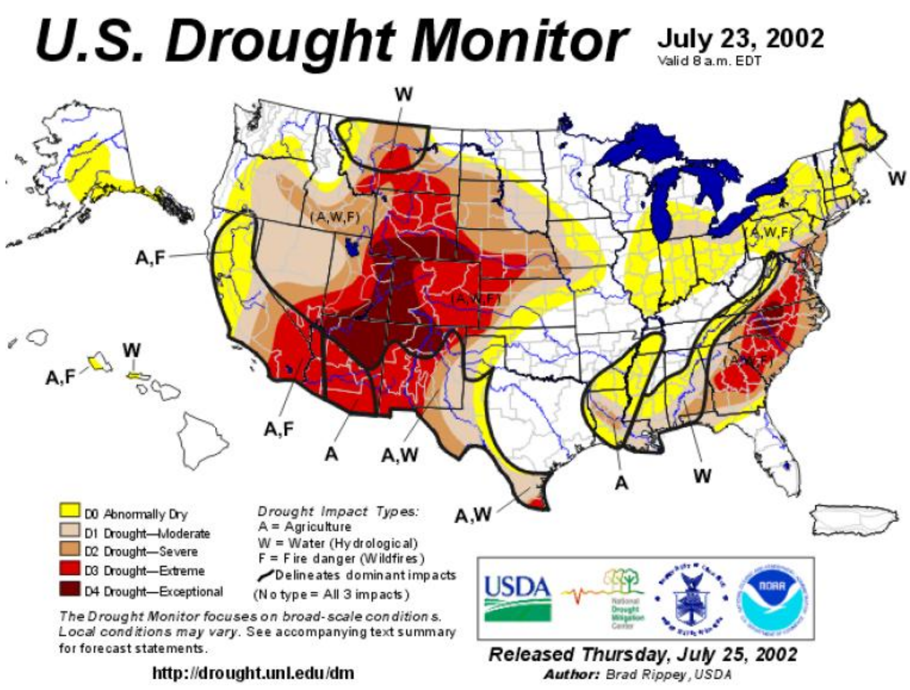
## Figure 12. June 2002 Precipitation as a Percent of the 1961-1990 Average




Source: *The Drought of 2002 in Colorado*. Nolan Doesken and Roger Pielke, Sr.

July brought a few changes. Below average precipitation persisted statewide and temperatures were above average for the fourth consecutive month. By late July, the entire state of Colorado was in a serious drought. (See Figure 13)

## Figure 13. 2002 Drought – Drought Monitor from July 23, 2002




Source: National Drought Monitor

The first several days of August brought some hope for a respite but the monsoon moisture surge was brief. By mid-August, 100°F+ temperatures led media reports to liken conditions to the great Dust Bowl of the 1930s. As the month neared its end, a subtle change in weather patterns brought a round of spring-like thunderstorms loaded with hail and high winds to portions of eastern Colorado. Humid and stormy weather continued into September and for the first time since August 2001, the majority of Colorado received above average rainfall.

Fortunately for Colorado, drought conditions continued to slowly recede during the end of 2002 and into 2003. The March 18, 2003 blizzard that hammered the Colorado Front Range with as much as 87 inches of snow significantly relieved many of the lingering effects of the drought. Some areas of the state, however, continued to experience moderate to severe drought conditions, but these droughts did not affect the state as a whole. The 2007 Drought Update reported that during calendar year 2006, at least some portions of the state also experienced severe drought conditions (D2 drought intensity) between March and December, while additional parts of the state experienced extreme drought conditions (D3 drought intensity) between May and September.

In the 2007 DWSA, many (64% of respondents) felt the drought had passed, and that the state had "fully recovered" from the 2002 drought. Since 2003 both drought conditions the state water situation has improved, but it has taken nearly eight years to recover from the 2002 drought. Discussion in the April 2010 WATF meeting suggested that the state's water situation was the best it had been since the late 1990s, with near average snowpack and reservoir storage in most basins in the state.

### *Historical Perspective of the 2002 Drought*

The year 2002 is considered the driest single year in recorded Colorado history. Statewide snowpack was at or near all time lows. Water year 2002 precipitation was extremely low when compared to 1961-1990 normal precipitation levels. There have been individual years in Colorado that have been drier at individual points or portions of the State – 1894, 1934, 1939, 1954 and 1966 are some examples. However, what made 2002 so unusual was that all of the State was dry at the same time. By all accounts, soil moisture was nearly depleted in the upper one-meter of the soil profile over broad areas of Colorado by late August 2002. 2002 was clearly the driest year in over 100 years of record based on streamflow. Reservoirs dropped to extremely low levels. The excess of the late 1990s helped Colorado survive the drought of 2002, but very little useable water remained even with strict enforced water restrictions. For a more detailed historical impact of the 2002 drought, see *The Drought of 2002 in Colorado*, authored by Nolan Doesken and Roger Pielke, Sr. and referenced many times in this Plan.

### *2002 Drought and the Impact Task Forces*

All eight impact task forces were activated by the Governor during the 2002 drought. One outcome was the 2003 Drought Impact and Mitigation Report. It identified impacts from the drought, as well as actions or mitigation measures that already had been, or would be taken to address the impacts of an ongoing drought. The report also indentified state and federal agencies and entities that are associated with actions and mitigation measures, as well as implementation status and related costs of those actions and mitigation measures. Each of the ITFs provided a summary table listing these actions and activities, also summarized in Appendix B.

**2011-2013 Drought** – Even though 2011 was very wet across northern Colorado, the extreme drought during this time in Texas, New Mexico and Oklahoma was also felt in the Rio Grande and Arkansas Basins in Colorado. This trend continued in those Basins as 2012 began but also increased in breadth across the rest of Colorado. Based on the U.S. Drought Monitor, approximately 50% of Colorado was already under drought conditions at the beginning of 2012. Minimal snow accumulation further exacerbated the already dry conditions as below average snowfalls and above average temperatures occurred in February and March. The above average temperatures continued into April and May, causing early runoff as the thin snowpack quickly melted. The entire State was under drought conditions by the end of May 2012, causing concern as it included the regions where 80% of the State's water supply originates. Streamflows measured only slightly better compared to the extreme drought years of 1934, 1954, 1977 and 2002 (Ryan and Doesken, 2013).

Agriculture was highly impacted. Soil moisture was low on the plains during the spring planting season and temperatures were high, giving crops little chance to establish and survive the summer. This was compounded by less water availability for summer irrigation diversions due to low snowpack and runoff. June was very hot, consistently over 100°F, especially in the eastern plains of the state. These temperatures rivaled those observed during the historic drought years of 1934 and 1954, with many other areas setting high temperature records. A majority of pasture and rangeland areas were classified as "poor" or "very poor" by August of 2012. Hay was hard to come by due to production decreasing to 10% to 50% of average and limited supplies from neighboring states also impacted by drought. This caused prices to drastically increase, necessitating trucking hay in from northern Montana and Idaho, and even as far away as the Carolinas. Crop prices also increased in 2012. For example, corn prices increased 43% over two years as nearby corn-producing regions in other states also struggled with drought. High commodity prices helped some producers through the drought as they were able to sell fewer commodities and still bring in enough to cover their costs. Still other producers were not able to take advantage of the high prices because the lacked the product to sell.

The multi-year drought in 2011-2013 also deteriorated vegetative cover across the state's Eastern Plains. The exposed soil, combined with heavy winds, created dust storms similar to those of the devastating 1930's Dust Bowl. Some farmers lost entire crops with one storm, causing immense financial strain and emotional hardship. In early June 2013, many areas on the Eastern Plains normally inhabited by crops or cattle were barren. Many ranchers sold their herds because grasses had gone dormant (or had even died) and hay was expensive and in short supply. Even the smallest wind can create dust storms in Southeastern Colorado where the soil has become very thin after repeated dry years. Recovering from these conditions will take time, but many farms are implementing updated farming practices to help mitigate the effects of drought. These techniques include no-till farming and allowing crop residue to remain after harvest to help anchor the soil (Denver Post, 2013).

Dust can have other impacts that exacerbate drought conditions. The dust-on-snow phenomenon has been increasingly evident in recent years, particularly in the spring of 2013. The snowpack that the State relies on for water supplies, agriculture, recreation, habitat, and for many other economic sectors melts out even faster due to the presence of dust that settles on the snow. This dust is borne from wind and often from storms that originate in Arizona, New Mexico and Utah. The absorption of heat from the dust-laden sun hastens snowmelt, causing rapid loss of snowpack instead of the slow melt over a longer period of time that is desired for capture in storage reservoirs. Dust-covered snow can absorb 70% more solar energy compared to the 5 to 20% that is absorbed with clean snow (Durango Herald, 2013). Snowpack may already be thin from little snowfall in the preceding winter, further compounding the issue. Dust events that occurred repeatedly in April 2013 were followed by large snow events in the San Juan Mountains, Steamboat Springs, Summit County, Vail and Aspen, thus layering the dust throughout the snowpack. Runoff greatly increases when the dust layers converge as melt occurs. Faster melting of snowpack decreases the likelihood that the water can effectively be captured in storage reservoirs for use in the summer when it is needed the most. This also affects late-season base flows in streams, a problem for irrigators who rely on this water for diversions (Denver Post, 2013b).

Drought conditions and a period of extremely hot temperatures in June 2012 also contributed to very dry forests, contributing to the conditions that led to the High Park fire in northern Colorado and the Waldo Canyon fire near Colorado Springs, two of Colorado’s most destructive. These wildfires prompted a Presidential Disaster Declaration to be declared the end of June 2012 to provide federal disaster assistance to supplement state and local recovery efforts. Insurance claims totaled more than more than $453.7 million for the Waldo Canyon fire (Associated Press, 2013). This does not include the costs to fight the fire. Wildfires continued to burn throughout the State in 2012 until the last fire, the Fern Lake Fire in Rocky Mountain National Park finally extinguished in January 2013, a testament to how dry the forests were coupled with a low snowpack at the end of the year. Dry conditions on the Eastern Plains also contributed to an extended grass fire season. Typically these fires occur in the spring, but in 2012 they were experienced well into the summer. Approximately 45,000 acres were scorched in a matter of days, destroying 23 structures, including 5 homes, as a result of the Last Chance Fire.

At the time, the Waldo Canyon Fire was the most destructive fire in Colorado history in terms of structures lost, burning approximately 346 total homes (The Gazette, 2012). However, the Black Forest Fire, also near Colorado Springs, surpassed it a year later when a record-setting 498 homes were destroyed and 28 damaged in June 2013 (El Paso County Sheriff’s Office, 2013).

Other impacts seen during the 2011-2013 drought were decreased rafting numbers in 2012 due to low streamflows and wildfire conditions making some river reaches inaccessible. Colorado’s ski industry, another important economic driver for the state, experienced an 11.9% decrease in visits for the 2011-2012 season as compared to the five year average. Many ski resorts closed early in 2012 because of minimal March snowfall and high temperatures. Both of these industries have developed marketing and operations strategies in recent years to mitigate economic impacts due to drought. In the agriculture sector, the Arkansas Basin lost approximately 1,300 jobs and $105 million in economic activity (Gunter et al., 2012).

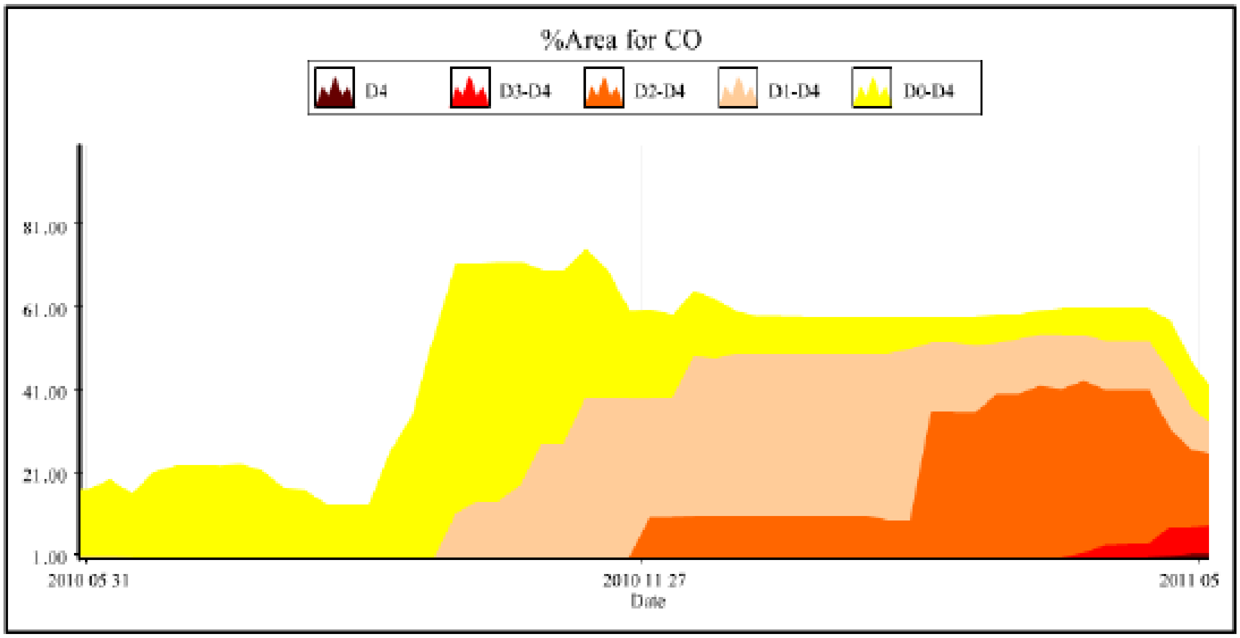
Reservoir levels in many portions of the State helped abate some of the drought impacts seen in 2011-2013. Had they not been at levels sufficient for carryover storage into 2012 due to record breaking high snowpacks in 2011 in many river basins, many of the impacts discussed above may have been worse. However, since May 2012, reservoir storage has dropped below average in most basins. Some relief was brought to northern Colorado from late spring storms that boosted snowpack in 2013, but reservoirs in the region remain below normal.

Figures 14 and 16 present time series graphs in year intervals beginning in May 2010 as a visual representation of the development of the 2011-2013 drought, These figures illustrate what percentage of the State was affected by drought according to the following intensities:

- D0: Abnormally Dry
- D1: Drought – Moderate
- D2: Drought – Severe
- D3: Drought – Extreme
- D4: Drought – Exceptional

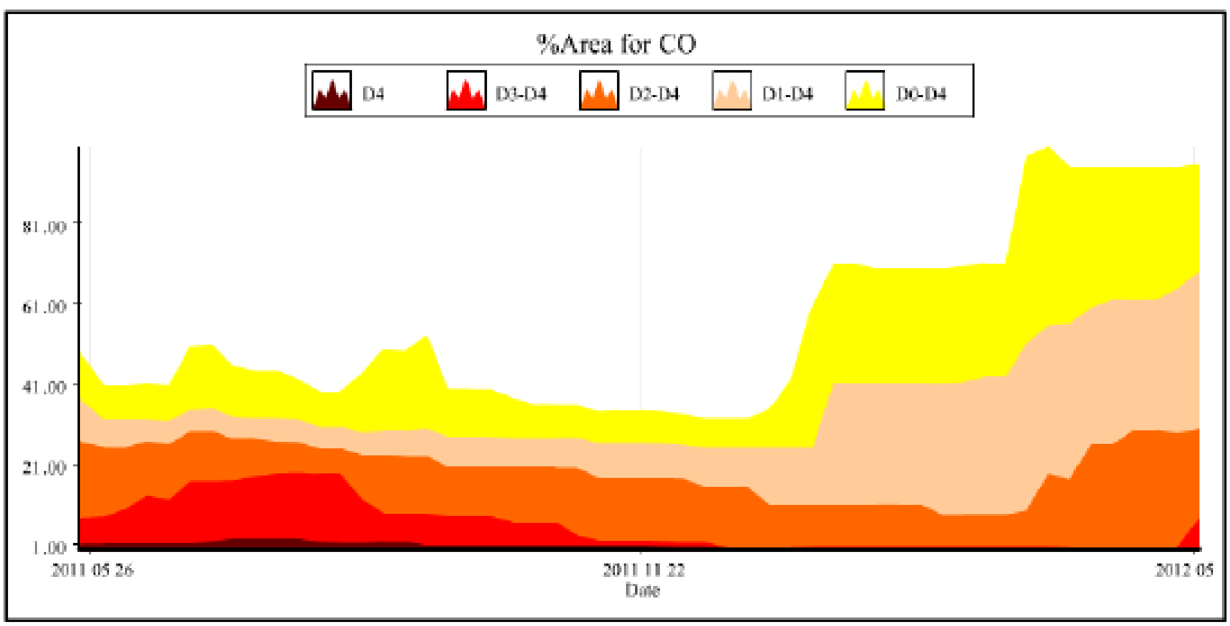
Beginning in May 2010, the majority of the state was not experiencing drought, though some regions were classified D0. By fall of 2010, some moderate drought conditions began, which elevated in intensity throughout the end of 2010 and into the beginning of 2011. However, the wet conditions during the spring and summer of 2011 suppressed the severity of drought conditions in northern Colorado. By early 2012 drought conditions began to expand and strengthen in intensity. The whole state was, at a minimum, under a severe drought by the summer of 2012. These conditions have generally persisted as of May 2013.

## Figure 14. Drought Time Series: May 2010-May 2011



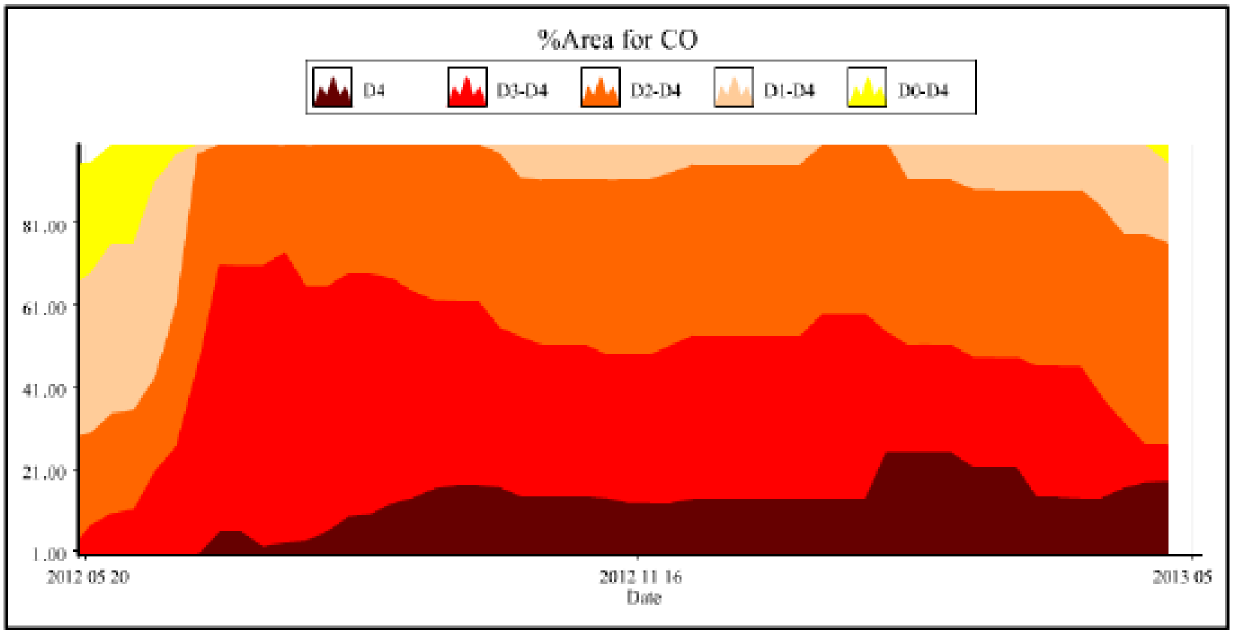

Source: NIDIS U.S. Drought Portal

## Figure 15. Drought Time Series: May 2011-May 2012




Source: NIDIS U.S. Drought Portal

## Figure 16. Drought Time Series: May 2012-May 2013




Source: NIDIS U.S. Drought Portal

### *2011-2013 Drought and the Impact Task Forces*

The Agricultural Impact Task Force met for much of 2011 and 2012 following activation by the Governor in 2011, bringing together Farm Service Agency personnel and state water managers to report failed and prevented planting acreages, updates on CRP (Conservation Reserve Program) grazing availability as well as emergency loan status and disaster declarations status by county.

Governor John Hickenlooper activated the Municipal Water Task Force (MWTF) in May 2013 response to growing water availability concerns. The MWTF began assessing pending and 2013 drought impacts on municipal water supply and public health impacts and make recommendations for response actions.

## Probability of Future Droughts

Historical analysis of precipitation shows that drought is a frequent occurrence in Colorado (McKee et al., 1999). Short duration drought as defined by the three-month Standardized Precipitation Index (SPI) occur somewhere in Colorado in nearly nine out of every ten years (McKee et al., 2000). However, severe, widespread multiyear droughts are much less common.

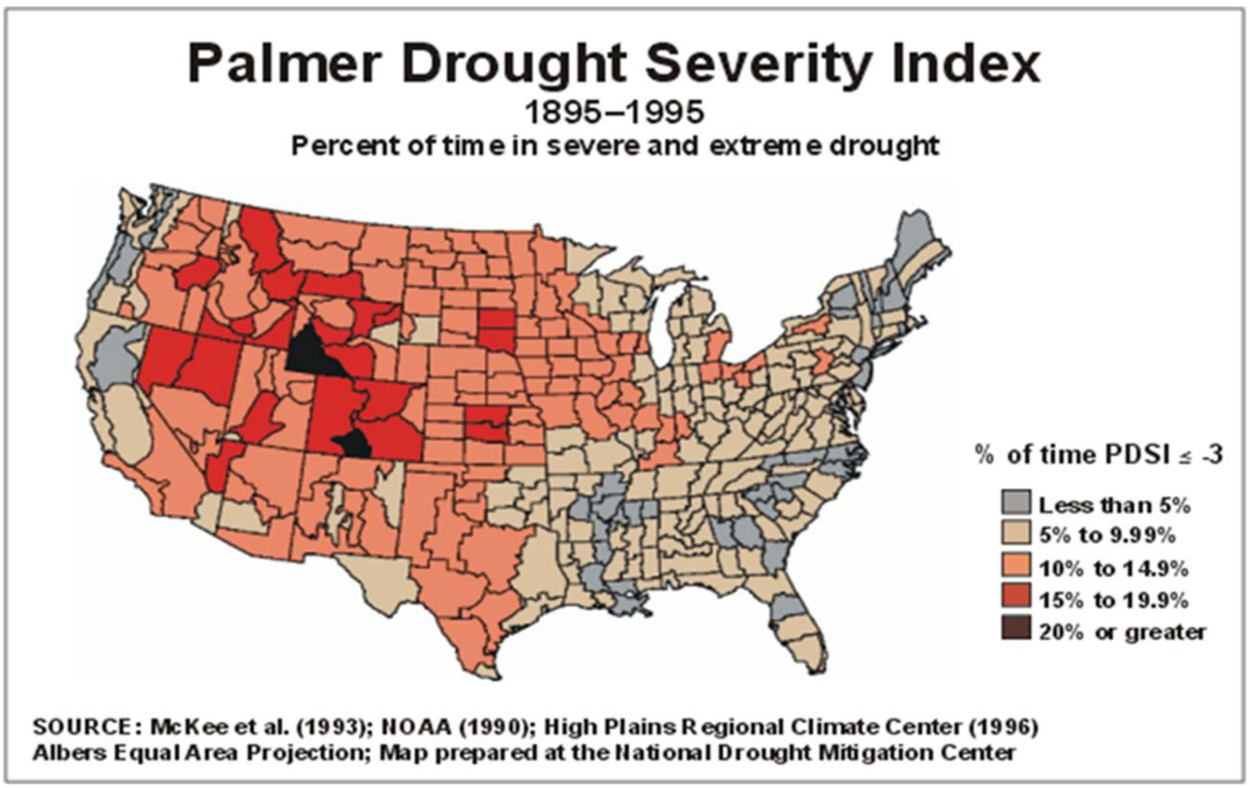
According to the *2004 Drought Water Supply Assessment* (DWSA), there have been six recorded drought incidents totaling 36 "dry" years which impacted the State of Colorado since 1893, or a span of 111 years. (2004-1893 = 111 years). This formula evaluates that the probability of a drought occurring in any given year is 32.4%. This is further supported by the statement that "short duration drought as defined by the 3-month SPI occur somewhere in Colorado in nearly nine out of every ten years." (McKee et al., 2000)

NOAA projects short term future probability by releasing U.S. Seasonal Drought Outlook maps that project anticipated drought conditions three months out. The June through September 2013 Outlook is shown as Figure 8. According to NOAA, in the short term, drought is expected to persist or intensify throughout most of Colorado, and will likely return to the Northern Front Range. A small portion in the Four Corners Region of the State is forecast to see some improvement in drought conditions.

Figure 17, from the NDMC, illustrates that most of Colorado has experienced severe or extreme drought between 15 and 19.9% of the time over a 100-year period.

Climate change could increase the frequency of drought in Colorado in the future. The next section (Section 3.2.5) discusses climate change as it relates to the probability of future droughts and its general implications for the State.

**Figure 17. United States: Percent of Time in Drought, 1895–1995**



### 3.2.5 Other Drought Implications in Colorado

#### Climate Change

The hydrology and water resources, and hence the economy of Colorado, is extremely sensitive to climate. Climate change researchers around the world have recognized mountain systems as sensitive bellwethers of regional change. The interannual variability of the snow resource, the impacts of rapidly emerging factors such as dust-on-snow, and the possibility that climate change could cause substantial long-term reductions in Colorado's seasonal snowcover, highlight the vulnerability of the state's mountain snowpack and the economies that depend on the predictable storage and release of the water supply from snowmelt.

Multifaceted stress on water supply such as irrigation and municipal demands, mandated biological flows, and the increasing need for hydropower, coupled with climate variability and change, are increasing the importance of supply forecasting to both water managers and business markets. While the scientific understanding of climate change is ever evolving and entails many complexities when linking it with future trends in drought, in general, climate change is projected to increase the frequency of drought events in Colorado. As a result of increasing temperatures, water yields will generally decrease. Warmer temperatures will likely result in precipitation occurring as rain rather than snow, decreased high-elevation snowpacks, an earlier spring melt of the decreased snowpack, more intense precipitation events, and increased evapotranspiration (WWA, 2011, CWCB 2008, CWCB 2010, Knowles et al., 2006, Mote 2006, Saunders 2005, Udall 2007). Consequently, runoff will start earlier and end earlier. Reservoirs will fill earlier, and what cannot be stored in the spring and early summer will be spilled when agricultural demands are not as great as they are later in the summer. Decreased runoff in the summer will result in additional reservoir drawdown and many studies agree that higher temperatures and lower precipitation during summer months will further increase agricultural demands, thus causing even more stress on reservoir storage even when annual total precipitation is projected to increase (CWCB, 2008; CWCB, 2012).

The International Panel on Climate Change (IPCC) indicated that predicted changes in mean flow or flow variability could cause physical infrastructure to be inadequate for intended purposes, or increase the risk of failure of the water resource system under extremes of drought (IPCC, 2007). While such risks may be somewhat buffered in large water systems by robustness and resilience in the design of the system, smaller systems may be extremely vulnerable under climate scenarios beyond those considered in their design. However, to illustrate the uncertainty and evolving understanding of climate change science, a report released in 2012 by the IPCC indicated that large uncertainties still exist in terms of trends with respect to drought on a global scale (Congressional Research Service, 2013). The State has been paying increased attention to climate change projections from the IPCC, particularly with a new IPCC report being released in 2013. The State has also been involved regionally and nationally in policy-making decisions to reduce vulnerabilities due to climate impacts to the various sectors that drive Colorado’s economy. The Climate Action Plan that was developed in 2007 identifies the need to investigate vulnerabilities of the State's water supplies to climate change and to plan for severe drought (as well as other risks) resulting from climate change. More recently, the Colorado Climate Preparedness Project completed in 2011 for the State of Colorado assessed impacts to five climate-sensitive sectors: water; wildlife, ecosystems and forests; electricity; agriculture; and outdoor recreation. By gathering information through interviews within each sector and background materials, the report summarized climate impacts, adaptation activities, options, and recommendations for each of these sectors to reduce impacts and losses and be as resilient as possible to changes in climate.

The State has also held conferences to bring water providers, planners, managers, and government officials together to assess drought risk, impacts, and preparedness in Colorado, and to consider the improvements that will be needed for management under different conditions such as climate change. The Governor's Conference on Managing Drought and Climate Risk was held in October 2008 and included attendees from state, federal and local agencies. The September 2012 CWCB Statewide Drought Conference program focused on building a drought resilient economy through innovation which included discussions on climate variability. These forums are important to bring stakeholders together to discuss adaptive strategies, incorporate variability into decision making, and understand the complexities and challenges associated with the constantly evolving nature of climate science. In addition to the formal conferences the Colorado Water Conservation Board and Western Water Assessment jointly held a series of three workshops on *'Dealing with Drought – Adapting to Climate Change'* in the Fall of 2009 that were targeted to local water utilities and municipalities.

Annex C contains a more detailed high level analysis of possible implications of climate change for drought in Colorado. Assessments at 16 locations conducted as part of the 2013 update place projections of future streamflow in context with the recent past, and reconstructions of pre-historic streamflows from records of tree-ring widths. The Colorado River Water Availability Study (CRWAS) sponsored by the CWCB, investigated water availability on the Colorado River under a range of climate change scenarios. CRWAS analyzed drought duration intensity and the likelihood for a range of possible future conditions. Refer to Annex C for the findings of this analysis.

## Water Rights

Under the Colorado system of prior appropriation, also known as "first in time, first in right," claims with earlier adjudication dates and earlier appropriation dates have senior rights while claims with more recent adjudication dates and appropriation dates have junior rights. During droughts, senior rights take precedence over junior rights. Use will be reduced or cut off for junior rights, protecting senior rights. Colorado's water supply fluctuates continually. During times of drought, when water is scarce, the prior appropriation doctrine has profound implications for water management. The topic of drought and Colorado Water Rights is discussed in more detail in Annex B Drought Vulnerability Technical Information. Included is a discussion on the system of prior appropriation, a summary of river administration during the

2002 drought, and recommendations for future studies. River administration during the 2011-2013 drought is not discussed because the 2013 update to the Drought Mitigation and Response Plan occurred in the midst of this multi-year drought and therefore only preliminary data were available. Once the drought event has concluded, future plan updates should include more detailed information on river administration during this timeframe.

## 3.3 Assessing Vulnerability by Jurisdiction

The state risk assessment is to include an overview and analysis of the State's vulnerability based on estimates provided in both the local and state risk assessments. The plan must also identify those jurisdictions that are most threatened and most vulnerable to loss and damage due to drought. The following section follows the FEMA requirements and explains the process used to analyze information from the local risk assessments, as well as a requirement that the Plan reflects changes in development in hazard prone areas.

According to FEMA's risk assessment guidance (FEMA 386-2), vulnerability is defined as being open to damage or attack, and risk is defined as the possibility of loss or injury. For this assessment, the vulnerability of a county is approximated by looking at previous impacts due to drought and identifying existing conditions, or "metrics," that would cause a county to be more or less impacted during future droughts. These metrics are determined on a sector-by-sector basis. In an attempt to expand upon previous vulnerability assessments for the State of Colorado, the scope has been widened to include six private/economic sectors in addition to state assets. The sectors are as follows: Agriculture, Energy, Environment, Municipal and Industrial (M&I), Recreation, and Socioeconomic. State assets that are considered at-risk from drought are as follows: state-owned or operated buildings, critical infrastructure, state lands, instream flows, and fish hatcheries. Only those facilities that are state-owned or operated are specifically addressed in the state assets section of the Plan, but the impacts and vulnerabilities identified for these facilities would apply to similar privately-owned facilities and lands as well.

In addition to the FEMA requirements the EMAP risk assessment standards require a consequence-based analysis. Table 8 outlines the detrimental impacts that drought can have on various subject areas as designated by EMAP.

**Table 8 EMAP Consequence/Impact Analysis: Drought**

| EMAP Risk Assessment Subject Area | Detrimental Impacts |
|---|---|
| Health and Safety of the Public | Water supply disruptions may adversely affect people. Reduced water quantity and quality could impact delivery of potable water, particularly in rural areas. Reduced air quality associated with blowing dust could have detrimental impacts. Mental health issues may be associated with loss of farm income in agricultural areas. See Socioeconomic Sector analysis for detailed impact discussion. |
| Health and Safety of Personnel Responding to the Incident | Nature of hazard expected to have minor impacts to properly equipped and trained personnel, though dust storms may require special equipment. |

| EMAP Risk Assessment Subject Area | Detrimental Impacts |
|---|---|
| Continuity of Operations Including Delivery of Services | Slow onset and nature of drought makes it unlikely to have an impact on continuity of operations.<br>Nature of hazard not expected to impact delivery of government services, except for moderate impact on water utilities. In extreme cases, municipal water delivery may be interrupted. Ability to deliver recreational services may be impacted at the local level. Food supply and delivery could be disrupted, with an associated increase in food prices. |
| Property, Facilities, and Infrastructure | Buildings: Nature of hazard expected to have minimal impact. Landscaping can be damaged or lost in event of severe municipal water restrictions or water rights out of priority. Increased risk of wildfire can threaten catastrophic loss of buildings.<br>Critical infrastructure (e.g., dams, transmountain ditches, and irrigation ditches): Infrastructure can be damaged by excessively dry expansive soil as it contracts. Dams and ditches can experience structural damage due to decreased pore water pressure, damage caused by high sediment loads when pulling water from the bottom of reservoirs, and damage caused by debris flows and flooding following wildfires.<br>State lands: Environmental quality of land can be impacted by overgrazing during drought conditions.<br>See State Assets Sector analysis for detailed impact discussion. |
| The Environment | May cause disruptions in wildlife habitat, resulting in an increasing interface with people, and reducing numbers of animals. Land quality can be negatively impacted by overgrazing during drought. Water quality can become degraded to the point of causing localized fish kills. See Environment Sector analysis for detailed impact discussion. Low streamflows will have negative impacts on riparian habitats and aquatic species. |
| Economic Condition | Local economy and finances dependent on abundant water supply or precipitation (i.e., snow at ski areas) adversely affected for duration of drought.<br>Agricultural economies adversely affected if drought results in widespread loss of crop or yield reductions.<br>Increased expenses for public education possible among M&I providers.<br>See sector analyses for Recreation and Tourism, Agriculture, State Assets, Energy, M&I, and Socioeconomic. |
| Regulatory and Contractual Obligations | Water trading between municipalities expected to occur on a voluntary rather than obligatory basis. Drought reservations or instream flows may be invoked to allow a reduction in bypass requirements and an interruption to agricultural leases (see M&I Sector analysis).<br>Interstate compact obligations could become stressed if long term or severe decrease in availability occurs.<br>Recreational in-channel diversions and instream flow rights are subject to water rights priority system and may become out-of-priority in a drought (see Recreation and Tourism and State Assets analyses). |
| Public confidence in the jurisdiction's governance | Ability to respond and recover may be questioned and challenged if planning, response, and recovery not timely and effective. State must balance *over* and *under* response to the drought hazard. |

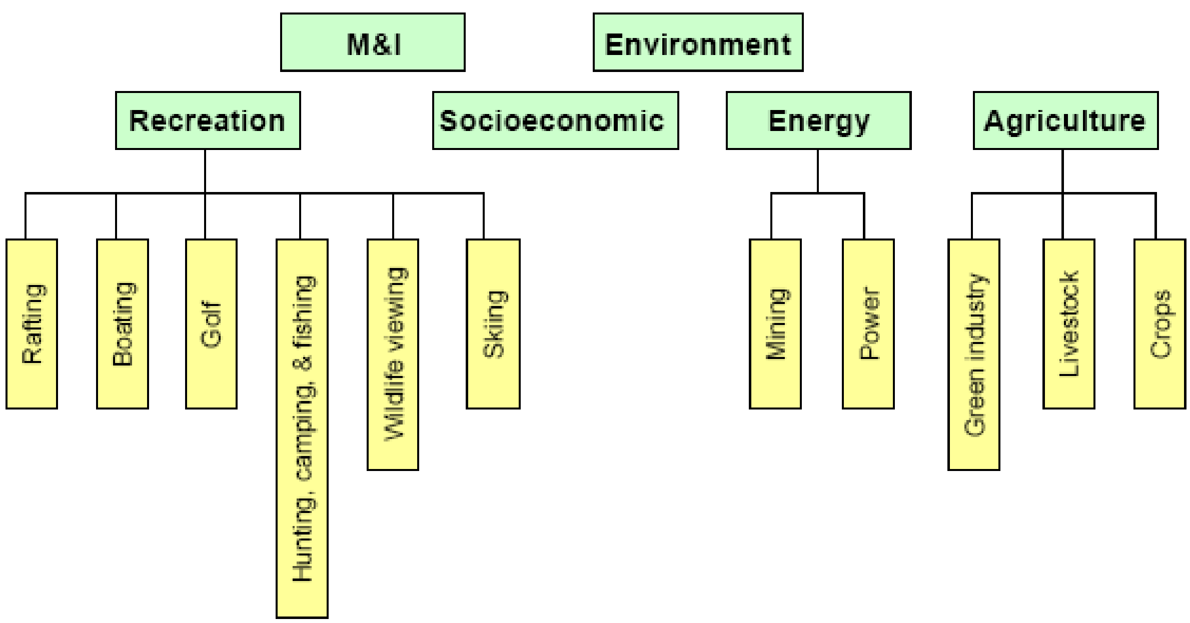
In the sections that follow, the process used to analyze information from previous work is explained, the methodology for assessing vulnerability by county is discussed, and the results of the vulnerability assessment, which is presented in Annex B, are presented.

### 3.3.1 Vulnerability Based on Local and State Risk Assessment

State and local hazard mitigation plans were reviewed to assess vulnerability on a jurisdictional level. Information was updated accordingly to reflect hazard mitigation plans that have been finalized since the previous update to this Plan was completed in 2010. During the 2010 Plan update, an extensive literature review was conducted to collect previously-reported impacts to drought and adaptive capacities that have been developed by sectors and the State. Interviews were conducted with individuals knowledgeable about a particular sector or state asset. The information was analyzed and incorporated into a spreadsheet to evaluate vulnerability in a quantitative as well as qualitative way. To the extent available, new reports and data available since the 2010 update were reviewed and incorporated into revised vulnerability analyses during the 2013 update.

The six sectors, listed in Figure 18, were divided into sub-sectors to facilitate analysis in cases when a sector is sufficiently diverse to warrant separate consideration. Figure 18 illustrates the six impact sectors and shows the sub-sectors, where applicable.

**Figure 18. Sectors and Sub-sectors for Drought Vulnerability Assessment**




As shown in Figure 18, Agriculture, Energy, and Recreation were divided into sub-sectors while Environment, M&I, and Socioeconomic were not.

From the literature review, previous drought impact reports (including local and state hazard mitigation plans), and interviews with agency directors, program employees, industry representatives, and academics who are continually involved in drought-related issues [1], impacts of drought to the sub-sectors and departments were identified and listed for analysis. Similarly, adaptive capacities were identified as they can mitigate the impacts to the sub-sectors. The existence of adaptive capacities helps offset the impacts and reduce overall vulnerability.

Using the list of impacts and adaptive capacities, data relating to the impacts that could be used to quantify the vulnerability of each sector were identified. An example of a vulnerability metric for state assets (specifically, state lands revenue) is the historic lease discount offered during the 2002 drought. For agriculture, an identified impact was crop loss due to drought; crop indemnity data is available by county specifically for drought, so these data were used as a metric for agriculture. The data were aggregated at a county level to satisfy the jurisdictional requirements of the FEMA regulation.

To determine the overall impact a sector or sub-sector has within a county, data were collected to assess the spatial density of the sub-sector in question. This enabled a presentation of sub-sector relative densities throughout the State. For example, Colorado State Parks were mapped and correlated to one or more counties where they are located. In this way only counties that contain state parks can be vulnerable to drought impacting state parks, or for agriculture, only counties that have grazing cattle can be vulnerable to grazing losses during a drought.

For each sector and/or sub-sector, spatial inventory data were used to determine its proportionality within the county. For example, a county with a high number of high-value state buildings and state-owned dams, but a low acreage of land managed by the State Land Board, would have its vulnerability rated proportionally higher for state-owned buildings and dams. Refer to Annex B (Drought Vulnerability Assessment Technical Information) for further discussion of the vulnerability assessment methodology.

[1] Including individuals from the Colorado Department of Agriculture (CDA), Colorado State University (CSU), U.S. Department of Agriculture (USDA), National Oceanic and Atmospheric Administration (NOAA), water division engineers, National Resources Conservation Service (NRCS), GreenCO, water commissioners, The Nature Conservancy (TNC), NatureServe, Audubon Society, Department of Local Affairs (DOLA), Colorado Energy Office (CEO), National Renewable Energy Laboratory (NREL), Tri-State Energy, Xcel Energy, Colorado Geological Survey (CGS), Division of Reclamation and Mining Safety (DRMS), Western Resource Advocates (WRA), Golf Course Superintendents Association of America (GCSAA), U.S. Geological Survey (USGS), Colorado River Outfitters Association (CROA), National Ski Areas Association (NSAA), Office of Economic Development and International Trade (OEDIT), State Office of Risk Management, State Land Board, fish hatchery managers, Colorado Park and Wildlife (CPW), Colorado Department of Public Health and Environment (CDPHE), and others.

### 3.3.2 Jurisdictions Most Threatened and Most Vulnerable to Damage or Loss

For a complete discussion of the State Assets Sector and other sector drought vulnerability in Colorado, please refer to Annex B. The following section discusses the results of that assessment for State Assets and includes a summary of other sector findings.

The Drought Impact Reporter from the NDMC is a useful reference for a statewide overview of historic impacts to drought. The NDMC developed the Drought Impact Reporter to provide a national database of drought impacts. Information comes from a number of sources, including newspapers, online reports, scientific publications, other media, government agencies, and members of the public who submit drought-related impacts online for their region. Table 9 shows the total number of drought impacts from all sources (e.g., government, NOAA, public, media, other) by county, from March 2010 (the date research was concluded for the 2010 drought plan update) to May 8, 2013.

## Table 9 National Drought Reporter Incident Summary

| County | Agriculture | Business & Industry | Energy | Fire | Plants & Wildlife | Relief, Response & Restrictions | Society & Public Health | Tourism & Recreation | Water Supply & Quality | Total* |
|---|---|---|---|---|---|---|---|---|---|---|
| Adams | 63 | 11 | 1 | 3 | 7 | 23 | 13 | 7 | 10 | **90** |
| Alamosa | 69 | 11 | 2 | 4 | 7 | 24 | 15 | 10 | 9 | **93** |
| Arapahoe | 62 | 11 | 1 | 3 | 6 | 21 | 12 | 7 | 6 | **86** |
| Archuleta | 62 | 10 | 1 | 3 | 4 | 20 | 13 | 9 | 4 | **85** |
| Baca | 76 | 10 | 1 | 4 | 8 | 24 | 15 | 7 | 9 | **99** |
| Bent | 72 | 10 | 1 | 5 | 7 | 23 | 13 | 7 | 9 | **94** |
| Boulder | 64 | 11 | 1 | 4 | 9 | 22 | 14 | 8 | 11 | **93** |
| Broomfield | 62 | 10 | 1 | 3 | 4 | 20 | 14 | 8 | 6 | **85** |
| Chaffee | 66 | 11 | 1 | 3 | 5 | 22 | 13 | 10 | 7 | **90** |
| Cheyenne | 66 | 10 | 1 | 4 | 5 | 23 | 12 | 7 | 7 | **88** |
| Clear Creek | 62 | 11 | 1 | 3 | 5 | 21 | 13 | 8 | 7 | **86** |
| Conejos | 66 | 10 | 1 | 4 | 4 | 25 | 13 | 9 | 8 | **91** |
| Costilla | 66 | 10 | 1 | 3 | 4 | 23 | 12 | 7 | 6 | **87** |
| Crowley | 73 | 10 | 1 | 3 | 5 | 23 | 14 | 7 | 7 | **96** |
| Custer | 67 | 10 | 1 | 5 | 4 | 22 | 14 | 8 | 7 | **92** |
| Delta | 63 | 10 | 1 | 3 | 4 | 21 | 13 | 9 | 9 | **87** |
| Denver | 62 | 11 | 1 | 4 | 16 | 27 | 14 | 10 | 12 | **101** |
| Dolores | 62 | 10 | 1 | 3 | 5 | 20 | 13 | 9 | 8 | **86** |
| Douglas | 64 | 11 | 1 | 4 | 7 | 23 | 14 | 9 | 8 | **93** |
| Eagle | 62 | 11 | 1 | 3 | 5 | 20 | 13 | 9 | 7 | **86** |
| El Paso | 64 | 10 | 1 | 3 | 8 | 24 | 15 | 8 | 8 | **93** |
| Elbert | 65 | 10 | 1 | 3 | 5 | 22 | 12 | 7 | 7 | **88** |
| Fremont | 78 | 10 | 1 | 3 | 5 | 22 | 14 | 9 | 10 | **102** |

| County | Agriculture | Business & Industry | Energy | Fire | Plants & Wildlife | Relief, Response & Restrictions | Society & Public Health | Tourism & Recreation | Water Supply & Quality | Total* |
|---|---|---|---|---|---|---|---|---|---|---|
| Garfield | 63 | 11 | 1 | 3 | 7 | 22 | 13 | 9 | 9 | **89** |
| Gilpin | 62 | 11 | 1 | 3 | 5 | 21 | 13 | 8 | 7 | **86** |
| Grand | 63 | 11 | 1 | 4 | 6 | 21 | 13 | 10 | 10 | **89** |
| Gunnison | 63 | 10 | 1 | 3 | 4 | 20 | 13 | 9 | 7 | **86** |
| Hinsdale | 62 | 10 | 1 | 3 | 4 | 20 | 13 | 9 | 7 | **85** |
| Huerfano | 69 | 10 | 1 | 4 | 5 | 22 | 14 | 8 | 9 | **92** |
| Jackson | 64 | 11 | 1 | 3 | 5 | 22 | 13 | 9 | 8 | **89** |
| Jefferson | 63 | 10 | 1 | 6 | 4 | 23 | 14 | 8 | 9 | **90** |
| Kiowa | 81 | 10 | 1 | 4 | 9 | 25 | 15 | 7 | 8 | **106** |
| Kit Carson | 66 | 10 | 1 | 5 | 5 | 23 | 12 | 7 | 7 | **88** |
| La Plata | 63 | 10 | 1 | 3 | 4 | 20 | 13 | 9 | 8 | **86** |
| Lake | 62 | 10 | 1 | 3 | 4 | 21 | 13 | 9 | 8 | **86** |
| Larimer | 72 | 11 | 1 | 9 | 11 | 26 | 17 | 10 | 14 | **107** |
| Las Animas | 73 | 10 | 1 | 5 | 7 | 26 | 13 | 7 | 9 | **97** |
| Lincoln | 65 | 10 | 1 | 3 | 5 | 22 | 13 | 7 | 6 | **88** |
| Logan | 63 | 11 | 1 | 3 | 6 | 21 | 12 | 7 | 7 | **86** |
| Mesa | 64 | 10 | 1 | 3 | 7 | 25 | 13 | 10 | 12 | **93** |
| Mineral | 65 | 10 | 1 | 3 | 4 | 23 | 13 | 9 | 7 | **88** |
| Moffat | 62 | 11 | 1 | 3 | 6 | 22 | 14 | 9 | 8 | **88** |
| Montezuma | 63 | 11 | 1 | 3 | 5 | 21 | 13 | 9 | 9 | **88** |
| Montrose | 62 | 10 | 1 | 3 | 4 | 20 | 13 | 9 | 7 | **85** |
| Morgan | 62 | 11 | 1 | 3 | 5 | 21 | 12 | 7 | 7 | **85** |
| Otero | 74 | 10 | 1 | 5 | 6 | 22 | 14 | 7 | 8 | **97** |
| Ouray | 63 | 10 | 1 | 3 | 4 | 21 | 14 | 9 | 9 | **87** |
| Park | 63 | 11 | 1 | 5 | 4 | 24 | 14 | 10 | 8 | **90** |

| County | Agriculture | Business & Industry | Energy | Fire | Plants & Wildlife | Relief, Response & Restrictions | Society & Public Health | Tourism & Recreation | Water Supply & Quality | Total* |
|---|---|---|---|---|---|---|---|---|---|---|
| Phillips | 63 | 11 | 1 | 3 | 5 | 21 | 12 | 7 | 6 | **85** |
| Pitkin | 62 | 10 | 1 | 3 | 6 | 21 | 15 | 10 | 8 | **89** |
| Prowers | 74 | 10 | 1 | 5 | 7 | 25 | 13 | 7 | 9 | **97** |
| Pueblo | 70 | 10 | 1 | 4 | 6 | 29 | 14 | 8 | 13 | **99** |
| Rio Blanco | 62 | 11 | 1 | 3 | 5 | 21 | 13 | 9 | 8 | **87** |
| Rio Grande | 68 | 10 | 1 | 5 | 6 | 24 | 14 | 9 | 7 | **92** |
| Routt | 62 | 11 | 1 | 3 | 5 | 22 | 13 | 10 | 10 | **89** |
| Saguache | 66 | 10 | 1 | 3 | 4 | 23 | 13 | 9 | 7 | **89** |
| San Juan | 62 | 10 | 1 | 3 | 4 | 20 | 13 | 9 | 7 | **85** |
| San Miguel | 62 | 10 | 1 | 3 | 4 | 20 | 13 | 9 | 7 | **85** |
| Sedgwick | 62 | 11 | 1 | 3 | 5 | 21 | 12 | 7 | 7 | **85** |
| Summit | 62 | 11 | 1 | 3 | 5 | 22 | 13 | 9 | 9 | **88** |
| Teller | 63 | 10 | 1 | 4 | 4 | 21 | 13 | 8 | 6 | **86** |
| Washington | 62 | 11 | 1 | 3 | 5 | 23 | 12 | 7 | 8 | **87** |
| Weld | 67 | 11 | 1 | 5 | 6 | 22 | 12 | 7 | 11 | **92** |
| Yuma | 74 | 12 | 1 | 8 | 16 | 21 | 20 | 7 | 8 | **98** |
| **Colorado** | 182 | 16 | 2 | 35 | 75 | 74 | 45 | 23 | 79 | **299** |

Source: National Drought Mitigation Center –March 16, 2010-May 8, 2013 search parameters; http://droughtreporter.unl.edu/

* Because more than one category may be selected for each impact, the total number of impacts for the county will likely be less than the sum of the counts for the individual categories for each county.

Note: These data reflect self-reported incidents and can include a range of accuracy and various levels of impact interpretation.

Table 9 above shows impacts that have been recorded by county but also individual impacts that have been reported at the state level and summarily "counted" for each county. For this reason the Drought Impact Reporter is not the best tool for discerning which counties have the greatest vulnerability to different types of impacts, because state-level data is mixed in with, and dominates, the "true" county-level data. Although the recent (2010-2013) data reflects a degree of county-specific impacts, they are still susceptible to the mixing of data as seen in the "Energy," "Fire," and "Plants & Wildlife" rows, where there is at least one state-level impact entry that has been entered in each county, along with several individual county-level entries.

The concept of the Drought Impact Reporter provides a technical foundation to facilitate web-based collection of impact data during a drought across sectors, at a detailed temporal and spatial level. Such information could be used to develop an ongoing record of drought impacts to sector assets that relate the specific impacts to different intensity and duration droughts at a location. Over time a detailed impact profile could be developed for vulnerable sectors so that the impact of future drought vulnerability could be better defined based on historic impacts.

In the DWSA report (CWCB, 2004) the impacts of the 2000-2003 drought were discussed in detail. The impacts were described for each of eight different impact areas (or sectors): agriculture, economic impacts, energy, health, municipal water, tourism, wildfire, and wildlife. Jurisdictions that are closely tied to any of these specialized sectors would be especially vulnerable to drought impacts, due to their heavy reliance on adequate water supplies.

### Drought Vulnerability by County Summary

By researching previous impacts to various sectors and by talking to people in the industries/agencies of concern, a methodology to "rank" vulnerability in a quantitative way was developed. This ranking process is described in Section 3.5.1 and in discussions by sector in Annex B and was updated in 2013. In many cases vulnerability scores did not change from 2010 due to lack of available quantitative data consistent statewide. Where changes did occur in the county listings, notably in state-owned buildings and infrastructure and state-owned recreational activities, this was due to incorporation of improved data. In terms of jurisdictions most threatened and most vulnerable to damage associated with drought, the following conclusions were reached:

- Vulnerability to state-owned buildings and critical infrastructure was found to be highest in these counties: Archuleta, Baca, Conejos, Eagle, Kit Carson, Larimer, Mesa, Park, Rio Blanco, Routt, and San Miguel. This is because these counties contain state-owned buildings and/or dams (as determined from data provided by the Colorado Risk Management Office and the National Inventory of Dams). The counties have proportionally more dams (since dams are more likely to be impacted by drought than buildings, this would make a county relatively more vulnerable) and there is a moderate to high wildfire threat as determined by the Colorado State Forest Service Wildfire Threat data, which poses a risk to state-owned buildings.

- Vulnerability to State Land Board lands and revenues in Figure 22 was found to be high in quite a few counties. In general, counties on the eastern plains were found to have the highest vulnerability to drought as it impacts state lands because these counties received the highest agricultural lease discounts in the 2002 drought. Several counties in the west/southwest also have high vulnerability scores for the same reason. In 2002, the State Land Board issued across-the-board agriculture lease discounts, something they do not intend to do in future droughts as it did not have the desired effect of encouraging ranchers and farmers to adjust their grazing/farming practices to reflect the lower carrying capacity of the drought-stressed land. Because of this, in future droughts State Land Board lease revenue will vary based on how many discounts are offered to individuals in each county (personal communication with State Land Board, 2010). While the spatial density metric (acres) was updated with the latest data, this vulnerability metric could not be updated for the 2011-2013 drought as the program was discontinued.

- Vulnerability to state-operated recreational activity (CPW) in Figure 23 was found to be highest in Archuleta, Chaffee, Delta, Eagle, Garfield, Gunnison, Huerfano, Jefferson, Las Animas, Logan, Mesa, Montezuma, Morgan, Park, Pueblo, Routt, and Weld counties. This is because these counties contain state parks with relatively high annual visitation numbers, the state parks they contain are water-based (which tend to attract more visitors and are more vulnerable to drought), and are in an area of moderate to high wildfire risk based on CSFS Wildfire Threat data.

- Vulnerability to aquatic habitat and species as shown in Figure 24 (consisting of instream flows and state-owned or operated fish hatcheries) was found to be highest in these counties: Alamosa, Arapahoe, Delta, Gilpin, Jefferson, Mesa, Moffat, Montrose, Ouray, Pueblo, San Miguel, and Teller. This is because these counties contain state-owned or operated hatcheries and/or instream flows (as determined from data obtained from CPW and the CWCB), and they have relatively junior instream flow rights.

Jurisdictional vulnerability to drought for the six private (i.e., not state-owned) sectors is discussed in detail in Annex B. General results by sector are as follows:

- Vulnerability to agriculture activities was higher in counties with significant proportions of dryland crops compared to total farmed acreage, and in counties with high numbers of grazing cattle and livestock feed program allocations. Vulnerability to the green industry (e.g., sod farms, nurseries, floriculture, etc.) was not evaluated due to lack of data. Unfortunately, the vulnerability calculation for the agriculture sector could not be updated in 2013 due to a lack of available data. Those counties listed below likely remain most vulnerable.
  - *Counties ranked high for drought vulnerability in the Agricultural Sector include Adams, Arapahoe, Baca, Cheyenne, Douglas, Elbert, Phillips, Lincoln, Crowley, Kiowa, Dolores, and Las Animas.*

Although the vulnerability analysis for the Energy Sector was performed on a county by county basis to be consistent with the drought vulnerability modeling methodology, it is important to note that energy production is regional, i.e., it is distributed over a grid which covers the entire western United States. Generally, the energy sector is fairly resilient to drought impacts. This is due to the broad spectrum of drought preparedness utilities and power providers implement which can range from diverse water rights portfolios to contract supplies from municipalities. The county-level analysis showed that vulnerability was higher in counties with high mining water use (as estimated in a 2005 study from the USGS), and of that water use, counties using a higher percentage of surface water (as opposed to groundwater) are considered more vulnerable to drought. Counties with renewable energy development options (wind and/or solar power) were considered to have an adaptive capacity and drought vulnerability is subsequently reduced. Unfortunately, the vulnerability calculation for the energy sector could not be updated in 2013 due to a lack of available data. Those counties listed below likely remain most vulnerable.

  – *The highest ranking counties for drought vulnerability in the overall Energy Sector are Rio Blanco, Grand, Montrose, and Park.*

- Vulnerability to the Environmental Sector was higher in counties with relatively low protected area status (as determined by stewardship rankings in the 2000 Southwest Regional Gap Analysis Program), a relatively high number of Environmental Protection Agency (EPA) 303(d) Listed Impaired Waters, forests currently infected by bark beetle (as determined by the USFS aerial surveys), moderate to high ranking in the wildfire threat data, relatively junior instream flow rights, and a relatively high number of high-order streams (as determined by the USGS National Hydrography Dataset flowline attributes).
  – *Counties ranked high for drought vulnerability in the Environmental Sector are Larimer, Las Animas, Garfield, Mesa, Moffat, and Weld.*

- Vulnerability to the M&I Sector is generalized to water divisions rather than specific counties or water providers. In general, providers will be better insulated from drought impacts if they have senior water rights, if they actively plan and are prepared for drought, and if they have a diverse portfolio. Specific county rankings were not available for this Sector. Drought and water resources planning information from M&I CWCB surveys conducted in 2004, 2007 and 2013 along with supplemental information from various resources were used to characterize M&I vulnerability.

- Vulnerability to drought specific to the Recreation Sector was higher in counties with little recreational diversity, or a high concentration of water-dependent activities. For example, a county with a strong economic dependence on the skiing industry is more vulnerable to drought impacts than a county with recreational attractions ranging from hiking and camping to rafting and boating.
  – *The highest ranking counties for drought vulnerability in the Recreation Sector are Archuleta, Moffat, Mesa, Garfield, Eagle, Grand, Routt, Fremont, and Pueblo.*

- Vulnerability to drought specific to the Socioeconomic Sector was higher in counties with little economic diversity. Counties that depend upon one main economic sector for the majority of their stability (for example, recreation or agriculture) are more vulnerable to drought conditions. This is because these counties lack other aspects of their economies that would not be impacted by drought to keep the overall economy functioning.
  - *Counties ranked high for drought vulnerability in the Socioeconomic Sector are Archuleta, Baca, Costilla, Custer, Eagle, Elbert, Gilpin, Grand, Hinsdale, Jackson, Kiowa, Kit Carson, Mineral, Morgan, Ouray, Park, Pitkin, Rio Grande, Saguache, San Juan, San Miguel, Sedgwick, Summit, Teller, and Weld.*

In some cases, the counties determined by the vulnerability assessment to have high vulnerability to drought are not as intuitive as others. The limitations and recommendations sections of the Drought Vulnerability Assessment Technical Information report, located in Annex B, include discussion of these instances.

### 3.3.3 Process Used to Analyze Information from Local Mitigation Plans

As of March 2013, five mitigation plans in Colorado had been approved by FEMA. This includes single-jurisdictional plans for the City of Boulder and City of Colorado Springs; a university plan for the University of Colorado at Boulder; and a tribal plan for the Ute Mountain Ute Tribe. The plans in Table 10 below are FEMA approved, or have an update that is approved pending adoption. Note that some plans have expired. These plans were reviewed and provided insight as to how individual jurisdictions view their vulnerability to drought. Many of these local mitigation plans included planning priorities for the different hazards, including drought. Where available, the planning priority level for drought was extracted from these plans and is presented in the following table.

**Table 10 Communities Identifying Drought as Planning Priority in their Multi-Hazard Mitigation Plans**

| Community | Planning Priority Level |
|---|---|
| Archuleta County<br>(2012 plan approved pending adoption) | High |
| Boulder County | High |
| City of Boulder | High |
| City of Colorado Springs | Identified as hazard, but not a high planning priority |
| Costilla County | High |
| Delta County | High |
| Denver Regional Council Of Governments (Adams, Arapahoe, Broomfield, Clear Creek, Denver, Douglas, Gilpin, Jefferson) | High for all counties |
| Dolores County<br>(Plan update in progress) | High |

| Community | Planning Priority Level |
|---|---|
| Eagle County<br>(Plan update in progress) | Identified as hazard, but not a high planning priority |
| Elbert County | Moderate |
| El Paso County<br>(Plan update in progress) | Identified as hazard, but not a high planning priority |
| Grand County<br>(2013 plan update in progress) | 'Secondary' |
| Gunnison<br>(2012 update Approved pending adoption) | "Highly Likely" and impacts noted as "potentially catastrophic" |
| Hinsdale County<br>(Expired) | High |
| Huerfano County | 'Secondary' |
| Jefferson County | Medium |
| Mesa County | High |
| Montrose County | High |
| Northeast Colorado (Cheyenne, Kit Carson, Lincoln, Logan, Morgan, Phillips, Sedgwick, Washington, Weld (and Greeley), and Yuma) | High for all counties |
| Northern Colorado Region<br>(Larimer County, Ft. Collins, Loveland) | "Likely" and impacts noted as "catastrophic." |
| Ouray County<br>(2013 plan update in progress) | Medium |
| Park County<br>(2013 plan update in progress) | Medium |
| Pitkin County<br>(2012 update Approved pending adoption) | Identified as hazard, but not a high planning priority |
| Prowers County<br>(Plan update in progress) | High |
| Pueblo County | Serious |
| Rio Blanco County<br>(Expired) | Identified in Risk Assessment and Mitigation Strategies |
| Routt County | 'Limited' Magnitude/Severity |
| San Luis Valley (Alamosa) | 'Critical' Magnitude/Severity |
| San Luis Valley (Conejos) | 'Critical' Magnitude/Severity |
| San Luis Valley (Mineral) | 'Negligible' Magnitude/Severity |
| San Luis Valley (Rio Grande)<br>(Pending adoption) | 'Limited' Magnitude/Severity |
| San Luis Valley (Saguache) | 'Critical' Magnitude/Severity |
| San Miguel County | High |
| Summit County<br>(2013 update in progress) | Medium |
| Teller County<br>(2013 update in progress) | High |
| University of Colorado, Boulder | Low/Non Critical Hazard |

| Community | Planning Priority Level |
|---|---|
| Upper Arkansas Area (Chaffee, Custer, Fremont and Lake) (Plan update in progress) | High |
| Ute Mountain Ute Tribe (Approved Pending Adoption) | Medium |

Source: Colorado Division of Homeland Security and Emergency Management

The results in Table 10 indicate that most counties consider drought a high priority hazard for planning purposes. Not all the plans included a priority ranking, and among those that did the ranking, systems were not uniform. A recommendation for future local planning efforts is to standardize the priority ranking system and drought vulnerability methodology so county-level plans can be easily compared. The statewide methodology presented in this Plan can be adapted and improved upon at the local level for improvement of local hazard mitigation plans.

### 3.3.4 Changes in Development Patterns

As part of the Plan revision process, changes in growth and development were examined in the context of drought vulnerability. Changes in growth and development naturally affect loss estimates and vulnerability, and when the population in a hazard area increases, so too does the vulnerability of the people and property unless mitigation measures are taken. When the population of a hazard area decreases, the burden of managing agencies and assuming loss to communal property may exceed the resources of the declining population.

Growth and development were primarily noted in the Socioeconomic and M&I Sector analyses, although population growth and decline will cause impacts from drought to manifest with more or less severity across the board. Population growth was factored into socioeconomic vulnerability by designating the fastest growing counties as most vulnerable to drought impacts. Drought can severely challenge a public water supplier through depletion of the raw water supply and greatly increased customer water demand; and any impacts to municipal providers can be exacerbated by increased water demands brought about by a growing population. If a county or city is growing rapidly, the entity may have difficulties securing new sources of water while maintaining a comfortable margin of storage in case of drought. In a general, counties experiencing higher growth are also likely to experience increased competition over existing water supplies.

Table 11 shows county population and growth rates, and Figure 19 shows population by county (illustrated with gray circles) and shading to represent projected growth rates of -10-0%, 0-9%, 10-49%, 50-99%, and 100% or greater, respectively, as a percentage increase from 2010- 2040. Counties with already large populations and high projected growth include Weld, El Paso, Larimer, Mesa, Douglas, and Adams Counties. These counties are expected to have correspondingly higher vulnerability to drought as it impacts the M&I and Socioeconomic Sectors (see the M&I and Socioeconomic Sector analyses in Annex B for more discussion). Washington County is projected to decrease in population by approximately 9%.

## Table 11 Future Growth in Colorado by County 2010-2040

| COUNTIES | Census 2010 | SDO Proj. July, 2015 | SDO Proj. July, 2020 | SDO Proj. July, 2025 | SDO Proj. July, 2030 | SDO Proj. July, 2035 | SDO Proj. July, 2040 | Average Annual Percent Change 10-15 | 15-20 | 20-25 | 25-30 | 30-35 | 35-40 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| COLORADO | 5,029,196 | 5,438,077 | 5,915,922 | 6,413,554 | 6,888,181 | 7,329,018 | 7,749,477 | 1.5% | 1.7% | 1.6% | 1.4% | 1.2% | 1.1% |
| | | | | | | | | | | | | | |
| Adams | 441,603 | 484,186 | 527,858 | 576,500 | 621,271 | 665,723 | 710,240 | 1.9% | 1.7% | 1.8% | 1.5% | 1.4% | 1.3% |
| Alamosa | 15,445 | 16,447 | 17,796 | 19,433 | 21,407 | 23,508 | 25,609 | 1.3% | 1.6% | 1.8% | 2.0% | 1.9% | 1.7% |
| Arapahoe | 572,003 | 620,974 | 667,037 | 715,869 | 762,228 | 805,459 | 843,400 | 1.7% | 1.4% | 1.4% | 1.3% | 1.1% | 0.9% |
| Archuleta | 12,084 | 13,730 | 16,850 | 20,298 | 23,937 | 27,516 | 31,037 | 2.6% | 4.2% | 3.8% | 3.4% | 2.8% | 2.4% |
| Baca | 3,788 | 3,826 | 3,893 | 3,971 | 4,052 | 4,127 | 4,194 | 0.2% | 0.3% | 0.4% | 0.4% | 0.4% | 0.3% |
| Bent | 6,499 | 6,425 | 6,596 | 6,740 | 6,776 | 6,731 | 6,650 | -0.2% | 0.5% | 0.4% | 0.1% | -0.1% | -0.2% |
| Boulder | 294,567 | 315,122 | 333,399 | 350,807 | 366,519 | 379,768 | 390,228 | 1.4% | 1.1% | 1.0% | 0.9% | 0.7% | 0.5% |
| Broomfield | 55,889 | 63,848 | 71,119 | 77,331 | 81,943 | 84,888 | 85,825 | 2.7% | 2.2% | 1.7% | 1.2% | 0.7% | 0.2% |
| Chaffee | 17,809 | 19,594 | 22,467 | 25,116 | 27,361 | 28,960 | 30,282 | 1.9% | 2.8% | 2.3% | 1.7% | 1.1% | 0.9% |
| Cheyenne | 1,836 | 1,976 | 2,115 | 2,205 | 2,292 | 2,352 | 2,416 | 1.5% | 1.4% | 0.8% | 0.8% | 0.5% | 0.5% |
| Clear Creek | 9,088 | 9,115 | 9,877 | 10,979 | 12,074 | 13,184 | 14,293 | 0.1% | 1.6% | 2.1% | 1.9% | 1.8% | 1.6% |
| Conejos | 8,256 | 8,644 | 9,118 | 9,550 | 9,909 | 10,186 | 10,443 | 0.9% | 1.1% | 0.9% | 0.7% | 0.6% | 0.5% |
| Costilla | 3,524 | 3,810 | 3,955 | 4,094 | 4,206 | 4,303 | 4,408 | 1.6% | 0.7% | 0.7% | 0.5% | 0.5% | 0.5% |
| Crowley | 5,823 | 6,033 | 6,405 | 6,865 | 7,319 | 7,751 | 8,194 | 0.7% | 1.2% | 1.4% | 1.3% | 1.2% | 1.1% |
| Custer | 4,255 | 4,890 | 5,757 | 6,619 | 7,467 | 8,239 | 8,979 | 2.8% | 3.3% | 2.8% | 2.4% | 2.0% | 1.7% |
| Delta | 30,952 | 33,694 | 39,206 | 45,122 | 50,563 | 54,921 | 59,142 | 1.7% | 3.1% | 2.9% | 2.3% | 1.7% | 1.5% |
| Denver | 600,158 | 650,792 | 688,053 | 718,402 | 746,166 | 773,898 | 808,921 | 1.6% | 1.1% | 0.9% | 0.8% | 0.7% | 0.9% |
| Dolores | 2,064 | 2,174 | 2,361 | 2,585 | 2,808 | 3,054 | 3,313 | 1.0% | 1.7% | 1.8% | 1.7% | 1.7% | 1.6% |
| Douglas | 285,465 | 314,619 | 351,832 | 391,576 | 425,118 | 454,908 | 482,604 | 2.0% | 2.3% | 2.2% | 1.7% | 1.4% | 1.2% |
| Eagle | 52,197 | 59,265 | 68,350 | 74,096 | 82,362 | 92,430 | 102,472 | 2.6% | 2.9% | 1.6% | 2.1% | 2.3% | 2.1% |
| Elbert | 23,086 | 26,415 | 36,268 | 45,141 | 52,427 | 58,691 | 64,373 | 2.7% | 6.5% | 4.5% | 3.0% | 2.3% | 1.9% |
| El Paso | 622,263 | 676,597 | 731,156 | 790,805 | 852,624 | 913,053 | 972,887 | 1.7% | 1.6% | 1.6% | 1.5% | 1.4% | 1.3% |
| Fremont | 46,824 | 50,300 | 54,070 | 57,813 | 61,284 | 64,391 | 67,306 | 1.4% | 1.5% | 1.3% | 1.2% | 1.0% | 0.9% |
| Garfield | 56,389 | 63,098 | 72,691 | 83,263 | 92,608 | 101,391 | 109,887 | 2.3% | 2.9% | 2.8% | 2.2% | 1.8% | 1.6% |

| COUNTIES | Census 2010 | SDO Proj. July, 2015 | SDO Proj. July, 2020 | SDO Proj. July, 2025 | SDO Proj. July, 2030 | SDO Proj. July, 2035 | SDO Proj. July, 2040 | Average Annual Percent Change 10-15 | 15-20 | 20-25 | 25-30 | 30-35 | 35-40 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gilpin | 5,441 | 5,849 | 6,384 | 6,918 | 7,437 | 7,972 | 8,501 | 1.5% | 1.8% | 1.6% | 1.5% | 1.4% | 1.3% |
| Grand | 14,843 | 15,778 | 18,008 | 20,672 | 23,282 | 25,752 | 28,028 | 1.2% | 2.7% | 2.8% | 2.4% | 2.0% | 1.7% |
| Gunnison | 15,324 | 16,552 | 17,987 | 19,217 | 20,273 | 21,222 | 22,107 | 1.6% | 1.7% | 1.3% | 1.1% | 0.9% | 0.8% |
| Hinsdale | 843 | 897 | 992 | 1,089 | 1,188 | 1,284 | 1,378 | 1.2% | 2.0% | 1.9% | 1.8% | 1.6% | 1.4% |
| Huerfano | 6,711 | 6,712 | 7,246 | 7,769 | 8,243 | 8,654 | 9,040 | 0.0% | 1.5% | 1.4% | 1.2% | 1.0% | 0.9% |
| Jackson | 1,394 | 1,430 | 1,520 | 1,581 | 1,633 | 1,687 | 1,732 | 0.5% | 1.2% | 0.8% | 0.6% | 0.7% | 0.5% |
| Jefferson | 534,543 | 551,582 | 575,088 | 597,230 | 616,453 | 627,315 | 633,587 | 0.6% | 0.8% | 0.8% | 0.6% | 0.3% | 0.2% |
| Kiowa | 1,398 | 1,490 | 1,541 | 1,601 | 1,669 | 1,739 | 1,809 | 1.3% | 0.7% | 0.8% | 0.8% | 0.8% | 0.8% |
| Kit Carson | 8,270 | 8,345 | 8,585 | 8,832 | 9,088 | 9,287 | 9,469 | 0.2% | 0.6% | 0.6% | 0.6% | 0.4% | 0.4% |
| Lake | 7,310 | 8,303 | 9,514 | 10,767 | 11,924 | 12,593 | 13,047 | 2.6% | 2.8% | 2.5% | 2.1% | 1.1% | 0.7% |
| La Plata | 51,334 | 58,445 | 66,752 | 74,436 | 81,308 | 87,643 | 93,368 | 2.6% | 2.7% | 2.2% | 1.8% | 1.5% | 1.3% |
| Larimer | 299,630 | 328,236 | 360,813 | 394,236 | 424,833 | 453,561 | 481,193 | 1.8% | 1.9% | 1.8% | 1.5% | 1.3% | 1.2% |
| Las Animas | 15,507 | 16,633 | 18,494 | 20,235 | 21,840 | 23,276 | 24,588 | 1.4% | 2.1% | 1.8% | 1.5% | 1.3% | 1.1% |
| Lincoln | 5,467 | 5,488 | 5,876 | 6,310 | 6,768 | 7,185 | 7,585 | 0.1% | 1.4% | 1.4% | 1.4% | 1.2% | 1.1% |
| Logan | 22,709 | 22,794 | 24,253 | 26,147 | 28,127 | 30,107 | 31,992 | 0.1% | 1.2% | 1.5% | 1.5% | 1.4% | 1.2% |
| Mesa | 146,723 | 153,296 | 166,683 | 181,835 | 196,709 | 211,413 | 226,263 | 0.9% | 1.7% | 1.8% | 1.6% | 1.5% | 1.4% |
| Mineral | 712 | 785 | 852 | 910 | 943 | 966 | 988 | 2.0% | 1.7% | 1.3% | 0.7% | 0.5% | 0.4% |
| Moffat | 13,795 | 13,862 | 14,619 | 15,683 | 16,814 | 17,729 | 18,481 | 0.1% | 1.1% | 1.4% | 1.4% | 1.1% | 0.8% |
| Montezuma | 25,535 | 27,643 | 30,624 | 33,880 | 37,053 | 40,051 | 42,947 | 1.6% | 2.1% | 2.0% | 1.8% | 1.6% | 1.4% |
| Montrose | 41,276 | 43,319 | 49,721 | 57,005 | 64,072 | 69,892 | 75,048 | 1.0% | 2.8% | 2.8% | 2.4% | 1.8% | 1.4% |
| Morgan | 28,159 | 29,891 | 32,592 | 35,642 | 38,653 | 41,753 | 45,098 | 1.2% | 1.7% | 1.8% | 1.6% | 1.6% | 1.6% |
| Otero | 18,831 | 19,781 | 20,760 | 21,355 | 21,718 | 22,036 | 22,284 | 1.0% | 1.0% | 0.6% | 0.3% | 0.3% | 0.2% |
| Ouray | 4,436 | 4,971 | 5,571 | 5,770 | 5,908 | 6,017 | 6,108 | 2.3% | 2.3% | 0.7% | 0.5% | 0.4% | 0.3% |
| Park | 16,206 | 18,276 | 22,380 | 27,382 | 31,385 | 33,515 | 34,283 | 2.4% | 4.1% | 4.1% | 2.8% | 1.3% | 0.5% |
| Phillips | 4,442 | 4,300 | 4,326 | 4,421 | 4,501 | 4,568 | 4,621 | -0.6% | 0.1% | 0.4% | 0.4% | 0.3% | 0.2% |
| Pitkin | 17,148 | 18,445 | 20,585 | 23,003 | 25,517 | 27,979 | 30,344 | 1.5% | 2.2% | 2.2% | 2.1% | 1.9% | 1.6% |
| Prowers | 12,551 | 12,970 | 13,530 | 14,099 | 14,576 | 14,987 | 15,334 | 0.7% | 0.8% | 0.8% | 0.7% | 0.6% | 0.5% |

| COUNTIES | Census 2010 | SDO Proj. July, 2015 | SDO Proj. July, 2020 | SDO Proj. July, 2025 | SDO Proj. July, 2030 | SDO Proj. July, 2035 | SDO Proj. July, 2040 | Average Annual Percent Change 10-15 | 15-20 | 20-25 | 25-30 | 30-35 | 35-40 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pueblo | 159,063 | 168,610 | 183,142 | 198,497 | 213,656 | 226,321 | 235,020 | 1.2% | 1.7% | 1.6% | 1.5% | 1.2% | 0.8% |
| Rio Blanco | 6,666 | 6,920 | 7,502 | 8,186 | 9,305 | 9,885 | 10,238 | 0.8% | 1.6% | 1.8% | 2.6% | 1.2% | 0.7% |
| Rio Grande | 11,982 | 12,688 | 13,756 | 14,586 | 15,382 | 15,947 | 16,348 | 1.2% | 1.6% | 1.2% | 1.1% | 0.7% | 0.5% |
| Routt | 23,509 | 25,407 | 28,243 | 31,615 | 36,034 | 40,403 | 44,610 | 1.6% | 2.1% | 2.3% | 2.7% | 2.3% | 2.0% |
| Saguache | 6,108 | 6,723 | 7,332 | 7,884 | 8,344 | 8,761 | 9,133 | 1.9% | 1.7% | 1.5% | 1.1% | 1.0% | 0.8% |
| San Juan | 699 | 716 | 740 | 762 | 767 | 780 | 803 | 0.5% | 0.7% | 0.6% | 0.1% | 0.3% | 0.6% |
| San Miguel | 7,359 | 8,750 | 10,284 | 11,916 | 13,474 | 14,963 | 16,426 | 3.5% | 3.3% | 3.0% | 2.5% | 2.1% | 1.9% |
| Sedgwick | 2,379 | 2,487 | 2,634 | 2,756 | 2,859 | 2,950 | 3,037 | 0.9% | 1.2% | 0.9% | 0.7% | 0.6% | 0.6% |
| Summit | 27,994 | 31,701 | 37,543 | 43,161 | 48,187 | 52,719 | 56,857 | 2.5% | 3.4% | 2.8% | 2.2% | 1.8% | 1.5% |
| Teller | 23,350 | 24,651 | 27,141 | 29,636 | 31,995 | 34,236 | 36,437 | 1.1% | 1.9% | 1.8% | 1.5% | 1.4% | 1.3% |
| Washington | 4,814 | 4,534 | 4,430 | 4,413 | 4,397 | 4,364 | 4,331 | -1.2% | -0.5% | -0.1% | -0.1% | -0.2% | -0.2% |
| Weld | 252,825 | 282,706 | 328,588 | 385,394 | 445,160 | 505,705 | 567,218 | 2.3% | 3.1% | 3.2% | 2.9% | 2.6% | 2.3% |
| Yuma | 10,043 | 10,537 | 11,060 | 11,545 | 11,985 | 12,367 | 12,691 | 1.0% | 1.0% | 0.9% | 0.8% | 0.6% | 0.5% |

Source: Colorado Department of Local Affairs, September 2012; U.S. Census, 2010

## Figure 19. Projected Population Growth by County

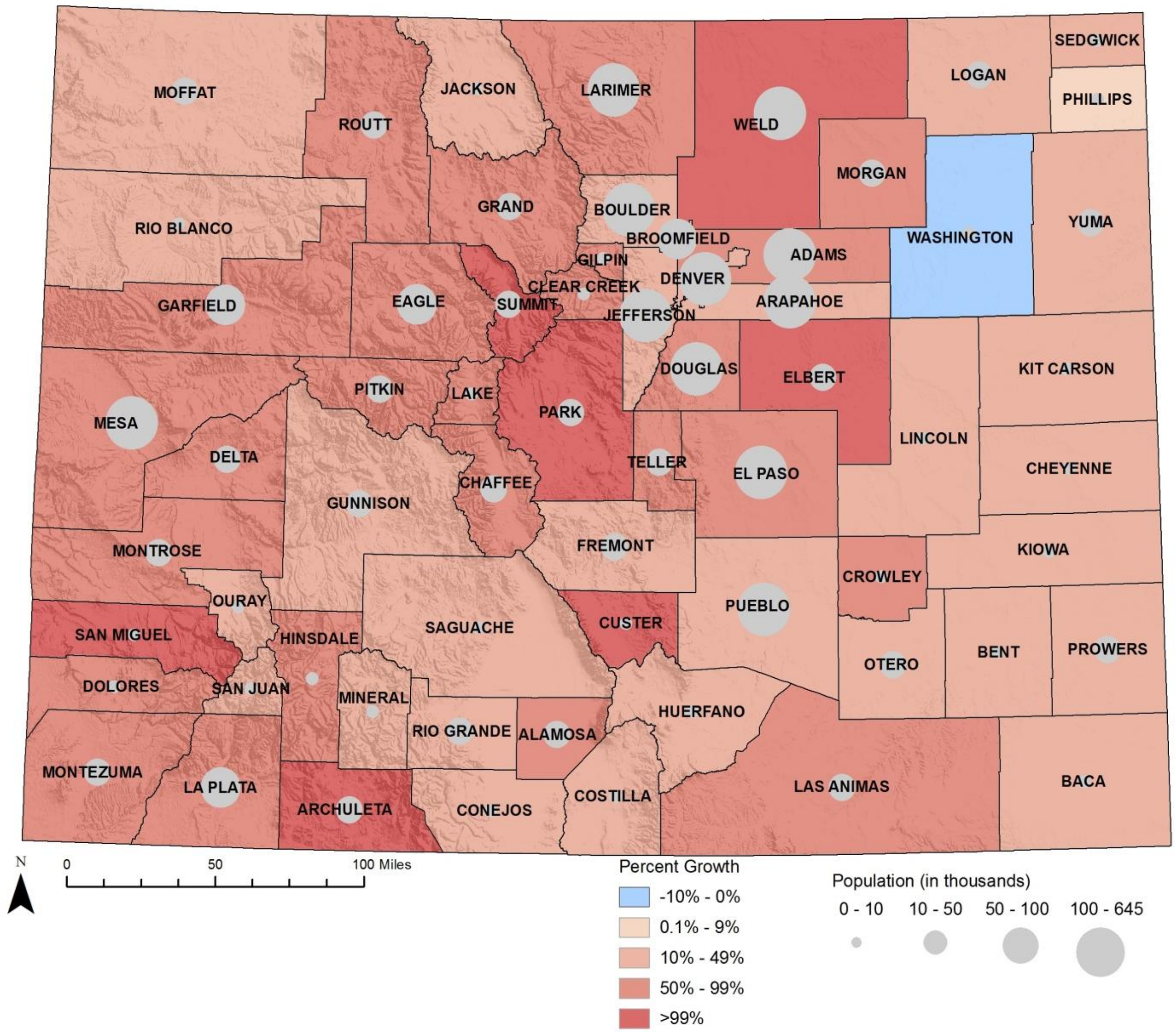



Figure Revised 2013

## 3.4 Assessing Vulnerability of State Facilities

Vulnerability to state facilities and other assets from drought varies depending on the asset. For state-owned or operated facilities (e.g., buildings, dams, ditches, etc.) the primary vulnerability is to catastrophic loss due to wildfires that can be made more severe by drought conditions. These facilities can be damaged due to prolonged droughts. For example, a building can be in an area with mandatory municipal watering restrictions, and as a consequence landscaping can be damaged or lost, incurring costs to the State. Dams and ditches, which are built to hold water, can become weakened if left dry for extended periods of time. The at-risk critical assets, impacts, and approximate value of assets are shown in Table 12, modified from the 2007 and 2010 Updates to the Colorado Drought Mitigation and Response Plan.

**Table 12 Critical Assets at Risk to Drought**

| State Assets at Risk (Buildings, Landscaping, Vehicles, Equipment, etc.) | Impacts | Approximate Value of Assets |
|---|---|---|
| Agricultural & Stock Businesses | Animal Program losses, economic loss, tourism, hatcheries, stock ponds, agriculture and stock activities, etc. | Unknown |
| Colorado Parks and Wildlife | Revenue from licenses, water activities, tourism, park visitation, revenue from water activities, biological loss – State Forest and park land trees – dead trees, beetle activity, wildfires, impacts to tourism | Unknown |
| State Buildings | Wells can dry up, would need to re-drill, loss of landscaping, possible wildfire exposure | Unknown |
| Instream Flows | Economic loss, biological loss | Unknown |

These at-risk state assets were reviewed and incorporated into the state assets assessment (the results of which are summarized in Section 3.3.2).

The following sections describe the types of facilities included in this assessment and present an overview of estimated monetary losses, where available.

### 3.4.1 Types of State Owned/Operated Facilities

For the vulnerability assessment of state assets, the sector was divided into the following sub-sectors: buildings, critical infrastructure, state lands, instream flows, and state fish hatcheries. Drought vulnerable critical infrastructure includes dams, transmountain ditches, and irrigation ditches. Instream flow rights are non-consumptive “in-channel” or “in-lake” water rights that can only be held by the Colorado Water Conservation Board. These rights designate minimum flows between specific points on a stream, or water levels in natural lakes.

The primary agencies responsible for drought-vulnerable state assets are the State Land Board, CWCB, and the CPW. Table 13 lists some key impacts to sub-sectors that were identified during the literature review and interview portion of the vulnerability assessment, in addition to those listed in Table 12.

**Table 13 State Assets Key Impacts**

| State Assets Sub-sector | Key Impacts |
|---|---|
| State-owned or operated buildings | Increased exposure to wildfires, increased wear and tear on building exterior and HVAC systems due to degraded air quality, and water shortages due to out-of-priority rights or restrictions imposed by municipality, landscaping loss. |
| Critical infrastructure | Decreased water levels in dams can cause structural damage, dry ditches can be damaged by animal holes and increased vegetative growth and high sediment loading resulting from low reservoir levels or wildfire debris can damage structures.<br>Drought causes extensive damages to state rights of way through accumulation of dust and dirt on right of way fences and stormwater diversion utilities. |
| State Land Board | Decreased forage and crop yields on leased lands, negative impacts to lands if lessees do not appropriately adjust grazing allowances, and decreased mining activity if water is not available for production. |
| State Parks | Low reservoir and stream levels can deter visitors and prevent water-based recreation, park closures and campfire restrictions can result from severe wildfires, negative media portrayal is possible, and visitation decline results in lower operating budget. |
| Aquatic habitat | Impacts to flow levels, water quality and fish populations and increased management requirements |
| Instream flow rights | Junior rights associated with instream flows mean that adequate water flow may not be maintained, resulting in environmental damages. |

# 3.5 Estimating Potential Losses by Jurisdiction

Many state assets are conservation areas or protected wildlife that cannot be adequately evaluated based on the revenue they generate. Colorado is renowned for its wilderness areas and outdoor recreation activities, and the value of these areas goes far beyond any revenue stream. Still, economic consideration is important because the revenues generated by state assets help to maintain protected areas. The following sections offer discussion on building values, land values, and revenue streams for the state agencies listed above.

## 3.5.1 Overview and Analysis of Potential Losses

A list of state-owned buildings was provided by the Colorado Risk Management Office. This list is fairly comprehensive but may not be a complete inventory of state buildings (i.e., university campuses are not reflected in the list and there are individual counties that maintain their own lists of local assets, which may be more comprehensive than the statewide dataset). Critical infrastructure data (limited to dams for the quantitative analysis) were obtained from the Homeland Security Infrastructure Program (HSIP) Freedom database, which in turn used information from the National Inventory of Dams from 2012. Table 14 summarizes building values and dam storage volumes by county, along with the vulnerability ranking (1 through 4, where 1 is the lowest vulnerability and 4 is the highest vulnerability) for the overall "structures" category. The vulnerability ranking is a weighted average of spatial inventory and vulnerability metrics – the spatial inventory establishes the relative presence of the drought-vulnerable item or sub-sector (in the case of structures, the items are buildings and dams), and the vulnerability metrics establish relative impacts to drought (for structures, the metrics are relative weight of dams to buildings and rating on the wildfire susceptibility index). The result of combining these into a weighted average based on spatial density is the overall vulnerability ranking. See Annex B for a thorough explanation of the vulnerability ranking methodology.

In Table 14, counties that are ranked 2.6 or above are highlighted to draw attention to the building values and the dam storage volume. Most of these counties have a considerable amount of storage in state-owned or operated dams, and their buildings may be within a moderate or high wildfire threat area. The next step to improving this loss estimate would be to expand the database to include not just dams, but other state-owned water conveyances like ditches and channels. Instead of storage volume, the cost to repair or replace these assets would be another source of information that could be used to estimate potential costs due to drought impacts.

**Table 14 Building Values and Dam Storage by County**

| County | State-owned or Operated Building Value | State Owned Dam Storage Volume (acre-feet) | Structure (buildings and dams) vulnerability ranking |
|---|---|---|---|
| Adams | $227,169,465 | 0 | 2.0 |
| Alamosa | $340,536,320 | 0 | 1.7 |
| Arapahoe | $249,051,917 | 85 | 2.0 |
| Archuleta | $10,491,399 | 2,149 | 3.3 |
| Baca | $1,764,023 | 75,241 | 3.0 |
| Bent | $158,109,450 | 0 | 2.0 |
| Boulder | $13,074,922 | 0 | 2.0 |
| Broomfield | $1,634,565 | 0 | 1.7 |
| Chaffee | $100,240,329 | 0 | 2.0 |
| Cheyenne | $727,793 | 0 | 2.6 |
| Clear Creek | $138,951,976 | 0 | 1.7 |
| Conejos | $60,349,568 | 14,965 | 3.0 |
| Costilla | $1,914,541 | 0 | 2.0 |
| Crowley | $83,299,224 | 0 | 1.7 |
| Custer | $938,983 | 0 | 2.0 |
| Delta | $35,834,072 | 1,333 | 2.3 |

| County | State-owned or Operated Building Value | State Owned Dam Storage Volume (acre-feet) | Structure (buildings and dams) vulnerability ranking |
|---|---|---|---|
| Denver | $3,297,933,750 | 0 | 1.7 |
| Dolores | $851,235 | 0 | 2.3 |
| Douglas | $34,133,292 | 0 | 2.3 |
| Eagle | $19,563,756 | 576 | 3.3 |
| El Paso | $254,453,976 | 0 | 2.0 |
| Elbert | $2,427,142 | 0 | 1.7 |
| Fremont | $462,374,405 | 0 | 2.3 |
| Garfield | $929,385,528 | 4,826 | 2.6 |
| Gilpin | $2,096,949 | 0 | 1.7 |
| Grand | $10,681,265 | 220 | 2.0 |
| Gunnison | $302,986,951 | 2,137 | 2.3 |
| Hinsdale | $583,278 | 12,829 | 2.4 |
| Huerfano | $41,029,129 | 2,760 | 2.6 |
| Jackson | $8,906,669 | 8,822 | 2.4 |
| Jefferson | $1,236,466,072 | 0 | 2.3 |
| Kiowa | $1,185,981 | 0 | 1.7 |
| Kit Carson | $2,492,585 | 1,360 | 3.0 |
| La Plata | $422,751,366 | 526 | 2.3 |
| Lake | $2,492,514 | 0 | 1.7 |
| Larimer | $98,570,247 | 3,039 | 3.0 |
| Las Animas | $164,491,063 | 0 | 2.6 |
| Lincoln | $104,404,158 | 345 | 2.0 |
| Logan | $234,618,622 | 950 | 2.3 |
| Mesa | $534,295,523 | 3,580 | 3.3 |
| Mineral | $1,872,978 | 3,199 | 2.4 |
| Moffat | $14,569,118 | 115 | 2.6 |
| Montezuma | $17,896,339 | 0 | 2.6 |
| Montrose | $18,555,405 | 0 | 2.6 |
| Morgan | $52,380,453 | 0 | 2.3 |
| Otero | $69,040,012 | 0 | 2.0 |
| Ouray | $35,381,460 | 0 | 2.0 |
| Park | $11,355,656 | 1,963 | 3.0 |
| Phillips | $152,605 | 106 | 2.4 |
| Pitkin | $549,861 | 0 | 2.0 |
| Prowers | $62,196,505 | 0 | 2.0 |
| Pueblo | $814,774,533 | 77 | 2.3 |

| County | State-owned or Operated Building Value | State Owned Dam Storage Volume (acre-feet) | Structure (buildings and dams) vulnerability ranking |
|---|---|---|---|
| Rio Blanco | $56,263,490 | 9,038 | 3.3 |
| Rio Grande | $127,343,200 | 5,158 | 2.3 |
| Routt | $16,453,405 | 29,249 | 3.3 |
| Saguache | $3,466,819 | 880 | 2.3 |
| San Juan | $602,206 | 131 | 1.7 |
| San Miguel | $1,887,024 | 7,081 | 3.0 |
| Sedgwick | $1,947,332 | 63 | 1.7 |
| Summit | $157,351,802 | 0 | 1.7 |
| Teller | $9,506,344 | 2,066 | 2.7 |
| Washington | $1,315,485 | 0 | 2.3 |
| Weld | $43,697,802 | 192 | 3.3 |
| Yuma | $13,792,987 | 143 | 2.0 |

Source: Risk Management Office, 2012; Homeland Security Infrastructure Program, 2012

The State Assets Sector analysis includes a thorough discussion of the ranking process, but in general the factors of vulnerability for structures were “relative importance of storage” and “wildfire threat ranking.” Structure rankings ranged from 1.7 to 3.3; a relatively small range. A higher ranking resulted from a high relative importance of water storage and location within the wildfire urban interface.

The State Land Board is the other sub-sector within state assets where a dollar-value for the revenue stream was available. The State Land Board generates revenue by leasing land for agricultural and industrial activities. They also lease mineral rights, and a significant portion of their income is produced by mineral royalties. Table 15 shows the leasing revenue by source for fiscal year 2010-2011. Although agricultural leases account for most of the land leases, they do not generate as much revenue as the mineral, oil, gas, and coal royalties.

**Table 15 State Land Board Revenue, FY 2010-2011**

| Gross Revenue Dollars by Source | |
|---|---|
| Agricultural Rental Income | $9,829,765 |
| Commercial Revenue | $2,457,441 |
| Gas Royalty | $15,973,369 |
| Oil Royalty | $17,202,090 |
| Coal Royalty | $7,372,324 |
| Bonus Income | $63,893,475 |
| All Other Income | $6,143,603 |
| **Total** | **$122,872,069** |

Source: Board of Land Commissioners, 2011

Drought impacts to this revenue stream are mainly incurred through agricultural leases. Based on conversations with State Land Board representatives, the mineral asset revenue is relatively drought tolerant; while it is likely that mineral producers would incur extra operating costs in a drought, it has not been the experience of the State Land Board that producing companies actually stop operations or postpone expansions. The large amount of Bonus Income is a product of advancements in horizontal drilling technology and oil prices. Parcels that were previously not thought to hold significant value were leased at record rates (Board of Land Commissioners, 2011). However, most mining activities do require water, and it is possible that in a severe drought mining operations would be unable to purchase the water they need for production. For a greater discussion, refer to the Energy Sector analysis for more information on mining. Given the importance of mining revenue to the State Land Board, this possibility should be taken seriously in any future planning efforts.

The most vulnerable State Land Board revenue stream is the agricultural lease revenue. Under drought conditions, rangeland carrying capacity can be significantly reduced, leading to overgrazing concerns and financial hardship for the agricultural lessees. Similarly, crop yields on agricultural leases may be reduced and/or crop failure may occur. Agricultural leases through the State Land Board are issued on a 10-year basis, which makes it difficult for farmers and ranchers to change the amount of leased area in response to drought. However, the State Land Board has a vested interest in the responsible stewardship of the land, and in the past they have been willing to offer lease discounts during drought in exchange for a reduction in grazing or other detrimental activity. In the 2002 drought, the State Land Board issued blanket lease discounts (between 10% and 40%) in an attempt to reduce grazing activity. The total cost of these discounts was estimated by State Land Board staff to be $1.9 million. These discounts did not have the intended mitigating impact because many lessees continued to manage the land as usual. As of the 2010 Plan Update, the State Land Board was planning on only offering lease discounts during future drought when applied for on a case-by-case basis (personal communication with State Land Board, 2010). However, the lease discount program was discontinued in 2012 (personal communication with State Land Board, 2013).

Other potential losses to state departments include reductions in visitation to state parks and fewer hunting and fishing license sales. Both visitation and license sales are important revenue streams for CPW. Data are available showing a decrease in visitation to Colorado state parks during the 2002 and 2011-2013 drought events, but no revenue loss figures are available. Similarly, losses are expected to occur to CPW during drought but no exact figures were obtainable for this assessment. To give a sense of the relative importance of licensing revenue to CPW, in fiscal year 2002-2003 licensing accounted for $60.6 million out of the $87 million revenue stream, and in fiscal year 2003-2004 it accounted for $67.4 million out of the $100.3 million revenue stream. CPW attributes $96.9 million out of $185.4 million in revenue to licenses, passes, fees, and permits for the 2011-2012 fiscal year, (CPW, 2013).

One way to estimate potential losses due to drought is to look at previously-reported losses and existing economic exposure of state assets. Table 16, taken from the 2007 Drought Update

Report, summarizes losses from recent droughts, and tabulates economic exposure of at-risk state assets.

## Table 16 Potential Drought Losses Based on Historic Economic Impacts

| Potential Economic Impacts to State Facilities | Where Potential Losses and Effects Could be Exhibited | State Economic Exposure and/or Past Drought Impacts |
|---|---|---|
| Costs and losses to agricultural and livestock producers | State lands leased for crops to crop producers for farming and livestock producers for grazing<br>Grazing, recreation, and forestry uses of Colorado State Forests | The State Land Board generates over $37 million annually in revenues from leases and royalties (including land leased for ranching/grazing, farming, mineral, oil and gas, and recreation). However, for the 2010-2011 fiscal year, they recorded record revenues of over $122 million.<br>In 2007 the State received between $7.64 and $10.22 per animal unit month (AUM) grazed on state lands.<br>There are 3 million surface acres of state trust lands; 400,000 acres leased by CPW for hunting, fishing, and other wildlife recreation. |
| Loss from fishery production | State-owned fish propagation and restoration facilities<br>Fishing license sales<br>Fish in streams throughout state (all wildlife is “owned” by the State) | CPW, citing BBC, 2008, estimates that fishing generated $725.2 million in direct visitor expenditures for the 2011-2012 fiscal year.<br>CPW operates 16 fish propagation facilities, including the Roaring Judy Hatchery for the propagation of endangered Colorado River fish.<br>In 2005, the fish production hatcheries and rearing units reared and stocked 54.3 million warm water fish; 3.4 million catchable trout; 795,000 native cutthroat trout; and 12.3 million fry and fingerling trout. 1.8 million pounds of fish were stocked in 2005.<br>In 2001, economic output resulting from anglers estimated at about $646 million from 9.3 million recreation days.<br>In 2002, anglers spent about $459 million on trip/equipment expenses in Colorado. Secondary impacts estimated at $820 million. This activity supports approximately 10,950 full-time jobs in Colorado.<br>In 2002, fishing license sales declined by about 15% from 2001, and there was a 13.4% decline in fishing recreation days from 2001 to 2002. |

| Potential Economic Impacts to State Facilities | Where Potential Losses and Effects Could be Exhibited | State Economic Exposure and/or Past Drought Impacts |
|---|---|---|
| Losses to wildlife | Hunting license sales<br>Wildlife throughout the State | CPW, citing BBC, 2008, estimates that hunting (big and small game) generated $292.6 million in direct visitor expenditures for the 2011-2012 fiscal year. This revenue helped support over 900 full time CPW employees.<br>In 2002, hunters spent about $338 million on trip/equipment expenses in Colorado. Secondary impacts estimated at $603 million. Total annual impact about $941 million (from 2.1 million recreation days). This activity supports about 8,250 full-time jobs in Colorado.<br>In 2001, trip/equipment expenditures primarily for wildlife watching activity over one mile from home estimated at $562 million. Secondary impacts estimated at $378 million. Total annual impact about $940 million. This activity supports an estimated 13,000 jobs. |
| Costs and losses to state parks | Revenues<br>Damage to parks themselves | For the 2011-2012 fiscal year, Colorado's state parks had over 12 million visitors.<br>Colorado's state parks attracted over 11 million visitors in FY 2005-2006.<br>Visitors to Colorado state parks contribute over $200 million annually to local economies.<br>In 2002, state parks experienced a 3% decline in visitation. |
| Losses due to hydrological effects | State-owned instream flows | CWCB has appropriated instream flow water rights on nearly 1,500 stream segments covering 8,500 miles of stream and 476 natural lakes.<br>Instream flow impacts during 2002 drought mitigated somewhat by downstream senior water rights calls. |

Source: 2007 Drought Update Report, modified in 2010 and 2013

Instream flow rights are considered assets, as they have a real value on the water rights market. This market is highly variable and not well-documented; therefore tabulating the 2013 value of CWCB water rights would be impractical from a logistical as well as value-added perspective. In future droughts it might be beneficial to track the value of instream flow rights to assess whether they gain or lose, and to collect data on additional expenditures by the CWCB to maintain a minimum flow to protect aquatic habitat during droughts.

In 2002 CPW learned that instream flows were not as adversely affected as precipitation conditions would have initially indicated, since low water supplies during the extreme drought resulted in a shift in typical water right administration and water use patterns. In 2002, there were significantly fewer and less depletions from junior water rights and the calling senior water rights were farther downstream thus having the effect of pulling water downstream through the watershed; the junior intervening instream flow water right became the unintended beneficiary of this pattern of water right administration. As a result, a number of higher order streams (i.e., first, second, and third order streams) experienced water levels greater than or equal to what is typically experienced under normal water supply conditions. Further, the 2002 experience highlighted the need for CPW and CWCB to increase their cooperative efforts regarding management of DOW's water right portfolio, in particular the use of our reservoirs and storage water rights, to examine the feasibility of releasing water to protect instream flows, releasing water to water uses downstream (CPW uses and other downstream uses) with the intervening instream flow reach becoming the incidental beneficiary of such practices.

Table 17 shows agricultural indemnities from 1998-2012 due to drought. The data were obtained from the USDA Risk Management Agency and filtered for losses incurred specifically by drought. It is interesting to note that 2002 was not the worst year for crop indemnities in some counties; for example, Adams County had over three times the indemnity amounts in 2003 as it did in 2002. Crop indemnities are just one dataset that can be used to estimate potential losses for drought. While not specific to state assets, agricultural losses have the potential to significantly impact a local economy, which in turn can reduce the tax base and cause decreased government revenue.

Based on the information in this table the total crop indemnity amount for all counties between 1998 and 2012 was $609 million. This equates to an average annual drought related crop indemnities amount of $40.6 million.

## Table 17 USDA Risk Management Agency Crop Indemnities Specific to Drought

| County | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Adams | $58,973 | $63,708 | $198,108 | $95,816 | $1,275,499 | $4,731,685 | $1,883,307 | $1,339,774 | $3,254,523 | $503,968 | $3,499,624 | $723,133 | $216,685 | $2,818,172 | $2,700,812 | $23,363,787 |
| Alamosa | - | - | - | - | - | $2,286 | - | - | - | - | - | - | - | - | - | $2,286 |
| Arapahoe | $4,016 | $15,186 | $75,631 | $29,868 | $814,095 | $2,039,321 | $1,038,090 | $742,511 | $1,917,827 | $54,239 | $1,496,292 | $184,892 | $54,077 | $2,301,413 | $1,872,548 | $12,640,006 |
| Archuleta | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Baca | $76,294 | $96,484 | $873,357 | $1,233,150 | $7,195,361 | $2,384,439 | $1,910,071 | $1,487,405 | $13,506,577 | $1,602,454 | $17,698,854 | $1,956,160 | $248,154 | $17,492,917 | $7,729,290 | $75,490,967 |
| Bent | - | - | $20,521 | $183,671 | $167,360 | $167,838 | $137,421 | $28,153 | $125,773 | $18,441 | $202,878 | $165,242 | - | - | - | $1,217,298 |
| Boulder | $34 | $3,124 | $2,173 | $3,916 | $1,387 | $221 | $4,035 | $786 | $6,275 | $13,071 | $1,786 | - | - | $16,471 | $4,326 | $57,605 |
| Broomfield | - | - | - | - | - | - | - | - | $49,081 | $2,208 | $18,372 | - | - | - | - | $69,661 |
| Chaffee | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Cheyenne | $187,556 | $338,151 | $2,643,779 | $3,459,660 | $13,572,942 | $11,619,901 | $11,224,968 | $2,284,535 | $6,766,958 | $945,174 | $7,882,762 | $391,249 | $119,675 | $2,413,174 | $11,019,936 | $74,870,420 |
| Clear Creek | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Conejos | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Costilla | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Crowley | - | - | $2,091 | $19,618 | $72,419 | $101,954 | $186,965 | $75,901 | $105,905 | $118,973 | $214,221 | $67,932 | - | - | - | $965,979 |
| Custer | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Delta | - | - | - | - | - | - | - | - | - | - | - | - | - | $3,142 | - | $3,142 |
| Denver | - | $3,295 | $10,488 | - | - | $28,347 | $14,455 | $46,462 | $87,696 | $27,306 | $189,666 | $42,457 | $26,221 | - | $46,375 | $522,768 |
| Dolores | $178 | $3,236 | $208,149 | $84,975 | $516,617 | $144,781 | $106,791 | $13,391 | $187,552 | $67,400 | $15,013 | $67,790 | $33,918 | $5,922 | $195,268 | $1,650,981 |
| Douglas | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Eagle | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| El Paso | - | - | - | - | $284 | $899 | - | - | - | - | - | - | - | - | - | $1,183 |
| Elbert | $9,883 | $34,590 | $57,088 | $129,894 | $802,476 | $533,263 | $958,240 | $301,966 | $925,701 | $113,246 | $1,364,535 | $107,573 | $81,346 | $2,331,133 | $2,359,588 | $10,110,522 |
| Fremont | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Garfield | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Gilpin | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Grand | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |

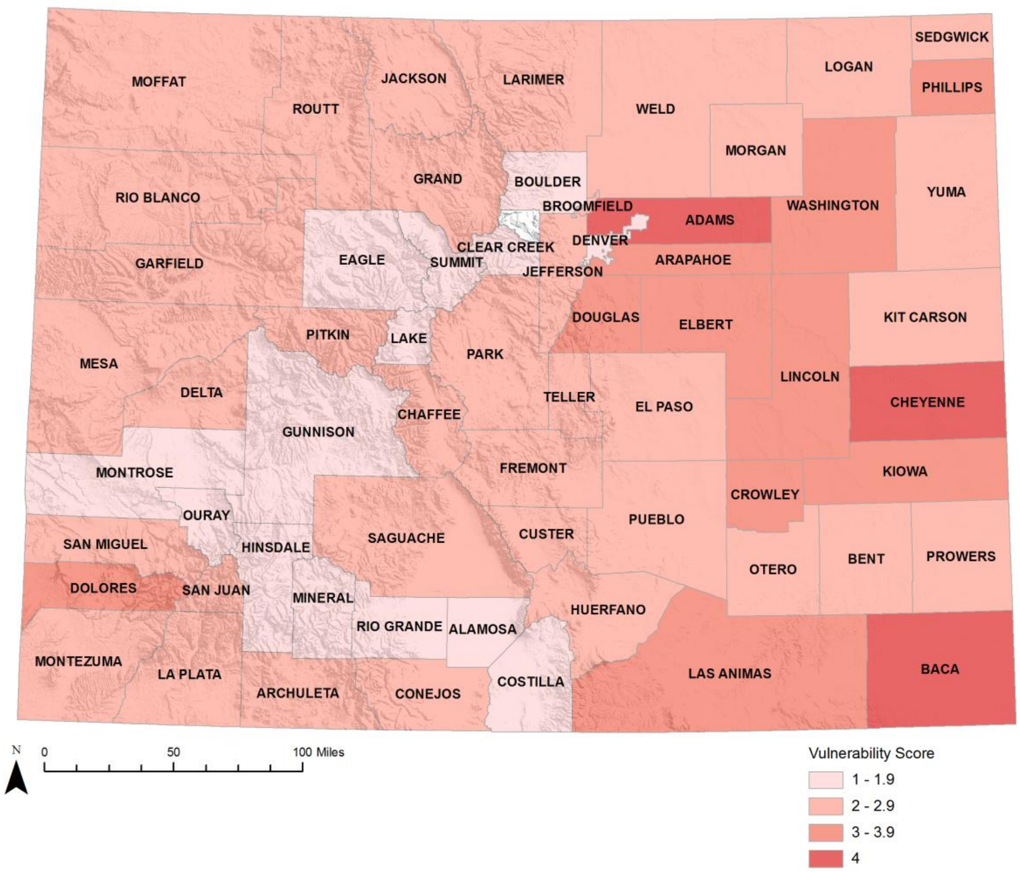
| County | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gunnison | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Hinsdale | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Huerfano | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Jackson | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Jefferson | - | $2,422 | $391 | - | $203 | - | - | - | - | - | - | - | - | - | - | $3,016 |
| Kiowa | $13,198 | $125,082 | $1,679,222 | $6,527,901 | $15,391,458 | $4,834,476 | $6,710,635 | $2,228,479 | $4,541,957 | $450,211 | $8,735,960 | $837,016 | $126,083 | $9,202,631 | $16,652,432 | $78,056,741 |
| Kit Carson | - | $105,755 | $4,407,646 | $5,468,269 | $15,346,669 | $13,004,368 | $22,161,011 | $5,995,050 | $11,334,464 | $1,406,961 | $6,076,579 | $69,240 | $2,695 | $1,852,104 | $21,137,655 | $108,368,466 |
| La Plata | - | $2,016 | $11,552 | $21,514 | $75,598 | $63,528 | $19,590 | $1,719 | $34,839 | $6,786 | $9,818 | $12,971 | - | - | $1,913 | $261,844 |
| Lake | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Larimer | $343 | - | - | $394 | $10,522 | - | $5,754 | - | $24,868 | $1,714 | $11,427 | $985 | - | $28,009 | $8,547 | $92,563 |
| Las Animas | - | - | $133 | $1,479 | $51,345 | $6,354 | $1,707 | - | $32,256 | - | $6,915 | $3,641 | - | - | - | $103,830 |
| Lincoln | $22,762 | $12,800 | $388,747 | $462,601 | $4,250,083 | $3,105,873 | $5,313,330 | $2,160,453 | $4,205,055 | $691,723 | $5,261,296 | $537,752 | $274,284 | $8,454,623 | $8,956,940 | $44,098,322 |
| Logan | $15,131 | $63,355 | $1,091,746 | $492,299 | $5,377,941 | $743,389 | $2,337,430 | $1,372,864 | $4,381,594 | $672,616 | $2,417,382 | $140,295 | $95,327 | $229,547 | $4,561,682 | $23,992,598 |
| Mesa | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Mineral | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Moffat | - | - | - | $9,109 | $34,191 | $24,599 | $2,388 | - | $16,474 | $8,774 | $22,357 | - | - | - | - | $117,892 |
| Montezuma | - | $4,785 | $42,401 | $5,474 | $127,788 | $34,661 | $25,152 | $3,825 | $45,930 | $8,951 | $10,124 | $15,374 | $5,511 | $4,090 | $7,948 | $342,014 |
| Montrose | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Morgan | $55,915 | $361 | $189,867 | $2,907 | $550,134 | $976,259 | $811,204 | $533,306 | $925,399 | $405,099 | $1,434,712 | $162,399 | $95,336 | $1,049,247 | $1,538,890 | $8,731,035 |
| Otero | - | - | - | - | $2,650 | - | - | - | - | - | - | - | - | - | - | $2,650 |
| Ouray | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Park | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Phillips | $21,431 | $71,642 | $3,248,339 | $826,092 | $7,356,138 | $1,562,649 | $3,604,401 | $3,416,059 | $7,257,880 | $36,084 | $979,974 | $25,360 | $40,301 | $799,348 | $11,289,932 | $40,535,630 |
| Pitkin | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Prowers | $50,482 | $37,536 | $264,646 | $1,585,737 | $4,936,093 | $1,478,303 | $2,060,395 | $594,925 | $3,254,990 | $182,671 | $5,322,967 | $713,272 | $139,104 | $4,988,061 | $3,510,978 | $29,120,160 |
| Pueblo | - | - | $3,081 | $124,949 | $141,089 | $125,409 | $119,810 | $131,607 | $147,819 | $199,391 | $286,625 | $113,814 | $197,635 | $174,188 | $356,115 | $2,121,532 |
| Rio Blanco | - | - | - | - | $1,074 | - | - | - | $2,554 | - | - | - | - | - | - | $3,628 |
| Rio Grande | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |

| County | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Routt | $216 | - | $3,768 | $15,820 | $23,702 | $8,349 | - | - | $10,781 | $842 | $7,745 | - | - | - | - | $71,223 |
| Saguache | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| San Juan | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| San Miguel | - | $2,856 | $10,321 | $4,976 | $25,642 | $30,770 | $3,398 | - | $3,433 | - | $115 | $4,525 | - | - | $7,517 | $93,553 |
| Sedgwick | $874 | - | - | - | - | - | - | - | - | - | - | - | $4,016 | $409,345 | $4,841,981 | $5,256,216 |
| Summit | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Teller | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Washington | $57,477 | $16,639 | $883,408 | $267,006 | $2,214,476 | $692,136 | $854,833 | $1,163,615 | $3,344,411 | $39,910 | $62,239 | $11,142 | $369,834 | $1,950,298 | $15,445,922 | $27,373,346 |
| Weld | $46,456 | $33,867 | $497,548 | $115,818 | $1,311,396 | $2,222,419 | $1,217,672 | $825,734 | $1,593,821 | $718,172 | $1,598,584 | $189,493 | $128,980 | $1,135,939 | $1,204,096 | $12,839,995 |
| Yuma | $90,564 | $306,659 | $1,621,441 | $554,436 | $4,211,141 | $1,432,124 | $4,258,657 | $2,449,147 | $3,685,976 | $92,118 | $949,968 | $51,824 | $26,117 | $449,490 | $6,343,688 | $26,523,350 |

Source: USDA

Crop indemnities due to drought, as shown in Table 17, were one factor in the vulnerability assessment for the Agricultural Sector. Other factors taken into consideration were head of cattle, dryland crop acreage, and livestock indemnities. In some cases there were significant uncertainty in the data and this is denoted as hash marks on the map. Figure 20 shows the results of the agriculture vulnerability assessment. See Annex B for a complete discussion of this assessment.

**Figure 20. Agriculture Overall Vulnerability Ranking**




## 3.5.2 Potential Losses Based on Estimates in Local and State Risk Assessments

There was little specific information available from the local multi-hazard risk assessments as it relates to drought vulnerability. Table 18 lists drought impacts reported or anticipated in local plans, along with any economic loss estimates contained within the plans.

## Table 18 Impacts and Estimated Losses from Local Hazard Mitigation Plans

| Local Risk Assessment | Reported or Anticipated Impacts | Estimated Losses |
|---|---|---|
| Archuleta County | The impacts will vary throughout the County, but a severe drought will affect the entire economy, particularly the tourism, recreation, and agricultural industries. Losses include: water restrictions associated with domestic supplies, agricultural losses and economic impacts associated with those losses, economic impacts to tourism and recreation industries, increased wildland firefighting costs, and increased costs for water. | No specific dollar values given, but drought impacts would be critical, with 25% to 50% of the planning area affected and 10% to 50% agricultural losses. |
| Boulder County | Impacts of future drought will vary by region. Agricultural industry expected to experience crop losses and livestock feeding expenses and deaths. The County will see an increase in dry fuels, beetle kill, associated wildfires, and loss of tourism revenue. Water supply issues for municipal, industrial, and domestic needs will be a concern for the entire county… vulnerability increases with consecutive winters of below-average snow pack. | None given. |
| City of Boulder | Drought impacts would be citywide and may include reduction in water supply and an increase in dry fuels and wildfire potential. Watering restrictions may be implemented if a drought occurs depending on severity. | None given. |
| City of Colorado Springs | The main drought impact is agricultural, followed by fire and social (those associated with the public or recreation/tourism, loss of human life from heat stress, loss of aesthetic values, etc.). | None given. |
| Costilla County | Agricultural impacts are one of the more significant economic effects to communities. Decrease in water availability can impact water quality and increase salinity, bacteria, turbidity, and temperature. Aquatic habitat can be impacted as a result. | Using exposure analysis of the wildfire red zone, the total value of structures at risk (located in the red zone) in Costilla County is estimated at $96.4 million. |
| Delta County | The most significant impacts are to water intensive activities such as agriculture, wildfire protection, municipal usage, commerce, and tourism and recreation. Water quality deterioration can also occur. | Data from Delta Area Development, Inc. indicates a total value of harvested cropland is $116.4 million. A future drought that causes a 20% loss of the total value in the county would result in potential losses of $23.3 million. |
| Delta County (Hotchkiss) | The town's domestic water source is surface water from Leroux Creek. In drier years, the town can call upon lesser decreed users to relinquish the water to the town first. | None given. |

| Local Risk Assessment | Reported or Anticipated Impacts | Estimated Losses |
|---|---|---|
| Denver Regional Council of Governments (Adams, Arapahoe, Broomfield, Clear Creek, Denver, Douglas, Gilpin, Jefferson) | Impacts due to drought include ensuring a constant, reliable supply of water for agriculture, manufacturing, tourism, commercial and domestic use. Physical and economic impacts can also occur. | None given. |
| Dolores County (Plan update in progress) | Drought was profiled but no vulnerability analysis was conducted. | None given. |
| Eagle County (Plan update in progress) | Drought can impact water supplies for individuals and the recreation and tourism sector. Low snowfall can cause decreases in skier visits. Reduced streamflow levels can greatly impact the rafting industry. Other outdoor activities including camping, hiking, fishing and biking can decrease due to closure of wilderness areas resulting from dry conditions. | None given. |
| Elbert County | The most significant impacts from drought are related to water-intensive activities, such as agriculture (i.e., crops and livestock), wildfire protection, municipal usage, commerce, recreation, and wildlife preservation; as well as a reduction of electric power generation and water quality deterioration. Secondary impacts of drought are wildfires, wind erosion, and soil compaction that can make an area more susceptible to flooding. | None given. |
| El Paso County (Plan update in progress) | Agricultural Sector is usually the first to be impacted because of heavy dependence on stored soil water. Those who rely on surface water (i.e., reservoirs and lakes) and groundwater are usually the last to be affected. | None given. |
| Grand County (2013 plan update in progress) | Drought can impact water supplies for individuals, ranchers, and the recreation and tourism sector. Low snowfall can cause decreases in skier visits. Reduced streamflow levels can greatly impact the rafting industry. Other outdoor activities including camping, hiking, fishing and biking can decrease due to closure of wilderness areas resulting from dry conditions. | None given. |
| Gunnison County (2012 update FEMA approved pending adoption) | Most of the impacts in Gunnison County due to drought are from agriculture. Wildfire, impacts to society and public health, and increased relief, response and restrictions are other impacts, Secondary impacts include reduction in vegetation cover which exposes soil to wind erosion, exacerbating flooding. Recreation and tourism can also be affected | Gunnison County was included in a drought disaster declaration in January 1977. The damage from this event was estimated at $4,873,838 in 2009 dollars according to the Public Entity Risk Institute. |

| Local Risk Assessment | Reported or Anticipated Impacts | Estimated Losses |
|---|---|---|
| Hinsdale County (Expired) | The entire region is vulnerable to drought. Impacts include increased fire danger in urban areas and wilderness areas, reduction in vegetation cover causing exposure of soil to wind and erosion, and decreased water quality in rivers and lakes. Domestic and agricultural water supply needs would also be affected. | None given. |
| Huerfano County | Individuals, tourism, farming and recreation can be disrupted by the effects of drought. Water supply distribution to irrigated lands in the lower areas of the county can become a concern during drought to farmers. | The agricultural lands in Huerfano County were assessed at $6,811,861 in 2008. If drought affected even a portion of these lands, the losses would be considerable. |
| Jefferson County | Impacts of future drought will vary by region. Although the agricultural industry is limited, it is expected to experience crop losses and livestock feeding expenses and deaths. The County will see an increase in dry fuels, beetle kill, associated wildfires, and some loss of tourism/recreation revenue. Water supply issues for municipal, industrial, and domestic needs will be a concern for the entire County. Lawn and tree impacts in suburban areas could result from water restrictions. Vulnerability increases with consecutive winters of below-average snow pack. | None given. |
| Mesa County | Drought can impact agriculture and related businesses, which comprise a significant portion of the economy in Mesa County. | None given. |
| Montrose County | Long droughts can impact the county by causing losses to fish and wildlife habitat, reduction in food and drinking water for wild animals, more diseases in wildlife, lower water levels in lakes and rivers, loss of wetlands, more wildfires, and erosion of soils. Reduced production of agriculture is another impact. Some of these can impact tourism, municipal water usage, commerce, recreation, wildlife preservation, electric power generation and water quality. | None given. |
| Northeast Colorado Region (Cheyenne, Kit Carson, Lincoln, Logan, Morgan, Phillips, Sedgwick, Washington, Weld, and Yuma) | The entire region is vulnerable to drought. With the majority land area of the region used for agricultural purposes, the planning area has significant exposure to this hazard. | Available crop insurance data indicates over $644 million has been paid to the region's agricultural landowners in insurance claims between 1980 and 2007. It is reasonable to assume that a significant amount of this is due to drought-related losses. |

| Local Risk Assessment | Reported or Anticipated Impacts | Estimated Losses |
|---|---|---|
| Northern Colorado Region (Larimer County, Ft. Collins, Loveland, and Greeley) | All residents, commercial facilities, industry, and agricultural businesses are impacted by this hazard. Specific buildings are not identified as being at risk since drought impacts the entire community. | None given. |
| Ouray County (2013 plan update in progress) | The agricultural economy of the northern county will experience hardships, including agricultural losses, associated with a reduction in water supply. The southern county will see an increase in dry fuels, beetle kill, and associated wildfires and some loss of tourism revenue during the ski season. Water supply issues for domestic needs will be a concern for the entire county during droughts. | None given. |
| Park County (2013 plan update in progress) | One of the most significant economic effects is the impact on agriculture. Environmental drought impacts include both human and animal habitats and hydrologic units. Potential for a variety of secondary impacts, such as impacts to local commerce including tourism and providers of goods and services to Park County's agricultural community. | None given. |
| Pitkin County (2012 update FEMA approved pending adoption) | Water-intensive activities are subject to the most significant impacts due to drought. This includes municipal water usage, agriculture (crops and livestock), wildfire protection, commerce, recreation, and wildlife preservation via maintained wetlands. Electric power generation reduction and water quality deterioration are additional impacts. Secondary impacts include wildfires, wind erosion, and soil compaction that can cause an area to be more susceptible to flooding. | None given. |
| Prowers County (Plan update in progress) | Since the economy of Prowers County is so closely tied to agriculture and related businesses, the potential economic impact is severe. | None given. |
| Pueblo County | Agricultural activity in Pueblo County provides a significant portion of its economic base. Drought conditions would therefore have a tremendous impact on the economy of the communities in the County. Impact would also be evident on other industries that rely on water, which would also affect Pueblo County's economy. | None given. |
| Rio Blanco County (Expired) | Water shortages due to drought may impact nature and society in the county. This also affects how much of an impact wildfires may have in the area. | None given. |

| Local Risk Assessment | Reported or Anticipated Impacts | Estimated Losses |
|---|---|---|
| Routt County | Some areas are more prone to beetle kill and associated wildfires as a result of ongoing drought. Air quality impacts due to dust, damage to the ranching economy, and reduction of tourism and recreation activities are other drought impacts. Routt County relies heavily on the ski industry and recreation/tourism in general so is very vulnerable to drought conditions. Population growth and increased water demands will affect existing supplies. | None given. |
| San Luis Valley (Alamosa) | Loss of reliable water supply is a severe impact of drought in unincorporated portions of Alamosa County due to the agricultural economy. Cities and towns are affected by water supply reliability, operations revenue and system flexibility during drought. Increased wildfire risk and impacts to water supplies for fighting fires are other drought impacts. | None given. |
| San Luis Valley (Conejos) | Water-intensive activities are subject to the most significant impacts due to drought. This includes municipal water usage, agriculture (crops and livestock), wildfire protection, commerce, recreation, and wildlife preservation via maintained wetlands. Electric power generation reduction and water quality deterioration are additional impacts. Loss of reliable water supply is a severe impact of drought in unincorporated portions of Conejos County due to the agricultural economy. Cities and towns are affected by water supply reliability, operations revenue and system flexibility during drought. Increased wildfire risk and impacts to water supplies for fighting fires are other drought impacts. | None given. |
| San Luis Valley (Mineral) | Water-intensive activities are subject to the most significant impacts due to drought. This includes municipal water usage, agriculture (crops and livestock), wildfire protection, commerce, recreation, and wildlife preservation via maintained wetlands. Electric power generation reduction and water quality deterioration are additional impacts. Loss of reliable water supply is a severe impact of drought in unincorporated portions of Mineral County due to the agricultural economy. The City of Creede is affected by water supply reliability, operations revenue and system flexibility during drought. Increased wildfire risk and impacts to water supplies for fighting fires are other drought impacts. | None given. |

| Local Risk Assessment | Reported or Anticipated Impacts | Estimated Losses |
|---|---|---|
| San Luis Valley (Rio Grande) (FEMA approved pending adoption) | Water-intensive activities are subject to the most significant impacts due to drought. This includes municipal water usage, agriculture (crops and livestock), wildfire protection, commerce, recreation, and wildlife preservation via maintained wetlands. Electric power generation reduction and water quality deterioration are additional impacts. Loss of reliable water supply is a severe impact of drought in unincorporated portions of Rio Grande County due to the agricultural economy. Cities and towns are affected by water supply reliability, operations revenue and system flexibility during drought. Increased wildfire risk and impacts to water supplies for fighting fires are other drought impacts. | None given. |
| San Luis Valley (Saguache) | Water-intensive activities are subject to the most significant impacts due to drought. This includes municipal water usage, agriculture (crops and livestock), wildfire protection, commerce, recreation, and wildlife preservation via maintained wetlands. Electric power generation reduction and water quality deterioration are additional impacts. Loss of reliable water supply is a severe impact of drought in unincorporated portions of Saguache County due to the agricultural economy. Cities and towns are affected by water supply reliability, operations revenue and system flexibility during drought. Increased wildfire risk and impacts to water supplies for fighting fires are other drought impacts. | None given. |
| San Miguel County | Drought would affect individuals in the county, and adversely impact the local economy. Mandatory domestic water restrictions, agricultural losses and impacts to tourism and recreation would result. Costs for fighting wildfires and costs for water would both increase. | None given. |
| Summit County (2013 update in progress) | Ongoing drought has left areas more prone to beetle kill and associated wildfires. Other past impacts of drought include degradation of air quality due to dust, reduction of tourism and recreation activities, and damage to the ranching economy in the Lower Blue Basin. | None given. |
| Teller County (2013 update in progress) | Impacts to agriculture including losses and livestock feeding expenses and deaths. Increase in dry fuels, beetle kill, associated wildfires, and some loss of tourism revenue. Water supply issues for domestic needs will be a concern for the entire county during droughts. | None given. |

| Local Risk Assessment | Reported or Anticipated Impacts | Estimated Losses |
|---|---|---|
| University of Colorado, Boulder | Increased wildfire danger and impacts to campus landscapes including loss of mature trees and water main bursts due to dry ground can result from drought conditions. | None given. |
| Upper Arkansas Area (Chaffee, Custer, Fremont and Lake) (Plan update in progress) | The vulnerability of community assets to drought is tending to increase through time as the demand for limited raw water resources goes up. Economic assets such as the rafting and skiing industries prosper and suffer as precipitation fluctuates and competition for water from the Front Range increases. | None given. |
| Ute Mountain Ute Tribe | Vegetation that stabilizes the sand dunes located in the four corners region may die as a result of drought, causing the dunes to be reactivated. The Tribe's lands could be impacted by wind-blown sand and moving dunes although most of these impacts would be seen on Navajo and Hopi lands. Living conditions, grazing and farming could be affected as a result. | The drought that ended in 2005 was estimated to cost the Tribe $6 million, according to the National Resource Conservation Service |

What becomes clear from reviewing the drought sections of existing local hazard mitigation plans is not many counties have data available on economic losses due to drought. A recommendation is to begin recording economic losses due to drought on a county level. This can help to highlight areas and/or economic sectors that are particularly hard-hit, and can help counties anticipate the magnitude of losses that could potentially occur in future droughts.

### 3.5.3 Impacts on Losses from Changes in Development

Drought losses to state assets and the M&I and Socioeconomic Sectors are expected to intensify with population growth and development unless mitigation strategies are adopted. Figure 19 shows projected population growth by county and identifies the fastest-growing and potentially most-vulnerable counties. Counties with the highest estimated growth rates from 2010-2040 (according to state demographer estimates) include Archuleta, Eagle, Elbert, Routt, San Miguel, and Weld. The impacts listed in Table 18, above, could become more severe in communities with a high rate of development and growth.

### 3.5.4 Estimating Potential Losses of State Facilities

It is difficult, if not impossible, to put a dollar value on potential losses to state-owned and operated facilities due to drought. The nature of this hazard is that it is slow-moving, long-lasting, and the exact start and end is not always clearly defined. Drought itself does not cause much damage to state facilities; rather, it is usually secondary hazards that arise because of drought that have the potential to cause catastrophic losses.

Because data were either not available or non-existent, dollar losses to state assets due to drought by county were not calculated. Instead, drought vulnerability of the state assets was quantified by identifying data that relates to previously-reported impacts. A full discussion of this approach is provided in Annex B, but results as they relate to this Plan are provided below.

The figures that follow show the overall impact scores and spatial density metrics for the five state assets sub-sectors. The shading on the maps represents the impact score and the size of the gray circle indicates the size of the sub-sector (inventory) in a given county.

The state owns structures in every county. As shown in Figure 21, vulnerability for these structures tends to reflect the wildfire threat and dams data. Highly rated counties are at the intersection of areas of greatest wildfire threat and locations where the state owns the most dams.

**Figure 21. State Assets – Structures Inventory and Impact Scores**

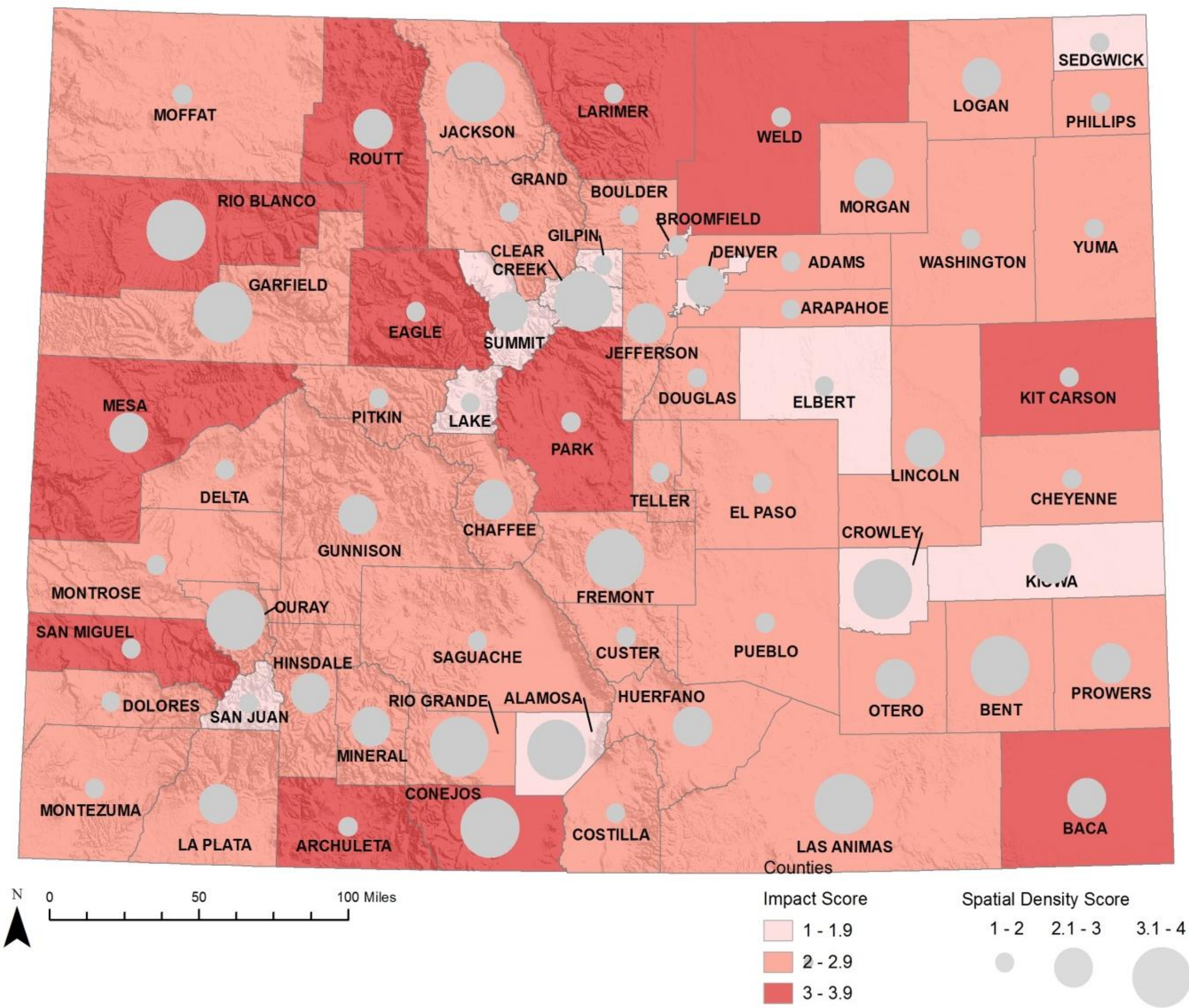



Figure updated in 2013

Vulnerability rankings for the State Land Board are completely dependent on the lease discounts issued in 2002. Figure 22 shows that the eastern half of the state as a whole tends to be more vulnerable than the west. This is largely due to the significant agricultural presence on the eastern plains (refer to the Agricultural Sector analysis for more information) and because the eastern part of the state received the highest lease discount, 40%. Furthermore, many of the counties with high impact scores in eastern Colorado also fall in the largest category for surface ownership by the State Land Board. As discussed previously, the lease discount program was not continued for 2012, so this vulnerability metric could not be updated. The spatial density metric, surface acres owned by the State Land Board, was updated for 2013.

**Figure 22. State Assets – Land Board Inventory and Impact Scores**

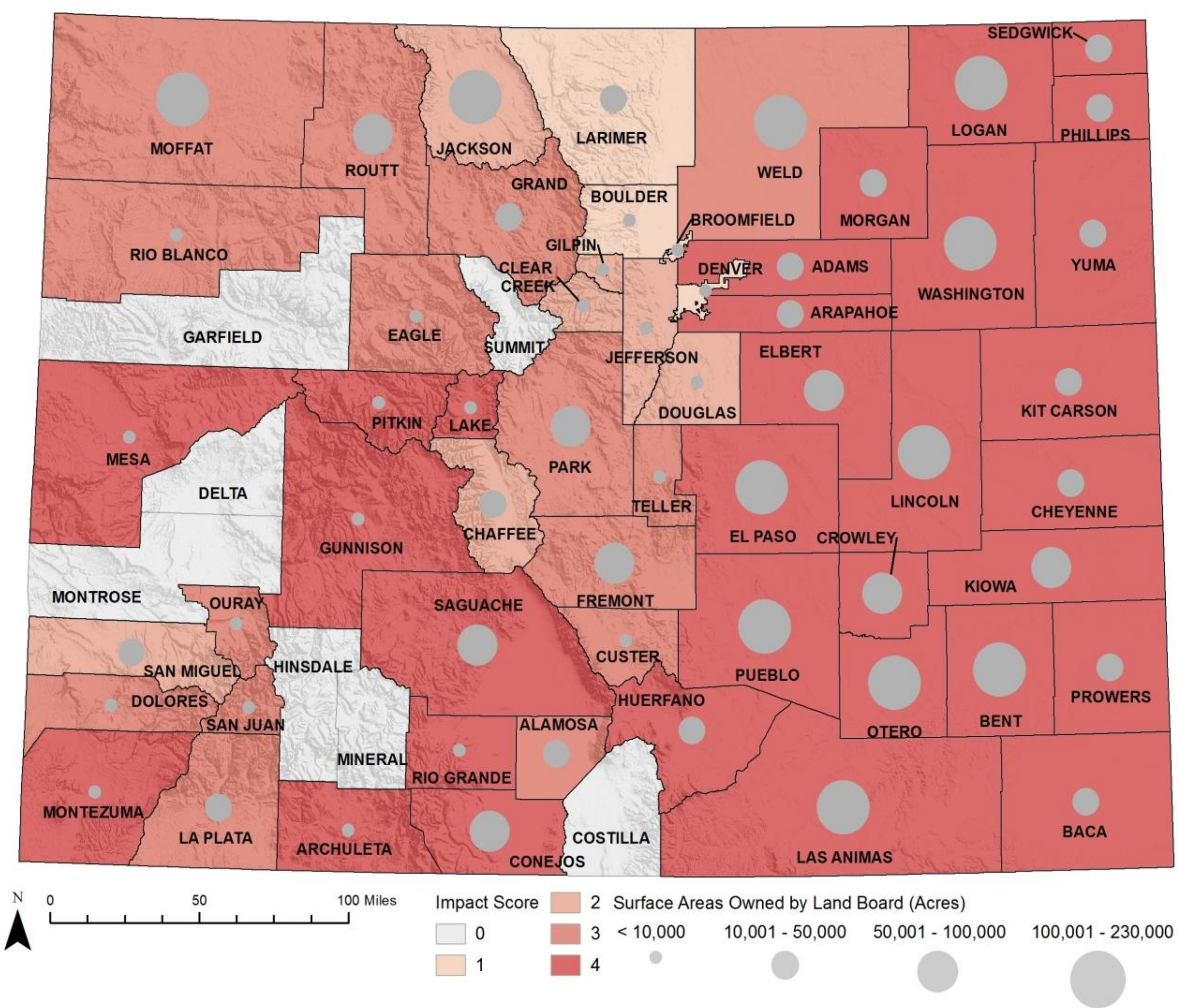



Figure updated in 2013

Figure 23 shows the vulnerability of recreation-based state revenue. Spatial vulnerability of State Parks revenue is highly dependent on the location of water-based state parks, since these tend to see the highest visitation numbers and thus generate the most revenue for the department.

Counties located in eastern Colorado with high vulnerability ratings all have state parks with water-based activities.

**Figure 23. State Assets – State Parks Inventory and Impact Scores**

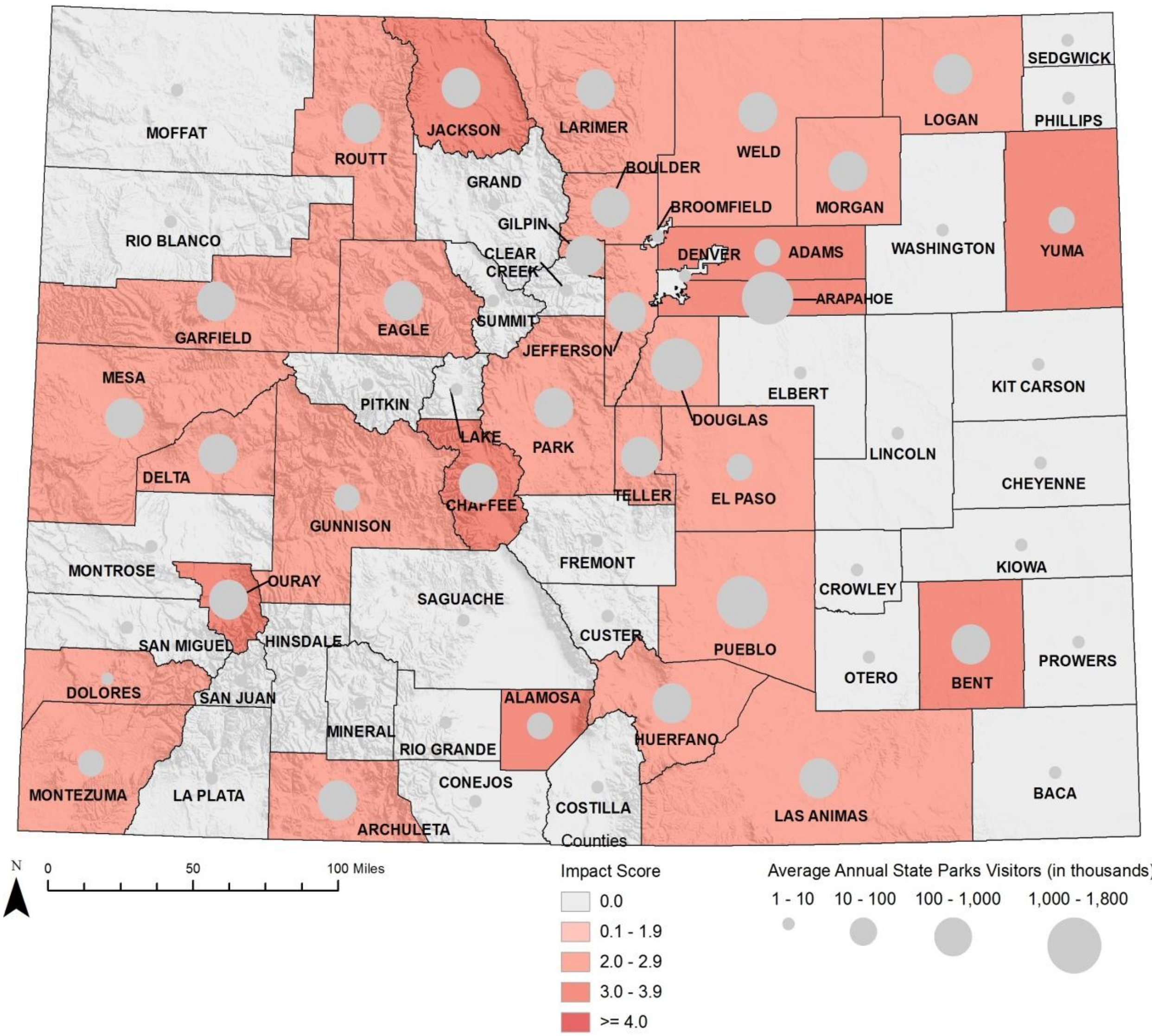



Figure updated in 2013

The final state asset assessed for vulnerability to drought is state-owned aquatic habitat, as defined by instream flows and hatcheries. These assets are managed by the CWCB and CPW, respectively. Specific locations of instream flow stream reaches and fish hatcheries are depicted in maps in Annex B in the State Assets Sector analysis. Counties with the highest impact scores have the most junior priority dates for their instream flow rights. The spatial density category is a count of instream flow reaches and hatcheries. San Miguel, Saguache, Gunnison, and Clear Creek are among those counties with higher vulnerability scores and higher spatial density rankings.

**Figure 24. State Assets – State Owned Aquatic Habitat Inventory and Impact Scores**

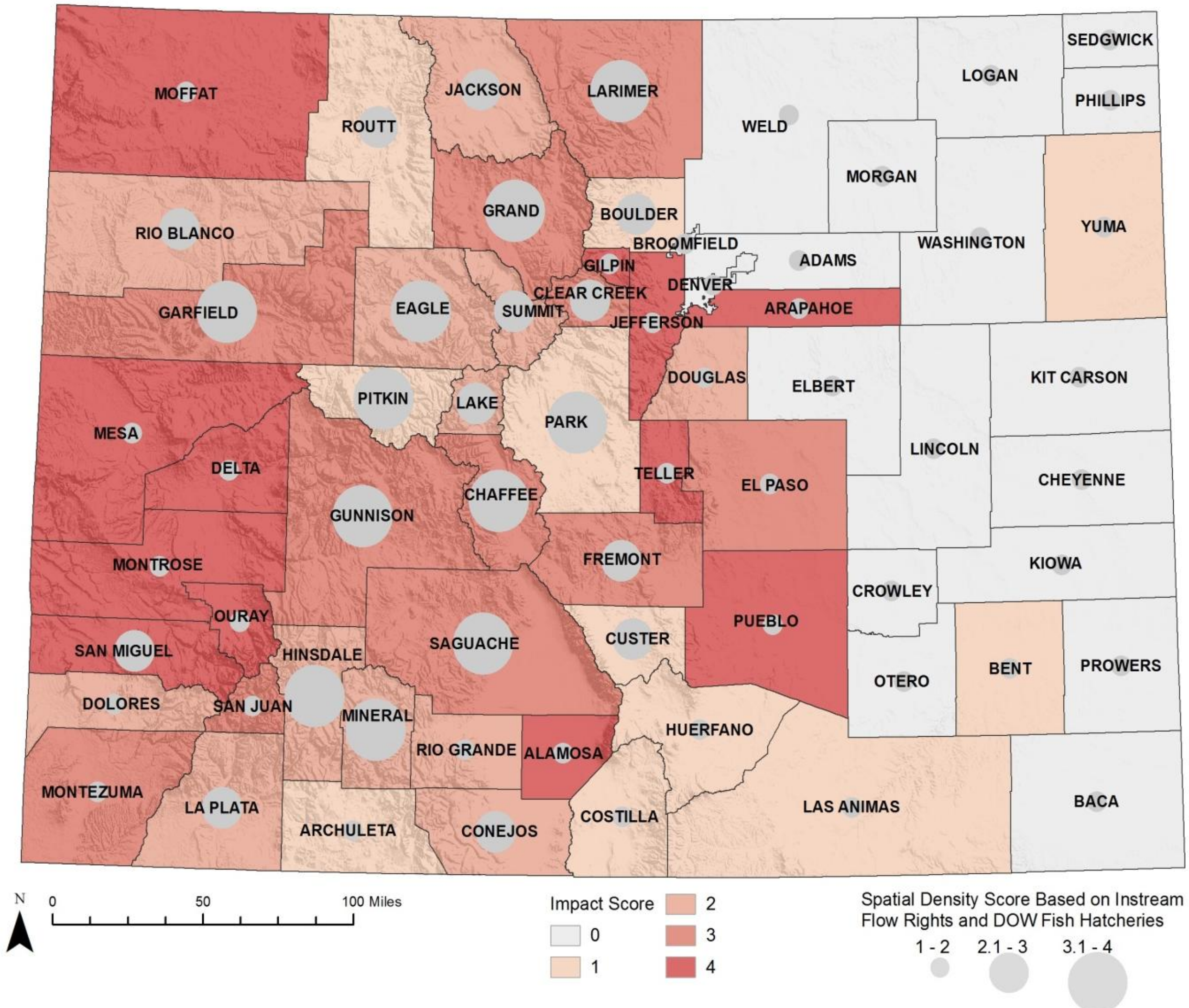



Figure updated in 2013

Taken as a whole, state assets overlap considerably with other sectors considered in this Plan. Work done by the State Parks and CPW helps preserve Colorado's natural environment and promotes public use of outdoor areas. Tourism in Colorado is strengthened by protected areas that are owned and managed by the State. Drought impacts to these assets directly translate to declines in tourism and related industries. Furthermore, decreased revenues for state agencies resulting from drought can reduce management budgets, which can have a detrimental impact on lands and wildlife. In 2002, state and local governments received $550 million in tax revenue from the tourism industry alone (State of Colorado Water Availability Task Force, 2002). For 2010 that number jumps to $750 million (Thomas & Wilhelmi, 2012). Clearly, the Environment and Recreation Sectors are important to the State. A large portion of the protected areas in the State are government (largely federal) managed, owned or operated, and degradation of natural areas can have compounded effects on society.

Table 14 showed building values per county and indicated the presence of state-owned dams (critical infrastructure). In some counties, the worst-case scenario for building and infrastructure losses would occur in a severe and wide-reaching wildfire, which could arise as a result of hot and dry drought conditions. CPW has experienced direct impacts as a consequence of drought-related wildfires in the past. The Hayman fire of June 2002 resulted in increased runoff from the burn areas and a corresponding increase in sediment load and deposition into the South Platte River via direct input and inflow from its tributary channels. Both Horse Creek and Wigwam Creek tributaries experienced direct loss of instream habitat. Similar degradation was produced in the Poudre River Drainage as a result of the 2012 High Park Fire. Increased sedimentation in the streambed negatively impacted macro-invertebrate (fish food) production and trout spawning habitat.

In addition to the vulnerability information summarized here, recommendations for "adaptive capacities" that could mitigate impacts to the various sectors have been developed. These suggested recommendations are captured in Annex B and organized by impact sector. This annex can serve the State as well as local governments, citizens, businesses and industry as a useful reference for mitigation strategies to be considered in the future. Mitigation action strategies that the State is currently involved with are discussed in the following section.

# 4 MITIGATION STRATEGY

## 4.1 Hazard Mitigation Goals

This chapter focuses on the State's hazard mitigation strategy. It is divided into five parts:

- Hazard Mitigation Goals
- State Capability Assessment
- Local Capability Assessment
- Mitigation Actions
- Funding Sources

### 4.1.1 Description of State Mitigation Goals

This section describes the goals of the Drought Mitigation Plan and the process used to identify and update the goals over the history of the Plan. The State has revised the framework of its mitigation strategy to improve its ability to track progress in meeting Plan goals and to improve alignment with local mitigation strategies (e.g., goals and actions). The framework of the State's drought mitigation strategy has two parts: goals and actions, which are defined as follows:

- The goals are broad based and described the overall direction that the State will take to reduce drought impacts.
- The actions describe the activities or projects used to support the accomplishment of the goals.

The following eight goals of the Colorado Drought Mitigation and Response Plan are listed below, in no particular order.

1. Improve Water Availability Monitoring and Drought Impact Assessment
2. Increase Public Awareness and Education
3. Enhance Mechanisms to Provide Water Supplies to Areas of Shortage During Droughts
4. Coordinate and Provide Technical Assistance for State, Local, and Watershed Planning Efforts
5. Reduce Water Demand/Encourage Conservation
6. Reduce Drought Impacts to Colorado's Economy, People, State Assets, and Environment
7. Develop Intergovernmental and Interagency Stakeholder Coordination
8. Evaluate Potential Impacts from Climate Change

### 4.1.2 Reassessment of Goals for Validity or Need for Revision

Goals specific to drought mitigation efforts were initially developed as part of the 2002 Drought Plan. These goals, as well as recommended actions to implement them, are presented in Table

21 below. Many of the recommendations came from special interest breakout sessions at the Governor's Flood and Drought Conference in December 1999. These six goals are listed below:

1. Improve Water Availability Monitoring
2. Increase Public Awareness and Education
3. Augment Water Supply
4. Facilitate Watershed and Local Planning
5. Reduce Water Demand/Encourage Conservation
6. Impact Reduction

In 2007, CWCB staff, DWR staff, and the ITF chairs discussed the above drought mitigation goals and recommended eight goals to replace the existing six. These are listed below:

1. Improve Water Availability Monitoring
2. Increase Public Awareness and Education
3. Support Substitute Water Supply Plans and Leasing Options to Augment Water Supply
4. Facilitate Watershed and Local Planning
5. Reduce Water Demand/Encourage Conservation
6. Impact Reduction
7. Develop Intergovernmental and Interagency Stakeholder Coordination
8. Evaluate Potential Impacts from Climate Change

For the 2010 revision to this Plan the DMRPC was asked to re-evaluate the goals in a planning workshop. The group decided that the number and intent of the goals should remain the same, but that some of the goals could be worded to better reflect their intent. The goals that changed and the justification for them include:

- Goal 1: Added "Drought Impact Assessment"
- Goal 3: Made less specific to include other options
- Goal 4: Expanded to include other ongoing efforts
- Goal 6: Expanded to better define the scope of Impact Reduction

For the 2013 revision to this Plan the DMRPC also re-evaluated the goals in a planning workshop. The group decided that the number and intent of the goals should remain the same, but that Goal 3 be re-worded. Goal 3 changed from "Augment water supply through mechanisms to transfer water from areas of surplus to areas of shortage during a drought" to "Enhance mechanisms to provide water supplies to areas of shortage during droughts." The group felt that this change better reflected the nature of the action items related to that goal.

In 2010 and 2013, the State of Colorado in their NHMP also revisited and validated the goals of the State for hazard mitigation. These are listed below:

1. Reduce the loss of life and personal injuries from natural hazard events
2. Reduce damage to state critical, essential, and necessary assets

3. Reduce damage to local government assets
4. Reduce state and local costs of disaster response and recovery
5. Minimize economic losses
6. Reduce damage to personal property

# 4.2 State Drought Mitigation Capability Assessment

## 4.2.1 Introduction

The state mitigation strategy must include a discussion of the State's pre- and post-disaster hazard management policies, programs, and capabilities to mitigate the hazards in the area, including an evaluation of state laws, regulations, policies, and programs related to drought mitigation as well as to development in drought-prone areas, and a discussion of state funding capabilities for hazard mitigation projects.

A thorough mitigation capability assessment was conducted as part of the 2010 revision process. This entailed an exhaustive review of the Colorado Revised Statutes, rules, regulations, and policy that contribute directly or indirectly to reducing drought losses. The process included incorporating Appendix A of the 2002 Drought Plan, which listed both state and federal drought assistance and related programs, and incorporating a summary of statutory programs related to drought from the 2007 Update report. During this process, the applicable Colorado Revised Statutes were compiled into a master excel spreadsheet and categorized by impact sector for a better synopsis of the strengths as well as any gaps or weaknesses of the State's existing drought mitigation capabilities across all impact sectors.

The spreadsheet identifies the name of the statute, the statute number and the date enacted, what state agency it affects, a definition of the statute, whether the statute was created for pre- or post-drought conditions, and whether it supports, facilitates, or needs improvement relative to reducing drought or water supply availability impacts. The spreadsheet has become a convenient reference document and has served as a tool to guide decisions through the Plan revision process; the results of this effort are captured in Appendix C Drought Mitigation Capability Summary. The 2013 update solicited input on changes or updates to these capabilities from multiple State and Federal agencies. The agencies had an opportunity to review the 2010 drought plan materials and provide updates on capabilities, mitigation and funding opportunities.

## 4.2.2 Pre-disaster Hazard Management Policies, Programs, Capabilities

State laws and regulations that provide authority to various agencies for pre-disaster programs are included in the existing State Hazard Mitigation Plan. Programs and the authorizing statutes that are specific to pre-drought disaster situations are identified in Appendix C Drought Mitigation Capability Summary (indicated by an 'x' in the pre or post disaster columns). In several cases the capabilities are both pre- and post-disaster. An example of this is the State's drought response capabilities, which can help mitigate losses through early warning and effective post disaster response. This capability has been further refined in 2010 and 2013 and captured in Annex A Drought Response Plan. The State's Water Availability Task Force, a major component of the response plan and the early warning mechanism, has been active for almost 33 years. Highlights of a few of these capabilities are summarized here:

#### *CWCB*

The Colorado Water Conservation Board's Office of Water Conservation and Drought Planning (OWCDP) promotes water use efficiency while providing public information and technical and financial assistance for water conservation planning. The OWCDP also promotes drought planning by encouraging and assisting communities to prepare and implement drought mitigation plans and by monitoring drought impacts and informing the public, media, and state officials. The office is a subset of the broader Water Supply Planning Section. The Office exists to perform the following:

- Maintain a clearinghouse of water conservation and drought information and disseminates information to the public
- Provide technical assistance and evaluate and approve water conservation and drought mitigation plans
- Provide financial assistance for water conservation planning, water efficiency, drought mitigation planning and implementation, and public education and outreach through one grant program
- Provide leadership through the Water Availability Task Force to monitor, forecast, mitigate, and prepare for drought
- Coordinate with multiple state and local agencies to provide public information

#### *State Land Board*

The State Land Board manages more than three million acres of land and four million acres of mineral rights that generate revenue for public education and other state institutions. The State Land Board maintains seven District Offices that follow drought and other disaster problems in their districts. The offices have the ability to handle any issues on State agricultural leases on a case-by-case basis at the request of State lessees, which has been found to be more effective than any broader action taken in anticipation of drought

### 4.2.3 Post-disaster Hazard Management Policies, Programs, Capabilities

Programs and the authorizing statutes that are specific to post-drought disaster situations are identified in Appendix C Drought Mitigation Capability Summary (indicated by an 'x' in the pre- or post-disaster columns). The State's Division of Homeland Security and Emergency Management coordinates all of the post-disaster management activities and has led to Colorado becoming one of twenty-two states certified by the Emergency Management Accreditation Program in 2009. To maintain accreditation, the State needs to meet certain requirements in all mitigation and response planning efforts.

Highlights of these capabilities are summarized here:

### *State Land Board*

The Board approved the 2013/2014 drought plan for state lands in March of 2013. It gives the authority to District Managers to make the decisions regarding drought management on state lands. The District Managers have the authority to make immediate cuts in carrying capacity, rental adjustments and refunds in response to requests by lessees. They frequently make adjustments even without a request if they determine it is appropriate.

Such cuts can result in reductions in the carrying capacity for cattle, which in turn can reduce the land rent since rent is based on carrying capacity. Lessees have been advised to contact the District Office if they have already reduced their numbers of cattle or will be reducing their numbers. In areas of severe to exceptional drought the District Manager may make a mandatory reduction in carrying capacity. The Board has authorized a reduction to zero if necessary to protect the long term productivity of the land.

Reductions also require the implementation of a monitoring plan which must be approved by the District Manager. This program is ongoing to ensure grazing will not be increased until the land is in an appropriate condition to sustain livestock. Lessees will be required to sign a rider to their lease outlining the provisions for managing the drought and the penalties for non-compliance. There will be some funding available to assist with establishing the monitoring plan, for weed and pest control and to improve watering facilities to help better utilize vegetation.

### *CPW*

CPW personnel who are responsible for the day-to-day operation, management, and use of CPW-owned and/or managed water shall endeavor to see that no waste, misuse, or inappropriate use of those water rights is occurring. On May 1, 2007 the Director of CPW (Division of Wildlife at the time) signed Administrative Directive A-9 which is a department wide policy to inform CPW personnel and others of potential drought impacts on CPW's water resources and specific actions needed to manage these drought impacts. During drought periods changes related to management of CPW water resources may be necessary to ensure compliance with relevant statutes as well as the Colorado's Drought Mitigation and Response Plan. Pursuant to Colorado Revised Statutes, Section 37-88-109 (2), C.R.S., 2005 CPW could be required to release water from CPW-owned and/or managed water resources stored in reservoirs for municipal and domestic purposes during drought. There may also be times and situations where CPW may be requested to bypass some of its senior irrigation rights to make water available for municipal and domestic uses. Any agreement to release or bypass CPW-owned or managed water for domestic or municipal purposes shall be submitted to and approved by the Colorado Parks and Wildlife Commission. In situations where "time is of the essence" the Director of the Colorado Parks and Wildlife department has the authority to act on behalf of the Colorado Parks and Wildlife Commission.

Also, since CPW receives federal fish and wildlife funds the eligibility rules regarding receipt of these federal funds place certain obligations on the management of CPW's properties, including water rights purchased with federal funds or wildlife cash. Prior to any release of CPW water from reservoirs or bypass of any direct flow water for domestic purposes, the State Attorney General's Office shall be contacted regarding federal aid obligations. Further, CPW has developed a detailed list of criteria to be followed for addressing requests for use of CPW-owned and/or managed water resources under drought circumstances.

Impacts to wildlife, wildlife habitat and to CPW's water resources can be addressed as drought conditions arise. Impacts could include release of water from CPW-owned and/or managed reservoirs for domestic and municipal purposes, or for protection of aquatic and wildlife habitats. Priorities for use of CPW-owned and/or controlled water or water rights during drought conditions will be to protect and conserve, to the extent possible and on a statewide basis, have been identified.

In 2007, the Colorado Department of Public Health and Environment Water Quality Control Commission (CDPHE WQCC) adopted revised water-quality standards for temperature for protection of aquatic life. The standards include an acute standard (a two hour daily maximum) for protection from lethal effects of elevated temperature and a chronic standard (i.e., a maximum weekly average temperature) for protection against sublethal effects on behavior, metabolism, growth, and reproduction. The standards also include seasonal adjustment for protection of spawning, and they include a narrative requiring that temperature maintain a normal pattern of daily and seasonal fluctuations and spatial diversity with no abrupt changes. These standards were implemented in the Upper and Lower Colorado basins in 2008 and in the South Platte Basin in 2009. The standards will be implemented in the San Juan, Dolores, and Gunnison Basins in 2012 and in the Rio Grande and Arkansas Basins in 2013.

Colorado's revised water-quality standards for temperature did not exist during the 2002 drought. Now a low-flow exclusion allows for temperature exceedances when the daily streamflow falls below an acute critical low flow or when the monthly average streamflow falls below a chronic critical low flow. This exclusion makes it unlikely that exceedances of the temperature standards during extreme drought would result in an impairment listing on the CDPHE WQCC 303(d) List. Regardless, the basis of Colorado's temperature standards in species-specific physiological tolerances to elevated temperature suggests that the standards will provide a useful benchmark against which to evaluate whether elevated temperatures resulting from drought conditions are likely to contribute to deleterious effects on fish communities. As real-time data capture becomes more economically viable as an option for temperature monitoring, it may become possible to explore real-time water-management alternatives to avoid lethal or chronic effects of elevated temperature during drought conditions. The implementation of the temperature standards has also prompted an increase in temperature monitoring, which will likely facilitate better evaluation of the influence of drought-associated flows and elevated temperature on fisheries during future drought conditions.

Although not identified during the 2002 drought, CPW now has an invasive species coordinator. CPW anticipates that during future droughts, increased efforts will be needed to monitor for the presence and spread of aquatic nuisance weed species such as Eurasian aquatic milfoil.

### 4.2.4 State Policies Related to Development in Drought Prone Areas

Several objectives and actions related to minimizing development in disaster-prone areas are included in the 2010 Colorado Natural Hazard Mitigation Plan.[2] For example, for the NHMP Goal: "Reduce the loss of life and personal injuries from natural hazard events", one of the objectives listed is to "assist communities interested in adopting or revising building codes, design standards, and land development regulations" in order to "encourage development in less hazardous areas". However, all areas of the State are drought-prone. Therefore, state policies related to development in drought-prone areas do not appear to be practical. Few Colorado statutes explicitly integrate land planning with water planning, although several tools are in place to encourage this and permit it to happen voluntarily. Legislation passed in 2008-09 requires developers to ensure sustainable water supplies with new development. Further, although state statutes support and permit intergovernmental cooperative agreements on water, planning, and service issues, coordination and sharing of information between local governments and water suppliers are largely voluntary. As water becomes scarcer in Colorado, the necessity of this collaboration becomes more apparent given the regional nature of water resources and the impact of local land development and uses on the resource.

The 2010 document "Colorado Review: Water Management and Land Use Planning Integration" prepared by the Center for Systems Integration on behalf of the CWCB is a compendium of integrated land use planning and water supply planning. The document also reviews the legal context that allows for land use planning, including municipal and county powers, intergovernmental cooperation, and special districts. It also covers state agencies and legislatively created organizations that provide assistance and resources related to land and water planning issues to local and county governments. The document summarizes the key statutes related to land use planning and cross-jurisdictional authorities as well as statutes addressing water conservation, quality, supply, management, and water law that are relevant to integrating land use and water planning.

### 4.2.5 State Funding Capabilities for Drought Hazard Mitigation Projects

The types of state-funded projects available for drought mitigation are included in Appendix C Drought Mitigation Capability Summary and in Section 4.5. Various sources exist including disaster emergency funds, water conservation funding, wildlife cash funds, flood and drought response fund, wastewater treatment plant and drinking water treatment plant construction funds. In addition, funding options are discussed in the 2010 Colorado Natural Hazard Mitigation Plan. This Plan includes information on state matching funds for federal programs (such as FEMA's);

---

[2] As the OEM updates the Colorado Natural Hazard Mitigation Plan in 2013, there may be changes to the actions.

the State Disaster Emergency Fund; grant programs of the CWCB, DWR, OEM, Natural Resources Conservation Service, and State Forest Service; and education and outreach program funds. The Hazard Mitigation Plan also discusses the types of mitigation grant programs managed by the Mitigation Staff of the Colorado Division of Homeland Security and Emergency Management that are available and contains the State's Response Plan to natural hazards.

In the 2010 revision process the DOLA representative on the DMRPC noted that funding resources have been reduced in certain of the programs that are used to support local infrastructure projects – primarily as a result of the 2010 state budget shortfall. The State Land Board noted that they have some funding available through either the Land and Water Management Fund or Enhancement funds to assist in drought mitigation projects. The Land Board Primarily engages in water development projects to ensure livestock can reach water even when ponds and springs are dry as a result of drought.

### 4.2.6 Changes in Hazard Management Capabilities of the State

Colorado became one of twenty-two states certified by the Emergency Management Accreditation Program (EMAP) in 2009. To maintain accreditation, the State needs to meet certain requirements in all mitigation and response planning efforts. This includes the EMAP accredited Natural Hazard Mitigation Plan which is going to be updated in 2013 by the OEM. The response elements of the Colorado Drought Mitigation and Response Plan underwent significant changes to modernize the Plan in 2010. This included aligning the Plan with modern emergency management standards, revisiting the number and composition of the ITFs, updating the drought indicators and associated responses, and streamlining the communication framework of the Plan. The response element became a "stand alone" annex (Annex A) to this mitigation Plan so that the response procedures are condensed for use during drought emergencies.

The State has undergone the following activities to improve its drought management capabilities over the past decade.

- In 2008, a full time drought and climate change technical specialist position was created at the CWCB. A significant portion of this position is to facilitate and enhance state and local drought planning efforts.
- In addition, the State's monitoring of drought has improved through the modernization of the Surface Water Supply Index (SWSI) for Colorado (available for the whole State since January 2013) and the validation of the Colorado Modified Palmer Index as a useful drought indicator (see Annex D). While progress has been made, funding needs remain for more climate monitoring stations and for sustaining monitoring programs, and further SWSI modernization. The State developed a web-based drought "Tool Box" in 2010, designed to help Colorado citizens, water providers, and local governments find information on drought status, drought planning, and other drought resources, including this Plan. This included the development of a "Local Drought Management Plan Guidance Document" and a "Sample

Municipal Drought Management Plan." These capabilities are discussed in further detail in Section 5.

- In the 2007 Drought Plan Update Report it was noted that increased awareness and attention to climate change and the associated potential impacts to state water supplies warrants further analysis and proactive adaptive planning strategies. The 2007 document also mentioned that the State will identify prospects for coordinating and including local governments in their climate change planning efforts. The State has been making strides toward increasing awareness and attention to climate change with various initiatives including the Colorado River Water Availability Study, the Joint Front Range Climate Change Vulnerability Study, Colorado Climate Preparedness Project, the Colorado Climate Action Plan and the integration of climate change aspects and drought monitoring improvements into the 2010 and 2013 update. Partnering with outside support institutions, such as the Colorado Climate Center/State Climatologist, NOAA, and the NDMC has helped to make these efforts successful.
- In 2012, the CWCB completed the Drought Assessment for Recreation and Tourism in Southwestern Colorado study (DART). This study evaluated the metrics used for the recreation sector in the 2010 State Drought Plan Vulnerability Assessment, identified additional data needs, and developed a stakeholder outreach framework.
- Colorado participated in the 2012 Bureau of Reclamation's Colorado River Basin Water Supply and Demand Study. This study identified existing and future imbalances with water demand and supplies within and in adjacent areas of the Colorado River Watershed. The study also developed and evaluated mitigation strategies to address these imbalances.
- Recent changes have been made to how Colorado reports drought information to the US Drought Monitor. Previously, a large email list was used to convey local State information for the national US monitor assessment where one or two representatives from Colorado would provide input. The new process entails weekly webinars during critical parts of the year or weekly written updates involving representatives from multiple sectors. Updated include comprehensive information on precipitation, snowpack, streamflow, reservoir storage, water demand as well as weather, climate and streamflow forecast updates. The new process allows for increased monitoring throughout the year which adds the value of being a "Drought Early Warning System" because sudden onset of high temperatures and low precipitation during critical times can deteriorate conditions rapidly. The new process also allows for more localized "boots on the ground" reporting from the Farm Service Agency and Bureau of Land Management to be included in the process and archived for future use.

Additional, information on the initiatives above and additional progress towards drought mitigation project implementation is presented in Sections 4.4.1 and 4.4.2.

## 4.3 Local Capability Assessment

Local governments in Colorado have long had policies, programs, and capabilities in place related to drought mitigation and a summary of those is presented in this section.

## 4.3.1 Local Mitigation Policies, Programs, and Capabilities

Information in this section was gathered by reviewing all existing Local Hazard Mitigation plans, summaries from the 2004 and 2007 DWSA's, and input collected from local water providers in 2010. A comprehensive review of existing local capabilities followed the collection of these plans. Relevant information was gathered in order to assess the capability of local governments to handle short- and long-term drought and captured in Table 19. The policies, programs, and capabilities highlighted below are not an exhaustive list, as some of the local hazard mitigation plans only date back to 2004. As of the writing of this plan, not every county (only 27 of 54) in Colorado have an approved hazard mitigation plan (see Figure 25). Local capabilities to handle drought may have changed since the writing of a portion of these plans.

Counties and cities in Colorado use a variety of tools to manage drought. Some of these tools can be found in both Table 19 and Table 20. For purposes of this plan, it is assumed that water efficiency is a component of drought mitigation. Entities with state approved water conservation plans are listed in Table 19. This list also includes entities that have drought response and management plans that are officially recorded by the State.[3] Mitigation actions contained in local hazard mitigation plans are contained in Table 22 in Section 4.4.6.

**Table 19 Local Mitigation Policies, Programs, and Capabilities**

| Plan | Policy, Program, or Capability |
|---|---|
| East Larimer County | Water Conservation Plan |
| City of Alamosa | Water Conservation Plan |
| City of Aurora | Drought Response Plan, Water Conservation Plan |
| City of Boulder | Drought Response Plan, Water Conservation Plan |
| City of Brighton | Water Conservation Plan |
| City of Cortez | Water Conservation Plan |
| City and County of Broomfield | Water Conservation Plan |
| City of Dacono | Water Conservation Plan |
| City of Durango | Water Conservation Plan |
| City of Evans | Water Conservation Plan |
| City of Fort Morgan | Water Conservation Plan |
| City of Fort Collins | Water Conservation Plan |
| City of Fort Lupton | Water Conservation Plan |
| City of Fountain | Water Conservation Plan |
| City of Glenwood Springs | Water Conservation Plan |
| City of Greeley | Water Conservation Plan |
| City of Lafayette | Water Conservation Plan |

[3] Other M&I water providers have drought mitigation and/or response plans. However, such plans are currently not tracked by the State.

| Plan | Policy, Program, or Capability |
|---|---|
| City of Lamar | Water Conservation Plan |
| City of Longmont | Water Conservation Plan |
| City of Monte Vista | Water Conservation Plan |
| City of Northglenn | Water Conservation Plan |
| City of Rifle | Water Conservation Plan |
| City of Salida | Water Conservation Plan |
| City of Sterling | Water Conservation Plan |
| City of Thornton | Water Conservation Plan |
| Town of Castle Rock | Water Conservation Plan |
| Town of Eaton | Water Conservation Plan |
| Town of Erie | Water Conservation Plan |
| Town of Firestone | Drought Management Plan, Water Conservation Plan |
| Town of Frederick | Water Conservation Plan |
| Town of Superior | Water Conservation Plan |
| Town of Windsor | Water Conservation Plan |
| Arapahoe County Water and Wastewater Authority | Water Conservation Plan |
| Arvada | Water Conservation Plan |
| Castle Pines Metropolitan District | Water Conservation Plan |
| Castle Pines North Metropolitan District | Water Conservation Plan |
| Centennial Water and Sanitation District | Water Conservation Plan |
| Cherokee Metropolitan District | Water Conservation Plan |
| Colorado Springs Utilities | Water Conservation Plan |
| Consolidated Mutual Water Company | Water Conservation Plan |
| Denver Water | Drought Response Plan, Water Conservation Plan |
| Donala Water and Sanitation District | Water Conservation Plan |
| Douglas County Regional Plan | Water Conservation Plan |
| Eagle River Water and Sanitation District | Water Conservation Plan |
| East Cherry Creek Valley WSD | Water Conservation Plan |
| East Larimer County Water District | Water Conservation Plan |
| Ft. Collins-Loveland Water District | Water Conservation Plan |
| Grand Valley Regional Plan | Water Conservation Plan |
| Left Hand Water District | Water Conservation Plan |
| Little Thompson Water District | Water Conservation Plan |
| Mount Werner Water District | Water Conservation Plan |
| North Table Mountain Water & Sanitation District | Water Conservation Plan |
| North Weld County Water District | Water Conservation Plan |
| Pagosa Area Water and Sanitation District | Drought Plan in Review by CWCB, Water Conservation Plan |
| Parker Water and Sanitation District | Water Conservation Plan |
| Pinery Water and Wastewater District | Water Conservation Plan |

| Plan | Policy, Program, or Capability |
|---|---|
| Platte Canyon Water and Sanitation District | Water Conservation Plan |
| Pueblo West Metropolitan District | Water Conservation Plan |
| Security Water and Sanitation District | Water Conservation Plan |
| St Charles Mesa Water District | Water Conservation Plan |
| Tri County Water Conservancy District | Water Conservation Plan |
| Widefield Water & Sanitation District | Water Conservation Plan |
| Willows Water District | Water Conservation Plan |

Note: Information for this table was provided by the CWCB. Entities recorded in this table as having a state approved Water Conservation Plan have a plan that meets the requirements set forth in the Water Conservation Act of 2004.

The 2007 DWSA findings concluded that additional drought preparedness planning is needed at the local level. Findings included:

- Only 27% of Colorado municipal water providers had a drought response plan in place and only 37% had assigned someone to be in charge of drought planning. However, most of the large providers had a plan and, based on reported population served, it was estimated that approximately 71% of the population was served by a provider that had a drought plan. These plans are not necessarily approved by the State and vary greatly in terms of how comprehensive they are.
- There is discrepancy in drought planning between large urban providers and smaller rural agencies. While most urban providers had a drought plan in place, the majority of Colorado water providers consisting predominantly of smaller, rural utilities had not developed a drought response plan.
- A further potential problem is that a majority of water agencies (63%) did not have a staff person in charge of drought planning. Staffing levels at many small agencies may not afford such an assignment to be made until drought conditions are encountered.
- The lack of drought response planning was an issue in all seven Colorado Water Divisions.

In the 2004 Colorado Drought and Water Supply Assessment, 49% of respondents reported having a drought management plan in place compared with only 27% in the 2007 DWSA update. The reduction in the number of agencies with a drought response plan in place is a surprising and troubling finding given the recurring likelihood of drought in Colorado. A possible explanation for the 20% decrease in the number of agencies reporting having a drought management plan may be that when the survey occurred in 2003 many agencies surveyed were still actively responding to drought conditions and may have responded "yes" to the question because drought measures were in place. This does not necessarily translate into having an 'on the shelf' drought response plan in place, per the 2007 survey.

### 4.3.2 Effectiveness of Local Mitigation Policies, Programs, and Capabilities

Chapter 7, "Tools for Managing Drought at a Local Level," of the 2004 DWSA presented the tools available to local communities to prepare for and manage the effects of drought. The chapter includes information on which tools are applicable to long-term mitigation or short-term drought response, and which can be effectively used to achieve different demand/supply outcomes. Table 20 summarizes this information for local scale drought management tools. As can be seen in the table, different tools are effective for different planning horizons and influence management goals. A variety of tools have been identified to facilitate development of effective local planning.

Additionally, as part of a 2004 DWSA survey, respondents identified what they thought were the "best" tools for managing drought. For municipalities, lawn and garden water restrictions were favored (by 41%), followed by public education/involvement programs (34%), fines for excessive water usage (30%), and water conservation programs (13%). Among agricultural users, the most effective controls were water conservation programs (27%), cooperative agreements (13%), and public education programs (7%).

## Table 20 Local Scale Drought Management Tools

| Tool | Planning Horizon | | Management Impact | | |
|---|---|---|---|---|---|
| | Short-Term Response | Long-Term Mitigation | Reduce Demand | Increase Supply | Other |
| **Public Policy and Assessment** | | | | | |
| Prepare and regularly update comprehensive water management plan with drought component | | ✓ | | | ✓ |
| Establish drought response principles, objectives, and priorities | | ✓ | ✓ | ✓ | ✓ |
| Establish authority for declaring a drought emergency | | ✓ | ✓ | ✓ | ✓ |
| Develop triggers for drought-related actions (establishing thresholds for mild, medium & severe droughts) | | ✓ | ✓ | ✓ | ✓ |
| Prepare ordinances on drought measures | | ✓ | ✓ | ✓ | ✓ |
| Evaluate impacts of drought on different groups, economic segments, and environmental receptors | | ✓ | | | ✓ |
| **Emergency Response** | | | | | |
| Declare a drought emergency | ✓ | | ✓ | ✓ | ✓ |
| Establish water hauling programs | ✓ | | | ✓ | ✓ |
| Extend boat ramps and docks | ✓ | ✓ | | | ✓ |
| Restrict/prohibit new taps | ✓ | | ✓ | | |
| Identify state and federal assistance | ✓ | ✓ | | | ✓ |
| **Public Education and Relations** | | | | | |
| Prepare position papers for the public, media and elected officials describing public drought policies | | ✓ | | | ✓ |
| Establish a public advisory committee | | ✓ | | | ✓ |
| Organize drought information meetings and workshops for public and media | ✓ | ✓ | | | ✓ |
| Create informational materials and establish a drought information center | | ✓ | | | ✓ |
| **Water Rights Management** | | | | | |
| Review water rights for modifications/flexibility during drought | | ✓ | | ✓ | |
| Dry year leasing of water rights | ✓ | | | ✓ | |
| Water banks established for the sale, transfer, and exchange of water | ✓ | | | ✓ | |
| Interruptible water supply agreements | ✓ | | | ✓ | |
| **Water Supply Augmentation** | | | | | |
| Rehabilitate reservoirs to operate at design capacity | | ✓ | | ✓ | |
| Inventory and review reservoir operation plans | | ✓ | | ✓ | ✓ |
| Aquifer storage and recovery; conjunctive use | | ✓ | | ✓ | |
| Weather modification (cloud seeding) | ✓ | ✓ | | ✓ | |
| New water storage facilities | | ✓ | | ✓ | |
| **Monitoring and Evaluation** | | | | | |
| Monitor water supply components (e.g. snow pack, stream flow, etc.) | ✓ | ✓ | | | ✓ |
| Monitor water quality | ✓ | ✓ | | | ✓ |
| Track public perception and effectiveness of drought measures | ✓ | ✓ | | | ✓ |
| Improve accuracy of runoff and water supply forecasts | | ✓ | | | ✓ |
| **Water Conservation** | | | | | |
| Develop, implement and monitor ongoing water conservation program | | ✓ | ✓ | | ✓ |
| Implement, upgrade water metering | | ✓ | ✓ | | |
| Implement, upgrade water loss control systems | | ✓ | ✓ | | |
| Water-efficient fixtures and appliances | | ✓ | ✓ | | |
| Low water use landscapes and efficient irrigation | | ✓ | ✓ | | |
| Improve commercial and industrial efficiencies | | ✓ | ✓ | | |
| Educational programs | ✓ | ✓ | ✓ | | |
| Rate structures to influence water use | ✓ | ✓ | ✓ | | |
| Water reuse | | ✓ | ✓ | | |
| Soil management such as soil-moisture monitoring | | ✓ | ✓ | | |
| Improved tillage practices | | ✓ | ✓ | | |
| Use drought or salinity tolerant crops | | ✓ | ✓ | | |

Source: 2004 DWSA

In addition to the drought tools in Table 20 above, the 2010 Municipal Drought Plan Guidance Document provides another comprehensive list of drought tools that Municipal & Industrial (M&I) water providers can use to select and implement to mitigate and respond to drought. The overall effectiveness of these tools will depend on the unique set of drought-related water supply challenges and set of circumstances faced by individual water users. For instance, the rehabilitation of reservoirs to operate at design capacity may be an effective drought tool for a water user that lost significant storage prior to the rehabilitation; while other users may only benefit moderately from reservoir rehabilitation. The nature of drought can also significantly impact the overall effectiveness of a particular management tool.

Water supply reliability planning can play a key role in the preparedness of M&I water providers. For instance, M&I providers with a junior portfolio of water rights that have not effectively incorporated drought planning into their long-term supply efforts will be more vulnerable to drought than those who have more senior water right and/or effective drought plans.

Since the 2002 drought, some water users have improved their drought planning and water supply reliability planning efforts. For instance, during the 2002 drought, Aurora Water learned that they were not sufficiently prepared for a drought of this magnitude as they experienced a storage reduction to 25% of total capacity. In response, Aurora Water has developed a variety of tools to enhance water supply forecasting and planning guidance during drought periods. This includes a Drought Contingency Plan, a water supply forecasting model based on reservoir levels and an annual water management plan that sets the water restrictions and level of enforcement for the upcoming year. The 2002 drought also initiated the development of the Prairie Waters Project which will increase Aurora's water supply by more than 20% by reusing return flows that remain reliable during a drought.

As a component of the 2013 State Mitigation Plan update, CWCB conducted municipal drought survey in May of 2013 to characterize statewide M&I impacts, adaptive capacities and vulnerability for the recent droughts that occurred in the early 2000s and in 2011-2013. Mandatory water restrictions were implemented by 59% of the survey respondents during 2002 which was significantly lower in 2012, when only 8% of the survey respondents implemented mandatory restrictions. This is largely attributed to the fact that during 2012 many providers had normal to above-normal reservoir storage to meet customer demands yet implemented voluntary restrictions in response to the drought. A larger percentage of the respondents generally considered water restrictions as a standard operating procedure in 2012 when compared to the drought in 2002/2003. This suggests that more water providers may be using water restrictions as a means to manage water demand during dry periods. Additionally 59% of survey respondents have either updated or performed a comprehensive revision to their drought management plan since 2002 while 15% of respondents do not have a drought management plan. 77% of respondents expressed that there is sufficient funding either in-basin or through state and federal sources to fund water supply reliability, conservation and drought planning efforts. Additional information on these survey results in provided in Section 9 of Annex B.

## 4.4 Mitigation Actions

The state mitigation strategy must identify, evaluate, and prioritize cost effective, environmentally sound, and technically feasible mitigation actions and activities the State is considering, and an explanation of how each activity contributes to the overall mitigation strategy. Local input should also be included when available. Additionally, with each update cycle the Plan must be reviewed and revised to reflect changes in development, progress in statewide mitigation efforts, and changes in priorities. The updated (revised) Plan must identify the completed, deleted, or deferred actions or activities from the previously approved Plan. It must also include any new actions identified since the previous Plan. The mitigation actions take into consideration the vulnerability and capability assessment, and are intended to address areas of high vulnerability or where capabilities should be strengthened.

The recommended actions for this Plan were derived from several sources in the planning process over the past 13 years. Mitigation was first incorporated into the Colorado Drought Response Plan with the 2000-2001 update process when the initial recommendations and actions were developed. These actions were reviewed and expanded during the 2007 update cycle, and incorporated some recommendations from the 2004 DWSA report. During the 2010 and 2013 updates the actions were reviewed for progress made, continued validity, and updates or changes. New actions were also developed through a process described in detail in Section 4.4.3. In the 2010 Plan there were 71 action items total; 36 of these actions were identified in 2010. In this Plan, there are 78 active action items total; eight additional new actions were identified in 2013 and three were deleted.

### 4.4.1 Identification of Actions under State Consideration

Table 21 identifies the actions under consideration by the DMRPC for the State of Colorado in 2013. The following recommendations represent the collaborative efforts of the DMRPC. Consistent with the FEMA and EMAP requirements, those actions that have been completed or are ongoing are identified. Many of the completed actions, such as drought conferences and workshops, are kept in this table to show progress made, but also because they are often repeated more than once. The projects are listed under the primary goal they are designed to help achieve, as an indication of how each action contributes to the overall mitigation strategy. Some actions help meet more than one goal, as indicated in the "Primary and Related Goal" column. A summary discussion of progress made toward implementing the action is included in the table under the "Status, Implementation, and Funding Comments" column, and discussed in the Section 4.4.2. Deleted and deferred actions are discussed in the section that follows the table.

Many of the recommendations can be implemented in the short term which is defined as the next three year update cycle; others must be viewed as long-term measures, and some will be implemented during drought cycles. The actions are prioritized and sorted by **H**igh, **M**edium and **L**ow (see Section 4.4.4 for a discussion of the prioritization process). In general the timeline of implementation is reflected in the prioritization: High- target implementation within three years;

Medium – within three to six years; Low - within ten years or as needed.  As part of the 2013 update some of the ongoing or periodically completed actions (e.g. periodic workshops) were moved to low priority.

## Table 21 State Drought Mitigation Actions Summary

| Priority | Recommended Action | Primary and Related Goal* | Lead Agency/ Entity | Action Dev. Date | Status 2013 Completed | Status 2013 Ongoing | Status, Implementation and Funding Comments |
|---|---|---|---|---|---|---|---|
| | **Goal 1: Improve Water Availability Monitoring and Drought Impact Assessment** | | | | | | |
| H | Integrate state flood and drought monitoring | **1** | CWCB | 2010 | | X | *Improve efficiency through better integration*<br>*CWCB Flood and drought response fund created in 2012 for flood and drought preparedness activities.* |
| H | Collect climatologic data at mid & lower elevations to fill existing gaps in the data collection network | 1 | WATF<br>NRCS, CCC<br>CoCo RAHS<br>CAIC | 2010 | | X | *The NRCS has installed one new SNOTEL site at 8920' since 2010, Black Mountain. Three new sites are planned for Colorado, two of which are at low and mid elevations. Additional sites may be installed at a later date if funding is made available.* |
| H | Additional Drought DSS support and development | 1 | CWCB<br>DWR-SEO | 2002 | | X | *Basin Needs Decision Support System development. BNDSS was created to track projects (i.e. reservoirs) and processes (i.e. conservation programs) that are being implemented by providers statewide, to meet the water needs "gap" originally identified by the Statewide Water Supply Initiative (SWSI) study. This could provide a foundation to integrate drought information and local drought plans moving forward.* |
| H | Additional SWSI Index modernization | 1 | NRCS, DWR | 2013 | | | *While this index was refined in 2010, additional work and automation is in progress and needed.* |
| M | Demonstrate Gap Filling Radars and Spatial Modeling for Water Supply Forecasts | 1 | CWCB,<br>NOAA,<br>NCAR,<br>USBR | 2013 | | | *In 2013-14 CWCB, NOAA, NCAR, Riverside Technologies, inc. and the Conejos Water Conservancy District are partners in a effort to: create a compact compliance DSS Tool, instrument the Rio Grande, and use two mobile radars in the Upper Rio Grande and Conejos basins to create radar QPE to drive a host of snow and hydromodels for comparison with existing forecast methodologies.* |
| M | Funding: stream gage improvements | 1 | USGS<br>CWCB | 2002 | 2001 | X | *Instream flow program coordinates with USGS. Funding set aside for program within CWCB*<br>*Investigating opportunity to expand partnership in 2013* |

| Priority | Recommended Action | Primary and Related Goal* | Lead Agency/ Entity | Action Dev. Date | Status 2013 Completed | Ongoing | Status, Implementation and Funding Comments |
|---|---|---|---|---|---|---|---|
| M | Improved Impact Assessment | 1 | CWCB and ITFs | 2010 | | X | *Impact analysis has always been a weak link. Need multiple impact reporting and data mechanisms & an impact czar. Adapt the tools developed for the 2010 drought vulnerability assessment.*<br>*DART study suggests a framework for impact collection for recreation and tourism.*<br>*CSU Drought Agricultural Impact study completed in 2013 to assess impacts from 2011-2012 drought.* |
| M | Improve soil moisture monitoring | 1 | NRCS<br>CCC<br>NIDIS | 2010 | | X | *Incorporate this data into improved streamflow forecast. The sites have been identified, yet NRCS is waiting on funding before this may occur. There is one soil climate analysis network in Colorado. The CCC has been installing soil moisture sensors at dryland CoAgMet sites since 2012 and the work is ongoing.* |
| L | Colorado Drought Status strategy | **1**,2 | WATF | 2002 | 2002 | X | *Monthly drought status update developed for state leadership;*<br>*www.coh2o.co website developed in 2013 for public access to drought conditions and municipal water restrictions*<br>*Some elements of this are being revised with 2013 update and will continue into the future.* |
| L | Vulnerability-weighted drought indexes | 1 | NCAR<br>CWCB CCC<br>NRCS | 2010 | | X | *Tie vulnerability issues (e.g., sectors, places, and times of year) with drought monitoring indexes to better gauge and weigh the significance of the drought. NCAR has been studying this but more work remains to be done as of 2013.* |
| L | Improve spatial monitoring and analysis of drought, including remote sensing for monitoring of consumptive use | 1 | NIDIS<br>CCC<br>CWCB | 2010 | | X | *Add spatially-explicit water demand, identified by sector, to water rights database -Refer to NCAR effort for NIDIS pilot*<br>*Identify and establish core geospatial data layers as well as data stewards to help track situations*<br>*Link crop remote sensing with WaterSMART activities.*<br>*Improved US Drought Monitor process.*<br>*CCC has done more robust spatial mapping of precipitation and redone our SPI to include Snotel and now rely heavily on the VegDRI and VHI products. For consumptive use monitoring CCC is using long term CoAgMet stations to put the current growing season into a historic perspective.* |

| Priority | Recommended Action | Primary and Related Goal* | Lead Agency/ Entity | Action Dev. Date | Status 2013 Completed | Status 2013 Ongoing | Status, Implementation and Funding Comments |
|---|---|---|---|---|---|---|---|
| L | Support dust-on-snow research regarding impacts on timing and magnitude of runoff | 1 | CSAS, CWCB, Denver Water, City of Grand Junction, USBR, various water conservation/ conservancy districts | 2013 | | | *Continue support for this research. The Center for Snow and Avalanche Studies is home to "CODOS", the Colorado Dust-on-Snow program, an applied science effort funded directly by a collaboration of Colorado and regional water management agencies. CODOS provides its funders (various agencies listed on the left) and their agency partners with a series of "Update" analyses of how dust-on-snow is likely to influence snowmelt timing and rates during the snowmelt runoff season. That information assists reservoir operators, municipal and agricultural water providers, flood risk managers, and others at local, state, and federal agencies responsible for managing the spring runoff.* |
| L | Collect data to monitor snowpack sublimation and develop data products and incorporate this data into water supply products | 1 | CCC NRCS NOAA CWCB NIDIS CSAS | 2010 | | X | *Sublimation has been a missing piece in monitoring and is difficult to quantify. CSU/CCC graduate student finished a modeling exercise of sublimation in the Upper Colorado River Basin in 2013 that may be a starting point.* |
| L | Develop and implement low-flow streamflow forecasts | 1 | NRCS | 2010 | | X | *Forecast the date at which a stream reaches a certain low-flow threshold. This could be done before next year's forecasts, by Jan 2014.* |
| L | Co River Basin Pilot Drought Forecasting – Look at expanding to other basins in the State. | 1 | NOAA/ NIDIS CCC CWCB | 2010 | | X | *Weekly water, climate and drought assessment webinars were done for the Upper Colorado River Basin only. As of 2013 weekly drought assessments and webinars are done for the entire State, resulting in improved coordination and outreach to water users.* |
| L | Coordinate input of groundwater monitoring into overall water availability picture | 1 | DWR, CWCB USGS | 2002 | 2001 | X | *Groundwater is typically not acutely impacted by drought, but rather is more heavily relied-upon during drought, thus it should be discussed as part of overall water availability. This action was revised in 2010 and 2013 to be more specific and current. The WATF coordinates with DWR , USGS, and local government for periodic groundwater monitoring input. Most DWR ground water monitoring is done on an annual basis and indicates long-term trends.* |

| Priority | Recommended Action | Primary and Related Goal* | Lead Agency/ Entity | Action Dev. Date | Status 2013 Completed | Status 2013 Ongoing | Status, Implementation and Funding Comments |
|---|---|---|---|---|---|---|---|
| L | Develop methods to assess rangeland condition of key game species and livestock | 1 | CPW<br>NRCS<br>BLM<br>CCA | 2010 | | X | *Rangeland monitoring is needed to gauge drought stress on key game species and livestock, detection of noxious weed spread and other ecosystem health concerns. CPW has been actively researching large game herd size. NRCS monitors private lands. See related action under Goal 5 regarding the Colorado Cattleman's Association Colorado Resource Monitoring Initiative (CRMI).* |
| | **Goal 2: Increase Public Awareness and Education** | | | | | | |
| H | Drought info website | 2 | CWCB | 2002 | 2001 | X | *Drought information is hosted on the CWCB website including drought status, planning and response. A drought web-based toolbox was developed as part of the 2010 revision of this Plan. See drought toolbox action. Development of a Colorado Drought Response website in 2012 (www.coh2o.co ) that provides current information on water restrictions and drought response activities for municipalities. Website users are able to specify a certain local community and obtain information on water restrictions.* |
| H | Develop technical drought planning toolbox | **2**,4 | CWCB | 2007 | X | X | *Initial version w was completed with 2010 revision of this Plan. Update and recommendations for enhancements will be done as part of 2013 update.* |
| H | Evaluate, improve, and coordinate the role and relationship of the CWCB public information and education efforts with those being conducted by local water authorities, utilities, users, and suppliers. | **2**,7 | CWCB | 2003 (DWSA) | 2013 | X | *Was initiated with 2010 revision of this Plan's mitigation and response elements. The Colorado Drought Response website (www.coh2o.co ) came online in 2013 and provides current information on water restrictions and drought response activities for municipalities.*<br>*CWCB has a new public outreach position.* |
| M | Resources to the Office of Water Conservation and Drought Planning for technical assistance, evaluating of drought plans, administering fund programs, and public education | **2**,4,5,7 | CWCB | 2007 | | X | *SB 10-025 The water efficiency grant program re-authorization bill; Request for severance tax funds for 2011 for implementing recommendations of drought mitigation plan*<br>*Flood and drought response fund added in 2012.* |
| M | Workshops: crop survival during drought | **2**,6 | CSU Coop Ext.<br>Ag Department<br>NRCS<br>Conservation Districts | 2002 | | X | Conducted on as needed basis, in coordination with Ag State Conservation Board and NRCS Conservation Districts |

| Priority | Recommended Action | Primary and Related Goal* | Lead Agency/ Entity | Action Dev. Date | Status 2013 Completed | Status 2013 Ongoing | Status, Implementation and Funding Comments |
|---|---|---|---|---|---|---|---|
| M | Workshops: livestock mgmt. during drought | **2**,6 | CSU Coop Ext. Ag Department NRCS Conservation Districts | 2002 | | X | Conducted on as needed basis, in coordination with Ag State Conservation Board and NRCS Conservation Districts |
| M | Examine the need for new or revised state water policy related to how CWCB provides public information and education, technical assistance, and infrastructure support from the Office of Water Conservation and other CWCB sections with regard to identified water user needs. | **2**, 7 | CWCB | 2003 (DWSA) | 2012 | X | *HB 10-1051 requiring data reporting on water conservation and water use annually. This will directly influence policy direction in the future.*<br>*Use of the Water Conservation Technical Advisory Group to help determine appropriate projects and policy directions for water conservation.*<br>*Integration of the OWCDP and the Water Supply Section within the CWCB*<br>*OWCDP work with Water Conservation Sub-Committee of the IBCC* |
| L | Workshops: water system management during drought | **2**,5,6 | CSU Coop Ext. Ag Department NRCS Conservation Districts DOLA, CWCB, CRWA, USGS, USBR, CDPHE-WQCD. CPW | | 2002 2003 2004 2011 | X – as needed | *Four workshops were held around the State between 2002-2004 which raised awareness of drought impacts such as water quality impacts, state and federal resources, water rights administration, emergency management principles, the State's plan and response to drought, weather modification programs, funding options, and regulatory perspectives*<br>*Five municipal drought planning workshops were held in Spring of 2011* |
| L | Examine and improve role and relationship of public information and education efforts by the CWCB with the DNR, DWR-SEO, and the Governor's Office. | **2**, 7 | CWCB | 2003 (DWSA) | X | X | *This was initiated with the 2010 revision of this Plan's mitigation and response elements and has led to improved coordination.* |
| L | Drought workshop for urban and land use planners | **2** | CWCB DOLA | 2010 | X | | *Focused training efforts for City and County planners*<br>*Five municipal drought planning workshops were held in Spring of 2011* |

| Priority | Recommended Action | Primary and Related Goal* | Lead Agency/ Entity | Action Dev. Date | Status 2013 Completed | Ongoing | Status, Implementation and Funding Comments |
|---|---|---|---|---|---|---|---|
| L | 2012 – Year of Water Education Initiative | **2** | CCC<br><br>CFWE | 2010 | 2012 | | *Education initiative for the State. Emphasis on youth education and community involvement. Completed in 2012. Colorado Water 2012 worked to: raise awareness about water; increase support for management and protection of Colorado's water; showcase exemplary models of cooperation, and collaboration; connect Coloradans to their water; and motivate them to participate in the future of their water resources.*<br>• *Colorado Water 2012 touched more than 500,000 Coloradans with its message of water awareness*<br>• *The relationships and partnerships that Colorado Water 2012 facilitated are one of the most powerful, if difficult to measure, successes of the initiative.*<br>• *The initiative also increased the amount of water education happening in Colorado, as well as the number of people participating in the discussion.*<br>• *Colorado Water 2012 was less successful at creating behavior change among the general public, which is generally a longer-term goal.*<br>• *Included the "Rain Gage in Every School" effort and CoCoRaHS outreach from CCC.* |
| L | Implement an improved process for educating municipal water users about conservation, xeriscaping, etc. | **2** | CO Water Wise | 2010 | X, 2010 | X | *Published the Guidebook of Best Practices for Municipal Water Conservation in Colorado in 2010; runs Xeriscape Colorado which promotes Xeriscape; working on Value of Water Campaign. The Grand Valley 'DRIP' program is a model example on the West Slope.* |
| L | "Drought Awareness Week" | 2 | CCC, OEM CWCB | 2002 | 2003, 2008, | X | *This action is related to Drought Conferences action, but it could become an annual regular occurrence or used as needed when emerging drought is occurring. OEM would support this with sponsorship and daily drought related blog postings to coemergency.com.* |
| L | Drought Information Brochure | 2 | CWCB<br>CFWE<br>Local providers | 2002 | 2011 | X | *CWCB Website has drought information that will be expanded with drought toolbox development in 2010. A brochure would supplement this and could be distributed at future public meetings and events.*<br>*Developed a brochure/flyer on the 2010 State Drought Plan update. Considering developing another on the benefits of drought planning* |

| Priority | Recommended Action | Primary and Related Goal* | Lead Agency/ Entity | Action Dev. Date | Status 2013 Completed | Status 2013 Ongoing | Status, Implementation and Funding Comments |
|---|---|---|---|---|---|---|---|
| | **Goal 3: Enhance mechanisms to provide water supplies to areas of shortage during droughts** | | | | | | |
| H | Fund water system improvements for drought mitigation and resiliency | **3**, 6 | DOLA<br>CWCB<br>WPA | 2002 | | X | *CWCB*<br>*Water and Power Authority (get EPA funding)*<br>*Water Project Loan Program*<br>*Efforts to fund improvements receiving emphasis in 2013.* |
| H | Encourage study of feasibility of alternative transfer methods | 3 | CWCB, DWR-SEO | 2013 | | X | *Additional research into the feasibility and implementation of Alternate Transfer Methods is needed. CWCB has an ongoing pilot program that is not fully utilized. HB13-1248, passed in 2013, which further encourages pilot project evaluations.* |
| M | Resolve emerging water use conflicts | 3, 6 | DWR-SEO | 2002 | | X | *DWR-SEO reviews and approves temporary water transfers through Substitute Water Supply Plans (for instream flow and other uses) and interruptible water supply agreements. Additional collaboration between involved parties may reveal creative solutions to water use conflicts.* |
| M | Explore technologies for water supply banking, floodwater diversion storage, aquifer recharge, snow banking | 3 | CWCB<br>CGS | 2002 | | X | *Arkansas Valley Pilot Water Bank Study completed in 2005 Colorado Water District is working on Water Banking compact. Other studies include the Statewide Aquifer Recharge Study, the Upper Black Squirrel Creek project, the Lost Creek project, the Gilcrest/ LaSalle project, the Colorado River Basin Study, the Water Bank Working Group, the Aspinall Unit Roundtable Water Banking Project and others.* |
| M | Evaluate the benefits of construction of water storage facilities on State Trust Land | **3** | State Land Board | 2010 | | X | *This project would evaluate the potential benefits of water storage on State Trust Land for municipal and agricultural uses, supplementation of instream flows. Could help fund and would create a revenue stream. Coordination with CGS for possible underground storage.* |
| M | Use of state water resources to address water shortages. | **3** | CPW, SLB, CWCB, DWR-SEO, AGO, USBR, COE, WCDs | 2013 | | | *Use water, water rights or interests in water to assist water short communities, industries, ag, in-stream flow and recreational resources while paying attention to the primary purpose of the agency's water.*<br>*Could be used to avoid loss of stream fisheries, los of flat water recreation resources, M&I and agriculture impacts. Funding could come from rate payers in water short entities.* |

| Priority | Recommended Action | Primary and Related Goal* | Lead Agency/ Entity | Action Dev. Date | Status 2013 Completed | Ongoing | Status, Implementation and Funding Comments |
|---|---|---|---|---|---|---|---|
| L | Promote legislation that provides for policy to allow for greater flexibility during drought conditions to protect instream flows and/or wetlands critical to the survival of species of greatest conservation need | **3** | CWCB Colorado Water Trust Attny General, DWR-SEO, CPW | 2010 | 2012 | X | *Action completed with enactment of 37-38-105 which enables entities in collaboration with CWCB to lease water for streams on short notice to protect the environment. This tool was the first used in 2012 to add water to streams during the drought and its use continues in 2013.* |
| L | Encourage Local Water Providers to include drought in water supply shortage planning | **3** | CWCB Local providers | 2010 | X | X | *Natural systems adjust water consumption to adapt for drought and limited water supply. Most human systems are built for uniform and reliable water use regardless of water supply and drought. This is encouraged in the 2010 Drought Management Plan Guidance Document* |
| L | Public/private partnerships to augment local water supplies | **3**,7 | Local water providers | 2002 | 2012 | X | *SB 02S-001 provides up to $1M for agricultural organizations for water augmentation in drought emergencies*<br>*Colorado Water Trust instream flow program* |
| | **Goal 4: Coordinate and Provide Technical Assistance for State, Local and Watershed Planning Efforts** | | | | | | |
| H | Make completion of local drought plans a priority; include vulnerability & risk assessments; incorporate info into next update | 4 | CWCB | 2007 | | X | *Local drought plan guidance document developed in 2010 to help facilitate local plan development. Sample drought plan completed in 2011. Roughly half a dozen pans are now under state review as of mid- 2013 (1 since 2010 and another under review).* |
| H | Risk-based water system assessments | 4 | CWCB | 2002 | X | X | *Tools and methods developed as part of the local plan guidance document in 2010* |
| H | Integrate results, tools and methods from the 2010 Statewide Drought Vulnerability Assessment to improve and standardize drought risk assessments in local hazard mitigation plans | 4 | OEM CWCB | 2010 | | X | *Utilize in Plan update cycles or in new plans that are developed. Being incorporated by reference into new or updated plans since 2010, but no formal process.* |
| H | Develop approaches and technology to help farmers adapt to drought | | Ag, State Conservation Board U.S.D.A | 2004 | | X | *University research grants to address grazing management, forage and crop systems, and irrigation strategies. The federal agency hopes the grants will lead to improvements such as enhancing soil's ability to hold water and developing grazing systems that can tolerate drought and reduce the potential for dust storms.*<br>*Increasing demonstrations and adoption of farming methods that improve soil health and water holding capacity so that lands will be more resistant/resilient to and during cyclic drought patterns.* |

| Priority | Recommended Action | Primary and Related Goal* | Lead Agency/ Entity | Action Dev. Date | Status 2013 Completed | Ongoing | Status, Implementation and Funding Comments |
|---|---|---|---|---|---|---|---|
| H | Integrate and correlate the State Drought Mitigation Plan with other statewide planning efforts | 4 | CWCB<br>CSFS<br>CEO | 2010 | 2011<br>2012 | X | *IBCC planning efforts , Forest Resource Assessment Planning;*<br>*Drought plan integrated with Colorado Energy Assurance Emergency Plan developed in 2012*<br>*Integration of the OWCDP and Water Supply Planning Section*<br>*Update of the State Emergency Operations Plan in April 2013*<br>*The Drought Plan will be linked with the proposed 2015 State Water Plan* |
| M | Require drought planning by Colorado municipalities, water providers and large agricultural producers | 4 | CWCB | 2010 | | | *Deferred. There is currently no mandate requiring local governments to implement drought planning. Such a mandate would require legislative changes. This topic may be revisited as an aspect of the State Water Plan development.* |
| M | Encourage cooperative sharing of water resources between municipalities and water districts within a watershed during a drought | 4 | CWCB<br>Local providers | 2010 | | X | *Cooperative projects continue to develop such as WISE and Southern Delivery System, which can improve drought resilience by diversifying water supplies for providers.* |
| L | Encourage "drought resistant" communities | 4 | OEM, DOLA, CWCB | 2002 | 2002 | X | *OEM continues to encourage communities to incorporate drought in multi-hazard risk assessments and mitigation strategies, as appropriate. CWCB has worked with NDMC's "Drought Ready Communities" initiative, which is similar to the NWS StormReady certification.*<br>*The state recovery plan completed in 2013 has increased emphasis on economic/environmental recovery and community sustainability efforts as part of the operational elements of that plan.* |
| L | Workshops for local drought plans | **4,** 2,5 | CWCB, DOLA | 2002 | 2000-2001, 2009<br>2010<br>2011 | X | *Workshop held in 2010 during the development of local plan guidance document*<br>*Dealing with Drought – Adapting to Climate Change workshops held in Fall of 2009*<br>*Held five workshops in the spring of 2011 on drought planning* |
| L | Integrate the State Drought Mitigation Plan with the Energy Assurance Emergency Plan | 4 | CEO, DORA-PUC | 2010 | 2012 | | *This was completed in May 2012.* |

| Priority | Recommended Action | Primary and Related Goal* | Lead Agency/ Entity | Action Dev. Date | Status 2013 Completed | Status 2013 Ongoing | Status, Implementation and Funding Comments |
|---|---|---|---|---|---|---|---|
| | **Goal 5: Reduce Water Demand and Encourage Water Efficiency** | | | | | | |
| H | Support development of local water conservation program | 5 | CWCB | 2002 | 2012- guidance document | X | *State Water Conservation planning requirement. 60 of 89 conservation plans for covered entities are completed. Rainwater Harvesting Pilot Project Program started in 2009 with one pilot project active; Water Conservation Technical Advisory Group meeting once per month; HB 1051 data collection beginning in 2014 with web portal for collecting date online; Water Efficiency Guidance document revised in 2012 with statewide workshops to follow in 2013-14; development of several regional water efficiency plans for smaller providers who group resources.* |
| H | Continue development and the appropriate allocation of resources to the Office of Water Conservation and Drought Planning in providing technical assistance to covered entities, evaluating submitted water conservation and drought plans, administering fund programs, and disseminating information to the public. | **5**, 4 | CWCB | 2003 (DWSA) | X | X | *Ongoing. Funds allocated through construction fund and severance tax fund; Full time drought planner hired in 2008; full time water conservation technical specialist hired in 2009* |
| H | Provide technical assistance and information on more efficient agricultural irrigation systems | **5** | CSU ext, Ag, USDA CWCB | 2010 | | X | *CSU has been working on this topic.*<br>*Possibly tie into water efficiency grant program* |
| H | Encourage and provide incentives for more efficient municipal irrigation systems, including State-owned properties | **5** | CWCB/ CRC/Green CO/Local Water providers | 2010 | X | X | *Use water efficiency grant program; Center for Resource Conservation irrigation audits funded by CWCB; EPA Watersense specifications for outdoor irrigation technologies; Green Industries of Colorado (GreenCO) Best Management Practices; Colorado Waterwise's Guidebook of Best Practices for Municipal Water Conservation in Colorado;* |
| M | Support economic incentives for individual investment in conservation including reduced lawn watering and irrigation maintenance | 5 | DNR | 2002 | | X | *Water Efficiency Grant Program – CWCB; Recharge Colorado: CWCB partners with Colorado Energy Office (CEO) energy and water efficient appliance rebates; Water Smart Home Initiative legislation (HB-10-1358 passed in 2010).* |
| L | Provide technical assistance and information on growing crops appropriate to semi-arid climate, or promote growing drought resistant crops | **5** | CSU ext., Ag, USDA, | 2010 | | X | *CSU has been working on this topic.*<br>*NRCS note- NRCS can potentially utilize its programs be prepare producers for mitigation measures that may be necessary to get through the drought for both grazing and crop (irrigated and dry) lands.* |

| Priority | Recommended Action | Primary and Related Goal* | Lead Agency/ Entity | Action Dev. Date | Status 2013 Completed | Status 2013 Ongoing | Status, Implementation and Funding Comments |
|---|---|---|---|---|---|---|---|
| L | Encourage minimizing building (particularly urban) water usage in cooling towers and explore other water-energy nexus connections | **5** | Local Water Providers<br><br>CWCB | 2010 | | X | *CWCB working with Western Resource Advocates on connection between distribution system water loss reduction and energy reduction in 2013*<br>*Recharge Colorado conducted a series of workshops funded by CWCB* |
| L | Establish BMP's for landscaping uses | **5** | CO WWC<br>CWCB | 2010 | X | | *BMPs developed through CO Water Wise Council in 2010; GreenCO developed green industry BMPs in 2008* |
| L | Reuse of water for cooling (full cycle) during power generation at coal and natural gas plants | 5 | Xcel Energy<br>DORA-PUC | 2013 | X | X | *Coal and natural gas power generation plants use water for cooling. Coal fired plants use considerably more water than gas fired plants (94% vs. 6%) however in both cases, the water used is recycled. Given the "Clean Air Clean Jobs Act" passed by the legislature, coal fired plants are eventually being replaced with natural gas. Xcel Energy is utilizing water reuse as a strategy to reduce water demands.* |
| L | Encourage reuse/recycling of water used in hydraulic fracturing and in oil and gas exploration and production. | 5 | CWCB | 2013 | | | Investigate incentives for recycling. |
| L | Landscape certification | 5 | CWCB | 2013 | | | Certification of water conservation oriented landscaping |
| | **Goal 6: Reduce Drought Impacts to Colorado's Economy, People, State Assets, and Environment** | | | | | | |
| H | Continue to pursue implementation funding for recommendations in this plan | **6**, all | CWCB | 2007 | | X | *Funding secured to implement some 2007 recommendations. $200k funding for implementation was set aside through construction funds in 2010. See Section 4.5 Funding Sources of plan for updated details.* |
| M | Create a sustainable funding source within State's Long Bill or CWCB budget to continue implementing all the recommendations in the Drought Plan – including monitoring and data collection | **6** | State Gov<br>CWCB | 2010 | | X | *Flood and Drought Response Fund created in 2012* |
| M | Continue weather modification research | 6 | CWCB | 2002 | | X | *Efforts continue by CWCB and Water Users downstream in the Colorado River Basin to assist water users and develop their programs to industry standards through grants and technical assistance. There are seven wintertime ground based cloud seeding programs in Upper Colorado River, Grand Mesa, Gunnison, Telluride, Western San Juan Mountains, and Eastern San Juan Mountains. A 2012 Rules update require target control evaluations each year and suggest evaluations and refinement techniques.* |

| Priority | Recommended Action | Primary and Related Goal* | Lead Agency/ Entity | Action Dev. Date | Status 2013 Completed | Ongoing | Status, Implementation and Funding Comments |
|---|---|---|---|---|---|---|---|
| L | Evaluate the relationship / interaction between both drought (low flows) and water conservation on water quality of streams as well as health related consequences | **6** | CDPHE-WQCD<br>CPW<br>CWCB<br>WRD | 2010 | | | *Deferred. Colorado's legal system for water supply does not specifically require an accounting of water-quality issues. This project should investigate weaknesses in water quality legislation in regards to drought and recommend adjustments where necessary. This project should identify high-risk discharges/watersheds, high risk non-point watersheds, and high risk aquatic life and human population centers. With particular emphasis on these high-risk areas, the project should focus on (1) implementing water-quality considerations in water-supply planning, education, and conservation efforts, (2) educating planners on existing tools, and (3) developing new tools where necessary. This project could include securing funding for wastewater dischargers to improve the quality of wastewater when stream flows are not high enough to provide the dilution necessary for attainment of water-quality standards. (See Annex B State Assets and Environmental sectors for more background)*<br>*Possible consideration under Executive Order 2013-005 Colorado Water Plan activities* |
| L | Leverage the NIDIS Drought Portal (www.drought.gov) "Drought Impacts Reporter" to compile Colorado-specific drought impacts | **6** | WATF<br>NOAA<br><br>NDMC/<br>CWCB | 2010 | | X | *CWCB sends data to NDMC regularly on drought impacts Drought Impacts Reporter data summarized in 2010 revision and 2013 update.* |
| L | Support agricultural research of drought tolerant species | **6** | CSU | 2010 | | X | *CSU has ongoing research into crop improvement for drought tolerance both at the molecular and plant breeding levels. Funded by the Ag Experiment Station and various granting agencies.* |
| | **Goal 7: Develop Intergovernmental and Interagency Stakeholder Coordination** | | | | | | |

| Priority | Recommended Action | Primary and Related Goal* | Lead Agency/ Entity | Action Dev. Date | Status 2013 Completed | Status 2013 Ongoing | Status, Implementation and Funding Comments |
|---|---|---|---|---|---|---|---|
| H | Develop a drought exercise to test procedures and train constituents | **7** | CWCB | 2010 | X | | *Updated plan was tested during actual drought in 2011-2012 when Agricultural Impact Task Force activated. Municipal Water ITF activated in 2013. Drought response plan undergoing revisions in 2013 based on lessons learned.*<br>*CWCB and NIDIS co-sponsored the first Colorado 'Drought Tournament' as a daylong event prior to the 2012 Governors Drought Conference. The tournament was designed to enhance multi-sector collaboration and creative response and mitigation in three simulated droughts.* |
| M | Evaluate, and where appropriate, engage alternative funding sources and mechanisms to provide resources for programs water users identified as being needed on a statewide, regional, and local basis. | 7 | CWCB | 2003 (DWSA) | X | X | CWCB finance section continues to work with communities to affordably meet raw water development needs. |
| M | Provide appropriate resources to continue to develop and administer opinion surveys of Colorado water users relative to important water issues, and to create a temporal database related to drought and water supply impacts, limitations, planning needs, and projects. | **7**,4,5,6 | CWCB | 2007 | 2007<br>2013 | X | *Basin Needs Assessment*<br>*DWSA 2007*<br>*House Bill 1051 requiring municipalities to report water conservation data*<br>*Basin Needs Decision Support System development*<br>*Survey to M&I providers during 2013 update of Drought Plan Vulnerability Assessment.* |
| L | Develop data base to track key information in local drought plans | **7,** 4, 5, 6 | CWCB | 2007 | | X | *Initial components completed as part of 2010 revision of this Plan*<br>*May be able to utilize HB-1051 data in the future.* |
| L | Participate in new monitoring guidelines process for Ag lands being facilitated by Colorado Cattlemen's Association. | **7, 1** | CCA, Ag, CSU- WRI | 2010 | | X | *The Colorado Cattleman's Association leads a Colorado Resource Monitoring Initiative (CRMI), which is a database for ranchers to input rangeland condition information. 15 ranchers were utilizing the database as of June 2013, with more interest in the program being generated through CCA education and outreach. Has participation from federal and state land management agencies and Ag producers.* |

| Priority | Recommended Action | Primary and Related Goal* | Lead Agency/ Entity | Action Dev. Date | Status 2013 Completed | Ongoing | Status, Implementation and Funding Comments |
|---|---|---|---|---|---|---|---|
| | **Goal 8: Evaluate Potential Impacts from Climate Change** | | | | | | |
| H | Statewide Climate Change Initiatives | 8 | CWCB<br>USBR | 2007 | 2007<br>2008<br>2009<br>2010<br>2011<br>2012<br>2013 | X | *2007 Governor's Climate Action Plan developed Dealing with Drought*<br>*2008 Climate Change in Colorado synthesis report*<br>*2009 Adapting to Climate Change workshops*<br>*2010 Climate Change Impacts and Vulnerability Assessment*<br>*2012 CWCB Colorado River Water Availability Study*<br>*2011 Colorado Climate Preparedness Project*<br>*2012 Joint Front Range Climate Change Vulnerability Study*<br>*2012 Colorado Climate Action Plan*<br>*2012 Colorado River Basin Water Supply and Demand Study* |
| H | Continue to assess potential climate change impacts on a variety of sectors | 6 | CCC<br>CWCB | 2010 | 2013 | X | *Continue to integrate information for projecting drought and the length and severity that might be anticipated from climate change to support future state and local planning efforts. Build on efforts from the 2010 Drought Plan revision.*<br>*2011 Colorado Climate Preparedness Project*<br>*2013 Climate Variability/Paleohydrology Analysis as part of Drought Plan update.* |
| H | Funding: Climate Monitoring Stations | 8 | CWCB<br>CCC | 2007 | 2012 | X | *CWCB Provided $25k for additional station in FY 11/12* |
| M | Host Statewide Drought Conference | 8, all | CWCB | 2007 | 1999, 2008, 2009, 2012 | X | *Drought and Climate change conference held in October 2008,*<br>*'Dealing with Drought – Adapting to Climate Change' workshops held in Fall of 2009 (three around the State)*<br>*Water and Land Use Planning for a Sustainable Future symposium Sept 2009*<br>*2012 Governors Drought Conference* |
| L | Assess how the hydrograph will change due to climate change for each major river system/ basin in the State | 6 | CWCB<br>CPW<br>USBR | 2010 | 2012<br>2013 | X | *2012 Colorado River Water Availability River Study*<br>*2012 Colorado River Basin Water Supply and Demand Study*<br>*2012 Joint Front Range Climate Change Vulnerability Study*<br>*2013 Climate Variability/Paleohydrology Analysis as part of Drought Plan update.* |
| L | Continue to pursue improved climate data to inform the planning process | 6 | CCC CWCB | 2010 | | X | *Formally communicate needs to appropriate federal agencies and congressional committees*<br>*Update to the 2008 Climate Report in collaboration with WWA anticipated in fall 2013* |

### *Deleted and Deferred Actions*

Several action items that were completed as part of the 2010 Plan revision process were deleted from the action summary table (see Table 21). Some of these were related to the standard state plan DMA plan update requirements and included:

- Comprehensive Update 2002 State Drought Plan
- Review and identify other possible drought mitigation activities that could be taken to protect state-owned facilities from drought impacts
- Re-survey state agencies re: state-owned facilities that are susceptible to drought impacts
- Develop Plan monitoring process
- Develop process to link local plans to state plan

Other actions that were removed from the 2010 action summary table included those related to the day to day missions of state agencies, such as the CWCB. These included:

- Revise CWCB long-range and strategic plans to ensure performance of the identified implementation tasks and activities.
- Evaluate funding options for education, construction and maintenance, technical assistance and for sustaining and expanding the construction fund (CWCB)

In 2010 only one action was deferred, effectively due to budget shortfalls in the 2010-2011 FY State budget (see action Funding: Climate Monitoring Stations in Table 21). The action remains in the table with the intent to implement when funding becomes available.

In 2013 three actions were deleted from the summary table including:

- Incentives for reduced lawn watering and irrigation maintenance
- "Colorado Water Watch"
- Develop a statewide drought messaging campaign

These actions were either no longer relevant or captured as aspects of other actions.

## 4.4.2 Progress in Statewide Mitigation Efforts

As evidenced in the number of completed and/or ongoing projects in the actions summary table the State has been making active progress in the implementation of drought mitigation efforts. Of the 35 actions identified prior to 2010, 34 have been completed or are ongoing. Additionally, several items associated with the significant effort of the 2010 Plan revision have been completed and removed from the action table, as discussed in the previous section.

This section provides a brief synopsis of the progress in statewide mitigation efforts, including additional efforts that are contributing to drought mitigation not previously identified in this plan.

The highlights are organized by goal and are based on input provided by the DMRPC during the revision process.

### *Goal 1 Progress Highlights: Improve Water Availability Monitoring and Drought Impact Assessment*

- Drought status strategy – Coh2o.co website developed in 2013 to communicate drought status at state and municipal level
- SWSI Modernization and Triggers and Indices study
- Drought Assessment on Recreation and Tourism (DART) study and CSU Agricultural Impact Study
- CWCB and CCC Participation with National Integrated Drought Information System efforts including Upper Colorado River Pilot Study

Related efforts and initiatives:

- Participation with National Integrated Drought Information System efforts and Drought Monitor improvements in CO

### *Goal 2 Progress Highlights: Increase Public Awareness and Education*

- Successful implementation of drought conferences and related workshops
- Dealing with Drought workshops in 2009
- Drought planning technical assistance workshops in 2011
- Successful implementation of the State Drought Conference in September of 2012
- Drought status strategy – Coh20.co
- Drought Tours 2012 and 2013

Related efforts and initiatives:

- Outreach and workshops as part of the Drought Plan updates
- CWCB and NIDIS partnered to develop an innovative stakeholder outreach gaming exercise called the "Drought Tournament" to promote drought planning and collaboration among sectors and basins.

### *Goal 3 Progress Highlights: Enhance mechanisms to provide water supplies to areas of shortage during droughts*

- Funding of water system improvements (DOLA and CWCB)
- Funding for water banking studies in Arkansas and Colorado River Valleys
- Public/private water system augmentation efforts through the Colorado Water Trust program in 2012 and 2013
- Continued analysis of water banking technologies

Related efforts and initiatives:

- Chatfield Reservoir Reallocation Project
- Statewide Water Supply Initiative
- Reuter-Hess Reservoir development

***Goal 4 Progress Highlights: Coordinate and Provide Technical Assistance for State, Local and Watershed Planning Efforts***

- Development of Local Drought Management Plan Guidance Document and web – based toolbox
- Local hazard mitigation plans and conservation plans
- Outreach and workshops as part of the Drought Plan updates
- Sample CWCB Municipal Drought Management Plan in 2010
- Integration of the Drought Mitigation Plan with the CO Energy Assurance Emergency Plan

Related Efforts and Initiatives:

- Community Wildfire Protection Plan development

***Goal 5 Progress Highlights: Reduce Water Demand/Encourage Conservation***

- Rainwater Harvesting Pilot Project Program started in 2009
- 63 state approved local water conservation plans completed; 26 completed since the last update of the Drought Mitigation and Response Plan

Related Efforts and Initiatives:

- Recharge Colorado: CWCB partnership with the Colorado Energy Office on energy and water efficient appliance rebates
- Update of the CWCB Municipal Water Efficiency Plan Guidance Document in 2011

***Goal 6 Progress Highlights: Reduce Drought Impacts to Colorado's Economy, People, State Assets, and Environment***

- Many actions related to updating and improving the Drought Mitigation and Response Plan completed as part of the 2010 update and 2013 revision.
- Improved and streamlined communication
- Expanded flood fund to include drought creating the Flood and Drought Response Fund in 2012
- CWCB – CPW cooperative projects for maintaining instream flows

Related Efforts and Initiatives:

- Ongoing research at CSU

### *Goal 7 Progress Highlights: Develop Intergovernmental and Interagency Stakeholder Coordination*

- The process of updating the State Drought Plan in 2010 and 2013 helped further achieve this goal
- CWCB State Drought Conference and Drought Tournament in 2012
- M&I sector water survey in May 2013 as a component of the State Drought Mitigation and Response Plan update

Related Efforts and Initiatives:

- Inter Basin Compact Committee and Basin Roundtable efforts
- State Water Plan initiative in 2013
- Statue 37-38-105 enables entities in collaboration with CWCB to lease water for streams on short notice to protect the environment. This tool has been available since 2003 yet it was first utilized by the Colorado Water Trust in 2012 to maintain water levels in at risk stream reaches during the drought. They are planning on doing the same program in 2013.

### *Goal 8 Progress Highlights: Evaluate Potential Impacts from Climate Change*

- Colorado River Water Availability Study
- Joint Front Range Climate Change Vulnerability Study
- Climate Change in Colorado synthesis report
- Drought and Climate Change conference in October 2008
- Dealing with Drought workshops in 2009
- CWCB Drought planning workshops in 2011

Related Efforts and Initiatives:

- 2012 CWCB Colorado River Water Availability Study
- 2011 Colorado Climate Preparedness Project
- 2012 Joint Front Range Climate Change Vulnerability Study
- 2012 Colorado Climate Action Plan
- 2012 Colorado River Basin Water Supply and Demand Study

Since the last Plan update, the National Integrated Drought Information System (NIDIS) Act of 2006 was authorized by Congress. NIDIS is a drought early warning system capable of fostering and supporting a research environment that focuses on impact mitigation and improved predictive capabilities. It is designed as a user-based drought information system that assesses potential drought indicators and impacts to provide tools for anticipating, preparing for, and mitigating the effects of drought. Colorado has a participatory role in NIDIS as it pertains to efforts in the Colorado River Basin. The State will continue to work with NIDIS and related U.S. government agencies, the Western Water Assessment, and the Regional Integrated Sciences and Assessments program in the Rocky Mountain region, to provide scientific knowledge to public and private water providers and stakeholders to anticipate, track, assess, and respond to drought threats at regional and local levels. Many of the goals and objectives of NIDIS coincide squarely with the State Drought Plan.

DOLA workshops in 2002, 2003, and 2004 raised awareness of drought impacts such as water quality impacts, state and federal resources, water rights administration, emergency management principles, the State's plan and response to drought, weather modification programs, funding options, and regulatory perspectives. These workshops could be held again on an as-needed basis.

All eight of the ITFs were activated by the Governor during the 2002 drought. One outcome was a report prepared in 2003 (i.e., 2003 Drought Impact and Mitigation Report). It identified impacts from the drought, as well as actions or mitigation measures that would be or already had been taken to address the drought impacts of the ongoing drought. The report also identified state and federal agencies and entities that are associated with actions and mitigation measures, as well as implementation status and related costs if available. Each of the eight ITFs provided a two or more page summary table listing these actions and activities. The actions taken in this and other droughts are summarized in Appendix B Actions Taken to Reduce Drought Impacts in Previous Droughts (see the 2003 Impact and Mitigation report for more information).

### 4.4.3 Evaluation and Selection of Actions and Activities

During the 2010 revision the DMRPC members were asked to generate new ideas for actions to be included in the plan. At a planning workshop DMRPC members were provided with several lists of alternative drought hazard mitigation actions. One of these was a compendium of tools typically used by states to mitigate drought, based on information from the National Drought Mitigation Center's website. A second handout was an excerpt from the report on the 2009 "Dealing with Drought Workshops" which included recommendations for state consideration based on feedback from workshop attendees. Another reference handout developed by AMEC titled "Drought Mitigation Plan Progress Snapshot and Recommendations" was distributed to the DMRPC. This handout listed the Plan's goals, a summary of progress made with the existing projects, a listing of related efforts and initiatives, and recommendations for existing actions and new actions. In addition to these handouts, a presentation at the workshop on the detailed vulnerability assessment included recommendations for "adaptive capacities" that could mitigate impacts to the various sectors. These suggested recommendations are captured in Annex B Drought Vulnerability Assessment Technical Information and organized by impact sector. This Annex can serve the State as well as local governments, citizens, businesses and industry as a useful reference for mitigation strategies to be considered in the future.

The following general categories of state level approaches to drought mitigation were considered:

- Administrative

- Emergency Services
- Financial
- Monitoring and Prediction
- Natural Resource Protection
- Projects to Reduce Impacts to State Assets
- Public Education
- Regulatory
- Structural Projects
- Studies, Publications, Planning efforts
- Technical Assistance
- Training and Exercises

A facilitated discussion took place at the workshop to examine and analyze the alternatives. With an understanding of the alternatives and progress on existing actions, a brainstorming session was conducted to generate a list of preferred mitigation actions. DMRPC members wrote project ideas on sticky notes. These were posted on flip charts organized by goal. The result was a number of new or revised project ideas that help to meet the identified goals. New actions identified through this process are indicated in Table 21 with a 2010 initiation date. Existing actions were also evaluated and revised during this process and are also included in Table 21.

Actions that were similar in nature were combined, or integrated into an existing action. Those actions that were more drought response oriented were integrated into the Annex A Drought Response Plan.

During the 2013 update a similar process was followed. DMRPC members were asked to review the mitigation sections of the 2010 plan and provide updates on the mitigation activities, which are reflected in Table 21. A brainstorming session was held to generate ideas for new actions. Comments from each of the DMRPC members are reflected in this table and throughout the updated Plan.

### 4.4.4 Prioritization of Actions and Activities

Once the mitigation actions were identified, the DMRPC members were provided with several sets of decision-making tools, including FEMA's recommended criteria, STAPLE/E (which considers social, technical, administrative, political, legal, economic, and environmental constraints and benefits).

- Social: Does the measure treat people fairly?
- Technical: Will it work? (Does it solve the problem? Is it feasible?)
- Administrative: Is there capacity to implement and manage the project?
- Political: Who are the stakeholders? Did they get to participate? Is there public support? Is political leadership willing to support the project?

- Legal: Does your organization have the authority to implement? Is it legal? Are there liability implications?
- Economic: Is it cost-beneficial? Is there funding? Does it contribute to the local economy or economic development? Does it reduce direct property losses or indirect economic losses?
- Environmental: Does it comply with environmental regulations or have adverse environmental impacts?

In accordance with the DMA requirements, an emphasis was placed on the importance of a benefit-cost analysis in determining project priority (i.e., the "economic" factor of STAPLE/E). Other criteria used to recommend what actions might be more important, more effective, or more likely to be implemented than another included:

- Does action address hazards or areas with the highest risk (from Risk Assessment)?
- Does action protect state assets or infrastructure?
- Does action improve the State capability to manage and implement mitigation (from Capability Assessment)?

With these criteria in mind, DMRPC members were given a set of eight sticky-dots and asked to place the dots on the identified actions as a means to prioritize projects. The projects with the most dots became the higher priority projects. This process provided both consensus and priority for the recommendations. The number of dots was converted into a relative low, medium, and high prioritization category using a score of 0-2 dots as low, 3-4 as medium, and 4-6 a high. The results of the project identification and prioritization exercise are summarized in Table 21 in the "priority" column.

The action identification and prioritization process is the first step in laying-out, in broad terms, what needs to be done to minimize the impact of the drought hazard in the State. Some of the actions can be accomplished with minimal cost or integrated into the work plans of the lead agency. While cost-effectiveness is required for FEMA funding of projects, many of the projects identified are non-structural and thus difficult to quantify cost-effectiveness. The detailed engineering studies, implementation costs, and benefit-cost analysis of specific projects will come at future points in the process. Additional discussion on this topic is included in Chapter 6 Plan Maintenance Process.

### *Changes in Priorities*

Existing actions were also re-evaluated during the revision process. The actions developed in 2007 or previous to that had not been prioritized. The lead agencies were asked to review and rank these projects, based on the STAPLE/E criteria, for projects that they were responsible for implementing. The prioritization of actions was reviewed again by the DMRPC during the 2013 update and the priorities were adjusted based on feedback from the DMRPC. Table 21 reflects the new priorities, which are grouped by relative priority under each goal. Some actions that have been partially implemented were revised to Low during the 2013 update.

### 4.4.5 Contribution of Each Activity to Overall State Drought Mitigation Strategy

Table 21 was reorganized in 2010 so that the proposed actions are grouped by the primary mitigation goal achieved. In some cases the proposed actions relate to several different goals. The grouping indicates that a balanced number of activities are proposed or ongoing to meet the eight goals.

### 4.4.6 Integration of Local Plans into Mitigation Strategy

FEMA recommends that the mitigation actions identified should be linked to local mitigation plans, where specific local actions and projects are identified; however, the absence of information on this piece will not cause FEMA to disapprove the plan. During the 2013 revision the available local hazard mitigation plans were reviewed to identify drought-related mitigation projects. Table 22 contains mitigation actions that local or regional jurisdictions have identified in their plans intended to mitigate the effects of drought. This data originated from local multi-hazard mitigation plans in effect in counties, cities and other local entities in Colorado as of March 2013. By connecting these local actions with the State Drought Plan, opportunities for targeted technical assistance and funding needs can be identified so the State can assist with the implementation of these activities.

**Table 22 Drought Mitigation Actions from Local and Regional Multi-Hazard Mitigation Plans**

| Plan Name/Jurisdiction | Mitigation Action |
|---|---|
| Archuleta County | 1) Water conservation program<br>2) Drought management plan update |
| Boulder County | No drought specific mitigation actions, but incorporated into multi-hazard activities |
| City of Boulder | 1) Identify and implement priority projects identified in the City's Drought Plan<br>2) Implement replacement planting program to meet three criteria |
| City of Colorado Springs | Coordinate with Colorado Springs Utilities to review their current water conservation and drought programs |
| Costilla County | 1) Contact Natural Resources Conservation Service regarding opportunities for technical assistance and financial assistance for drought preparedness and response.<br>2) Initiate appropriate drought preparation actions as specified in the Costilla County Drought Preparedness Action Guide. |
| Delta County | No drought specific mitigation actions, but incorporated into multi-hazard activities. Various drought-related activities also considered under alternative mitigation actions. |
| Denver Regional Council of Governments | 1) Coordinate with local water providers to continually identify and promote water conservation measures<br>2) Monitor proceedings of the Colorado Water Availability Task Force. When necessary, support water providers in the implementation of conservation measures. |
| Dolores County | No drought specific mitigation actions identified |
| Eagle County | No drought specific mitigation actions identified |
| Elbert County<br>Town of Elizabeth | Implement water delivery system improvements |

| Plan Name/Jurisdiction | Mitigation Action |
|---|---|
| Elbert County<br>Town of Kiowa | Implement water delivery system improvements |
| Elbert County<br>Town of Kiowa | Develop education and incentives program to encourage water saving measures by citizens. |
| El Paso County | No drought specific mitigation actions identified |
| Grand County | No drought specific mitigation actions identified |
| Gunnison County | 1) Monitor water issues in City of Gunnison area<br>2) Monitor city's wells for contamination or dropping water tables<br>3) Continue acquiring water rights in the area |
| Hinsdale County | No drought specific mitigation actions identified |
| Huerfano County | No drought specific mitigation actions identified |
| Jefferson County | 1) Replacement of the aged section of the main pipeline from Clear Creek County and Jefferson County line east for approximately ½ mile<br>2) Installation of meters on lateral line connections that serve various communities<br>3) Partial renovation and improvement to sections of the main pipeline<br>4) Conduct a leak detection survey |
| Mesa County | 1) Improve water conservation practices<br>2) Education of citizens on importance of water conservation<br>3) DRIP Program (Drought Response Information Project) |
| Montrose County | No drought specific mitigation actions identified |
| Northeast Colorado<br>Cheyenne County<br>Kit Carson County<br>Lincoln County<br>Philips County<br>Sedgwick County<br>Washington County<br>Weld County<br>Yuma County | Reduce losses from drought by:<br>-Improving water supply<br>-Seek grazing on Conservation Reserve Program land<br>-Use of low-water crops |
| Northeast Colorado<br>Logan County | 1) Construct a multi-purpose flood control dam at Pawnee Pass<br>2) Construct additional small retention ponds throughout the watershed |
| Northeast Colorado<br>Morgan County | Development and implementation of a Source Water Protection Plan |
| Northern Colorado Region | 1) Public information campaign expansion<br>2) On-line access to water history<br>3) Low income retrofit program<br>4) Irrigation technology rebates<br>5) Facility audit program expansion<br>6) Financial incentives for commercial water saving upgrades |
| Ouray County | Develop additional raw storage for the Town of Ridgway |

| Plan Name/Jurisdiction | Mitigation Action |
|---|---|
| Park County | 1) Educate the public about ways to lessen the effects of drought and the need to be water wise.<br>2) Identify those municipalities and unincorporated communities in Park County most at risk due to drought, develop Community Water Conservation Plans, and alternate water supply locations for those communities, and implement those plans.<br>3) Identify specific locations and specific parameters for a long-term drought monitoring program and implement the program. Obtain assistance and technical recommendations from the Natural Resources Conservation Service for an improved program of drought preparedness and drought response.<br>4) Create an Emergency Services Council sub-committee to address weather related mitigation issues (e.g., drought, flooding, and winter storms) |
| Pitkin County | No drought specific mitigation actions, but incorporated into multi-hazard activities |
| Prowers County | 1) Reduce the vulnerability of municipal water supplies<br>2) Improve water conservation practices<br>3) Protect senior water rights in the valley |
| Pueblo County | No drought specific mitigation actions, but incorporated into multi-hazard activities |
| Rio Blanco County | 1) Drought preparedness planning<br>2) Wolf Creek Reservoir, drought, erosion/deposition |
| Routt County | 1) Water use reduction projects<br>2) Water conservation education and outreach |
| San Luis Valley Multi-Hazard Mitigation Plan Alamosa County | Prepare a Drought Preparedness Action Guide |
| San Luis Valley Multi-Hazard Mitigation Plan Conejos County | Develop a drought action plan based on state guidelines |
| San Luis Valley Multi-Hazard Mitigation Plan Mineral County | No drought specific mitigation actions, but incorporated into multi-hazard activities |
| San Luis Valley Multi-Hazard Mitigation Plan Region-wide | Develop a regional drought action plan |
| San Luis Valley Multi-Hazard Mitigation Plan Rio Grande County | 1) Develop an action/response plan for drought<br>2) Increase public awareness in regard to drought |
| San Luis Valley Multi-Hazard Mitigation Plan Rio Grande Water Conservation District | Prepare a Drought Preparedness Action Guide |
| San Luis Valley Multi-Hazard Mitigation Plan Saguache County | 1) Prepare a drought action plan<br>2) Work with Saguache Creek Water Users (and other similar organizations) to develop a plan and strategy for mitigating drought and flooding |
| San Miguel County | Additional water storage for fire and drought mitigation |
| Summit County | No drought specific mitigation actions, but incorporated into multi-hazard activities |
| Teller County | Strategic snow stockpiling for Cripple Creek |
| University of Colorado, Boulder | No drought specific mitigation actions |

| Plan Name/Jurisdiction | Mitigation Action |
|---|---|
| Upper Arkansas Area | 1) Acquire more senior water rights<br>2) Construction of more water storage facilities<br>3) Establish “Water Banks” or similar mechanism to protect both the agricultural and municipal centers in the region<br>4) Implement and Promote “Waterwise” programs<br>5) Implement water-use fee policies that promote conservation<br>6) Prepare public relations campaign to accurately portray drought impacts to recreational assets<br>7) Publicize findings of expert panel |
| Ute Mountain Ute Tribe | No drought specific mitigation actions, but incorporated into multi-hazard activities |

# 4.5 Funding Sources

The state mitigation strategy includes an identification of existing and potential sources of federal, state, local or private funding to implement mitigation activities. Colorado uses a variety of sources to fund state and local drought mitigation activities that are described in the next section.

## 4.5.1 Identification of Existing Federal, State, Local Funding Sources

The state has loan and grant programs for which drought and other hazard mitigation activities are eligible. Funding sources traditionally used have been energy impact funds, gaming funds, general funds, and severance tax. Many agencies have grant programs, including, but not limited to local and state agencies such as the State Forest Service, CWCB, DWR, and the OEM. Existing funding sources available for drought mitigation and recovery projects in Colorado from local and state agencies are presented in Table 23. Drought-related Federal response programs are shown in Table 24. New funding sources made available since the 2010 update are included in these tables as applicable.

## Table 23 Local and State Drought Mitigation Funding Sources Available in Colorado

| PROGRAM | GRANT/LOAN FUNDS AVAILABLE | USES/REQUIREMENTS | AGENCY |
|---|---|---|---|
| CWCB Construction Fund & Severance Tax Trust Fund | -No limit<br>-Loans typically range from $50,000 to $5,000,000<br>Loans can be made up to $10,000,000 without legislative authorization within the CWCB process | Raw water projects (e.g., dams, pipelines, ditches, wells, new projects or restorations)<br>-Available to any organization (e.g., municipalities, agriculture, ditch companies, homeowners assn., special districts, etc.)<br>-Must receive CWCB Board and Legislative approval if > $10M; CWCB Board approval if <$10M | CWCB |
| Water Pollution Control Revolving Fund (WPCRF) | -Fire-related nonpoint source projects can be given priority status<br>-Direct loans under $2,000.000 available with Board approval<br>-$10K grants available for planning (fire-related O.K.) | Low-interest loans for public waste water treatment system needs and watershed nonpoint source control projects<br>-Available to governmental agencies<br>-Emergency projects can be identified at any time throughout the year<br>-Loan funds require board review, study grants available immediately | Colorado Water Quality Control Division, Division of Local Government, Water Resources and Power Development Authority |
| Drinking Water Revolving Fund (DWRF) | -Fire-related nonpoint source projects can be given priority status<br>-Direct loans under $2,000,000 available with Board approval<br>-$10K grants available for planning (fire-related O.K.) | Low-interest loans for drinking water treatment system needs<br>-Available to governmental agencies<br>-Emergency projects can be identified at any time throughout the year<br>-Loan funds require board review, study grants available immediately | Colorado Water Quality Control Division, Division of Local Government, Water Resources and Power Development Authority |
| Nonpoint Source Pollution Grants | Typical awards range from $30K to $150K | -Applicants can include governmental and non-governmental organizations<br>-Applicants generally evaluated through a stakeholder process, but this can be waived<br>-40% non-federal match required | Colorado Water Quality Control Division |
| Agricultural Emergency Drought Response Fund | $1 million fund for loans and grants | -For emergency drought-related water augmentation purposes<br>-Limited to agricultural organizations | CWCB |
| Community Development Block Grant (CDBG) | $500,000 (guideline) | Public facilities including water and wastewater | DOLA field staff |
| CWCB Water Conservation & Drought Mitigation Planning Grant Program | No limit, as long as funding is available | Water Conservation Planning; Drought Mitigation Planning | CWCB |

| PROGRAM | GRANT/LOAN FUNDS AVAILABLE | USES/REQUIREMENTS | AGENCY |
|---|---|---|---|
| CWCB Water Efficiency Grant Program | No limit, as long as funding is available | To aid in achieving goals in Water Conservation Plans<br>To promote the benefits of water resource conservation for education and outreach aimed at demonstrating the benefits of water efficiency | CWCB |
| Flood and Drought Response Fund | Up to $300,000 | Flood and drought preparedness and for response and recovery activities following flood or drought events and disasters | CWCB |
| Watershed Restoration Grants | $500,000 (fiscal year beginning July 1, 2012) | Watershed/stream restoration and flood mitigation projects. These grants were utilized in response to the 2012 High Park and Waldo Canyon Fires | CWCB |
| Energy & Mineral Impact Assistance Fund | Tier I grants of up to $200,000; Tier II grants, of up to $1,000,000. | Public facilities including water and wastewater | DOLA Field Staff |
| Colorado Water Resources and Power Development Authority Revenue Bonds Program | $100,000,000 ($300,000 minimum) | Water and wastewater | CWR&PDA |
| CWCB Water Project Loan Program | Limited to fund availability. Loans typically range from $100,000 to $10,000,000 | Raw water projects (e.g., dams, pipelines, ditches, wells, new projects or rehabilitation). | CWCB |

Source: 2007 Drought Plan Update, modified in 2010 and 2013

## Table 24 Federal Drought Mitigation Funding Sources Available in Colorado

| PROGRAM | GRANT/LOAN FUNDS AVAILABLE | USES/REQUIREMENTS | AGENCY |
|---|---|---|---|
| Water2025 Challenge Grant Program for Western States | Up to $250,000 | Projects that can be completed within 24 months and that reduce conflicts through water conservation, efficiency, and markets | USBR |
| Water Conservation Field Services Program | Up to $25,000 | Funds projects that improve water use efficiency and improve water management practices | USBR |
| U.S. Economic Development Administration Grant (EDA) | No limit (subject to federal appropriation) | Water and wastewater | EDA |
| General Matching Grants Program | Varies | Funds projects that promote fish and wildlife conservation as well as conservation of their habitats | FWS |

| PROGRAM | GRANT/LOAN FUNDS AVAILABLE | USES/REQUIREMENTS | AGENCY |
|---|---|---|---|
| Hydrologic Research Grants | Up to $125,000 | To conduct joint research and development on pressing surface water hydrology issues common to national, regional, local operational offices. Eligible applicants are federally recognized agencies of state or local governments, quasi-public institutions such as water supply or power companies, hydrologic consultants and companies involved in using and developing hydrologic forecasts. | NOAA |
| Natural Resources Conservation Service – Emergency Watershed Protection Program | -Funding available though the Simplified Acquisition Procedures (SAP) ranges from $25K to $100K<br>-Funded through contracts between project sponsors and the NRCS. There are no grants. The NRCS pays 75% of the costs. | Installing/repairing conservation measures to control flooding and prevent soil erosion. Generally, more than one individual should benefit from the project. Public or private landowners or others who have a legal interest or responsibility for the values threatened by the watershed emergency | NRCS –Initial contacts should be made with NRCS county offices when an emergency exists. |
| Rural Development (U.S. Department Of Agriculture) | Subject to federal appropriation | Water, wastewater & stormwater projects | USDA |
| Watershed Processes and Water Resources | $100,000 | Sponsors research that address two areas: (1) understanding fundamental watershed processes; and (2) developing appropriate technology and management practices for improving the effective use of water (consumptive and non-consumptive) and protecting or improving water quality for agriculture and forestry production | USDA |
| National Research Initiative Standard Research (Part T): Watershed Processes and Water Resources | $500,000 | Innovative research in understanding fundamental processes that affect the quality and quantity of water resources at diverse spatial and temporal scales, ways on improving water resource management in agriculture, forested, and rangeland watersheds, and developing appropriate technology to reach those goals. | USDA |
| Emergency Community Water Assistance Grants | $150,000 to $500,000 | Available to rural communities with populations over 10,000 people with a median household income less than $65,900. Provides assistance to communities who have experienced a decline in quantity or quality of drinking water as a result of an emergency including drought. | USDA |

| PROGRAM | GRANT/LOAN FUNDS AVAILABLE | USES/REQUIREMENTS | AGENCY |
|---|---|---|---|
| USDA Rural Development 502 Direct Housing Loan Program | -Loans limited by individual county mortgage limits<br>-Most counties have loan limit of $108,317 | Available for wells and water connections – Applicants must be very low income, owner/occupant, unable to obtain conventional credit, and in rural communities and areas | 8 USDA Rural Development offices in Colorado |
| Colorado Rural Water Association (CRWA) Revolving Loan Program | $100,000 or 75% of the total project (whichever is less) | Provides loans for pre-development costs associated with water and wastewater projects and for existing systems in need of small-scale capital improvements. | USDA Rural Utilities Service |

The State, through OEM, has instituted an effective and comprehensive all-hazard mitigation program. Through a variety of programs, and the wise use of available federal and state funds, the State has been successful in mitigating areas against the devastating effects of drought and other hazards. As of the writing of this Plan, FEMA's hazard mitigation assistance programs are the primary sources of funding for Colorado's mitigation activities.[4] These programs are the Pre-Disaster Mitigation Program and Emergency Management Planning Grant. Each of these programs, as they pertain to drought, is discussed further below. Additional information on existing funding sources available for mitigation projects is found in an Appendix of the State's 2010 Hazard Mitigation Plan.

### *Pre-Disaster Mitigation Program*

**Program Summary**: The Pre-Disaster Mitigation (PDM) program is a FEMA grant program. In 2009, Congress amended the Robert T. Stafford Disaster Relief and Emergency Assistance Act to reauthorize the pre-disaster mitigation program of FEMA. In addition, there is the Legislative Pre-Disaster Mitigation (L-PDM) program funded through the National Legislative Pre-Disaster Mitigation Fund. The purpose of PDM and L-PDM programs are to provide funds to states, territories, Indian tribal governments, and communities for hazard mitigation planning and the implementation of mitigation projects prior to a disaster event. Funding these plans and projects reduces overall risks to the population and structures, while also reducing reliance on funding from actual disaster declarations. Planning grants are available for new plan development, plan upgrades, and comprehensive plan reviews and updates.

**Amount**: Since 2003, Congress has allocated between $50 million and $150 million annually for the PDM and L-PDM program, with an average of $107 Million between 2003 and 2009.[5] In

[4] FEMA's hazard mitigation assistance programs, particularly the Pre-Disaster Mitigation Program, have been targeted for reductions in the President's 2013 budget proposal because of lack of available funding. Both the chambers' appropriations committees funded the program to a modest degree but a lot of uncertainty related to this program remains as of early 2013.

[5] Congressional Research Service. "FEMA's Pre-Disaster Mitigation Program: Overview and Issues."

2010, 2011 and 2012, each state will receive at least $575,000 or the amount that is equal to 1% of the total funds appropriated to carry out this section for the fiscal year. In 2008, 24 Colorado communities secured just over $3 million in federal funds to reduce risk (hazard mitigation).

**Eligibility**: In Colorado, OEM serves as the applicant for all PDM and L-PDM grants. State-level agencies, including state institutions (e.g., state hospital or university); federally recognized Indian tribal governments; local governments (including state recognized Indian tribes and authorized Indian tribal organizations); public colleges and universities; and Indian Tribal colleges and universities are eligible to apply to OEM for assistance as subapplicants. Private nonprofit organizations and private colleges and universities are not eligible to apply to the State, but an eligible, relevant state agency or local government may apply on their behalf. OEM reviews and prioritizes subapplications and submits the grant application with subapplications to FEMA for review and approval.

For project grants, subapplicants must have a FEMA-approved local, tribal, or disaster resistant university mitigation plan. All activities submitted for consideration must be consistent with the local mitigation plan as well as the Colorado State Hazard Mitigation Plan.

**Cost-Share Requirements**: PDM and L-PDM grants are provided on a 75%federal/25% nonfederal cost share basis. Small and impoverished communities may be eligible for up to a 90% federal cost-share.

**Requirements**: Recipients of PDM and L-PDM **planning** grants must produce FEMA-approved hazard mitigation plans.

***More Information:***

Pre-Disaster Mitigation Program - www.fema.gov/government/grant/pdm/index.shtm

### *Emergency Management Performance Grant*

**Program Summary**: The Emergency Management Performance Grant (EMPG) program is a FEMA grant program. Federal EMPG funding provides the vast majority of financial resources for Colorado's state and local emergency management programs. As outlined in the FY 2010 EMPG guidance, the program is intended to advance three national priorities: Implementing NIMS and the National Response Framework, expanding regional collaboration and strengthening planning priorities. An all-hazards approach to emergency response, including the development of a comprehensive program of planning, training, and exercises, sets the stage for an effective and consistent response to any threatened or actual disaster or emergency, regardless of the cause. States have the opportunity to use EMPG funds to further strengthen their ability to support emergency management mission areas while simultaneously addressing issues of national concern as identified in the National Priorities of the National Preparedness Guidelines.

**Amount**: The national allocation for EMPG in 2010 was $329,799,991. According to the FY 2010 EMPG Guidance, Colorado received $5,641,026. OEM distributed approximately $3 million directly to fifty-eight counties, ten municipalities and two tribes. These funds help local governments to sustain their all-hazards emergency management programs, including staff, emergency operations centers, disaster plans, public education campaigns, and training and exercise activities[6]. OEM uses EMPG funding to support general staff time to cover drought related efforts.

For FY 2008, OEM used these funds to support a number of critically unfunded preparedness initiatives across the State which include:

- Communications systems in the Northwest Region to support public warnings due to the increased wildfire threat from forest beetle infestation
- Hazard Mitigation Planning in the Northeast and San Louis Valley Regions to update existing federally approved plans
- Planning for State Continuity of Operations and Continuity of Government
- Planning to support Volunteer and Donations Management, Mass Care, Special Needs Populations, and Animal Response Teams

Equipment purchases to improve and upgrade local emergency operations centers with computer hardware/software, radios, telecommunications equipment, displays and backup generators.

**Eligibility**: In Colorado, OEM serves as the applicant for all EMPG grants. State-level agencies, including state institutions (e.g., state hospital or university); federally recognized Indian tribal governments; local governments (including state recognized Indian tribes and authorized Indian tribal organizations); public colleges and universities; and Indian Tribal colleges and universities are eligible to apply to OEM for assistance as subapplicants. Private nonprofit organizations and private colleges and universities are not eligible to apply to the State, but an eligible, relevant state agency or local government may apply on their behalf. OEM reviews all applications to determine eligibility.

To be eligible to receive EMPG funding, applicants must meet NIMS compliance requirements. State, territory, tribal, and local governments are considered to be in full NIMS compliance if they have adopted and/or implemented the previous funding year's compliance activities, as determined by the NIMS Capability Assessment Support Tool (NIMSCAST) or other accepted means.

The period of performance for EMPG funds is 24 months. Although EMPG is an annual award, this period of performance will allow state and local emergency management agency's maximum flexibility to plan and coordinate the use of EMPG funds.

[6] EMPG funds supporting the State Hazard Mitigation Program ***may*** not be available for the remainder of 2013 because of the Federal budget sequestration.

**Cost Share Requirements**. EMPG has a 50% Federal and 50% state cost share cash- or in-kind match requirement. Unless otherwise authorized by law, Federal funds cannot be matched with other Federal funds. In addition, grantees are required to apply no less than 25% of their EMPG grant award toward planning activities.

**Requirements**: Recipients of EMPG grants may use the funds for the following:

- Planning Costs
- Organizational Costs
- Equipment Costs
- Training Costs
- Exercise Costs
- Management and Administrative Costs

### *More Information*

EMPG - http://www.fema.gov/emergency/empg/empg.shtm

### *DOLA*

Funding through DOLA has been an important means of meeting local needs created by drought conditions. DOLA has compiled a listing of available financial assistance programs for water and wastewater assistance available at: http://www.colorado.gov/cs/Satellite/DOLA-Main/CBON/1251594652627Drought related programs from this list have been integrated into Table 23.

### *Local*

Local governments have the required TABOR (Taxpayers Bill of Rights) reserves for use during emergencies. Local districts have used taxing mechanisms, such as mill levies, to support prevention activities. Local governments also actively pursue grant opportunities through federal and state agencies and use general funds or in-kind services to meet the local match requirement.

Local communities are constantly seeking sources of funding to maintain programs and install or upgrade water systems. Unfortunately, funds for these types of projects are limited and the need strongly outweighs the availability. Even if communities get startup funds, continuation of programs creates new financial needs on already very tight budgets with competing demands. Despite this, Colorado communities have made great strides and progress in prevention and preparedness activities and continue to do more each year by taking advantage of limited opportunities.

### 4.5.2 Identification of Potential Federal, State, Local Funding Sources

#### Federal

If a disaster occurs, the State may utilize Hazard Mitigation Grant Program (HMGP) and Public Assistance (PA) mitigation funds. PA mitigation funds will be used in accordance with program requirements and will be used for damaged facilities. HMGP funds may be used primarily in the affected area or may be used statewide at the Governor's and/or his representative's (GAR's) discretion.

Large projects continue to be completed with federal and state funds and technical assistance from federal agencies other than FEMA. Examples include, but are not limited to, the U.S. Department of Transportation (USDOT), BLM, NPS, the USFS, and the USACE. NRCS has programs for projects both exigent and not, including the Emergency Watershed Protection Program.

Small Business Administration (SBA) has come in on several Presidential, USDA, and SBA Administrative declarations in the past. USACE General Investigations and Continuing Authorities Programs provide opportunities for water resources projects, studies, design and engineering, and technical expertise.

#### State

The governor can move funds into the State Disaster Emergency Fund to fund emergency types of activities, such as fire suppression or drought response activities. Table 23 listed previously and Appendix C Drought Mitigation Capability Summary lists the existing funding sources that could be used in pre- or post-disaster situations. Funding for implementing some of the recommendations from the 2010 Plan were appropriated from CWCB Construction Funds, including $100,000 for fiscal year 2010/2011 and another $100,000 for fiscal year 2011/2012. Severance tax funding of $75,000 was set aside for FY2012 and there is $20,000 available for FY2014.

##### *USDA*

The U.S. Department of Agriculture's Household Water Well System Grant Program provides grants to qualified private nonprofit organizations to establish lending programs for household water wells. Homeowners or eligible individuals may borrow money from an approved organization to construct or upgrade their private well systems. The website for the program is at: http://www.usda.gov/rus/water/well.htm. The Notice of Funding Availability is published each year. The funds have never all been used nationwide.

##### *State Land Board*

The State Land Board has funding that could potentially be applied to drought mitigation projects including:

- State Land Board - Land and Water Management Fund
- State Land Board - Enhancement Fund
- Potentially, State Land Board Investment and Development Fund
- State Trust Land Improvement Account - SLB funds administered by the Colorado State Forest Service.

#### CDPHE - Colorado Water Quality Control Division (WQCD)

The eligible projects that can be funded by the Drinking Water Revolving Fund have expanded with the new emphasis on encouraging Green Infrastructure. These projects are primarily water conservation oriented, which could be considered a component of drought mitigation. Funding has been provided to small community drinking water suppliers. Eligible costs associated with water efficiency projects may include:

- Planning and design activities for water efficiency that are reasonably expected to result in a capital project.
- Purchase of water efficient fixtures, fittings, equipment, or appliances.
- Purchase of leak detection devices and equipment.
- Purchase of water meters, meter reading equipment and systems, and pipe.
- Construction and installation activities that implement capital water efficiency projects.
- Costs associated with development of a water conservation plan if required as a condition of DWSRF assistance.

### Local

The economic downturn that began in 2008 and continued through 2010 resulted in state and local government budget shortfalls. In general, this means that less local funding is available for mitigation activities. There will be increased reliance on grants and other sources of assistance in the future to implement projects. Funding cuts have impacted the State's grant and loan programs as well.

### 4.5.3 Sources of Funding Used to Implement Previous Mitigation Activities

The CWCB, Colorado Department of Agriculture (CDA), and the Department of Agricultural and Resource Economics at Colorado State University (DARE-CSU) initiated a project in 2011 to develop a better understanding of the 2011 drought impact on the Rio Grande and Arkansas basins. The project consisted of the following: (1) a preliminary assessment of agriculture activity in the Arkansas and Rio Grande River basins from 1998-2011, (2) a survey of producers in the impacted basins, and (3) an analysis of the impact of the drought on economic activity. This project was expanded to a statewide study in 2012.

### *OEM*

FEMA Pre-Disaster Mitigation (PDM) grants and Emergency Management Performance Grants (EMPG) have both been used to fund local plans that include drought components.

### *CWCB*

A comprehensive follow up to the 2004 DWSA was conducted by the CWCB and focused on gathering data on the state of drought planning and preparedness by municipal and industrial water providers throughout the State; this study was completed in 2007 and funded by CWCB.

The following drought-related mitigation and response funds have been provided through the CWCB in the past three years.

- Agriculture Emergency Drought Response Fund
- Flood and Drought Response Fund
  CWCB Watershed Restoration Grants in response to the High Park and Waldo Canyon Fires

### *Construction Fund and Severance Tax*

The following funding sources were used to implement statewide planning activities in the past three years.

Construction Fund $ (Annual funds rollover if not used)

- FY 08-09 CO Drought Mitigation & Response Plan Implementation ($300K was the initial allocation)
- FY 08-09 CO Drought Mitigation Planning Technical Assistance ($150K was the initial allocation)
- FY 08-09 Climate Change Effects on CO Water Resources ($500K)

Severance Tax

- FY08-09 Drought Toolbox Scoping Document ($24,000)
- FY09-10 Drought Mitigation & Response Plan – Plan Coordination ($25,000)
- FY09-10 Drought Mitigation & Response Plan – Vulnerability Assessment ($50,000)

- FY10-11 Drought Planning and Water Adaptation ($100,000)
- FY11-12 Drought Planning & Response Implementation ($60,000)
- FY12-13 Drought Planning and Response Update ($75,000)
- FY12-13 Conservation and Drought Planning Program Management ($25,000)
- FY 13-14 Drought Preparedness and Response ($20,000)

### *CDPHE*

The Nonpoint Source Program administered by the CDPHE's WQCD is charged with monitoring, protecting and restoring the quality of the State waters. Activities under Section 319 of the Clean Water Act fall under this program and typically involve development of watershed-based plans, implementation and construction of best management practices, and outreach/education. Depending upon funding available, water quality assessments may also be conducted.

For the 2013 funding cycle, the Nonpoint Source Program allocated $400,000 to be used to address reclamation activities associated with the 2012 Waldo Canyon and High Park wildfires, The $200,000 going to each site will likely not be available until mid-August 2013, so it is anticipated that reclamation activities will not begin until summer of 2014. These funds will be leveraged with the CWCB's Watershed Restoration Program's matching funds. In addition, the High Park fire area will likely receive further funds because it was chosen as a 2013 program under the NRCS's Environmental Quality Incentives Program (EQIP) fund. The CDPHE is working closely with local communities at both wildfire sites in developing plans for their reclamation efforts.

### *Colorado Water Resources and Power Development Authority*

The Colorado Water Resources and Power Development Authority donated $300,000 to CWCB in August 2012 for wildfire restoration work but did not specify which fire area would be priority. The CWCB will be administering these funds to assist with mitigation activities associated with the fires.

# 5 COORDINATION OF LOCAL MITIGATION PLANNING

## 5.1 Local Funding and Technical Assistance

This section includes a description of the State process to support, through funding and technical assistance, the development of local mitigation plans and drought management plans. This section also describes the funding and technical assistance the State has provided in the past three years to assist local jurisdictions in completing approvable mitigation plans, and the process to prioritize planning and project grants.

As water demand and population continues to increase in many areas of the State and climate change is resulting in greater uncertainty regarding the availability of future water supplies, the importance of drought planning at a local level is increasing in necessity. However, many local entities have not yet developed drought mitigation plans. This State Drought Mitigation and Response Plan continues to encourage and emphasize the importance of local drought planning.

### 5.1.1 Description of State Process to Support Local Plan Development

The overall state process to encourage and support the development of local plans is discussed in the Colorado Hazard Mitigation Plan. As of the writing of this Plan, there is not a requirement for local entities to adopt a drought mitigation plan. However, CWCB strongly supports the development of local drought mitigation plans. State staff continuously meets with local utilities and water suppliers, to provide drought management information, technical assistance, and drought planning at a grassroots level.

In 2010, the CWCB developed a Municipal Drought Management Plan Guidance Document (Drought Guidance Document) as a means to assist municipal providers and local governments with their drought planning efforts. This Drought Guidance Document serves as a reference tool that municipal entities throughout the State can use in developing local drought management plans. The objectives of the Drought Guidance Document are as follows:

- Provide a comprehensive background on municipal drought management planning and recommend drought mitigation and response planning steps and components useful in developing local plans.
- Disclose the essential and recommended elements of an effective local drought management plan.
- Ensure that the Drought Guidance Document is applicable and useful to stakeholders statewide that vary by geographic location, size, water supply sources, financial resources, etc.

In 2011 the CWCB developed a Sample Drought Management Plan (Sample Plan) as another tool to assist in the development of local drought plans. The Sample Plan provides an example of what a plan developed with the Drought Guidance Document might contain and is based on a fictitious jurisdiction/watershed with attributes common to many Colorado communities. The Drought Guidance Document and Sample Plan are designed to be used in conjunction with CWCB's Drought Toolbox and other drought-related information presented on the CWCB website. The CWCB Drought Toolbox is a web-based tool, developed in 2010, to provide a point location for the state, local government, and the general public to access information on drought and drought planning. The toolbox specifically contains information on the following:

- Resources for local drought planning – links to the Drought Guidance Document, potential funding sources, other drought assistance related programs, examples of municipal drought management plans submitted to the CWCB for approval, information on drought impacts experienced by local entities statewide and other resources water providers and local governments can use for drought planning
- Frequently Asked Questions – geared toward the public to raise drought awareness and educate the public
- Funding sources – list of current and potential funding sources
- Technical resources – links to drought monitoring data and other monitoring resources
- Current drought status – information on the current drought status
- Contacts - regional and field contacts useful to the public and local governments for drought related information
- Internet resources – links to other drought-related websites
- Discussion on drought and climate change

The Drought Toolbox will be updated regularly, providing the most up-to-date information on drought management planning.

In addition, the CWCB promotes and provides assistance with local water conservation plans development. In 2012 the CWCB updated its water conservation guidance document with the development of the "Municipal Water Efficiency Plan Guidance Document." It serves as a reference tool for water providers and local governments throughout the State of Colorado for developing state approved local water efficiency plans. Similar to the Drought Guidance Document, the Municipal Water Efficiency Guidance Document is accompanied by a Sample Municipal Water Efficiency Plan to assist entities in developing their water efficiency plans.

The role of the Mitigation staff within the OEM is described in an appendix of the 2010 Colorado Hazard Mitigation Plan. Mitigation staff is responsible to provide technical assistance and training to local governments to assist them in developing local mitigation plans and project applications. The Mitigation staff also is responsible to review and submit all local mitigation plans.

### Funding/Technical Assistance Provided in Past Three Years

In the past three years (2010 - June 2013) three communities have applied for drought planning grants and two are in the process of completing and submitting revised drought plans to CWCB for review and approval. As of the writing of this plan one local drought management Plan had been approved by CWCB. The CWCB continues to speak with communities regarding their desire to do drought planning and hopes to increase the number of approved plans in the coming years. The CWCB conducted a series of workshops on drought and climate change in fall of 2009 that many providers statewide attended. Information and resources for planning were presented there as well. There was a significant push to get more communities thinking about local drought planning in 2011. Following the 2010 State Drought Plan Revision CWCB staff completed five municipal drought planning workshops around the State to get out the word on the Plan and the Toolbox, Guidance Document, and other resources.

Financial assistance was initially made available in 2004 under the Drought Mitigation Planning Grant Program (authorized by §37-60-126.5 C.R.S.), available to local and state governmental entities to assist them in developing drought mitigation plans. In 2007, with the passage of SB07-008, the State's Water Efficiency Grant Program, (authorized by §37-60-126 C.R.S.) provided additional monies through 2012 to support water providers' efforts to plan and implement drought mitigation strategies. The program was extended again through legislation in 2010. Covered entities which are retail water providers that sell 2,000 acre-feet or more on an annual basis, are required to develop water conservation plans. They are also strongly encouraged to develop drought mitigation plans. This group of water providers accounts for the majority, by population, of the municipal water supply in Colorado. Since it was created in 2004, the Water Efficiency Grant Program Fund has given out \$3.4 million for drought and water conservation planning and implementation projects. Currently the CWCB has under \$1 million available for new grants.

In 2004, the Colorado General Assembly passed House Bill (HB) 04-1365, which was then signed by the Governor. HB 04-1365 expanded the mission and duties of the Office of Water Conservation and Drought Planning to reflect the State's involvement in drought mitigation planning and the need to provide more information relating to drought to water users and the public. The Office maintains a clearinghouse of drought information and disseminates information to the public; provides technical assistance and evaluates and approves drought mitigation plans; and provides financial assistance for drought mitigation plans through various grant programs. Further information on available technical and financial assistance, including the Water Efficiency Grant Program, can also be found on the CWCB website.

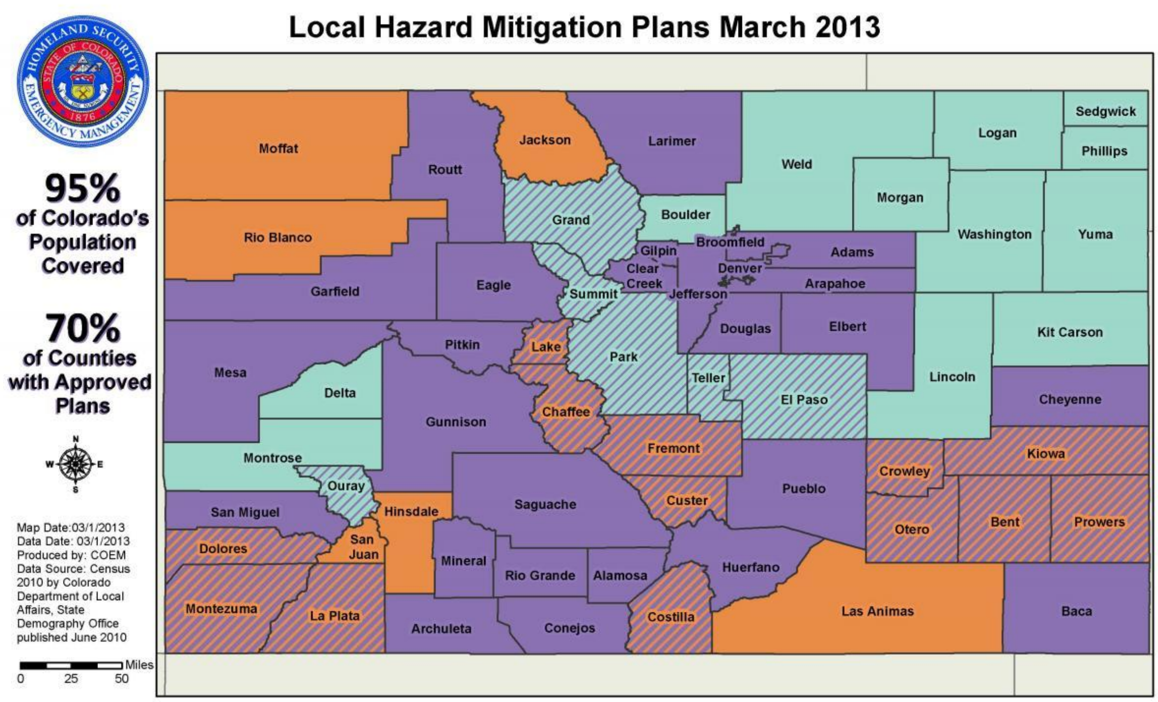
DOLA noted that eligible projects that can be funded by the Drinking Water Revolving Fund have expanded with the new emphasis on encouraging Green Infrastructure - Eligible costs associated with water efficiency projects may include:

- Planning and design activities for water efficiency that are reasonably expected to result in a capital project.
- Costs associated with development of a water conservation plan if required as a condition of DWSRF assistance.

In the past three years the OEM has used FEMA PDM grants and EMPG to fund local plans that include drought components. The multi-hazard plans funded are detailed in the State Hazard Mitigation Plan. The State will continue to apply for mitigation grants to support multi-hazard plan development. It is the role of the preparedness and mitigation staff of OEM to help communities locate potential sources of available federal and state funding. As grants from different sources are posted, OEM staff advertises to the communities and special districts.

According to the DOLA 2008 Annual Report, in 2008, the PDM staff assisted 22 counties with securing federal funds to begin the process of updating their plans. As of March 2013, 6 counties were in the planning process to update and 13 counties were developing a new local or regional hazard mitigation plan. Twelve counties have plans up for revision and 6 counties do not have a plan. Figure 25 identifies the status of hazard mitigation planning in Colorado as of March 2013.

**Figure 25. State of Colorado Pre-Disaster Mitigation Plan Status March 2013**




| Plan Status | Counties | 2010 Population (% of total) |
|---|---|---|
| Approved Plan | 27 ( 42% ) | 3,371,540 (67% ) |
| Up for Revision | 18 ( 28% ) | 1,414,995 (28% ) |
| No Approved Plan | 19 (30% ) | 242,661 (5% ) |
| Total | 64 | 5,029,196 |

March 2013 Plan Status

- Approved
- Plan - Revision in Progress
- Plan - Up for Revision
- No Approved Plan - Planning in Progress
- No Approved Plan

Source: Colorado Division of Homeland Security and Emergency Management

Since 2000, the Agriculture ITF has attempted to quantify the economic impact of drought on agricultural sectors; provided public education on the impact of drought on agriculture and served as media spokespeople; provided landowner education on drought response; developed a website of drought-related information for producers; offered decision tools to agricultural producers making economic choices; and responded to risk management agency needs for field verification letters.

The Colorado State Forest Service noted the following increases in capabilities since 2007:

- Hazard Fuels Mitigation projects in various locations around the State.
- Increase in local and county level Community Wildfire Protection Plans (CWPPs).
- Increased technical assistance and service.
- Legislative support for technical assistance and incentive programs for landowners.

# 5.2 Local Plan Integration

The following section includes a description of the State process and timeframe by which the local plans are reviewed, coordinated, and linked to the State Mitigation Plan and Drought Mitigation and Response Plan.

## 5.2.1 Process and Timeframe to Review Local Plans

In May 2005, the CWCB adopted guidelines that address the process and timeline for review of local plans. These guidelines were revised and adopted again in July 2011 to be more in line with the Municipal Drought Management Plan Guidance Document. These "Guidelines for the Office to Review and Evaluate Drought Mitigation Plans Submitted by Covered Entities and Other State or Local Governmental Entities" are available on the CWCB website. Upon receipt of a completed local Drought Mitigation Plan, the Office must review and either approve or not approve the Plan within 90 days by providing written notice to the submitting entity. Procedural guidelines for contesting Plan disapproval are also included. Plan content requirements include: 1)Municipal Drought Management Plan Guidance Document (use of this document is strongly encouraged to obtain CWCB approval); 2) Model Plan (preparing a Plan according to this outline will lead to a more valuable planning document); 3) information on Plan Adoption; 4) a discussion of how each of the eight Plan Elements were considered in the entity's program: Stakeholders and Plan Objectives and Principles; Historical Drought and Impact Assessment; Drought Vulnerability Assessment; Drought Mitigation and Response Strategies; Drought Stages, Trigger Points, and Response Targets; Staged Drought Response Program; Implementation and Monitoring; and Plan Review and Updates; ; and 4) Plan Public Review procedures.

Local hazard mitigation plans are reviewed initially by OEM and approved by FEMA and are updated every five years. With each State Plan update cycle any new or updated plans will need to be reviewed for assimilation and incorporation of information relevant to the State plan, including drought related vulnerability and loss estimates, capabilities, and mitigation strategies.

### 5.2.2 Process and Timeframe to Coordinate and Link Local Plans to State Mitigation Plan

Linking local county hazard mitigation plans and water provider drought management plans to the State's Plan is integral to building a more effective mitigation program over time. Local drought plans will first be reviewed and approved by CWCB using the guidelines in Section 5.2.1. Local hazard mitigation plans are reviewed initially by OEM and approved by FEMA and are updated every five years. With each State Plan update cycle any new or updated plans will need to be reviewed for assimilation and incorporation of information relevant to the State Plan, including drought related vulnerability and loss estimates, capabilities, and mitigation strategies.

During the 2010 revision, CWCB initiated a process to develop a database to track key information in local drought and hazard plans. Information in this centralized database will eventually be used for updates to the State Plan. This will improve the value of the State Plan as well as assist in coordinating state drought response efforts and periodically assessing overall drought vulnerability and adaptive capacity actions at a regional and local level. The limiting factor is the small number of local drought plans available as of 2013.

One key component of this effort is to develop a system where information from local drought plans and drought related information in other local plans can be incorporated into broader CWCB planning efforts. This result in the extraction of data and information that local governments and water providers can provide to CWCB as a component of their drought management planning effort, potentially using tables from the Municipal Drought Management Plan Guidance Document. Items in these tables will consist of basic entity information (e.g., size, location, population served, water demands, etc); historic and recent drought impacts; potential future impacts; and drought mitigation and response strategies incorporated into the entity's drought planning efforts. Implementation of HB 1051 may also yield useful data and information.

## 5.3 Prioritizing Local Assistance

### 5.3.1 Description of Criteria for Prioritizing Planning and Project Grants

As noted above in Section 5.2.1, the CWCB (Board) adopted the most recent guidelines for reviewing and approving local drought mitigation plans submitted to the CWCB in July 2011. Section 9a of these guidelines called for the development of a set of additional guidelines associated with the prioritization and distribution of grant monies for assisting covered entities and other state or local governmental entities in their drought mitigation planning activities.

The "Intent of the Board" is defined as follows: It is the explicit intent of the Board to work with water users and local entities to increase drought planning in the State by: 1) increasing the number of covered entities and state or local governmental entities with CWCB approved drought mitigation plans; 2) improving the nature and breadth of drought mitigation practices at the local level; and 3) increasing the amount of technical assistance that the CWCB provides to local entities. With these objectives in mind, the Board intends to administer the Grant program for purposes of providing assistance to the following: 1) covered entities or state or local entities that desire to improve, update, and/or create Drought Mitigation Plans; 2) entities, given expected growth trends, which either require or desire Drought Mitigation Plans; and 3) entities which sustained severe adverse impacts during the recent 2000-2003 drought.

#### Project Grants

The SWSI Phase 1 report prioritized projects for both structural and nonstructural projects to provide additional water supplies to help mitigate the effects of drought. Projects are recommended by basin, county, or subbasins; a table summarizing these projects can be found in the Executive Summary of the SWSI Report. Criteria used to prioritize these projects are described in detail in the SWSI Report.

The criteria and process used to prioritize post-disaster funding assistance requests are described in the State's Hazard Mitigation Grant Program (HMGP) Administration Plan on file with OEM. When a Notice of Interest (for receipt of financial assistance) is submitted to the State, it must meet certain minimum criteria. These include whether the project: complies with the State's hazard mitigation strategies; meets funding eligibility requirements; is an independent solution to the problem; does not duplicate other funding sources, has a beneficial impact on the declared area, and is cost-effective and environmentally sound. When projects are competing for limited funding, projects are scored and ranked. Under the direction of the State Hazard Mitigation Officer (SHMO) and the Governor's Authorized Representative, a subcommittee of the State Hazard Mitigation Team convenes to score and rank the projects. The ranking is to be based on criteria derived from 44 CFR 206.434(b), and may or may not be specific to the disaster. There has not been a presidential disaster declaration under the Stafford Act for drought in the lower 48 states since 1980 (as opposed to the more frequently used USDA drought declaration). However, related disasters, such as the 2002 and 2012 fires in Colorado were declared presidential disasters, and as a result HMGP funding was made available.

### 5.3.2 Cost-Benefit Review of Non-Planning Grants

For projects funded under HMGP or with PDM funds a requirement of eligibility of all projects is cost-effectiveness of the project. The exception would be the HMGP 5% set-aside funds, which could be used to funds projects that are difficult to quantify as cost-effective.

### 5.3.3 Criteria Regarding Areas of High Risk and Intense Development Pressures

As noted previously, as part of the criteria used to rank projects, points are given for the following: 1) entities that, given expected growth trends, either require or desire Drought Mitigation Plans (Rate of Expected Growth in Service Demand), and 2) entities which sustained severe adverse impacts during the 2000-2003 drought.

# 6 PLAN MAINTENANCE PROCESS

## 6.1 Monitoring, Evaluating and Updating the Plan

Implementation and maintenance of the Plan is critical to the overall success of hazard mitigation planning. This section describes the State's system for monitoring implementation of mitigation actions and reviewing progress toward meeting Plan goals, and any changes in the system since the previously approved plan.

### 6.1.1 Method and Schedule for Monitoring Plan

The CWCB is charged with the overall responsibility for Plan monitoring and evaluation, with assistance from the DMRPC. CWCB, in its capacity as support agency to the DMRPC, is responsible for coordination and leadership of the DMRPC. CWCB's responsibilities for monitoring and evaluating the Plan include the following:

- Communicating the schedule and activities for Plan updating and maintenance to the DMRPC
- Facilitating meetings of the DMRPC
- Assisting other agencies with the implementation of mitigation actions
- Coordinating with agencies between DMRPC meetings
- Coordinating and conducting outreach to other stakeholders or interested parties and the public
- Obtaining local mitigation Plan data to be used in Plan update cycles
- Conducting all Plan evaluation and monitoring activities that are not otherwise assigned to another agency
- Monitoring, capturing, and communicating mitigation success stories
- Documenting and incorporating the findings of the evaluation and monitoring analyses into the next edition of the Drought Hazard Mitigation and Response Plan
- Updating the DMRPC on grant funds available or dispersed for actions
- Engaging and maintaining the interest of the agencies participating on the DMRPC
- Monitoring progress of local drought and water efficiency plan development and providing technical and financial assistance

As participants of the DMRPC state agencies have the following responsibilities for Plan monitoring and evaluation:

- Participating in meetings of the DMRPC
- Leading the implementation of their agency's respective mitigation action(s)
- Providing progress reports on their agency's respective mitigation action(s)
- Monitoring and documenting disasters of significance to state agencies and providing this information to OEM

- Suggesting Plan revisions to reflect changes in priorities, regulations, policies, or procedures
- Taking action as needed to effectively monitor and evaluate the agency's role in the planning process

OEM will keep the CWCB/DMRPC abreast of changes or opportunities with FEMA mitigation grants or policies

The DMRPC will convene at least once yearly, ideally in the fall. The meeting will include the WATF members and the Chairs of the Impact Task Forces. The fall meeting will focus on the progress made on mitigation actions, with status reports discussed by the respective agency and/or Task Force so that progress can be noted in the CWCB annual report that is developed in November. This meeting will also be used to discuss any lessons learned from response to drought conditions that may have been present during the year. WATF and Drought Task Force members also meet each as part of regular meetings of the WATF. The spring WATF/DTF meeting will discuss the drought outlook and any preparation needs and review the response procedures in the plan. These regular meetings also will help to ensure that staffs remain up to date on the activities related to the Mitigation plan and the response procedures.

### 6.1.2 Method and Schedule for Evaluating Plan

A thorough evaluation of the Drought Plan occurred within the 2007-2010 revision cycle, resulting in a concerted effort to modernize the plan. The CWCB recognized that the Plan needed to reflect advances in drought monitoring, integrate the latest climate change science, and re-evaluate the drought response structure. While the Plan will undergo evaluation during each update cycle, the level of effort used in the 2010 revision effort will occur less frequently.

The criteria utilized to evaluate the Plan will be obtained from the FEMA Standard Plan Review Crosswalk, or the Enhanced Plan Crosswalk should the Natural Hazard Plan achieve Enhanced status in 2013. FEMA uses the Crosswalk to record information regarding required and recommended changes during its review of the NHMP and drought mitigation plan annex. The plan's outline mirrors that of the FEMA crosswalk in part to facilitate the review and evaluation process. Each section and element of the Plan Review Crosswalk will be reviewed and additional data requirements or information identified as indicated by the FEMA reviewer. Plan improvement recommendations are noted in the Crosswalk and addressed as appropriate in revisions associated with the next update to the plan.

In addition, any drought plan should be evaluated after droughts. Consistent with this commitment, the CWCB undertook the Drought and Water Supply Assessment after the drought of 2000-2003. The goals of this assessment were to determine how prepared Colorado has been for drought, and identify limitations and related measures to better prepare Colorado water users for future droughts. The DWSA was completed in 2004, and contained several findings and recommendations which have been integrated and discussed previously in this document.

The response elements of this Plan (Annex A Drought Response Plan) should be exercised periodically to evaluate the Plan and identify any shortcomings, as well as to train and educate Plan users. This should occur at least once every four years, particularly after a change in administration so that Governor's Office staff and departmental leadership are aware of the plan, its intentions, and they key role they have in implementing it. A drought exercise is one of the ideas captured in the mitigation actions table in 2010.

### 6.1.3 Method and Schedule for Updating Plan

Updates to state hazard mitigation plans are required the DMA every three years. In February 2013 FEMA entered a proposed rule to the Federal Register for changing the state mitigation plan update requirement from three to five years. As an annex to the Colorado Hazard Mitigation Plan, the Drought Plan will need to remain aligned with the update schedule of that plan. Updates to the Plan must conform to the latest DMA 2000 and EMAP planning requirements. The next update of the Colorado Hazard Mitigation Plan will need to be reapproved by FEMA by December of 2016, or 2018 if the proposed rule goes into effect. The CWCB and DMRPC will aim to complete the Plan by early September of the year the update is due to allow enough time for OEM to integrate it with the Hazard Mitigation Plan and submit to FEMA to review the Plan and for the State to readopt it. The Plan will need to be approved by the CWCB by September of the update year. The Plan will be readopted by the Governor as part of the overall Hazard Mitigation Plan.

OEM will coordinate with the CWCB on the schedule and specific needs for the State Hazard Mitigation Plan update. Funding needs for the next update cycle should be identified and pursued so that the necessary resources are in place in advance of the update year. At the fall WATF/DMRPC meeting prior to the update year the CWCB will issue a schedule for the drought plan update. This schedule will establish a timeline for the following (and other activities as needed):

- Plan update meetings
- Determining involvement and activities of newly participating state agencies (as well as changes in existing ones), including assessment of vulnerabilities, analysis of programs and policies, and identification of new mitigation actions
- Updating the status of mitigation actions identified in the 2010 plan
- Contracting consultant assistance, as necessary

### 6.1.4 Evaluation of Methods, Schedule, Elements, and Processes Identified in Previous Plan

The overall process defined for monitoring, evaluating, and updating the Plan appears to be working. With the 2010 revision this section was made more specific in regards to agency responsibilities, DMRPC duties, and timelines. As a result of the 2013, 2010 and 2007 review of the existing drought hazard mitigation plan, CWCB staff has identified opportunities to incorporate several expanded elements into future drought planning efforts. These include statewide water conservation efforts, formulation of a broad drought vision for the State, and a statewide climate change initiative tied to drought planning efforts and an examination of adaptation strategies to deal with potential water shortages. The 2010 revision has incorporated relevant aspects of these opportunities, but for others the groundwork for integration and collaboration has recently been established through the revision planning process. A result of this evaluation includes the expansion of goal # 4 from "Facilitate Watershed and Local Planning" to "Coordinate and Provide Technical Assistance for State, Local and Watershed Planning Efforts" as well as validating goal #7 "Develop Intergovernmental and Interagency Stakeholder Coordination."

## 6.2 Monitoring Progress of Mitigation Activities

### 6.2.1 Monitoring Mitigation Measures and Project Closeouts

The process used to monitor mitigation project completions and closeouts funded by FEMA is described in the HMGP Administration Plan. Projects must be completed and reconciled within three years of the disaster declaration. For project completions, subgrantees shall submit a letter with all final project documentation and a final inspection report to OEM requesting closeout. The State Hazard Mitigation Officer, mitigation staff, and financial officer are responsible to review all paperwork for completion and determine that all eligible work was completed within the performance period. Site visits and inspections are conducted when deemed necessary. Procedures regarding the transmittal of closeout documents to FEMA are also described in the HMGP Administration Plan. Similar procedures are used for projects funded through the Pre-Disaster Mitigation Program, also administered by OEM.

### 6.2.2 Reviewing Progress on Achieving Goals in Mitigation Strategy

Progress towards achieving this plan's goals will be checked in on annually through the annual meeting of the DMRPC mentioned previously. The progress will be evaluated and assessed in more detail in year three of the three year update cycle. All of the proposed actions listed in the Table 21 in Section 4 support one or more of these goals. As the progress on these recommended actions is tracked, progress on achieving the above eight goals will also be monitored and summarized in Section 4.4.2 Progress in Statewide Mitigation Efforts. If any of the goals are not receiving adequate attention, it will become apparent as the table is periodically updated.

### 6.2.3 Changes in System for Tracking Mitigation Activities

CWCB staff will be responsible for reviewing and tracking progress made on all of the activities identified on the Mitigation Actions Summary Table (Table 21) in Section 4. It was recommended that this table be updated at least annually, and new projects/initiatives be added as they are developed. Effectively this process did not change in 2010, but improvements in the State Drought Mitigation Actions Summary table in Section 4 have been made which should facilitate easier tracking of mitigation activities. The only other change is that the process is more clearly defined in Sections 6.1 and 6.2. In 2013 a process for revisiting these action items at a fall DMRPC meeting was refined in Section 6.1.1. Bi-annual meetings of the DMRPC was changed to annual, recognizing that many members of this group also meet as part of the WATF/DTF during the spring each year, or more frequently during times of drought. Regular meetings continue to be important to allow new DMRPC members to become familiar with the Plan as staff turnover or re-assignment occurs.

For FEMA-funded projects, quarterly progress reports are required from subgrantees, which are to reflect project and cost status. These reports are reviewed by Mitigation staff and the State Hazard Mitigation Officer, and submitted to FEMA. This process has not changed but the quarterly reporting forms changed in 2009.

### 6.2.4 System for Reviewing Progress on Implementing Activities and Projects of Mitigation Strategy

The procedures for reviewing the progress associated with implementing activities and projects related to the mitigation strategy were discussed in the previous two sections. It is further recommended that the CWCB/DMPRPC prepare an annual report on progress towards mitigation projects, and incorporate this information into other agencies' periodic reports where applicable (e.g., CWCB, DOLA, Agriculture, etc.)

### 6.2.5 Implementation of Previously Planned Mitigation Actions

The State Drought Mitigation Actions Summary table (Table 21) in Section 4 shows those actions that have been implemented to date, as well as those that are ongoing. Several mitigation actions have been implemented as planned and many more are ongoing. The discussion under Section 4.4.2 Progress in Statewide Mitigation Efforts contains a summary discussion of action implementation. This discussion will be updated with each three year update cycle so that successes and challenges with action implementation are documented.

# COLORADO DROUGHT RESPONSE PLAN

ANNEX A TO THE DROUGHT MITIGATION AND RESPONSE PLAN

August 2013

Prepared Pursuant to
Disaster Mitigation Act 2000 & Section 409, PL 93-288

Prepared by
Colorado Water Conservation Board
Department of Natural Resources
in Cooperation with
the Department of Local Affairs
Division of Emergency Management

The Colorado Drought Response Plan

August 2013

ANNEX A to the Colorado Drought Mitigation Plan
ANNEX X to the State Emergency Operations Plan
Drought Annex to the Colorado Natural Hazards Mitigation Plan

Colorado Department of Natural Resources
Colorado Water Conservation Board

Original document developed by
Department of Local Affairs
Division of Local Government
Office of Emergency Management

J. Truby, L. Boulas 1981

Revised by J Truby,  L. Boulas, and R. Kistner in 1986 and 1990.

Revised by J. Brislawn, M. Gally, L. Boulas, J. Truby, T. Grier, P. White, and M. Koleis in 2001.

Revised by the CWCB and AMEC Environment and Infrastructure in coordination with the Drought Mitigation and Response Planning Committee in 2010 and 2013

# Table of Contents

Table of Contents ........ iii

Record of Changes ........ iv

I. Introduction ........ 1

II. Authority ........ 2

III. Special Definitions ........ 2

IV. Purpose ........ 4

V. Scope ........ 5

VI. Situation ........ 5

VII. Planning Assumptions ........ 6

VIII. Concept of Operations ........ 7

IX. Organization and Assignment of Responsibilities ........ 13

X. Impact Task Force Organization and Assignment of Responsibilities ........ 16

XI. Information Collection and Dissemination ........ 29

XII. Communications ........ 30

XIII. State Emergency Operations Organization ........ 30

XIV. Administration, Logistics, and Mutual Aid ........ 30

XV. Plan Development and Maintenance ........ 31

XVI. Addendum ........ 33

TAB 1: USDA Drought Declaration Process ........ 33

TAB 2: Sample Drought Emergency Declaration ........ 36

TAB 3: Sample Governor's Memorandum of Potential Drought Emergency ........ 37

## Record of Changes

All changes are to be annotated on the master copy of the Colorado Drought Response Plan. Should the change be significant in nature, updates shall be made to applicable Web pages. If not, changes will be reviewed and incorporated into the plan during the next scheduled update.

| Date Posted | Change | Page/paragraph/line | Recommending Agency/Individual |
|---|---|---|---|
| 6/2013 | See notes below | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

During the 2010 revision of the Colorado Drought Mitigation and Response Plan, significant changes were made in coordination with the Drought Mitigation and Response Planning Committee (DMRPC), including:

- Separation of response elements from the 2002 document into this Annex A so that the response elements can be easily referenced in one location.
- Modernization and alignment of the response plan in accordance with National Incident Management System (NIMS), the National Response Framework (NRF), and the Emergency Management Accreditation Program standards.
- Evaluation and modernization of drought indices and thresholds used to define drought phases and associated recommend actions.
- Evaluation and revision of the Impact Task Force (ITF) structure, including reducing the number of task forces from nine to seven. The Health Impact Task Force was combined with the Municipal Water Task Force and economic impacts tracking (formerly a responsibility of the Economic Impact Task Force) became incorporated as an element of each of the remaining task forces.
- Update of roles, responsibilities, and membership of the ITFs.
- Renaming of the Review and Reporting Task Force as the Drought Task Force (DTF).
- Replacement of the Interagency Coordinating Group with the Governor's Disaster Emergency Council.
- Clarification of Drought Task Force framework and State agency roles.

During the 2013 update of the Colorado Drought Mitigation and Response Plan additional changes were made in coordination with the (DMRPC) which are summarized below:

- Revisited and clarified drought indices and thresholds used to define drought phases and associated recommend actions.
- Removal of the Governor's Disaster Emergency Council from the response framework.
- Review of Drought Task Force framework and State agency roles.
- Evaluation and revision of the Impact Task Force (ITF) structure, including reducing the number of task forces from seven to five. The Tourism Task Force and Wildfire Task Forces have been removed while preserving input and participation from these sectors in the overall Drought Task Force.
- Updated Tab 1 USDA Drought Declaration Process to reflect streamlined procedures implemented in 2012.

# I. INTRODUCTION

The Colorado Drought Mitigation and Response Plan is a compilation of an in-depth assessment of the drought hazard and its risk and vulnerability impacts on the State of Colorado. It serves as an annex to the Colorado State Hazard Mitigation Plan, which is itself an annex to the State Emergency Operations Plan (SEOP). The Colorado Drought Response Plan was developed by the Colorado Water Conservation Board (CWCB) as an annex to the Drought Mitigation and Response Plan in 2010 so that response elements could easily be referenced in one location.

In Colorado, each level of government has the responsibility for the safety and security of its residents. Citizens expect both state and local governments to keep them informed and provide ample assistance in the event of an emergency or disaster. There are four phases of Emergency Management: Preparedness, Response, Recovery, and Mitigation. The SEOP serves as a standardized response model that provides emergency operations direction as it relates primarily to the "Response" phase of Emergency Management.

Over the course of a disaster or emergency incident, response activities are normally short-term measures that deal with the immediate needs of the victims and the management of the incident as it unfolds in order to minimize further complications and secondary impacts. However, the mitigation and recovery phase may continue for months or years following the initial event. Preparedness is an ongoing activity developed through training, exercises, policy change, and a variety of other daily functions within state and local government operations.

The drought hazard is characteristically unique and very different from other natural hazards. Where most natural hazards impact quickly and without warning, drought could be characterized as the "slow motion" disaster or a silent calamity. It unfolds initially with hidden symptoms revealed only to those with expertise in a specific field. Sometimes onset impacts are not usually visible to the average citizen.

Initial response activities to a drought hazard event are primarily observatory and often include increased monitoring and data gathering. As drought signs and symptoms intensify, and impacts become more evident across a variety of societal and environmental sectors, response actions involve a consortium of state, federal, and local agencies focused on water conservation and drought relief programs.

The following response framework provides an operational system to serve the State of Colorado in responding to drought from the early stages of a drought event through sustained periods of drought conditions, with the intent to assess and reduce impacts to the State.

## II. AUTHORITY

A. State

i. Title 24, Article 33.5, Part 701 et. seq., Colorado Revised Statutes, as amended; entitled the Colorado Disaster Emergency Act of 1992.
ii. State Emergency Operations Plan, April 2013

B. Federal

i. Robert T. Stafford Disaster Relief and Emergency Assistance Act (42 U.S.C. §§ 5121-5207)
ii. The National Response Framework, May 2013
iii. Code of Federal Regulations (CFR) Title 44 - Emergency Management and Assistance, revised October 1, 2008
iv. Title 7 Code of Federal Regulations (CFR) Part 1945 – Emergencies Subpart A and Parts 759 and 762 Disaster Designation Process
v. Agricultural Assistance Act of 2003, P.L. 108-07
vi. Plant Protection Act
vii. Food, Agriculture, Conservation, and Trade Act of 1990

## III. SPECIAL DEFINITIONS

The following terms are used throughout this document and have the following special meanings:

A. **Federal departments and agencies**. Those executive departments enumerated in 5 U.S.C. 101, together with DHS; independent establishments as defined by 5 U.S.C. § 104(1); government corporations as defined by 5 U.S.C. § 103(1); and the U.S. Postal Service.

B. **State**. For the purposes of the Colorado Drought Response Plan (Plan), when "the State" is referenced, it refers to the State of Colorado.

C. **Federal definition**: Any state of the United States, the District of Columbia, the Commonwealth of Puerto Rico, the Virgin Islands, Guam, American Samoa, the Commonwealth of the Northern Mariana Islands, and any possession of the United States.

D. **Local government**. The elected officials of each political subdivision (counties and municipalities) have responsibility for reducing the vulnerability of people and property to the effects of emergencies and disasters. They should ensure local governmental agencies are capable of efficient and responsive mobilization of resources in order to protect lives, minimize property loss, and expedite response efforts during an emergency or disaster. They should ensure that an Emergency Management Office serves the jurisdiction.

E. **Non-governmental organization**. Includes entities that associate based on the interests of their members, individuals, or institutions that are not created by a government, but may work cooperatively with government. Such organizations serve a public purpose, not a private benefit. It may include entities in the private sector.

F. **Private sector**. Organizations and entities that are not part of any governmental structure. It includes for-profit and non-profit organizations, formal and informal structures, commerce and industry, and private voluntary organizations.

G. **Major disaster**. As defined by the Robert T. Stafford Disaster Relief and Emergency Assistance Act, as amended (42 U.S.C. §§ 5121-5206), a major disaster is "any natural catastrophe, including, among other things, hurricanes, tornadoes, storms, earthquakes, or, regardless of cause, any fire, flood, or explosion" determined by the President to have caused damage of sufficient severity and magnitude to warrant major disaster assistant under the Act.

H. **Disaster**. As defined by State statute (C.R.S. 24-33.5-703(3)), a disaster means the occurrence or imminent threat of widespread or severe damage, injury, or loss of life or property resulting from any natural cause or cause of human origin, including but not limited to fire, flood, earthquake, wind, storm, wave action, hazardous substance incident, oil spill (or other water contamination requiring emergency action to avert danger or damage), volcanic activity, epidemic, air pollution, blight, drought, infestation, explosion, civil disturbance, or hostile military or paramilitary action.

I. **Emergency**. As defined by the Stafford Act, an emergency is "any other occasion or instance for which the President determines that Federal assistance is needed to supplement state, local, and tribal efforts to save lives and to protect property, and public health and safety; or to lessen or avert the threat of a catastrophe in any part of the United States."

J. **Catastrophic incident**. Any natural or manmade incident, including terrorism, that results in extraordinary levels of mass casualties, damage, or disruption severely affecting the population, infrastructure, environment, economy, national morale, and/or government functions. A catastrophic event could result in: sustained national impacts over a prolonged period of time; almost immediately exceeds resources normally available to state, local, tribal, and private sector authorities; and significantly interrupts governmental operations and emergency services to such an extent that national security could be threatened.

K. **Preparedness**. The range of deliberate, critical tasks and activities necessary to build, sustain, and improve the operational capability to prevent, protect against, respond to, and recover from domestic incidents. Preparedness is a continuous process involving efforts at all levels of government and between government and private sector and nongovernmental organizations to identify threats, determine vulnerabilities, and identify required resources. In the context of the NRF, preparedness is operationally focused on actions taken in response to a threat or potential incident.

L. **Prevention**. Involves actions taken to avoid an incident or to intervene to stop an incident from occurring. For the purposes of this Plan, this includes applying intelligence and other information to a range of activities that may include such countermeasures as deterrence operations; security operations; investigations to determine the full nature and source of the threat; public health and agricultural surveillance and testing; and law enforcement operations aimed at deterring, preempting, interdicting, or disrupting illegal activity and apprehending perpetrators.

M. **Response**. Involves activities that address the short-term, direct effects of an incident. These activities include immediate actions to preserve life, property, and the environment; meet basic human needs; and maintain the social, economic, and political structure of the affected community. Response also includes the execution of emergency operations plans and incident mitigation activities designed to limit loss of life, personal injury, property damage, and other unfavorable outcomes.

N. **Recovery**. Involves actions and the implementation of programs necessary to help individuals, communities, and the environment directly impacted by an incident to return to normal where feasible. These actions assist victims and their families; restore institutions to regain economic stability and confidence; rebuild or replace destroyed property; address environmental contamination; and reconstitute government operations and services. Recovery actions often extend long after the incident itself. Recovery programs may include hazard mitigation components designed to avoid damage from future incidents.

O. **Mitigation**. Activities designed to reduce or eliminate risks to persons or property or to lessen the actual or potential effects or consequences of an incident. Mitigation measures may be implemented prior to, during, or after an incident. Mitigation measures are often developed in accordance with lessons learned from prior incidents. The NRF distinguishes between hazard mitigation and incident mitigation. Hazard mitigation includes any cost-effective measure which will reduce the potential for damage to a facility from a disaster event. Measures may include zoning and building codes, floodplain property acquisitions, home elevations or relocations, and analysis of hazard-related data. Incident mitigation involves actions taken during an incident designed to minimize impacts or contain the damages to property or the environment.

## IV. PURPOSE

The purpose of the Colorado Drought Response Plan is to:

A. Provide an effective and systematic means for the State to reduce the impacts of water shortages on Colorado’s people, property, and environment over the short term or long term.

B. Activate a network of task forces that will identify the need and guide response resources to the State and affected local jurisdiction(s). The term “response resources” is normally defined as immediate service (includes, but not limited to, personnel, equipment, and program assistance) that is intended to restore institutions to regain economic stability and confidence, rebuild or replace impacted property, address environmental contamination, reconstitute government operations and services, and satisfy public safety needs during the response phase of a disaster event. However, due to the long term nature and slow onset of drought, "response resources" for a drought includes long term situational monitoring from professionals within certain agencies that serve on specific impact task forces that collectively make up the State's DTF.

C. Provide in-state mutual aid.

D. Work within the State Emergency Operations Plan system.

E. Assist local governments through available State programs relative to drought and drought conditions.

F. Coordinate Intergovernmental relations throughout the response period.

G. Provide an operational structure that mirrors the NIMS and the NRF that applies to drought related response necessities.

## V. SCOPE

The scope of this Plan applies to the entire state and is designed to be scalable to address events that may impact limited or extensive areas of the state. The scope includes a full range of requirements for response operations to a drought event. The implementation of short, intermediate, and long-term actions will be determined by the degree necessary to adequately conserve and preserve water resources for the purpose of preserving life and wildlife, sustaining the economy, and protecting the environment.

The Drought Response Plan Annex identifies specific response roles and responsibilities of State departments, agencies, quasi-governmental, non-governmental organizations, and non-profit organizations involved in the response phase of a drought event.

The Drought Response Plan Annex has been developed to provide a seamless link between local-state, state-state, and state-federal operations by following the premise outlined in the NRF relative to response operations and more specifically tailored to the drought hazard.

## VI. SITUATION

Colorado is susceptible to droughts that can have significant long term impact to the state's environment, economy, and population. Drought impacts will vary depending on where the drought occurs. Refer to the base Drought Mitigation Plan for an in-depth Hazard Identification and Risk Assessment (HIRA). The HIRA includes information on:

- Relative probability and impact of drought.
- Vulnerability by jurisdiction.
- Estimates of impacts by sectors that include: agriculture, energy, environmental, municipal and industrial, recreation and tourism, socioeconomic, and state assets.

In Colorado, an early drought response is vital. Gathering information that is suggestive of drought conditions allows for early planning discussions specific to the most likely affected impact sectors. Appendix C of the base Drought Mitigation and Response Plan captures information on actions taken to reduce impacts by previous droughts, by impact sector and/or ITF.

The response phase of an emergency or disaster is often defined as restoring a community to its pre-disaster condition or re-establishing a state of normalcy in the affected communities. While immediate lifesaving activities are normally occurring in the response phase, activities are simultaneously occurring to transition from the response phase to the recovery and mitigation phase. For a drought hazard, the situational awareness unfolds much slower than typical emergency response for other hazards.

## VII. Planning Assumptions

A. A drought emergency or disaster can occur at any time and any location. It may create significant degrees of human and/or animal suffering, property damage, and economic hardship to individuals, governments, the environment, and the business community.

B. Response and recovery operations may overlap requiring simultaneous efforts; however, recovery and mitigation operations may move into a longer term strategic process.

C. A standard of operating procedures consistent with the NIMS.

D. A standard of operating procedures consistent with NRF.

E. An established central coordination and pre-designated responsibilities exist.

F. The Colorado drought response team is organized in the form of a DTF comprised of the directors of key State agencies and chairpersons of ITFs that represent specific sectors vulnerable to drought.

G. The DTF will respond appropriately to the drought conditions with the intent to protect, conserve, and preserve water resources to sustain life; and to advise and make recommendations to the Governor who may provide additional drought assistance or seek a Presidential drought disaster declaration.

H. Priorities for response management include:

i. Ensuring health and safety “best practices” are standard protocol for any necessary field response task that is related to drought or water supply availability data collection and considered top priority.
ii. Operating consistent with the NIMS standard throughout the disaster event including recovery and mitigation operations.
iii. Documenting all response operations expenditures.
iv. Following prompt and efficient reimbursement practices.
v. If possible, using immediate mitigation strategies to stabilize current vulnerabilities, which reduce harmful effects from possible secondary impacts.

I. Private and volunteer organizations may provide assistance to the DTF.

J. The Governor may request of the President to declare a drought disaster for activation of federal assistance programs to help drought affected communities.

## VIII. CONCEPT OF OPERATIONS

A. Drought Response Plan Annex implementation

The Plan consists of four components: monitoring, assessment, mitigation, and response. These four actions are designed to work within the existing framework of government, pulling together key personnel from both federal and state levels. Drought monitoring and long-term mitigation are ongoing activities and the responsibility of the Water Availability Task Force (WATF). Drought assessment involves activation of specific ITFs. When the Plan is activated drought response and incident mitigation is the collective responsibility of the DTF. As drought conditions worsen, the Governor may coordinate assistance among state agencies and request outside assistance from other federal agencies and neighboring states. The general sequence of actions is outlined in Table 1.

The Drought Response Plan has the force and effect of law as promulgated by the Governor. Implementation and the subsequent supporting actions taken by the ITFs or supporting state agencies are driven by the specifics of the emergency or disaster situation. Implementation is influenced by the timely attainment and assessment of information gathered from affected jurisdiction(s) by the ITFs that collectively make up the DTF. The Director or their designee for the Department of Natural Resources (DNR), the Department of Local Affairs (DOLA), Department of Public Safety (DPS) and the Colorado Department of Agriculture (CDA) will serve as the lead agency(s) for the DTF. They will report and recommend to the Governor (based on information from the ITFs) about the existing and expected conditions of the drought situation and advise the Governor with supporting documentation for his/her decision to activate the DTF and seek federal assistance, possibly through a Presidential Drought Declaration.

The Drought Response Plan can be partially or fully implemented allowing maximum flexibility to meet the unique response requirements for any level of pre-drought or drought conditions. Drought monitoring is ongoing in Colorado under the purview of the WATF. A description of the drought monitoring indices used to recommend activation of various phases of the Plan can be referenced in Table 1. More information on these indices can be referenced in the base Drought Mitigation Plan in Section 3 and Annex D Drought Monitoring Indices.

B. Drought monitoring and assessment operations include actions required to:

- i. Increase monitoring activities across impact sectors
- ii. Share information among ITF chairs
- iii. Review, report, and recommend based on drought monitoring indices in Table 1
- iv. Determine the level of activation necessary per Table 1 to provide response resources to affected or potentially affected jurisdictions
- v. Activate the DTF

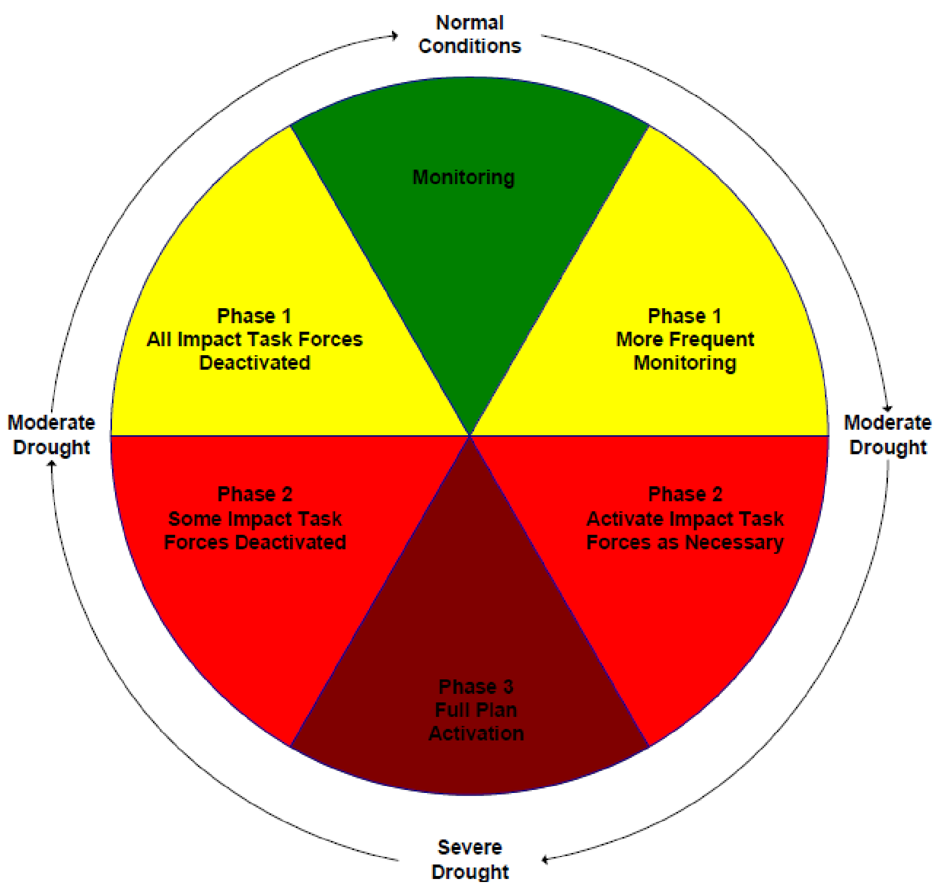
C. General response functions include:

- i. Drought monitoring, warning and information sharing
- ii. Recommendations for DTF and ITF(s) activation
- iii. Initial DTF meeting
- iv. Potential impact analysis across sectors:
  - a Agricultural
  - b Energy
  - c Municipal Water
  - d Water Availability
  - e Wildlife Impact
- v. Review and report to Chairs of the DTF
- vi. Implement actions in Table 1 depending on drought severity
- vii. Procurement and resource tracking
- viii. Implement response actions relative to:
  - a State government
  - b Local government
- ix. Develop public information messages
- x. Implement applicable state drought programs
  - a Federal Programs Implementation
    1. USDA Program Assistance
    2. Small Business Administration Declaration
    3. Economic Development Administration (EDA) Program
- xi. Request for Presidential Disaster Declaration (if applicable)
- xii. Long-term drought recovery planning

Figure 1 graphically depicts, and Table 1 outlines, the general sequence of events of the Drought Response Plan. *Severity indices are intended to provide a general framework and by themselves do not initiate response actions.* Expert judgment from the WATF and further data analysis may be required to fully understand impacts of abnormally dry conditions suggested by the indicators.

Recommendations for action may also be dependent on timing, location, extent, water supply, and subjective considerations, and recognize that different parts of the State may be in different phases at different times.

**Figure 1 Drought Plan Implementation Cycle**



## Table 1 Drought Response Plan Summary Action Table

| Severity Indicators and Impacts (U.S. Drought Monitor, Colorado Modified Palmer Drought Index (CMPDI), SWSI, SPI) | Drought Phase and Response Summary | Actions to be Considered |
|---|---|---|
| Drought Monitor<br>D0 Abnormally Dry<br>D0 ranges:<br>CMPDI or SWSI[1]: +2.0 to -1.9<br>SPI[2]: -0.5 to -0.7<br>Indicator blend Percentile: 21-30<br><br>Impacts: short-term dryness slowing planting, growth of crops or pastures.<br><br>CMPDI<br>-1 to positive indices in all river basins or modified Palmer climate division<br><br>SPI<br>-0.5 to positive (six month) | Normal Conditions<br>Regular Monitoring | • CWCB/WATF monitors situation on monthly basis, discusses trends with National Weather Service (NWS), State Climatologist, State Engineer, Natural Resource Conservation Service (NRCS), and others as appropriate.<br>• Data reviewed for drought emergence and summarized in monthly drought updates.<br>• Implement long-term mitigation actions identified in drought mitigation plan<br>• ITF chairs meet once yearly to monitor progress on long-term drought mitigation and review any lessons from previous drought periods, and review the response plan. |
| Drought Monitor<br>D1 Moderate Drought D1 ranges:<br>CMPDI or SWSI[1]: -2.0 to -2.9<br>SPI[2]: -0.8 to -1.2<br>Indicator blend Percentile: 11-20<br><br>Impacts: Some damage to crops, pastures; streams, reservoirs, or wells low, some water shortages developing or imminent; voluntary water-use restrictions requested<br><br>CMPDI<br>-1.0 to -2.0 in any river basin or modified Palmer climate division<br><br>SPI<br>-0.6 to -1.0 (six month) | **Phase 1**<br>More close monitoring of conditions for persisting or rapidly worsening drought; Official drought not yet declared | • ITF chairs alerted of potential for activation, monitoring of potential impacts.<br>• Assess need for formal ITF and DTF activation depending on timing, location, or extent of drought conditions, existing water supply, and recommendation of WATF; DTF is comprised of WATF, ITF chairs, and Lead Agencies.<br>• DTF Lead Agencies (CDA/DOLA/DNR/DPS) notified of need for potential activation. |

| Severity Indicators and Impacts (U.S. Drought Monitor, Colorado Modified Palmer Drought Index (CMPDI), SWSI, SPI) | Drought Phase and Response Summary | Actions to be Considered |
|---|---|---|
| Drought Monitor<br>D2 Severe Drought<br>D2 ranges:<br>CMPDI or SWSI[1]: -3.0 to -3.9<br>SPI[2]: -1.3 to -1.5<br>Indicator blend Percentile: 6-10<br><br>Impacts: Crop or pasture losses likely; water shortages common; water restrictions likely to be imposed<br><br>CMPDI<br>Less than -2.0 in any river basin or modified Palmer climate division<br><br>SPI<br>Less than -1.0 (six month) | **Phase 2**<br>Drought Task Force and Impact Task Forces are activated; Potential Drought Emergency Declared | • DTF Chairs prepare Governor's Memorandum of potential drought emergency based on recommendations from WATF.<br>• Governor's Memorandum activates the Drought Task Force and necessary Impact Task Forces.<br>• The DTF Chairs and CWCB meet with activated Impact Task Force chairs to outline Phase 2 activity.<br>• Activated ITF's make an initial damage or impact assessment (physical and economic).<br>• ITF's recommend opportunities for incident mitigation to minimize or limit potential impacts<br>• Periodic reports are made by the ITF chairs to the DTF Chairs.<br>• ITF chairs designate their respective department Public Information Officer (PIO) to interface with media for their relative area of concern and develop media messages.<br>• Relevant state agencies undertake response and incident mitigation actions with their normal programs with available resources.<br>• The DTF conducts a gap analysis identifying any unmet needs that cannot be handled through normal channels. |
| Drought Monitor<br>D3 Extreme Drought to<br>D4 Exceptional Drought<br><br>D 3 Ranges<br>CMPDSI or SWSI[1]: -4.0 to -4.9<br>SPI[2]: -1.6 to -1.9<br>Indicator blend Percentile: 3-5<br>Impacts: Major crop/pasture losses; widespread water shortages or restrictions very likely to be imposed<br><br>D4 Ranges:<br>CMPDI or SWSI: -5.0<br>SPI*: -2.0 or less<br>Indicator blend Percentile: 0-2<br>Impacts: Exceptional and widespread crop/pasture losses; shortages of water in reservoirs, streams, and wells creating water emergencies<br><br>CMPDI<br>Lowest reading at -2.0 to -3.9 in any river basin or modified Palmer climate division<br><br>SPI<br>Less than -1.0 to -1.99 SPI (six month) | **Phase 3**<br>Drought Emergency is declared by Proclamation of the Governor. | • Governor's Memorandum updated to activate additional Impact Task Forces as necessary.<br>• Activated ITFs continue to assess, report, and recommend response measures and incident mitigation.<br>• Unmet needs are reported to the DTF Chairs.<br>• DTF Chairs determine the unmet needs that can be met by reallocation of existing resources. Those which cannot are forwarded to the Governor with recommendations to support a request for a Presidential Drought Declaration.<br>• Governor may request a Presidential Declaration.<br>• If approved, Federal-State Agreement establishes Colorado Office of Emergency Management Director as the State Coordinating Officer (SCO).<br>• Work with the Governor's office on long-term recovery operations |

<table>
<tr><th>Severity Indicators and Impacts (U.S. Drought Monitor, Colorado Modified Palmer Drought Index (CMPDI), SWSI, SPI)</th><th>Drought Phase and Response Summary</th><th>Actions to be Considered</th></tr>
<tr><td>Lowest reading at -1.6 in any river basin or modified Palmer climate division<br>-0.8 SPI (six month)</td><td>Return to Phase 2</td><td rowspan="2">• DTF Chairs determines if all requirements for assistance are being met within the DTF and State agency channels.<br>• DTF briefs the Governor and prepares Proclamation to end drought emergency.<br>• Long-term recovery operations continue<br>• ITFs continue assessments.<br>• ITFs issue final report and conclude formal regular meetings.<br>• The DTF issues a final report and is deactivated.</td></tr>
<tr><td>D1 Moderate Drought<br>Coming out of drought: some lingering water deficits; pastures or crops not fully recovered</td><td>Return to Phase 1</td></tr>
<tr><td>Lowest reading at -1.0 in any river basin<br><br>-0.5 SPI (six month)</td><td>Return to normal conditions</td><td>• CWCB/WATF resume normal monitoring.</td></tr>
</table>

[1] SWSI will likely be changed to a percentile-based index by late 2013

[2] The SPI timeframe used for the Drought Monitor can vary from 1 to 24 months.

D. Impact Task Forces (ITFs)

Specialized ITFs are activated as needed to coordinate the assessment of drought impacts as well as appropriate response and mitigation actions. The ITFs are made up of professionals with specific expertise to monitor and analyze the onset of drought and pre-drought conditions to make informed recommendations for the implementation of measures to reduce existing or potential impacts to Colorado's citizens, environment, and economy. The five Task Forces are:

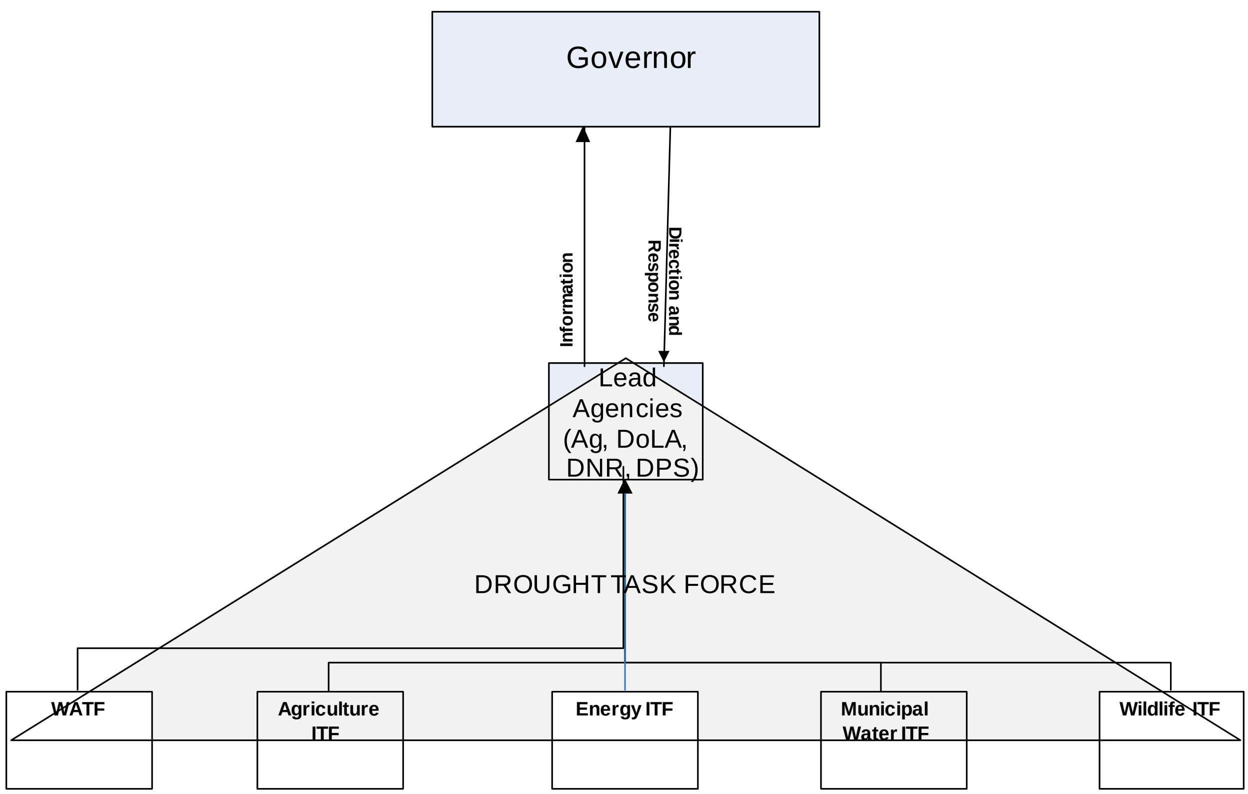
i. Agricultural Impact Task Force
ii. Energy Impact Task Force
iii. Municipal Water Task Force
iv. Water Availability Task Force
v. Wildlife Impact Task Force

During the 2010 Plan revision, the number of ITFs was reduced from nine to seven. The Health Impact Task Force was combined with the Municipal Water Task Force and economic impacts tracking (formerly a responsibility of the Economic Impact Task Force) became incorporated as an element of each of the remaining task forces. During the 2013 Plan update the number of task forces went from seven to five. The Tourism Task Force and Wildfire Task Forces, which have historically not been activated, have been removed while preserving input and monitoring from these sectors by representatives participating in the overall Drought Task Force. The State has wildfire monitoring and response mechanisms already in place that are sufficient to meet the needs and do not warrant a separate task force related to drought.

E. Drought Task Force (DTF)

The purpose of the DTF is to evaluate and recognize the need for early implementation of water conservation programs and other drought response measures that are intended to minimize the impacts of drought and reduce the potential for secondary hazard vulnerability. Figure 2 illustrates the DTF framework and how it consists of the ITF chairs and lead agencies. Information is shared and analyzed by the DTF and provided to the Governor, who provides direction for state agencies to implement drought response or mitigation actions.

**Figure 2 Drought Task Force Framework**




F. Public Information (CRS 24-33.5-704(4))

An executive order will be disseminated promptly to bring its contents (information related to the emergency or disaster) to the attention of the general public. Each ITF will designate a Public Information Officer (PIO), who will be the liaison to the media and/or public interest groups relative to the purpose of that specific ITF.

## IX. ORGANIZATION AND ASSIGNMENT OF RESPONSIBILITIES

A. State departments and agencies responsibilities

i. General: All state agencies or departments are required under the authority of Colorado Disaster Emergency Act of 1992 (Act) and this Plan to carry out assigned activities related to mitigating the effects of a major emergency or disaster and to cooperate fully with each other, the Office of Emergency Management (OEM), and other political subdivisions in providing emergency assistance. In addition to assigned functional responsibilities, all state departments will take the following general actions, as appropriate, in accordance with response operations:

a Initial Response Phase (Phases 1 and 2 in Table 1). Upon request, provide personnel, equipment and other required resources to support initial response relief operations:

b Intermediate Response Phase (Phases 2 and 3 in Table 1). Continue to monitor response operations, unmet needs, and public information. Analysis and strategic planning is necessary from all involved state agencies and non-governmental agencies to move smoothly into long-term recovery operations.

c Long-term Recovery Phase. (Phase 3 and return in Phases 2 and 1 in Table 1) Develop a long-term response committee (if not already established) to provide multi-agency oversight of the long-term missions necessary to satisfy the unmet needs of victims.

d Transition Phase. The long-term recovery committee is tasked with identifying the trigger points that would transition specific recovery projects back to specific local authority oversight

ii. A comprehensive list of state agency and non-governmental agencies responsibilities relative to "typical" disaster response and recovery is further defined in the SEOP and the State Recovery Plan.

B. Specific to drought or water supply availability incidents:

i. All state agencies or departments are required under the authority of the Colorado Disaster Emergency Act of 1992 to fully cooperate with each other and any other political subdivisions in providing the specific assistance necessary to respond to a disaster or emergency. The Act also applies to all state agencies or departments that serve as members of the DTF and/or ITFs. This Plan identifies the manner in which to carry out assigned activities relative to drought or water supply availability incidents which vary from normal response activities due to the atypical manner in which drought or water supply availability incidents unfold. The roles of state agencies or departments in this Drought Response Plan are specified in Table 2.

C. The Director or their designee for the DNR, the DOLA, and the CDA will serve as the Lead Agencies for the DTF.

D. The CWCB will provide additional support to the DTF, the WATF, and all ITFs, where needed.

## Table 2 State Agency Roles in Drought Emergencies

| Responsibility | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Agency** | **Specialization** | **Track Impacts Related to Water Shortages** | **Improve Water Availability Monitoring** | **Increase Public Awareness and Education** | **Augment Water Supply** | **Facilitate Watershed and Local Planning** | **Reduce Water Demand/ Encourage Water Conservation** | **Support Programs to Reduce Impact** | **Provide Other Technical Support** |
| Department of Agriculture | Support to Agriculture and Agribusiness | X | | X | | X | X | X | X |
| Department of Local Affairs | Support to Municipal Water Systems | X | | X | X | X | X | | X |
| Department of Military Affairs | Resources Support | | | | | | | | X |
| Department of Natural Resources | Wildlife, Water Administration, Drought and Water Planning | X | X | X | X | X | X | X | X |
| Department of Public Health and Environment | Public Health and Water Quality | X | | X | | | | | X |
| Office of Economic Development and International Trade | Tourism | X | | X | | | | | X |
| Department of Public Safety | Life Threatening Situations and Federal Disasters, Wildfires | X | X | X | | X | | | X |
| Colorado's Energy Office and Department of Regulatory Affairs - PUC | Energy | X | | X | | | | | X |
| Office of State Planning/Budget | Economic Impacts | X | | X | | | | | |

## X. IMPACT TASK FORCE ORGANIZATION AND ASSIGNMENT OF RESPONSIBILITIES

The following section describes the roles of the WATF and the ITFs, their membership, and responsibilities.

### Individual ITF Member Roles and Responsibilities

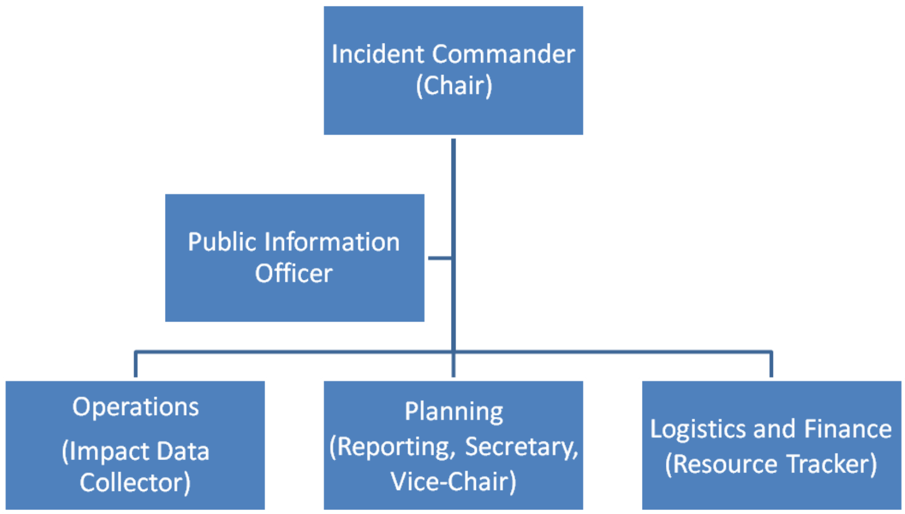
Each ITF will have designated roles with corresponding responsibilities. Listed below are suggested roles for each task force. Individual task forces will have varying need for these positions. Some task forces will fill all roles, while others may fill only a few. A definition for each role is provided in Table 3. Individual roles can be assigned as needed by each ITF.

**Table 3 Suggested ITF Member Roles and Responsibilities**

| Role | Definition |
|---|---|
| Chair | The Chair leads the task force and manages its principal relationships. The Chair ensures that relevant policies are brought to the attention of members of the task force and ensures that it performs appropriately with regard to: adherence to its objectives; risk management; accountability to the CWCB and the Governor; and financial accountability. Other responsibilities include:<br>• Participate in regular meetings of the WATF.<br>• Recommend activation of the ITF when climatic conditions indicate potential for drought development.<br>• Notify the WATF and ITF members of scheduled meeting dates.<br>• Prepare briefings of findings after each meeting for distribution to the WATF, chairpersons of other ITFs, and other agencies as requested.<br>• Invite participation from agencies or individuals as necessary to enhance the effectiveness of the ITF. |
| Vice-Chair | The Task Force Vice-Chair assists the Chair where needed. |
| Secretary | The level of support the Task Force Secretary provides will vary. The Board Secretary may be responsible for administrative support, such as taking Task Force meeting minutes, circulating papers, and liaison between the Task Force and the CWCB and the Governor. |
| Impact Data Collector | This position supports the Task Force by collecting impact data relevant to the Task Force. The data collected will include economic impacts where possible relevant to the Task Force. (i.e., the Agricultural Impact Data Collector will collect data from the USDA, NRCS, and other agricultural entities). |
| Resource Tracker | This position supports the Task Force by locating and securing ever changing resources to assist the Task Force in accomplishing its tasks. Tracks financial resources needed and expended. |
| Reporting | This position supports the Task force by creating situation reports for internal and external distribution regarding the Task Force's area of interest. Analyzes information from the Impact Data Collector and works with the ITF chair as to recommend actions for drought response and mitigation. |
| Public Information Officer | Public Information Officers (PIOs) are the communications coordinators or spokespersons of the Task Force, typically associated with the department that is the Task Force chair. |

Figure 3 is an Incident Command System (ICS) organizational chart that is used as part of the NIMS as a standard, systematic approach to integrate the best existing processes and methods into a unified national framework for incident management. Incident management refers to how incidents are managed across all emergencies, including prevention, protection, response, mitigation, and recovery. Each ITF can apply the concept of ICS to managing their aspect of the drought response. The items in parentheses suggest how the individual ITF roles could fit with the ICS structure. This structure can be collapsed or expanded to meet the needs of the individual ITF and/or scope of the drought.

**Figure 3 ICS Structure Diagram**




## A. Water Availability Task Force (WATF)

### Purpose

The purpose of the WATF is to monitor the state's water situation to detect signs of emerging drought. In drought situations the WATF monitors the state to detect areas of potential impacts and provides information for decision support. The WATF also serves as the forum for monitoring of implementation of long-term drought mitigation activities during non-drought times.

### Activation

The WATF is always activated as the monitoring element of this Plan. Throughout the water year (October through September), the WATF collects data on snowpack, soil moisture, reservoir levels, streamflow, precipitation, and temperatures. The members meet monthly to share information, discuss projections, and assess the water situation. Meetings may occasionally be held in conjunction with the Colorado Flood Task Force. The WATF recommends to the Governor activation of the Drought Response Plan when conditions warrant, based on the indices and phases outlined in Table 1 and expert judgment. When the drought plan is activated, the WATF (in association with the other ITF Chairs) and the Directors of the CDA, DNR, and DOLA, forms the core of the DTF.

## Members

The WATF is comprised of Colorado's water supply specialists, emergency management professionals, federal land managers, scientists, and experts in climatology and weather forecasting.

***Lead Agencies***

- CWCB (Chair)
- Colorado Division of Water Resources (Co-Chair)

***Core***

- OEM
- Office of the State Climatologist
- National Oceanic and Atmospheric Administration (NOAA)
- NRCS

***Supporting Stakeholders***

- Chairs of other ITFs
- Governor's Office
- Bureau of Land Management (BLM)
- Bureau of Reclamation (USBR)
- NWS
- United States Geological Survey (USGS)

- Local water providers
- Private parties

## Tasks

- Monitor drought forecasts and climate conditions
- Compile and report on the following indicators and outlooks:
  - Snowpack
  - Precipitation
  - Temperatures
  - Streamflow
  - Reservoir levels
  - Groundwater levels
  - Soil Moisture
  - Palmer indexes
  - Historical climate norms

- Long term precipitation and temperature outlooks
- Climate variations associated with La Nina and El Nino conditions

- Determine requirements for routine and special reports.
- Provide other task forces with this information.
- Identify resource information gaps and make recommendations to address them.
- Coordinate and respond to special data requirements of the other Task Forces.

**Impact Assessment**

The task force assesses current and pending impacts to Colorado's water supply including water storage and precipitation deficits that could lead to potential impacts to sectors. Data reported by the WATF supports other ITFs by indicating the sectors and portions of the state likely to be affected by pending or current drought conditions. Long range forecasting has been improving over the years and may become a factor in the indicators noted in Table 1 in future updates to this plan.

**Primary Data Sources and Indicators**

- Monthly Water Supply Report
- U.S. Drought Monitor
- Monthly Climate Report
- Historical norms
- Weather forecasts and long-term outlooks
  - Experimental Precipitation Statistical Forecast - three month outlook and others
- Reservoir levels
- Streamflow data
- Rain gauge sites
- NRCS Snow Telemetry Network (SNOTEL) sites
- USBR Snow Data Assimilation System (SNODAS)
- SPI
- SWSI
- CMPDI

## B. Agricultural Industry Task Force (AITF)

**Purpose**

The AITF assesses pending and current drought impacts on the agricultural industry and recommends mitigation and response actions. Findings and recommendations of this task force facilitate effective response capabilities, as well as provide documentation for any emergency declaration.

## Activation

Activation of this task force occurs upon recommendation of the WATF and/or request of the Governor's Office based on monitoring of the following indicators:

- Precipitation deficits in summer/fall in a major agricultural area resulting in reduced dry-land wheat and pasture land growth.
- Snowpack deficits in mountains, resulting in inadequate irrigation prospects based on drought severity indicators.
- Soil moisture conditions that may result in dust storms in certain critical areas during wind events.
- Federal Drought Designations.
- Prevented Planting Declaration from USDA.

Given that agricultural impacts are typically the first to develop in a drought, it is expected that the AITF will begin monitoring early drought development during Drought Phase 1 in coordination with the WATF.

## Members

### *Lead Agencies*

- Colorado State University (CSU) – Water Resource Institute (Co-Chair)
- CDA (Co-Chair)
- Colorado Agricultural Commission
- Colorado Agriculture Council

### *Core*

- USDA
- NRCS (State Technical Committee)
- Farm Services Agency (FSA)
- Colorado Division of Water Resources (DWR)
- State Conservation Board
- Colorado State Land Board
- CSU Extension
- Colorado Climate Center

### *Supporting Stakeholders*

- CWCB
- Agricultural industry groups
- Local conservation districts

- Local and regional water districts
- Cattle, grain, and dairy associations
- Colorado Counties, Inc.
- Colorado Municipal League
- Others as needed

**Tasks**

- Review drought reporting in relationship to current and/or potential threats on the sector.
- Identify the current or anticipated drought-related problems to the sector.
- Define and assess societal impacts, severity, loss and costs.
- Collect and evaluate impact data.
- Assess current and potential severity of impacts.
- Identify sources of assistance related to agriculture.
- Evaluate state and local capacity for response.
- Identify and recommend response actions.
- Maintain supporting data and records of activities.
- Estimate and report on costs of needed water resource augmentation activities.
- Analyze barriers and needs to meet projected threats.
- Identify key contact points with support service agencies and agricultural industries.
- Coordinate with other task forces.
- Report findings and actions in Drought Task Force memos to the Governor.
- Determine ongoing and residual needs.
- Maintain supporting data and records of activities.
- Provide coordination and liaison with USDA agencies, state agencies, local government, and agricultural industry groups.
- Assess and project the impacts of drought on the agricultural economy and provide information to the DTF.
- Provide input to support Agricultural Disaster Declarations from the USDA.
- Make requests and recommendations on the use of Governor's Agricultural Emergency Fund.

**Impact Assessment**

Collect, record, and analyze impacts from:

- Crop loss
- Livestock loss
- Insect and pest issues
- Highway closures or accidents from blowing dust
- Overall economic impacts to the sector (present and projected)
- Social impacts from loss of farming and ranching income

**Primary Data Sources**

- Natural Disaster Damage Assessment Report (USDA)
- USDA Flash Situation Report (Department of Agriculture)
- Economic Outlook Reports
- Regional Outlook (Western Livestock Roundup)
- Pest reports (e.g., grasshoppers, etc.)
- Agricultural and Economic Outlook Reports
- Colorado Ag Update
- Crop Progress report
- Colorado Agricultural Statistics

These reports are available from Colorado Agricultural Statistics 303-236-2300 or Toll-Free at 1-800-392-3202. Online report sources are www.nass.usda.gov and www.ers.usda.gov/.

## C. Municipal Water Task Force (MWTF)

### Purpose

The MWTF assesses pending and current drought impacts on municipal water supply and public health impacts and recommends and implements mitigation and response actions. Findings and recommendations of this task force facilitate effective response capabilities, as well as provide documentation for any emergency declaration.

### Activation

Activation of this task force occurs upon recommendation of the WATF and/or request of the Governor's Office based on monitoring of the following indicators:

- Declining reservoir levels
- Declining groundwater resources or aquifer depletions
- Activation of local drought management plans
- Activation of local water conservation measures
- Local drought emergency declarations

### Members

***Lead Agencies***

- DOLA-DLG (Co-chair)
- CWCB (Co-chair)

***Core***

- Colorado Department of Public Health and Environment (Water Quality Control Division and Air Pollution Control Division)
- OEM
- DWR
- Colorado Municipal League
- Colorado Counties, Inc.
- Special District Association
- USDA (Rural Development)
- Colorado Rural Water Association

***Supporting Stakeholders***

- US Army Corps of Engineers
- Department of Fire Science Technology (Red Rocks Community College)
- Colorado Water Utility Council
- Fire Chief's Association
- Fire Marshall's Association
- Economic Development Administration
- Water Resources and Power Development Authority
- Other agencies as needed

## Tasks

- Review drought reporting in relationship to current and/or potential threats on the sector.
- Identify the current or anticipated drought-related problems to the sector.
- Define and assess societal impacts, severity, loss, and costs.
- Collect and evaluate impact data.
- Assess current and potential severity of impacts.
- Identify sources of assistance related to municipal water.
- Evaluate state and local capacity for response.
- Identify and recommend response actions.
- Maintain supporting data and records of activities.
- Estimate and report on costs of needed water resource augmentation activities.
- Analyze barriers and needs to meet projected threats.
- Identify key contact points with support service agencies.
- Coordinate with other task forces.
- Report findings and actions in the Drought Task Force Drought Situation Report.
- Determine ongoing and residual needs.
- Assess and prioritize impact of drought conditions on municipalities and report to the Drought Task Force and appropriate response and funding agencies.

- Develop and implement a follow-up process to determine health actions where impact is identified.
- Recommend bottled water advisories.
- Develop and assign reporting responsibilities where appropriate.
- Develop a method for periodic contact with municipalities noted in critical areas.
- The DOLA Division of Local Government will review and evaluate data to determine if the impact of the drought is beyond local capabilities in order to prepare appropriate response to an emergency situation.
- Co-chairs will work directly with municipalities/governments impacted by drought on their options such as substitute water supply plans or temporary water transfers and provide technical and financial assistance as appropriate.

**Impact Assessment**

Collect, record, and analyze impacts from:

- Municipal water supply shortages
- Municipal water supply water quality impacts
- Overall economic impacts to the sector (present and projected)
- Social impacts from water rationing

**Primary Data Sources**

- See WATF data sources
- Field reports from Division of Local Government Field Services Staff
- Municipal water providers
- Field reports from DHSEM – OEM Regional Field Managers

## D. Wildlife Task Force (WTF)

**Purpose**

The WTF assesses the impacts of drought upon wildlife (e.g., fish, game and non-game) and recommends mitigation and response actions.

**Activation**

Activation of this task force will be upon recommendation of the WATF and/or request of the Governor based on monitoring of the following indicators:

- Young of year monitoring/impacts
- Forage impacts
- Wildfire impacts in critical habitats
- Streamflow forecasts and potential impacts to state wildlife areas

- Reservoir depletions at state parks and wildlife areas

## Members

### *Lead Agency*

- DPW (Chair)

### *Core*

- CWCB (Instream flow Section)
- U.S. Fish and Wildlife Service
- National Park Service
- U.S. Forest Service
- BLM
- NRCS

### *Supporting Stakeholders*

- Colorado Wildlife Federation
- Trout Unlimited
- The Nature Conservancy
- Others as needed

## Tasks

- Identify the current or anticipated drought-related problems to the sector.
- Identify potential and/or existing drought-related wildlife impacts (see Impact Assessment below).
- Manage DPW-owned water rights in accordance with DPW Administrative Directive A-9
- Recommend measures to prevent or mitigate wildlife losses (see DPW Administrative Directive A-9 Appendix B).
- Establish contact with appropriate federal and state agencies to solicit input and assistance.
- Develop and coordinate public information releases regarding assessment of drought conditions on wildlife.
- Synthesize assessment data for the DTF and Drought Situation Reports/Governors Memorandums.
- Coordinate with other Task Forces – notably  Municipal Water.

## Impact Assessment

Collect, record, and analyze impacts with emphasis placed on:

- Wildlife losses on DPW-controlled properties and public lands such as fish hatcheries, reservoirs, streams, terrestrial wildlife habitats, and associated recreational areas.
- Estimate potential short-term wildlife losses and long-term projections for losses over the assessment periods.
- Evaluate impact on DPW-held water rights on reservoirs, streams, hatcheries, etc.
- Assess impacts to fish/fishery resources for threatened and endangered and priority species, including streams/lakes/reservoirs with potential for significant fish mortality and/or areas where angling restrictions might be necessary.
- Assess overall health condition and distribution of key game species and populations.
- Assess condition of critical winter ranges for key game species including identification of areas with new or expanding weed infestations.
- Assess impacts to bird production, nesting success, and brood rearing for upland game birds and waterfowl species.
- Assess impacts to water levels and wetland dependent vegetation for priority wetlands and riparian corridors.
- Identify wildfires and/or areas with drought-related forest health issues that have potential for direct or indirect impacts to wildlife.
- Economic impacts from wildlife including loss of revenue from decrease fishing and hunting license sales, water rights transfers.
- Assess impacts on state wildlife areas and state parks, including tourism and economic impacts
- Coordinate with other ITFs

**Primary Data Sources**

- DPW's regional office reports and information provided by other task force agencies.

## E. Energy Impact Task Force (EITF)

**Purpose**

The EITF assesses pending and current drought impacts on the energy sector and recommends mitigation and response actions. Findings and recommendations of this task force facilitate effective response capabilities.

**Activation**

Activation of this task force occurs upon recommendation of the WATF and/or request of the Governor's Office based on monitoring of the following indicators:

- Declining water availability in relation to hydroelectric generation and other power generation
- Increased wildfire risk

## Members

### *Lead Agency*

- Colorado's Energy Office (Co-Chair)
- Colorado Department of Regulatory Agencies - Public Utility Commission (Co-Chair)

### *Supporting Stakeholders*

- CWCB
- Rural Electric Cooperatives and Utility Districts
- Utility providers
- DNR (State Land Board)
- DNR (Oil and Gas Conservation Commission)
- DNR (Division of Reclamation, Mining, and Safety)
- Western Area Power Administration (WAPA)

## Tasks

- Review drought reporting in relationship to current and/or potential threats on the sector.
- Identify the current or anticipated drought-related problems to the sector.
- Define and assess societal impacts, severity, loss, and costs.
- Collect and evaluate impact data.
- Assess current and potential severity of impacts.
- Identify sources of assistance related to the sector.
- Evaluate state and local capacity for response.
- Identify and recommend response actions.
- Maintain supporting data and records of activities.
- Estimate and report on costs of needed water resource augmentation activities.
- Analyze barriers and needs to meet projected threats.
- Identify key contact points with support service agencies and energy industries.
- Coordinate with other task forces, particularly the WPTF to identify areas of enhanced risk to utility lines.
- Implement related components of the Colorado Energy Assurance Plan where applicable
- Report findings and actions in the Drought Task Force Drought Situation Report.
- Determine ongoing and residual needs.
- Maintain supporting data and records of activities.
- Develop Media Talking Points specific to the sector.
- Develop assessment and report to the DTF.

## Impact Assessment

Collect, record, and analyze impacts from:

- Drought-related power supply interruptions
- Drought-related mining industry interruptions
- Economic impacts related to the sector from drought related interruptions and emergency measures

### Primary Data Sources

- Utility providers
- State Land Board
- Public Utilities Commission

## F. Drought Task Force (DTF)

### Purpose

The DTF reviews all task force assessments and recommends overall drought response and incident mitigation actions. The DTF syntheses economic impact information from each ITF to aid in decision support and identification of response resources needs.

### Activation

Activation of this task force will be upon Governor's memorandum, based upon the recommendation of the WATF.

### Members

***Lead Agencies***

- DNR Executive Director
- CDA Executive Director
- DOLA Executive Director
- DPS Executive Director

***Core***

- Chair of the Water Availability Task Force
- Chair of the Municipal Water Impact Task Force
- Chair of the Agricultural Industry Impact Task Force
- Chair of the Wildlife Impact Task Force
- Chair of the Energy Impact Task Force
- Colorado Water Conservation Board
- Colorado Division of Water Resources
- Colorado Office of State Planning and Budgeting
- Governor's Office

- Colorado Department of Revenue
- Colorado Department of Public Safety Division of Homeland Security and Emergency Management
- Colorado Department of Public Safety Division of Fire Prevention and Control
- Colorado Office of Economic Development and International Trade - Office of Tourism
- Colorado State University (CSU) – Water Resource Institute
- Colorado Department of Labor and Employment
- U.S. Department of Agriculture - NRCS

**Tasks**

- Solicit and review the assessments of the ITFs and summarize the findings for a Drought Situation Report to the Governor (when activated).
- Assess overall societal impacts, severity, loss, and costs from drought.
- Assess current and potential severity of impacts.
- Identify sources of assistance.
- Evaluate state and local capacity for response.
- Identify and recommend response actions.
- Maintain supporting data and records of activities.
- Recommend actions to mitigate drought impact.
- Synthesize economic impacts from ITF chairs for the Drought Situation Report for the Governor and decision support.
- Develop coordinated media messages.

**Primary Data Sources**

- WATF and ITF's
- Governor's Office of State Planning and Budgeting (OSPB) economic model

## XI. Information Collection and Dissemination

Information collection will be the responsibility of each ITF as outlined in Section IX. Information will be compiled in individual ITF reports. ITF chairs will be responsible for reporting at meetings of the DTF. This information will be synthesized at the DTF level into a Drought Summary Memorandum/Situation Report for the governor..

The CWCB website will be used to synthesize information for local governments and the general public regarding the drought status and response activities. The CWCB will be responsible for updating and maintaining the information on the website on at least a monthly basis.

## XII. Communications

Communications among ITFs will be with typical methods including email, telephone or teleconference, and regularly scheduled meetings.

## XIII. State Emergency Operations Organization

A. State Emergency Operations

a General: The SEOC provides the primary location through which the OEM Director (or the SCO during a declared disaster emergency) can coordinate support to local governments in disaster situations. The SEOC serves as the principal point for coordinating and tasking State departments and volunteer agencies in the delivery of emergency assistance to affected jurisdiction(s). The SEOC provides the Governor with a secure location to: assemble and analyze critical disaster or Homeland Security information; facilitate the decision making process; coordinate the response activities of State government; and ensure interagency cooperation, coordination, and communications. The State emergency operations organizational structure is designed to be flexible, easily expandable, and proactive to the needs of local government. The organization of state agencies by functional elements provides for a uniform linkage between state and federal systems.

b Specific to drought or water supply availability incidents: In a drought hazard incident, the State emergency operations organization will be driven by the information delivered by the ITFs and the activation of the DTF. The DTF will report to the Governor and any additional resources necessary to handle the impacts of the incident or ongoing conditions will be determined by the Governor. The Governor may request a USDA Drought Declaration from the Secretary of Agriculture, which activates programs to assist in recovery operations. Water supply availability incidents where the onset of impact is rapid, the State emergency operations organization should follow the components of ICS and NIMS as they are designed in collaboration with the WATF.

## XIV. Administration, Logistics, and Mutual Aid

A. Administration

During an emergency or disaster, state (and local) government shall determine, if necessary, what, if any, normal administrative procedures shall be suspended, relaxed, or made optional in order to prevent unnecessary impediments of emergency operations and response activities. Such action should be carefully considered and the consequences should be projected realistically. Any state government departure from the usual methods of doing business will normally be stated in the Governor's declaration or Executive Order of Disaster/Emergency, or as specified in this Plan and its supporting documents. Mutual aid, if needed from other states, will follow protocols outlined in the SEOP and any existing memorandums of understanding or mutual aid agreements in place.

B. Finance

i. A major disaster or emergency may require the expenditure of large sums of state (and local) funds. Financial operations may be carried out under compressed schedules and intense political pressures which will require expeditious actions that still meet sound financial management and accountability requirements. Although drought and water supply availability incidents may dictate a different process for declaration, the requirement for financial support is nonetheless vital.
ii. State financial support for emergency operations shall be from funds regularly appropriated to state departments. If the demands exceed available funds, the Governor may make additional funds available from the Disaster Emergency Fund. If money available from the fund is insufficient, the Governor has the authority under a State Declaration of Disaster/Emergency to transfer and expend money appropriated for other purposes.
iii. State departments designated as Lead Agencies for Emergency Support Functions conducting emergency support activities will be responsible for organizing their functional activities to provide financial support for their operations. Each department is responsible for maintaining appropriate documentation to support requests for reimbursement, for submitting bills in a timely fashion, and for closing out assignments.
iv. State and local government entities are responsible for documenting all emergency or disaster related expenditures using generally accepted accounting procedures. Care must be taken throughout the course of the emergency to maintain logs, records, receipts, invoices, purchase orders, rental agreements, etc. These documents will be necessary to support claims, purchases, reimbursements, and disbursements. Record keeping is necessary to facilitate closeouts and to support post response audits.
v. Sources of funding for drought mitigation and response efforts are outlined in Section 4 of the Colorado Drought Mitigation Plan. Additional reference for funding and relief options can be referenced in Appendix C Drought Mitigation Capabilities Summary.

## XV. PLAN DEVELOPMENT AND MAINTENANCE

A. Subsequent revisions supersede all previous editions and are effective immediately for planning, training and exercising, and preparedness and response operations.

B. Individual implementation plans and procedures may be developed by agency or ITF as needed. These procedures will detail who (by title), what, when, where, and how emergency tasks and responsibilities will be conducted.

C. This Plan and appendixes, state department plans, and implementation procedures shall be maintained and kept current by all parties on the following schedule:

i. Updates can occur at any time based upon the change of federal guidance.
ii. A cursory review of the Drought Response Plan will occur annually in conjunction with a fall WATF meeting.
iii. A complete review and update of the Drought Response Plan, its tabs, and appendices will occur every three (3) years (at a minimum), or when a change in administration occurs, or in concert with the update cycle of the Drought Mitigation Plan. This review will consist of all partners having the opportunity to comment on all elements and will be forwarded to the Governor's Office for signature. The CWCB will lead the update effort, with support from OEM.
iv. Review and revise procedures following critiques of actual emergency or disaster operations and/or exercises where deficiencies were noted.

D. All changes, revisions, and/or updates to the Drought Response Plan shall be forwarded to CWCB for review, publication and distribution to all holders of the Drought Response Plan following the efforts of the lead agency to coordinate with its supporting agencies. If no changes, revisions, and/or updates are required, CWCB shall be notified in writing by the agency lead that respective plans, annexes, appendices, etc., have been reviewed and are considered valid and current.

# XVI. ADDENDUM

## TAB 1: USDA Drought Declaration Process

### Overview

Agricultural-related disasters are quite common. One-half to two-thirds of the counties in the United States have been designated as disaster areas in each of the past several years. Producers may apply for low-interest emergency (EM) loans in counties named as primary or contiguous under a disaster designation.

The Secretary of Agriculture is authorized to designate counties as disaster areas to make emergency (EM) loans to producers suffering losses in those counties and in counties that are contiguous to a designated county. In addition to EM eligibility, other emergency assistance programs, such as FSA disaster assistance programs, have historically used disaster designations as an eligibility requirement trigger.

The FSA streamlined the USDA Disaster Designation process in 2012 to make assistance more readily available and with less burdensome paperwork.

FSA administers four types of disaster designations:

1) USDA Secretarial disaster designation (most widely used)
2) Presidential major disaster and Presidential emergency declarations;
3) FSA Administrator's Physical Loss Notification, and
4) Quarantine designation by the Secretary

The first three types of disaster declarations are authorized under 7 CFR 1945-A. The fourth is the result of a statutory requirement, under the Plant Protection Act or animal quarantine laws as defined in § 2509 of the Food, Agriculture, Conservation and Trade Act of 1990 (mentioned in 7 CFR part 761, which includes a definition of "quarantine" in accordance with 7 U.S.C. 1961). These declarations are described further below.

### Secretarial Disaster Designation Procedures for Extreme Drought

The Secretarial disaster designation is the most widely used. In the past the USDA Secretarial disaster designations must be requested of the Secretary of Agriculture by a governor or the governor's authorized representative, or by an Indian Tribal Council leader. As of 2012 the disaster designation process for severe drought occurrences has been streamlined by utilizing the U.S. Drought Monitor as a tool to automatically trigger disaster areas, yet preserves the ability of a state governor or Indian Tribal Council to request a Secretarial Disaster Designation if desired.

The streamlined process provides for nearly an automatic designation for any county in which drought conditions as reported in the U.S. Drought Monitor (http://droughtmonitor.unl.edu/)

meet a drought intensity value of D2 (Severe Drought) for eight consecutive weeks. A county that has a portion of its area in a drought intensity value of D3 (Extreme Drought) or higher at any time during the growing season would also be designated as a disaster area. The new process helps reduce paperwork and documentation requirements at the local FSA level, making the process more efficient and timely. Individual producer losses still need to be documented for Emergency Loan (EM) Program eligibility.

For all other natural disaster occurrences and those drought conditions that are not considered severe, the county must either show a 30 percent production loss of at least one crop or a determination must be made by surveying producers that other lending institutions will not be able to provide emergency financing.

The location of regulation governing the disaster designation process is contained in the Federal Register dated July 13, 2012, at:

http://www.gpo.gov/fdsys/pkg/FR-2012-07-13/html/2012-17137.htm

**Presidential Disaster Declarations**

Presidential major disaster declarations, which must be requested by a governor to the President, are administered through the Federal Emergency Management Agency (FEMA). A Presidential major disaster declaration can be made within days or hours of the initial request. FEMA immediately notifies FSA of the primary counties named in a Presidential declaration.

**FSA Administrator's Physical Loss Notification**

An FSA Administrator's Physical Loss Notification (APLN) is for physical losses only, such as a building destroyed by a tornado. Livestock related losses are considered physical losses. An APLN is requested of FSA's Administrator by an FSA State Executive Director (SED).

**Quarantine designation by the Secretary**

A quarantine designation is requested of the FSA Deputy Administrator for Farm Programs by an FSA SED. A quarantine designation authorizes EM loans for production and physical losses resulting from quarantine.

**Circumstances Affecting Secretarial Disaster Designations**

Disaster designations offer flexibility and can accommodate circumstances such as:

- Continuing adverse weather. When a natural disaster continues beyond the date on which a Secretarial determination is made, and continuing losses or damages are occurring, the incidence period and termination date may be extended up to 60 days.

- Insufficient data. When the data is determined insufficient to make a designation, the request remains active, but is deferred until sufficient information is received to make a determination.

**FSA Programs Initiated by Designations and/or Declarations**

All four types of designations (Secretarial disaster designations, Presidential disaster declarations, APLNs, and quarantine designations), immediately trigger the availability of low-interest FSA EM loans to eligible producers in all primary and contiguous counties.

Other programs use Secretarial designations as an eligibility requirement trigger. These programs include the Supplemental Revenue Assistance Payments (SURE) Program.

## TAB 2:  Sample Drought Emergency Declaration

WHEREAS, during the period (day) (month) (year) through (day) (month) (year), increasingly severe conditions of drought have impacted the State of Colorado; and

WHEREAS, the normal system of State Government is not able to cope adequately with the situation; and

WHEREAS, there is every indication that the present drought conditions will not abate in the near future; and

WHEREAS, these conditions may in fact become more severe; and

WHEREAS, extraordinary measures are necessary to protect public health, ensure public safety and welfare and render relief for those most severely impacted; and

WHEREAS, the aforementioned conditions constitute a threat to the safety and welfare of the State, and create an emergency disaster situation within the meaning of the Disaster Emergency Act, 24-33.5-705(2) C.R.S.

NOW THEREFORE, under powers vested in me by section 24-33.5-704 of the Disaster Emergency Act of 1973, and the other enabling provisions, I, (          ), Governor of the State of Colorado, do hereby declare a State of Drought Emergency to exist. I further declare that based on this State Drought Disaster Emergency, the Drought Task Force in the Colorado Drought Mitigation and Response Plan shall be activated with full power to address those unmet needs brought about by the drought and to take those actions within their authority to address such needs or to recommend for my action or that of the legislature those items that are beyond the authority of  the Emergency Council to resolve.

This Executive Order shall expire thirty (30) days from the date hereof unless further extended by Executive Order.

GIVEN under my hand and the Executive Seal of the State of Colorado; this (_) day of (_), A.D., 20_.

(          )

Governor

## TAB 3: Sample Governor's Memorandum of Potential Drought Emergency

TO: Executive Directors, Departments of State Government

FROM: ( ), Governor, State of Colorado

RE: Activation of the Colorado Drought Mitigation and Response Plan

DATE:

Drought conditions have developed along the ( ) and ( ) River Basin(s) to the degree that counties in the ( ) and ( ) are likely to receive severe impacts to their environments and to the various sectors of their economy. If present trends continue, other river basins and sectors of the entire state's economy may soon be affected.

Under these circumstances, and based on a recommendation from the WATF and directors from the Departments of Natural Resources, Agriculture, Public Safety and Local Affairs, I have decided to activate the State's Drought Mitigation and Response Plan so that specific impacts may be identified, and expeditious and effective remedial action may be taken.

As of the date of this memorandum, the Colorado Drought Mitigation and Response Plan is in effect; the following actions, as specified in the Plan will be taken:

5) Drought Task Force will be activated under chairmanship of directors from the Departments of Natural Resources, Agriculture, Public Safety and Local Affairs. The first meeting of the Task Force will be held within five days of receipt of this memorandum.
6) The following Impact Task Forces (ITF) will be activated: ( ), and ( ). The ITF chairpersons will call their first meeting as soon as possible after the Drought Task Force meeting.
7) All addressees will assign: (1) A senior level manager who can commit the resources of the department to act as a drought coordinator and (2) Task Force chairpersons and participants as indicated the Colorado Drought Mitigation and Response Plan Annex A.
8) Lead agencies will be prepared to take action for drought response and to mitigate drought impacts as appropriate.

DROUGHT VULNERABILITY ASSESSMENT TECHNICAL INFORMATION

ANNEX B TO THE COLORADO DROUGHT MITIGATION AND RESPONSE PLAN

August 2013

Prepared Pursuant to
Disaster Mitigation Act 2000 & Section 409, PL 93-288

Prepared by
Colorado Water Conservation Board
Department of Natural Resources
and AMEC Environment and Infrastructure

# Table of Contents


1 Introduction ....1

2 Drought Vulnerability Assessment Approach ....4

3 Numerical Vulnerability Assessment Tool ....5
- 3.1 General Approach ....5
- 3.2 Computation Details ....6
  - 3.2.1 Determination of Sub-sectors ....7
  - 3.2.2 Quantitative Metrics ....8
  - 3.2.3 Quantitative Sub-sector Impact Scores ....9
  - 3.2.4 Qualitative Adjustments ....10
  - 3.2.5 Overall Vulnerability Score ....11

4 Influence of Water rights on drought vulnerability ....13
- 4.1 Drought and Colorado Water Rights ....13
  - 4.1.1 Introduction to the Prior Appropriation System and Drought ....14
  - 4.1.2 River Administration during the 2002 Drought ....17
  - 4.1.3 Recommendations for Future Studies ....20
- 4.2 References ....21

5 State Assets Sector ....22
- 5.1 Introduction to Sector ....24
- 5.2 Vulnerability of State Asset Sector to Drought ....26
  - 5.2.1 Aspects of Vulnerability ....26
  - 5.2.2 Previous Work ....28

5.3 Assessment of Impacts and Adaptive Capacities ....31
  - 5.3.1 State-Owned Buildings ....31
  - 5.3.2 Critical Infrastructure ....34
  - 5.3.3 Land Board ....37
  - 5.3.4 Colorado Parks and Wildlife ....43
  - 5.3.5 Instream Flow and Natural Lake Rights ....59
- 5.4 Measurement of Vulnerability ....64
- 5.5 Vulnerability Metrics ....64
  - 5.5.1 Structures ....64
  - 5.5.2 Land Board Revenue ....65
  - 5.5.3 Recreation ....66
  - 5.5.4 Aquatic Species and Habitat ....67
  - 5.5.5 Protected Areas ....68
  - 5.5.6 Results ....68
  - 5.5.7 Spatial Analysis ....75
  - 5.5.8 Compound Impacts ....75
- 5.6 Recommendations ....76
  - 5.6.1 Adaptation to Drought ....76
  - 5.6.2 Improving Vulnerability Assessment ....77
- 5.7 References ....80

6 Agriculture Sector ... 82
6.1 Introduction to Sector ... 83
6.2 Vulnerability of Agricultural Sector to Drought ... 93
6.2.1 Aspects of Vulnerability ... 93
6.2.2 Previous Work ... 95
6.3 Assessment of Impacts and Adaptive Capacities ... 116
6.3.1 Potential Impacts ... 116
6.3.2 Adaptive Capacity Actions ... 122
6.4 Measurement of Vulnerability ... 125
6.5 Vulnerability Metrics ... 126
6.5.1 Livestock ... 126
6.5.2 Crops ... 127
6.5.3 Green Industry ... 129
6.5.4 Results ... 129
6.5.5 Spatial Analysis ... 133
6.5.6 Compound Impacts ... 136
6.6 Recommendations ... 136
6.6.1 Adaptation to Drought ... 136
6.6.2 Improving Vulnerability Assessment ... 137
6.7 References ... 139

7 Energy Sector ... 142
7.1 Introduction to Sector ... 144
7.2 Vulnerability of Energy Sector to Drought ... 151
7.2.1 Aspects of Vulnerability ... 151
7.2.2 Previous Work ... 154
7.3 Assessment of Impacts and Adaptive Capacities ... 163
7.3.1 Potential Impacts and Adaptive Capacities of Mining ... 163
7.3.2 Potential Impacts and Adaptive Capacities of Power Production ... 172
7.4 Measurement of Vulnerability ... 180
7.5 Vulnerability Metrics ... 180
7.5.1 Mining ... 180
7.5.2 Power ... 181
7.5.3 Results ... 183
7.5.4 Spatial Analysis ... 187
7.5.5 Compound Impacts ... 187
7.6 Recommendations ... 188
7.6.1 Adaptation to Drought ... 188
7.6.2 Improving Vulnerability Assessment ... 189
7.7 References ... 191

8 Environmental Sector ... 194
8.1 Introduction to Sector ... 195
8.2 Vulnerability of Environmental Sector to Drought ... 200
8.2.1 Aspects of Vulnerability ... 200
8.2.2 Previous Work ... 201
8.3 Assessment of Impacts and Adaptive Capacities ... 207
8.3.1 Potential Impacts ... 207

8.3.2 Adaptive Capacity Actions ....................209
8.4 Measurement of Vulnerability ....................214
8.5 Vulnerability Metrics ....................215
8.5.1 Environment ....................215
8.5.2 Results ....................217
8.5.3 Spatial Analysis ....................221
8.5.4 Compound Impacts ....................223
8.6 Recommendations ....................223
8.6.1 Adaptation to Drought ....................223
8.6.2 Improving Vulnerability Assessment ....................224
8.7 References ....................230

9 Municipal & Industrial Sector ....................233
9.1 Introduction to Sector ....................235
9.2 Vulnerability of M&I Sector to Drought ....................238
9.2.1 Drought and Seasonal Variability ....................238
9.3 Assessment of Impacts and Adaptive Capacities ....................238
9.3.1 Potential Impacts ....................239
9.3.2 Adaptive Capacity Actions ....................245
9.4 Measurement of Vulnerability ....................253
9.4.1 Regional Assessment ....................260
9.4.2 Aspects of Vulnerability ....................299
9.5 Recommendations ....................302
9.5.1 Adaptation to Drought ....................302
9.5.2 Improving Vulnerability Assessment ....................303
9.6 References ....................304

10 Recreation Sector ....................306
10.1 Introduction to Sector ....................308
10.2 Vulnerability of Recreation Sector to Drought ....................328
10.2.1 Aspects of Vulnerability ....................328
10.2.2 Previous Work ....................330
10.3 Assessment of Impacts and Adaptive Capacities ....................335
10.3.1 Impacts and Adaptive Capacities ....................335
10.4 Measurement of Vulnerability ....................343
10.5 Vulnerability Metrics ....................344
10.5.1 Skiing ....................344
10.5.2 Wildlife Viewing ....................345
10.5.3 Hunting, Fishing, and Camping ....................346
10.5.4 Golfing ....................347
10.5.5 Boating ....................347
10.5.6 Commercial Rafting ....................348
10.5.7 Results ....................349
10.5.8 Spatial Analysis ....................357
10.5.9 Compound Impacts ....................360
10.6 Recommendations ....................361
10.6.1 Adaptation to Drought ....................361
10.6.2 Improving the Vulnerability Assessment ....................362

10.7 References ... 366

11 Socioeconomic Sector ... 371
11.1 Introduction to Sector ... 372
11.2 Vulnerability of Socioeconomic Sector to Drought ... 372
11.2.1 Aspects of Vulnerability ... 372
11.2.2 Previous Work ... 373
11.3 Assessment of Impacts and Adaptive Capacities ... 378
11.3.1 Secondary Economic Impacts ... 378
11.3.2 Behavioral Health Impacts ... 386
11.3.3 Public Health ... 389
11.4 Measurement of Vulnerability ... 391
11.5 Vulnerability Metrics ... 392
11.5.1 Results ... 393
11.5.2 Spatial Analysis ... 398
11.5.3 Compound Impacts ... 399
11.6 Recommendations ... 399
11.6.1 Adaptation to Drought ... 399
11.6.2 Improving Vulnerability Assessment ... 399
11.7 References ... 401

# 1 INTRODUCTION

A vulnerability assessment is the process of identifying, quantifying, and prioritizing (or scoring) the vulnerabilities in a system. Vulnerability from the perspective of drought planning means assessing the threat from potential drought hazards to various sectors across social, economic, environmental, and political fields. In this study, the assets of the State of Colorado, as they pertain to drought, are considered in detail. Vulnerability assessments are typically performed according to the following steps:

1) Cataloging assets and resources in a system and across sectors
2) Assigning quantifiable value (or at least rank order) and importance to those resources
3) Identifying the vulnerabilities or potential threats to each resource
4) Mitigating or eliminating the most serious vulnerabilities for the most valuable sectors/assets

Vulnerability assessment has many things in common with risk assessment. Risk assessment for natural hazard planning is principally concerned with investigating the risks surrounding infrastructure (or some other object) and people. Such analyses tend to focus on causes and the direct consequences for the studied object. Risk assessment thus involves determination of vulnerabilities and hazards to establish risks and risk probabilities in terms of frequency of occurrence, magnitude and severity, and consequences.

Vulnerability analyses, on the other hand, focus both on consequences for sectors (as well as objects such as physical plant assets) and on primary and secondary consequences for related sectors and/or the surrounding environment. It also examines the possibilities of reducing such consequences and improving the capacity to manage future incidents by adapting. A drought vulnerability analysis serves to categorize sectors and assets in order to drive the risk management process. It is necessary for a comprehensive vulnerability assessment to be conducted prior to starting a risk assessment. The simplified, standard formula for assessing the risk posed by natural hazards (Risk = Hazard x Vulnerability) highlights that a highly vulnerable sector can be impacted significantly by even a moderate hazard (in this case drought). Assessment of a sector's or asset's ability to withstand a hazard is as important as assessment of the hazard itself. Both hazard and vulnerability aspects need to be handled thoughtfully and preferably within the same assessment framework.

In Colorado, the drought hazard can be both spatially and temporally variable, while the various sectors vulnerable to drought have variable distributions and often possess complex interrelationships. Much can be gleaned by considering the drought hazard simultaneous with the elements at risk, and this is the approach taken in this study. By incorporating the notion of differential susceptibility and differential impacts of the drought hazard, this Drought Plan revision seeks to incorporate both the negative and positive attributes from the physical and social environments that increase risk and susceptibility and/or limit resistance and resilience to drought events.

Because of the challenges presented in assessing both the drought hazard and the vulnerable sectors and assets at risk, the science and process of drought vulnerability assessment is not well developed, at least when compared to other natural hazards such as flood and earthquake. Until recently, drought assessment and management has, in most states, been largely response oriented. A detailed vulnerability assessment can assist with the development of targeted drought mitigation and response strategies.

The vulnerability assessment, initially developed as part of the 2010 Drought Mitigation and Response Plan, created a new platform for drought risk assessment by developing an enhanced drought vulnerability assessment approach that highlighted drought exposure and adaptive capacity for sectors and state assets, county-by-county within Colorado.

Vulnerable state assets included in this study are:

- Losses to wildlife
- Cost and losses to state parks
- State buildings
- Instream flows
- Agricultural & livestock businesses
- Fisheries

Vulnerability sectors included in this study are:

- Municipal and Industrial Water Supply (M&I)
- Agriculture
- Recreation
- Environment
- Tourism
- Socioeconomic
- Power and Mining

Since the development of the 2010 Drought Mitigation and Response Plan, Colorado has been impacted by a significant drought. This event, which started in 2011 and continues to persist as of July 2013 (heretofore referred to as the 2011-2013 drought), is having a severe impact in multiple sectors. These latest extremes have revealed new information regarding drought vulnerabilities in Colorado. For example, this drought has seriously impacted the agricultural economy and extreme dry conditions have been at least partly responsible for several damaging wildfires. Agricultural economics studies and reports on damages to property and infrastructure resulting from wildfire are just two areas where new economic impact information have recently been collected and analyzed. The results of such studies have provided the opportunity to assign new and reliable vulnerabilities to specific sectors, or to validate the results of the initial vulnerability study conducted in 2010.

The update of this vulnerability assessment during an ongoing drought provided both opportunities and challenges. An effort was made to update the various sector analyses using the best available data. Some formal reports and/or quantitative data have been released that describe the impacts of, and responses to, the 2011-2013 drought event. For example, a survey of farm and ranch managers' responses to the drought in 2011 was completed by Colorado State University researchers. In cases where new reports and data regarding drought vulnerabilities in Colorado have been developed since the 2010 Drought Mitigation and Response Plan was finalized, this information has been integrated into the 2013 vulnerability assessment. In other cases, new information regarding the impacts of the 2011-2013 drought event are either anecdotal or qualitative and thus required validation and interpretation to ensure it was suitable for this update. Much of the information that was available for this Plan update has yet to be formalized since relatively little time has passed since development of the 2010 Plan, and also because the drought is ongoing and impacts are still being experienced. Data and reports describing impacts of the 2002 drought (which was used as a baseline event in the 2010 Drought Mitigation and Response Plan) typically took at least four years to reach publication. Also, many of the impacts of the 2002 drought persisted for years, such as the widespread beetle kill that affected drought-stressed trees. Finally, as a result of this vulnerability study update, it is apparent that a lack of systematic impact data collection is still a major challenge. This is likely due to the challenges associated with collecting data and the reality that responding agencies are dealing with the day to day management challenges of a serious and persistent drought event. Mitigation strategy recommendations for impacts data collection improvements were made in the 2010 Drought Mitigation and Response Plan and implementing these should remain a high priority.

Where possible, the 2013 Drought Mitigation and Response Plan Update used new drought impacts data across the various sectors to update the existing vulnerability assessment tool (VAT), and to re-compute the overall vulnerability scores for each sector and for state assets. Due to the reasons noted above, much of the available data was not in formats consistent with the previously collected information, nor was it in a geographically comprehensive format (e.g., useful impacts data might be available for one major basin in Colorado, but not the others). For example, considerable drought impacts data has emerged for the Agriculture sector since 2010 as a result of various surveys and research studies. However, this new information focuses on different categories of impacts than those developed for the original VAT, and is not consistent across basins (and not available for all basins). While extremely useful for updating impacts in study-specific basins or locations, this information was often not in a format that could be easily integrated into the VAT-based vulnerability assessment approach to provide a full Colorado-wide update.

The 2012 Drought Assessment for Recreation & Tourism (DART) study attempted to improve on the VAT-based approach for this sector. Much of this study focused on developing recommendations for the type of impacts data that should be collected to improve assessment of vulnerability in this sector, and how this might be achieved (but was focused on only southwestern Colorado and did not develop new impacts data suitable to update the Plan). On the other hand, new data and tools, such as that available from the National Aeronautics and Space Administration's (NASA) Carnegie Ames Stanford Approach (CASA) model can provide a consistent means for agriculture and resource managers to assess drought-induced vegetation stress at a synoptic scale in a manner that lends itself well to the statewide VAT impacts assessment approach. Future updates to this plan should continue to take into account both emerging data and new impact assessment methods. New data such as that created by the CASA model can greatly enhance the synoptic (i.e. statewide) vulnerability assessment focus of the VAT-based approach by providing consistent data statewide, while more focused impacts assessment approaches such as those suggested in the DART study may be necessary to enable finer-grain analysis (e.g. more detailed sub-sector vulnerabilities to be assessed). Building and strengthening the capabilities of both approaches is important for ongoing drought risk assessment.

# 2 DROUGHT VULNERABILITY ASSESSMENT APPROACH

The approach developed in 2010 and utilized again in 2013 for this study employs a hybrid quantitative and qualitative approach, described in more detail in Chapter 3 Numerical Vulnerability Assessment Tool Technical Methodology. It is important to recognize that little of this type of work has been done to date, thus integration of qualitative data and use of quite broad definitions of drought "impacts", and "vulnerabilities", during data collection and interviews were necessary to gather all relevant information, and to encourage the inclusion of sometimes only marginally relevant efforts. Results provided an empirical basis for reporting vulnerability across assets of state agencies as well as sectors. Results were analyzed spatially and used to make recommendations for drought planning and mitigation.

Quantitative elements of the vulnerability assessment were conducted where sound data existed to support this, or where data could be developed efficiently. A focus of the quantitative approach was to assess impacts and the ability to reduce and mitigate those impacts, both short term and long term. Each sector analysis also includes recommendations on what data will be required to improve this approach in the future, and how this information can or should be collected. Qualitative information, particularly data gained from interviews, was also introduced where appropriate. The VAT developed for this study was, via a process of scoring, normalization, and weighting, able to integrate these informal data into the assessment, enhancing the analysis based on quantitative data alone.

The approach incorporates information on impacts and adaptive capacities. The combination of these components results in a net impact or vulnerability to drought. For example, a greater hazard exposure and higher sensitivity lead to higher potential impact and higher vulnerability; higher adaptive capacity reduces vulnerability due to resilience. Finally, these data were used to calculate vulnerability scores for elements being assessed, to extrapolate these results as necessary (e.g., when a sample has been used to represent the larger group), and then generate average results for sectors within each county.

Results have been analyzed spatially in a GIS and are presented in map form to illustrate how drought vulnerability varies across the State for state assets and critical sectors. In almost all cases assessment of each asset/sector is depended upon a combination of both qualitative and quantitative analysis. Portrayal in a GIS enabled depiction of drought vulnerability patterns (e.g., moderate, severe, etc.) by county, allowing for identification of spatial patterns (i.e., mountain counties were found to be most vulnerable to drought's wildfire and tourism impacts, while agriculture was found to have the greatest loss potential in the eastern plains and San Luis Valley).

The results presented in following sections also consider drought vulnerability from the perspective of indirect impacts on society and the economy (e.g., increased unemployment due to failure of an industry because of drought). For example, during and following the 2002 drought many rafting businesses failed in Colorado, and many businesses are again struggling as a result of drought in 2012-13. The reduced numbers of adventure tourists visiting towns near rafting waters also had a serious impact on the hospitality and other industries dependant on tourists. In order to assess the overall vulnerability of communities in counties across Colorado, various organizations were surveyed and data were sourced from business associations, agricultural extension agents, the census, and employment figures.

The following sections identify, quantify, and prioritize (score) the drought vulnerabilities of state assets and sectors by county.

# 3 NUMERICAL VULNERABILITY ASSESSMENT TOOL

## 3.1 General Approach

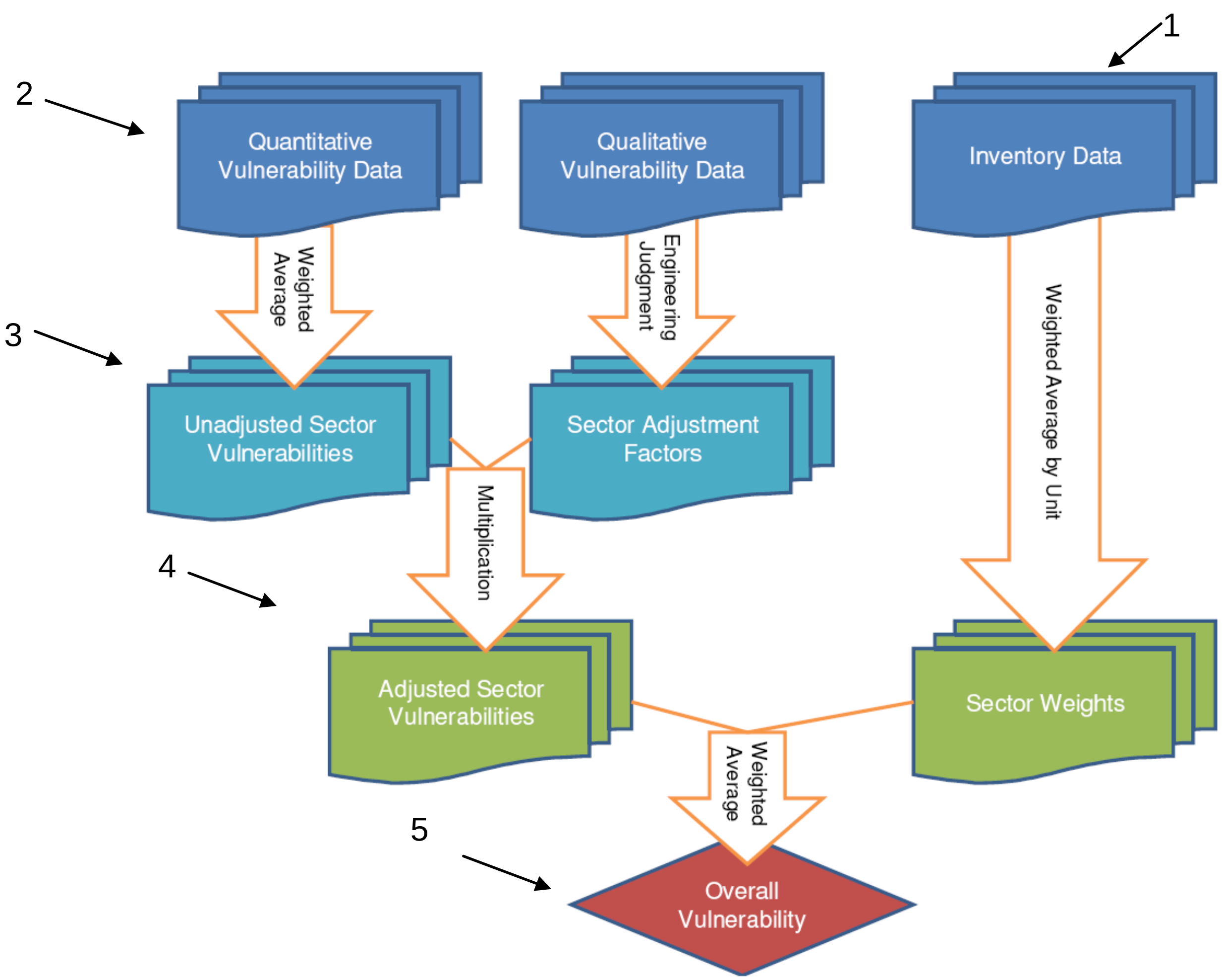
This section describes the methodology used in the VAT. This excel-based tool was developed to assess drought vulnerability in a quantitative spatial manner. Separate workbooks were set up for each sector discussed in the report. All numerical analysis was done on a county scale following the general framework described here. However, the metrics used and other adaptations vary from sector to sector. These variations are described in individual sector reports. Please refer to the Vulnerability Metrics section of each report for detailed data descriptions.

The outputs of the vulnerability assessment tool are numerical vulnerability scores of 1-4 for each county and each sector. For this analysis a score of 1 is the least vulnerable and a score of 4 is the most vulnerable. The list below outlines the steps that were followed for each sector. Figure 3.1 is a graphic representation of the vulnerability assessment methodology. Numbers in this diagram correspond to the five steps listed below.

1) Divide sector into impact categories (sub-sectors) and gather spatial density data
2) Define impact metrics and assemble data (quantitative)
3) Combine impact metrics to one sub-sector quantitative impact score

4) Scale sub-sector quantitative impacts using qualitative information to get a sub-sector adjusted impact score
5) Combine sub-sector impacts scores to overall sector vulnerability score. Sub-sectors are combined using a weighted average where weights are determined based on spatial density

**Figure 3.1. Methodology Schematic**




## 3.2 Computation Details

The following sections detail the five computation steps outlined above and the methods used to transition from one step to the next. The information in this section of the report relates to the general methodology framework. As previously noted, this framework was adapted for each of the sectors analyzed for this project. For information on specific sector methodology adaptations refer to the sectoral write-ups.

### 3.2.1 Determination of Sub-sectors

**Figure 3.2. Sub-Sector Division**

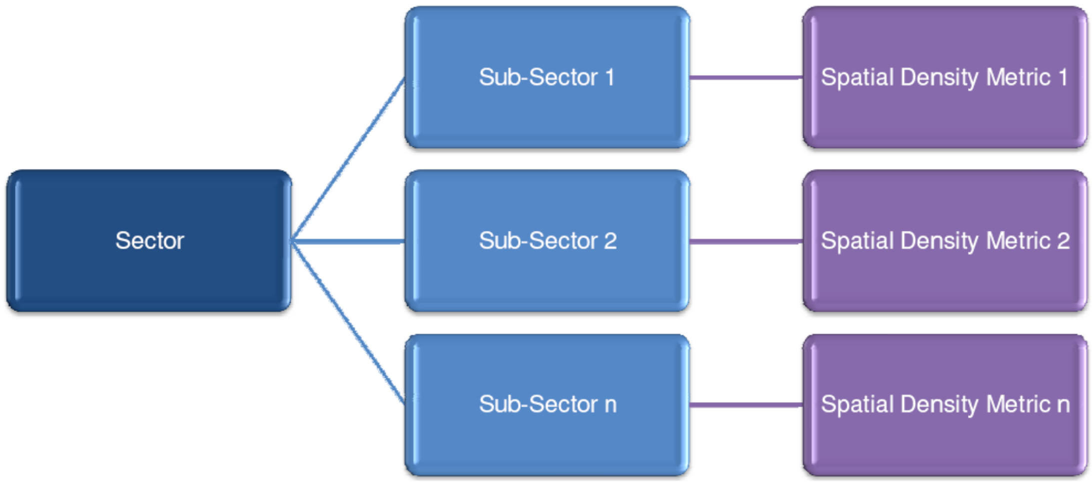
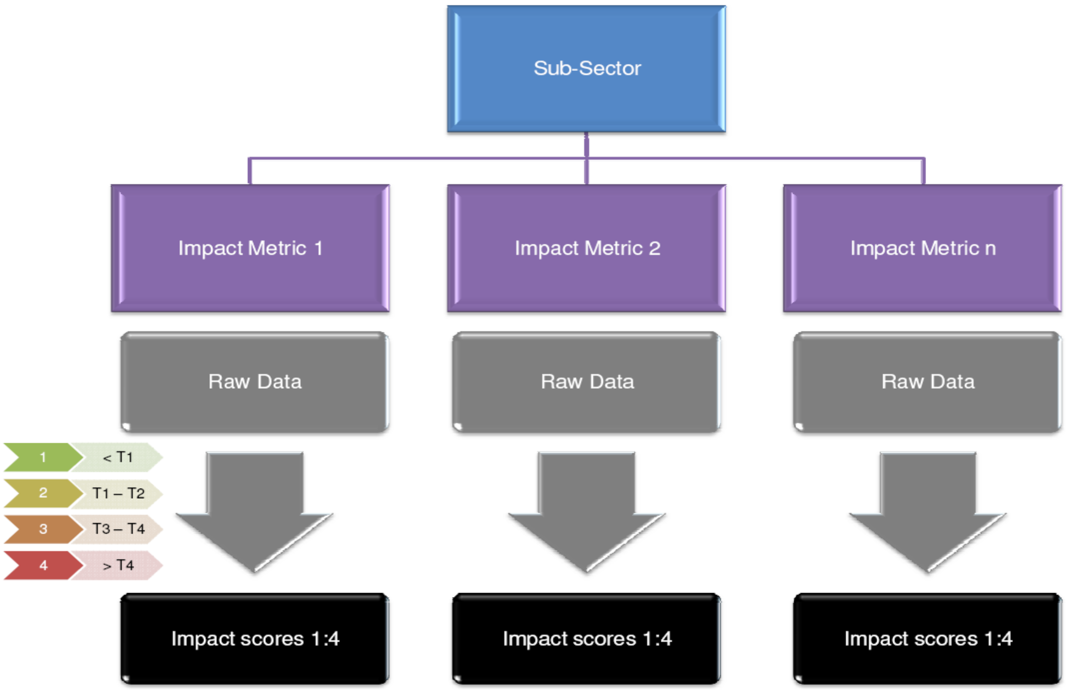



Figure 3.2 outlines the process of assigning spatial density metrics to sectors. Sub-sectors, also referred to as impact groups, are defined when the sources of vulnerability within a sector are sufficiently diverse to warrant separate consideration. For example, the Energy Sector covers power providers and mining operations. The different water dependencies of these two groups make it difficult to analyze impacts together. Therefore, the Energy Sector is divided into two sub-sectors. Impact group division is not necessary in all cases. The Socioeconomic Sector was not divided because all of the impacts to this group relate to the population as a whole.

Once it has been determined whether or not sub-sectors are necessary, and once they have been appropriately defined, spatial density metrics must be determined for each group. The purpose of the spatial density metric is to define the spatial extent of an impact group. For example, in the State Assets Sector one impact group is State Land Board (Land Board) revenue. The spatial density metric for the sub-sector is the total surface acres leased by the Land Board per county.

## 3.2.2 Quantitative Metrics

**Figure 3.3. Quantitative Data Adjustments (T = Threshold)**




One or more quantitative impact metrics are defined for each sub-sector. Quantitative metrics are impacts that can be measured and reported on a county scale across the State. Example impact metrics include total water use for the power sub-sector or economic diversity for the Socioeconomic Sector. As these examples demonstrate, impact metrics can take a variety of forms and there is little consistency of units. Therefore, raw impact data are translated to impact scores of 1 through 4. This is accomplished using thresholds. Typically the data set is divided into quartiles. The bottom quartile of data are assigned an impact rating of 1 up to the top quartile of data which are assigned a value of 4. This process is illustrated in Figure 3.3. In cases where there are no data for a significant number of counties, thresholds are adjusted so that only the non-zero values are divided into four groups.

In many cases quantitative data are not currently available for many of the direct vulnerability measures that would be most informative. Therefore, proxy metrics are often used. Metrics that are applicable but may require further examination are marked with an "uncertainty flag." For example, in the Energy Sector the percentage of groundwater (as opposed to surface water) used by power producers is a quantitative metric. Generally speaking groundwater users are less vulnerable to drought. However, there is a large amount of uncertainty in this assumption depending the specifics of water rights administration. Therefore, these data were assigned an uncertainty flag. The choice of quantitative impact measures and uncertainty flags is discussed in detail in individual sector reports.

In other situations it may not be relevant to divide data this way. For example, in the Socioeconomic Sector one of the impact metrics is whether a county is designated as having a "mental health man power shortage" or not. In this case an impact score of 4 was assigned to all counties with a shortage, and a value of 2 was assigned to counties without.

All threshold adjustments are noted in the "Vulnerability Metrics" section of each sector report. The final results of this step are county scores of 1 to 4 for each quantitative impact metric in a sub-sector.

In some cases quantitative adaptive capacity metrics are also defined. For example, the presence of renewable energy development areas in a county can make power providers less vulnerable. Adaptive capacity data are translated to adaptive capacity scores of 1 to 4 following the same guidelines outlines above. However, with adaptive capacities a score of 4 represents a county with the highest adaptive capacity and a score of 1 is a county with the least adaptive capacity.

### 3.2.3 Quantitative Sub-sector Impact Scores

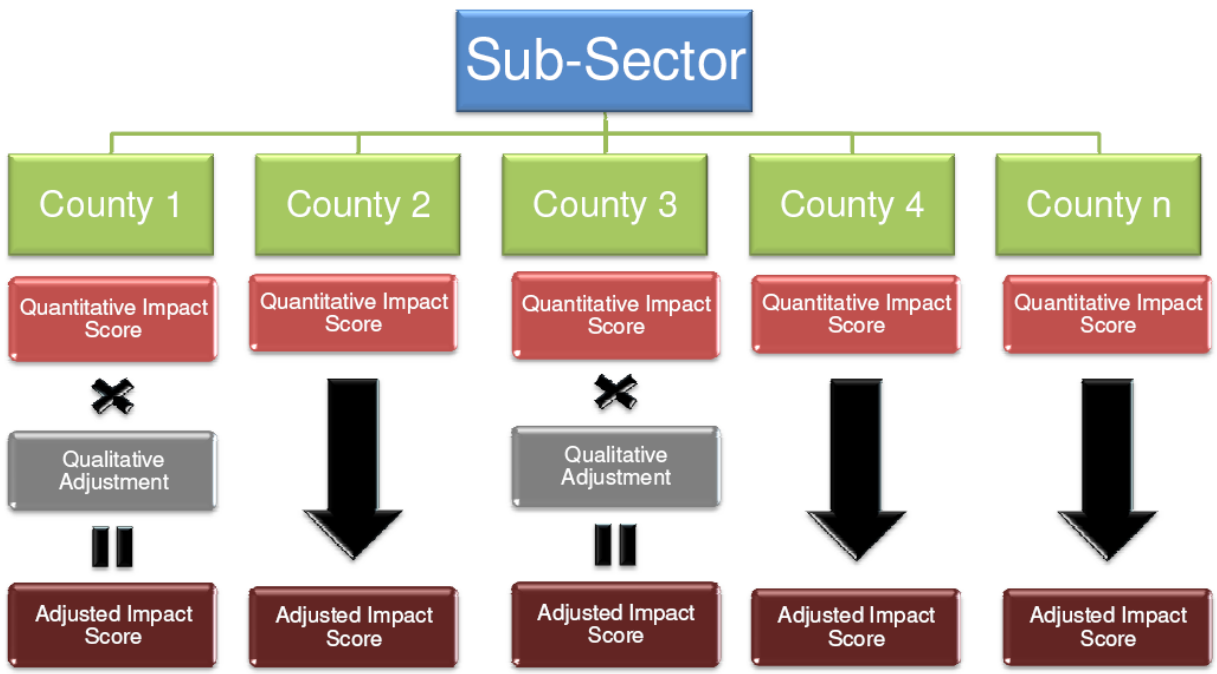
**Figure 3.4. Quantitative Impact Calculations**


In cases where there is more than one impact metric per sub-sector these metrics must be combined to get one quantitative sub-sector impact score (refer to Figure 3.4). To do this, weights are assigned to each of the impact metrics using engineering judgment. Metrics are combined using a weighted average based on the determined weights. Also, the number of uncertainty flags associated with metrics to be combined are counted. This process is repeated for each sub-sector. If there is only one metric for a sub-sector no adjustment is required.

If there are multiple adaptive capacity metrics, they are combined the same way as impact metrics to determine an overall sub-sector adaptive capacity score. When quantitative adaptive capacity data is available, overall impact rating is determined by dividing the total impact score by the total adaptive capacity score.

### 3.2.4 Qualitative Adjustments

**Figure 3.5. Qualitative Adjustments**




In many cases there are additional variables that significantly influence the vulnerability of a specific county or region that cannot be accounted for in quantitative metrics. Often this information may come from interviews or personal experience. For example, a water commissioner may say that a specific group in his or her region is less vulnerable because of a cooperative agreement that they have in place. In situations like this, it may be appropriate to adjust the quantitative impact score for a sub-sector. The goal of the qualitative worksheet is to make these adjustments transparent and easily traceable.

Qualitative vulnerability information is recorded for specific counties and sub-sectors, when applicable, and the descriptions are translated into impact scalars according to Table 3.1. In cases where the qualitative information is particularly subjective an uncertainty flag can be added to the adjustment. This flag will be counted along with the quantitative uncertainty flags. Where qualitative adjustment data exists sub-sector quantitative impact scores are adjusted by multiplying by the qualitative scalar (refer to Figure 3.5). For example, if for a given sub-sector there is one county which is known to be “highly adaptive”, for whatever reason, their impact score will be cut in half.

**Table 3.1. Qualitative Adjustment Levels**

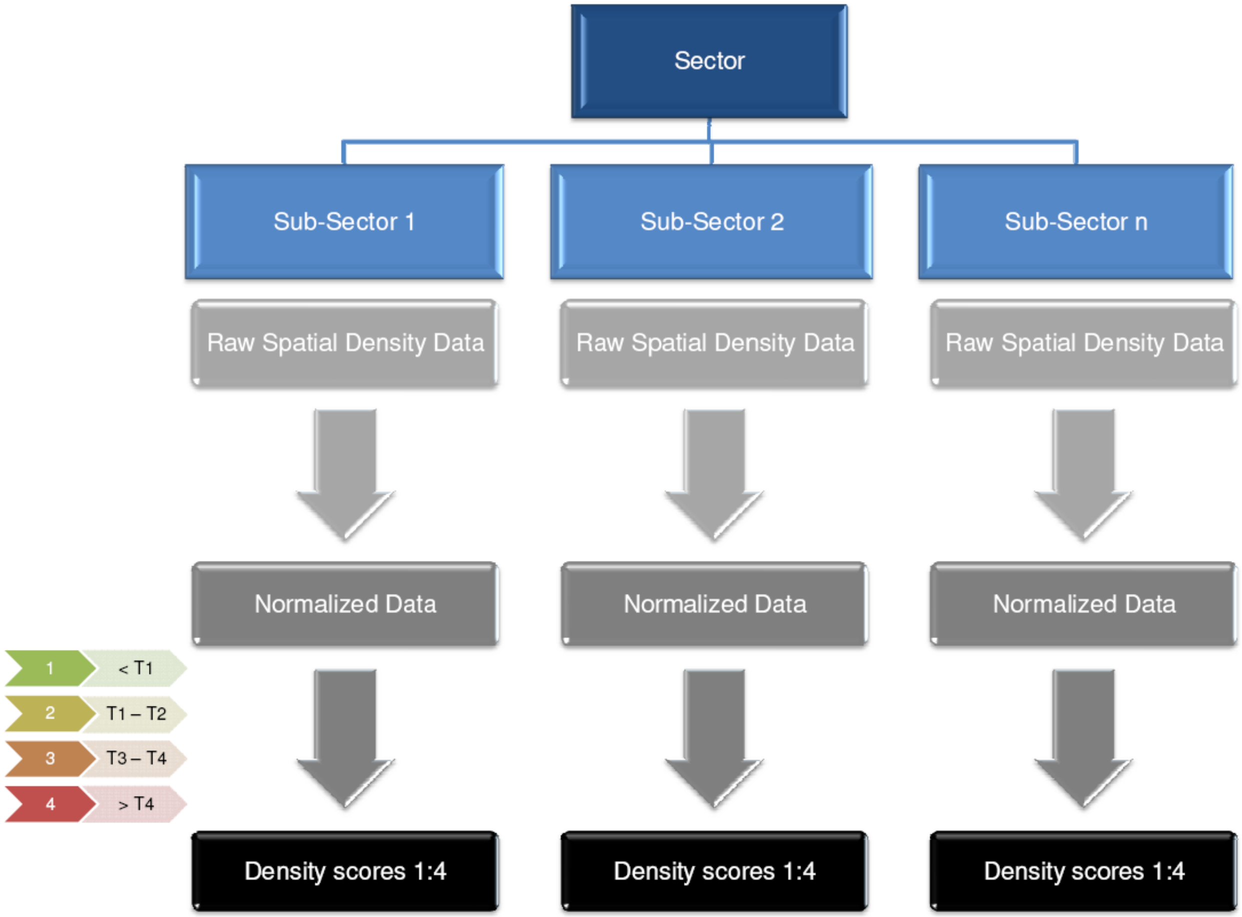
| Qualitative Adjustment Description | Numerical Scaling |
| --- | --- |
| Highly adaptive | 50% |
| Somewhat adaptive | 25% |
| Somewhat greater impact | 125% |
| Much greater impact | 150% |

### 3.2.5 Overall Vulnerability Score

The result of steps 2 through 4 are adjusted impact scores for each sub-sector. Sub-sector scores are combined to an overall sector vulnerability score using weighted averages. The weight of each sub-sector varies by county according to its spatial density.

In step 1, spatial density information was gathered for each sub-sector. As with impact metric data, there is a lot of variability in metrics and raw data must be translated to a consistent scale of 1 to 4 before any comparisons can be made. Given the range of county sizes within the State, most spatial density metrics have to be normalized using either the population or the size of the county. For example, one inventory metric for agriculture is the total area harvested. To determine the relative importance of agriculture within a county, the area harvested has to be normalized by dividing by the total area of the county. In some cases, as with state assets, this normalization step is not necessary because the assets are not relative to the size of the county. Next, the normalized values are converted to scores of 1 to 4 using the same threshold method described in step 3. Figure 3.6 outlines this process.

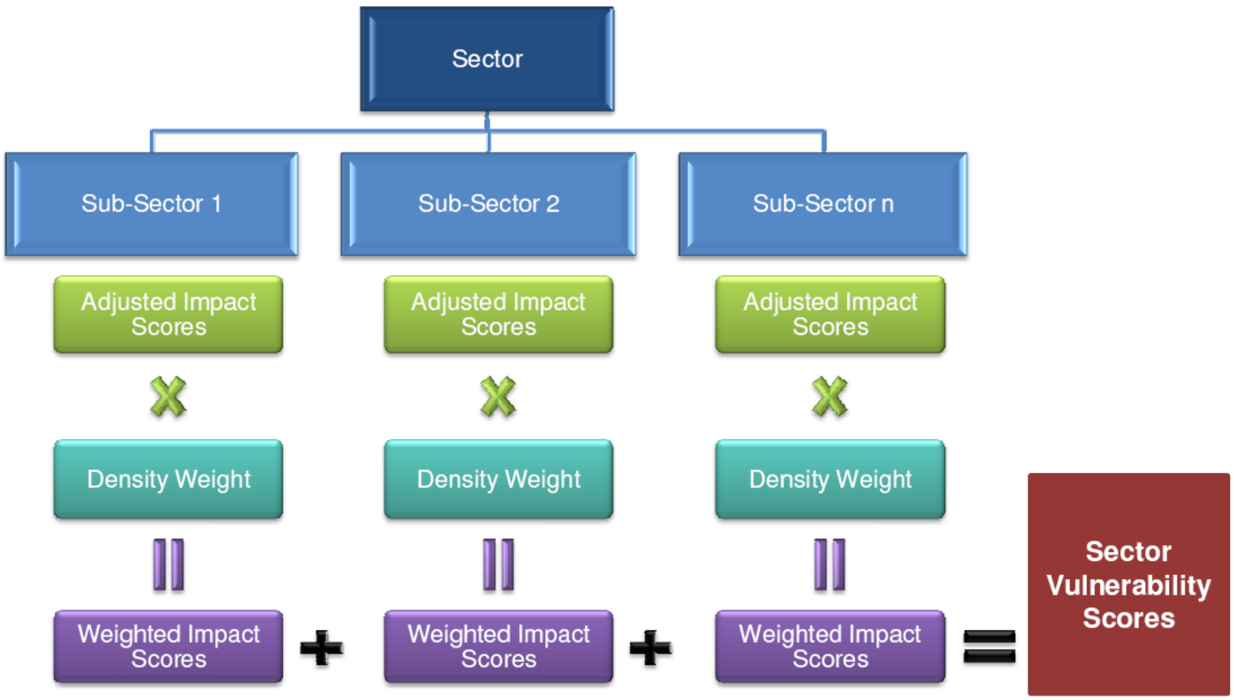
**Figure 3.6. Spatial Density Score Calculation (T=Threshold)**




To determine the relative weight of each sub-sector within a county the density score for a given sub-sector is divided by the sum of the density scores for all sub-sectors with the county.

Overall sector vulnerability is calculated by multiplying the sub-sector adjusted impact scores by the county specific sub-sector weights and summing across all sub-sectors (refer to Figure 3.7). Any quantitative or qualitative uncertainty flags are counted and a total uncertainty flag count is assigned to the overall vulnerability score.

**Figure 3.7. Overall Sector Vulnerability Calculation**




# 4 INFLUENCE OF WATER RIGHTS ON DROUGHT VULNERABILITY

## 4.1 Drought and Colorado Water Rights

Drought vulnerability within the State of Colorado is highly affected by the legal framework used to allocate water in Colorado. This framework is based on the prior appropriation doctrine described as "first in time first in right." Under this doctrine, rights to water are granted upon the appropriation and beneficial use of water. The dates of appropriation and adjudication determine the priority of the water right, with the earliest dates of appropriation and adjudication establishing the most senior or superior right. Thus, the right to the beneficial use of water in Colorado is based on a diversion for beneficial use through prior appropriation and adjudication confirmed by water right decree obtained by a water court, rather than by grant, or permit, from the State (DWSA, 2004).

While the allocation of water supplies during dry periods via the prior appropriation system is essential to a comprehensive evaluation of drought vulnerability, the nature of individual water user's water right portfolios, general allocation of these rights, and historical water right case study is extremely complex. Although some generalizations may be developed for study purposes, each water user has a unique portfolio of water rights and consequently neighboring water users can be impacted very differently during periods of drought.

The inclusion of the prior appropriation system as a means to evaluate drought vulnerability is beyond the scope of this study. However, it is recommended that future drought vulnerability studies incorporate the prior appropriation system at a level that is both feasible and sufficiently addresses drought vulnerability on a water division or district level when viable data are available. The 2013 update to the Drought Mitigation and Response Plan occurred in July, which was in the midst of a multi-year drought. The drought began in 2011 in portions of the State and continued to persist through July of 2013, particularly in southern Colorado. While there was preliminary information available on river administration during the time of update, additional information will be available and incorporated into future plan updates once the 2011-2013 drought event has concluded and there is more time for data collection that captures the extent of the impacts.

Although there was only preliminary information available regarding water rights administration during the 2013 Plan update, one program worth noting is the Colorado Water Trust's leasing program which began in 2012. Since 2003, *Statue 37-38-105* enables entities in collaboration with CWCB and DWR to lease water for streams on short notice to protect the environment. The Colorado Water Trust was the first entity to use this legislative tool by coordinating the leasing of water rights to preserve instream flows during the drought. The program was implemented again in 2013. This is an example of a new innovative adaptive capacity that can be operated within the framework of the State's prior appropriation system to reduce drought-related environmental and recreational impacts. Such adaptive capacities, in addition to drought impacts, are important data to acquire during and immediately following drought. Future updates of the State's Drought Mitigation and Response Plan should provide additional information on river administration in relation to the 2011-2013 drought.

The remainder of this section provides a general overview of Colorado's prior appropriation system, an overview of basin-wide river administration during the 2002 drought, and general recommendations for future studies.

### 4.1.1 Introduction to the Prior Appropriation System and Drought

This section describes the prior appropriation system and drought. Information in this section is directly taken from Colorado Water Conservation Board's (CWCB) 2004 Drought and Water Supply Assessment (DWSA) study. For specific case study citations relevant to this discussion review the 2004 DWSA posted on CWCB's website.

The right to appropriate and use water is a valuable property right that arises by the act of placing unappropriated water to beneficial use. This right is protected under Colorado law and is rooted in Colorado's Constitution, which establishes that public uses of water in Colorado are subject to the right to appropriate a water right for private use:

> *The water of every natural stream, not heretofore appropriated, within the State of Colorado, is hereby declared to be the property of the public, and the same is dedicated to the use of the people of the State, subject to appropriation as hereinafter provided*. Colo. Const. Art. XVI, § 5.
>
> *The right to divert the unappropriated waters of any natural stream to beneficial uses shall never be denied*. Colo. Const. Art.XVI, § 6

Like other property rights, vested water rights may not be taken without payment of just compensation, and may be bought and sold separately from land on which they are used. Colorado does not have a "public trust doctrine," like some states and "the public interest" is not a factor considered in adjudicating a water right. However, while the legislature in Colorado cannot prohibit the appropriation or diversion of unappropriated water for beneficial use based on public policy concerns, it can regulate the manner of effecting an appropriation. Important tools for the management of water resources have been developed through case law and statutory enactments governing the diversion and use of water.

As the doctrine of prior appropriation has been interpreted through case law, two major principles have emerged based on the constitutional requirement of "beneficial use" and the conception of water as a property right. First, water must be used efficiently and a water right does not include the right to waste the resource. Second, the right to use water must be sufficiently flexible to accommodate changes of use and the free transferability of water rights in order to allow the maximum use of water in times of scarcity. With regard to the former principle, Colorado courts have required water users to employ an efficient means of diversion, and have limited the amount of water that may be appropriated to the amount necessary for the actual use. Regarding the second principle regarding flexibility of water rights, Colorado law recognizes water storage rights, conditional water rights, augmentation plans, changes to water rights, and instream flow rights, all of which allow water users to make the most of a scarce resource.

In summary, the absence of a permit system or a public interest test in Colorado requires the State to work within the bounds of the priority system, and to respect private property rights, in managing the resource for public purposes in times of drought. However, the prior appropriation system, itself, provides opportunities for management of the resource.

The DWSA 2004 provides additional information on: 1) the elements of the prior appropriation doctrine which promote efficient use of a scarce resource, and which, themselves, are tools for drought management; 2) a summary of federal, state and local legal tools available for drought management in Colorado; and 3) statutory tools adopted by Colorado's legislature to manage water resources within the parameters of the prior appropriation system. The statutory tools are instrumental to managing water supplies during periods of drought for many water users throughout the State and the bulleted items below introduce these tools.[1]

- Instream flows – The ability of the State to appropriate and acquire water within the priority system for instream flow purposes is essential to its ability to protect wildlife and the environment during times of drought.
- Conditional water right – A conditional water right allows an appropriator to secure a priority before water has been applied to beneficial use, based on a showing that the "first step" towards the appropriation has been taken. Conditional water rights are a tool that may be used by cities or individuals to complete major water projects, including storage reservoirs, trans-mountain diversion projects, or pipelines, for managing scarcity in times of drought.
- Storage water rights - A storage right allows the user to store water for later application to beneficial use. Storage rights, like other water rights, are assigned a priority and must be exercised without injury to other water rights. Storage rights are obviously a very important mechanism for ensuring that water supplies will be adequate in times of drought.
- Change in water right – A change in water right allows water users flexibility to maximize potential uses of water by changing the beneficial uses of a water right. A change of water rights includes "a change in the type, place, or time of use, or a change in the point of diversion," and changes in the manner or place of storage. A change of water rights must be approved by the water court and is subject to the "no injury rule," which requires a finding that the change "will not injuriously affect the owner of, or persons entitled to use, water under a vested water right or a decreed conditional water right."
- Leases of water rights – Leases of water, particularly by municipalities during dry years, are common in Colorado. Municipalities will often temporarily lease senior agricultural water rights from farmers to meet demands during a drought. This provides the municipality additional water while allowing farmers to earn some income during a drought year when their crops are not likely to be successful, without permanently changing or selling their water rights. Additionally, the State can lease agricultural and other water rights for instream flow use, which can assist in preserving the natural environment during a drought and provides the same benefits to farmers and municipal leases.
- Augmentation and substitute water supply plans - Augmentation plans and substitute water supply plans allow a water user to divert water out-of-priority from its decreed point of diversion, so long as replacement water is provided to the stream from another source, to make up for any deficit to other water users. An augmentation plan must be approved by the water court while a substitute water supply plan may only be implemented on a temporary basis until an augmentation plan is decreed and is administered by the State Engineer. In times of scarcity, these plans allow a water user to continue diverting even under a relatively junior priority, so long as it can purchase replacement water to satisfy the needs of downstream senior water users.

[1] Additional information on each of these tools is provided in the DWSA 2004.

- Voluntary Measures - During the summer of 2002, when Colorado's drought was at its worst, many water users undertook voluntary measures to ease the impact of drought on other water users and on the environment by abstaining from enforcing their priorities against junior water users. Some water users developed payment arrangements under which senior water users temporarily agreed to forego calling out junior users.

## 4.1.2 River Administration during the 2002 Drought

Historical drought impacts are not a direct predictor of future potential drought impacts. Each drought is unique in severity, scale, and duration and can impact a water user in different ways. Furthermore, water users may have improved their overall adaptive capacity in response to a drought through water supply and drought planning efforts. However, historical impact data can provide valuable insight into the general vulnerability of a water user/region and a useful set of lessons learned to apply to future drought planning and response efforts. Historical data also provide useful information on how river administration can change during a drought and consequently impact water users without requiring a thorough examination of the prior appropriation system.

The remainder of this section provides an overview of changes to river administration during the 2002 drought by the seven water divisions. This overview is simply a summary of some of the administrative changes and drought impacts that occurred in 2002 based on a presentation by the State Engineer, Hal Simpson, at the 2004 Colorado Drought Conference and information provided in the 2004 DWSA. It is recommended that a more thorough assessment of historical drought related administrative changes be conducted in follow-up studies.

### *South Platte River Basin - Division 1*

In 2002, the calls came on in the South Platte River Basin very early (April 1) and there were direct flow calls all summer into the end of October. Normally the call changes from direct flow to storage, sometime around October 1. However in 2002, the direct flow rights call extended until November 1 and storage water rights did not become active until after November 1. Generally, the majority of reservoirs on the plains that served the South Platte River were emptied. Because of the long call, the amount of augmentation water for the wells, including that held by the largest augmentation associations on the South Platte (Groundwater Appropriators of the South Platte [GASP], Lower South Platte Water Conservancy, and Central Water Conservancy District [Central]) was insufficient, and well users had to acquire additional replacement water or face the potential of curtailment. As a result, there were a lot of creative actions taken by the water users and the State Engineer's Office (SEO) to maintain pumping during the irrigation season.

There was a lot of cooperation among water users within the basin. M&I water providers in the Denver Metropolitan Area leased usable return flows to GASP to help them continue pumping by offsetting depletions in the upper part of GASP's service area. Denver, Aurora, and Thornton developed a three-way deal that resulted in effluent being made available to GASP and Central. Additionally, the Colorado legislature appropriated $1 million towards grants for augmentation associations to acquire additional water.

#### *Arkansas River Basin - Division 2*

The Arkansas River Basin ran into a number of very senior calls in 2002. Generally, there is a call on the Arkansas River year-round as a result of the Arkansas River being heavily over appropriated; although the seniority of the call varies. For the first time in history, in 2002, the 1869 water right of the Rocky Ford Highline Canal called. This call took out the Pueblo Board of Water Works' 1874 water right for 45 cfs, which is the foundation of their water supply. Pueblo assumed that they would always have the 45 cfs available, so when the call came on they had to quickly adapt. In response, Pueblo reduced demand by instituting mandatory outdoor watering restrictions and temporarily suspending extra-territorial raw water lease contracts for what they thought was surplus water to downstream augmentation groups and the City of Aurora. The decline in available augmentation and replacement supplies caused the SEO to cut back the pumping of some of the augmentation associations. The Arkansas Groundwater Users Association had to cut back allocations by 25 %.

#### *Rio Grande River Basin - Division 3*

The drought conditions in 2002 resulted in record low streamflows in the Del Norte and Rio Grande Rivers. Releases from Rio Grande, Continental, and Santa Maria reservoirs were initially maximized; however, the reservoir owners stopped making releases due to high transit losses which were as high as 50%. The owners thought that the releases were too much of a waste of a valuable resource, so they stopped running reservoir water and decided to carry it over into the following year. Significant problems also occurred with the Closed Basin in 2002. Decreases in groundwater levels caused a number of wells to pump air where water levels in the aquifer were below the intake to a number of pumps. There was fear that if the following year did not receive sufficient runoff and recharge the aquifer, there would be a very serious impact of drought carried into 2003.

#### *Gunnison River Basin - Division 4*

One of the most notable situations in the Gunnison River Basin during the 2002 drought was administration with respect to the Gunnison Tunnel call. Since the Blue Mesa Reservoir was constructed, the Gunnison Tunnel call had never moved upstream of Blue Mesa Reservoir. Historically, there had been sufficient water in the river in addition to releases from Blue Mesa Reservoir to keep the senior call off. However in 2002, the call was placed in April and stayed on most of the summer which caused the SEO to regulate water rights junior to 1901. This had not happened for about 50 years and there was a new generation of ranchers and people living in the area that simply did not understand the priority system and how the SEO could shut down their water rights. It was a difficult situation for the water commissioner to have to regulate water rights that had not been regulated for over 50 years.

Between the fall of 2002 and April 2003, Redlands Power Authority reduced its demand from 750 to 600 cfs, benefiting the entire Gunnison River Basin and allowing water to be stored in the Aspinall Unit. Redlands was compensated primarily by the Colorado River Water Conservation District for revenue lost due to decreased electrical generation.

### *Colorado River Basin - Division 5*

Reservoirs within the mainstem of the Colorado River Basin had to be managed very closely in 2002. Up to 20,000 acre-feet of replacement water generally stored in Green Mountain Reservoir was not available. This required a lot of cooperation between the Colorado River Water Conservation District, and the Northern Colorado Water Conservancy District in finding an additional 20,000 acre-feet. Surplus water in Ruedi Reservoir was eventually purchased to offset the 20,000 acre-feet of replacement water not available out of Green Mountain.

Also during the summer of 2002, certain Grand Valley entities, including the Grand Valley Water Users Association, Orchard Mesa Irrigation District and the Grand Valley Irrigation Company reduced their call for water to conserve water stored in upstream reservoirs for the next year. This had the added benefit of helping Denver Water by reducing the water it owed under certain contractual arrangements to Green Mountain Reservoir. In addition, during 2002, several large power companies reduced their demand in order to allow reservoirs to fill, benefiting water users all over Colorado who were dependent on stored water.

### *Yampa River Basin - Division 6*

Water users in the Yampa River Basin used most of the reservoir water available to them in 2002. Several reservoirs including Stagecoach, Steamboat, and Elkhead Reservoirs release water for power plants in dry years. In order to sustain the power plants through the summer in 2002, when they had very little, if any, direct flow rights, reservoir releases were necessary to meet the power plant needs. This was a new situation for the water commissions who had never had to protect reservoir releases that far down into the system where the power plant divisions are located.

### *San Juan/Dolores River Basin - Division 7*

In 2002, many of the perennial streams in the San Juan/Dolores River Basin that normally flow year round went dry. This was not due to diversions but simply to low runoff. Many of the reservoirs were down to dead storage or to Division of Wildlife conservation pools to protect the fish population. Colorado was not able to meet the La Plata River Compact obligations to New Mexico. In 2002, 26 miles of the La Plate River dried up and the SEO ceased deliveries to New Mexico because the transit losses were too high. In response diversions below the critical reach of the river were curtailed and return flows were delivered to New Mexico, however, it was only about half of what they were entitled to. This was the fourth consecutive year Colorado did not meet its La Plata River Compact obligations.

## 4.1.3 Recommendations for Future Studies

The prior appropriation system coupled with river administration during periods of drought is an essential component to assessing drought vulnerability throughout the State of Colorado. While a thorough evaluation of this is beyond the scope of this particular study, the following recommendations address how the prior appropriation system and river administration can be incorporated into follow-up drought vulnerability studies. Specific issues and projects that could impact future drought vulnerability are also addressed.

- *Basin-wide assessment of river administration* – The existing and future water demands, types of water use, politics, economic base, water development, etc. within each of the seven water divisions in Colorado is very different. Consequently, the future challenges faced by each division basin to administer supplies and meet future water demands during both normal and drought years are unique to each basin. Future drought vulnerability studies should assess river administration at the division and where appropriate at the water district level.
- *Basin-wide assessment of water users* – Water users throughout Colorado have water right portfolios of various seniorities and consequently drought vulnerability is essentially unique to individual users. While it is not feasible to evaluate the vulnerability of each water user within the State, larger water users, in addition to users of highest vulnerability (which are often smaller water users), should be identified for each water division basin and where appropriate at a water district basin scale.
- *Historical drought data* – Historical drought data provide useful information on how river administration can change during a drought and consequently impact water users without requiring a thorough examination of the prior appropriation system. These data include historical drought indicators data (e.g., streamflows, reservoir storage levels, snowpack, etc.), applicable diversions, interstate compact compliance, call data, etc. At a minimum, 2002, 2003 and 2011-2013 drought-related data should be examined and, where appropriate, previous drought-related data of different magnitudes and severity may also provide insight into the vulnerability of a region. These data should be reviewed on a water division level at a minimum and at a local district level when appropriate. Comprehensive surveys distributed among water users in the State and/or an interactive web-based program designed to receive drought impact data from water users would be useful tool to compile historical and future drought-related data.
- *Basin-wide modeling of river administration* – In order to thoroughly assess future administration during periods of drought and overall drought vulnerability, basin-wide modeling will be necessary. Historical drought-related data discussed above could be used to help calibrate or verify the model.
- *Future river administration changes* - As Colorado continues to grow and develop, water demands will increase placing greater stress on the State's finite water resources and will cause changes to river administration. Additionally, there are several relatively large-scale water development projects being studied as of 2013. Many of these projects involve transbasin diversions which if constructed could have significant impacts on streamflows in

certain river reaches and effect future river administration.  Furthermore, as the State's water resources continue to be developed, meeting compact obligations during dry periods could be a greater challenge. In particular, there is concern that a severe Colorado River Compact call could result in the curtailment of all water users. The earliest date of curtailment would be November 24, 1922, the date of the compact signing.  Future drought vulnerability studies should consider the potential administration changes previously described and quantitatively assess how these changes could affect drought vulnerability on a regional scale where feasible and at a local scale where appropriate.

## 4.2 References

CWCB. 2004. *Drought and Water Supply Assessment.* Chapter 5 – Statutory Framework for Drought Management in Colorado. Prepared by: Jim Lochhead and Avra Morgan

Simpson, Hal. 2004. Conference Drought Proceedings for the Colorado Drought Conference. Administering Water Rights During the 2002 Water Year Lessons Learned. Pg 45.

# 5 STATE ASSETS SECTOR

## Key Findings

- Key drought vulnerabilities for state-owned buildings include damage to structures from resulting wildfires, loss of landscaping, and impacts to correctional facilities and correctional industry programs.

- Critical infrastructure like dams and ditches can be damaged by low water levels and debris flows resulting from wildfires.

- State agencies like Colorado Parks and Wildlife (CPW) (formerly the Division of Wildlife (DOW) and State Parks) and the State Land Board have increased management requirements during drought and may also see decreases in revenue. Since the 2010 update to the Drought Mitigation and Response Plan and the 2011-2013 drought, these agencies have responded by implementing strategies such as using structural and non-structural measures to ensure water-based recreation can continue as long as possible despite drought conditions, and coordinating amongst stakeholders and interested parties to manage water resources for recreational purposes and habitat enhancement. It may be difficult to maintain instream flow rights during low flow periods. However, there are cases where senior calls downstream may inadvertently maintain flows during drought.

- Although systematic documentation is lacking, the impacts to protected areas and ecosystems can be severe and in some cases irreversible. This section addresses impacts as they relate to state assets. Broader analysis can be found in the Environmental sector.

The 2011-2013 drought was, at the time of the 2013 Plan update, ongoing. As a result, comprehensive data related to State Assets were not yet available because they were still being collected. While the full extent of the impacts of the 2011-2013 drought have yet to be seen or measured, many observations are available for inclusion in this update and still provide useful insight into the impacts drought has on State Assets.

## Key Recommendations

The following key recommendations were originally developed in 2010 and continue to be relevant in 2013. Many of these were taken into account during the 2013 update.

- Increased drought awareness and planning could benefit all of the state assets discussed in this section. Every agency should have a drought plan that addresses the vulnerabilities noted in this report.

- Agencies should be aware of their specific vulnerabilities and start developing policies to provide additional response and flexibility during drought.

- Lack of coordinated media outreach is often cited as a shortcoming during the 2002 drought. Since that time, efforts have been made to improve the situation. For example, in 2012 and 2013, the Public Information Officers of the Front Range Water Council collaborated and communicated on media and messaging campaigns. Nonetheless, additional media plans and coordination should be developed now to avoid confusion when a drought does occur.

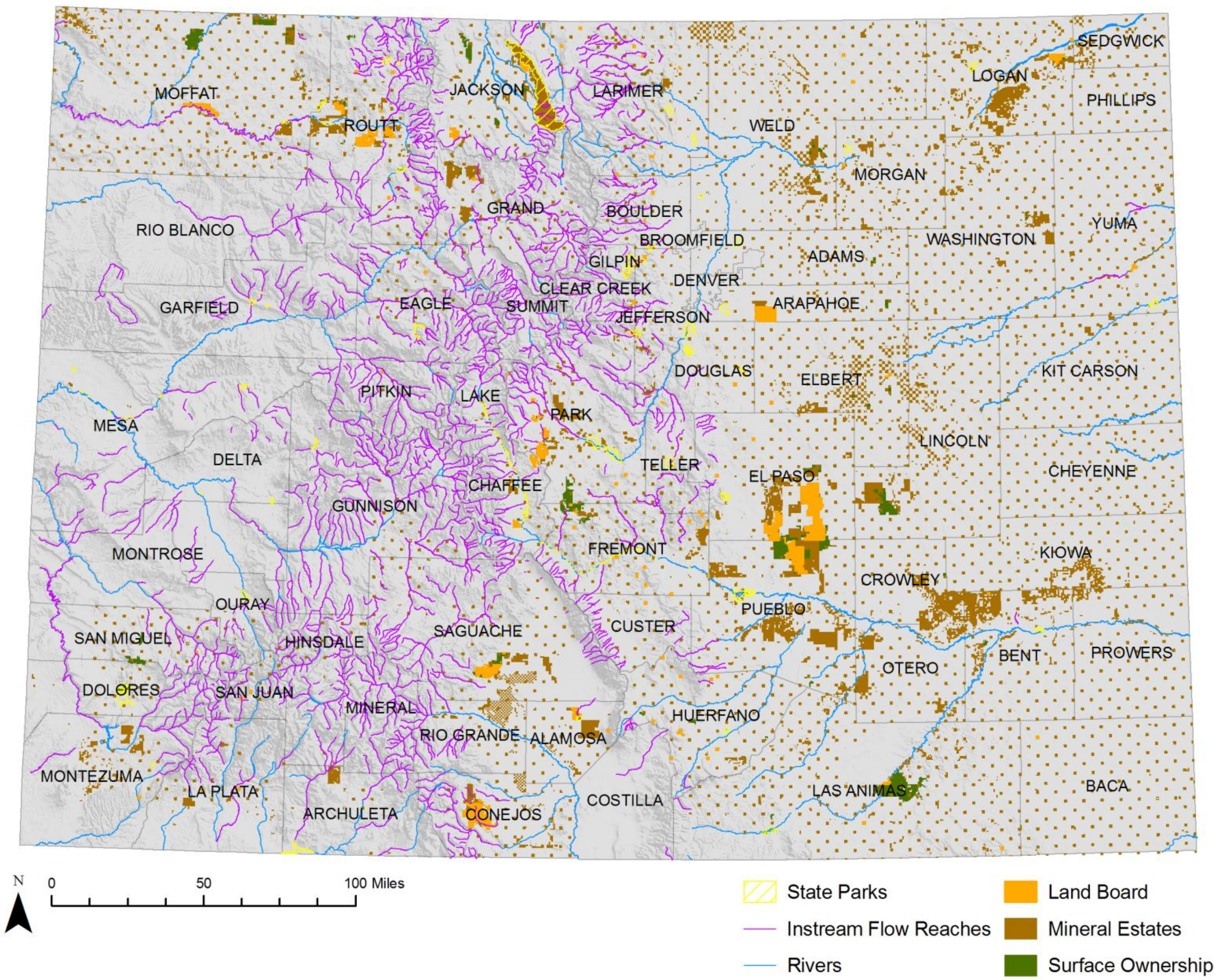
- In many cases vulnerability data are not available consistently statewide. Section 5.6.2 outlines future data gathering tasks for each impact category.

## 5.1 Introduction to Sector

The State of Colorado owns and/or operates numerous assets, which for the purposes of this report include: buildings, critical infrastructure, state lands, instream flows, and state fisheries. Drought vulnerable critical infrastructure includes: dams, transmountain ditches, and irrigation ditches. Instream flow rights are non-consumptive “in-channel” or “in-lake” water rights that can only be held by the Colorado Water Conservation Board (CWCB). These rights designate minimum flows between specific points on a stream, or water levels in natural lakes. Figure 5.1 shows the major state-owned lands and instream flow reaches.

The primary agencies responsible for drought vulnerable assets are the State Land Board (Land Board) and CPW. The intent of this section is not to exhaustively cover the impacts of drought on all state agencies; rather, the focus is placed on the agencies that control the majority of the physical assets within Colorado that are vulnerable to drought. Given the wide variety of state asset types and their spatial distribution, vulnerability to drought is highly variable. It should also be noted that many of the state assets discussed in this section are natural resources. As such, there is significant overlap between this sector and the Environmental sector. The analysis of state asset vulnerability focuses on drought impacts as they relate to state operations and management practices. For a broader analysis of ecosystem vulnerability refer to the Environmental sector. For a general description of the vulnerability assessment approach refer to Chapter 2 (Annex B).

## Figure 5.1. Distribution of State Assets




Source: Land Board, COMaP, and CWCB, data provided 2013; Figure revised 2013

Many state assets are conservation areas or protected wildlife that cannot be adequately evaluated based on the revenue they generate. Colorado is renowned for its wilderness areas and outdoor recreation opportunities. The value of these areas goes far beyond any land value or revenue stream. Still, economic considerations are important because the revenues generated by state assets help to maintain protected areas. In fiscal year 2010-2011, the Land Board generated approximately $123 million in gross revenue from leases and mineral royalties, an all-time high and more than double the previous year. This is mostly due to unprecedented returns from the Land Board's minerals estate and interest on the part of energy companies to lease land for oil and gas development (Board of Land Commissioners, 2011). This money gives funding to public schools among other beneficiaries including public universities and penitentiaries. In the following year Colorado state parks had total visitation of over $12 million. From this CPW generated over $96 million in revenue from licenses, passes, fees and permits, which is approximately 52% of its funding (CPW, 2013). This revenue helps fund conservation efforts by the division. While it is inaccurate to value state assets based on these revenues, it is important to note revenue sources and assess their drought vulnerabilities.

State assets have significant overlap with the Environmental, Recreation, and Municipal and Industrial sectors. The State owns or operates vast areas across the State, much of which is protected from development. State agencies like the CPW and the Colorado State Forest Service (CSFS) are responsible for much of the environmental and species management across the State. These agencies are important resources for the Environmental sector as a whole. The State is also an important investor in critical infrastructure, such as dams which provide important storage for municipal water providers. Revenue from the Land Board provides funding for public schools and other public amenities. As a whole, state assets contribute immeasurably to the value and quality of life of the State. This in turn impacts population growth, real estate value and the economic vitality of the State as a whole. Conversely, state agencies are dependent on tax revenue, thus impacts to other sectors can directly impact operating budgets.

## 5.2 Vulnerability of State Asset Sector to Drought

### 5.2.1 Aspects of Vulnerability

The diversity of state assets is reflected in their wide range of drought vulnerabilities. Specific impacts and adaptive capacities will be covered in more detail by asset in Section 5.3.

Table 5.1 outlines the impacts and adaptive capacities for state assets. Environmental assets such as instream flows and protected areas can be detrimentally impacted by drought. Decreased streamflows threaten instream flow rights and aquatic habitat. Low flows can also result in higher water temperatures that change water chemistry, harming some aquatic species. State-owned fish hatcheries may experience decreased water supply that could threaten their operations. Terrestrial habitat is also impacted by drought. Plants become stressed and are more susceptible to disease and infestation. Beetle kill and increased occurrence of wildfire are often cited as secondary drought impacts. Plant stress and decreased forage translate directly to animal stress. In times of drought there are often increased incidents of crop damage by animals.

Drought can also impact vital revenue streams. As reservoir levels decline so does visitation to water-based state parks. Wildfires and fire restrictions can also impact visitation numbers. In 2002, forage production on state-owned lands was so severely impacted that the Land Board issued countywide lease discounts to encourage responsible management practices.

Buildings and critical infrastructure such as dams and ditches are usually omitted from drought vulnerability assessments despite potential costly impacts. For example, building foundations can be damaged if they are on expansive soil that dries out. Landscaping can be damaged or lost if municipal water restrictions are imposed or water rights are out of priority. Wildfire resulting from drought conditions can destroy buildings in its path and create air quality issues that affect a much larger radius. Decreased pore water pressure can cause structural damage to dams. Water supply ditches that remain dry for extended periods of time are prone to animal damage and overgrowth.

Adaptive capacities for state assets vary as much or more than vulnerabilities. As noted above they are discussed in more detail in Section 5.3. Most agencies could benefit from additional drought planning and awareness of possible drought impacts. Coordination between agencies and media relations is key during drought and these protocols should be established in advance. In the case of CPW, additional monitoring is needed during periods of drought to assess and prioritize direct impacts to priority species and habitats and identify particularly vulnerable species and habitats. Additional instream flow and natural lake rights will also help preserve aquatic environments in times of drought.

**Table 5.1. Key Impacts and Adaptive Capacities of Drought Vulnerable Assets**

| State Asset | Key Impacts | Key Adaptive Capacities |
|---|---|---|
| State Buildings | • Damage due to wildfires<br>• Loss of landscaping<br>• Damage to structure as a result of soil drying | • Invest in less water intensive landscaping<br>• Make a drought plan |
| Critical Infrastructure | • Structural damage to dams and ditches resulting from low water levels<br>• Damage caused by high sediment loads when pulling water from the bottom of reservoirs<br>• Damage caused by debris flows and flooding from wildfires | • Budget for additional maintenance and oversight during and following a drought<br>• Take advantage of low water levels to maintain and repair structures |
| Land Board | • Damage to rangeland and agricultural areas<br>• Loss of agricultural lease revenue | • Offer lease discounts in return for less intensive land use |

| State Asset | Key Impacts | Key Adaptive Capacities |
|---|---|---|
| Parks and Wildlife | • Decrease in water-based recreation resulting from low water levels and degraded water quality<br>• Decrease in recreation resulting from wildfires or fire restrictions<br>• Damage to protected habitat and possible loss of protected species<br>• Increased management requirements<br>• Loss of licensing revenue for CPW | • Increased press relations coordination<br>• Decrease operating costs by cutting seasonal staff<br>• Land and angling closures<br>• Change the number of licensees released<br>• Increased monitoring efforts and drought planning during non-drought times |
| Instream Flows | • Inability to maintain instream flow rights resulting in impacts to fisheries and aquatic habitat | • Increase water rights portfolio<br>• Obtain conditional lease agreements for drought conditions |

### 5.2.2 Previous Work

The 2010 update to the Colorado Drought Mitigation and Response Plan (Plan) was the first time a quantitative vulnerability assessment was conducted for state assets. However, at the time of the 2013 Plan update, the 2011-2013 drought was ongoing and therefore the full extent of the drought was unknown in terms of reliable, measured data. As a result, much of the vulnerability assessment discussed below focuses on the 2002 drought, the most recent complete drought event. Where applicable, updated data are presented, including observations that are worth noting regarding the impacts of drought on State Assets.

In the past, drought mitigation plans have assessed vulnerability only on a cursory level. For example, the CWCB conducted a Drought Water Supply Assessment (DWSA) in 2004 to determine the State's preparedness for drought and identify limitations to better prepare for future droughts. The details of this work are discussed in Section 4.1.1. It entailed a survey, or opinion instrument, where 537 responses were received statewide on specific impacts experienced during the dry period of 1999-2003. Various entity types were surveyed including power, industry, agriculture, municipal, state, federal, water conservancy and conservation districts, and tribes and counties.

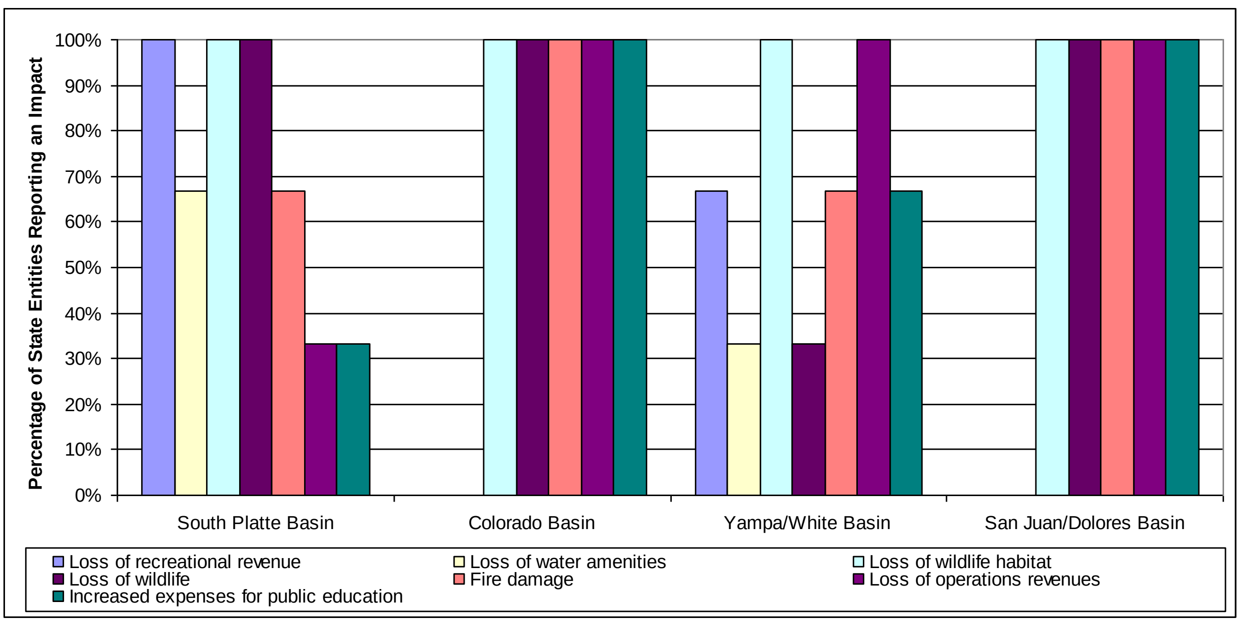
The results of the DWSA survey are helpful in understanding the opinions of Colorado's water users statewide and on a basin-wide scale in terms of existing and future water conditions. However, responses were not received from everyone in the state and coverage is not sufficient to examine results on a county level.  These spatial limitations, along with uncertainty in the interpretation of specific survey questions by the respondents, make it impossible to incorporate DWSA results into the vulnerability methodology developed for this study. However, there is pertinent information that should be analyzed in a qualitative way to inform and verify vulnerability findings.

Figure 5.2 provides the percentage of surveyed State entities that experienced the impacts listed at the bottom of the figure. State entities surveyed included the Division of Water Resources

(DWR), Colorado State University (CSU) Cooperative Extension, CSFS, Land Board, Steamboat Lake State Park, Department of Corrections, CPW[1], and the CWCB. It is important to note that only those categories that are applicable to the State Assets sector are shown in the figure. For example, results from loss of crop yield or loss of livestock are not shown. Additionally, only state entities within the South Platte, Colorado, Yampa/White, and San Juan/Dolores Basins responded to the survey with impacts and therefore only their results are shown. Of the eight state entities surveyed, impacts were reported in the following categories during the 1999-2003 drought period:

- Loss of recreational revenue
- Loss of water amenities
- Loss of wildlife habitat
- Loss of wildlife
- Fire damage
- Loss of operations revenue
- Increased expenses for public education

**Figure 5.2. 1999 - 2003 Drought Impacts to State Assets**




Note: Despite a comprehensive review and internal testing process of the survey tool, these DWSA 2004 surveyed impact results are subjective. The impacts in the figure above are a reflection of the surveyees' interpretation of the listed impacts.

All state entities within each of these four basins reported impacts due to loss of wildlife habitat. Nearly all of the entities experienced loss of wildlife and loss of operations revenue. Fire damage and increases for public education were also categories that impacted state entities. Loss of

[1] At the time the DWSA survey was conducted, Colorado State Parks and the Division of Wildlife were separate agencies. They are referred to herein as CPW due to their merger in 2012.

recreational revenue and loss of water amenities were only reported in the South Platte and the Yampa Basins.

In general, the impact categories identified in the DWSA findings are well aligned with the impacts covered in this vulnerability assessment. It is difficult to compare results spatially because many of the agencies surveyed have activities across the State (e.g., DWR, Land Board, etc.), but they only provided a single set of responses. Further surveying is needed to determine spatial extent.

Another relevant previous study that has been conducted in Colorado is the Statewide Water Supply Initiative (SWSI), and the 2010 update (SWSI 2010 update). Although it did not specifically focus on drought as the DWSA did, the SWSI process was another important initiative undertaken and directed by the CWCB to understand existing and future water supply needs, and how those needs might be met through various water projects and water management techniques. SWSI used a statewide and basin-level view of the water supply conditions in Colorado. In 2010 the CWCB completed a Non-consumptive Needs Assessment (NCNA) Focus Mapping Report (CWCB 2010b). The NCNA expands upon the existing set of environmental and recreational attribute maps that were developed through the SWSI 2010 update process and develops aggregated maps of Colorado's critical waters based on the concentration of environmental and recreational qualities. The maps are intended to be a guide for water supply planning, so that future conflicts over environmental and recreational water needs can be avoided.

Many of the in-channel, flow-based, and non-consumptive uses discussed in SWSI and NCNA are completely or partially state assets. For example, instream flows and CPW coverages such as critical habitat areas were analyzed throughout the State in light of how they can affect water supply planning and management. Although these assets are not traditionally used in water planning, they were used in SWSI and further investigated in NCNA to highlight the increased importance that stakeholders feel they are playing in enhancing recreational and environmental uses of water. In the NCNA, instream flows were used as one measure in determining the initial basis for estimating future uses for recreation and environment. Providing instream flows for recreational activities, such as rafting and kayaking, and maintaining minimum instream flows to protect critical habitat areas are seen as important aspects to consider in the planning process. Data on instream flows and critical habitat were gathered and are available as geographical coverages in Section 4 of the SWSI 2010 update and in the NCNA (CWCB, 2010; CWCB, 2010b). NCNA results and their applicability to this vulnerability assessment are discussed in more detail in the Recreation and Environment sectors.

Municipal water suppliers and agriculture are usually considered to be the most drought vulnerable and therefore drought planning efforts often focus on these groups. This drought vulnerability assessment goes further by specifically considering environmental, recreational, state asset, and general socioeconomic drought vulnerabilities. The emphasis placed on these groups in SWSI planning efforts supports the approach taken here and corroborates the interconnectivity of these groups.

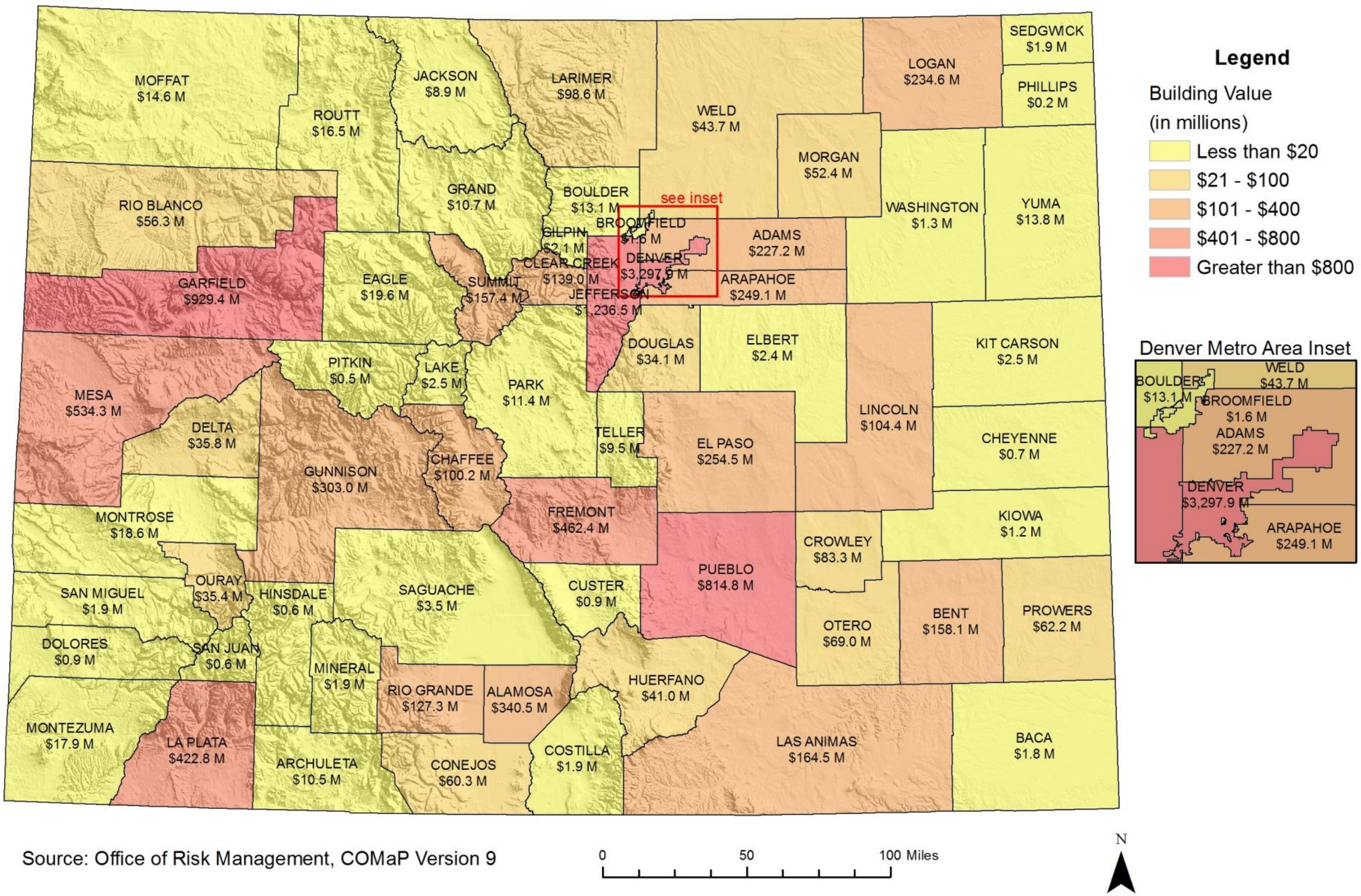
## 5.3 Assessment of Impacts and Adaptive Capacities

In the following section, potential impacts and adaptive capacities for state assets are discussed in detail. The discussion is organized around the following sub-sectors: buildings, critical infrastructure, Land Board, CPW, and instream flow rights. There is significant overlap between the State Assets and the Environmental sector. The discussion in this section is directed toward vulnerabilities as they impact state assets specifically. For more detailed information on drought impacts to the environment as a whole refer to the Environmental sector.

### 5.3.1 State-Owned Buildings

The State of Colorado owns thousands of buildings through a myriad of state agencies and programs. Figure 5.3 shows the total building value by county for all state-owned buildings. There are state-owned buildings in every single county, with the highest concentration of assets located along the central Front Range.

**Figure 5.3. Total State-Owned Building Value by County (Data provided by the Office of Risk Management 2013)**




Source: Office of Risk Management, COMaP Version 9

Figure revised 2013

Drought impacts to buildings are rarely mentioned because they are not as dramatic as the impacts from other hazards. However, there are several drought-related damages that should be considered. Table 5.2 outlines the main impacts and adaptive capacities identified for this asset.

If the building is located on expansive soils, foundation cracking can occur as soil moisture decreases and clay-based soils contract. While this is a well known relationship, no work has been done to directly relate drought and structural degradation.

Buildings may also be forced to change operations and maintenance procedures during drought. As with the structural issues identified above, no work has been done to directly analyze these impacts. Most state buildings rely on the municipal supplier for water, so they will be impacted in similar ways to residential and industrial water purchasers. They will be subject to whatever watering restrictions or surcharges their water providers impose.[2] Water restrictions can impact landscaping and damage lawns. The same impacts, or greater, may be seen for properties with their own water rights. If these water rights are junior, watering could be completely cut off. Similarly, properties using groundwater may be impacted by declining water tables or augmentation plans that are difficult to fulfill during drought.

One of the biggest threats to state-owned buildings during drought is from increased occurrence of wildfire. Buildings located in high wildfire hazard areas are more vulnerable to catastrophic losses as a result of drought-induced wildfires. Wildfire hazard areas are discussed in more detail in the Environmental sector. In addition to fire damage to buildings, smoke and ash in the air can harm heating, ventilating, and air conditioning (HVAC) systems in affected areas. Ash can also cause extra wear and tear on building exteriors.

The Colorado Department of Corrections (CDOC) has state-owned facilities in 11 counties and private prison contracts in four more. Three facilities are solely dependent on their own public water supply systems for potable and fire protection water. Several others depend on municipalities without sufficient senior water rights or are basin-dependent on water. Both situations increase water supply vulnerability during times of drought. For particularly vulnerable facilities, an extended drought could result in significant operational impacts like interim facility closures or extensive trucking operations to supply potable and fire protection water. Additionally, the Division of Correctional Industries has several programs in its agricultural sector which are directly vulnerable to drought (e.g., crops, greenhouses, hatcheries, etc.). If these programs are damaged by drought, population management concerns can result from idleness.

In 2013, CDOC is mainly concerned about those facilities located in the Arkansas basin, due to the conditions that exist there. If the drought persists, CDOC believes that water allocations from the Fryingpan-Arkansas Project will become less available, making Crowley County Water Association augmentation less feasible. In 2011-2013, level II drought restrictions were implemented and directly impact facility landscaping. An indirect impact of the watering

[2] Refer to the Municipal sector for information on drought vulnerabilities of water providers

restrictions can be higher local temperatures. Irrigation increases the amount of water available for plants to release into the air through evapotranspiration. When the soil is wet, part of the sun's energy is diverted from warming the soil to vaporizing its moisture, creating a cooling effect. Watering restrictions can thus have the indirect impact of local warming as well as increasing dust in the air as soils become dry. Costs are associated with both impacts, including greater use of air conditioning and increased housekeeping and equipment maintenance to contend with dust. There are no concerns for CDOC facilities on the western slope and in the metropolitan Denver area (CDOC, 2013a). The CDOC does not anticipate serious water shortages for their agriculture program, as it is supported by relatively senior water rights. Their other specialty programs, such as the aquaculture, wild horse, and fisheries programs are on potable water systems and providers do not anticipate significant shortages in 2013 (CDOC, 2013b).

**Table 5.2. State Buildings Impacts and Adaptive Capacities**

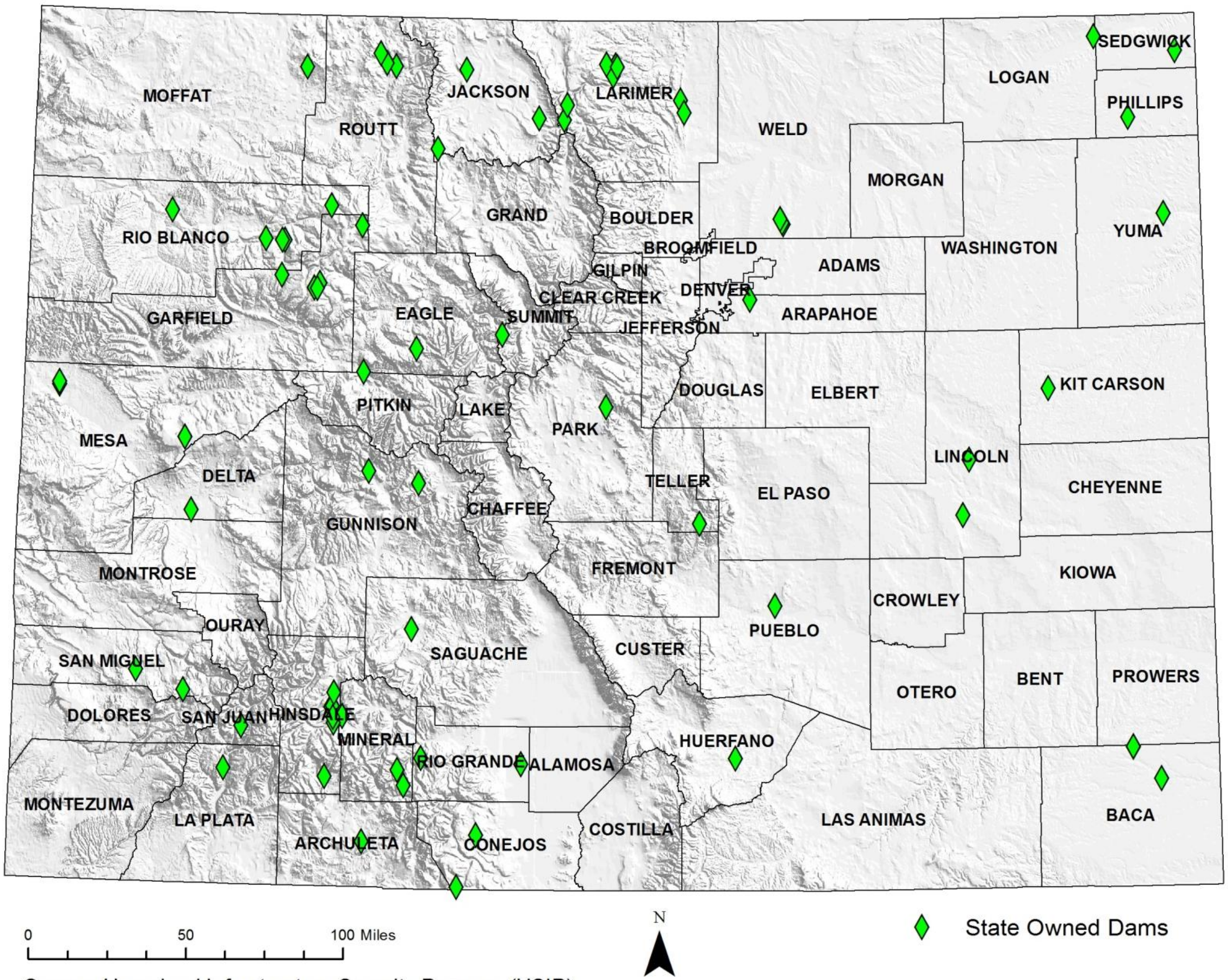
| Key Impacts to State Buildings | Key Adaptive Capacities or Mitigation Strategies |
|---|---|
| Increased exposure to wildfires | • Coordinate with local officials<br>• Create a fire barrier and do additional pruning |
| Increased wear and tear on building exterior and HVAC systems due to air pollution | • Identify which buildings are in high-risk areas and plan to replace or upgrade exteriors and HVAC systems as part of Operations and Management budget |
| Water shortages due to out-of-priority rights or restrictions imposed by municipality | • Plan landscaping to incorporate drought-resistant or native plant species that are capable of surviving on reduced water.<br>• Limit access to stressed lawns during drought |
| Possible water shortages for correctional facilities and industry programs | • Secure back up water supplies for facilities identified as highly vulnerable.<br>• Make sure drought plans are in place to react efficiently if water shortages do occur |

## 5.3.2 Critical Infrastructure

Critical infrastructure refers to state-owned or operated infrastructure that could be impacted by drought. For this assessment this covers water storage and delivery infrastructure such as: dams, transmountain ditches, and irrigation ditches. This does not cover all state-owned critical infrastructures, but focuses on those assets that could be directly impacted by drought.

The highest value critical infrastructure for the State is dams. Figure 5.4 shows the state-owned dams and water facilities. Transmountain ditches are vital conveyance infrastructure used to move water from one basin to another. In general, water is transferred from the western slope to the Front Range. Figure 5.5 outlines the major transmountain ditches in the State. It is important to note that these are not all state-owned projects.

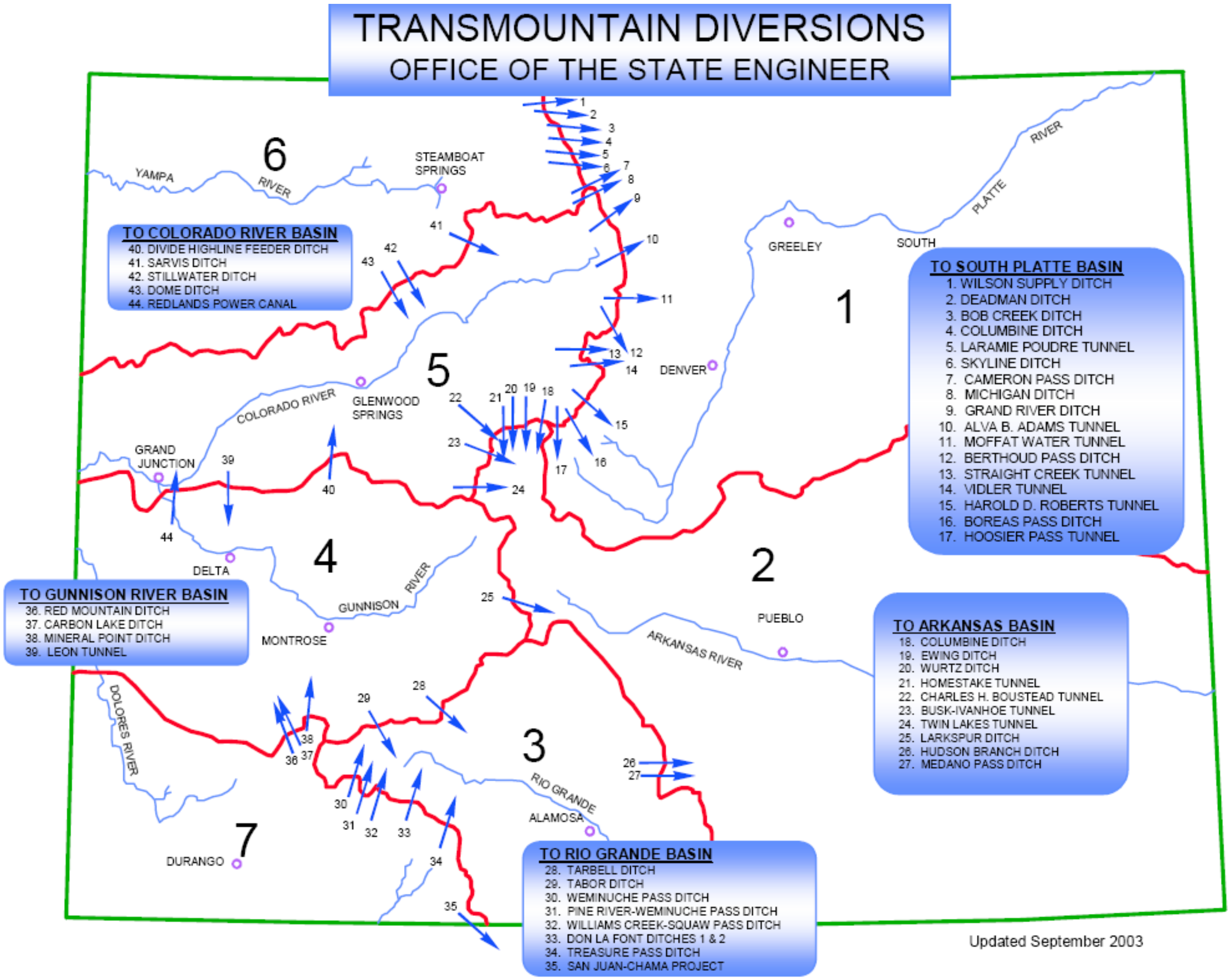
## Figure 5.4. State-Owned Dams




Source: Homeland Infrastructure Security Program (HSIP), COMaP Version 9

Figure revised 2013

## Figure 5.5. Transmountain Diversions




Source: Byers and Wolfe, 2003

Drought has several primary and secondary impacts to critical infrastructure. Decreased water levels in dams and ditches can lead to structural damage as pore water pressure decreases. In personal communications with water commissioners, increased animal holes and overgrowth of ditches that remained dry for extended periods of time were cited. In general, increased maintenance and oversight are required for these structures during drought. In some cases decreased water levels can be taken advantage of to perform maintenance on areas that would normally be submerged.

As reservoir water levels decline the sediment load increases. In severe cases this can cause damage to outlet structures and water treatment facilities. Water quality can also be impacted by drought induced wildfires which lead to debris flows and flooding. This can significantly impact structures, including potentially catastrophic damage to dams.

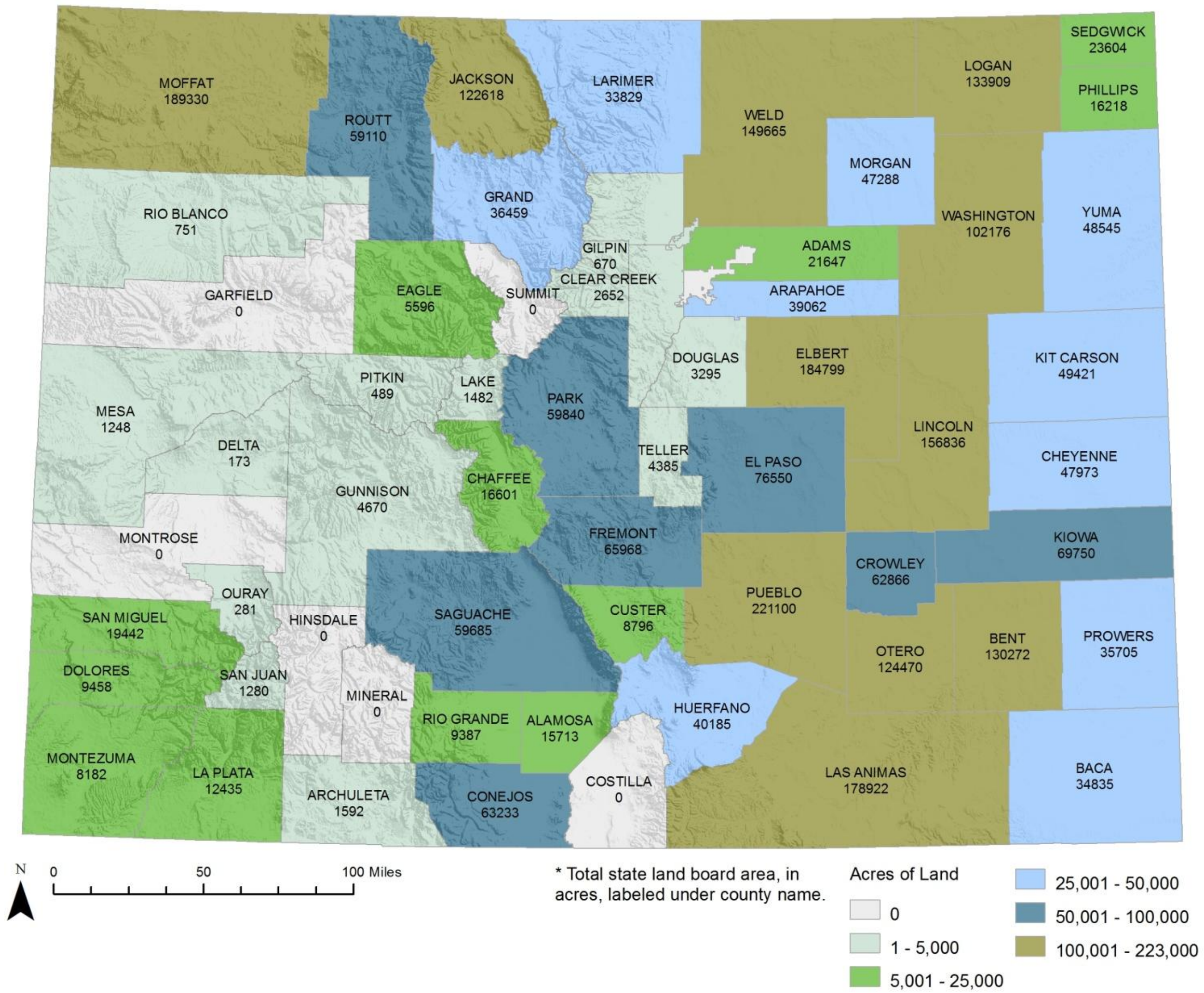
**Table 5.3. Critical Infrastructure Impacts and Adaptive Capacities**

| Key Impacts to State Buildings | Key Adaptive Capacities or Mitigation Strategies |
|---|---|
| Decreased water levels in dams can cause structural damage | • Take advantage of low water levels to conduct maintenance |
| Dry ditches can be damaged by animal holes and increased vegetative growth | • Budget for additional ditch maintenance following drought |
| High sediment loading resulting from low reservoir levels or wildfires can damage structures. | • Pre-emptive fire management in key supply basins<br>• Focused beetle kill management in key supply basins |
| Flash flooding following wildfires can damage structures | • Pre-emptive fire management in key supply basins<br>• Focused beetle kill management in key supply basins |

## 5.3.3 Land Board

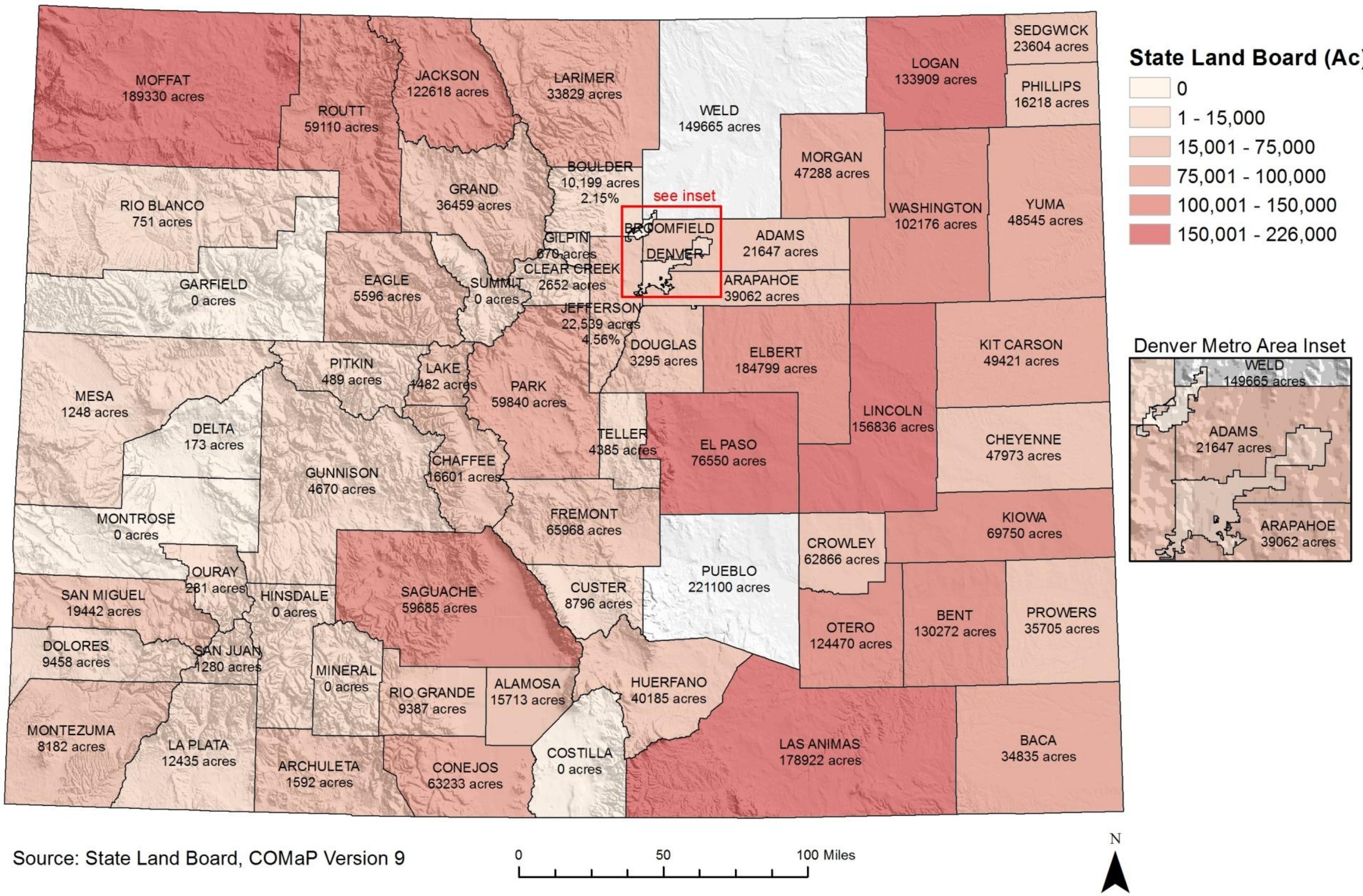
The Land Board is responsible for managing more than three million acres of land and four million acres of mineral rights given to the State by the federal government in 1876. Figure 5.6 and Figure 5.7 show the total Land Board ownership by county for both surface and mineral rights respectively. As can be seen from these maps, distribution of state-owned land is greatest in the eastern half of the State. The State does, however, own surface and/or mineral rights in nearly every county in Colorado.

## Figure 5.6. Land Board Land Ownership




Source: Land Board, data provided 2010. Figure revised 2013

## Figure 5.7. Land Board Mineral Rights




Source: State Land Board, COMaP Version 9

Figure revised 2013

The Land Board generates revenue by leasing land for agricultural and industrial activities. They also lease mineral rights and receive a significant portion of their revenue from mineral royalties. Revenue generated by the Land Board goes to public schools, parks, prisons, and other public buildings. Table 5.4 lists the eight trusts that receive Land Board funding and the total revenue generated for each in fiscal year 2010-2011. Public schools are by far the largest beneficiary. Table 5.5 gives the leasing revenue by source for fiscal year 2010-2011. Agricultural leases account for most of the land leases, but they do not generate as much revenue as the mineral assets and the oil/gas/coal royalties.

### Table 5.4. Land Board Trust Recipients

| Revenue Dollars to All Trusts FY 2010-2011 | |
|---|---|
| School | $120,557,802 |
| CSU | $891,938 |
| CU | $29,329 |
| Internal Improvements (Parks) | $509,076 |
| Saline Trust (Parks) | $25,244 |
| Penitentiary | $11,741 |
| Public Buildings | $737,340 |
| Hesperus (Fort Lewis) | $6,036 |
| Forest /Other | $103,562 |
| **Total** | **$122,872,069** |

Source: Board of Land Commissioners 2011; Total Income

### Table 5.5. Land Board Leasing Revenue

| Gross Revenue Dollars by Source | |
|---|---|
| Agricultural Rental Income | $9,829,765 |
| Commercial Revenue | $2,457,441 |
| Gas Royalty | $15,973,369 |
| Oil Royalty | $17,202,090 |
| Coal Royalty | $7,372,324 |
| Bonus Income | $63,893,475 |
| All Other Income | $6,143,603 |
| **Total** | **$122,872,069** |

Source: Board of Land Commissioners 2011

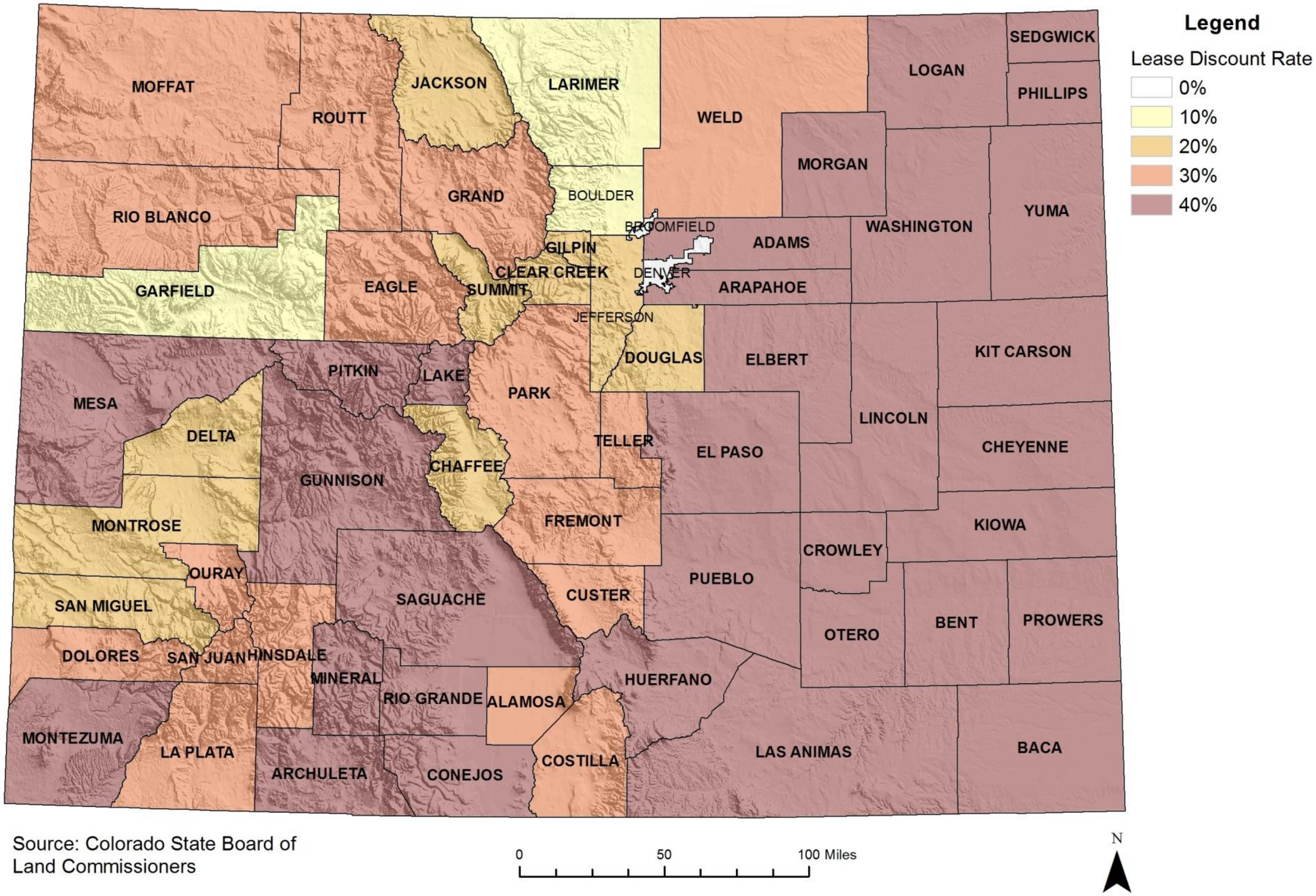
Table 5.6 outlines the key impacts and adaptive capacities of the Land Board during drought. Based on conversations with Land Board employees, mineral asset revenue is relatively drought tolerant. While it is likely that mineral producers may incur extra operating costs in a drought, it is unlikely that the producing companies would actually stop operations or postpone planned expansion. However, most mining activities do require water. It is possible that in a severe drought mining operations would be unable to purchase the water they need for production.[3] Given the importance of mining revenue to the Land Board this possibility should be taken seriously in any planning efforts.

The most vulnerable revenue stream for the Land Board is the agricultural lease revenue. Under drought conditions the impacts to rangeland and resulting carrying capacity reduction can lead to serious overgrazing concerns and financial hardship for the agricultural lessees. Similarly crop yields on agricultural leases may be significantly decreased or, in extreme cases, crop failure may occur. Agricultural leases through the Land Board are issued on a 10-year basis making it difficult for farmers and ranchers to increase or decrease leased area in response to drought. However, the Land Board has a vested interest in the responsible stewardship of the land and may be willing to offer lease discounts during drought. The intent of such discounts would be to give land mangers financial incentive to decrease land use intensity.

In the 2002 drought the Land Board found that forage production on some of their lands was down as much as 90-100% (Board of Land Commissioners, 2002). Given the severity of the drought and the widespread impact, the Land Board issued blanket agricultural lease reductions based on county scale drought indices developed from the Standard Precipitation Index. Figure 5.8 shows the lease discount percentage per county that was applied between September 2002 and August 2003. This program was not offered during the 2011-2013 drought because it was discontinued in 2012.

[3] Refer to the Energy sector for more information on mining

## Figure 5.8. Land Board Agricultural Lease Discounts in 2002




Source: Colorado State Board of Land Commissioners

Figure revised 2013

The total cost of the 2002 lease discounts was estimated by Land Board staff to be just over $1.9 million (Board of Land Commissioners, 2002). Unfortunately, these discounts did not have the intended mitigating impact because many lessees continued to manage the land as usual in spite of the discount, and did not decrease grazing intensity. As a result of this experience, during future droughts the Land Board was intending to only offer lease discounts when applied for on a case-by-case basis because past experience had shown that lessees are personally involved in applying for a discount and negotiating terms with the Land Board. Unilateral discounts do not require communication on the part of the operator and are too extensive to be sufficiently monitored by the Land Board. However, this program was discontinued in 2012 and will not be available for use in future droughts. Given the nature of most lands owned by the Land Board, there is little that they can do to mitigate against dry land crop yield and forage decreases in drought.

This is a good example of the interconnectedness of the State Assets Sector with the other sectors. From the view point of the Land Board, possible decreases in lease revenue represent drought vulnerability. This, in turn, is a vulnerability to all of the trusts receiving funding from the Board. However, from the viewpoint of agricultural lessees, the ability to negotiate lease terms in times of drought is an important adaptive capacity.

**Table 5.6. Land Board Impacts and Adaptive Capacities**

| Key Impacts to State Trust Land | Key Adaptive Capacities or Mitigation Strategies |
|---|---|
| Decreased forage and crop yields on leased lands – negative impacts to lands if lessees don't appropriately adjust grazing management | • Offer agricultural leases at discounted rates in return for decreased intensity of land use. |
| Decreased mining activity if water is not available for production | • Increased drought planning by mining companies |

## 5.3.4 Colorado Parks and Wildlife

CPW manages 42 state parks, nearly 350 state wildlife areas, 19 state fish hatcheries, and all 960 species of Colorado wildlife (CPW, 2013). CPW also works to protect and recover threatened and endangered species and conducts research to provide wildlife management and species protection information to the public and other land management agencies.

Figure 5.9 shows the location of all the state parks, colored according to the activities available. River corridor parks were designated as "River" any park with fishing or boating activities listed was designated "Water" and parks without any boating or fishing activities were designated "Land." Figure 5.10 shows the average annual visitation for each of the state parks. This map is instructive from a statewide perspective and shows that the most popular parks are located in urban areas. However, it is important to note that smaller parks in less developed areas often contribute proportionally to the local economy. Further discussion on the impacts to areas surrounding state parks is included in the Socioeconomic Sector. Figure 5.10 highlights the fact that visitation can vary by orders of magnitude from park to park. Revenue is also generated by river outfitter licensing and rafting trips. CPW gets a portion of all rafting trip revenue for trips that go through state parks.

Figure 5.11 shows the lands owned and/or managed by the CPW. CPW's influence is primarily focused in the western half of Colorado, but the CPW also has important lands in the Northeast and Southeast of the State. The land within CPW is owned by multiple entities/agencies and is divided as follows: Land Board, 36%; CPW, 23%; US Army Corps of Engineers, 12%; US Bureau of Reclamation, 11%; Local government/other, 8%; irrigation companies, 7%; and US Forest Service/Bureau of Land Management, 3% (CPW 2013). In addition to land management and ownership, CPW owns the facilities within state park boundaries (e.g., visitor centers and restrooms) and two marinas. CPW also holds numerous construction easements on lands.

The CPW operating budget comes mainly from licenses, passes, fees and permits; lottery and Great Outdoors Colorado (GOCO) funds; and Federal and State grants. Table 5.7 shows the contribution of various revenue sources to CPW for fiscal year 2011-2012.

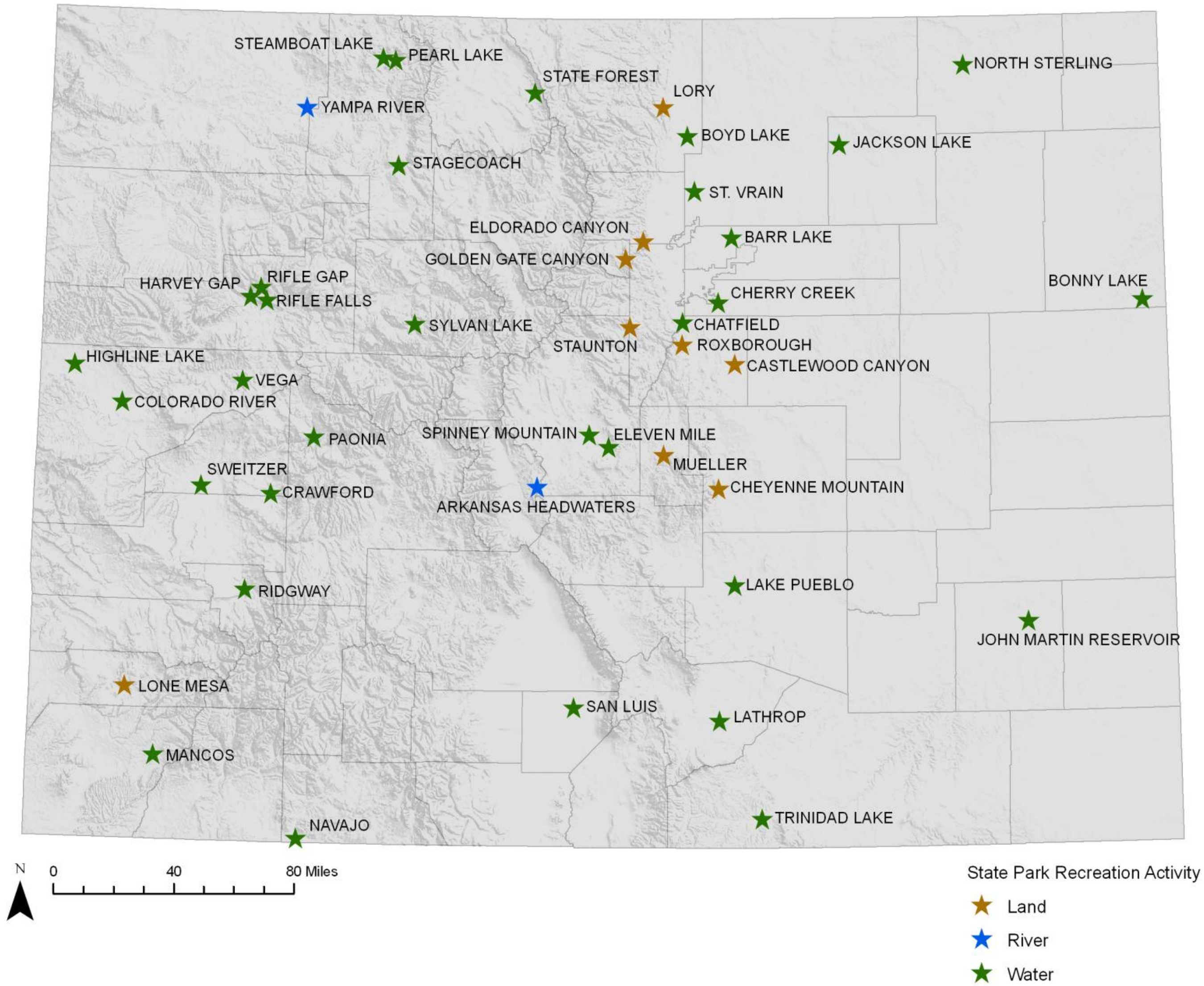
**Table 5.7. CPW Funding 2011-2012**

| Source of Revenue | FY 11-12 |
|---|---|
| Licenses, Passes, Fees and Permits | $ 96,888,669 |
| Lottery and Great Outdoors Colorado | $36,005,547 |
| Federal and State Grants | $28,657,416 |
| Registrations | $8,557,113 |
| Sale of Goods, Services and Assets | $2,761,584 |
| Donations | $1,471,773 |
| Interest Income | $1,066,313 |
| Other Revenues | $1,430,794 |
| Severance Tax | $8,514,076 |

Source: CPW 2013

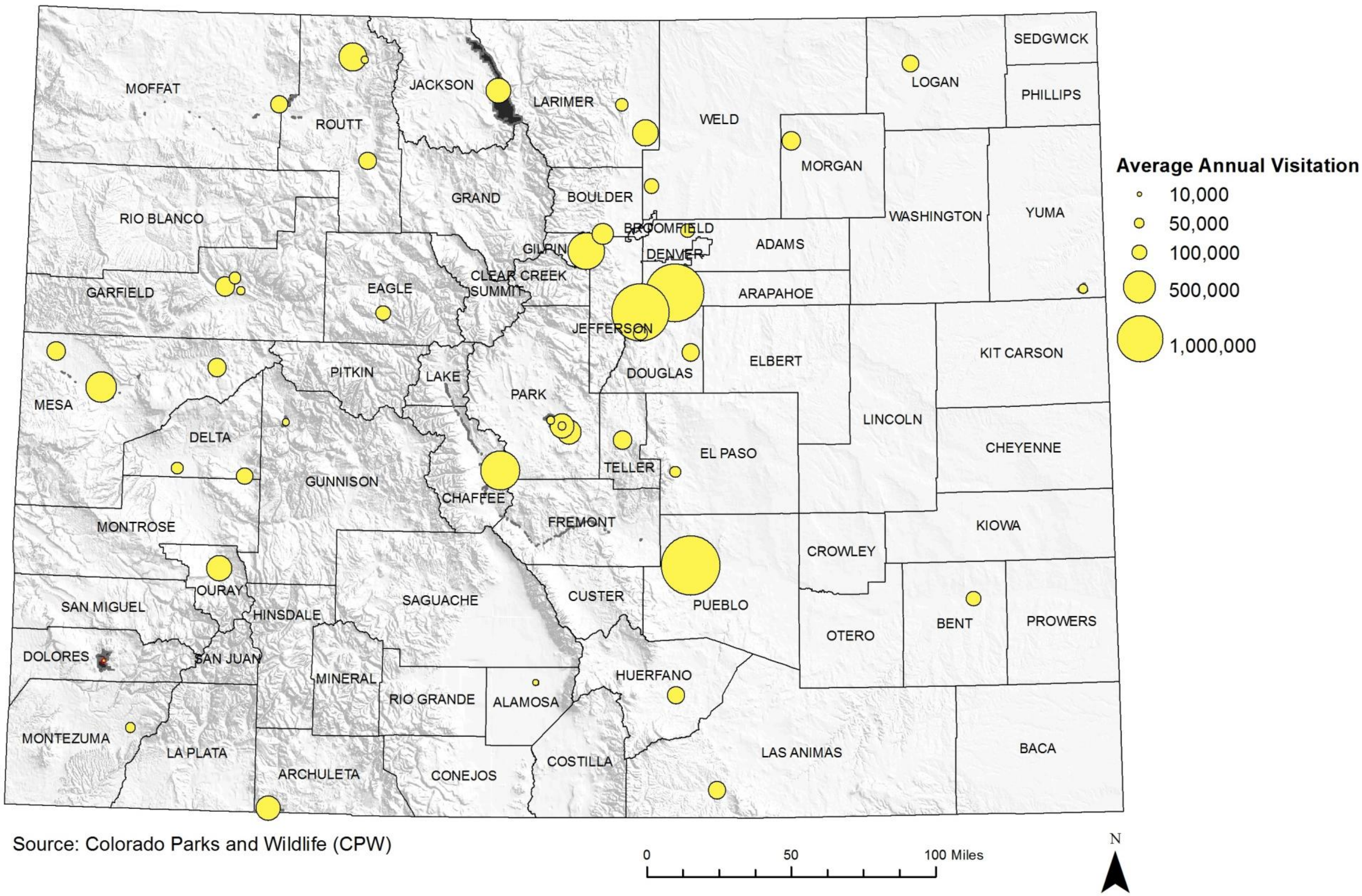
The CPW construction budget, which is different than the operating budget, is funded primarily by lottery money and by the GOCO fund. These funds are less variable and not reliant on visitation numbers. Based on conversations with CPW employees, the operating budget is much more drought vulnerable than the construction budget. This study did not specifically investigate the impacts of drought on lottery and Great Outdoors Colorado. Further work is needed to understand drought impacts on these funds and how such impacts can translate into changes in funding for CPW. It is also important to note that even if funding stays constant, drought conditions may put a strain on the construction budget. This could occur if drought-related facility modifications (e.g., extending boat ramps) or repairs are required.

## Figure 5.9. State Parks Locations and Activity Types




Source: CPW website 2010 (formerly State Parks)

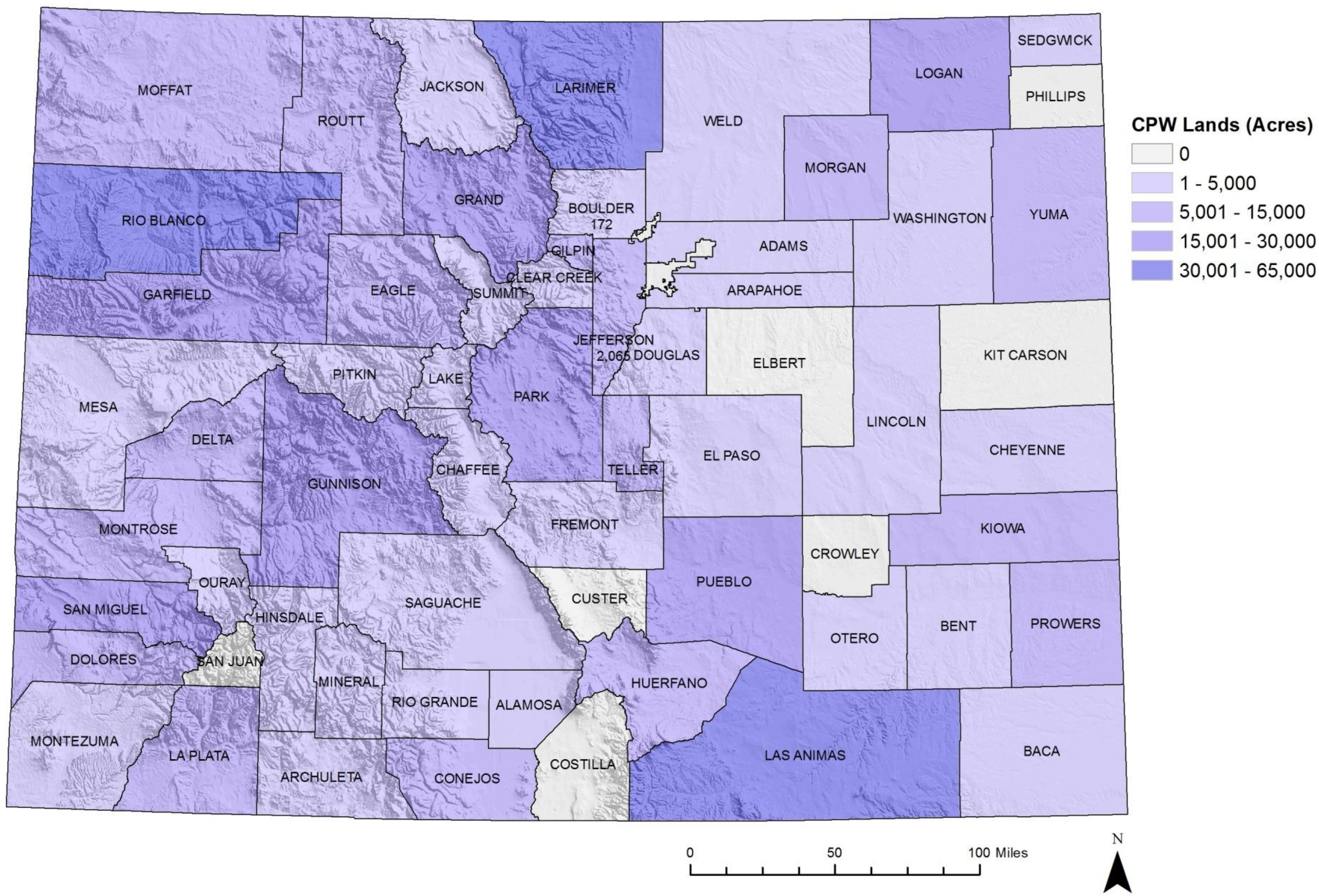
## Figure 5.10. State Parks Average Annual Visitation, 2005-2012




Source: Colorado Parks and Wildlife (CPW)

Figure revised 2013

## Figure 5.11. CPW Land by County

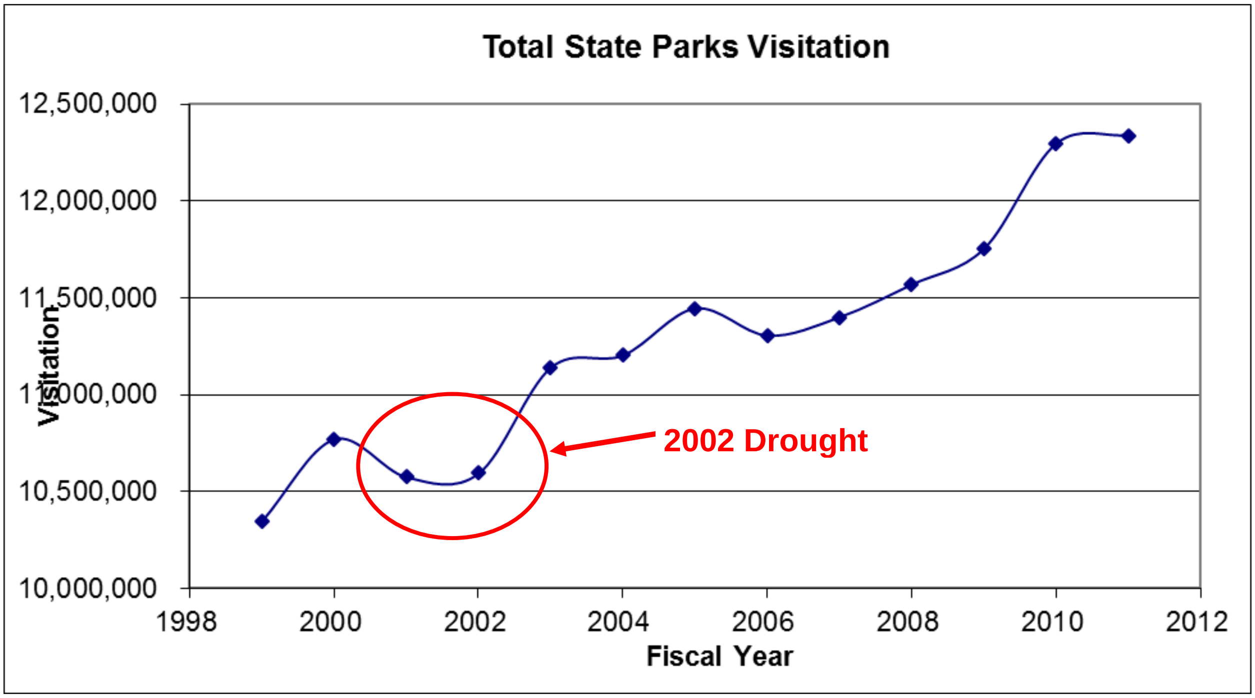



Source: COMaP Version 9

In the past, CPW has been impacted by drought in various manners. One manifests itself in reduced visitation numbers. Boating and fishing are two of the biggest activities in the State parks and are directly impacted by lower reservoir levels. Boat ramps can become unusable if reservoir levels drop below a certain point. Camping at water-based parks can decline as a result. Because CPW operating revenue is so dependent on park pass sales, this impact is felt almost immediately. Parks with water-based activities are most vulnerable to this initial impact because of the direct drought vulnerabilities of these facilities. However, land based parks are not immune to initial drought impacts. Hiking and wildlife viewing experiences may be compromised as a result of drought-related environmental degradation. Access may be restricted to sensitive areas to protect stressed ecosystems.

However, for the 2011-2013 drought, overall state park visitation has slightly increased (Figure 5.12), although several parks have seen significant decreases in use when compared to 2002-2009 averages. Parks experiencing significant decreases in visitation include: Castlewood Canyon, James R Robb Colorado River, Pearl Lake, and North Sterling. Figure 5.12 shows a clear decrease in state park visitation during the 2002 drought but relatively little change during the 2011-2013 drought event. It is estimated that state park visitation was down about 5% overall in the summer of 2002 which equates to a total loss of about 1 million visitors (Luecke et al., 2003). However, it should be noted that this loss is most likely not fully attributable to drought. For example, it is unclear how to separate potential visitors whose recreational budgets were impacted for various reasons from those who could not recreate because of drought. Other factors such as decreased travel following September 11, 2001 could also have contributed to the 2002 visitor decline. Similar statements could be made about much of the drought impact data used throughout all sectors of the vulnerability assessment. Careful interpretation of data is required to determine if impacts are actually drought related or just coincidental. While it is impossible to completely separate drought-related impacts from other factors, by interviewing knowledgeable people a sufficient degree of accuracy can be achieved. In the case of visitor decline to State Parks in 2002, employees confirmed that the visitor decline was mostly drought related but there were other factors involved.

**Figure 5.12. Annual State Park Visitation**




Source: Colorado Parks and Wildlife, 2013. Figure revised 2013.

Another impact involves the increased risk of forest fires due to drought. This impacts CPW in several ways. As wildfire risk increases, fire bans may be necessary which can negatively impact camping. If a forest fire actually reaches a state park, the park will be closed and all visitor revenue will stop for the duration of the wildfire event. Even after a fire is extinguished visitation may be slow to return to normal levels as a result of public perception. Even when state parks are not in direct danger of wildfire, they can be impacted by public perception that the parks are closed. In the 2002 drought, national forests in Colorado were closed. State parks remained open, but the public was not aware of this distinction and assumed state parks were also closed. Visitation numbers also dropped sharply after Governor Owens' comment that "all of Colorado is burning" (June 9, 2002). During the 2012 wildfires, particularly the High Park, Flagstaff, Springer and Waldo Canyon fires, smoke and road closures nearby resulted in numerous reservation cancellations for campgrounds and day-use areas (CPW, 2012).

Beetle kill can also impact state park campgrounds and hiking trails by forcing them to close during tree removal, which can be a safety hazard. Forests, such as White River and Rocky Mountain National Forests, are being heavily impacted by beetle infestation, and portions of numerous parks throughout Colorado were closed for dead tree removal (Hartman, 2009).[4] Refer to the environmental sector for additional information on forest health.

Species and habitat managed by CPW are also affected by drought. During the 2002 drought, the Wildlife Impact Task Force chaired by the CPW (then the DOW) set the following priorities to

[4] For more information on beetle kill and drought refer to the Environmental Sector

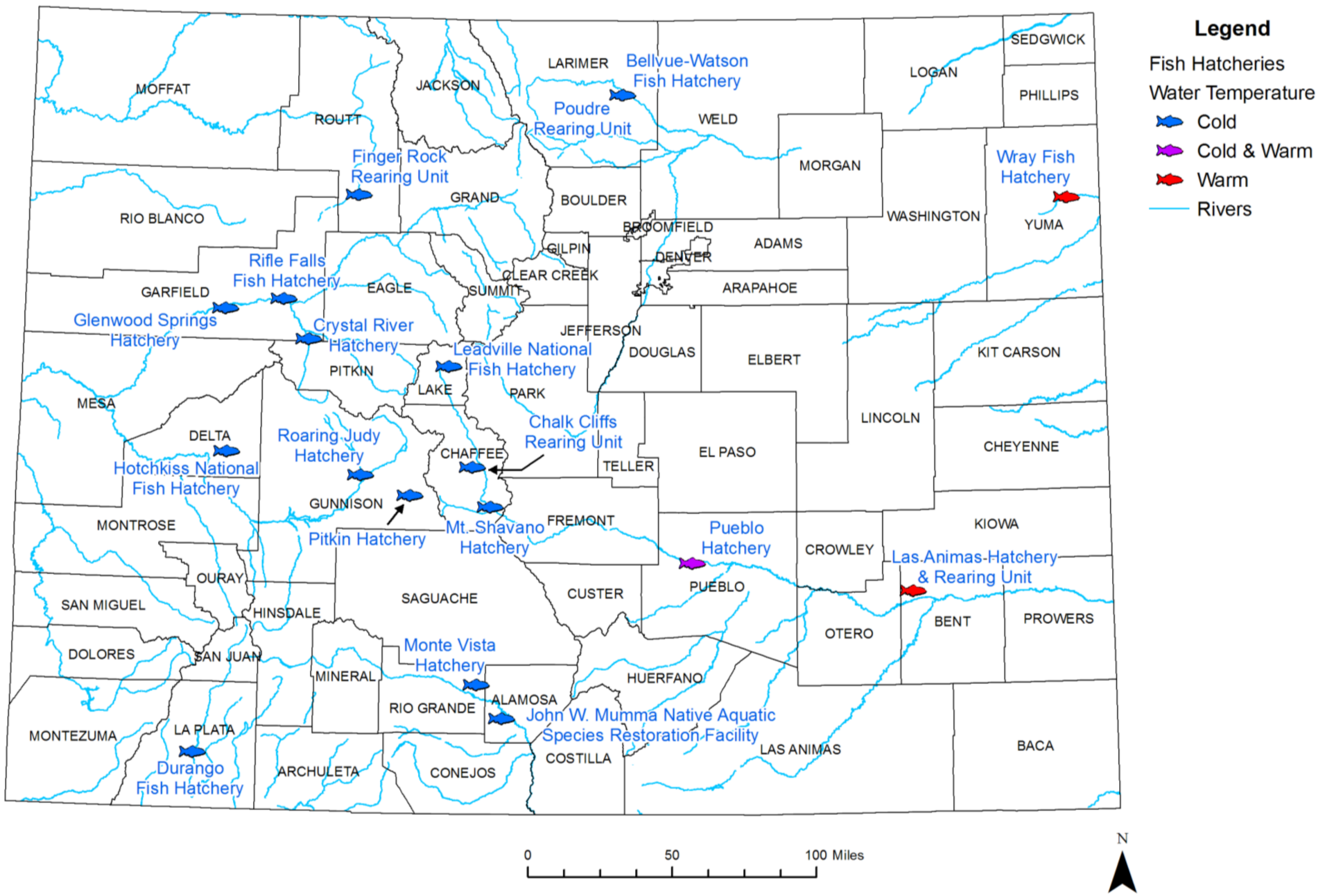
protect and conserve: 1) threatened or endangered wildlife populations such as greenback cutthroat trout or Colorado River native fishes; 2) wildlife populations that are at risk of being listed as threatened or endangered such as Rio Grande cutthroat trout, eastern plains minnows; and 3) recreationally significant wildlife populations such as tail-water trout fisheries. Although the Wildlife Impact Task Force was not activated in 2012, these priorities are expected to remain the same during future droughts. However, the specific species of priority to fit these criteria will need to be revisited at the onset of future drought events.

Long term drought impacts to wildlife and their habitats are complex and often not well documented, while short-term direct impacts to species and habitats are easier to detect. For example, increases in the presence and spread of noxious or pest weed infestations in priority habitats during drought may be difficult to quantify because of a lack of baseline data to compare to.

Aquatic species are especially vulnerable to drought. They are impacted by low water levels, increased water temperatures, and decreased water quality. During the 2002 drought, streams throughout the State were identified and prioritized so that CPW could rescue critical species at risk, such as genetically pure strains of cutthroat trout. Brood source cutthroat trout were captured from pools within various, at-risk headwater streams and transported manually to the Pitkin Fish Hatchery. The Pitkin Fish Hatchery has a quarantine facility which allowed for rescued wild cutthroat trout to be held temporarily while not compromising the health of existing hatchery fish at the facility. Several other fish populations had to be salvaged from areas no longer providing suitable habitat. For example, the Greenback Cutthroat trout population was salvaged from Como Creek and transferred to a nearby lake environment. Similarly, Roundtail Chub were moved from La Plata and Mancos Creeks to the Mumma Native Aquatic Species facility. Other populations were destroyed, as was the case with several Cutthroat Trout populations in the Rio Grande and the trout fishery in Antero Reservoir (DOW Staff, 2009; Luecke et al., 2003). It is important to note that over 94% of the lakes, reservoirs, and pond acreage in the South Platte River basin are man-made, which means that CPW does not control the water interests and that fisheries are secondary to the primary use of the water, typically municipal/industrial or agricultural. As a result, these water impoundments have to be managed from a recreational fishing perspective. Finally, streams that are designated to be "gold medal" fisheries, due to their large fish size and biomass characteristics, are typically streams that are in good ecological condition and better able to resist the impacts of drought. Accordingly, these streams were not considered to be as vulnerable to the impacts of the 2002 drought as streams containing populations of genetically pure wild cutthroat trout.

As shown in Figure 5.13 there are a total of 18 hatcheries in the CPW system. The vulnerability of a specific hatchery is highly dependent on its water sources and operating procedures. Of the 19 hatcheries, 16 are groundwater-fed relying on a groundwater well as the primary water supply while only 2 rely on surface water for their primary water supply. The 2 hatcheries that rely on surface water are the Chalk Cliff Hatchery drawing water from Chalk Creek and the Watson Hatchery drawing water from the Poudre River. During the 2002 drought, all hatchery fish from the Watson Hatchery had to be rescued and relocated to a hatchery with isolation and quarantine facilities. In 2012, CPW experienced a loss of water supply for several hatcheries. Additionally, wildfires have impacted hatcheries, as debris flows have increased sedimentation, reducing viable habitat and food sources for hatchery fish. Catchable sized trout were removed from the Watson Hatchery, located on the Poudre River, in order to prevent fish kills. These fish were relocated to areas with improved water quality, e.g., Horsetooth and Carter Reservoirs. A large portion of CPW's capital construction budget is targeted at maintaining and/or improving our hatchery facilities and the water supplies that support them. For example, CPW has been diligent in looking for opportunities to improve recovery systems, aeration systems, and operating efficiencies that will allow the hatcheries to function at lower flows. In addition, CPW is also diligent in searching for new sites for eastern plains hatcheries that have the potential for both warm water and cold water facilities. This process involves evaluation and acquisition of water rights, land, and infrastructure; and the potential to improve CPW's capacity to protect and maintain eastern plains fisheries.

## Figure 5.13. State Fish Hatcheries




Source: CPW website, accessed 2010

Aquatic species, especially fish may be very sensitive to municipal and industrial wastewater effluent, particularly during low flow times when waters have diminished volume or flow with which to dilute pollutants. This can have detrimental effects on native fish species as well as lucrative sport species. The 2002 drought illuminated the inability of water quality and water quantity legislation to respond to drought coherently because they are managed in two separate arenas. For example, wastewater treatment operators were legally allowed to continue discharges into state waters experiencing very low flows even though discharge calculations were completed for flow levels higher than the flow levels at the time. When and where these situations actually occurred and whether such conditions impacted aquatic life was difficult to assess in real time, making monitoring a difficult and reactive task. Many new water transactions and management plans have been developed since 2002 and impacts from future droughts will probably not parallel past experience. Colorado's water quality regulations do not provide a framework for overall review of water-quantity projects nor can they inhibit the exercise of water rights. Similarly, water-quantity regulations cannot incorporate literal water-quality considerations. As such, future planning and education efforts are needed to reduce the potential for water-quality impacts and conflicts.

In 2007, the Colorado Water Quality Control Commission adopted revised water-quality standards for protection of aquatic life. The standards include an acute standard (a 2-hr daily maximum) for protection from lethal effects of elevated temperature and a chronic standard (a maximum weekly average temperature) for protection against sub-lethal effects on behavior. The standards also include seasonal adjustment for protection of spawning, and they include a narrative requiring that temperature maintain a normal pattern of daily and seasonal fluctuations and spatial diversity with no abrupt changes. Colorado's revised water-quality standards for temperature did not exist during the 2002 drought. Further, a low-flow exclusion allows for temperature exceedences when the daily stream flow falls below an acute low flow or when the monthly average stream flow falls below a chronic critical low flow. The basis of Colorado's temperature standards in species-specific physiological tolerances to elevated temperature suggests that the standards will provide a useful benchmark against which to evaluate whether elevated temperatures resulting from drought conditions are likely to contribute to deleterious effects on fish communities. The implementation of the temperature standards has prompted an increase in temperature monitoring, which will likely facilitate better evaluation of the influence of drought-associated flows and elevated temperature on fisheries during future drought conditions.

In addition to temperature monitoring, CPW staff have been intensively monitoring flow and dissolved oxygen levels at many rivers and streams throughout the State in response to the 2011-2013 drought. With this increased effort, they are able to proactively implement fishing restrictions and/or closures, thus reducing fishing pressure on already stressed fish. CPW continues to remind anglers to fish early in the day, and to monitor water temperatures throughout the day, moving on when temperatures rise above 68 degrees Fahrenheit (CPW, 2012).

In responding to the 2002 drought, CPW learned that instream flows were not as adversely affected as one might expect, since low water supplied during the extreme drought resulted in a shift in typical water right administration and water use patterns. In 2002, there were significantly fewer and less depletions from junior water rights and the calling senior water rights were farther downstream thus having the effect of pulling water downstream through the watershed; the junior intervening in-stream flow water right became the unintended beneficiary of this pattern of water right administration. As a result, a number of higher order streams (first, second, and third order streams) experienced water levels greater than or equal to what is typically experienced under normal water supply conditions. Further, the 2002 experience highlighted the need for the CPW and the CWCB to increase their cooperative efforts regarding management of the CPW's water right portfolio, in particular, the use of our reservoirs and storage water rights to examine the feasibility of releasing water to protect instream flows, releasing water to water uses downstream (both CPW uses and other downstream uses) with the intervening instream flow reach becoming the incidental beneficiary of such uses.

For the 2011-2013 drought, CWCB's instream flow program, DWR and CPW helped mitigate low stream conditions on the White River. In June of 2012, CPW was approved by the DWR to perform an emergency release into the White River from Lake Avery to support the White River Fishery and to maintain instream flow levels. Ultimately, the release was not needed due to cooperation between local landowners and beneficial rains that followed in July and August, but the approved lease agreement is in place if needed in the future (CPW, 2012). In addition, Steamboat Lake released to the Elk River to help protect Mountain Whitefish spawning in late 2012.

With regard to drought vulnerability and impacts on terrestrial ecosystem, many land based animals are impacted by food supply reductions during drought. This can lead to greater susceptibility to disease, expansion into areas of human development, and decreased birth rates. Little is known about the impacts to specific species during the 2002 drought. In general, the drought had limited impact on big game populations; however, it did have consequences for bird production including pheasants, quail, and waterfowl species. CPW was insufficiently staffed to monitor conditions and could only conduct follow-up reconnaissance during scheduled monitoring the following year (CPW Staff, 2009). Unfortunately, when personnel effort is most needed to understand impacts of drought, CPW staff often have other, more pressing responsibilities. Coordinating efforts with other conservation agencies can help minimize staff requirements for the CPW. For 2011 and 2012, CPW observed a number of drought impacts to terrestrial species. Generally reductions in food and habitat have weakened and/or altered the behavior of many species. Black bears are emerging earlier from their dens, and bear-human conflicts slightly increased in 2012 (CPW, 2012).

Birds from several different ecosystems have been impacted by the drought. Lesser Prairie Chicken numbers are down 35% from 2011, partially due to the lack of recruitment into the population. Increased predation of sage grouse is expected to occur through most of its range, a result of reduced cover and degradation of brood rearing habitat. Habitat for upland game birds has been severely diminished, as the 2011-2013 drought has affected their food, water, and cover. Emergency grazing on Conservation Reserve Program lands has also contributed to the loss and degradation of habitat, including the ability to provide cover, nesting habitat or feeding. While waterfowl breeding was poor in many areas of the State such as North Park, the San Luis Valley and the Yampa/White River area, the largest impacts to waterfowl are expected to result from changes in migration, e.g., birds are traveling farther north instead of wintering in Colorado because the habitat conditions required to attract them are deteriorating due to drought (CPW, 2012). An option to mitigate this is to develop ways to keep some stock water tanks filled even when ranchers de-stock cattle and to provide wildlife ladders so wildlife species have access to water during drought conditions.

From 2011 to 2012, pronghorn antelope herds in southeastern Colorado experienced reduced recruitment, as well as changes in their spatial distribution. Due to persisting drought conditions, CPW expects these declines to continue in 2013. In this case, the drought is helping to bring large populations of pronghorn antelope in this area of the State to more sustainable levels (CPW, 2012).

Operational procedures also impact CPW drought vulnerability. Previously, annual passes to state parks were sold based on calendar year regardless of when the pass was purchased. As a result of this policy, annual passes were generally purchased early in the year. By the time the 2002 drought became big news a large number of annual passes had already been sold. In recent years park pass policy has changed so that annual passes are good for 12 months from the date of purchase. This policy could result in more people buying passes later in the year. If this is the case annual pass revenue may be more vulnerable to drought than previously noted, as a majority of passes are sold at the start of summer, at which time possible park pass buyers may have been alerted to drought conditions and not purchase a pass.

Drought mitigation strategies for CPW have not been clearly defined in the past. Past reactions from CPW management included laying off or not hiring temporary workers and stopping any irrigation to park lands. When reservoir recreation is threatened, CPW can lengthen boat ramps to allow reservoirs to remain open under lower water levels. During the 2002 and 2011-2013 drought periods, state parks experienced increased camping reservation cancellations. In previous years there were no cancellation fees and therefore cancellations would have been a 100% loss. However, in January of 2002, the department enacted cancellation fees. As a result, CPW was able to generate some revenue from cancellations.

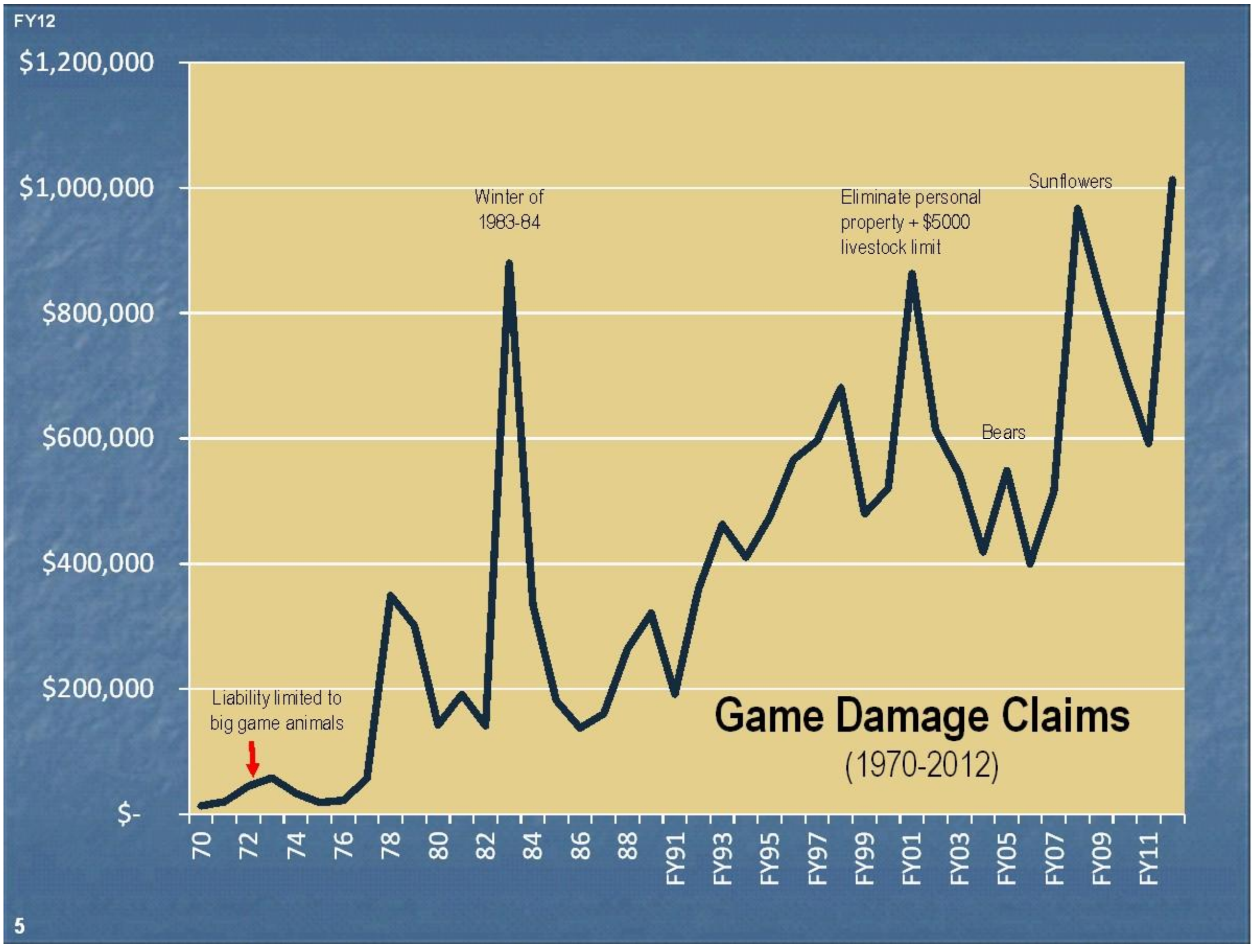
One key mitigation strategy for future droughts is effective public relations to ensure the public receives correct information. Historically, CPW has not employed a full-time public relations person to control the message sent out to the public. Communications improved between agencies after the 2002 drought, as well as in 2012. Development of a formal communication plan for drought may be considered by the CWP in the future.

During drought, there are opportunities to expand the CPW system. In times of stress, land values are often reduced. National parks and forests may consider selling some land. If prepared, CPW can capitalize on these scenarios to expand. It is possible that acquisitions may also increase adaptive capacity by increasing recreational areas (i.e., revenue sources) and expanding habitat. The potential impact of any land acquisition would be highly dependent on the planned land use and its location.

The adaptive capacity of CPW is not static and is in many ways dependent on economic conditions. As discussed above, if operating budgets are decreased, either for drought or non-drought related reasons, CPW may decrease staff. Decreased operating budget decreases options for responding to drought. Furthermore, without adequate staff the ability to react efficiently is impaired.

However, during a drought, management demands on the CPW are high. Staff stated that during the 2002 drought many individuals went months without any days off (DOW Staff, 2009). Manpower was needed across the State to respond to bear conflicts and species in distress. For vulnerable native fish populations, the time between identification of severe stress and salvage/rescue is very short thus mandating quick action and on the fly responses (DOW Staff 2009). CPW pays damage claims when big game animals, (e.g., elk, deer, bear, mountain lion, pronghorn antelope, moose and bighorn sheep), damage private property. Figure 5.14 shows the total annual big game damage claims from 1970 to 2012. There was a clear spike in damage claims during the time of the 2002 drought, and an even larger increase in 2012. For the four years prior to fiscal year 2011 to 2012, the average game damages paid by CPW was $770,500 to pay 320 annual claims. In 2011 to 2012, that number increased to $1,013,373 on 297 game damage claims (CPW, 2012b). While it is reasonable to attribute these claim increases to drought, further verification is needed to determine if there are additional causes for this change. No quantitative estimates are available for the past or future costs of restocking destroyed fisheries and re-establishing rescued populations. It is recommended that CPW create a monitoring plan to better quantify species impacts in future droughts. As part of these efforts they should track costs associated with species preservation both during a drought and for reclamation efforts following a drought.

**Figure 5.14. Annual Game Damage Claims**




Source: CPW 2012b

There is little evidence that CPW experienced large drought related decreases in licensing revenue in 2002. Fishing license sales remained constant and hunting license sales actually increased in 2002. Fearing that many elk would not survive the winter after being seriously stressed by drought conditions, CPW released 16,000 extra cow elk hunting licenses in September (Luecke et al., 2003). Bear licenses were reduced due to concerns about the low vigor of female bears going into hibernation. Several voluntary angling closures were instituted to minimize impact to stressed salmonids. An assessment being performed by CPW to examine economic impacts of hunting and fishing, as well as outdoor recreation, will be useful in evaluating revenue impacts due to the 2011-2013 drought. This report is expected to be released the first part of 2014 (CPW, 2013b).

Controlling license sales does impact revenue, but it allows for adaption to changes in animal populations. Fish losses can be offset by relocating populations and stocking other areas or restocking damaged areas after the drought (State of Colorado Water Availability Task Force, 2002). CPW also has an emergency process that allows the director to close areas to activity in times of stress (DOW Staff, 2009). Many of the adaptive measures taken in the 2002 drought were responsive in nature. In the future, adaptive capacity could be increased by focusing efforts between droughts on making habitats more drought resistant. Also, looking for opportunities to increase the capacity for monitoring during non-drought years will provide a better understanding of baseline conditions and allow for better quantification of impacts in the future. Monitoring the wide range of habitats and species CPW manages is no small task and is probably an unrealistic goal given 2013 resources. However there are other groups, like the Nature Conservancy and Colorado State University that do similar work and could provide mutually beneficial collaboration. Effective collaboration will require increased communication and planning efforts to ensure consistent methods and compatible data.

In order to mitigate impacts to terrestrial species, CPW has implemented annual monitoring of a number of key species. These efforts have been further supplemented with aerial surveys in 2012 of pronghorn antelope as this species is suspected to be particularly affected by drought. CPW is also actively managing herds with careful thought and flexibility built in to population objectives. For example, in 2012 additional antelope doe licenses were made available for southeastern Colorado to assist in reducing population levels in that area. CPW, recognizing the importance of habitat enhancement during drought as well as non-drought conditions, also participates in programs designed to protect and conserve habitat for all species (e.g., Wetland Wildlife Conservation Program, Colorado Wildlife Habitat Protection Program) (CPW, 2012).

Table 5.8 summarizes the key impacts to CPW discussed above and adaptive capacities or mitigation strategies that can be employed for future droughts.

**Table 5.8. CPW Impacts and Adaptive Capacities**

| Key Impacts to CPW | Key Adaptive Capacities or Mitigation Strategies |
|---|---|
| Lower reservoir and stream levels can impact water based recreation | • Lengthen boat ramps to accommodate lower water levels<br>• PR campaign to educate the public about alternative activities to boating/fishing<br>• Implement monitoring programs, voluntary closures, and emergency fish salvages that can help identify those aquatic resources exposed to the most risk.<br>• Increase collaboration with water users to develop and maintain flow levels that can sustain aquatic life and the rafting industry. |
| Impacts from wildfires, including park closures and campfire restrictions | • Communicate with media to emphasize which state parks are still open and which counties don't have campfire restrictions |
| Negative media portrayal | • Maintain communication with other state agencies and the governor<br>• PR campaign to educate the public about state parks activities in times of drought |
| Decreased operating budget as a result of visitation decline | • Cut operating costs by decreasing seasonal staff |
| Lower (surrounding) land values | • Opportunities for expansion and to acquire more habitat for protected species |

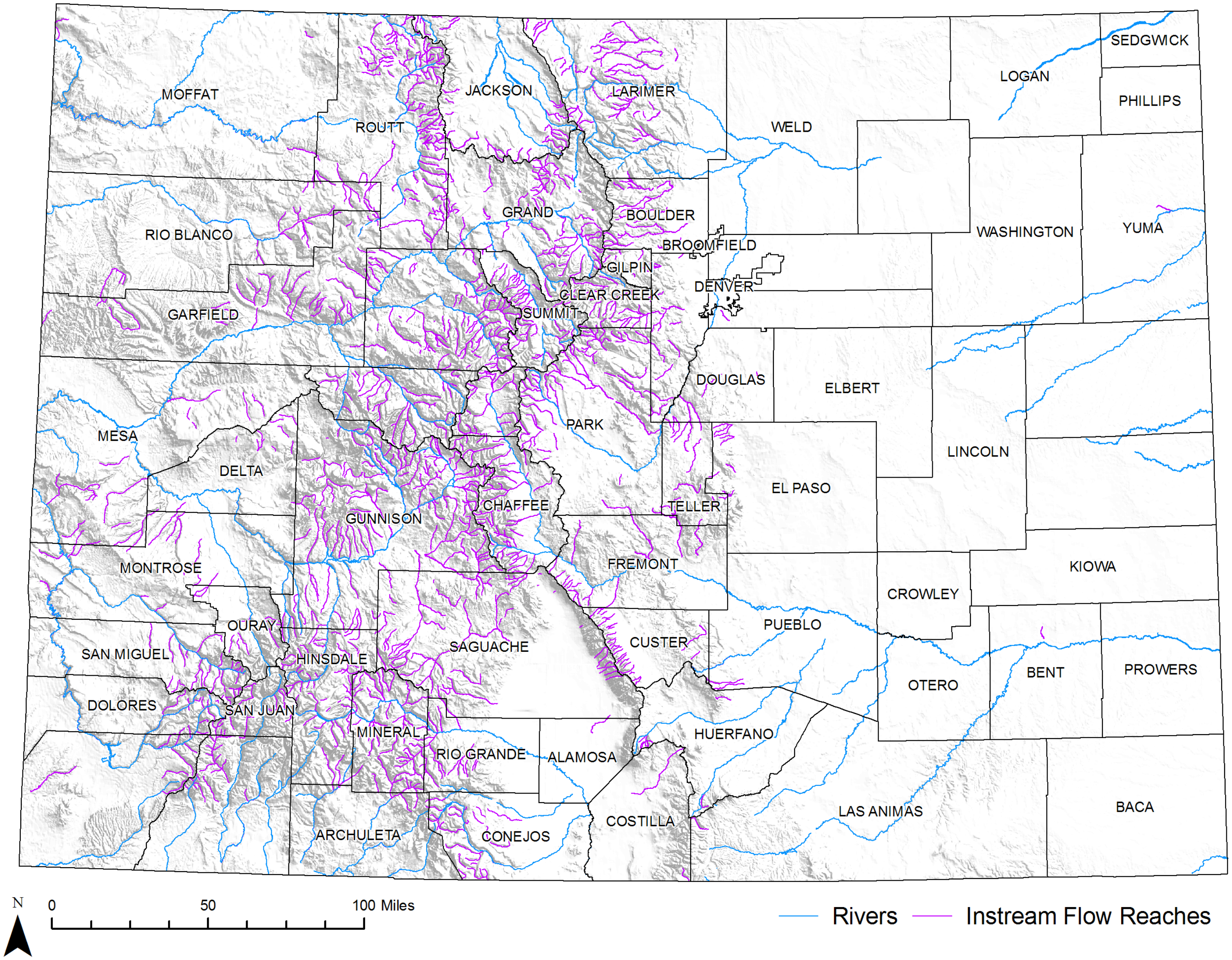
| Key Impacts to CPW | Key Adaptive Capacities or Mitigation Strategies |
|---|---|
| Impacts to fish populations | • Relocate populations<br>• Restock impacted areas after drought<br>• Voluntary angling closures<br>• Better monitoring of baseline conditions<br>• Establish more drought resilient habitats<br>• Work with other entities to maintain water quality and quantity |
| Impacts to terrestrial species | • Change the number of hunting licenses released<br>• Restrict access to sensitive areas<br>• Establish more drought resistant habitats<br>• Better monitoring of baseline conditions |
| Increased management requirements | • Hire additional staff<br>• Develop collaborative relationships with other researchers (e.g., share data, develop consistent approaches, share analytical burden) |

## 5.3.5 Instream Flow and Natural Lake Rights

The instream flow program began in 1973 when the Colorado State Legislature recognized the need to preserve the natural environment and gave the CWCB authority to appropriate and acquire water for instream flows. An instream flow is a non-consumptive, "in-channel" or "in-lake" use of water. The rights designate minimum flows between specific points on a stream, or water levels in natural lakes. The instream flow program protects habitats such as: cold and warm water fisheries (various streams and lakes); waterfowl habitat; unique glacial ponds and habitat for neotenic salamanders; unique hydrologic and geologic features; and critical habitat for endangered, native, warm-water fish. Since 1973, the CWCB has appropriated instream flow water rights on nearly 1,500 stream segments covering 8,500 miles of stream, and 476 natural lakes (CWCB, 2010). Appropriated rights are new, junior rights that have an upper and a lower terminus, usually identified as the confluence with another stream. Water acquisitions involve permanent transfers of water rights, or long term leases or contracts for water. These acquisitions are generally more senior than the appropriated rights since they consist of previously-existing water rights that have been purchased by CWCB for instream use. Figure 5.15 shows the stream reaches in the state with instream flow rights.

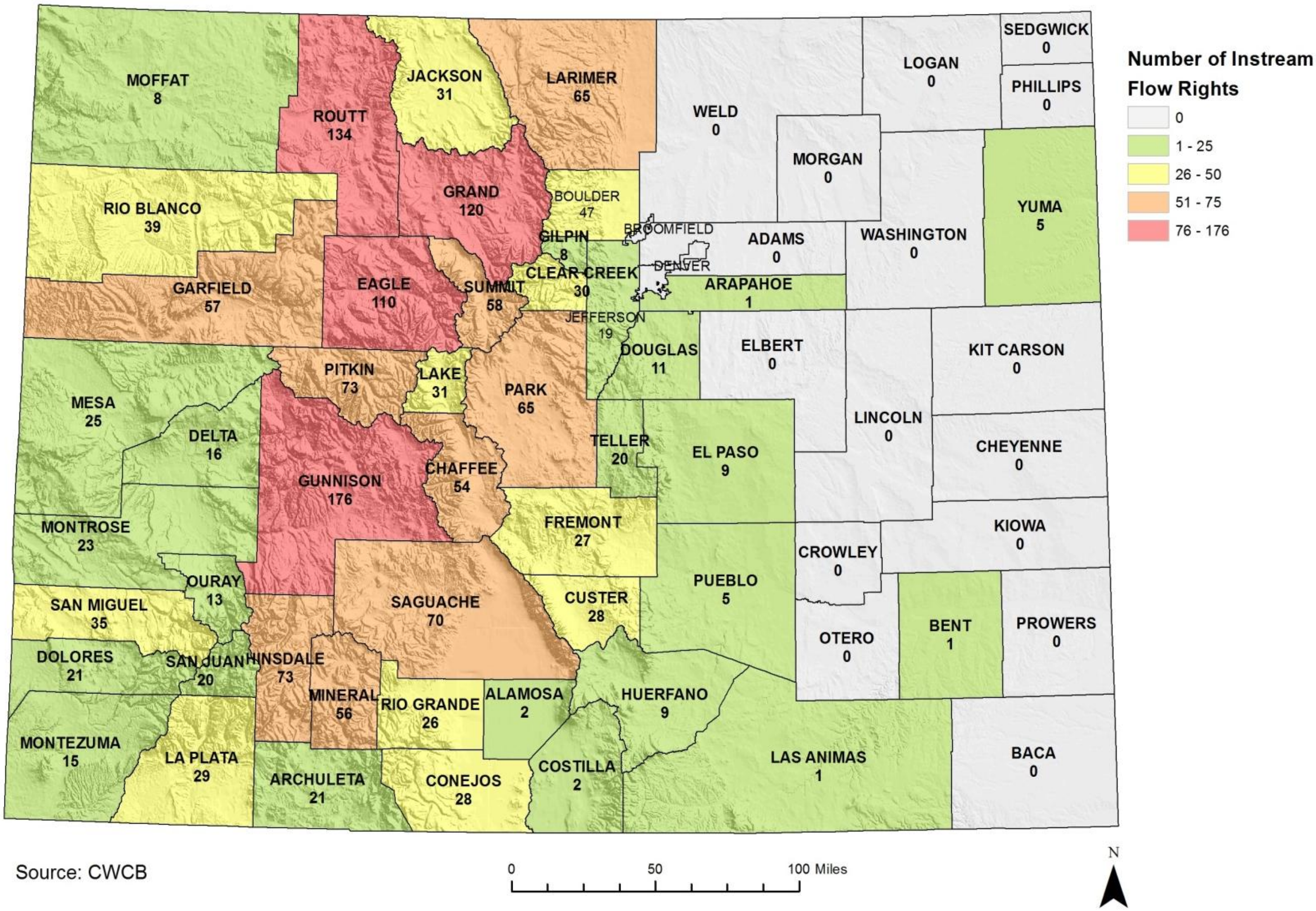
Instream flow rights are considered assets, not only in an environmental sense but as real property. However, the water rights market is highly variable and not well documented. Therefore tabulating the existing value of CWCB water rights would not be practical from a logistical as well as a value added perspective. Figure 5.16 shows the total number of instream flow rights per county. As can be seen from this map, water rights tend to be concentrated in the western half of the State especially in mountainous areas.

## Figure 5.15. Instream Flow Reaches




Source: CWCB, data provided 2010

## Figure 5.16. Number of Instream Flow Rights by County




Data provided 2013, does not include pending rights. Figure revised 2013.

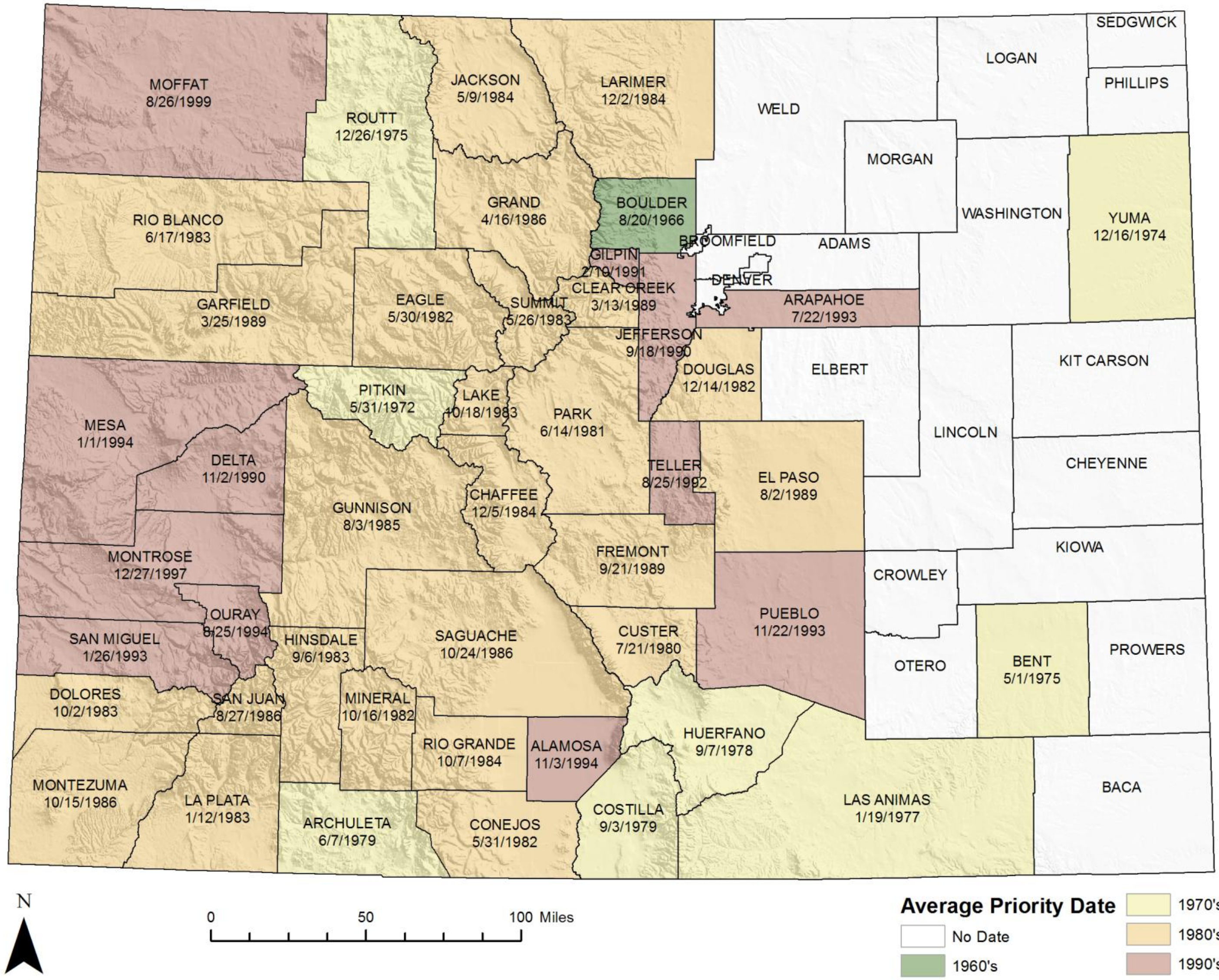
Instream flows are administered as any other water right in Colorado according to the Doctrine of Prior Appropriations. During a drought, it is possible that instream flow rights would be out of priority and therefore non-functioning. This could potentially leave habitat unprotected in the most stressful (drought) situation. Given that instream flow rights are created for environmental protection purposes, any vulnerability of the water right is actually a vulnerability of the environment.[5] In the 2002 drought, there was no systematic analysis done to measure losses and relate them directly to decreased flows.

Vulnerability of instream flow rights can be considered from two angles: the sensitivity of a reach to change; and the probability that an instream flow will not be maintained. The sensitivity of protected reaches to small environmental changes can provide information on likely losses if an instream flow is not in priority. However, this analysis would be a significant undertaking given the number of variables to consider (e.g., water quality, disease, and invasive species). Future work should assess the feasibility of such analysis and gather data where applicable.

Priority dates provide information on the likelihood that a given right will be out of priority. Dates for all instream flow rights are publicly available. Figure 5.17 shows the average priority date for instream flow rights by county. However, the date alone does not provide enough information to conduct this assessment. Accurate analysis will need to consider the instream flow appropriation date relative to other calls on the water body. As previously noted, it is beyond the scope of this vulnerability assessment to complete a detailed water rights assessment. Future water rights analysis will also need to consider situations where instream flow rights are satisfied by coincidence even when their calls are out of priority. In the 2002 drought, there were actually several instream flow reaches that experienced greater flow even when their rights were out of priority. This is because the drought caused senior downstream users to make calls earlier in the summer. This curtailed upstream users, keeping more water in the stream longer. Also, many users requested that contract water be released from federal reservoirs earlier in the season (Merriman, 2002).

[5] Refer to the environmental sector for additional information on the environmental impacts of decreased stream flow.

## Figure 5.17. Average Instream Flow Priority Dates




Source: CWCB, data provided 2013. Figure revised 2013.

While it is true that several instream flows were inadvertently protected even when they were out of priority, this is not a reliable mitigation strategy. The CWCB is constantly working to acquire additional instream flow rights and these efforts should continue. Establishing good relations with watershed groups can also aid cooperation during drought. Conditional agreements can be made where individuals are compensated for loaning water to the CWCB or exchanging water to downstream users to keep a specific stretch wet (State of Colorado Water Availability Task Force, 2002).

**Table 5.9. Instream Flow and Natural Lake Rights and Impacts and Adaptive Capacities**

| Key Impacts to Instream Flows | Key Adaptive Capacities or Mitigation Strategies |
|---|---|
| Instream flow or natural lake rights are out of priority and required levels are not maintained resulting in environmental damages | • Increase natural flow rights portfolio especially with respect to senior rights<br>• Cooperate with watershed groups<br>• Obtain conditional agreements for drought conditions<br>• Cooperative effort with CPW on use of CPW water rights, reservoirs, etc. to maintain instream flow levels |

# 5.4 Measurement of Vulnerability

For the purposes of numerical analysis state assets were divided into five impact categories; structures, aquatic habitat and species, protected areas, Land Board revenue, and recreational activity. For each impact group a spatial density metric was defined along with several impact metrics. Each metric is described in detail below. Refer to Section 3.1 of Chapter 3 (Annex B) for a general description of the numerical methodology. For the aquatic habitat and protected areas categories impact data was not sufficient. This is a data gap that is identified for future work. Because impacts could not be calculated for two key categories vulnerability results are presented for the available subcategories but an overall state asset vulnerability score is not calculated.

# 5.5 Vulnerability Metrics

## 5.5.1 Structures

### Spatial Density Metrics

There are two metrics for the spatial density of state-owned structure: 1) total state-owned building value, and 2) total storage volume for state-owned dams. The final spatial density score is the average of the individual density scores of the two variables.

### *State-owned buildings*

State-owned building value was provided by the Office of Risk Management. Building value was summed by county using the zip code of the building address.

### *State-owned dams*

Storage in state-owned dams was calculated using the Homeland Security Infrastructure Program database. The source of this information is the National Inventory of Dams from 2012. Nearly one-third of all counties do not contain state-owned storage. This makes the typical percentile thresholds invalid. Therefore, thresholds were adjusted to create equal bins for the non-zero data set. The adjusted percentile thresholds used were: 72%, 81% and 91%.

## Impact Metrics

There are two metrics for structural vulnerability: relative importance of dams versus buildings; and the percentage of county area in a wildfire hazard area. To calculate overall structural impact relative importance of dams was weighted 70% and wildfire hazard was weighted 30%.

### *Relative importance of dam storage*

The purpose of this variable is to reflect the fact that dams are more likely to be impacted by drought than state-owned buildings. The relative importance of dams versus buildings was calculated using the spatial density scores (1 through 4) previously calculated. The dam storage score was divided by the sum of the dam storage score and the building value score. Counties where the relative importance of dam storage is less than 50% were given a score of 2. Counties with values greater than 50% were given a score of 3.

### *Wildfire hazard area*

The Colorado State Forest Service maintains on online data portal that contains a number of wildfire specific datasets.[6] Wildfire threat is defined as the annual probability of a wildfire occurring. Threats were divided into six main categories: very low, low, moderate, high, very high and none. For the purposes of this analysis the percentage area by county with a risk level of moderate or above was calculated by county. Counties were then ranked according to the percentage of area with moderate or higher wildfire risk.

6 http://www.coloradowildfirerisk.com/

## 5.5.2 Land Board Revenue

### Spatial Density Metrics

#### *Total surface ownership*

Surface ownership by county was obtained from the Land Board website (Land Board, 2013). The Land Board owns property in nearly every county so the normal 25%, 50% and 75% thresholds could be used. Ideally areas leased for agricultural purposes would be considered independently. However, this data is not readily available from the Land Board. Fortunately, using total surface ownership introduces very little error as most of the other land leases cover very small areas relative to the extent of agriculture.

### Impact Metrics

#### *Lease discounts offered in 2002*

Since the lease discount program was discontinued in 2012, the percentage discount for agricultural leases offered in 2002 was used. Information was provided by county in an internal Land Board memo (Board of Land Commissioners, 2002). The Land Board offered 10%, 20%, 30%, and 40% discounts depending on drought monitor status. Impact scores of 1, 2, 3, or 4 were assigned to each discount respectively. While it should be noted that future droughts may look different and that the Land Board will not be offering across the board discounts, this is still a measure of what counties may be seeking larger discounts.

## 5.5.3 Recreation

### Spatial Density Metrics

#### *Average annual state park visitation*

State park visitation data was provided by CPW (former Division of Parks and Outdoor Recreation). Average annual visitation from 2005 to 2012 was calculated for each park and assigned to counties. Nearly all state parks fall within a single county. Parks that straddle county lines were assigned to the county with the majority of the area. With the exception of Chatfield State Park which was split between Douglas and Jefferson Counties because the park is relatively evenly divided between the two counties. Yampa River State Park was assigned to Routt County and the Arkansas Headwaters Park was assigned to Chaffee County based on information provided by State Parks employees. While this is a good marker for revenue for the state parks, this data does not cover fishing and hunting activity. Hunting and fishing data by county was not available. Ideally, these data could be combined in with the state parks visitation numbers. However, from the perspective of state assets these data are not required because the CPW does not sell licenses for specific areas of the State.

## Impact Metrics

There are two impact metrics for recreation: the relative importance of water-based recreation; and the percentage of county area in a wildfire hazard area. To calculate overall structural impact relative importance of water based recreation weighted 75% and wildfire hazard was weighted 25%.  Wildfire hazard was assigned a lower weight because of the uncertainty that wildfire would occur in recreation areas even if the county hazard score is high.

### *Relative importance of water based recreation*

This variable reflects the fact that water-based activities are generally more vulnerable to drought than land-based ones. The two river corridor parks (Arkansas Headwaters and Yampa) were assigned the highest impact rating of 4. All parks with boating or fishing on their listed activities were assigned impact ratings of 3. All parks with no boating or fishing were assigned impact ratings of 2. Overall county ratings were calculated using a weighted average of impact ratings based on park visitation. Park visitation numbers were assigned to counties using the same guidelines outlined for the inventory metric. Counties with no state parks were assigned an impact rating of zero

### *Wildfire hazard area*

Refer to the wildfire hazard description in the Section 5.5.1 category. Wildfire hazard data was used in exactly the same way here.

# 5.5.4 Aquatic Species and Habitat

## Spatial Density Metrics

Two metrics are used to spatially characterize the State's investment in aquatic habitat and species. These metrics are instream flows and state fish hatcheries. Other aquatic areas owned by the State are covered in the protected areas category.

Currently, impact data, other than professional observations on hatcheries is not available so the overall vulnerability score aquatic species habitat is calculated based on instream flow rights only. While fish hatchery data are included as a spatial density metric, it could not be utilized in the vulnerability calculation because the impact data was not available for this assessment. Future work should analyze the vulnerability of fish hatchery water supplies and incorporate this information as an impact metric.

### *Instream Flow Rights*

The number of instream flow rights per county was calculated using the primary county designation from the CWCB instream flow decision support system (ISFDSS). Reaches covering more than one county were assigned to their primary county designation. Nearly one third of counties have zero instream flow rights. Therefore, thresholds were adjusted to create equal bins for the non-zero data set. The adjusted percentile thresholds used were: 46%, 64%, and 82%.

#### *State fish hatcheries*

The number of state fish hatcheries per county was calculated using data available on the CPW website. There are 18 state-owned hatcheries in the State. Counties with one fish hatchery were assigned a score of 2, two hatcheries a score of 3, and three hatcheries a score of 4.

### Impact Metrics

As of the writing of this Plan, there is currently only one impact metric for aquatic resources. This is the average priority date for instream flows by county. As noted above future work should calculate impact metrics for fish hatcheries.

#### *Average instream flow priority date*

Average priority date by county was calculated using data from the CWCB instream flow database. Similar to the total number of instream flows, dates were assigned to counties based on the primary county designation of a right. Percentile thresholds were also adjusted to the same thresholds used for the spatial density metric (46%, 64%, and 82%). While it is acknowledged (and discussed in detail in Section 5.3) that average priority date must be considered relative to surrounding water rights, this metric provides a starting point.

## 5.5.5 Protected Areas

### Spatial Density Metrics

#### *Protected area*

The total state-owned protected area by county was calculated from COMaP data (v9). The State owns land in every county and no adjustments were made to the baseline thresholds.

### Impact Metrics

As of the writing of this plan, there are currently no quantitative impact metrics for state-owned protected areas. As noted in Section 5.3 there has not been adequate monitoring of drought-related impacts on these lands to identify metrics that determine vulnerability. Refer to the Environmental Sector for a greater analysis of countywide environmental vulnerability. Future work should improve monitoring efforts and identify specific drought vulnerable attributes.

## 5.5.6 Results

Figure 5.18 through Figure 5.21 show the overall impact scores and spatial density metrics for the five state assets subcategories. The shading on these maps represents the impact rating and the size of the grey circle indicates the size of the sub-sector in a given county. As noted in Section 5.5 there were no impact metrics available for state-owned protected areas. As such Figure 5.22 shows spatial density but no impact metrics.  For the aquatic habitat and structures sub-sectors there were multiple spatial density metrics. Therefore, the combined spatial density score is displayed on the map. For the three other sub-sectors the spatial density metrics used can be seen in the legends of the maps. Discussion of these results is included in the following section.

## Figure 5.18. Structures Impacts and Spatial Density by County

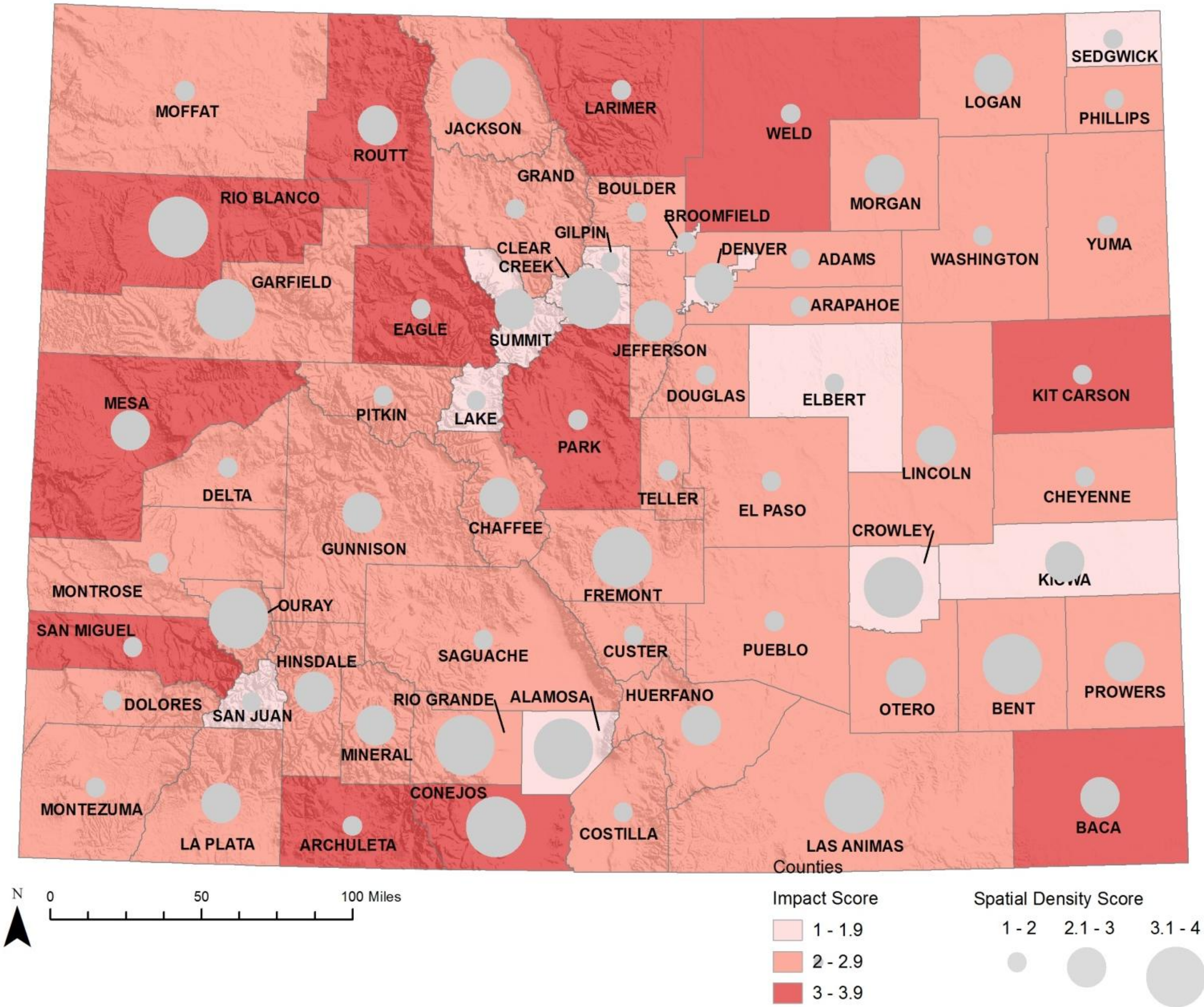



Figure revised 2013

## Figure 5.19. Land Board Impacts and Spatial Density by County

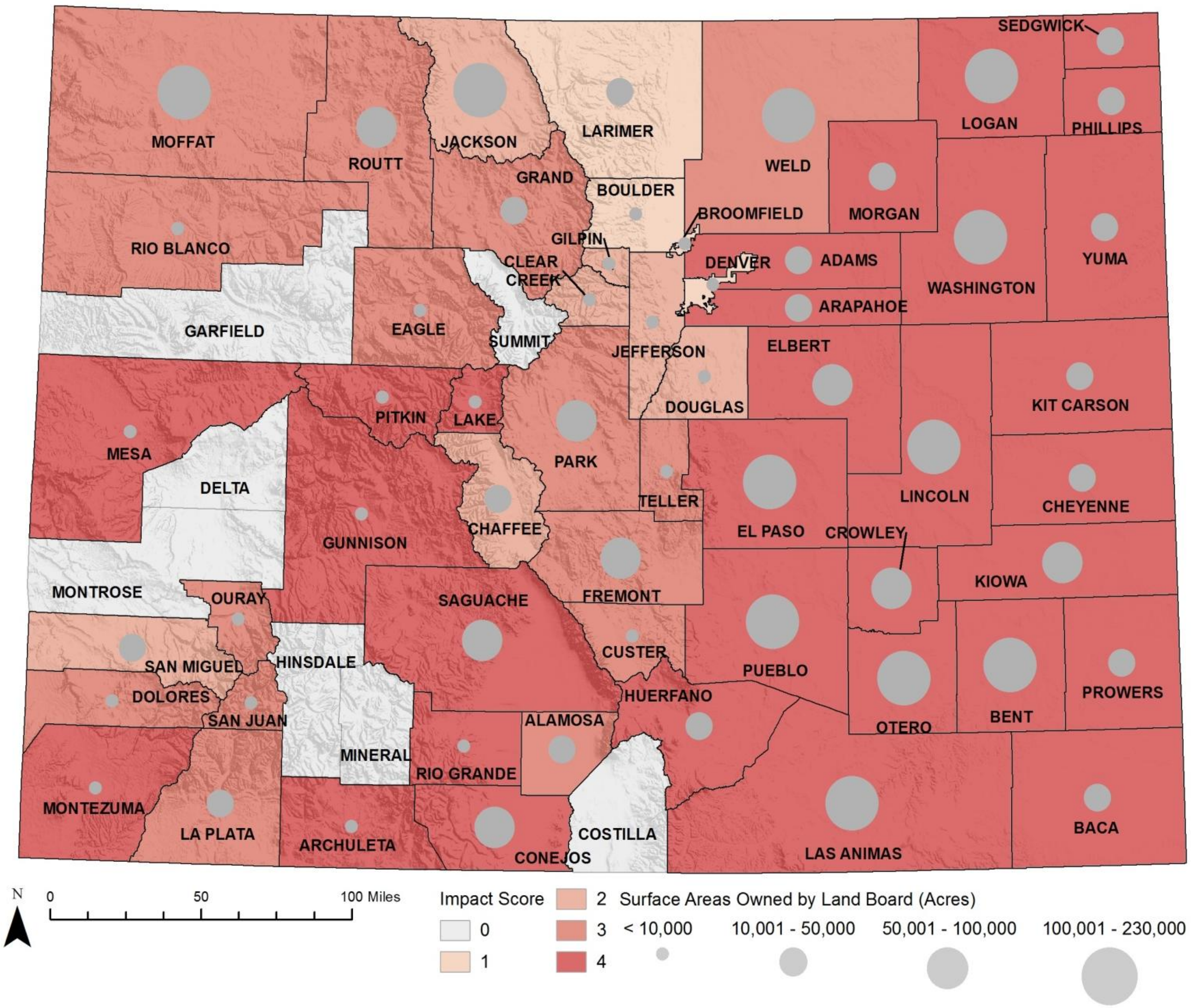



Figure revised 2013

## Figure 5.20. State Parks Recreation Impacts and Spatial Density by County

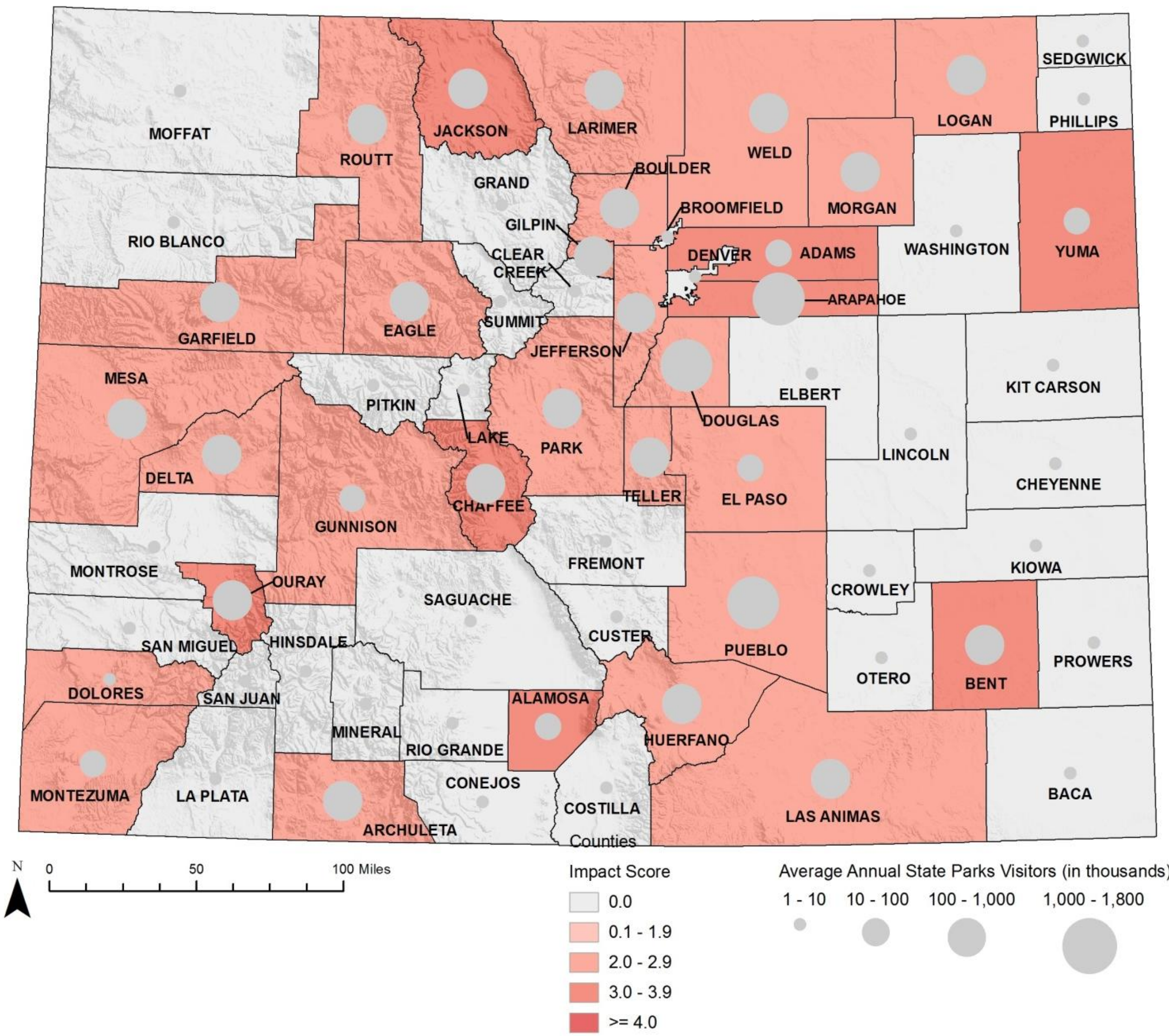



Figure revised 2013

## Figure 5.21. Aquatic Habitat Impacts and Spatial Density by County

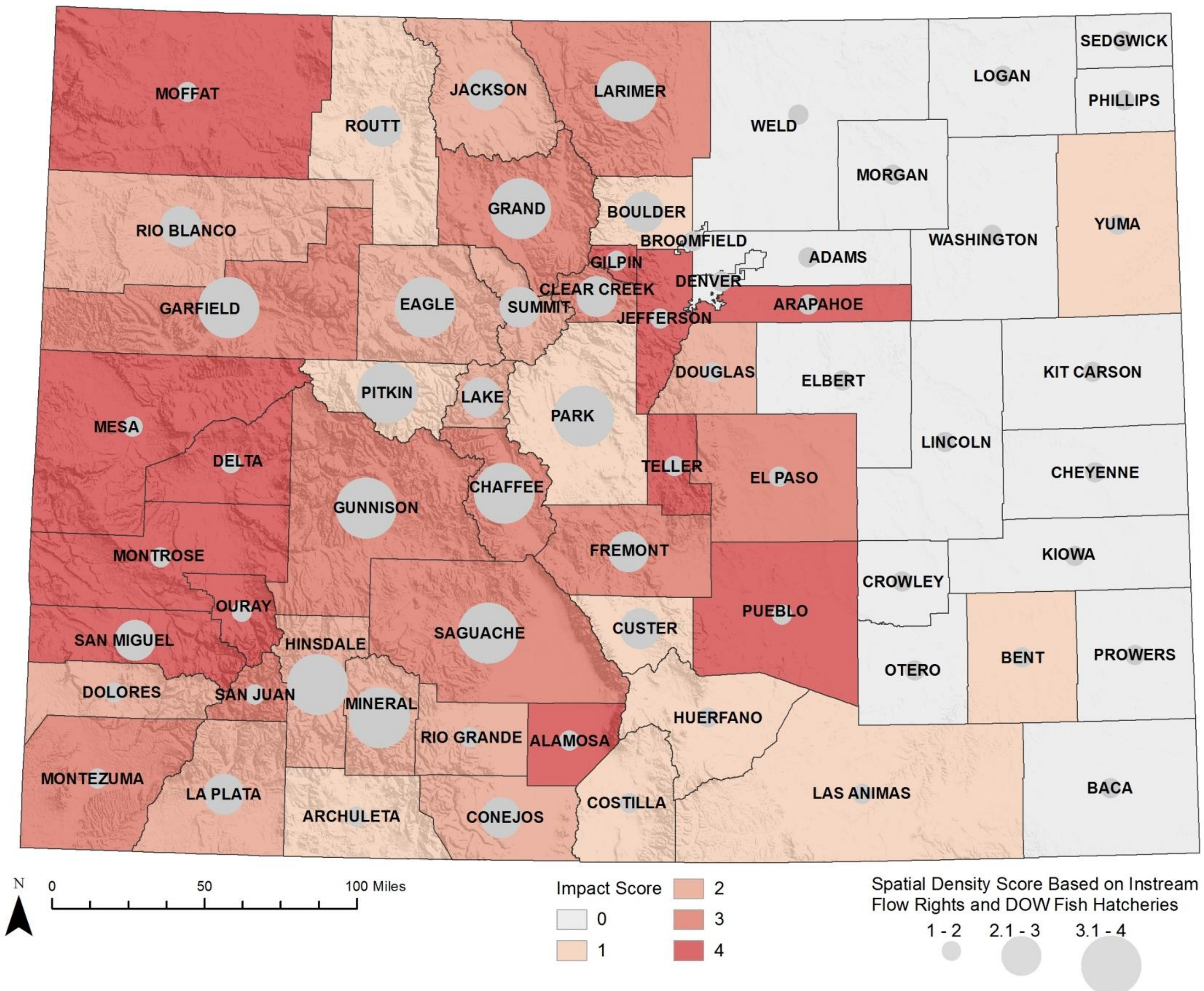



Figure revised 2013

**Figure 5.22. State-Owned Protected Areas by County**

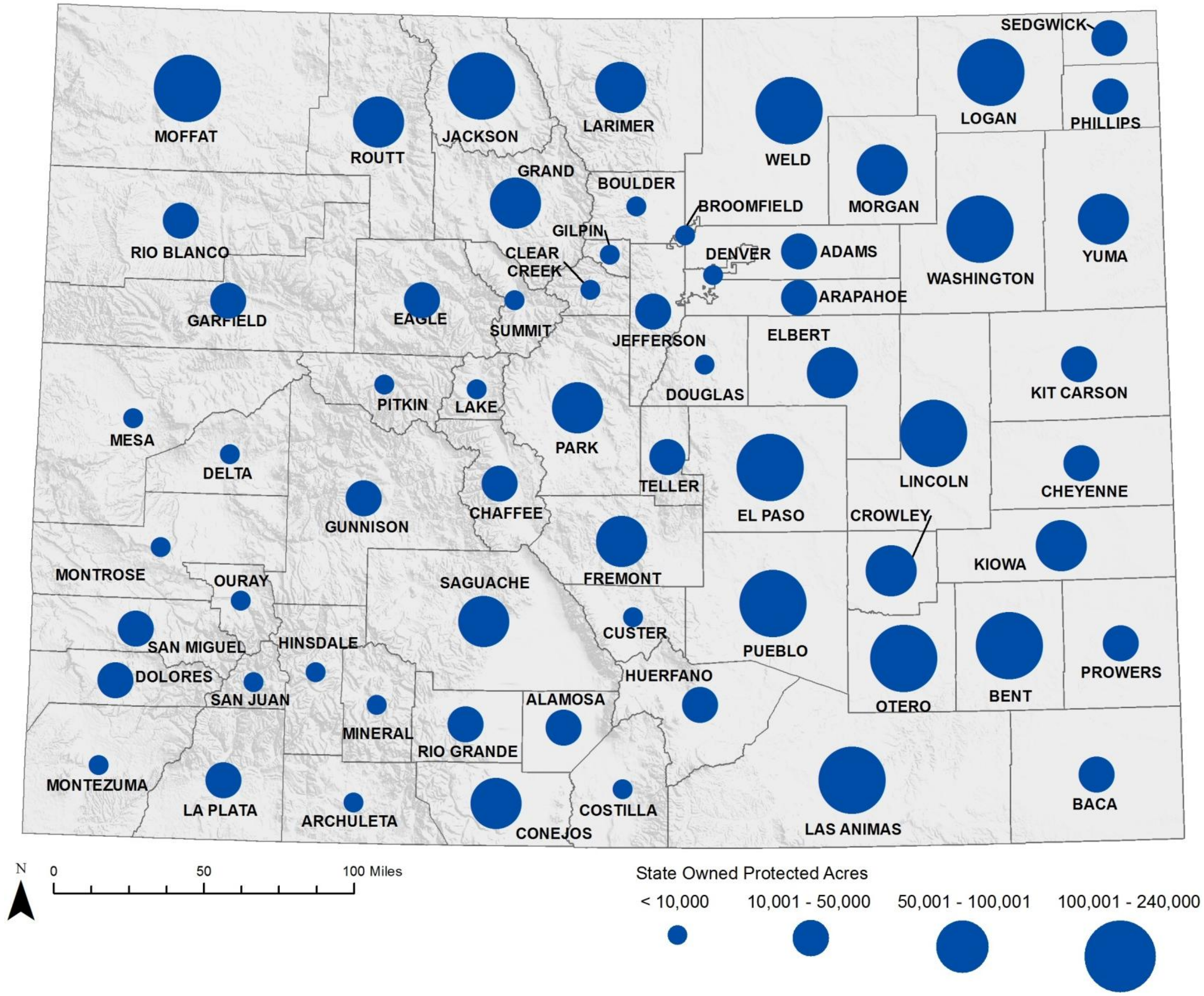



Figure revised 2013

## 5.5.7 Spatial Analysis

The State owns structures in every county. As can be seen in Figure 5.18 vulnerability for these structures is relatively distributed over the State. A few more vulnerable counties are seen in the west, a result of higher wildfire hazard and due to the presence of a majority of state-owned dams. On the eastern plains more counties have seen increases in their vulnerability rating due to the improved availability of wildfire data.

Vulnerability scores for Land Board revenue are completely dependent on the discounts issued in 2002. Figure 5.19 shows that the eastern half of the State tends to be more vulnerable. Furthermore, many of the counties with high impact ratings in eastern Colorado also fall in the largest category for surface ownership by the Land Board. The Land Board no longer owns any acreage in Mineral County.

Spatial vulnerability of recreation revenue is highly dependent on the location of water-based state parks. Chaffee County has the highest impact score due to the presence of a river-based park and high wildfire hazard score. Routt County is the other county with a river-based park but has a lower overall impact score because its wildfire hazard score is lower. Counties in eastern Colorado with high scores all have state parks with water-based activities.

State-owned aquatic habitat, as defined by instream flow rights, is generally concentrated in the western half of the State. Those counties with the highest impact ratings have the most junior priority dates for their instream flow rights. Ouray and Alamosa Counties have the highest impact scores and are also in the highest spatial density category. Relatively few instream flow rights have been acquired since 2010, but many are pending and will be incorporated into future analysis.

State-owned protected acres are distributed across every county (Figure 5.22). Ownership tends to be highest in the eastern half of the State and in the northwest. This may seem counterintuitive given all of the protected areas in western Colorado. However, it is important to note that this map is only representing state-owned areas which are largely dominated by the Land Board. Other protected areas owned by federal agencies such as the Bureau of Land Management and the US Forest Service are not included in this analysis.

## 5.5.8 Compound Impacts

Taken as a group, state assets overlap considerably with other sectors considered in this study. The potential for overlapping and often compounding impacts is thus important to consider. The work done by the CPW helps preserve Colorado's natural environment and promote public use of this valuable resource. Tourism in Colorado is a major industry[7] strengthened by the protected areas owned and managed by the State. Drought impacts to these assets directly translate to declines in tourism and related industries. Furthermore, decreased revenues for state agencies

[7] Refer to the Recreation Sector for additional information

resulting from drought can impact management budgets and further impact the asset. Budget reductions may occur when tax bases are impacted. In 2002, state and local governments received $550 million in tax revenue from the tourism industry alone (State of Colorado Water Availability Task Force, 2002). In 2012, revenue increased to $750 million (Thomas & Wilhelmi, 2012). The importance of Colorado's environment to the quality of life and identity of the State cannot be underestimated. A large portion of the protected areas in the State are government owned or operated. Degradation of natural areas can have compound effects on society as a whole.[8]

The Land Board is closely connected to agriculture. Decreased production on their lands directly impacts yields of farmers and ranchers. However, this can be a cooperative relationship because the Land Board is willing to negotiate lease discounts during drought. This may actually increase the adaptive capacity for farmers and ranchers leasing Land Board land versus those with mortgages. While this is a good thing for agriculture, lease discounts create compound impacts for public schools and other trust beneficiaries of Land Board fund.

## 5.6 Recommendations

### 5.6.1 Adaptation to Drought

One clear theme that emerged from interviews with state employees is that in the 2002 drought, reactions were not coordinated and media communications were unclear. Efforts were made during the 2011-2013 drought to enhance coordination and messaging such as with the Front Range Water Council. Although steps have been taken in response to the 2011-2013 and 2002 droughts by some agencies to better prepare them for dry conditions, all of the state assets discussed in this section could benefit from greater drought awareness and planning. Every agency should have a drought plan that addresses the vulnerabilities noted in this report, including a communication plan. It is important for all state agencies to identify opportunities for cooperation and coordinated media communication before drought occurs. Taking the time to be aware of existing support systems and existing vulnerabilities will greatly increase the relevance of planning efforts. Management strain on many agencies, especially the CPW, was significant during the 2002 drought. Where possible, agencies should set up emergency funds to be used during drought. Having the ability to hire additional staff during drought would significantly increase the adaptive capacity of the CPW and other management agencies.

In Section 5.4, specific adaptation opportunities were discussed for each asset group individually. In addition to increased awareness and planning efforts, agencies can start developing policies to provide additional flexibility during times of drought. For example, the CPW has the ability to close access to stressed areas, while the Land Board can negotiate lease prices in response to decreased yields. In many cases statewide action will not be effective because of the wide spatial dispersion of state assets. Thus, mitigation planning has to be

[8] Refer to the Socioeconomic Sector for additional information

flexible. In addition to coordinated efforts, individual state parks and buildings will need to assess operations and determine response. Individual stream reaches and fish hatcheries should be assessed for specific vulnerabilities. As noted in Section 5.3.5, impacts can vary greatly depending on water sources, sensitivity of species, and water rights in the basin. To adapt appropriately these variables will need to be considered and planned for on a case-by-case basis.

### 5.6.2 Improving Vulnerability Assessment

The vulnerability assessment conducted for state assets in this study is the first of its kind. While most assets have been quantitatively evaluated, there are several data gaps that could further improve results if filled. Future work should focus on gathering statewide data in a consistent manner to input into the framework developed here.

For the purposes of this analysis the relative importance of dams versus buildings was used as a metric assuming that dams are more likely to be damaged by drought. Future work should analyze the types of dams that are most likely to be damaged and the ditches that are most junior and likely to remain dry for extended periods of time.

Seniority of the instream flow rights was used as an impact metric for protected aquatic habitat. Future work should develop other statewide metrics to further classify this resource. Identification of those areas that are most sensitive could be completed with additional monitoring to determine baseline conditions and the sensitivity of fish populations to environmental perturbations. Using this information, instream flow reaches and natural lakes could be assigned sensitivity scores to be input into the vulnerability assessment. Since 2010, CPW has increased their monitoring efforts and may be able to begin assembling this data.

Detailed water rights analysis with respect to other calls could also inform on the likelihood of water levels not being maintained. For example, modeling exercises could be completed to determine the minimum flow for which an instream flow level will likely be maintained, taking into account probable calls by other water rights. The resulting minimum flow numbers can be used as a vulnerability metric where those rights with the lowest minimum flows are the least vulnerable.

CPW provided helpful qualitative information on the impacts to several fish hatcheries during the 2002 and 2011-2013 droughts. However, systematic data on water sources, and operations information were not readily available in an aggregated format and it was beyond the scope of this project to investigate hatcheries on an individual basis. Future work is needed to investigate the potential drought impacts to individual fishery operation and determine relative vulnerabilities. As with instream flows it would be important to determine the minimum flow in the river under which the hatchery can still effectively operate (once again taking the requirements of other water rights into consideration). Most hatcheries operate on wells or spring collection systems for whirling disease mitigation. The number of state-owned hatcheries is small and it could be feasible to survey hatcheries one by one. Some modeling most likely also would be required. In addition to minimum flows, sedimentation resulting from wildfire damage and subsequent debris flows were reported several times as being particularly damaging to hatcheries. Information on debris flow and where they might occur could prove useful to future vulnerability calculations.

The spatial extent of state-owned protected areas is well documented; however, detailed information on management practices and vulnerabilities is not available. Furthermore, drought impacts have not been monitored in a consistent manner well suited for spatial analysis. Wildfire hazard and beetle kill can be used to measure secondary impacts, but this does not adequately define the stress on the system as a whole. Refer to the Environmental Sector for more detailed analysis on wildfire and beetle kill vulnerability. Future monitoring efforts should focus on identifying drought vulnerable species and habitats.

Similar analysis would be helpful for Land Board lands. In this case there are impact data from 2002; however, changes in Land Board operations (i.e., changes in lease discount administration) indicate that future responses will be different. Spatial drought sensitivity information would be of great value.

In this methodology, outdoor recreation revenue was characterized by visitation to state parks. Hunting and fishing license sales are an important funding source for the CPW. They were not included in the methodology as the data had no spatial distribution. Future work should analyze the types of hunting and fishing that are most vulnerable to drought. Cross referencing these vulnerabilities with the hunting areas for the respective activities would provide spatial information on revenue vulnerability. Coordination with the CPW is required to determine if spatial analysis is relevant to their operations.

One aspect of state assets not specifically considered here are the administrative costs of drought. Employees at the CPW and the State Engineers Office specifically noted a significant increase in workload responding to drought-related issues. The State is responsible for many public service agencies which may also be in high demand responding drought impacts across all sectors. These agencies often provide important assistance and increase the adaptive capacities of the sectors they work with. In 2000, the Hi Meadow and Bobcat wildfires cost state and local governments about $6.5 million (State of Colorado Water Availability Task Force, 2002). While management costs are not included as a state asset, future work should analyze the potential cost incurred by all state agencies in responding to drought. Appropriate preparation should be taken so that state agencies anticipate drought-related issues and are prepared to expand their services when they are needed the most.

**Structures**

- Identify other state-owned water infrastructure.
- Conduct a water rights analysis for state-owned ditches to determine the likelihood that they will be dry for extended periods during a drought.

- Conduct a vulnerability assessment for every state-owned dam considering the construction material and the possible low water levels during drought.
- Gather data on irrigation practices and their water sources for state-owned properties.

**Land Board Revenue**

- Spatial drought sensitivity information for Land Board properties based on ecological conditions and land use.

**Recreational Revenue**

- Estimate costs of drought management for CPW.
- Determine spatial distribution of CPW revenue sources.

- The spatial analyses of how animal populations respond to drought could offer additional information about which species, areas, and activities are most susceptible to drought.

**Aquatic habitat**

- Conduct a vulnerability assessment for state-owned aquatic habitat to determine sensitivity to environmental perturbations.
- Conduct water rights analysis for instream flow reaches and natural lakes to determine the minimum flow levels which can maintain required levels.
- Survey state-owned fish hatcheries and differentiate operational practices that increase vulnerability.

**Protected areas**

- Identify and map drought-vulnerable species and habitats. These efforts should be coordinated with the Environmental Sector.

## 5.7 References


Board of Land Commissioners. 2011. Colorado State Board of Land Commissioners Annual Report Fiscal Year 2010-11.

Board of Land Commissioners. 2002. Decision on drought relief for agricultural leases.

Byers, Jack, and Dick Wolfe. Responsibilities and Roles in Water Resources. Colorado Division of Water Resources.

Colorado Department of Corrections (CDOC). 2013a. Written communication with John Gillogley on 4/25/2013.

CDOC. 2013b. Written communication with John Gillogley on 5/1/2013.

Colorado Division of Wildlife (DOW). 2004. Colorado Division of Wildlife 2004 Annual Report.

DOW. 2010. Private Land Habitat Programs 2009/2010.

DOW Staff. 2009.

Colorado Parks and Wildlife (CPW). 2013. 2013 Fact Sheet.

CPW. 2013b. Personal communication with Brian Kurzel, Acting Supervisor of the Policy and Planning Unit. Communication via email May 24, 2013.

CPW. 2012. 2012 Drought Impacts. Internal Communication.

CPW. 2012b. FY 11-12 Game Damage Program Report Overview.

Colorado State Land Board. *Trust Land Ownership by County, as of June 2010.* 2010. Available from http://trustlands.state.co.us/MapsandData/Pages/MapsAndData.aspx.

Colorado State Parks. 2010. Historic Visitation.

Colorado Water Conservation Board (CWCB). *CWCB website, new appropriations tab*. 2013. Available from http://cwcb.state.co.us/StramAndLake/NewAppropriations/.

CWCB. 2010. Statewide Water Supply Initiative (SWSI). 2010 Update. Colorado's Water Supply Future. January 2011.

CWCB. 2010b. Non-consumptive Needs Assessment Focus Mapping. July.

CWCB. 2004. Colorado Drought Water Supply Assessment.

Hartman, Todd. 2009. Pine beetle epidemic hits Colorado campgrounds; Infestation forces closing, delays openings at sites. *Rocky Mountain News*, April 11, 2008.

Luecke, Daniel F., John Morris, Lee Rozaklis, and Robert Weaver. 2003. What the Current Drought Means for the Future of Water Management in Colorado.

Merriman, Dan. 2002. How did the drought of 2002 affect instream flow water rights? Paper read at Colorado Drought Conference; Managing water supply and demand in the time of drought.

Natural Resource Ecology Laboratory. 2011. Colorado Ownership, Management, and Protection v9 database. Colorado State University, Natural Resource Ecology Laboratory.

State of Colorado Water Availability Task Force. 2002. Impact Task Force Drought Assessment and Recommendations.

Thomas, Deborah, and Olga Wilhelmi. 2012. *Drought Assessment for Recreation & Tourism: Southwestern Colorado report.* The Colorado Water Conservation Board.

# 6 AGRICULTURE SECTOR

## Key Findings

- Three key impact categories were identified for agriculture: crops, livestock, and the green industry.
- Key drought vulnerabilities for crops include crop loss from lack of precipitation (in the case of dryland crops) or insufficient irrigation, and/or damage to crops due to reduced quality of irrigation water.
- Grazing lands are vulnerable to drought, resulting in limited forage availability and disturbance of the managed ecosystem.
- The green industry (which consists of nursery, greenhouse, floriculture, and sod) is vulnerable to municipal water restrictions as well as water-availability reductions that could cause income and job loss.
- For the livestock subsector, the 2011-2013 drought event was a culmination of difficult circumstances. The widespread nature of the drought impacted local and regional rangelands limiting the abundance of healthy pasture and feed hay production. The drought also impacted the Midwestern corn feed crop, driving up the price of feed. Many ranchers were forced to sell breedstock and are unsure if they will be able to stay in business if the drought persists.

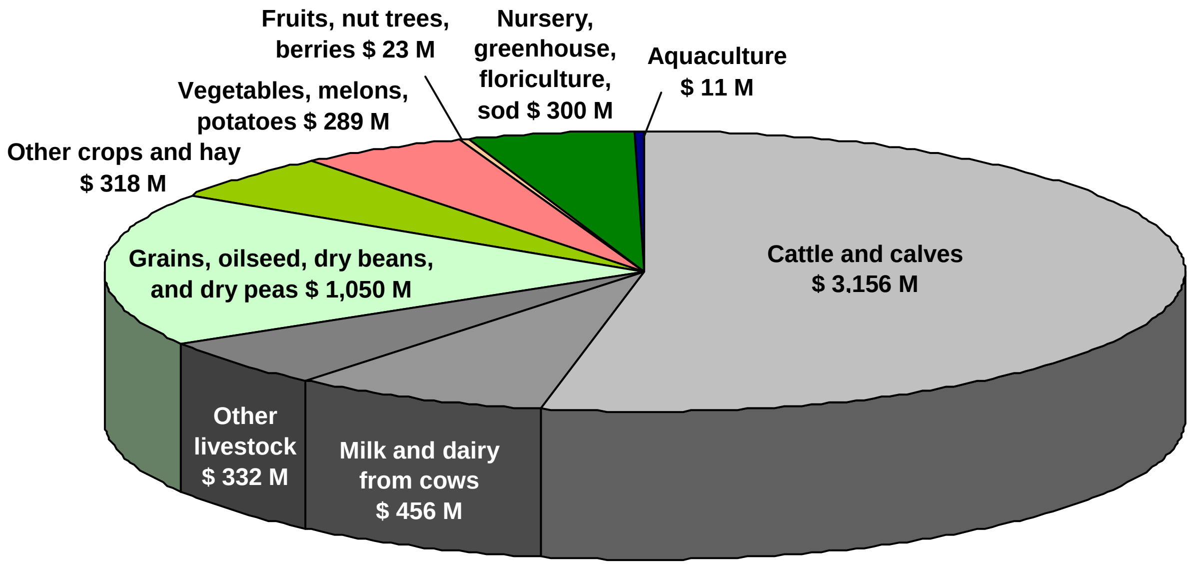
## Key Recommendations

- Crop diversification and advanced planning for drought scenarios can benefit all sub-sectors within the Agriculture Sector.
- In this assessment, dryland crops were identified as the most vulnerable. In future studies, a specific analysis of irrigated crops and water availability is recommended.
- Best management practices developed by the green industry might have applications for irrigated crop producers.
- Due to the small sample size of green industry producers, public data on this sub-sector is not available. A survey instrument might be a valuable tool to collect information about the industry in the future.
- NASA's CASA (Carnegie-Ames-Stanford Approach) model provides a way for resource managers to measure drought impacts in Colorado at a synoptic scale.

## 6.1 Introduction to Sector

The Agriculture Sector is a key economic driver in Colorado, and some form of agriculture activity is found in nearly every county in the State. The Colorado Department of Agriculture (CDA) estimates the value of grown, processed, and marketed agricultural products to be $15 billion annually[1] (CDA, 2010). The U.S. Census of Agriculture, which collects statistics on farms and producers throughout the country, reported that the total market value, before value-added processing, of agricultural products in Colorado in 2007 was $6.1 billion. Figure 6.1, from the U.S. Department of Agriculture (USDA) National Agricultural Statistics Service (NASS), shows how that $6.1 billion is broken down between different agricultural groupings. Unfortunately the census is published every 5 years, with the 2012 update expected to be available in 2014. Figure 6.1, though based on 2007 data, remains relevant as an overall representation of agricultural products in Colorado.

**Figure 6.1. Market Value of Agricultural Products in Colorado, 2007**




Source: USDA NASS, 2007

Cattle and calves constitute a large percentage of the overall agricultural products in Colorado. Along with dairy cows and other animals, the "livestock" sub-sector contributes over $3.9 billion to the Sector. Other than livestock, sub-sectors identified for this study include crops (which consist of irrigated and non-irrigated) and the green industry (which consists of nursery, greenhouse, floriculture, and sod). The one sub-sector shown above that is not discussed in detail

[1] http://www.colorado.gov/cs/Satellite/Agriculture-Main/CDAG/1220439013141

is aquaculture, due to its minor economic role in the overall sector. Discussion of and impacts to state-run fish hatcheries, which are expected to be similar to privately-owned hatcheries, are located in the State Assets and Recreation Sector.

For this assessment, the livestock sub-sector consists of cattle and calves, although livestock owners in Colorado do raise other animals (e.g., sheep, goats, horses, etc.). The focus on cattle is due to the nature of grazing. Drought can severely impact ranchers by limiting forage availability, thus reducing the carrying capacity of traditional grazing areas. In response local, state, and federal land-holders restrict the number of grazing leases issued in a drought year. Raising cattle for meat also depends on having adequate pasture and finishing feed sources (e.g., corn, hay, alfalfa, etc.) (Luecke et al., 2003). The herd is turned out to graze in the summer and brought back in the winter, where they are fed stored hay and grain. The stored feed is either grown by the rancher or purchased from an outside source, either an in-state farmer or an out-of-state one. This reliance on supplemental feed in the wintertime (generally hay, which can be both irrigated or dryland) means that cattle ranchers are vulnerable to drought impacting the crop sub-sectors as well.

Other animals that are housed in feedlots or on small farms generally consume hay and grains purchased from both in- and out-of-state growers and water from various sources such as municipalities, private wells, or surface water rights. These operations can be secondarily affected by drought in that feed may become more expensive or hard to obtain, and their water supply may become reduced or restricted. However, the value of the livestock is generally such that operators have invested in senior water rights or another secure supply of food and water (much like high-value irrigated crop farmers tend to invest in senior water rights to ensure the viability of their fields). Dairy production is mentioned here but not considered in this assessment because the dairy operations are accustomed to purchasing feed on a year-round basis, and thus are fairly insulated from localized droughts (communication with CDA, 2010). The map shown in Figure 6.2 is a head count of total cattle per county. The data comes from the NASS survey program and should be updated with the 2012 census numbers when that dataset becomes available.

The crops sub-sector consists of irrigated and dryland (non-irrigated)[2] crops grown around the state. Major dryland crops are winter wheat (grown on the eastern side of the state), pastureland, and beans (McKee et al. 2000). Dryland millet production has increased substantially in the last decade. Roughly 90% of Colorado's wheat is grown under dryland conditions, while about 75% of corn grown for grain is irrigated (Situation Statement, Colorado State University [CSU], 2010).

[2] Dryland crops are crops that are not irrigated and are grown in a semiarid climate. In Colorado, non-irrigated crops are essentially dryland crops, although this may not hold true for other states and other climate regions.

Dryland crops, which are entirely dependent on precipitation, are distinguished from irrigated crop for this assessment because they are more susceptible to damage by droughts. Dryland crops are particularly vulnerable to severe, “single season” droughts that deplete soil moisture (McKee et al., 2000). Figure 6.5 shows the concentration by county of dryland crops in Colorado (NASS, 2007). Wheat is the dominant crop on Colorado’s 8.9 million acres of non-irrigated cropland. Annually, it occupies about one quarter of these acres, which is more than the total of the next five most extensively grown dryland crops (e.g., corn, sorghum, hay, proso millet, and sunflowers). (Situation Statement – CSU, 2010). After winter wheat, other crops primarily found on the eastern plains include corn, sorghum, proso millet, sudex, and sunflowers. These crops are commonly rotated with wheat. Livestock producers, located throughout the state, often plant annual forage (dryland) to feed their herd in the winter months.

There is a wide range of irrigated crops grown in Colorado, such as irrigated hay on the western slope, irrigated vegetables located throughout the state; and fruit orchards and vineyards, which are concentrated mainly in Mesa County. Specific examples of irrigated crops in Colorado include corn, sorghum, dry beans, barley, potatoes, sugar beets, and vegetables (McKee et al., 2000). Due to the extensive variety of crops grown in Colorado, specific crop discussion is limited except as it relates to geographic areas of the state.

Geographic distribution of total crop acreage is shown in Figure 6.3, which illustrates that there is a higher percentage of land (as a percentage of county land area) in farms on the eastern plains than on the western slope (NASS, 2007). Figure 6.4 shows the distribution of some common crops as they are grown throughout Colorado. The image was created by classifying land cover types from a Landsat image with a ground sampling distance of 30 m. Some trends in cropping include fruit orchards and vineyards in Mesa County, oats and barley in the San Luis Valley, and the dominance of the eastern plains by pasture/grass (yellow-green) and winter wheat (brown).

The final sub-sector in the Agriculture Sector is the green industry, which contains a number of significant secondary sub-sectors such as landscape labor fields (e.g., landscaping companies and grounds maintenance) and landscape designers (e.g., landscape architects, etc.). These industries would be impacted by drought if the growers were unable to provide plants, or if the owners of the yards voluntarily chose or were mandated to reduce watering and/or stop new planting. However, the main focus of this report is on the primarily impacted areas - namely, the growers (e.g., nurseries, floriculture, sod, etc.). These producers within the green industry are impacted when drought impedes their ability to grow a product that can be sold to the consumer.

According to an independent study by CSU, the green industry in Colorado contributed more than $1.8 billion in sales to the economy in 2007 (Thilmany et al., 2007). The direct market value of nursery, greenhouse, floriculture, and sod products in 2007 was $300 million, according to the USDA NASS. This illustrates the “value added” multiplier that green industry products (and other agricultural products) have as they are processed and sold to consumers.

For USDA statistical purposes, the following "crops" or categories are considered part of the green industry in Colorado (as listed in the NASS CO Ag Census 2007):

- Aquatic plants
- Bulbs, corms, rhizomes, and tubers
- Cuttings, seedlings, liners, and plugs
- Floriculture crops - bedding/garden plants, cut flowers and cut florist greens, foliage plants, potted flowering plants, and floriculture and bedding crops
- Flower seeds
- Greenhouse fruits and berries
- Greenhouse vegetables and fresh cut herbs
- Mushrooms
- Nursery stock and crops
- Vegetable seeds and transplants
- Sod harvested
- Cut Christmas trees

As shown in Figure 6.6, green industry producers (e.g., greenhouses, nurseries, sod growers, etc.) are primarily located in Weld, Larimer, and Boulder Counties on the east slope and in Mesa and Delta Counties on the west slope. In general, the green industry producers are located near urban population centers. There are some producers throughout the west and the south, and there very few on the eastern plains and near the southwestern part of the state (in the vicinity of San Juan, Hinsdale, Mineral, and Archuleta Counties).

Since the Agricultural Sector is quite large, different seasons of drought will impact different sub-sectors. Table 6.1, below, discusses water use and seasonality in the Agricultural Sector.

**Table 6.1. Seasonality and Water Use in the Agricultural Sector**

| Sub-sector | Season | Water Use |
|---|---|---|
| **Crops: dryland** | • Successful crop depends on precipitation in the fall to start plant germination, and in the spring to develop the grain (McKee et al., 2000).<br>• Winter wheat, the prominent dryland crop in Colorado, is generally planted on a 2-year rotating basis to allow the soil to accumulate enough moisture to support it. | • Water is required for adequate soil moisture to germinate and grow.<br>• These crops are entirely dependent on precipitation. |
| **Crops: irrigated** | • Water demands for most irrigated crops begin increasing in late April, peak in early July, and drop off into late October (McKee et al., 2000). | • Irrigation water is used to supplement natural precipitation and ensure the crop has adequate moisture to grow and produce the desired yield. |

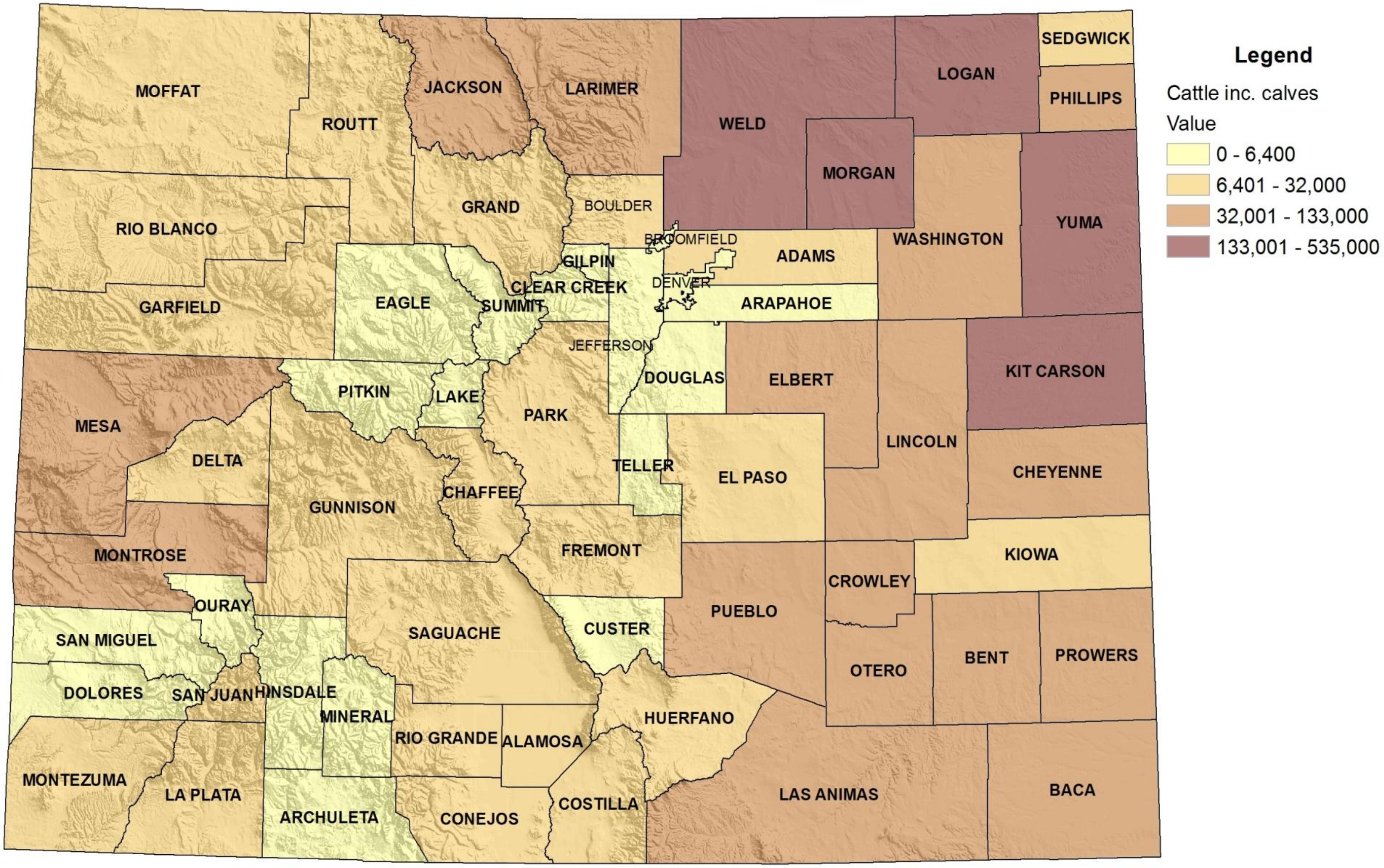
| Sub-sector | Season | Water Use |
|---|---|---|
| **Livestock** | • Cattle released to grazing pasture in early summer, return around the time of the first snowfall. | • Animals need clean drinking water and plenty of forage land or pasture. Most cattle ranchers grow their own forage, either with irrigation water or through dryland practices. |
| **Green Industry** | • Year-round production for greenhouses.<br>• Some greenhouses ship their plants to "winter" in the southeast part of the U.S. (communication with CSU economist, 5/26/10). | • Water is required to grow and maintain plants, trees, and sod.<br>• Source water is diverse - some growers have water rights, some have ditch rights, and some buy from municipalities. |

Table 6.1 demonstrates that impacts from drought are not confined to a single growing season. In addition to being a year-round industry, the Agriculture Sector influences a number of other sectors of the economy and state, namely municipal and socioeconomic. The sub-sectors described above were chosen based on their economic impact to the overall agricultural industry and their immediately recognizable vulnerability to drought. Other sub-sectors that are not covered in this report but worth mentioning include:

- Livestock other than cattle, such as sheep, goats, chickens, pigs, etc. These animals would be impacted by drought but are much smaller in numbers than cattle.
- Fruit orchards and vineyards near Grand Junction on the western slope. Not only do these farms produce and sell fruit, but a growing tourism industry is developing around wine-based activity in Colorado, and this sub-sector would benefit from future study. A report was conducted by CSU in 2006 on the economic contribution of the wine industry in Colorado. Among their findings: the 2005 Winefest in Mesa County directly contributed $1.3 million to the local economy, direct wine sales including returns to wine grape producers and their contribution to the economy added $21.1 million to the statewide economy in 2005, and the industry as a whole is experiencing robust growth (Kress and Thilmany, 2005).
- "Agri-tourism," which is tourism centered on agricultural attractions (e.g., wineries), is a small but growing sub-sector within agriculture. It would be worth attention in the future, perhaps in conjunction with a recreation and tourism assessment.

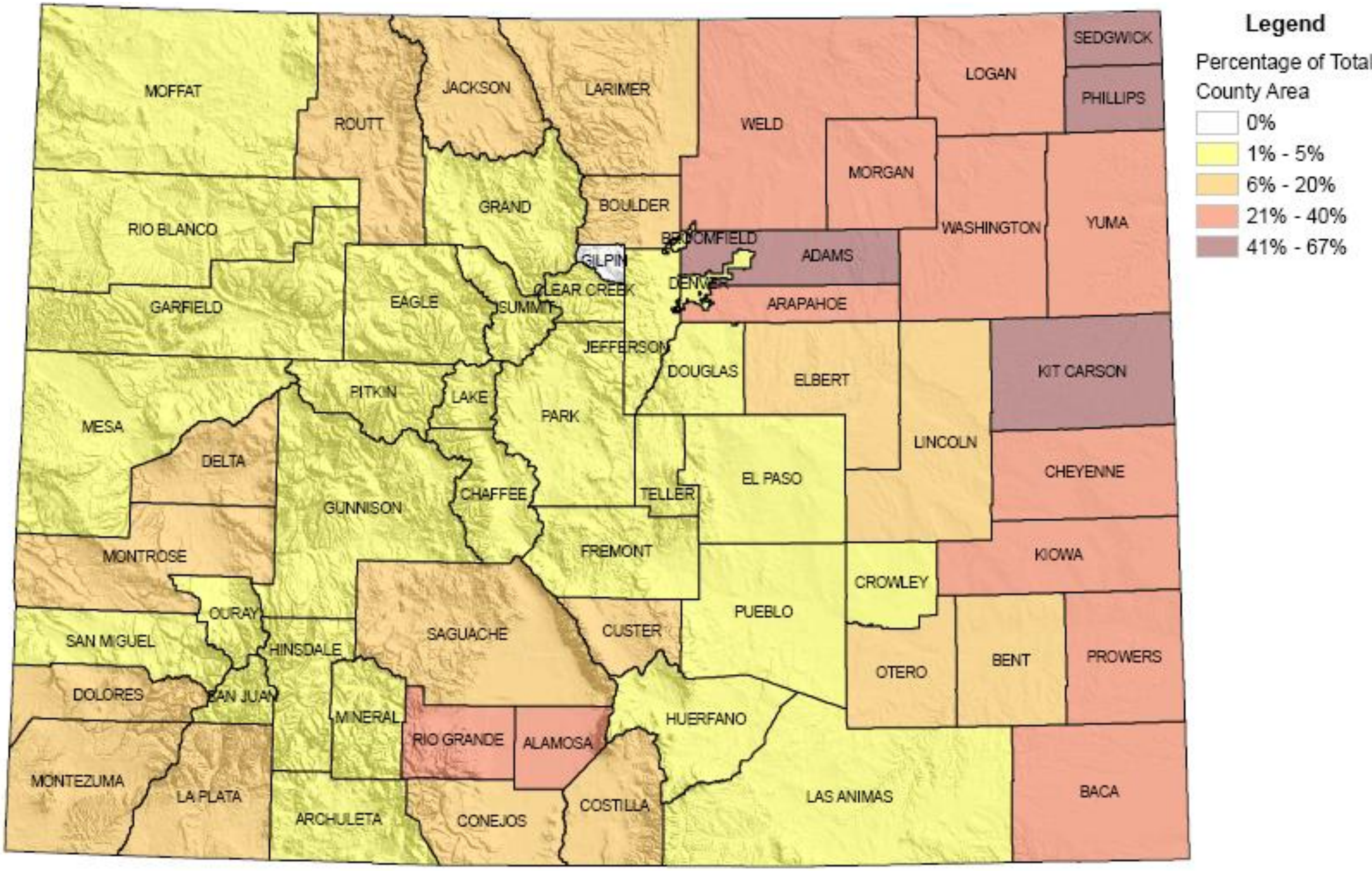
The following sections discuss aspects of vulnerability to drought in the Agriculture Sector, and cover adaptive capacities used to mitigate the impacts. For a general description of the vulnerability assessment approach refer to Chapter 2 of Annex B.

## Figure 6.2. Cattle Head Count per County



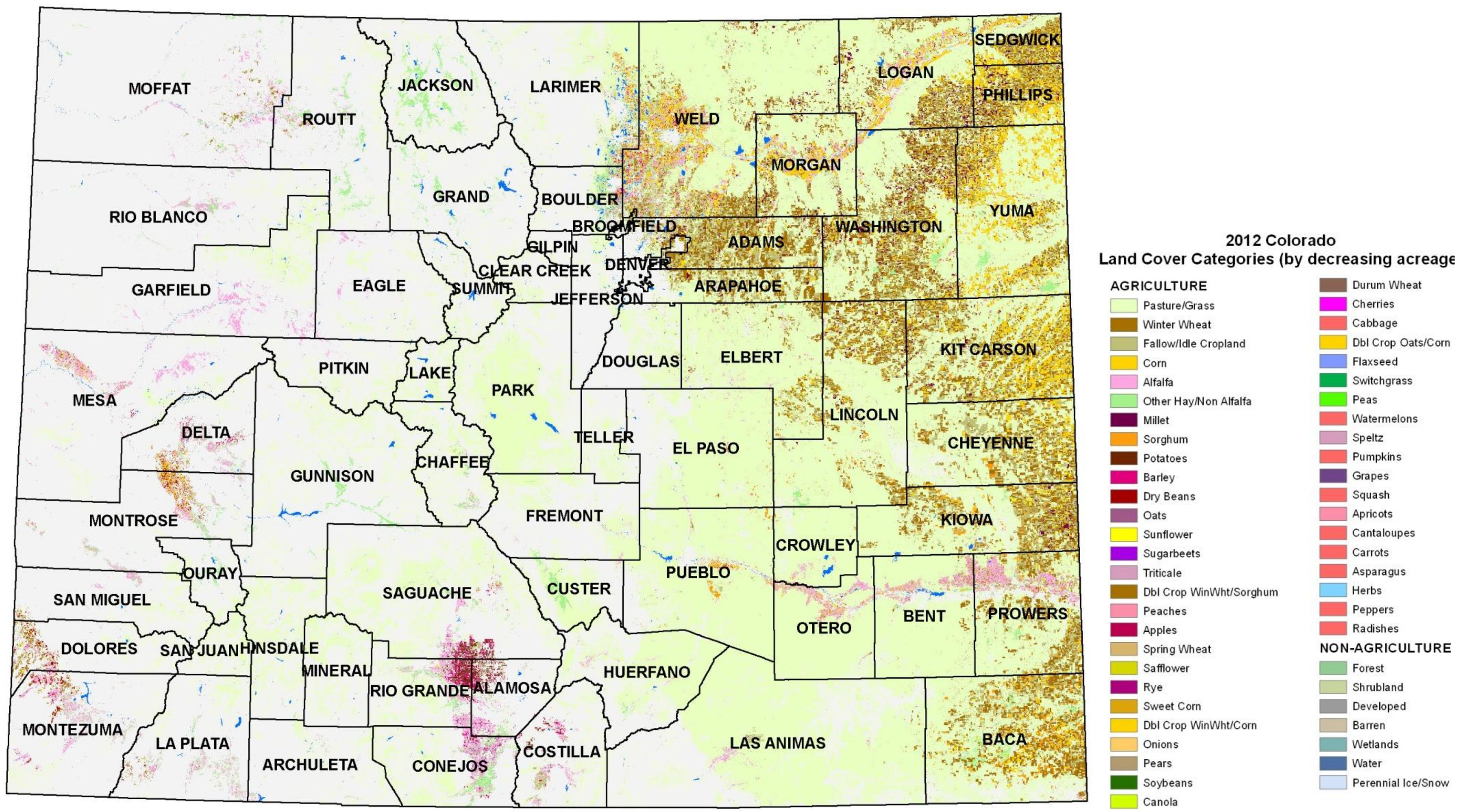

Source: NASS, 2009

**Figure 6.3. Percentage of Total County Area Dedicated to Farmland**



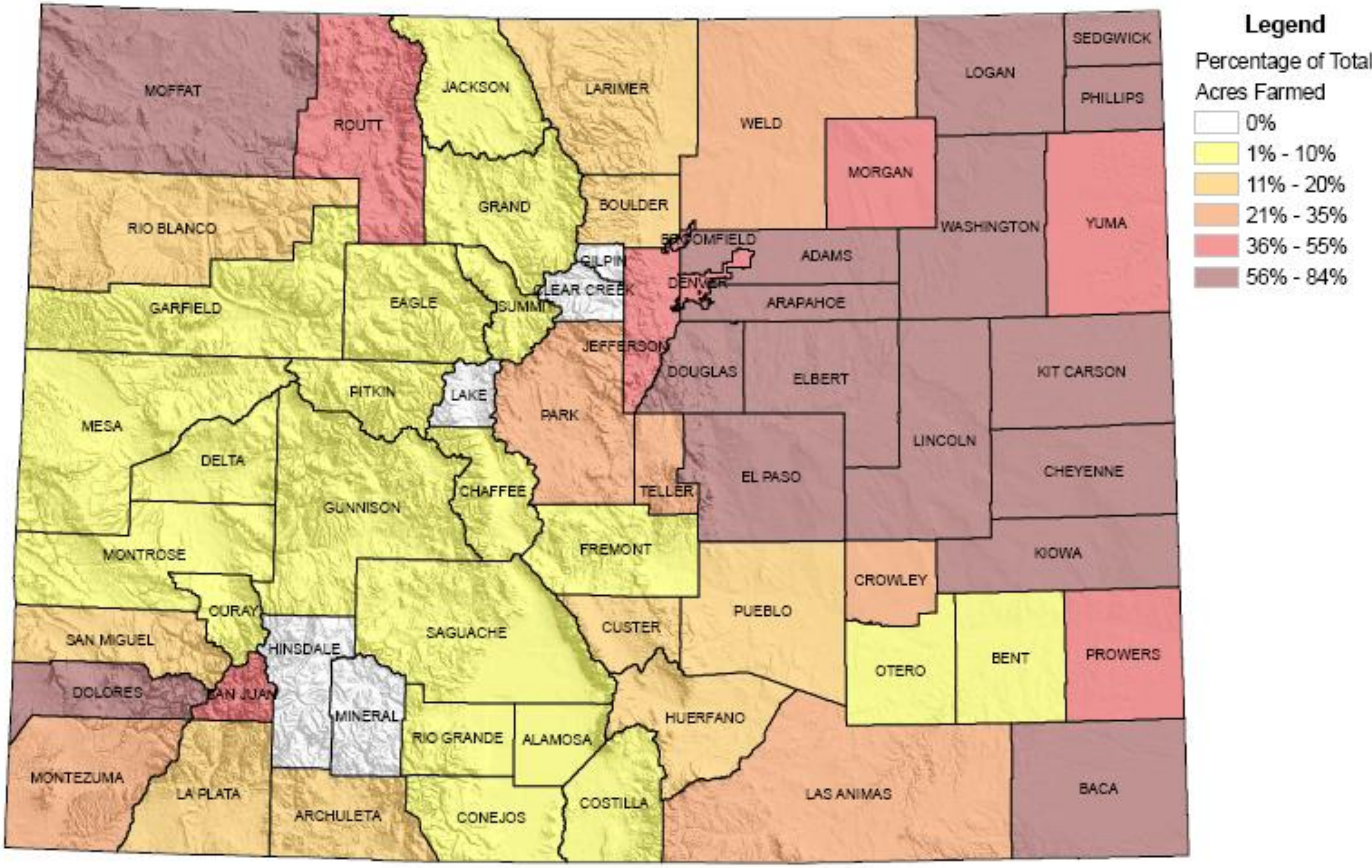

Source: NASS, 2007

## Figure 6.4. Crop Types Across Colorado



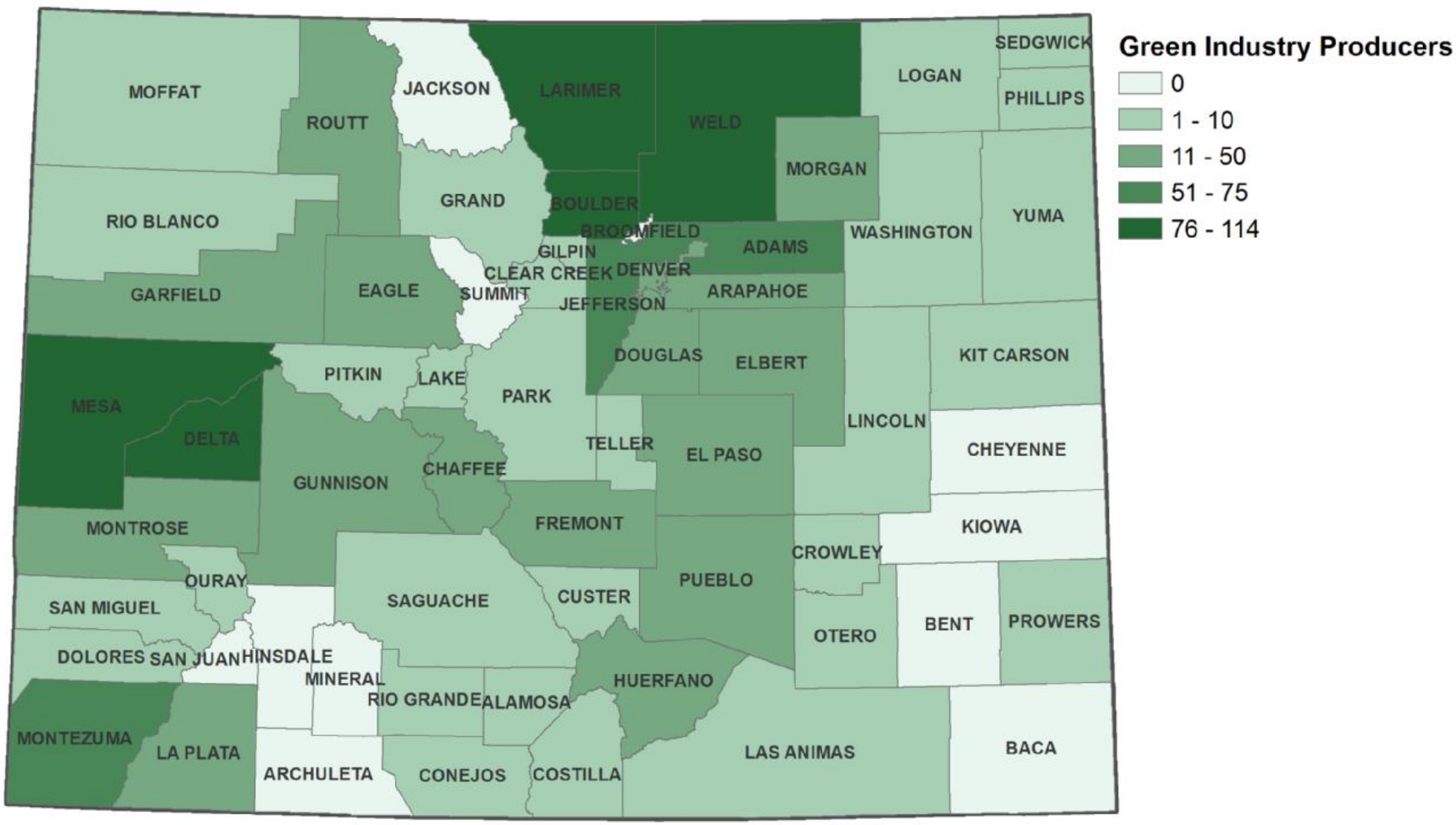

Source: USDA, NASS Crop Data Layer Program, 2012

## Figure 6.5. Percentage of Farmland Consisting of Dryland Crops




Source: NASS, 2007

## Figure 6.6. Location of Green Industry Producers




Source: NASS, 2007

## 6.2 Vulnerability of Agricultural Sector to Drought

### 6.2.1 Aspects of Vulnerability

Agriculture is vulnerable to drought when there is not enough water to sustain crops or livestock and livestock forage. This is largely dependent on precipitation, water rights, and relative magnitudes of supply versus demand that exist in the area.[3] Agricultural users have four sources of water: direct precipitation, streamflow diversions, reservoir storage and releases, and groundwater withdrawals (McKee et al., 2000).

Agriculture is the dominant water use in Colorado. Estimates from the Statewide Water Supply Initiative (SWSI) show that 85 % – 89 % of the water diverted and consumed in Colorado goes to irrigate crops (SWSI, 2007). As urban development continues and the state's population grows, entities seeking new water supplies will increasingly look to agriculture to meet their growing demands for urban water (SWSI, 2007). This statement from SWSI highlights the supply versus demand issue – in fast-growing areas, demand will outpace supply and municipal demands to purchase agricultural water rights could put pressure on farmers to sell. There is also long-term increased competition for water from other sectors, such as recreation and the environment.

In addition to reduced water quantity due to drought conditions, the quality of irrigation water is a concern, as crops are sensitive to salts and other impurities in the water. Lower flows can concentrate soluble salts and result in lower crop yield (Bauder et al., 2007).

Table 6.2 and Table 6.3 are examples of how reduced water quality can injure crops and reduce crop yield. Degraded water quality is one effect of drought. Table 6.2 shows potential yield reduction from saline waters, and Table 6.3 shows plant susceptibility to injury from contact with saline water.

[3] For example, agriculture faces growing competition with urban areas as population increases and municipalities seek to acquire new water rights.

## Table 6.2. Potential Yield Reduction from Saline Water for Selected Irrigated Crops

| Crop | Percent yield reduction at measured ECw* 0% | 10% | 25% | 50% |
|---|---|---|---|---|
| Barley | 5.3 | 6.7 | 8.7 | 12 |
| Wheat | 4.0 | 4.9 | 6.4 | 8.7 |
| Sugarbeet | 4.7 | 5.8 | 7.5 | 10 |
| Alfalfa | 1.3 | 2.2 | 3.6 | 5.9 |
| Potato | 1.1 | 1.7 | 2.5 | 3.9 |
| Corn (grain) | 1.1 | 1.7 | 2.5 | 3.9 |
| Corn (silage) | 1.2. | 2.1 | 3.5 | 5.7 |
| Onion | 0.8 | 1.2 | 1.8 | 2.9 |
| Beans | 0.7 | 1.0 | 1.5 | 2.4 |

*$EC_w$ is electrical conductivity of the irrigation water in dS/m at 25 degrees Celsius and is a common measure of salinity. Source: Bauder et al., 2007

## Table 6.3. Susceptibility Ranges for Crops to Foliar Injury from Saline Sprinkler Water

| | Na or Cl concentration (mg/L) causing foliar injury* | | | |
|---|---|---|---|---|
| Na concentration | <46 | 46-230 | 231-460 | >460 |
| Cl concentration | <175 | 175-350 | 351-700 | >700 |
| | Apricot | Pepper | Alfalfa | Sugarbeet |
| | Plum | Potato | Barley | Sunflower |
| | Tomato | Corn | Sorghum | |

*Foliar injury, which is damage to the surface or leaves of the plant, is also influenced by cultural and environmental conditions. Source: Bauder et al., 2007

Vulnerability to the livestock sub-sector is primarily a function of forage and pastureland availability. When the lands are stressed by drought and the quality of hays and grasses for cattle to graze upon is decreased, ranchers can see sickness and deaths in herds. Decreased water quality is also a concern, as grazing cattle can become sickened if watering holes are contaminated, filled with sediment, or completely dry. In drought conditions rangelands may become unviable for grazing at the same time as feed costs soar. At some point the situation may become unviable and ranchers may be compelled to sell breeding cows to out-of-state interests. A significant impact of such an action is that it can take several years to rebuild the loss of genetic diversity from such sales. Grasslands may recover from drought (and the over-grazing that can result) very slowly, giving invasive weeds and other undesirable species the advantage over native grassland plants. Associated with a decrease in production is an increase in toxicity during drought. When the usual forage becomes scarce, cattle may reach to plants that are potentially toxic. These plants are generally grouped into nitrate accumulators, prussic acid producers, and noxious weeds.

The green industry is vulnerable to drought in much the same way the irrigated crop sub-sector is. Junior surface water rights can be called out of priority during a drought, leading to less water available for irrigation, which could cause reduced plant yield or plant loss. There is a minority of growers who rely on municipal supplies and could be subject to municipal restrictions. Decreased water quality (i.e., increased salinity or other contaminates) can cause foliar (leaf) injury and limit the ability of the grower to sell their plants to the public and whole-sale distributers. Municipal restrictions on water use can cause consumer demand for landscape plants and new turf to sharply decrease, resulting in fewer sales for growers and loss of revenue.

### 6.2.2 Previous Work

A review of previous works dealing with drought and agriculture in Colorado was conducted. Data and research for the 2012 and ongoing drought event are starting to become available and those limited works are discussed below. Most of the reports presented below discuss the drought of 2000-2003, as this was the most recent event. Table 6.4 summarizes the impacts and results of the literature review.

## Table 6.4. Previously Reported Agricultural Impacts

| Sub-sector | Previously reported impacts | Sources |
|---|---|---|
| **Livestock** | • In response to the 2002 drought, ranchers ran short of pasture grass and finishing feed and were forced to sell off some of their herds. Estimates are that the herds in Colorado declined by 50%. The Colorado Farm Bureau estimated the direct loss to the livestock sector at $154 million.<br>• For 2002, crop and livestock losses due to drought were estimated at $150 million for ranchers and $300 million for farmers… As a result of reduced forage and water for livestock, the emergency grazing provisions of the Conservation Reserve Program lands were implemented through USDA Natural Resource Conservation Service (NRCS).<br>• In 2002, cattle – 50% of cows were sold statewide, 80% of the cows in the southern third of Colorado were sold equating to about 450,000 head of cows, over 1 million statewide. Financial impact: $154 million loss… Some ranchers paid high prices to move their cattle out of state to feed them in the fall and winter.<br>• During 2002, sheep – range in poor conditions (fall and winter), lack of crop aftermath for winter grazing (lack of wheat stubble, corn stocks, alfalfa field, etc.)<br>• For the 2012 drought, ranchers were once again forced to sell part of their herds, including breeding stock in some cases.<br>• Ranchers noted decreases in cow health, weaning rates, and breeding rates, the effects of which will carry over into subsequent years.<br>• Production costs increased for ranchers as a result of decreased production on ranchlands. The cost is estimated at roughly $110 million, which is a 10-15% increase over the period 2005-2010.<br>• Due to the reduction of forage and feed production the cost raising a cow increased ~40%<br>• Survey results suggest that the number of cows statewide decreased 48% from normal during 2012.<br>• Due to the spatial extent of drought in 2012, ranchers were unable to transport their animals to more productive ranchlands, as the drought covered increasingly significant portions of the western US. | Luecke et al., 2003<br><br>DWSA 2004<br><br>Christensen 2002<br><br>Nelson et al., 2012<br><br>Gunter et al., 2012<br><br>Pritchett et al., 2013<br><br>Pritchett et al., 2013<br><br>LMIC, 2013 |
| **Crops - dryland** | • During the 2002 drought wheat was particularly hard hit. The loss from the drought was between 30 and 45 million bushels with an average price around $4 during 2012.<br>• For 2002, the dryland corn crop was a near total loss from about 20 million bushels.<br>• Wheat – economic loss of '02 winter wheat was estimated at $120 million. Crop projected at only 38 million bushels (83.4 million bushels is 10-year average – smallest harvest since 1968). 30% (700,000 acres) abandoned and not harvested.<br>• Dryland corn – "toast" (implying almost complete loss).<br>• During 2002 irrigated corn – early projections showed reduced yields by at least 10-15% or more.<br>• Sunflowers – down 71% in production<br>• For the 2012 drought, the Arkansas basin, which is ~37% dryland, saw significant decreases in crop yields (refer to Table 6.5 below). Revenues decreased approximately $85 million from the 1998 to 2010 average.<br>• Secondary impacts in the Arkansas Basin from the decrease in crop yield include a decrease in economic activity of roughly $105 million, including loss of approximately 1300 jobs. | Luecke et al., 2003<br><br>Christensen 2002<br><br>Gunter et al., 2012Gunter et al., 2012 |

| | | |
|---|---|---|
| **Crops-irrigated** | • During the 2002 drought, yields in irrigated cornfields approached normal, although some farmers apparently cut fields early to use as silage.<br>• Fruit farmers on the Colorado and Arkansas Rivers were able to utilize their very senior water rights in the 2002 drought, and thus suffered only small decreases in yield.<br>• For the 2012 drought, irrigated crops in the Rio Grande Basin were not impacted, showing slight increases in barley, potatoes, and wheat. Revenues were $12 million greater than the 1998-2010 average.<br>• An increase in yield in the Rio Grande Basin generated an approximately $5 million increase in economic activity and 42 new jobs through secondary impacts. | Luecke et al., 2003<br><br>Gunter et al., 2012<br><br>Gunter et al., 2012 |
| **Green industry** | • Harm to producers due to municipal restrictions/limitation; secondary impacts to landscaping companies.<br>• In 2002 the green industry in Colorado lost about 15,000 jobs and $75 million in revenue. | Reported impact survey, municipal workshop conducted January 2010<br><br>Proctor 2003 |

The following commentary highlights impacts to the ranching community during the 2002 drought (Christensen, 2002):

"*Many farmers and ranchers are soul-searching on whether to stay in agriculture or not. Older farmers and ranchers have or are ready to retire… The younger farmers and ranchers are struggling getting started, but have not necessarily made big investments and may choose to get out. Perhaps the most vulnerable group might be the middle-aged group of farmers and ranchers. They are in it too far to just quit, but still have a long ways to go before retirement.*"

From the 2002 Colorado Drought Conference, the following drought mitigation successes were reported (Christensen, 2002):

*Federal disaster assistance was requested by the governor and the USDA announced all counties in Colorado were eligible for drought disaster. Emergency grazing on Conservation Reserve Program (CRP) acres was approved by the USDA for numerous counties, extended through December 31 or until disaster no longer exists. USDA also announces $752 million in Livestock Compensation assistance for livestock producers, which includes beef and dairy cattle, sheep, goats, and buffalo producers.*

These sentiments are also true for the 2011-2013 drought event. Farmers and ranchers are struggling with decisions to stay in the business with many saying they will leave if the drought continues (Pritchett et al., 2013). Through fiscal years 2011 and 2012 the FSA delivered $342.8 and $395.6 million (respectively) in federal program payments and loans to Colorado farmers and ranchers.

In order to better understand the impacts of drought on the agriculture sector, the CWCB, Colorado Department of Agriculture (CDA), and Colorado State University (CSU) initiated a study of drought impacts for 2011. The project consists of three parts, including a history of agriculture in the Arkansas and Rio Grande River basins, a survey of producers in the impacted regions, and an economic analysis of drought impacts in the same regions.

The goal of the survey (Nelson et al., 2012) was to describe how farm and ranch managers changed their business practices in response to drought in 2011. The survey focused on 17 counties located within the Arkansas and Rio Grande River basins that FEMA designated as disaster areas in 2011 due to drought severity. 56 surveys were fully completed, with the majority of respondents from the Arkansas Valley. The following impacts were noted:

- Reduced regional spending by agricultural producers on inputs to farming operations negatively impacted associated businesses and households;
- Higher feed costs associated with a decrease in ranchland production;
- Ranchers saw significant impacts in cow health conditions, weaning rates and breeding rates;
- Ranchers were forced to sell breeding livestock to cope with the drought;

- Some ranchers were able to move livestock, substitute feed, and/or sell portions of their herd to mitigate for the drought

The survey also pointed out the relatively uneven distribution of impacts between irrigated versus dryland farming. Irrigated areas reported equal or greater profits, partially a result of being able to sell crops at relatively high prices.

The 2011 economic study by Gunter et al. (2012) built upon the survey mentioned above to examine the economic impacts of drought on agriculture in the Arkansas and Rio Grande basins in southern Colorado. Due to the severity of the drought FEMA declared 17 counties as disaster areas within these two basins. The study represents the third and final part of a study undertaken by the Colorado Water Conservation Board (CWCB), Colorado Department of Agriculture (CDA), and the Department of Agricultural and Resource Economics at Colorado State University (DARE-CSU).

For the study, drought impacts were divided into primary and secondary effects. Primary effects are those that directly impact productive capacity (e.g., yields), while secondary impacts are those industries indirectly impacted, via forward (e.g., output sold to consumers) or backward linkages (e.g., amount paid to labor). The total economic impact of drought within the region is the sum of the primary impacts, plus the secondary impacts to households and/or industries not directly impacted by the drought.

Impacts to production costs are most felt by industries in the forward linkages, such as meat packing plants. Production costs can be impacted by a decrease in the supply of key inputs (e.g., grain products) and by an increase in demand for feed products because of reduced productivity on grazing lands. Both lead to an increase in production costs.

### Impact of Drought on Productivity

Impacts to primary industries were calculated as the difference between actual reported revenue and what they might have earned under normal (i.e. non-drought) conditions (these calculations assume that the drought was not anticipated, so planting behavior was unaltered, and that the prices of associated goods and services were similar to those observed in non-drought conditions.) Drought impacts in the study area were quite different between the two basins examined. This is largely thought to be a result of the fundamental difference in crop composition in each of the basins. The Rio Grande basin has a much smaller percentage of dryland farming (<10%) than the Arkansas (~37%), and the disparity between the two basins can be seen in yield numbers in Table 6.5. In the Rio Grande, yields were actually higher for some crops (i.e., barley, potatoes, and wheat), while in the Arkansas significant reductions were reported in all crops.

## Table 6.5. Actual and Adjusted Average Yields

| | Rio Grande | | | Arkansas | | |
|---|---|---|---|---|---|---|
| **Crop** | **Adjusted Actual** | **Average** | **% Difference** | **Adjusted Actual** | **Average** | **% Difference** |
| Barley | 135.10 | 133.86 | 0.93% | - | - | - |
| Corn (grain) | - | - | - | 136.00 | 147.00 | -7.48% |
| Hay | 2.72 | 2.90 | -6.21% | 2.70 | 2.97 | -9.09% |
| Potatoes | 393.00 | 372.10 | 5.62% | - | - | - |
| Sorghum (bu/ac) | - | - | - | 28.00 | 34.70 | -19.31% |
| Sunflowers (lbs/ac) | - | - | - | 945.00 | 1242.69 | -23.96% |
| Wheat (bu/ac) | 102.00 | 100.00 | 2.00% | 27.00 | 30.19 | -10.57% |

Source: Gunter et al., 2012

Adjusted average yield is calculated as the average of 1998 to 2010 excluding the highest and lowest reported yields from that period.

The difference in yield is also observed in revenue, where in the Arkansas basin revenues were approximately $85 million less than revenues earned in ‘normal’ years. This is in sharp contrast to revenues for the Rio Grande basin, which were approximately $12 million greater than actual 2011 revenue.

Secondary impacts were calculated through the use of input-output models. These models essentially generate multipliers which are then applied to the numbers calculated for the direct costs. In summary, the Rio Grande saw an increase in economic activity by roughly $5 million, including ~42 new jobs. The Arkansas basin experienced a decrease of approximately $105 million, including ~1300 jobs.

### *Modeling Forward and Backward Linkages*

Forward and backward linked industries were modeled using the Colorado Equilibrium Displacement Mathematical Programming Model (CEDMP) developed at CSU. While originally developed for other purposes, the model provides an opportunity to investigate the impacts of drought to livestock.

Results suggest that the impact of the drought on production levels was negligible - a reduction of less than 1% of total revenues statewide. However, production costs increased significantly as ranchers were forced to provide supplemental feed because of the lost production on grazing lands. The increase in cost is estimated to be approximately $110 million, or a 10-15% increase over the period 2005-2010, as cited in CAS, 2011.

### *Conclusions of the economic study*

The analyses presented in Gunter et al., 2012 estimates the economic impact of drought to the Rio Grande and Arkansas basins for the 2011 drought. The report notes that insurance payments (totaling roughly $50 million) were not taken into account, as their influence on secondary impacts is unclear. The analysis is, quite obviously, only appropriate for short-term conclusions. On-going drought impacts are likely compounding in ways not addressed in this report. For example, ranchers began selling off cattle herds in anticipation of an extended drought, but the analysis does not reflect those sales.

## Statewide Updates to the Economic Studies

Studies similar to those conducted for the Arkansas and Rio Grande are currently underway for the entire state. As of May 2013 only the survey portion of the study has been completed. Final conclusions have yet to be published, but preliminary survey results offer much insight into the impacts of the 2012 drought to the agriculture sector. A statewide survey was made available online and distributed to various stakeholder groups. The survey opened in December of 2012, closed in March 2013, and focused on impacts to production, managerial response, and local community impacts. 533 surveys were completed with 412 revealing their location with zip codes, covering roughly 4.4 million acres of agricultural land (Pritchett et al., 2013).

### *Impacts to Production*

The first goal of the survey was to determine the extent of drought impacts on agricultural production. Nearly 50% of respondents reported lower than normal revenues. Using the zip codes to disaggregate the results on location, that number increases to over 60% reporting lower than normal revenues in the East Central agricultural district. This is contrasted against the Northwest and Mountains agricultural district where nearly 60% of respondents reported near normal revenues. Statewide less than 10% of respondents reported greater than normal revenues, with the highest percentage at just over 10% in the northeast district. The district with the lowest percentage of respondents reporting greater than normal revenues is the northwest and mountains (Pritchett et al., 2013).

The 2012 drought also impacted hay and forage production. Alfalfa, grass, and pasture production decreased by 37%, 40%, and 45% respectively. This decrease in production has direct impacts to Animal Unit Months (AUMs)[4], which decreased on grazing lands (40% owned pasture, 9% private lease, 31% federal lease, and 34% state lease), yet increased 51% for purchased hay.

---

[4] AUMs are calculated by multiplying the number of animal units by the number of months spent grazing. It is one way to track the amount of forage consumed. An animal unit is a consumption estimation tool based on a 1000 pound cow consuming 26 pounds of forage dry matter per day.

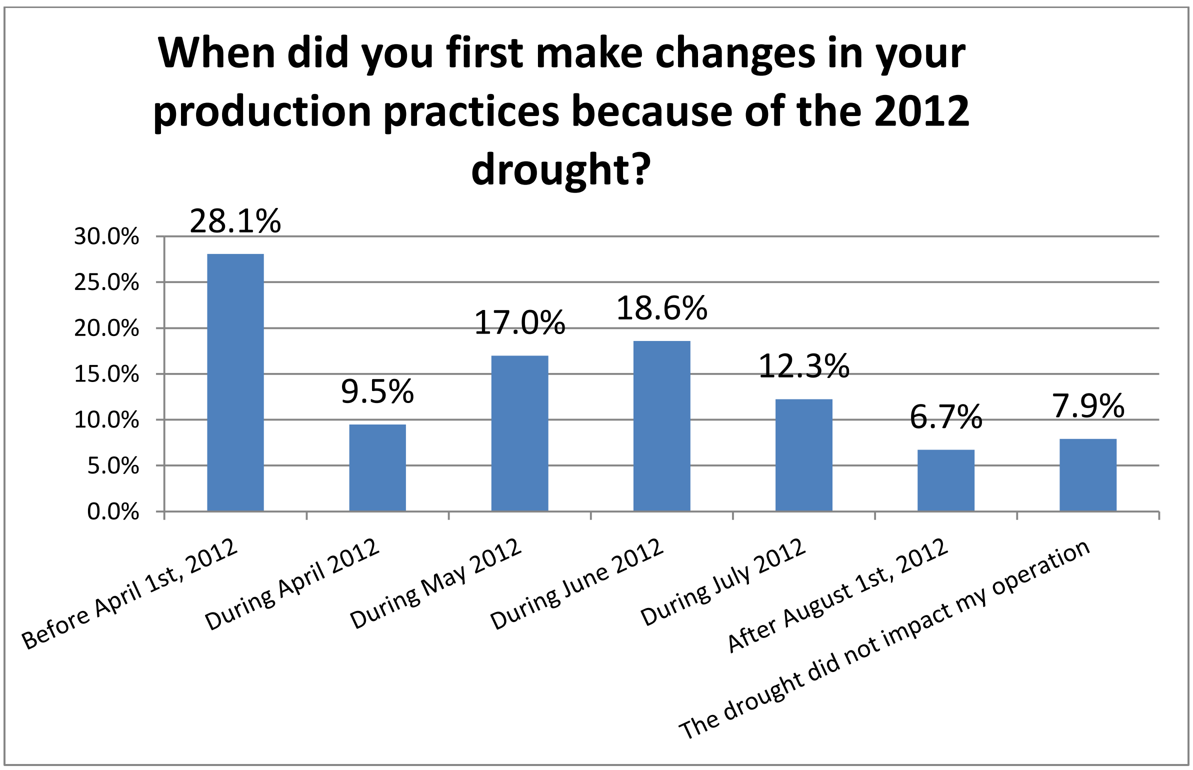
This impact to forage and feed production was felt in cow and calf production rates. The overall number of cows decreased 48% from normal with a culling rate of 21% (meaning roughly 1 out of every 5 cows was removed from the herd for one reason or another). Overall cow health was also affected by the lack of forage production. Cow condition and average weaning weight decreased by 18% and 16% respectively. Ultimately, the average cost of each cow increased 40% (Pritchett et al., 2013).

### *Managerial Response*

A second goal of the survey was to examine whether or not ranch managers altered their operations in anticipation of, or in response to, the drought. Survey respondents answered questions about when they took action and what those actions were. While proactive actions generally improve flexibility, they may limit the opportunities to take advantage of indirect impacts (Pritchett et al., 2013).

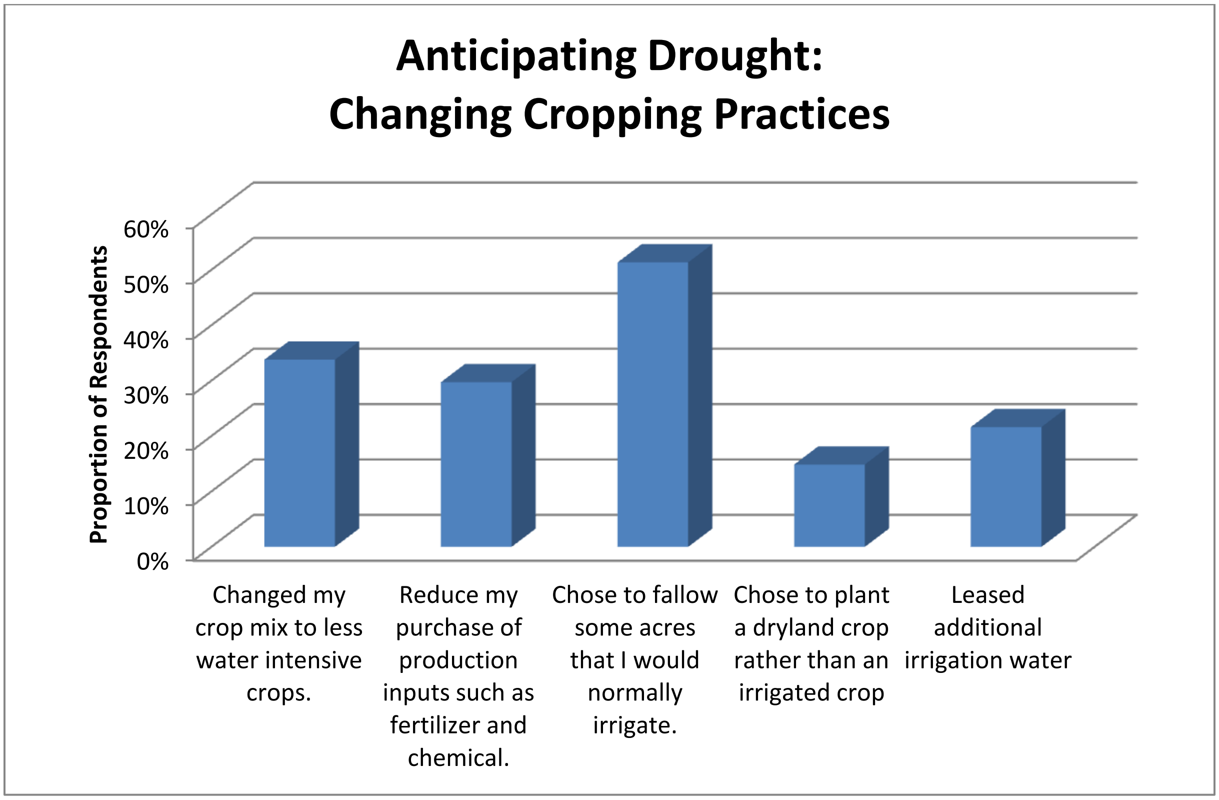
Figure 6.7 below shows when respondents chose to alter their operations in response to drought. Over 90% of respondents took action at some point during the 2012 season, with nearly 30% acting before April 1st. Figure 6.8 shows what those actions included for crop operations. The most common response was to reduce water use by setting acres aside that would normally be irrigated (Pritchett et al., 2013).

**Figure 6.7. Respondent Drought Response Times**




Source: Pritchett et al., 2013

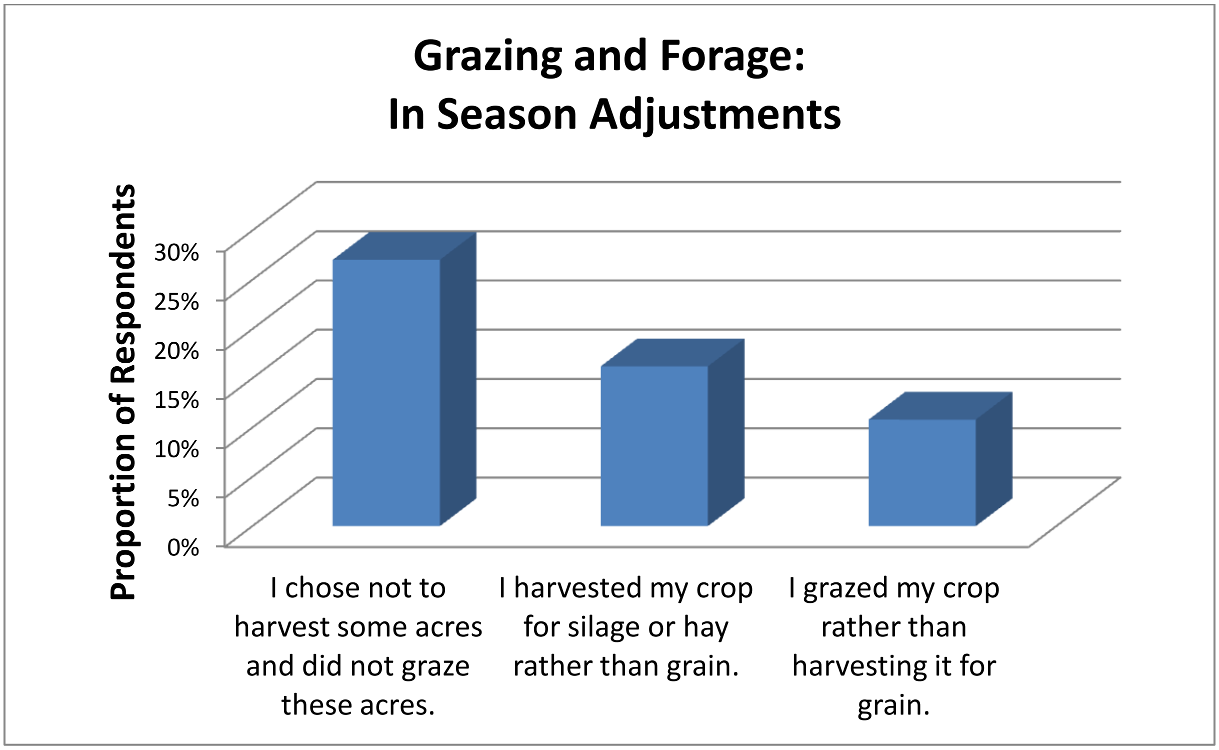
**Figure 6.8. Crop Respondent Actions Taken During the 2012 drought**




Source: Pritchett et al., 2013

Managers of irrigated farmland took a number of actions to reduce their water use. Roughly half of the respondents reduced their water use by focusing resources on a particular portion of their operation while reducing in other areas (Pritchett et al., 2013). Other common mitigation actions included reducing the amount of water used per watering (~30%), and reducing the number of irrigated fields overall (~40%) (Pritchett et al., 2013). For those operations focused on grazing and forage, Figure 6.9 indicates that the most popular action was to selectively harvest and graze certain acreage.

**Figure 6.9. Adjustments Made by Those Operations Focused on Grazing and Forage**




Source: Pritchett et al., 2013

Farmers and ranchers were also asked how the drought has impacted the way they manage their assets and cash. Questions were posed by asking what respondents had done and what they thought they might do if the drought persisted. The most common approach used to reduce impacts to cashflow was to reduce family expenses (59%), while 40% indicated family expense reduction would be the main way to save money if the drought persisted (40%). One quarter of respondents sought to supplement income with off-farm employment. Assets were managed more conservatively with the most popular response being to sell breeding livestock (41%). Selling equipment (13%) and land (2%) were not commonly sought options, with few indicating either would be an option (Pritchett et al., 2013).

Finally, respondents were asked questions about their likelihood to remain in the industry (whether or not the drought persisted). The majority of respondents (~80%) indicated they are not likely to leave the industry if the drought ends. However, if the drought persists that number decreases to approximately 45%.

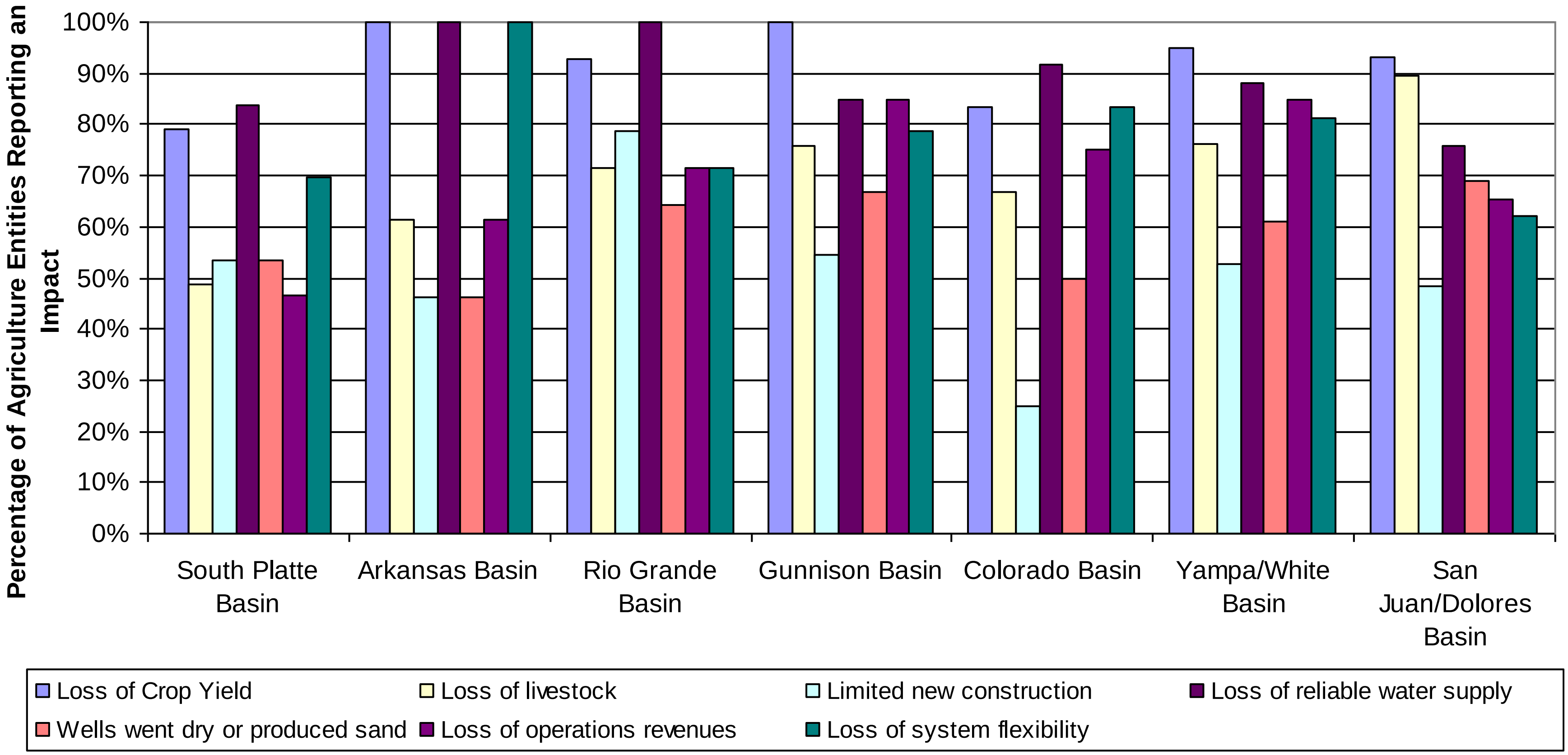
## Drought Water Supply Assessment

To determine the State's preparedness for drought conditions, the Colorado Water Conservation Board (CWCB) conducted a Drought Water Supply Assessment (DWSA) in 2004. As discussed in the introduction, this study identified limitations and related measures to better prepare for future droughts (DWSA, 2004). It entailed a survey, or opinion instrument, where 537 responses were received statewide on specific impacts experienced during the dry period of 1999-2003. Various entity types were surveyed including power, industry, agriculture, municipal, state, federal, water conservancy and conservation districts, and “other” (e.g., tribes and counties).

The results of the DWSA survey are helpful in understanding the opinions of Colorado’s water users statewide and on a basin-wide scale in terms of current and future water conditions. However, the results do not provide impacts related to drought on a county level and therefore cannot be used in the spatial context of this assessment. The DWSA results are informative nonetheless and useful as a starting point.

Figure 6.10 provides the percentage of surveyed agricultural entities that experienced the impacts listed at the bottom of the figure. Examples of the agricultural entities surveyed include irrigation districts, ditch companies, ranches, and land and cattle companies.

**Figure 6.10. 1999-2003 Drought Impacts to the Agricultural Sector (DWSA, 2004)**




Note: Despite a comprehensive review and internal testing process of the survey tool, these DWSA 2004 surveyed impact results are subjective. The impacts in the figure above are a reflection of the surveyees' interpretation of the listed impacts.

It is important to note that only categories applicable to the Agriculture Sector are shown in Figure 6.10.[5] Of the 203 agriculture entities surveyed across each of the state's seven basins, at least 25% of them reported impacts to the following categories during the 1999-2003 drought period:

- Loss of crop yield
- Loss of livestock
- Limited new construction
- Loss of reliable water supply
- Wells went dry or produced sand
- Loss of operations revenue
- Loss of system flexibility

Loss of crop yield was the most frequently experienced impact throughout the state by the Agriculture Sector, followed by loss of reliable water supply and loss of system flexibility. While difficulties were felt in each basin by construction being limited and wells going dry or producing sand, fewer entities reported these categories as causing an impact. Overall, the 1999-2003 drought caused widespread hardship to the Agriculture Sector. No singular basin fared worse than any other as evidenced by the fairly consistent survey results seen across basins and impact categories. This information is another way of confirming that the Agriculture Sector is very sensitive to times of low water supply. Without sufficient supplies of water to irrigate crops, impacts are felt in every area of the Sector, all resulting in lost revenue.

### Statewide Water Supply Initiative

On May 15, 2013 an Executive Order from Governor John Hickenlooper was issued directing the Colorado Water Conservation Board to commence work on a statewide Water Plan. The plan will address a number of water related issues, including drought, agricultural transfers, and interstate compact rights. The plan will also address the water supply and demand gaps forecasted as part of the Statewide Water Supply Initiative (SWSI). A draft of the plan is due December, 2014, with a final report expected December 2015.

Although it did not specifically focus on drought as the DWSA did, the SWSI process was another important initiative taken and directed by the CWCB to understand existing and future water supply needs and how those needs might be met through various water projects and water management techniques. As described in Chapter 1, SWSI also uses a statewide and basin-level view of the water supply conditions in Colorado.

[5] The DWSA survey included other sectors, such as municipalities, water conservation districts, power providers, etc. These entities reported impacts that would not necessarily apply to agricultural producers. These impacts have been omitted from this analysis.

A large portion of SWSI addresses agriculture because of its importance to Colorado's economy and due to its majority share of overall statewide water use. One of SWSI's water management objectives is to "sustainably meet agricultural demands" in large part because competition for water is intensifying throughout the state as a result of increased population growth. Increases in Municipal & Industrial (M&I) demands in the future may cause a reduction in irrigated lands as providers seek additional supplies from senior water right holders, many of which are associated with agriculture. This decrease in irrigated acreage may be larger if the existing identified projects and processes are not successfully implemented to the degree planned for. As a result, SWSI sought to develop families of options to provide solutions or mitigation to the remaining water supply gaps that would also help to preserve agriculture. The options related to agricultural transfers include:

- Permanent Agricultural Transfers
- Interruptible Agricultural Transfers
- Rotating Agricultural Transfers (Fallowing) with Firming for Agricultural Use
- Water Banks

It is important to note that other options exist including: M&I and agricultural conservation; additional storage development; conjunctive use of surface water and groundwater; M&I reuse; and control of non-native phreatophytes. SWSI noted that some combination of these options should be explored so that increased M&I demands are met through various approaches and management objectives. However, a brief overview of only the agricultural transfer options is presented in Table 6.6 to illustrate how future water management throughout the state may affect the Agriculture Sector in times of both ample water supply and drought conditions.

**Table 6.6. Potential Benefits and Issues Surrounding Options for Resolving Supply and Demand Gaps**

| Agricultural Transfer Option | Description |
|---|---|
| Permanent Agricultural Transfer | • The acquisition of agricultural water rights and the cessation of irrigation on these historically irrigated lands. Water rights are transferred to other uses. |
| Interruptible Agricultural Transfer | • An agreement with agricultural users that allow for the temporary cessation of irrigation so that the water can be used to meet other needs. |
| Rotating Agricultural Transfer (Fallowing) with Firming for Agricultural Use | • An agreement with a number of agricultural users that provides for the scheduled fallowing of irrigated lands on a rotating basis so that the water not irrigating fallowed lands can be used for other uses. Includes a set aside and storage of some of the yield to provide a pool for use by the agricultural users during below average water supply years. |
| Water Banks | • A mechanism where water users can announce they have unused supplies that can be leased by other users. |

Source: SWSI 2004

Some of these options, particularly Interruptible Agricultural Transfer and Rotating Agricultural Transfer (Fallowing) with Firming for Agricultural Use, can benefit the Agriculture Sector in times of drought in the following ways:

- Provides a more stable income during droughts
- Preserves the land for future agricultural use rather than causing a permanent dry-up
- Less water development and additional storage is needed in order to provide reliable water supply
- A firming of agricultural supplies may be necessary. This would require additional storage, infrastructure and advanced water treatment.

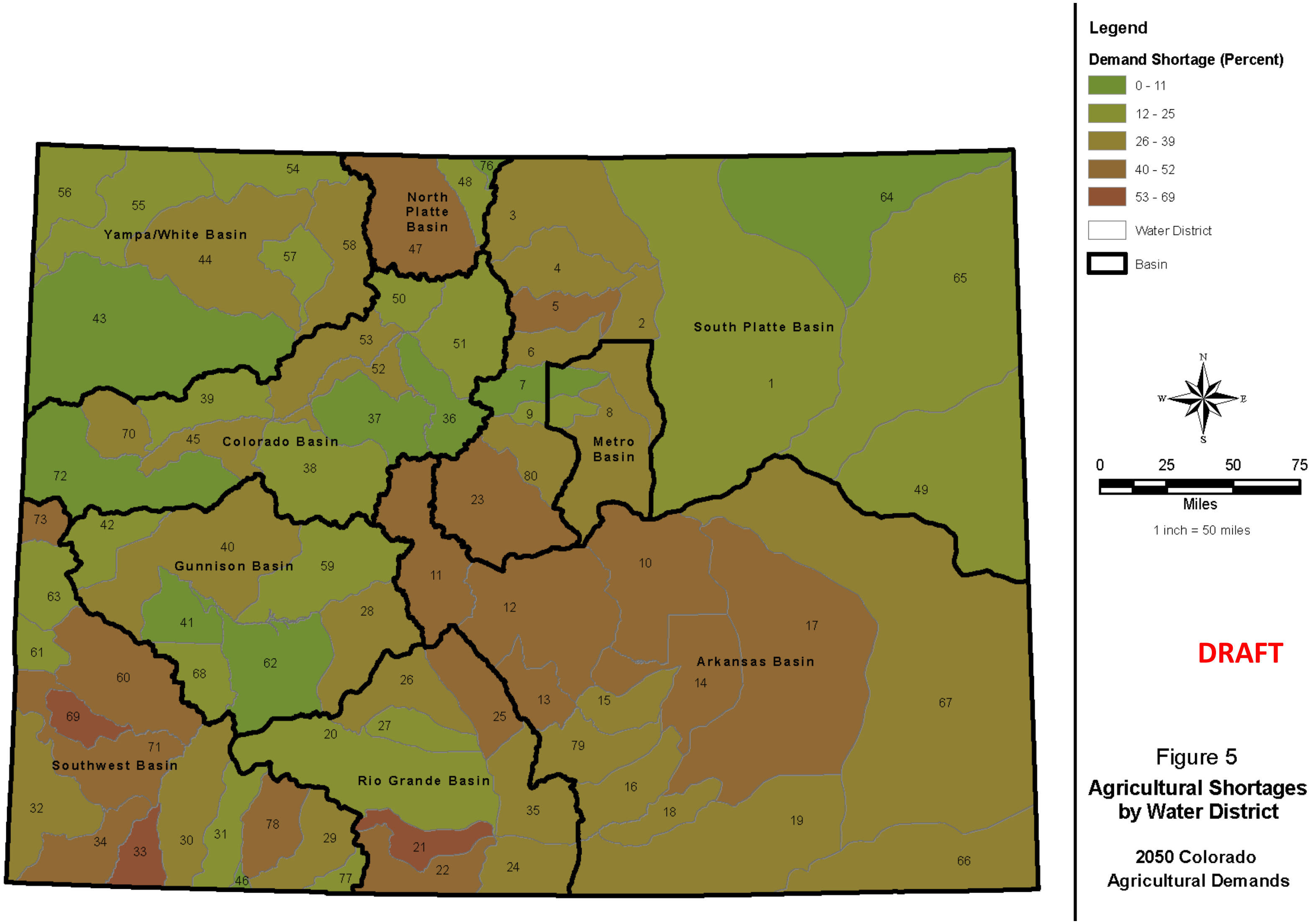
However, the permanent agricultural transfer option has negative implications for not only the Agriculture Sector, but also the local economy and socioeconomic associations. This is because less income to farming communities can result in reduced property taxes to schools and local governments and less revenue to local businesses. As a result, as part of SWSI Phase 2 in 2007, a technical roundtable (TRT) was created to address alternatives to the option of permanent agricultural transfer. Recognizing that all basins in the state have agricultural water shortages no matter what hydrologic conditions exist, the TRT worked on refining which areas of the State have more severe shortages. It is evident that the South Platte, Arkansas, and Rio Grande Basins are losing agricultural production to permanent transfer of water rights and voluntary groundwater reductions. As a result, two structural water supply concepts, one in the Arkansas Basin (Arkansas River Agricultural Pumpback) and one in the South Platte Basin (South Platte River Agricultural Pumpback), were developed by the TRT to illustrate alternative agricultural transfer methods. More information may be found in the second phase of SWSI regarding this topic.

SWSI also discussed how conservation may benefit the Agricultural Sector in times of drought. Examples of efficiency measures include ditch lining, conversion of flood irrigation to gated pipe, and sprinkler or drip system installation. These measures may assist agricultural water users by, extending existing supplies in terms of the increased ability to deliver water and decreasing the likelihood that new diversions would be required. However, it is also important to note that some efficiency measures, like drip irrigation and sprinklers, can increase a crop’s consumptive use of water.

A draft technical memorandum from CWCB (CWCB, 2010) was produced to estimate current (2010) and 2050 agricultural demands across Colorado. This work shows historical trends in farmland and irrigated acres, estimated current agricultural demand by basin, and a map of projected 2050 demand shortages by water district, which is shown in Figure 6.11. The areas with the highest 2050 demand shortages are located in the Arkansas, North Platte, and Southwest Basins, with lesser demand projected in the Yampa/White, Colorado, and Gunnison Basins. The Rio Grande and South Platte Basins show water districts with both high and low demand shortages. Overall, the memorandum concluded that statewide irrigated acres are projected to decrease between 15 % and 20 % between now and 2050. The basins with the largest expected decreases in irrigated acres from current usage to 2050 are the Yampa/White, South Platte, and Colorado Basins.

The dialogue on how agriculture can be sustained throughout the state while still providing for increased M&I demands, particularly during drought conditions, will only continue on a more detailed level. The SWSI process brings together interested parties to work towards options that will mitigate negative impacts to affected sectors, and continuing work by CWCB in the form of current and 2050 agricultural demands projections further the exchange of ideas. SWSI will be updated again in 2016.

## Figure 6.11. Projected 2050 Agricultural Demand Shortages

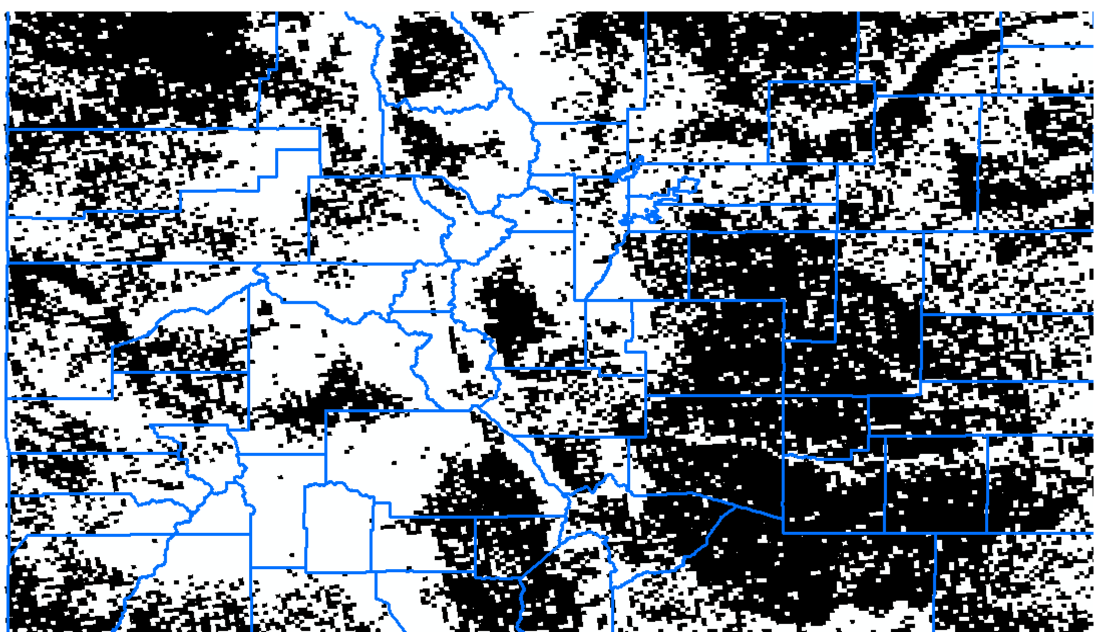



Source: CWCB 2010

## NASA CASA Model

As reported in several of the studies above (e.g., Pritchett et al., 2013), the impact of drought on rangeland production is an issue for ranchers, and also for wildlife. Researchers at the NASA Ames Research Center's Ecosystem Modeling Group have been using remotely sensed data to develop a monitoring system that can be used to measure and track the health of rangelands across the state. The Carnegie-Ames-Stanford Approach (CASA) model combines satellite image analysis with plant production modeling to examine the spatial variability in monthly plant production and soil moisture. Synoptic "greenness" data from the MODIS (Moderate Resolution Imaging Spectroradiometer) sensor are collected at 16-day intervals at a 5 km ground sampling distance (Li et al., 2012). (Greenness refers to the Enhanced Vegetation Index data product which has been shown to be useful in assessing processes that depend on absorbed light, such as gross primary production (Li et al., 2012). By comparing subsequent datasets and model outputs with a defined baseline condition, managers can track the severity of the drought through the health of vegetation on the ground. The CASA model was applied to rangelands in Colorado for 2012, using 2010 as a non-drought baseline year, in order to calculate losses in forage production. Rangelands across Colorado were identified using National Land Cover Database (NLCD) categories for grassland, pasture/hay, and shrub/scrub. The black pixels in Figure 6.12 below show the extent of rangeland, as defined above, in Colorado.

**Figure 6.12. Colorado rangeland as defined using the NLCD database**

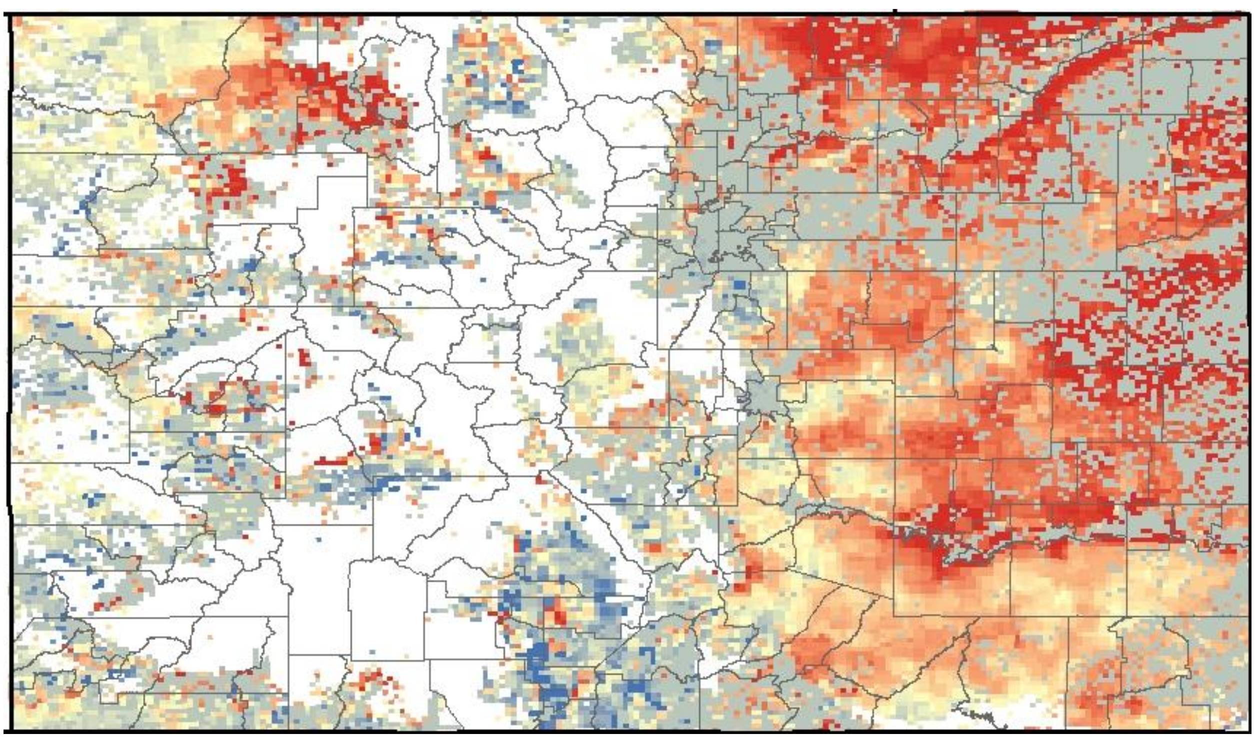


Source: Fry et al., 2011

Using NLCD rangeland extent to identify the areas of Colorado to be modeled, the CASA model was run for 2012. Figure 6.13 below shows the model results. Red-yellow pixels indicate a loss of rangeland production in 2012, while blue shades indicate gains in production. Many of the gains are associated with irrigated agriculture. For example, there are significant blue patches in the San Luis Valley. Significant losses can be seen in the Arkansas Valley in the southeast and along the South Platte in the northeast (personal communication, Christopher Potter on March 11, 2013).

The relatively high spatial resolution of the MODIS sensor allows the model results to be aggregated up to county (or any other spatial boundary) levels. For example, if the results shown in Figure 6.13 are summed for each county, it is possible to rank counties based on the total loss of biomass measured for rangelands. Referring to Figure 6.14, nearly all counties experienced a net decrease in rangeland production for 2012. San Juan does not have any pixels classified as rangeland in the NLCD database. Conejos County experienced a slight net gain in rangeland production, as a result of irrigation in the San Luis Valley. Figure 6.14 can also be somewhat misleading as relatively few pixels can create the illusion of dire conditions. For example, many of the mountain counties (e.g., Mineral, Hinsdale) only have a few pixels, yet the entire county is shaded as an overall decrease in production.

**Figure 6.13. CASA Model Results for 2012**



## Figure 6.14. CASA Results Aggregated to the County Scale, Showing Net Total Change in Biomass

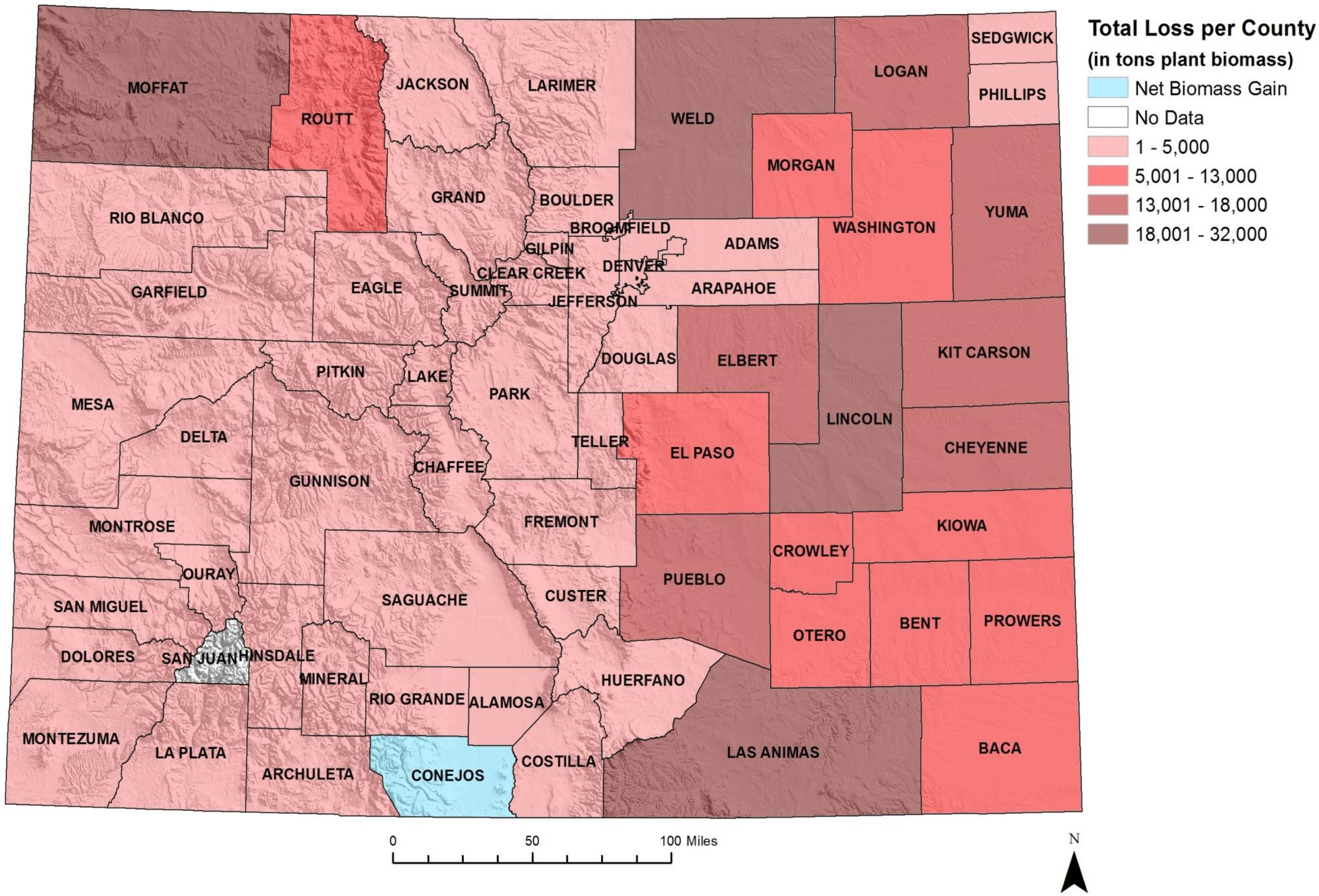
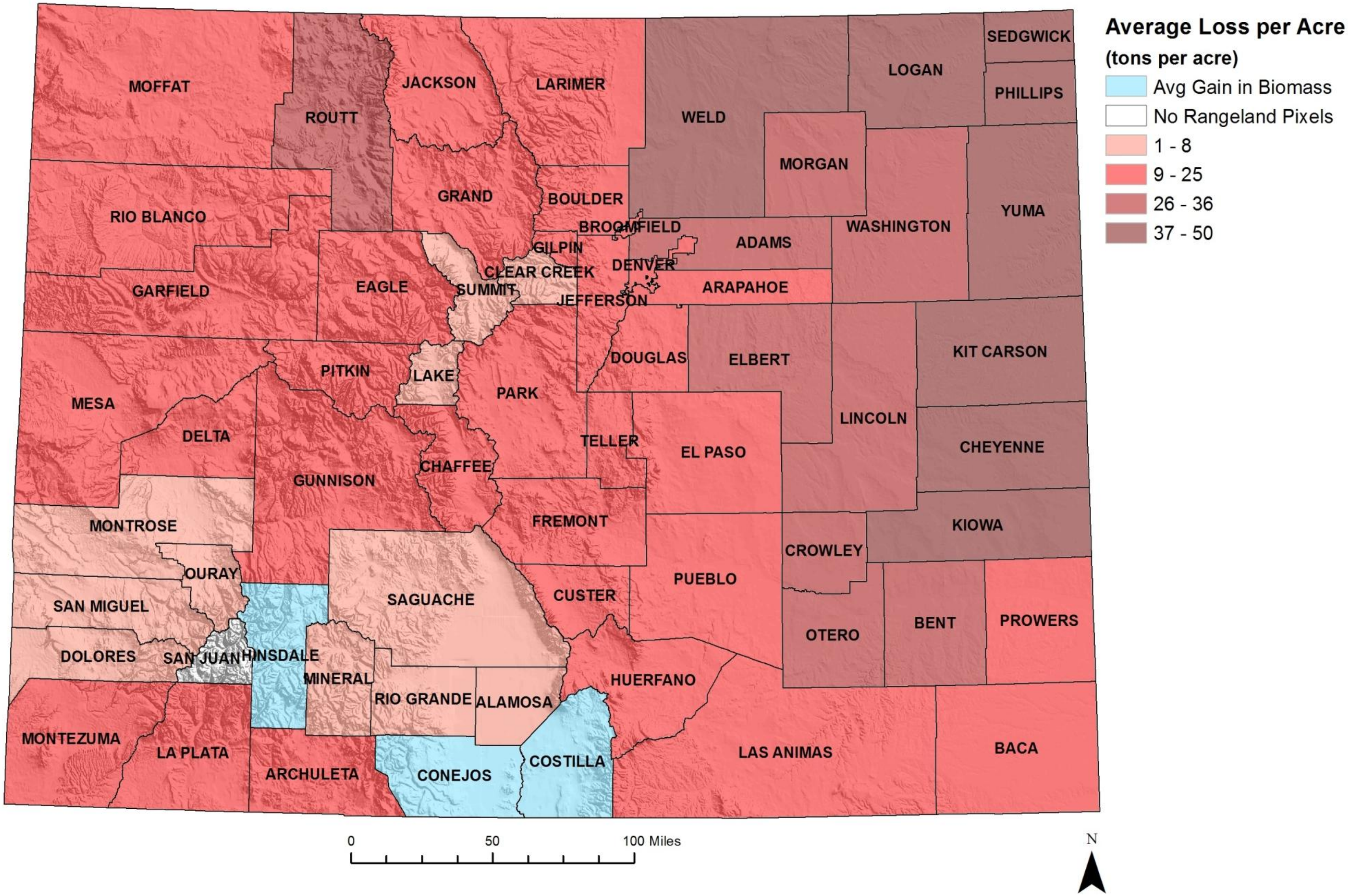


**Figure 6.15. CASA Results Aggregated to the County Level, Showing Mean Biomass Change per Acre**



Alternatively, results can be classified by the average biomass loss (or gain) for all the pixels that fall within the county. For example, Figure 6.15 shows the mean loss per acre. Hinsdale and Costilla counties now also show a gain in biomass, but it is a per acre gain, relative to the county-wide loss seen in Figure 6.14. Again, similar perception issues as those discussed above for Figure 6.14 are generated here, suggesting that county aggregations may not be the best way to present environmental data. The CASA model has been run for portions of west Texas and New Mexico for some time (personal communication, Christopher Potter on March 25, 2013). Model output, along with several other datasets (e.g., evapotranspiration; soil moisture change), is being served online through NASA's Drought Assessment and Response Tools (DART) website. Several other western states, including Colorado, have recently been added, and users can query and download any relevant datasets.

CASA model output has clear application to future drought studies and management plans. It allows managers to measure specific impacts to particular land cover types in a synoptic, cost effective and efficient manner. Future applications of the model involve taking advantage of the model's spatial resolution and applying the results to other land cover types and drought sectors. The CASA model operates on a 5 km spatial resolution which provides opportunities to disaggregate (or aggregate) model output in various ways. For example, instead of examining rangeland production on a county scale, output could be summarized based on watershed boundaries, land ownership, and/or management units. This could help focus resources on the area(s) most affected by the hazard. Other potential applications include monitoring forest health, although managers should take caution in attributing a decrease in forest production solely to drought as Colorado's forests are subject to multiple stresses (e.g., beetle infestation, disease) (personal communication, Christopher Potter on March 11, 2013).

## 6.3 Assessment of Impacts and Adaptive Capacities

The Agricultural Sector is split into three specific impact groups: livestock, crops, and the green industry. This section contains a discussion of the potential impacts and actions for adaptive capacity these sub-sectors have during drought.

### 6.3.1 Potential Impacts

As noted in Section 6.2, previous reports on agriculture impacts from drought identify large losses of revenue in each sub-sector. Table 6.7 below, outlines some potential/general drought impacts.

## Table 6.7. Drought Impacts to Agriculture

| Sub-sector | General Impacts |
|---|---|
| **Livestock** | • Short-term or severe summer drought can significantly reduce grazing forage available to herds. Ranchers could be forced to supplement with purchased feed, causing increased costs to the farm. If purchased feed is not available due to drought conditions or short supply, ranchers could be forced to sell portions of their herd or ship the herd to greener pastures. Cost of freight is problematic. Greener pastures may not be available within feasible shipping distances.<br>• Poor grazing conditions may lead to more livestock poisoning as they feed on poisonous plants normally eliminated. Nitrate, sulfate and prussic acid toxicity may occur, as may anthrax.<br>• Colorado has a large confined animal feeding industry which may become unprofitable as cattle price drops and feed prices increase.<br>• The condition of the animal deteriorates as food becomes scarce. This drives the value of the cattle down, while the cost of raising that animal increases.<br>• Secondary impacts to beef processors and related industry if the ranchers are shipping their cattle out-of-state.<br>• Long-term impacts to ranchers if they sell portions of their herd at a loss (price of cattle will fall when the market is flooded with ranchers trying to offload some of their herd) and years later have to rebuild the herd at additional expense. Also increases competition with out-of-state ranchers who were able to build up their herds by purchasing Colorado cattle at a lower price. |
| **Crops - dryland** | • Lack of fall precipitation could inhibit seed germination. Inadequate spring and summer precipitation could keep the grain from sprouting, causing crop loss for the farmer.<br>• Long-term drought can deplete soil moisture and make dryland crops unviable, forcing changes in livelihood and farming practices.<br>• Weeds may outcompete crops<br>• Soil erosion can occur due to decreased cover and increased blowing. |
| **Crops - irrigated** | • Junior water rights holders could see a reduced irrigation allocation or be cut off entirely, causing reduced or lost crop yield.<br>• Decreased water quality can impair plant growth (Table 6.2 and Table 6.3). |
| **Green industry** | • Nurseries and sod growers on junior water rights could see their irrigation allocation reduced or cut off entirely, causing lost products and revenue.<br>• Landscape nurseries see reduced product demand if municipal water restrictions are implemented on the public. In addition, utilities can ban lawn watering and laying new sod, impacting the sod growers.<br>• Short-term revenue loss, but also potential for revenue gain after the drought ends when people buy new plants to replace landscape that died during watering restrictions. The inverse of this is public demand for drought-resistant plants may manifest faster than the industry can produce the plants.<br>• Secondary impacts to landscape service industry if workload is reduced, laying-off some of their employees might be necessary. |

The agricultural sub-sectors are interrelated – a drought that impacts crop growers will also have an effect on livestock owners. Livestock owners may also be hay and feed producers. Dryland farmers provide much of the supplemental feed (e.g., hay, alfalfa, etc.) for the cattle ranchers, and if the crops fail, ranchers will be faced with higher prices for feed or be forced to look outside of the state. In all cases, secondary impacts will occur to the rural communities where farming is the primary economic driver. This "trickle down" effect of lost farm revenue can significantly impact local economies, making small communities where farming is prevalent more vulnerable to drought than communities where the economy is more diversified. Wheat returns more than 25% of crop sales in eight Colorado counties: Kiowa (98%), Washington (53%), Cheyenne (49%), Baca (>25%), Kit Carson (>25%), Sedgwick (>25%), Logan (>25%), and Prowers (>25%) (Situation Statement - CSU, 2010), making potential impacts in those counties large.

Figure 6.16 depicts the total harvested acreage per county separated by dryland and irrigated crops and averaged for 10 years (1999-2008). Harvested acreage is actual yield. The other data type in the NASS database are "planted" acreage, which measures the total acreage the farmer planted but might not have been able to harvest for any number of reasons, including drought, hail, fire, pests, etc. "Harvested" acres were used for this vulnerability ranking assessment.

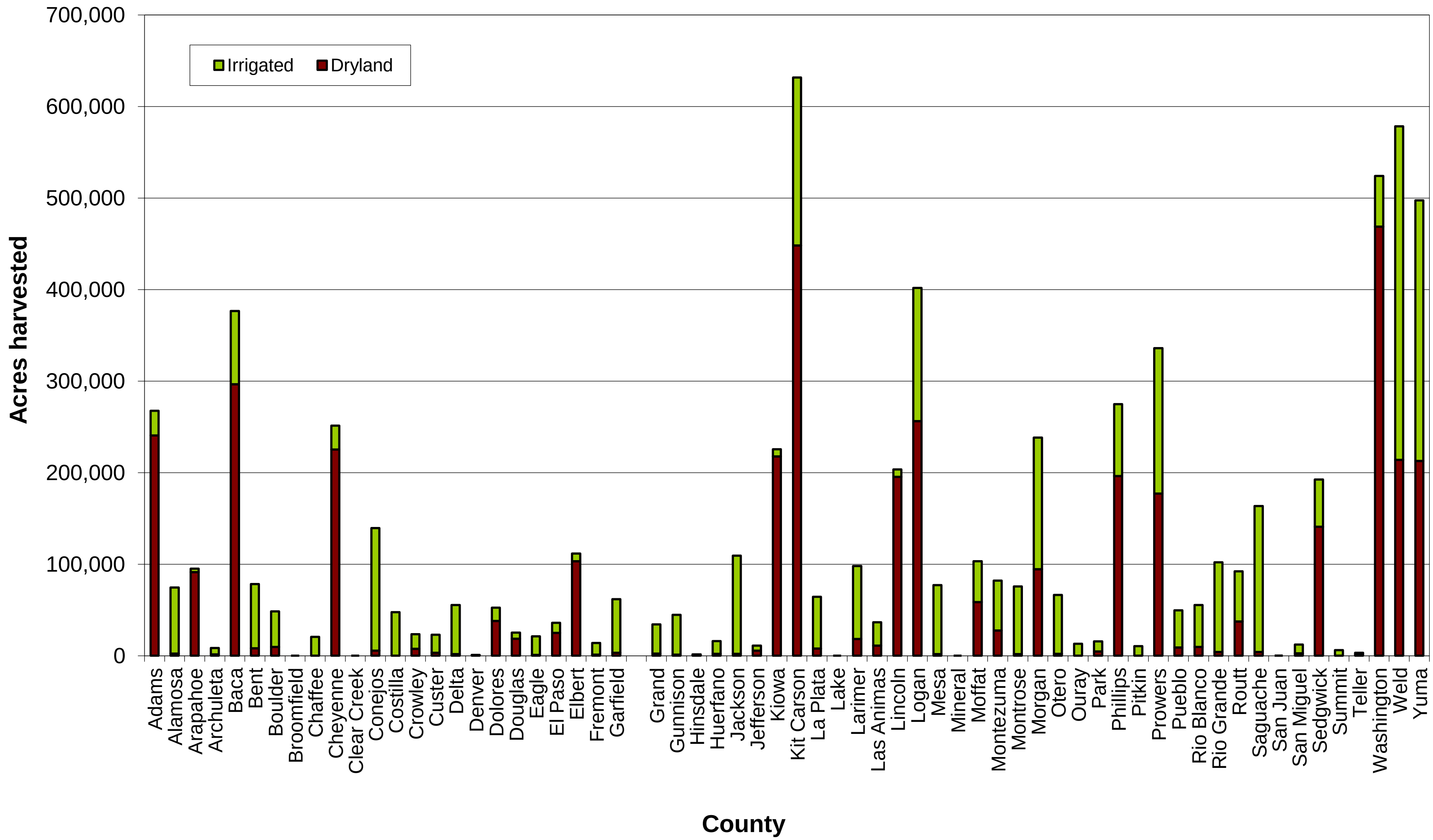
As noted in the discussion of the Colorado State University economic impact studies above, there have been anecdotal reports of ranchers selling off portions of herds as a result of the drought. One auction house located on the western slope has seen the numbers of animals sold nearly double since 2010. However, they do not know how many animals were cows, but do notice more cows selling, as well as people selling 'more deeply into their herds' (personal communication, May 21, 2013).

During 2012, the drought was nationwide, impacting resources in Colorado as well as feed supply areas in the Midwest. As a result, feed production decreased across the region, driving the price up. For example, in 2010 the price of alfalfa hay ranged from $110 to $120 per ton, but increased to $215 to $221 per ton through April of 2013 (NASS online database, 2013). This made it significantly more expensive for ranchers in Colorado to send their livestock to feedlots, or purchase feed themselves. One potential adaptive capacity is for ranchers to transport cattle to more productive rangelands. For example, ranchers in Texas and Oklahoma moved livestock to other western states, including Colorado, during the 2010 (and ongoing) drought event. Since the drought covered a significant portion of the west during 2012, there were fewer productive rangelands to which to move the herds (LMIC, 2013), though some may have moved herds to Montana (e.g., Woodka, 2011).

Data showing the decrease in cattle is sparse, but the NASS database provides estimated numbers. By querying the database for beef cows, the percentage decrease from 2012 to 2013 for many counties in Colorado can be seen (Figure 6.17). As this data is the result of a survey effort, numbers for all counties were not available. For those counties containing estimates, all showed either no change or a decrease in cattle numbers ranging from 2% in La Plata County to

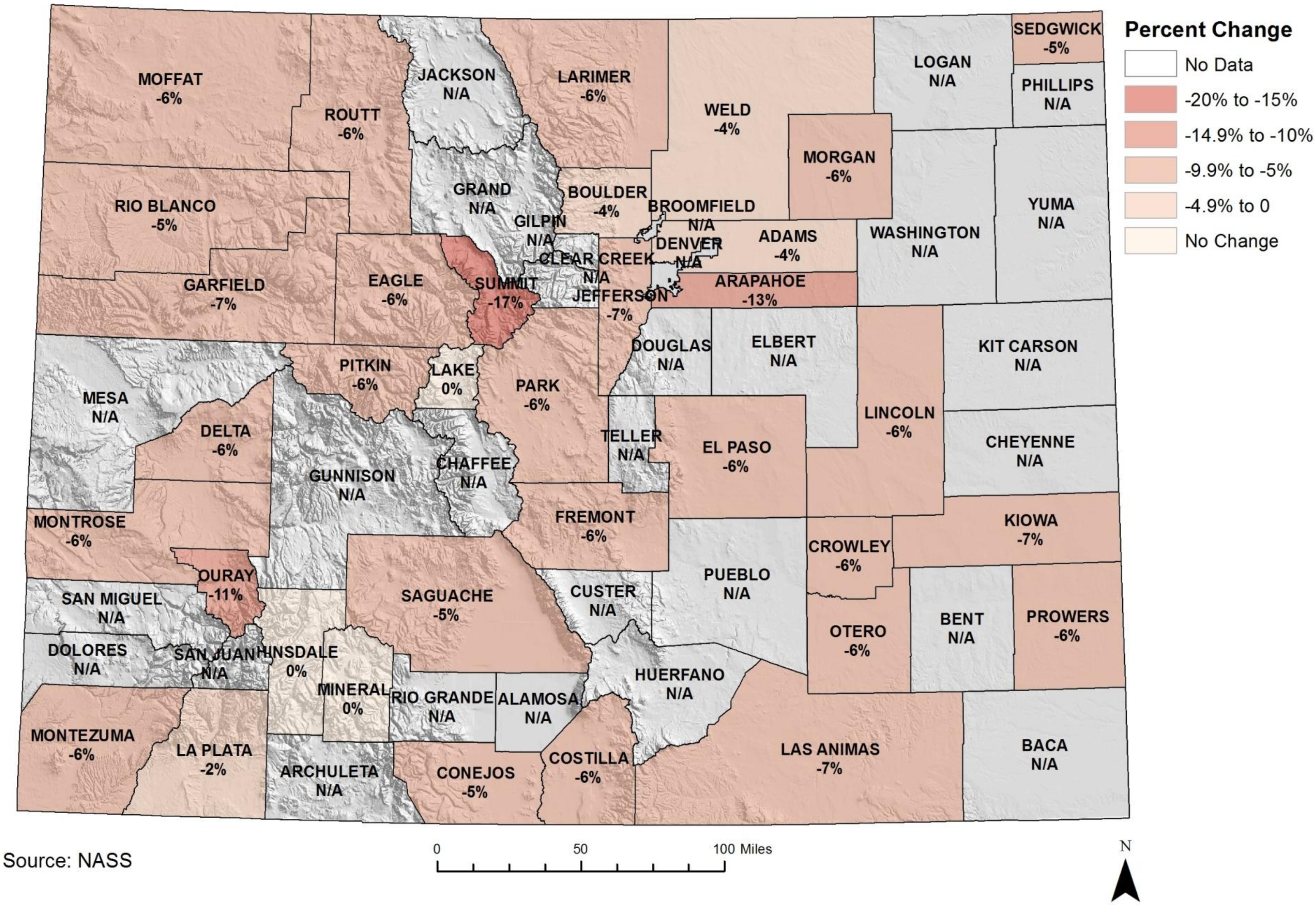
17% in Summit County. When the 2012 Census of Agriculture is made public data will be available for each county and it is recommended that these new numbers be used to update subsequent plans.

## Figure 6.16. Total Crop Acreage by County, 1999-2008 Annual Average




Source: NASS, 2010

**Figure 6.17. Percentage decrease in the number of beef cows per county between 2012 and 2013**




Source: NASS

Potential impacts to the green industry include restrictions on water use imposed by utilities and municipalities. Growers rely both on water rights and municipal supply. A limited amount of water for irrigation can cause plant loss or degraded plant quality, which will affect the ability of the grower to sell the product, resulting in lost revenue. Secondary impacts within the green industry include job and revenue losses to landscape designers and landscape maintenance companies, who rely on both the availability of plants and public demand for their installation. Landscaping companies can also be impacted by municipal water restrictions that target landscaping water restrictions in the earliest stages of drought.

## 6.3.2 Adaptive Capacity Actions

Adaptive capacities work to offset the impacts of drought, which reduces the overall vulnerability. There are a number of adaptive capacities for ranchers and farmers. When producers are faced with reduced surface water supplies, they have three options that will allow them to continue production: 1) reduce irrigated acreage; 2) reduce irrigation amounts to the entire field (i.e., limited irrigation agriculture); and 3) include different crops that require less irrigation (Schneekloth and Andales, 2009). Cattle ranchers also may have several options in a drought: 1) use stored feed and/or purchase supplemental feed; 2) change operation, move herd to pastures that are not impacted by drought or reduce herd; and 3) cull the herd (communication with CDA, 2010). However, as seen in the 2011-2013 drought, larger events may limit the ability of ranchers to both purchase feed and move their animals to more productive rangeland. Table 6.8 lists adaptive capacities for agriculture and provides a comment of the pros and cons to each option.

**Table 6.8. Agriculture Adaptive Capacities**

| Sub-sector | Adaptive Capacities, Pros and Cons |
|---|---|
| **Livestock (cattle)** | **1. Use stored feed.**<br>**<u>Pros</u>**<br>• Enables the herd to stay intact.<br>**<u>Cons</u>**<br>• Using feed in the summer may deplete stores for the winter.<br>• Use of stored feed requires proper management of low- and high-quality feed to maintain cattle health.<br>• Creates dependence on the ability to grow feed crops.<br><br>**2. Change operation, move herd or lease grazing fields in another area.**<br>**<u>Pros</u>**<br>• If operational change is possible, enables herd to stay intact.<br>**<u>Cons</u>**<br>• Cost of freight for cattle can exceed the cost of a year's worth of supplemental feed.<br>• As seen in 2012, healthy rangelands may be in short supply.<br><br>**3. Sell portion or all of herd.**<br>**<u>Pros</u>**<br>• Short-term monetary gain for rancher.<br>**<u>Cons</u>** |

| Sub-sector | Adaptive Capacities, Pros and Cons |
|---|---|
| | • An influx of cattle to the market changes the market structure by reducing prices.<br>• Selling quality cattle at artificially low prices (due to large supply) can put ranchers at long-term disadvantage as out-of-state ranchers are able to build competitive herds at low prices.<br>• Rebuilding the herd may take several years.<br><br>**4. Avoid growing the herd above a certain limit, leave some flexibility for the next drought.**<br>**Pros**<br>• A management practice that does not require any investment of funds, just advance planning.<br>**Cons**<br>• Rancher could miss out on possible monetary gains in years with ample water and forage supply. |
| **Crops - dryland** | • Relatively few adaptive capacities identified: winter wheat, a major dryland crop in Colorado, is planted on a two-year rotating cycle, making it less flexible to planting changes.<br>• Suggestions include forgoing summer dryland crops, reducing tillage, selecting drought tolerant wheat varieties, and shifting dryland corn to less water intensive crops (e.g., millet, sorghum, sunflower).<br><br>**1. Apply for crop insurance.**<br>**Pros**<br>• Ensures a payment if the crop fails due to drought.<br>**Cons**<br>• Insurance may not be available for all crops in all areas. |

<table>
<tr><th>Sub-sector</th><th>Adaptive Capacities, Pros and Cons</th></tr>
<tr><td>Crops - irrigated</td><td>1. Dry-year leasing, a mechanism that allows for temporary water transfer (usually from agriculture to municipalities) during dry years when farming is less feasible or profitable (DWSA 2004).<br><u>Pros</u><br>• Provides an income to the farmer even when growing crops is not practical or possible.<br><u>Cons</u><br>• Requires agreements between multiple parties<br><br>2. In principal, growers could significantly reduce water use by switching between crops (Frisvold 2009).<br><u>Pros</u><br>• When applicable, a viable way to maintain income by planting less water-intensive crops and choosing drought tolerant alternatives.<br>• Shift some crops to fall or spring crops.<br><u>Cons</u><br>• May not be practical in some instances.<br>• It assumes the farmer is sufficiently diversified for new crop to be successful.<br><br>3. Practice deficit irrigation.<br><u>Pros</u><br>• A way to produce a crop with less irrigation.<br><u>Cons</u><br>• May not yet be recognized by insurance agencies as a valid adaptive method, and could prevent the farmer from receiving insurance money if the crop fails anyway.<br><br>4. Apply for crop insurance.<br><u>Pros</u><br>• Ensures a payment if the crop fails due to drought.<br><u>Cons</u><br>• Insurance may not be available for all crops in all areas.<br><br>5. Reallocate irrigation water to higher-value crops.<br><u>Pros</u><br>• If possible, allows the farmer to prioritize crop irrigation and still receive an income.<br><u>Cons</u><br>• May not be feasible in all situations, may require transfer agreements with multiple parties.<br>• Machinery and operations may make it difficult to switch crops without large capital investment on the part of the farmer.</td></tr>
<tr><td>Green industry</td><td>1. Focus on edibles (e.g., vegetables, fruit trees, and berries), native, and drought-tolerant plants (Haight 2010).<br><u>Pros</u><br>• Demand for these products is generally strong.<br><u>Cons</u><br>• Increased cost of switching plant focus, and a lag in production time (i.e., public demand happens sooner than plants are ready to go on the market).<br><br>2. Focus on xeriscape materials, look for regional markets outside of Colorado, add ability to help people redesign their landscapes (i.e., diversify services), cooperative agreements with landscape designers (conversation with green industry representative, 2010).<br><u>Pros</u><br>• Diversifying services can help insulate against major drought impacts to one specific market.<br><u>Cons</u><br>• Requires advance planning, so not an immediate fix to drought impacts.</td></tr>
</table>

Adaptive capacities for the green industry are similar to those in the Recreation Sector; meaning public perception is a key concern, and growers who are more diversified are better adapted for drought conditions. Sod growers have experienced difficulties because the public perception is shifting away from grassy lawns and towards less water-intensive plantings (Proctor, 2003). Xeriscaping has continued to grow in popularity (e.g., Boldery, 2012), possibly in response to the restrictions imposed during, and the impacts of drought in 2002. Again, in similar fashion to the rafting industry, the green industry is re-working their operations to maximize the use of the limited water they do have by carefully focusing their water applications (Kluth, 2012). During the 2002 drought some utilities actually banned installation of new turf in order to further conserve water, which had an adverse impact on the sod growers specifically. One landscaping company, in response to municipal lawn-watering restrictions in 2002, began offering lawn-painting services for customers who wanted green lawns but were not able to water them (Proctor, 2010). Nurseries that offer drought-resistant and other low-water plants, whether in anticipation of future drought or in direct response to consumer demand, are consequently less vulnerable to drought than nurseries that do not have these offerings. Public interest in sustainability and environmentally-friendly products means that xeriscaping and edibles are gaining popularity. Educating producers is a valuable adaptive capacity in the green industry. For example, in 2008 GreenCO, the umbrella organization for the green industry in Colorado, developed best management practices to educate producers on efficient ways to use water prior to and during drought. Additionally, they have worked to market drought resistant alternatives to homeowner's associations and communities, and they have supported research with Colorado State University (Kluth, 2012). As a result of these efforts, the industry expects to be more prepared during the next drought in Colorado.

## 6.4 Measurement of Vulnerability

The vulnerability metrics are quantifiable factors that can be analyzed to assess the vulnerability of this sub-sector. These can be offset or mitigated by existing or future adaptive capacities. Priority of water rights, which is not included in this analysis, will have a significant impact on a farmer's vulnerability. The following section presents the vulnerability metrics used for each agriculture sub-sector. Refer to Section 3.1 of Chapter 3 (Annex B) for a general description of the numerical methodology.

# 6.5 Vulnerability Metrics

## 6.5.1 Livestock

### Spatial Density Metrics

#### *Head of cattle per county*

This data was obtained from the NASS database, querying for *cattle, including calves* as of January 2013. The total cattle head count gives an idea of which counties have the biggest herds and how the cattle industry is distributed throughout the state.

### Impact Metrics

#### *Livestock indemnity allotments, 2010*

These indemnity data are dollar amount allotments for 2010, and were obtained from the USDA. The program is called the "Livestock Forage Assistance Program." The data are money allotted in 2010 by the USDA to each county to pay claimants specifically for drought-related damages. It does not indicate the amount that has already been paid; rather, this is the amount set aside for each county. Unfortunately, the Livestock Forage Assistance Program was cancelled prior to the 2012 drought event. Data is not available for 2011, so this metric cannot be updated. For the 2010 Drought Plan, it was assumed that the higher the amount allotted to a specific county, the more vulnerable it is expected to be. Because only eight counties were allotted funds through this program in 2010, the percentile thresholds were adjusted to account for the zero data set. The adjusted thresholds were: 90%, 94%, and 97%. This metric was only weighted 25%, mainly because data was not available for so many counties in the state.

#### *Reduction in herd size*

The reduction in herd size indicates which counties had more ranchers selling portions of their herds during the 2011-2013 drought. A major impact reported by ranchers during both the 2002 and 2011-2013 drought events was there was not enough forage for their cattle, and because of this they were forced to sell portions of their herds to ensure survival of the animals.[6] The metric is a comparison of the head of cattle per county on January 1, 2010 to the average head of cattle on January 1st in the years 2012-2013 A higher percent reduction, which implies more ranchers in that county were forced to sell cattle, equates to a higher vulnerability ranking. Data for historical herd sizes per county were obtained from the USDA NASS. Eight counties in Colorado saw an increase in herd size or do not have cattle, so the percentile thresholds were

[6] Some ranchers, instead of selling their cattle, shipped them to pastures located out-of-state during 2002. For 2011-2013 the spatial extent of the drought complicated the application of this mitigation action.

adjusted slightly to account for this. The bins are: 39%, 59%, and 79%. This metric is weighted 75% because of the lack of indemnity data available.

Ultimately, using an overall reduction in herd size as a drought impact metric should be replaced with reductions to the number of beef cows per county. Using the total head of cattle, the decreases seen in each county are slight (0 – 3%), with some counties increasing overall. This is contradictory to anecdotal reports (e.g., LMIC, 2013) and study conclusions (e.g., Pritchett, 2013) that suggest a larger culling effort. The overall cattle numbers may be up because ranchers had yet to sell calves when the data was collected, and/or more cattle were sent to feed lots to be prepared for slaughter (personal communication with James Pritchett on May 24th, 2013). Unfortunately, beef cows are only tracked in some counties for the NASS survey program.

#### *Number of dairy cattle, 2013*

This metric serves as an adaptive capacity, since dairy cattle are confined and the dairy owners have sufficient flexibility that feed can be obtained out-of-state if need be (this can cost more, but is anticipated by the dairies and generally does not disrupt operations). Querying the NASS database, nine counties had dairy cattle data, with a significant amount (~8% of the state total) of animals attributed to “other counties”. To apply the adaptive capacity, if the county had 1 to 10,000 dairy cows the livestock vulnerability was divided by 1.1, and if the county had greater than 10,000 dairy cows the vulnerability ranking was divided by 1.2. While it is acknowledged that other cattle operations, like feed lots, may have a similar adaptive capacity, data for these groups are not available across the state in a consistent manner. It is recommended that future work investigate the feeding practices of other livestock operations to update this adaptive capacity metric.

## 6.5.2 Crops

### Spatial Density Metrics

#### *Acres of total farmland per county, 2009*

This metric provides a rough impression of how many acres of farmland are in production per county. The data are obtained from the USDA NASS, 2007. This information is not updated as part of the NASS Survey Program. This metric should be updated when the 2012 NASS Census data becomes available.

### Impact Metrics

#### *Percent dryland acreage out of total acreage, 2009*

Dryland crops are more vulnerable to drought because they are entirely reliant on precipitation. The percentage of dryland acreage out of total acreage was calculated from data obtained from the USDA NASS, 2007. Every county but six has dryland crops, so the thresholds are based on standard percentile thresholds: 30%, 54%, and 77%. This metric is weighted 50% because of the clear vulnerability and lack of adaptive capacity of these crops. The data associated with this metric is only available as part of the NASS Census Program.

#### *Crop indemnities due to drought, 2012*

These data were obtained from the USDA Risk Management Agency, 2012. It indicates how much insurance each county received for insured crops in 2012, specifically for drought-related damages incurred in 2012.[7] The payouts for each crop type were summed to obtain a total indemnity payment per county; the higher the payment, the higher the vulnerability weighing. Only 24 counties had indemnities data for 2012, so the percentile bins were adjusted to account for the zero data set. Approximately 3% of the total indemnity for all counties was attributed to "All Other Counties" and could not be included in the analysis. The adjusted thresholds are: 42%, 62%, and 81%. This metric is weighted equally (25%) with the non-insured assurance program allotments to reflect the fact that neither metric has a clear advantage over the other.

#### *Non-insured assurance program outlay, 2012*

The non-insured assurance program (NAP) is run by the USDA and provides coverage for non-insurable crops.[8] The metric is the outlay requested per county (i.e., money set aside to be distributed if necessary), and the assumption is the higher the outlay, the more vulnerable the county. Data were obtained from the USDA. Forty-nine counties have allotment data for 2012, so the percentile bins were adjusted to be evenly distributed across the non-zero data set. The adjusted thresholds are as follows: 43%, 61%, and 81%. This metric is weighted 25%, the same as the previous metric, to reflect the fact that neither has a clear advantage over the other.

[7] This metric differs from the livestock indemnity allotment in that these indemnities are the actual amount paid to claimants, whereas the livestock metric is money set aside to be paid out if necessary.

[8] There are many factors that go into a crop being non-insurable, and these can vary across counties. No generalities are made regarding the types of crop or irrigation style that are covered by this program.

## 6.5.3 Green Industry

The vulnerability of the green industry is not represented in this assessment due to lack of data. There are not enough green industry producers for the USDA to publicly release data and still be able to maintain the anonymity of the producers. Vulnerability of the green industry is somewhat reflected in the "crops" sub-sector in Section 6.5.2, since greenhouses and nurseries are essentially irrigated crops. Qualitative impacts to the green industry are discussed in other sections.

A map of the spatial distribution of green industry producers, as listed in Section 6.1, is shown in Figure 6.6.

## 6.5.4 Results

Overall the results of the vulnerability analysis are incomplete because of the lack of statewide data. Many of the datasets should be updated when the 2012 census becomes available. Many of the impacts discussed above indicate that the conclusions below will likely continue to be applicable to the 2011-2013 drought event. The vulnerability analysis shows higher vulnerability to drought exists on the eastern plains, where the dryland crop production is highest and farming activity is a key economic driver, a conclusion echoed in the economic study by Gunter et al., 2012 for the Arkansas Basin. Results by county are presented in Table 6.9:

**Table 6.9. Results of Vulnerability Assessment**

| Counties | Overall Vulnerability Score |
|---|---|
| Gilpin | 0 |
| Alamosa, Boulder, Clear Creek, Costilla, Denver, Eagle, Gunnison, Hinsdale, Lake, Mineral, Montrose, Ouray, Rio Grande, Saguache, Summit | 1-1.9 |
| Archuleta, Bent, Broomfield, Chaffee, Conejos, Custer, Delta, El Paso, Fremont, Garfield, Grand, Huerfano, Jackson, Jefferson, Kit Carson, La Plata, Larimer, Logan, Mesa, Moffat, Montezuma, Morgan, Otero, Park, Pitkin, Prowers, Pueblo, Rio Blanco, Routt, San Juan, San Miguel, Sedgwick, Teller, Weld, Yuma | 2-2.9 |
| Arapahoe, Crowley, Dolores, Douglas, Elbert, Kiowa, Las Animas, Lincoln, Philips, Washington | 3-3.9 |
| Adams, Baca, Cheyenne | 4 |

These rankings indicate different levels of agricultural activity within each county and different levels of adaptive capacity within those activities. Below is a discussion of each ranking. Gilpin County has no agricultural activity reflected in the livestock and crops data obtained from the USDA NASS, so it was ranked "zero" to reflect this absence.

Counties ranked 1 for overall vulnerability (lowest vulnerability):

A 1 ranking means that agricultural activity is largely absent from the county or there is a small proportion compared to the size of the county. Most of the counties in this category are located in the mountainous regions of the State, which have more dominant recreation and tourism sectors than agriculture. The notable exceptions are Alamosa, Saguache, and Rio Grande Counties, which do have significant crop activity but not necessarily dryland. Their vulnerability is not reflected through the dryland area metric.

Counties ranked 2 for overall vulnerability:

A 2 ranking indicates that agriculture is present but may not be the dominant activity in the county. Most of the counties in the state fall within this ranking category. Without significant tracts of crops and herds of cattle, these counties are not expected to experience devastating agricultural losses during a drought. Some of the eastern plains counties, such as Bent and Otero, do not have as high a percentage of dryland crops as other counties in the region, and therefore have low vulnerability scores. Yuma and Morgan Counties have a low vulnerability scores for cattle which decreases their overall vulnerability scores.

Counties ranked 3 for overall vulnerability:

A 3 ranking implies there is significant agricultural activity in the county, but it may not be entirely dominated by dryland crops or there may not be much in the way of allocated insurance funds. Most of the counties in this category are located in the eastern portion of the state and have a fair amount of dryland crops. The differences between counties ranked 3 and 4 are relatively small and counties in this category should be given equal attention with respect to mitigating for future drought. Dolores County is in this category because it saw fairly significant reductions in cattle herd size between 2001 and 2002-2005. However, its herd sizes are still small compared to other counties so this might merit further investigation. Inclusion in this category also could indicate significant agricultural activity in one sub-sector but not another.

Counties ranked 4 for overall vulnerability (highest vulnerability):

A 4 ranking reflects significant agricultural activity, a high percentage of dryland crops, and/or large cattle herds that saw a noticeable decline following the 2002 drought. Adams, Baca, and Cheyenne Counties are currently the only counties in this category due to high vulnerability rankings in both livestock and crops sub-sectors.

Figure 6.18 and Figure 6.19, on the following pages, demonstrate graphically the inventory and impact results for the livestock and crops sub-sectors. Figure 6.19 could not be updated because of a lack of crop data. It should be updated when the 2012 Agriculture Census is published in 2014.

**Figure 6.18. Livestock Inventory and Vulnerability Ranking**

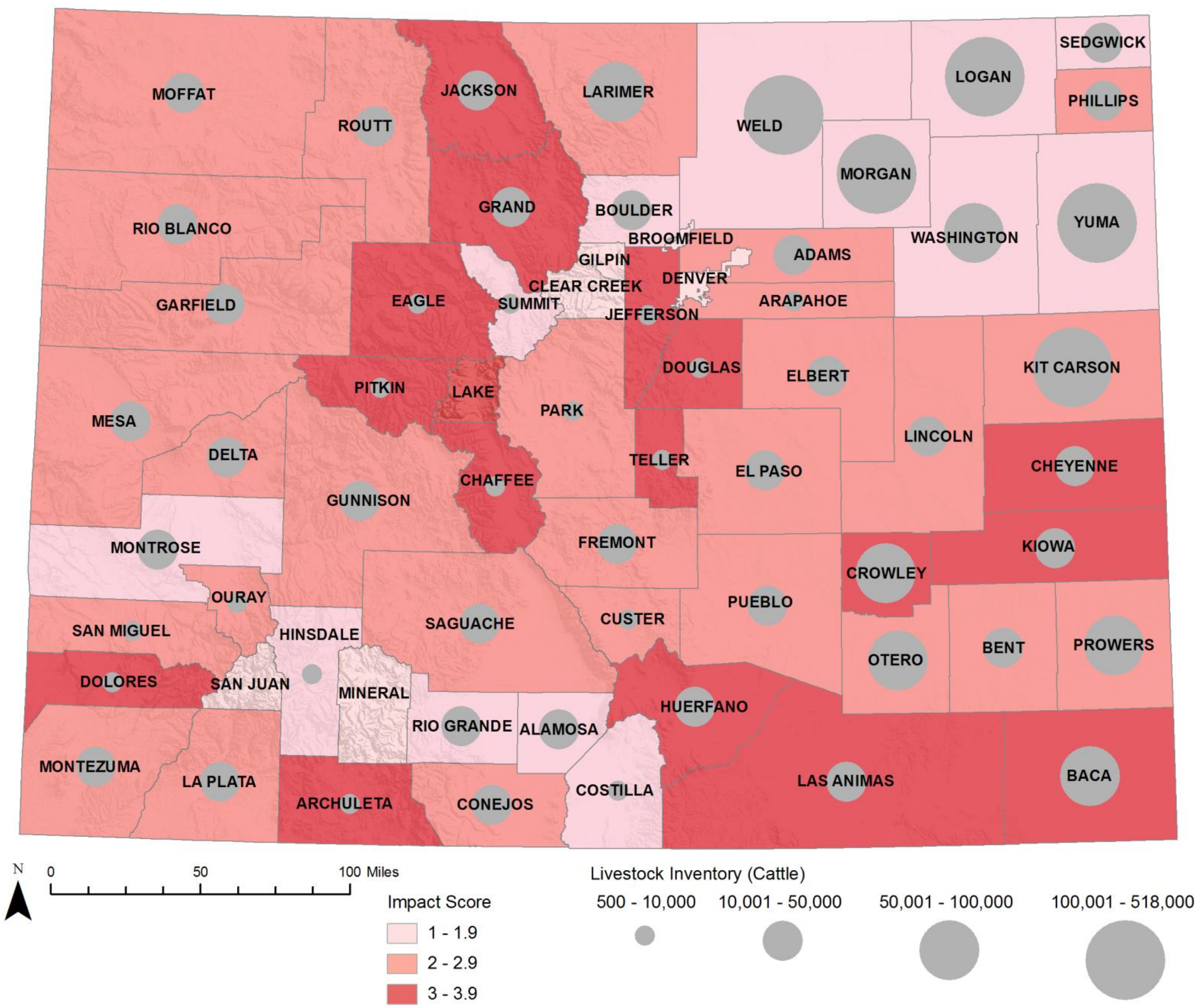
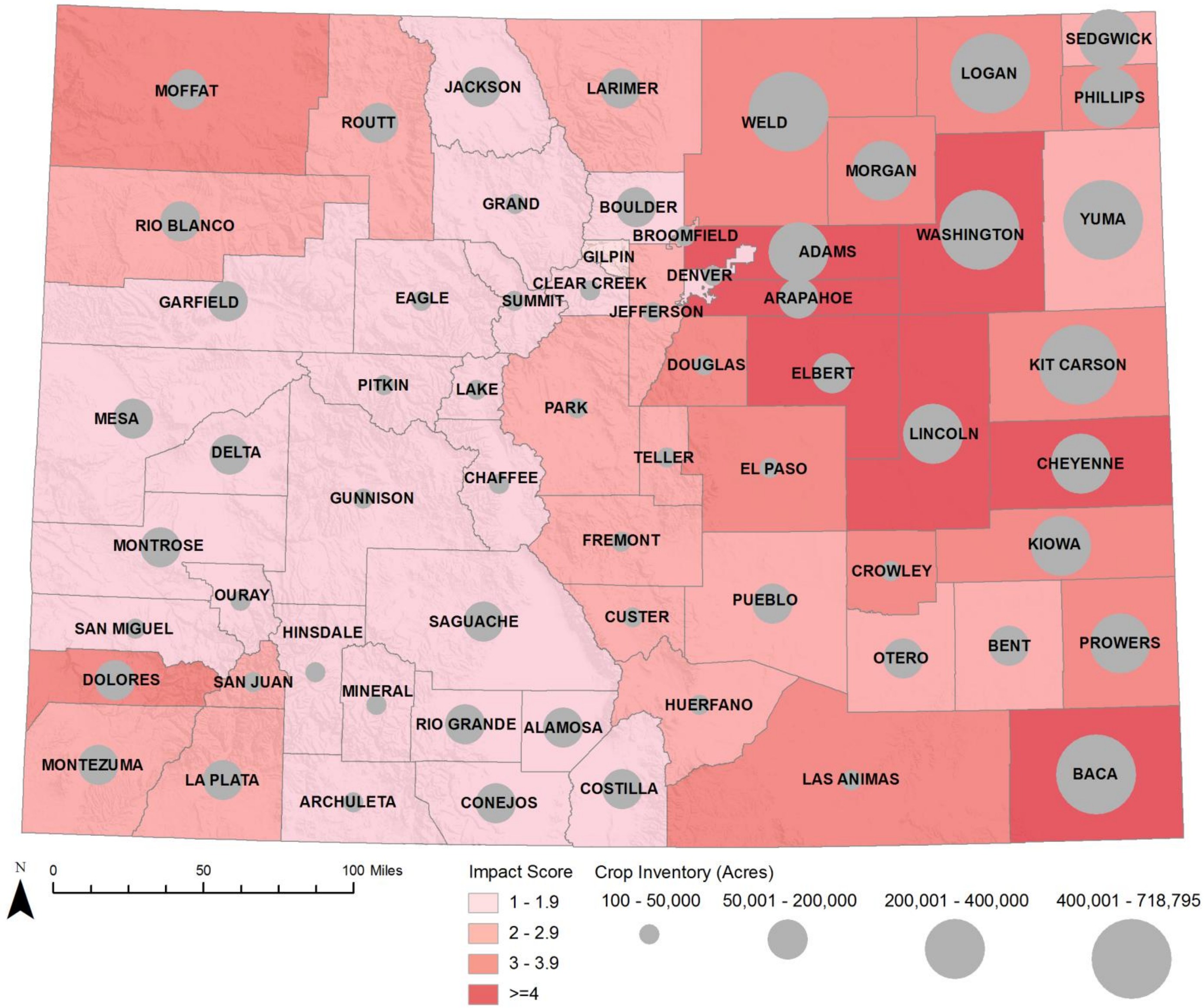



Figure updated 2013.

**Figure 6.19. Crop Inventory and Vulnerability Ranking**



## 6.5.5 Spatial Analysis

Spatially, the Agriculture Sector as a whole is fairly well distributed around the state. There are distinct concentrations of crop and livestock activity, primarily on the eastern plains (e.g., dryland crops, cattle), the northeast corner of the state (cattle), and in the San Luis Valley (crop inventory).

The livestock inventory shows a low number of cattle in the Denver Metro area, the central Rockies, and near the south-central and southwest parts of Colorado. The highest numbers of cattle are found in the northeast corner of the state, especially in Weld County. High numbers of cattle are also located in Morgan, Logan, Yuma, and Kit Carson Counties.

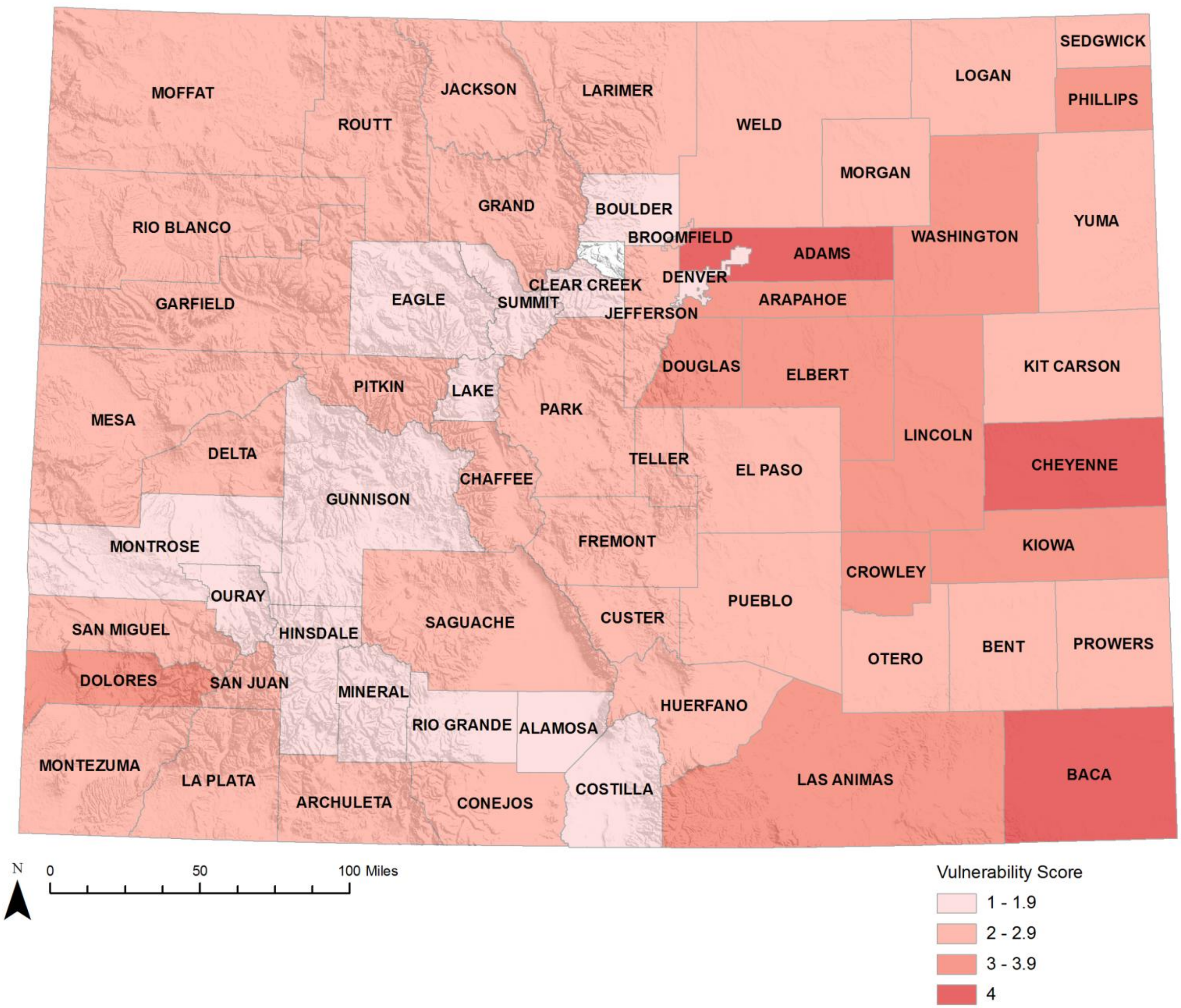
Crop acreage is distributed similarly to livestock. Highest crop acreage is found in the east and northeast, and the least amount of planting is in the central portion of the state and in the mountainous regions.

The livestock vulnerability metric is insurance allotments (Livestock Forage Assistance Program 2010), comparison of herd size between 2010 and 2012-2013 average, and number of dairy cattle as an adaptive capacity. The Livestock Forage Assistance Program was cancelled prior to the 2011-2013 drought so this data was not updated. Most of the counties in the state have an impact ranking of 2. This indicates that cattle ownership is well-distributed across the state. Weld and Morgan Counties are good examples of how the dairy cow adaptive capacity metric works. Weld County has a large number of cows, but over 10% of those are dairy cows, and Weld did not have a sharp decline in cattle following the summer of 2010. Morgan County, which also has a large number of cattle, has no livestock forage allotments in 2010, saw a very slight decrease in herd size following the 2002 drought, and roughly 10% of its cows are dairy cows. These factors combined give it a relatively low impact score for livestock, and highlights the point that even though the county has many cattle, it is not necessarily highly vulnerable to drought. Counties that are ranked 3.1-3.9 are counties with livestock forage program allotments and no dairy industry. The insurance allotments indicate their historic struggle with livestock. As discussed above, this metric should be changed to reflect the decrease in beef cows when the Agriculture Census is published.

The crop vulnerability metric is percent dryland crops, crop indemnities due to drought in 2012, and non-insured assurance program outlays in 2012. Rankings here actually go above a "4" in some counties because of qualitative adjustments to counties with over 70% dryland crops. (Counties with this qualitative adjustment include Adams, Arapahoe, Douglas, Elbert, Lincoln, Kiowa, Cheyenne, and Baca). Again, this map (Figure 6.12) could not be updated. However, the overall spatial patterns of vulnerability are likely similar to those depicted above, produced for the 2010 drought plan. In general, the map gives a sense of where dryland crops are located and, to a lesser degree, the counties that received crop indemnities in 2002 and are slated for non-insured assistance in 2010. The limitation of using dryland crops as a metric is reflected in the relatively low vulnerability rankings assigned to counties in the San Luis Valley. This area is a crop-producing region, and the literature review and interviews conducted indicated the area experienced significant impacts from the 2002 drought. However, Gunter et al., 2012 were able to show a net economic gain to the region for the 2011-2013 drought, suggesting a possible discrepancy between perception and reality. Future work should seek to identify drought specific datasets and metrics that can be used to accurately track the impacts of drought. NASA's CASA model and the joint Colorado State University-CWCB economic studies provide examples of how to move forward.

The overall vulnerability scores and map for the state cannot be updated for 2013 because of the data constraints discussed above. The publication of the 2012 agriculture census will allow these metrics to be updated. Results from the 2010 drought plan are presented in Figure 6.20. In the absence of data suggesting contrary, the results are assumed to be applicable to the 2011-2013 drought event. Overall agriculture vulnerability scores were calculated by combining subsector impact and inventory information. A notable feature is the abundance of counties with a 1 or 2 ranking in the central-western portion of the state, reflecting the fact that agricultural activity takes place in these counties but perhaps not to the degree that would make them highly vulnerable to drought. In general the eastern portion of the state is ranked more vulnerable to drought than the west due to the presence of dryland crops and, to a lesser degree, large numbers of cattle. The western half of the state does have agricultural activity, but it is more often irrigated and therefore is not as immediately vulnerable to drought as the dryland producers. Qualitative adjustments were applied to counties in the San Luis Valley. Vulnerability scores were increased to indicate a greater expected impact due to the existence of agricultural activity that was not reflected in the dryland crop metric. Other counties receiving the same qualitative adjustments include Montrose, Gunnison, and Delta, due to the presence of orchards and other irrigated crops in these counties. For detailed information on the qualitative adjustment methodology refer to Chapter 3. Counties that are mountainous and sparsely populated (e.g., Lake, Hinsdale, Mineral, etc.) are the lowest ranked because there is a very small amount of agriculture compared to the rest of the state.

## Figure 6.20. Overall Agriculture Vulnerability Ranking



### 6.5.6 Compound Impacts

Compound impacts are secondary, or indirect, impacts brought about by changes in sectors that are directly impacted. For example, direct drought impacts to the Agricultural Sector may entail loss of revenue to farmers, ranchers, and greenhouse/nursery/sod growers. This loss of revenue can in turn contribute to an overall slowing of the local economy as farmers spend less money on equipment, supplies, and other consumer items, thus compounding the initial impact. If spending decreases for a prolonged amount of time, effects such as loss of agribusiness jobs (e.g., seed retailers, farm equipment suppliers, crop insurance sales, and raw food processors) and population decline in rural communities could be seen. These impacts have been seen in the Arkansas Basin for the 2011-2013 drought (Gunter et al., 2012).

Another compound impact of drought occurs to the environment – in past emergency situations, the government has authorized grazing on lands otherwise closed to cattle (i.e., the USDA approved emergency grazing on Conservation Reserve Program acres for numerous counties during the summer of 2002 [Christensen 2002]). Increased cattle grazing can negatively impact plant life and have a detrimental effect on the local wildlife. Decreased plant life can lead to increased soil erosion, which can impact water quality due to increased sediment. Degraded water quality can have a negative effect on aquatic life and downstream communities.

If surface water supplies are inadequate for irrigation demands, farmers may turn to groundwater to supplement. A general decline in aquifer storage is seen in times of drought. On the very eastern side of Colorado, there is no surface water supply and all irrigation water is obtained from the Ogallala Aquifer (Simpson 2002). Lack of precipitation can result in increased pumping and decreased recharge, which causes aquifer drawdown. This has two impacts: 1) to the environment as the aquifer generally does not recharge as quickly as it is depleted (it can take multiple years of management to return water levels to pre-drought conditions); and 2) on the energy side, more energy to run the pumps means greater power demand and higher cost to the pump operators. Finally, drought tends to come with more sun and heat, leading to increased evapotranspiration, which means crops need more water in a time of water scarcity.

As discussed in the review of previous works (Section 6.2.2), farmers can lease or transfer their water rights to municipalities to offset lost revenue during a drought. Permanent agricultural transfer has negative implications for not only the Agriculture Sector, but also the local economy and community as it can lead to unemployment and population decline.

## 6.6 Recommendations

### 6.6.1 Adaptation to Drought

As with other sectors, diversification and early warning within the Agricultural Sector are key adaptive capacities. Planning ahead and developing strategies to cope with drought is a mitigation strategy that can benefit all farmers and ranchers. For example, ranchers can develop business relationships with multiple feed providers in case one or two providers are unable to meet the demand. Early warning to the anticipated drought allows ranchers and growers to be more flexible with their operations. Crop growers would benefit from having drought-resistant crops in their rotation along with the flexibility to lease water to municipalities in years when it is impractical to plant their fields. Alternative transfer options (as detailed in SWSI Phase 2) could also be explored as ways for farmers to adapt to drought.

The best management practices developed by the green industry might have applications for irrigated crops as well. A formalized set of best management practices could also be developed for dryland farmers. The CSU Extension maintains a helpful website with educational articles on numerous farming topics including techniques for managing crops during a drought.[9]

## 6.6.2 Improving Vulnerability Assessment

The Agriculture Sector is large and diverse, and would benefit from a more specific analysis. For crops, instead of just irrigated or dryland, the crop type could be included in the discussion of vulnerability (e.g., separating vegetables from feed). Since crops vary depending on how much and what quality of water is needed, those two factors could be part of an expanded analysis. Additionally, irrigated and dryland crops could just become separate impact groups. For livestock, an analysis of where the cattle are sent to graze should be conducted (i.e., who owns the land and what is the land owners' historical reaction to drought as it influences cattle grazing). The number of cattle living in confinement could be refined from just dairy cattle to include stockyard cattle, a statistic not available from NASS in 2013 but that could be calculated on a county level by obtaining each county's stockyard capacity.

The 2013 update was challenged by a number of data limitations, including a lack of statewide data. While the 2012 agriculture census effort is likely to fill in many of these data gaps, the reality is that it may or may not paint an accurate picture of the impacts felt during the 2011-2013 drought. This assessment is also limited by a reliance on data that is only published every 5 years. Advancements in remote sensing, such as those provided by NASA's CASA model, provide examples of how to measure and monitor drought events as they occur.

The green industry is too small to obtain statistics through the USDA, but a survey effort might be effective to find vulnerabilities specific to a region or a type of grower.

The bullets below are some suggested vulnerability metrics that could enhance this assessment in the future.

- Livestock:
  - Limit analysis to beef cows.

[9] http://www.ext.colostate.edu

- Refine cattle data to reflect grazing vs. confined cattle.
- Expand focus to include other animals (e.g., sheep, goats, pigs, chickens, etc.)

- Crops:
  - Include details such as crop type and crop sensitivity to reduced and/or degraded water quality.
  - Perform a detailed soil analysis by county and make available to the public. Specifically focus on soil texture and available water holding capacity (which is a function of soil texture and organic matter [Ball 2001]) to identify areas where soil moisture may be depleted more rapidly than others during a drought. Available water holding capacity generally ranges from 0.25 inches of water per foot of depth (for coarse sand) to 2.5 inches of water per foot of depth (for silty loam) (Ball, 2001). This range of root-zone available water is fairly limiting, however, as the time difference between the worst-case (coarse sand) and best-case (silty loam) soils is only a week or two, given the evapotranspiration rate of the crop (average plant evapotranspiration is on the order of 0.33 inches per day) and the water infiltration rate (the rate the water percolates down through the soil) (conversation with CSU Extension, 2010). Soil data are available from the USDA NRCS soil survey data mart.

- Green industry:
  - In the absence of publicly available data, conduct a survey designed to identify areas and growers that are more vulnerable to drought than others.
  - Develop metrics that all business owners can track, and that will help state water managers monitor drought impacts

## 6.7 References

Ball, Jeff. *Soil and Water Relationships*. Online article from The Samuel Roberts Noble Foundation, Inc., "Ag News and Views." September 2001. Accessed May 14, 2010. http://www.noble.org/ag/Soils/SoilWaterRelationships/Index.htm

Bauder, T.A., R.M. Waskom, and J.G. Davis. *Irrigation Water Quality Criteria*. Crop Series No. 0.506, Colorado State University Extension. Available at: http://www.ext.colostate.edu/pubs/crops/00506.pdf

Boldery, Ryan. 2012. *Xeriscape OK in Highlands Ranch.* ourColoradoNews.com. Available at http://www.ourcoloradonews.com/highlandsranch/news/xeriscape-ok-in-highlands-ranch/article_ebe5c71c-af30-11e1-b147-0019bb2963f4.html

Bouvette, Tracy et al. Drought and Water Supply Assessment. 2004

Christensen, Ray C. Executive Vice President for the Colorado Farm Bureau. "Managing Water Supply and Demand in the Time of Drought." Colorado Drought Conference proceedings, December 4, 2002. Co-Sponsored by Colorado Water Resources Research Institute and the Colorado Water Conservation Board.

Colorado Department of Agriculture. "Agricultural Industries." Accessed May 19, 2010. Updated 2010. http://www.colorado.gov/cs/Satellite/Agriculture-Main/CDAG/1220439013141

Croissant, R.L., G.A. Peterson, and D.G. Westfall. *Dryland Cropping Systems.* Crop Series No. 0.516, Colorado State University Extension. Available at: http://www.ext.colostate.edu/pubs/crops/00516.pdf

CWCB. July 16, 2010. *Draft Technical Memorandum, State of Colorado Current and 2050 Agricultural Demands.* From: Nicole Rowan and Hal Simpson, CDM; Meg Frantz, AECOM; and Ed Harvey, Harvey Economics. To: CWCB.

Frisvold, George B. and Kazim Konyar. *Effects of Water Shortages on Southwestern Agriculture.* Paper presented at the International Water Resource Economics Consortium, University of California, Berkeley. November 6 and 7, 2009.

Fry, J., Xian, G., Jin, S., Dewitz, J., Homer, C., Yang, L., Barnes, C., Herold, N., and Wickham, J., 2011. Completion of the 2006 National Land Cover Database for the Conterminous United States, *PE&RS*, Vol. 77(9):858-864.

Gunter, Allison, Goemans, Christopher, Pritchett, James, and Dawn Thilmany. 2012. *The economic impact of the 2011 drought on southern Colorado: A combined input-output and EDMP analysis.* Department of Agricultural and Resource Economics, Colorado State University. July, 2012.

Haight, Abby. “The nursery industry is facing tough times.” The Associated Press. February 19, 2010. Accessed May 22, 2010. http://www.csmonitor.com/The-Culture/Gardening/2010/0219/The-nursery-industry-is-facing-tough-times

Kress, George and Dawn Thilmany. *The Economic Contribution of Colorado's Wine Industry.* Colorado State University. Fall of 2005. Available at: http://www.coloradowine.com/pdf/EconImpact2006.pdf

Kluth, Bill. 2012. *Vulnerability of Urban Landscapes*. Presentation prepared for the CWCB's 2012 Statewide Drought Conference. Available at http://cwcb.state.co.us/water-management/drought/Pages/2012CWCBStatewideDroughtConference.aspx

LeValley, R. Baird. *Alternative Feeds for Cattle During Drought*. Livestock Series No. 1.626. Colorado State University Extension. Available at: http://www.ext.colostate.edu/pubs/livestk/01626.pdf

Li, Shuang, Potter, Christopher, & Cyrus Hiatt. 2012. *Monitoring of net primary production in California rangelands using Landsat and MODIS satellite remote sensing*. Natural Resources, 3, 56-65.

Livestock Marketing Information Center (LMIC). 2013. Personal communication with James Robb on May 29th, 2013.

Luecke, Daniel F., John Morris, and Lee Rozaklis and Robert Weaver with Hydrosphere Resource Consultants. *What the Current Drought Means for the Future of Water Management in Colorado*. January 2003.

McKee, Thomas B., Nolan J. Doesken, and John Kleist, Colorado Climate Center, Atmospheric Science Department, Colorado State University; and Catherine J. Shrier, Colorado Water Resources Research Institute; in collaboration with William P. Stanton, Colorado Water Conservation Board. *A History of Drought in Colorado: Lessons Learned and What Lies Ahead*. No. 9 – Second Edition. February 2000.

Nelson, Ron, Pritchett, James, and Christopher Goemans. 2012. *Survey summary: Farm and ranch managers' responses to the 2011 drought.* Department of Agricultural and Resource Economics, Colorado State University. July, 2012.

Potter, Christopher, Klooster, Steven, & Vanessa Genovese. 2012. *Net primary production of terrestrial ecosystems from 2000 to 2009*. Climatic Change, Vol. 115, 2, 365-378.

Pritchett, James, Goemans, Christopher, and Ron Nelson. 2013. *Economic Impacts and Farmer Adaptation to Drought.* Presentation prepared for the Colorado Water Conservation Board and the Colorado Department of Agriculture.

Proctor, Cathy. “Continuing water worries put crimp in landscape biz.” April 4, 2003. Denver Business Journal. Accessed May 24, 2010. Available at: http://denver.bizjournals.com/denver/stories/2003/04/07/story2.html

Schneekloth, J. and A. Andales. *Seasonal Water Needs and Opportunities for Limited Irrigation for Colorado Crops.* Crop Series No. 4.718, Colorado State University Extension. Available at: http://www.ext.colostate.edu/pubs/crops/04718.pdf

Schuck, Eric and W. Marshall Frasier. *Management Response by Agricultural Producers During the 2002 Drought.* Agricultural and Resource Policy Report. Colorado State University Extension. October 2003 to April 3, 2010. Available at: http://www.ext.colostate.edu/drought/ag_producers.pdf

Simpson, Hal. State Engineer. “Administering Water Rights during the 2002 Water Year: Lessons Learned.” Colorado Drought Conference proceedings, December 4, 2002. Co-Sponsored by Colorado Water Resources Research Institute and the Colorado Water Conservation Board.

Situation Statement: Wheat Improvement Work Program. Team leaders: Bruce Bosley and Frank Peairs. Colorado State University Extension. Available at: http://www.ext.colostate.edu/staffers/program/csas_wheat_pow.pdf

Thilmany, Dawn, Jessica Hernandez, Anita Pena, and Phil Watson. *Green Industries of Colorado Economic Contribution to the Colorado Economy, 2007.* Department of Agricultural and Resource Economics, Colorado State University and the University of Idaho. 2007.

Woodka, Chris. 2011. *Southeast Colorado ranchers cutting herds.* The Pueblo Chieftain. Published September 12, 2011.

USDA National Agricultural Statistics Service. *2007 Census of Agriculture State Profile: Colorado.* Available at www.agcensus.usda.gov.

# 7 ENERGY SECTOR

## Key Findings

- Thermoelectric power plants can be impacted by inadequate water supplies and increased cost of water during drought.

- Although the percentage of electricity that is provided by hydropower in Colorado is only about 4%, hydropower generation capacity can decrease as reservoir levels drop and releases decrease. Colorado also has a number of "run-of-river" hydropower plants which could also be affected by reduced streamflows.

- Colorado is home to a prosperous and diverse mining industry. Mining activities are spread out across the State but are generally concentrated in the western half. Water use for mining varies greatly depending on the mineral extracted and technology used.

- Mining operations can be impacted by increased costs of water for operations and may have to slow down if sufficient water is not available.

- The energy sector is generally drought tolerant. Power providers and mining operations tend to have very senior water rights portfolios and some power providers already have conditional drought agreements in place.

Due to budget cuts and personnel decreases as a result of the recession that occurred between the 2010 revision and 2013 update, many agencies that provide data used for the vulnerability analysis did not publicize or update data, such as mineral and energy reports or energy production data. For this reason, and because the energy sector is fairly resilient through drought, the vulnerability analysis was not updated in 2013. It can be assumed that results from 2010 also apply in 2013, but it is also important to realize that portions of the analysis are out of date. For example, some energy generation plants may have since closed in certain areas, e.g., Mesa County, although the area may still appear to be highly drought vulnerable. Further, the full impact of the 2011-2013 drought was not apparent as of the 2013 update and therefore comprehensive data related to the Energy Sector are not yet available because they are still being collected and evolving. However, many observations are available for inclusion in this update and still provide useful insight into the impacts drought has on the Energy Sector.

## Key Recommendations

The following key recommendations were originally developed in 2010 and continue to be relevant in 2013. Many of these were taken into account during the 2013 update. These recommendations should be considered in light of regional differences. For example, planning decisions regarding infrastructure in urban or high-density areas are different than those that are applicable to rural communities.

- To protect critical infrastructure during drought conditions and possible secondary influences, power providers should continually assess their systems to identify areas prone to failure or impact. For example, Xcel Energy has recently begun efforts to reduce vulnerability of their infrastructure due to pine beetle impacted forests and the wildfires that may result in these areas attributed to dry conditions. Light detection and ranging technology (LiDAR) is being used to identify dead and dying trees that could fall on power lines. Debris management then occurs in critical areas to reduce costly impacts (Denver Post, 2013).

- Although power production was not curtailed during the 2011-2013 or 2002 droughts, power providers are still vulnerable to curtailment in severe droughts. As population expands, power demand increases and competing demand on water resources intensifies. Power providers should be aware of this possibility and diversify their water rights portfolio. Purchasing additional water rights and conditional drought lease agreements and using the water in accordance with Colorado water law is also helpful. Demand-side management, integration of low water-use renewable generation methods, and use of legally-reusable effluent for cooling can also reduce drought impacts. Companies involved in fracking should also continue to invest to research innovative ways to reuse produced water.

- Power providers can decrease vulnerability by transitioning to less water intensive generation methods while considering available fuel choices. Renewable generation methods like wind and solar use negligible amounts of water and are part of the legislated mandate of 30% renewable energy sources by 2020. Increasing renewables reduces the water required for systemwide generation on an annual basis, but water supplies are required to operate conventional plants and those plants need to be prepared at all times, in case renewable generation is not adequate on any given day or time.

- As additional renewable power generation facilities come on line, transmission line capacity should be increased to facilitate flexibility during drought.

- Mining companies should increase their drought awareness and consider technologies that are less drought intensive.

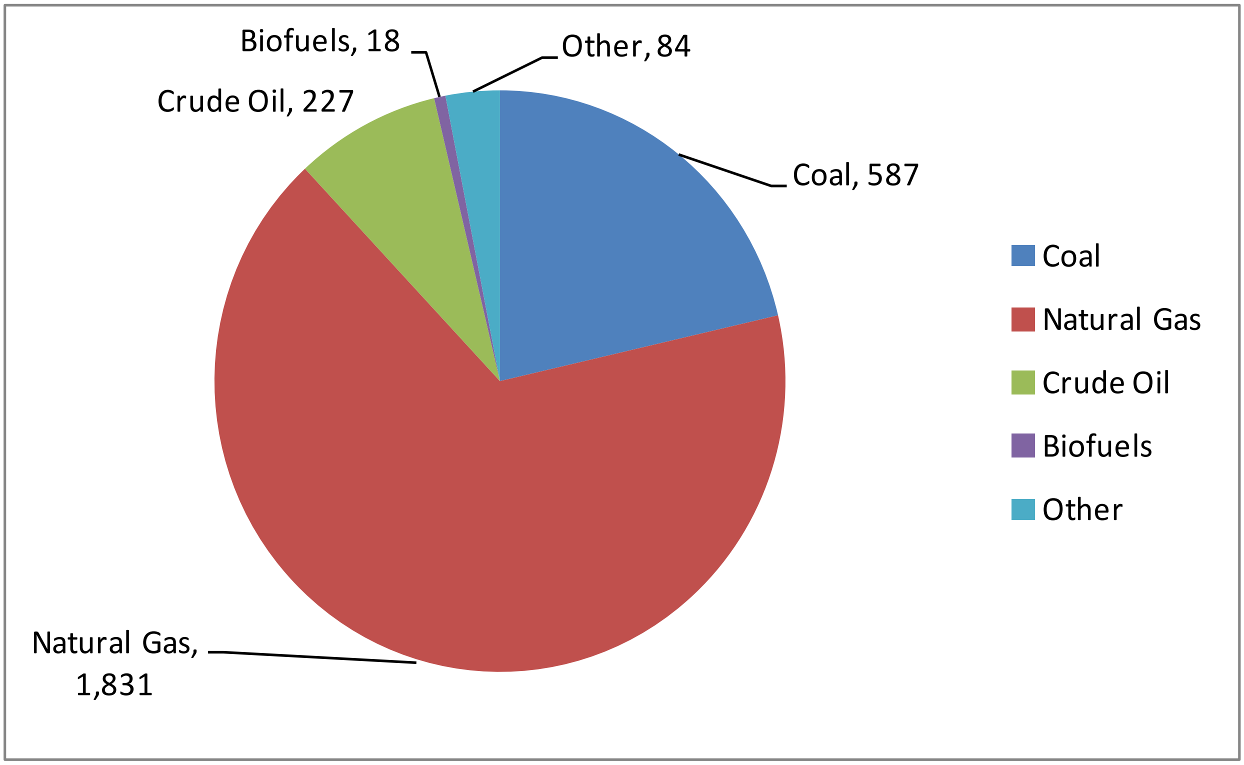
## 7.1 Introduction to Sector

The Energy Sector encompasses mining and power production. While these two activities are often interrelated, their use and dependence on water resources is quite different. As such, for the purpose of this analysis, the Energy Sector has been divided into two sub-sectors: power and mining. For a general description of the vulnerability assessment approach refer to Chapter 2 (Annex B).

Colorado is a state rich in mineral reserves and mining is an important part of the economy. The total value of mineral and energy production in 2007 was estimated to be $11.8 billion. In addition, the total economic contribution for all oil and gas related activities in the State was estimated to be $22.9 billion (Burnell, Carroll, and Young, 2008). Due to personnel decreases since the 2010 Plan update, the Colorado Geological Survey (CGS) has not updated their annual mineral and energy activities report since 2007. In 2011, coal mines in Colorado purchased over $318 million in equipment, services and supplies (Colorado Mining Association, 2011). The future of mining in Colorado remains promising. Colorado is the number one molybdenum producing state and the number four gold producing state in the nation. The State has 10 of the nation's 100 largest natural gas fields and three of its 100 largest oil fields (U.S. Energy Information Administration, 2013). In 2008, the Rockies Express Pipeline began service, greatly enhancing Colorado's ability to export natural gas to Midwest markets. Colorado's oil and gas production continues to expand year after year, with oil production reaching its highest level since 1957 when over 49 million barrels were produced in 2012, as estimated by the Colorado Oil and Gas Conservation Commission (COGCC). This is a 25% increase in oil production over 2011, which was a 20% increase as compared to 2010 (COGCC, 2013). Marketed natural gas production rose 27% from 2007 to 2011 (U.S. Energy Information Administration, 2013).

Additionally, there are enormous deposits of oil shale in the western part of the State estimated to hold one trillion barrels of oil. If mined, this is equivalent to the entire world's proven oil reserves, but to date extraction of this resource has been limited by high costs. Colorado is also a top state for proven coalbed methane reserves (nearly 30% of the national total) (U.S. Energy Information Administration, 2013). Figure 7.1 shows the relative magnitude of production of the various energy activities in the State in 2011 in trillion British thermal units (Btu).

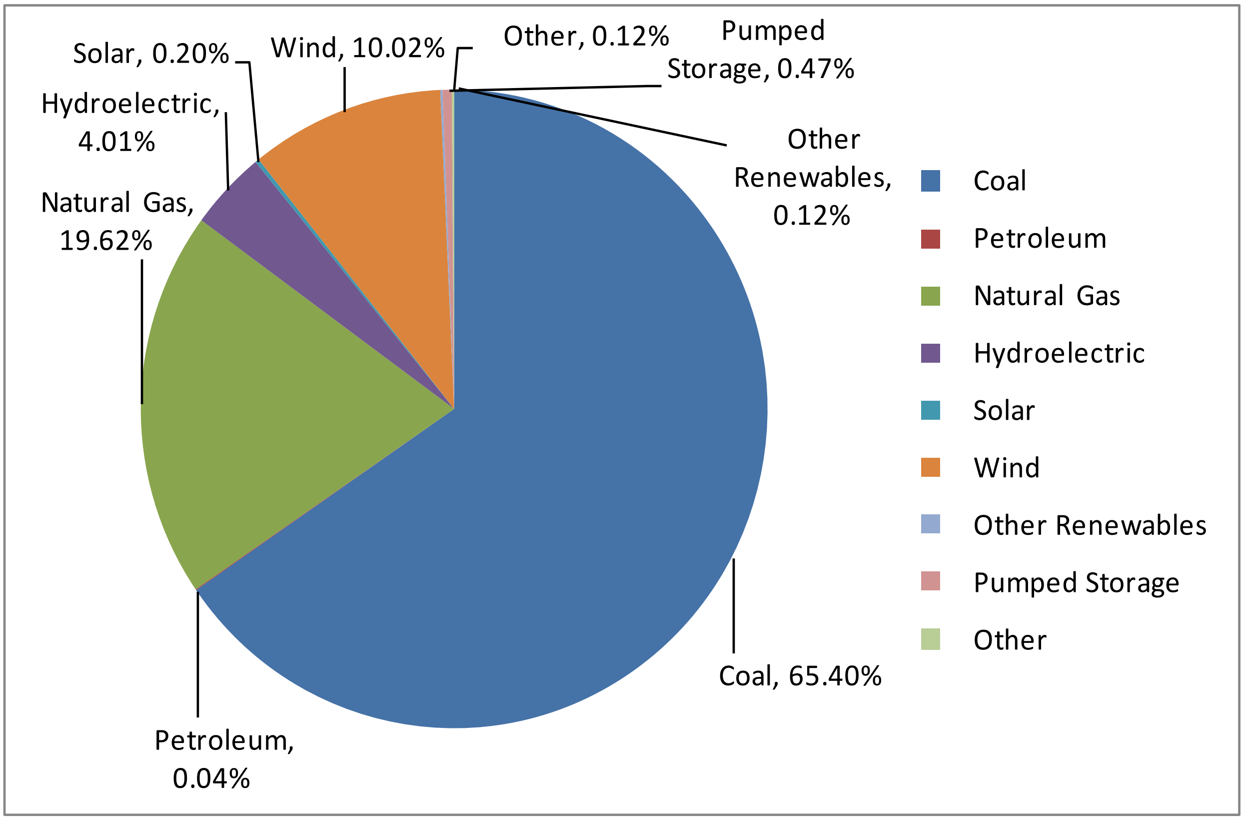
**Figure 7.1. Colorado Energy Production Values, 2011 (Trillion Btu)**




-'Other' includes all renewable energy sources except biofuels (biomass inputs (feedstock) for fuel ethanol production).
Source: U.S. Energy Information Administration, Figure revised 2013

In 2010 (the most recent data available due to lack of available resources according to U.S. Energy Information Administration (EIA)), 65 retail power providers generated nearly 53 million megawatt-hours (MWh) of energy for total retail sales of $4.8 billion (U.S. EIA, 2010). The economic impact of power generation goes far beyond this revenue or the jobs directly created. It is nearly impossible to fully quantify the impact of power production on the State. Without reliable power generation nearly all other sectors would be crippled. Figure 7.2 shows the 2011 distribution of power generation by fuel type in Colorado. The vast majority of Colorado's generation (~85%) is thermoelectric. The remainder comes from renewables, mainly wind (10%) and hydroelectric (4%). It is important to note that Colorado's electricity profile is changing. Amendment 37 was adopted in 2004 to require large utilities to obtain 10% of their energy from renewable resources by 2015. This standard was modified by the Colorado General Assembly in 2007 to require large utilities to obtain 20% of their energy from renewable resources by 2020. In 2010, House Bill (HB) 1001 increased this requirement to 30% for investor owned utilities by 2020. It is expected that a large portion of this will be provided by wind, hydroelectric, and solar technology. In 2011, Colorado's 91 megawatt (MW) photovoltaic (PV) capacity was the fifth largest in the United States (U.S. Energy Information Administration, 2013). Similar to Amendment 37 but for rural utilities, the 2013 Senate Bill (SB) 252 requires rural electric co-ops to obtain 20% of their energy from renewable sources by 2020. It also encourages the use of methane capture technologies.

**Figure 7.2. Electrical Generation by Fuel Type in Colorado, 2011**




-'Other Renewables' includes biogenic municipal solid waste, wood, other wood waste, landfill gas, and other biomass.
-'Other' includes non-biogenic municipal solid waste, batteries, chemicals, hydrogen, pitch, purchased steam, sulfur, tire-derived fuels and miscellaneous technologies.
Source: U.S. Energy Information Administration, Figure revised 2013

The Energy Sector is closely connected to water resources both through mining processes and power generation. Power producers consume water through evaporative cooling and evaporation from reservoirs for hydroelectric plants. CWCB's Statewide Water Supply Initiative (SWSI) has analyzed water usage by various economic sectors. Self-supplied industry, which includes the energy sector, consumes approximately 2% of water in the State annually (CWCB, 2004). Self-supplied industry includes a variety of activities, including thermoelectric generation, snowmaking, gravel mining, and other activities. It is estimated that thermoelectric generation comprises approximately 1% of water consumption in the State, approximately half of the sector water consumption. SWSI 2010 predicts that water consumption by self-supplied industry will grow to 3% by 2050 (CWCB, 2011).

Water consumption by the municipal and industrial (M&I) and agricultural sectors consume approximately 12% and 86%, respectively. By 2050, SWSI predicts that water consumption by M&I and agriculture will be 15% and 82%, respectively. Because of the relatively small water footprint of electric generation within Colorado, caution should be used when extrapolating the drought benefits resulting from implementation of generation technology which uses less water, particularly when those technologies take significant time to implement, are very expensive, and may or may not be available in sufficient quantity during drought-related weather conditions of high temperatures, e.g., dry cooling.

The National Renewable Energy Laboratory estimates that in Colorado, thermoelectric generation requires 0.51 gallons of water per kilowatt hour (gal/KWh) and hydroelectric requires 17.91 gal/KWh (Torcellinin, Long, and Judkoff, 2003). It is important to note that while hydroelectric generation requires more water, it is non-consumptive, i.e., it is typically available for other uses following its usage for energy generation, while thermoelectric generation is consumptive. Water use for mining varies greatly depending on the resource extracted and the methods used. Water is often used for drilling and transport. Conversely, large quantities of water (often of impaired quality) can be produced during production. Table 7.1 outlines the primary connections between water and energy as detailed in Cameron et al. 2006. This information will be discussed in more detail in later sections.

**Table 7.1. Connections between the Energy Sector and Water Availability and Quality**

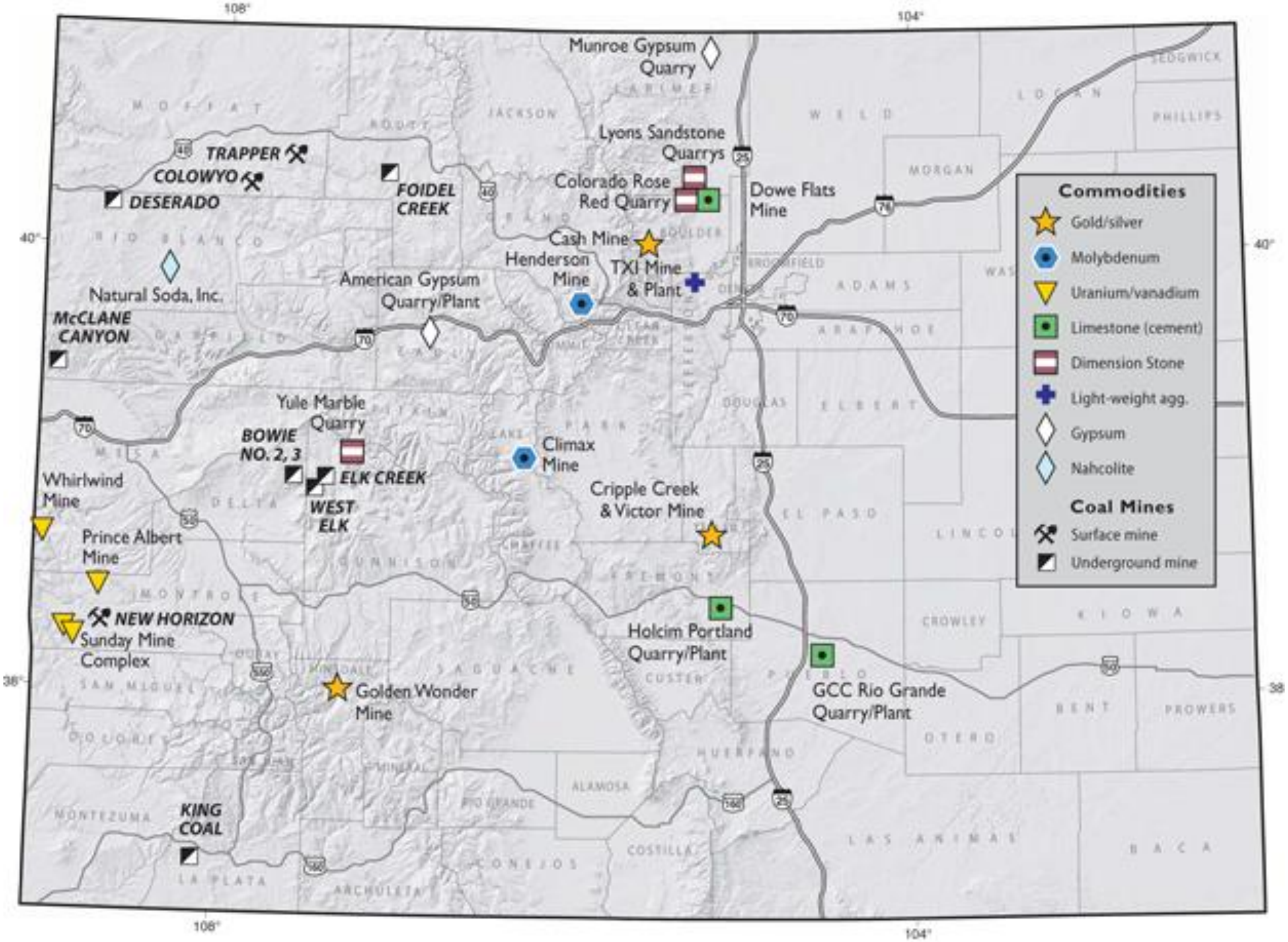
| Energy Element | Connection Water Quantity | Connection to Water Quality |
|---|---|---|
| **Energy Extraction and Production** | | |
| Oil and Gas Exploration | Water for drilling, completion, and fracturing | Impact on shallow groundwater quality |
| Oil and Gas Production | Large volume of produced, impaired water | Produced water can impact surface and groundwater |
| Coal and Uranium Mining | Mining operations can generate large quantities of water | Tailings and drainage can impact surface water and groundwater |
| **Electric Power Generation** | | |
| Thermoelectric (fossil, biomass, nuclear) | Surface water and groundwater for cooling and scrubbing | Thermal and air emissions impact surface waters and ecology |
| Hydroelectric | Reservoirs lose large quantities to evaporation | Can impact water temperatures, quality, ecology |
| Solar PV and Wind | None during operation; minimal water use for panel and blade washing | |
| **Refining and Processing** | | |
| Traditional Oil and Gas | Water needed to refine oil and gas | End use can impact water quality |
| Biofuels and Ethanol | Water for growing and refining | Refinery wastewater treatment |
| Synfuels and Hydrogen | Refining water for synthesis or steam reforming | Wastewater treatment |
| **Energy Transportation and Storage** | | |
| Energy Pipelines | Water for hydrostatic testing | Wastewater requires treatment |
| Coal Slurry Pipelines | Water for slurry transport; water not returned | Final water is poor quality; requires treatment |
| Barge Transport of Energy | River flows and stages impact fuel delivery | Spills or accidents can impact water quality |
| Oil and Gas Storage Caverns | Slurry mining of caverns requires large quantities of water | Slurry disposal impacts water quality and ecology |

Source: Cameron et al. 2006

The implications of hydraulic fracturing, or “fracking”, used in oil and gas development has become an important topic throughout Colorado, especially the Front Range, as large-scale drilling intensifies. The water demands associated with fracking, including the water required to drill the wells, has been estimated to be 22,100 to 39,500 acre-feet annually in Colorado. This is equivalent to serving the water needs of 66,400 to 118,400 homes in the State for an entire year (Western Resource Advocates, 2012). Due to its water requirements, and because most new oil and gas activities on the Front Range use municipal water supplies, the fracking process is vulnerable to the impacts of drought and scarce water supplies. However, it is unclear how water supplies will be allocated during drought. Water providers may continue to sell higher priced water to the oil and gas industry while asking their customers to conserve water during drought, or, industry may find itself dealing with the same water use restrictions as the rest of the general population. Due to this uncertainty, and to the water requirements of the process, the fracking industry should continue to fund research to develop innovative ways to reuse the water that is produced rather than treating it as a waste product and reinjecting it into the ground.

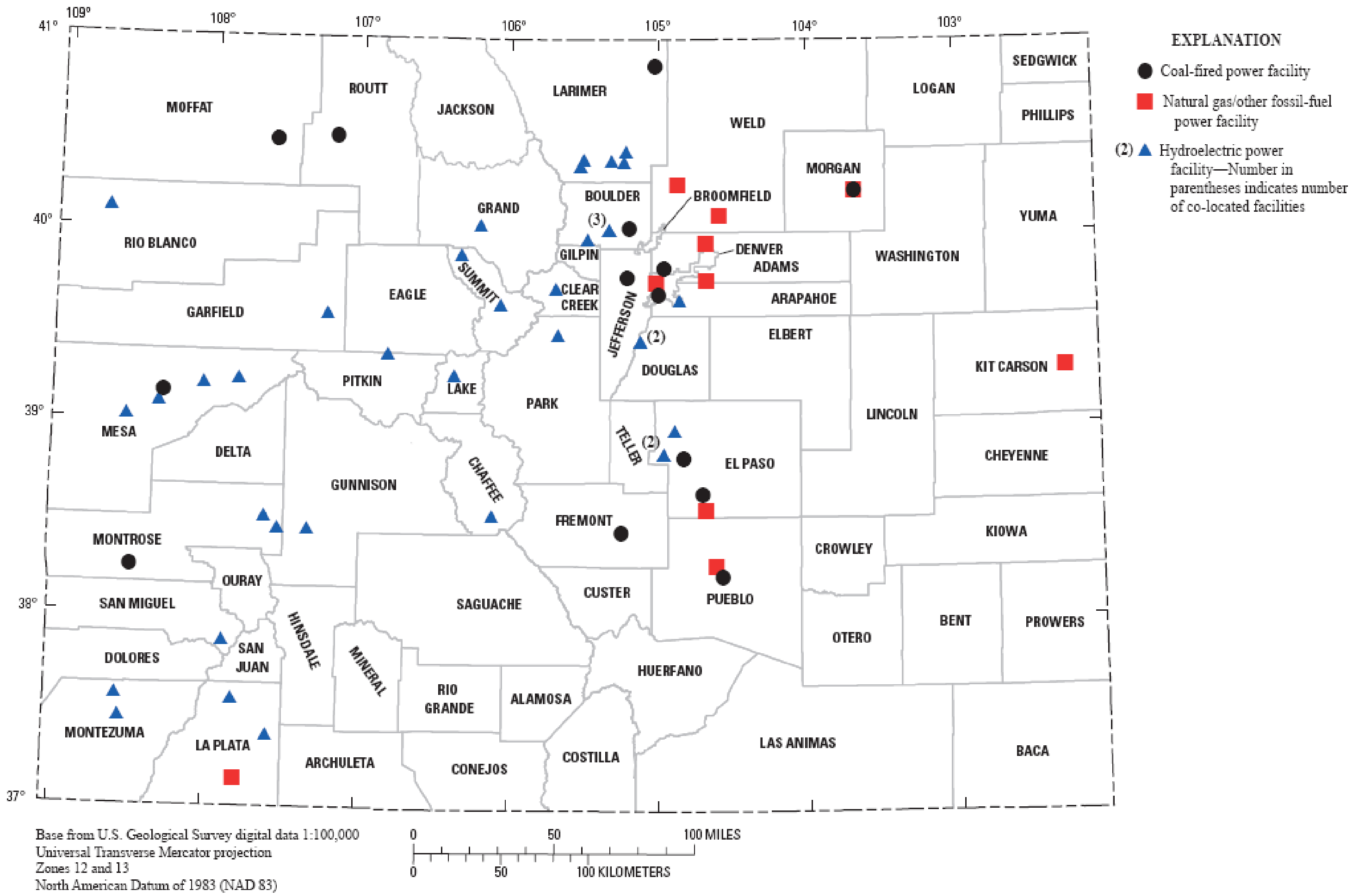
The Energy Sector is distributed across the State but more concentrated in the western half. The following figures illustrate the spatial distribution of mining activities and water intensive power production across the State. Figure 7.3 shows the distribution of major mines across the State, excluding clay and aggregate mines. Clay and aggregate mines tend to be spread out across the State but in close proximity to population centers and transportation corridors. Distribution of individual resources is discussed in more detail in Section 7.3. Figure 7.4 shows the distribution of thermoelectric plants that use cooling water and hydroelectric plants in Colorado.

## Figure 7.3. Significant Industrial Mineral Mines in Colorado




Source: Burnell, Carroll, and Young 2008

## Figure 7.4. Location of Water Cooled and Hydroelectric Power Generating Facilities 2005[1]

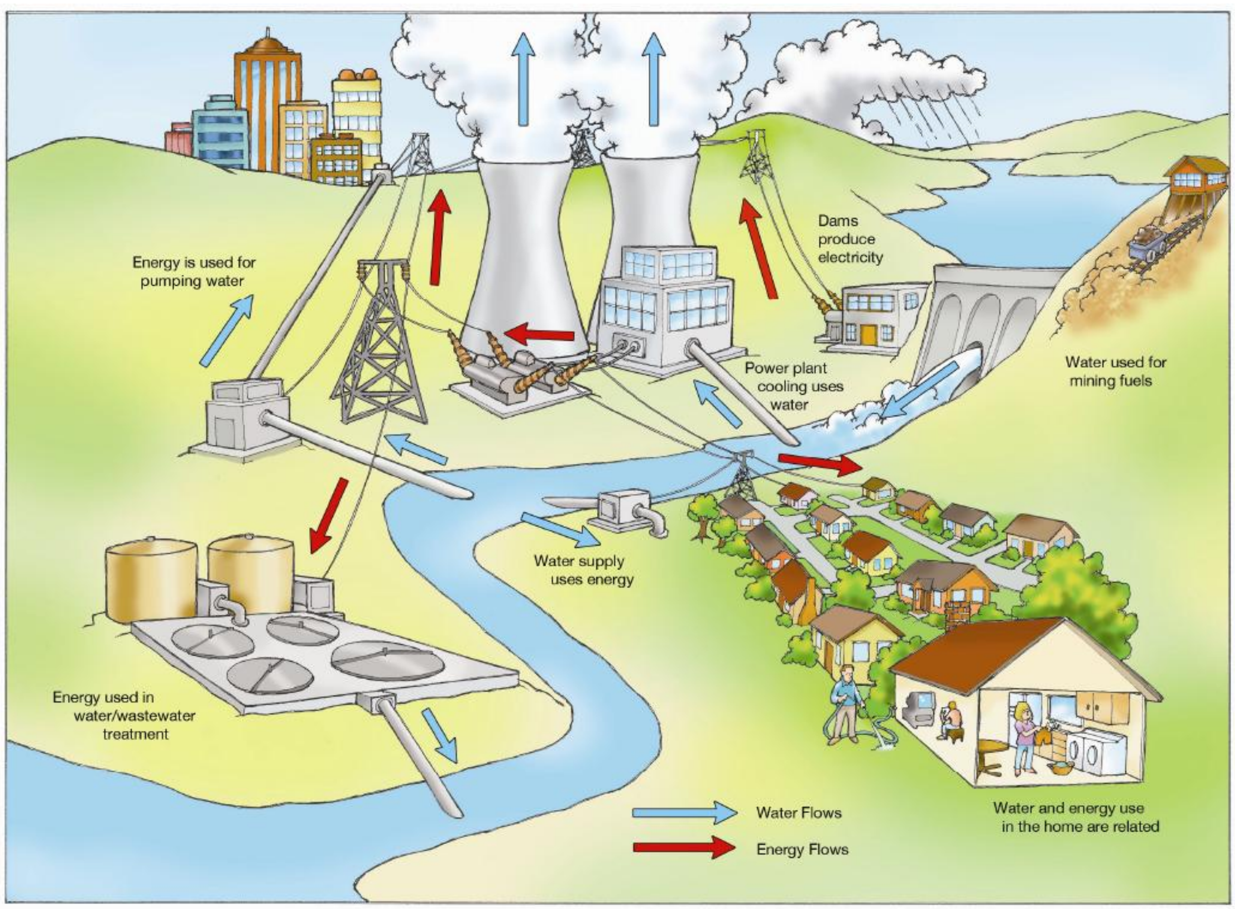



Source: USGS 2010

[1] Note that this map is pulled from a 2005 report. Any facility changes that have occurred after 2005 are not represented in this figure.

There are few activities in the State that are not reliant on the stability of the Energy Sector. There are obvious connections between power providers and all of the industries and individuals who rely on their power in Colorado; but power producers are, in turn, dependent on reliable fuel sources often provided by Colorado mines. Throughout the United States, 3% of all power generation is used for water supply and treatment. Electricity represents approximately 75% of the cost of municipal water processing and distribution (Cameron et al., 2006). Without power many municipal providers who rely on pumps and power for treatment processes are unable to supply water. The same is true for agriculture, especially groundwater irrigation which also relies on pumps. Figure 7.5 details some of the basic interrelationships between water and energy.

**Figure 7.5. Examples of the Interrelationships between Water and Energy**




Source: Cameron et al. 2006

# 7.2 Vulnerability of Energy Sector to Drought

## 7.2.1 Aspects of Vulnerability

Table 7.2 outlines the key impacts and adaptive capacities of the Energy Sector with respect to drought. The primary vulnerability to power providers during a drought is loss of cooling water supply for thermoelectric power. To compensate for this, electric providers may perform load-sharing, e.g., reducing load where dry conditions are prevalent and moving energy in from other areas that are not as affected. Transferring load and balancing power for the Western Grid, which Colorado is a part of, is coordinated by the Western Electricity Coordinating Council (WECC) to ensure electric system reliability throughout the Western U.S. This can be an effective management strategy during drought because power can be bought and sold on a nearly instantaneous manner (Personal communication with Xcel Energy, 2013). However, widespread drought, such as that in Texas in 2011, can pose problems to entire electric grids, especially where 'once-through' cooling based on river flow is the dominant technology. Several thousand MW of power generation were at risk of not being available due to the severe drought there which prompted considerations to close some facilities (The Texas Tribune, 2011). This is due in part because the grid supplying electricity to Texas is located solely in the State. In contrast, the Western Grid includes approximately half of the country so Colorado is not as at risk for this type of problem (Personal communication with Colorado Energy Office, 2013). Additionally, cooling towers, which do not require high water volumes to operate (as opposed to 'once-through' cooling), is the dominant technology in Colorado. This technology is less vulnerable to drought and is therefore used more in the Western United States.

Although demand may be met by other providers if production in one location declines for any reason, shifts in production method may result in increased impacts to the environment or costs to the consumer as well. In a worst-case scenario, the generation capacity could be so impaired that rolling blackouts or outages would result. Neither of these scenarios is that likely in Colorado as power providers tend to have very senior water rights and historical drought curtailment has been non-existent. However, with population growth and the resulting increase in demand for power and strain on water resources, the situation could be more tenuous in future droughts.

Infrastructure related to electric power distribution is also vulnerable during drought conditions, and secondary drought impacts can be most significant. For example, falling timber due to wildfires and beetle kill can fall on transmission lines, causing power outages and necessitating prompt repair. For example, during the Four Mile fire west of Boulder in September 2010, many of Xcel Energy's transmission lines were damaged (Personal communication with Xcel Energy, 2013). Steep terrain and challenging access where many wildfires occur requires power providers to sometimes have equipment and firefighters dropped in via helicopter to protect critical infrastructure, a costly and dangerous process. To assist with mitigating these impacts, Xcel Energy is currently using LiDAR to identify mountain pine beetle impacted trees near its 13,000 miles of power lines. Typically each line is checked once every five years but in pine-beetle prone areas, this frequency has increased to every two years. More than 250,000 trees have been removed in the past four years at a cost of approximately $17 million (Denver Post, 2013).

Hydroelectric generation capacity can also be impacted by decreased reservoir elevations, although the magnitude of this impact is minimal due to the small amount of power generation in

Colorado supplied by hydroelectric (~4%). Often, providers can compensate for this by purchasing additional water during a drought; however, if this is not possible, power production at some plants may be decreased or shut down completely. Across the WECC region, hydroelectric generation can drop by up to 30% in a severe drought year (Colorado Energy Office, 2012). Additionally, several major utilities in Colorado purchase hydroelectric power from the Western Area Power Administration. If drought is prevalent in other western states, these utilities may need to purchase more expensive generation sources (Personal communication with Colorado Energy Office, 2013).

Power providers can decrease their vulnerability to drought by diversifying water sources and increasing water right portfolios. Additionally, continuing to research and develop ways to recycle and reuse produced water from fracking is another means to decrease vulnerability associated with low water supplies during drought. Since the 2002 drought, some providers have purchased conditional lease water from agriculture as a backup during times of drought and there are proven thermoelectric technologies like combined cycle plants and dry cooling systems which require significantly less water. Reducing the use of conventional coal-fired power plants and increasing reliance on certain types of renewable energy, combined cycle natural gas plants, and advanced cooling systems (like dry cooling) could reduce the amount of water used for electricity generation in the State. Many renewable energy options like wind and solar PV require virtually no water. Increasing use of these alternatives may lessen the impacts when a drought occurs.

Although these technologies are expensive and take time to implement, they are beginning to be implemented in Colorado. However, it is important to recognize the technical challenges with some of these technologies. For example, dry-cooling relies on temperature differentials, i.e., an increased duration of elevated temperatures, which may not be present during drought. Further, retrofitting existing, larger power plants to dry-cooling may not be an option. Although the effectiveness of these technologies may be limited under various climatic conditions, other options exist that may provide more protection during drought. For example, Xcel's Comanche Unit 3 in Pueblo is a hybrid-cooled facility which takes advantage of dry-cooling when ambient air temperature differentials are sufficient, but uses water cooling when they are not, i.e., water savings are greatest in cooler months of the year. Energy providers can also pursue temporary water supplies, e.g., through interruptible supply agreements or other mechanisms, to sustain operations during drought. This approach is a more cost-effective means of providing drought protection and also benefits other sectors. For example, the entity supplying the water (typically agriculture), will receive much-needed revenue to sustain it during periods of drought when water supplies are not sufficient for growing crops.

As a State, Colorado can increase transmission line capacity to enhance flexibility among power sources; currently transmission limitations inhibit utilization of low water energy sources in some regions of the State. Investment in transmission lines is required parallel to investment in new renewable energy production areas.

Although the mining industry does require some water, vulnerability to drought is generally considered to be minimal and has not been analyzed in detail. Presumably mining activity could be halted if companies are unable to obtain the necessary water rights to maintain production; however these purchases generally take place years in advance and are not typically impacted by short-term droughts.

As mentioned above, Colorado has vast oil shale reserves in the northwestern part of the State that are not currently in production. It is estimated that 3-4 barrels of water would be required for each barrel of shale oil extracted. At a production rate of 1.55 million barrels per day this would result in an annual water demand of more than 378,000 acre feet (Western Resource Advocates, 2009). Given this substantial water requirement, drought vulnerability for oil shale should be specifically investigated as part of any feasibility analysis.

**Table 7.2. Summary of Impacts and Adaptive Capacities**

| Impacts | Adaptive Capacities |
|---|---|
| Decreased power generation due to inadequate water supply for evaporative cooling | Power providers can diversify water sources |
| Increased costs for power providers to purchase additional water during drought | Power providers can purchase conditional water leases |
| Decreased hydropower generation due to lower reservoir levels | Transition to less water intensive generation methods using traditional fuels or renewable energy resources |
| Decreased power generation due to inability to discharge waste water | Increase transmission line capacity to allow for greater versatility |
| Change in power supply mix and operation costs can result in increased price for electricity | New mining technology that is less water intensive |
| Severe power cutbacks could results in rolling blackouts | |
| Environmental impacts from shifts in power production | |
| Increased intake water temperatures can decreased plant efficiency | |
| Plant shut downs due to water levels dropping below intake elevations | |
| Increased costs for mining operations to obtain water rights | |
| Decreased mining activity due to inability to obtain water rights | |

## 7.2.2 Previous Work

While there is a considerable body of work on the water-energy nexus, there is relatively little specific to drought vulnerability.

However, this appears to be a topic which is gaining more attention. For example, in 2009 the National Energy Technology Laboratory (NETL) conducted a modeling project to analyze the effect of drought on electric power generation in the western U.S. (National Energy Technology

Laboratory, 2009). They used data from the U.S. EIA and previous evaluations of cooling water intake location and depths. Power generation was modeled on an hourly basis using a probabilistic dispatch model.

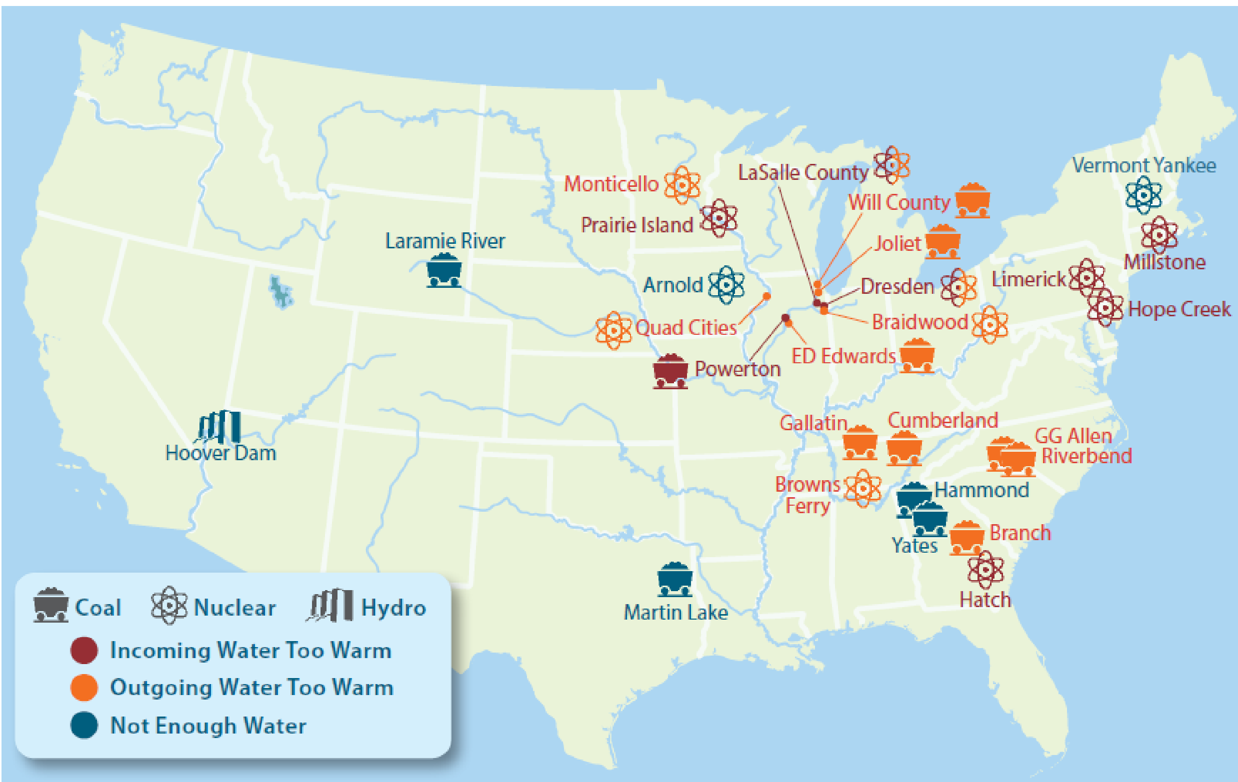
In their analysis, hydropower generation was curtailed during drought based on historical drought operations. Thermal power plants were cut back in areas designated as undergoing a moderate or more severe drought (U.S. drought monitor analysis). Based on this analysis, 3,284 MW of power were identified for possible drought curtailment. Under drought conditions, generation from coal plants dropped by 20.6TWh (8% from baseline) and hydroelectric power dropped nearly 30%. Natural gas plants were identified as likely candidates to fill power gaps left by hydropower reduction because they generally operate below capacity. However, because the cost of generation is much higher for natural gas, this shift resulted in a $4.5 billion increase in production costs and rate hikes of more than 30% in summer months. Furthermore, increased reliance on fossil fuels results in a 5% increase in $CO_2$ emissions.

The NETL study covers the entire western U.S. and is not specific to Colorado. Vulnerability to the State may be overestimated in this report for several reasons. First, Colorado's reliance on hydropower is very small (~4%). Also, based on interviews with power providers and industry experts in this study, there is no previous occurrence of power curtailment in Colorado because power providers in the State tend to have very senior water rights and are not likely to shut down unless drought is more severe than has been previously experienced. Still, the results from the NETL study are informative with respect to the far-reaching impacts power curtailment could have on the State.

One recent on-line publication from the Union of Concerned Scientists (http://www.ucsusa.org/clean_energy/our-energy-choices/energy-and-water-use/water-smart-power.html) provides a useful synthesis of policy-relevant research on the water demands of energy production in the context of climate variability and change. This document highlights the severe impacts that recent drought has had on the U.S. electricity sector, including, for example, Texas power plant operators having to truck in water from miles away to keep power plants running in 2011, and power plants from the Gallatin coal plant in Tennessee to the Vermont Yankee nuclear plant on the Connecticut River being forced to reduce their output or shut down during 2012.

The report's examination of the electricity-water landscape reveals some prominent challenges, including the reliance of many power plants on lakes, rivers, and groundwater for cooling water that can exert heavy pressure on those sources while also leaving the plants vulnerable to energy-water collisions during drought. The report argues that such energy-water collisions are likely to worsen in a warming climate, as the power sector itself helps drive climate change, which in turn can negatively impact the availability and quality of water. Plants have recently run into three kinds of challenges: incoming cooling water that is too warm for efficient and safe operation, cooling water that is too hot for safe release into nearby rivers or lakes, and inadequate water supplies. In response, operators must reduce plant output or discharge hot water anyway, at times when demand for electricity is high and rivers and lakes are already warm. However, from the standpoint of Colorado, it is noteworthy that the energy-water collisions noted in this report are primarily in the eastern United States (see Figure 7.6). The lack of drought-related impacts in the western US is likely due to the fact that energy providers in the west have evolved to varying degrees to be resilient to drought. The Western US is arid and energy generation facilities with inadequate water supplies have always been subjected to drought-related curtailment any number of times during previous drought events, and have thus developed mitigation and adaptation strategies over time, and as a matter of course. Further, Western states have evolved institutions which are more adapted to drought and arid/semi-arid conditions versus the Midwest and coastal regions of the US.

**Figure 7.6. Energy-Water Collisions at Power Plants Nationwide**




Source: http://www.ucsusa.org/clean_energy/our-energy-choices/energy-and-water-use/water-smart-power.html

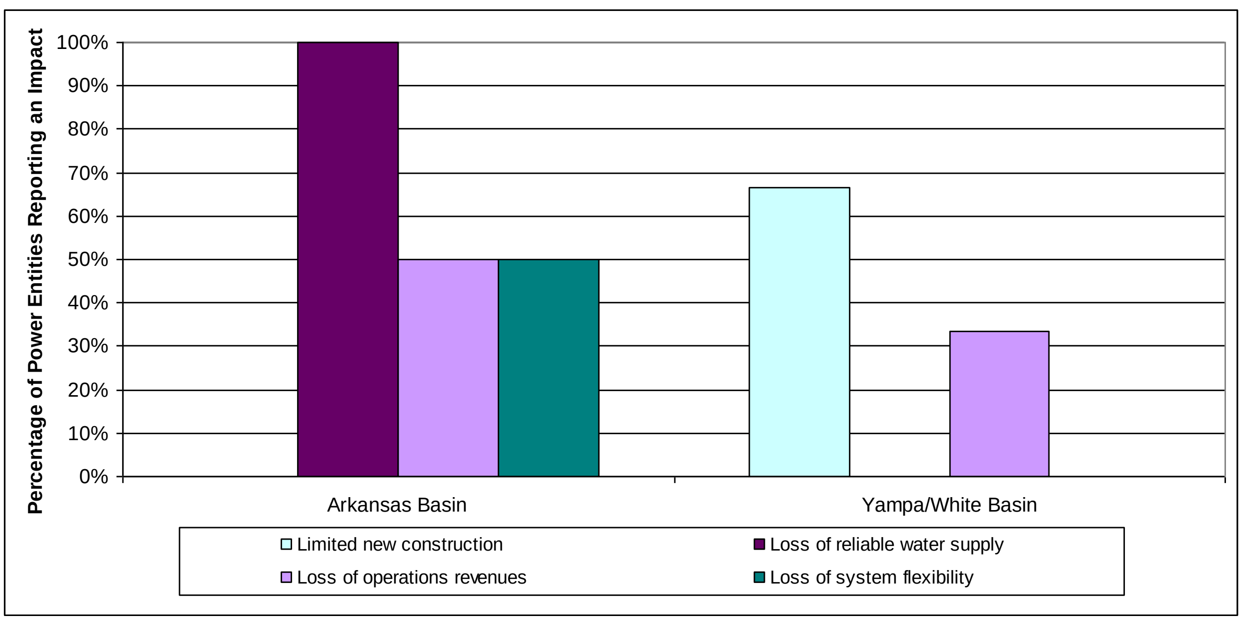
Energy specific drought vulnerability analysis has not been conducted specifically for Colorado. However, there are several studies that address drought and water supply planning in the State that are relevant. The Colorado Water Conservation Board (CWCB) conducted a Drought and Water Supply Assessment (DWSA) in 2004 to determine the State's preparedness for drought and identify existing limitations that inhibit preparation for future droughts. The details of this work are discussed in Chapter 1: Introduction. The DWSA entailed a survey, or opinion instrument, where 537 responses were received statewide on specific impacts experienced during the drought of 2002. Various interests were surveyed including power, industry, agriculture, municipal, state, federal, water conservancy and conservation districts, and "other," e.g.,tribes and counties).

The results of the DWSA survey are helpful in understanding the opinions of Colorado's water users in terms of current and future water conditions. However, responses were not received from everyone in the State and coverage is not sufficient to resolve results to a county level. These spatial limitations along with uncertainty in the interpretation of specific survey questions by the respondents make it difficult to incorporate DWSA results into the vulnerability methodology developed for this study. However, there is pertinent information that should be analyzed in a qualitative way to inform and verify vulnerability findings.

Figure 7.7 provides the percentage of surveyed power entities that experienced the impacts listed. The power entities surveyed included various energy stations, many of them owned by Xcel Energy. It is important to note that only those categories that are applicable to the power sector are shown in the figure. Additionally, only power entities within the Arkansas and Yampa/White Basins (e.g., Xcel Energy stations) responded to the survey and therefore only their results are shown. Of the five power entities surveyed, over 30% of them reported impacts to the following categories during the drought of 2002:

- Limited new construction
- Loss of reliable water supply
- Loss of operations revenue
- Loss of system flexibility

**Figure 7.7. 1999 – 2003 Drought Impacts to the Power Sector**

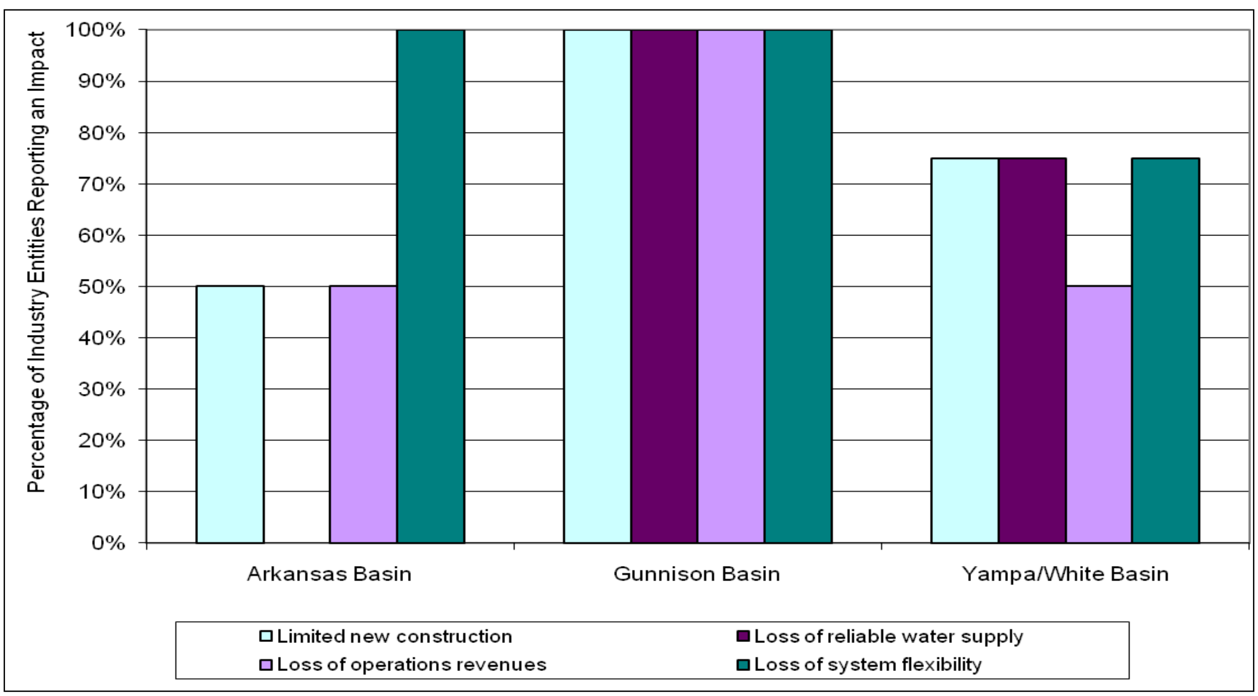


In the Arkansas Basin, both of the power entities surveyed experienced loss of reliable water supply, whereas none of the three entities in the Yampa/White Basin did. Construction was limited in the Yampa/White Basin and the Arkansas entities felt a loss of system flexibility during this time period. Loss of operations revenue was an impact in both basins. Given the sparse survey results it is difficult to draw spatial conclusions from these results. However, it is clear that power providers are aware that drought does impact them. This is a significant finding because many of the power experts interviewed for this study noted that they were well prepared for drought and do not expect severe impacts in future droughts.

The DWSA survey also included industrial entities such as various mining and mineral companies. A total of eight mineral and mining entities were surveyed. Two of which were located in the Arkansas, one in the Gunnison, and four in the Yampa/White Basins. As shown in Figure 7.8, seven of these entities noted that they experienced impacts during the drought of 2002 in one or more of the following categories:

- Limited new construction
- Loss of reliable water supply
- Loss of operations revenue
- Loss of system flexibility

**Figure 7.8. 1999 – 2003 Drought Impacts to the Industrial Sector**




Loss of system flexibility was reported to be an impact by 75% of all the entities surveyed. Limited new construction was reported by five of the eight entities and loss of operations revenue and loss of flexible water supply were both reported by four entities. Overall, mining in the Gunnison Basin had the greatest occurrence of impacts. Similar to the power analysis, these finding are informative because few mining professional surveyed for the DWSA could cite drought related impacts to them directly.

Another relevant Colorado specific study is the Statewide Water Supply Initiative. Although it did not specifically focus on drought as the DWSA did, the Statewide Water Supply Initiative process was another important initiative taken and directed by the CWCB to understand existing and future water supply needs and how those needs might be met through various water projects and water management techniques. As described in Chapter:1 Introduction, the Statewide Water Supply Initiative also used a statewide and basin-level view of the water supply conditions in Colorado and created basin roundtables as a forum for collecting and sharing information and ideas.

In the Statewide Water Supply Initiative, the Energy Sector was included in the self-supplied industrial (SSI) category which included coal-fired and natural gas power generating facilities that consume significant quantities of water, snowmaking facilities, and other identified industrial facilities with significant water use such as brewing, manufacturing, and food processing. The Statewide Water Supply Initiative process estimated baseline and projected water use to 2050 for SSI. The SSI sector was divided in the following sub-sectors: large industry, snowmaking, thermoelectric power generation, and energy development. Where applicable, water demands were presented for each sub-sector under low, medium, and high growth scenarios to illustrate the range of possibilities given the uncertainty in their future development (CWCB, 2011, 2010). With respect to the Energy Sector discussed herein, the thermoelectric power generation and energy development sectors were updated with new data (e.g., water demands, population) to reflect expected energy development scenarios in the northwestern portion of the State, as discussed below.

Although the Statewide Water Supply Initiative and the 2050 M&I Water Use Projections studies did not specifically address drought impacts to the Energy Sector, they provide specific areas in the State that use water for industrial purposes that may be more vulnerable to a water supply shortage in times of drought. Future work could build on these findings by incorporating Energy Sector growth scenarios into the vulnerability assessment methodology and analyzing future drought vulnerability scenarios.

In addition to the reports referred to above, the CWCB funded another Colorado specific study on energy development and associated water needs in the northwestern portion of the State. Phase I of the Energy Development Water Needs Assessment, performed for the Colorado, Yampa, and White River Basin Roundtables Energy Subcommittee, estimated the amounts of water required to support the operations of natural gas, coal, uranium and oil shale industry within those basins. The study used a series of energy production scenarios for near-, mid-, and long-term planning horizons to develop water demands for each Energy Sector (CWCB, 2008).

The second phase of this project focused on refining estimates for the water needed for oil shale development. Water requirements for natural gas, coal and uranium development developed in Phase I were not changed in Phase II. These refined water use estimates for the oil shale industry were also broken down into components to allow water use to be disaggregated spatially as required by water resources modeling. For example, location, priority, and amount of physical and legally available water supplies were considered when investigating various scenarios (CWCB, 2011b). This information provides not only a spatial context for water use related to energy development, but also the timing of the water use. Due to the potential magnitude of water development in northwestern Colorado associated with energy development, this detailed information can assist stakeholders in understanding potential impacts during any hydrologic condition, including drought, so that appropriate water management techniques can be employed.

Drought and its implications on Colorado's energy sector were also investigated in the 2012 Colorado Energy Assurance Emergency Plan (CEAEP), prepared by the Colorado Energy Office in conjunction with the Colorado Department of Regulatory Agencies - Public Utilities Commission and the Colorado Division of Emergency Management. In the CEAEP, drought ranked 18th out of 19 natural hazards in terms of a risk score to the energy sector; therefore, its impact on the sector is categorized as negligible. However, the level of impact can vary considerably depending on the electric power mix and a range of other factors in the impacted area (Colorado Energy Office, 2012). As discussed above, generating capacity can be lost during drought due to decreased water supplies for various processes, namely for thermal power plants and those using water or steam turbines. Because droughts typically occur during the peak summer electrical demand period, the energy sector can experience additional impacts. Having flexibility in generating output during drought periods is an important mitigation tool. Switching to energy generation using natural gas, which requires less water than coal fired plants, nuclear or hydroelectric generation, can be used to cover the load during dry periods. This may cause shortages or increases in natural gas and electric prices but provides a region the ability to compensate and meet power needs. Recognizing that not all loads may be transferrable to natural gas generating plants during drought, interruptible supply agreements can also be obtained to cover water supply at existing plants. As mentioned above, this also benefits other sectors such as agriculture when it receives revenue from temporarily selling its water supplies when they are too low to plant crops. The CEAEP ranked twenty-five counties at risk for drought by comparing their energy asset inventory to their drought risk ranking. As shown in Table 7.3 and Figure 7.9, Weld County has the highest hazard score for inventory related to energy assets out of these high drought risk counties.

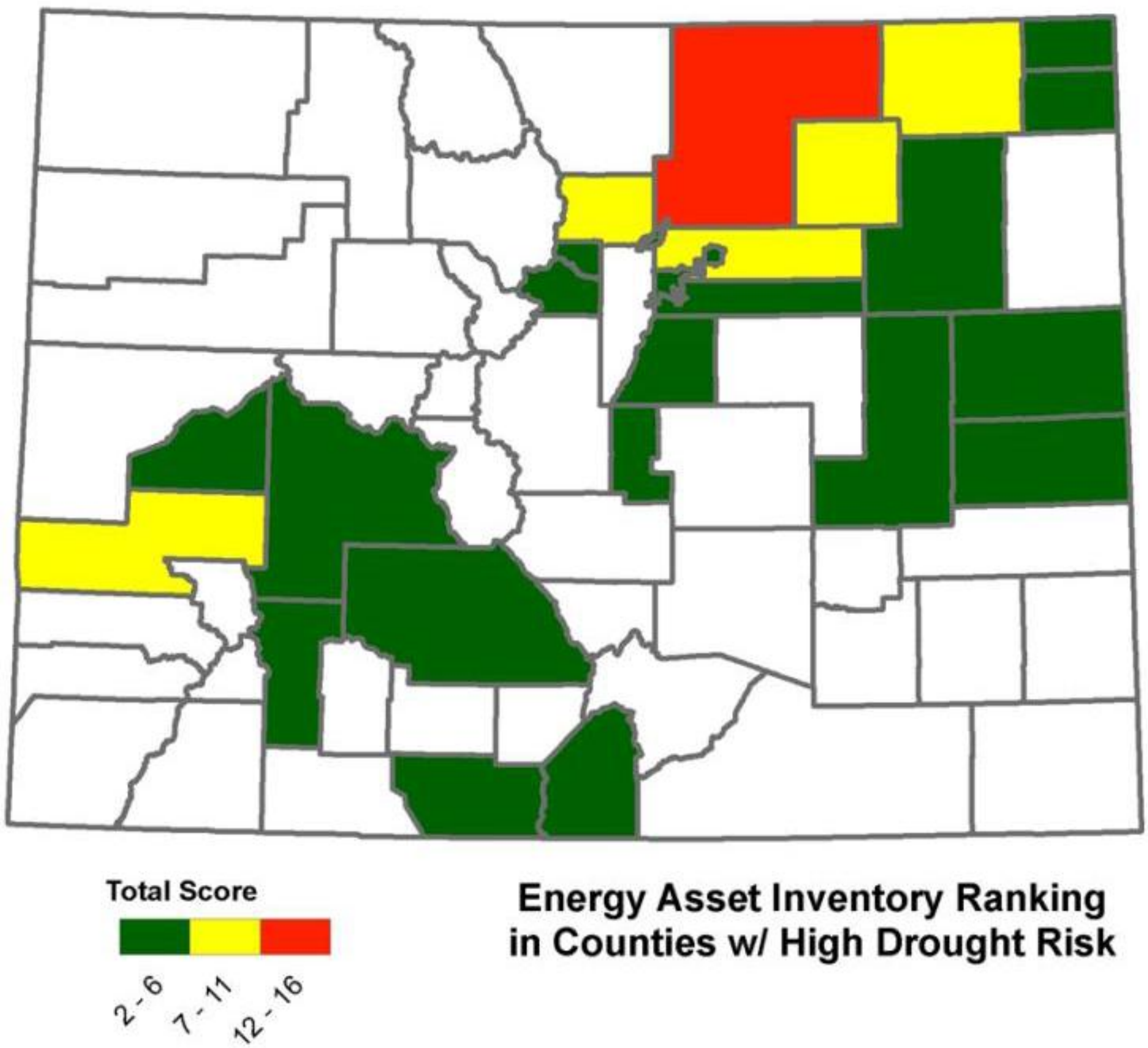
**Table 7.3. Energy Asset Inventory Ranking by High Drought Risk County**

| County | Drought Risk | Transmission Score | Pipeline Score | Substation Score | Plant Score | Hazard Score |
|---|---|---|---|---|---|---|
| Weld | High | 4 | 4 | 4 | 4 | **16** |
| Adams | High | 2 | 2 | 3 | 3 | **10** |
| Logan | High | 2 | 1 | 2 | 2 | **7** |

| County | Drought Risk | Transmission Score | Pipeline Score | Substation Score | Plant Score | Hazard Score |
|---|---|---|---|---|---|---|
| Montrose | High | 2 | 1 | 2 | 2 | **7** |
| Boulder | High | 1 | 1 | 2 | 3 | **7** |
| Morgan | High | 2 | 1 | 2 | 2 | **7** |
| Denver | High | 1 | 1 | 2 | 2 | **6** |
| Arapahoe | High | 2 | 1 | 2 | 1 | **6** |
| Douglas | High | 2 | 1 | 2 | 1 | **6** |
| Lincoln | High | 2 | 1 | 1 | 2 | **6** |
| Washington | High | 2 | 1 | 1 | 1 | **5** |
| Kit Carson | High | 2 | 1 | 1 | 1 | **5** |
| Phillips | High | 1 | 1 | 1 | 1 | **4** |
| Sedgwick | High | 1 | 1 | 1 | 1 | **4** |
| Delta | High | 1 | 1 | 1 | 1 | **4** |
| Gunnison | High | 1 | 1 | 1 | 1 | **4** |
| Clear Creek | High | 1 | 1 | 1 | 1 | **4** |
| Cheyenne | High | 1 | 1 | 1 | 1 | **4** |
| Conejos | High | 1 | 1 | 1 | 0 | **3** |
| Saguache | High | 1 | 1 | 1 | 0 | **3** |
| Broomfield | High | 1 | 1 | 1 | 0 | **3** |
| Teller | High | 1 | 1 | 1 | 0 | **3** |
| Gilpin | High | 1 | 1 | 1 | 0 | **3** |
| Costilla | High | 1 | 0 | 1 | 1 | **3** |
| Hinsdale | High | 1 | 0 | 1 | 0 | **2** |

Source: Colorado Energy Office 2012

**Figure 7.9. Energy Asset Inventory Ranking in Counties with High Drought Risk**




Source: Colorado Energy Office 2012

## 7.3 Assessment of Impacts and Adaptive Capacities

In this section, specific impacts and adaptive capacities are covered in more detail separately for power production and mining. Impacts are further differentiated by activity where vulnerability differences are sufficient to warrant this distinction.

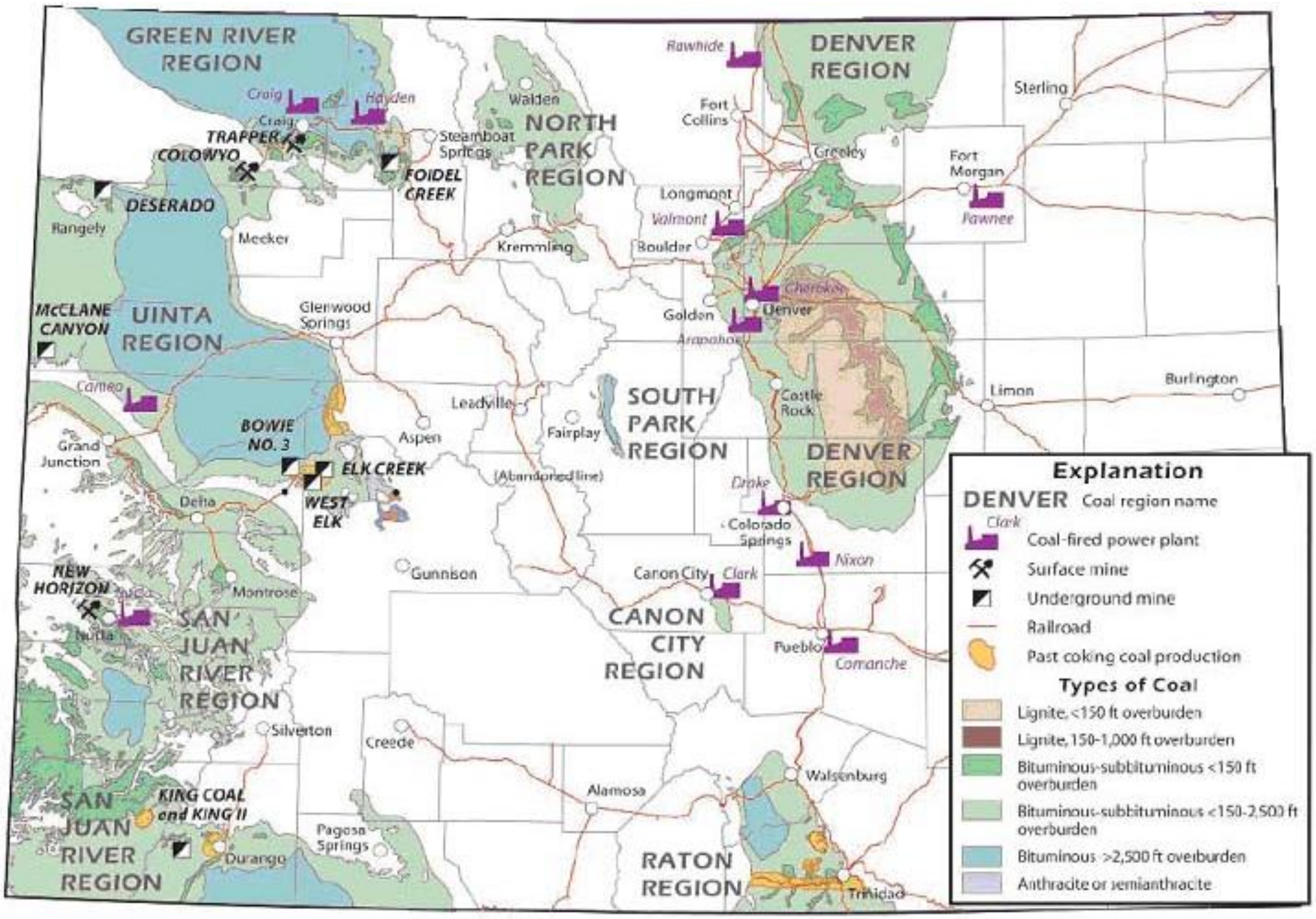
### 7.3.1 Potential Impacts and Adaptive Capacities of Mining

Mines use water for quarrying, dewatering, milling, and other site preparation. Data on additional water used to process the raw materials such as oil refining and slurry pipelines are not available and hence not included as part of the mining water use estimates. In 2005, according to a U.S. Geological Survey (USGS) survey, there were 20 active hard rock mines in Colorado. Of this, 13 were coal mines (eight underground and five surface), four uranium/vanadium, one gold, one gold/silver, and one molybdenum. Water withdrawals from hard rock mines were estimated to be 10,000 gallons per day (GPD) (USGS, 2010).

In 2005, roughly 1,150 sand, gravel, and construction aggregate operations produced 47 million tons of material (USGS, 2010). These operations run almost exclusively on groundwater and it is estimated that each mine used approximately 0.004 MGD (USGS, 2010). Gravel operations reuse water for 100% consumption in the aggregate washing process and evaporation from settling ponds. Overall water withdrawals for sand and gravel operations were estimated to be 4.17 MGD in 2005 (USGS, 2010).

Colorado is second only to Illinois in bituminous coal reserves, but is the leader in clean air compliant coal reserves (Burnell, Carroll, and Young, 2008). As of 2011, over 2,500 Coloradoans were employed by coal mines (Colorado Mining Association, 2011). Figure 7.10 shows the location of coal reserves, mines, and coal-fired power plants across the State. Coal mining requires water for cutting in underground mines, dust suppression for surface activities, and reclamation and revegetation in the post-production phase. Estimated water requirements for mining activities range from 10 to 100 gallons per ton of coal mined (Cameron et al., 2006). Water pumped from the mine is often used for cutting. Excess process water is often contaminated and requires treatment via settling ponds or other processes. In 2005, the USGS estimated that the total water use for coal mining in Colorado was 2.66 MGD (USGS, 2010).

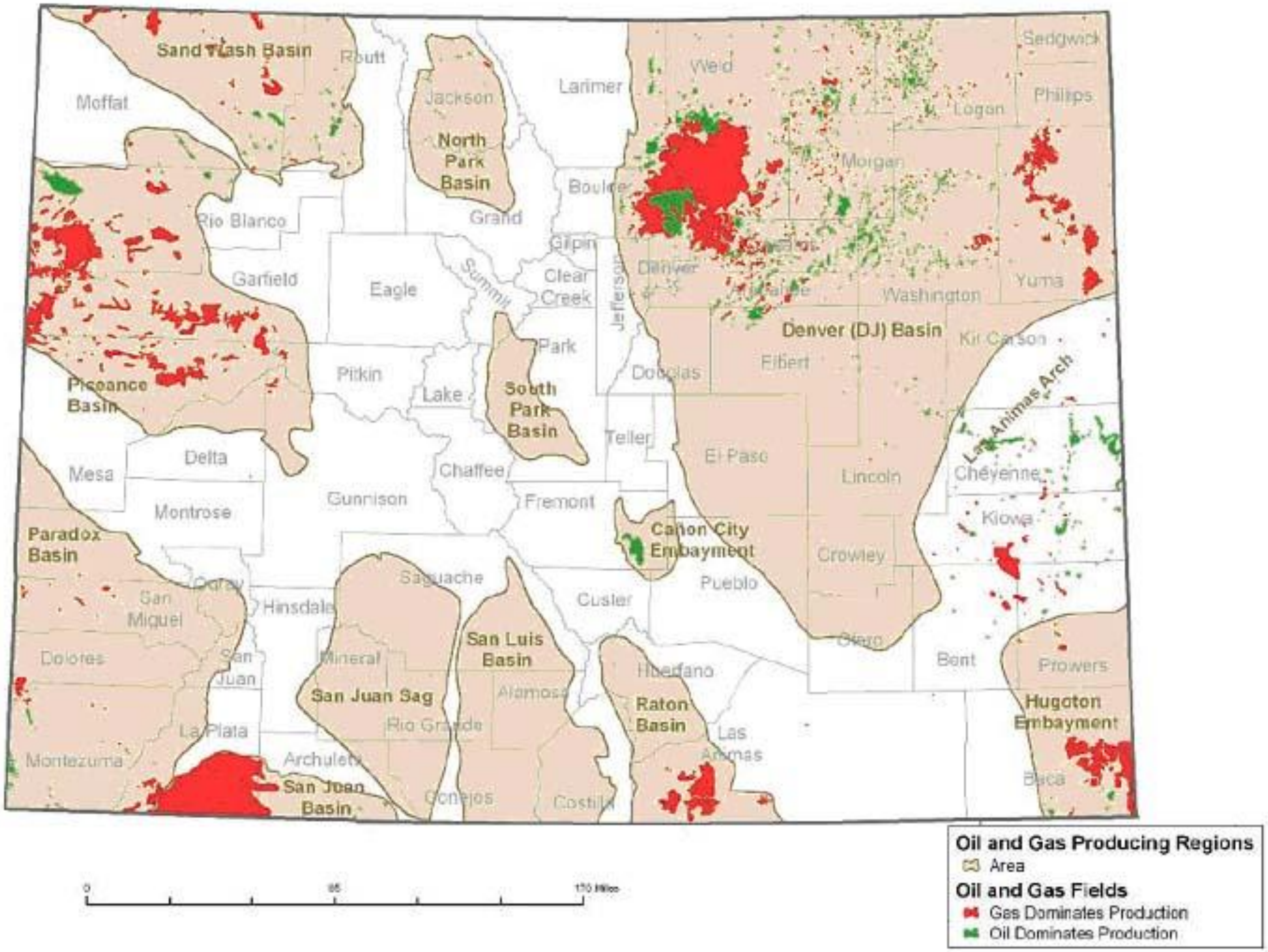
## Figure 7.10. Coal Mining in Colorado




Source: Burnell, Carroll, and Young 2008

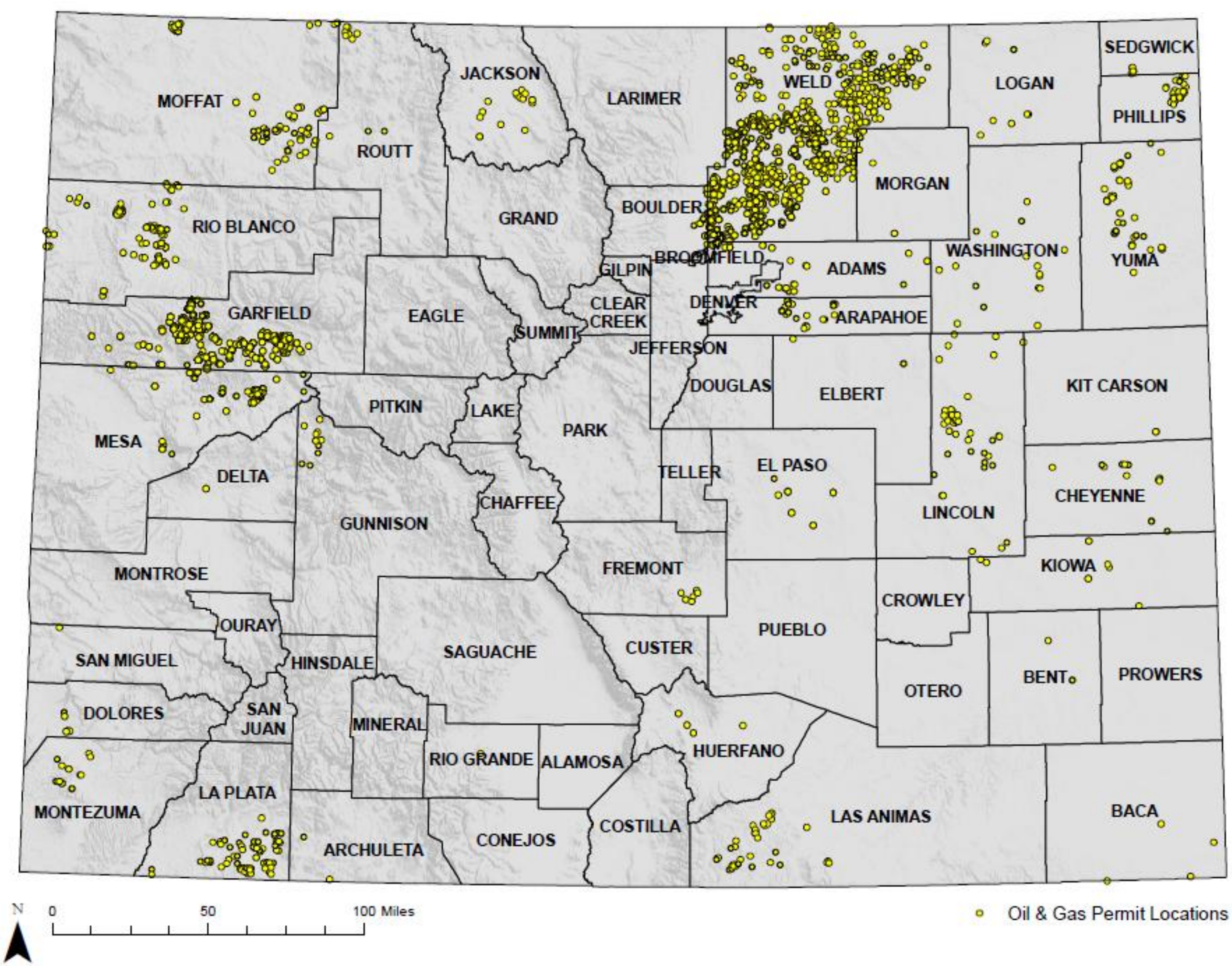
Figure 7.11 shows the major oil and gas producing regions in the State and Figure 7.12 displays the permit locations for oil and gas wells. These points represent locations that are approved for drilling and/or recompletion (COGCC, 2013b). The majority of the permitted locations are in Weld County. Figure 7.12 shows the total production value by county. There are eight counties in Colorado with an estimated production value greater than $100 million. Combined, these counties represent 93% of the statewide production value (Burnell, Carroll, and Young, 2008). Oil and natural gas production tends to be a net producer of water. Coal-bed natural gas production in the San Juan Basin is about 8 gallons of water per barrel of oil equivalent (boe) (Cameron et al., 2006). Water use for natural gas extraction is negligible. Oil extraction requires 5 to13 gal/boe. The biggest water requirement for oil and gas in is enhanced oil and gas recovery. In this process, water is injected down recovery wells in order to move oil and gas to nearby wells. Enhanced oil recovery can require anywhere from 81 to14,000 gal/boe equivalent (Cameron et al., 2006). Water used for enhanced recovery is often recycled production water. In 2005, the USGS estimated that 14.59 MGD of saline water was withdrawn and reinjected for oil and natural gas production (USGS, 2010). Possible future oil shale production is not included in these numbers.

## Figure 7.11. Oil and Gas Production in Colorado



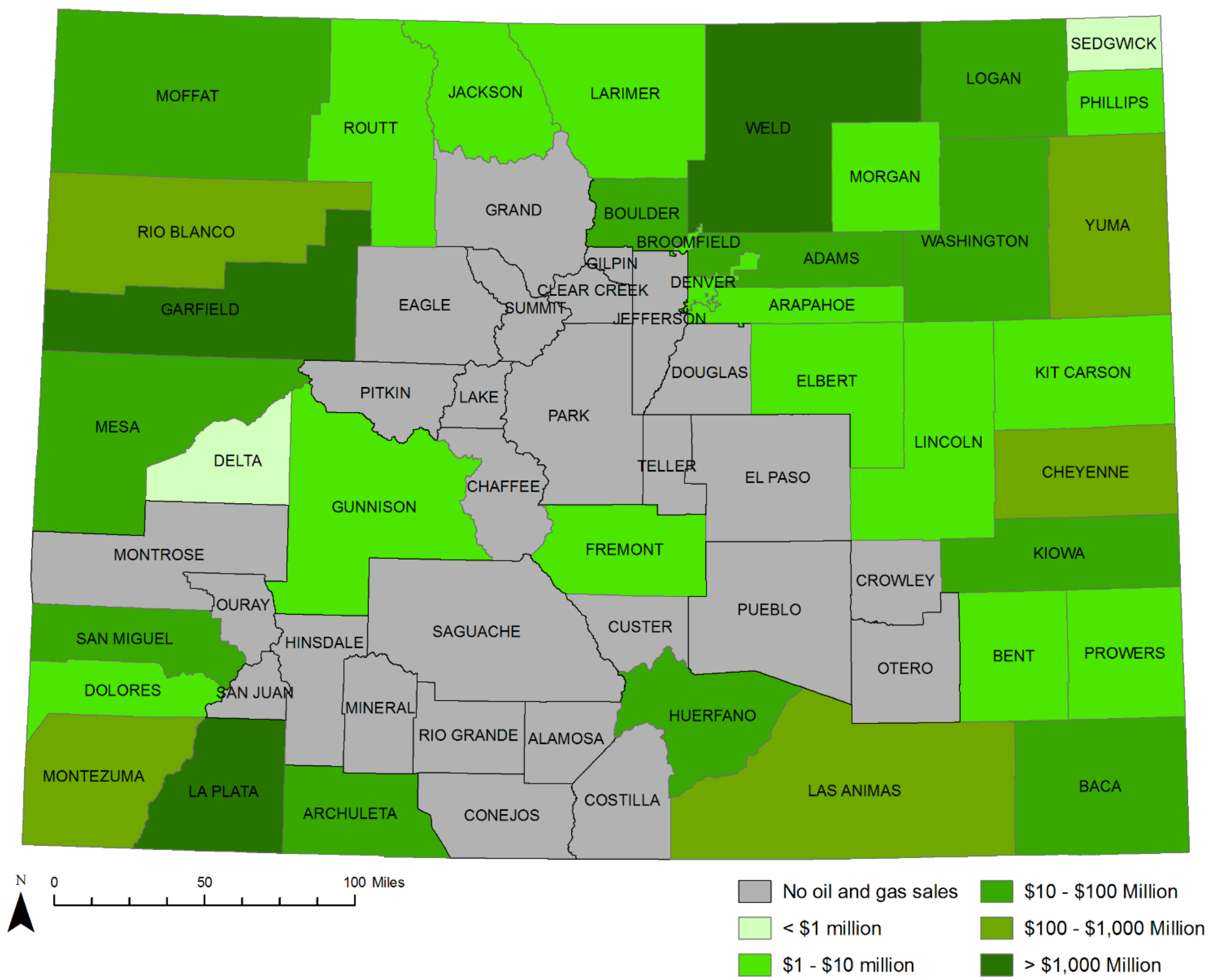

Source: Burnell, Carroll, and Young 2008

## Figure 7.12. Oil and Gas Permit Locations




Source: Colorado Oil and Gas Conservation Commission, 2013b

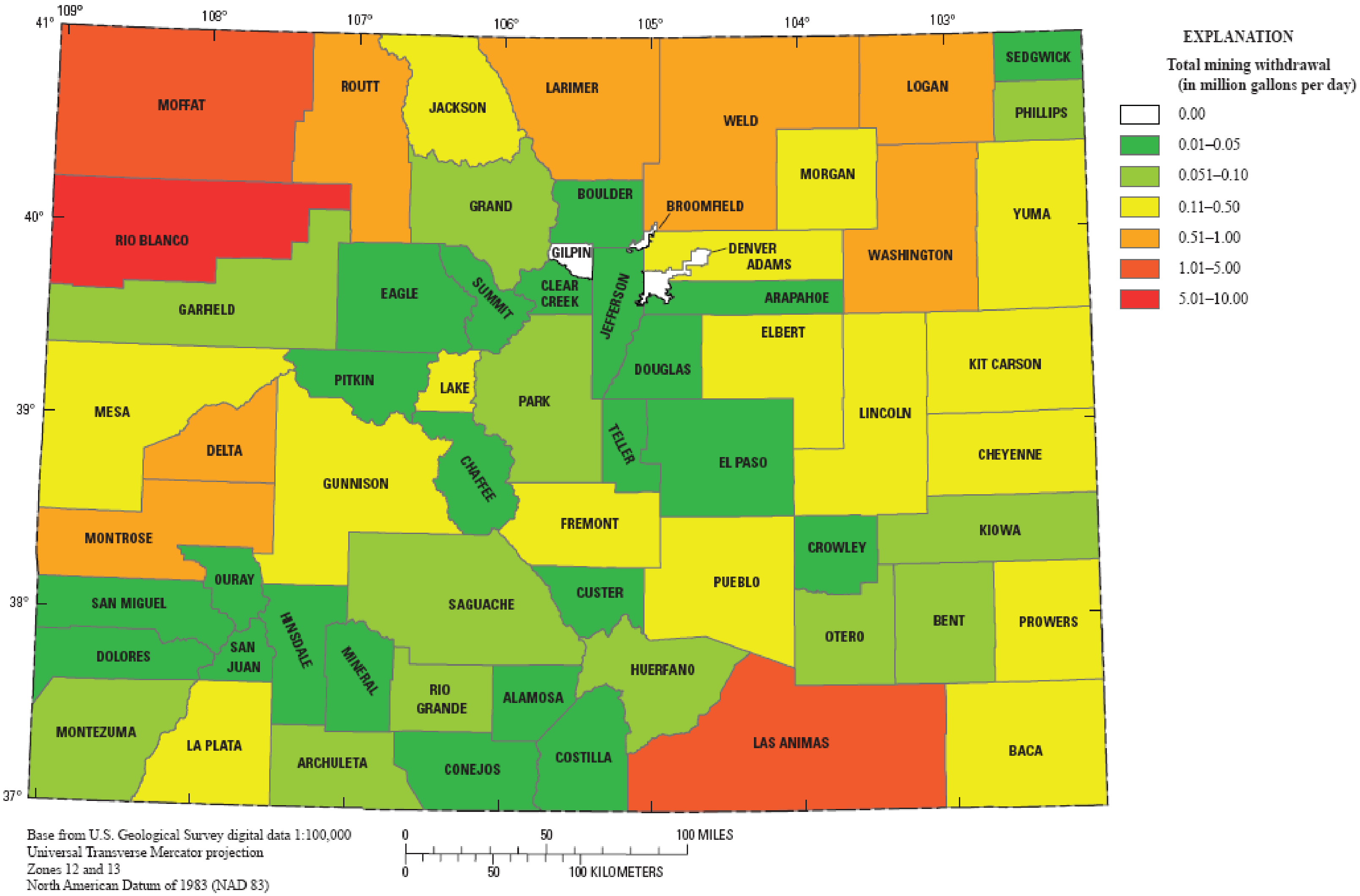
## Figure 7.13. Oil and Gas Sales by County




Source: Reproduced from: Burnell, Carroll, and Young 2008

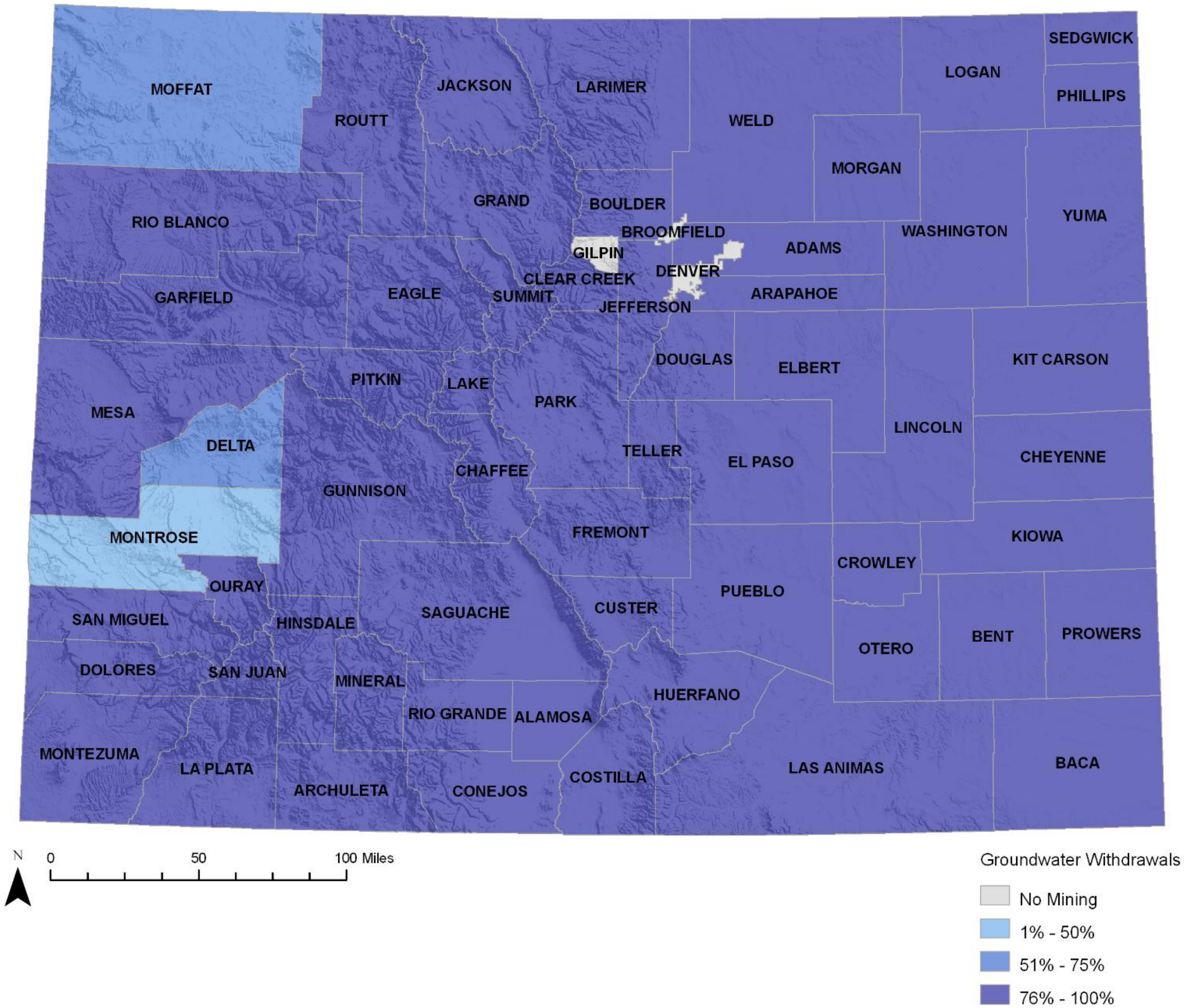
Figure 7.14 shows the total estimated water withdrawals for all mining activity in 2005 (the most recent data available). Water use for mining activity is distributed across the State but generally higher along the northern edge. Figure 7.15 shows the proportion of these withdrawals that come from groundwater. There are only three counties in the State that get less than 75% of their mining water from groundwater. It is clear that without water, mining activities in the State would not be able to operate. However, there is no comprehensive analysis examining the impacts of drought on mining operations costs and production rates. Mining experts throughout the State are consistent in stating that drought does not impact them dramatically because they purchase water rights far in advance of starting operations. No person interviewed could cite any specific damage incurred in the 2002 drought.  Even without specific impacts to cite, there are still ways that mines can improve their adaptive capacity for future, more severe droughts. Mining operations can invest in technology or choose methods that will decrease their reliance on water. Also they can diversify their water rights holding and purchase conditional leases that would take effect during a drought. As noted in Section 7.2.1, drought vulnerabilities for mining are subject to change based on future mining resources and techniques. If oil shale becomes an economically feasible option, water needs may change significantly.

## Figure 7.14. Total Water Withdrawals for Mining 2005




Source: USGS 2010

## Figure 7.15. Percentage of Mining Water Use Originating from Groundwater




Source: USGS 2010

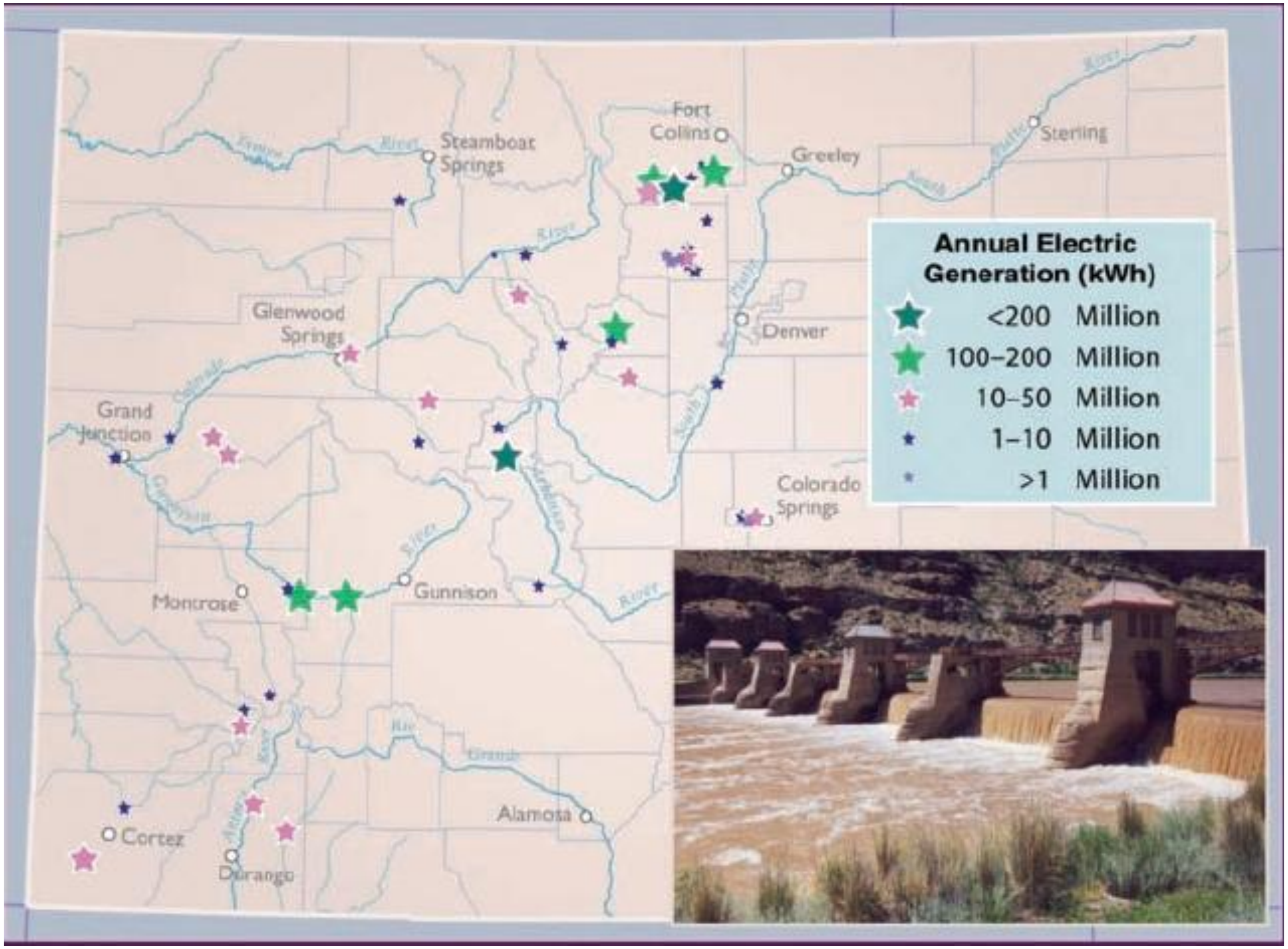
## 7.3.2 Potential Impacts and Adaptive Capacities of Power Production

The vast majority of Colorado's power is produced by coal or natural gas fired thermoelectric power plants. These plants can run off fuel sources such as nuclear, oil and biomass (see Figure 7.2). Regardless of fuel source, all thermoelectric plants use steam to drive a turbine generator and require cooling to condense the steam and the turbine exhaust. Open-loop ('once-through') plants, which are becoming more uncommon in Colorado as they close, use cooling where water is withdrawn for cooling and then directly discharged after heating. These plants generally have very large water withdrawals but evaporative losses are only about 1%, i.e., consumptive use is low (Cameron et al., 2006). When the 2010 USGS report was published, Colorado had five 'once-through' plants (USGS, 2010). The Cameo plant closed in 2010 and the Valmont plant is expected to close in 2017. However, the Valmont plant, and Platte River Power Authority's Rawhide station use reservoirs for cooling and do not need the continuous, high-volume replacement of water that is typical of 'once-through' facilities.

Most plants installed since the 1970s use closed loop systems where cooling is achieved by evaporation and withdraw less than 5% of the water withdrawn by open loop systems, but almost all of this is consumptive (Cameron et al., 2006). Colorado has 14 closed loop thermoelectric plants (USGS, 2010).

Colorado has 37 hydroelectric plants that generate about 3% of the State's power demand (see Figure 7.16). The amount of water that flows through hydropower plants is much larger than thermoelectric plants, however this is primarily non-consumptive. The main consumptive use of hydropower generation is the evaporation of water from reservoirs which are typically also used for other purposes such as municipal water supply storage

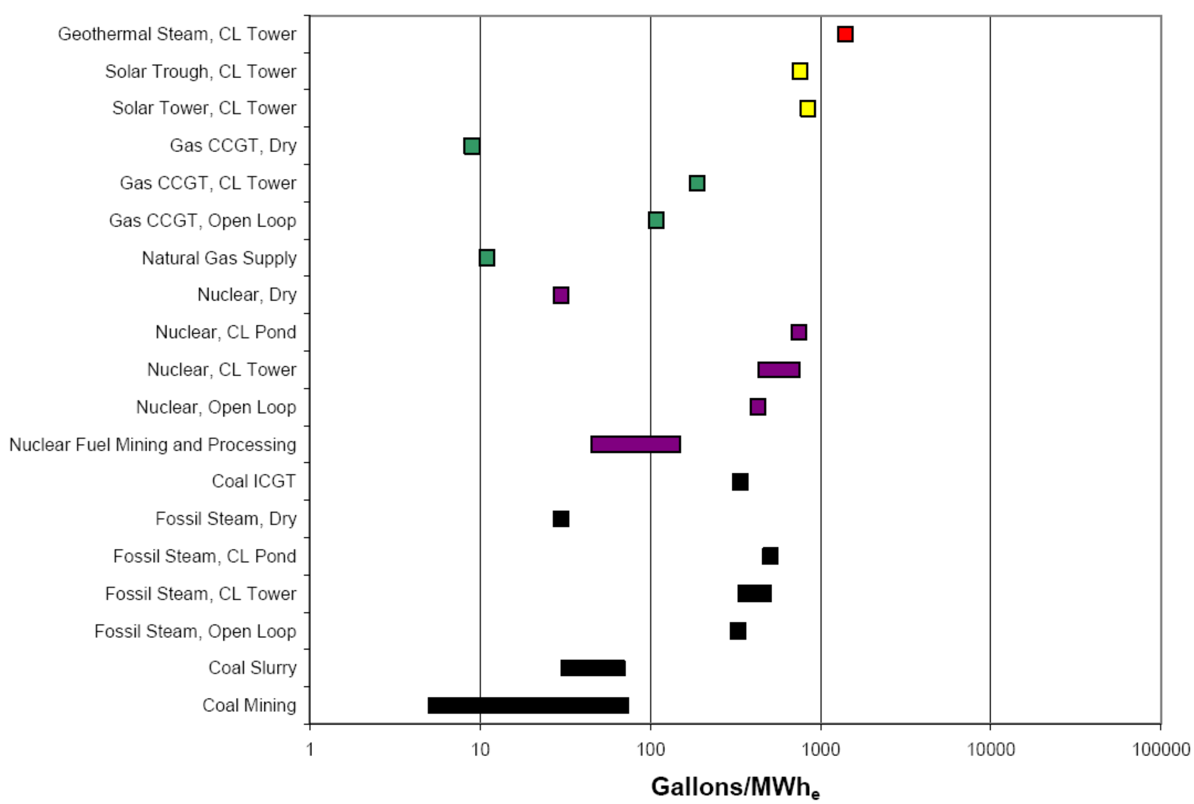
## Figure 7.16. Hydroelectric Power Plants




Source: Burnell, Carroll, and Young 2008

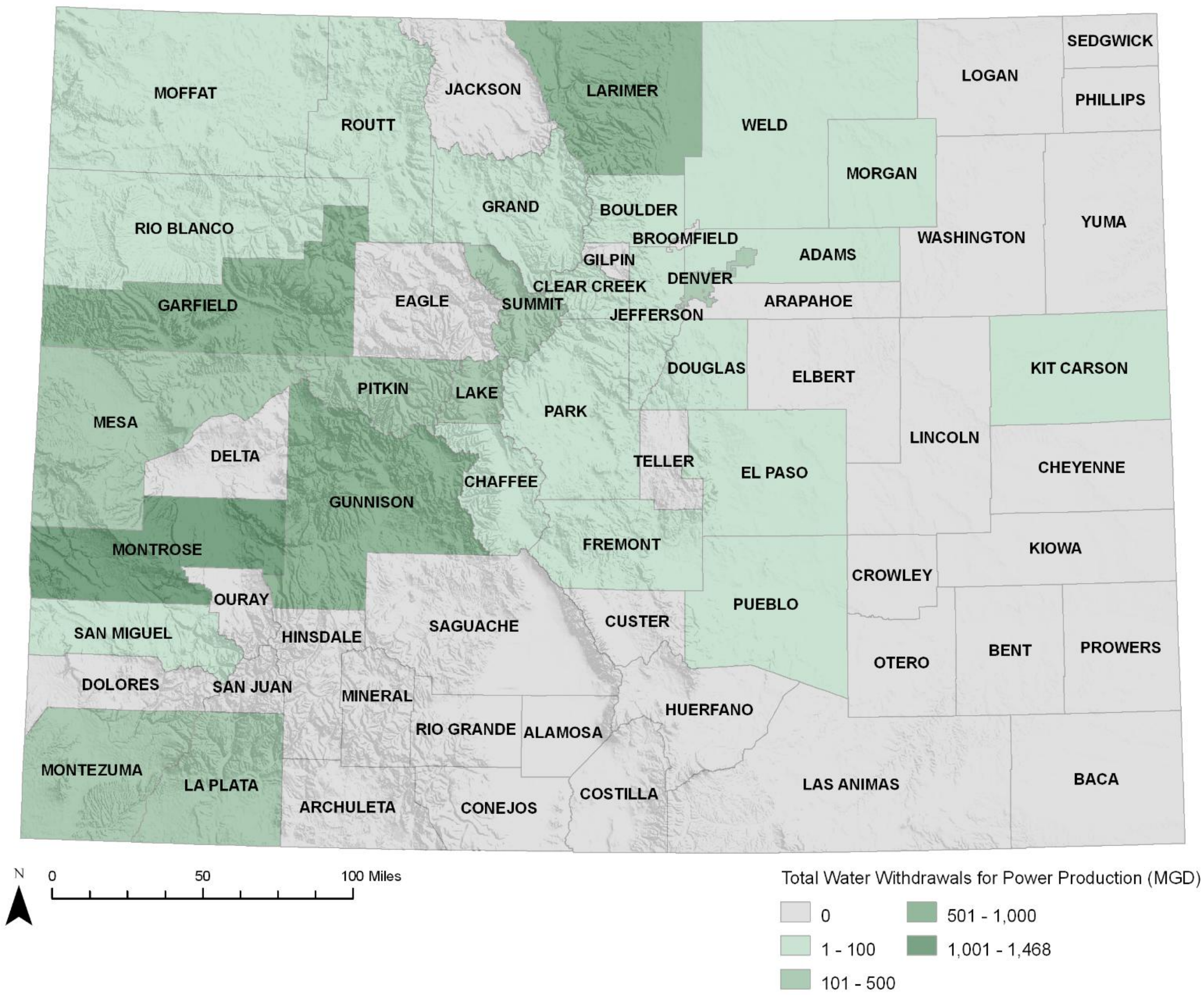
Figure 7.17 shows the water consumption for various power generation methods. This shows that closed loop cooling methods generally have the highest consumption rates. Figure 7.18 and Figure 7.19 displays total water consumed for power production by county and the generation makeup, respectively. In Figure 7.19, steam turbines include nuclear, geothermal and solar steam and combustion turbines include gas and diesel. These maps show that power generation, and its resulting water use, occurs statewide. Hydropower is prevalent in the western half of the State but does not account for large generation capacity. The counties with the largest generation capacities generally have no contribution from renewable resources.

**Figure 7.17. Water Consumption for Power Generation**



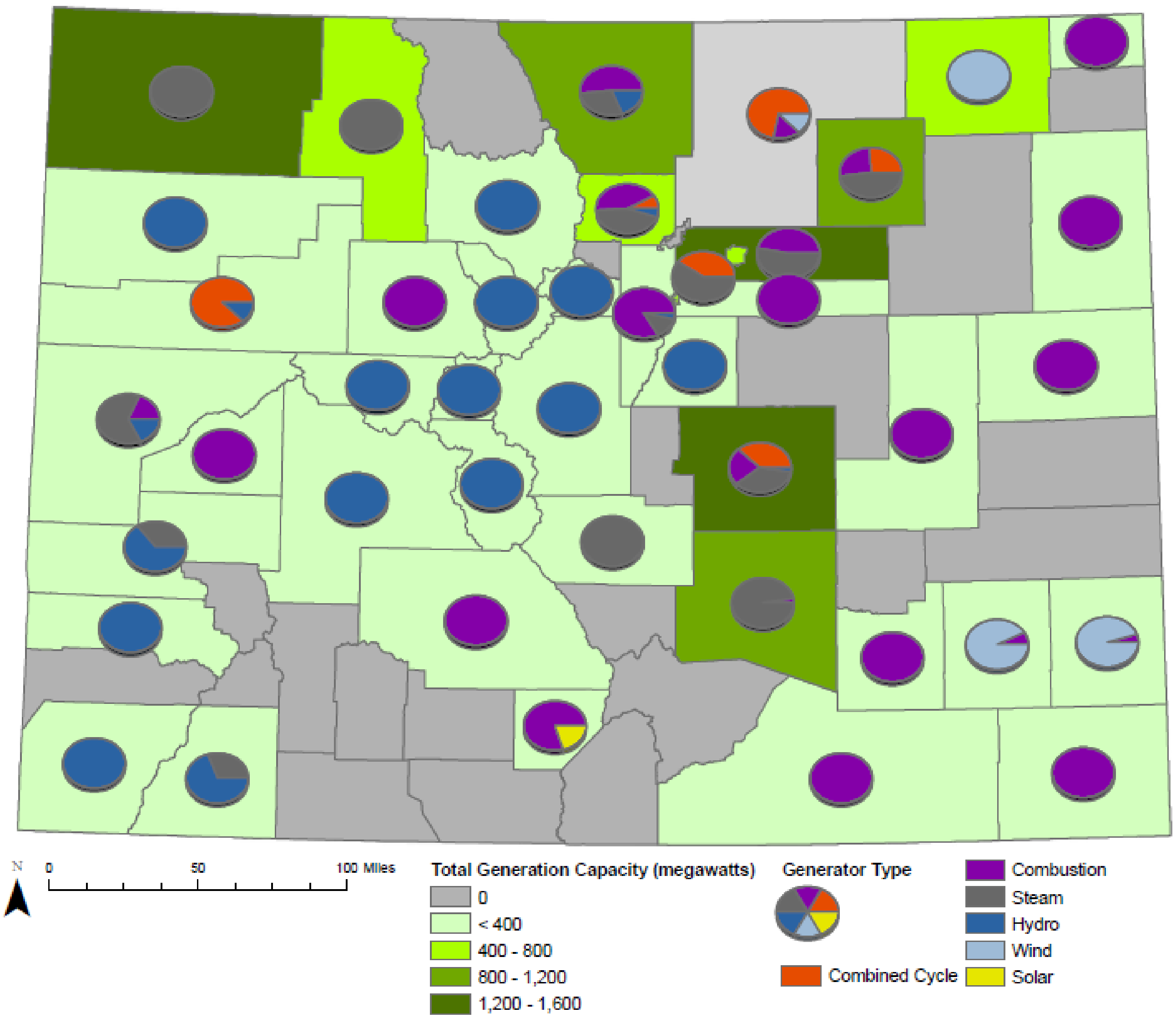

Source: Cameron et al. 2006

## Figure 7.18. Total Water Withdrawals for Power Production by County




Source: USGS 2010

**Figure 7.19. Generator Type by County - Pie Charts Based on Nameplate Generation Capacity**




Source: U.S. Energy Information Administration

Drought impacts to power producers are potentially devastating. Without adequate water for cooling, Colorado's thermoelectric dominated power supply could be threatened (refer to Section 7.2.1). However, based on interviews with power experts across the State, power providers do not seem to be all that sensitive to drought and there were no energy generation curtailments during the 2011-2013 and 2002 droughts. Power plants tend to have senior water rights and the ability to purchase additional rights if necessary. However, power providers acknowledge that had the 2002 drought continued longer, they could have been in trouble. After this experience many providers purchased additional water rights and conditional lease agreements. Even though power producers in Colorado have historically not been heavily impacted by drought, it is important to remember that the impacts in Table 7.2 are still applicable. As Colorado's population and power demands expand, and climate changes, construction of new power plants may become more difficult and drought impacts could become a much larger issue. However, new energy generation can be added without increasing the overall water demand on the providers supply portfolio. For example, Xcel's Fort St. Vrain Station in Platteville was originally built as a 356 MW nuclear power plant but was converted to a 1,000 MW natural gas facility in 1989. Because the water demand was therefore reduced, those supplies have been integrated with other Xcel facilities to provide a more robust, flexible water supply.

The lack of drought related impacts to the energy sector speaks to the strong adaptive capacities they already have in place. Power providers can further increase their adaptive capacity by continuing to purchaseadditional water rights and engaging in drought planning. Another step is to continue to decrease water consumption. This can be accomplished with conventional fossil fuels by converting to combined cycle turbines or dry cooling systems. Another option is to switch to renewable non-water dependent production methods. With its mandate of 30% renewable energy by 2020, Colorado is already improving its adaptive capacity to drought. Much of the renewable resources that will be developed are wind and solar PV, which require very little water. In 2010, Colorado was third in the nation for both wind and solar PV capacity (US DOE, 2011). In terms of wind energy potential, Colorado ranked 11$^{th}$ in the nation in the same year (Colorado Energy Office, 2010). The Colorado Energy Office (formerly the Colorado Governor's Energy Office) estimates that Colorado has the potential to produce 83 million MWh annually using solar technology (Burnell, Carroll, and Young, 2008). Figure 7.20 shows the future development areas for wind and solar resources that have been identified by the Colorado Energy Office. As shown in the figure, the eastern plains of Colorado provide the most potential for wind energy and the south-central portion of the State for solar.

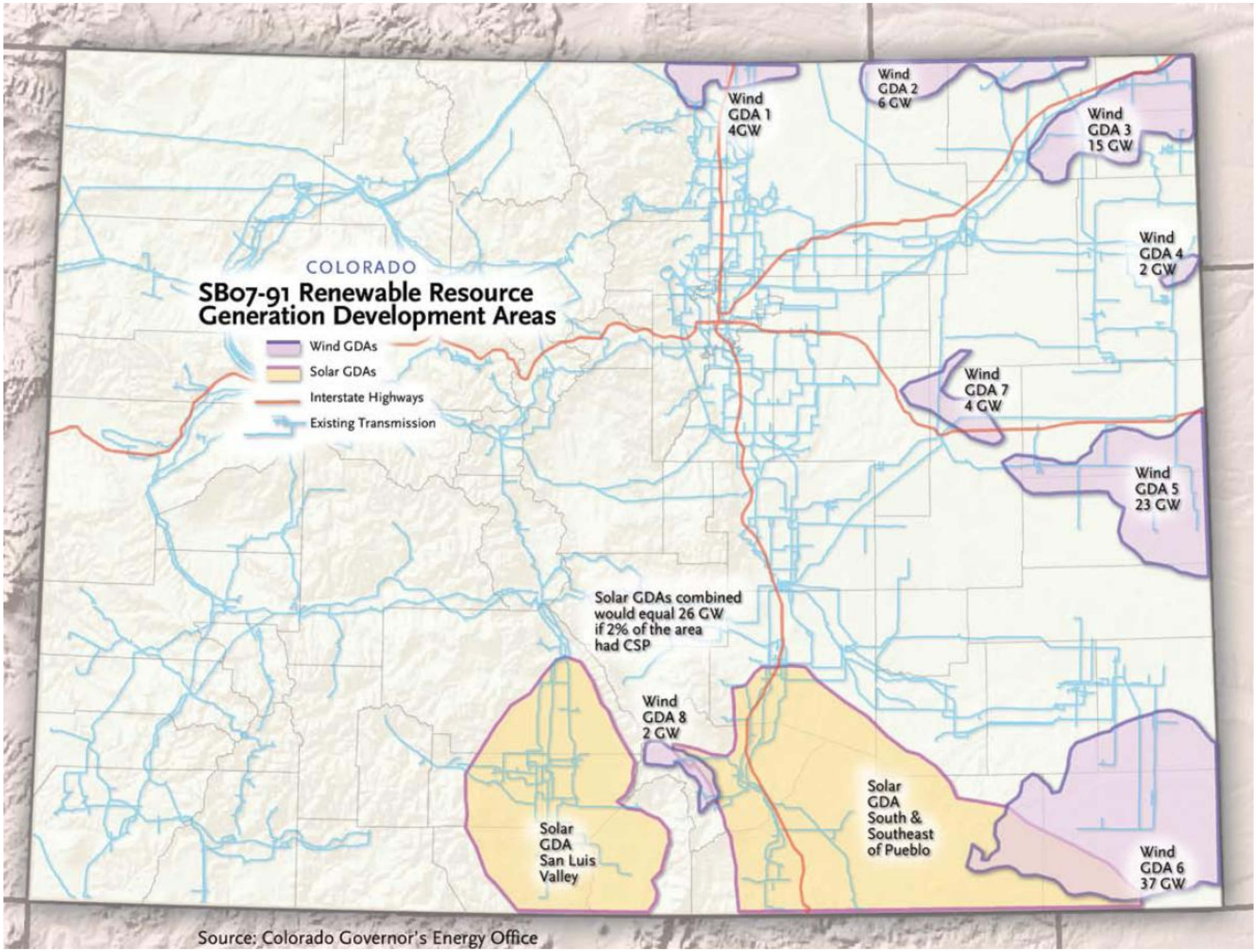
Colorado has experienced steady growth in the renewable energy industry, particularly wind energy, since 2005. However, economic hardship in recent years coupled with lower electrical demand, lack of long-term U.S. energy policies and resulting uncertainty for businesses has delayed or even suspended construction of some systems (Colorado Energy Office, 2010b). Nevertheless, some systems have come online in recent years despite the economic downturn, illustrating the promising future the renewable energy industry has in Colorado in the years to come.

In 2012, a significant year for the addition of wind energy in Colorado, Xcel Energy began purchasing 400 MW from the Limon I and II Wind Energy Centers. In Lincoln and Elbert Counties, the 252 MW Cedar Point Wind Energy Project began operations in September 2011 using turbines manufactured in Colorado. At its full build-out potential, this is enough renewable energy to meet the annual power demands of approximately 80,000 Colorado households. The 30,000 acre Cedar Creek 2 Wind Farm in Weld County was completed in June 2011 and generates 250.8 MW of renewable wind power (Colorado Energy Office, 2010b). In November 2010, Tri-State Generation and Transmission Association Inc. completed its first major wind acquisition. The 51 MW Kit Carson wind project northwest of Burlington off I-70 sits on a 6,000 acre site. The 300-600 MW Cheyenne Ridge Wind Project is under development as of the 2013 update. It straddles the Cheyenne and Kit Carson County border and if all phases are completed, has the potential to produce power for approximately 180,000 Colorado homes (Tradewind Energy, 2013).

The solar industry in Colorado also experienced notable growth in 2012. The 30 MW San Luis Valley Solar Ranch, located in Alamosa County, began commercial operation in March 2012. The 220 acre site was formerly farmland, but now holds approximately 110,000 PV panels. Xcel Energy purchases all of the solar energy produced there, enough to power 7,500 homes (Iberdrola Renewables, 2013). A proposed solar thermal project in Saguache County received land use permitting in March 2012 for its two 100 MW facilities. However, as of a year later, the facility was not yet under construction due to lack of a Power Purchase Agreement from a power utility such as Xcel Energy (The Crestone Eagle, 2013).

Although some new systems can use existing transmission lines as was the case with the Kit Carson wind system, Colorado should work to improve transmission line capacity in conjunction with new renewable power capacity. This infrastructure will help support new power supplies and add versatility to the system.

**Figure 7.20. Renewable Resources Development Areas**




Source: Colorado Energy Office 2009

## 7.4 Measurement of Vulnerability

The Energy Sector was divided into two impact groups - power and mining - for the numerical vulnerability assessment. For each impact group a spatial density metric was defined along with several impact metrics. Each metric is described in detail below. Refer to Section 3.1 of Chapter 3 (Annex B) for a general description of the numerical methodology.

Although the vulnerability to the Energy Sector was performed on a county by county basis to be consistent with the methods utilized for the various sectors of this vulnerability assessment, it is important to note that energy production is regional, i.e., it is distributed over a grid which covers the entire western United States. Generally, the energy sector is fairly resilient to drought impacts due to the broad spectrum of drought preparedness utilities and power providers implement which can range from diverse water rights portfolios to contract supplies from municipalities.

## 7.5 Vulnerability Metrics

As mentioned above, due to lack of new data, the vulnerability assessment was not updated in 2013. It can be assumed that the results in 2010 are applicable in 2013.

### 7.5.1 Mining

#### Spatial Density Metric

##### *Total mining jobs*

The total number of mining jobs is per county from 2009, based on economic base data available in the regional profiles produced by the State Demographer's Office (State Demography Office, 2009). In Region 3, Adams, Arapahoe, Boulder, Broomfield, Denver, and Douglas Counties were combined into one Denver Metro category. To fill these counties, mining sector data was also used from the State Demography Office.[2] However, this data was only available through 2008. Mining job data was normalized by county population.

#### Impact Metrics

There are two metrics for mining vulnerability. The total water use by county and the percentage of water used that is surface water. For the overall mining impact calculation, total water use was weighted 75% and the contribution of groundwater was weighted 25%. Additional uncertainty flags were added for Rio Blanco and Garfield Counties because of the possibility of future oil shale development.

---

[2] https://www.dola.state.co.us/demog_webapps/jsn_parameters.jsf

#### *Total water use*

Total water use by county for mining purposes was estimated in a 2005 USGS study (USGS, 2010). It is very difficult to get accurate data on the production value and methods by county for the wide range of mining activities in Colorado. Total water use reflects the overall water dependence of mining activities without requiring in-depth data on mining practices. Refer to the USGS study for details on the assumptions made for the water use calculation. Given the insensitivity of the mining industry to drought, thresholds were adjusted so that no scores of 4 would be assigned for this impact category. This is to reflect the fact that even mines using significant amounts of water are generally not shut down during drought. The final thresholds used were: 0.5, 1.0, and 10.0.

#### *Percent of water use that is surface water*

Most mining activities have drawn completely from groundwater, however, there are some that use surface water. Based on the experience of other water users across the State, it is assumed that mining activities relying on surface water will be more vulnerable to drought. Surface water withdrawal data also came from the 2005 USGS study (USGS, 2010). A score of 1 was given to all counties using 100% groundwater, 3 for counties using less than 50% surface water and 4 for counties using more than 50% groundwater. No previous work has specifically considered the impacts to surface water supplied versus groundwater supplied mines. This data was therefore assigned an uncertainty flag.

## 7.5.2 Power

### Spatial Density Metric

#### *Power generation capacity*

Power generation capacity by county was calculated using data from the U.S. Energy Information Administration's annual report for 2008 (U.S. Energy Information Administration, 2009). Generation capacity (nameplate capacities) was summed for all power plants identified as operational or on standby. After calculating power generation capacity by county it was noted that nearly one-third of all counties had zero generation. The large number of counties with no generation makes the typical thresholds for spatial density scores invalid. Therefore, thresholds are adjusted to create equal bins for the non-zero data set. The adjusted percentile thresholds used were: 49.5%, 66%, and 82.5%.

### Impact Metrics

There is one impact metric and two adaptive capacity metrics for power generation. Similar to mining, the impact metric is overall water use by county. The two adaptive capacity metrics are groundwater contribution and renewable energy development potential. Overall adaptive capacity was calculated by weighting renewable energy 75% and groundwater contribution 25%.

Groundwater contribution was weighted less because further investigation is needed to determine the impact groundwater has on a case by case basis. The power impact score was calculated by dividing the impact score by the overall adaptive capacity score.

### *Annual water use*

Annual water use was extracted from the 2005 USGS study (USGS, 2010). This metric reflects the generation makeup within a county. Counties already using less water dependant generation techniques will have lower overall water use. As with the generation capacity, data threshold percentiles were adjusted to account for the fact that 54% of counties had zero water withdrawals. A value of 1 was assigned to all counties not withdrawing water for power production not zero because there are cases where power is generated without water, and the rest of the data were divided into three equal groups. The thresholds for these groups were 54%, 69%, and 85%.

### *Groundwater contribution*

Water supply sourced from groundwater increases adaptive capacity, as groundwater is typically more drought tolerant. Groundwater percentages were calculated using data from the 2005 USGS study (USGS, 2010). Counties on 100% groundwater were given an adaptive capacity score of 3 and counties with some groundwater capacity were given a slightly lower adaptive capacity score of 2. There are only four counties that use groundwater for power production. Kit Carson and Morgan Counties were given a score of 3 for using 100% groundwater, Adams and El Paso Counties were given a score of 2 for having some groundwater capacity. The groundwater contribution metric is assigned an uncertainty flag because it is not certain that the use of groundwater will decrease vulnerability. Groundwater sources may be impacted or overdrawn during drought, which could negatively impact uses by the energy sector. The ability to increase pumping rates during drought and the operation of augmentation plans need to be investigated on a case by case basis to determine how much adaptive capacity groundwater rights actually provide.

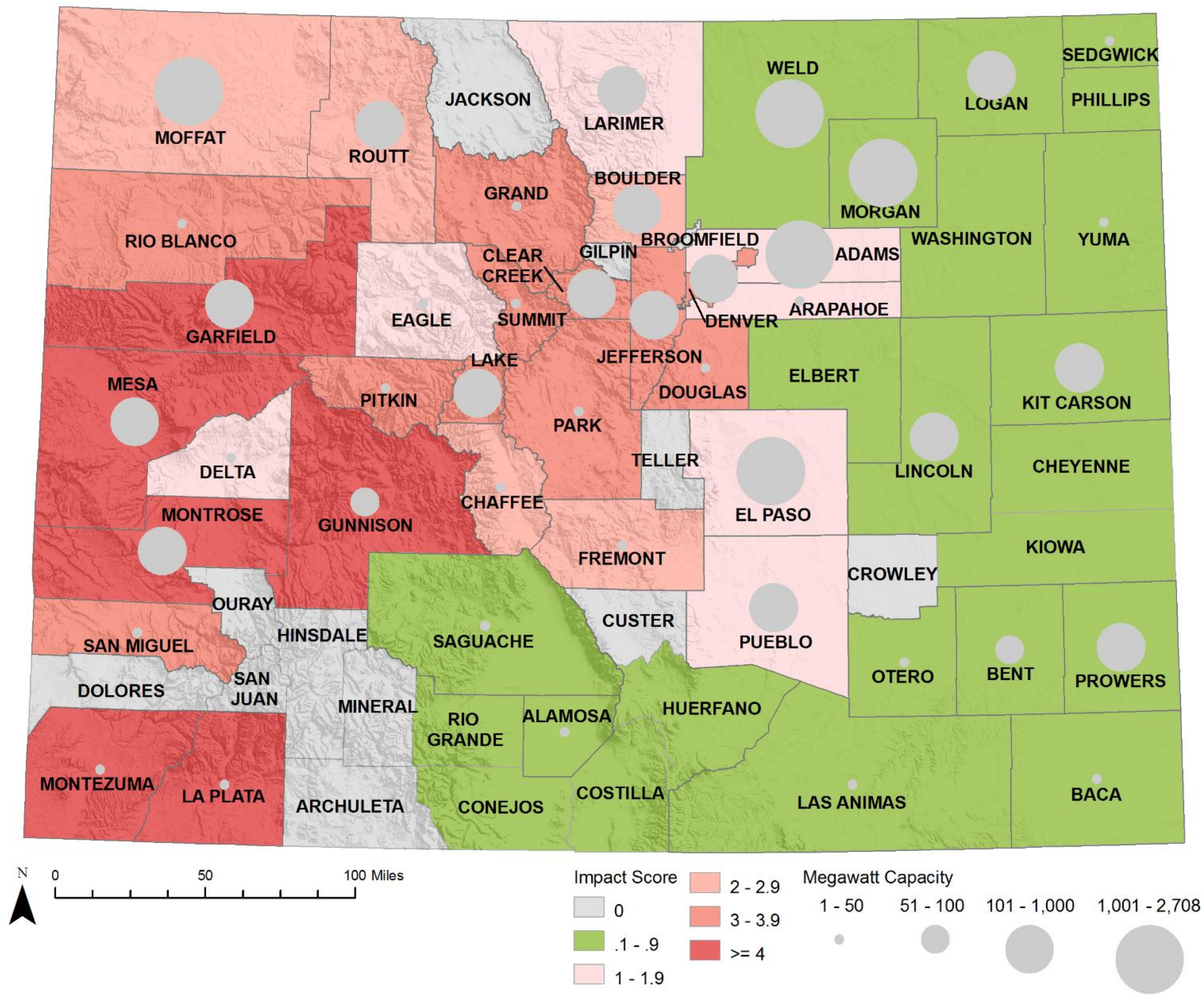
### *Renewable energy development opportunities*

In a 2009 report by the Colorado Energy Office, several renewable resource generation development areas (GDAs) for wind and solar power generation were identified (Colorado Energy Office, 2009). Using a map of GDAs (see Figure 7.20), counties with either a wind or a solar GDA were given an adaptive capacity score of 3 and counties with both were given a 4. This metric is assigned an uncertainty flag because most of this development not occurred yet and specific development plans have yet to be determined. As of the end of 2009, 1,246 MW of wind generation capacity has been installed in Colorado. Additionally, there are two PV sites near Alamosa with a combined capacity of 25 MW.

### 7.5.3 Results

Figure 7.21 and Figure 7.22 show the overall impact scores for power and mining respectively, along with their spatial density metrics. The shading represents the impact rating and the size of the grey circle indicates the size of the sub-sector in a given county. Impact ratings less than one are considered to be net adaptive capacities and are shaded in green. Impact ratings greater than 1 are shown in shades of red. For power, the spatial density metric used to display sub-sector size is the total MW generation capacity and for mining it is the number of mining jobs. Figure 7.23 shows the overall vulnerability scores combining power and mining results. Discussion of these maps is included in the following section.

## Figure 7.21. Power Inventory and Impact Scores by County



## Figure 7.22. Mining Inventory and Impact Scores by County

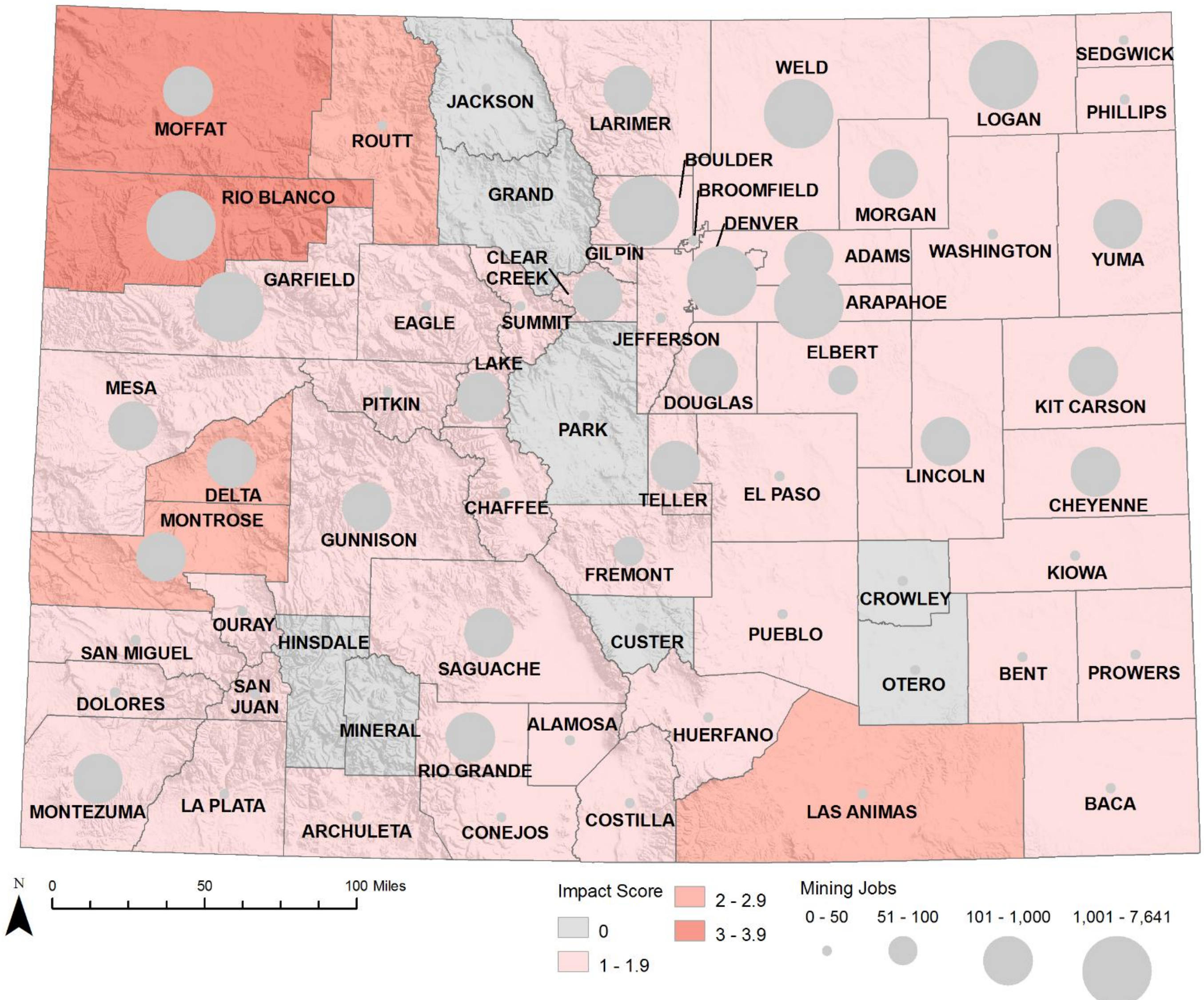
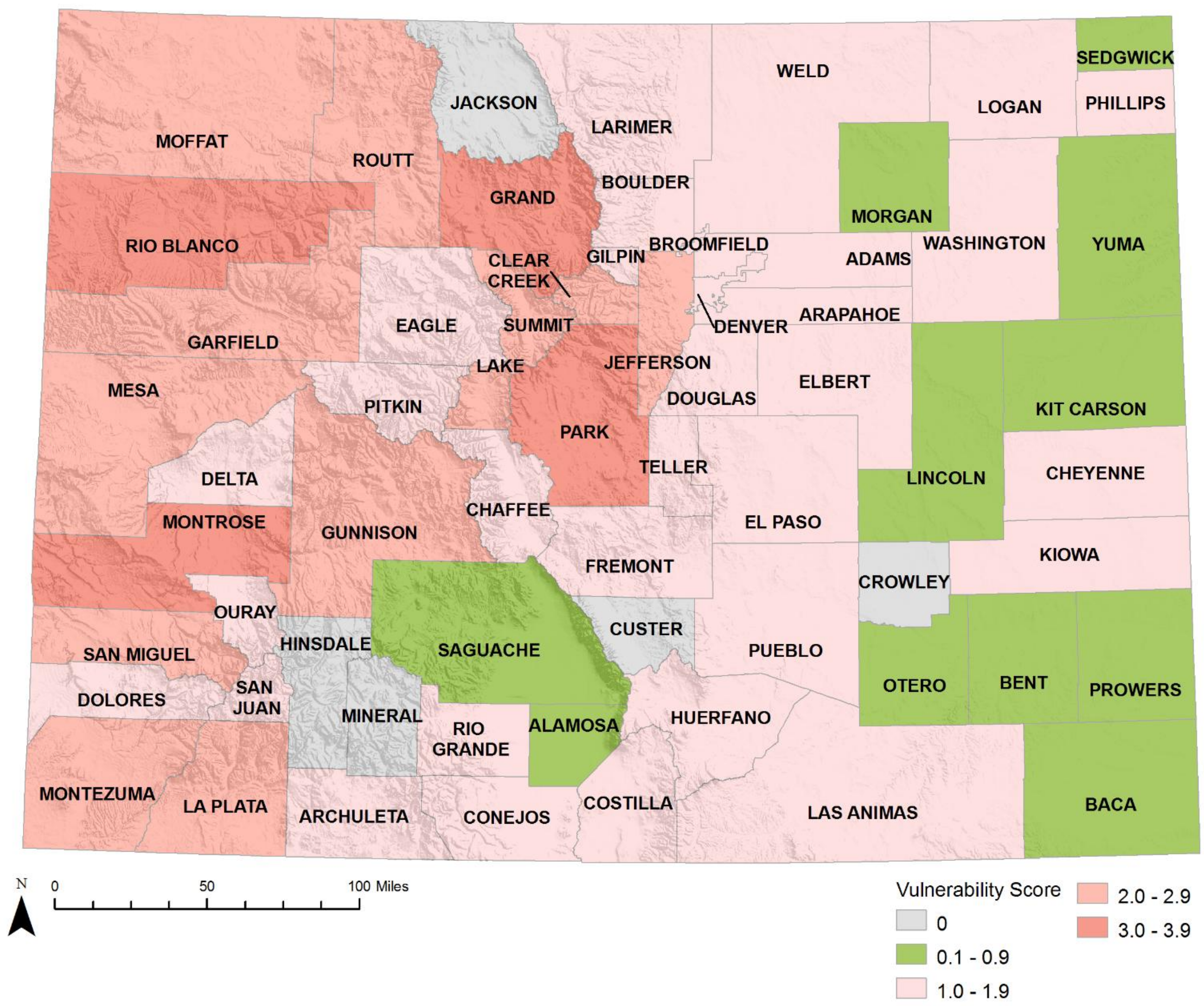


**Figure 7.23. Overall Energy Vulnerability by County**



### 7.5.4 Spatial Analysis

Vulnerabilities in the power sub-sector are highest in the western half of the State (Figure 7.21). This is a result of a number of counties that use large amounts of water for power generation coupled with the lack of wind or solar development plans in these areas. Large power producing counties in the Denver area, like Adams, Weld, and Morgan Counties, do not use nearly as much water for their production. Furthermore, both Adams and Weld Counties use groundwater in addition to surface water, which provides adaptive capacity. Morgan County also has a high adaptive capacity because of the wind generation development area (GDA) in the County. As previously noted, Front Range counties using large amounts of water may be assigned a higher vulnerability scores than western slope providers in the future if a detailed water rights assessment is integrated into the vulnerability analysis.

High impact scores in the mining sub-sector indicate counties where large amounts of surface water are used for mining production (Figure 7.22). Las Animas and Routt Counties both have high surface water use (i.e., impact ratings) but the number of mining jobs created for this water use is very small. Counties like Moffat, Rio Blanco, Delta, and Montrose are of greatest concern because they have high vulnerability and a high number of jobs dependent on mining.

Overall, Montrose County has the highest vulnerability score for the Energy Sector. This is due to its high score with respect to both the power and mining sub-sectors. Uncertainty flags were assigned for counties where groundwater information was used, either for mining or power, and when renewable energy GDAs were used, the maximum number of uncertainty flags is three. All counties with power production or potential renewable energy development have at least one uncertainty flag. This reflects the need for further investigation into water rights vulnerabilities and future renewable power development for the Energy Sector.

### 7.5.5 Compound Impacts

As previously noted the Energy Sector is closely tied with the Municipal and Industrial (M&I) Sector. One of the most critical compound impacts is the relationship between power generation and water supply as shown in Figure 7.5. Beyond this there are compound impacts between power producers and the mining industry because nearly all of the current power generation in the State is fossil fuel based. Any impacts to the mining industry will in turn impact power providers and the effects will cascade back to water providers, mining, and society as a whole. The list below outlines some of the key interconnections between Energy Sector impacts and the rest of society. This list is not exhaustive but does cover the general categories of impact.

- Impacts from power outages
  - Public health and safety concerns
  - Disruption of water supply for municipal providers
  - Disruption of well pumping
  - Economic impact for businesses unable to operate without power

- Impacts from changes in power generation mix
  - Fluctuations in energy prices
  - Environmental impacts and possible increased emissions
  - Large shifts could change demand for various resources, locally affect mineral prices

- Impacts from decreased mining activity
  - Loss of mining jobs
  - Impacts to mining related industries
  - Impacts to mining communities
  - Decreased supply could locally affect prices

- Positive impacts of "new energy economy"
  - Drought mitigation steps can positively affect society by creating jobs and creating funding for investment in new technology. Although the renewable energy industry shows great promise in Colorado, economic challenges in recent years have delayed or even suspended construction of some solar and wind systems.

# 7.6 Recommendations

## 7.6.1 Adaptation to Drought

The Energy Sector does not seem to be highly vulnerable to drought. They have escaped with relatively minor impacts during previous droughts and tend to have senior water rights portfolios which will help protect them during future droughts. However, the Energy Sector is highly water dependent and should take drought mitigation very seriously. Future population growth, increased water demand, and potential impacts from climate change could put a larger strain on the Energy Sector and significantly alter drought vulnerability.

Power providers can reduce vulnerability without changing their generation technology by purchasing additional senior water rights and drought-contingent leases. They can also diversify their water sources and implement water reuse practices during the electric cooling process. The fracking industry can also investigate ways to recycle and reuse produced water. The best solution is to decrease the water required for power generation. In the case of traditional fuel sources, this can be achieved by implementing dry cooling and combined cycles technology. Renewable resources like wind and solar require almost no water for generation.

At the State level, government has already moved to support less water dependent power generation with the 30% renewable by 2020 mandate. Further government support of water-independent technology will lower drought vulnerability. Also, improving transmission line capacity increases the ability of the State to react and fill deficits if power generation is curtailed as a result of drought. Increasing transmission line capacity to other states will provide additional flexibility to import power if necessary.

It is not clear that the mining industry considers drought vulnerability in their operations. However, in the future, mines may have more trouble obtaining adequate water rights, even far in advance. Currently, there is not sufficient data available to analyze the impact of drought on the ability of the mining industry to obtain water rights, or the price of those rights. At the very least, mining companies should start considering drought vulnerability in their long term planning process.

Another important consideration for the mining industry is Colorado's vast oil shale reserves. This mining activity was not investigated in detail as part of this assessment, since it is not yet technologically and economically feasible. However, significant research is currently being conducted on this topic and any assessment of oil shale extraction feasibility should take into account drought vulnerability. Similarly, hydraulic fracturing and its drought vulnerability should also be investigated as data on water use and water supplies, specifically in times of drought, become available.

## 7.6.2 Improving Vulnerability Assessment

One of the key data gaps for the Energy Sector is an analysis of water right holdings. In the analysis it is assumed that mines and power providers more reliant on surface water are more vulnerable to drought than those reliant upon groundwater. While this is a reasonable assumption, there are certainly differences in the reliability of groundwater and requirements for augmentation plans. Furthermore, it is likely that water right seniority plays a bigger role than the groundwater-surface water relationship. This is very difficult to analyze because most large power providers have a complex portfolio of water rights with a range of seniority dates. Future assessments should consider the seniority of water rights, the amount of surplus water held, and drought contingent leases.

The spatial density metric for mining was the number of mining jobs by county. A better metric would be the total mine production value by county. While these data are readily available for several individual resources like coal and natural gas, data on total production value of all mined resources were not easily found. Future assessments should incorporate these data, if possible, and test their use as a density metric for mining.

The water withdrawal data used to estimate impacts for both power and mining came from estimates made by the USGS based on 2005 data. Future assessments should update these data if revised numbers are available. Also, the USGS was forced to make many assumptions in their calculations because not all water use by the Energy Sector is reported. More accurate reporting would improve the quality of this analysis.

The list below outlines data collection tasks identified through this study that could improve future vulnerability assessments. In some cases these data may already exist but requires some additional manipulation to be used for these purposes. This is by no means an exhaustive list, but is intended to be a starting point for future work. As future investigations are completed changes to vulnerability metrics and data collection tasks will likely need to occur.

### Mining

- Total mining production value by county for all resources
- Projected production value by county
- Current and projected water use for mining activities obtained directly from mines
- Water rights volumes and priority dates for operating mines
- Water rights yield analysis under a range of drought scenarios for mining operations

### Power Producers

- Similar analysis of total water rights portfolio yield on a plant by plant basis for power providers
- Quantification of surplus water rights held and drought contingent rights for power providers
- Verification of the water use estimates done by USGS

## 7.7 References

Burnell, James R, Christopher Carroll, and Genevieve Young. 2008. Colorado Mineral and Energy Industry Activities, 2007. Edited by D. N. R. Colorado Geological Survey.

Cameron, Christopher, Michael Highttower, Jefferey Hoffmann, and Cathy Wilson. 2006. Energy Demands on Water Resources, Report to Congress on the Interdependency of Energy and Water. Edited by U. S. Department of Energy.

Clean Air Task Force, and The Land and Water Fund of the Rockies. 2003. The Last Straw, Water Use by Power Plants in the Arid West. Edited by H. Foundation.

Colorado Energy Office. 2012. Colorado Energy Assurance Emergency Plan. Prepared in conjunction with the Colorado Department of Regulatory Agencies - Public Utilities Commission and the Colorado Division of Emergency Management. June.

Colorado Energy Office. 2010. 2010 Colorado Utilities Report.

Colorado Energy Office. 2010b. STAR: Strategic Transmission and Renewables. A Vision of Colorado's Electric Power Sector to the Year 2050.

Colorado Energy Office. 2009. Connecting Colorado's Renewable Resources to the Markets in a Carbon-Constrained Electricity Sector.

Colorado Mining Association. 2011. 2011 Coal Production and Employment.

Colorado Oil and Gas Conservation Commission (COGCC). 2013. Colorado Oil and Gas Production – Update. April. Accessed at http://cogcc.state.co.us/Announcements/ColoradoOilProd.pdf

COGCC. 2013b. Oil and Gas Permit Locations. GIS shapefile.

Colorado Water Conservation Board (CWCB). 2011. Colorado's Water Supply Future, Statewide Water Supply Initiative 2010.

CWCB. 2011b. Energy Development Water Needs Assessment Phase II. Prepared for the Colorado River Basin Roundtable and Yampa/White River Basin Roundtable. February.

CWCB. 2010. Final State of Colorado 2050 Municipal and Industrial Water Use Projections.

CWCB. 2008. Energy Development Water Needs Assessment (Phase I Report), prepared for Colorado, Yampa and White River Basin Roundtables Energy Subcommittee.

CWCB. 2004. Colorado Drought and Water Supply Assessment.

CWCB. 2004. Statewide Water Supply Initiative (SWSI).

Denver Post. 2013. Xcel keeps dead trees off power lines with LiDAR mapping. July 1.

Iberdrola Renewables. 2013. San Luis Valley Solar Ranch Fact Sheet. Accessed at http://www.iberdrolarenewables.us/pdf/san-luis-fact-sheet.pdf.

National Energy Technology Laboratory. 2009. An Analysis of the Effects of Drought Conditions on Electric Power Generation in the Western United States. edited by U.S. Department of Energy: National Energy Technology Laboratory.

Personal communication with the Colorado Energy Office. 2013. Information from Cabell Hodge, Policy, Regulatory, and Outreach Associate. July 17.

Personal communication with Xcel Energy. 2013. Phone conversation with Pete Judiscak, Senior Program Manager, Enterprise Continuity. June 6.

State Demography Office. 2009. Regional Socio-Economic Profile.

The Crestone Eagle. 2013. SolarReserve asking for support for power-tower project. March 29. Accessed at http://www.crestoneeagle.com/solarreserve-asking-for-support-for-power-tower-project/.

The Texas Tribune. 2011. Drought Could Pose Problems for Texas Power Plants. September 16.

Torcellinin, P., N. Long, and R. Judkoff. 2003. Consumptive Water Use for U.S. Power Production. Edited by National Renewable Energy Laboratory.

Tradewind Energy. 2013. Cheyenne Ridge Wind Project. Accessed at http://www.tradewindenergy.com/Project.aspx?id=1572.

U.S. Department of Energy (DOE). 2011. 2010 Renewable Energy Data Book. September.

U.S. Energy Information Administration. 2013. Colorado State Energy Profile.

U.S. Energy Information Administration. 2010. Annual Electric Power Industry Report

U.S. Energy Information Administration. 2009. Annual Electric Power Industry Report

USGS. 2010. Estimated Withdrawals and Use of Water in Colorado, 2005.

USGS. 2009. Estimated Use of Water in the United States in 2005.

Western Resource Advocates. 2012. Fracking our Future: Measuring Water & Community Impacts from Hydraulic Fracturing.

Western Resource Advocates. 2009. Water on the Rocks: Oil Shale Water Rights in Colorado.

# 8 ENVIRONMENTAL SECTOR

### Key Findings

- Colorado's natural environment is diverse and drought vulnerabilities are expected to vary spatially based on ecology and existing precipitation regimes.
- During the 2011-2013 drought as well as in 2002, Colorado Parks and Wildlife (CPW) reported severe impacts to several fish populations and was even forced to relocate some populations to fisheries or protected stream reaches for protection.
- Increased wildfires and beetle infestation are common secondary drought impacts. While the occurrences of these are well documented, the resulting impacts to forest species are not.
- During the 2011-2013 drought, sedimentation of aquatic habitat, resulting from wildfires, was reported in several instances as being particularly damaging to fisheries.
- The 2011-2013 drought impacted many wildlife species by decreasing available water, habitat, and population recruitment.
- Monitoring resources are limited and comprehensive impact information even for the most recent drought is not available.

### Key Recommendations

The following key recommendations were originally developed in 2010 and continue to be relevant in 2013. Many of these were taken into account during the 2013 update.

- Recommendations by the Wildlife Impact Task Force highlight the need for identification of critical areas and additional monitoring.
- Agencies should approach monitoring in a collaborative fashion to decrease redundancy and increase the amount that can be achieved with limited resources.
- While the need for additional monitoring and impact measurement is great, previous studies should not be overlooked. There is a considerable amount of data available for Colorado that, with additional analysis, may be usable in improving drought preparedness and response.
- Future work should, where possible, build on the foundation of previous studies that have been conducted.
- As additional data becomes available the drought vulnerability metrics used in this analysis should be updated.

## 8.1 Introduction to Sector

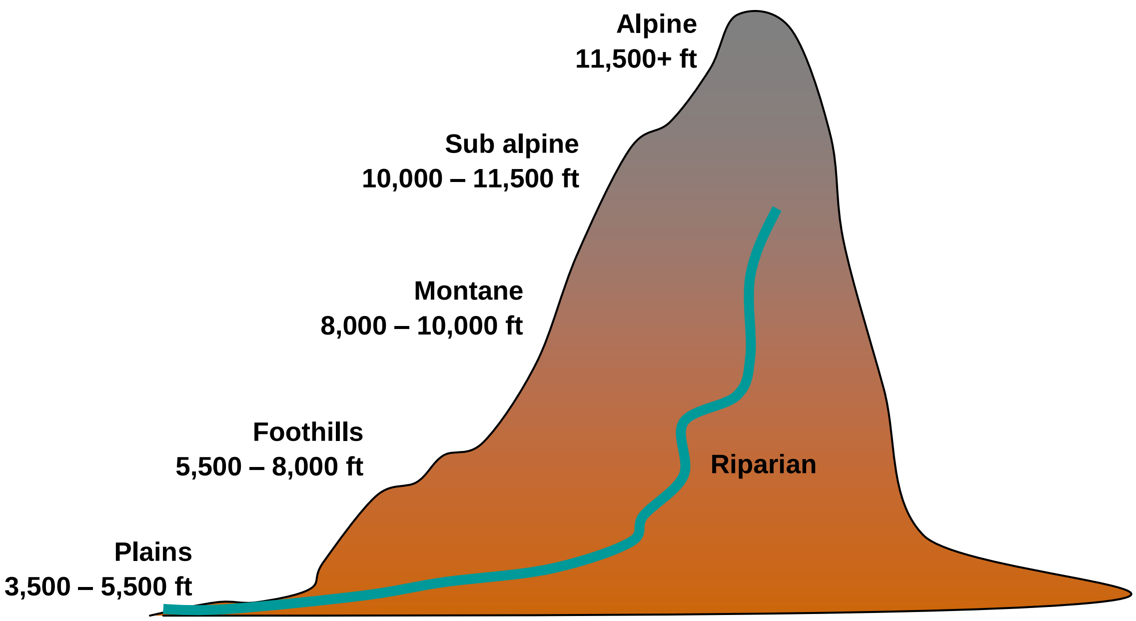
Colorado has an exceedingly diverse environment, with elevations ranging from 3,300 ft at the Kansas border to over 14,000 ft in the Rocky Mountains. The State is home to over 960 wildlife species (CPW, 2013) and many more plants, insects, and other organisms.

While it is impossible to assign monetary value to Colorado's environment, it is important to acknowledge the role it plays in our economy. Colorado attracts tourists and residents with its outdoor recreation opportunities, physical beauty, and high quality of life. Total direct travel spending in Colorado was estimated to bring $15.9 billion dollars into the State annually (Dean Runyan Associates, 2011). This included lodging, food and gas. Wildlife species in the State attract tourists and residents who enjoy wildlife viewing, hunting, and fishing. The scenic beauty of aspen trees and the Rocky Mountains are another big attraction to the State.

The success of all the other sectors discussed in this assessment is linked to environmental quality to varying degrees. For example, the recreation and tourism industry is driven by Colorado's scenery, undeveloped lands, and array of outdoor activities, and relies on the environment in Colorado to attract visitors to parks and generate revenue. Socioeconomically, the condition of the environment contributes to the overall quality of life of people who live in the State.

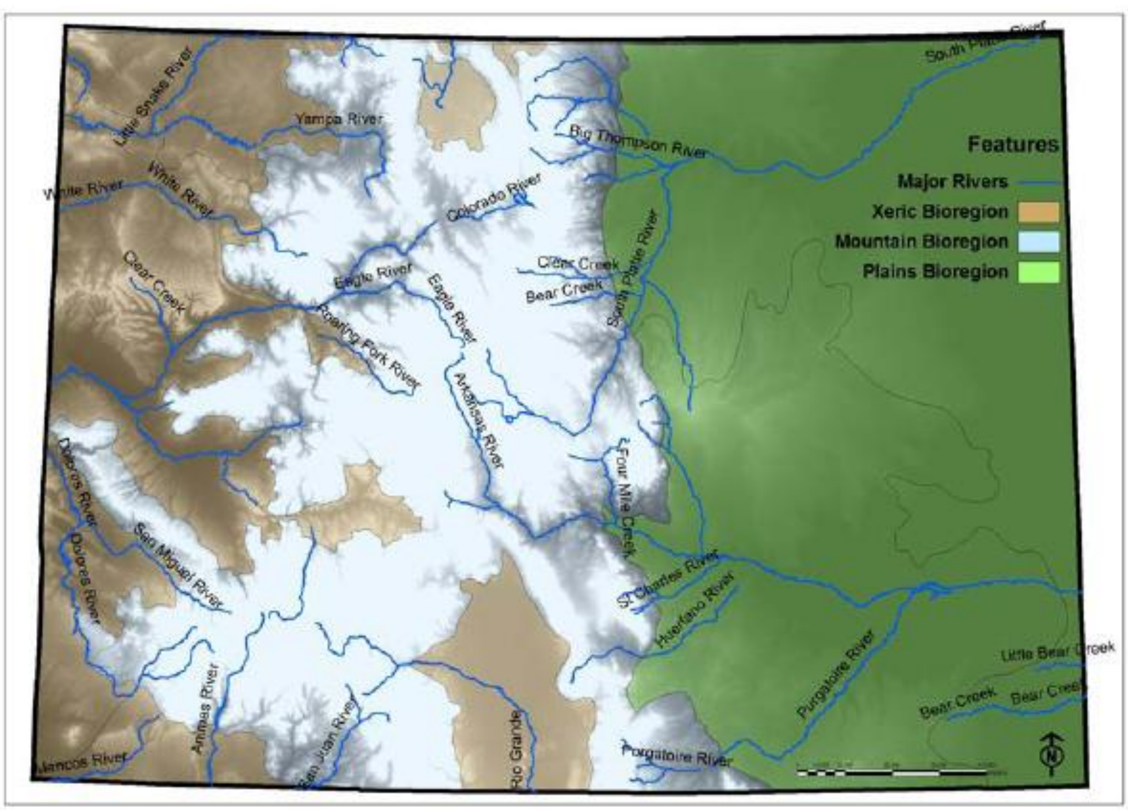
Given the diverse nature Colorado's environment, accurate analysis is difficult and requires division into assessment categories. Previous work has created ecological groups based on; elevation (so-called "life zones"), bioregion, watershed, and forest type, to name a few. Division by major river basins has also been used in other studies, such as the Non-consumptive Needs Assessment (CWCB, 2010). The figures that follow illustrate graphically Colorado's ecological diversity and various categorization approaches. Figure 8.1 shows life zones in Colorado as determined by elevation. The Colorado Department of Public Health and the Environment (CDPHE) Ecological Monitoring and Assessment Report delineated the three main bioregions show in Figure 8.2. The Naturall Resource Ecology Laboratory (NREL) at Colorado State University (CSU) mapped seven ecoregions across the State (Figure 8.3). Forest types are mapped by the Colorado Division of Forestry in Figure 8.4.

## Figure 8.1. Bioregions and Life Zones



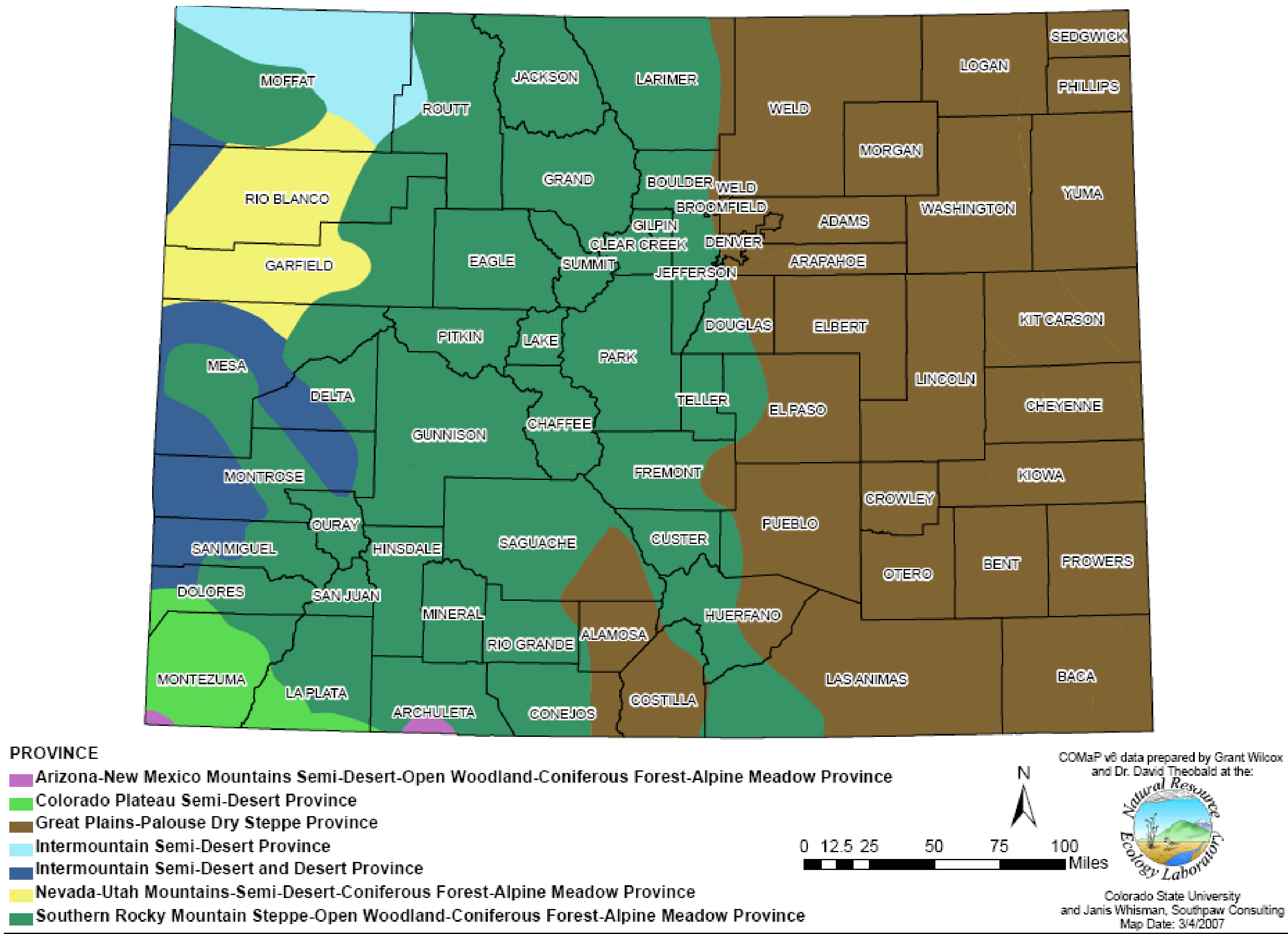

Source: Adapted from NREL 2009

## Figure 8.2. Bioregions and Major Rivers



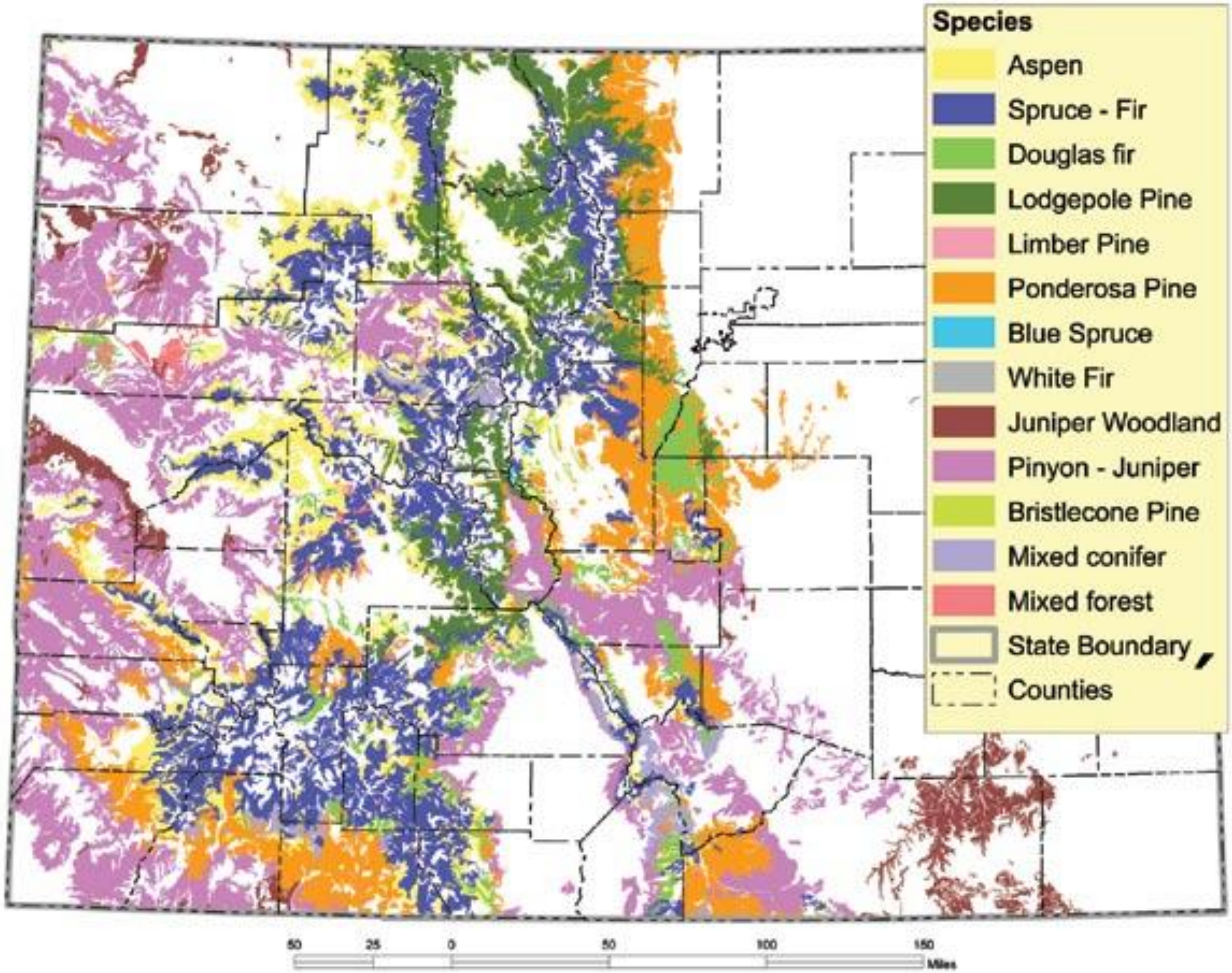

Source: CDPHE 2007

## Figure 8.3. Colorado Ecoregions by County




Source: NREL 2007

**Figure 8.4. Forest Types in Colorado**




Source: Colorado Division of Forestry 2001

From these four figures, a clear distinction can be seen between the eastern and western halves of the State as the plains transition into the Rocky Mountains, and the Continental Divide at the crest of the mountains creates a barrier to moisture transport (McKee et al., 2000). The eastern portion consists of the plains bioregion and ecoregion. This area is generally not forested, has less surface water, and is considerably flatter than the western half. Closer to the mountains forests become more prominent and varied, and the topography becomes significantly more rugged. This is also reflected in the change of bioregions and ecoregions. On the western half of the State considerably more surface water is present and there appears to be a greater variety of forest and ecoregion types. Although not shown in these figures, plant, and animal species vary greatly depending on water availability, forest type, elevation, and topography.

Precipitation around the State averages 17 inches a year but varies widely from 7 inches annually in the middle of the San Luis Valley to over 25 inches in most areas above 10,000 feet (McKee et al., 2000). More than 70% of the precipitation above 10,000 feet falls as snow (McKee et al., 2000), while on the Front Range and the eastern plains a large portion of precipitation comes during spring and summer rain and hail storms. The wettest time of year for much of the Front Range and northeastern Colorado is early March to early June. On the west side of the divide, the wettest period is late fall through early spring. Precipitation patterns are naturally correlated with natural ecology but should be noted because the severity of drought impacts will vary depending on local precipitation regimes.

The combination of environmental and climatological diversity described above makes an accurate high level vulnerability assessment challenging. Numerical assessment is further limited by the lack of usable data. Although a vast array of environmental studies have been conducted in Colorado, the majority could not be incorporated within the scope of this project. This was generally due to the following factors: 1) data analysis was not done relative to drought; 2) the studies did not cover the entire state; and 3) underlying data was not available in the appropriate spatial resolution or would require significant spatial manipulation. As such, environmental vulnerability is not assessed according to the classification systems described above. Instead vulnerability is calculated for the environment as a whole. Particular attention is paid to riparian areas because of their direct dependency on streamflow and their importance. Riparian areas, which are the land-water interface, are found throughout the State, and roughly 75% of the wildlife species known or likely to occur in Colorado are dependent on these areas for a portion of their life cycle (Natural Diversity Information Source [NDIS], 2004). Although this assessment recognizes other areas are impacted by drought (for example, snow- and groundwater-dependent habitats), riparian areas were chosen due to the availability of data and because these areas are widespread throughout the State. A secondary focus is on the existing quality and health of the region, such as existing forest health and water quality. This assessment is intended to be a starting point for future assessments and provide a template for data collection and analysis efforts. As additional data becomes available the assessment should be updated. For a general description of the vulnerability assessment approach refer to Chapter 2 of Annex B.

# 8.2 Vulnerability of Environmental Sector to Drought

## 8.2.1 Aspects of Vulnerability

Drought impacts the natural environment in many ways. One of the factors that can influence an area's vulnerability to drought is land use. Human modification to a land area can exacerbate drought impacts, such as when livestock are allowed to graze on over-stressed pastures. Competition between municipal, industrial, and agricultural users can further impact an area that is already experiencing negative impacts due to drought.[1] For wildlife, a species' ability to relocate to areas that are not as impacted by drought influences their adaptive capacity. Animal mobility can be aided or encumbered by land use and human activities that either encourage, discourage, or prevent the migration of wildlife.

Some examples of drought impacts are listed below:

- Aquatic habitat can be impacted by lower streamflows, and mountain vegetation can be impacted by reduced soil moisture in the spring and summer.
- Fish populations may decline as a result of limited wintertime habitat for mature fish. Wintertime habitat is a limiting factor to species proliferation, lower wintertime streamflows, can decrease the available habitat for adult fish.
- Late summer is also a limiting time period for fish particularly in times of drought. Both flow and temperature can become detrimental, especially for coldwater species.
- Increased human wildlife interactions can occur when plan forage becomes less abundant as a result of decreased moisture. Elevated wildfire risk and subsequent wildfires can further increase habitat stress.
- More large scale fires, continued insect and disease epidemics, and changes in species dynamics and range can result from drought conditions exacerbated by warm temperatures (CSFS, 2008). Continual grazing, fire exclusion, and drought are possible contributing factors to lack of regeneration noted around stands of aspen in the western half of the State (CSFS, 2008).
- During a drought, already-stressed systems can become further impacted by increased pollution, surface water diversions, and groundwater depletions. Low elevation riparian systems are often subject to heavy grazing and/or other agricultural use.

Adaptive capacities largely depend on human willingness to effectively manage wild areas or leave them undisturbed. Management decisions that have been implemented in past droughts include: forest management that allows for natural forest fires; closing sensitive lands to grazing

[1] Ongoing planning by the CWCB is focused on identifying environmentally and recreationally important waterways and providing the maps and tools necessary to avoid conflict over these areas in the future. More discussion on this is provided in Section 8.2.2.

when carrying capacity decreases; and maintaining instream flows at a level sufficient for aquatic life survival. Maintaining the natural environment at a high level of integrity during non-drought times helps ensure that when a drought does occur there are fewer areas that are already stressed and therefore more susceptible to damage.

## 8.2.2 Previous Work

A number of studies have been conducted for specific subsectors of the Colorado environment. These reports were reviewed for information on environmental impacts respect to drought. Table 8.1 outlines the findings of this literature review.

### Table 8.1. Impacts from Literature Review

| Topic | Impacts | Source |
|---|---|---|
| General environment | **Impact:** Extreme climate events can interact with other disturbances (e.g., catastrophic wildfire, insect outbreak, grazing, erosion) to drive semi-arid ecosystems past ecological thresholds, leading to changes in vegetation and desertification. | Enquist et al. 2008 |
| Aquatic environment | **Impact:** In 2002 Antero Reservoir's fishery was lost, mostly due to draining of the reservoir. | DWSA, 2004 |
| | **Impact:** Decreased water levels in Tarryall Reservoir, Spinney Mountain Reservoir, and Elevenmile Reservoir also resulted in significant aquatic impacts. | DWSA, 2004 |
| | **Impact:** The lower South Platte River reservoirs experienced the loss of fishery resources. | DWSA, 2004 |
| | **Impact:** In the San Luis Valley, the Home, Smith, Mountain Home, Million, and La Jara reservoirs were all drained dry with a total loss of fish. | DWSA, 2004 |
| | **Impact:** Wildfires in the South Platte, Animas, La Plata, Los Pinos, and Mitchell Creek Watersheds, and their aftermath, resulted in serious loss of quality habitat in these watersheds. | DWSA, 2004 |
| | **Impact**: Sediment and ash from wildfires impacted fisheries in Trinidad State Park, Lake Dorothy State Wildlife Area, the Poudre River, Marcos River, Sand Creek, and Piedra Rivers. | CPW, 2012 |
| | **Impact:** Low water levels, high temperatures and low dissolved oxygen levels contributed to fish kills in the Las Animas Hatchery, Williams Creek Reservoir, and created stressful conditions for many fish species in streams throughout the State. | CPW, 2012 |
| | **Impact:** A fish kill was observed in the Colorado River above Dotsero after a monsoon event transported a large amount of sediment into the river. | CPW, 2012 |
| Mountain pine beetle | **Impact:** Extreme cold temperatures are a key factor to controlling the spread of beetle populations. The spread of mountain pine beetle can be exacerbated through warmer temperatures that often accompany drought, and because trees that are weakened by lack of water are more susceptible to infestation. | Leatherman 2007 |

| Topic | Impacts | Source |
|---|---|---|
| Extreme wildfires | **Impact:** Reports from the summer of 2002 indicate that elk were incinerated, watersheds were at risk, streams were choked with ash and sediment, and reservoirs that were already low were at risk of filling up with ash and sediment. | Holsinger, 2002 |
| | **Impact:** The 2002 fire season was heightened by extended drought conditions that caused well below average fuel moistures in wildland fuels. This resulted in increased potential for fire starts and more intense fire behavior. Wildfires are a separate hazard from drought, but the dry and hot conditions accompanying a drought exacerbate the wildfire problem. | DWSA, 2004 |
| | **Impact**: Debris flows that result from wildfires deliver large amounts of sediment to stream channels, The sedimentation of the channel deteriorates habitat vital for aquatic life. This impact is observed along the Poudre River, downstream of the 2012 High Park fire. | CPW, 2012 |
| Noxious weeds | **Impact:** Noxious weeds can proliferate when native vegetation is stressed by lack of water due to drought.<br><br>**Impact:** They also create heightened competition for water, which in a drought can damage surrounding vegetation by consuming excess soil moisture. | CSFS, 2008 |

In addition to the works cited above, environmental impacts due to drought were included in the 2004 Drought and Water Supply Assessment (DWSA). The CWCB conducted the DWSA in 2004 to determine the State's preparedness for drought, and to identify limitations to better prepare for future droughts (DWSA, 2004). It entailed a survey, or opinion instrument, where 537 responses were received statewide on specific impacts experienced during the drought years of 1999-2003. Various entities were surveyed including power, industry, agriculture, municipal, state, federal, water conservancy and conservation districts, and other entities such as tribes and counties. Although the survey did not include any groups related to the Environmental Sector, the DWSA did mention drought related impacts (noted in Table 8.1) regarding extreme wildfires and the aquatic environment. Additionally, the DWSA identified the need to thin or remove moisture-competitive trees and brush in watersheds in order to increase yields for streams and aquifers. This task falls on the U.S. Forest Service (USFS), Colorado State Forest Service (CSFS), and the Department of Natural Resources (DNR). The eradication of the invasive tamarisk plant was also identified as a goal in an Executive Order by the Governor in 2003; the DNR was responsible for developing a plan to eliminate the tamarisk tree from all public lands within 10 years.

The CWCB also sponsored the Statewide Water Supply Initiative (SWSI). Due to its importance to the State economy, quality of life and because population growth is expected to place competing demands among many water uses, the Environmental Sector had a prominent role in the SWSI process.. One of SWSI's water management objectives was to "Provide for Environmental Enhancement." Similar to the Recreational Sector, a detailed assessment of how drought may impact the Environmental Sector was not performed in the first phase of SWSI. However, the SWSI process identified many environmental resources on a statewide basis that are potentially vulnerable as a result of population growth and the resulting strain on water resources.

The resources pertaining to the Environmental Sector (as defined by the SWSI 2010 update) include the following:

- Gold Medal fisheries/lakes
- Water Quality Control Division (WQCD): Monitoring and Evaluation List, 303(d) List
- Audubon important bird areas
- Colorado Natural Heritage Program
- Instream flows

Data associated with these resources were collected, delineated, and summarized in GIS coverages as a part of the SWSI 2010 update. The data and associated tools are available to decision makers to prioritize environmental areas and ensure these resources are considered when establishing water management strategies throughout the State. Additionally, the SWSI 2010 update recommended that preservation of environmental resources needs to occur when water development projects are being considered to avoid conflict between water providers and the environmental and recreational community.

The CWCB completed the work started in SWSI and the SWSI 2010 update with a Non-consumptive Needs Assessment (NCNA) Focus Mapping report (CWCB, 2010). This report covers non-consumptive water uses in the nine basin roundtable areas of Colorado (eight major river basins and the Denver metro area). The NCNA expands upon the existing set of environmental and recreational attribute maps that were developed through the process to update SWSI in 2010 and develops aggregated maps of Colorado's critical waters based on environmental and recreational qualities. The maps are intended to be a guide for water supply planning, so that future conflicts over environmental and recreational water needs can be avoided.

The data resources used in the NCNA assessment include the following:

**SWSI 2010 update Environmental and Recreational GIS Shapefiles**

- Arkansas darter
- Audubon important bird areas
- Bluehead sucker
- Bonytail chub
- Boreal toad critical habitat
- WQCD 303(d) listed segments
- Colorado pikeminnow
- Colorado River cutthroat trout
- CWCB instream flow rights

- CWCB natural lake levels
- CWCB water rights where water availability had a role in appropriation
- Flannelmouth sucker
- Gold Medal trout lakes and streams
- Greenback cutthroat trout
- Humpback chub
- Rafting and kayaking reaches
- Rare riparian wetland vascular plants
- Razorback sucker
- Recreational in-channel diversions
- Rio Grande cutthroat trout
- Rio Grande sucker
- Roundtail chub
- Significant riparian/wetland communities

**Additional Environmental and Recreational GIS Shapefiles**

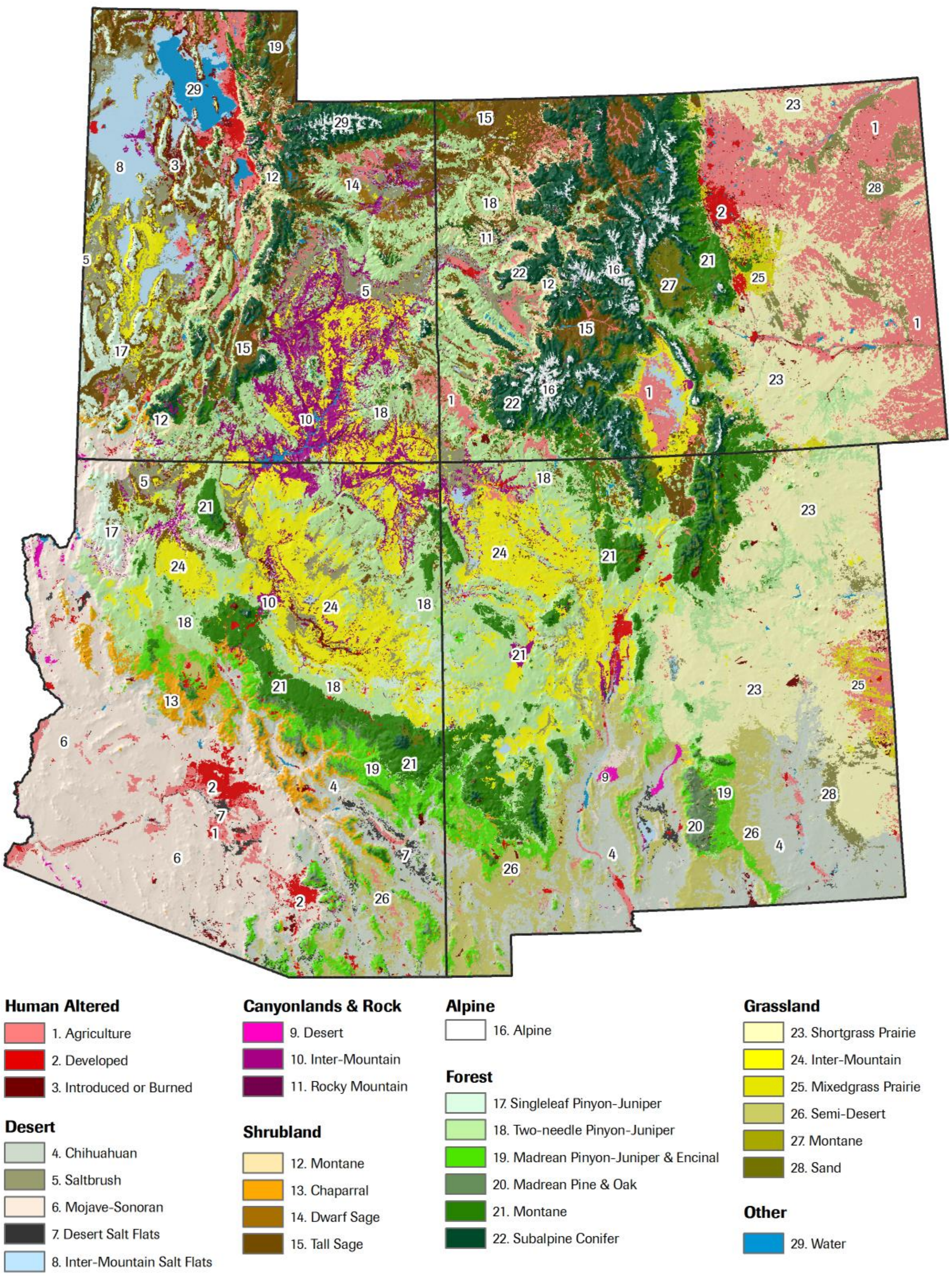
- Additional fishing, greenback cutthroat trout waters, and paddling/rafting/kayaking/flatwater boating
- Bald eagle winter concentration, active nest sites, summer forage, and winter forage
- Brassy minnow
- Colorado birding trails
- Colorado outstanding waters
- Common garter snake
- Common shiner
- Ducks Unlimited project areas
- Educational segments
- Eligible/suitable Wild and Scenic rivers
- Grand Mesa, Uncompahgre, and Gunnison wilderness waters/areas
- High recreation areas
- Least tern
- National wetlands inventory
- Northern leopard frog locations
- Northern redbelly dace
- Osprey nest sites and foraging areas
- Piping plover
- Plains minnow
- Plains orangethroat darter
- Preble's meadow jumping mouse
- River otter confirmed sightings and overall range
- Rocky Mountain Biological Laboratory (scientific and educational reaches)

- Sandhill crane staging areas
- Southwestern willow flycatcher
- Stonecat
- Waterfowl hunting areas
- Wild and Scenic study rivers
- Wildlife viewing
- Yellow mud turtle

As can be noted by the extensive list above, the NCNA is an expansive undertaking that provides valuable aquatic ecosystem data aggregation. While it does not speak to drought vulnerability specifically, the data gathered and resulting stream reach designations are a useful environmental inventory metric. However, in the NCNA process basins produced different maps based on their selected mapping technique and priority data layers (CWCB, 2010). The methodology for the Drought Vulnerability Study was developed to facilitate analysis that could be consistent across watershed and county boundaries in Colorado, this requiring selection of categories and data types that were available and comparable at the county level. In contrast data developed for the NCNA analysis, while often rich in terms of the number and types of data used, are variable across basins. This precluded extraction of this information in a manner that would have facilitated direct use of the NCNA results. Furthermore, all of the NCNA analysis was done with respect to subbasins and stream reaches. Significant analysis is required to convert these findings into county designations that could be incorporated into this methodology. Although numerical integration is not possible at this time, the applicability of this data for future analysis is unquestionable. Additional work should be supported to build on the NCNA findings.

Finally, there are ongoing environmental studies by various groups in Colorado that are attempting to classify bioregions and assess vulnerability, primarily to climate change. Figure 8.5, provided by The Nature Conservancy (TNC), is modified from a regional study conducted by NatureServe in 2009 to classify habitats in the southwest. Habitats were determined using a GIS dataset of vegetation units called “macrogroups.” Macrogroups are groups of plant communities with a common set of growth forms and dominant plants that share a broadly similar geographic region, regional climate, and disturbance regime (TNC, 2010). This classification unit is broader than ecological systems and has been included in the most recent version of the U.S. National Vegetation Standard. As with NCNA the results of this study, while informative, are not (as of 2013) in a form that is readily usable for the vulnerability assessment methodology of this project. Information like this may be beneficial in future drought vulnerability work and is a good candidate for additional analysis.

## Figure 8.5. Southwest Region Macrogroups




Source: NatureServe, 2009 and TNC 2010

## 8.3 Assessment of Impacts and Adaptive Capacities

While there is a significant body of work concerning the ecological diversity of Colorado, comprehensive drought impact information is not available. Specific impacts to vegetation, aquatic species, and wildlife have been noted in previous droughts, but not in a systematic way. The primary sources of this information are CPW and the Wildlife Impact Task Force (part of the Drought Task Force). Many of the impacts noted here relate to riparian areas and secondary impacts to forest health (wildfires and beetle infestation). Particular attention is also paid to endangered species. Relevant information is presented in this section. However, it should be noted that there is a general lack of information about drought impacts to the environment as a whole and to species and areas that are not heavily managed. Therefore, the specific impacts discussed here may be more heavily weighted towards managed species and areas.

### 8.3.1 Potential Impacts

The following list outlines the experiences reported by CPW staff during the 2002 drought. Many of the comments highlight aquatic species and riparian areas' direct vulnerability to drought.

- Statewide decrease in forage for wildlife; in some cases resulting in increased conflicts between humans and bears.
- Aquatic impacts due to low stream levels and significantly higher water temperatures. Salmonid populations were effected in several low-water streams. Voluntary angling closures were employed on some streams to minimize impact to already-stressed salmon.
- Several endangered fish species were threatened and had to be transferred to a protected stream reach or hatchery. For example, greenback cutthroat trout were pulled from Como Creek and roundtail chub from La Plata and Mancos Creeks.
- A baseline condition for the majority of native aquatic wildlife species had not been established prior to 2002, therefore it was impossible to accurately describe the impact of the drought on these species.
- Monitoring resources are limited and it was not possible to track impacts to some native wildlife resources, including fish, birds, small mammals, and amphibians.

Additionally, CPW has observed impacts associated with the 2011-2013 drought event. The impacts, summarized below, are similar to those observed for the 2002 drought event.

- Significant decreases in forage, water, food, cover, and habitat stressed populations, creating concerns about the health and survival of game species through the winter.
- Fish kills observed in reservoirs, lakes, ponds, and streams as a result of low water levels, high water temperatures, anoxic conditions, and sedimentation.
- Black bears emerged earlier from their dens due to abnormally hot and dry conditions during the spring of 2012.

- Waterfowl production in breeding areas such as North Park, San Luis Valley, and the Yampa River was generally poor in 2012.
- Pronghorn antelope herd distribution has changed significantly during 2011-2012 and experienced reduced recruitment.

A secondary impact of drought is increased incidence of wildfires, which can also negatively affect riparian areas. In 2002, the CPW reported impacts from the Hayman fire that included increased runoff from the burn areas and a corresponding increase in sediment load and deposition in the South Platte River. The increased sedimentation caused direct loss of aquatic habitat, negatively influenced macro-invertebrates, and degraded trout spawning habitat. As a result of these impacts the CPW had to increase stocking of fingerlings and sub-catchable (5 to 8 inch) trout to replace year class losses. They worked closely with water providers throughout the basin to implement sediment trap areas on tributaries that would increase opportunities for flushing flows to move the sediment bed load downstream and were involved in a variety of other stream and riparian habitat enhancements to restore watershed function (communication with DOW, 2010). CPW staff note that the ecosystem is slowly recovering but impacts from the fire are still noticeable today.

Similar impacts were observed as a result of wildfires during the 2011-2013 drought. A fish kill at Lake Dorothy State Wildlife area was caused by high sediment loads from ash and sediment resulting from the 2011 Track Fire. Additionally, the health of the fishery in the Poudre River basin has been negatively impacted by the ash and sedimentation associated with the Hewlett Gulch and High Park fires.

Compound impacts are secondary, or indirect, impacts brought about by changes in sectors that are directly impacted. Given the strong inter-reliance between other sectors and the environment, compound impacts can be dramatic. As previously noted, Colorado's beautiful environment is a big attraction and is often cited as an important factor in the high quality of life for residents of the State. Loss of vegetation and drought induced wildfires can impact society as a whole. Furthermore, when drought puts stress on ecosystems that are the basis for recreational activity the recreation and tourism industries suffer. For example, CPW has implemented voluntary recreational closures on portions of rivers during periods when high water temperatures stress fish (communication with DOW, 2010; CPW, 2013). Many of the preserved natural spaces in Colorado are controlled by government agencies. Responding to the environmental impacts of drought can put stress on agencies like CPW and the State Forest Service. Both CPW and the State Engineer's Office reported increased cost resulting from additional manpower to manage environmental resources during the 2002 drought.

Aquatic species, especially fish may be very sensitive to municipal and industrial wastewater effluent, particularly during low flow times when waters have diminished volume or flow with which to dilute pollutants. This can have detrimental effects on native fish species as well as lucrative sport species. The 2002 drought illuminated the inability of water quality and water quantity legislation to respond to drought coherently because they are managed in two separate arenas. For example, wastewater treatment operators were legally allowed to continue discharges into state waters experiencing very low flows even though discharge calculations were completed for flow levels higher than the flow levels at the time. When and where these situations actually occurred and whether such conditions impacted aquatic life was difficult to assess in real time, making monitoring a difficult and reactive task. Many new water transactions and management plans have been developed since 2002 and impacts from future droughts will probably not parallel past experience. Colorado's water quality regulations do not provide a framework for overall review of water-quantity projects nor can they inhibit the exercise of water rights. Similarly, water-quantity regulations cannot incorporate literal water-quality considerations. As such, future planning and education efforts are needed to reduce the potential for water-quality impacts and conflicts[2].

## 8.3.2 Adaptive Capacity Actions

In May 2002, the Wildlife Impact Task Force assembled a list of potential mitigation strategies for aquatic and terrestrial habitats as part of the Impact Task Force Drought Assessment and Recommendations. These strategies involved actions that government agencies and/or environmental groups could take to mitigate impacts during the drought. That table is reproduced below (Table 8.2).

**Table 8.2. Mitigation Strategies from the 2002 Wildlife Task Force**

| Potential Mitigation Strategy | Agencies or Organizations Involved |
|---|---|
| **Aquatic Habitat** | |
| Identify critical stream reaches, lakes, and reservoirs. Critical stream reaches would be identified based on designated criteria such as species of concern, threatened and endangered species, recreational or historic importance, and instream flow reaches where senior water rights could help mitigation. | DOW, CWCB, USFW, USFS, and Trout Unlimited (TU) |
| Develop processes to monitor critical stream reaches, lakes, and reservoirs. A process for monitoring flow rates, water levels, and temperatures needs to be developed. This process would incorporate citizens, schools, environmental/wildlife groups, and state and federal agencies. In addition, criteria would be set for emergency actions. | DOW, CWCB, CDPOR, DWR, CDPHE, USFW, USFS, TU, and citizen groups |
| Identify mitigation alternatives for critical stream reaches, lakes, and reservoirs where practical. | DOW, CDPOR, DWR, CWCB, CDPHE, USFW, USFS, and TU |

[2] Stringent treatment standards could require extensive re-working of existing facilities and/or new facilities which may not be feasible for some entities. Such implications in addition to water rights implications would need to be evaluated on a case-by-case basis.

| Potential Mitigation Strategy | Agencies or Organizations Involved |
|---|---|
| Provide emergency instream flow protection. CWCB will work with the DNR, Governor's Office, Division of Water Resources (DWR), SEO, DOW, and the public to provide emergency instream flow protection on streams where water rights may be temporarily made available for such purposes. In 2003, the general assembly revised the instream flow statutes to allow irrigators to temporarily "loan" unused water to CWCB for instream flow purposes at times when the Governor declared a drought (Colo. H. 03-1320, 64$^{th}$ Gen. Assembly, 1$^{st}$ Reg. Sess. [June 5, 2003]). In 2005 this section was again revised to allow for such loans in three out of every ten years, thus eliminating the requirement that the Governor declare an emergency (Colo. H. 05-1039, 65$^{th}$ Gen. Assembly, 1$^{st}$ Reg. Sess. [Mar. 25, 2005]). | CWCB, DWR, DOW, TU, and other water users |
| Develop process for enacting drought emergency closures, fishing restrictions, and fish salvage operations. Education and notification of the public on the process and the status of fisheries is also included under this strategy. | DOW |
| Monitor hatchery water levels and stocking conditions. Based on this monitoring, modify production levels and stocking procedures as needed. | DOW, USFW |
| **Terrestrial Habitat** | |
| Identify priority areas and monitor drought impacts on threatened and endangered species, and other species of concern. | DOW, USFW, and USFS |
| Continue to identify and assess how drought may impact predator and human interactions. This task includes public education. | DOW, USFW, and USFS |
| Evaluate process for compensating private landowners for game damage associated with drought issues. This task should include identifying lag effects on game damage. | DOW |
| Monitor waterfowl production impacts. Identify any local, hunting, or migratory impacts to waterfowl from drought. | DOW, USFW, and USFS |
| **Aquatic and Terrestrial Habitat** | |
| Evaluate and optimize state agency water use as necessary to best maintain habitat, stream flows, and reservoir levels. Includes development of water conservation measures for state-owned water rights. | DOW, CDPOR, CWCB, and DWR |
| Coordinate and research federal drought assistance funding, including research into whether federal drought relief money may be available to compensate irrigators and for CWCB to lease senior rights for instream flows. | DOW, CWCB, USFW, and USFS |
| Educate water users on conservation practices to aid wildlife during drought and on what to expect during drought conditions. | DOW, CDPOR, DWR, CWCB, USFW, USFS, and TU |
| Continue close communication and coordination between the DOW, DWR, and the Water Quality Control Division to reduce adverse impacts to the aquatic ecosystem per the 1998 MOU. | DOW, DWR, and CWQCD |

In addition to the mitigation strategies assigned to specific agencies in Table 8.2, the impact task force also recommended: 1) statewide voluntary conservation measures intended to conserve water to benefit wildlife; and 2) coordinate public education and media releases to increase clarity and visibility of drought conditions and mitigation actions.

Many of the mitigation strategies discussed above involve identifying critical areas and monitoring impacts. This speaks to the lack of impact data noted in the previous section. It is difficult to develop specific mitigation strategies without a clear spatial understanding of impacts. For example, there are many wildlife species in dry regions of Colorado are already adapted to drought, and are able to survive in dry conditions or have the mobility to seek less stressful habitat elsewhere (communication with DOW, 2010). Future monitoring and identification work should quantify qualitative observations like this. Only after drought impacts have been systematically observed can specific vulnerable areas and species be identified and targeted mitigation efforts designed.

In 2007, the Colorado Water Quality Control Commission adopted revised water-quality standards for protection of aquatic life. The standards include an acute standard (a two hour daily maximum) for protection from lethal effects of elevated temperature and a chronic standard (a maximum weekly average temperature) for protection against sub-lethal effects on behavior. The standards also include seasonal adjustment for protection of spawning, and they include a narrative requiring that temperature maintain a normal pattern of daily and seasonal fluctuations and spatial diversity with no abrupt changes. Colorado's revised water-quality standards for temperature did not exist during the 2002 drought. Further, a low-flow exclusion allows for temperature exceedences when the daily streamflow falls below an acute low flow or when the monthly average streamflow falls below a chronic critical low flow. The basis of Colorado's temperature standards in species-specific physiological tolerances to elevated temperature suggests that the standards will provide a useful benchmark against which to evaluate whether elevated temperatures resulting from drought conditions are likely to contribute to deleterious effects on fish communities. The implementation of the temperature standards has prompted an increase in temperature monitoring, which will likely facilitate better evaluation of the influence of drought-associated flows and elevated temperature on fisheries during future drought conditions.

In 2011-2013 CPW has implemented a number of response actions targeted at aquatic resources. They have been intensively monitoring stream flow levels, water temperatures, and dissolved oxygen levels in rivers and streams throughout the State. These are temporary actions but are being documented and, hopefully institutionalized, so that re-invention is not necessary for future droughts. This effort has allowed CPW to implement fishing restriction and/or closures when warranted. To support this action, CPW is encouraging anglers to monitor water temperatures, moving to other locations if or when temperatures rise above 68 degrees Fahrenheit. This helps to reduce stress on coldwater species. CPW has also been collaborating with other agencies to obtain emergency releases of water when the conditions require increased flow for basic habitat needs, temperature moderation, dissolved $O_2$, and for spawning migration. For example, CPW was able to work with the CWCB and the Division of Water Resources to release water from Lake Avery to help maintain the White River fishery. Similarly, water was released from Steamboat Lake for the Elk River fishery.

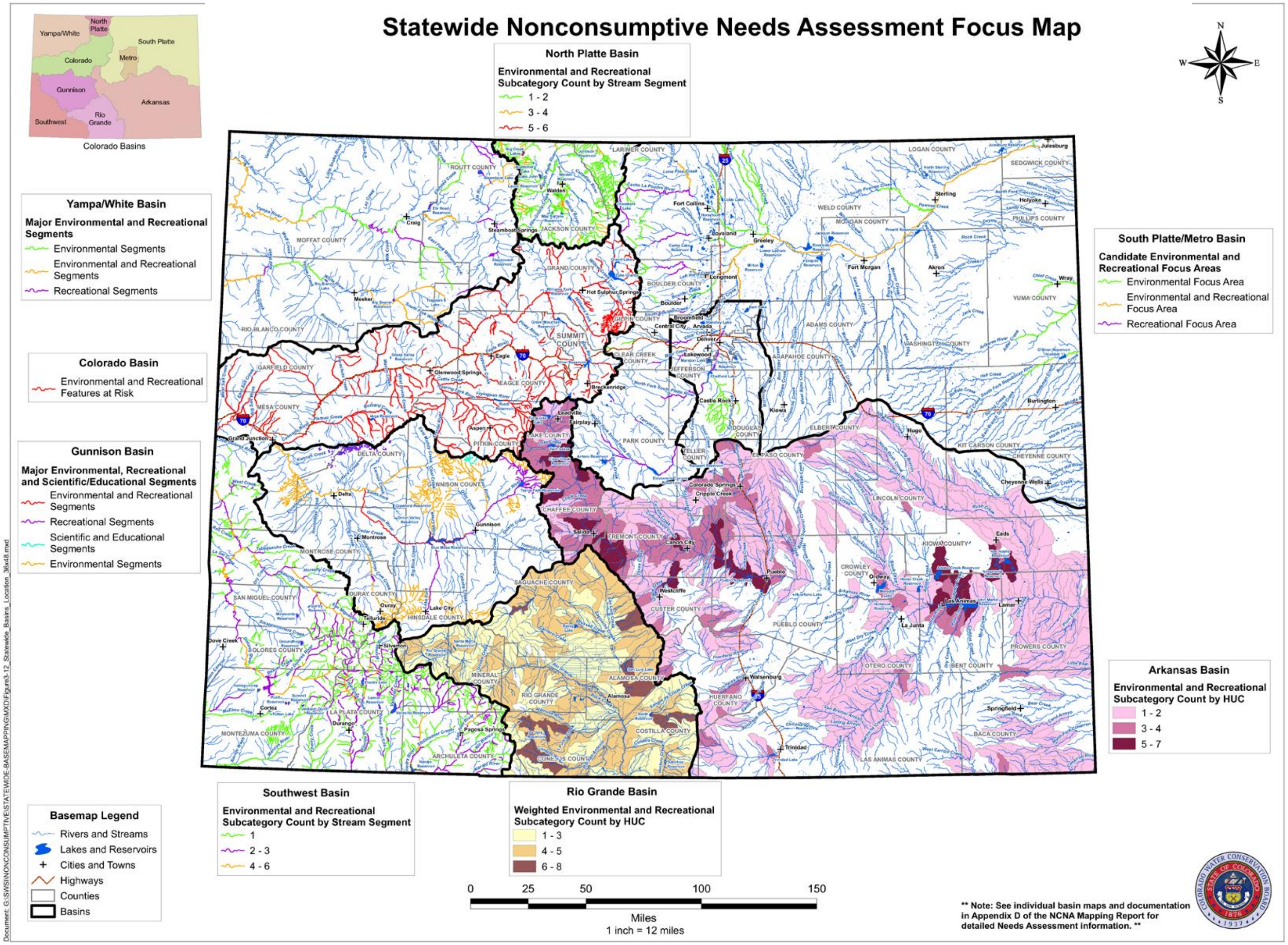
In response to the High Park Fire, CPW, along with other federal, state and county agencies, participated in the burn area emergency response effort to assess the impacts of the fire on the aquatic habitat and cold water fisheries of the Poudre River (CPW, 2012).

CPW has also implemented response actions for wildlife and the terrestrial environment. Annual monitoring efforts provide information about overwinter survival, recruitment, population estimates, and pre- and post-hunt age and sex ratios for priority game species. In 2012 this monitoring effort was supplemented with aerial surveys to assess the pronghorn antelope, a species identified as being especially vulnerable to drought.

CPW implements herd management principles that account for drought and are ultimately flexible to changing weather conditions. For example, CPW made additional doe antelope licenses available in southeastern Colorado to help reduce the population to sustainable levels. CPW also participates in programs that aim to preserve and/or enhance habitat for a number of species (e.g., Wetland Wildlife Conservation Program, Colorado Wildlife Habitat Protection Program) (CPW, 2012) which may also assist in mitigating drought impacts.

The 2010 NCNA provides valuable "identification" information which is the necessary first step to future monitoring and impact tabulation. Figure 8.6 shows stream segments identified as critical for environmental and recreational reaches through each basin's environmental and recreational analysis. It should be noted that the "critical" designation assigned in the NCNA process is a function of the environmental characteristics selected for analysis and does not denote drought vulnerability. Still, these results can be used to delegate limited resources by prioritizing areas for additional study and monitoring resources.

## Figure 8.6. Statewide Non-consumptive Needs Assessment Focus Map




Source: CWCB 2011 Revised for 2013 Update

Instream flow rights owned by the CWCB are a drought mitigation strategy that is already in place. Instream flow rights are designed to maintain streamflows above critical levels even when water is scarce (refer to the State Assets section for detailed discussion). A systematic analysis of the impacts to instream flow protected reaches during the 2002 drought is not available; but it was noted by the CPW after the 2002 drought that maintaining existing stream habitat at a high level provides resilience against drought and sediment loads during and after wildfires. This includes maintaining the capacity for streams to pass increased peak flows and/or sediment loads (communication with DOW, 2010). However, the instream flow program historically has been focused on maintaining streamflow rather than protecting habitat. Future study of its effectiveness in protecting fish and other habitat would be beneficial to understand to what extent the instream flow program can be considered an adaptive capacity for drought-stressed areas. *Statue 37-38-105* enables entities in collaboration with CWCB to lease water for streams on short notice to protect the environment. This tool has been available since 2003 yet the Colorado Water Trust was the first to use it in 2012 to add water to streams during the drought. They are planning on doing the same program in 2013.

Mitigation strategies are also in place for the spread of noxious weeds. As noted in the literature review, drought can increase the spread of weeds as native plants become stressed due to lack of water. Prevention seems to be the best adaptive capacity thus far to dealing with aggressive noxious weeds. A number of management techniques are used by the Colorado Department of Agriculture (CDA), United States Forest Service (USFS), United States Department of Agriculture (USDA) and other local government entities that focus on prevention, eradication and control of noxious weeds and other invasive plants. These programs also emphasize rehabilitation and restoration to help heal, minimize or reverse the harmful effects from invasive species (USFS, 2004). The USDA produces noxious weed books and provides support to county level weed projects. CPW has hired an invasive species coordinator and anticipates the need for increased efforts to monitor for the presence and spread of aquatic nuisance weed species in future droughts (communication with CPW, 2010). Rehabilitation actions are particularly important following wildfire to prevent the establishment of noxious weeds.

## 8.4 Measurement of Vulnerability

Considerations when addressing environmental vulnerability include:

- Criteria used to characterize the existing condition of the habitat or species
- Driving processes and exposure of a particular area
- Hydrologic regime and whether there is significant riparian presence
- How changes to the climate and precipitation patterns impact the region
- How stress is characterized.

Before conducting a vulnerability assessment, the approach and vulnerability criteria need to be clearly defined. The existing lack of state-scale quantitative impact data is a limiting factor in this numerical vulnerability assessment. As such, the environmental sector is not divided into sub-sectors for analysis. Vulnerability metrics were chosen to reflect water based ecosystems, impaired aquatic areas and forest health hazard areas. As future monitoring and impact assessment work is completed these metrics should be updated. The limitations of this approach and suggestions for future expansion are discussed in the Section 8.6. Refer to Section 3.1 of Chapter 3 (Annex B) for a general description of the numerical methodology.

# 8.5 Vulnerability Metrics

## 8.5.1 Environment

### Spatial Density Metric

#### *Acres per county*

The spatial density metric for the environment is the total county area. This metric was chosen over protected or natural areas as a more accurate reflection of all natural areas. Future assessments will benefit from disaggregating based on wildlife, geography, and other defining factors and analyzing vulnerability for each subgroup individually.

### Impact Metrics

The impact metrics chosen focus on protected area status, existing impaired waters (i.e., water quality), general forest health, and presence of riparian habitat. There are six vulnerability metrics each weighted equally (17%) for the overall vulnerability score.

#### *Southwest Regional GAP stewardship status*

The Gap Analysis Project (GAP) was conducted in 2002 by the Division of Wildlife (DOW) which is now the CPW, University of Wyoming, and USGS Biological Resources Division and was a cooperative effort between DOW, the Natural Resource Ecology Center, and state, federal, and private natural resource groups in Colorado. Its major objectives were to: develop GIS databases to describe vegetation/land cover, terrestrial, vertebrate wildlife distributions, and land management status; identify land cover types and species that are not represented or under-represented in long-term management areas; and facilitate development and use of the information to allow for effective stewardship of Colorado’s natural resources. The information from this study is available online.[3]

The GAP project determined “stewardship” status across the State. Stewardship status denotes a relative degree of management for biodiversity maintenance for a particular tract of land. It is a ranking of 1 through 4 of land ownership categories and their internal biodiversity management boundaries and policies. The status categories can be generally defined as:

[3] http://fws-nmcfwru.nmsu.edu/swregap/

- an area having permanent protection from conversion of natural land cover and a mandated management plan in operation to maintain a natural state;
- an area like above, but which may receive use or management practices that degrade the quality of existing natural communities;
- an area having permanent protection from conversion of natural land cover for the majority of the area, but subject to uses such as logging and/or mining; and
- an area with no known public or private institutional mandates or legally recognized easements to prevent conversion of natural habitat types – generally allows conversion to unnatural land cover (Schrupp et al., 2000).

Status by county were tabulated to achieve an average ranking of 1 (least vulnerable) through 4 (most vulnerable) for the entire county.

#### *Impaired streams and water bodies*

These data were downloaded from the EPA's Reach Address Database (RAD). Impaired streams and water bodies were chosen as a metric based on the assumption that already-impaired water bodies are more apt to be negatively impacted by drought. The EPA's 303(d) Listed Impaired Waters program system provides impaired water data and impaired water features reflecting river segments, lakes, and estuaries designated under Section 303(d) of the Clean Water Act. Each state establishes "total maximum daily loads" (TMDLs) for these waters. The "impaired waters" layer does not represent all impaired waters reported in a state's Integrated Report, but only the waters comprised of a state's approved 303(d) list. Future analysis could expand the impaired water layer to include other state-recognized impaired waters. Some counties have no impaired waters. A large number of counties had no impaired streams or water bodies making the typical percentile thresholds invalid. Therefore, thresholds were adjusted to create equal bins for the non-zero data set. The adjusted percentile thresholds used were: 41%, 61%, and 81% for impaired reach length and 58%, 72%, and 86% for impaired water bodies.

#### *Bark beetle aerial extent*

Bark beetle infestation is having a profound effect on the health of Colorado's forests. The U.S. Forest Service and the Division of Parks and Recreation have been forced to close campgrounds in order to clear beetle-damaged trees in danger of falling, and spray high-value trees in an attempt to protect them (Finley, 2010). Data for the extent of beetle infestation is available from the USDA Forest Service, Forest Health Technology Enterprise Team who maintains an online spatial database of forest health data that can be queried and downloaded. The latest datasets, containing survey data from 2012 were obtained. The database was queried for areas of beetle infestation (all beetle types) for the entire period of record (1997-2012). The percentage of total acres in a county that fall within the hazard zone was calculated. A large number of counties had no beetle infestation making the typical percentile thresholds invalid. Therefore, thresholds were adjusted to create equal bins for the non-zero data set. The adjusted percentile thresholds used were: 47%, 65%, and 82%.

### *Wildfire Threat Area*

Wildfire threat data[4] developed by the Colorado State Forest Service was used to rank counties threat of wildfire. Threats were divided into six main categories: very low, low, moderate, high, very high and none. To isolate the high risk areas, moderate to very high zones were extracted to give a ranking by county. Some counties did not have any wildfire threat acreage. All counties have some amount of acreage with the moderate threat designation.

### *Instream flow rights*

The number and average priority date of instream flow rights per county was calculated using the primary county designation from the CWCB instream flow database. Reaches covering more than one county were assigned to their primary county designation. Nearly one third of counties have zero instream flow rights. Therefore, thresholds were adjusted to create equal bins for the non-zero data set. Instream flow rights historically have not been focused on protecting habitat; rather they ensure a minimum flow in a given stream. Future studies could be performed to assess the effectiveness of instream flows at protecting species and habitat that would otherwise be at risk. However, because instream flows often result in water being retained in a stream that may otherwise have been diverted, this metric is considered an adaptive capacity and is treated as such in the spreadsheet.

### *Riparian habitat*

Riparian habitat was approximated by use of USGS National Hydrography Dataset (NHD) flowlines. Flowlines were filtered for order in the NHD Value Added Attribute table in order to display various network densities and filter for mainstems and major tributaries. Once the flowlines were filtered, the reach length was summed by county. The counties with the highest summed river and stream lengths were considered most vulnerable, counties with the least stream length were considered least vulnerable for riparian habitat.

## 8.5.2 Results

The results of the numerical vulnerability assessment are presented here. The existing metrics used in the vulnerability tool are general indicators of environmental conditions and speak to broad areas that would potentially be impacted by drought. Vulnerability scores by county are presented in Table 8.3 and in Figure 8.7 and described in more detail below.

[4] https://www.coloradowildfirerisk.com

### Table 8.3. Vulnerability Rankings

| Counties | Overall Vulnerability Ranking |
| --- | --- |
| Alamosa, Archuleta, Chaffee, Cheyenne, Costilla, Custer, Dolores, Douglas, Eagle, Gilpin, Hinsdale, Huerfano, Kit Carson, Lake, Mineral, Montezuma, Ouray, Phillips, Pitkin, Rio Grande, Routt, Saguache, San Juan, San Miguel, Teller, Washington, Yuma | 1-1.9 |
| Adams, Arapahoe, Baca, Bent, Boulder, Broomfield, Clear Creek, Conejos, Crowley, Delta, Denver, El Paso, Elbert, Fremont, Grand, Gunnison, Jackson, Jefferson, Kiowa, La Plata, Las Animas, Lincoln, Logan, Moffat, Montrose, Morgan, Otero, Park, Prowers, Pueblo, Rio Blanco, Sedgwick, Summit | 2-2.9 |
| Garfield, Larimer, Las Animas, Mesa, Moffat, Weld | 3-3.9 |

**Counties scoring 1 or 2 for overall vulnerability:**

Many counties fit this category. In general, a 1 or a 2 ranking implies the county has a mix of attributes that overall do not add up to high vulnerability. For example, there could be protected lands, the county may have impaired waters but not extremely so, there are instream flow rights, etc. The nature of the environmental analysis is that each metric is weighted equally, so unless most or all of the metrics indicate high vulnerability, the overall result will be moderate. Also, there were two counties that originally had scores slightly less than 1, indicating a net adaptive capacity. The scores for these two counties were adjusted to 1 to reflect the fact that without more complete impact data it is inaccurate to designate counties as 'not impacted'. The 2013 update of this vulnerability study resulted in eleven counties changing from a ranking of 1 to 2[5] and Huerfano and Montezuma Counties changing from a ranking of 2 to 1. This is partially attributed to newly available data. For example, wildfire data was available for all counties during the 2013 update, whereas these data were limited for the 2010 version of the vulnerability study.

**Counties with a 3 or higher overall vulnerability score:**

There are three counties, Larimer, Weld, Las Animas, Garfield, Mesa and Moffat counties that had 3 or higher rankings following the 2013 update. In contrast the 2010 version of the vulnerability study had rankings of 3 or higher for Larimer, Garfield and Mesa. As described above, this is partially attributed to the availability of data as well as data revisions. To achieve vulnerability score of 3 or higher a county must rank highly in several of the impact categories. For example, Weld County moved into the higher vulnerability category because the amount of 303(d) impaired stream lengths (totaled by length) increased. Larimer County remained in the higher category because both the amount of impaired stream length and amount of beetle

[5] This includes the following counties: Sedgewick, Hinsdale, Denver, Arapahoe, Broomfield, Conejos, Summit, Jefferson, Gilpin, Logan and Dolores.

affected forest increased. The result for each of these counties is an overall high vulnerability ranking for environment.

## Figure 8.7. Environmental Vulnerability Ranking

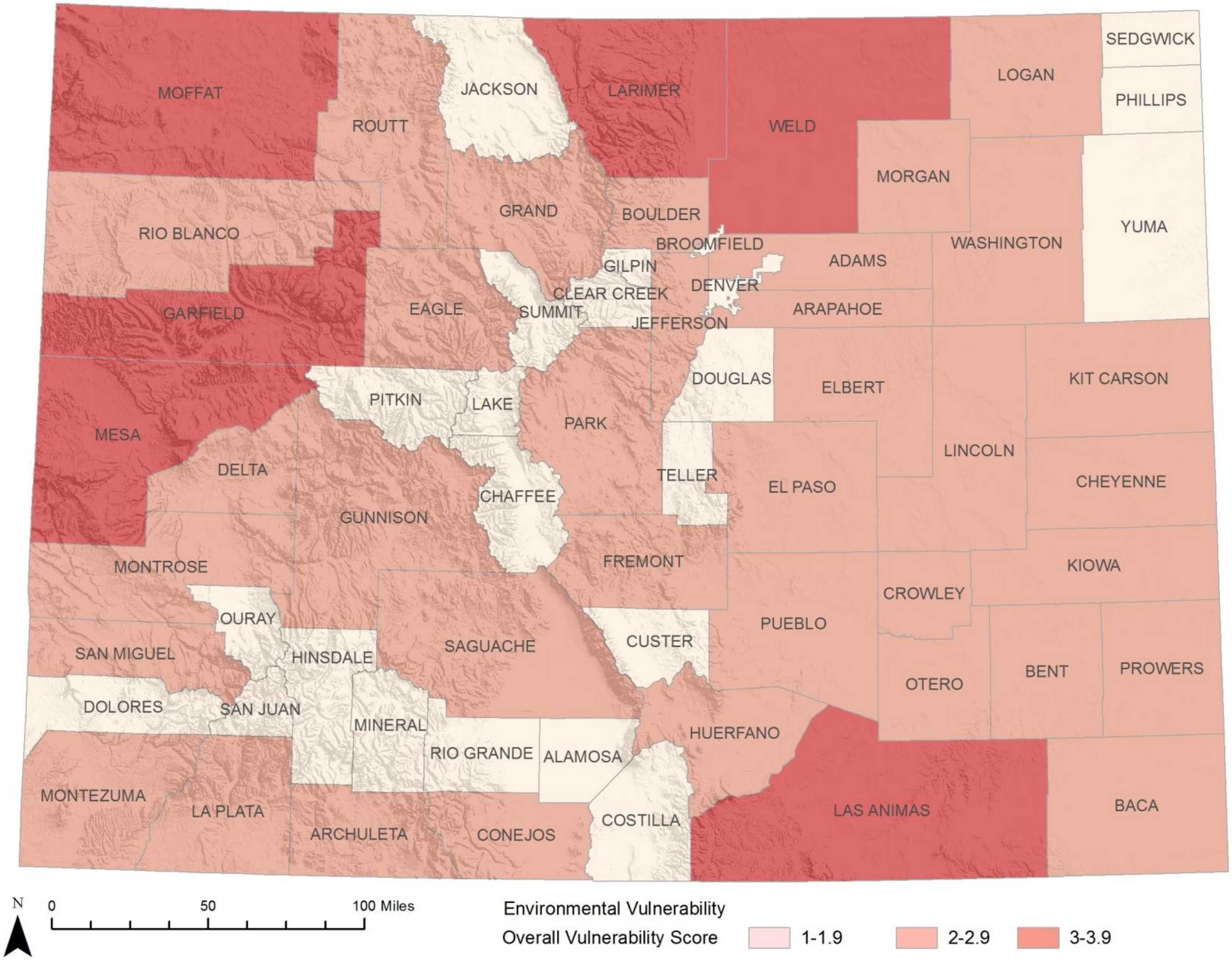



Figure revised with 2013 update

## 8.5.3 Spatial Analysis

Spatially it is difficult to identify trends given the broad nature of the vulnerability metrics used. There are bands of low vulnerability, such as in and immediately west of the San Luis Valley and in the northeastern portion of the State. Most of the State falls into the 2 category, as seen in Figure 8.7. One interesting result of this analysis is, unlike some of the other sectors, there is not a clear division between the eastern and western halves of the State. The concentrations of lowest vulnerability appear in the northeast, the Rio Grande basin, and the south-southwestern corner. In keeping with the vulnerability methodology of this project, all assessments were done on a county basis. However, in the case of environment political boundaries are probably less relevant than physical ones. Future work could investigate the same analysis aggregated on a basin scale. While overlaying the basins on the results map (Figure 8.8) does not reveal a clear trend, recalculating the metrics using watershed framework could alter the vulnerability landscape revealing spatial trends hidden by the county framework.

The sensitivity of this analysis is contained in the weighting given to the different vulnerability metrics. Without quantitative impact data it was determined that there was little basis for weighting some impact metrics more than others. As such, each factor was weighted equally to arrive at a combined vulnerability score. This approach has limitations in that most of the results show low to moderate vulnerability, and there is little distinction between aquatic factors like stream lengths and land-based vulnerability factors like bark beetle infestation. A suggestion for future analysis is to sub-divide the environment into aquatic and land-based flora and fauna and conduct a more detailed vulnerability analysis with metrics specific to the sub-sectors.

Additionally, further thought should be given to how the wildfire threat and beetle infestation layers are used. The wildfire threat layer is based off of 2008 survey data and cannot include weather information, an important variable controlling the ignition, spread, and behavior of wildfires. The beetle infestation data contains the spatial extent of all the years of survey data available (1997-2012). It may or may not be appropriate to treat all 16 years equally in the vulnerability calculation.

## Figure 8.8. Environmental Results with Watershed Divisions

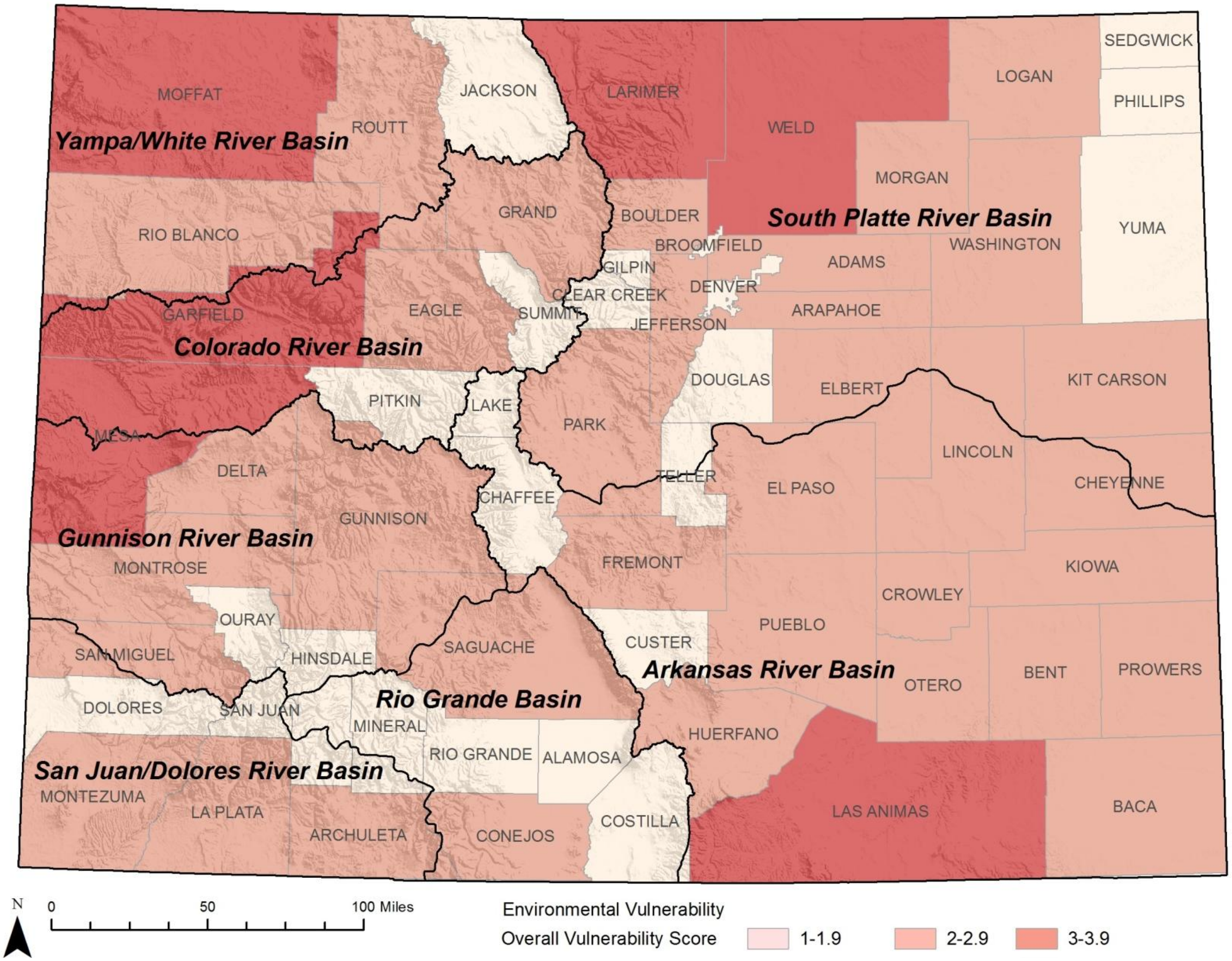



Figure revised with 2013 update

### 8.5.4 Compound Impacts

Compound impacts occur from when direct drought impacts cause additional effects themselves. The previous section presented the drought vulnerability ranking of the Environmental Sector as determined by the vulnerability tool. The condition of the environment extends to every aspect of the State, and impacts to this sector can compound across sectors and/or state assets to magnify overall vulnerability.

Damage to the environment has broad impacts to the Recreation Sector, which in turn affects regional economies by reducing visitation. Indirectly, services such as hotels, restaurants, groceries, gasoline, and retail are also impacted. Socially, this can result in loss of jobs, localized recessions in recreation and tourism-dependent counties, and overall hardship and depression. For other sectors in competition with the environment for water, drought can cause increased conflicts and other social tensions. A specific example is competition between the Agriculture Sector for irrigation water, the Recreation Sector for recreational use water, and the Environmental Sector for instream flows.

The operations of state assets, like Colorado Parks and Wildlife in particular, are reliant on environmental conditions. If a drought causes degradation of the environment and loss of wildlife habitat, visitation to the parks and open areas may decline. State revenue can suffer if significant visitation and licensing decreases occur. Also, during a drought state agencies may need to increase their management effort. This could include wildlife feeding programs or reservoir maintenance that comes with lower water levels. These efforts require funding, which during a drought could be lower than average, further stressing the department.

## 8.6 Recommendations

### 8.6.1 Adaptation to Drought

One effective way to safeguard the natural environment from drought impacts is to maintain a high level of environmental integrity so that when a drought occurs, the area is better able to withstand it. This applies to forest health, water quality, and wildlife. For example, CPW notes that streams designated as “gold medal” fisheries are expected to be less vulnerable to drought because of their strong ecological condition.

Other adaptive capacities include increased management on the part of state agencies (such as CPW) to identify areas that are experiencing environmental stress, followed by efforts to rehabilitate them. CPW and federal agencies did some of this in 2002, as they are for the 2011-2013 drought event.

CPW noted that threatened and endangered species were not severely impacted during the 2002 drought because so much attention was put on them from state and federal agencies. Where possible, stream levels were maintained for those endangered aquatic species, all in an attempt to help them survive the drought. Additionally, residual stock of these species is maintained in CPW hatcheries. Similar efforts could be expanded to other areas of the natural environment.

The first step would be to identify areas already under stress that would benefit from increased state attention during future drought. To accomplish this, a collaborative effort is recommended to identify these areas of environmental concern. The NCNA provides a good starting point for these efforts. However, further work is needed to evaluate NCNA findings on a county scale across the State and to incorporate drought specific information.

In the State Asset and Socioeconomic Sectors, it was noted that state agencies often incur additional costs during drought due to heightened management requirements. The resources required to achieve a collaborative drought analysis would require spending by the State, but the preparation efforts, especially if they result in increased awareness of existing support systems and linkages between agencies, could result in lower operating and management costs during times of drought.

### 8.6.2 Improving Vulnerability Assessment

It is difficult to put a dollar value on the natural environment, and possibly that is the reason environmental impacts from drought have not been quantified except as they relate to man-made elements (for example, environmental costs that force a reaction, like sediment and ash in the water supply forcing municipalities to clean the reservoir, or similarly degraded water quality in prime fishing streams forcing management agencies to salvage the fish for future anglers). The approach of this assessment has been to use readily-available data to identify attributes of the environment that would indicate vulnerability to drought. Available datasets were used where applicable and when available in a usable spatial format. While the need for additional monitoring and impact measurement is great, previous studies should not be overlooked. There is a significant amount of data available for Colorado that may be usable given additional analysis with respect to drought.

As of 2013, additional vulnerability indices are being developed by other organizations that may also be utilized in future analysis. For example, the Climate Change Vulnerability Index developed by NatureServe[6] is designed to identify plant and animal species that are particularly vulnerable to the effects of climate change. Since part of the tool involves a "climate wizard" that allows the user to specify the climate setting, the Climate Change Vulnerability Index tool could likely be adapted to drought scenarios. Part of the NatureServe vulnerability study includes a rating of species with multi-factor criteria (e.g., dispersal methods, reproductive patterns, distribution and habitat, natural history factors, and exposure), intended to help forecast whether a species will likely suffer a range contraction, population reductions, or both under climate change scenarios. This could also aid in identifying habitats more vulnerable to drought.

---

[6] Available at http://www.natureserve.org/prodServices/climatechange/ClimateChange.jsp.

Because there are a number of ongoing studies to classify ecosystems and assess their vulnerability to various climatic stressors, a collaborative effort to assess vulnerability of the natural environment to drought is recommended. This could include the CWCB, CPW, and any number of environmental groups such as The Nature Conservancy, NatureServe, and the Colorado Natural Heritage Program. An in-depth look at species vulnerability and habitat loss due to drought would provide a better statewide picture of vulnerable environmental species and habitats. The "Species of Greatest Conservation Need" identified by the CPW in their 2006 *Colorado's Wildlife Action Plan* and is a good start to this effort. This report identifies 210 species and 13 major habitats and incorporates Colorado GAP Analysis data to map species extent and land use. These data could be used to begin an analysis of drought vulnerability. Another study recently conducted by NatureServe and TNC included a detailed look at habitat and vegetation as it is impacted by climate change in specific portions of southwestern states (Utah, Colorado, New Mexico, and Arizona). Findings and data from that research could be incorporated into a drought vulnerability assessment. However, this analysis does not cover the entirety of each southwestern state. The basin-specific environmental subcategories identified by stream segment in the 2010 NCNA would also provide a geographic backdrop to any future vulnerability study.

Potential partners or stakeholders in environmental research were identified in the 2006 State Wildlife Action Plan (DOW, 2006). Table 8.4, taken from that report, lists these organizations and the taxonomic group in which they would likely be interested.

### Table 8.4. Potential Partners for Environmental Research

| Potential Partners | | | | | | |
|---|---|---|---|---|---|---|
| Organization or Type of Organization | Taxonomic Group(s) | | | | | |
| | All Taxonomic Groups | Invertebrates | Fish and Mollusks | Reptiles and Amphibians | Birds | Mammals |
| **Federal Agencies** | | | | | | |
| USDA Forest Service | x | | | | | |
| Bureau of Land Management | x | | | | | |
| U.S. Fish and Wildlife Service | x | | | | | |
| National Park Service | x | | | | | |
| U.S. Geological Survey | x | | | | | |
| Natural Resources Conservation Service/Farm Service Agency | x | | | | | |
| Bureau of Indian Affairs | x | | | | | |

| Potential Partners | | | | | | |
|---|---|---|---|---|---|---|
| **Organization or Type of Organization** | **Taxonomic Group(s)** | | | | | |
| | **All Taxonomic Groups** | **Invertebrates** | **Fish and Mollusks** | **Reptiles and Amphibians** | **Birds** | **Mammals** |
| Bureau of Reclamation | x | | | | | |
| U.S. Corps of Engineers | x | | | | | |
| Federal Emergency Management Agency | x | | | | | |
| **Tribes** | x | | | | | |
| **State Agencies** | | | | | | |
| Colorado Division of Wildlife | x | | | | | |
| State Forest Service | x | | | | | |
| State Universities | x | | | | | |
| Department of Natural Resources | x | | | | | |
| Department of Agriculture | x | | | | | |
| Department of Transportation | x | | | | | |
| Department of Health and Environment | x | | | | | |
| Water Quality Control Commission | x | | | | | |
| Colorado Natural Heritage Program | x | | | | | |
| Colorado State University Extension Offices | x | | | | | |
| Division of Parks and Outdoor Recreation | x | | | | | |
| Division of Water Resources | x | | | | | |
| Oil and Gas Commission | x | | | | | |
| Division of Minerals and Geology | x | | | | | |
| Water Conservation Board | x | | | | | |
| Great Outdoors Colorado | x | | | | | |
| **Local Government** | | | | | | |
| Cities | X | | | | | |
| Counties | X | | | | | |
| Water Conservancy Districts | X | | | | | |

| Potential Partners | | | | | | |
|---|---|---|---|---|---|---|
| **Organization or Type of Organization** | **Taxonomic Group(s)** | | | | | |
| | **All Taxonomic Groups** | **Invertebrates** | **Fish and Mollusks** | **Reptiles and Amphibians** | **Birds** | **Mammals** |
| **State Agriculture and Ranching Associations** (e.g., Colorado Cattlemen's Association, Farm Bureau, Colorado Wool Grower's Association) | X | | | | | |
| **Nongovernmental Organizations** | | | | | | |
| Rocky Mountain Bird Observatory | | | | | X | |
| Audubon (e.g., important bird area programs) | | | | | X | |
| The Nature Conservancy | X | | | | | |
| Colorado Natural Heritage Program | X | | | | | |
| Local land trusts | X | | | | | |
| Ducks Unlimited, Quail Unlimited, Pheasants Forever, Trout Unlimited, sport groups, etc. | | | x | | X | x |
| Joint ventures (e.g., Playa Lakes) | | | | | X | |
| Bird Conservation initiative | | | | | X | |
| Partners in Amphibian and Reptile Conservation | | | | x | | |
| Colorado Weed Management Association | X | | | | | |
| Colorado Association of Conservation Districts | X | | | | | |
| Environmental Defense | X | | | | | |
| Southern Rockies Ecosystem Project | X | | | | | |
| **Museums** | X | | | | | |
| **Zoos** | X | | | | | |

| Potential Partners | | | | | | |
|---|---|---|---|---|---|---|
| Organization or Type of Organization | Taxonomic Group(s) | | | | | |
| | All Taxonomic Groups | Invertebrates | Fish and Mollusks | Reptiles and Amphibians | Birds | Mammals |
| **Biological professional societies** (e.g., Colorado Herpetological Society, American Fisheries Society, The Wildlife Society) | X | | | | | |
| **Private sector** (e.g., land owners, pet shops, nurseries) | X | | | | | |
| **Watershed groups and other local environmental groups** | X | | | | | |

Recruiting some of these stakeholders for future drought vulnerability assessments would have significant benefits. Management agencies could bring their knowledge of wildlife areas, and economic impacts such as hunting, fishing, and camping revenue. These state and federal agencies are often on the forefront of environmental response, so involving them in this process could inform everyone as to the resources available between agencies. Bringing expert biologists and ecologists into the process could enhance the quantitative assessment with specific details about different species and habitat. Together, government agencies, environmental groups, and local user groups would have the connections and expertise necessary to identify environmentally vulnerable areas of the State.

CPW has been engaged with CSU to evaluate, among other things, the vulnerability of existing fish populations including cutthroat trout, mountain whitefish, sculpins, and wild spawning fish such as rainbow, brown, and brook trout. A report containing more detailed information regarding preparations for future droughts is scheduled to be completed at the end of 2010 (communication with DOW, 2010). In-depth studies such as this would benefit other subsectors of the environment beyond just fish species.

Finally, the NCNA (CWCB, 2010) provides a detailed inventory of environmental water uses within each basin. This report contains valuable aggregated information on aquatic areas of environmental importance. As previously noted this report can be used to guide future monitoring and impact assessment efforts. Also, given a revised spatial aggregation, these results could serve as the aquatic inventory metric in future disaggregated vulnerability assessments.

As additional data becomes available it is recommended that environmental vulnerability be divided into assessment sub-sectors. One simple division would be to consider aquatic and terrestrial habitats separately. The type of division will vary depending on the additional data to be incorporated and could eventually become quite complex.

## 8.7 References

Colorado Department of Public Health and the Environment. *Colorado Ecological Monitoring and Assessment Report.* 2007. Available at: http://www.cdphe.state.co.us/wq/WaterShed/ColoradoEMAPReport.pdf

Colorado Division of Forestry in conjunction with the Department of Natural Resources. *2001 Report on the Condition of Colorado's Forests.* 2001. Available at: http://csfs.colostate.edu/pdfs/01fhr.pdf

Colorado Division of Wildlife. "About the Division of Wildlife." No date. Accessed May 24, 2010. Available at: http://wildlife.state.co.us/About

Colorado Department of Wildlife, various managers. Written communication with AMEC, May 2010.

Colorado Department of Wildlife. *Colorado's Comprehensive Wildlife Conservation Strategy*. November 2, 2006. Prepared for the Citizens of Colorado and its Visitors by the Colorado Division of Wildlife.

Colorado Parks and Wildlife (2013). 2013 Fact Sheet.

Colorado Parks and Wildlife (2012). *2012 Drought Impacts*. Internal Communication.

Colorado State Forest Service (CSFS). Colorado Statewide Forest Resource Assessment: A Foundation for Strategic Discussion and Implementation of Forest Management in Colorado. 2008. Available online at: http://csfs.colostate.edu/pages/statewide-forest-assessment.html

Colorado State University Extension. "Impacts of Drought on Wildlife." Updated May 12, 2010. Accessed May 19, 2010. http://www.ext.colostate.edu/drought/wildlife.html

Colorado Water Conservation Board. Non-consumptive Needs Assessment Focus Mapping. July 2010. Prepared by Camp Dresser & McKee, Inc. and Amy Ackerman, Water Resources Specialist.

Colorado Water Conservation Board. 2011. Colorado's Nonconsumptive Needs and Project and Methods Implementation Fact Sheet. Accessed June 2013. Available at: http://cwcb.state.co.us/environment/non-consumptive-needs/Documents/NonconsumptiveFactSheet.pdf

Dean Runyan Associates. The Economic Impact of Travel on Colorado 1996-20011. November 2011. Prepared for the Colorado Tourism Office, Office of Economic Development and International Trade, Denver, Colorado.

DWSA (Drought and Water Supply Assessment), 2004. Colorado Water Conservation Board.

Enquist, Carolyn A.F., Evan H. Girvetz, and David F. Gori. A Climate Change Vulnerability Assessment for Biodiversity in New Mexico, Part II: Conservation Implications of Emerging Moisture Stress due to Recent Climate Changes in New Mexico. December 2008. Climate Change Ecology & Adaptation Program, The Nature Conservancy in New Mexico. Available at: http://nmconservation.org/dl/CC_report2_final.pdf

EPA. “303[d] Impaired Waters, Live Data and Maps.” Updated January 8, 2010. Accessed May 10, 2010. Available at: http://epamap32.epa.gov/radims/

Forest Health Management, Rocky Mountain Region, USDA Forest Service. *Sudden Aspen Decline in Colorado*. February 5, 2009. Available at: http://csfs.colostate.edu/pages/documents/sad_faqs_CSFS.pdf

Holsinger, Kent. Assistant Director for Water, Colorado Department of Natural Resources. Speaker, Luncheon Address at the Colorado Drought Conference, December 4, 2002. Co-sponsored by the Colorado Water Resources Research Institute and the Colorado Water Conservation Board.

Klett, J., B. Fahey, and R. Cox. *Native Trees for Colorado Landscapes*. Gardening Series, Trees & Shrubs, no. 7.421. Colorado State University Cooperative Extension, June 2002. Revised July 2008. Available at: http://www.ext.colostate.edu/pubs/garden/07421.pdf

Leatherman, D.A., I. Aguayo, and T.M. Mehall. *Mountain Pine Beetle*. Insect Series, Trees & Shrubs, no. 5.528. Colorado State University Cooperative Extension, February 1999. Revised April 2007. Available at: http://csfs.colostate.edu/pdfs/MPB.pdf

Lloyd, Jillian. “Pinwheels replace posies in flint-dry Boulder.” The Christian Science Monitor. July 17, 2002. Online article, accessed May 24, 2010. Available at: http://www.csmonitor.com/2002/0717/p02s02-ussc.html

McKee, Thomas B., Nolan J. Doesken, and John Kleist at the Colorado Climate Center Atmospheric Science Department CSU and Catherine J. Shrier with Colorado Water Resources Research Institute, in collaboration with William P. Stanton with the Colorado Water Conservation Board. *A History of Drought in Colorado: Lessons Learned and What Lies Ahead*. February 2000.

National Diversity Information Source (NDIS). “Colorado Division of Wildlife Riparian and Wetland Mapping Page, Wetland versus Riparian.” Webpage created by Dave Lovell and Seth McClean. Updated January 27, 2004. Accessed June 8, 2010. Available at: http://ndis1.nrel.colostate.edu/riparian/Ripwetdef.htm

Natural Resource Ecology Laboratory (NREL). “Human Impacts on the Colorado Life Zones,” presentation. 2009. Available at: http://www.nrel.colostate.edu/projects/gk12-track2/Projects/ColoradoLifeZones-HumanImpacts.ppt

NREL. “Colorado Ecoregions at the Province Level.” COMaP v6 data prepared by Grant Wilcox and Dr. David Theobald, NREL CSU, and Janis Whisman, Southpaw Consulting. March 4, 2007. Available at: http://www.nrel.colostate.edu/projects/comap/download_documents/Report_Tables_and_Maps/Figure9.pdf

Rocchio, Joe. *Rocky Mountain Alpine-Montane Wet Meadow Ecological System: Ecological Integrity Assessment.* Colorado Natural Heritage Program, Colorado State University. Fort Collins, CO. December 2005. Available at: http://www.natureserve.org/getData/pdf/rocky_mtns/Rocky_Mountain_Alpine-Montane_Wet_Meadow_assessment.pdf

Schrupp, D.L., W.A. Reiners, T.G. Thompson, L.E. O’Brien, J.A. Kindler, M.B. Wunder, J.F. Lowsky, J.C. Buoy, L. Satcowitz, A.L. Cade, J.D. Stark, K.L. Driese, T.W. Owens, S.J. Russo, and F. D’Erchia. 2000. Colorado Gap Analysis Program: A Geographic Approach to Planning for Biological Diversity – Final Report, USGS Biological Resources Division, Gap Analysis Program and Colorado Division of Wildlife, Denver, CO.

UC Berkeley Museum of Paleontology. “The world’s biomes: Alpine tundra.” No date. Accessed May 24, 2010. Available at: http://www.ucmp.berkeley.edu/exhibits/biomes/tundra.php#alp

University of Texas. Perry-Castañeda Library Map Collection. Reference map of Colorado, JPEG image, compiled by the USGS 2001. Accessed June 8, 2010. Available at: http://www.lib.utexas.edu/maps/us_2001/colorado_ref_2001.jpg

# 9 MUNICIPAL & INDUSTRIAL SECTOR

### Key Findings

- Although M&I water use comprises less than 10 percent of Colorado's overall water use, it is vital to sustaining the urban economy (CWCB, 2004).

- An M&I provider's vulnerability to drought depends on the reliability of a provider's water supply system and their ability to effectively respond to drought.

- Drought vulnerability can vary significantly among M&I providers. There are many complex factors including water supply, water distribution, water demand and adaptive capacity factors that influence the overall reliability of individual M&I water supply systems and their ability to respond to a drought. Each of these factors are unique to individual M&I providers and consequently water providers are effected in many different ways and magnitudes during a drought.

- A thorough statewide evaluation of M&I drought vulnerability would require a means to account for and incorporate the uniqueness of each M&I provider. Such an intensive effort is beyond the scope of this study. A qualitative assessment of M&I vulnerability at regional basin-wide level in addition to a survey distributed to M&I providers throughout the State was deemed to be appropriate for this study.

- CWCB is actively engaged in several processes to enhance the ability to further asses M&I drought vulnerability in the future. This includes the development of a Municipal Drought Management Plan Guidance Document, that informs M&I providers on how they may evaluate drought vulnerability and incorporate this information into their drought plans; and a Basin Needs Decision Support System that will include a database of useful information for future water supply planning efforts.

### Key Recommendations

- Encourage water supply reliability planning

- Develop state policy requiring/encouraging M&I providers to develop drought plans.

- Continue to provide technical and financial assistance to M&I providers for drought planning efforts.

- Ensure dissemination of CWCB technical information into drought and water supply reliability studies (i.e. Colorado River Water Availability Study and the Joint Front Range Climate Change Vulnerability Study)

- Develop a means to characterize water supply reliability at a more local level (i.e. by district) in future M&I drought vulnerability studies.
- Collaborate with the National Drought Mitigation Center (NDMC) in recording local impacts within the State by using NDMC's Drought Impact Reporter

## 9.1 Introduction to Sector

Although Municipal and Industrial (M&I) water use comprises less than 10% of Colorado's overall water use, it is vital to sustaining the urban economy.[1] M&I water is used to meet: domestic and residential needs; commercial uses including retail and professional services; institutional needs (i.e., schools and hospitals); and other industrial needs. Individual M&I providers are generally responsible for supplying their particular service area. The source of water supplies, reliability and particular demands of a provider's customer base is unique to each individual provider.

In 2011, Colorado's population was approximately 5.2 million[2] with the majority of people living along the Front Range in the Arkansas and South Platte Basins between Fort Collins and Pueblo. This is shown in Figure 9.1.

[1] CWCB. 2004. *Statewide Water Supply Initiative (SWSI*). Prepared by: CDM.
[2] The population estimates provided in this section are based on the 2011 population data provided by the Department of Local Affairs.

## Figure 9.1. 2011 County Population Estimates

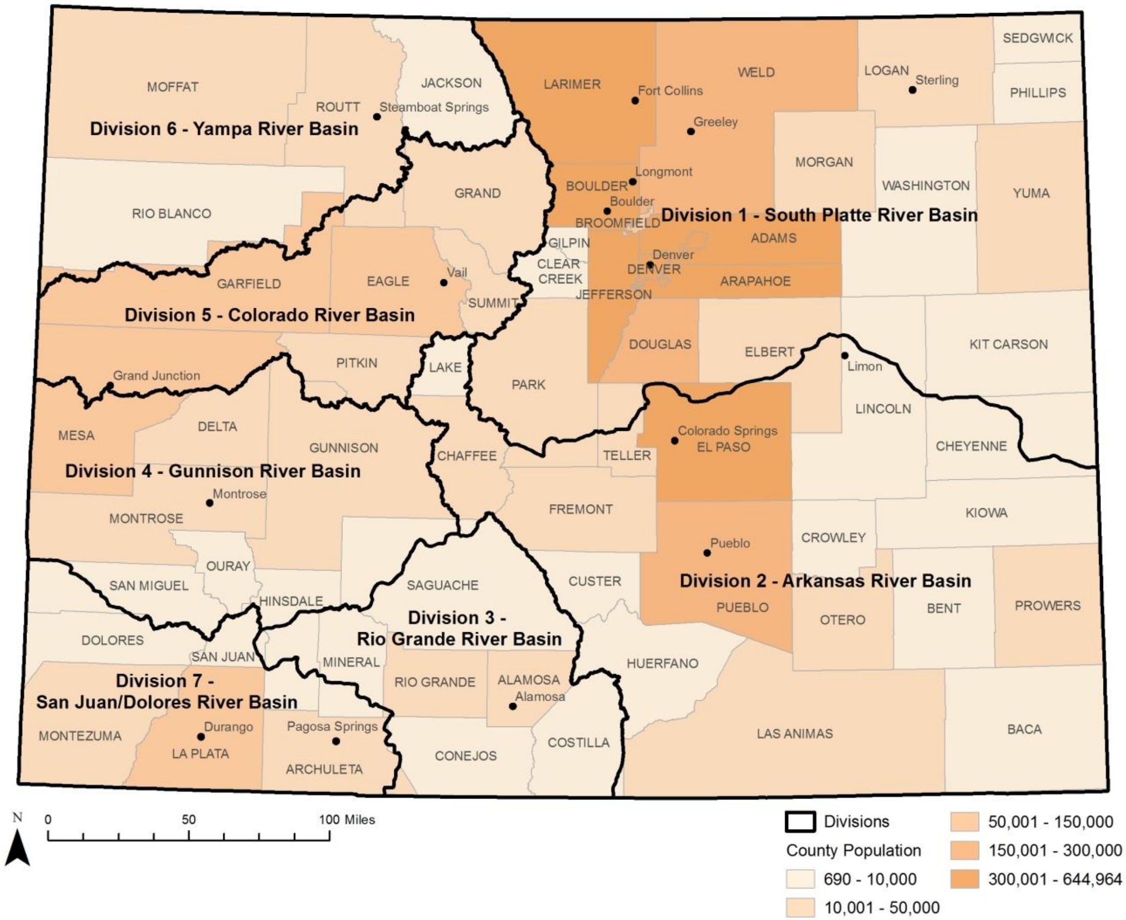



Figure revised with 2013 update

The State's population is expected to double by 2050 to between 8.6 and 10.0 million people (CWCB, 2010), consequently, M&I water demands are projected to increase from 977,000 acre-feet in 2008 to approximately 1.5 million acre-feet by 2035. Water demands in 2050 could range from 1.7 to 1.9 million acre-feet (CWCB, 2010). Figure 9.2 shows that the majority of projected M&I water use in 2050 is likely to occur in the South Platte, Arkansas, and Colorado River Basins[3]. This growth will place a greater demand on the State's limited water resources, especially during periods of drought. As the State continues to develop, it will be crucial that M&I providers take into account drought preparedness in their water supply reliability planning efforts to ensure that essential demands can be met during periods of deficits.

[3] The data presented in Figure 9.2 is based on the Baseline M&I forecast for the medium 2050 growth scenario presented in *Final State of Colorado 2050 Municipal and Industrial Water Use Projections*.

## Figure 9.2. Projected County Water Demands in 2050

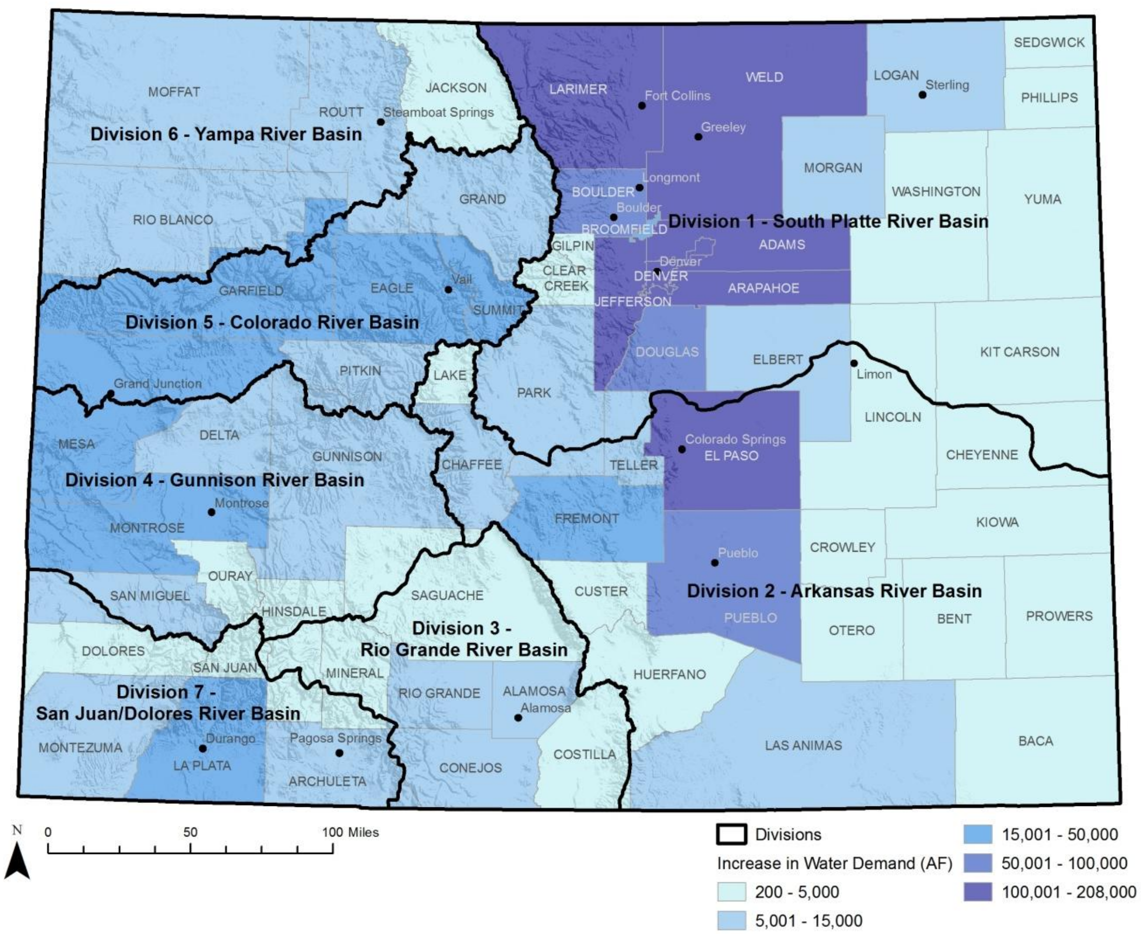



Figure revised with 2013 update

The vulnerability of the M&I sector to drought is an important consideration for water managers and planners. Given the complex nature of water rights portfolios held by many M&I providers, costs associated with completing a comprehensive statewide analysis and a lack of available data, it was determined that a high level quantitative analysis of the M&I sector would not be feasible. Consequently, a series of surveys conducted in 2004, 2007 and 2013 were used to characterize impacts and adaptive capacities and qualitatively assess drought vulnerability. While this approach may not capture all the aspects of M&I drought vulnerability, it does provide additional information that was not previously available.

## 9.2 Vulnerability of M&I Sector to Drought

### 9.2.1 Drought and Seasonal Variability

M&I water demands in Colorado vary significantly throughout the year. A significant portion of residential water use is for outdoor purposes, typically occurring during the summer months (June through mid-September).

Many M&I providers in Colorado rely on mountain runoff from snowpack during the spring to meet water demands. Consequently, M&I providers frequently monitor snowpack conditions from January through April for drought forecasting purposes, as this is when the mountain areas receive the greatest amount of snow. Reservoir levels and other drought indicator data are also monitored closely throughout the year in order to determine water supply conditions, and to help assess whether any level of drought response is necessary. Drought response may be more intensive during consecutive drought years which can further stress water supplies and significantly decrease providers' water storage.

## 9.3 Assessment of Impacts and Adaptive Capacities

This assessment relies on a variety of surveys conducted by the CWCB. This includes the 2004 Drought and Water Supply Assessment (DWSA) survey, the 2007 Drought and Water Supply Update (DWSU) survey and a newly conducted survey from 2013. The DWSA 2004 involved a comprehensive survey to evaluate the State's drought preparedness, and identification of measures that could improve the State's future preparedness. A total of 241 municipalities responded to this survey providing information on impacts experienced during the 1999-2003 dry period.[4] Information was also utilized from the follow-up DWSU survey in 2007, which involved a comprehensive M&I provider survey of 200 municipalities. While the 2007 survey did not address specific drought-related impacts, general information was obtained on municipal providers' water resources planning efforts (adaptive capacities) and drought awareness at a basin-wide level. As a component of the 2013 State Mitigation Plan update, CWCB conducted an additional municipal drought survey in May of 2013 to characterize statewide M&I impacts, adaptive capacities and vulnerability for the recent droughts that occurred in the early 2000s and in 2012/2013. Eighty-six survey responses were received statewide.[5] Table 9.1 shows the number of survey responses for each of the seven major river basins of the State. This survey was not intended to be a statistically significant survey but to rather collect M&I drought related information that was previously not available.

[4] The DWSA 2004 survey was developed with significant input, design, communiqués, rewrites, internal testing, before the instrument was finalized with the approval of the CWCB, GEO, and DOLA. Despite this comprehensive process, these data only provide a general indication of impacts. The perceived severity and interpretation of the listed impacts are subject to the interpretation of the provider being surveyed.

[5] While 84 water providers responded to the survey, some providers did not respond to all of the questions.

**Table 9.1. Survey Responses by Basin for the 2013 CWCB Drought Survey**

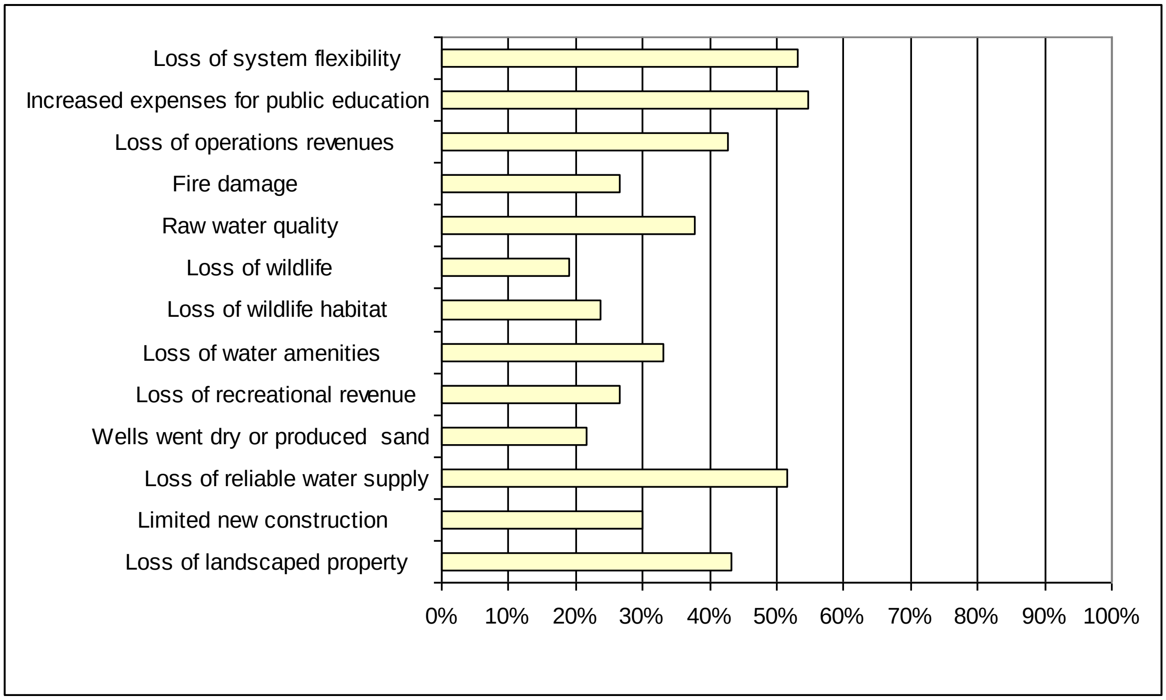
| Basin | Response Percent | Response Count |
|---|---|---|
| Division 1 - South Platte Basin | 48.8% | 42 |
| Division 2 - Arkansas River Basin | 11.6% | 10 |
| Division 3 - Rio Grande River Basin | 3.5% | 3 |
| Division 4 - Gunnison River Basin | 8.1% | 7 |
| Division 5 - Colorado River Basin | 12.8% | 11 |
| Division 6 - Yampa River Basin | 5.8% | 5 |
| Division 7 - San Juan/Dolores River Basin | 9.3% | 8 |

## 9.3.1 Potential Impacts

Municipalities may experience a variety of drought-related impacts. Figure 9.3 provides the percentage of surveyed M&I providers statewide that experienced given impacts from the 2004 DWSA survey. The loss of system flexibility, increased expenses for public education, and loss of reliable water supply were the most frequently experienced impacts statewide.[6]

[6] The DWSA 2004 survey used the 5-point Likert Scale, with 1 representing no impacts and 2-5 reflecting the severity of the impact with a 5 being of greatest severity. All impacts data presented in this section reflects providers that gave an impact rating of 2-5.

### Figure 9.3. 2004 DWSA Survey M&I Statewide Impacts[7]




Source: DWSA 2004 survey data.

Additional impacts commonly experienced by M&I providers that were not included in the DWSA survey are included in Table 9.2.

### Table 9.2. Provider Specific Drought Impacts

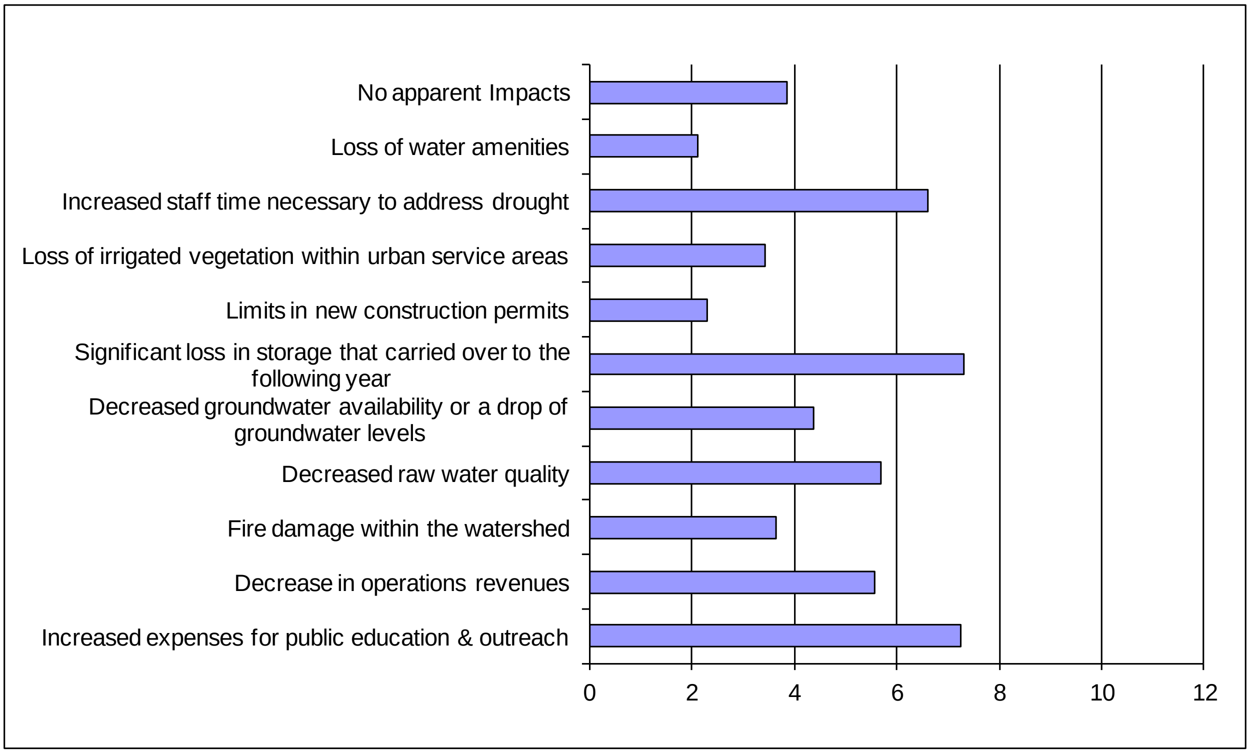
| | |
|---|---|
| Reduction in M&I well production | Increased costs and staff time to implement drought plan |
| Reduction in storage reserves | Increased data/information needs to monitor and implement drought mitigation plan |
| Disruption of water supplies | Costs to acquire/develop new water supplies/water rights transfers |
| Degraded water quality | Costs to increase water use efficiency |
| Higher water treatment costs | Public perception regarding drought response |
| Sediment and fire debris loading to reservoirs following a wildfire | Scarcity of equipment and other water related services (i.e., contractors to repair wells) |

The 2013 CWCB drought survey addressed the frequency and relative level of M&I impacts that occurred during the 2012 drought, anticipated impacts in 2013 and the duration of residual effects from the 2002 drought. Figure 9.4 presents the frequency of drought impacts where a ranking of 12 designates the highest frequency and most severe of impacts and a 0 represents the

[7] Note: A comprehensive review and internal testing process of the survey tool was conducted, yet it is important to recognize that these DWSA 2004 surveyed impact results are subjective. The impacts in the figure in many cases are a reflection of the DWSA's authors interpretation of the listed impacts.

lowest level of impact. The impacts with the highest ranking were 1) a significant loss in storage that carried over the following year and 2) increased expenses for public education & outreach whereas the lowest ranking impacts were 1) the loss of water amenities and 2) limits in new construction permits.

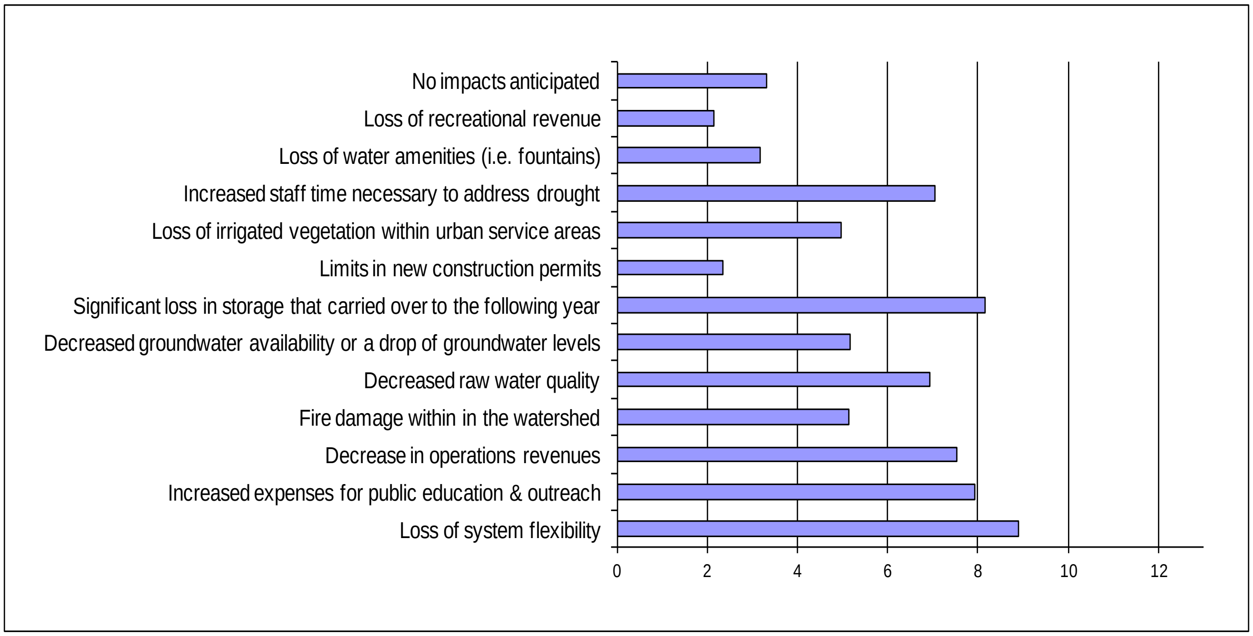
**Figure 9.4. Frequency and Relative Level of Impacts During the 2012 Drought**




Source: CWCB 2013 drought survey data
Note: These results are based on 46 survey responses

Figure 9.5 presents the anticipated impacts for 2013 statewide where a ranking of 0 represents impacts of no concern and a ranking of 12 denotes impacts of highest concern. The loss of system flexibility followed by significant loss in storage that carried over the following year was of greatest concern. Increased staff time necessary to address drought and increased expenses for public education and outreach were also among the higher rankings. Loss of recreational revenue and limits in new construction permits were of least concern to those who responded.

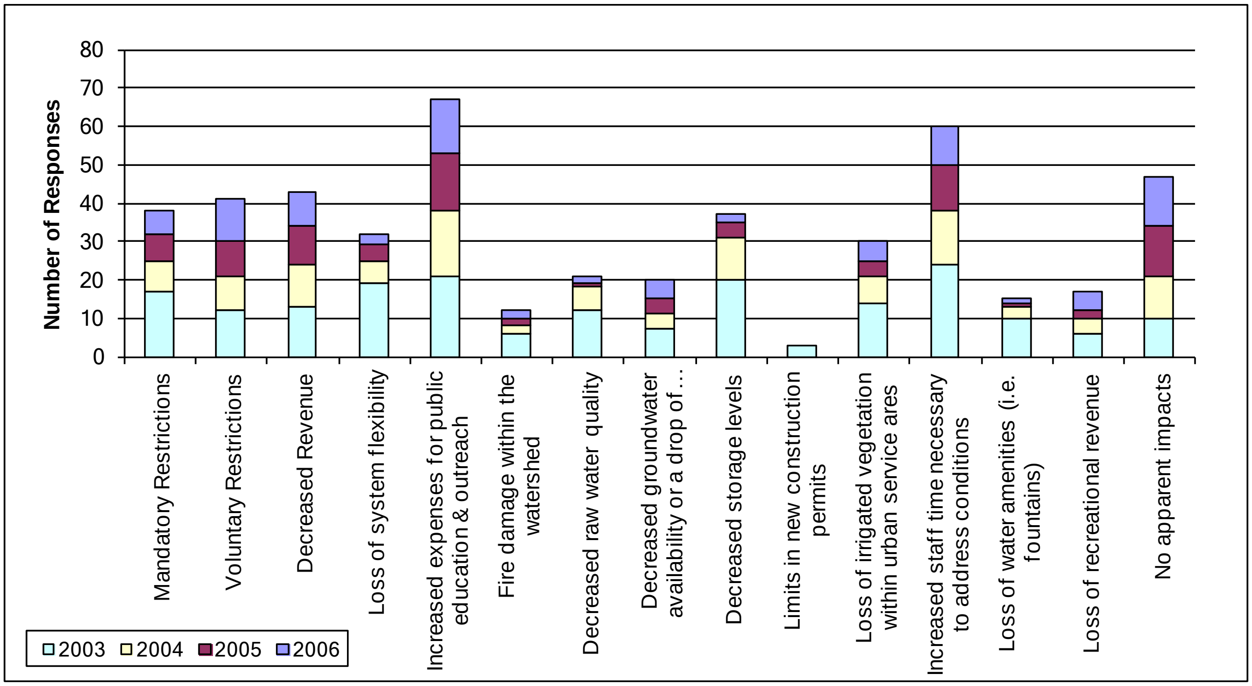
## Figure 9.5. Statewide Anticipated Impacts For 2013




Source: CWCB 2013 drought survey data
Note: These results are based on 46 survey responses

Figure 9.6 shows the statewide residual effects of the 2002 drought from 2003 to 2006. Impacts experienced for the longest duration included the increased expenses for public education & outreach, followed by the increased staff time necessary to address conditions. The impact of shortest duration, limits in construction permits, was only experienced in 2003. Of the 46 respondents, an average of 12 (from 2003 to 2006) indicated that they did not experience impacts following the 2002 drought.

**Figure 9.6. Statewide Residual Effects from the 2002 Drought**




Source: CWCB 2013 drought survey data
Note: These results are based on 46 survey responses

Table 9.3 lists the highest ranking impacts identified by the respondents of the 2013 CWCB drought survey by basin. Similar to the statewide results described above, the highest ranking impacts were 1) loss of system flexibility, 2) significant loss in storage that carried over to the following year, 3) increased staff time necessary to address drought and 4) increased expenses for public education and outreach. Although additional studies (i.e. statistically significant surveys with a larger sampling pool size) would be necessary to confirm the results, it may be concluded from both the 2004 DWSA and 2013 CWCB drought survey that state and local efforts targeting the mitigation of these specific impacts could reduce M&I drought vulnerability throughout the State. Efforts could also be made to focus on other high ranking impacts identified at a basin-by-basin level. For instance, the decrease in groundwater availability is a high ranking impact in the Rio Grande Basin. Actions could be taken in advance of a drought to mitigate for such an impact by making arrangements with other entities for replacement supplies in times when groundwater resources are depleted.

## Table 9.3. Highest Ranked Basin Impacts

| Basin | Impacts During 2012 | Anticipated Impacts for 2013 | Longest Residual Effects from 2002 to 2006 |
|---|---|---|---|
| South Platte Basin | 1) Loss of system flexibility<br>2) Significant loss in storage that carried over to the following year<br>3) Increased staff time necessary to address drought<br>23 *respondents* | 1) Loss of system flexibility<br>2) Significant loss in storage that carried over to the following year<br>3) Increased staff time necessary to address drought<br>23 *respondents* | 1) Increased expenses for public education & outreach<br>2) Increased staff time necessary to address conditions<br>3) Voluntary restrictions<br>23 *respondents* |
| Arkansas Basin | 1) Loss of water amenities<br>2) Increased staff time necessary to address drought<br>3) Loss of irrigated vegetation within urban service areas<br>7 *respondents* | 1) Loss of system flexibility<br>2) Significant loss in storage that carried over to the following year<br>3) Loss of recreational revenue<br>7 *respondents* | 1) Decreased storage levels<br>2) Loss of irrigated vegetation<br>3) Increased staff time necessary to address drought<br>4) Mandatory restrictions<br>5) Increased expenses for public education & outreach<br>7 *respondents* |
| Rio Grande Basin | 1) Decreased groundwater availability<br>2) Significant loss in storage that carried over to the following year<br>3) Loss of system flexibility<br>1 *respondent* | 1) Loss of system flexibility<br>2) Significant loss in storage that carried over to the following year<br>3) Decrease in operations revenue<br>1 *respondent* | 1) Loss of system flexibility<br>2) Increased expenses for public education & outreach<br>3) Decreased groundwater availability<br>4) Decreased storage levels 5) Increased staff time necessary to address drought<br>6) Loss of recreational revenue<br>1 *respondent* |
| Gunnison Basin | 1) Loss of system flexibility<br>2) Significant loss in storage that carried over to the following year<br>3) Increased staff time necessary to address drought<br>3 *respondents* | 1) Loss of system flexibility<br>2) Significant loss in storage that carried over to the following year<br>3) Increased staff time necessary to address drought<br>3 *respondents* | 1) Loss of system flexibility<br>2) Decreased raw water quality<br>3) Increased staff time necessary to address drought<br>3 *respondents* |

| Basin | Impacts During 2012 | Anticipated Impacts for 2013 | Longest Residual Effects from 2002 to 2006 |
|---|---|---|---|
| Colorado Basin | 1) Decreased raw water quality<br>2) Loss of system flexibility<br>3) Increased expenses for public education & outreach<br>7 *respondents* | 1) Increased expenses for public education & outreach<br>2) Loss of system flexibility<br>3) Decreased raw water quality<br>7 *respondents* | 1) Voluntary restrictions<br>2) Mandatory restrictions<br>3) Increased expenses for public education & outreach 4) Decreased storage levels<br>7 *respondents* |
| Yampa Basin | 1) Loss of irrigated vegetation within urban service areas<br>2) Significant loss in storage that carried over to the following year<br>3) Decrease in groundwater availability or drop of groundwater levels<br>2 *respondents* | 1) Loss of irrigated vegetation within urban service areas<br>2) Significant loss in storage that carried over to the following year<br>3) Decrease in groundwater availability or drop of groundwater levels<br>2 *respondents* | No apparent impacts<br><br>2 *respondents* |
| San Juan/Dolores Basin | 1) Increase staff time necessary to address conditions<br>2) Limits in new construction permits<br>3) Loss or irrigated vegetation within urban service areas<br>3 *respondents* | 1) Limits in construction permits<br>2) Loss of irrigated vegetation with urban service areas<br>3) Loss of recreational revenue<br>4) Increased staff time necessary to address conditions<br>3 *respondents* | 1) Voluntary restrictions<br>2) Decreased revenue<br>3) Increased expenses for public education and outreach<br>4) Decreased storage levels<br>5) Increased staff time necessary to address conditions<br>3 *respondents* |

Source: CWCB 2013 drought survey data

Notes: The ranking is based on the frequency and perceived intensity of impact

## 9.3.2 Adaptive Capacity Actions

M&I drought vulnerability can be reduced significantly through the implementation of adaptive capacity actions to mitigate drought impacts and respond to a drought. As previously mentioned, mitigation refers to actions taken in advance of a drought event that reduce potential drought-related impacts. Response actions are implemented to address drought when it occurs. Table 9.4 provides a list of long-term mitigation and short-term response actions. Many of these items may either be implemented as long-term mitigation or as short-term response actions.

**Table 9.4. Long and Short Term Mitigation Actions**

| Adaptive Capacity - Mitigation and Response Actions | Long-term Mitigation | Short-term Response Actions |
|---|---|---|
| **Elements of a Drought Management Plan** | | |
| Establish drought response principles, objectives, and priorities | X | |
| Establish authority & process for declaring a drought emergency | X | |

| Adaptive Capacity - Mitigation and Response Actions | Long-term Mitigation | Short-term Response Actions |
|---|---|---|
| Develop drought stages, trigger points, and response targets | X | |
| Prepare ordinances on drought measures | X | |
| Evaluate historical drought impacts | X | |
| Monitor drought indicators (e.g., snow pack, stream flow, etc.) | X | X |
| Monitor water quality | X | X |
| Track public perception and effectiveness of drought measures | X | X |
| Improve accuracy of runoff and water supply forecasts | X | |
| **Emergency Response** | | |
| Declare a drought emergency | | X |
| Establish water hauling programs | X | X |
| Restrict/prohibit new taps | | X |
| Identify state and federal assistance | X | X |
| Provide emergency water to domestic well users | | X |
| Import water by truck/train | | X |
| **Public Education and Relations** | | |
| Establish a public advisory committee during drought planning and/or drought response efforts | X | X |
| Develop Drought Public Education Campaign with long-term and short-term strategies | X | X |
| Educate provider/municipal staff on how to save water | X | X |
| Provide instructional resources to business on developing an office/business specific drought mitigation and response plan | X | X |
| Provide acoustical meters to assist customers in identifying leaks | X | X |
| **Water Supply Augmentation** | | |
| Establish drought reserves | X | |
| Draw from drought reserves | | X |
| Increase groundwater pumping | | X |
| Deepen wells | X | X |
| Develop supplemental groundwater/conjunctive use | X | |
| Reactivate abandoned wells | | X |
| Flush existing wells to develop maximum flow rates | X | X |
| Blend primary supply with water of lesser quality to increase supplies | | X |
| Rehabilitate operating wells | X | X |
| Employ desalination of brackish groundwater | X | |
| Increase use of recycled water | X | X |
| Utilize ditch water or treated effluent for irrigating landscaping/parks | X | X |
| Build new facilities to enhance diversion or divert new supplies | X | |
| Lower reservoir intake structures | X | X |
| Use reservoir dead storage | | X |
| Acquire additional storage | X | |
| Build emergency dams | X | X |

| Adaptive Capacity - Mitigation and Response Actions | Long-term Mitigation | Short-term Response Actions |
|---|---|---|
| Reactivate abandoned dams | X | X |
| Cloud seeding | X | X |
| **Water Rights Management and Cooperative Agreements**[8] | | |
| Call back water rights that others are allowed to use | | X |
| Pay senior water user to not place a "call" on the river | | X |
| Pay upstream water user to allow diversion of more water | | X |
| Purchase water from other entities (e.g, neighboring cities, federal projects) | | X |
| Arrange for exchanges | X | X |
| Lease irrigation rights from farmers | | X |
| Lease private wells | | X |
| Cancel M&I leases of water to farmers | | X |
| Use irrigation decrees | | X |
| Invoke drought reservations that allow reduction in bypass requirements | | X |
| Negotiate purchases or “options” | X | X |
| Renegotiate contractually controlled supplies | X | X |
| Develop water transfers with other entities | X | X |
| Develop water bank to facilitate water transfers in times of drought | X | |
| Develop interconnects with other entities | X | X |
| Trade water supplies with other entities to increase yield | | X |
| **Improve Water Distribution Efficiency** | | |
| Conduct distribution system water audit | X | X |
| Repair leaks in distribution system | X | X |
| Reduce distribution system pressure | | X |
| Replace inaccurate meters | X | |
| Calibrate all production, commercial, industrial, and zone meters | X | |
| Install meters at key distribution points to isolate areas of overuse and probable leakage | X | |
| Minimize reservoir spills | X | X |
| Change operations to optimize efficiency and distribution of supplies | X | X |
| Change pattern of water storage and release operations to optimize efficiency | X | X |
| Reduce reservoir evaporation (i.e., reduce storage in reservoirs with high evaporation rates) | X | X |
| Reduce reservoir seepage (i.e., reduce storage in reservoirs with high seepage rates) | X | X |

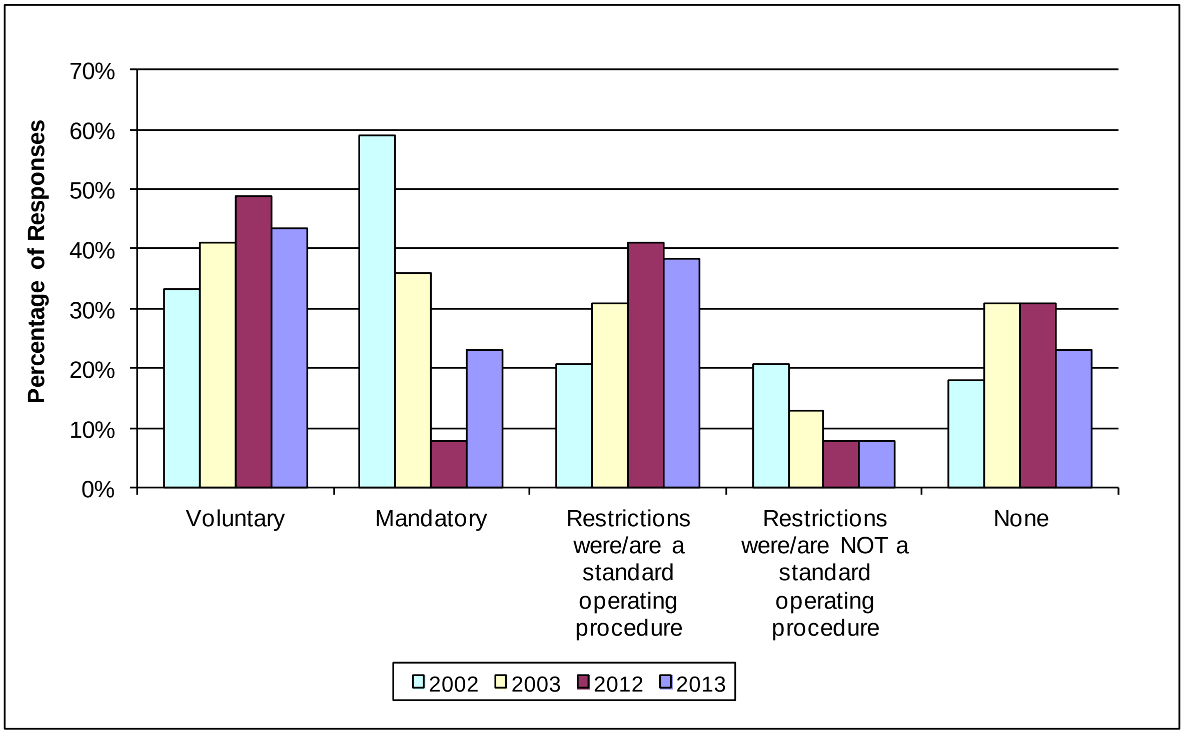
[8] Cooperative agreements are becoming increasingly important within Colorado, creating flexibility within the otherwise rigid prior appropriation system. Cooperative agreements provide the means to allow for temporary transfers of water between users, and allow for the more efficient use of water in periods of water scarcity. For example, agricultural users can utilize cooperative agreements to allow for the temporary lease, exchange and/or transfer of water to a needy municipal entity, when the limited availability of water may have impacted crop yield or production. In this way, the agricultural community can find sources of revenue while municipalities find emergency and/or short-term water supplies in dry and drought years.

| Adaptive Capacity - Mitigation and Response Actions | Long-term Mitigation | Short-term Response Actions |
|---|---|---|
| Recirculate wash water | X | |
| Enhance efficiency of water treatment facilities | X | |
| **Demand Management** | | |
| Establish and enforce percent water use reduction goals | X | X |
| Identify high water use customers and develop water saving targets | X | X |
| Implement conservation measures that also provide water saving benefits during drought periods (i.e., water fixture rebates) | X | |
| Establish and enforce percent water use reduction goals | X | X |
| Identify high water use customers and develop water saving targets | X | X |
| Implement conservation measures that also provide water saving benefits during drought periods (i.e., water fixture rebates) | X | |
| Adopt a modified rate structure for drought periods | X | X |
| Implement drought surcharges | | X |
| Provide historical monthly water usage on water bills | X | X |
| Restrict the issuance of new taps | | X |
| Prohibit/limit use of construction water | | X |
| Limit/prohibit installation of new sod, seeding, and/or other landscaping | | X |
| Develop policy guidelines/limitations for installation of new sod and/or other landscaping | X | X |
| Conduct irrigation audits on parks and open spaces | X | X |
| Promote residential/commercial irrigation audits | | |
| Eliminate/reduce irrigation on municipal parks and other landscaping (i.e., street medians) | X | X |
| Enforce landscape watering restrictions | X | X |
| Limit outdoor watering to specific times of the day | X | X |
| Limit number of watering days per week | X | X |
| Set time limit for watering | X | X |
| Prohibit watering during fall, winter, and early spring | | X |
| Promote/enforce conversion of sprinkler to low volume irrigation where appropriate | X | |
| Enforce restrictions on outdoor misting devices | | X |
| Reduce/eliminate street cleaning, sidewalk, and driveway washing | | X |
| Prohibit/limit non-recirculating fountains in buildings and parks | | X |
| Turn off public drinking fountains | | X |
| Limit/prevent washing of municipal fleet vehicles | | X |
| Prohibit/limit residential vehicle washing | | X |
| Prohibit/limit dealership washing of vehicles | | X |
| Enforce water use restrictions on commercial car washes | | |
| Promote commercial car washes to install water recycling technology and/or other BMPs | X | X |
| Limit hydrant washing and flushing | | X |
| Limit use of water for fire training | | X |

| Adaptive Capacity - Mitigation and Response Actions | Long-term Mitigation | Short-term Response Actions |
|---|---|---|
| Prohibit/limit filling and use of swimming pools | | X |
| Conduct/promote indoor water audits for commercial and residential sector | X | X |
| Enforce indoor water restrictions | | X |
| Install water saving fixtures, toilets, and/or appliances | X | |
| Require water efficient fixtures and/or appliances on house resale or remodeling | X | |
| Promote/require graywater use | X | X |
| Promote/conduct indoor audits | X | X |
| Promote/enforce reduction of water-cooled air conditioning | | X |
| Promote service of water in restaurants only upon request | X | X |
| Promote reduction in frequency of linen and towel washing in hotels | X | X |
| Promote/encourage conversion of cooling towers and other industrial water using processes | X | |
| Require buildings with water cooled air conditioning to raise the temperature modestly | | X |

The CWCB 2013 drought survey provides information on water providers' adaptive capacities. The statewide results of the survey are presented in Figures 9.7 through 9.10 below. Figure 9.7 shows the percentage of survey respondents who implemented water restrictions during 2002/2003, during 2012 and are anticipating implementing restrictions during 2013. These results show that mandatory water restrictions were implemented by 59% of the survey respondents during 2002. This was significantly lower in 2012, when only 8% of the survey respondents implemented mandatory restrictions. This is largely attributed to the fact that during 2012, many providers relied upon normal to above-normal reservoir storage to meet customer demands yet implemented voluntary restrictions in response to the drought. The percentage of respondents planning to implement mandatory restrictions in 2013 is much higher than 2012. This is likely attributed to below average reservoir storage and that severe to exceptional drought conditions are anticipated for a large portion of Colorado. Figure 9.7 also indicates that a larger percentage of the respondents generally considered water restrictions as a standard operating procedure in 2012 when compared to the drought in 2002/2003. This suggests that more water providers may be using water restrictions as a means to manage water demand during dry periods. Twenty-six percent of the respondents did not implement water restrictions in 2002/2003 or 2012/2013.

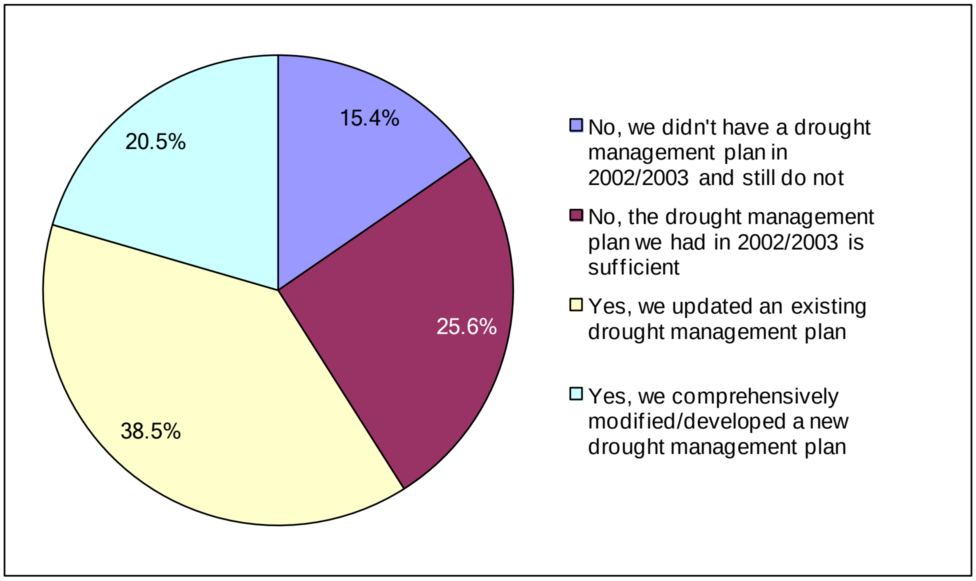
**Figure 9.7. Water Restrictions**




Source: CWCB 2013 drought survey data
Note: These results are based on 39 survey responses

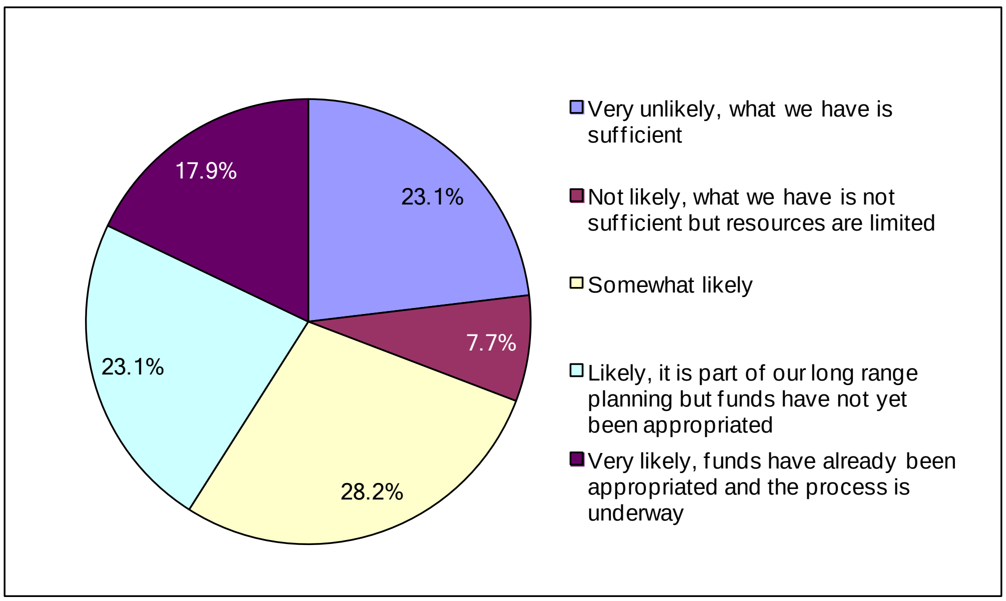
Figure 9.8 shows that 59% of survey respondents have either updated or performed a comprehensive revision to their drought management plan since 2002 while 15% of respondents do not have a drought management plan. Figure 9.9 indicates that 51% of respondents will likely improve their system's level of drought preparedness following the 2012/2013 drought event. Sixty-seven percent of respondents expressed that there is sufficient funding either in-basin or through State and Federal sources to fund water supply reliability, conservation and drought planning efforts. This is shown in Figure 9.10.

## Figure 9.8. Drought Management Plan Update Since 2002



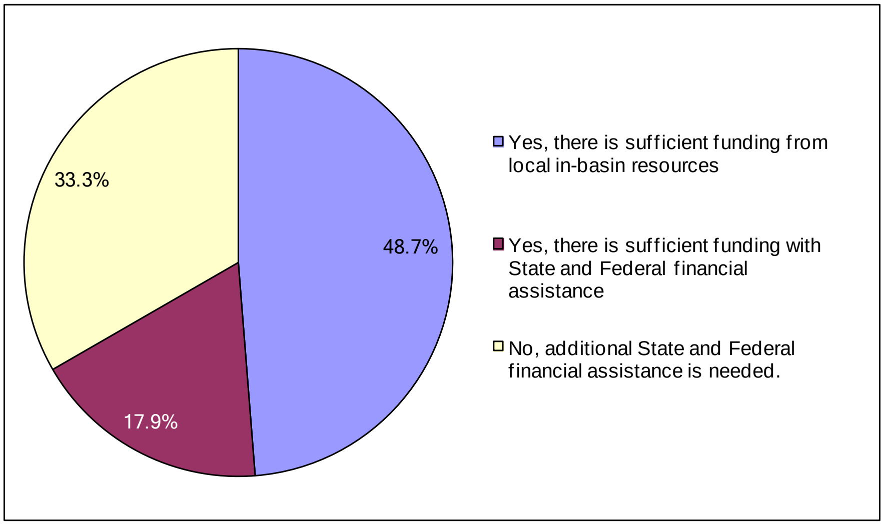

Source: CWCB 2013 drought survey data
Note: These results are based on 39 survey responses

## Figure 9.9. Likelihood to Improve Drought Preparedness Following 2012/2013




Source: CWCB 2013 drought survey data
Note: These results are based on 39 survey responses

**Figure 9.10. Sufficient Funding to Support M&I Water Supply Reliability, Conservation and Drought Planning**




Source: CWCB 2013 drought survey data
Note: These results are based on 39 survey responses

Table 9.5 highlights the basin-level results of the 2013 CWCB drought survey showing the percentage of survey respondents within each basin that updated/developed drought plans following the 2002 drought, are anticipating improving drought preparedness following 2012/2013 and perceive that there is sufficient funding for water supply reliability, conservation and drought planning. These results indicate that over half of the respondents in the South Platte, Arkansas, Gunnison and Colorado basins developed/updated their drought plans after the drought in 2002. A smaller percentage of respondents in the majority of basins plan to improve their drought preparedness following 2012/2013. However, over 60% of the respondents in the South Platte, Arkansas, Colorado, Yampa and San Juan/Dolores basins perceive there is sufficient funding for water supply reliability, conservation and drought planning. This percentage could be increased through stakeholder outreach that addresses the availability of funding sources for water resources planning. Education on the importance of planning to key decision-makers may also be of benefit to reducing drought vulnerability.

**Table 9.5. Basin M&I Drought Planning**

| Basin | Updated / comprehensive revision to drought plan since 2002 | Likely improve drought preparedness following 2012/2013 | Perceives there is sufficient funding for planning available (in-basin, state or federal) |
|---|---|---|---|
| South Platte Basin | 53%<br>19 respondents | 42%<br>19 respondents | 68%<br>19 respondents |
| Arkansas Basin | 56%<br>7 respondents | 0%<br>7 respondents | 72%<br>7 respondents |
| Rio Grande Basin | 0%<br>Zero respondents | 0%<br>Zero respondents | 0%<br>Zero respondents |

| Basin | Updated / comprehensive revision to drought plan since 2002 | Likely improve drought preparedness following 2012/2013 | Perceives there is sufficient funding for planning available (in-basin, state or federal) |
|---|---|---|---|
| Gunnison Basin | 100%<br>3 respondents | 100%<br>3 respondents | 0%<br>Zero respondents |
| Colorado Basin | 67%<br>6 respondents | 50%<br>6 respondents | 64%<br>6 respondents |
| Yampa Basin | 0%<br>1 respondent | 0%<br>1 respondent | 100%<br>1 respondent |
| San Juan/Dolores Basin | 67%<br>3 respondents | 33%<br>3 respondents | 67%<br>3 respondents |

Source: CWCB 2013 drought survey data

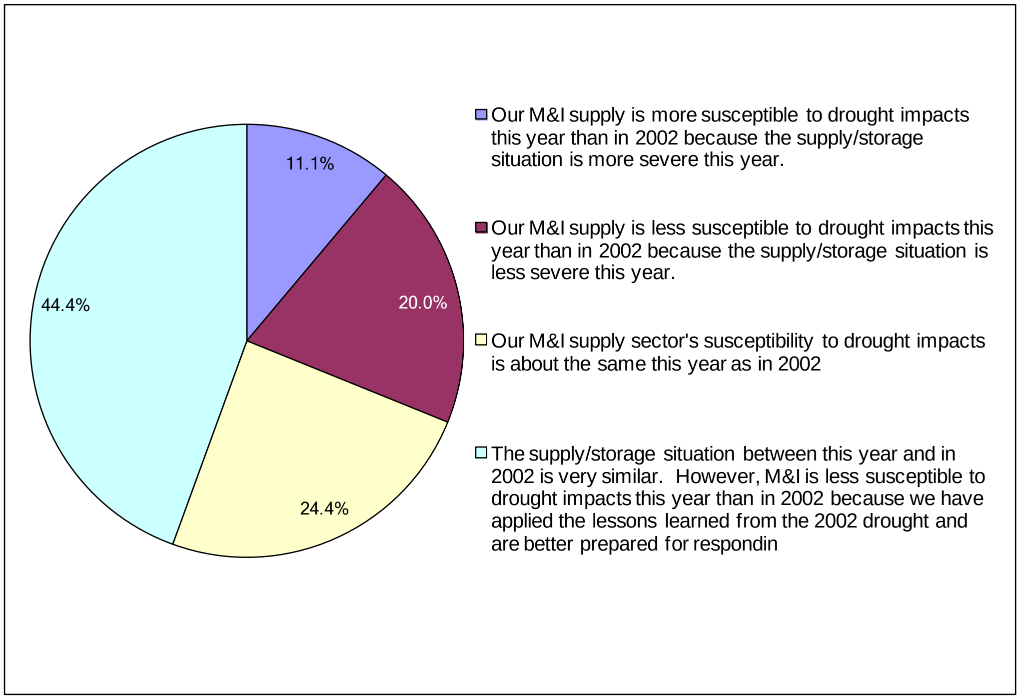
## 9.4 Measurement of Vulnerability

Drought vulnerability can significantly vary among M&I providers. Section 9.3 introduced the many water supply, distribution system, demand, and adaptive capacity factors that influence M&I drought vulnerability. Each of these factors is unique to individual M&I providers and can affect providers in many different ways and magnitudes during a drought. For example, a provider with a relatively reliable water supply and a senior water rights portfolio will likely not experience as many impacts during a drought when compared to a neighboring provider that has a more junior water rights portfolio.

A comprehensive evaluation of M&I drought vulnerability would require extensive characterization of individual M&I providers' water right portfolios, storage capabilities, distribution system efficiencies, demands, adaptive capacities, etc. Additionally M&I water providers use different approaches and methods to evaluating water supply reliability and planning for future growth. Consequently, there is not a standardized method that can be applied to evaluating drought vulnerability for every M&I provider. A thorough statewide evaluation of M&I drought vulnerability would thus require a means to account for and incorporate the uniqueness of each M&I provider. Such an intensive effort is beyond the scope of this study. For this assessment, a qualitative assessment of M&I vulnerability was conducted at regional basin-wide level in addition to the CWCB 2013 drought survey which included three questions specific on drought vulnerability.

Figures 9.11 through 9.14 summarize the statewide results of the CWCB 2013 drought survey on vulnerability. Figure 9.11 shows that 44% of the survey respondents indicated that while conditions between 2002 and 2013 are similar, they are less susceptible to drought impacts in 2013 than in 2002 because they are better prepared. Eleven percent of the respondents indicated that they are more susceptible to drought in 2013 because the supply/storage situation is more severe than in 2002.[9] Table 9.6 summarizes the basin results, indicating that over 40% of respondents in the South Platte, Arkansas, Gunnison, Colorado and San Juan/Dolores basins feel that they are less susceptible to drought impacts in 2013 than in 2002 although conditions in 2002 and 2013 are similar. This suggests that the drought vulnerability of the M&I sector in many regions throughout the State may be lessening as a result of lessons learned from the 2002 and 2012 droughts in addition to improved M&I mitigation and drought response.

**Figure 9.11. Drought Vulnerability in 2002 and 2013**




Source: CWCB 2013 drought survey data
Note: These results are based on 45 survey responses

[9] The survey period began in early May 2013 before a series of snowstorms occurred in central and northern Colorado and concluded after the snow events. Anticipated water supply shortages were reduced or eliminated for certain M&I providers following the snow events. Consequently, results of the survey may be somewhat skewed depending on when the respondents completed the survey.

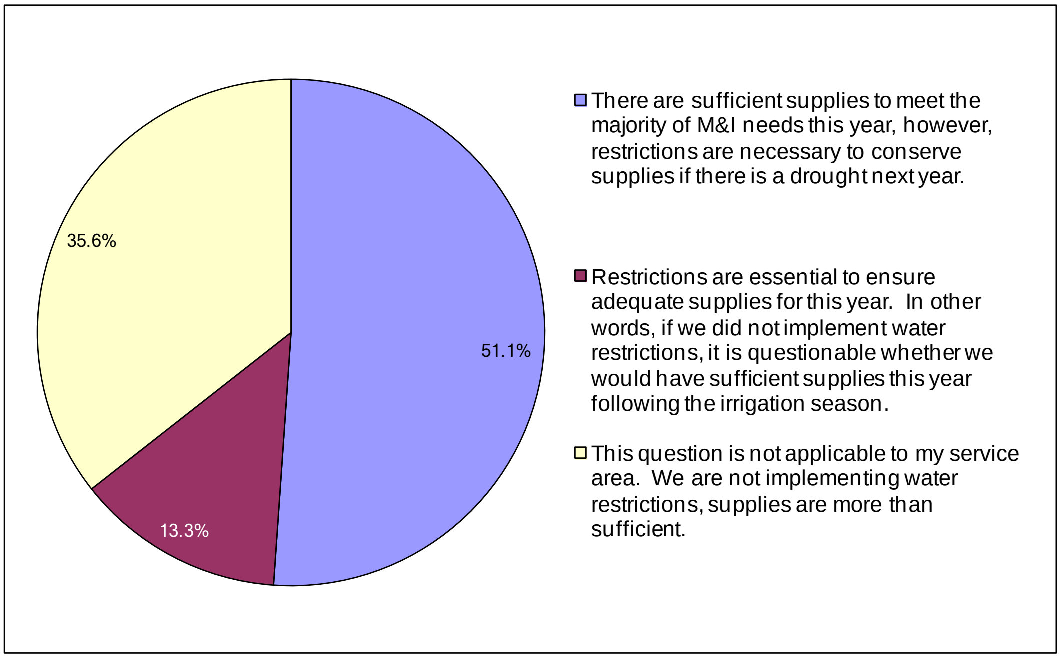
## Table 9.6. Basin Drought Vulnerability in 2002 and 2013

| Basin | More susceptible to drought impacts in 2013 than in 2002 because the supply/storage situation is more severe in 2013 | Less susceptible to drought impacts in 2013 than in 2002 because the supply/storage situation is less severe in 2013 | Susceptibility to drought impacts is about the same in 2013 as in 2002 | The supply/storage situation between 2013 and in 2002 is very similar. However, M&I is less susceptible to drought impacts in 2013 than in 2002 because of the lessons learned from the 2002 drought and are better prepared |
|---|---|---|---|---|
| South Platte Basin | 13%<br>23 respondents | 22%<br>23 respondents | 17%<br>23 respondents | 48%<br>23 respondents |
| Arkansas Basin | 14%<br>7 respondents | 14%<br>7 respondents | 29%<br>7 respondents | 43%<br>7 respondents |
| Rio Grande Basin | 0%<br>1 respondent | 0%<br>1 respondent | 100%<br>1 respondent | 0 |
| Gunnison Basin | 0%<br>3 respondents | 0%<br>3 respondents | 33%<br>3 respondents | 67%<br>3 respondents |
| Colorado Basin | 0%<br>6 respondents | 34%<br>6 respondents | 17%<br>6 respondents | 50%<br>6 respondents |
| Yampa Basin | 0%<br>2 respondents | 50%<br>2 respondents | 50%<br>2 respondents | 0%<br>2 respondents |
| San Juan/Dolores Basin | 33%<br>3 respondents | 33%<br>3 respondents | 33%<br>3 respondents | 67%<br>3 respondents |

Source: CWCB 2013 drought survey data

The statewide survey results in Figure 9.12 indicate that 13% of the survey respondents must implement water restrictions in 2013 as a cautionary means to conserve supplies should the drought persist another year while 51% of the respondents have sufficient supplies to meet demands. The basin-level survey results in Table 9.7. The percentage of respondents that plan to implement 2013 water restrictions significantly varies among the basins. This is indicative that water supply reliability among individual M&I water providers and the availability of M&I supplies depends on drought conditions within a geographic area. It is important to note that these results are based on a limited sampling size and may or not be reflective of the M&I sector within the whole basin. For instance, 57% of the seven Arkansas Basin respondents indicated that their supplies are sufficient and water restrictions are not necessary in 2013 whereas only 35% of the 23 South Platte Basin respondents indicated that they will not need to implement water restrictions. While this may be reflective of the specific survey respondents, this is in contrast to weather patterns experienced in May of 2013 where central and northern Colorado experienced a degree of drought relief through a series of snow events, yet southern Colorado continued to experience severe drought conditions.

## Figure 9.12. Water Restrictions in 2013




Source: CWCB 2013 drought survey data
Note: These results are based on 45 survey responses

## Table 9.7. Basin Water Restrictions in 2013

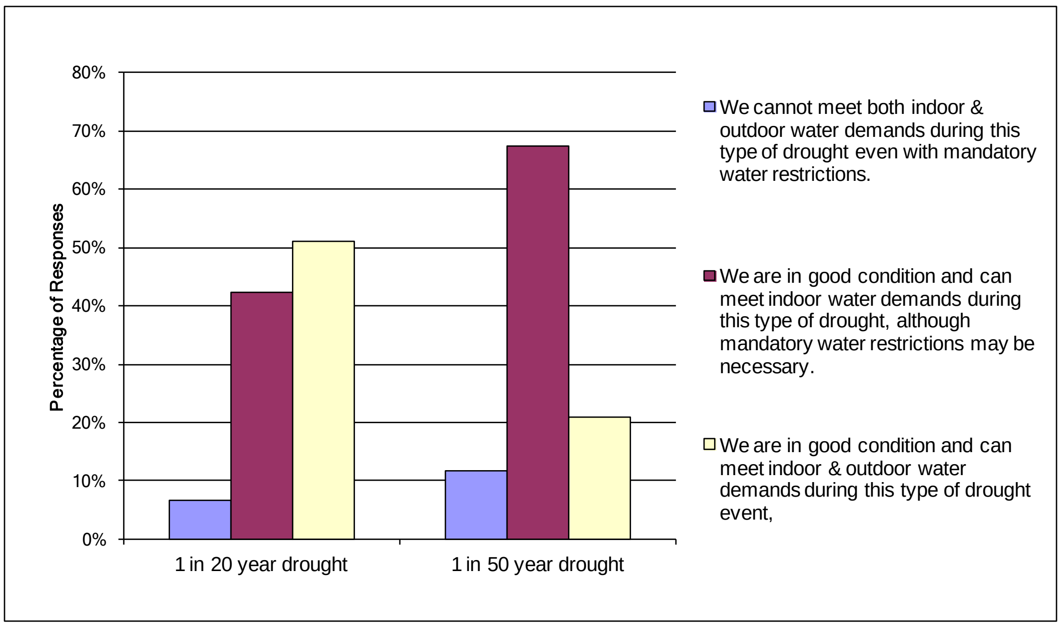
| Basin | Sufficient supplies to meet the majority of M&I needs in 2013, however, restrictions are necessary to conserve supplies if there is a drought in 2014 | Restrictions are essential to ensure adequate supplies for this year. | Supplies are sufficient and water restrictions are not necessary |
|---|---|---|---|
| South Platte Basin | 48%<br>23 respondents | 17%<br>23 respondents | 35%<br>23 respondents |
| Arkansas Basin | 29%<br>7 respondents | 14%<br>7 respondents | 57%<br>7 respondents |
| Rio Grande Basin | No respondents | No respondents | No respondents |
| Gunnison Basin | 67%<br>3 respondents | 33%<br>3 respondents | 0%<br>3 respondents |
| Colorado Basin | 83%<br>6 respondents | 0%<br>6 respondents | 17%<br>6 respondents |
| Yampa Basin | 0%<br>2 respondents | 0%<br>2 respondents | 0%<br>2 respondents |
| San Juan/Dolores Basin | 100%<br>3 respondents | 0%<br>3 respondents | 0%<br>3 respondents |

Source: CWCB 2013 drought survey data

Figure 9.13 indicates that over 50% of respondents statewide can meet their indoor and outdoor water needs during a 1-in-20 year drought without mandatory water restrictions while only 21%

can meet these needs during a 1-in-50 year drought without restrictions. Twelve percent of respondents cannot meet their indoor or outdoor needs with mandatory water restrictions during a 1-in-20 year drought while 7% cannot meet these needs during a 1-in-50 year drought. Table 9.8 shows the basin results, indicating that all of the surveyed providers in the Rio Grande Basin and Gunnison Basin anticipate meeting water demands without needing water restrictions during a 1-in-20 year drought. However, these results are based on a small number of respondents. Over 60% of the South Platte Basin respondents (which is the largest sample size) anticipate not needing to implement restrictions during a 1-in-20 year drought. This is reduced to 30% of the South Platte Basin respondents during a more severe 1-in-50 year drought. While the information in Table 9.8 is informative, additional studies incorporating a larger number of M&I respondents would be needed to draw conclusions on M&I water supply reliability and overall drought vulnerability on a basin-wide level.

**Figure 9.13. Water Restrictions for a 1-in-20 and 1-in-50 year Drought**




Source: CWCB 2013 drought survey data
Note: These results are based on 45 survey responses

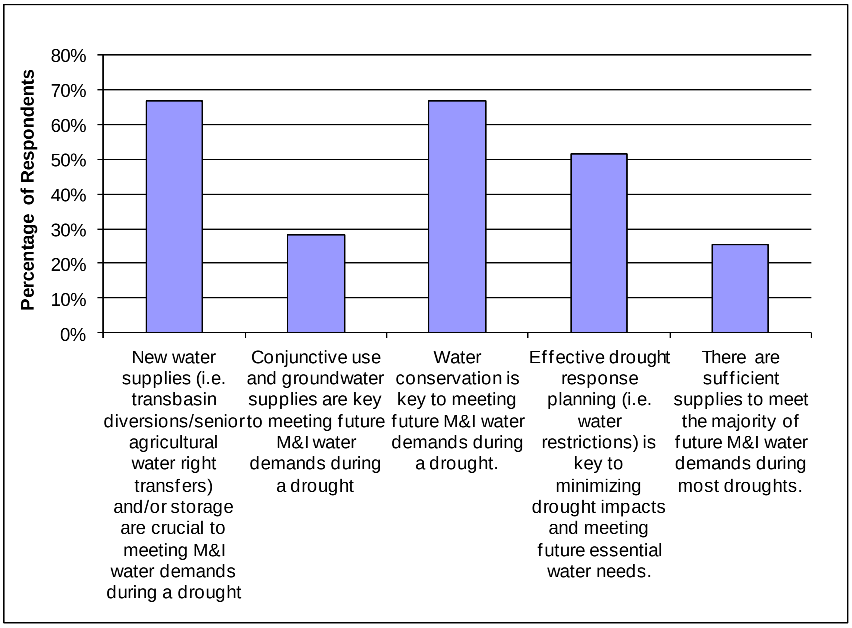
## Table 9.8. Basin Water Restrictions for a 1-in-20 and 1-in-50 year

| Basin | 1-in-20 year drought | | | 1-in-50 year drought | | | Number of Respondents |
|---|---|---|---|---|---|---|---|
| | Can meet indoor & outdoor water demands | Can meet indoor water demands, although mandatory water restrictions may be necessary | Cannot meet indoor & outdoor water demands even with mandatory water restrictions | Can meet indoor & outdoor water demands | Can meet indoor water demands, although mandatory water restrictions may be necessary | Cannot meet indoor & outdoor water demands even with mandatory water restrictions | |
| South Platte Basin | 66% | 30% | 4% | 22% | 74% | 4% | 23 |
| Arkansas Basin | 57% | 43% | 0% | 43% | 43% | 14% | 7 |
| Rio Grande Basin | 0% | 100% | 0% | 0% | 0% | 0% | 1 |
| Gunnison Basin | 0% | 100% | 0% | 0% | 67% | 33% | 3 |
| Colorado Basin | 20% | 80% | 0% | 0% | 100% | 0% | 6 |
| Yampa Basin | 100% | 0% | 0% | 50% | 0% | 0% | 2 |
| San Juan/Dolores Basin | 33% | 0% | 67% | 0% | 33% | 67% | 3 |

Source: CWCB 2013 drought survey data

Municipalities are planning to implement a variety of water supply and demand management options to meet their future long-term needs. Figure 9.14 indicates that over 60% of the 2013 CWCB drought survey respondents statewide, plan to develop new water supplies and also rely on water conservation in meeting their future water needs. Twenty-six percent of the respondents stated that they have sufficient supplies to meet their needs during most droughts. Table 9.9 highlights the basin results, also indicating that new water supplies and water conservation tends to be the highest ranking long-term water supply options, however, M&I providers' ability to meet long-term water supplies varies among the basins. For instance, fifty-seven percent of the survey respondents in the Arkansas Basin indicated that they have sufficient long-term supplies to meet their future needs, whereas none of the respondents in the Rio Grande and Gunnison Basins have sufficient supplies. Such needs for additional water supplies is being addressed through the Statewide Water Supply Initiative and roundtable process which provides a means to facilitate collaboration among basin stakeholders on how long-term water supply needs may be met in the future.

## Figure 9.14. Long-term Water Supply Planning




Source: CWCB 2013 drought survey data
Note: These results are based on 39 survey responses

## Table 9.9. Basin Long-term Water Supply Planning

| Basin | Highest two ranking long-term supplies | Percentage with sufficient long-term supplies |
|---|---|---|
| South Platte Basin | 1) New water supplies<br>2) Water conservation | 21% |
| Arkansas Basin | 1) New water supplies<br>2) Water conservation | 57% |
| Rio Grande Basin | No respondents | No respondents |
| Gunnison Basin | 1) Water Conservation<br>2) New water supplies | 0% |
| Colorado Basin | 1) Drought response<br>2) New water supplies<br>3) Water Conservation | 67% |
| Yampa Basin | 1) New water supplies<br>2) Sufficient supplies | 100% |
| San Juan/Dolores Basin | 1) New Water Supplies<br>2) Sufficient supplies | 0% |

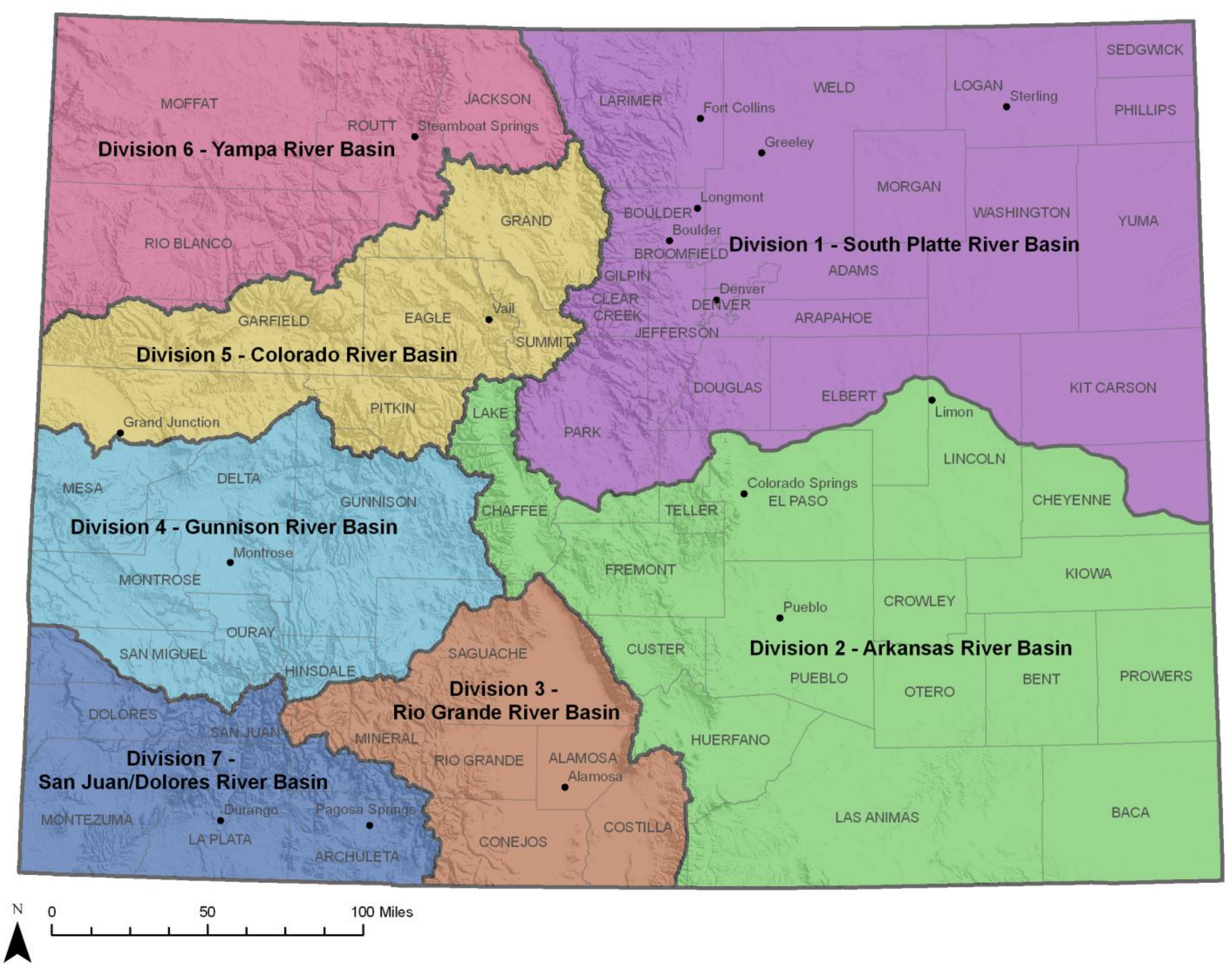
Source: CWCB 2013 drought survey data

As a component of the State drought planning process, the CWCB has developed a Municipal Drought Management Plan Guidance Document for water providers and local governments to use when developing local Drought Mitigation and Response Plans. This Guidance Document informs providers on how they may evaluate drought vulnerability and incorporate this information into their plans. Municipal providers are encouraged to submit their local plans to the CWCB. These individual local drought mitigation and response plans will serve as a vehicle to inform the State of local M&I drought vulnerability in the future. Additionally, CWCB is in the process of developing a Basin Needs Decision Support System that will include a database of useful information for future water supply planning efforts. This database will include information on municipal providers' water supply and drought planning efforts which can be incorporated into future statewide drought vulnerability assessments. Recommendations for conducting a more detailed statewide M&I drought vulnerability assessment are made in Section 9.5.

### 9.4.1 Regional Assessment

For purposes of this regional assessment, the State was divided into Colorado Division of Water Resource's seven division basins (Figure 9.15). Drought vulnerability was evaluated by assessing historical drought impact information from the recent 2002 drought coupled with information on future population growth and adaptive capacities M&I providers have subsequently pursued to address drought and water supply reliability.

**Figure 9.15. Colorado Water Division Basins**

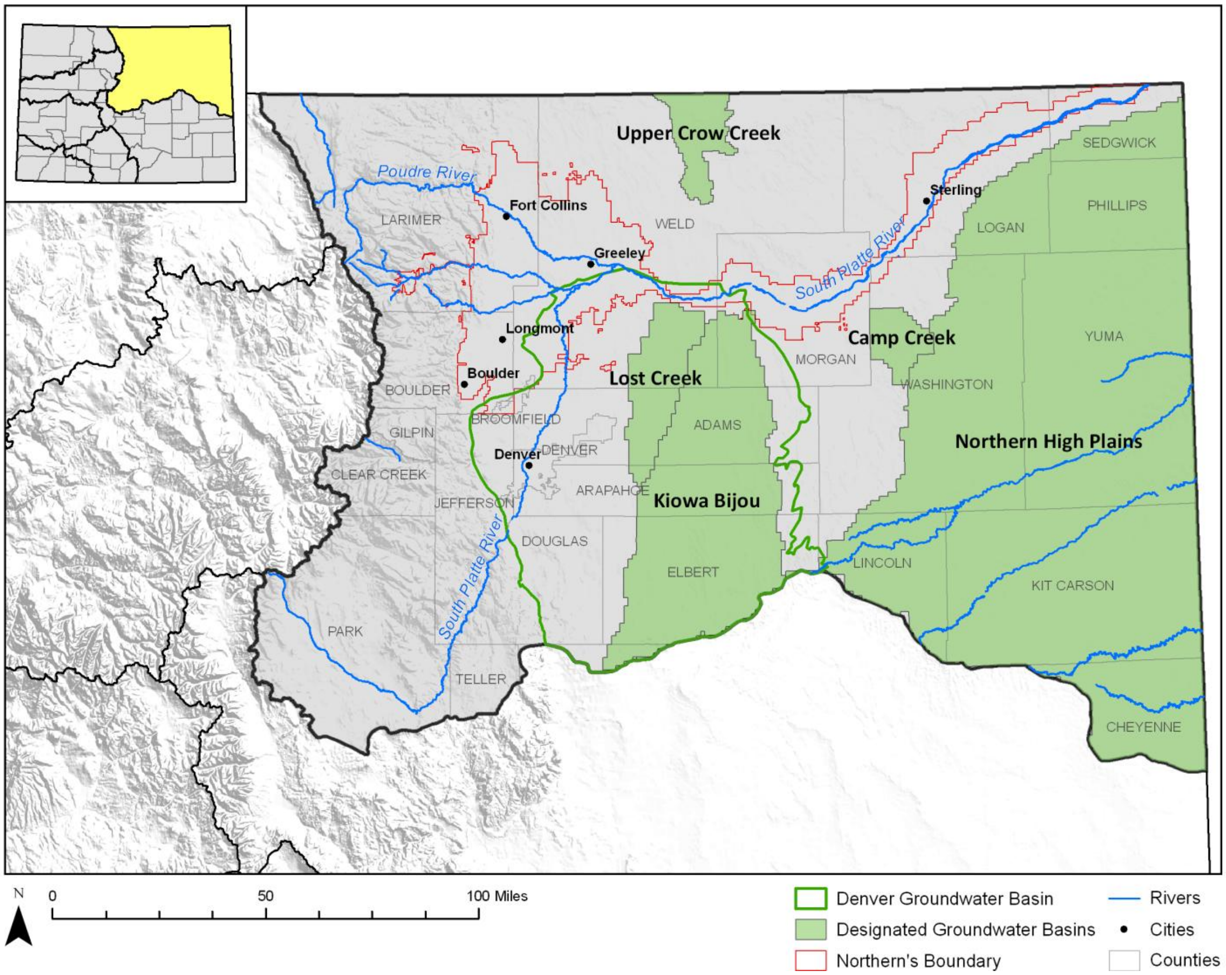


While historical drought information is not a direct reflection of 2013 drought vulnerability, historical 2002 drought impact data do provide a relatively recent snapshot of M&I drought vulnerability in a specific drought situation. The majority of historical drought-related impact information was obtained from CWCB's 2004 DWSA and CWCB 2013 survey. Information on these surveys is provided in Section 9.1. Data on projected future water supply demands was obtained from CWCB's *State of Colorado Draft 2050 Municipal and Industrial Water Use Projections* developed for the Statewide Water Supply Initiative process. Case study information was also used for the assessment of the Front Range metropolitan area in the South Platte River Basin.

### *Division 1 - South Platte River Basin*

The majority of the State's population is located in the Division 1 - South Platte Basin with the densest population centers in the Denver Metropolitan Area and urban development along the northern Front Range. M&I water needs are met through a combination of surface water supplies delivered via the South Platte River and tributaries, transbasin diversions, tributary groundwater supplies and nontributary/designated groundwater shown in Figure 9.16. Many of the municipalities in the northern service area specifically rely on Colorado - Big Thompson (C-BT) transbasin water. (Bureau of Reclamation project operated by the Northern Colorado Water Conservancy District [Northern]).

Figure 9.16. South Platte River Basin




## Historical Drought Impacts

The 2002 drought was one the worst drought years on record in terms of streamflow for many areas of the State. While M&I providers generally had sufficient supplies to meet demands, the majority of the Front Range area had to comply with mandatory water restrictions. Many of the M&I providers that enforced water restrictions used them as a precautionary response given that they did not know whether the drought would be over by 2003 and water savings achieved through restrictions would be essential to meeting future demands. M&I providers' were concerned their storage reserves would not last through another year or two of similar 2002 drought conditions.

The 2004 DWSA survey results shown in Figure 9.17 indicates that over 40% of the 97 surveyed M&I providers in the South Platte River Basin experienced the following impacts during the 1999-2003 drought period:

- Loss of system flexibility

- Loss of operations revenue
- Loss of reliable water supply
- Loss of landscaped property
- Increased expenses for public education

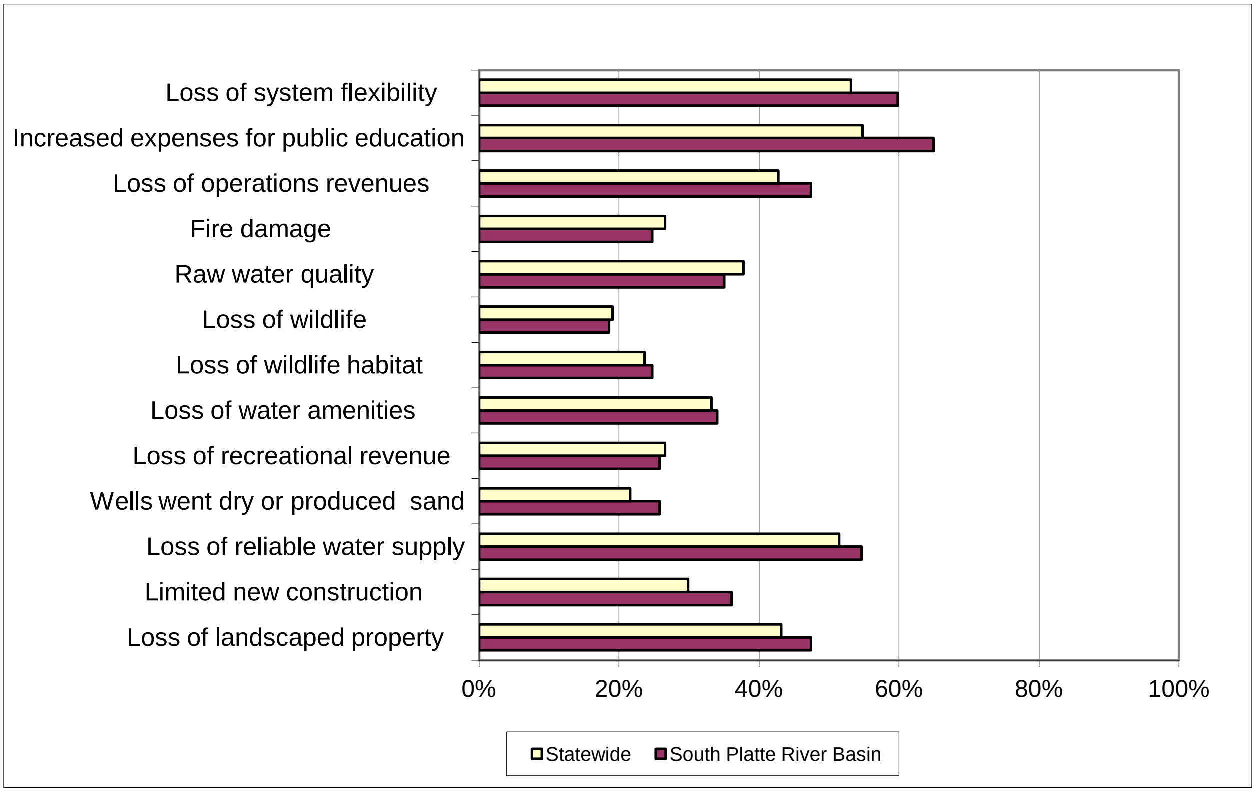
The increased expense for public education was the most frequently experienced impact, exceeding the statewide level percentage and suggesting that South Platte Basin M&I providers on average placed more financial investment into responding to the drought through public education than other basins in the State. While the majority of basin impacts shown in Figure 9.17 exceed the frequency of impact on a statewide level, they are still relatively close to the percentage of impacts recorded on a statewide level.

The 2013 CWCB drought survey impacts ranked as having the highest frequency/level of concern in 2012, anticipated for 2013 and experienced for the longest duration from 2002 to 2006 were the following:

- Loss of system flexibility
- Significant loss in storage that carried over to the following year
- Increased staff time to address drought
- Increased expenses for public education and outreach
- Voluntary water restrictions

These impacts are similar to the 2004 DWSA survey. Losses in system flexibility, reliability of water storage and increased expenses for public education as well as staff time to manage drought are common high ranking impacts among both surveys.

**Figure 9.17. South Platte River Basin 1999-2003 Drought Impacts**[10]




Source: DWSA 2004 survey data.

## Adaptive Capacities

In 2002, most M&I providers focused on implementing drought response measures to reduce demands as well as to increase supplies. The City of Louisville appears to have been the first major water provider along the Front Range of the South Platte River Basin to implement mandatory water restrictions. Most other M&I providers adopted mandatory restrictions, but generally not until mid-July or early August. Only Aurora, Berthoud, and Denver adopted pricing surcharges. Very few water M&I providers placed any restrictions on the issuance of new taps (Luecke et al., 2003).

Some M&I providers also implemented measures to increase their supplies. Examples included canceling or not renewing M&I leases of water to farmers, leasing irrigation rights from farmers, reducing minimum streamflow bypasses, increased utilization of ditch water or treated effluent for irrigating park lands, drilling supplemental wells, and in the case of some small water systems, trucking in emergency water supplies. Lafayette traded C-BT project water to Boulder for Boulder’s Baseline Reservoir water. This trade allowed each city to give up water that it

[10] Note: A comprehensive review and internal testing process of the survey tool was conducted, yet it is important to recognize that these DWSA 2004 surveyed impact results are subjective. The impacts in the figure above are, in many cases, a reflection of the surveyees’ interpretation of the listed impacts.

controlled but could not easily use in exchange for water that was more directly deliverable. In a similar fashion, Eldora ski area acquired a lease on C-BT water and traded that water to Louisville in an exchange, whereby water from Louisville's Marshall Reservoir was supplied to facilitate increased snowmaking diversions from South Boulder Creek for the 2002-2003 season (Luecke et al., 2003).

A few utilities began building facilities to allow them to make better use of their existing water rights. Lafayette began building a new diversion from Boulder Creek upstream of Boulder's wastewater discharge in order to maximize use of its Boulder Creek water rights. Broomfield continued developing facilities to increase its reuse of treated wastewater effluent for irrigation (Luecke et al., 2003).

M&I providers also invoked a variety of drought reservations that allowed them to reduce bypass requirements and to interrupt agricultural leases. Denver Water invoked drought reservations that allowed it to reduce its minimum flow bypasses at its Fraser Basin points of diversion and at Strontia Springs Reservoir, and to stop other irrigation diversions temporarily above Williams Fork Reservoir. Boulder invoked its drought reservation with the CWCB in order to use senior water rights for M&I purposes, even though Boulder had previously conveyed these rights to the CWCB for instream flow purposes. In spite of this action, Boulder Creek streamflows remained at nominal levels. This is because the low water levels caused senior water rights at the bottom of Boulder Creek to place call for water forcing many users upstream from them to stop diverting. As a result water that normally would have been diverted at upstream locations was left in the creek until it got to the downstream call (Luecke et al., 2003).

The severe 2002 drought condition was a wake-up call for many M&I providers. Since this drought, municipalities and special districts have improved public education on the importance of water conservation as well as drought response and management. Some M&I providers have also developed or refined drought mitigation and response plans, while several M&I providers have been successful in regulating outdoor water use and implementing alternative water pricing programs.

Table 9.10 indicates that 72% of the 2007 DWSU surveyed municipalities in the South Platte River Basin incorporate drought recurrence in long-term water supply planning. One-third of the surveyed municipalities have drought management plans and over half have conservation and raw or treated master plans, however, the comprehensiveness of these plans varies widely. Although these values are above the statewide average, there is a large portion of municipalities in the basin that lack formal plans to address drought. Generally, the larger M&I providers have the resources to develop comprehensive plans while other communities that are either small, or growing, or both, may not have the skills or resources to plan for periods of drought.

**Table 9.10. South Platte Provider Planning Efforts 2007 DWSU Survey Results**[11]

| Drought-Related Planning Efforts | South Platte River Basin | | Statewide Average | |
|---|---|---|---|---|
| | Percentage of Surveyed M&I providers | Percentage of Plans Updated Since 2002 | Percentage of Surveyed M&I providers | Percentage of Plans Updated Since 2002 |
| Have a drought management plan | 33% | 27% | 25% | 19% |
| Have a raw and/or treated master plan | 60% | 44% | 61% | 37% |
| Have a conservation plan | 51% | 38% | 44% | 30% |
| Drought recurrence is considered in long-term water supply and conservation planning | 72% | n/a | 66% | n/a |

Source: CWCB, 2004. DWSA 2004 Survey

The 2013 CWCB drought survey indicated that 53% of the survey respondents either updated or developed a new comprehensive plan following the 2002 drought and 42% anticipate improving their drought preparedness following the 2012 – 2013 dry period. Sixty-eight percent perceive that there is sufficient funding either in-basin or through state/federal resources to support water supply reliability, conservation and drought planning.

## Drought Vulnerability

The largest urban growth in the South Platte River Basin is anticipated to occur along the Front Range corridor. M&I drought vulnerability will largely depend on drought planning efforts and how effectively drought is incorporated into long-term water supply reliability planning as the region continues to develop.

During the 2004 SWSI process, most M&I providers indicated that they would be able to meet future 2030 demands from increasing population, through existing supplies, current projects being developed, and planned future projects. Table 9.11 lists the major projects and processes currently identified to address long-term water supply needs. Many of these projects will be instrumental in maintaining water supply reliability and either directly or indirectly meeting demands during drought periods.

[11] Note: A relationship between drought vulnerability and the adaptive capacities provided in this table cannot be deciphered solely using these data. While these results provide a general indication of the number of drought, conservation and raw/treated master plans, they do not provide information on the content and "overall effectiveness" of the plans. However, they do provide a general indication of M&I drought awareness on a basin-wide level.

## Table 9.11. Major Identified Projects and Processes in the South Platte River Basin[12]

| M&I Providers | Project | IPP Type |
|---|---|---|
| Colorado Springs Utilities, Aurora, Vail Consortium (Eagle River W&SD, Upper Eagle W&SD, Vail Associates), the Colorado River Water Conservation District, Cyprus Climax Metals Company | Eagle River Joint-Use Project (Eagle River MOU) | New Transbasin Project<br>Firming Transbasin Rights |
| Town of Castle Rock | Renewable Water Project Phase I | |
| | Renewable Water Project Phase II | |
| City of Brighton | South Platte and Beebe Draw Well Project | Agricultural Transfers |
| | Westminster Agreement | Regional In-Basin Project |
| | Recapture and Exchange | Reuse |
| Aurora Water | Prairie Waters Project | Reuse |
| Centennial Water and Sanitation District | ECCV Pipeline Agreement | |
| | Conservation | |
| Consolidated Mutual Water Company | Consolidated Mutual Water District Reservoir Construction | |
| Arvada | Highway 93 Lakes | Regional In-Basin Project |
| | Ag Transfer | Agricultural Transfers |
| | Existing Supplies | Growth into Existing Supplies |
| Denver Water & Arvada | Moffat Collection System Project | New Transbasin Project |
| East Cherry Creek Valley, South Metro Water Supply Authority | Northern Project Pipeline | |
| Parker Water and Sanitation District, Castle Rock, Castle Pines North, Stonegate | Rueter Hess Reservoir Enlargement | Regional In-Basin Project |
| City of Northglenn | Ag Transfer | Agricultural Transfers |
| | Reuse Plan | Reuse |
| | New Storage Projects | Firming In-Basin Rights |
| City of Thornton | Thornton Northern Project | Regional In-Basin Project |
| | Conservation | |
| | Recapture and Exchange with Gravel Lakes | Reuse |
| | Existing Water Rights and Infrastructure Portfolio | Growth into Existing Supplies |

[12] Note: The draft list of Identified Projects and Processes (IP&Ps) in this table is based on the best available information at the time of publishing (2013) and does not include conservation. Due to the evolving nature of IP&P's planned by providers this information will change over time with regards to IP&P details, new IP&P's, completed IP&P's, and unsuccessful or withdrawn IP&P's. As a basic list of major IP&P's it does not include things such as a water provider growing into its existing supply, planned transfers of agricultural water rights, or the vast majority of water conservation programs. The CWCB is working to collect better data on IP&P's, including conservation programs, through the development of its Basin Needs Decision Support System and its associated survey of water providers.

| M&I Providers | Project | IPP Type |
|---|---|---|
| City of Fort Collins | Halligan Reservoir Enlargement | Firming In-Basin Rights |
| City of Greeley | Milton Seaman Reservoir Enlargement | Firming In-Basin Rights |
| | Conservation | |
| | Water Rights Acquisition | |
| | Acquisition of Poudre ag rights | Agricultural Transfers |
| Erie | Reclaimed Water | Reuse |
| Town of Erie, City of Lafayette, Left Hand Water District, City of Fort Morgan, City of Dacono, Town of Eaton, Town of Windsor, City of Fort Lupton, Fort Collins - Loveland Water District, Central Weld County Water District, Town of Evans, Morgan County Quality Water, Town of Severance, Town of Firestone, Town of Frederick | Northern Integrated Supply Project | |
| Northern Colorado Water Conservancy District, Town of Erie, City of Lafayette, Longmont, Louisville, Broomfield, Loveland, Greeley, Fort Lupton, Superior, Central Weld County Water District, Evans, Little Thompson Water District | Windy Gap Firming Project | Firming Transbasin Rights |
| Aurora Water , Brighton, Central Colorado WCD, Colorado Division of Parks and Outdoor Recreation, Denver Botanic Gardens at Chatfield, Western Mutual Ditch Company, Castle Pines Metro District, Castle Pines North Metro District, Centennial WSD, Center of Colorado WSD, Mount Carbon Metro District, Perry Park Country Club, Roxborough WSD, South Metro Water Supply Authority, Town of Castle Rock | Chatfield Reservoir Storage Reallocation Project | Regional In-Basin Project |
| Longmont | Union Pumpback Pipeline | Reuse |
| | Union Reservoir Enlargement | Regional In-Basin Project |
| | Conservation | |
| | Ag Transfer Water Rights Dedication Policy | Agricultural Transfers |
| | Adequate Existing Rights | Growth into Existing Supplies |
| Loveland | Ag Transfer Water Rights Dedication Policy | Agricultural Transfers |
| | Unused existing firm yield | Growth into Existing Supplies |
| Aurora, South Metro Water Supply Authority, Denver Water | Water Infrastructure Supply Efficiency (WISE) Partnership | |
| Denver Water | Denver Water System Refinements / Modifications | Growth Into Existing Supplies |
| City and County of Broomfield | Additional yield from existing portfolio | Growth Into Existing Supplies |
| City of Englewood | Existing Supplies | Growth Into Existing Supplies |

| M&I Providers | Project | IPP Type |
|---|---|---|
| Town of Castle Rock | Water Infrastructure Supply Efficiency (WISE) Partnership or ECCV Northern Project | Regional In-Basin Project |

Smaller communities along the eastern plains are anticipated to either decrease in population, or experience much less growth than on the Front Range. However, as the South Platte River Basin continues to develop and administration of the river changes, drought vulnerability for smaller communities relying on surface and tributary groundwater supplies can be reduced. This may be accomplished if these communities are aware of, and prepared for, how changes in river administration can affect their overall water supply reliability during times of drought. Generally, communities with relatively senior water right portfolios, or using relatively stable nontributary groundwater supplies (along the eastern plains) are less vulnerable to drought than communities relying on more junior rights to meet their needs.

The populous Front Range area is divided into the northern Front Range, Denver Metropolitan Area, and South Metro for further discussion purposes.

*Northern Front Range* – M&I water demands in Boulder, Larimer, and Weld Counties are anticipated to increase by 337,000 acre-feet by 2050.[13] These counties include municipalities of moderate size such as Boulder, Fort Collins, Greeley, Longmont, and Loveland and smaller communities and rural domestic water districts in the region that are experiencing rapid growth. Many of these entities are purchasing C-BT units and transferring the units from agricultural to M&I use. This trend is expected to continue as the area develops further. The C-BT project has a relatively reliable water supply and can provide a certain level of drought reliability, as was demonstrated during 2002 conditions. However, supplies were affected and took several years to fully recover.[14] C-BT water can also be physically delivered to many northern Front Range communities. Delivery can be achieved by various exchanges and trades municipalities may be willing to develop during periods of drought. While many smaller fast-growing communities may not be sufficiently prepared for a drought, on a regional scale, emergency water needs may be provided by C-BT water and also by agricultural transfers. The northern Front Range is adjacent to the largest agricultural producing area of the State, where forgoing agricultural production by temporary transfers can be used to meet M&I needs during periods of drought. The opportunities for coordination among C-BT shareholders, holders of senior agricultural water rights, and municipalities in need of water can greatly reduce the overall drought vulnerability of the northern Front Range. Despite these opportunities, it is important to emphasize that the exchange potential along the South Platte River and tributaries, and the

[13] These data are based on the Baseline M&I forecast for the medium 2050 growth scenario presented in CWCB. 2010. *Final State of Colorado 2050 Municipal and Industrial Water Use Projections*.

[14] C-BT storage was affected by below-average supplies in 2000 and 2001. In 2002, NCWCD only set a 70% quota and C-BT storage was significantly depleted by the end of 2002. This resulted in low (50% to 60%) quotas in 2003 and 2004 that reflected limited C-BT supplies. C-BTC-BTC-BT.

overall ability to meet demands through augmentation and substitute water supply plans, will generally decrease during periods of drought as streamflows, the availability of some replacement supplies (specified in augmentation and substitute water supply plans), system flexibility and overall water availability decline. Growing communities that have not incorporated drought into their long-term water supply planning efforts will thus be more vulnerable to future droughts.

*Denver Metropolitan Area* – M&I water demands in Adams, Denver, and Jefferson Counties are anticipated to increase by 424,000 acre-feet by 2050[15] The majority of the Denver Metropolitan Area is serviced by Denver Water and Aurora Water. Denver Water customers alone amount to almost one fourth of the State's population with an average use of 250,000,000 acre-feet. This water is supplied to the City and County of Denver in addition to the surrounding suburban population (Denver Water, 2013). The majority of Denver Water's supplies come from the South Platte, Blue, Williams Fork, and Fraser River watersheds, but supplies are also provided from the South Boulder Creek, Ralston Creek and Bear Creek, watersheds.

During the 2002 drought, Denver Water experienced a variety of drought-related impacts including the reduction in storage reserves, disruption of water supplies, loss of revenue from reduction in water sales, increased costs to respond to the drought and degraded water quality. An indirect impact was the Hayman wildfire that caused significant erosion and disrupted South Platte River supplies. Denver Water primarily responded to the drought through mandatory water restrictions and an effective drought public education campaign encouraging wise water use and conservation. Despite the 2002 drought impacts mentioned above, Denver Water was able to meet the essential needs of its service area during 2002.

Drought vulnerability within the Denver Metropolitan Area is relatively low when compared to other regions within the State. This is primarily attributed to the fact that Denver Water owns one of the most senior urban water rights portfolios along the Front Range. Denver Water has also taken additional drought mitigation actions since 2002 to further improve water supply reliability. As of 2013, Denver Water is in the permitting process for enlarging the Gross Reservoir to help resolve three major water supply challenges: a future water shortfall, the risk of running out of water in a future drought, and an imbalance in the collection system. Denver Water has also partnered with the Colorado State Forest Service, US Forest Service, local counties, and other M&I providers to develop watershed management plans, which will develop specific forest management practices for reducing wildfire risks with the intention of reducing water supply impact during future wildfires. Denver Water's board of directors has also adopted a policy to review and consider any proposed "cooperative action" that regions outside its service area may bring during periods of drought. Denver Water staff has subsequently discussed future possibilities for cooperative actions with suburban water suppliers in the south, northwest and northeast regions, Summit County, Grand County, Eagle County, and the City of Aurora.

[15] These data are based on the Baseline M&I forecast for the medium 2050 growth scenario presented in CWCB. 2010. *Final State of Colorado 2050 Municipal and Industrial Water Use Projections*.

Aurora Water has a diverse water rights portfolio both in the South Platte and Arkansas River Basins with a substantial portion of senior water rights. Additionally, Aurora Water has also undergone a significant effort to develop additional supplies and improve overall water supply reliability during drought periods. During the 2002 drought, Aurora Water's storage was reduced to 25 % of total capacity. Aurora Water learned that they were not sufficiently prepared for a drought of this magnitude. In response, Aurora Water developed a variety of tools to enhance water supply forecasting and planning guidance during drought periods. This includes a Drought Contingency Plan, a water supply forecasting model based on reservoir levels and an annual water management plan that sets the water restrictions and level of enforcement for the upcoming year. The 2002 drought also initiated the development of the Prairie Waters Project which when operating in full capacity will increase Aurora's water supply by more than 20% by reusing return flows that remain reliable during a drought.

These efforts further reduce drought vulnerability within the Denver Metropolitan Area, although it is important to note that drought will impact individual M&I providers within the region quite differently. M&I providers with a more junior portfolio of water rights that have not effectively incorporated drought planning into their long-term supply efforts will be more vulnerable to drought than those who have more senior water right and/or effective drought plans.

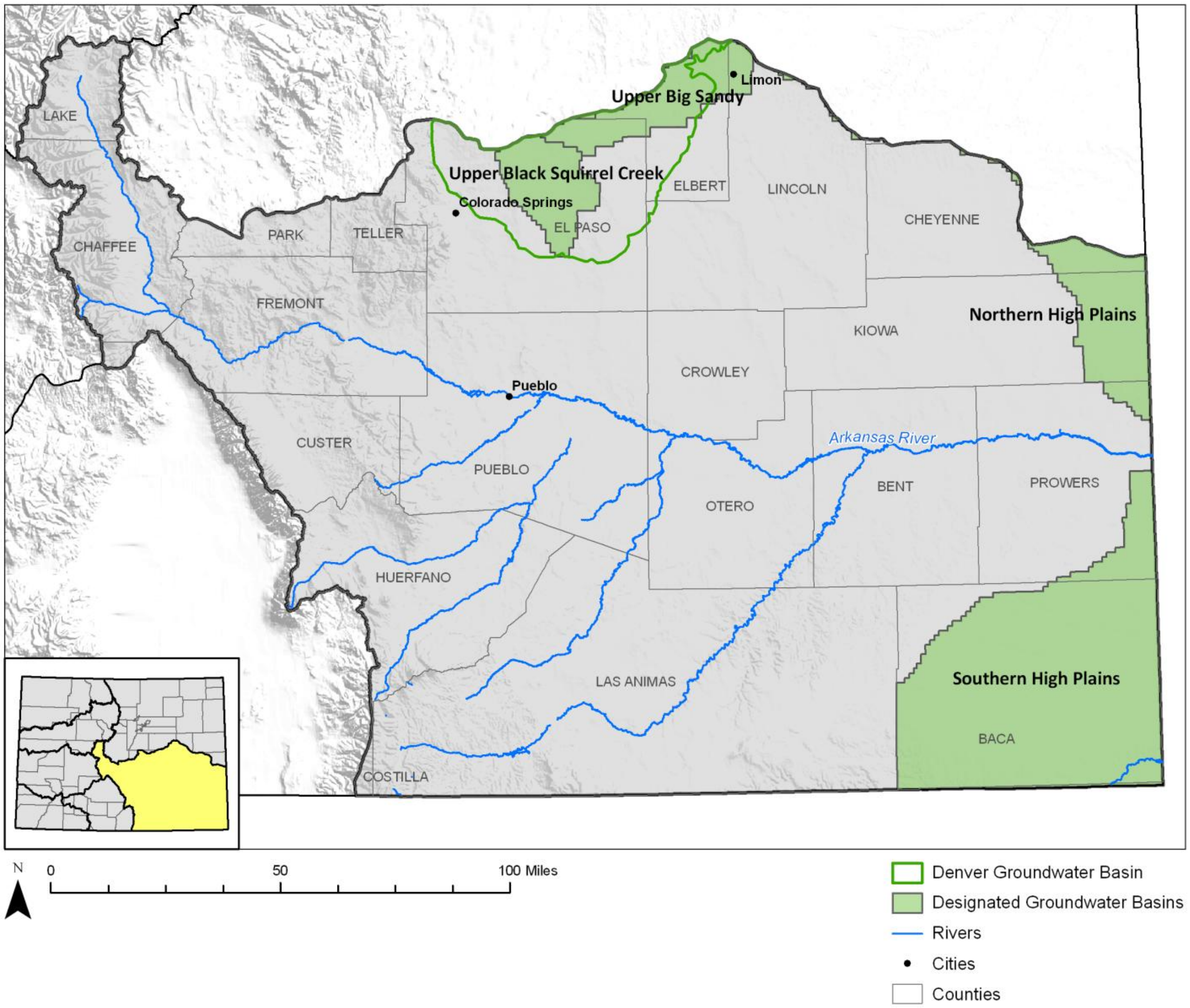
*South Metro* - The South Metro region primarily consists of Douglas and portions of Arapahoe County south of the Denver Metropolitan Area. This area has been one of the country's fastest growing areas over the past decade. M&I providers in this region primarily rely on non-renewable Denver Basin groundwater as their principal source of supply, although some also use some relatively junior surface water flows from Cherry Creek, Plum Creek, and the South Platte River as well. While there is still a large amount of groundwater in the Denver Groundwater Basin, well pumping in response to continued growth now exceeds the aquifers' natural recharge and well water levels are declining. It will eventually become prohibitively expensive to pump at existing and projected withdrawal levels without significant increases in artificial recharge, or deployment of more advanced well technology; both of which are likely to be relatively costly. M&I providers and local government are proactively addressing the long-term implications of continued reliance on finite groundwater, and have formed the Douglas County Water Resource Authority and South Metro Water Supply Authority to explore strategies for a sustainable water supply future including the development of additional renewable water supplies, maximize reuse, aquifer storage and recovery (ASR), and continued water conservation (South Metro Water, 2013; Douglas County Water, 2013).

Despite long-term water supply concerns, the South Metro Area was not severely affected by the 2002 drought. Relatively few water providers enforced mandatory watering restrictions. Loss of well production was observed in some areas as a result of increased demands. However, despite these well production declines, the Denver Groundwater Basin is not affected by drought to the extent as surface water and consequently provides a more "stable" supply during drought. Consequently, the South Metro Area is not as vulnerable to drought as other municipalities along the Front Range that rely on surface water and tributary groundwater supplies. However, if alternative renewable supplies are not developed in a timely manner to address water supply reliability, the water supply reliability within the region will be at risk and long-term drought vulnerability could increase. The future vulnerability of the region to drought will depend on how reliable the new renewable water supplies actually are during periods of drought and how successfully drought planning is incorporated into long-term planning efforts.

### *Division 2 - Arkansas River Basin*

The Division 2 - Arkansas River Basin supports the second largest population in the State and contains the largest number of municipalities in the State, although the majority of the population centers are relatively small rural communities. M&I water needs are met through a combination of surface water supplies primarily delivered via the Arkansas River and tributaries, transbasin diversions, tributary groundwater supplies, and nontributary/designated groundwater shown in Figure 9.18. M&I providers in the Southeastern Colorado Water Conservancy District (SCWCD) are heavily reliant on Fry-Ark allocations. Other large transbasin diversions that provide M&I supplies include Homestake, Blue River, and Twin Lakes. El Paso County and eastern plain communities rely on nontributary groundwater while Custer, Huerfano, and Las Animas Counties primarily rely on tributary groundwater and surface water supplies.

**Figure 9.18. Arkansas River Basin**




## Historical Drought Impacts

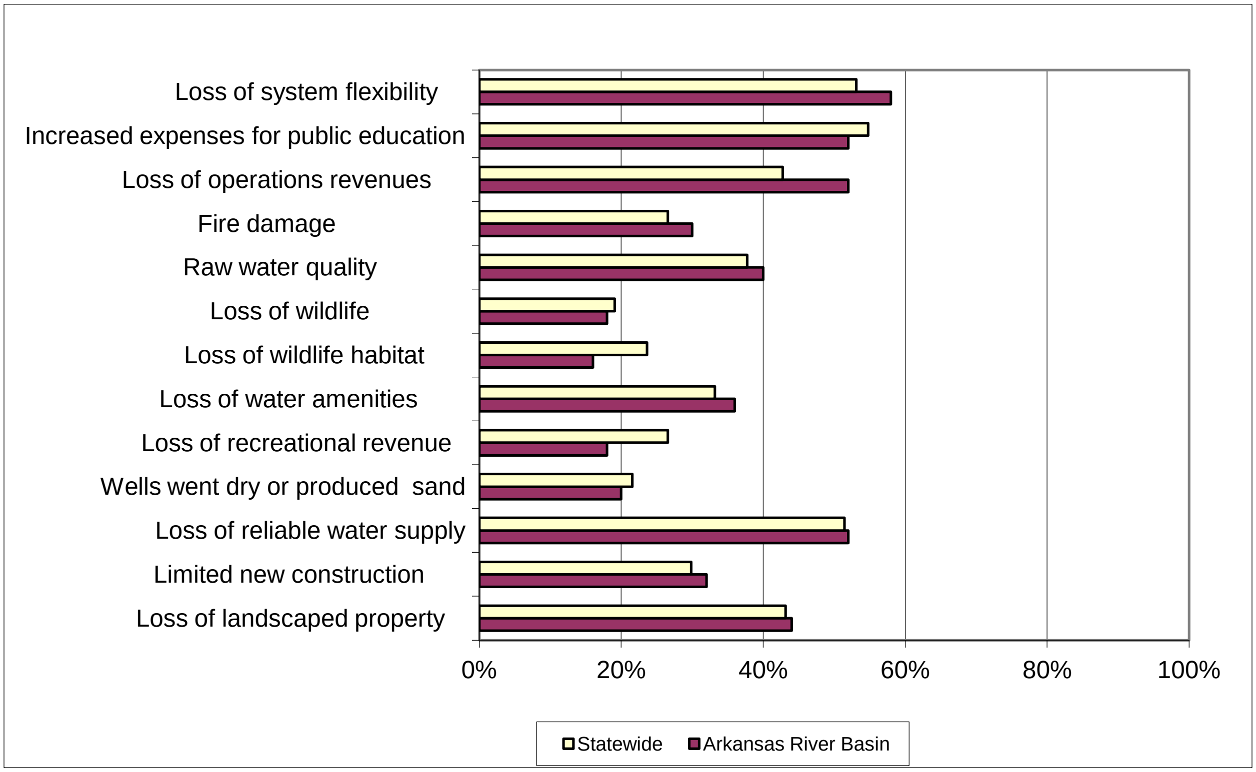
The 2004 DWSA survey results shown in Figure 9.19 indicates that over 40% of the 50 surveyed M&I providers in the Arkansas River Basin experienced the following impacts during the 1999-2003 drought period:

- Loss of system flexibility
- Increased expenses for public education
- Loss of operations revenues
- Loss of reliable water supply
- Loss of landscaped property

The loss of system flexibility appeared to be the most frequently experienced impact. All of these impacts listed above, with exception of increased expenses for public education, exceeded the frequency of impact on a statewide level. However, Figure 9.19 shows that the percentage of

M&I providers that experienced impacts in the Arkansas River Basin was relatively similar to statewide surveyed impacts. The percentage of impacts at the basin level and statewide is relatively similar.

**Figure 9.19. Arkansas River Basin 1999-2003 Drought Impacts**[16]




Source: DWSA 2004 survey data.

The 2013 CWCB drought survey impacts ranked as having the highest frequency/level of concern in 2012, anticipated for 2013 and experienced for the longest duration from 2002 to 2006 were the following:

- Loss of water amenities
- Loss of system flexibility
- Significant loss in storage that carried over to the following year
- Increased staff time necessary to address drought
- Loss of irrigated vegetation within urban areas
- Loss of recreational revenue
- Increased expenses for public education and outreach
- Mandatory restrictions

[16] Note: A comprehensive review and internal testing process of the survey tool was conducted, yet it is important to recognize that these DWSA 2004 surveyed impact results are subjective. The impacts in the figure above are, in many cases, a reflection of the surveyees' interpretation of the listed impacts.

Of the survey impacts listed above, 1) loss of system flexibility, 2) increased expenses for public education and 3) loss of landscaped property were high ranking impacts recorded for both the 2013 CWCB survey and 2004 DWSA.

### Adaptive Capacities

Table 9.12 indicates that 70 % of the 2007 DWSU surveyed municipalities in the Arkansas River Basin incorporate drought recurrence in long-term water supply and conservation planning. Twenty-seven percent of the surveyed municipalities have drought management plans and 53% and 64% have water conservation plans and raw or treated water master plans, respectively. Although these values are above the statewide average, they still suggest that there is a large portion of municipalities in the basin that lack formal plans to address drought. Generally, the larger M&I providers have the resources to develop comprehensive plans while smaller communities may not have the staff or resources to sufficiently plan for periods of drought.

**Table 9.12. Arkansas River Provider Planning Efforts 2007 DWSU Survey Results[17]**

| Drought-Related Planning Efforts | Arkansas River Basin | | Statewide Average | |
|---|---|---|---|---|
| | Percentage of Surveyed M&I providers | Percentage of Plans Updated Since 2002 | Percentage of Surveyed M&I providers | Percentage of Plans Updated Since 2002 |
| Have a drought management plan | 27% | 20% | 25% | 19% |
| Have a raw and/or treated master plan | 64% | 43% | 61% | 37% |
| Have a conservation plan | 53% | 39% | 44% | 30% |
| Drought recurrence is considered in long-term water supply and conservation planning | 70% | n/a | 66% | n/a |

Source: CWCB, 2004. DWSA, 2004 Survey.

The 2013 CWCB drought survey indicated that 56% of the survey respondents either updated or developed a new comprehensive drought plan following the 2002 drought and 72% perceive that there is sufficient funding either in-basin or through state/federal resources to support water supply reliability, conservation and drought planning. None of the respondents anticipate improving their drought preparedness following the 2012 – 2013 dry period.

### Drought Vulnerability

M&I drought vulnerability will largely depend on drought planning efforts and how effectively drought is incorporated into long-term water supply reliability planning as the region continues

[17] Note: A direct relationship between drought vulnerability and adaptive capacity cannot be deciphered solely using these data. While these results provide a general indication of the number of drought, conservation and raw/treated master plans, they do not provide information on the content and "overall effectiveness" of the plans. However, they do provide a general indication of M&I drought awareness on a basin-wide level.

to develop. During the 2004 SWSI process most major M&I providers indicated that they would be able to meet future 2030 demands through existing supplies, projects being developed and planned future projects (CWCB, 2004). Table 9.13 lists the major projects and processes identified in 2013 to address long-term water supply needs. Many of these projects will be instrumental in maintaining water supply reliability and either directly or indirectly meeting demands during drought periods.

**Table 9.13. Major Identified Projects and Processes in the Arkansas River Basin[18]**

| M&I Providers | Project | IPP Type |
|---|---|---|
| Colorado Springs Utilities, Fountain, Security WSD, Pueblo West MD | Southern Delivery System Phase I (with Local System Improvements)<br>Southern Delivery System Phase II (with Local System Improvements) | |
| Colorado Springs Utilities, Aurora, Vail Consortium (Eagle River W&SD, Upper Eagle W&SD, Vail Associates), the Colorado River Water Conservation District, Cyprus Climax Metals Company | Eagle River Joint-Use Project (Eagle River MOU) | New Transbasin Project<br><br>Firming Transbasin Rights |
| El Paso County Water Authority | Groundwater | Regional In-Basin Project |
| | Reuse | Reuse |
| Upper Arkansas Water Conservancy District | Augmentation Plan | Firming In-Basin Rights |
| East Twin Lakes Ditches & Waterworks Economic Development | Cache Creek Reservoir | |
| Southeastern Colorado Water Conservancy District | Arkansas Valley Conduit | Firming Transbasin Rights |
| | Preferred Storage Option Plan - Fry-Ark | |
| | Preferred Storage Option Plan - Pueblo Reservoir | |
| | Preferred Storage Option Plan - Turquoise Reservoir | |
| Pueblo Board of Water Works | Water Rights Acquisition – Bessemer Ditch | Agricultural Transfers |
| | Reuse Plan | Reuse |

The largest urban growth in the Arkansas Basin is anticipated in the Colorado Springs and Pueblo metropolitan areas. These municipalities have a relatively diverse portfolio of water

[18] Note: The draft list of IP&Ps in this table is based on the best available information at the time of publishing (2013) and does not include conservation. Due to the evolving nature of IP&P's planned by providers this information will change over time with regards to IP&P details, new IP&P's, completed IP&P's, and unsuccessful or withdrawn IP&P's. As a basic list of major IP&P's it does not include things such as a water provider growing into its existing supply, planned transfers of agricultural water rights, or the vast majority of water conservation programs. The CWCB is working to collect better data on IP&P's, including conservation programs, through the development of its Basin Needs Decision Support System and its associated survey of water providers.

supplies and undergo relatively comprehensive raw water master planning efforts. Consequently, they are not as vulnerable to drought as other smaller communities in the Basin. Additionally, the Southern Delivery System, in the construction phase, will provide additional drought protection to Colorado Springs, Fountain, Security, and Pueblo West.

Communities in the headwaters of the Basin are also anticipated to experience high growth rates, and this area will find it challenging to develop augmentation water necessary to augment well requirements (CWCB, 2004). Communities in the eastern plains are not anticipated to experience as much growth (CWCB, 2004); however, many of these communities rely on more junior surface and tributary groundwater rights in additional to nontributary groundwater. Water quality is also a concern in part of the lower portions of the Basin. The Colorado Department of Public Health and Environment (in a February 2002 report) stated: “The Lower Arkansas River in Colorado is the most saline stream of its size in the United States. The average salinity levels increased from 300 ppm TDS east of Pueblo to over 4,000 ppm near the Kansas state line. The shallow alluvial groundwater along the river has a similar salinity.” The Arkansas Valley Pipeline will help relieve some of the water quality concerns for M&I water providers and reduce drought vulnerability. It could be constructed as early as 2018. This pipeline will convey water from Pueblo Reservoir to M&I water providers along the Arkansas River east to Lamar, Colorado.

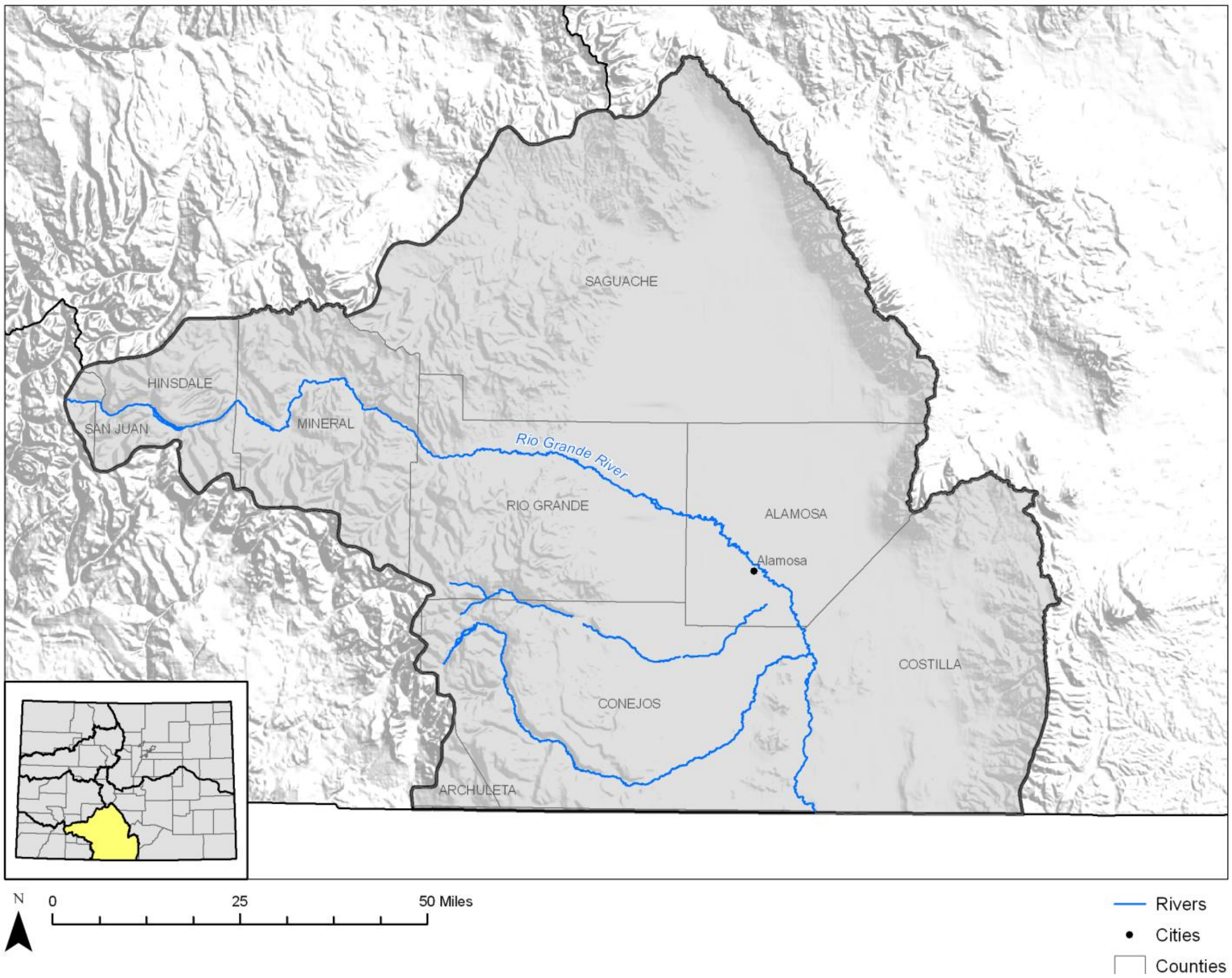
There is interest and economic incentive to sell agricultural rights to municipalities outside of the Basin (Arkansas Valley Irrigator Incorporated, 2013). In response to these exports, the Super Ditch Company has been developed as a means to transfer water to municipalities during times of water shortage without permanently drying up farmland. The first leasing arrangement occurred toward the end of 2009 although it is anticipated that it will take some time for the program to be fully operational. This program could facilitate mutually beneficial reductions in M&I drought vulnerability while also reducing agricultural impacts within the lower Arkansas River Basin.

As the Arkansas River Basin continues to develop, Arkansas River compact obligations will still need to be met. The drought vulnerability of smaller communities, relying on surface and tributary supplies, can be reduced if these communities are prepared for how changes in river administration can affect overall water supply reliability during times of drought. Generally, communities with senior water right portfolios and diverse supplies or using relatively stable nontributary groundwater supplies have relatively high water supply reliability. These communities are less vulnerable to drought than communities relying on less reliable junior surface rights to meet their needs. However, it is important to note that unsustainable use of nontributary groundwater can result in long-term water supply concerns.

#### *Division 3 - Rio Grande River Basin*

The Division 3 - Rio Grande River Basin contains some of the State’s oldest and most productive agricultural lands, with relatively little urban development compared to other basins. M&I water needs in the Basin are largely met through groundwater pumping and make up a very small amount of the overall water demands in the Basin (CWCB, 2004). The State and existing groundwater users in the Basin are engaged in rulemaking and management activities to ensure that groundwater pumping is maintained at sustainable levels.

**Figure 9.20. Rio Grande River Basin**




## Historical Drought Impacts

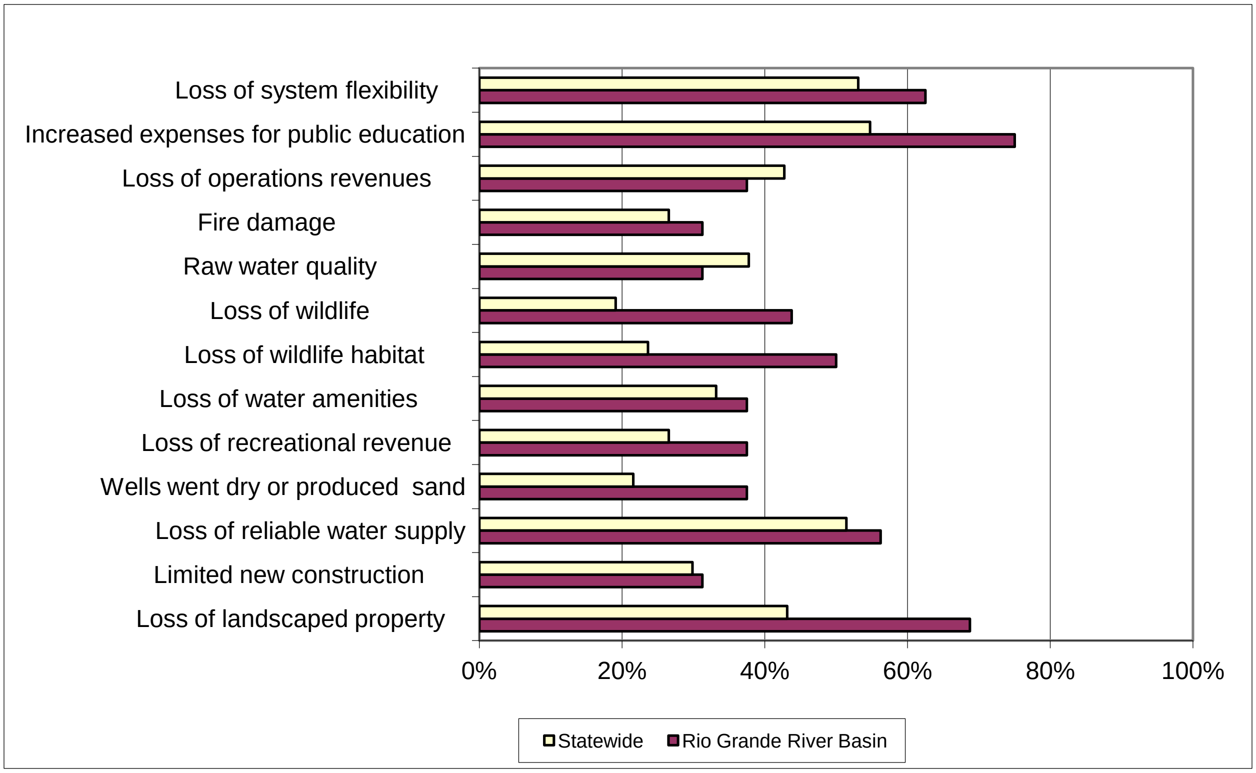
The 2004 DWSA survey results shown in Figure 9.21 indicates that over 40% of the 16 surveyed M&I providers in the Rio Grande River Basin experienced the following impacts during the 1999-2003 drought period:

- Loss of system flexibility
- Increased expenses for public education
- Loss of wildlife
- Loss of wildlife habitat
- Loss of reliable water supply

- Loss of landscaped property

Increased expenses for public education followed by loss of landscaped property were the most frequently experienced impacts. All of the impacts with exception to raw water quality and loss of operations revenues exceeded statewide levels suggesting that M&I drought-related impacts were generally greater than experienced at a statewide level.

**Figure 9.21. Rio Grande River Basin 1999-2003 Drought Impacts**[19]




Source: DWSA 2004 survey data.

The 2013 CWCB drought survey impacts ranked as having the highest frequency/level of concern in 2012, anticipated for 2013 and experienced for the longest duration from 2002 to 2006 were the following:

- Decreased groundwater availability
- Significant loss in storage that carried over to the following year
- Loss of system flexibility
- Decrease in operations revenue
- Increased expenses for public education and outreach

[19] Note: A comprehensive review and internal testing process of the survey tool was conducted, yet it is important to recognize that these DWSA 2004 surveyed impact results are subjective. The impacts in the figure above are, in many cases, a reflection of the DWSA author's interpretation of the listed impacts.

- Loss of recreational revenue
- Increased staff time necessary to address conditions

Of the survey impacts listed above, loss of system flexibility and increased expenses for public education were high ranking impacts recorded for both the 2013 CWCB survey and 2004 DWSA.

### Adaptive Capacities

Table 9.14 presents 2007 DWSU survey results. This shows that 56% of the surveyed municipalities in the Rio Grande River Basin incorporate drought recurrence in long-term water supply planning. Eleven percent of the surveyed municipalities have drought management plans while 22% and 33% have water conservation and raw or treated water master plans, respectively. These planning efforts are below the statewide average.

**Table 9.14. Rio Grande River Basin Provider Planning Efforts 2007 DWSU Survey Results[20]**

| Drought-Related Planning Efforts | Rio Grande River Basin | | Statewide Average | |
|---|---|---|---|---|
| | Percentage of Surveyed M&I providers | Percentage of Plans Updated Since 2002 | Percentage of Surveyed M&I providers | Percentage of Plans Updated Since 2002 |
| Have a drought management plan | 11% | 0% | 25% | 19% |
| Have a raw and/or treated master plan | 33% | 11% | 61% | 37% |
| Have a conservation plan | 22% | 11% | 44% | 30% |
| Drought recurrence is considered in long-term water supply and conservation planning | 56% | n/a | 66% | n/a |

Source: CWCB, 2004. DWSA 2004 Survey.

### Drought Vulnerability

Population in the Rio Grande River Basin is not anticipated to increase substantially relative to the remainder of the State,[21] and consequently future M&I demand growth is expected to be relatively small.[22] There will likely be sufficient groundwater supplies to meet future M&I demands, although some augmentation of groundwater pumping will be necessary (CWCB, 2004).

[20] Note: A direct relationship between drought vulnerability and adaptive capacity cannot be deciphered solely using these data. While these results provide a general indication of the number of drought, conservation and raw/treated master plans, they do not provide information on the content and "overall effectiveness" of the plans. However, they do provide a general indication of M&I drought awareness on a basin-wide level.

[21] This is based on the Baseline M&I forecast for the medium 2050 growth scenario presented in CWCB. 2010. *Final State of Colorado 2050 Municipal and Industrial Water Use Projections*

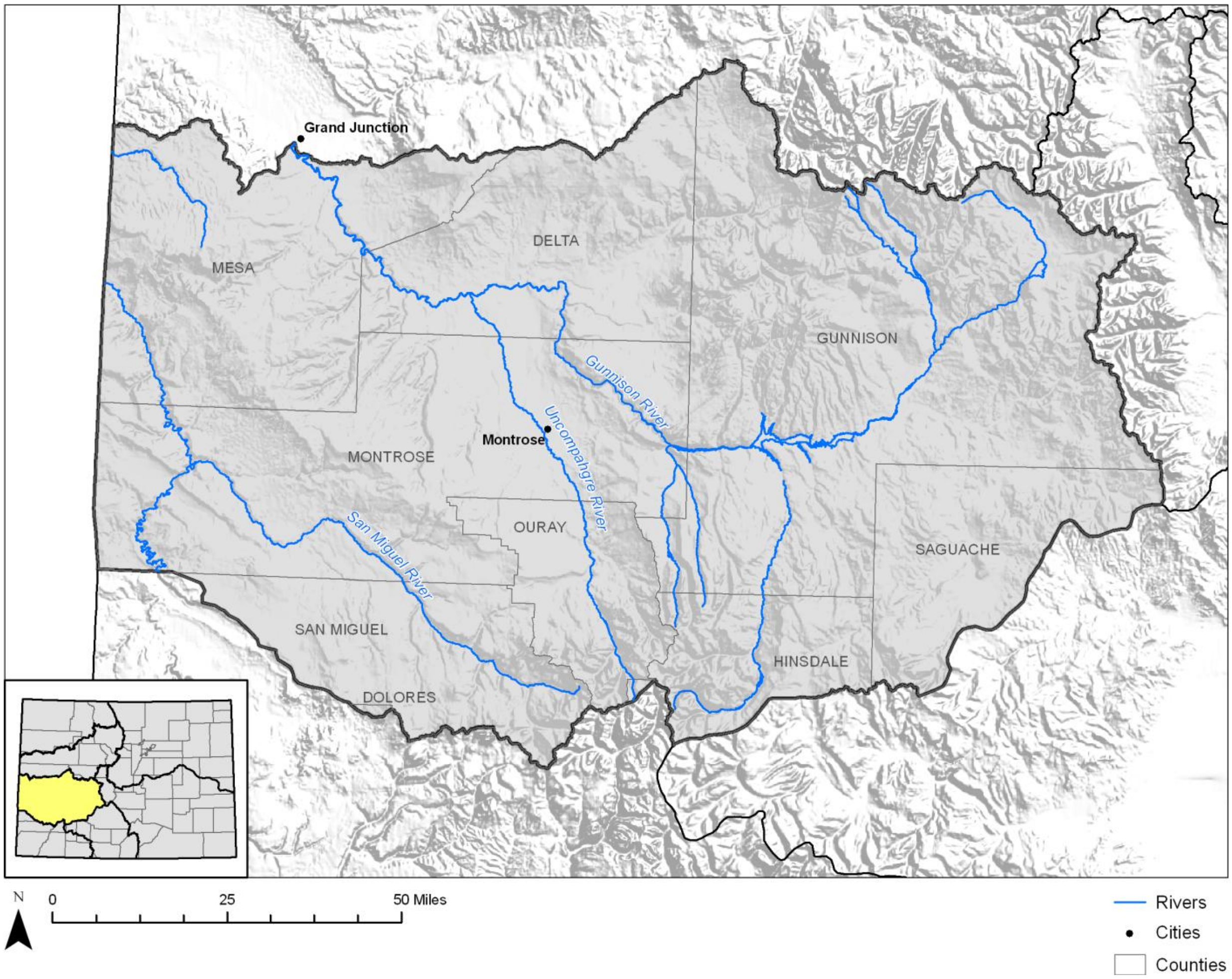
[22] These data are based on the Baseline M&I forecast for the medium 2050 growth scenario presented in CWCB. 2010. *Final State of Colorado 2050 Municipal and Industrial Water Use Projections*.

Significant declines in groundwater levels occurred during the 2002 drought and have since recovered substantially. It is worth noting that 2004 DWSA survey results indicate a higher occurrence of M&I drought impacts during the 1999-2003 dry period than were seen at the statewide levels. Relatively recent rules require the augmentation of stream depletions from groundwater pumping and maintenance of pumping at sustainable levels. Water users in the Basin are collaboratively working together to develop a means to maintain groundwater levels and augment stream depletions while also meeting the Rio Grande Compact out-of-state delivery requirements. The Rio Grande Compact's delivery requirements coupled with the recently new rules limits the development of new water in the Basin. Consequently, augmentation of M&I well pumping will likely be provided through existing transbasin water rights diverted from the San Juan/Dolores River Basin and existing and future agricultural transfers. Future M&I drought vulnerability will largely depend on the seniority and reliability of M&I augmentation supplies during periods of drought.

#### *Division 4 - Gunnison River Basin*

The Division 4 - Gunnison River Basin is sparsely populated and the M&I water demands are relatively minor compared to other basins in the State. The most populated urban areas are in the lower western portions of the Basin. The M&I water needs are primarily met through a combination of surface water supplies delivered via the Gunnison River and its tributaries and tributary groundwater supplies (CWCB, 2004).

## Figure 9.22. Gunnison River Basin



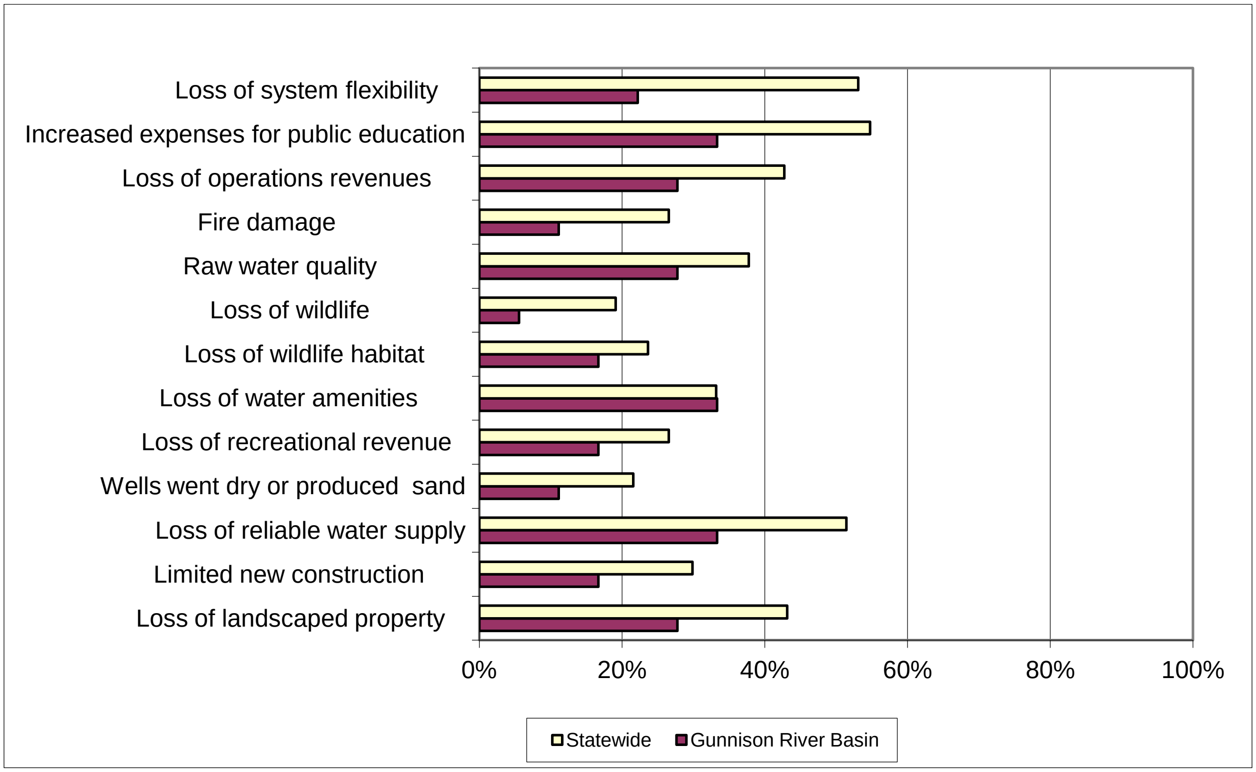

## Historical Drought Impacts

The Gunnison River Basin, along with the Yampa River Basin, had the lowest number of impacts during the 1999-2003 drought period based on the 2004 DWSA survey results. The 2004 DWSA survey impacts for the Gunnison River Basin are shown in Figure 9.23. Impacts with the highest percentage of occurrence among the 18 surveyed M&I providers were the following:

- Increased expenses for public education
- Loss of water amenities
- Loss of reliable water supply

All impacts with exception to loss of water amenities were less than statewide levels.

**Figure 9.23. Gunnison River Basin 1999-2003 Drought Impacts[23]**




Source: DWSA 2004 survey data.

The 2013 CWCB survey impacts ranked as having the highest frequency/level of concern in 2012, anticipated for 2013 and experienced for the longest duration from 2002 to 2006 were the following:

- Loss of system flexibility
- Significant loss in storage that carried over to the following year
- Increased staff time necessary to address drought
- Decrease raw water quality

None of the high ranking impacts in the CWCB 2013 drought survey were the same impacts identified during the 2004 DWSA. However, each of the surveys capture impacts related to water supply reliability which include loss of system flexibility, loss in carryover storage and loss in overall system reliability.

[23] Note: A comprehensive review and internal testing process of the survey tool was conducted, yet it is important to recognize that these DWSA 2004 surveyed impact results are subjective. The impacts in the figure above are, in many cases, a reflection of the surveyees' interpretation of the listed impacts.

## Adaptive Capacities

Table 9.15 indicates that 40 % of the 2007 DWSU surveyed municipalities in the Gunnison River Basin incorporate drought recurrence in long-term water supply and conservation planning, which is lower than the statewide average. Thirty percent of the surveyed municipalities have drought management plans while 50% have conservation and raw or treated master plans, respectively. Drought and conservation planning is above the State average while conversely, treated/raw master planning is below the State average.

All of the 2013 CWCB drought survey respondents (3 respondents) indicated that they have either updated or developed a new comprehensive plan following the 2002 drought and anticipate improving their drought preparedness following the 2012 – 2013 dry period. None of the respondents feel that there is sufficient funding to support water supply reliability, conservation and drought planning.

**Table 9.15. Gunnison River Basin Provider Planning Efforts 2007 DWSU Survey Results [24]**

| Drought-Related Planning Efforts | Gunnison River Basin | | Statewide Average | |
|---|---|---|---|---|
| | Percentage of Surveyed M&I providers | Percentage of Plans Updated Since 2002 | Percentage of Surveyed M&I providers | Percentage of Plans Updated Since 2002 |
| Have a drought management plan | 30% | 10% | 25% | 19% |
| Have a raw and/or treated master plan | 50% | 30% | 61% | 37% |
| Have a conservation plan | 50% | 30% | 44% | 30% |
| Drought recurrence is considered in long-term water supply and conservation planning | 40% | n/a | 66% | n/a |

Source: CWCB, 2004. DWSA 2004 Survey.

## Drought Vulnerability

Many of the municipalities in the Gunnison River Basin are anticipated to substantially grow by 2050. Urban development will mainly be concentrated in Delta, Montrose, and Mesa Counties. Many of these M&I providers have identified plans for meeting future water needs that include local storage projects and agricultural transfers. Table 9.16 lists the major projects and processes identified to address long-term water supply needs. These projects will be instrumental in maintaining water supply reliability and either directly or indirectly meeting demands during drought periods.

[24] Note: A direct relationship between drought vulnerability and adaptive capacity cannot be deciphered solely using these data. While these results provide a general indication of the number of drought, conservation and raw/treated master plans, they do not provide information on the content and "overall effectiveness" of the plans. However, they do provide a general indication of M&I drought awareness on a basin-wide level.

## Table 9.16. Major Identified Projects and Processes in the Gunnison River Basin[25]

| M&I Providers | Project | IPP Type |
|---|---|---|
| Upper Gunnison River Water Conservancy District | Plan for augmentation for non-agricultural purposes using Aspinall Unit | Firming In-Basin Rights |
| | Reservoirs on Cochetopa Creek | |
| Mt. Crested Butte and the Upper Gunnison River Water Conservancy District | Augmentation Storage for Mt. Crested Butte | Firming In-Basin Rights |
| Upper Gunnison River Water Conservancy District and Hinsdale County Commissioners | Lake San Cristobal water development | Regional In-Basin Project |

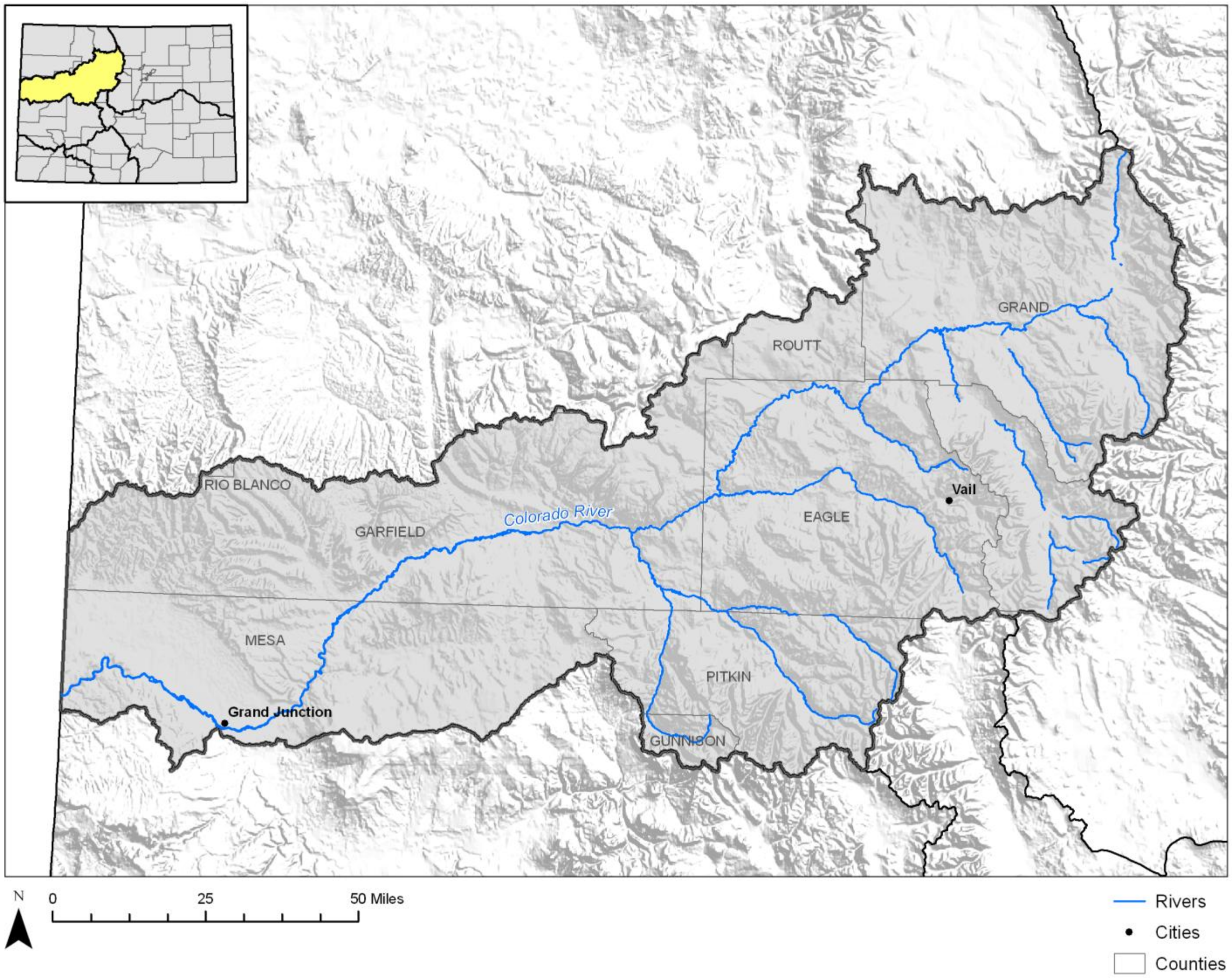
The headwaters of the Gunnison River Basin are also anticipated to experience significant growth (Crested Butte) if adequate supplies for M&I and snowmaking can be developed. Well augmentation water is necessary to meet many of the M&I demands in the upper Gunnison and Uncompahgre sub-basins. These will be a challenge to acquire while maintaining senior agricultural right diversions (CWCB, 2004). The drought impacts recorded in Figure 9.24 are generally well below the statewide average. However, future M&I growth may stress water supplies, especially during times of drought. M&I drought vulnerability could increase for some M&I providers if drought is not effectively incorporated into long-term water supply reliability planning.

### *Division 5 - Colorado River Basin*

The Division 5 - Colorado River Basin supports growing mountain resort communities in Eagle, Summit, Pitkin, and Grand Counties as well as Grand Junction and the agricultural community of Palisade. M&I water needs are met through a combination of surface water supplies primarily delivered via the Colorado River and its tributaries and tributary groundwater supplies.

[25] Note: The draft list of IP&Ps in this table is based on the best available information at the time of publishing (2013) and does not include conservation. Due to the evolving nature of IP&P's planned by providers this information will change over time with regards to IP&P details, new IP&P's, completed IP&P's, and unsuccessful or withdrawn IP&P's. As a basic list of major IP&P's it does not include things such as a water provider growing into its existing supply, planned transfers of agricultural water rights, or the vast majority of water conservation programs. The CWCB is working to collect better data on IP&P's, including conservation programs, through the development of its Basin Needs Decision Support System and its associated survey of water providers.

**Figure 9.24. Colorado River Basin**



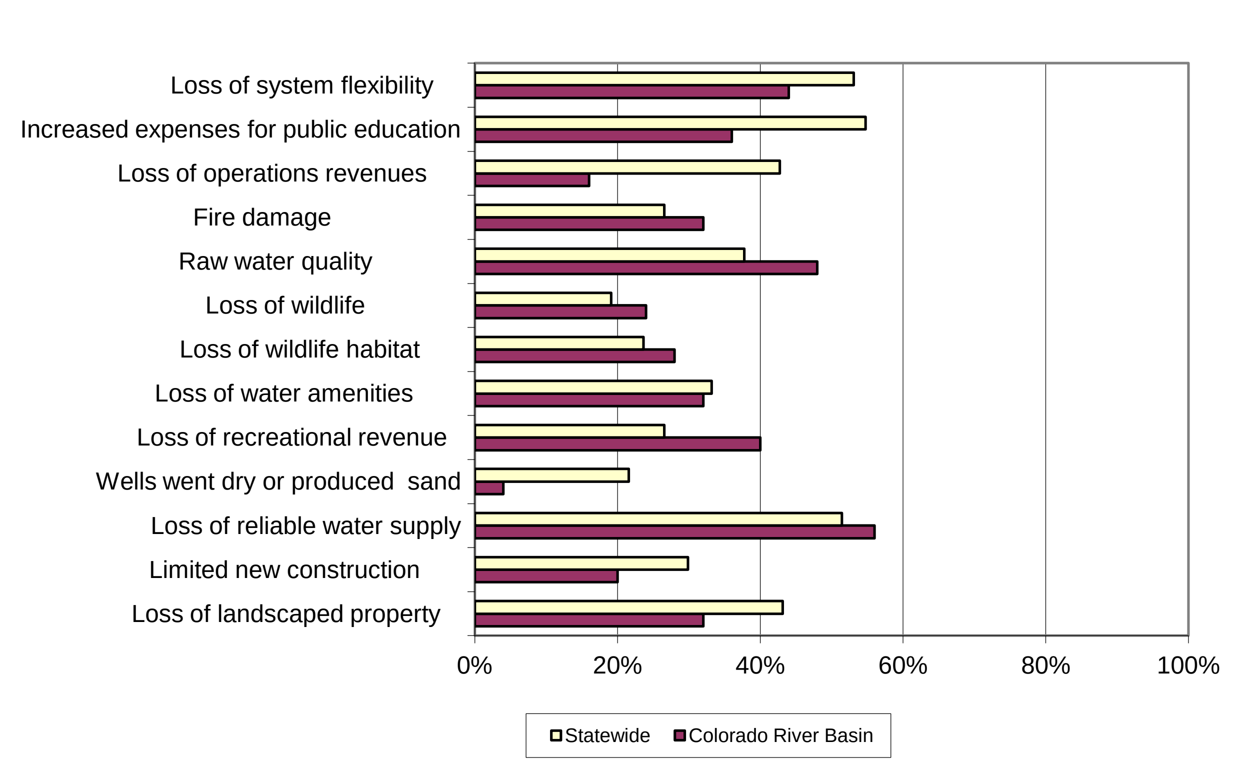

## Historical Drought Impacts

The 2004 DWSA survey results shown in Figure 9.25 indicate that over 40% of the 25 surveyed M&I providers in the Colorado River Basin experienced the following impacts during the 1999-2003 drought period:

- Loss of system flexibility
- Raw water quality
- Loss of reliable water supply

The loss of reliable water supply was the most frequently experienced impact, exceeding the statewide level percentage. Raw water quality and the impacts related to recreation, wildlife, and fire damage also exceeded statewide levels. However, many of the impact percentages were significantly lower than statewide levels with the greatest differences observed for the loss of operations revenues, wells went dry and increased expenses for public education impacts.

**Figure 9.25. Colorado River Basin 1999-2003 Drought Impacts[26]**




Source: DWSA 2004 survey data.

The 2013 CWCB drought survey impacts ranked as having the highest frequency/level of concern in 2012, anticipated for 2013 and experienced for the longest duration from 2002 to 2006 were the following:

- Loss of system flexibility
- Decreased raw water quality
- Increased expenses for public education and outreach
- Voluntary water restrictions
- Mandatory water restrictions
- Decreased storage levels

Losses in system flexibility and decreased raw water quality were high ranking impacts among both the 2004 DWSA and 2013 CWCB drought surveys.

The 2003 Upper Colorado River Basin Study (UPCO) identified the following major impacts during the 2002 drought that resulted in local M&I water shortages (Hydrosphere, 2003):

[26] Note: A comprehensive review and internal testing process of the survey tool was conducted, yet it is important to recognize that these DWSA 2004 surveyed impact results are subjective. The impacts in the figure above are, in many cases, a reflection of the surveyees' interpretation of the listed impacts.

- Problems occurred with Green Mountain Reservoir including exhausting the historic users pool and the impact of the Heeney slide, which prevented full use of the reservoir's available storage;
- Denver Water reduced its by-pass flows past their Moffat Collection System, significantly reducing streamflows in the Fraser River Basin;
- Due to agreements between water users and Xcel Energy, there were changes in the administration of the Shoshone call;
- Clinton Reservoir failed to fill for the majority of the 1999-2003 dry period, causing shortages in the planned 3-year supply for certain shareholders; and
- Denver Water nearly exhausted its Williams Fork Reservoir supply and resorted to use of Dillon Reservoir to augment its Fraser River diversions.

**Adaptive Capacities**

Table 9.17 indicates that 74% of the 2007 DWSU surveyed municipalities in the Colorado River Basin incorporate drought recurrence in long-term water supply and conservation planning. This is higher than the statewide average. Twenty-six percent of the surveyed municipalities have drought management plans, while 40% and 63% have conservation and raw or treated master plans, respectively. The percentage of surveyed providers with conservation plans in the Basin is below the State average while conversely, treated/raw master planning is above the State average.

**Table 9.17. Colorado River Basin Provider Planning Efforts 2007 DWSU Survey Results[27]**

| Drought-Related Planning Efforts | Colorado River Basin | | Statewide Average | |
|---|---|---|---|---|
| | Percentage of Surveyed M&I providers | Percentage of Plans Updated Since 2002 | Percentage of Surveyed M&I providers | Percentage of Plans Updated Since 2002 |
| Have a drought management plan | 26% | 22% | 25% | 19% |
| Have a raw and/or treated master plan | 63% | 48% | 61% | 37% |
| Have a conservation plan | 40% | 26% | 44% | 30% |
| Drought recurrence is considered in long-term water supply and conservation planning | 74% | n/a | 66% | n/a |

Source: CWCB 2004. DWSA 2004 Survey.

Sixty-seven percent of the 2013 CWCB drought survey respondents (6 respondents) indicated that they have either updated or developed a new comprehensive plan following the 2002 drought and 50% anticipate improving their drought preparedness following the 2012 – 2013 dry

[27] Note: A direct relationship between drought vulnerability and adaptive capacity cannot be deciphered solely using these data. While these results provide a general indication of the number of drought, conservation and raw/treated master plans, they do not provide information on the content and "overall effectiveness" of the plans. However, they do provide a general indication of M&I drought awareness on a basin-wide level.

period. Sixty-four percent of the respondents feel that there is sufficient funding to support water supply reliability, conservation and drought planning.

**Drought Vulnerability**

Figure 9.2 indicates that by 2050, M&I providers in Garfield, Eagle, and Summit Counties are anticipated to experience the greatest increase in M&I demands within the Colorado River Basin.[28] These communities are in the headwater counties and could be more vulnerable to drought if drought is not effectively incorporated into long-term water supply reliability planning. Table 9.18 lists the major projects and processes identified to address long-term water supply needs. Many of these projects will be instrumental in maintaining water supply reliability and either directly or indirectly meeting demands during drought periods.

**Table 9.18. Major Identified Projects and Processes in the Colorado River Basin[29]**

| M&I Providers | Project | IPP Type |
|---|---|---|
| Colorado Springs Utilities, Aurora, Vail Consortium (Eagle River W&SD, Upper Eagle W&SD, Vail Associates), the Colorado River Water Conservation District, Cyprus Climax Metals Company | Eagle River Joint-Use Project (Eagle River MOU) | New Transbasin Project Firming Transbasin Rights |
| Colorado River Water Conservation District, Denver Water | Wolford Reservoir Enlargement | |
| Colorado River Water Conservation District, Denver Water, City of Aurora, Eagle River Water and Sanitation District, Northern Colorado Water Conservancy District, Upper Eagle Regional Water Authority | Wolcott Reservoir | |
| Upper Colorado River Basin Study (UPCO) | Grand County M&I | Regional In-Basin Project |
| | Summit County M&I and Environmental | Regional In-Basin Project |
| Dillon and Silverthorne | Old Dillon Reservoir Expansion | |
| Ute Water Conservancy District | Hunter Reservoir Enlargement | Firming In-Basin Rights |
| Town of Eagle | Acquired water right (20% of 2050 firm yield) | Regional In-Basin Project |
| Town of Eagle | Planned Water Rights (80% of 2050 firm yield) | Growth Into Existing Supplies |
| Town of Silt | Water Rights Acquisition | Regional In-Basin Project |

[28] [28] The data presented in the table is based on the Baseline M&I forecast for the medium 2050 growth scenario presented in *Final State of Colorado 2050 Municipal and Industrial Water Use Projections*

[29] Note: The draft list of IP&Ps in this table is based on the best available information at the time of publishing (2013) and does not include conservation. Due to the evolving nature of IP&P's planned by providers this information will change over time with regards to IP&P details, new IP&P's, completed IP&P's, and unsuccessful or withdrawn IP&P's. As a basic list of major IP&P's it does not include things such as a water provider growing into its existing supply, planned transfers of agricultural water rights, or the vast majority of water conservation programs. The CWCB is working to collect better data on IP&P's, including conservation programs, through the development of its Basin Needs Decision Support System and its associated survey of water providers.

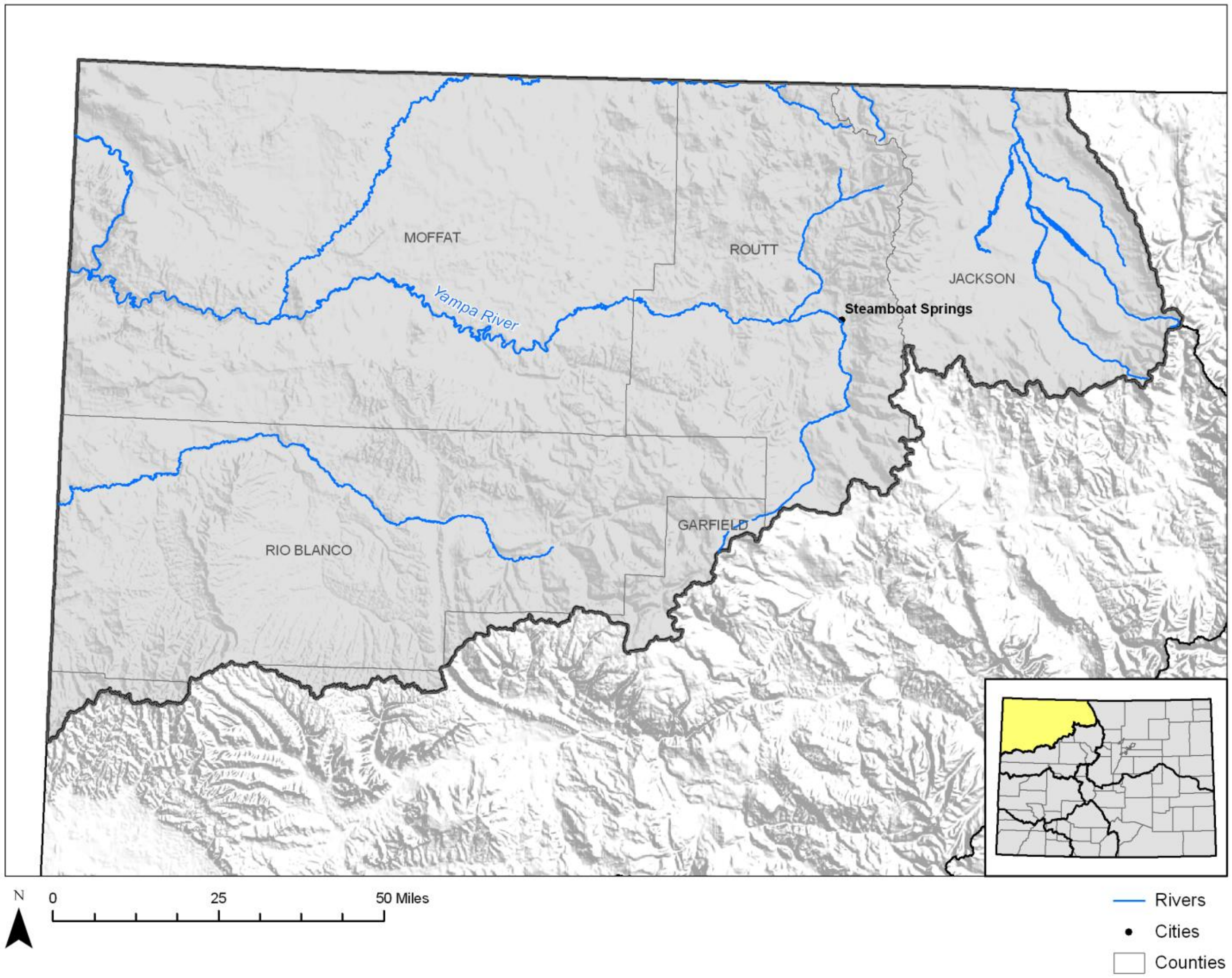
| M&I Providers | Project | IPP Type |
|---|---|---|
| | Reudi Contracts | Regional In-Basin Project |
| | Last Chance Ditch change of use | Agricultural Transfers |
| Aspen | Golf Course Reuse / West Aspen Reclaimed Project | Reuse |
| Town of New Castle | Ag Transfer Water Rights Dedication Policy | Agricultural Transfers |
| Winter Park WSD | Bypass flows in Fraser River | Growth Into Existing Supplies |

It is anticipated that augmentation contracts available out of Ruedi, Green Mountain, and Wolford reservoirs will be an important part of meeting existing and projected 2030 demands in the Basin, especially in the upper headwater counties. As indicated above, problems occurred with Green Mountain Reservoir during the 2002 drought exhausting the historic users pool, and the impact of the Heeney slide ultimately prevented full use of the reservoir's available storage. Low streamflows also reduced the amount of water physically available for diversions, impacting several upper basin M&I providers. These areas may continue to be more vulnerable to drought unless supply alternatives and effective response measures can be developed for drought periods. Additionally, there are several large scale transbasin projects in the permitting phase that could influence future river administration. During the permitting process, measures are being identified to mitigate potential impacts.

### *Division 6 - Yampa River Basin*

The Division 6 - Yampa River Basin is sparsely populated with Steamboat Springs and Craig being the largest towns. M&I water needs are mainly met through surface water supplies delivered via the Yampa River and tributaries and secondarily by tributary wells.

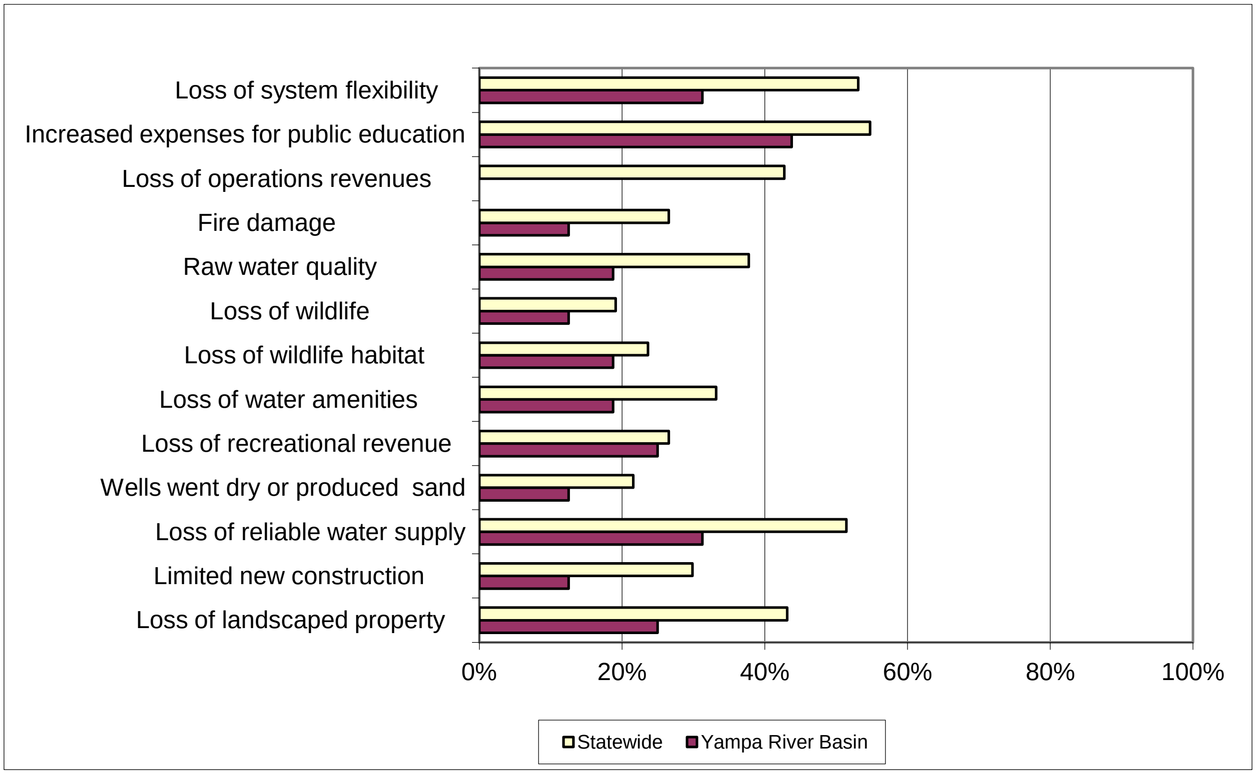
**Figure 9.26. Yampa River Basin**




## Historical Drought Impacts

The Yampa River Basin, along with the Gunnison River Basin, had the lowest number of impacts during the 1999-2003 drought period based on the 2004 DWSA survey results. The 2004 DWSA survey impacts for the Yampa River Basin are shown in Figure 9.27, The greatest impact was increased supplies for public education (40 % of the 16 surveyed M&I providers reported this). Loss of system flexibility and loss of reliable water supply were the next most frequent impacts. All impacts, with the exception of lost of crop yields, were lower than statewide levels.

**Figure 9.27. Yampa River Basin 1999-2003 Drought Impacts[30]**




Source: DWSA 2004 survey data.

The 2013 CWCB drought survey impacts ranked as having the highest frequency/level of concern in 2012, anticipated for 2013 and experienced for the longest duration from 2002 to 2006 were the following:

- Loss of irrigated vegetation within urban service area
- Significant loss in storage that carried over to the following year
- Decrease in groundwater availability or drop of groundwater levels

Losses in system flexibility and loss of irrigated vegetation/landscaped property were high ranking impacts recorded among both the 2004 DWSA and 2013 CWCB drought surveys.

## Adaptive Capacities

Table 9.19 indicates that 60% of the 2007 DWSU surveyed municipalities in the Yampa River Basin incorporate drought recurrence in long-term water supply. None of the surveyed M&I providers had drought management plans and while 20% and 60% have conservation and raw or treated master plans, respectively. These planning efforts are below the statewide averages.

[30] Note: A comprehensive review and internal testing process of the survey tool was conducted, yet it is important to recognize that these DWSA 2004 surveyed impact results are subjective. The impacts in the figure above are, in many cases, a reflection of the surveyees' interpretation of the listed impacts.

## Table 9.19. Yampa River Basin Provider Planning Efforts 2007 DWSU Survey Results[31]

| Drought-Related Planning Efforts | Yampa River Basin | | Statewide Average | |
|---|---|---|---|---|
| | Percentage of Surveyed M&I providers | Percentage of Plans Updated Since 2002 | Percentage of Surveyed M&I providers | Percentage of Plans Updated Since 2002 |
| Have a drought management plan | 0% | 0% | 25% | 19% |
| Have a raw and/or treated master plan | 60% | 10% | 61% | 37% |
| Have a conservation plan | 20% | 10% | 44% | 30% |
| Drought recurrence is considered in long-term water supply and conservation planning | 60% | n/a | 66% | n/a |

Source: CWCB 2004. DWSA 2004 Survey.

The 2013 CWCB drought survey results are limited to one respondent in the Yampa Basin. This respondent indicated that they have not updated or developed a new comprehensive plan following the 2002 drought nor anticipate improving their drought preparedness following the 2012 – 2013 dry period. The respondent feels that there is sufficient funding to support water supply reliability, conservation and drought planning.

### Drought Vulnerability

Although the Yampa River Basin is expected to grow, projected increases in M&I water demands are still anticipated to be relatively low compared to other more rapidly growing and already densely populated basins in Colorado. Future M&I needs are anticipated to be met through existing water rights and storage in Stagecoach, Elkhead, and Yamcolo reservoirs. However, it is worth noting that in certain areas high transit losses were observed in delivering downstream supplies during portions of the 1999-2003 dry period (CWCB, 2004). As a result, projected M&I firm yields could be lower than anticipated during future drought, requiring the development of additional M&I water. Table 9.20 lists the major projects and processes identified to address long-term water supply needs. These projects will be instrumental in maintaining water supply reliability and either directly or indirectly meeting demands during drought periods.

[31] Note: A direct relationship between drought vulnerability and adaptive capacity cannot be deciphered solely using these data. While these results provide a general indication of the number of drought, conservation and raw/treated master plans, they do not provide information on the content and "overall effectiveness" of the plans. However, they do provide a general indication of M&I drought awareness on a basin-wide level.

## Table 9.20. Major Identified Projects and Processes in the Yampa River Basin[32]

| M&I Providers | Project | IPP Type |
|---|---|---|
| Steamboat Springs | Elk River Project | Regional In-Basin Project |
| Upper Yampa Water Conservancy District | Stagecoach Reservoir Enlargement | Regional In-Basin Project |
| | Morrison Creek Reservoir Project | Regional In-Basin Project |
| Colorado River Water Conservation District, Town of Craig | Elkhead Reservoir Enlargement Project | Growth into Existing Supplies |
| Steamboat Springs/Mt. Werner District | Fish Creek Direct Flow and Storage; Yampa Wells | Growth into Existing Supplies |

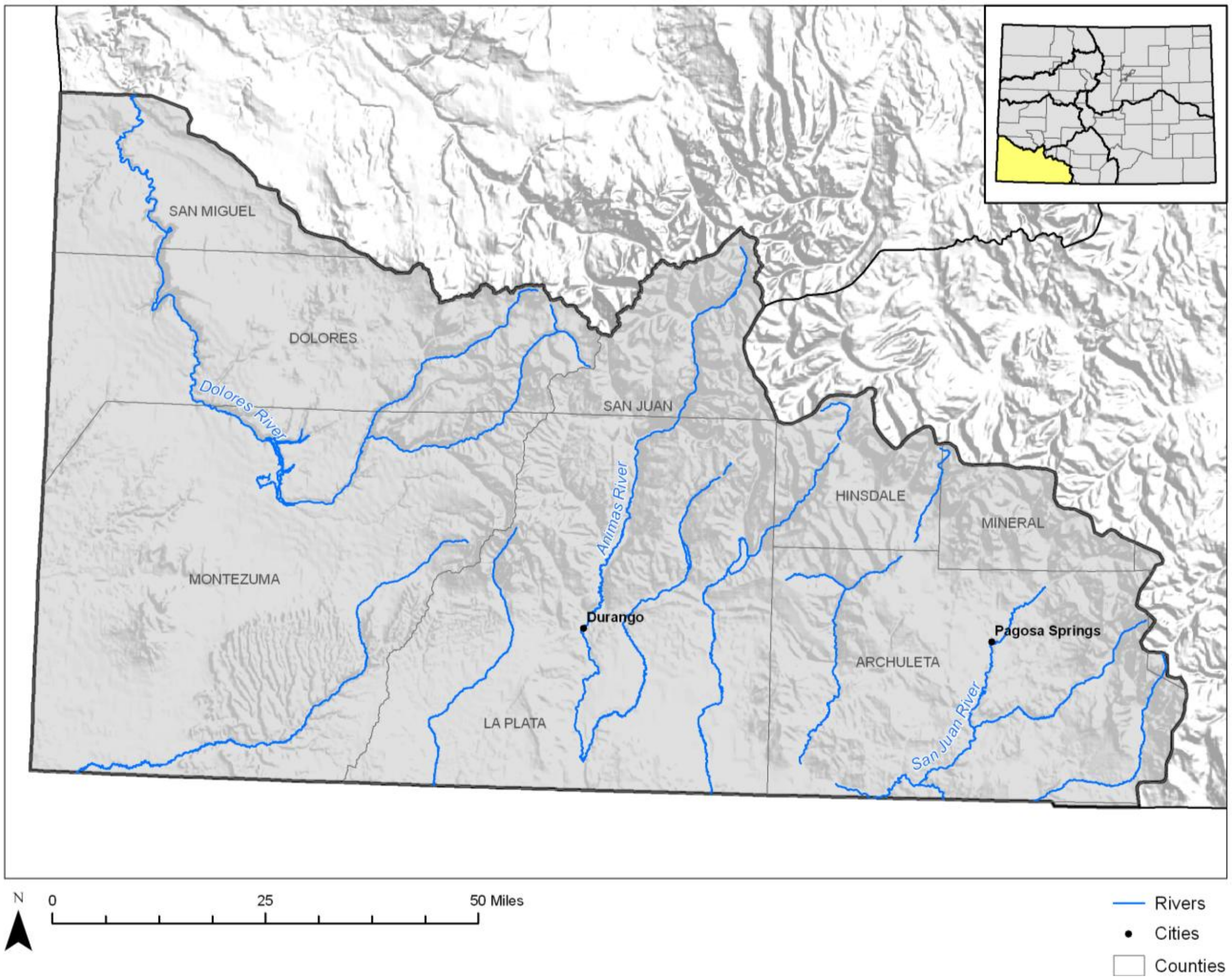
Historically, the mainstem of the Yampa River has not been administered and the 1999-2003 drought impacts recorded in Figure 9.28 are generally well below the statewide average. However, future M&I growth coupled with significant growth in the Energy Sectors within the Basin could further stress water supplies during dry periods and will likely necessitate tighter administration of the river. Additionally new storage projects or enlargements of existing reservoirs may be necessary to meet future demands in the Basin. Several proposed transbasin diversions including the Yampa Pumpback and Flaming Gorge Reservoir Pipeline could alter river administration which could impact future operations of some M&I providers. Background information on these transbasin projects is provided in Section 9.3.

### *Division 7 - San Juan/Dolores River Basin*

The Division 7 - San Juan/Dolores River Basin has a relatively low population density with Durango and Cortez being the largest population centers. M&I water needs are met through a combination of surface water supplies and tributary groundwater supplies (CWCB, 2004).

[32] Note: The draft list of IP&Ps in this table is based on the best available information at the time of publishing and does not include conservation or agricultural transfers. Due to the evolving nature of IP&P's planned by providers this information will change over time with regards to IP&P details, new IP&P's, completed IP&P's, and unsuccessful or withdrawn IP&P's. As a basic list of major IP&P's it does not include things such as a water provider growing into its existing supply, planned transfers of agricultural water rights, or the vast majority of water conservation programs. The CWCB is working to collect better data on IP&P's, including conservation programs, through the development of its Basin Needs Decision Support System and its associated survey of water providers.

Figure 9.28. San Juan/Dolores River Basin



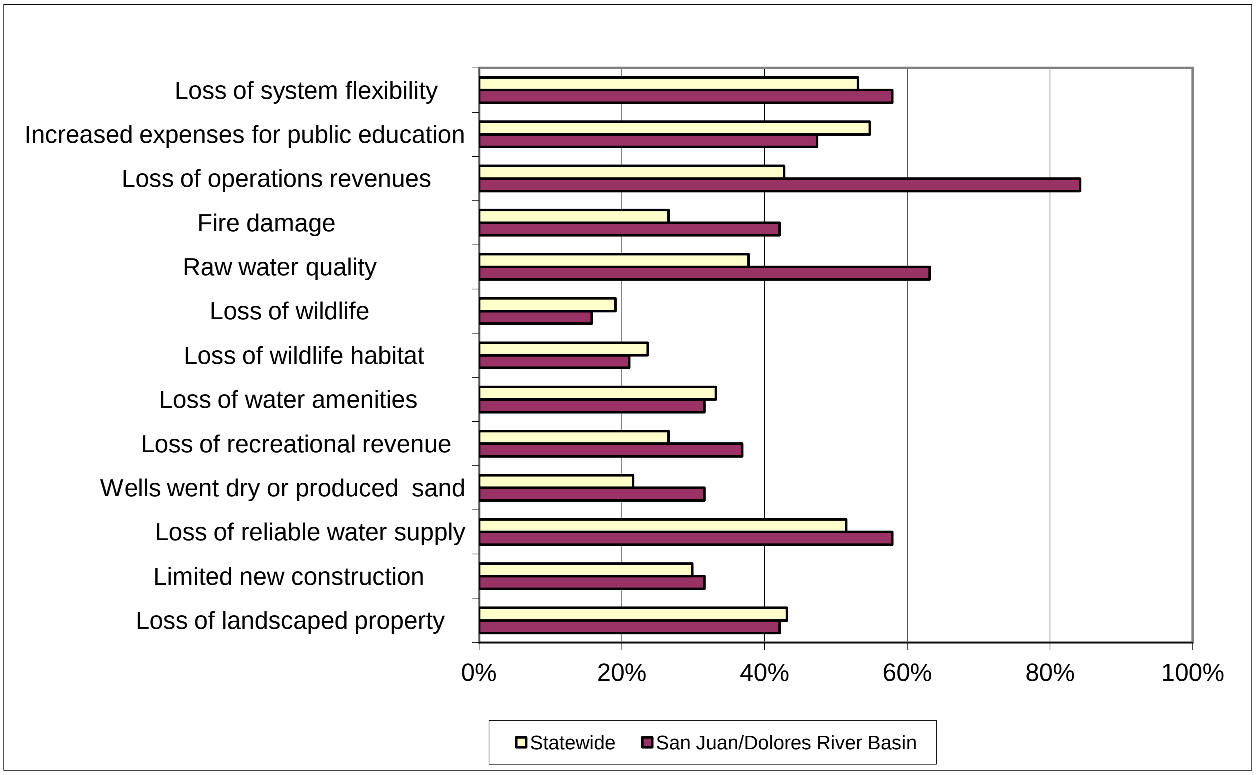

## Historical Drought Impacts

The 2004 DWSA survey results shown in Figure 9.29 indicates that over 40% of the 19 surveyed M&I providers in the San Juan/Dolores River Basin experienced the following impacts during the 1999-2003 drought period:

- Loss of system flexibility
- Increased expenses for public education
- Loss of operations revenues
- Fire damage
- Raw water quality
- Loss of water supply
- Loss of landscaped property

The increased expenses of public education were the most frequently experienced impact, closely followed by losses of system flexibility and water supply reliability. Almost all of the impacts listed above exceeded the frequency of impact on a statewide level, and loss of operations revenues and raw water quality were significantly higher than statewide levels. Impacts with lower percentages of occurrence (less than 30 percent) were generally lower than statewide levels.

**Figure 9.29. San Juan/Dolores River Basin 1999-2003 Drought Impacts**[33]




Source: DWSA 2004 survey data.

The 2013 CWCB drought survey impacts ranked as having the highest frequency/level of concern in 2012, anticipated for 2013 and experienced for the longest duration from 2002 to 2006 were the following:

- Increase staff time necessary to address conditions
- Limits in new construction permits
- Loss or irrigated vegetation within urban service areas
- Loss of recreational revenue
- Increase staff time necessary to address conditions

[33] Note: A comprehensive review and internal testing process of the survey tool was conducted, yet it is important to recognize that these DWSA 2004 surveyed impact results are subjective. The impacts in the figure above are, in many cases, a reflection of the surveyees' interpretation of the listed impacts.

- Voluntary restriction
- Decreased revenue
- Increased expenses for public education and outreach
- Decreased storage levels

Increased expenses for public education, loss of revenue and water supply/storage in addition to the loss of landscape property were high ranking impacts recorded among both the 2004 DWSA and 2013 CWCB drought surveys.

**Adaptive Capacities**

Table 9.21 indicates that 82% of the 2007 DWSU surveyed municipalities in the San Juan/Dolores River Basin incorporate drought recurrence in long-term water supply and conservation planning. This is higher than the statewide average. Twenty-four percent of the surveyed municipalities have drought management plans, which is close to the State average. 53% and 65%, have conservation and raw or treated master plans, respectively, which is above the State average.

**Table 9.21. San Juan/Dolores River Basin Provider Planning Efforts 2007 DWSU Survey Results[34]**

| Drought-Related Planning Efforts | San Juan/Dolores River Basin | | Statewide Average | |
|---|---|---|---|---|
| | Percentage of Surveyed M&I providers | Percentage of Plans Updated Since 2002 | Percentage of Surveyed M&I providers | Percentage of Plans Updated Since 2002 |
| Have a drought management plan | 24% | 18% | 25% | 19% |
| Have a raw and/or treated master plan | 65% | 35% | 61% | 37% |
| Have a conservation plan | 53% | 24% | 44% | 30% |
| Drought recurrence is considered in long-term water supply and conservation planning | 82% | n/a | 66% | n/a |

Source: CWCB 2004. DWSA 2004 Survey

The 2013 CWCB drought survey indicated that two of the three survey respondents either updated or developed a new comprehensive drought plan following the 2002 drought and 2 out of the 3 respondents perceive that there is sufficient funding either in-basin or through state/federal resources to support water supply reliability, conservation and drought planning. One of the three respondents anticipates improving their drought preparedness following the 2012 – 2013 dry period.

[34] Note: A direct relationship between drought vulnerability and adaptive capacity cannot be deciphered solely using these data. While these results provide a general indication of the number of drought, conservation and raw/treated master plans, they do not provide information on the content and "overall effectiveness" of the plans. However, they do provide a general indication of M&I drought awareness on a basin-wide level.

## Drought Vulnerability

Future population growth is projected to mainly occur in Montezuma and La Plata Counties along the San Juan Skyway including Cortez and Durango as well as in the Telluride Canyon. Future M&I water needs are anticipated to be met through the Dolores and Animas-La Plata projects. Table 9.22 lists the major projects and processes identified to address long-term water supply needs. These projects will be instrumental in maintaining water supply reliability and, either directly or indirectly, meeting demands during drought periods.

**Table 9.22. Major Identified Projects and Processes in the San Juan/Dolores River Basin[35]**

| M&I Providers | Project | IPP Type |
|---|---|---|
| City of Cortez | Purchase of Additional McPhee Water | Growth into Existing Supplies |
| Montezuma Water Company | Water from McPhee Reservoir and other sources | Growth into Existing Supplies |
| Rico Alluvial Pipeline Water Supply Project | Rights to water from Dolores Water Conservancy District; Potable supplies from Montezuma Water Company | Growth into Existing Supplies |
| City of Durango | Animas-LaPlata Contract Purchase | Regional In-Basin Project. Growth into existing supplies |
| | Horse Gulch Reservoir | |
| | Excess supply from water right on Animas and Florida River, plus minimal storage in terminal reservoir | |
| | La Posta Pumping Station | |
| | Recreation Complex | |
| | Water for Wetland Replacement | |
| La Plata Archuleta Water District | Water System | Regional In-Basin Project |
| La Plata West Water Authority | Western La Plata County Domestic Water System | Regional In-Basin Project |
| Pagosa Area Water and Sanitation District, San Juan Water Conservancy District | Dry Gulch Reservoir & Inlet Pump Station Project | Regional In-Basin Project |
| | Stevens Reservoir Enlargement | Regional In-Basin Project |
| Dolores Water Conservancy District | WETPACK Lawn and Garden M&I Water | |

[35] Note: The draft list of IP&Ps in this table is based on the best available information at the time of publishing (2013) and does not include conservation. Due to the evolving nature of IP&P's planned by providers this information will change over time with regards to IP&P details, new IP&P's, completed IP&P's, and unsuccessful or withdrawn IP&P's. As a basic list of major IP&P's it does not include things such as a water provider growing into its existing supply, planned transfers of agricultural water rights, or the vast majority of water conservation programs. The CWCB is working to collect better data on IP&P's, including conservation programs, through the development of its Basin Needs Decision Support System and its associated survey of water providers.

| M&I Providers | Project | IPP Type |
|---|---|---|
| | Totten Reservoir | |
| Ute Mountain Ute Tribe | Unspecified M&I Project | Regional In-Basin Project |
| Florida Water Conservancy District (FWCD) | Multipurpose Project (M&I and Ag) - New Bureau Contract, Augmentation Rights, Ditch Improvements | Regional In-Basin Project |

M&I users in the Norwood area will need to develop additional supplies to meet anticipated growth. The headwater areas above McPhee Reservoir will need augmentation rights senior to existing CWCB instream flow rights in order to develop new tributary wells to meet growing demands (CWCB, 2004). Many of the drought impacts recorded in Figure 9.29 are above the statewide average. Future M&I growth could stress water supplies especially during times of drought. M&I drought vulnerability could increase for some M&I providers if drought is not effectively incorporated into long-term water supply reliability planning.

## 9.4.2 Aspects of Vulnerability

An M&I provider's drought vulnerability depends on the reliability of a provider's water supply system and their ability to effectively respond to drought. However, there are many complex factors that influence the overall reliability of M&I water supply systems and effectiveness of adaptive capacities. Below are many of the factors that can influence overall system reliability, for discussion purposes these factors are grouped into water supply, water distribution, water demand, and adaptive capacity factors.

### Water Supply Factors

*Source of water supplies* – M&I water supplies are generally surface water, tributary groundwater hydraulically connected to the stream, or deep groundwater. Deep groundwater may be divided into nontributary, designated groundwater, or Denver Basin groundwater. Designated and Denver Basin groundwater lie within a designated groundwater basin that is managed by the Colorado Groundwater Commission. Nontributary groundwater may be defined as water that is outside of a designated basin whose pumping will not affect surface water levels within 100 years. In contrast to tributary and surface water, designated groundwater and nontributary groundwater is not subject to the prior appropriation system and consequently the availability of supplies are not legally limited in times of drought. Consequently, municipalities strictly using designated groundwater and nontributary groundwater are not directly impacted by a drought due to surface water declines. However, the increase of pumping to meet greater outdoor demands during drought periods can lower groundwater levels below "normal" levels and impact municipalities that depend on aquifers already stressed during non-drought periods.

*Seniority of water rights* – Surface water and tributary groundwater are administered by the prior appropriations system, as discussed in the Chapter 1 Introduction. Municipalities with a more senior water rights portfolio will likely be less impacted by drought than municipalities more reliant on junior water rights. Lower stream flows during periods of drought can also lower exchange potential[36] and replacement supplies for augmentation and substitute water supply plans. This can reduce the availability of water supplies for many M&I providers relying upon exchanges, substitute water supply plans and augmentation plans. Reduced streamflows can also physically limit the amount of water a municipality may divert from a stream and limit a municipalities' ability to fill its reservoir(s) within priority.

*Storage Capacity* – Storage can improve the reliability of an M&I water supply system and can lesson drought vulnerability. However, droughts can physically and legally limit the amount of water available to fill reservoirs. Droughts of multi-year duration further stress water supply systems and can significantly deplete storage reserves by reducing the ability for reservoirs to fill in sequential years.

*Diversity of supplies* – The severity of a drought can vary across different watersheds. M&I water supply systems with sources in different watersheds may be impacted less during a drought if the drought does not extend over a large geographic area. M&I providers that have a diversity of supplies may also have greater flexibility to adjust the management of their water supplies to better meet water needs during drought periods. For instance, conjunctive use is often an effective drought management tool for providers that have surface and nontributary groundwater supplies. Conjunctive use involves the management of surface water and groundwater supplies to maximize the yield of total water supplies. During periods of drought providers can draw from their nontributary groundwater to compensate for less available surface water supplies.

### Water Distribution System Factors

*Distribution system efficiency* – M&I providers that have inefficient water distribution systems can lose significant amounts of water as system losses (i.e. leaky pipes or ditches with high seepage rates) before reaching the end user. This can reduce a provider's ability to meet demands during normal conditions as well as periods of drought.

*Distribution system redundancy* – System redundancy can enhance a provider's ability to meet demands in specific parts of its service area during drought by providing multiple means in distributing water throughout the service area. If a particular water source is depleted during a drought, distribution systems with adequate redundancy can deliver replacement supplies to the locations by utilizing other sources. .

---

[36] An exchange allows an upstream water user to divert water that a downstream water user would normally receive as long as the water is replaced at the time, place, quantity, and suitable water quality that the downstream user would have used if the exchange had not taken place. Exchange potential refers to the ability to implement exchanges along a particular stream reach without causing legal injury to senior downstream users. Exchange potential is generally higher when streamflows are relatively high and there are "surplus" flows to exchange as opposed to low flow conditions when all of the water in the stream is owed to senior users downstream.

*Water quality implications* – Drought can degrade water quality by lowering stream and reservoir levels resulting in higher temperatures and increased concentration of pollutants. Drought can also cause M&I providers to pull water from intakes situated lower in the reservoir which may have higher sediment concentrations and decreased quality. Degraded water quality can increase water treatment costs and have implications for taste and odor.

*Wildfire* – Wildfires are a natural phenomenon. The occurrence and severity of wildfires can increase under dry conditions. When wildfires occur debris and sediment runoff as can severely degrade water quality within a watershed and drastically increase sediment loading to reservoirs as well as affect the overall health of the watershed. M&I providers can help reduce impacts associated with wildfires through the support of proper forest management.

### Water Demand Factors

*Customer drought response and total demands* – Customer water demands can either increase or decrease during a drought depending on how effectively customers alter water use behavior. Generally, soil moisture and evapotranspiration rates increase during drought periods, in turn increasing irrigation requirements. However, an effective drought response program can encourage customers to conserve water and significantly reduce total demands relative to normal conditions.

*Outdoor water demand* – M&I providers often require mandatory watering restriction during periods of severe drought thus reducing demands and conserving water for more essential needs. Outdoor water demand generally offers a significant source for potential for M&I water savings during drought periods.

### Adaptive Capacity Factors

*Drought mitigation and response efforts and planning* – Drought mitigation refers to actions taken in advance of a drought that reduce potential drought-related impacts when the event occurs. For purposes of this study, drought mitigation is considered a component of a municipality's capacity to adapt to drought. Drought response planning addresses the conditions under which a drought induced water supply shortage occurs and specifies the actions that should be taken in response.

*Water supply reliability planning* – Many M&I providers throughout the State have found it necessary to assess the reliability of their supplies under stressed drought conditions in order to ensure that they have sufficient supplies to meet anticipated existing and future plans. This is often referred to as water supply reliability planning. Water supply reliability planning plays a crucial role in mitigating the drought vulnerability of communities experiencing rapid growth. M&I providers that account for future growth and plan for additional demands considering stressed water supplies during times of drought will be less vulnerable to drought when compared to M&I providers that do not effectively incorporate drought into their planning efforts.

*Conservation efforts and planning* – Water conservation planning involves a combination of strategies for reducing water demand while also maintaining or improving water use efficiency and increasing reuse of water. The main objective of a water conservation plan is to achieve lasting, long-term improvements in water use efficiency, reducing overall water demands. However, some conservation measures can serve the dual purpose of providing long-term water saving benefits during normal and drought periods. For example, a xeriscape landscape requires less overall water, and is also more likely to survive during drought periods when strict outdoor watering restrictions are enforced. Large areas of xeriscape landscape can reduce drought-related landscaping impacts in a community while also conserving water during normal periods.

There is a common notion that conservation can result in demand hardening which may be defined as follows: "By saving water, long-term conservation can also reduce the water saving potential for short-term demand management strategies during water shortages" (Flory, J.E., and T. Panella 1994). For instance, during times of drought, savings achieved via outdoor watering restrictions may be used for more essential indoor uses. If the amount of irrigated turf is reduced in advance of a drought through conservation measures, less of a "water savings potential or buffer" through outdoor irrigation savings is available during times of drought. Whether this "water saving potential" is actually smaller prior to conservation than with conservation largely depends on how the saved water is used during normal and wet years. Water saved through conservation can be stored in drought reserves and improve a provider's drought adaptive capacity. Conversely, providers that sell all their conserved water to meet increasing demands from population growth could reduce their ability to respond to drought.

## 9.5 Recommendations

### 9.5.1 Adaptation to Drought

A variety of mechanisms can be used to further reduce M&I drought vulnerability by encouraging local water supply reliability and drought management planning. These include the following:

- House Bill 08-1141 was passed in 2008 preventing all local governments from approving new development permits until they determine, at their discretion, that the proposed water supply for the development will be adequate. Information must be submitted to local governments on the development's water supply requirements at buildout, physical source of supply, projected water supply yield under various hydrologic conditions, planned conservation efforts, etc. Continued implementation of this policy helps to ensure that growing communities have a reliable water supply during dry periods reducing drought vulnerability.
- Develop state policy requiring M&I providers to develop drought management plans that specify essential elements for effective drought management planning. Among these elements includes a stakeholder drought management plan development process, a formal drought declaration protocol, and specific drought mitigation and response actions.

- Continuation of CWCB financial assistance to covered M&I providers that have retail water deliveries of over 2,000 acre-feet annually. This program provides incentive and valuable financial resources especially for smaller providers that are in need of assistance for drought management planning.
- The CWCB offers technical assistance to municipalities developing drought management plans. This includes an M&I Drought Management Guidance Document, sample M&I drought plan, a web-based drought toolbox and CWCB staff consultation. Broader utilization of these tools at the local level will decrease drought vulnerability. .

## 9.5.2 Improving Vulnerability Assessment

There are a variety of factors that influence the drought vulnerability of M&I providers. Each of these factors is unique to individual M&I providers and can affect providers in many different ways and in varying magnitudes during a drought. The basin-wide vulnerability assessment presented in this study addressed drought vulnerability from a qualitative perspective. Although beyond the scope of this study, future quantitative analyses that also incorporate river administration and the prior appropriation system in more detail would provide a more detailed characterization of M&I vulnerability. Recommendations for further studies are itemized below.

*Prior appropriation system and river administration* - As indicated above, the prior appropriation system and river administration play a significant role in M&I water supply reliability, and ultimately drought vulnerability. To better understand how these systems function during drought, future studies should, to the extent possible, incorporate a review of river administration and call data during the 2002 drought at a minimum by water division and where appropriate at the district level. Potential future changes to the river administration as a result of planned water development projects could also be incorporated into the analysis.

*Water supply reliability* - There are several significant water supply factors that influence M&I water supply reliability and drought vulnerability. These include the type of water supplies, water rights, storage, and diversity of supplies. The characterization of these factors on a local scale coupled with implementation of HB-1051 which creates a mechanism to collect water efficiency data could further enhance the ability to access M&I drought vulnerability.

*Collection of historical drought impact data* – Historical drought impact data provides a snapshot of an M&I provider’s drought vulnerability. Although these impacts are not a direct reflection of drought vulnerability, historical impact information coupled with a provider’s drought preparedness efforts provide valuable insight into characterizing overall M&I drought preparedness. It is recommended that CWCB coordinate efforts with NDMC on recording local drought impacts within the State through NDMC’s Drought Impact Reporter.

## 9.6 References

Arkansas Valley Irrigator Incorporate "Super Ditch Company." 2013. Accessed at: http://www.lavwcd.com/news/superditch.html. Accessed on: June 2013.

Colorado Department of Local Affairs. 2013. Population Totals for Colorado Counties. Access on: http://www.colorado.gov/cs/Satellite?c=Page&childpagename=DOLA-Main%2FCBONLayout&cid=1251593346867&pagename=CBONWrapper

Coyote Gulch. 2010. Arkansas Valley Conduit Update. Access on: http://coyotegulch.wordpress.com/category/colorado-water/arkansas-valley-conduit/CWCB. 2004. *Drought and Water Supply Assessment.* Appendix C. Prepared by: Bouvette Consulting, Resolution Research & Marketing, Inc, et al.

CWCB. 2004. *Drought and Water Supply Assessment.* Raw survey data. Prepared by: Bouvette Consulting, Resolution Research & Marketing, Inc, et al.

CWCB. 2004. *Drought and Water Supply Assessment.* Basin Fact Sheets. Accessed at: http://cwcb.state.co.us/. Accessed on May 2009.

CWCB. 2004. *Statewide Water Supply Initiative (SWSI*). Prepared by: CDM.

CWCB. 2007. *Drought and Water Supply Update*. Prepared for: Peter Mayer, P.E. Aquacraft, Inc. Water Engineering and Management, Sonya Wytinck. National Research Center, Inc.

CWCB. 2007. *Drought and Water Supply Update.* Raw survey data. Prepared by: Peter Mayer, P.E. Aquacraft, Inc. Water Engineering and Management, Sonya Wytinck. National Research Center, Inc.

CWCB. 2010. *Final State of Colorado 2050 Municipal and Industrial Water Use Projections*. Prepared by: CDM.

CWCB. 2013. M&I Drought Survey. May 2013.

Daniel F. Luecke, John Morris, and Hydrosphere Resource Consultants, Inc. 2003. What the Current Drought Means for the Future of Water Management in Colorado.

Denver Water. 2013. Access at: www.denverwater.org. Accessed on: June 2013.

Douglas County Water Resources Authority. 2013. Access at: http://www.dcwater.org/. Accessed on: June 2013.

Flory, J. E., and T. Panella. 1994. "Long-Term Water Conservation & Shortage Management Practices: Planning that Includes Demand hardening". California Urban Water Agencies. Tabors Caramanis and Associates.

GEI Consultants, Inc. 2003. Final Report Feasibility Evaluation of the Arkansas Valley Pipeline La Junta, Colorado. Prepared for: Water Works! Committee.

House Bill 08-1141. 2008. *Concerning Sufficient Water Supplies for Land Use Approval*. State of Colorado.

Howe, C.W. and C. Goemans. (2007). *The Simple Analytics of Demand Hardening*. Journal of the American Water Works Association, October 2007, Volume 99 Number 10.

Hydrosphere Resource Consultants, Inc. 2003. *Upper Colorado River Basin Study Phase II*.

Knutson, Cody et al. 1998. *How to Reduce Drought Risk.* Western Drought Coordination Council. March 1998.

South Metro Water Supply Authority. 2013. Accessed at: http://www.southmetrowater.org/. Accessed on: June 2013.

Wilhite, Donald L., ed et al., 2005. *Drought and Water Crises: Science, Technology, and Management Issues.* CRC Press. Pp 93-135. Accessed from National Drought Mitigation Center Website: http://drought.unl.edu/plan/handbook/10step_rev.pdf. Accessed on January 26, 2010.

# 10 RECREATION SECTOR

## Key Findings

- Key drought impacts for skiing include higher operating costs due to increased snowmaking, loss of revenue due to decreased visitation, and seasonal layoffs.
- Wildlife viewing and hunting have been impacted by lower production and recruitment numbers and by animals moving away from traditional viewing/hunting areas due to lack of water, loss of vegetative cover, and/or heat.
- Fishing areas have been impacted by lower reservoir and lake levels, decreased streamflows, sedimentation, and fish decline.
- Impacts to camping include forced closure of campsites and surrounding forest due to wildfires and risk of wildfires and/or hazard trees; both conditions exacerbated by drought.
- Golf courses are impacted if municipalities impose watering restrictions or if water rights become out of priority due to low streamflows.
- Lower reservoir and lake levels have placed restrictions upon and made boating impossible by rendering boat ramps unusable and can act as a deterrent to potential boaters.
- Swim beach closures due to either water quality concerns or low water.
- Rafting companies have been impacted by low flows, resulting in loss of revenue.
- Diversification and communication with the public, media, and local governments was found to be the most widely-repeated strategy for adapting to drought conditions.
- As a result of both the diversity in the sector and a lack of understanding regarding drought, data appropriate for measuring the impacts of drought on the sector if difficult to come by. Therefore, specifics measures of drought impacts on the sector are difficult to determine.

## Key Recommendations

- Public perception is a primary concern among all recreation sub-sectors. Public relations plans and strategies can help mitigate or prevent negative public perception during drought.
- Diversifying the recreational activity and/or tourist area is an adaptive capacity cited in numerous sources and interviews. Adjusting the seasonality and variety of offerings can mitigate against a severe one-season drought by allowing for income in the other half of the year.
- The methods and model of stakeholder engagement laid out in the Drought Assessment for Recreation and Tourism (DART) Report should be used as a guideline for determining how best to incorporate stakeholders into the process of developing meaningful drought metrics.

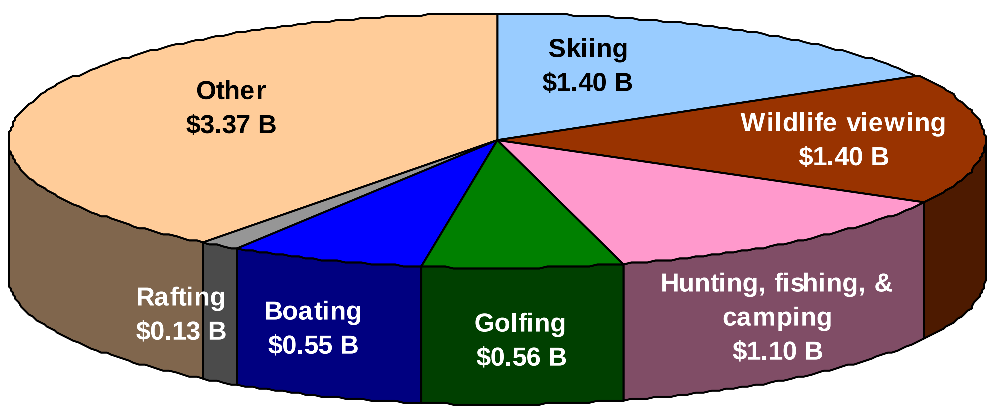
Incorporating stakeholders will help facilitate data collection, create awareness about the linkages between drought and recreation/tourism, and identify successes from which best practices can be identified.

# 10.1 Introduction to Sector

Recreation and tourism is an important industry in Colorado, attracting tourists and residents with its outdoor recreation opportunities, physical beauty, and high quality of life. Total direct travel spending in Colorado is estimated to bring $15.9 billion dollars into the State annually (Dean Runyan Associates, 2011). This includes lodging, food and gas. In 2010, the industry contributed $750 million in local and state tax revenue, which was approximately equivalent to 19% of Colorado's economy (Thomas & Wilhelmi, 2012).

Recreation and tourism is a broad category that encompasses numerous activities. As such, only key, representative sub-sectors were chosen for analysis. The following sub-sectors were chosen based on their significance to the Colorado economy and their dependence on water resources: downhill skiing, wildlife viewing, hunting/fishing/camping, golfing, boating, and rafting. Other recreation and tourism activities not specifically analyzed in this assessment are listed at the end of this section (Section 10.1), and include bicycling, hiking, and other trail-based activities; touring the State; tourism based around agriculture; and water- and snow-based activities other than downhill skiing, boating, and rafting. Figure 10.1, which assumes an overall $8.5 billion impact, presents a general picture of the relative economic importance of sub-sectors within the Recreation Sector.

**Figure 10.1. Recreation and Tourism Economic Impact in Billions[1]**




The statewide impact is not the whole picture, because the spatial distribution of these industries and the timing of their activities have an impact at a county level. For example, the rafting sub-sector is not as big a statewide economic driver as skiing, but for the handful of counties where rafting is concentrated, the localized economic impact can be quite significant. Another consideration is the season in which the activity occurs; for example, golfing is primarily a warm month activity while skiing occurs primarily in the cold months. The temporal nature of the

[1] Source of estimates: 1) skiing, Wilhelmi et al. 2004; 2) wildlife viewing, FWS 2006; 3) hunting, fishing, & camping, BBC Research and Consulting 2008; 4) golf, Davies et al 2004; 5) boating, Luecke et al 2003; 6) rafting, Shrestha 2009.

recreation activity will have a seasonal effect on the counties in which these activities are prominent. The timing of drought can influence which sectors are impacted or not. Table 10.1, below, shows the sub-sectors, their seasonality, and the way they use water.

### Table 10.1. Seasonality and Water Use of Sub-sectors

| Seasonality and Water Use of Sub-sectors | | |
|---|---|---|
| **Sub-sector** | **Season** | **Water Use** |
| Skiing | October through April, handful of resorts open past April | Ski areas depend on natural snowfall for most of terrain coverage and use surface water for snowmaking. Primarily impacted by lack of winter precipitation; however, below-normal summer precipitation can result in lower streamflows leading into the fall, which could cause water rights to be out of priority when resorts start making snow in the late fall and early winter. |
| Wildlife viewing | Year-round | Animals depend on plant and water availability and will migrate to different geographic areas to find food/water. Depending on migration patterns, this could increase or decrease the wildlife viewing opportunities in a given area. |
| Hunting, fishing, and camping | Year-round, but more participants in the summer months | Game animals can be impacted by water and food shortages. Fishing requires adequate water in reservoirs, rivers, and streams. Campsites generally require little water for consumptive use but are often dependent on water-based recreation for visitors. |
| Golfing | April through October, with May through September being the peak time | Golf courses depend on water to irrigate course. Water source can be surface rights, groundwater, purchased from municipalities, or reused (purchased) from wastewater treatment plants. |
| Boating | April through October | Reservoir, river, and stream levels can be impacted by less snowmelt to initially fill reservoirs/lakes and/or lack of spring/summer precipitation. Higher-than-normal temperatures and lower precipitation in a spring-fall drought will cause higher evaporation rates. |
| Rafting | April through September, with late June through mid-August being the peak time | Ability to run a stretch of river depends on the streamflow, which can be decreased early in the season by below-normal or too-early snowmelt, and later in the season by a lack of summer precipitation. |

## Skiing

Downhill skiing has been a large part of Colorado tourism for several decades, and is growing more visible as resorts expand and advertise to new consumers across the country (ColoradoSkiHistory.com). However, the skiing sub-sector includes more than just downhill, as there is also a large market for cross-country/Nordic skiing and an increasing interest in backcountry skiing. Apart from skiing, other snow-based activities that are popular include snowmobiling and snowshoeing. A secondary beneficiary of snow-based activities is hut and yurt camping, which are structures with basic amenities generally located in remote areas that are rented by various agencies and accessible by snowshoe, snowmobile, or cross-country skiing. These activities are mentioned here to point out their existence/importance in the snow-based recreation arena, but they will not be covered in further detail within the skiing sub-sector. For the purpose of this assessment, "skiing" refers to downhill skiing or snowboarding at an established ski area with motorized lifts and lift pass sales.

There are 26 downhill resorts in Colorado. Table 10.2 gives the name of the resort and the county in which it is located.

**Table 10.2. Ski Area Names and Location**

| Ski Area Names and Location (County) | | | |
|---|---|---|---|
| **Name** | **County** | **Name** | **County** |
| Arapahoe Basin | *Summit* | Loveland | *Clear Creek* |
| Aspen Highlands | *Pitkin* | Monarch Mountain | *Chaffee* |
| Aspen Mountain | *Pitkin* | Powderhorn | *Mesa* |
| Beaver Creek | *Eagle* | Silverton Mountain | *San Juan* |
| Breckenridge | *Summit* | Ski Cooper | *Eagle* |
| Buttermilk | *Pitkin* | Snowmass | *Pitkin* |
| Copper Mountain | *Summit* | Granby Ranch | *Grand* |
| Crested Butte | *Gunnison* | Steamboat | *Routt* |
| Durango (Purgatory) | *La Plata* | Sunlight | *Garfield* |
| Echo Mountain | *Clear Creek* | Telluride | *San Miguel* |
| Eldora | *Boulder* | Vail | *Eagle* |
| Howelson Hill | *Routt* | Winter Park | *Grand* |
| Keystone | *Summit* | Wolf Creek | *Mineral* |

A review of ski area websites shows that most (>90%) of these areas have snowmaking machines. Snowmaking capabilities are relevant to a drought vulnerability discussion because they allow ski resorts to determine their opening date (i.e., ensure ski-able terrain) even in a dry winter. Water rights are typically obtained by the resort from nearby streams. The water use is considered non-consumptive because when the snow melts in the spring the water returns to the streams as runoff. In general ski areas are not in competition with agriculture or other recreation because they are high in the watershed and are diverting water in an “off” season.

In Colorado, the total acreage of the ski areas ranges from 85 acres (Echo Mountain) to 5,289 acres (Vail), and the base elevation ranges from Howelson Hill at 6,696 feet above sea level (asl) to 10,800 feet asl at Loveland. As shown in Figure 10.5,[2] the ski areas are all located in mountainous regions of the State and are primarily west of the continental divide (with the exception of Echo Mountain and Eldora).

[2] All figures referenced in this section are located at the end of Section 10.1, before the start of the Vulnerability discussion.

## Wildlife Viewing

Wildlife can be viewed anywhere in the State, from the mountains to the eastern plains. Because there are no geographic requirements for this activity, it is difficult to present the total distribution of areas where wildlife viewing is possible. However, Colorado Parks and Wildlife (CPW), formerly the Division of Wildlife, has a viewing guide on their website with over 200 suggested parks, natural areas, and fish hatcheries. Figure 10.6 shows these areas as they are located around the State; note there is no real concentration of suggested wildlife viewing areas. There are only a handful of counties (Cheyenne, Crowley, Costilla, and Custer) without a specific site, but this does not mean wildlife is absent from those counties. Important waterfowl hunting and viewing areas were identified in the South Platte Basin in the 2010 Non-consumptive Needs Assessment (NCNA) Focus Mapping Report (CWCB 2010). The results are presented in Figure 10.7. Wildlife viewing sites tend to be concentrated in the mountains and the southwest portion of the State. Overlapping recreational activities often accompany wildlife viewing in a given county. For example, if a visitor was already planning to visit El Paso County to see Pikes Peak, they could be further enticed to drive up the mountain to see big-horned sheep.

## Hunting, Fishing, and Camping

Similar to wildlife viewing, hunting, fishing, and camping activities occur throughout the State. The only stipulation for each of these activities is a designated camping spot or allowable dispersed camping, a body of water for fishing, and/or the presence of wildlife for hunting. Maps for this sub-sector show: 1) the number of acres of CPW land in Colorado, which generally corresponds to lands open to hunting and fishing; and 2) the location of campgrounds, state parks, fish hatcheries, and CPW suggested wildlife viewing areas (see Figure 10.6 and Figure 10.8).

Like wildlife viewing, there are hunting, fishing, and camping areas throughout the State with a higher concentration of all in the western half and southwest corner. There is a notable absence of large tracts of parks, wilderness areas, and state and federal owned lands in the central eastern plains region.

## Golf

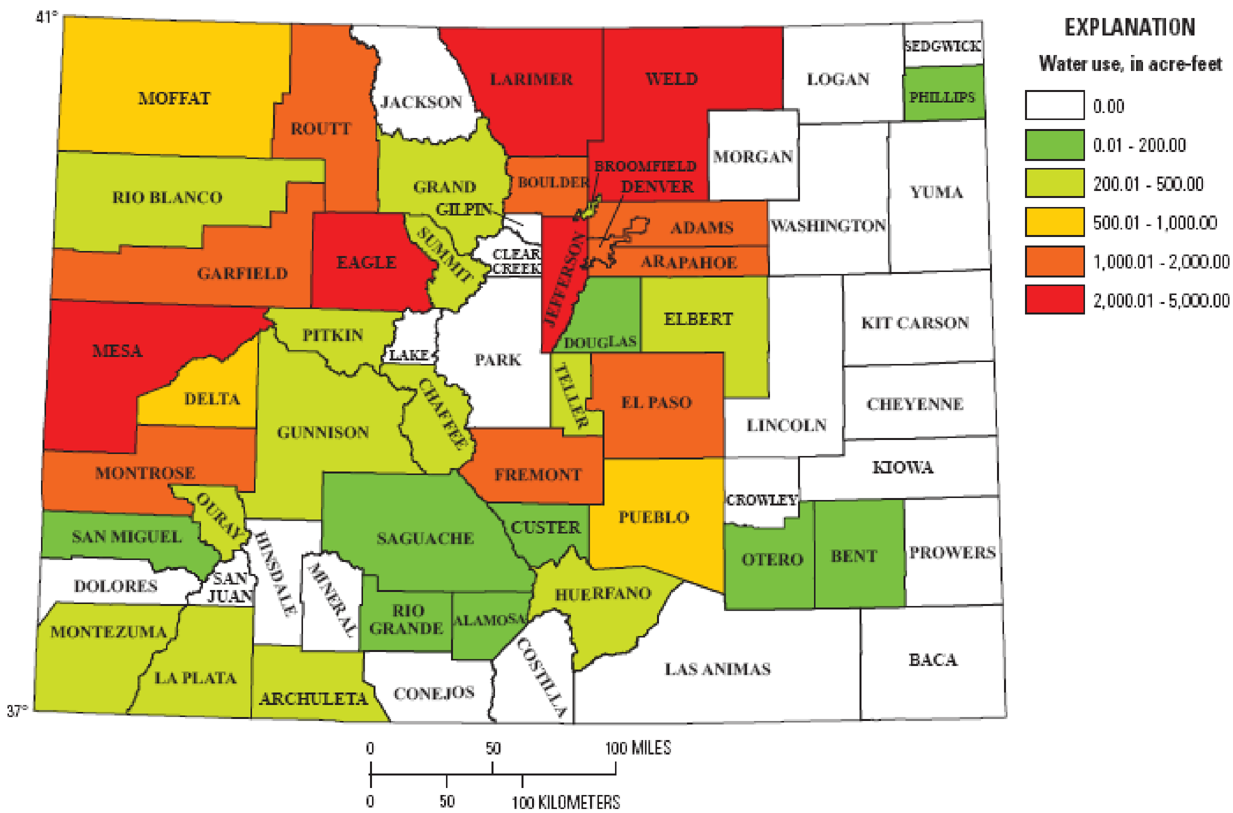
There are approximately 260 golf courses throughout Colorado (Ivahnenko, 2009). (Other sources[3] suggest that number may be closer to 250 as of 2011, but the source of that information cannot be confirmed. The USGS survey discussed below and Ivanhenko, 2009 are believed to be the best available data sources.) Figure 10.9 shows the number of courses per county. Jefferson, Arapahoe, and El Paso Counties have the highest number of golf courses (23, 22, and 20 respectively) as of 2005. As of 2005, eleven counties had no golf courses. There are two sand courses in Colorado, one in Baca County and one in Lincoln County. Sand courses require little to no irrigation and are considered in this assessment as alternatives to typical grass courses.

[3] http://www.aarp.org/entertainment/arts-leisure/info-08-2011/golf-courses.html

Data for golf courses in Colorado is available from a 2005 study conducted by the United State Geological Survey (USGS) that examined water use by golf courses in Colorado. A survey was distributed to the members of the Rocky Mountain Golf Course Superintendents Association, and additional information was collected through telephone. For the courses that responded (43% returned the survey and an additional 225 phone calls were made for follow-up information), the survey found that about 64% use surface water as part of their irrigation supply, 23% use groundwater as part of the supply, 14% use purchased potable water for part of their supply, and 14% use reclaimed wastewater for a portion of the supply (Ivahnenko 2009).

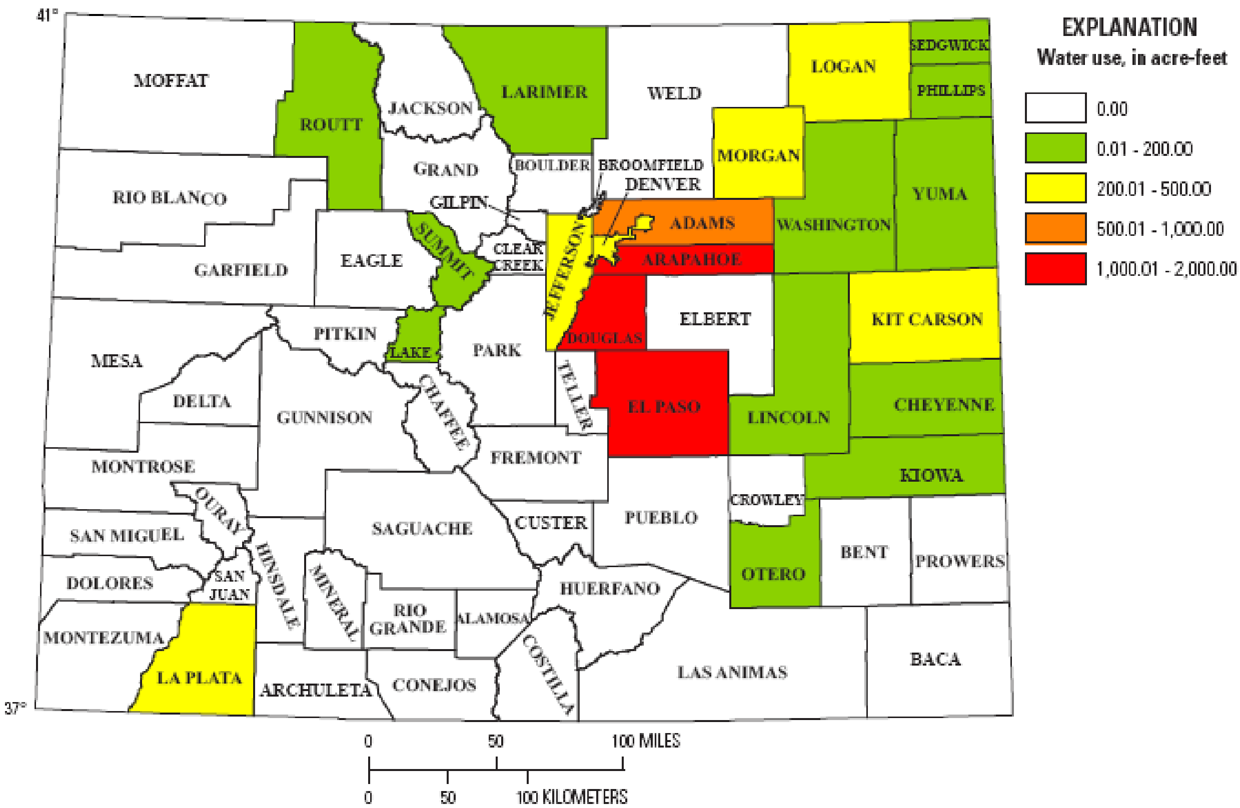
The USGS report included a table showing the estimated golf course irrigation water use by source water (i.e., surface, groundwater, potable water, or reclaimed wastewater). Although the data are available, it is not possible to make a general statement about what type of irrigation water is more vulnerable to drought. There are complicating factors to this, primarily the water rights priority system and municipal attitudes towards golf courses and other visible users of water. The two figures below (Figure 10.2 and Figure 10.3), extracted from the USGS report, highlight the spatial variability in surface water use compared to groundwater use.

**Figure 10.2. Surface Water Golf Course Irrigation Water Use, by Colorado County, 2005**




Source: Ivahnenko 2009

**Figure 10.3. Groundwater Golf Course Irrigation Water Use, by Colorado County, 2005**




Source: Ivahnenko 2009

As these maps show, surface water is the primary source for golf course irrigation water. Groundwater use is more common on the eastern half of the state. Potable water and reclaimed water (maps not shown) are seen mainly, but not exclusively, along the Front Range.

## Boating

Boating takes place at reservoirs, lakes, and rivers around the state. CPW manages boating registrations and maintains a list of “boat-able” waters on their website. Although it is listed here as a sub-sector of recreation and tourism, boating contributes to a portion of State Parks revenue from licensing and visitation fees and thus influences state assets as well.

Boating is a general designation for water-based activities involving a boat; and can include sailing, motorized watercraft, towed water sports, and scuba diving and swimming off the side of a boat. Boating also involves rafting, kayaking, and canoeing, but these activities are discussed within the “rafting” sub-sector of this chapter.

Table 10.3 provides a snapshot of boating registrations in Colorado over the last 12 years.

**Table 10.3. Annual Boat Registrations, 2000-2004 (Colorado State Parks 2010, CPW, 2013)**

| Annual Boat Registration | |
|---|---|
| Year | Number of Boats |
| 2000 | 104,946 |
| 2001 | 104,500 |
| 2002 | 101,948 |
| 2003 | 100,580 |
| 2004 | 98,076 |
| 2005 | 98,572 |
| 2006 | 98,063 |
| 2007 | 98,976 |
| 2008 | 96,222 |
| 2009 | 96,719 |
| 2010 | - |
| 2011 | 90,090 |
| 2012 | 88,007 |

Table 10.3 shows the general magnitude of personal watercraft in the state (data was not available for 2010). There is a significant drop in registrations from 2009 to 2011 and 2012. However, it is difficult to separate the impacts of drought from the economy. Assuming each registered boat represents 2-10 boaters, the number of boaters would be closer to half a million. With an estimated population of a little over five million people (US Census Bureau 20010 the boating registrations shown above indicate that close to 10% of the population takes part in boating activities. The map at the end of this section (Figure 10.10) shows the state parks and other recreation areas within Colorado.

CPW operate many of the reservoirs and boating facilities; a great deal of boating within the state occurs at state parks. Table 10.4 lists the state parks where water-based activities are offered and the county or counties in which the parks are located.

**Table 10.4. State Parks with Boating Activities (Colorado State Parks Website 2010)**

| Water-based State Parks | | |
|---|---|---|
| State Park Name | Activities | County |
| Barr Lake State Park | Fishing, boating, bicycling, horseback riding, hiking | Adams |
| Bonny Lake State Park | Boating, fishing, hunting, camping | Yuma |
| Boyd Lake State Park | Boating, fishing, swimming, hiking, biking, hunting | Larimer |
| Chatfield State Park | Boating, biking, hiking, camping | Douglas/Jefferson |
| Cherry Creek State Park | Boating, horseback riding, shooting range, biking, camping, fishing | Arapahoe |

| Water-based State Parks | | |
| --- | --- | --- |
| **State Park Name** | **Activities** | **County** |
| Crawford State Park | Fishing, boating, hiking, water sports | Delta |
| Harvey Gap State Park | Fishing, small boats, ice fishing | Garfield |
| Highline Lake State Park | Fishing, boating, birding | Mesa |
| Jackson Lake State Park | Swimming, boating, fishing, waterskiing | Morgan |
| James M. Robb-Colorado River State Park | Fishing, hiking, swimming | Mesa |
| John Martin Reservoir State Park | Boating, fishing | Bent |
| Lake Pueblo State Park | Boating, fishing | Pueblo |
| Lathrop State Park | Boating, fishing, swimming | Huerfano |
| Mancos State Park | Canoe, kayak, fishing, camping | Montezuma |
| Navajo State Park | Boating, camping, fishing | Archuleta/La Plata |
| North Sterling State Park | Boating, fishing, hunting, camping | Logan |
| Paonia State Park | Fishing, boating, camping | Gunnison |
| Pearl Lake State Park | Camping, fishing, canoeing | Routt |
| Ridgway State Park | Camping, biking, boating, winter sports, birding | Ouray |
| Rifle Falls State Park | Camping, fishing, hiking | Garfield |
| Rifle Gap State Park | Boating, fishing, swimming, water-skiing, windsurfing, camping | Garfield |
| San Luis State Park | Biking, boating, camping, fishing, hiking, hunting | Alamosa |
| Spinney Mountain State Park | Fishing, bird watching, boating | Park |
| St. Vrain State Park | Biking, boating, camping, fishing, hiking | Weld |
| Stagecoach State Park | Biking, bird watching, boating, camping, fishing, ice fishing | Routt |
| State Forest State Park | Moose watching, backcountry camping, biking, bird watching, boating, camping, fishing, hiking, hunting, ice fishing | Jackson/Larimer |
| Steamboat Lake State Park | Backcountry camping, biking, birding, boating, camping, cross-country skiing, fishing, hiking, horseback riding, hunting, ice fishing, jet skiing, sailboarding, snowmobiling, snowshoeing, swimming, water skiing | Routt |
| Sweitzer Lake State Park | Biking, boating, cross-country skiing, fishing, hiking, hunting, jet skiing, sailboarding, swimming, water skiing | Delta |
| Sylvan Lake State Park | Biking, boating, camping, cross-country skiing, fishing, hiking, hunting, ice fishing, snowmobiling, snowshoeing | Eagle |
| Trinidad Lake State Park | Biking, boating, camping, fishing, hiking, horseback riding, ice fishing, jet skiing, snowshoeing, water skiing | Las Animas |
| Vega State Park | Fishing, boating, water skiing, hiking, ice fishing, cross-country skiing | Mesa |
| Yampa River State Park | Birding, boating, camping, fishing, hiking, hunting, whitewater rafting | Routt/Moffat |

Although there is a notable majority located in the western and southern regions, reservoirs and lakes for boating exist throughout the state.

## Rafting

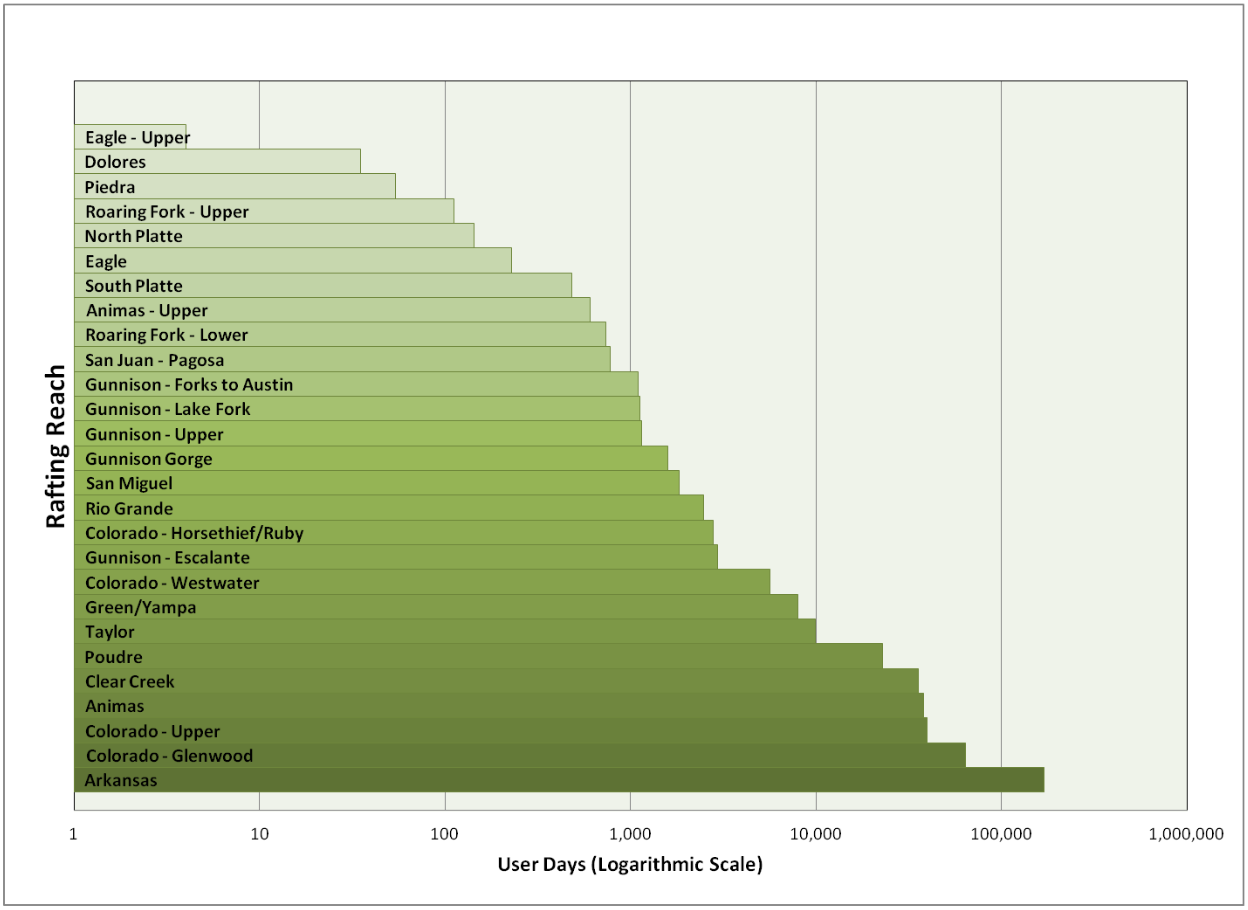
Whitewater rafting, kayaking, and canoeing take place on rivers and streams throughout Colorado. Whitewater rafting in particular is a segment of the tourism industry that has a significant presence in certain areas of the state. Commercial rafting outfitters will be the focus of this sub-sector, and although kayaking and canoeing do have a presence and economic impact in Colorado, they are not discussed here in detail because the data required to disaggregate the rafting numbers are not available.

Figure 10.11 is from the Statewide Water Supply Initiative Phase 2 report (SWSI Phase 2 2007) and shows “American Whitewater” rafting reaches around the state. More detailed whitewater rafting reaches were identified by river basin in the 2010 Non-consumptive Needs Assessment (NCNA) Focus Mapping Report (CWCB 2010). Figure 10.11 shows the whitewater and flatwater rafting/paddling map generated for the South Platte Basin.

One trade group for commercial rafting outfitters in Colorado is the Colorado River Outfitters Association (CROA), which maintains a variety of rafting data including user days[4] for commercially-rafted rivers in Colorado. In order to portray a general picture of the rafting industry in Colorado, Figure 10.4 shows the rivers and the user days per river in 2012. User days per river are graphically represented in Figure 10.13, at the end of this section.

[4] A “user day” is defined as a paying guest on a river for any part of a day (CROA 2010).

**Figure 10.4. 2012 Commercial Rafting User Days**




Source: CROA, 2012

The Arkansas River is by far the most popular river for commercial rafting in Colorado. The magnitude of these numbers is similar to those of previous years, which are available on the CROA website going back to 1988.

Counties within the Arkansas River Basin (primarily Chaffee and Fremont) experience the most commercial rafting activity due to the number of people who raft the Arkansas River. Reasons for the river's popularity include the range of difficulty of rafting stretches (floating sections to expert-only rapids), the proximity to urbanized areas, and the volume of trips offered by numerous different outfitters (Shrestha 2009).

The North Platte River Basin has one commercially rafted reach that sees on average less than 1,000 user days per year, making this basin the least rafted in the state. The Rio Grande Basin is the second least-rafted basin, since there are only a couple of commercially rafted stretches of the Rio Grande that see on average less than 2,400 user days per year (CROA 2012).

The sub-sectors described above were chosen based on their economic impact to the overall tourism industry and their immediately recognizable vulnerability to drought. Other sub-sectors that are not covered in this report but that are still worth mentioning include:

1) Touring the State, either through road trips or through other modes of transportation, with the purpose of scenic viewing or other specific activities. Heritage areas (towns, parks, or other areas with rich and publicized history) are a notable draw to the state. Another touring activity is aspen tree leaf viewing in the fall.

2) Bicycling, hiking, and other trail-based activities. Although these activities are not covered, they could be potentially impacted during a drought due to park/land closures, increased wildfire risk, and/or decreased air quality, decreased "scenic" quality of landscape, and decreased quality of unpaved hiking and biking trails.

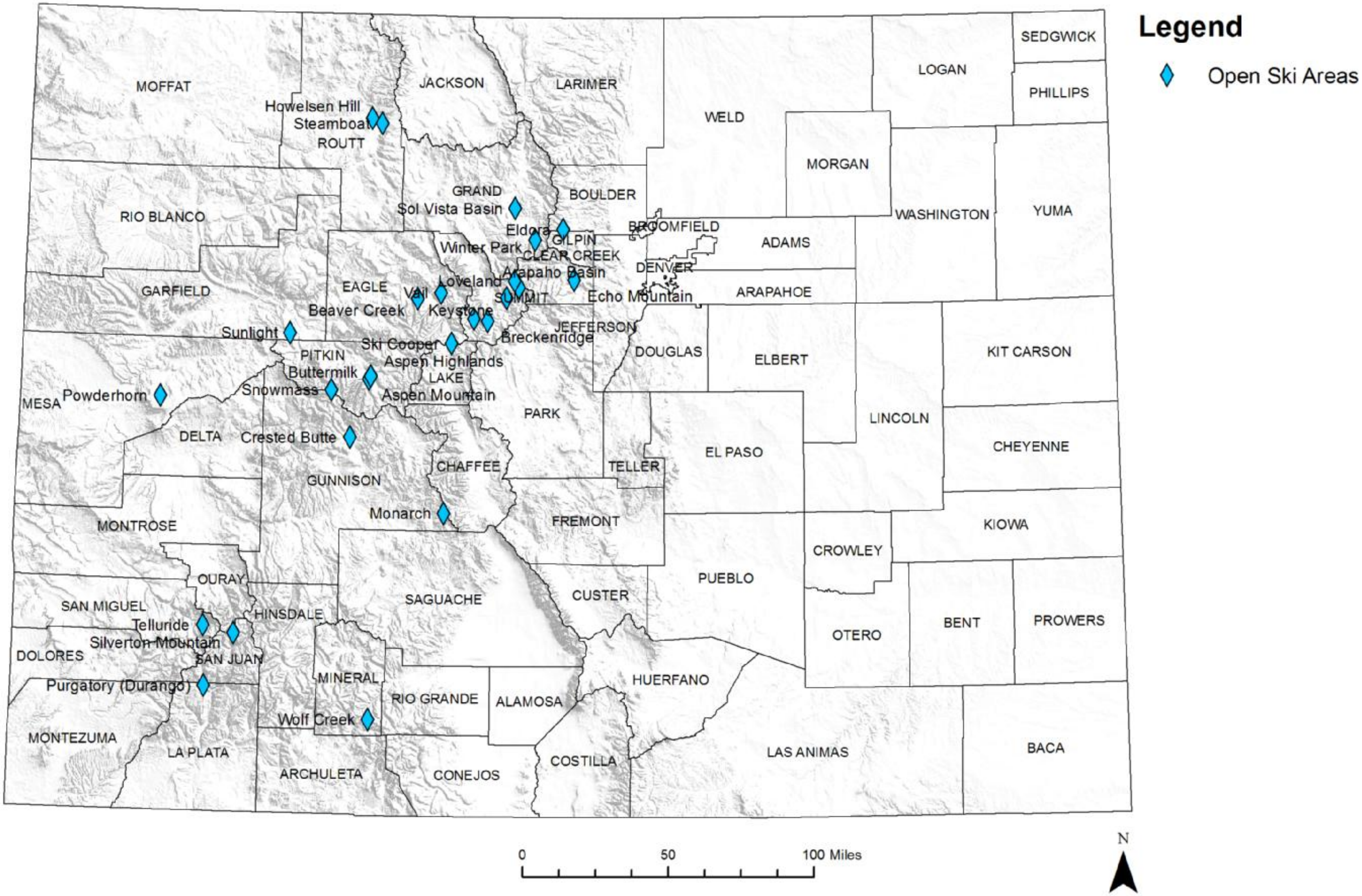
3) Cross-country and back country skiing, snowshoeing, and 10th Mountain Division hut trips. These are popular activities and are suggested for inclusion in the future studies.

4) Kayaking and canoeing are water-based recreation activities that could be included in future studies.

5) "Agri-tourism," which is tourism centered on agricultural attractions. A prominent example of this is the growing wine industry in Mesa County. As of 2013, this is a small economic portion of the Recreation Sector, but may warrant attention in the future.

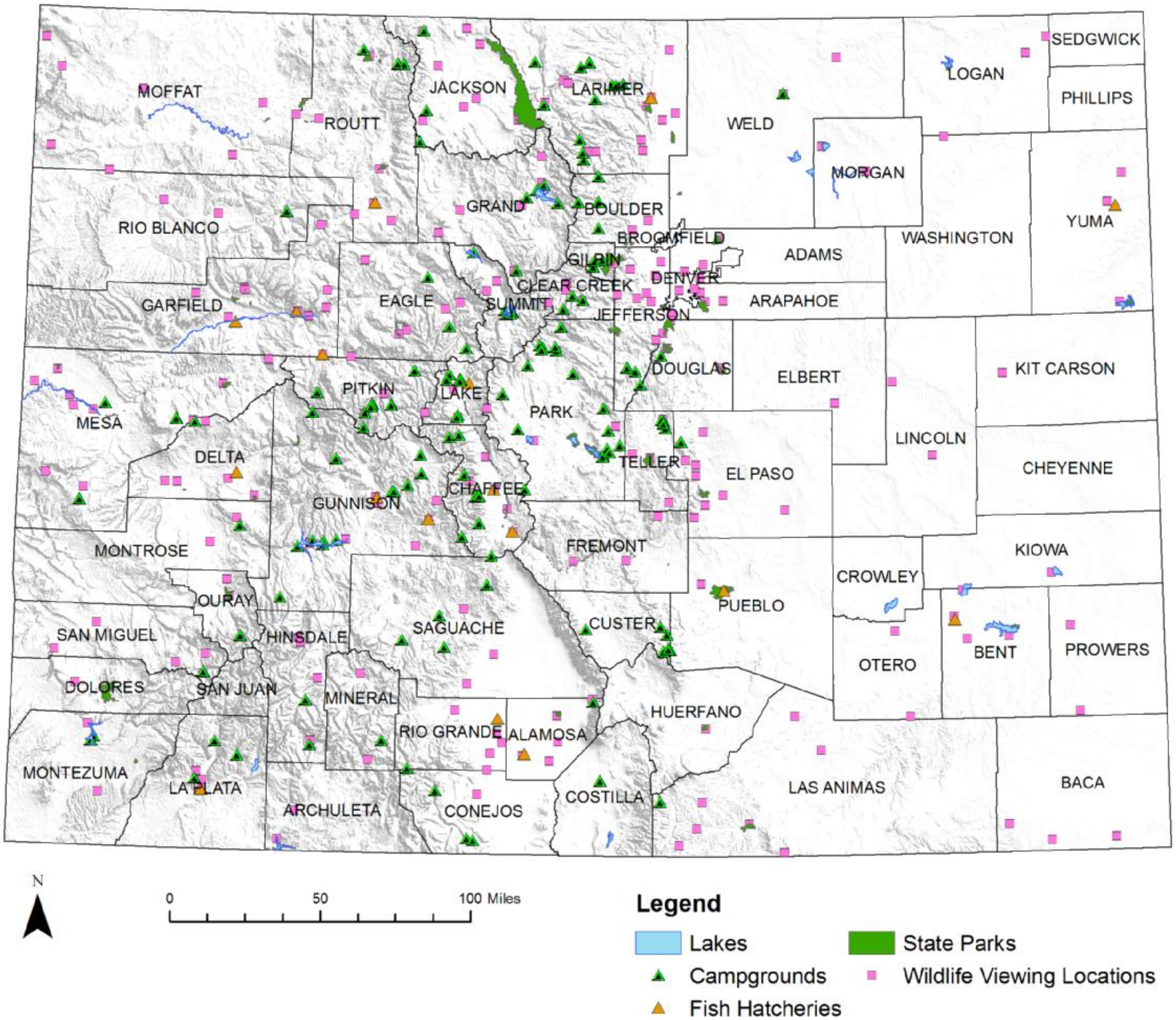
As evidenced by the previous discussion, the Recreation Sector is quite diverse, and ties into numerous other sectors of the economy and state; namely the Environment, State Assets, and Agriculture Sectors. The following sections discuss aspects of vulnerability to drought in the Recreation Sector and cover adaptive capacities used to mitigate the impacts. For a general description of the vulnerability assessment approach refer to Chapter 2 of Annex B.

**Figure 10.5. Ski Resort Locations in Colorado**



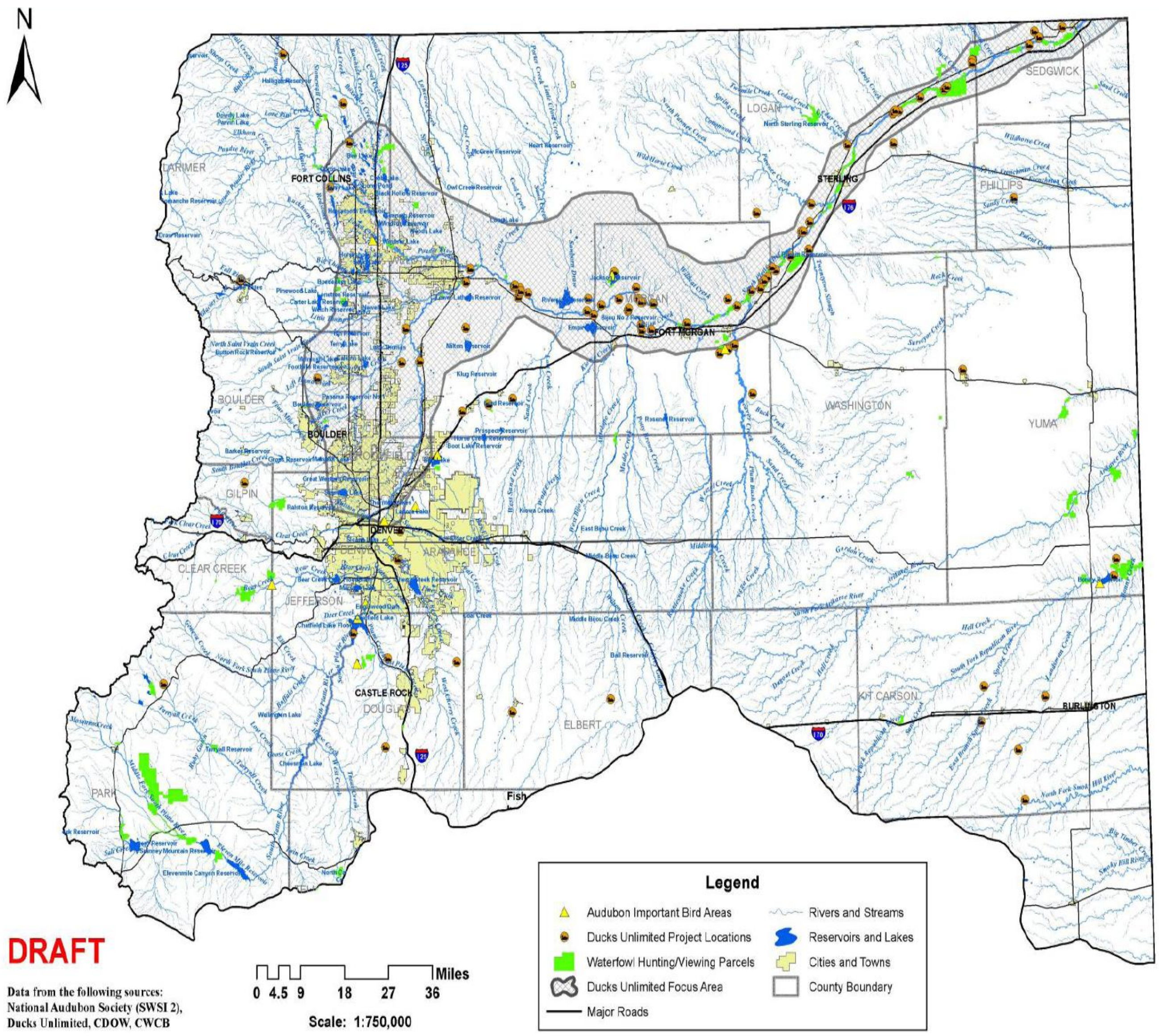

National Operational Hydrologic Remote Sensing Center 2009 and individual ski resort websites

**Figure 10.6. CPW Suggested Wildlife Viewing Areas**




Source: DOW 2010

## Figure 10.7. Waterfowl Hunting/Viewing and Habitat, South Platte Basin (NCNA 2010)



## Figure 10.8. CPW Owned or Managed Lands in Colorado

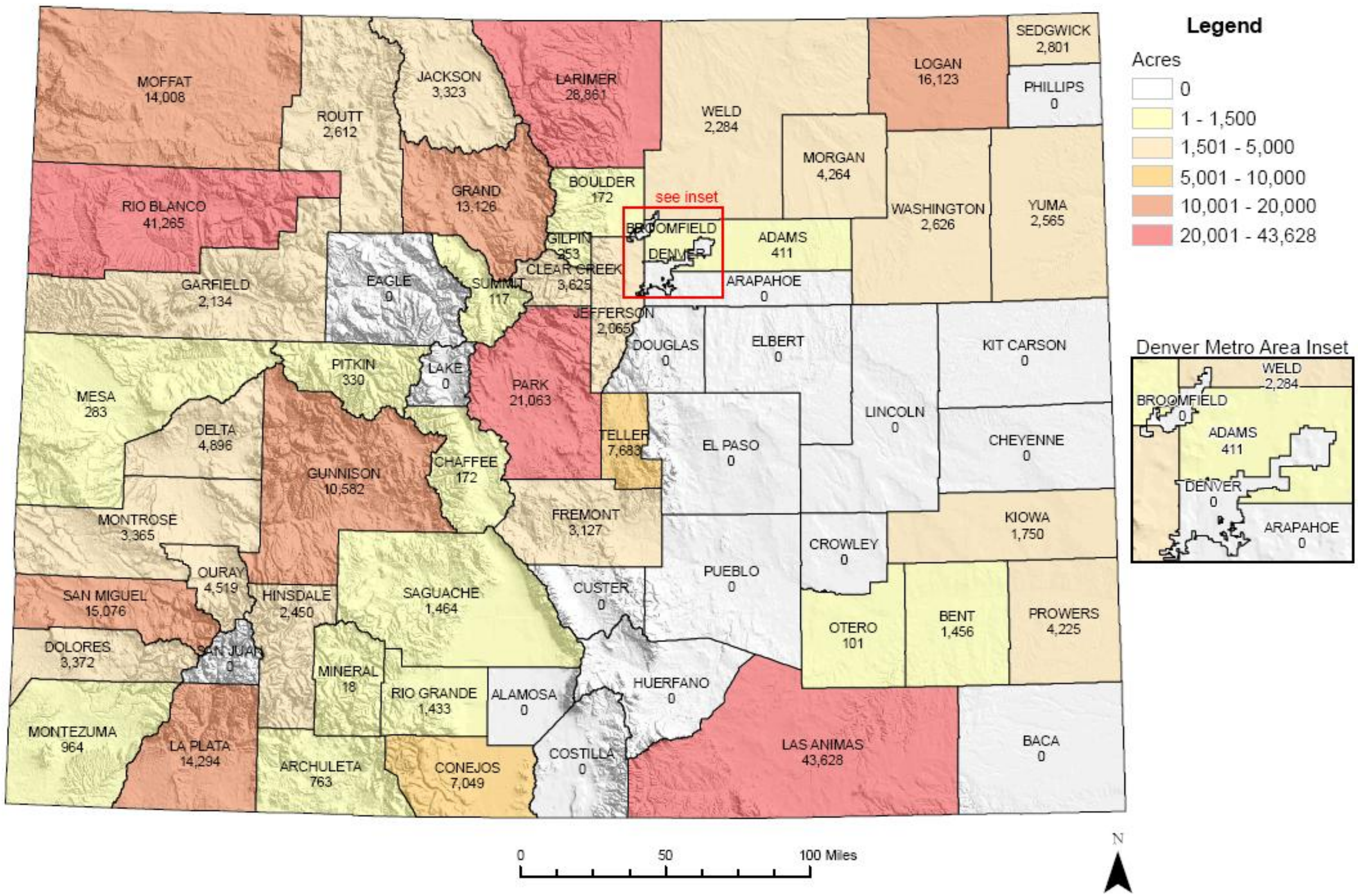
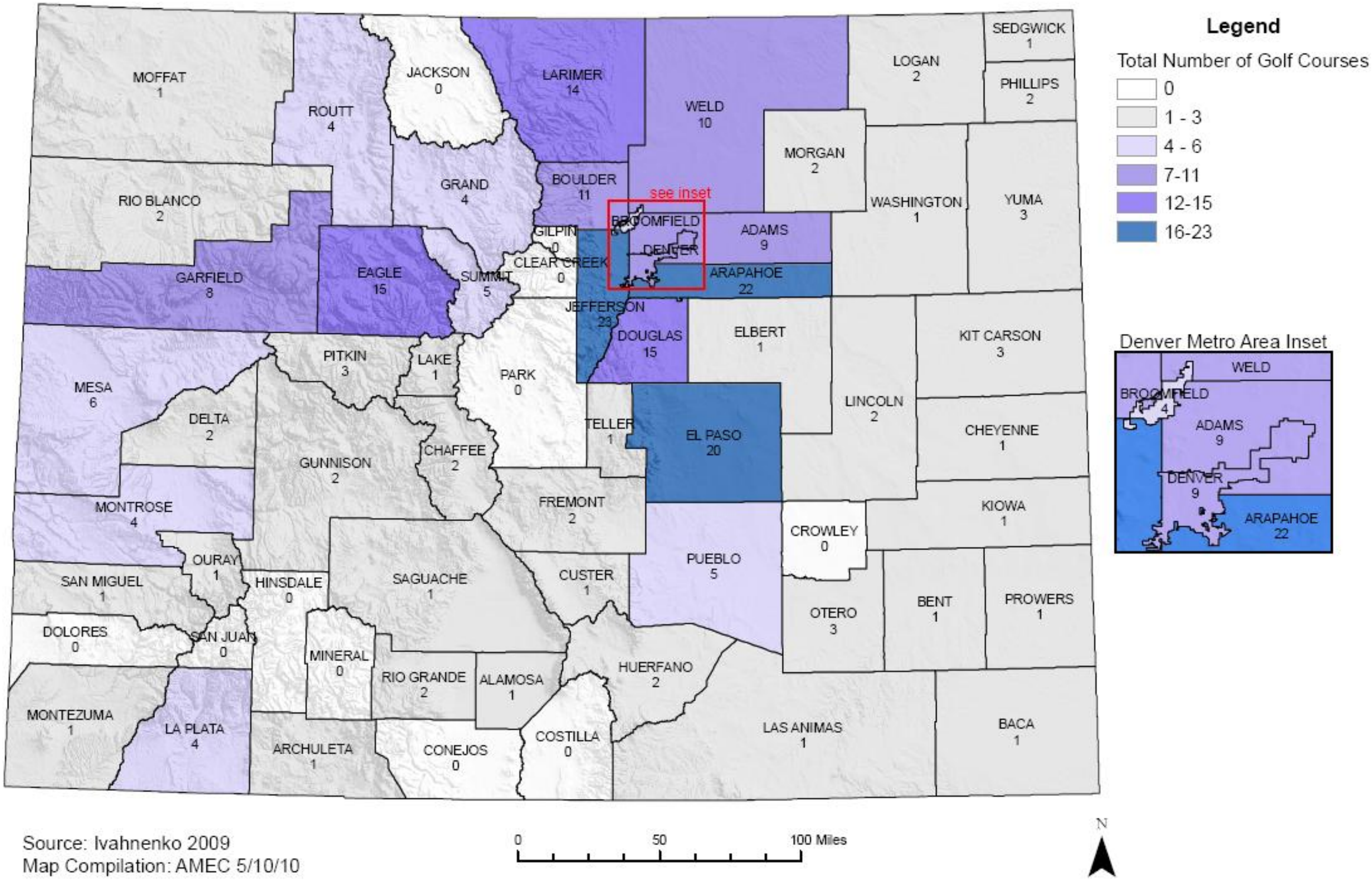
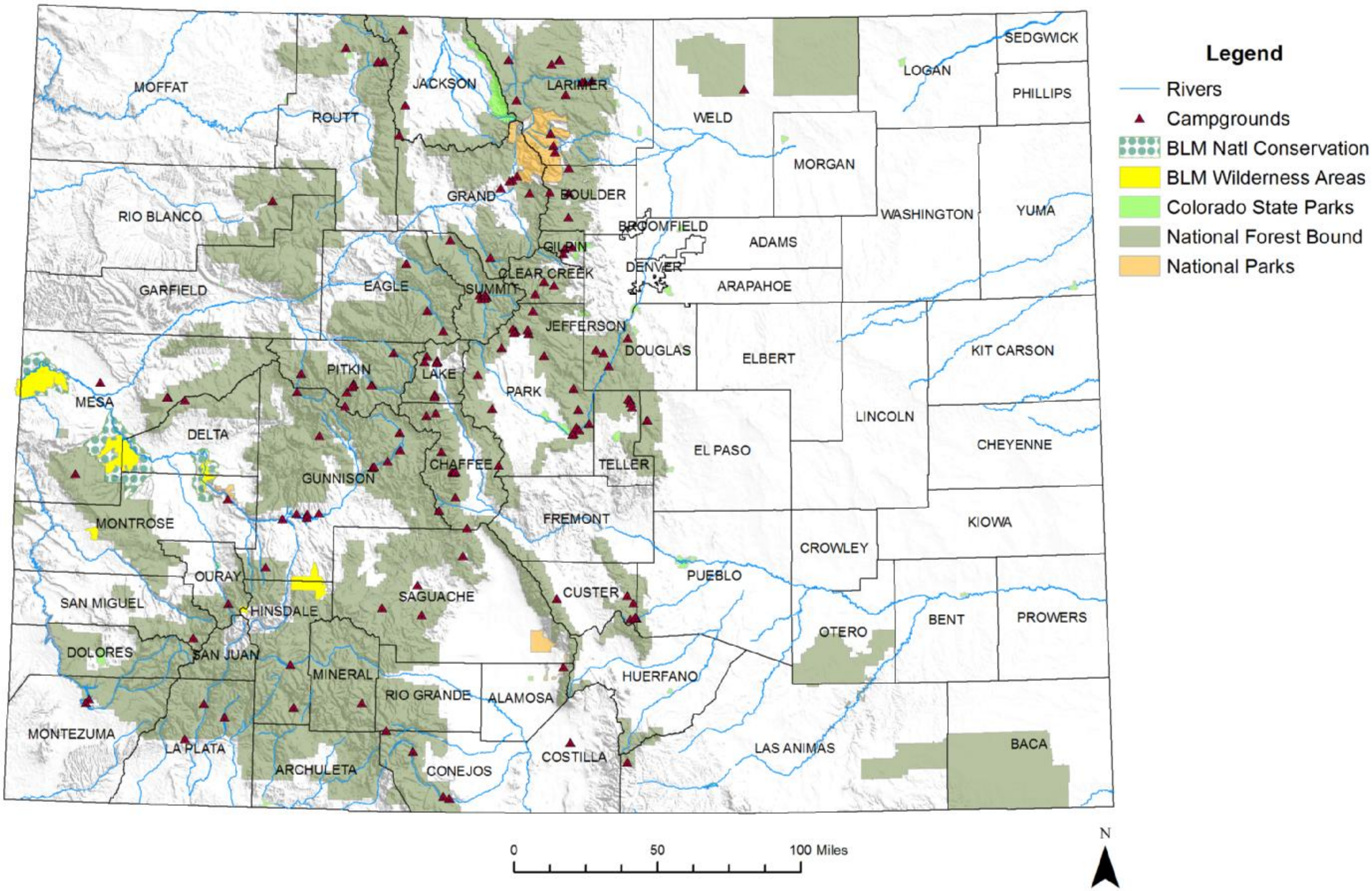


**Figure 10.9. Golf Courses in Colorado**



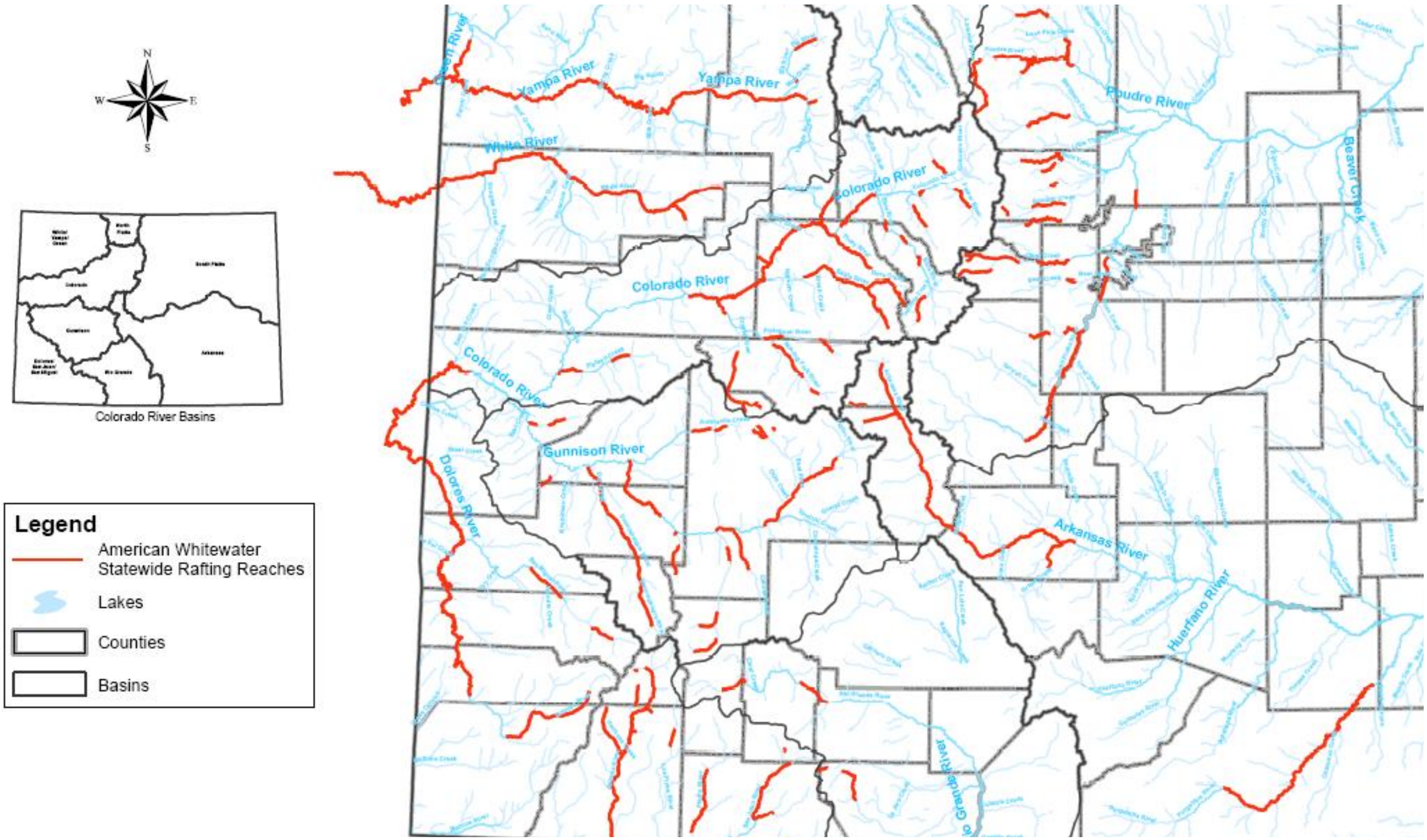

Source: Ivahnenko 2009
Map Compilation: AMEC 5/10/10

## Figure 10.10. Recreation Areas in Colorado



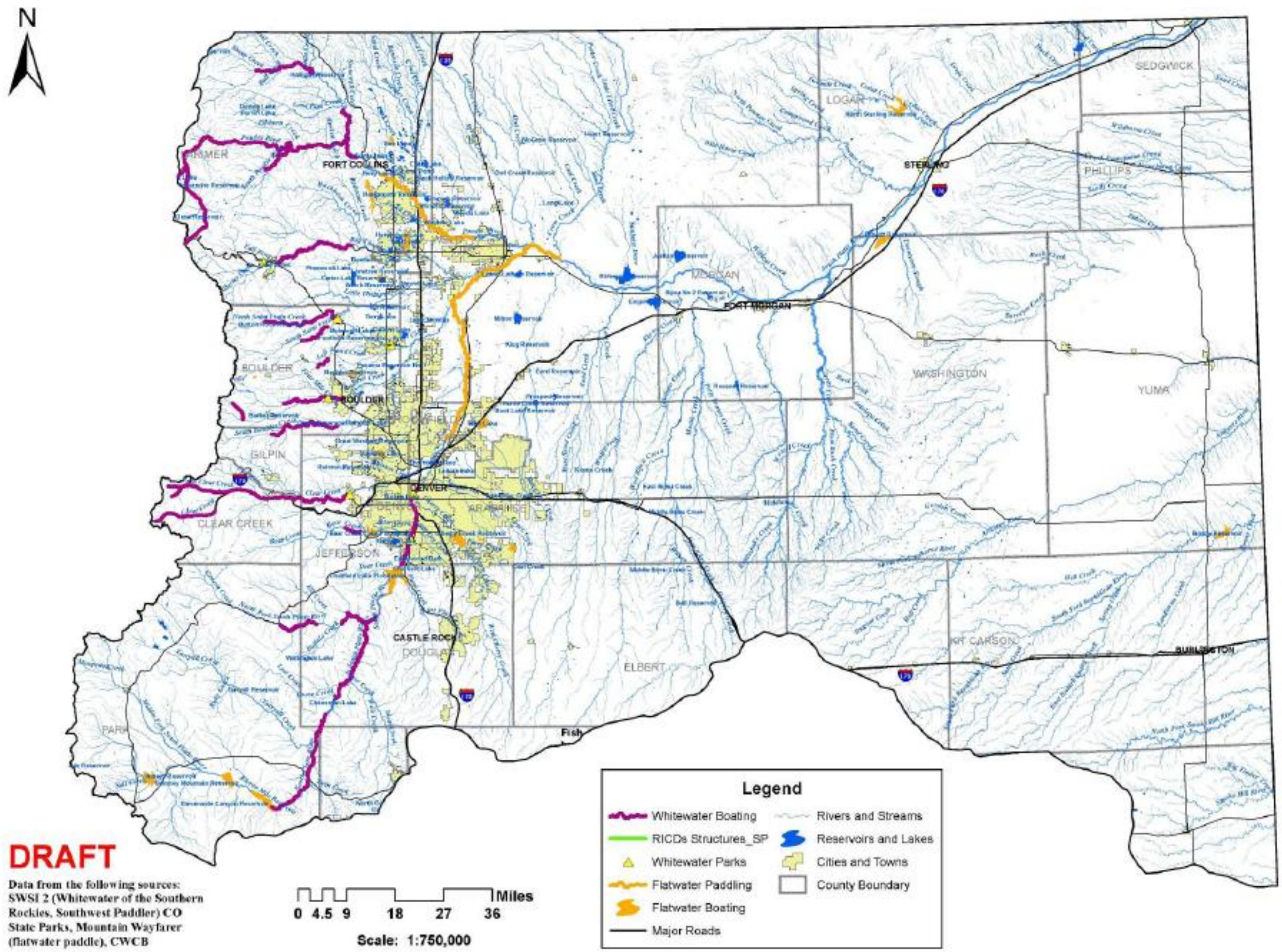

Source: BLM, NFS, State Parks

**Figure 10.11. American Whitewater Statewide Rafting Reaches**



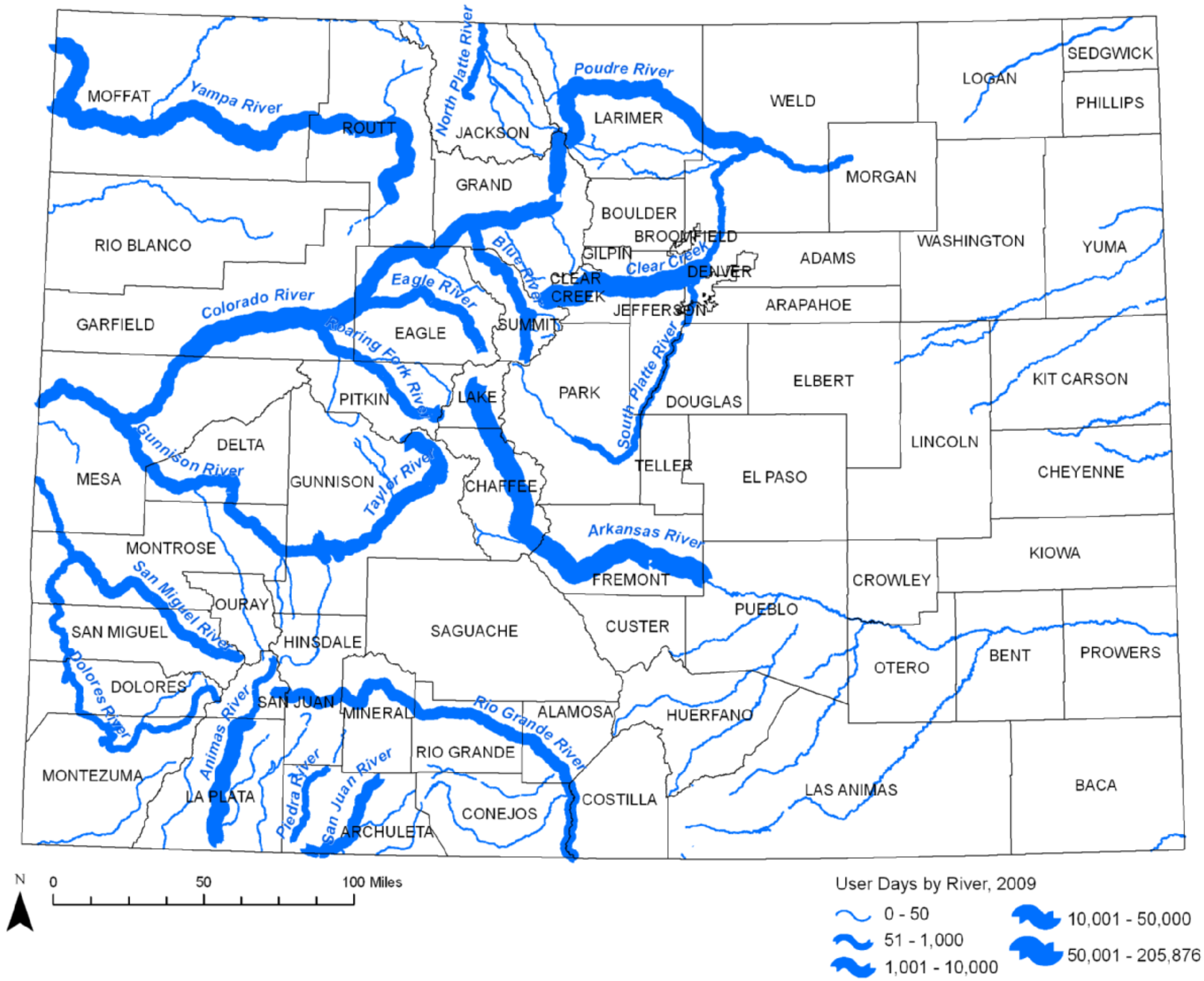

Source: SWSI Phase 2 (TNC, SWSI, CWCB, 2007)

## Figure 10.12. Whitewater and Flatwater Paddling Reaches, South Platte Basin, NCNA 2010




Source: CWCB 2010 (*Data from the following sources: SWSI Phase 2 [Whitewater of the Southern Rockies, Southwest Paddler] CO State Parks, Mountain Wayfarer [flatwater paddle]*, CWCB)

## Figure 10.13. Commercial Rafting User Days per River, 2009




Source: CROA 2009 (This graphic not updated as the pattern of relative use between rafting reaches has not significantly changed for 2012.)

# 10.2 Vulnerability of Recreation Sector to Drought

## 10.2.1 Aspects of Vulnerability

Potential drought impacts to the Recreation Sector vary based on the activity, location, and season (as shown in Table 10.1). The impacts and adaptive capacities discussed in this section were obtained from previous studies done on drought in the tourism industry (listed in the sector bibliography) and from conversations/interviews with people working in or representing the particular sub-sector.

Table 10.5 gives a broad view of how each sub-sector is impacted by drought.

**Table 10.5. Drought Impacts to Recreation and Tourism**

| Sub-sector | Potential Impacts |
|---|---|
| Skiing | Winter season drought (i.e., less-than-normal snowfall) can impact ski area revenues if potential skiers are deterred.<br><br>Ski areas could experience higher operating costs if forced to increase snowmaking – both due to increased need for man-made snow and to the additional energy costs of making snow in warmer temperatures.<br><br>Seasonal staff could be laid off if skier visitation stays low. |
| Wildlife viewing | Stress to animals due to lack of water, loss of vegetative cover, and/or heat could keep them away from traditional viewing areas. |
| Hunting, fishing, and camping | Stress to animals due to lack of water, reduction in forage, loss of vegetative cover, and/or heat could keep them away from traditional viewing areas and decrease the overall health of the population.<br><br>Animal scarcity and/or loss of vegetative cover could detract hunters and result in decreased hunting license revenue for the CPW.<br><br>With less resources (food, water, habitat) available, population production and recruitment will likely decrease for many species.<br><br>A reduction in water resources will generally influence the behavior of all game, but waterfowl numbers specifically are likely to decrease with a reduction in habitat.<br><br>Fish populations could decline due to lower streamflows, lower reservoir and lake levels, decreased dissolved oxygen, too-warm water temperatures, and otherwise degraded water quality.<br><br>Fish scarcity could detract anglers and result in decreased fishing license revenue for the CPW (public perception).<br><br>Fish hatcheries could incur higher operating costs if they have to either transfer their fish to a different location, or go to streams, rivers, and lakes to retrieve endangered species that were released in the wild but now are at risk due to decreased natural water quality and availability.<br><br>Forced closure of campsites due to lack of water (from on-site wells) but more prominently due to risk of wildfires and/or hazard trees (trees that are dead or dying and are at risk of falling). |

| Sub-sector | Potential Impacts |
|---|---|
| Golfing | Water scarcity and/or municipal restrictions could cause parts of course to become harder to play, go brown, or otherwise become stressed.<br><br>Drought-stressed turfgrass has diminished playability and performance, resulting in fewer golfers and a loss of revenue.<br><br>As putting greens become more dry, they become more firm. Firm greens increase the challenge to golfers, which can result in fewer golfers if playing conditions are too difficult.<br><br>Golfer participation could decrease due to negative perception of course aesthetics, and/or courses could face higher operating costs to maintain existing turf.<br><br>Increased time and expense to golf courses following the drought to induce damaged turfgrass to recover. These expenses are incurred immediately after a period of limited revenue, which can place courses in a difficult financial position. |
| Boating | Lower reservoir and lake levels could detract boaters from visiting and/or registering their boats for a season.<br><br>State Parks could experience decreased revenues due to lower visitation and registration. |
| Rafting | Lower streamflows could force rafting outfitters to use smaller boats, resulting in less revenue per trip.<br><br>Negative public perception of drought and associated hazards (e.g., wildfires) could result in decreased rafting customers and/or cancellations. |

These impacts can be offset through adaptive capacities. The recreation industry has experienced drought before, and each time the ability to adapt and mitigate the impacts becomes more refined as companies diversify and figure out what they need to do to remain in business through the drought. Table 10.6 lists some adaptive capacities that have been developed and utilized during past droughts.

### Table 10.6. Recreation and Tourism Adaptive Capacities

| Sub-sector | Adaptive Capacities |
|---|---|
| Skiing | Use snowmaking machines to better predict and control season opening date; this also helps mitigate against lack of natural snow later in the season.<br><br>Cloud seeding has been used by Vail Resorts since the 1970s. They identify cloud seeding impacts to total snowfall as being in the range of 15 to 18 percent over the course of the ski season.<br><br>The comparative investment is $58,000 a month for three months of seeding compared to $50,000 each night that snowmaking is used for eight acres of land (Sink 2003). |
| Wildlife viewing | CPW feeding programs to avoid catastrophic animal loss. |

| Sub-sector | Adaptive Capacities |
|---|---|
| Hunting, fishing, and camping | CPW feeding programs to avoid catastrophic animal loss. Conversely, the CPW can release more hunting licenses than they would have otherwise, with the rationale that the animals are likely to die anyway due to drought (Luecke et al. 2003).<br><br>CPW can implement drought specific herd management principles for priority game species (CPW, 2012).<br><br>Fish hatcheries can transfer fish to streams, lakes, and/or other hatcheries that are not as negatively impacted.<br><br>Campsite managers can advertise areas that are not impacted (if such areas exist). |
| Golfing | Many of these adaptive capacities are already widely used in golf course management and include: use of chemical wetting agents to increase uniform water distribution in soil column, eliminate irrigation in selected areas, reduce rough irrigation, hand-water tees, and control the growth of grass by not cutting it as short and adjusting fertilization practices. |
| Boating | Use lower water levels as an opportunity to do maintenance on boat ramps; advertise areas in the state that are not heavily impacted (if such areas exist).<br><br>CPW can work with local, state, and federal agencies to maintain certain flows for recreational purposes as there is a direct correlation between adequate water levels and state park revenue (CPW, 2012).<br><br>Conversely, halt maintenance to save money and reduce staff. |
| Rafting | Diversify business by offering trips on more rivers, offer different lengths of trips to attract new customer base, and/or offer kayaking or fishing trips that may not need as high a flow volume in the river.<br><br>Cut back on staffing.<br><br>CPW can work with local, state, and federal agencies to maintain certain flows for recreational purposes as there is a direct correlation between adequate water levels and state park revenue (CPW, 2012).<br><br>Focus on a different demographic that may be attracted to lower-flow, less physically demanding trips.<br><br>Rafting organizations can also work with the government and media to control the message relayed to the public. This would help to maintain a positive public perception of rafting throughout the drought. |

### 10.2.2 Previous Work

A review of previous works dealing with drought impacts in the Recreation Sector was conducted to assess vulnerability and adaptive capacities. Most of these works discuss the 2002 drought, as it was the most recent complete drought event.[5] The 2011-2013 drought is, at the time of this update, ongoing. While the full extent of the impacts of the drought have yet to be seen or measured, many observations are available for inclusion in this update. Table 10.7 summarizes the impacts reported for both the 2002 and 2011-2013 drought events.

[5] Estimates put the frequency of the 2002 drought as a 300- to 500-year event (Luecke et al., 2003). Although the summer of 2002 was severe, the overall drought was relatively short with respect to previous multi-year droughts recorded in Colorado.

## Table 10.7. Summary of Previous Works

| Sub-sector | Previously reported impacts | Source |
|---|---|---|
| Skiing | Out of 25 Colorado ski resorts and ski areas, 21 made snow early in the season (from October to December). Overall though, the direct winter impacts were minor compared to the summertime impacts on other sectors of the recreation and tourism industry.<br><br>For the 2011/12 season, skier visits to Colorado Ski Country USA (CSCUSA) resorts were down 11.9%.<br><br>A decrease in skier visits continued into the 2012/13 season with CSCUSA resorts seeing a 4.2% decrease through February 28th, 2012. | Wilhelmi et al. 2004<br><br>CSCUSA, 2012<br><br>CSCUSA, 2013 |
| Wildlife viewing | Documented cases of birds shifting their migratory grounds in response to environmental changes, including higher temperatures often associated with drought.<br><br>It is unknown the extent to which extreme climatic events, especially heat waves and drought, will push different species physiological tolerances for heat and dehydration to or above their limits, resulting in increased mortality.<br><br>Animals may move to higher elevations to avoid warm temperatures during summer drought. | Audubon 2009<br><br>Audubon 2010<br><br>Kohler 2010 |
| Hunting, fishing, and camping | The State released 16,000 extra cow elk licenses in September for fear that the elk would die over the winter anyway.<br><br>The fishing industry fought a battle of perception all summer. According to representatives from three separate fishing shops, their biggest obstacle was convincing people that the fishing was actually very good. Low water level and high water temperatures led to good fishing in certain areas. | Luecke et al. 2003<br><br>Schneckenburger and Aukerman 2002 |
| Golfing | Estimated that a typical Front Range golf course would need to increase their irrigation by about 25% to offset the effects of high temperatures and low precipitation to provide the aesthetics, performance, and playability golfers expect during non-drought years.<br><br>Note that the estimated 25% increase in irrigation needs is for illustration purposes. In practice, during the drought in 2002 golf courses used approximately the same amount of water as in non-drought years by employing water conservation techniques (see Table 10.6) such as not irrigating parts of the golf course (usually the rough) and reducing irrigation on other parts of the golf course (usually fairways). | Watson et al. 2004<br><br>Communication with Golf Course Superintendents Association of America 2010 |
| Boating | Boating in general was down. Water-based state parks reported reductions between 20% and 53% in revenues as boat ramps were left unusable by low water levels. Estimated loss of about $140 million. Extremely low levels in many reservoirs and rivers throughout Colorado presented a major challenge for this sub-sector.<br><br>Due to the 2002 drought, State Parks was forced to close several lakes and reservoirs early due to low water levels and the inability to launch boats. | Luecke et al. 2003<br><br>Wilhelmi et al. 2004<br><br>Schneckenburger and Aukerman 2002 |

| Sub-sector | Previously reported impacts | Source |
|---|---|---|
| Rafting | Trip cancellations and significant customer declines; forced to layoff staff; increased injury among guides due to low water levels.<br><br>According to the Colorado River Outfitters Association, a 39 % drop in whitewater rafting days was evident as compared to 2001 levels. This equates to a difference in over 200,000 user days (523,587 in 2001; 319,562 in 2002). Each user day is estimated to provide $391 of revenue.<br><br>The total number of user days for the state for 2012 decreased 17.1% compared to 2011, which saw a 0.5% decrease from 2010.<br><br>The total estimated economic impact of the 2011-2013 drought on the rafting industry is approximately $128 million | Shrestha 2009<br><br>SWSI Phase 1 2004<br><br>CROA, 2012<br><br>CROA, 2012 |

The 2012 Drought Assessment for Recreation & Tourism (DART) study was funded by the CWCB and is a pilot project intended to examine the relationship between drought and recreation and tourism in southwestern Colorado. While initial goals of the report included evaluating the metrics used in the Colorado State Drought Mitigation and Response Plan and identifying existing data to be used for drought management, baseline data from which to work was found lacking. Data required to evaluate the metrics from the drought plan were not available in many cases. Ultimately, the DART Report authors were able to propose a model of stakeholder engagement that both echo, and can be used to address, several recommendations made in the 2010 Drought Mitigation and Response Plan. The DART report thus provides some details of drought vulnerabilities and impacts to the sector in southwestern Colorado, but also is a guide about how best to begin collecting data through stakeholder involvement in order to determine and assess the impacts of drought on recreation and tourism.

The 2012 DART Report offers insights to the assessment of drought impacts to the recreation/tourism sector in southwestern Colorado. The report builds upon several of the conclusions and themes established in the 2010 CWCB Drought Plan and establishes a general framework for future studies. While many of the methods will likely be transferrable, the recreation and tourism sectors in other parts of the state may function differently, requiring alterations to the approach. Overall the report makes clear that little is known about the linkages between drought and the recreation/tourism sector, and thus this focused study is a significant step forward to improving this situation.

Key summary conclusions from the DART are as follows:

- The diversity of the sector presents some challenges, but also provides a great capacity for adaptation. Communities that can offer many different options for recreation and tourism will be better off than those that cannot.

- In order to control the negative public perception associated with drought, wildfires, etc, communities will need to effectively market the diversity of options they can present to tourists. In association with a diverse marketing strategy, public relation plans will also be important in order to prevent a negative public perception of the drought event.

- A level of awareness about the linkages between drought and the recreation/tourism needs to be communicated and developed at the stakeholder level.

- The linkages between drought and primary impacts to the recreation/tourism sector are obvious in some cases and more obscure in others. In many cases, the secondary impacts are unknown. Data collection and information dissemination are key to understanding trends and providing evidence for informing planning and policy. Drought specific methods and metrics need to be developed in order to understand how drought impacts the sector. One possible way to determine these metrics is to follow the framework developed for the stakeholder involvement model.

- Successes from each sub-sector need to be identified and translated into best practices that other business can follow or employ as part of a drought that includes strategies for preparedness, response, mitigation, and recovery.

Studies addressing past drought events include CWCB's Drought Water Supply Assessment (DWSA) in 2004 which had the goal of determining the State's preparedness for drought conditions. This study aimed to determine how prepared Colorado has been for drought and to identify limitations, and related measures, to better prepare for future droughts (DWSA 2004). It entailed a survey in which 537 responses were received statewide regarding specific impacts experienced during the drought years of 1999 to 2003. Various entities were surveyed including power, industry, agriculture, municipal, state, federal, water conservancy and conservation districts, and other entities like tribes and counties. Although the survey did not include any recreation or tourism groups, various case studies were conducted and included a rafting company owner on the Arkansas River. The goal of the case studies was to describe the social impacts that were felt on the business owners as a result of the most recent drought. Impacts reported in those case studies are similar to those reported in Table 10.5 and Table 10.7.

Another previous study that is useful to discuss is the Statewide Water Supply Initiative (SWSI). Although it did not specifically focus on drought as the DWSA did, the SWSI process was directed by the CWCB to understand existing and future water supply needs and how those needs might be met through various water projects and/or water management techniques. As described in the introduction, SWSI used a statewide and basin-level view of the water supply conditions in Colorado and created basin roundtables as a forum for collecting and sharing information and ideas.

The SWSI report in 2010 discussed recreation and tourism as it relates to water availability in Colorado. One of SWSI's recommendations is to "enhance recreational opportunities." While SWSI did not provide a detailed assessment of drought impacts to the Recreation Sector, it did identify some areas where water management techniques could be employed, whether in a drought or not, to enhance this important component to not only bring economic vitality to the State, but to also provide quality of life for its residents and visitors. A major finding in SWSI Phase 2, re-emphasized for SWSI 2010, was that population growth in the state would cause the environmental and recreational uses of water to increase, and that there would be competing demands for water across use categories (e.g., domestic, municipal, industrial, and recreational).

Conflict will arise between these groups if no mechanism to fund environmental and recreational enhancements exists alongside water projects beyond what is normally required by law during the permitting process. Recognizing this, the SWSI process seeks to maintain a dialogue between stakeholders to identify potential funding sources or options for enhancing recreational and environmental uses when reliable sources of water are developed.

One specific example of cooperative multiple use of water discussed in SWSI Phase 2 is the Yampa River Flow Enhancement program. This project is one where operational flexibility was maintained between major water users and suppliers to mitigate drought impacts to a fishery in the Yampa River. In 2002, flow increases through the upper reaches that were allowed via re-operation/exchange minimized the effects of high water temperatures on the fishery. A similar scenario played out during 2012 when the Yampa experienced severe drought. The Colorado Water Trust and CWCB leased 4,000 acre-feet for instream flows (Smith & Koziol, 2012). The 2010 update to SWSI compiled information from the basin roundtables about their existing and future needs and supplies for both consumptive and non-consumptive uses. This information was then used to project supply and demand through 2050, including non-consumptive use needs, upon which much of the recreation and tourism sector relies. The Statewide Nonconsumptive Needs Assessment Focus Map[6] presents each basin's projected needs which includes 33,000 miles of streams and lakes containing or offering recreational and environmental value.

SWSI Phase 2 provided additional examples of recreational enhancements, including providing instream flows for rafting and kayaking and providing permanent reservoir pools for flat-water recreation. As part of the SWSI process, all decreed instream flow and recreational in-channel diversion (RICD) water rights were inventoried. As discussed in the State Assets section, the CWCB, through its Instream Flow Program, protects the natural environment by obtaining instream flow water rights. This program is an important one to ensure certain streamflows and lake water levels are maintained to protect important habitats. While the focus of instream flow rights is environmental protection, there are secondary recreation benefits.

As mentioned above, the Non-consumptive Needs Assessment (NCNA) Focus Mapping report (CWCB 2010) discusses non-consumptive water uses in the nine basin roundtable areas of Colorado (eight major river basins and the Denver Metropolitan Area). The NCNA expands upon the existing set of environmental and recreational attribute maps that were developed through the SWSI Phase 2 process and develops aggregated maps of Colorado's critical waters based on the concentration of environmental and recreational qualities. The maps are intended to be a guide for water supply planning, so that future conflicts over environmental and recreational water needs can be avoided.

The NCNA is an expansive undertaking that provides valuable aquatic recreation data aggregation. While it does not speak to drought vulnerability specifically, the data gathered and

[6] This document, along with the rest of SWSI 2010 can be found at:
http://cwcb.state.co.us/water-management/water-supply-planning/pages/swsi2010.aspx

resulting stream reach designations are a useful recreation inventory metric (several results maps from this study have been presented in previous sections). The NCNA focused on three main water-based recreation areas; boating, fishing and waterfowl hunting. Each roundtable group identified their own priority data layers to address the three main recreation categories. For example, in the Arkansas basin significant fishing areas were divided into: trout lakes, trout streams, Arkansas State Wildlife Areas and State Fish Units, Pueblo Fishing and Arkansas Headwaters Recreation Area; while in the Rio Grande basin fishing was only divided into gold medal trout streams and significant fishing waters based on local knowledge. The methodology for the Drought Vulnerability Study was developed to facilitate analysis that could be consistent across watershed and county boundaries in Colorado, this requiring selection of categories and data types that were available and comparable at the county level. In contrast data developed for the NCNA analysis, while often rich in terms of the number and types of data used, is variable across basins. This precluded extraction of this information in a manner that would have facilitated direct use of the NCNA results. Furthermore, all of the NCNA analysis was done with respect to sub-basins and stream reaches. Significant analysis is required to convert these findings into county designations that could be incorporated into this methodology. Although numerical integration is not possible at this time, the applicability of these data for future analysis is unquestionable. Additional work should be supported to build on the NCNA findings and create an aquatic recreation inventory metric that can be applied directly to drought.

## 10.3 Assessment of Impacts and Adaptive Capacities

Recreation and tourism is a large and diverse industry in Colorado. For this assessment, focus is placed on water-based activities (e.g., skiing, boating, and rafting) and activities that are secondarily impacted by drought and that comprise a significant portion of the recreation and tourism industry (e.g., hunting, fishing, wildlife viewing, and golfing). In the previous sections, drought impacts and adaptive capacities were introduced. This section expands on that framework.

### 10.3.1 Impacts and Adaptive Capacities

#### Skiing

In 1977 there was a severe winter drought. In response, most resorts installed snowmaking machines (considered a mitigation strategy to winter drought). In addition to protecting the ski area against little or no natural snow, snowmaking capabilities allowed the resorts to set firm opening dates and better control seasonal staffing and other business-related factors. As a result of the prevalence of snowmaking, the ski industry was not significantly impacted by the lack of snow in the winter of 2001/2002. Also during the mid-1970s, Vail Resorts started a cloud seeding program which has continued to the present. Snowmaking and cloud seeding could be considered adaptive capacities for the skiing sub-sector. It is difficult to determine whether or not snowmaking influenced skier behavior during the 2012 season. Through the end of February, 2013 skier visits were slightly down (CSCUSA, 2013), but resorts are able to open prior to sufficient snowfall because of snowmaking capabilities.

The timing of drought is a key factor as to whether ski areas will be impacted (i.e., a drought occurring in the summer will not impact the ski season). Spatial variability is also important since a drought in the southeast corner of the State will have little impact on the ski areas. However, because ski areas are concentrated in a small area, the likelihood of a drought affecting many areas at once is high.

For the 2009/2010 ski season, each ski area hired a number of seasonal part- and full-time employees. The National Ski Areas Association provided full-time winter season employment numbers. For example, ski areas in Summit County hired approximately 4,270 full-time employees last year and ski areas in Eagle County hired almost as many (4,150). The four ski areas in Pitkin County hired approximately 1,350 full-time employees. For these counties, which have populations at or under 50,000 people, the ski area hiring represents close to 10% of the population. Impacts to ski areas during a drought would potentially affect a large segment of the employed population in the counties where resorts are major employers. The adaptive capacities that were described for ski areas in the previous section could help avoid large-scale layoffs during a winter drought.

In some drought situations, snowmaking capacity may be limited by water availability. The ski resorts in Colorado that use snowmaking machines have the capacity to cover between 15 acres and 650 acres of terrain.[7] Depending on the temperature, each acre-foot of snow generated requires about 160,000 gallons of water (Ratnik Inc. 2010). Therefore, snow generation can require millions of gallons of water annually. Ski resorts have rights for this water but their ability to divert water can be limited by instream flow rights during drought. The impact to specific resorts will vary by location and depending on where diversions occur relative to other rights. Some resorts may not be impacted at all during drought but can still be hurt by public perception of ski conditions.

Colorado Ski Country USA tracks the number of skier visits through the season. Skier visits are metrics used to track participation in the activity, and one skier visit is defined as one person participating in the sport of skiing or snowboarding for any part of one day at a mountain resort (CSCUSA, 2013). As expected, skier visits have declined during the 2011-2013 drought period.

For the 2011/12 season, CSCUSA resorts experienced a decrease in skier visits of 11.4% compared to the 2010/11 season, which was the fourth best on record. Relative to a 5 year average, the drop in skier visits is approximately 11.9%. Colorado's western slope experienced its third driest and seventh warmest winter on record. While the statewide trend showed a decrease in skier visits, some areas of Colorado saw increases in visitation days (CSCUSA, 2012).

[7] Self-reported snowmaking coverage, individual websites accessed 2010.

As of the end of February, 2013, CSCUSA resorts saw similar decreases in skier visits for the 2012/13 season. Skier visits were down 4.2%, through the end of February, compared to the period of 2011/12. The resorts seem to have benefitted from somewhat consistent storms through the first part of 2013. Comparing numbers for January through February $28^{th}$, skier visits slightly increased (1.3%), relative to the same period of 2011/12 (CSCUSA, 2013).

### Wildlife Viewing

According to a 2011 survey conducted by the US Fish and Wildlife Service (USFWS), there were 1.8 million U.S. residents (16 year old or older) who fed, observed, or photographed wildlife in Colorado (approximately the same amount as reported in USFWS, 2006). The same survey estimates that wildlife watchers spent $1.4 billion on wildlife watching activities in 2011 (again, nearly equivalent to figures reported in USFWS, 2006); this includes food and lodging, transportation, equipment rental, and other trip expenses. The average of the trip-related expenditures for participants away from their homes (defined as one mile or more away from home) was $786 per person in 2011 (up from $607 in 2006) (USFWS, 2011).

This economic contribution to rural economies could be reduced if a drought caused a decline in wildlife herds. A localized shortage of food and/or water could cause animals to migrate away from traditional habitat. Adaptive capacities such as CPW feeding programs could maintain animal populations and help secure tourist revenue for wildlife watching areas. Many wildlife species in regions of Colorado where drought is common are already adapted to it, and can either survive in drought-stressed habitats or are able to migrate to better conditions elsewhere (communication with DOW, 2010). Therefore, one adaptive strategy may be to identify where the animals are and change the wildlife viewing program accordingly.

### Hunting, Fishing, and Camping

During 2007, there were roughly 12.7 million hunting and fishing activity days in Colorado, and the estimated total direct expenditures in support of hunting and fishing were approximately $1.1 billion (BBC Research & Consulting 2008). This level of economic activity is estimated to support approximately 21,000 full-time jobs in Colorado, which especially in rural counties can represent an important part of the economy (BBC Research & Consulting 2008).

For 2012, Colorado Parks and Wildlife have observed a number of impacts related to the hunting, fishing and camping sub-sector for the 2011-2103 drought event (CPW, 2012). Overall, park visitations dropped by an estimated 25%, which corresponds to a revenue loss of over $1 million. Visitations and revenue for the Northwest and Southwest regions (18 state parks) was reduced by 20-35%, and for the Northeast and Southeast regions, reduced 15-30% (24 state parks).

CPW has found the drought has generally reduced the resources available to many species (CPW, 2012). This has lowered animal fat reserves, reducing the likelihood of winter survival. Production and recruitment are expected to be reduced for upland game birds, waterfowl, lesser prairie chicken, sage-grouse, and pronghorn antelope. CPW is concerned about the availability of wintertime forage for big game, and thus the survival of several species, especially mule deer (CPW, 2012).

In order to combat these concerns, CPW has implemented population monitoring programs and drought-specific herd management principles for priority game species (CPW, 2012).

Impacts to the fishing sub-sector include fish kills, loss of flow or water level, and damaging floods (CPW, 2012). Fish kills at reservoirs, lakes, ponds, and streams have resulted from high water temperatures, anoxic conditions, excessive ash from recent wildfires, and high sediment loads. A heavy precipitation event on July 24, 2012 flushed sediment and debris into a reach of the Colorado River above Dotsero, killing a large amount of fish. Wildfires have generally contributed to poor habitat conditions for aquatic species. Ash and sediment from the Track Fire (2011) elevated 2012 water temperatures causing a fish kill at Lake Dorothy State Wildlife Area in Las Animas County. Additionally, habitat in the Poudre River basin has been negatively impacted by post fire sediment loads from the Hewlett Gulch and High Park fires (CPW, 2012).

CPW has initiated several mitigation efforts. These include emergency fish salvages at several reservoirs, voluntary fish closures, and emergency evacuation of brood stock to other hatcheries. In the White River, CPW worked with the CWCB and Division of Water Resources to gain approval for an emergency release to maintain in-stream flows in order to protect cold-water species. In response to the High Park fire, catchable sized fish from the Watson Hatchery were relocated to the Horsetooth and Carter reservoirs (CPW, 2012).

A priority of CPW during the 2002 drought was to protect recreationally significant wildlife populations. The State increased the number of elk licenses released and instituted over-the-counter elk licenses due to concern that the elk population was too large and would not survive the winter given the limited forage. This solution was ineffective as it created confusion among hunters and did little to reduce elk numbers (communication with DOW 2010). As a result of the 2002 drought, CPW now has a process to close areas to activity in case of emergency conditions, including drought. This is expected to leave staff better prepared to deal with drought emergencies as they arise by providing a framework in which the staff can respond quickly (communication with DOW 2010).

Significant impacts were also noted for aquatic recreation during the 2002 drought. For example, the Kokanee salmon, a high value sport fishery in Colorado, was threatened by low flows in a critical spawning run on the Gunnison River. Flows were so low during the late summer that the Kokanee salmon run could not swim past a barrier west of the town of Gunnison. CPW staff had to manually transport the fish to the Roaring Judy Fish Hatchery on the East River for spawning operations. They also removed, redesigned, and reconstructed the concrete barrier to better allow for future fish passage (communication with DOW 2010). Reservoir fisheries were also impacted. In 2002 Denver Water completely drained Antero Reservoir to avoid evaporative losses. Antero Reservoir was a rare trout fishery known for producing large trout. The recreational fishery was closed during the drought and remained closed until 2007 when the reservoir was reopened for recreational use. Antero Reservoir was nearly drained again in 2013, but significant April precipitation has allowed Denver Water to keep the reservoir open (Associated Press, 2013).

Voluntary angling closures were also instituted in 2002 due to drought. Public response to these closures was favorable. CPW has continued to implement voluntary closures in the Upper Yampa River near Steamboat Springs in 2004, 2005, 2007, and 2012. When water temperatures reach certain elevated levels in the Yampa, the City of Steamboat Springs puts out a public notice through local media and posts notifications to anglers. This process has worked well and resulted in strong compliance. CPW staff notes that getting word out early and garnering local support is key to their success (communication with DOW 2010).

### Golfing

During 2002, golf course superintendents found that it was important that municipalities let golf courses manage a set quantity of water rather than be given strict timing on watering (i.e., the municipality enforcing a schedule of watering on certain days for a closed time period). Golf course superintendents are experienced at managing irrigation and the course will benefit from not having a rigid watering regime (communications with golf course superintendents 2010).

In fall 2002, one municipality required golf courses to stop watering completely for the rest of the season. This had significant impacts. Golf courses experienced decreased revenue due to poor conditions that led to reduced golfer interest. Fall is a popular time of year to play golf in Colorado. Loss of business during this season significantly impacts total annual revenue. Furthermore, turf needs to enter the winter season in relatively good shape in order to make a quick recovery in the spring. Because the golf courses were forced to cut off water early in the fall the turf entered the winter in a water-short condition. As a result, it required more time and expense in the spring to replace/rehabilitate the turf. In general, when favorable temperatures and moisture return following a drought, golf courses often must induce the drought-damaged turfgrass to recover. This requires seed, sod, fertilizer, water, labor, and other inputs. These expenses occur following a period of limited revenue, which places the golf course in a difficult financial position (communication with golf course superintendents 2010).

Where irrigation water comes from plays a part in how vulnerable a golf course is to drought, but it is difficult to make generalizations about this. While it may be true that groundwater is less immediately vulnerable to a drought that causes low streamflows, many groundwater wells are bound by augmentation plans that require them to supplement groundwater withdrawals to prevent injury to senior surface rights holders. Using reclaimed waste water for irrigation is a possible solution, but water purchases are limited by the obligation of the wastewater treatment plant (WWTP) to deliver a certain volume of return flow to the stream. Finally, public attitude towards golf courses could create a conflict over water use during drought. Golf courses are visible users of water, and although they may be recognized as an industry along with other industrial water users, they become easy targets when watering restrictions become an issue.

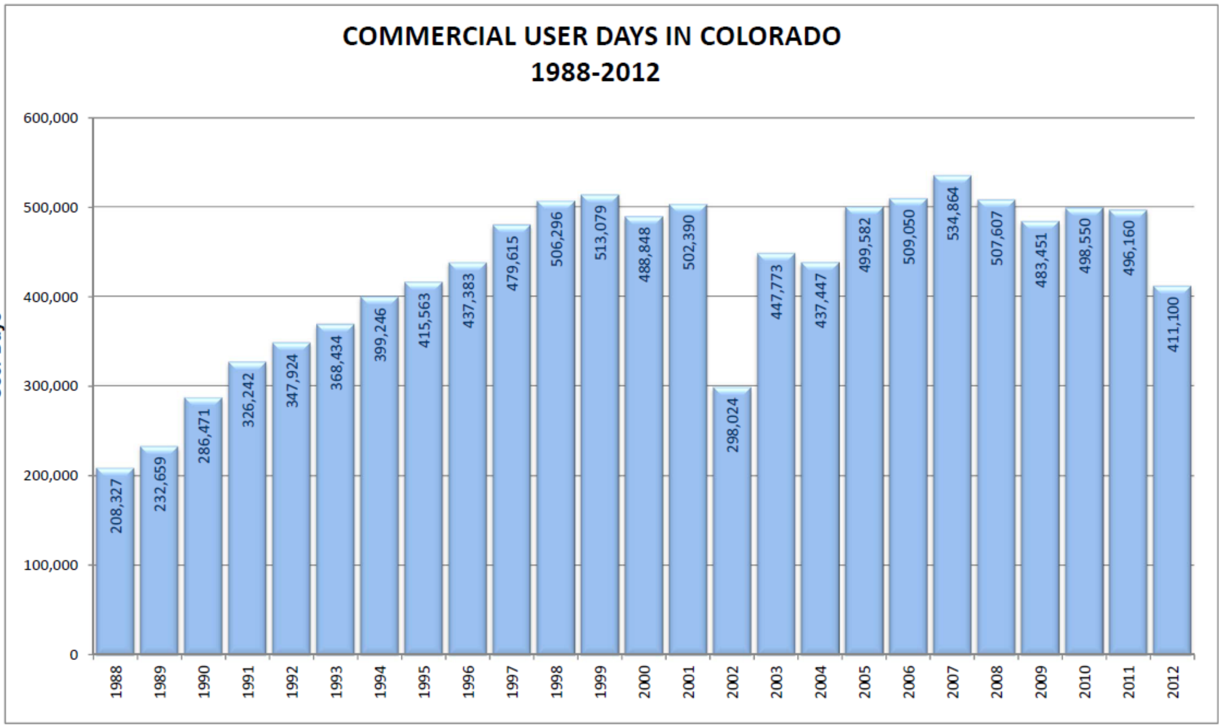
Given that there are multiple options of water sources for golf courses to obtain irrigation water (e.g., surface, ground, potable, and reclaimed), it is safe to say that diversifying the supply would provide a measure of protection against one source being cut off or depleted in a drought.

### Rafting and Boating

The commercial rafting outfitters in Colorado reported being most impacted by the negative public perception surrounding the wildfires in the summer of 2002. Most outfitters interviewed about the drought criticized the governor's comments about the wildfires and the subsequent media coverage, and attributed that event to the decline in customers more so than the low streamflows (Shrestha 2009). However, low flows still impact rafting. In 2012, outfitters in the Arkansas Headwaters Recreation Area were forced to reduce the number of rafters per boat, thus impacting revenues (CPW, 2012). Rafting companies also had to transport clients to more raftable reaches. Profit losses were estimated around 25%. Low water levels resulted in many boat ramp closures and/or restrictions all across the State. Impacted reservoirs include the Blue Mesa, Brush Hollow, Horsetooth, Jumbo, and many others (CPW, 2012).

Figure 10.14 below, taken from the 2012 CROA Commercial River Use in the State of Colorado Economic Report, highlights the significant decrease in user days both in 2002 and 2012 (user days on y-axis).

**Figure 10.14. Commercial User Days, 1988-2012**




Source: CROA 2012

Similar to the ski industry, public perception of river conditions can be a significant factor for rafting revenues. Rafting companies can be impacted when droughts are publicized regardless of flow conditions for their specific operations. To combat this issue, the professional organization CROA hires a public relations (PR) firm every year. This helps them control the message reaching the public and stay ahead of any negative perception that may be developing. The PR firm also helps respond to other threats to the rafting industry like public perception of wildfires or fatalities on the river. CROA (2012) speculates that impacts to the rafting industry for 2012 could have approached 2002 levels had they not maintained a positive public narrative throughout the season.

Additionally, CPW has worked with local, state, and federal agencies to maintain certain flow levels in the Arkansas River when limited water is available. As state park revenue levels correlate well with water resources levels, CPW has made in-stream flows a high priority (CPW, 2012).

CROA (2012) estimates the economic impact of the drought by multiplying direct expenditures by the number of user days and an economic multiplier (2.56) that estimates the number of times a dollar is spent in the local area before leaving that area. Direct expenditures are defined as the amount spent on rafting and associated goods and services spent in the local area by one river rafting customer in one day. Applying this relatively simple method, Table 10.8 shows the calculated economic impact by river. The Arkansas has suffered the most economic impact, which might be expected given the basin has been hit particularly hard by the drought. However they also benefit from the greatest number of user days, thus have good potential to mitigate for reduced income from rafting by providing alternative activities (a key recommendation from the CWCB Drought Plan and the DART Report). Since the majority of the rafting in Colorado takes place on the Arkansas, impacts to that basin will proportionately impact the industry as a whole. Table 10.9 shows the relative change in user days from 2010 through 2011 for each of the rivers. Note that many of the lesser used rivers suffered dramatic decreases in user days, potentially shutting business down on these basins (CROA, 2012).

**Table 10.8. 2012 Impact by River (CROA, 2012)**

| RIVER | USER DAYS | DIRECT EXPENDITURES | ECONOMIC IMPACT |
|---|---|---|---|
| Animas | 38,000 | $4,605,954 | $11,791,241 |
| Animas - Upper | 603 | $73,089 | $187,108 |
| Arkansas | 169,486 | $20,543,280 | $52,590,798 |
| Blue | 0 | $0 | $0 |
| Clear Creek | 35,422 | $4,293,476 | $10,991,299 |
| Colorado - Glenwood | 64086 | $7,767,820 | $19,885,618 |
| Colorado - Upper | 39,645 | $4,805,343 | $12,301,678 |
| Colorado - Horsethief - Loma | 2792 | $338,416 | $866,346 |
| Colorado - Westwater | 5,623 | $681,560 | $1,744,793 |
| Dolores | 35 | $4,242 | $10,860 |
| Eagle - Upper | 4 | $485 | $1,241 |
| Eagle - Lower | 227 | $27,515 | $70,437 |
| Green/Yampa | 7,983 | $967,614 | $2,477,092 |
| Gunnison Gorge | 1579 | $191,389 | $489,957 |
| Gunnison - Upper | 1,150 | $139,391 | $356,840 |
| Gunnison - Escalante | 2950 | $357,567 | $915,373 |
| Gunnison - Forks to Austin | 1,100 | $133,330 | $341,325 |
| Gunnison - Lake Fork | 1123 | $136,118 | $348,462 |
| North Platte | 143 | $17,333 | $44,372 |
| Piedra | 54 | $6,545 | $16,756 |
| Poudre | 22,780 | $2,761,148 | $7,068,539 |
| Rio Grande | 2486 | $301,326 | $771,395 |
| Roaring Fork - Above Basalt | 112 | $13,575 | $34,753 |
| Roaring Fork - Below Basalt | 736 | $89,210 | $228,378 |
| San Juan - Pagosa | 778 | $94,301 | $241,410 |
| San Miguel | 1828 | $221,571 | $567,221 |
| South Platte | 484 | $58,665 | $150,183 |
| Taylor | 9891 | $1,198,881 | $3,069,136 |
| | | | |
| **Totals** | **411,100** | **$49,829,146** | **$127,562,613** |

**Table 10.9. Individual River Commercial Rafting Statistics – 3 Year Range (CROA, 2012)**

| RIVER | 2010 USER DAYS | 2011 USER DAYS | 2012 USER DAYS | % CHANGE '10 - '11 | % CHANGE '11 - 12 | 2010 % MARKET SHARE | 2011 % MARKET SHARE | 2012 % MARKET SHARE |
|---|---|---|---|---|---|---|---|---|
| Animas | 41,000 | 45,000 | 38,000 | 9.8% | -15.6% | 8.2% | 9.1% | 9.2% |
| Animas - Upper | 411 | 411 | 603 | 0.0% | 46.7% | 0.1% | 0.1% | 0.1% |
| Arkansas | 211,150 | 208,329 | 169,486 | -1.3% | -18.6% | 42.4% | 42.0% | 41.2% |
| Blue | 1,181 | 6,580 | 0 | 457.2% | -100.0% | 0.2% | 1.3% | 0.0% |
| Clear Creek | 51,301 | 60,644 | 35,422 | 18.2% | -41.6% | 10.3% | 12.2% | 8.6% |
| Colorado - Glenwood | 61,890 | 44,007 | 64,086 | -28.9% | 45.6% | 12.4% | 8.9% | 15.6% |
| Colorado - Upper | 41,626 | 32,842 | 39,645 | -21.1% | 20.7% | 8.3% | 6.6% | 9.6% |
| Colorado - Horsethief - Loma | 2,718 | 2,907 | 2,792 | 7.0% | -4.0% | 0.5% | 0.6% | 0.7% |
| Colorado - Westwater | 7,621 | 6,069 | 5,623 | -20.4% | -7.3% | 1.5% | 1.2% | 1.4% |
| Dolores | 194 | 515 | 35 | 165.5% | -93.2% | 0.0% | 0.1% | 0.0% |
| Eagle - Upper | 1,640 | 1,286 | 4 | -21.6% | -99.7% | 0.3% | 0.3% | 0.0% |
| Eagle - Lower | 1,710 | 4,362 | 227 | 155.1% | -94.8% | 0.3% | 0.9% | 0.1% |
| Green/Yampa | 4,803 | 4,218 | 7,983 | -12.2% | 89.3% | 1.0% | 0.9% | 1.9% |
| Gunnison Gorge | 1,390 | 2,148 | 1,579 | 54.5% | -26.5% | 0.3% | 0.4% | 0.4% |
| Gunnison - Upper | 2,669 | 2,669 | 1,150 | 0.0% | -56.9% | 0.5% | 0.5% | 0.3% |
| Gunnison - Escalante | 1,784 | 2,749 | 2,950 | 54.1% | 7.3% | 0.4% | 0.6% | 0.7% |
| Gunnison - Forks to Austin (n | 0 | 0 | 1,100 | | | 0.0% | 0.0% | 0.3% |
| Gunnison - Lake Fork | 149 | 284 | 1,123 | 90.6% | 295.4% | 0.0% | 0.1% | 0.3% |
| North Platte | 482 | 850 | 143 | 76.3% | -83.2% | 0.1% | 0.2% | 0.0% |
| Piedra | 190 | 190 | 54 | 0.0% | -71.6% | 0.0% | 0.0% | 0.0% |
| Poudre | 37,392 | 37,869 | 22,780 | 1.3% | -39.8% | 7.5% | 7.6% | 5.5% |
| Rio Grande | 2,016 | 2,016 | 2,486 | 0.0% | 23.3% | 0.4% | 0.4% | 0.6% |
| Roaring Fork - Above Basalt | 2,404 | 6,672 | 112 | 177.5% | -98.3% | 0.5% | 1.3% | 0.0% |
| Roaring Fork - Below Basalt | 1,366 | 912 | 736 | -33.2% | -19.3% | 0.3% | 0.2% | 0.2% |
| San Juan - Pagosa | 4,986 | 6,171 | 778 | 23.8% | -87.4% | 1.0% | 1.2% | 0.2% |
| San Miguel | 1,762 | 1,900 | 1,828 | 7.8% | -3.8% | 0.4% | 0.4% | 0.4% |
| South Platte | 383 | 430 | 484 | 12.3% | 12.6% | 0.1% | 0.1% | 0.1% |
| Taylor | 14,332 | 14,130 | 9,891 | -1.4% | -30.0% | 2.9% | 2.8% | 2.4% |
| **Totals** | **498,550** | **496,160** | **411,100** | **-0.5%** | **-17.1%** | **100.0%** | **100.0%** | **100.0%** |

# 10.4 Measurement of Vulnerability

Vulnerability metrics are quantifiable factors that begin to portray the vulnerability of the sub-sectors. These factors are offset by existing or future adaptive capacities. The following section presents the vulnerability metrics suggested for each sub-sector. Some of these metrics have existing data. However, other metrics require additional data and future collection efforts are recommended. Refer to Section 3.1 of Chapter 3 (Annex B) for a general description of the numerical methodology.

# 10.5 Vulnerability Metrics

## 10.5.1 Skiing

### Spatial Density Metric

#### *Location*

The location of the ski resorts is spatial data obtained from the ski resorts' addresses and general location based on their websites and maps. Additional ski resort point locations were obtained from a shapefile on the National Weather Service National Operational Hydrologic Remote Sensing Center website (http://www.nohrsc.nws.gov/gisdatasets/). The shapefile data were compared to maps to verify its accuracy. Ski resorts that existed in the past but are now closed were not considered.

Only 14 out of the 64 counties contain one or more ski areas, making the typical percentile thresholds invalid. The thresholds were adjusted for the spatial density and the impact metrics to create equal bins for the non-zero data set. The adjusted percentile thresholds used in assigning an impact score are: 0-83.5% (1), 83.5%-89% (2), 89%-94.5% (3), and 94.5%-100% (4).

### Impact Metrics

The two metrics used to assess vulnerability at ski areas are ski area acreage and use of snowmaking technology. The acreage of a ski area can be an indicator of vulnerability because larger resorts tend to have other amenities that make them an appealing destination for non-ski activities like dining, shopping, spas, skating etc. Resorts offering a wide variety of activities are better able to adapt to poor snow conditions because they have diversified revenue sources.

Snowmaking allows ski resorts to artificially compensate for poor natural conditions that may result from a winter drought. However, snowmaking machines generally only cover a small percentage of the total ski area acreage, so they cannot completely mitigate a bad snow year. Given this limitation snowmaking capacity was weighted 30% and ski acreage was weighted 70% for the overall impact score calculation.

The metrics chosen for this evaluation provide a good high level vulnerability evaluation. Additional vulnerability metrics, not possible at this time due to data limitations, could enhance this analysis. Recommendations for other impact metrics are presented in Section 10.6.

#### *Acreage of ski area*

The data for this metric are easy to obtain from the individual ski resort websites and trade group websites.[8] The size of the ski areas can be directly summed to arrive at a total acreage per

[8] http://www.skiareacitizens.com/index.php, www.coloradoskihistory.com, http://www.goski.com/content/ski-colorado and individual resort websites

county. For this metric, the larger the ski area, the less vulnerable it is assumed to be. The rationale for this assumption is that the larger ski areas have invested in other activities (such as spas, fine dining, timeshares, etc.) to broaden their appeal. The smaller ski areas are assumed to focus primarily on skiing without the added attractions of the larger resorts.

#### *Snowmaking ability*

In a winter drought, snowmaking machines can supplement natural snowfall to allow the ski areas to open or maintain trails that may not have otherwise had enough snow. Information on snowmaking abilities of specific resorts is available online.[9]

Ski resorts with snowmaking abilities were assigned an impact score of 1 and those without were assigned a score of 0. To aggregate this metric to a county level for counties with multiple ski resorts, an average was calculated. For example, in Eagle County there are three ski areas: Beaver Creek (snowmaking), Ski Cooper (no snowmaking), and Vail (snowmaking). The averaged impact score for Eagle County is therefore 0.67.[10]

To improve this metric, integration of additional information and data would be useful. For example, the number of acres that are covered by snowmaking equipment could be calculated relative to the total acreage of a resort. These data exists publicly for several resorts, but are not available for all of the snowmaking resorts in the State. Also, the relative seniority of specific water rights and the spatial relationship of diversion points to instream flow rights could be analyzed for each resort.

## 10.5.2 Wildlife Viewing

### Spatial Density Metric

#### *Areas of Suggested Viewing*

Wildlife viewing can occur wherever there is wildlife in the State, but the list of suggested viewing areas on the CPW website provides a starting point to understanding the spatial distribution of viewing areas. The viewing area coordinates (latitude/longitude) were input in a GIS and aggregated by county. The data entered into the vulnerability spreadsheet represents the count of viewing areas per county.

[9] http://www.skiareacitizens.com/index.php, www.coloradoskihistory.com, http://www.goski.com/content/ski-colorado and individual resort websites
[10] (1+0+1)/3

## Impact Metric

### *Wildfire Threat Ranking*

The Colorado State Forest Service maintains on online data portal that contains a number of wildfire specific datasets.[11] Wildfire threat is defined as the annual probability of a wildfire occurring. Threats were divided into six main categories: very low, low, moderate, high, very high and none. To isolate the high risk areas, moderate to very high raster points were extracted and tallied by county. Counties were ranked according to the percentage of high risk area relative to the total size of the county.

# 10.5.3 Hunting, Fishing, and Camping

## Spatial Density Metric

### *Direct Spending per County (Hunting & Fishing only)*

Direct spending per county for hunting and fishing activity was obtained through a research report completed for the CPW in 2008. The estimates are based on data from a number of different sources, including CPW game harvest information for 2007, a survey of Colorado anglers conducted by CPW in early 2008, CPW expenditure data for the 2007 fiscal year, and the USFWS 2006 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation (BBC Research & Consulting, 2008). The data, in dollars, were normalized by county population. Updated economic data is not expected to be available until 2014, so these figures could not be updated in time for incorporation into this study.

## Impact Metrics

### *Wildfire Threat Ranking*

As with wildlife viewing, wildfire can impact hunting, fishing, and camping. High wildfire risk can lead to fire bans which may be a deterrent for camping. When wildfires do occur access will be closed for the affected areas and the resulting smoke will severely impair air quality in a much larger area. This dataset was processed and used as described in the Wildlife Viewing sector above. This impact metric was weighted equally with the beetle infestation extent metric (50%), because neither metric has a clear advantage over the other.

### *Beetle Infestation Extent*

Bark beetle infestation is having a profound effect on the health of Colorado's forests. The U.S. Forest Service and CPW have been forced to close campgrounds in order to clear beetle-damaged trees in danger of falling, and spray high-value trees in an attempt to protect them (Finley, 2010). Data for the extent of beetle infestation is available from the USDA Forest

[11] http://www.coloradowildfirerisk.com/

Service, Forest Health Technology Enterprise Team,[12] who maintains an online spatial database of forest health data that can be queried and downloaded. The latest datasets, containing survey data from 2012 were obtained. The database was queried for areas of beetle infestation (all beetle types) for the entire period of record (1997-2012). 45 of the 64 counties have no bark beetle infestation data. Therefore, the thresholds were adjusted to create equal bins for the non-zero data set. The adjusted percentile thresholds used in assigning an impact score are: 0-47% (1), 47%-65% (2), 65%-82% (3), and 82%-100% (4).

## 10.5.4 Golfing

### Spatial Density Metric

#### *Number of Courses per County*

The number of courses per county was obtained from the USGS study (Ivahnenko, 2009). Throughout the State there are only 11 of the 64 counties that do not have golf courses. Consequently, threshold values for the impact score calculations were adjusted to account for the zero-data set; the revised percentile bins are 38%, 59%, and 79%.

### Impact Metric

#### *How many irrigated golf course acres in the county?*

The USGS survey collected and tabulated data on irrigated golf course acres per county. This metric identifies the area vulnerable to significant loss if irrigation water is not available during drought. This metric could be further refined by separating out irrigated golf course features like roughs and surrounding landscape that could go without water and not impact the playing experience (aesthetic qualities aside). This is discussed as a recommendation in Section 10.6.

## 10.5.5 Boating

Boating is difficult to assess, because the activity is still possible even if reservoir levels are slightly lower than normal. However, boating becomes impossible when the reservoir goes completely dry or drops to unacceptable safety levels (i.e., exposed rocks and detritus), or when the boat ramps are rendered unusable by falling water levels. To add to the complexity, reservoir operations are generally dictated by water owners and not recreational users. In a drought, the water rights priority system could cause normal reservoirs operations to change, resulting in recreational impacts.

[12] http://foresthealth.fs.usda.gov/portal

### Spatial Density Metric

#### *Location of Water-based State Parks*

The location of the water-based state parks serves as an inventory metric for flat water boating activity. This information was obtained from CPW and tabulated by county (as a count).

### Impact Metric

#### *Visitation numbers from 2002 at water-based state parks, and Relative Visitation, 2002 compared to 2002-20011 annual average*

Park visitation numbers from 2002 to 2011 were obtained from State Parks. The intent is to assess which parks had the greatest visitation declines in 2002 and to extrapolate this trend as a potential vulnerability to future droughts. Data is only available through CPW's 2011 fiscal year, which shows a 0.4% increase from the previous year. Since the fiscal year only goes through June, 2003 to 2011 averages were considered relative to 2002.

The main limitation of this approach is attributing a decrease in park visitation solely to drought, when park visitation could be impacted by a number of factors (e.g., wildfires, economy). This analysis assumes that parks impacted by drought in 2002 will be impacted again. Based on conversations with State Parks employees this is a reasonable assumption. Still, future work should investigate the operations of specific parks and determine if any adjustments are warranted.

The visitation data were averaged for the summer months (May through September) since most of the visitation gains and losses occurred over the summer. For the year 2002, data started in July so only July through September visitation was included in the average. Out of the 64 counties, 36 do not contain a water-based state park. Therefore, the thresholds were adjusted to create equal bins for the non-zero data set. The adjusted percentile thresholds used in assigning an impact score are: 0-67% (1), 67%-78% (2), 78%-89% (3), and 89%-100% (4).

## 10.5.6 Commercial Rafting

### Spatial Density Metric

#### *American Whitewater Rafting Reaches*

American Whitewater is a national nonprofit dedicated to conserve and restore whitewater resources and enhance opportunities to enjoy them (American Whitewater, 2010). A map of American Whitewater rafting reaches was included in the Statewide Water Supply Initiative Phase 2 report (SWSI Phase 2, 2007); this map was reworked to tabulate the number of rafting reaches that start and end in each county. This count was entered into the spreadsheet as the spatial density metric. The original map from SWSI Phase 2 is included as Figure 10.11.

### Impact Metrics

#### *Average annual user days, 2000-20012*

Data for average annual user days were obtained from the Colorado Rafting Outfitters Association website. The value of this metric provides a sense of how popular the river is; with more user days implying more commercial rafting outfitters and more secondary industries built around rafting in that region. Therefore, higher user days indicate higher vulnerability. However, it could also be the case, as with the ski resorts, that the more interest in a particular river, the more sophisticated the offerings will become (i.e., more offerings result in diversification; an adaptive capacity). For example, some rafting companies also offer fishing trips.

#### *Relative visitation, 2012 compared to 2000-2012 annual average*

Similar to the boating metric, relative rafting visitation provides information on which rivers experienced the biggest drop in visitation in 2012. Some limitations include: future drought likely will not occur in the exact same manner as 2012; drought could hit one portion of the State but not another; adaptive capacities could change; and non-related variables such as wildfires and the larger economic issues likely also contributed to the overall decrease in visitation for the rafting industry.

## 10.5.7 Results

Results presented here are based on an overview of sub-sectors and data gathering from various agencies, industry groups, and previous reports. In order to rank counties as more, or less, vulnerable than others, generalizations based on research and interviews were necessary, these may not apply to each individual sub-sector. However, the intent of this assessment is to present concentrations of recreation and correlate them to vulnerability on a county level. These results, and the data required, should be regularly updated for future review, assessment, and focusing of drought mitigation resources. Table 10.10 summarizes the vulnerability assessment results.

**Table 10.10. Results of Vulnerability Assessment**

| Counties | Overall Vulnerability Score |
|---|---|
| Alamosa, Bent, Broomfield, Cheyenne, Costilla, Crowley, Custer, Denver, Dolores, Elbert, Gilpin, Jackson, Kiowa, Lake, Lincoln, Otero, Phillips, Prowers, Sedgwick, Teller, Yuma | 1-1.9 |
| Adams, Arapahoe, Archuleta Baca, Boulder, Chaffee, Clear Creek, Conejos, Delta, Douglas, El Paso, Gunnison, Hinsdale, Huerfano, Jefferson, Kit Carson, La Plata, Larimer, Las Animas, Logan, Mineral, Montezuma, Montrose, Morgan, Ouray, Park, Pitkin, Pueblo, Rio Blanco, Rio Grande, Saguache, San Juan, San Miguel, Summit, Washington, Weld | 2-2.9 |
| Eagle, Fremont, Garfield, Grand, Mesa, Moffatt, Routt | 3-3.9 |
| None | 4 |

These rankings indicate different levels of recreational activity within counties and varied levels of adaptive capacity in those activities. Below is a discussion on each ranking.

**Counties ranked "1" for overall vulnerability:**

A "1" ranking implies one of the following situations:

- Recreation industry existing in this county is small compared to the overall population and land area;
- Recreational activity has a measure of adaptive capacity that insulates it from drought vulnerability; and
- The recreational activity is not prominent in this county.

Most of the counties in this category (e.g., Cheyenne, Kiowa, etc…) are located in the eastern plains, which is more prominent for agricultural activity than recreation and tourism.

**Counties ranked "2" for overall vulnerability:**

A "2" ranking implies one of the following situations:

- There may be a distinct recreational draw to the county, but it is small compared to the population; and
- There is a diverse offering of recreational activities.

Most of the counties in this category (e.g., Boulder, Gunnison, Weld, etc.) do have a distinct tourist draw, but are not prominent tourism-centric counties and/or do not appear to rely heavily on tourism. Several of the counties in this category seem to be prominent tourist counties (e.g., Park, Pitkin, and Summit). They have adaptive capacities in the skiing sub-sector that lower their overall ranking.

**Counties ranked "3" for overall vulnerability:**

A "3" ranking implies a distinct recreational draw to the county that is significant compared to the population. There may be adaptive capacities or sufficient diversification that a county has recreation exposure, but not necessarily high vulnerability to drought. Counties in this category include Eagle, Larimer, and Routt.

**Counties ranked "4" for overall vulnerability:**

A "4" ranking implies a distinct recreational draw and perhaps a lack of recreational diversification that would act as an adaptive capacity to offset drought impacts. No counties are ranked a "4", but the hypothetical county would have a fairly low population, be strongly dependent on tourism for economic activity, and would have low recreational diversity. The following section includes maps showing the spatial distribution of the recreation and tourism sub-sectors.

## Figure 10.15. Skiing Inventory and Impact Scores

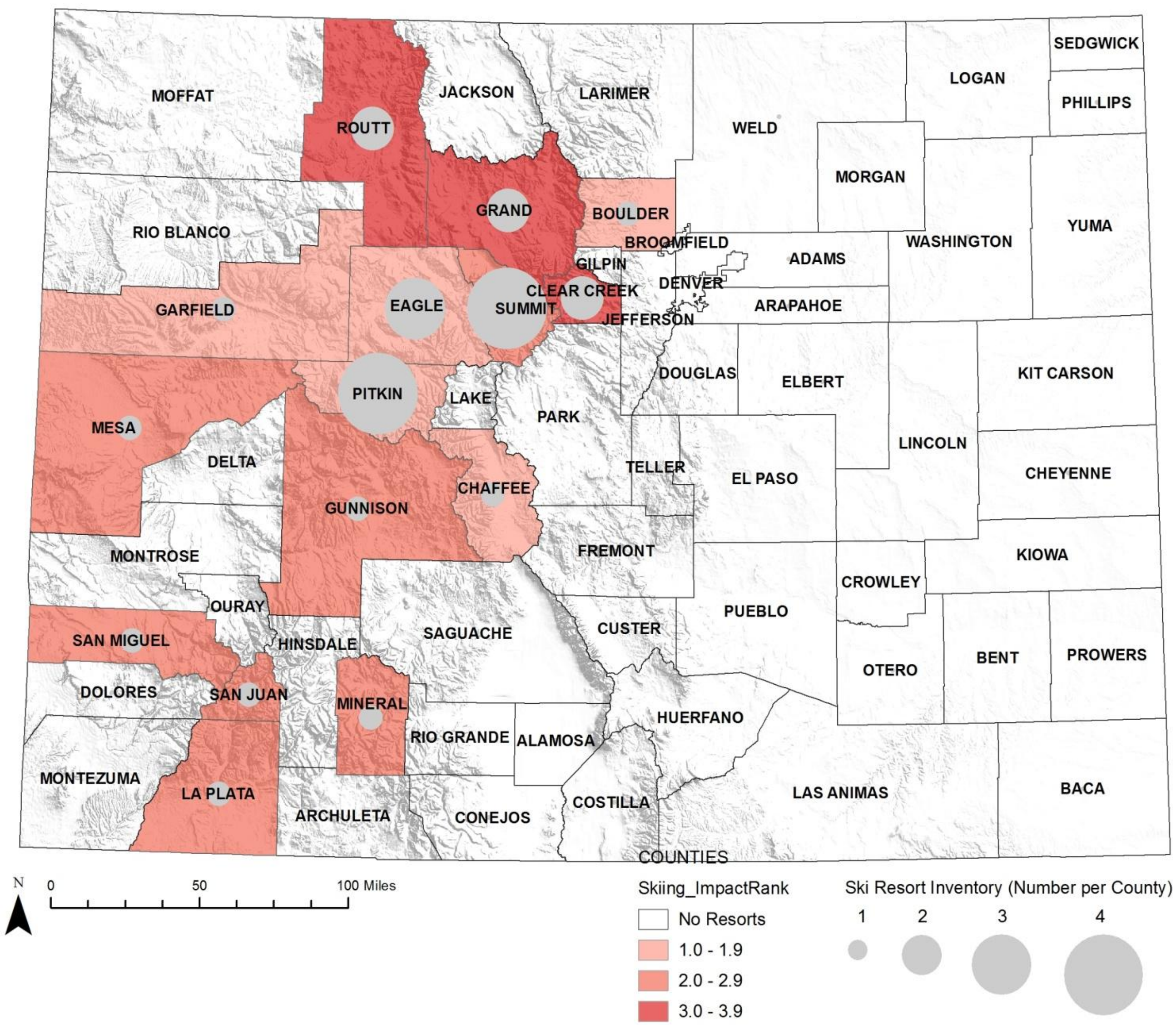



Figure updated 2013.

## Figure 10.16. Wildlife Viewing Inventory and Impact Scores

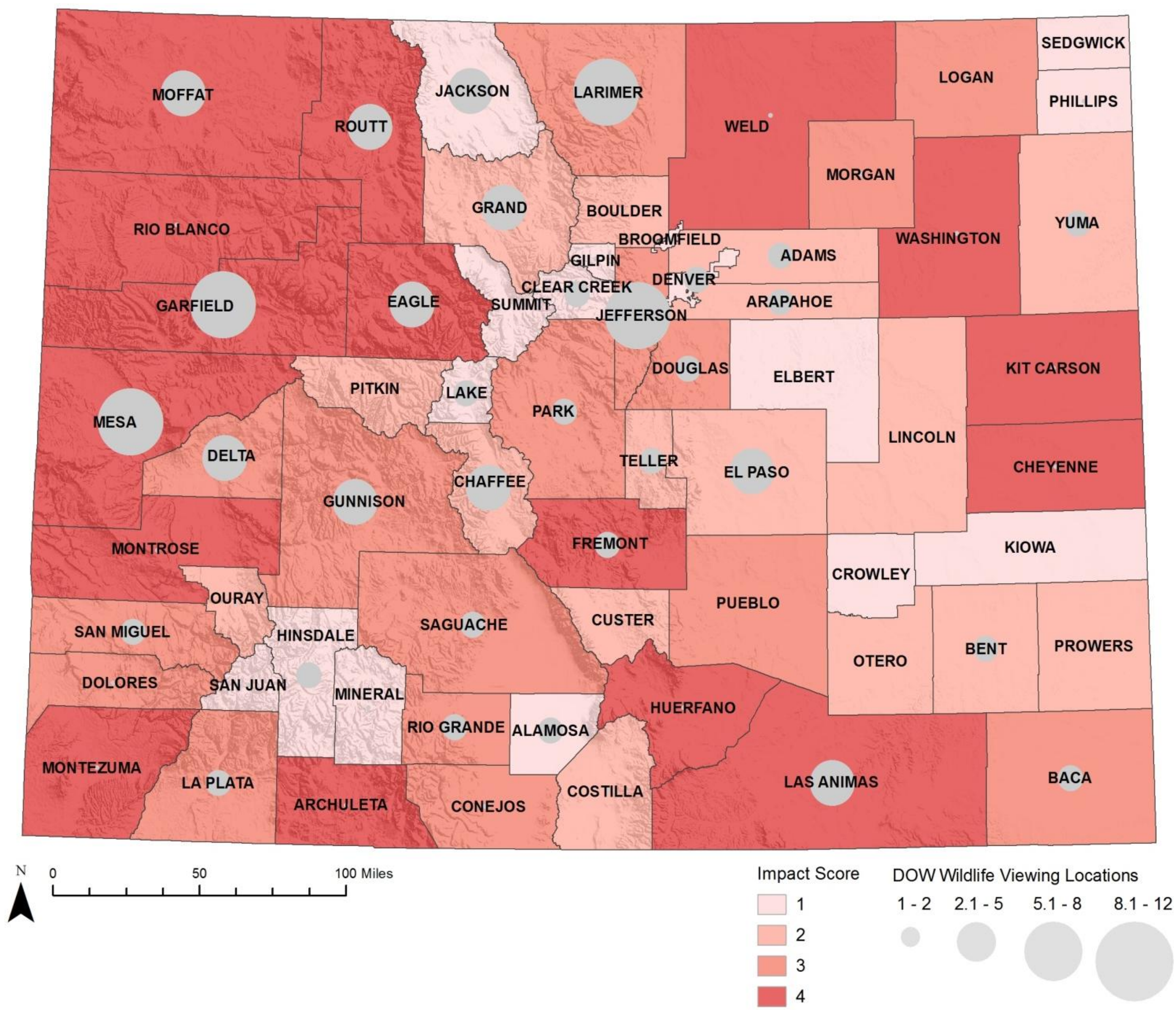



Figure Updated 2013

**Figure 10.17. Hunting, Fishing, and Camping Inventory and Impact Scores**

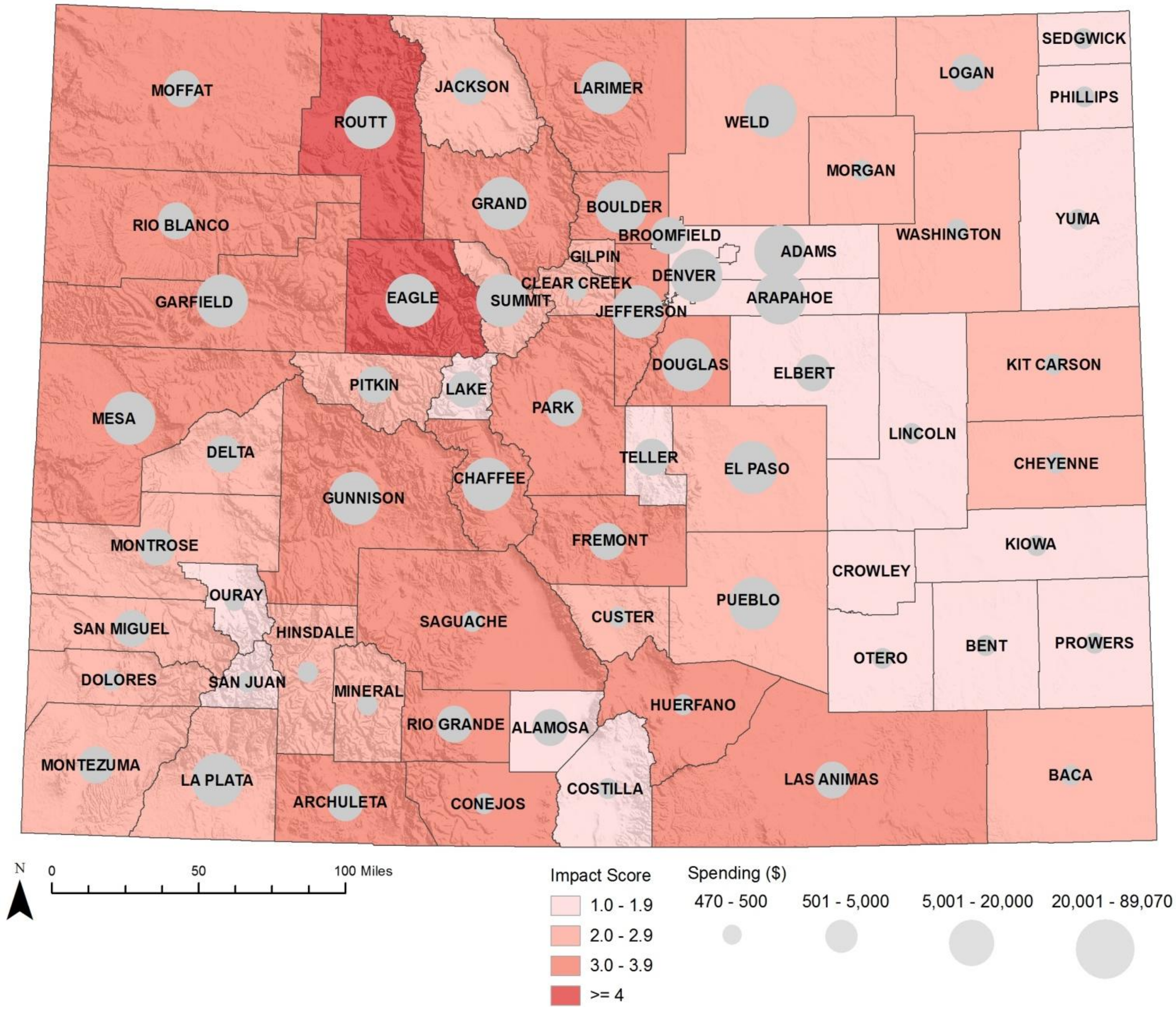
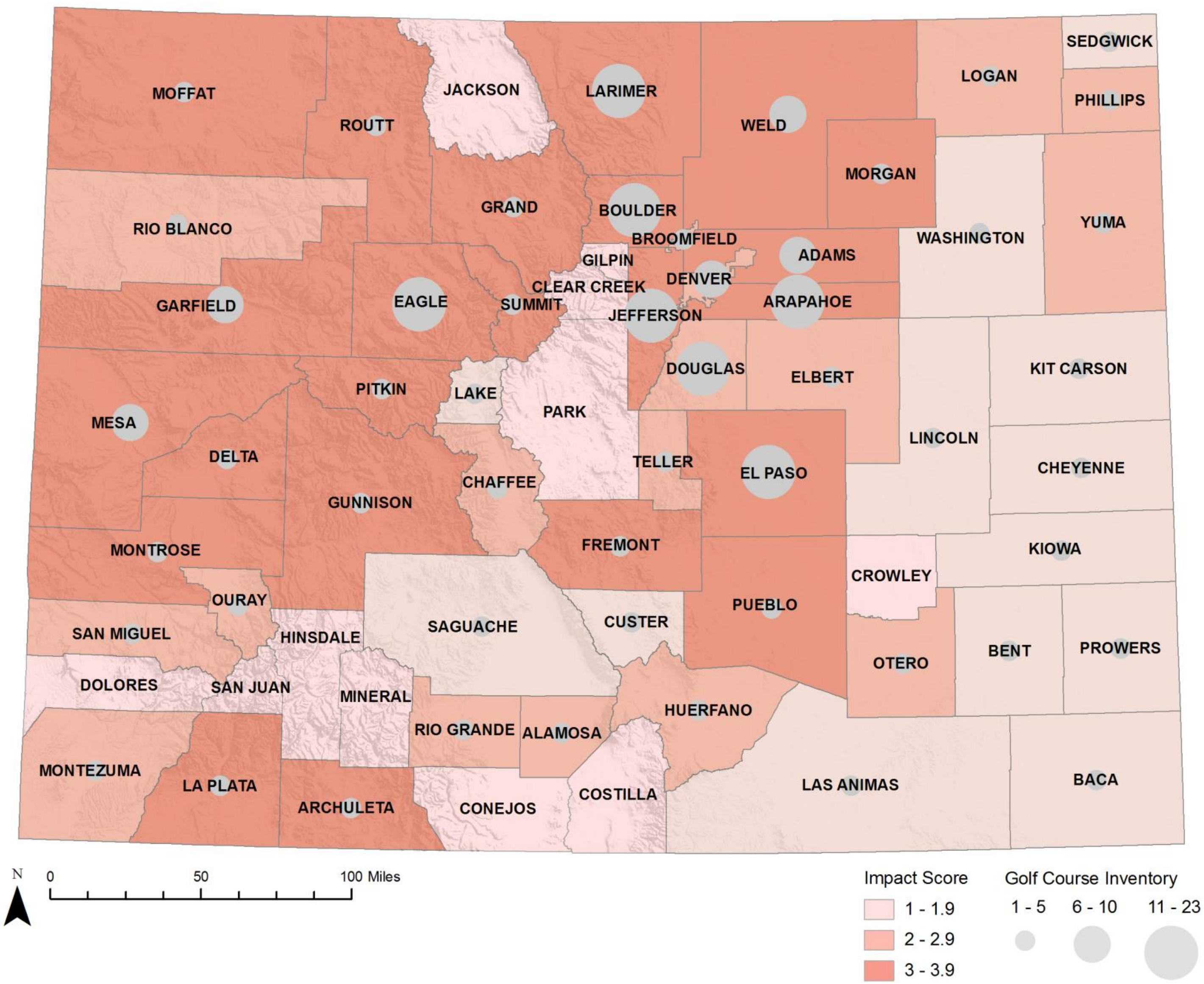
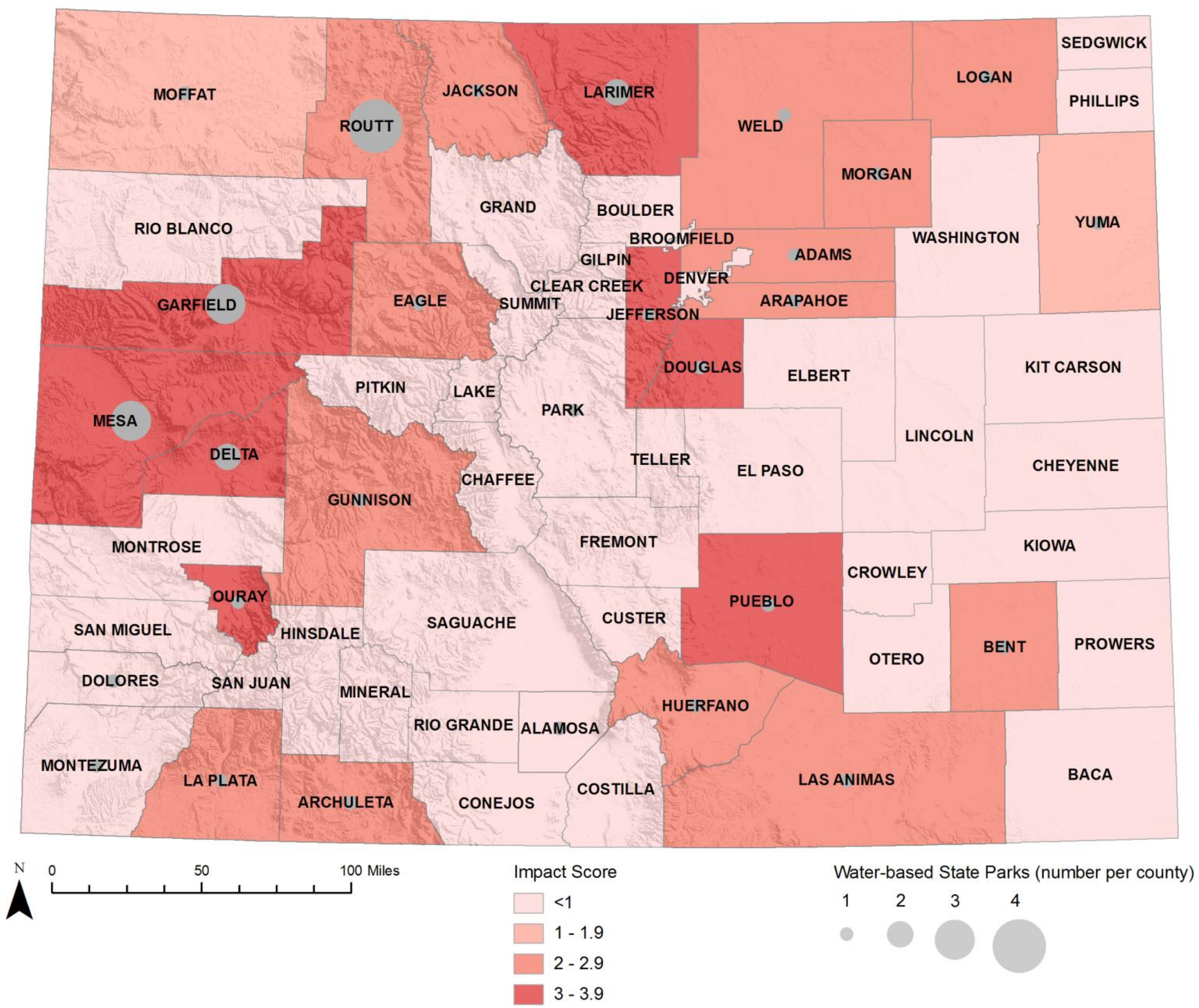



Figure updated 2013

## Figure 10.18. Golf Course Inventory and Impact Scores



## Figure 10.19. Boating Inventory and Impact Scores




Data updated for 2013 with no significant changes.

## Figure 10.20. Rafting Inventory and Impact Scores

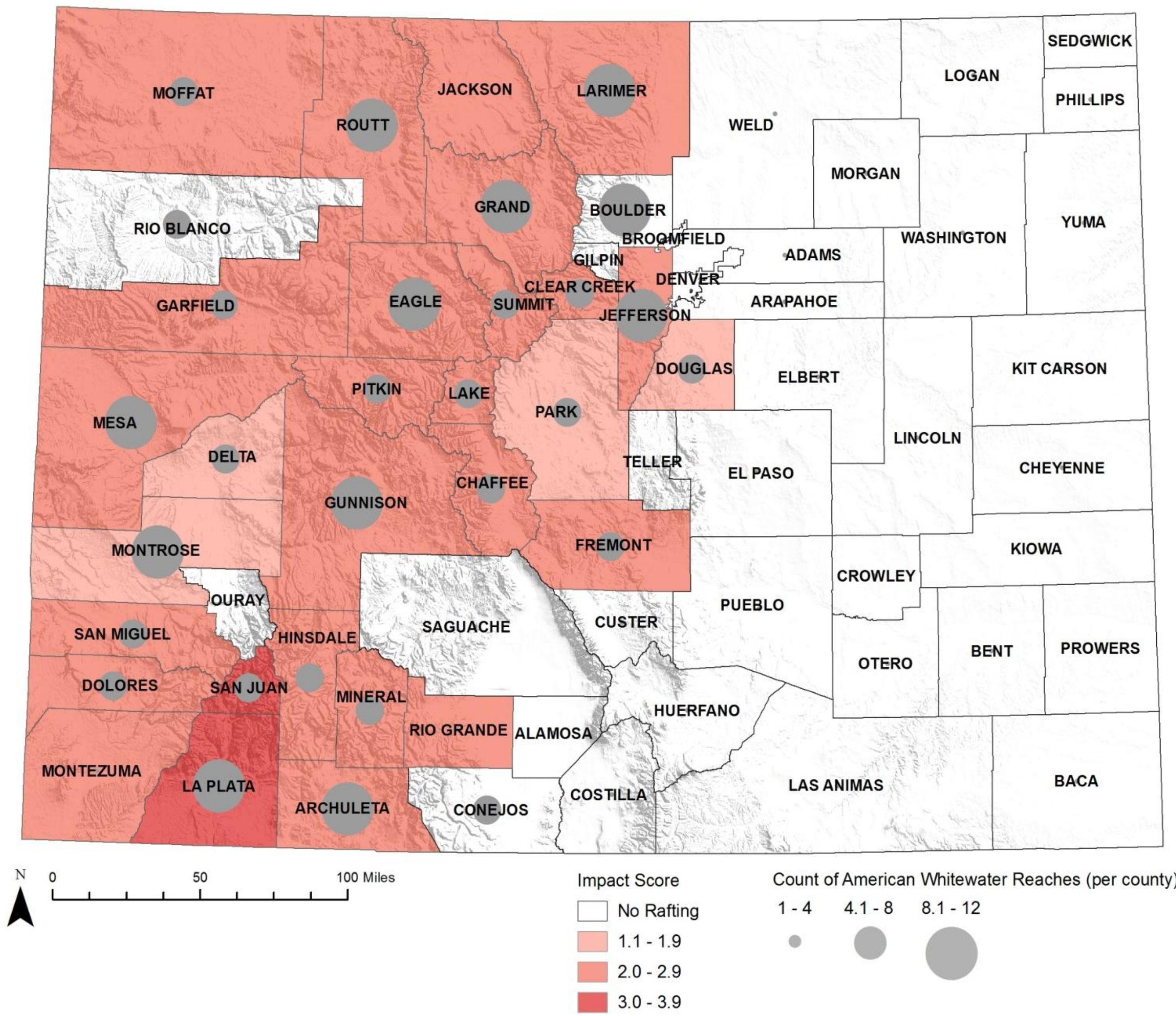



Figure revised 2013

## 10.5.8 Spatial Analysis

Spatially, the recreation and tourism sub-sectors are fairly concentrated in the western, southern, and southwestern portions of Colorado. This is especially true with ski resorts, which exist, with few exceptions, on the western slope and are concentrated in the central-western portion of the State.

Vulnerability for the ski resort sub-sector is naturally centered in mountain counties. The two vulnerability metrics identified for this study were the size of the ski resort and the snowmaking capabilities. Eagle, Summit, and Pitkin Counties stand out with large ski resorts that are not ranked as being particularly vulnerable. This is attributed to the adaptive capacity linked to their size (again, the assumption is that large resorts have invested in diverse activities to appeal to a range of visitors) and that they all have snowmaking in their resorts. Conversely, Routt and Grand Counties have less expansive ski resorts and not all of the resorts have snowmaking capabilities.

Wildlife viewing areas, are not as centrally located as ski areas, but rather fairly distributed around the State. As a result, their vulnerability is well distributed around the State. The inventory is CPW viewing locations, but the vulnerability metric is wildfire susceptibility index. So, the vulnerability map is largely a function of the wildfire threat data used for the analysis. This approach is limited by the dependence upon wildfire data. Other variables, such as beetle kill, may also alter wildlife behavior. More research is needed to identify additional metrics that could be used in the wildlife viewing subsector.

The hunting, fishing, and camping spatial metric is spending per county, which has not been updated since the 2010 drought plan. An update to the CPW economic data will be available in 2014 and should be used to update this metric. As would be expected, the more populated counties have more spending. Here the concentration is along the Front Range, with the urban areas of Fort Collins (Larimer County), Denver (Denver County), and Colorado Springs (El Paso County) probably contributing to the spending in those three counties. The primary vulnerabilities reflect the updated beetle kill and wildfire data, since the spending data was not available. The vulnerability metric used was the same (wildfire susceptibility index) and the second metric, beetle infestation extent, is impacting the same forested area that is impacted by wildfire.

Golf course concentration by county is another sub-sector with a large presence along the Front Range. There is a strong correlation to the presence of a golf course and the presence of a high-population area. That there are few to no golf courses in the southern portion of the State speaks to this correlation. Golf course vulnerability is dependent on the number of golf courses and the size of the golf courses (aggregated by county). For this reason, it is fairly logical that the counties with the most golf courses would also have the most golf course acreage and be the most vulnerable to drought. These counties are found along the Front Range and within the more populated regions of the western slope.

Boating vulnerability is dependent on the inventory (i.e., existence of a water-based state park) and the relative decrease in visitation between 2002 and the 2002-2011 average. This is one sub-sector of recreation that appears on the eastern plains of the State as well as the western half. In fact, some of the more vulnerable counties (e.g., Pueblo, Douglas, and Jefferson) are located east of the mountains. This update relates visitation to numbers recorded for the 2002 drought. The calculation should be updated for the 2011-2013 drought event once it has concluded.

Like skiing, rafting is concentrated in the mountainous regions of the State. The inventory is American Whitewater (AW) rafting reaches (as shown in Figure 10.11), and the metrics are average annual user days (to establish volume of visitation) and percent reduction in 2012 drought (to establish which rivers saw a more dramatic drop in visitation), as obtained from commercial visitation data compiled from the CROA. Given the vulnerability metrics, rafting vulnerability correlates to both the presence and the popularity of a commercially rafted river. The difference between the AW reaches and the CROA visitation data are apparent in Boulder, Rio Blanco, Weld, Gilpin, and Ouray Counties. These counties have an inventory of AW reaches but are not assigned an impact score because the set of commercially-rafted river stretches does not pass through them.

The sub-sector impact scores discussed above were combined to one overall sector vulnerability score. Figure 10.21 on the next page shows these results for each county.

## Figure 10.21. Overall Recreation and Tourism Vulnerability Scores

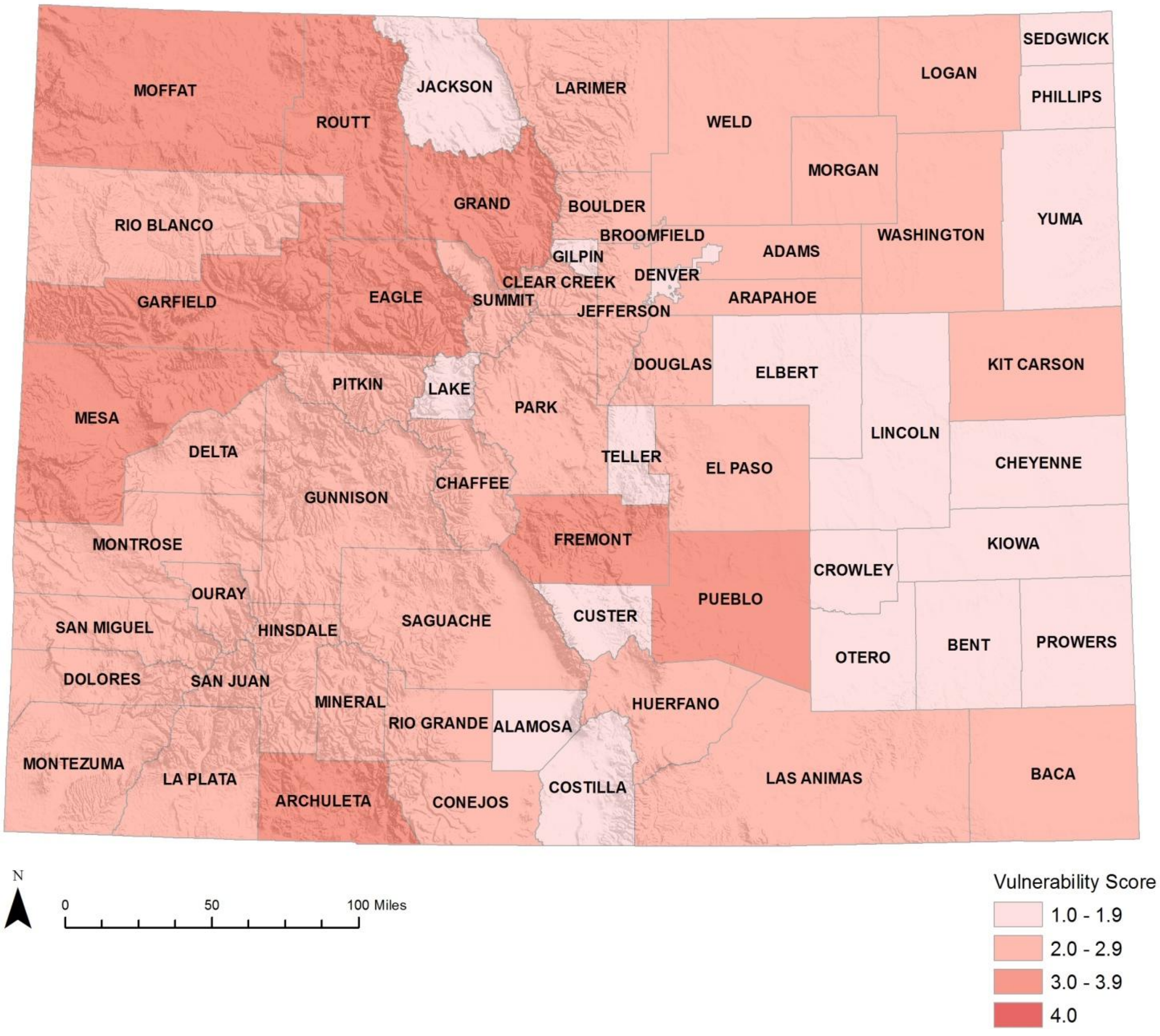



Figure updated for 2013.

Overall, the results show the main vulnerabilities to be located in the northwest portion of the State. Skiing, hunting/fishing/camping, and wildlife viewing are all large sub-sectors for the northwestern counties and contribute to their high ranking. El Paso and Douglas Counties have high scores for golf, which contribute to a high overall ranking. Archuleta received a high vulnerability rating because of a high wildlife viewing vulnerability score – a result of the updated wildfire dataset. Fremont and Pueblo counties received higher scores because of golf and the updated wildfire data increasing vulnerabilities in the wildlife viewing and hunting, fishing, and camping sub-sectors. The counties on the eastern plains are ranked as lower vulnerability since recreation and tourism do not contribute as much to their economy. Those counties in the eastern plains with a ranking of 2.0-2.9 generally received those scores as a result of the updated wildfire data.

## 10.5.9 Compound Impacts

Compound impacts are secondary or indirect impacts brought about by changes in sectors that are directly impacted. For example, direct drought impacts to the Recreation Sector may entail loss of revenue to ski resorts, golf courses, tour guides, and state agencies such as CPW. This loss of revenue can in turn contribute to an overall slowing of the local economy as workers are laid off, leading to less local spending on gasoline, groceries, restaurants, retail, hotels, and more; thus compounding the initial impact. When recreation and tourism in Colorado suffer, so do the services that depend on this industry (Schneckenburger and Aukerman, 2002). If the stakeholder involvement model laid out in the 2012 DART Report is applied in a drought impact assessment, it will be important to include these secondary services as stakeholders in the process. These services potentially offer important metrics for tracking the impact of drought on these recreation and tourism based economies.

Recreation-based economies are found in the central mountain region, the south, and the southwest portions of Colorado (WATF, 2002). These sub-sectors all contribute to the local economy, which can be strained in compound ways if one or more sub-sector is negatively impacted by drought. As discussed in the DART Report (2012), communities can help themselves by marketing different options to visiting tourists. While one specific industry may be more impacted than others during a drought event (e.g., rafting), communities can help absorb those impacts by offering alternative activities (e.g., mountain biking). Probably the closest link to another sector is to environment, since these activities depend on a healthy environment to make them possible/enjoyable.

State assets, like CPW, are highly dependent on recreation and tourism. Both divisions' revenues are dependent on people recreating in Colorado. The socioeconomic impacts of drought can cause people to reduce recreation, which in turn impacts state assets and the tourism industry. State revenue can decrease with a decline in park visitation and hunting/fishing license sales. During a drought, CPW may need to increase their management effort, whether for wildlife feeding programs or for reservoir maintenance that comes with lower water levels. These efforts require funding, which during a drought could be lower than average; further stressing the agencies.

Another compounding factor is the water rights system in Colorado. Boating and rafting may be aided by instream flows, and there were documented instances during the 2002 drought when senior calls to the river caused portions of it to flow that otherwise would have been dried up by junior rights holders. Earlier in this report it was discussed that ski resorts can mitigate with snowmaking, but need senior water rights to do so. If there is increasing competition for water during a drought, ski resorts may see growing opposition to snowmaking and other water diversions. Golf courses can be affected by water rights as well. The majority of golf courses in Colorado are on surface water, but that does not mean that they necessarily own the rights. In some cases the course will lease the surface water rights from the municipality, which can leave it vulnerable to watering restrictions.

## 10.6 Recommendations

### 10.6.1 Adaptation to Drought

One overriding theme from the 2010 drought plan was that public perception is a primary concern. However, the recreation sector appears to have applied lessons learned from the 2002 drought event to the 2011-2013 event. The rafting and ski industries, which have their own trade groups, have hired public relations (PR) firms to help educate the public about recreational opportunities during drought. These firms help control the message distributed by the media at all times and mitigate negative perceptions from out-of-state visitors about drought and wildfire conditions. Having a public relations plan in place before a crisis situation (i.e., drought) helps industries stay a step ahead by influencing public perception early on, before there is the need to manage widespread negative perception.

In addition to effective marketing, another important adaptation strategy for all sub-sectors is diversifying activities. Recreation companies who offer activities throughout the year and not just in one season are less impacted by short droughts. Similarly, recreation-based towns and communities will benefit from marketing a range of activities that are not dependent upon drought-impacted resources (Thomas & Wilhelmi, 2012). Communities can also coordinate with neighboring counties to combine marketing efforts. Including attractions in nearby counties as well as local attractions in recreation marketing efforts increases the audience for each area, and may prove doubly beneficial by attracting new visitors interested in a range of activities that can only be found by traveling within two or more counties. It is also important to diversify across sectors. Economies that are highly dependent on recreation and tourism are more vulnerable to drought and other disaster events. Developing stronger interrelationships between resort communities and surrounding agricultural areas can improve economic diversity and reduce overall vulnerability to drought (Wilhelmi et al. 2004).

Lastly, there is also opportunity for improved policies and mitigation efforts at a county level. Because public perception is a key concern for this sector, it is critical to communicate with local governments so a united front can be presented to the public. It is important that local agencies are on the same page in order to prevent conflicting messages about recreation activities during the drought. Local governments working together can advertise more activities and create a bigger tourist draw by promoting neighboring counties.

## 10.6.2 Improving the Vulnerability Assessment

To improve the drought vulnerability assessment, key data gaps or limitations for the Recreation Sector are identified below and followed by recommendations for future data collection and analysis.

### Skiing

Vulnerability is more complex than the size of the resort and its snowmaking capabilities. In general, snowmaking covers a small percentage of the total resort area, and is subject to the water rights priority system, which means that a drought occurring in the fall *and* winter could prevent a ski area from making snow. Also, snowmaking is not a comprehensive adaptive capacity. While snowmaking is an important tool for covering area early in the season and setting firm opening dates, it cannot cover the entire resort area or compensate completely for decreased snow throughout the season. Also, some groups argue that snowmaking is detrimental to the environment. If this becomes a significantly contentious issue it could impact the ability of resorts to secure water rights in the future.

Future work should analyze historic snow telemetry (SNOTEL) records in close proximity to ski resorts and at similar elevations. These data are readily available but would require analysis. Additionally, many resorts collect snow data as part of daily ski patrol operations. This information is likely much more useful as it is collected by professionals at the resort. Using base elevation along with historic snowfall could identify areas that receive more snowfall, and could point out ski areas that are more or less prone to decreases in snow pack. These data should also be evaluated with respect to climate change projections. A report about climate change in Colorado completed in 2008 by CU-NOAA Western Water Assessment noted that ski resorts above 10,000 ft are least vulnerable to climate change and increasing temperatures.

### Wildlife viewing

The only vulnerability metric used at present is viewing areas within wildfire hazard zones. Future work should investigate the competing water demands that can influence habitat (is there competition from other sectors, such as agricultural or municipal withdrawals?). The wildlife viewing sub-sector could also incorporate beetle-kill data as reports suggest that some species alter their behavior as a result of the dead forests[13]. Also the level of protection through state or

[13] https://wildlife.state.co.us/Hunting/PlanYourHunt/Pages/PlanYourHunt.aspx

federal laws, and the adaptive capacities of specific species should be determined. Wildlife viewing corresponds strongly to the Environmental and State Assets Sectors, so insight gained in those sections can be related to this sub-sector and vice versa.

Work completed in the NCNA could help improve the inventory data for water-based wildlife viewing areas. Viewing areas have been assessed in all basins, and future work could concentrate on summarizing the findings across the State in a manner consistent with this methodology and analyzing the results using a drought-specific outlook. For example, the Rio Grande basin used “waterfowl hunting” alone as a recreational non-consumptive need, while the Southwest basin included waterfowl hunting/viewing, Audubon Important Bird Areas, waterfowl hunting/viewing parcels, and Ducks Unlimited Projects. These data sets, while certainly relevant to the basins in which they apply, would need a degree of manipulation in order to apply them in a meaningful way to a drought vulnerability analysis.

Additionally, in some basins the NCNA tallied rare or imperiled plant communities and riparian plants. If these data are assessed state-wide with respect to drought impacts they could be combined with water-based wildlife viewing areas to determine vulnerability. However, some assessment would also be required to determine if rare or imperiled plant communities and riparian plants are the most vulnerable to drought. It is likely that this metric would need to be combined with several others to capture the information accurately.

### Hunting, fishing, and camping

The existing spatial inventory is “dollars spent on hunting and fishing per county,” and does not include camping. This dataset has not been updated, but new information is expected to be made available in the early part of 2014. Future analysis could benefit from looking at these activities individually. A limitation to this approach is spending in one county does not necessarily imply that is where the activity took place. Because spending appears to be strongly correlated to urban population centers, it is safe to say a portion of people purchased items in those counties and traveled elsewhere for the recreation activity.

This sub-sector is strongly tied to the CPW, so recommendations made in the State Assets Sector will apply to hunting, fishing, and camping as well. The two vulnerability metrics, “acres of beetle kill extent” and “wildfire susceptibility index” could be made more specific by splitting these activities into separate sections. For example, camp sites are sensitive to beetle kill because excess dead trees prompt campground closures, but hunting opportunities may be more closely related to animal stress and the number of hunting licenses the CPW issues in a given year. The wildfire threat database does reflect all three activities as they are all impacted by wildfire.

The NCNA identified fishing as one of its main recreational study areas and has assembled a substantial amount of data. However, as noted in the previous section, the basin-specific data would require manipulation in order to apply them in a meaningful way to a drought vulnerability analysis. Future work should use the NCNA findings as a starting point and assemble a uniform county level data set for the entire state. This data set can serve as a fishing inventory metric and may also contribute to impact metrics pending future work that identifies those species and habitats which are most vulnerable to drought.

## Golfing

From interviews with golf course superintendents, a large part of water management depends on the individual course and how it is managed. This is hard to quantify but factors into whether or not a golf course will be injured during a drought. Golf course managers who increase efficiency (decrease water demand) under normal conditions are better able to respond during drought. Another factor is the vulnerability of the municipal water providers servicing golf courses and their policies on water restrictions. Golf courses should work with their water provider to develop plans to limit water use in an efficient way during drought.

A suggested metric for future vulnerability assessment efforts is: "How many acres of the golf course consist of essential areas?" Here, "essential" is defined as the tees, fairways, and putting greens. The proportion of critical areas to the total could be calculated to understand how many acres a golf course could stop irrigating before the course were severely impacted. Certainly it could be included in a county or statewide plan, but this information would also be useful to golf course managers as a way to identify vulnerability of specific courses.

## Boating

The boating sub-sector is strongly related to CPW, so further research could be done in tandem with the State Assets Sector. The boating registration data used for this plan are for the entire state, and a suggested vulnerability metric is "boating registrations by county." The benefit of this information would be two-fold: 1) it would provide a spatial picture of any boating "hot-spots" around the State; and 2) registrations could be tracked by year to detect any changes that could be explained partly by drought. Limitations to this metric include: 1) the county where the boat is registered does not indicate the county where the boating occurs and 2) from conversations with State Parks employees, boating registrations are more impacted by the economy (i.e., in a recession less people register their boats). Since the 2002 drought also occurred during a minor economic recession, boating registration numbers may give the false impression that drought was the reason for lower registrations. A similar sentiment was conveyed by CPW staff (CPW, 2013) for the 2012 drought – boat registrations were likely more impacted by the economic recession than the drought.

Another suggested vulnerability metric is to look at any compacts a lake or reservoir is subject to (i.e., the John Martin Reservoir provides storage for the Arkansas River compact between Kansas and Colorado, 1949 [KSDA, 2010]). These compacts could dictate a specific reservoir volume that would facilitate boating in a drought, or conversely they could cause a reservoir to drain below normal levels in order to fulfill the water delivery.

As noted in the wildlife viewing and fishing sections, data assembled in the NCNA process could improve the boating inventory metrics. Future work should use the NCNA findings as a starting point and assemble a uniform county level data set for the entire state.

### Rafting

One limitation for the rafting sub-sector is correlating river reaches to specific counties. There are reaches that encompass multiple counties, and there are also cases where rafting outfitters meet with customers in one county, then drive to an adjacent county to begin the trip. In either case, although the river passes through a county, that county does not necessarily see an economic benefit from the rafting industry. Further analysis is recommended to identify counties that have been included in the rafting spatial distribution metric but that do not experience a strong benefit. Also, since the industry is fairly small and concentrated to the western half of the State, it would be feasible for someone with intimate knowledge of rafting to identify towns and/or counties that are highly dependent on rafting as an economic driver.

A thorough analysis of existing instream flows, water flow agreements, recreational in-channel diversions and their respective seniorities could point to rivers that are more or less vulnerable to being depleted below raftable levels during a drought. An example of an existing water flow agreement is the 2006 agreement between the Southeastern Colorado Water Conservancy District, the Colorado Department of Natural Resources, CPW, Chaffee County, Arkansas River Outfitters Association, and Trout Unlimited to manage the flow on the Arkansas River above the Pueblo Reservoir to allow for recreational and fishery purposes.

As noted in the wildlife viewing and fishing sections, data assembled in the NCNA process could improve the rafting inventory metrics. Future work should use the NCNA findings as a starting point and assemble a uniform data set for the entire state that could be summarized by county.

Future data collection efforts should seek to find drought specific metrics following the model presented in Thomas & Wilhelmi, 2012. Educating and coordinating stakeholders in data collection would not only help measure drought impacts, but would also serve to help outfitters identify their own personal vulnerabilities.

The bullets below offer some suggested vulnerability metrics that could enhance this assessment in the future.

- Skiing:
  - What is the base (or peak) elevation of the resort
  - Analyze historic SNOTEL record and records kept by resort snow scientists

- Wildlife viewing:
  - Rate the sensitivity of habitat
  - Collect information regarding competition for water from other sources

- Is the habitat protected through state or federal laws (this can be broken out as protected acres per county)
- How adaptable and/or mobile is the species in question (refer to Environmental Sector for additional discussion)

- Hunting, fishing, and camping:
  - Collect data regarding fish hatchery operations (refer to State Assets Sector for additional discussion)
  - Hunting and fishing license records by county and by year

- Golf:
  - Assess how many acres within the course are considered "essential" for irrigation

- Boating:
  - Collect registration data by county
  - Analyze storage agreements and/or interstate compacts as they relate to reservoir water levels

- Rafting:
  - Use expert input or demographer data to identify towns and/or counties where economy is highly dependent on rafting
  - Analyze instream flows, water use agreement, and recreational in-channel diversions as they relate to streamflows
  - Suggest inclusion in future survey efforts

## 10.7 References

Agreement, by and among the Southeastern Colorado Water Conservancy District, the Colorado Department of Natural Resources, the Colorado Division of Wildlife, Colorado Division of Parks and Outdoor Recreation, Chaffee County, Arkansas River Outfitters Association, and Trout Unlimited. August 4, 2006.

American Whitewater. "Our Organization." Accessed May 23, 2010. Updated 2010. Available at: http://www.americanwhitewater.org/content/Wiki/aw:about/

Associated Press. 2013. *Antero Reservoir won't be drained after all.* Published in the Denver Post on April, 24, 2013. Available at http://www.denverpost.com/denver/ci_23101716/antero-reservoir-wont-be-drained-after-all

Audubon. Birds and Climate Change: Ecological Disruption in Motion. A Briefing for Policymakers and Concerned Citizens. February 2009.

Audubon. The State of the Birds 2010 Report on Climate Change, United States of America. 2010.

BBC Research & Consulting, prepared for Colorado Division of Wildlife. *The Economic Impacts of Hunting, Fishing and Wildlife Watching in Colorado*. September 26, 2008. Available at: http://wildlife.state.co.us/NR/rdonlyres/777626FF-9E01-49D7-98EF-0B087AFD4832/0/08DOWEconomicImpactReport.pdf

Bouvette, Tracy et al. Drought and Water Supply Assessment (DWSA). 2004

Colorado Parks and Wildlife (CPW) 2012. *2012 Drought Impacts*. Internal Communication.

Colorado Parks and Wildlife (CPW). 2013. Personal communication with Boating Registration office on 6/21/13.

Colorado River Outfitters Association (CROA). *Commercial River Use in the State of Colorado, 1988-2009.* Available at https://croa.org/pdf/2006_Commercial_Rafting_Use_Report.pdf.

Colorado River Outfitters Association (CROA). 2012. *Commercial River Use in the State of Colorado, 1988-2012.* Retrieved 4/19/13 from http://www.croa.org/media/documents/pdf/2012-commercial-rafting-use-report.pdf

Colorado Ski Country USA. "Colorado Ski Resorts." Accessed May 10, 2010. http://www.coloradoski.com/Resorts/ColoradoSkiResorts/

Colorado Ski Country USA (CSCUSA), 2012. *Colorado sees skier visits recede for 2011/12 season.* June, 6 2012. Accessed April 10, 2013 from http://www.coloradoski.com/media_manager/mm_collections/view/89

Colorado Ski Country USA (CSCUSA), 2013. *Colorado Ski Country USA sees mid-season momentum.* March, 22 2013. Accessed April 10, 2013 from http://www.coloradoski.com/media_manager/mm_collections/view/115

Colorado Ski Resort Guide. SkiTown.com, 2010. Accessed May 10, 2010. http://www.coloradoskicountry.com/

Colorado University (CU)-NOAA Western Water Assessment for the CWCB. Climate Change in Colorado: A Synthesis to Support Water Resources Management and Adaptation. 2008.

Colorado Water Conservation Board (CWCB). Non-consumptive Needs Assessment Focus Mapping. July 2010. Prepared by Camp Dresser & McKee, Inc. and Amy Ackerman, Water Resources Specialist.

CWCB. Statewide Water Supply Initiative (SWSI). Phase I Report. November 2004.

CWCB. Statewide Water Supply Initiative (SWSI). Phase II Report. Colorado's Water Supply Future. November 2007.

CWCB. 2010. Statewide Water Supply Initiative (SWSI). 2010 Update. Colorado's Water Supply Future. January 2011.

Davies, Steve, Phil Watson, Amanda Cramer, and Dawn Thilmany. *The Economic Contribution of Colorado's Golf Industry*. Colorado State University Department of Agricultural and Resource Economics. June 2004. Available at: http://www.cogolf.org/uploads/impact/econ.pdf

Dean Runyan Associates. The Economic Impact of Travel on Colorado 1996-2011. November 2012. Prepared for the Colorado Tourism Office, Office of Economic Development and International Trade, Denver, Colorado.

Division of Parks and Outdoor Recreation (Colorado State Parks), 2010. "Annual Boat Registrations."

Division of Parks and Outdoor Recreation (Colorado State Parks), 2010. "Total Visitation, FY 2002-2009."

Dvorak Expeditions. *Kayak & Rafting Expeditions*. 2009. Accessed March 13, 2010. Available at: http://www.dvorakexpeditions.com

Finley, Bruce with The Denver Post. Campsite openings teetering: The Forest Service will close areas to clear beetle-damaged timber in danger of toppling. May 11, 2010.

Ivahnenko, Tamara, 2009, Estimated Colorado golf course irrigation water use, 2005: U.S. Geological Survey Open-File Report 2008–1267, 25 p. Available at: http://pubs.usgs.gov/of/2008/1267/

Kansas Department of Agriculture, 2010. *Arkansas River Compact, Kansas-Colorado, 1949*. Available at: http://www.ksda.gov/includes/document_center/interstate_water_issues/IWI_Docs/KS_CO_Ark_River_Compact.pdf

Kohler, Judith. The Associated Press. "Conservationist: Colorado sees climate change effects." Published February 7, 2010. Accessed June 1, 2010. Available at: http://www.aspentimes.com/article/20100207/NEWS/100209852

Luecke, Daniel F., John Morris, and Lee Rozaklis and Robert Weaver with Hydrosphere Resource Consultants. *What the Current Drought Means for the Future of Water Management in Colorado*. January 2003.

Lyman, Gregory T., Clark S. Throssell, Mark E. Johnson, and Greg A. Stacey, Golf Course Superintendents Association of America; and Clark D. Brown, National Golf Foundation. *Golf Course Profile Describes Turfgrass, Landscape, and Environmental Stewardship Features*. Applied Turfgrass Science. Published 7 November 2007.

No author, Coloradoskihistory.com. “Colorado Skiing History.” Updated May 2010. Accessed May 18, 2010. http://www.coloradoskihistory.com/History.html

Ostmeyer, Terry. *Lessons Learned: Note taking and proactive public relations loomed large during the hot, dry summer of 1999*. Golf Course Management Online. November 1999. Accessed March 22, 2010. http://www.gcsaa.org/gcm/1999/nov99/11lessons.html

Ratnik Industries, Inc. “Snowmaking 101.” Updated 2010. Accessed June 2, 2010. Available at: http://www.ratnik.com/snowmaking.html

Schneckenburger, Chad A. and Robert Aukerman. “The Economic Impact of Drought on Recreation and Tourism.” Paper, Colorado Drought Conference, December 4, 2002. Co-Sponsored by Colorado Water Resources Research Institute and the Colorado Water Conservation Board.

Seidl, A. and E. Gardner. *Agricultural Land Use and Economic Trends in Four North-Central Colorado Mountain Counties: Routt, Jackson, Grant and Summit*. Agricultural and Resource Policy Report, No. 5. Colorado State University Extension. July 2001. Available at: http://dare.colostate.edu/pubs/apr01-05.pdf

Shrestha, P. August 2009. *Economic Impacts of Drought on the Whitewater Rafting Industry in Colorado*. Master’s Thesis, University of Nebraska, Lincoln. 72 p.

Sink, Mindy. The New York Times. “Can Rain be Bought? Experts Seed Clouds and Seek Answers.” Published October 14, 2003. Accessed June 1, 2010. Available at: http://www.nytimes.com/2003/10/14/science/can-rain-be-bought-experts-seed-clouds-and-seek-answers.html

Smith, Zack & Edalin Koziol. 2012. *Drought Watch 2012: Water leases save Yampa River this summer.* Summit Daily. Published August 26, 2012.

State of Colorado Water Availability Task Force (WATF). Impact Task Force Drought Assessment and Recommendations. May 1, 2002.

Throssell, Clark S., Greg T. Lyman, Mark E. Johnson, and Greg A. Stacey, Golf Course Superintendents Association of America; and Clark D. Brown, National Golf Foundation. *Golf Course Environmental Profile Measures Water Use, Source, Cost, Quality, and Management and Conservation Strategies.* Applied Turfgrass Science. Published 29 January 2009.

Thomas, Deborah, and Olga Wilhelmi. 2012. *Drought Assessment for recreation & Tourism: Southwestern Colorado report.* The Colorado Water Conservation Board.

U.S. Census Bureau. 2010. *State & County QuickFacts*. Accessed 5/29/13. Available at: http://quickfacts.census.gov/qfd/states/08000.html

U.S. Fish and Wildlife Service. *2006 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation: Colorado.* Issued January 2008. Available at: http://www.census.gov/prod/www/abs/fishing.html

U.S. Fish and Wildlife Service. *2011 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation: Colorado.* Issued March 2013. Available at: http://www.census.gov/prod/www/fishing.html

Watson, P., S. Davies, and D. Thilmany. December 2008. *Determining Economic Contributions in a Recreational Industry: An Application to Colorado's Golf Industry*. Abstract, Journal of Sports Economics. Accessed March 22, 2010. http://jse.sagepub.com/cgi/content/abstract/9/6/571

Watson, Philip, Stephen Davies, and Dawn Thilmany. *The Economic and Environmental Aspects of Colorado's Golf Industry*. Presented at Western Agricultural Economics Association Annual Meeting, June 30 – July 2, 2004, Honolulu, Hawaii.

Wilhelmi, O. V., D. Thomas, and M. Hayes. 2004. *Colorado Resort Communities and the 2002-2003 Drought: Impacts and Lessons Learned*. Quick Response Research Report 174. Natural Hazards Research and Applications Information Center, University of Colorado, Boulder. Available at: http://www.colorado.edu/qr/qr174/qr174.html.

Wilson, Josh, Phil Watson, Dawn Thilmany, and Steve Davies. *Golfers in Colorado: The Role of Golf in Recreation and Tourism Lifestyles and Expenditures*. Colorado State University. August 2004.

# 11 SOCIOECONOMIC SECTOR

## Key Findings

- Socioeconomic impacts fall into three main categories; secondary economic impacts, behavioral health impacts, and public health concerns.

- There are a number of counties in Colorado whose economic base is more than 60% agriculture or tourism. The economic reliance of these counties on particularly drought vulnerable industries increases the vulnerability of the county as a whole.

- Most of the counties in Colorado have federally identified Health Professional Shortage Areas for behavioral health. Much of the state will have a difficult time responding adequately to the increased behavioral health issues that can occur during drought.

- Drought induced public health issues can include: impaired drinking water quality, increased incidence of mosquito born illness, respiratory complications resulting from impaired air quality, and an increase in wildlife-human confrontations.

## Key Recommendations

- Economic diversification is a key mitigation strategy for drought. This should occur both on a regional level and in individual business plans.

- Cooperative alliance and community planning that occurs before a drought can greatly increase the efficiency and effectiveness of drought responses.

- Many of the behavioral and public health issues resulting from drought are coordinated by governmental entities. Statewide agencies should increase their understanding of societal impacts of drought and focus on collaborative opportunities to mitigate drought impacts.

- Colorado has a shortage of behavioral health resources. While the Governor has recently taken steps to address funding issues, the effort may not be enough to bring the state up to recommended levels of access. Given broader economic issues, federal funds are also limited, consequently Colorado should explore alternatives.

- Significant data gathering and additional monitoring are required to spatially characterize social vulnerability. Refer to Section 11.6 for more detailed data gathering recommendations.

## 11.1 Introduction to Sector

As has been stated multiple times throughout this report, drought is a slow moving far reaching hazard that can affect nearly every aspect of society. As such, it is not adequate to assess only those groups with direct water dependences. Although they are often the most difficult to track and measure, the socioeconomic impacts of drought can reach the largest number of people and linger long after direct impacts have dissipated. For a general description of the vulnerability assessment approach refer to Chapter 2 (Annex B).

Historically drought has been tied to a broad range of social tension. The connection between water and conflict is well established throughout human history. Even today, in developing countries drought can result in serious famine, loss of life, and discord. Often the social implications of drought are overlooked in more developed areas because they are not as drastic as those noted in the developing world. However, this is not to say that serious drought-related impacts do not occur in the developed countries. Experience in Australia, which experienced its worst drought of record from 2006 to 2012, highlights the breakdown of entire communities that can occur during severe drought. Even in moderate droughts, secondary economic impacts are serious and widespread, and public health issues are real.

In the context of this analysis, socioeconomic impacts fall into the three categories: public health, behavioral health, and secondary economic impacts. These categories are necessarily broad, and in the sections that follow, these categories will be examined in more detail. In many cases drought impacts are based on specific experiences and reported incidents. Comprehensive statewide analysis for most of the issues noted here is not available. As detailed in this report, socioeconomic drought impacts have the potential to impact the most people and create compounded impacts with the other sectors. As such, more attention should be focused on this sector in the future.

## 11.2 Vulnerability of Socioeconomic Sector to Drought

### 11.2.1 Aspects of Vulnerability

Table 11.1 outlines the key socioeconomic impacts and adaptive capacities covered in more detail in Section 11.3. Societal drought impacts can include: decreased public health; greater unemployment; reduced income; poor housing sales; residential and business relocations; weakened tax base; diminished quality of life; and increased crime rates (Klein and Udall, 2004). A decline in public health can result from “compromised quantity and quality of potable water, increased recreational risks, effects on air quality, diminished living conditions, compromised food and nutrition, and increased incidence of illness and disease” (Kalis, Miller, and Wilson, 2009). Environmental degradation and the financial implications of drought often cause increased stress which can result in behavioral health issues and even suicide.

Air quality can be degraded by increased particulates in the air. In the "Dust Bowl" of the 1930s the air quality was so impaired that cases of dust pneumonia were reported. Aerosolization of spores in soil can increase risk of infectious diseases like coccidioidomycosis (Valley Fever). Air quality can also be impaired by wildfires. Smoke from fires can exacerbate chronic respiratory illness and increase the risk of acute respiratory infection (Kalis, Miller, and Wilson, 2009).

Under drought conditions rainfall and runoff often decrease while effluent discharges remain the same. This can have significant impacts on water quality. Total dissolved solids may increase (especially with runoff from wildfires), and bacteria levels may become dangerous. Incidence of vector borne disease could also increase as water bodies shrink and stagnate, creating optimal breeding ground for mosquitoes. In some cases, lack of surface water can force mosquitoes to increase breeding in swamp or bog ecosystems. This results in a convergence of mosquitoes and avian hosts. During previous droughts these circumstances have been associated with outbreaks of St. Louis Encephalitis, Eastern Equine Encephalitis, and West Nile Virus (Kalis, Miller, and Wilson, 2009).

**Table 11.1. Key Impacts and Adaptive Capacities**

| Key Impacts | Key Adaptive capacities |
|---|---|
| Secondary economic impacts | • Economic diversification<br>• Cooperative alliances and community planning |
| Behavioral health impacts | • Increased public awareness about possible drought implications and the signs of behavioral health issues<br>• Increased funding for behavioral health professionals especially in high vulnerability areas |
| Decreased water and air quality and resulting public health concerns | • Increased monitoring and spatial analysis of drought-related impacts<br>• Increased awareness and drought preparation by public agencies |

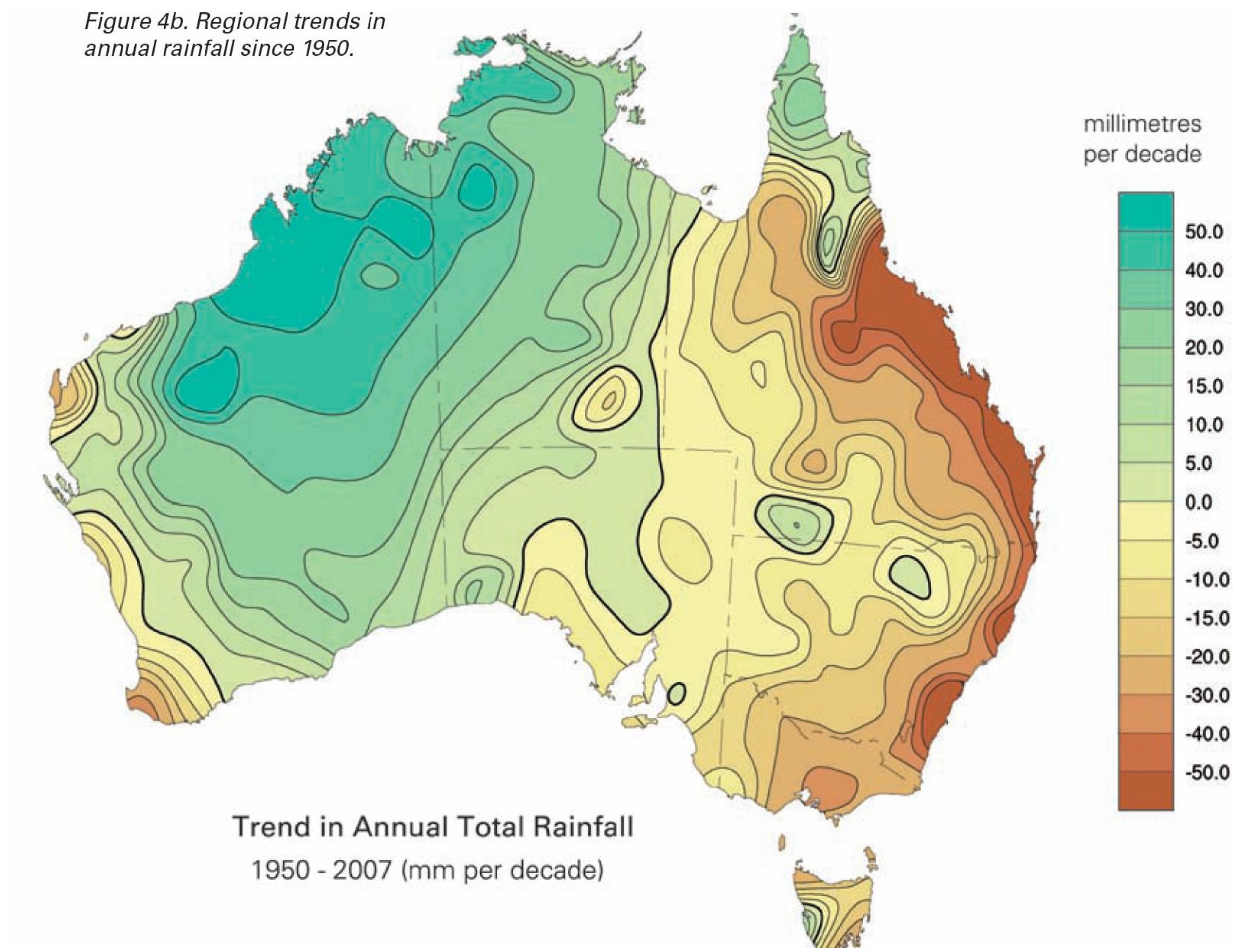
## 11.2.2 Previous Work

The Environmental Health Services Branch (EHSB) at the Center for Disease Control (CDC) conducted a literature review for drought-related public health studies. They found some information on drought, but no consolidated scientific evidence in a format that would be helpful to public health officials (Kalis, Miller, and Wilson, 2009). This study notes that, in general, public officials are underinformed on the expected impacts of drought. The literature review conducted for this project found that this is true in Colorado. There is monitoring of many air and water quality parameters, but no work has been done to connect these variables to drought. No focused studies connecting diseases like West Nile and bacterial infections to drought were found in this review.

In Florida, a study was conducted to analyze the connection between St. Louis encephalitis outbreaks and drought using a dynamic hydrology model. This study found that springtime drought can force Cx. nigripalpus mosquitoes to breed in densely vegetated marsh habitats in close proximity to wild birds. The convergence of mosquito vectors and avian hosts provided the ideal situation for rapid amplification of the virus (Shaman, Day, and Stieglitz, 2002). While this type of mosquito is not present in Colorado, one of the conclusions of this report is that the same amplification mechanisms may be relevant in other outbreaks like West Nile Virus. Future work should analyze the relevance of these findings to Colorado.

Over the past 60 years, Australia has experienced the worst drought on record. Figure 11.1 shows the annual trends in total rainfall from 1950-2007. Sustained severe drying has occurred in eastern and southwest Australia. Financial hardships caused the government to declare "exceptional circumstances." For example, one lake dried up so much that the remaining water turned into sulfuric acid as lake-bed soils got exposed to the air. There were fears that people in the area could be exposed to acid dust blowing off the lake (Kraemer, 2009).

**Figure 11.1. Rainfall Trends in Australia**

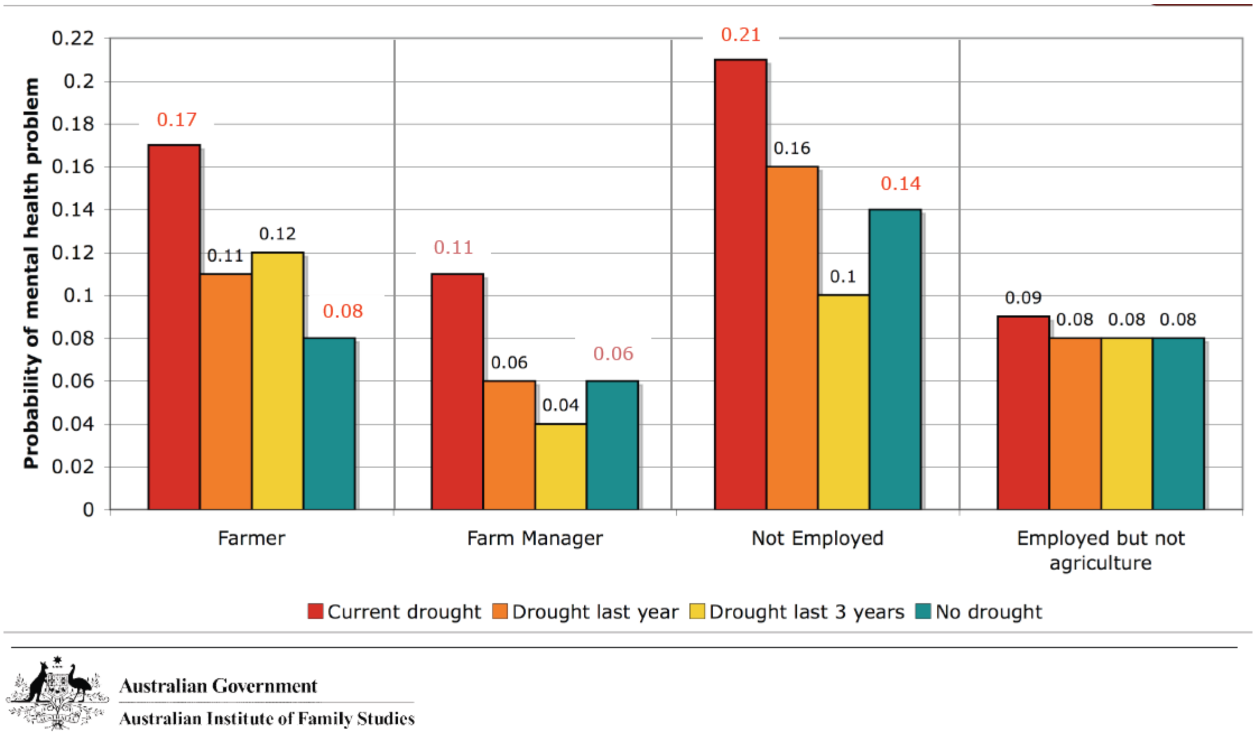



Source: Edwards, Gray, and Hunder 2009

The unprecedented duration and intensity of the drought resulted in serious social consequences. Large agricultural areas were rendered unproductive, threatening not just production but a way of life. Social repercussions gained the attention of the government and researchers.

The Australian Institute of Family Studies sponsored a study on the effects of drought on behavioral health and alcohol use. Figure 11.2 shows some results from this study. The probability of behavioral health problems for those unemployed or employed in agriculture drastically increased during the drought. For farm employees and managers, the probability of behavioral health problems in the drought was nearly double the probability with no drought. Those employed in other fields only showed marginally increased probability.

**Figure 11.2. Relationship between Drought and Behavioral Health by Employment**




Source: Edwards, Gray, and Hunder 2009

A study conducted in 2006 surveyed children from rural and remote areas of New South Wales to determine the emotional impact of drought. Below are several quotes from survey participants (Dean and Stain, 2007):

- *Lots of stress-people – get frustrated easily – get upset emotionally – there have been a couple of people drown themselves because of the drought*
- *People are sick of feeding everyday and watching the stock die – they have put their life into the farm – they expect to follow on in their father's footsteps – they can't provide the money to support their family*

- *Lots of people are talking about selling their farm, so if the drought continues some people might leave – the would be leaving their friends and families*
- *The lack of money and water were the really big things. You try to do things and you can't because you haven't got the money … you just get poor.*

In response to the social impacts being felt in rural and remote areas, the Australian government tried to improve behavioral health outreach. They raised awareness and promoted illness prevention and early intervention models. Much of the work was new but could serve as a quality guide for programs in Colorado. The Australian drought was more severe than any drought dealt with in modern times in Colorado and should be viewed as a learning opportunity to help Colorado prepare for future drought scenarios.

Prior to the 2010 version of the Colorado Drought and Mitigation Response Plan, drought vulnerability for the socioeconomic had not been evaluated for Colorado. Yet, there were several studies addressing drought and water supply planning. The Colorado Water Conservation Board (CWCB) conducted a Drought Water Supply Assessment (DWSA) in 2004 to determine the State's preparedness for drought and identify limitations to better prepare for future droughts (CWCB, 2004). The details of this work are discussed in Chapter 1 Introduction. It entailed a survey, or opinion instrument, where 537 responses were received statewide on specific impacts experienced during the dry period of 1999 to 2003. Various entity types were surveyed including power, industry, agriculture, municipal, State, Federal, water conservancy and conservation districts, and "other" (i.e., tribes and counties).

The all encompassing nature of the Social Sector does not lend itself to clear survey subjects. The DWSA did not specifically consider the Socioeconomic Sector through the various case studies it conducted. However, the study incorporated a diverse group of business owners across the state to describe the social impacts that were felt as a result of the 2002 drought. Interviews were conducted with a rafting company owner on the Arkansas River, a farmer and cow calf rancher in the San Luis Valley, a dry land farmer in southeastern Colorado, a nursery/greenhouse owner in the Denver Metropolitan Area, and a truck farmer in the Grand Valley. A common theme among their responses was that impacts were felt in both the short and long term (i.e., business plans had to be redeveloped). Changes include, modifications in the way crops were planted, employees were hired, and purchases were made. When coupled with other business-related drought strains such as changes in the ways services are provided, these adjustments may have lasting impacts on the business. The long-term impacts identified in the interviews were even more distressing largely because they entail mostly irreversible actions such as selling the family farm or business. This results in longer term financial strain in the form of unemployment and increased debt. Overall, a ripple effect was felt throughout these industries due to the 2002 drought because it impacted not only these businesses, but their local communities and families as well.

Another relevant Colorado specific study is the Statewide Water Supply Initiative (SWSI). Although this study does not specifically focus on drought, the SWSI process is another important initiative taken and directed by the CWCB to understand existing and future water supply needs and how those needs might be met through various water projects and water management techniques.

The SWSI does not address specific social and economic impacts due to drought conditions, but does state that the statewide social and economic setting may be greatly affected when water supplies are scarce. This is because the state relies heavily on snowpack for much of its water supplies, which in turn is a driver for the viability of many economic segments such as the urban economy, agriculture, mineral/mining, and recreation and tourism (Colorado Water Conservation Board, 2004, 2007). The SWSI notes that consideration of the social and economic setting should occur in future water supply planning efforts to mitigate any negative implications on Colorado’s overall economic health.

Coverage of water issues from various media outlets throughout the state has been increasing, particularly since the 2002 drought. The Statewide Water Supply Initiative process helped provide information for residents about water issues occurring in other basins, through the same media outlets as well as public meetings, so that the water situation for the state as a whole could be understood. Realizing that each basin has a unique “way of life,” this information helped stakeholders more fully understand that there is not a one-size-fits-all solution for all regions. One of the Statewide Water Supply Initiative’s water management objectives is to “protect cultural values” by maintaining quality of life unique to each basin. This can be achieved by maintaining existing landscape and irrigation practices in residential areas, continuing to make agriculture viable in rural areas, and preserving open space areas. With this approach, the hope is that even in times of short water supply, economic vitality, and quality of life is maintained as much as possible by using a suite of management techniques and options to mitigate impacts.

Municipal water providers and agriculture are usually considered to be the most drought vulnerable and often the social implications of drought are overlooked. The emphasis placed on socioeconomics in Statewide Water Supply Initiative planning efforts, supports the approach taken in this drought vulnerability assessment and further highlights the implications drought can have on society.

- The National Drought Mitigation Center (NDMC) was established at the University of Nebraska-Lincoln in 1995. Their mission includes helping people and institutions “…develop and implement measures to reduce societal vulnerability to drought, stressing preparedness and risk management rather than crisis management.” NDMC maintains the Drought Impact Reporter which is an online database of drought impacts from a variety of sources, including media, government agencies, and the public. Impacts listed in the Drought Impact Reporter, related to the socioeconomic sector from May 2012 to May 2013 are provided below. Increases of blowing dust from idle croplands near Springfield.

- An overall degradation of lawns and landscaping in a particular neighborhood in Colorado Springs. Many lawns have been replaced with bare dirt and/or weed patches. Many trees are dying. This has the effect of increasing local temperatures, contributing to reduced air quality, and reducing the overall quality of the viewshed for some folks.

- Drought, dust storms leave land barren in southeastern Colorado (Cheyenne, Kiowa and Powers Counties)

- Reduced air quality from blowing dust in Kiowa and Yuma Counties. Reduced vegetative and crop cover has generated dust that has reduced visibility, closed highways, and affected breathing.

- In Lincoln County, 9news reported that a particularly strong windstorm inundated crop fields in 6 to eight inches of sand.

- Colorado wildlife officials estimate that 300 to 500 mule deer have been making the town of Alamosa home since the 2002 drought. Town residents have filed complaints of the deer feasting on trees and gardens.

- On Sunday, April 14, 2013 strong winds and blowing dust created hazardous driving conditions on I-25 north of Pueblo. The storm produced multiple car wrecks.

- There have been multiple reports of bears breaking into cars, stores, and houses in search of food. Some bears were put down as they posed a danger to people.

- Hay thefts have increased as a result of higher hay prices

## 11.3 Assessment of Impacts and Adaptive Capacities

Splitting the Socioeconomic Sector into specific impact groups is impractical given the broad and interconnected nature of this category. Instead Section 11.3 is split into three main impact categories: secondary economic impacts, behavioral health impacts, and public health impacts.

### 11.3.1 Secondary Economic Impacts

The five other sectors analyzed individually in this report were chosen based on importance to the economy of the state and water dependency. However, many industries not reliant on water are impacted by drought through their relationships with other sectors. The direct impacts of drought are just the starting point for impacts to propagate. It is beyond the scope of this project to do a detailed spatial analysis of the entire Colorado economy as it relates to drought. For this section results have been assembled from economic impact studies done for state parks visitation and hunting and fishing. These are examples of the economic importance of recreation to surrounding communities and secondary industry. Both studies relate to the Recreation Sector.

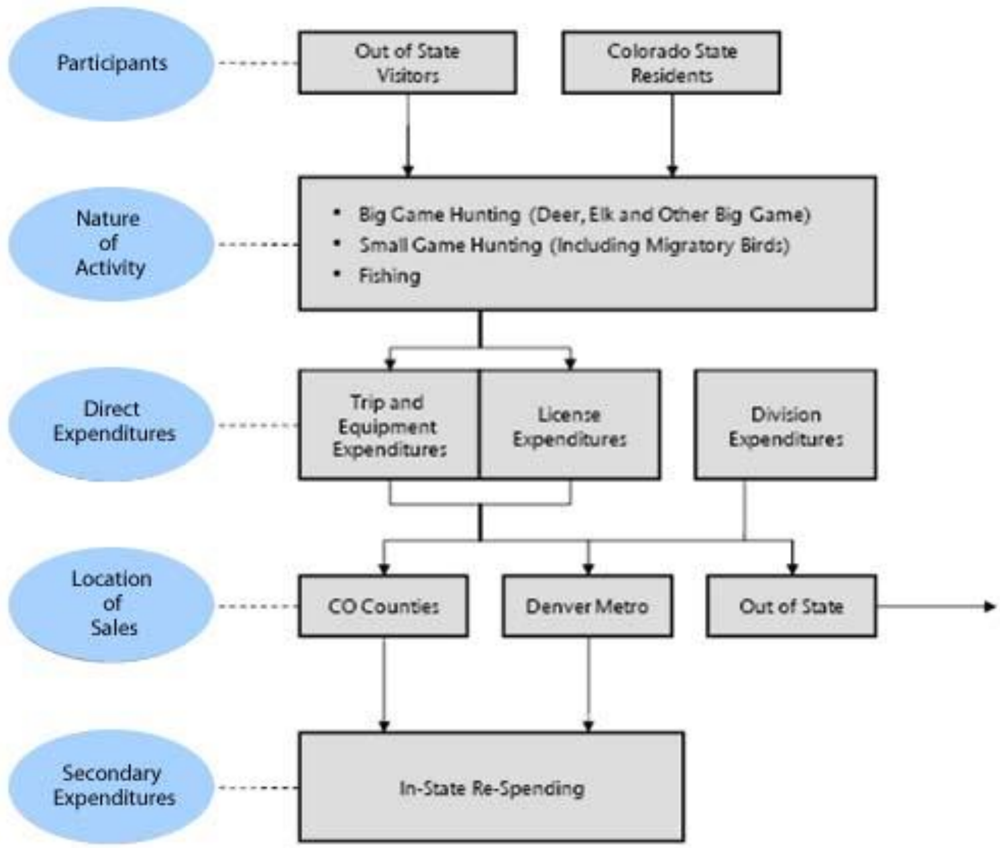
Similar analysis for the other sectors is not available for the state but should be a focus of future work. Three key secondary economic impact categories are provided below.

- Loss of business for industries dependant on those groups that are directly impacted by drought. For example tourism based businesses in the vicinity of state parks or decreased business to landscaping companies as the demand for sod goes down.
- The multiplier effect of decreased business revenue can impact the entire economy. When an individual looses or decreases their income all of the goods and service providers they usually support will also be impacted.
- Business downturn can decrease property value and erode the tax base.

Colorado Parks and Wildlife (CPW) maintains an economic impact model for hunting and fishing activities. Inputs to the model were last updated by BBC Research & Consulting (BBC) in 2008 using the most recent game harvest information, surveys, and CPW financial information (BBC Research & Consulting, 2008). Figure 11.3 is a schematic of the economic model that was used. The model encompasses direct spending on licenses, gear, CPW expenses, and trip expenses as well as secondary expenditures when this money gets re-spent in state. Secondary spending accounts for the money those businesses that receive direct spending pay to employees or use to purchase goods and services from other business. This re-recirculation of spending is often termed the "multiplier" effect.

Direct expenditures by hunters and fisherman for equipment and other trip expenses were estimated in the BBC study to be $1.0 billion in 2007. Spending by CPW to support hunting activities was $58 million. The secondary impact of this spending was $767 million and an overall economic impact of $1.8 billion. Furthermore, it was estimated the economic impact of these activities supports 21,000 full-time jobs in Colorado. This study also estimated, in addition to the economic impact of hunting and fishing, the total economic impact of wildlife watching to be $1.2 billion, enough to support 12,800 full-time jobs (BBC Research & Consulting, 2008).

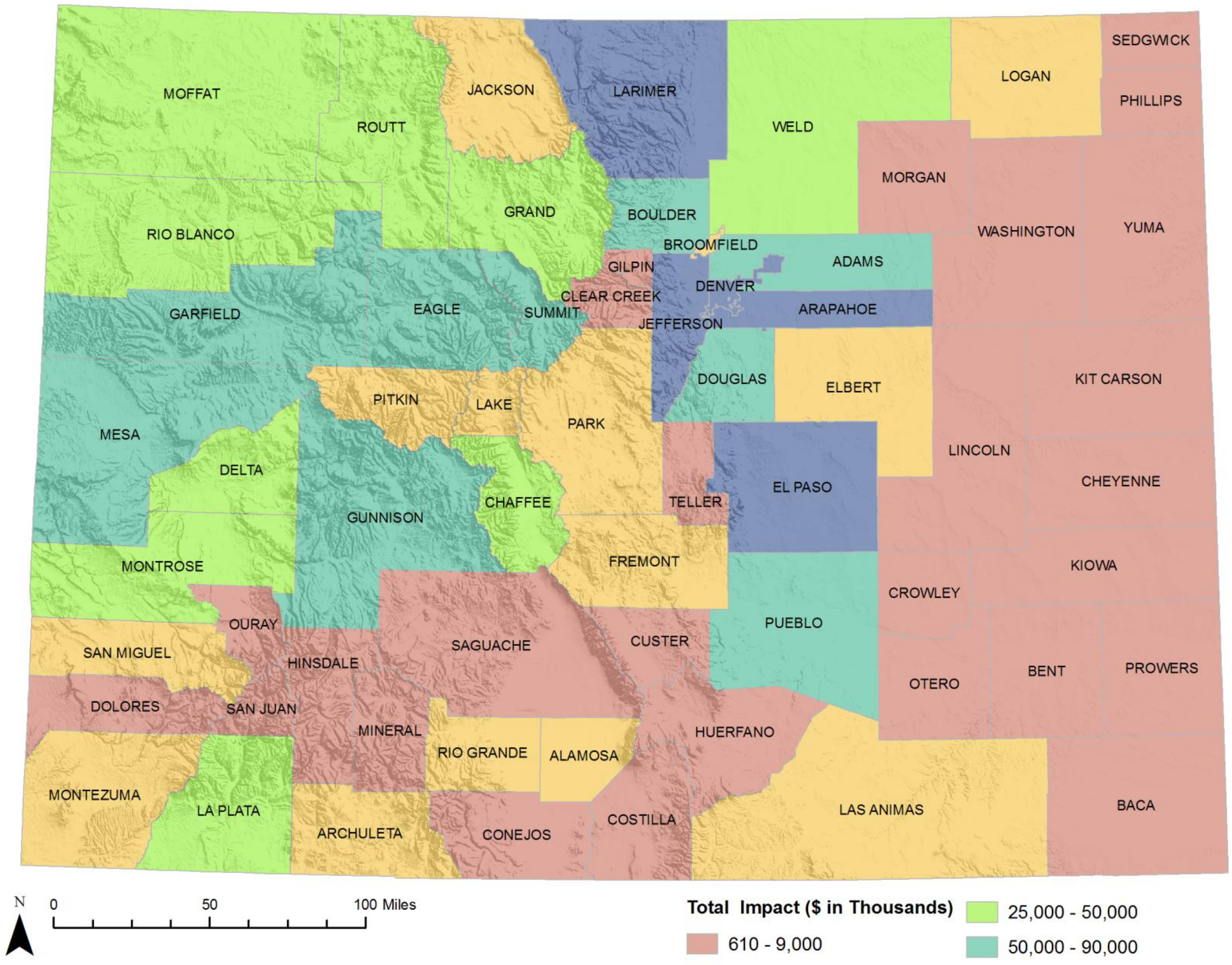
**Figure 11.3. Economic Impact Model for Hunting and Fishing**




Source: BBC Research & Consulting 2008

While these numbers are impressive on a statewide scale, it is important to understand their spatial distribution. Figure 11.4 shows the total economic impact (direct spending plus secondary spending) by county. The BBC study noted that the largest economic impact from fishing and hunting is actually in the counties with the largest population (See Denver County in Figure 11.4). This is because equipment expenditures generally take place where the hunters and anglers live. However, the counties where hunting and fishing has the largest relative importance are generally rural counties. In Jackson County, jobs from hunting and fishing account for 12% of all jobs (BBC Research & Consulting, 2008).

## Figure 11.4. Total Economic Impact of Hunting and Fishing




Source: BBC Research & Consulting 2008

A similar study to the BBC study was also conducted in 2008, evaluating direct spending. Information from surveys, focus groups, and direct spending analysis was used. This study found that from June of 2008 to May of 2009 visitors to state parks spent $571 million in local communities within a 50 mile radius of the park. As to be expected, local visitors spent less in surrounding areas than visitors coming from further away. Average spending within the 50 mile radius by local residents was $48 per visitor, while average spending per non-local visitor was $80. Lake Pueblo had the highest expenditures generating nearly $98 million for local economies (Corona Research, 2009). Table 11.2 summarized the total expenditures by region. However, as with hunting, the relative contribution of spending to the local economy is more important than the total spending.

There are counties in Colorado that are highly dependent on recreation and tourism. Eagle, Grand, Pitkin, and Summit counties are some of the most dependent. In these areas tourism accounts for nearly 51% of employment and 76% of income. The second highest recreation dependant area encompasses Archuleta, Dolores, La Plata, Montezuma, and San Miguel counties. Here, recreation and tourism accounts for 27% of income and 21% of employment (Schneckenburger and Aukerman, 2002).

**Table 11.2. Total Visitor Spending within 50 Mile Radius of State Parks by Region**

| Regional Totals | Total Expenditures |
|---|---:|
| Denver Metro | $74,627,053 |
| High Plains | $77,708,457 |
| Rocky Mountain | $207,610,661 |
| Southeast | $211,408,310 |

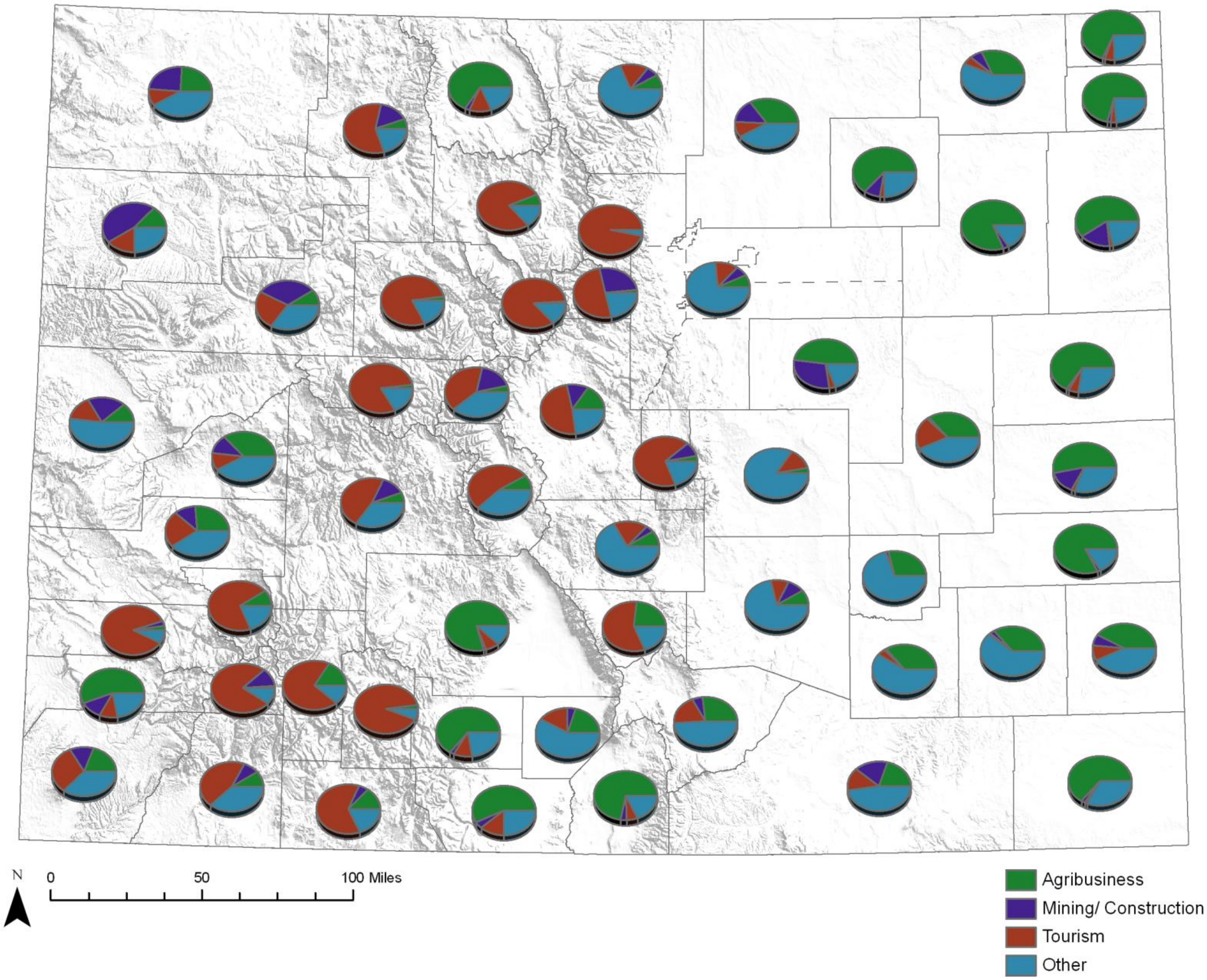
Source: Corona Research 2009

The two studies discussed above provide quantitative information on how specific activities can connect to the larger economy. Results show that recreation in Colorado generates much more revenue than the licensing and park entrance fees alone. While these studies provide a good baseline for economic activity, no study has been completed to assess how these numbers may change during drought.

Many of the businesses involved in Recreation Sector are small businesses less able to cope with prolonged stress. For example, in the 2002 drought the marine/boating industry was hit hard. Two local marine dealers said they experienced revenue reductions of nearly 50%. This trend was not entirely attributable to the drought as a general economic downturn was another important factor. These dealers were able to continue doing business by working with their manufactures on volume-buying programs and inventory control (Schneckenburger and Aukerman, 2002). Representatives from fishing shops said that gear sales were down 30% and guided trips were down 20%. One of the biggest issues cited by the fishing shops was public perception. Even in cases where low water levels and high temperatures had actually resulted in very good fishing, people were under the impression that fishing was bad everywhere and they went out of state (Schneckenburger and Aukerman, 2002).

The preceding examples indicate the multiplier effect drought can have on general business and industry. Figure 11.5 shows pie charts of the economic base employment by county, based on regional profile analysis by the State Demographer's Office. This map shows the western half of the State to be tourism driven, while the eastern half is agriculturally driven. It stands to reason that in counties with little economic diversification, all businesses could be impacted by a downturn in agriculture. In the future, drought estimates should be made regarding impacts to local economies as a whole, not solely to those directly impacted by drought. In counties dependent upon drought vulnerable activities, prolonged drought could result in far reaching economic downturn. On a statewide scale this could lead to increased unemployment, declining housing markets, and loss of industry. Particular attention must be paid to separating drought-related impacts from other causes. For the 2011-2013 drought event, consideration should be given to how national and international economic issues can be both separated from the regional impacts of drought and factored in as a compounding or exacerbating variable. For instance, international food markets can have a significant impact on the local agricultural economy. Such impacts can play an even greater role on a local scale when local regions are undergoing a drought. Secondary economic impacts are very complex and a broad range of compounding factors can play a role. Extreme droughts of long duration can be expected to touch nearly everyone, as recently experienced in Australia.

## Figure 11.5. Economic Base Employment by County




State Demography Office 2009 - Adams, Arapahoe, Denver, Douglass, Boulder, Broomfield and Jefferson counties are combined to form the Denver Metro area.

It is difficult to define specific adaptive capacities for such a broad range of activities. Communities that are diversified and businesses that are flexible are best able to respond to stress. To better prepare for drought, individual businesses need to consider the industries they are dependent on and how direct drought impacts on others could propagate to their operations. However, businesses can take actions to insulate their operations. Communities can help businesses by forming cooperative alliances and coordinating public relations. These steps are best taken before a drought occurs so that working relationships are already established before stress arises.

***Community Agriculture Alliance***

> "*To preserve the agricultural heritage of the Yampa River Valley by initiating, supporting and encouraging actions, programs, and policies that mutually benefit and connect agricultural producers and consumers (Community Agriculture Alliance Inc.)"*

The Community Agriculture Alliance (CAA) was established in 1999 to serve Routt County and the Yampa River Valley in Northwestern Colorado. The Yampa Valley has a long history of ranching dating back to the 1870s and a historically strong mining industry. More recently, Steamboat Ski Resort has evolved to become an internationally acclaimed ski destination and an important part of the economy in this area. Tourism is not limited to the winter as the beautiful scenery and mountain setting attracts outdoor recreation enthusiasts year round.

The CAA recognizes that "all segments of the area are dependent upon each other for economic survival because of soaring land prices, continual residential and commercial growth, and the desire to maintain the rural way of life." Therefore they work "to ensure that the agricultural community can adapt to changes in the local and regional economy and still be active and vital in the Yampa River Valley for generations to come (Community Agriculture Alliance Inc.)"

They have outlined the following four goals for themselves:

1. Unite the Residents of our Community
2. Education and Awareness of Agricultural Issues
3. Preserve and Protect Agricultural lands
4. Develop Agricultural Business Activities

Since its establishment in 1999, the CAA has been involved in many community relations programs and has helped create a cooperative working relationship between agriculture, Steamboat Resort, and associated tourism based businesses. They help sponsor several events and write a weekly newspaper column to provide perspective on agricultural activities. The CAA is working on the Northwest Colorado Products Program to develop a network of producers and retailers in northwest Colorado. They also provide education on responsible land stewardship.

The CAA does not have any drought specific goals or programs, yet their activities greatly increase the adaptive capacity of the region. Establishing cooperative relationships and channels of communication in non-drought conditions can translate to more coordinated mutually beneficial drought responses. Coordinated economic development helps keep agriculture viable while putting everyone in a better position when a stressor like drought occurs.

## 11.3.2 Behavioral Health Impacts

The economic discussion above illustrated the ways that drought can spread through society. Direct financial stress and general economic downturn can negatively impact behavioral health. Farmers and ranchers are one of the groups under the most financial stress during drought, but they are not the only people impacted.

There is a large body of literature on “farm crisis in behavioral health.” Financial farm stress can lead directly to psychological distress that can manifest through depression, substance abuse, increased farm accidents and suicide (Fetsch, 2007). In 2010, Colorado was ranked as having the 8$^{th}$ highest suicide rate in the nation (McIntosh, 2012). In 2002, Colorado’s suicide rate was the 7$^{th}$ highest in the nation and the leading external cause of death for farmers and ranchers in the state was suicide. In the agricultural crisis of the 80’s, suicide rates among farmers and ranchers were three times the rates for the rest of the State (Fetsch, 2007). Experience in Australia (refer to Section 11.2.2) also has shown the impact severe drought can have on behavioral health. Awareness is key in preventing suicides. Impacted communities need to be aware that during times of drought stress can increase the risk of suicide, and pay attention for signs of suicidal inclinations. Materials have been developed by the extension service, among others, noting the signs of suicide and how to get help. Extra attention should be paid to farmer, ranchers, and other small business owners who are risk of losing their land or going out of business.

### *Central Colorado Water Conservancy District Experiences in the 2002 Drought*

The following experts are from a presentation given by Tom Cech, executive director of the Central Colorado Water Conservancy District, at the Colorado Drought Conference in 2002. The Central Colorado Water Conservancy District provides augmentation water for about 1,000 irrigation wells. His comments illustrate the stress experienced by his constituents during the 2002 drought.

> *We started this spring with hope. I was hopeful that El Nino would kick in during the month of June and bring a substantial rainfall. That was my outlook for the spring… It didn’t happen. We went from hope to fear. The first part of June I got a call from the Division Engineer’s Office, Jim Hall, and he said, “You know*

*what? I think your member wells are going to be shut off, or some other wells in the neighborhood, in a week or two. We have to do something." There wasn't enough replacement water to put back in the South Platte to keep the wells pumping.*

*We then had a meeting with the Farmers Independent Ditch Company – at Frank Eckhart's place near LaSalle. Jim Hall showed up – one of Hal Simpson's assistant division engineers – and met with about ten farmers saying, "If you don't do something drastic here, your wells get shut off."….*

*One guy was sitting there looking right at me, a local producer, and I will never forget the look on his face when he heard those words that his well might be shut off. His jaw dropped, no lie, about six inches toward the floor. From the look on his face, he had just lost his farm. That is the human side of drought. Part of this is legal fallout from Empire Lodge, but there are guys out there who will lose their farms because of the drought.*

*So it is June, 2002 and everyone is fearful. Then Central started having more meetings with local ditch companies. The Greeley No. 3 Ditch Company – we met with them about five times because it appeared that certain shareholders kept taking our water. We were meeting with them because we needed that water to augment our wells. We met in a room kind of like this one in Greeley; there were about 100 people; the president stands up and says, "You know what? We are going to start locking headgates to prevent shareholders from taking too much water" And no one said a word! What does that tell you? Extra water was being diverted. So, they started locking headgates.*

*Two weeks later we had another meeting with the same shareholder, and you know what? There was not enough water available in the Cache la Poudre River to get to the end of the ditch. The president of the Greeley #3 Ditch said, "we will have to section the ditch – the top half gets water for three days, then the bottom half for three days. That is how we will share our limited water."*

*We had another meeting two weeks later. It was so dry on the Poudre River that the ditch company had to section it into thirds. This is a ditch that was build in 1870 by the Union Colony, had never been in sections during that entire period, and here they went from locking the headgates to going to halves, to going to thirds, and by August we quit fighting. There was simply no water to fight about. We were like good ol' boys, then, commenting on how the ditch was just plain dry. So it went from hope to fear to resolution – "It's dammed dry out here."*

*Let's talk about fights. I give presentations to school kids and used to say, "You know, there hasn't been a fight over water in Colorado since 1980 where someone physically got hurt. I think it was the San Luis Valley fist fight. Well, they*

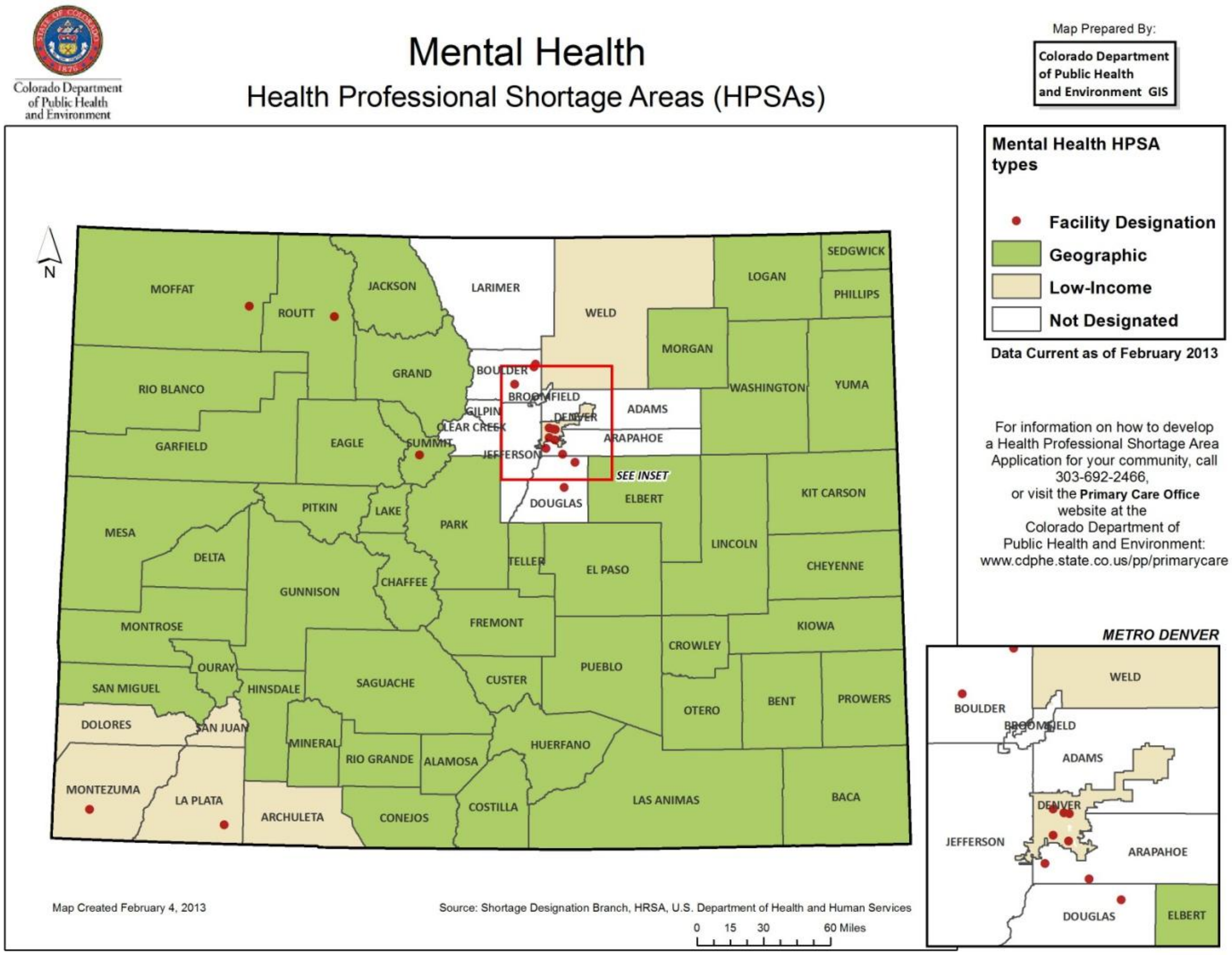
> *had a fight east of Greeley by Kersey this past August, in 2002. A fellow broke his leg, fisticuffs in the ditch…*
>
> *Next year, the wells may not get to pump. That would mean tens of thousands of acres of Colorado's farm ground will dry up and blow away, or there will be a lot of dryland wheat and small grains. We have farmers calling every day asking, "What should I plant? Will I have water next year?" We don't know. "What will the Legislature do?" We don't know. Will the Governor say, "Oh, let the wells pump. Don't' worry about the senior ditches." I doubt it, but we don't know. What's the solution? There is none – or no easy solution, that is for sure. These are really tough times, historic times. ... The numbers – streamflows, reservoir levels, etc. - are really important but the human side ... is the fascinating and historic side.*

In the urban environment, parks and green spaces are very important to behavioral health, and improve quality of life in a variety of ways. For example, a survey of desk workers found that those with a natural view from their desk found their job more challenging and were less frustrated (Wolf 1998). Another study found that people who view nature after stressful situations show "reduced physiological stress response, as well as better interest and attention and decreased feeling of fear and anger or aggression" (Wolf, 1998). While neither of these studies specifically considered the impacts of drought on behavioral health, given the proven importance of natural areas in urban areas, the health costs of plant die off or brown out during drought should be considered.

Lack of access to professionals able to recognize and treat behavioral health problems makes a community more vulnerable to the potentially devastating impacts of this problem, regardless of the causes or exacerbating stressors. Figure 11.6 shows the counties in Colorado that have been designated as low income or identified as lacking behavioral health professionals which are designated as Health Professional Shortage Areas (HSPA) (CDPHE, 2013). Most counties in Colorado are designated as having either a low-income or are located in a HSPA. Those counties not carrying any type of designation are located around Denver, extending north along the Front Range. Additional local medical facilities and services are necessary in HSPAs to meet behavioral health needs. .

Mitigating the behavioral health impacts of severe drought will require public awareness and intervention. The lack of support in these counties could represent a greater vulnerability to drought; especially in communities where agriculture and associated agribusiness are dominant employers (see Figure 11.5). While behavioral health professionals have dealt with insufficient resources for some time, Governor Hickenlooper put aside $20 million to address Colorado's behavioral health shortages in January 2013 (Steffen & Robles, 2013). The need for increased behavioral health resources is on the state's radar.

**Figure 11.6. Behavioral Health Shortage Areas**




## 11.3.3 Public Health

Public health issues during drought can result from impaired water quality and air quality. The Colorado Department of Public Health and Environment (CDPHE) is responsible for air and water quality monitoring in Colorado. Unfortunately, they have not had sufficient resources to analyze the relationship between drought and public health variables. As such, there is not systematic spatial data available for Colorado. Based on experiences in other locations and qualitative information from Colorado, the major drought-related impacts can be identified. However, future work should focus on quantifying these impacts. The key public health issues identified in this project are as follows:

- Impaired water quality resulting from sediment loading and decreased dilution.
- Decreased reservoir levels and increased temperatures can results in algae blooms.
- Additional water treatment may be required as municipalities are forced to draw water from lower reservoir levels.

- Increased bacteria loading in water bodies can pose public health risks for water based recreation.
- Air born particulate levels can climb when there are extended periods without rain. If levels get too high some residents may experience respiratory complications.
- Drought induced wildfires can significantly decrease air quality and lead to respiratory complications.

Water quality can be impaired during drought as sediment loading increases and dilution decreases. Wildfires can exacerbate this problem with debris flows and flooding. In 2002, the Southern Ute Indian tribe had to shut off its water treatment plant intake on the Pine River because of post-fire mud and debris flows into the Vallecito Reservoir. Turbidity levels generally around one Nephelometric Turbidity Units (ntu) reached 1,700 ntus (Newsome 2002). In other areas there was concern about contamination from trihalomethane (THM), a potentially carcinogenic compound. THM forms as a result of the interaction between chlorine, used in water treatment, and dissolved organic carbon, present in runoff from burnt areas. Communities serving 10,000 or more people have been required to check for THM since 1979 (Old Lyons Recorder, 2002). However, when wildfires occur, additional monitoring and treatment are required to maintain the same safety standards. This is a potentially costly undertaking and data on the extent to which this effort is carried out by individual water providers are not readily available.

Waste water treatment systems are designed based on assumptions about the flow of the water body receiving the treated discharge. If dilution levels are not adequate (i.e., receiving body flows are less than those assumed in the system design) impaired water quality can cause problems for downstream users and fish. Bear Creek between the Evergreen waste water facility and the Morrison intake experienced decreased flows and consequently increased concentration of pollutants in 2002. Fish were killed in the intervening reach and Morrison was forced to issue a bottled water advisory (Norbeck, 2002).

Changes in reservoir levels and water temperatures for municipal water sources can lead to decreased drinking water quality and increased treatment requirements. Elevated water temperatures resulting algae blooms will impact the taste and odor of drinking water even after treatment. In 2002, the water levels in Boyd Lake dropped below Greeley's water intake line and the city was forced to draw water from Loveland Lake which was experiencing a large algae bloom. Many residents complained about the bad flavor of the water (Fanciulli 2002). Water drawn from lower levels in reservoirs may contain higher levels of dissolved solids and have different properties which may subsequently impact the treatment process. For example, in the most recent drought the Mancos Rural Water Company experienced high mineral levels in their water. This was caused by low water levels in Jackson Gulch reservoir and resulted in lowered pH. When this abnormally low pH water went through the distribution lines it released mineral deposits from the inside of the pipes (Vaughan, 2002). As described in Section 11.2.2, connections have been drawn in other locations between low reservoir levels and mosquito borne diseases. This connection has not been established in Colorado but should be considered in future work.

The largest public health concern with respect to water quality is increased bacteria loading. Giardia and cryptosporidium are parasites that live in warm blooded animals and can be found in human and animal feces. If ingested they can cause intestinal illness. During drought conditions, without regular moisture to wash them away, feces accumulate on the ground. In floods or heavy rains following a period of prolonged drought, large amounts of feces can be washed into the waterways causing increased levels of contamination (Sydney Catchment Authority). In 2002, bacteria levels in Boulder Creek exceeded standards for recreational use. Officials believed the source of the bacteria was waste from wild animals and domestic pets, and that low water levels increased the concentration. In response to this hazard the city of Boulder placed signs around the creek warning that “unsafe bacteria levels in Boulder Creek may occur at any time” (Vaughan, 2002). However, there have not been studies conducted in Colorado specifically correlating drought with increased incidents of water borne disease.

Air quality can also be impaired by drought, usually with respect to particulate matter. Precipitation events can wash particulates out of the air. During prolonged dry spells this “wash out” does not occur and particulate levels can climb. Also, increased dust can enter the air as the ground becomes drier and vegetative covers dies off. Furthermore, wildfires can severely impair air quality many miles away from the fire itself. Recent analysis considered the relationship between air pollution levels, forest fires, and hospital admissions during the 2003 California wildfires. This study found that during wildfire burning periods, $PM_{2.5}$ (fine particulates less than 2.5 micrometers in size) levels increased to 3 to 6 times the EPA limit. Also coinciding with burn periods were significant increases in childhood and adult asthma, bronchitis, pneumonia, and cardiovascular disease hospital admission rates (Delfino, 2009). Hospital admission rates for asthma are not easily accessible for Colorado. Future work should investigate the connection and respiratory complications in Colorado.

As with the other impact categories for the Socioeconomic Sector, it is impossible to outline specific mitigation strategies without first understanding the specifics of the impacts. Future work should focus on correlating drought conditions with impaired air quality and water quality. Understanding these relationships is an adaptive capacity as it allows the State to focus on locations of greatest concern. State health agencies need a clear understanding of the public health issues that could result from drought and they need be prepared to respond with additional resources. Many of the water quality issues are handled by water service providers. Refer to the Municipal and Industrial Sector for additional information on municipal adaptive capacities.

## 11.4 Measurement of Vulnerability

Impacts to the Socioeconomic Sector cannot be accurately divided into impact groups. This sector encompasses the entire population of each county. As such, there are no subgroups analyzed individually. Refer to Section 3.1 of Chapter 3 (Annex B) for a general description of the numerical methodology.

# 11.5 Vulnerability Metrics

## Spatial Density Metric

### *Total Population*

All of the impacts covered for this sector have the potential to impact society as a whole. Therefore, total population was chosen as the spatial density metric. Clearly, future assessments will benefit from disaggregating based on potentially more or less vulnerable groups as well as geographies (e.g., high income, low income, young, old, etc.). July 2012 population estimates were obtained from the State Demographer's Office.[1]

## Impact Metric

Three metrics were selected on which to assess socioeconomic impacts: projected population growth, economic diversity, and behavioral health manpower shortfalls. Population growth and economic diversity were both assigned weights of 40% and behavioral health man-power shortage was weighted 20%. The behavioral health metric was weighted less than the other two because it relates to a narrower range of impacts. Also, this metric reflects the existing situation while future growth could result in other changes to shortage areas.

### *Projected population growth*

In a study examining social vulnerability to environmental hazards, it is noted that population growth is one of the social vulnerability characteristics most often cited in literature (Cutter, Boruff, and Shirley 2003). This study notes that quality housing and social services often lag behind fast population growth. Also, new residents may not be familiar with the support systems in place (Cutter, Boruff, and Shirley, 2003). All of these factors increase vulnerability. Population projections for July 2040 were obtained from the State Demographers Office[2] and the percentage increase from July 2012 population was calculated. Counties with a projected growth less than 10% were given an impact score of 1, growth rates 10-50%, 50-100%, and greater than 100% were assigned scores of 2, 3, and 4 respectively. In the future, counties with projected growth rates less than 10% should be investigated further, as this could be a sign of economic stagnation which may warrant a higher impact score.

[1] http://www.dola.state.cu.us/deog/ctf_2009estimates.html

[2] http://www.dola.state.co.us/dlg/demog/pop_cnty_forecasts.html

#### *Economic Diversity*

Economic diversity is a good indicator of the susceptibility of the general population to impacts from one specific sector. Economic base data were obtained from regional reports from the State Demographer's Office website.[3] Percentage of jobs in "agribusiness" and "tourism" were calculated by county as a percentage of the total economic excluding the "household basic" category. Counties with greater than 60% concentration in either agriculture or tourism were given impact scores of 4 and all other counties were given scores of 2. The typical four category designation used for most other impact metrics is not employed here because of the broad economic sector divisions of the economic base data. Additional analysis is needed using more detailed economic subsector data before these scores can be further differentiated.

#### *Behavioral Health Man-Power Shortages*

This metric reflects a counties ability to respond to stress during drought, as all of the counties containing any type of HSPA designation for behavioral health were given the highest impact score of 4. Counties without this designation were assigned impact scores of 2. No scores of 1 are assigned because there is no information showing which counties have superior services. Therefore, to be conservative all counties not designated as having a shortage were assigned an average score of 2.

### 11.5.1 Results

As previously discussed, there are no sub-sectors for the Socioeconomic Sector. Therefore, the ratings of individual impact metrics were mapped instead. Figure 11.7 through Figure 11.10 show the impact ratings for the socioeconomic impact metrics used along with the existing county population. In these maps shading represents the impact rating and the size of the grey circle indicates the county population. Figure 11.10 shows the overall socioeconomic vulnerability scores combining the three impact metrics. Discussion of these maps is included in the following section.

[3] http://www.dola.state.co.us/demog_webapps/eba_parameters.jsf

Figure 11.7. Population Growth Impact Score and Population Inventory by County

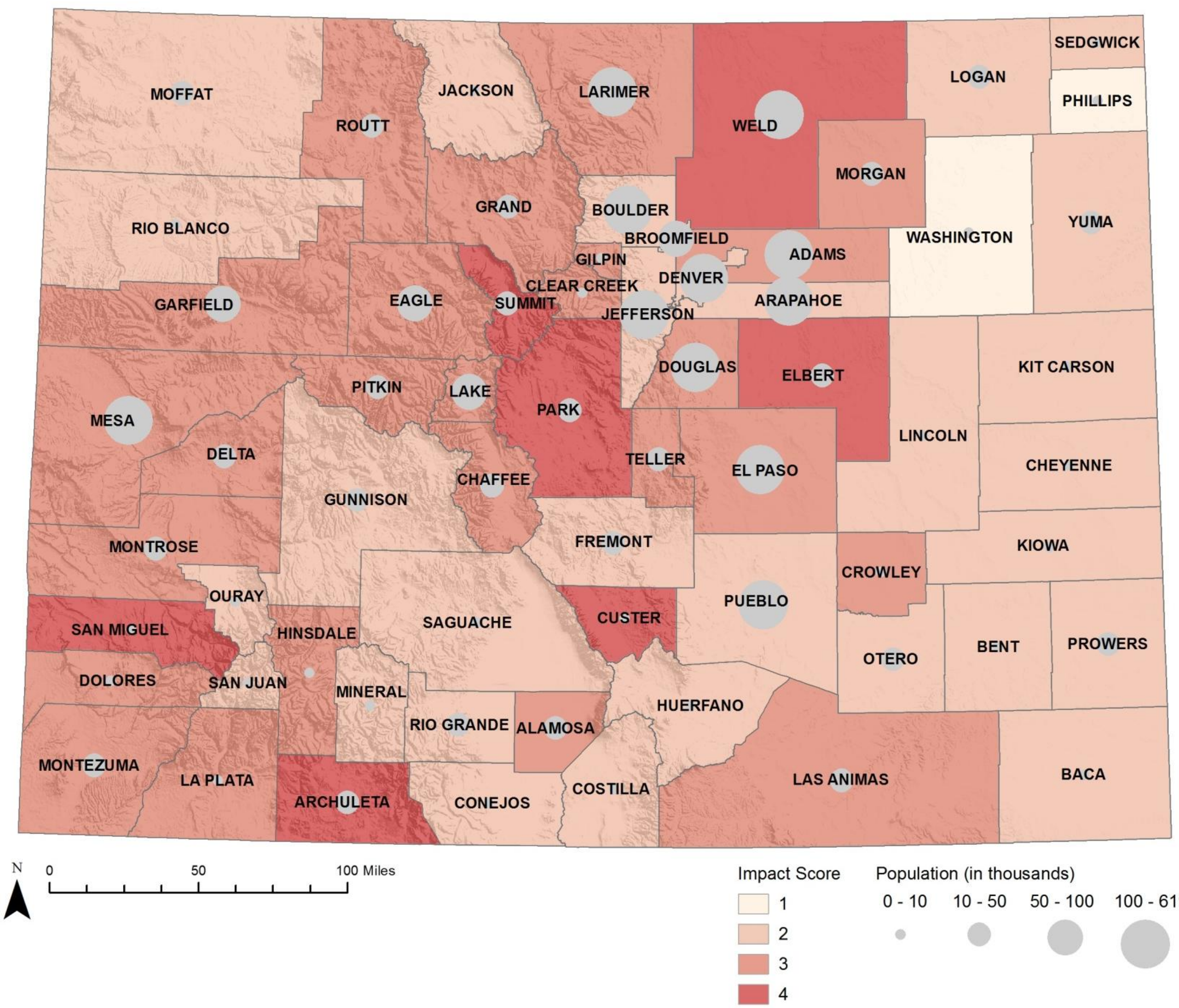



Figure Revised 2013

**Figure 11.8. Economic Diversity Impact Score and Population Inventory by County**

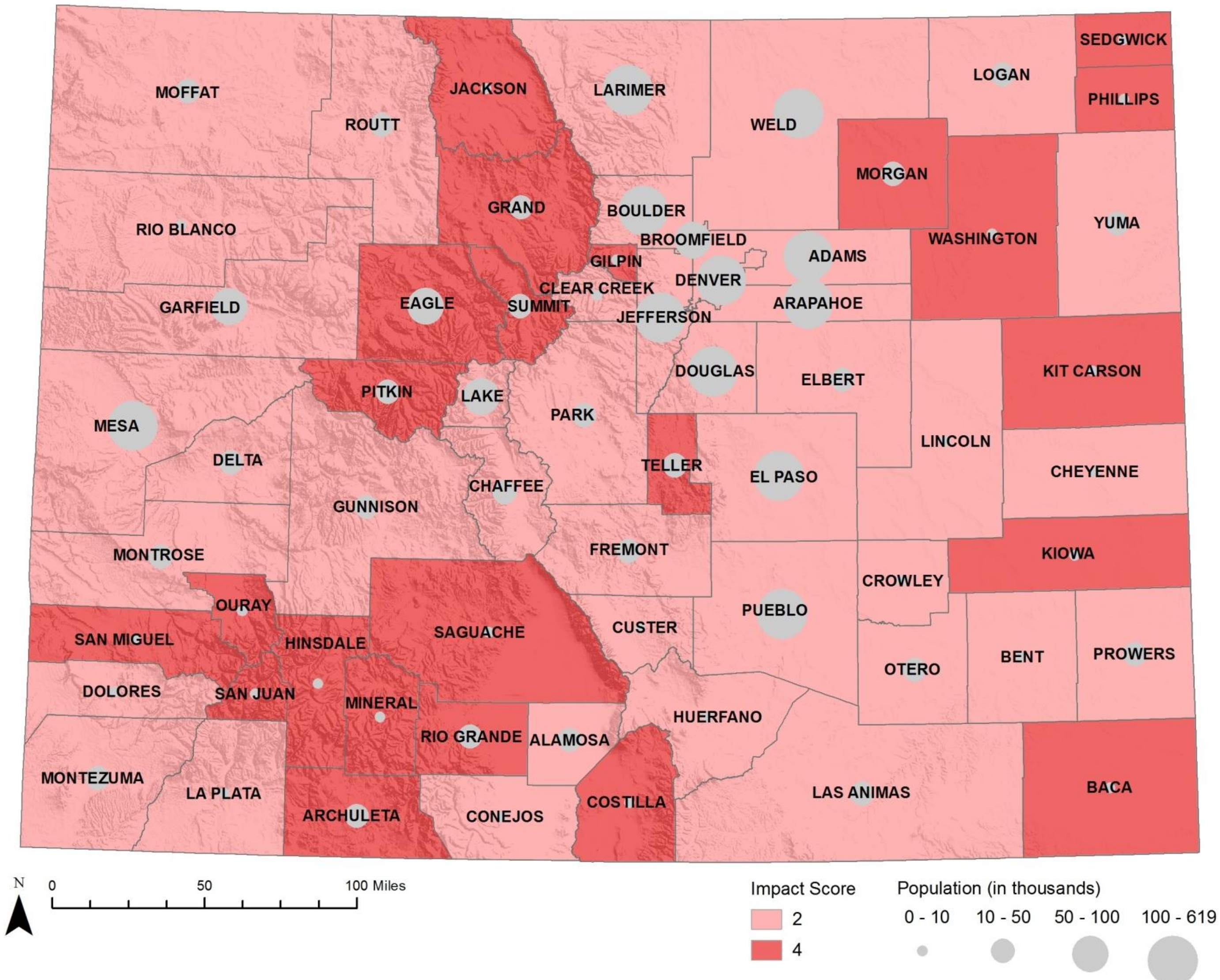



Figure Revised 2013

**Figure 11.9. Behavioral Health Manpower Shortage Impact Score and Population Inventory by County**

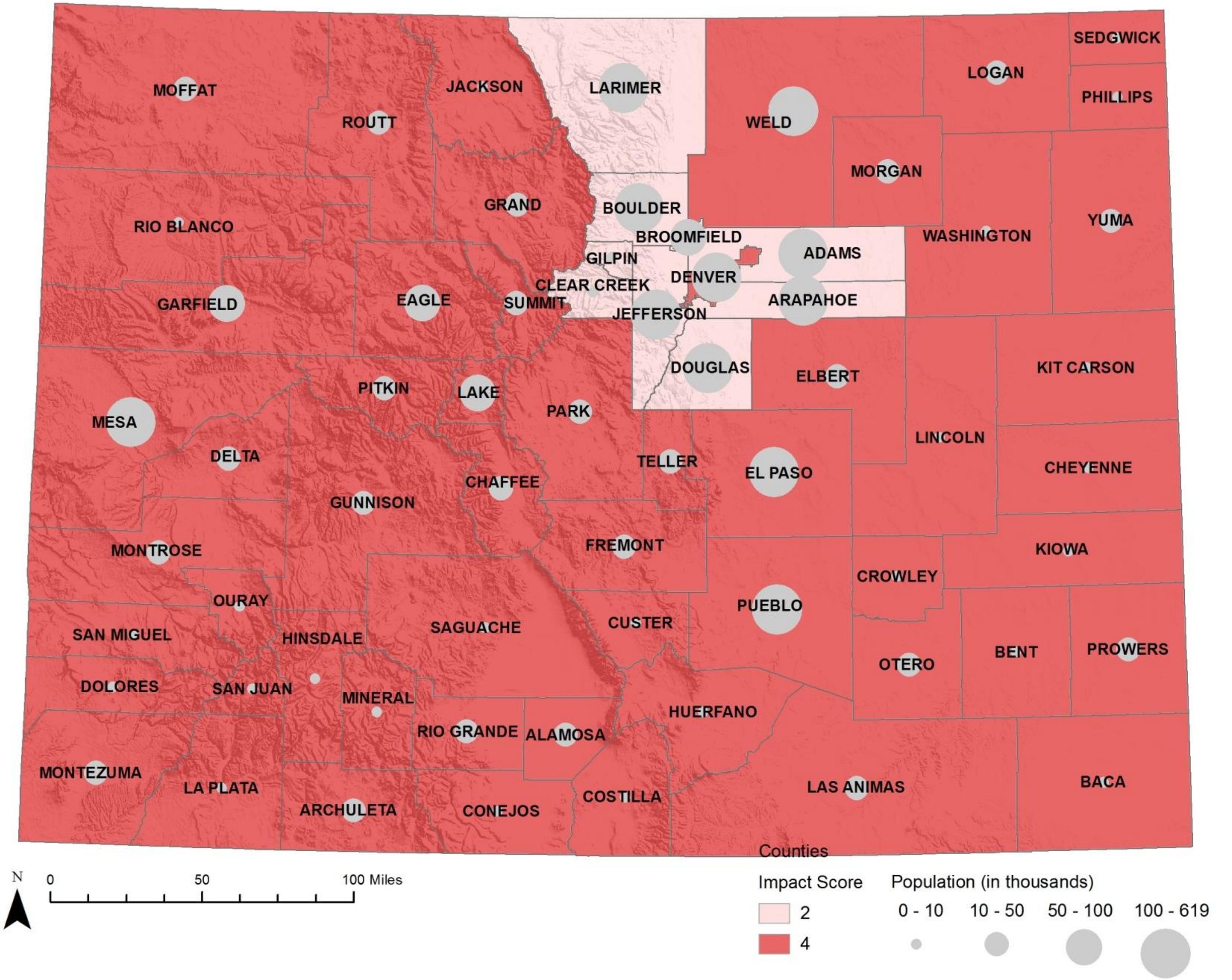



Figure Revised 2013

## Figure 11.10. Overall Socioeconomic Vulnerability Score by County

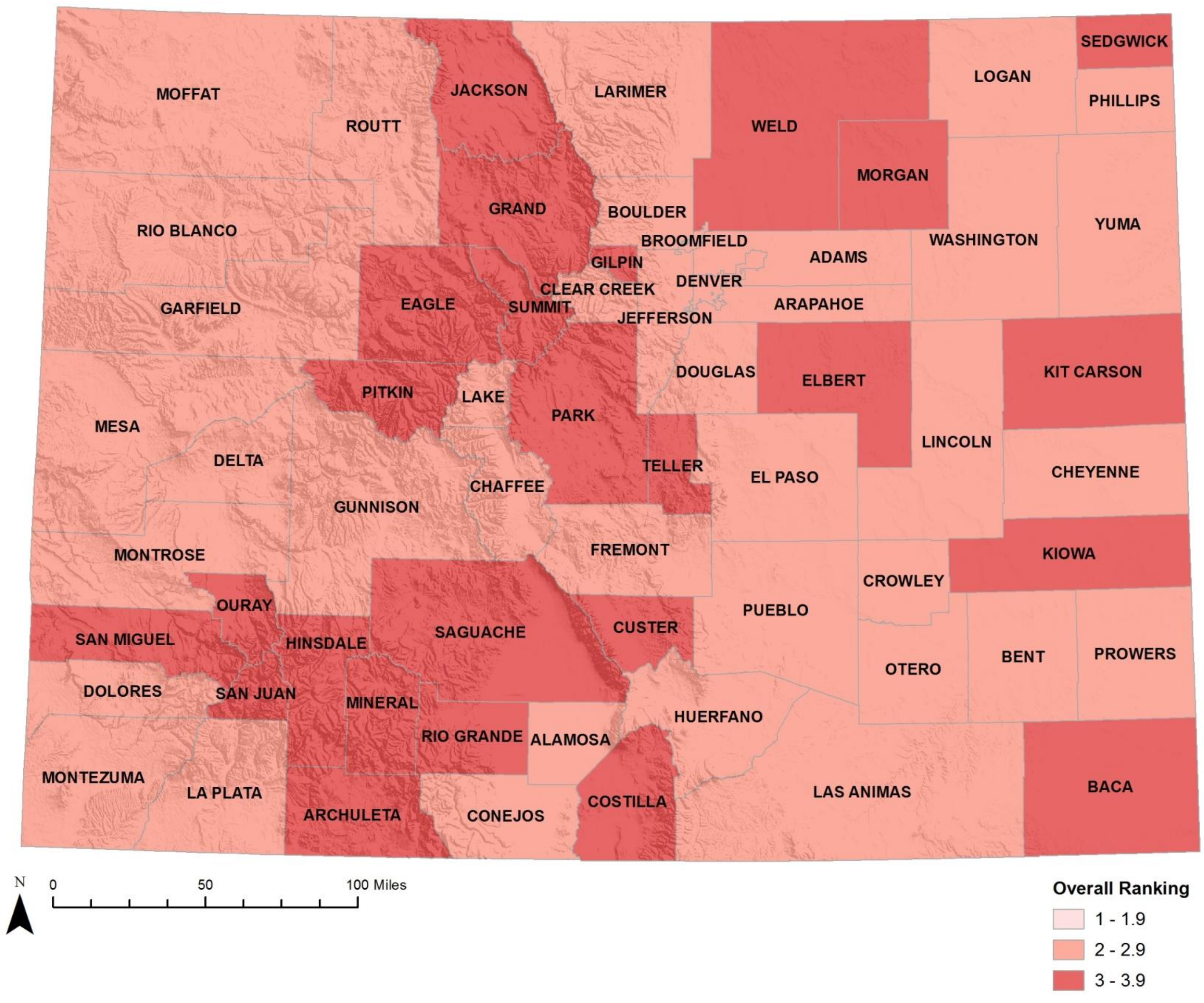



Figure Revised 2013

## 11.5.2 Spatial Analysis

Figure 11.7 shows that population growth is expected throughout the state. The counties with the lowest projected growth rates are in the eastern plains. The counties surrounding Denver and in the western portion of the state generally have higher growth forecasts. Both Summit and Park counties have the highest growth forecasts. The 2013 update has resulted in the changing of several counties' impact scores as a result of updated county population projections. For instance, the impact scores for San Miguel and Summit counties increased as a result in an increase in population projections whereas the impact score for Rio Blanco County decreased.

As explained in Section 11.5, economic diversity was assigned an impact rating of either 2 or 4. Counties whose economic base is comprised of more than 60% tourism or agriculture were assigned impact rating of 4, and all other counties were assigned an impact rating of 2 (i.e., low economic diversity leads to a high impact rating). There has not been a significant change in economic base since the 2010 Drought Mitigation Plan and Response Plan and therefore the 2013 update did not result in a change in any of the county impact scores. The high impact areas displayed in Figure 11.8 correlate with agricultural and tourism centers in the state. All counties with economic diversity impact scores of 4 on the eastern plains are centered around agriculture and tend to have very small populations. Most of the high scoring counties in other areas of the State have and economic base that is more than 60% tourism with the exception of: Jackson, Saguache, Rio Grande, and Costilla counties (they are more than 60% agriculture). Eagle County has the largest population of the counties with an impact score of 4.

Figure 11.9 shows that most of the state has a high impact ranking due to a lack of behavioral health professionals. Counties which have some form of HSPA designation for behavioral health were given a rating of 4. Many of these counties also lack economic diversity. With the exception of Gilpin, all of the counties lacking economic diversity also have behavioral health HSPA designation. This combination could lead to compounding of social implications under drought conditions.

Figure 11.10 shows the overall socioeconomic vulnerability scores. All of the counties show medium to high scores, which largely results from Colorado's expected growth and lack of economic diversity. For instance, many of the plains counties have a high reliance on agribusiness while many of the mountain counties have a high reliance on tourism and are projected to experience significant population growth. This includes Grand, Summit, Eagle, Teller, and Pitkin, counties which rely on skiing as one of the main tourist attractions. Many of the ski resorts are looking to diversify by adding summer operations (e.g., lift-accessed mountain biking). Future analysis is needed to determine if low projected growth results in decreased vulnerability.

### 11.5.3 Compound Impacts

Compound impacts are secondary effects that result from changes in sectors that are directly impacted. Many of the economic vulnerabilities discussed in this sector are secondary impacts. Section 11.3 describes many of these connections in more detail. Economic impacts are compounding in nature and continue to propagate across the Socioeconomic Sector far beyond the direct drought impact. Public health and behavioral health issues can translate directly to economic costs. Often the administrative cost of dealing with public health issues falls to the government. This can strain operating budgets and possibly divert funds from programs geared toward other sectors. There are also personal costs incurred to those affected. This could include the monetary cost of seeking treatment, time away from work or lost income. These costs compound impacts already felt across the economy. The stress of financial strain, dealing with loved ones suffering from behavioral health issues, and uncertainty about the future can result in additional behavioral health issues.

## 11.6 Recommendations

### 11.6.1 Adaptation to Drought

Socioeconomic drought adaptation should come from cooperation and planning on an individual business, community, regional, and statewide level. Businesses big and small need to consider their operations and how clients and supply chains might be impacted. Long term planning should take these possibilities into account and business operations should be designed to sustain during times of drought. It is important to establish regional cooperation across sectors during non-drought conditions so they are already in place when a disaster occurs. Those who have the ability to be flexible will be the most adaptive to drought. Obviously this will be easier for some groups than others, but in many cases adaptive capacity can be improved by fostering cooperative relationships with others and gaining a better understanding of the potential impacts.

Many of the behavioral and public health issues resulting from drought are coordinated by government entities. Statewide agencies should increase their understanding of societal impacts of drought and focus on collaborative opportunities to mitigate drought impacts. Adequate analysis does not exist to identify specific high public health hazard areas. Once vulnerable populations have been identified from a public health perspective, specific adaptive capacities can be developed for these communities. By working to assemble this information and incorporating drought into planning efforts, state agencies can improve their response capabilities. Agencies should anticipate social issues resulting from drought events and plan for additional resources during these times.

### 11.6.2 Improving Vulnerability Assessment

Data for drought induced public health and behavioral health impacts in Colorado are lacking. Based on individual reports from the 2002 and 2011-2013 droughts in Colorado and studies done in other locations, there are clear connections between health and drought that should be further examined. Until these investigations are completed it is not possible to spatially identify public health hazards resulting from drought. A data collection framework should be set up. Data on the potential public health impacts identified in Section 11.3 can be measured during future droughts.

The degree to which drought planning and business cooperation exists was not measured as part of this study. Cooperation among the private sector could be analyzed as part of future work as adaptation capabilities already in place and integrated as an adaptive capacity metric.

The list below outlines possible data collection tasks identified through this study that could improve future vulnerability assessments. In some cases these data may already exist but requires some additional manipulation to be used for these purposes. This is by no means an exhaustive list, but is intended to be a starting point for additional work. As previously noted, many of the socioeconomic drought relationships identified here have not been rigorously tested in Colorado. As this work is completed, changes to vulnerability metrics and data collection tasks will naturally need to occur.

- Data on cross sector cooperative economic groups.
- Identification and mapping of industries most vulnerable to secondary drought impacts.
- Drought-related suicide vulnerability by county (suicide risk by county already exists but these numbers will need to be adjusted for drought conditions).
- Spatial mapping of mosquito activity.
- Analysis of the water bodies in the State that are most likely to have impaired water quality with drought.
- Develop a spatial and temporal database of air quality related health warnings (e.g., blowing dust advisories, wildfire smoke) that can be correlated with respiratory-related hospital visits as a measure of drought impacts.
- Analysis on the vulnerability of municipal water supplies to impaired quality.

## 11.7 References

BBC Research & Consulting. 2008. The economic impacts of hunting, fishing and wildlife watching in Colorado. Colorado Division of Wildlife.

Colorado Department of Public Health and Environment (CDPHE). 2013. *Mental Health – Health Professional Shortage Areas (HSPAs)*. Map prepared February 4, 2013. Available at http://www.colorado.gov/cs/Satellite/CDPHE-PSD/CBON/1251618793013

Colorado Water Conservation Board. 2004. Colorado's Water Supply Future; Statewide Water Supply Initiative - Phase 1.

Colorado Water Conservation Board. 2004. Colorado Drought Water Supply Assessment.

Colorado Water Conservation Board. 2007. Colorado's Water Supply Future; Statewide Water Supply Initiative - Phase 2.

Community Agriculture Alliance Inc. The History of the Community Agriculture Alliance. Available from http://www.communityagalliance.org.

Corona Research. 2009. Colorado State Parks Marketing Assessment; Visitor spending analysis, 2008-2009.

Cutter, Susan L, Bryan J. Boruff, and W. Lynn Shirley. 2003. Social Vulnerability to Environmental Hazards. *Social Science Quarterly* 84 (2):242-261.

Dean, John, and Helen J. Stain. 2007. The impact of drought on the emotional well-being of children and adolescents in rural and remote New South Wales. *National Rural Health Association* Fall 2007:356-364.

Delfino, Robert. 2009. The relationship of respirator and cardiovascular hospital admission to the southern California wildfires of 2003. In *Occupational and Environmental Medicine*.

Edwards, Ben, Matthew Gray, and Boyd Hunder. 2009. The Impact of Drought on Mental Health and Alcohol Use. Paper read at Australian Social Policy Conference, at Sydney.

Fanciulli, Jesse. 2002. What is that yucky taste in the water? *Greeley Tribune*, August 9, 2002.

Fetsch, R. J. 2007. Managing stress during tough times.

Kalis, Martin A., Mark D. Miller, and Rachel J. Wilson. 2009. Public Health and Drought. *Journal of Environmental Health* 27 (1):10-11.

Klein, Bobbie, and Brad Udall. 2004. 2008 Drought Impact Report, A report to the governor. *Natural Hazards Observer* (July 2004):5-6.

Kraemer, Susan. 2009. Human health endangered by Australian drought. edited by E. localizer.

McIntosh, J. L., & Drapeau, C. W. (for the American Association of Suicidology). 2012. *U.S.A. suicide 2010: Official final data. Washington, DC: American Association of Suicidology* Accessed at: http://www.suicidology.org. Accessed on: June 2013.

Newsome, Brian. 2002. Southern Utes turn to wells for water. *Durango Herald*, June 24, 2002.

Norbeck, Carl. 2002. Drought impacts on water quality. Paper read at Colorado Drought Conference; Managing water supply and demand in the time of drought.

Schneckenburger, Chad A., and Robert Aukerman. 2002. The economic impact of drought on recreation and tourism. Paper read at Colorado Drought Conference; Managing water supply and demand in the time of drought.

Shaman, Jeffrey, Johnathan F. Day, and Marc Stieglitz. 2002. Drought-induced amplification of Saint Louis encephalitis virus, Florida. *Engineering Infectious Diseases* 8 (6):575-580.

State Demography Office. 2009. Regional Socio-Economic Profile.

Steffen, Jordan and Yesenia Robles. 2013. *Colorado mental health programs see chance for improvements.* Denver Post, March 17, 2013.

Sydney Catchment Authority. Giardia and Cryptosporidium.

Vaughan, Thomas. 2002. Water really is safe, just looks unhealthy. *Cortez Journal*, October 5, 2002.

Wildfires will hurt Colorado water quality. 2002. *Old Lyons Recorder*, July 25, 2002.

Wolf, Kathy. *Urban Nature Benefits: Psycho-Social Dimensions of People and Plants* 1998. Available from http://www.naturewithin.info/UF/PsychBens-FS1.pdf.

# CLIMATE CHANGE IMPLICATIONS

ANNEX C TO THE DROUGHT MITIGATION AND RESPONSE PLAN

August 2013

Prepared Pursuant to
Disaster Mitigation Act 2000 & Section 409, PL 93-288

Prepared by
Colorado Water Conservation Board
Department of Natural Resources
in Cooperation with
The Department of Public Safety
Division of Homeland Security and Emergency Management
and the Drought Mitigation and Response Planning Committee

## Table of Contents

1 Introduction ........................................................................................................ 1

2 Placing Historical Conditions in Context: Past and Future ............................................ 3

3 Other Climate Change Findings in Colorado........................................................................ 7

3.1 Colorado River Water Availability Study ..................................................................... 7

3.2 The Boulder Climate Change Study............................................................................. 21

4 Incorporating Climate Change into Planning .................................................................... 24

5 Appendix 1: Flow Comparison Charts ............................................................................... 26

6 References.......................................................................................................................... 54

# 1 Introduction

The hydrology and water resources of Colorado, and hence the economy of the state, are extremely sensitive to climate. Multifaceted stress on water supply such as irrigation, municipal demands, mandated biological flows, and the increasing need for hydropower, coupled with climate variability and change, are increasing the importance of supply forecasting to both water managers and business markets. This section of the Colorado Drought Mitigation and Response Plan was motivated by the question "what could drought look like in the future." What follows is a high level analysis of possible implications of climate change for drought in Colorado.

The International Panel on Climate Change (IPCC 2007) has indicated that projected changes in mean flow or flow variability could cause physical infrastructure to be inadequate for intended purposes, or increase the risk of failure of the water resource system under extremes of drought. While such risks may be somewhat buffered in large water systems by robustness and resilience in the design of the system, smaller systems may be extremely vulnerable under climate scenarios.

A significant body of work exists considering the effect of climate change on water availability in the western United States (refer to bibliography). While there is a large amount of uncertainty regarding future climate scenarios and how these may translate to physical conditions, it is clear that current climate is not stationary and responsible planning efforts should take into account this uncertainty. Planning approaches that rely on stationary climate and notions of hydrologic history repeating itself are inherently flawed. Water managers need to understand how the nature of drought might vary in the future and incorporate that understanding into their planning processes.

Climate change has implications both in terms of inter-annual droughts and intra-annual runoff patterns. Intra-annual spring warming can shift peak runoff earlier in the year; important for Colorado, where hydrology is driven by snowmelt. Furthermore, many studies agree that higher temperatures could lead to an increased ratio of precipitation falling as rain versus snow as well as a higher snowline, which reduces the natural storage effect of Colorado's mountain snowpack (i.e., CWCB 2008, CWCB 2012, Knowles et al 2006, Mote 2006, Saunders 2005, Udall 2007). Consequently, runoff could start earlier and end earlier. If this is the case, reservoirs would fill earlier, and what could not be stored in the spring and early summer would be spilled when agricultural demands are not as great as they are later in the summer. Decreased runoff in the summer would result in additional reservoir drawdown and many studies agree that higher temperatures and lower precipitation during summer months would further increase agricultural demands, thus causing even more stress on reservoir storage (CWCB 2008, CWCB 2012). These factors could reduce the amount of water available for year-to-year carryover storage, thus increasing drought vulnerability.

The effects of climate change are not expected to be spatially consistent across the state. For example, there may be areas that receive additional moisture even in a "drier" climate.

Recently, the Colorado Water Conservation Board commissioned a synthesis report summarizing climate change science as it relates to Colorado's water supply (CWCB 2008). Some of their key findings are copied below. Regional studies suggest a reduction in total water supply in Colorado by the mid-21st century. Temperature increases and the resulting changes in evaporation and soil moisture will also add to a trend of decreasing runoff for most of Colorado's basins (CWCB 2008). However, when all of the available climate projections are considered, about one-third indicate no change or an increase in average streamflow in the Upper Colorado River Basin (i.e. at Lees Ferry Arizona). (Harding et al., 2012)

- In Colorado Temperatures increased about 2º F from 1977-2006. All regions examined within the state warmed during this time period, except the far southeast corner, in which there was a slight cooling trend.
- Climate models project Colorado will warm 2.5º F (+1.5º F to +3.5º F) by 2025, relative to the 1950-1999 baseline, and 4º F (+2.5º F to +5.5º F) by 2050. The 2050 projections show summers warming by 5º F (3º F to 7º F). These projections also suggest that typical summer monthly temperatures will be as warm as or warmer than the hottest 10% of summers that occurred between 1950 and 1999.
- Winter projections show fewer extreme cold months, more extreme warm months, and more strings of consecutive warm winters. Typical projected winter monthly temperature, although significantly warmer than current, are between the 10th and 90th percentiles of the historical record. Between today and 2050, typical January temperatures of the Eastern Plain of Colorado are expected to shift northward by ~150 miles. In all seasons, the climate of the mountains is projected to migrate upward in elevation, and the climate of the Desert Southwest to progress up into the valleys of the Western Slope.
- Projections show a precipitous decline in lower-elevation (below 8,200 ft) snowpack across the western part of the state by the mid-21st century. Modest declines are projected (10-20%) for Colorado's high-elevation snowpack (above 8,200 ft) within the same timeframe.
- Between 1978 and 2004, the spring pulse (the onset of streamflow from melting snow) in Colorado has shifted earlier by two weeks. Several studies suggest that shifts in timing of streamflows are related to warming spring temperatures. The timing of runoff is projected to shift earlier in the spring, and late-summer flows may be reduced. These changes are projected to occur regardless of changes in precipitation.
- Throughout the western part of the state, less frequent and less severe drought conditions have occurred during the 20th century than revealed in the paleoclimate records over the last 1,000 years. Precipitation variations are the main driver of drought in Colorado and low Lake Powell inflows, including the recent drought of 2000-2007, and these variations are consistent with the natural variability observed in long-term and paleoclimate records. However, warming temperatures may have increased the severity of droughts and exacerbated drought impacts.

The drought vulnerability assessment conducted for this project considers vulnerability to drought in a contemporary sense. However, the climate change implications noted above could exacerbate future drought vulnerability for a broad array of water users. Table 1.1 outlines the connection between climate change and water management issues. As can be seen from this table impacts touch nearly every sector covered in the vulnerability assessment.

**Table 1.1. Challenges Faced by Water Managers and Projected Changes**

| Issues | Observed and/or Projected Change |
|---|---|
| Water demands for agriculture and outdoor watering | Increasing temperatures raise evapotranspiration by plants, lower soil moisture, alter growing seasons, and thus increase water demand. |
| Water supply infrastructure | Changes in snowpack, streamflow timing, and hydrograph evolution may affect reservoir operations including flood control and storage. Changes in the timing and magnitude of runoff may affect functioning of diversion, storage, and conveyance structure. |
| Legal water systems | Earlier runoff may complicate prior appropriation systems and interstate water compacts, affecting which rights holders receive water and operations plans for reservoirs |
| Water quality | Although other factors have large impact, “water quality is sensitive both to increased water temperatures and changes in patterns of precipitation” (CCSP SAP 4.3, p. 149). For example, changes in the timing and hydrograph may affect sediment load and pollution, impacting human health. |
| Energy demand and operating costs | Warmer air temperatures may place higher demands on hydropower reservoirs for peaking power. Warmer lake and stream temperatures may affect water use by cooling power plants and in other industries. |
| Mountain habitats | Increasing temperature and soil moisture changes may shift mountain habitats toward higher elevation. |
| Interplay among forests, hydrology, wildfires, and pests | Changes in air, water, and soil temperatures may affect the relationships between forests, surface and groundwater, wildfire, and insect pests. Water-stressed trees, for example, may be more vulnerable to pests. |
| Riparian habitats and fisheries | Stream temperatures are expected to increase as the climate warms, which could have direct and indirect effects on aquatic ecosystems (CCSP SAP 43.), including the spread of instream non-native species and diseases to higher elevation and the potential for non-native plant species to invade riparian areas. Changes in streamflow intensity and timing may also affect riparian ecosystems. |
| Water – and snow – based recreation | Changes in reservoir storage affect lake and river recreation activities; changes in streamflow intensity and timing will continue to affect rafting directly and trout fishing indirectly. Changes in the character and timing of snowpack and the ratio of snowfall to rainfall will continue to influence winter recreational activities and tourism. |
| Groundwater resources | Changes in long-term precipitation and soil moisture can affect groundwater recharge rates; coupled with demand issues, this may mean greater pressure on groundwater resources. |

Source: Reproduced from CWCB, 2008

# 2 Placing Historical Conditions in Context: Past and Future

As a component of the 2013 update to this Plan, projections of future streamflow were obtained for a number of locations in the Colorado, South Platte and Arkansas River basins from the CRWAS and the Joint Front Range Climate Change Vulnerability Study (Front Range Study, WRF, 2012). Reconstructions of prehistoric flows have been made for a large number of stream gauges in Colorado (NOAA, 2013). Sixteen locations were selected where both climate change projections and prehistoric reconstructions exist. These locations, and the sources of data for the comparisons, are shown in Table 1.2.

## Table 1.2. Gauge Locations for Comparisons

| BASIN | PALEO GAGE | PROJECTED GAGE | |
|---|---|---|---|
| | | CRWAS | JFRCCVS |
| **Upper Arkansas** | | | |
| Arkansas | Arkansas River near Canon City (07096000) | - | UC_Ark_Salida 07091500 |
| **Colorado** | | | |
| Animas | Animas River at Durango, CO (09361500) | ARDUR 9361500 | - |
| Blue | Blue River above Green Mountain Reservoir (09053500) | BRBGM 9057500 | UC_GreenMountain 9057500 |
| Colorado | Colorado River near Kremmling, CO (09058000) | CRKRE 9058000 | - |
| Dolores | Dolores River near Cisco, UT (09180000) | DRGAT 09179500 | - |
| Fraser | Fraser River at Granby (09034000) | - | UC_Fraser 09034000 |
| Roaring Fork | Roaring Fork at Glenwood Springs, CO (09085000) | RFGWS 09085000 | - |
| San Juan | San Juan River near Archuleta, NM (09355500) | SJRAR 09355500 | - |
| White | White River near Watson, UT (09306500) | WRCUT 09306395 | - |
| Yampa | Yampa River near Maybell, CO (09251000) | YRMBL 09251000 | - |
| **South Platte** | | | |
| Big Thompson | Big Thompson River at Mouth of Canyon near Drake (06738000) | - | SP_BigThompson 6738000 |
| Boulder Creek | Boulder Creek at Orodell | - | SP_BoulderCreek |
| Cache la Poudre | Cache la Poudre River at Mouth of Canyon (06752000) | - | SP_Poudre 06752000 |
| South Platte | South Platte River at South Platte (06707500) | - | SP_SouthPlatte |
| South Platte | South Platte River below Cheesman Reservoir | - | SP_Cheesman |
| St. Vrain | St. Vrain Creek at Canyon Mouth near Lyons | - | SP_StVrain |

At these locations, graphical comparisons of prehistoric, historical and projected flows were developed that provide context within which to consider the 56-year period experienced from 1950 through 2005. Figure 1.1 shows the comparison for the Yampa River near Maybell. The 56 year running average of the paleo data is the solid blue line. The end of the solid blue line represents average conditions over the most recent 56 years. The dashed lines show the averages for each climate-impacted flow scenario. The highest and lowest 56-year average flows in the prehistoric data encompass most of the climate impacted flow averages, with the exceptions of the warm, wet scenarios for both 2040 and 2070.

Figure 1.2 shows the comparison for the Arkansas River at Salida. In contrast to the Yampa, the prehistoric flows show much less variability, and all but one of the projected scenarios fall outside the maximum and minimum flows of the prehistoric reconstruction. Also in contrast to the Yampa, six of the eight projected scenarios fall below the historical average flow (indicated by the end of the blue trace). This difference is indicative of a trend that is generally apparent in the CRWAS and Front Range Study results, where projections of future flows tend to be wetter in the northernmost portions of the State, and tend to be drier in the more southerly portions of the State.

## Figure 1.1. Flow Comparison, Yampa River near Maybell

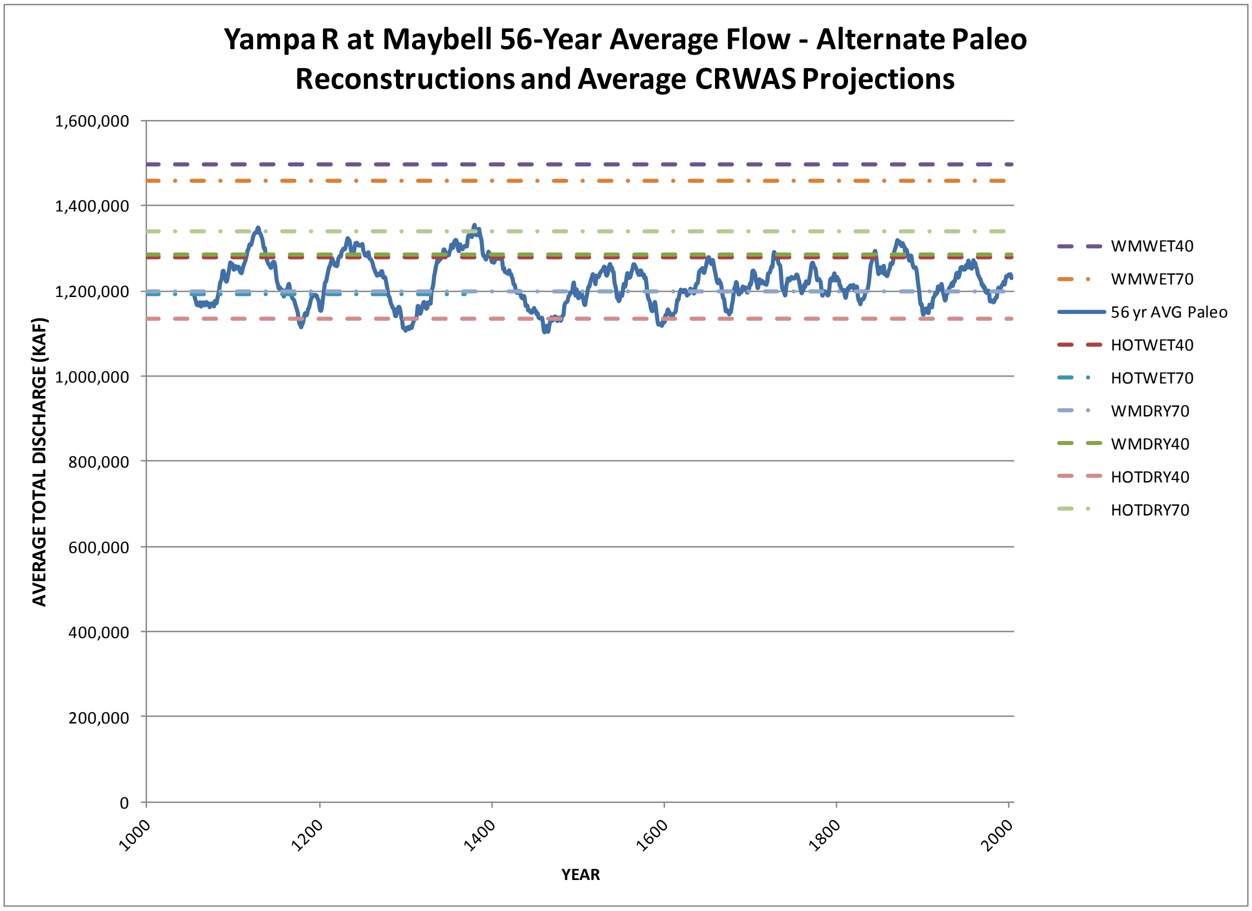
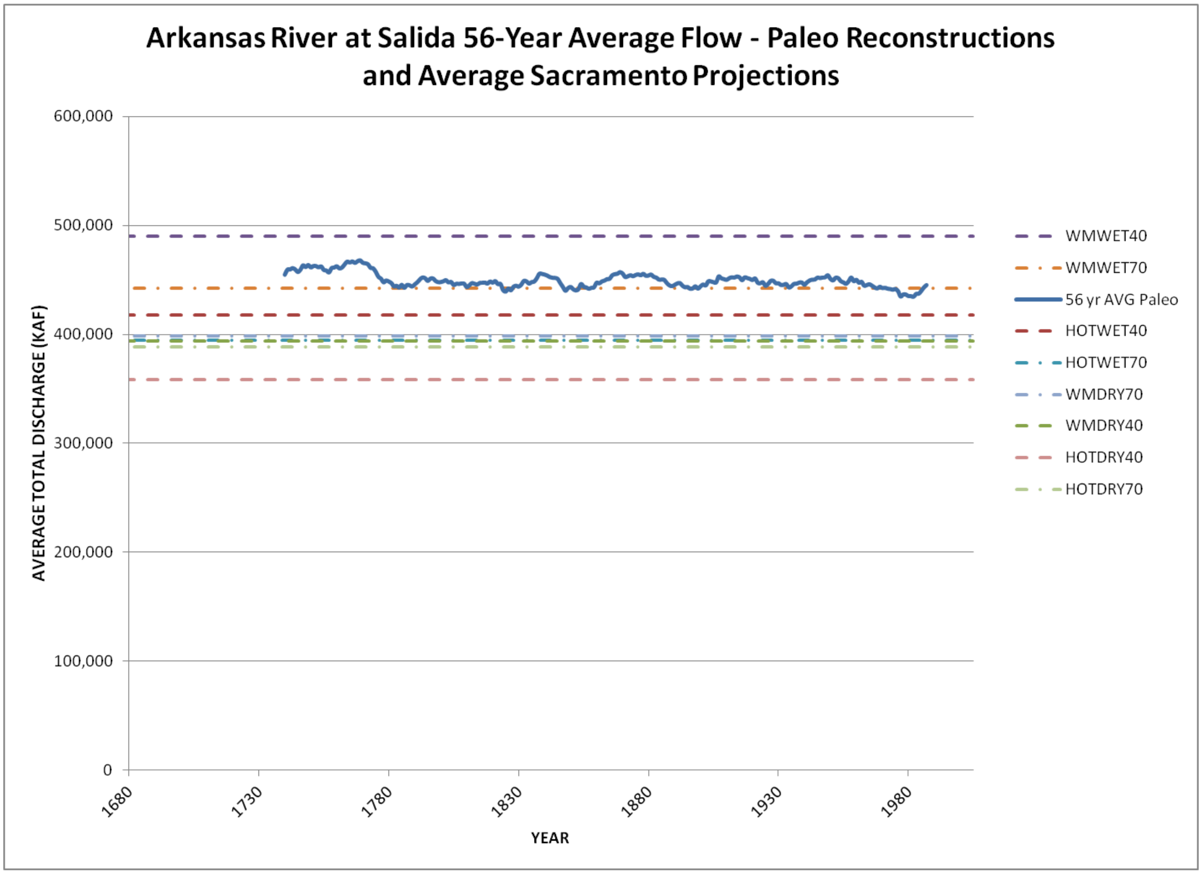


**Figure 1.2. Flow Comparison, Arkansas River at Salida**




Comparisons for all sixteen locations can be found in Appendix 1 to this Annex. The comparisons can be used to better understand the degree to which projected, climate-impacted streamflows differ from historic and prehistoric conditions. Because there is greater scientific confidence in the quantification of prehistoric flows than in the quantification of projected flows, there is a better scientific basis to support adaptation measures based on the variability of prehistoric flows. In the case of the Yampa, a system that performs acceptably over the range of prehistoric flows can be expected (within the limits of our current state of knowledge) to be reasonably well-adapted to future climate. In contrast, on the Arkansas, most of the projections fall outside the range of the prehistoric flows, and therefore decisions regarding adaptation must primarily consider the projections of future flow in order to develop management strategies that will meet future needs. .

It is important to keep in mind that these comparisons use 56-year average flows. Annual droughts, and multi-year spells will be superimposed on the average flows, so the curves and projections do not represent the most severe conditions that may face a system.

# 3 Other Climate Change Findings in Colorado

## 3.1 Colorado River Water Availability Study

The Colorado River Water Availability Study (Water Availability Study) sponsored by the Colorado Water Conservation Board, investigated water availability on the Colorado River under a range of climate change scenarios. The Study Area for this work was the Colorado River Basin within the State of Colorado.[1] The methods are discussed in more detail in the following section. The discussion below outlines the primary findings of this study based on climate projections for 2040.

### Preliminary Colorado River Water Availability Study Findings

Compared to current conditions, CRWAS Phase I findings show that projected future climate conditions may lead to the following changes to hydrologic conditions in the Colorado River basin within western Colorado.

#### *Temperature*

- At northern climate stations (e.g., Grand Lake, Yampa, and Hayden), temperature increase is less than for the Study Area average.
- Every climate projection shows an increase in average annual and monthly temperature
- Study Area average annual increases range from 1.8°F to 5.2°F

#### *Precipitation*

- Generally increases in the winter months and decreases in the summer months
- Average winter increases are larger in the northern portion of the Study Area, and smaller in the southwestern portion of the Study Area
- Increase in temperatures causes a shift from snow to rain in the early and late winter months
- Study Area winter average changes by 102% to 116% of historical
- Study Area April through October average changes by 82% to 105% of historical

#### *Crop Irrigation Requirement (based on acreage and crop types identified in a 1993 acreage inventory)*

- Increases for each of the climate projections throughout the Study Area
- Increases are primarily due to higher temperature and lower irrigation-season precipitation, which increase:
  - the number of days in the growing season for perennial crops, and
  - the crop demand for irrigation water

---

[1] The CRWAS also evaluated the impact of climate change on streamflows at Lee's Ferry on the Colorado River.

- Peak CIR continues to occur in the same month as it has historically
- Study Area average annual CIR increases by 1.9 to 7.4 inches for individual climate scenarios
- Study Area average annual growing season increases by 8 to 32 days

### *Crop Irrigation Requirement for Study Basins*

- Every Study Basin shows an increase for all climate scenarios
- The White River basin shows the largest percentage increase
- The Yampa River basin shows the smallest percentage increase

### *Natural Flow*

#### Historical Hydrology

- The longest (historic) wet spells range from 4 to 16 years in length, with only 4% longer than 7 years
- Historic dry spells range from 3 to 11 years in length with 95% being 5 or 6 years long
- Moving from north to south, historic dry spells generally become shorter and historic west spells generally become longer

#### Extended Historical Hydrology

- The return interval of historic wet and dry spells vary widely from location to location
- Return intervals are shorter for locations that have shorter historic spells and longer for locations that have longer historic spells
- At 90% of the sites, the return interval of the historic dry spell ranges from about 8 to about 200 years, and the return interval of the historic wet spell ranges from about 13 to about 100 years
- In very general terms, locations with shorter historic spells should expect longer spells and vice versa

#### Climate-Adjusted Hydrology

- At over 80% of the sites, the majority of climate cases suggest a decrease in annual flow.
- Annual flow is more likely to increase in parts of the Yampa River basin and in some higher elevation watersheds
- Annual flow is more likely to decrease in southwestern watersheds and at lower elevations
- At 75% of locations, all climate cases showed a shift toward earlier runoff, and at all locations, some climate cases showed a shift toward earlier runoff
- Higher peak flows may be beneficial for riparian health; however, lower flows in late summer and fall may impact other non-consumptive needs
- At three locations, all climate cases showed increases in average annual flows. At the remaining 224 locations, the climate cases contained the historic average annual flow

- Runoff shifts earlier by an average of 8 days

### *Modeled Streamflow*

- Flows are generally higher than historical in May and June and lower in July through March
- Flows are generally lower than historical in three of the five climate projections, but generally higher than historical in two projections
- The historical annual low-flow values generally fall within the range of projected low-flow values

### *Water Available to Meet Future Demands*

- Upstream locations on main rivers and smaller tributaries generally have less flow available to meet future demands as a percent of modeled streamflow than gages farther downstream that include more tributary inflow
- Most locations show less water availability for three of the five climate projections. However, for one of the projections, the locations selected to display CRWAS results show more water available.
- The climate projects generally indicate more water availability in April and May, corresponding to the shift in the natural flow hydrographs
- The historical annual minimum water availability values generally fall within the range of projected minimum water availability values for 2040 throughout the Study Area

### *Modeled Reservoir Storage*

- Earlier peak runoff, reduced flows during the peak irrigation season, and increased crop demands result in more use of reservoirs (more reservoir fluctuation)
- Reservoirs are generally drawn down to lower levels, and generally fill to historical levels

### *Modeled Consumptive Use*

- Average annual consumptive use in the Yampa, White, Upper Colorado, and Gunnison basins is greater for every climate projection. Average annual consumptive use in the San Juan basin is less for every climate projection
- Total consumptive use for the Study Area is greater than for historical climate conditions for most climate projections
- Although modeled consumptive use generally increases, not all crop demands are met in any basin. Similar to historical conditions, there continue to be water shortages on tributaries and in the late irrigation season for the projected conditions
- Projected consumptive use increases in most months in every basin except the San Juan. Projected consumptive use in the San Juan generally increases in spring months only

Phase I of the Water Availability Study considered five climate change scenarios, all treated as if they were equally probable. Temperature and precipitation changes from Global Climate Models

(GCMs) were translated to natural flows using the Variable Infiltration Capacity (VIC) model. The historical hydrology used for comparison is the observed flow over the 56-year period from 1950-2005. Additionally, historical streamflow records were extended using previously published tree ring records dating back more than 1,200 years. The 56 year historical hydrology was re-sequenced into 100 equally likely 56 year traces based on the probabilities of transitioning between wet and dry years that were derived from the paleohydrology record. These traces are called the alternate historical hydrology traces in this report. The discussion in the following section outlines the technical approach of the Water Availability Study in more detail. The results of the Water Availability Study include information about how projected future climate might affect drought duration, drought intensity and drought frequency.

The Water Availability Study analyzed drought frequency and intensity compared to the longest drought observed throughout the 56-year period of record. Modeled natural flow results from each of the five equally likely climate change scenarios and the historical hydrology were each re-sequenced to produce a record 5,600 years long, equivalent to 100, equally likely, 56 year hydrology traces Drought durations and intensities (the degree to which flows are reduced during the drought) were calculated for each of the 100 traces. Drought conditions were defined as any time flow drops below the historical mean flow.

All of the droughts identified for each of the six scenarios (five climate change scenarios and the alternate historical hydrology) were used to calculate the return interval and the intensity of a dry or wet spell that has the same length as the longest spell experienced during the historical period. This approach answers the question: What is the likelihood that a spell of a particular length will begin next year (now, or in 2040 or 2070)?

### Colorado River Water Availability Study Technical Approach Summary

- Historical Hydrology includes hydrology observed for period 1950-2005.
- Paleohydrology is based on an extended record dating to AD 762 (more than 1,200 years ago)
  - Provides estimated streamflow duration/frequency/intensity for years prior to gaged data.
  - Estimated using statistical models applied to tree ring data.
  - Paleohydrology flow magnitudes are derived from the historical flow record (1950-2006).
  - Flow sequences are derived from paleohydrology flow record to provide more robust variety of year to year flow sequences than historical record.
  - Re-sequencing – Future sequences of wet and dry years cannot be predicted; therefore, a 5600-year hydrologic trace was developed.
    - This is statistically equivalent to the 10056-year traces used for modeling in CRWAS.
    - Each 56-year period in the 5600-year trace is equally probable.
- Climate-Adjusted Hydrology is based on five climate projections selected in consultation with the State's Climate Change Technical Advisory Group.

- Five climate projections were chosen for each of the 2040 and 2070 planning horizons.
- Each of the selected climate projections is treated as being equally probable; but differs from the others.
- Projections are “downscaled” to the Colorado River basin and temperature and precipitation changes were translated into effects on hydrology using the VIC hydrologic model. Flow sequences (dry/wet spells) were derived from those used in the paleohydrology flow record because it has been shown in the literature that GCM’s alone do not simulate flow sequences reliably.

Selected results from CRWAS are displayed in Tables 1.3 through 1.6 and Figures 1.3 through 1.8. Results for 42 sub-basins and selected weather stations and reservoirs may be found in Appendix C of the CRWAS final report (CWCB 2012a)

Tables 1.3 through 1.6 present the characteristics of spells for the observed period, the Extended Historical Hydrology (EHH) and the Climate-Adjusted Hydrology (CAH). (CWCB, 2012a, Appendix C)

The observed spells are characterized in the top panel of the table. For example, for the Colorado River near Cameo (Table 1.3), the observed drought (during the period 1950 through 2005) was six years in length and, for those six years, the flow was, on average, 19 percent below the long-term mean flow. Similarly, the observed surplus was five years in length and flows were 46 percent greater than the mean during that period.

The statistics of the EHH (developed by re-sequencing) are shown in the first row of the bottom panel. The results in Table 1.3 show that droughts of six years in length returned every 31 years and surpluses of five years in length returned every 19 years. The average drought intensity for six-year droughts was -24 percent, somewhat greater than the historical intensity (-19 percent). The average intensity of surplus spells of five years in length was 27 percent, less than the historical intensity (46 percent).

The statistics for the CAH are in the ten rows below the statistics for the EHH in the lower panel. The first five rows are the results for the projections for 2040 while the next five rows are the results for the projections for 2070. Because the CAH and the EHH are based on the same year sequences, it is best to compare those two results rather than trying to compare the CAH to the historical observed event. On that basis, in Table 1.3 for the 2040 time frame cases A, B and C show more frequent six-year droughts than is the case in the EHH; cases D and E show droughts that are less frequent. For 2070, cases F and G show six-year droughts that are substantially more frequent than the EHH, cases H and I show 6-year droughts that are approximately as frequent as in the EHH, and case J shows droughts that are substantially less frequent. For the 2040 time frame, cases A, B and C show five-year surpluses that are less frequent than was the case in the EHH, case D shows 5-year surpluses that are approximately as frequent as the EHH and case E shows 5-year surpluses that are substantially more frequent than the EHH. For the 2070 time frame, cases F, G and H show five-year surpluses that are less frequent than was the case in the

EHH, case I shows 5-year surpluses that are approximately the same frequency as in the EHH, and case J shows more frequent surpluses than in the EHH. Deficit intensities vary from case to case, but not by a large amount except for cases E and J; surplus intensities vary over a wider range.

When a spell of a length equal to or exceeding the historical spell is not encountered in a particular climate case this is designated by a double dash in the return interval and intensity fields. For example, in Table 1.4, Yampa River near Maybell, a drought of six years in length was not encountered in climate case J for 2070.

**Table 1.3. Colorado River near Cameo**

| | Observed Spells | | | |
|---|---|---|---|---|
| | Length of Spell (years) | | Intensity of Spell (% of mean) | |
| | Drought | Surplus | Drought | Surplus |
| | 6 | 5 | -19% | 46% |

| Alternative Hydrology Spells | | | | |
|---|---|---|---|---|
| | Return Interval of historic spell length (years) | | Average Annual Deficit/Surplus (% of mean) | |
| Case | Drought | Surplus | Drought | Surplus |
| Alternative Historical | 31 | 19 | -24% | 27% |
| 2040 Climate A | 6 | 933 | -30% | 23% |
| 2040 Climate B | 27 | 47 | -29% | 19% |
| 2040 Climate C | 22 | 49 | -28% | 18% |
| 2040 Climate D | 53 | 20 | -25% | 29% |
| 2040 Climate E | 800 | 6 | -19% | 36% |
| 2070 Climate F | 6 | 5600 | -31% | 24% |
| 2070 Climate G | 12 | 267 | -31% | 18% |
| 2070 Climate H | 27 | 66 | -32% | 17% |
| 2070 Climate I | 30 | 22 | -23% | 27% |
| 2070 Climate J | 127 | 13 | -19% | 38% |

## Table 1.4. Yampa River near Maybell

| | Observed Spells | | | |
|---|---|---|---|---|
| | Length of Spell (years) | | Intensity of Spell (% of mean) | |
| | Drought | Surplus | Drought | Surplus |
| | 6 | 5 | -26% | 48% |

| Alternative Hydrology Spells | | | | |
|---|---|---|---|---|
| | Return Interval of historic spell length (years) | | Average Annual Deficit/Surplus (% of mean) | |
| Case | Drought | Surplus | Drought | Surplus |
| Alternative Historical | 31 | 14 | -28% | 31% |
| 2040 Climate A | 15 | 79 | -30% | 28% |
| 2040 Climate B | 56 | 21 | -29% | 34% |
| 2040 Climate C | 56 | 21 | -28% | 35% |
| 2040 Climate D | -- | 6 | -- | 51% |
| 2040 Climate E | 800 | 8 | -21% | 46% |
| 2070 Climate F | 24 | 51 | -34% | 29% |
| 2070 Climate G | 62 | 17 | -29% | 43% |
| 2070 Climate H | 66 | 15 | -28% | 41% |
| 2070 Climate I | 1120 | 8 | -23% | 44% |
| 2070 Climate J | -- | 2 | -- | 78% |

## Table 1.5. Gunnison River near Grand Junction

| | Observed Spells | | | |
|---|---|---|---|---|
| | Length of Spell (years) | | Intensity of Spell (% of mean) | |
| | Drought | Surplus | Drought | Surplus |
| | 5 | 6 | -33% | 50% |

| Alternative Hydrology Spells | | | | |
|---|---|---|---|---|
| | Return Interval of historic spell length (years) | | Average Annual Deficit/Surplus (% of mean) | |
| Case | Drought | Surplus | Drought | Surplus |
| Alternative Historical | 17 | 20 | -30% | 30% |
| 2040 Climate A | 5 | 2800 | -40% | 26% |
| 2040 Climate B | 13 | 187 | -35% | 32% |
| 2040 Climate C | 12 | 187 | -36% | 29% |
| 2040 Climate D | 18 | 35 | -31% | 36% |
| 2040 Climate E | 30 | 15 | -22% | 48% |
| 2070 Climate F | 4 | -- | -40% | -- |
| 2070 Climate G | 8 | 311 | -39% | 15% |
| 2070 Climate H | 13 | 187 | -38% | 28% |
| 2070 Climate I | 13 | 187 | -33% | 37% |
| 2070 Climate J | 19 | 48 | -28% | 47% |

**Table 1.6. San Juan River near Carracas**

| | Observed Spells | | | |
|---|---|---|---|---|
| | Length of Spell (years) | | Intensity of Spell (% of mean) | |
| | Drought | Surplus | Drought | Surplus |
| | 4 | 6 | -35% | 47% |

| Alternative Hydrology Spells | | | | |
|---|---|---|---|---|
| | Return Interval of historic spell length (years) | | Average Annual Deficit/Surplus (% of mean) | |
| Case | Drought | Surplus | Drought | Surplus |
| Alternative Historical | 17 | 34 | -36% | 35% |
| 2040 Climate A | 2 | -- | -40% | -- |
| 2040 Climate B | 6 | 207 | -38% | 31% |
| 2040 Climate C | 11 | 86 | -37% | 45% |
| 2040 Climate D | 14 | 57 | -33% | 52% |
| 2040 Climate E | 61 | 16 | -34% | 54% |
| 2070 Climate F | 3 | -- | -44% | -- |
| 2070 Climate G | 3 | -- | -46% | -- |
| 2070 Climate H | 9 | 509 | -44% | 45% |
| 2070 Climate I | 6 | 200 | -38% | 33% |
| 2070 Climate J | 18 | 64 | -39% | 57% |

The Water Availability Study also provided information that helps frame projected low-flow conditions in the context of conditions over the 56-year historical baseline. Figure 1.3 illustrates the effect of projected future climate conditions on mean flows and on low-flow events.

**Figure 1.3. Low Flow Comparison Chart, Colorado River near Cameo**

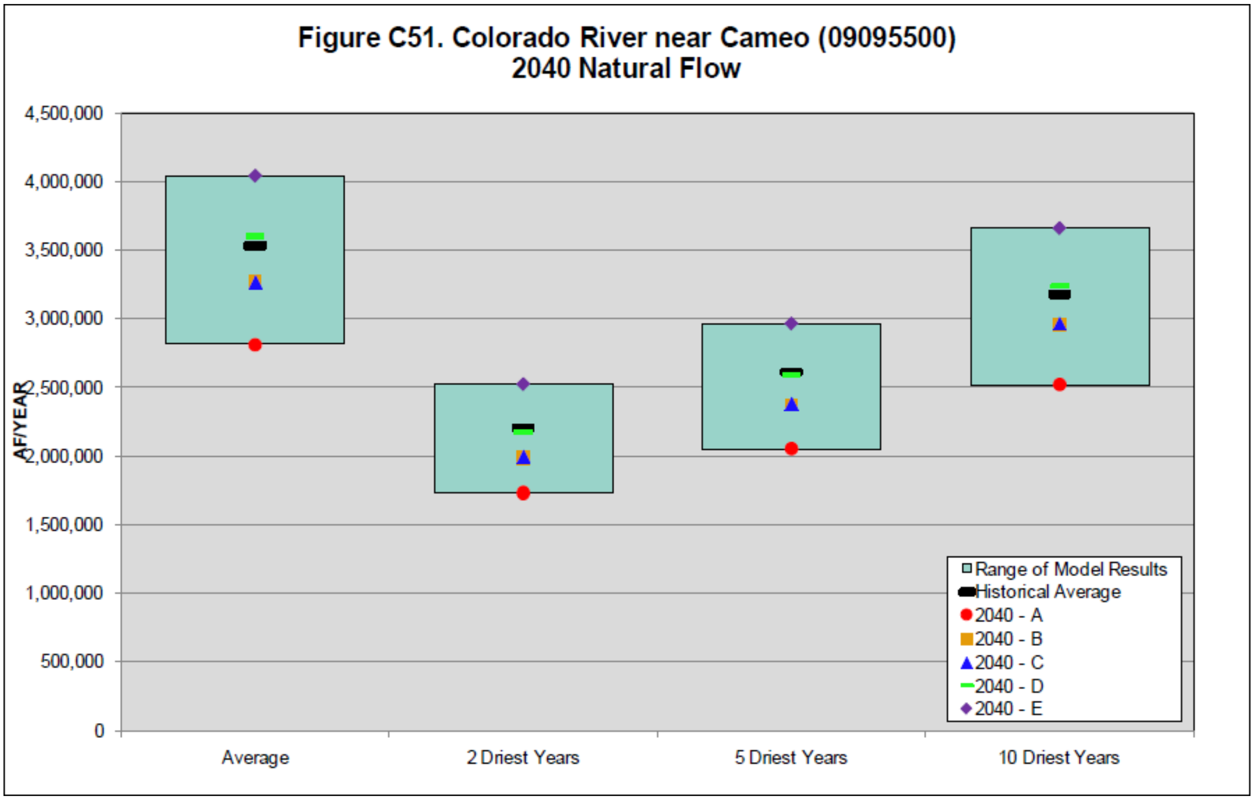
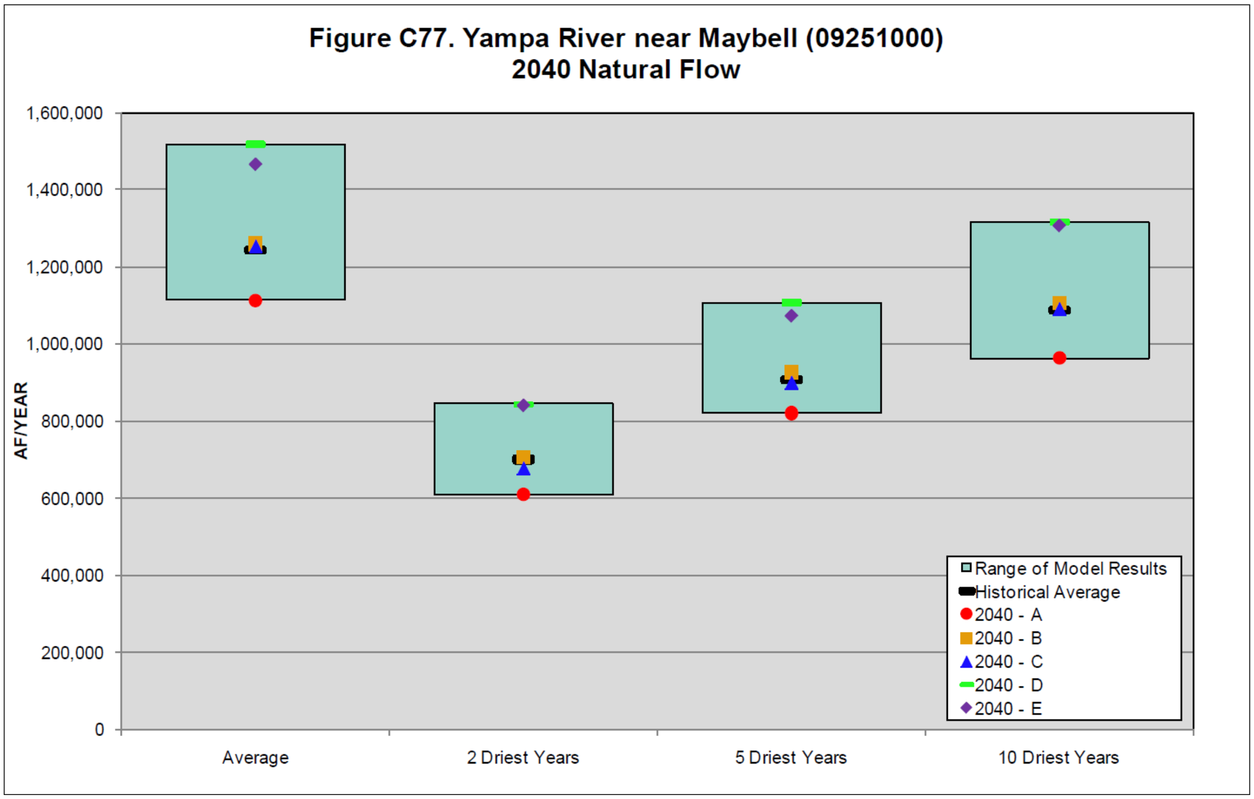


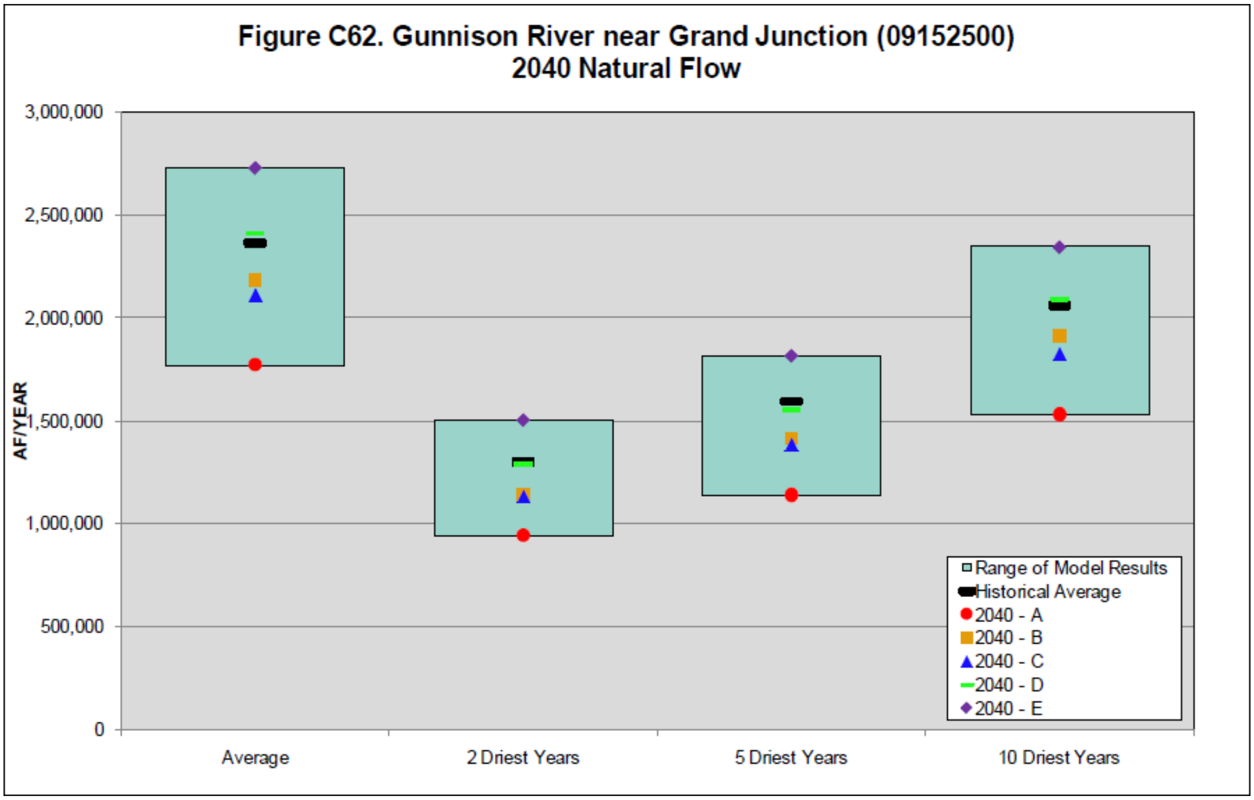

Figure 1.3 provides a direct comparison of projected conditions to conditions at Cameo during the 56-year historical baseline. From left to right, the chart represents four statistics of annual flow: average annual flow over the 56-year study period, the lowest consecutive 2-year average flow in the 56-year study period, the lowest consecutive 5-year average flow in the 56-year study period and the lowest consecutive 10-year average flow in the 56-year study period (CWCB 2012a). For each statistic, several pieces of information are shown. The red filled diamond represents the value of the statistic from the historical record during the study period. The estimated values of the statistics for the five different projections of future climate are represented by dashes. The wide cyan-colored bars show the overall range of the projected future values of the statistic.

Depending on the selected projections, average flows and low flows for durations of 2, 5, and 10 years may be greater or lesser than the corresponding condition during the 56-year historical baseline. As noted above, wetter scenarios will tend to exhibit droughts that are shorter and less intense that those experienced during the 56-year baseline period. Conversely, drier scenarios will tend to exhibit droughts that are longer and more intense than those experienced during the 56-year baseline period. Figures 1.4, through 1.6 show the same information for the Yampa River near Maybell, the Gunnison River near Grand Junction, and the San Juan River near Carracas.

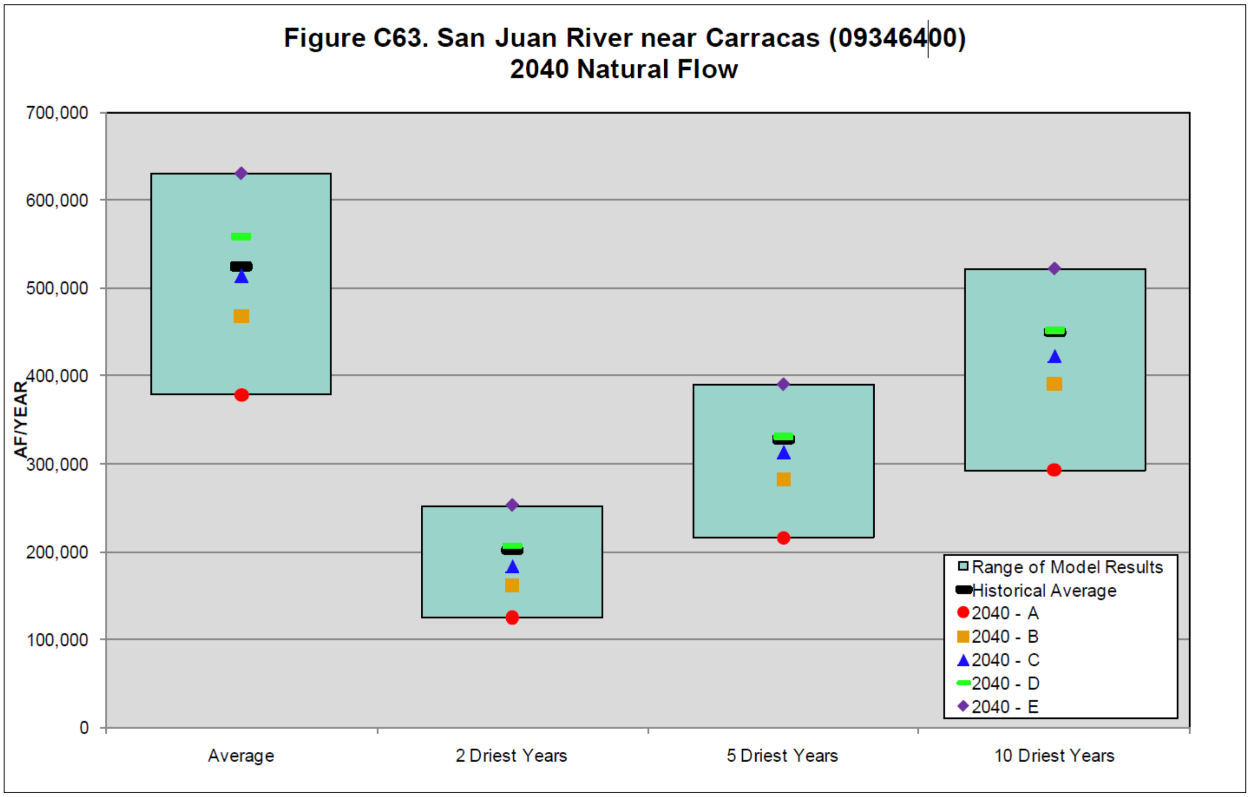
## Figure 1.4. Low Flow Comparison Chart, Yampa River near Maybell



## Figure 1.5. Low Flow Comparison Chart, Gunnison River near Grand Junction



## Figure 1.6. Low Flow Comparison Chart, San Juan River near Carracas




Figures 1.3 through 1.6 reflect the spatial pattern of the impact of projected climate on streamflow in Colorado: in the selected projections, natural flow increases (or decreases less) more often in more northerly parts of the state (and at higher elevations) while the converse is true in more southerly areas (and at lower elevations).

Figure 1.7 illustrates the impact of projected climate conditions on crop irrigation requirement (CIR), the amount of water (expressed as depth, in inches) necessary to supplement precipitation in order to fully supply a crop's water needs. Figure 1.7 shows that because temperature increases in all projections, CIR increases even if the projections indicate an increase in precipitation.

## Figure 1.7. Average Monthly CIR Comparison

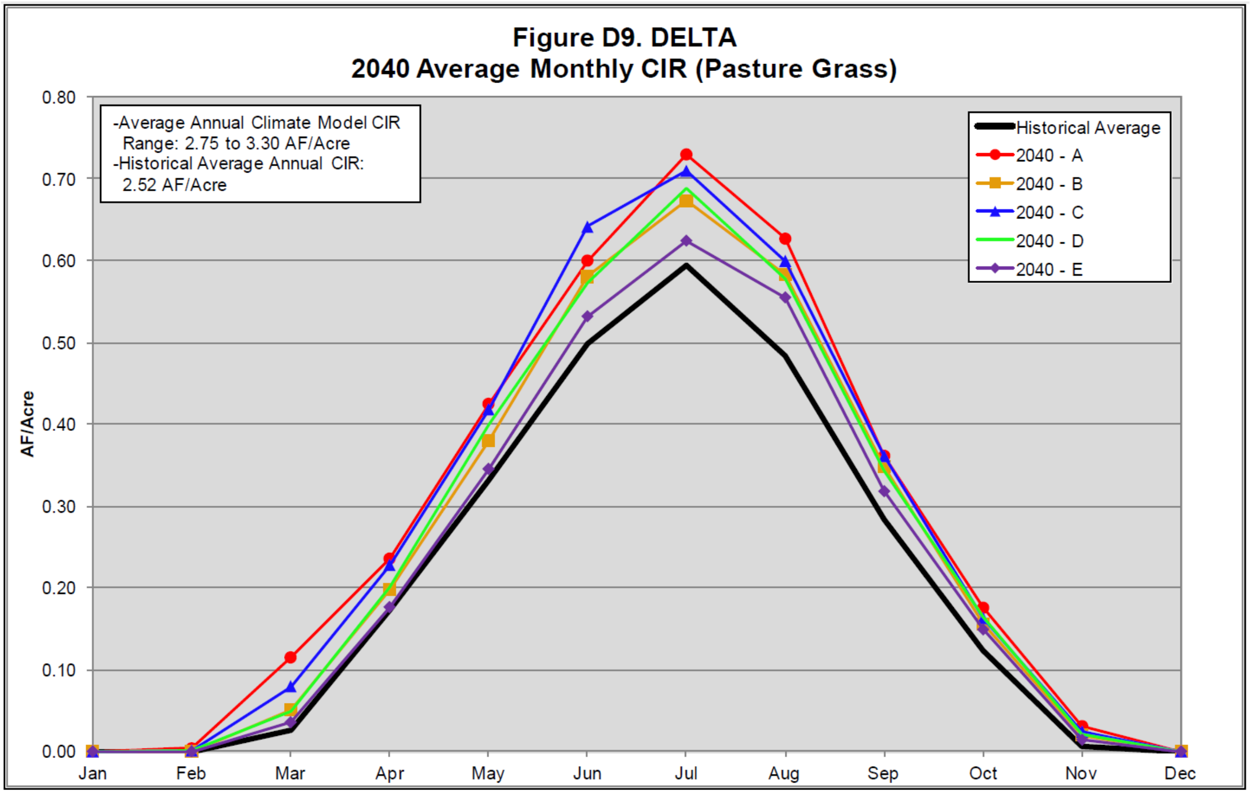
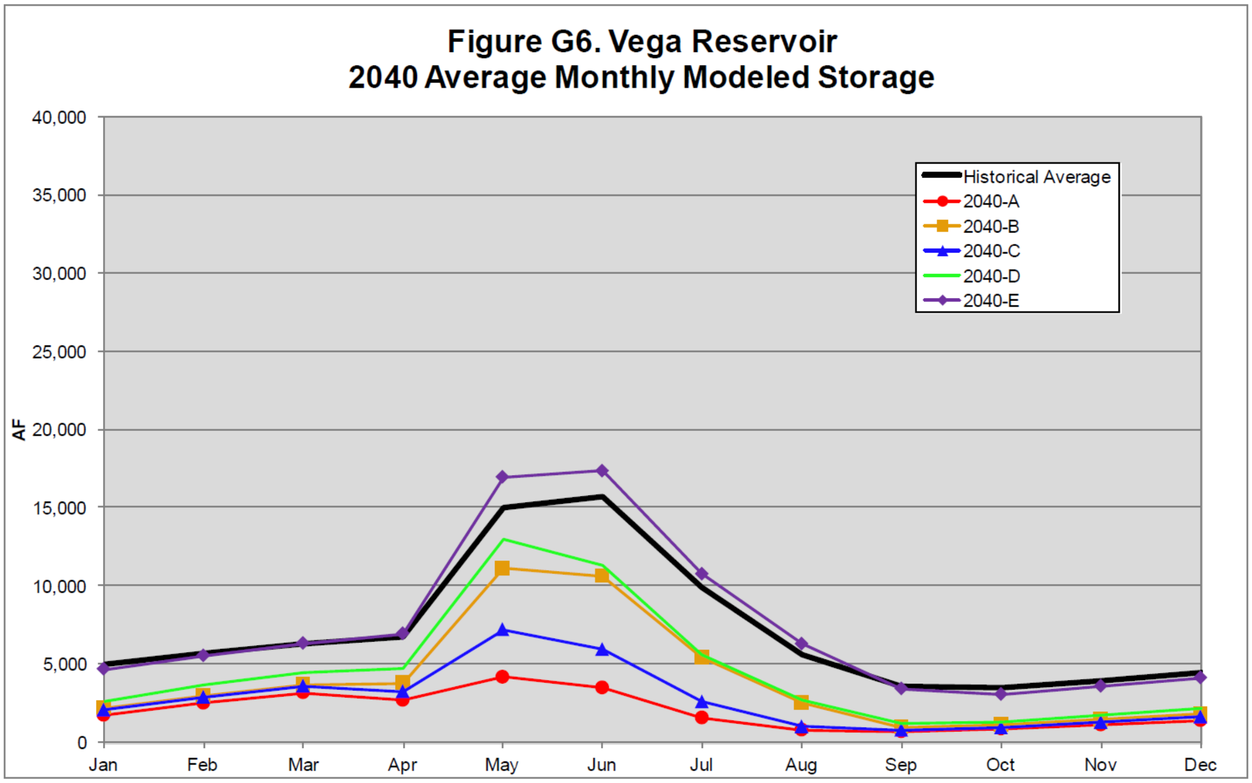



Figure 1.8 brings together the effects of climate on natural flow and agricultural water demand. It shows average monthly modeled Vega Reservoir content over the 1950 through 2005 study period for historical climate conditions, and for each of the 2040 climate projections. These results, which are from StateMod modeling done as part of the Water Availability Study, reflect the operation of Vega reservoir in the context of the climate-impacted natural flows, climate-impacted water demands, and the water rights and operating rules in the basin. Figure 1.8 illustrates the significance of changes in the monthly pattern of precipitation and increasing temperature – even the climate projections that result in natural flows similar to or greater than historical conditions show increased impacts on reservoir storage. This is due to increased agricultural water demand as is illustrated in Figure 1.7. Because average end-of-water-year storage is reduced in all climate projections the amount of water available for year-to-year carryover storage is reduced which will increase vulnerability to drought.

**Figure 1.8. Vega Reservoir - 2040 Average Monthly Modeled Storage Contents**




The Water Availability Study provides excellent information for the Colorado River. However, given the diversity of Colorado's river basins and the spatial differences noted just within the Colorado River, it is not appropriate to translate the results of the Water Availability Study to other basins.

## 3.2 The Boulder Climate Change Study

The potential impacts of climate change on a Front Range municipal water supply system was the subject of a NOAA-sponsored study entitled "Potential Consequences of Climate Change for the City Boulder, Colorado's Water Supplies" (the Boulder Climate Change Study). This study combined the potential impacts of climate change with long-term climate variability to examine their effects on the City of Boulder's water supply system. For this project, output from the Boulder Climate Change Study was evaluated to examine the effects of climate change on droughts on Boulder Creek. The hydrology of Boulder Creek is generally representative of the major mountain tributaries of the South Platte River.

The study examined outputs from 21 general circulation models (GCMs) for the area covering the Boulder Creek basin and the Colorado-Big Thompson and Windy Gap projects. All of the models project higher temperatures for this area. Roughly half of the models project decreased precipitation, and half project increased precipitation. While there is significant variation from model to model, in general the models tend to project wetter winters and drier summers. Four GCMs were selected to reflect a range of potential changes in precipitation. Outputs from the selected models reflecting three greenhouse gas emission scenarios (B1, A1-B and A2) were evaluated. Estimates of climate change for 20-year periods centering on 2030 and 2070 were used.

The study incorporated long-term climate variability exhibited by 437-year (1566-2002) tree ring-based streamflow reconstructions for Boulder Creek, South Boulder Creek, and the Colorado River (Woodhouse and Lukas 2006). A “nearest neighbor” approach was used to match natural streamflows and observed temperature and precipitation for 1953 through 2004 (for which climate records are available for the mountains above Boulder) with tree ring-derived annual streamflows. Years from 1953 through 2004 were used as proxies for pre-1953 years. A non-parametric re-sampling method was used to generate a 1,000 member ensemble of climate change scenarios (and a base case “no-climate-change” scenario), each comprised of 437 “years” selected from the 1953-2004 population that reflects the statistical properties of the 437-year long paleo-streamflow reconstruction.

A runoff model was calibrated using historical (1953-2004) weather data from the Niwot Ridge C1 station located west of Boulder and monthly natural streamflows for Boulder Creek at Orodell, South Boulder Creek near Eldorado Springs, and the Colorado River at Hot Sulphur Springs. Temperature and precipitation changes from the GCMs were applied to the runoff model to generate altered monthly flows that were reflected in the ensembles. Temperature and precipitation changes from the GCMs were also used to adjust Boulder Creek basin irrigation demands and South Platte River calls.

The effects of altered streamflows, precipitation and temperature upon Boulder’s water supply system were evaluated using the Boulder Creek Model, developed by the City of Boulder to analyze water supply reliability. The Boulder Creek Model simulates the operation of Boulder’s water supply system given natural streamflows, water rights, water demands and return flows, and diversion and storage facilities in the Boulder Creek basin and calls from downstream South Platte rights.

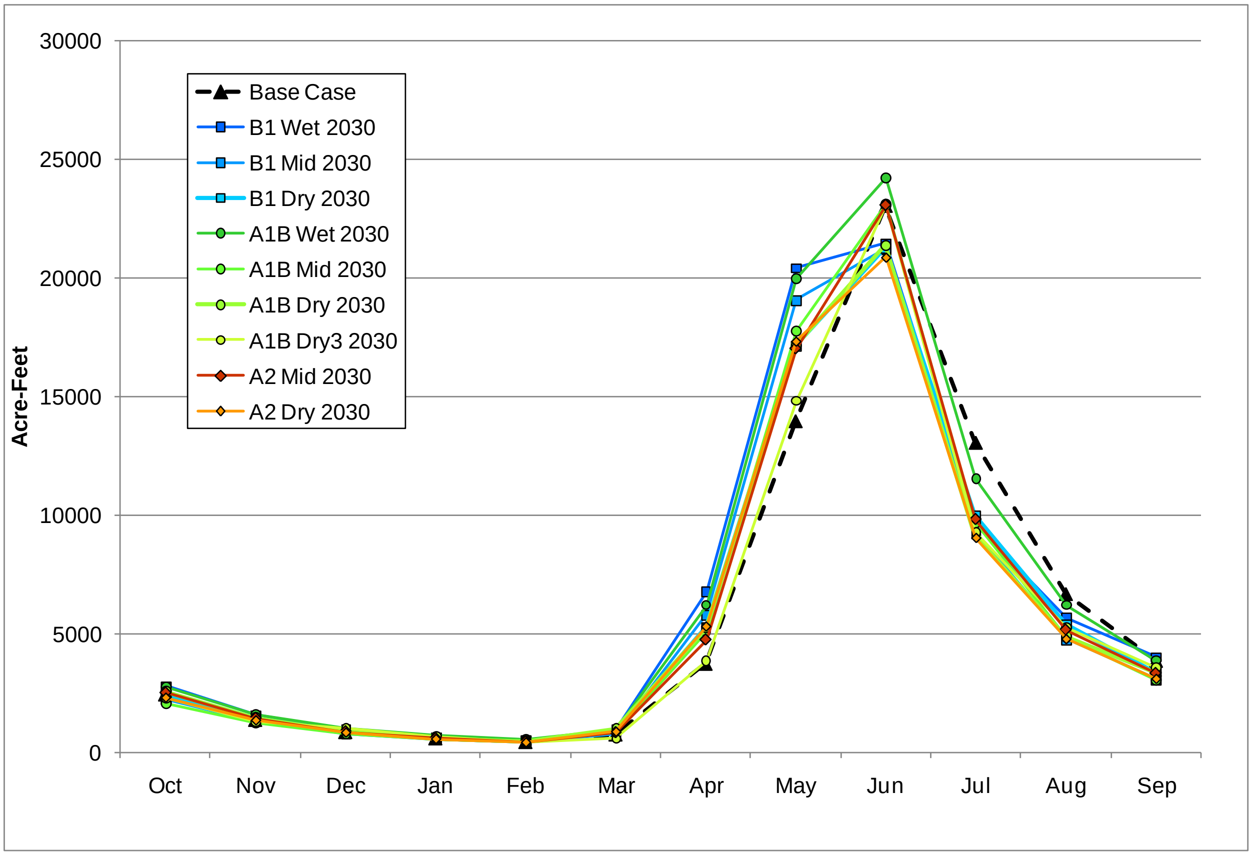
Results from the Boulder Climate Change Study (shown in Table 1.7) indicate that, in seven out of the nine climate change scenarios evaluated, droughts on Boulder Creek are likely to be significantly longer than those simulated in the base-case.

## Table 1.7. Table 5: Drought Lengths, Boulder Creek Near Orodell (2030 Conditions)

| Average Length of Maximum Drought (years) | Maximum Drought Length (years) |
|---|---|
| **Base Case Hydrology** | |
| 10.6 | 13 |
| **Projected Climate Scenarios** | |
| 7.6 | 11 |
| 12.5 | 20 |
| 12.6 | 20 |
| 4.4 | 5 |
| 13.4 | 21 |
| 14.1 | 20 |
| 24.0 | 24 |
| 12.5 | 20 |
| 22.9 | 24 |

Increase in temperature alone was estimated to have little effect on the total annual volume of runoff, but by 2030 would result in significant increases in runoff in April and May and significant decreases in runoff in July and August, as shown in Figure 1.9. These seasonal changes (e.g., higher spring flows, lower summer flows) were estimated with increased or decreased precipitation. Annual runoff is quite sensitive to change in precipitation, with runoff decreasing with reduced precipitation and increasing with higher precipitation.

**Figure 1.9. Mean Monthly Flows for Base Case and Climate Change Scenarios, Boulder Creek Near Orodell**




# 4 Incorporating Climate Change into Planning

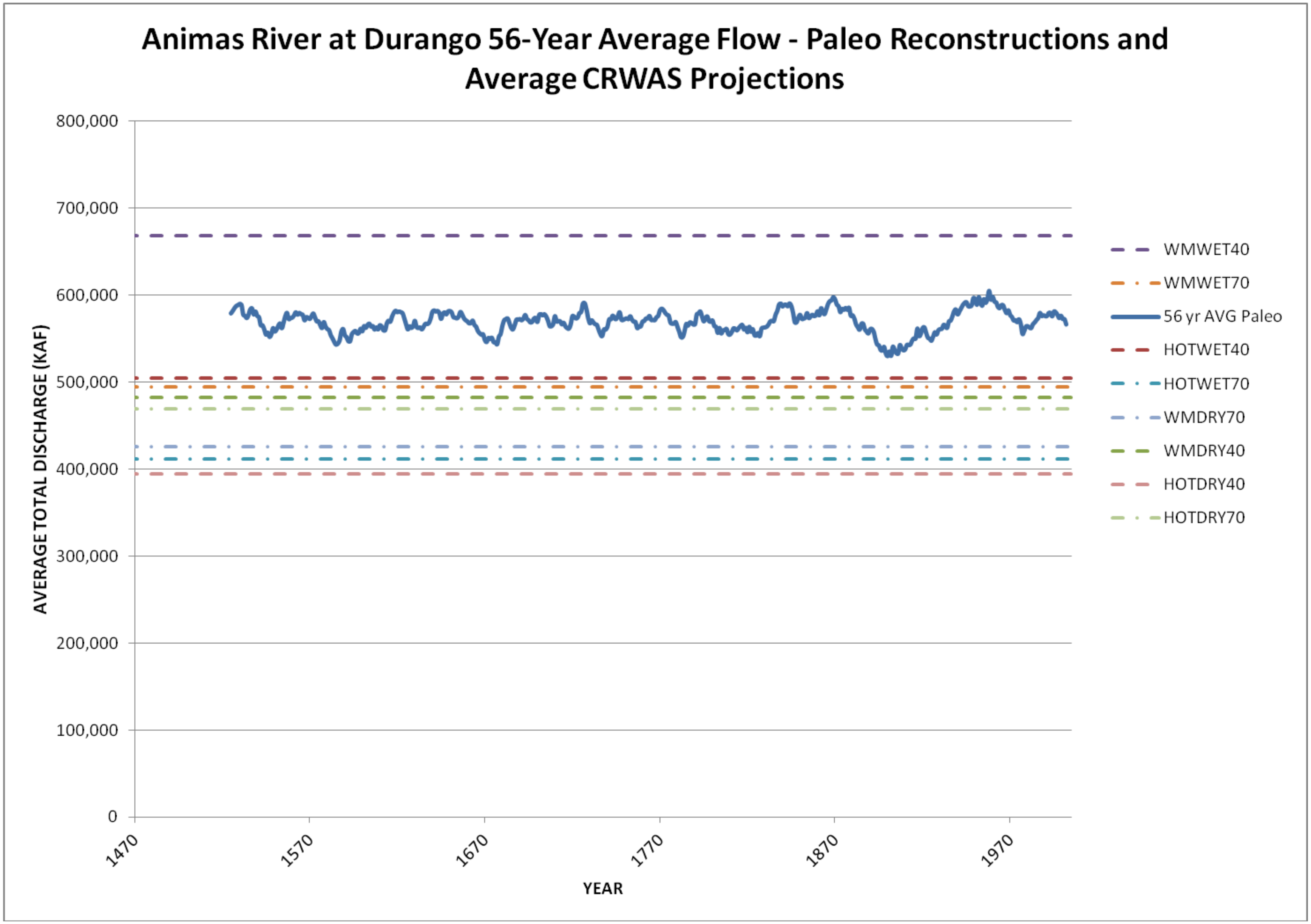
The results discussed above highlight possible changes to drought risk in a future climate. While there is no way to be certain what future hydrology may look like, it is important for planners to be aware that the future is unlikely to repeat the observed hydrology, and it is likely that the state will experience more severe and sustained droughts than seen in the last 56 years.

There are two main pathways for integrating climate information in water resources management. The first is a top-down perspective, in which projections are used to drive resource models and project future impacts. Conversely a bottom up approach starts with knowledge of specific system and analyzes the potential climate changes that would be most threatening to long-range plans or operations (CWCB 2008). No matter the approach, water resources managers and planners must make decisions based on a range of possible future scenarios. Integrated Resource Planning (IRP) is a widely used long-term planning approach to help managers keep open a wide range of options and maintain flexibility in the face of uncertainty (CWCB 2008).

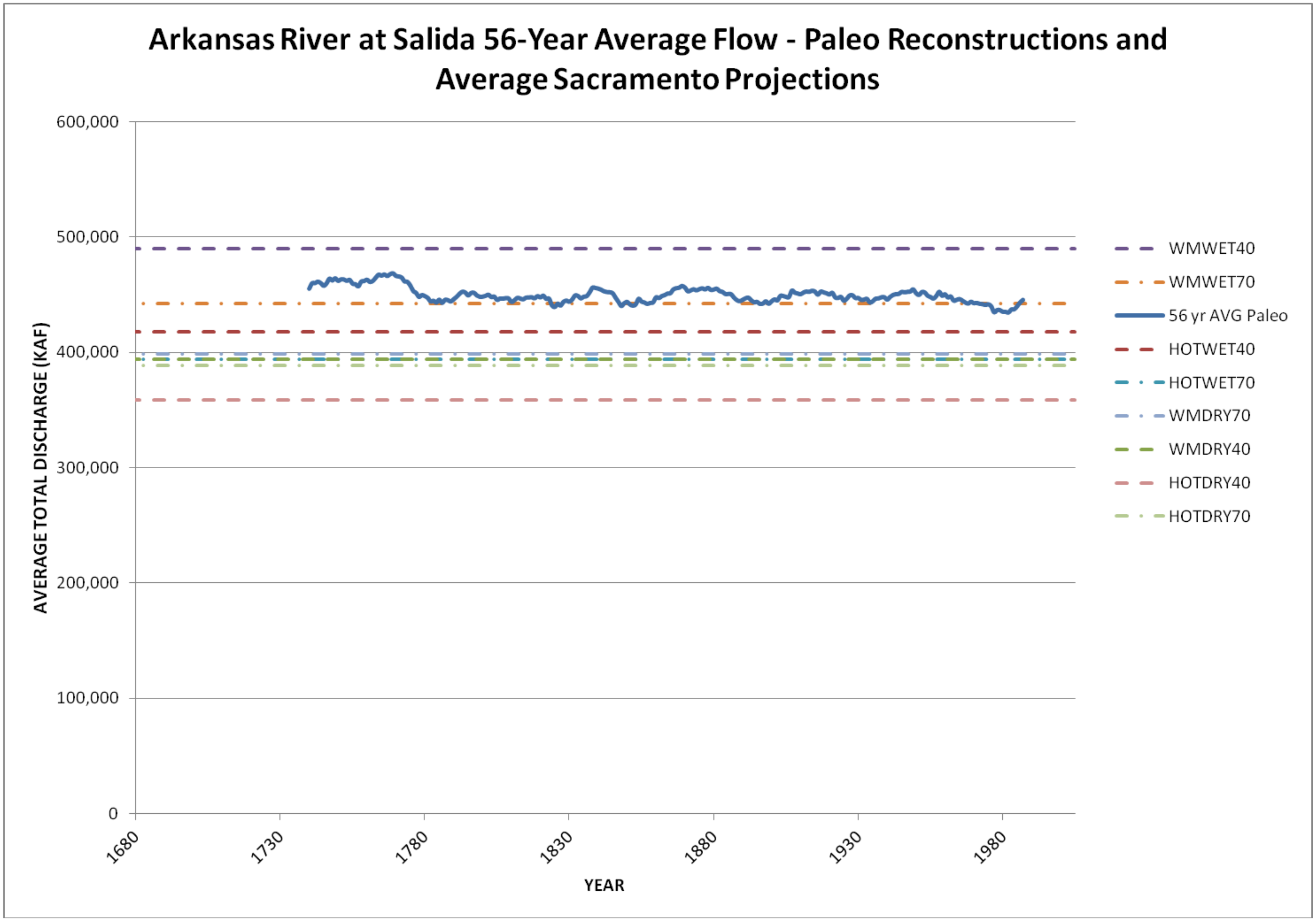
Over the last seven years, the state has been paying increased attention to climate change projections from the Intergovernmental Panel on Climate Change (IPCC) and has developed a Climate Action Plan which includes the need to investigate vulnerabilities of the state's water supplies to climate change and to plan for severe drought (as well as other risks) resulting from climate change. In 2008, the state held a conference to assist water providers, planners, managers, and agency and local government officials assess drought risk, impacts, and preparedness in Colorado, and the improvements that will be needed for management under different conditions such as climate change.

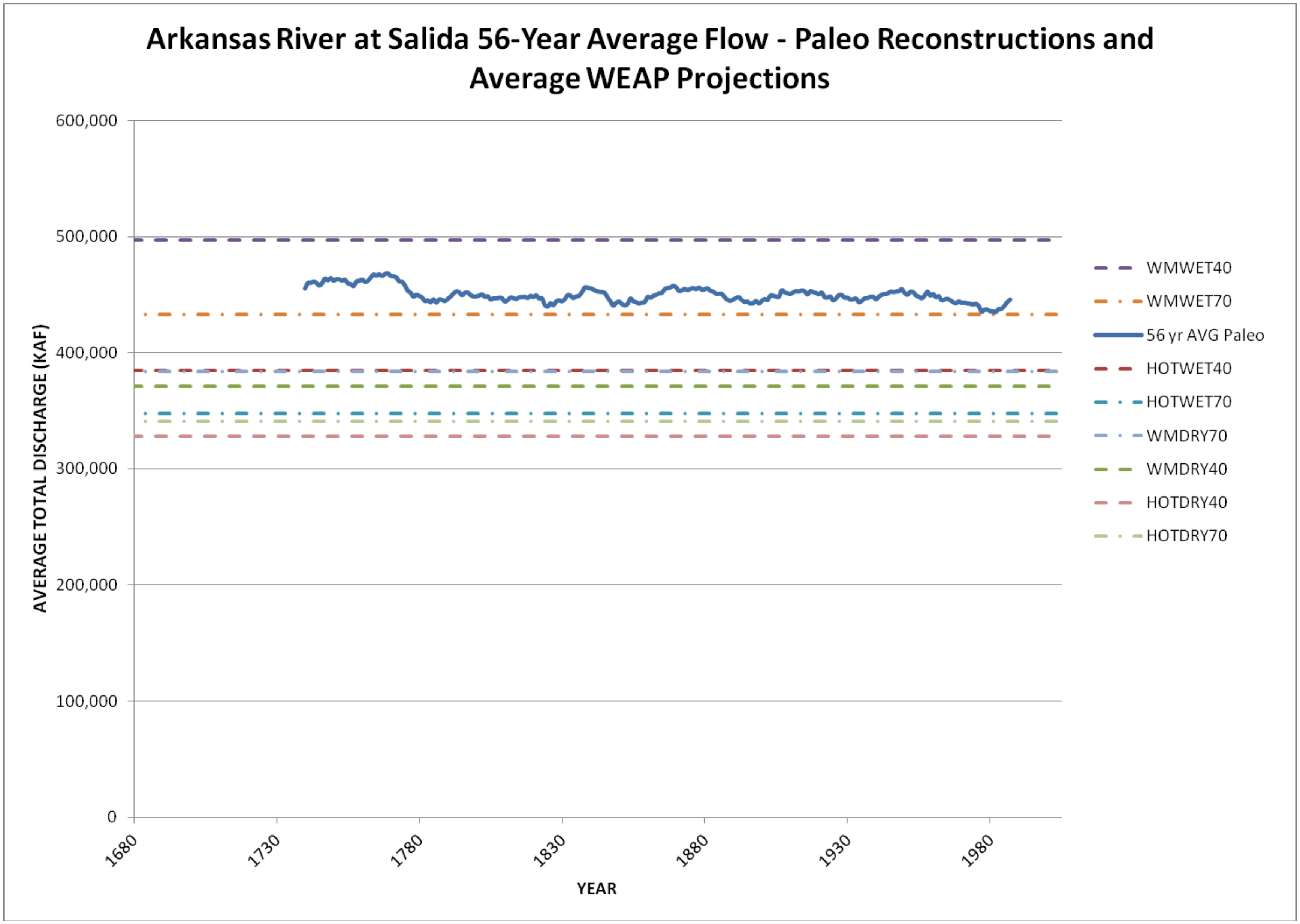
Future climate change analysis should be used in conjunction with the vulnerability assessment completed here to inform the hazard profile and to support a drought risk assessment that incorporates vulnerability to possible future droughts.

# 5 Appendix 1: Flow Comparison Charts

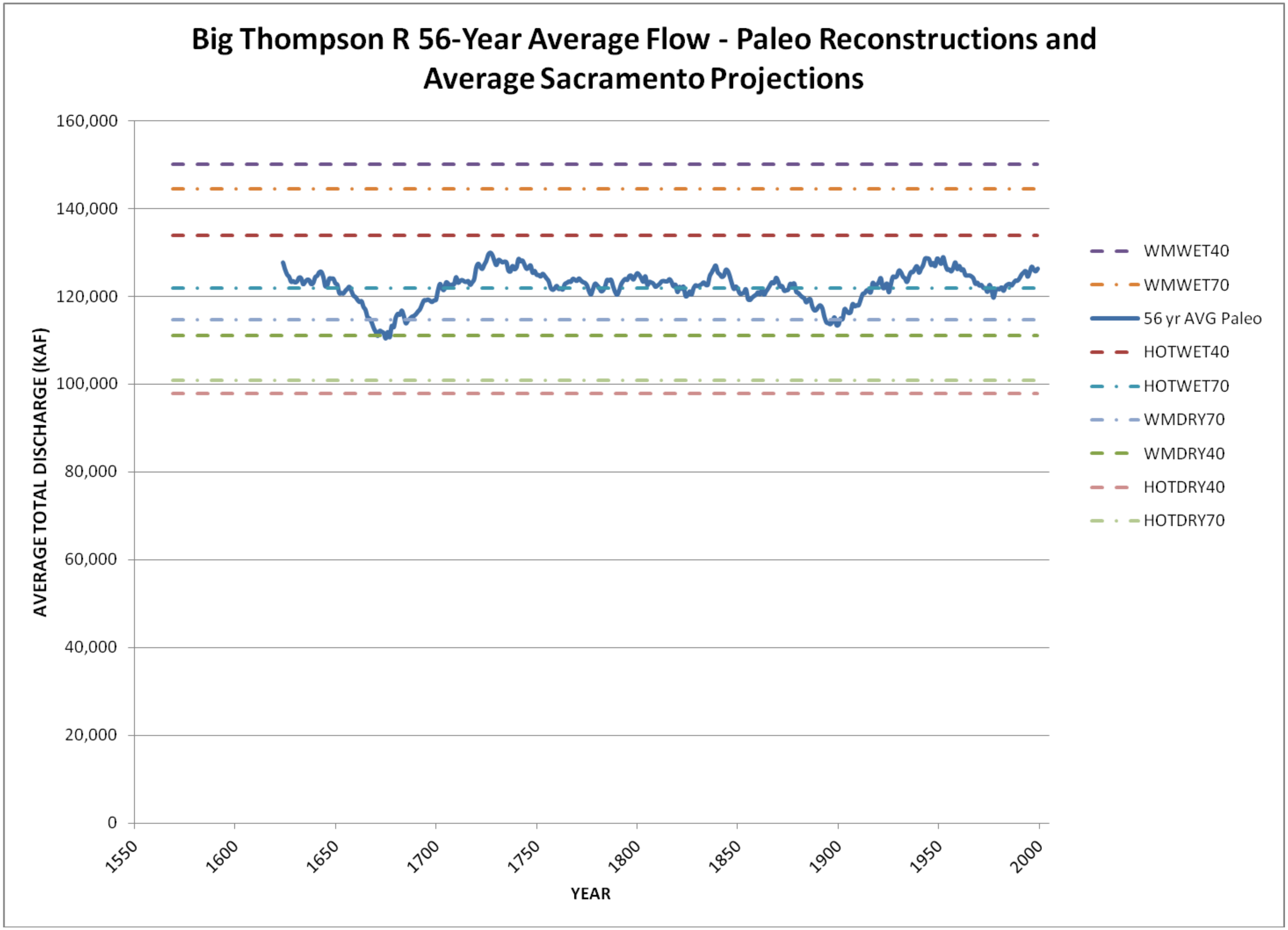


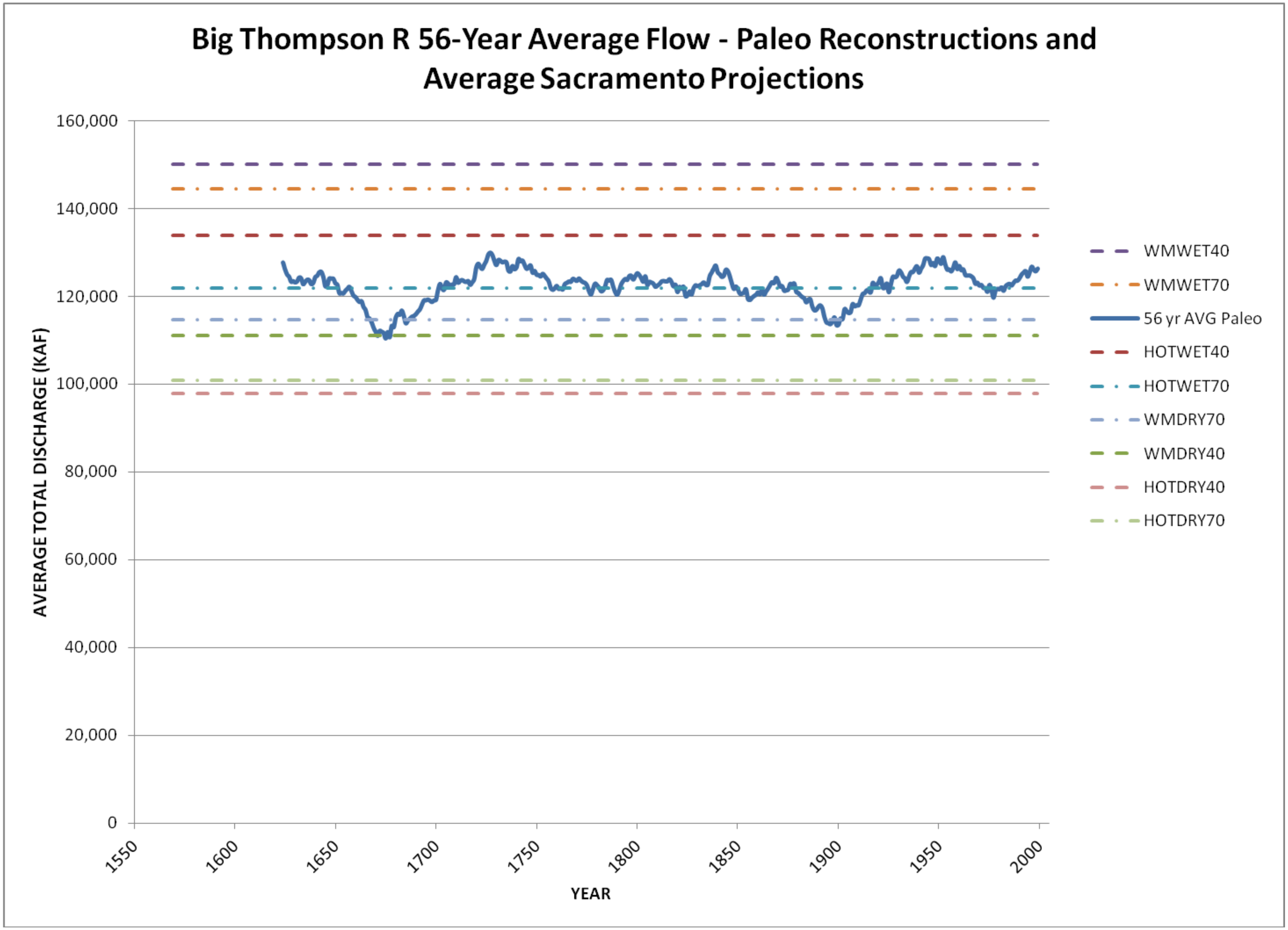
Animas River at Durango 56-Year Average Flow - Paleo Reconstructions and Average CRWAS Projections
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
AVERAGE TOTAL DISCHARGE (KAF)
1470
1570
1670
1770
1870
1970
YEAR
WMWET40
WMWET70
56 yr AVG Paleo
HOTWET40
HOTWET70
WMDRY70
WMDRY40
HOTDRY40
HOTDRY70


Arkansas River at Salida 56-Year Average Flow - Paleo Reconstructions and Average Sacramento Projections
600,000
500,000
400,000
300,000
200,000
100,000
0
AVERAGE TOTAL DISCHARGE (KAF)
1680
1730
1780
1830
1880
1930
1980
YEAR
WMWET40
WMWET70
56 yr AVG Paleo
HOTWET40
HOTWET70
WMDRY70
WMDRY40
HOTDRY40
HOTDRY70

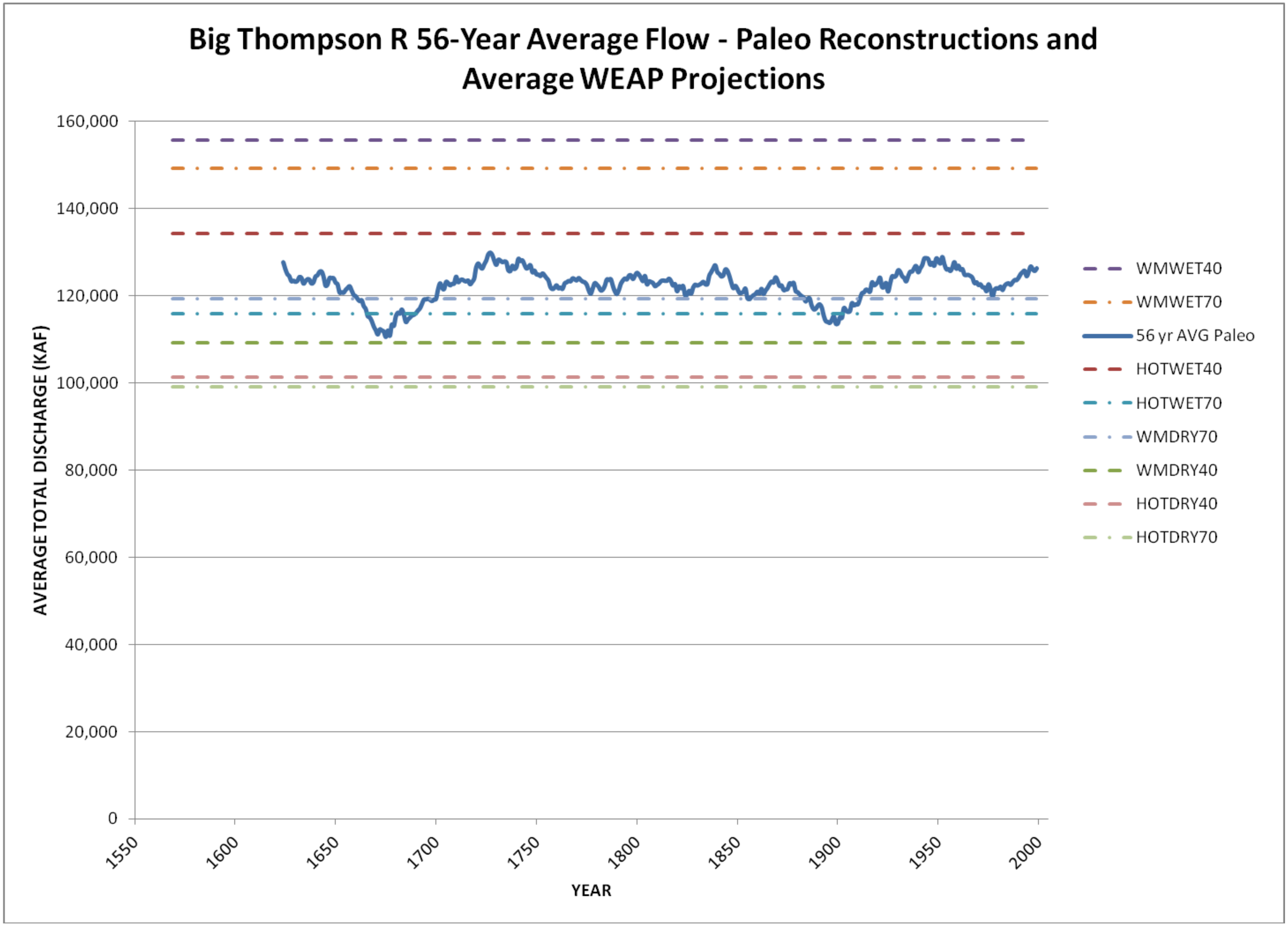


Arkansas River at Salida 56-Year Average Flow - Paleo Reconstructions and Average WEAP Projections
600,000
500,000
400,000
300,000
200,000
100,000
0
AVERAGE TOTAL DISCHARGE (KAF)
1680
1730
1780
1830
1880
1930
1980
YEAR
WMWET40
WMWET70
56 yr AVG Paleo
HOTWET40
HOTWET70
WMDRY70
WMDRY40
HOTDRY40
HOTDRY70

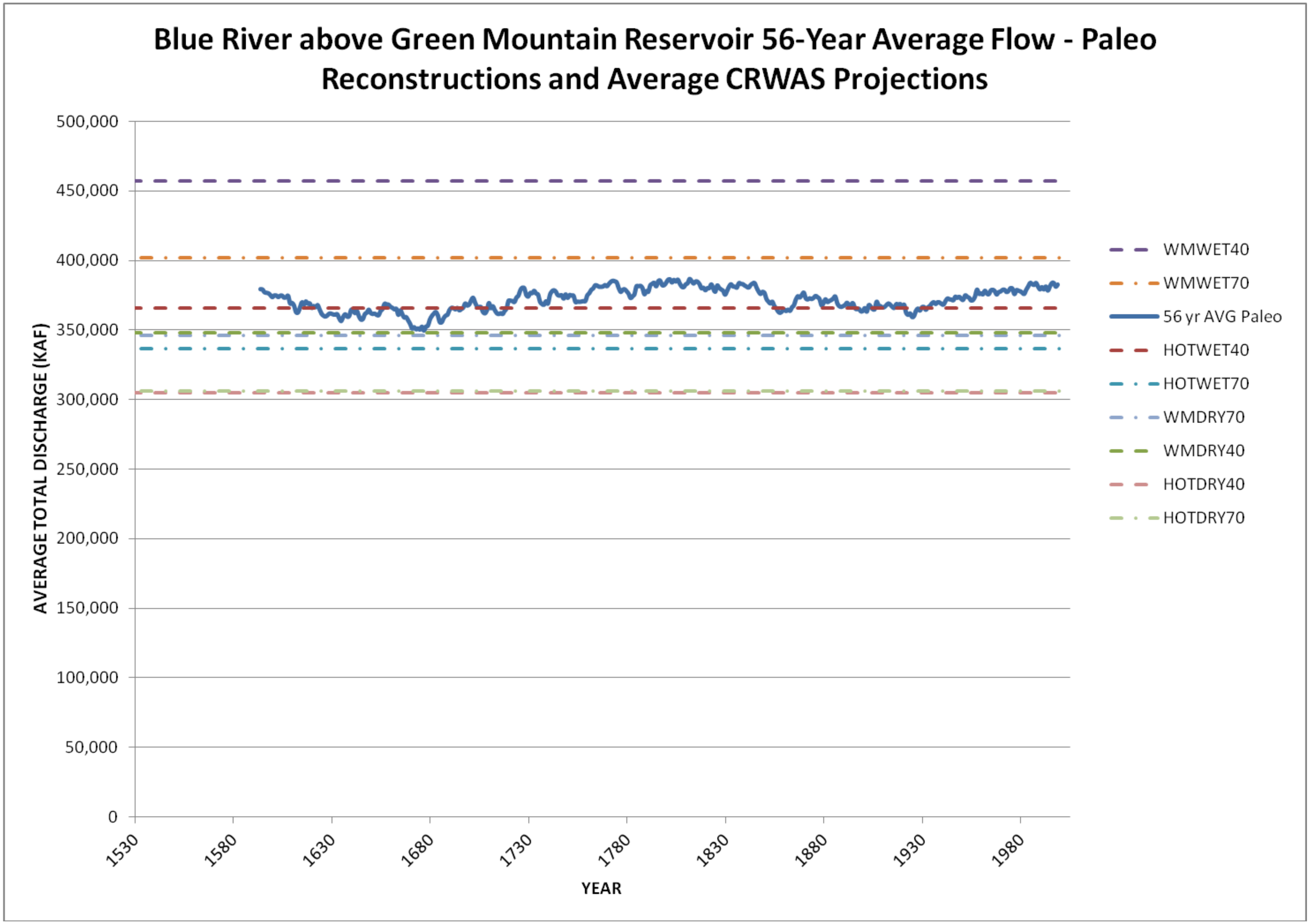

Big Thompson R 56-Year Average Flow - Paleo Reconstructions and Average Sacramento Projections
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
AVERAGE TOTAL DISCHARGE (KAF)
1550
1600
1650
1700
1750
1800
1850
1900
1950
2000
YEAR
WMWET40
WMWET70
56 yr AVG Paleo
HOTWET40
HOTWET70
WMDRY70
WMDRY40
HOTDRY40
HOTDRY70

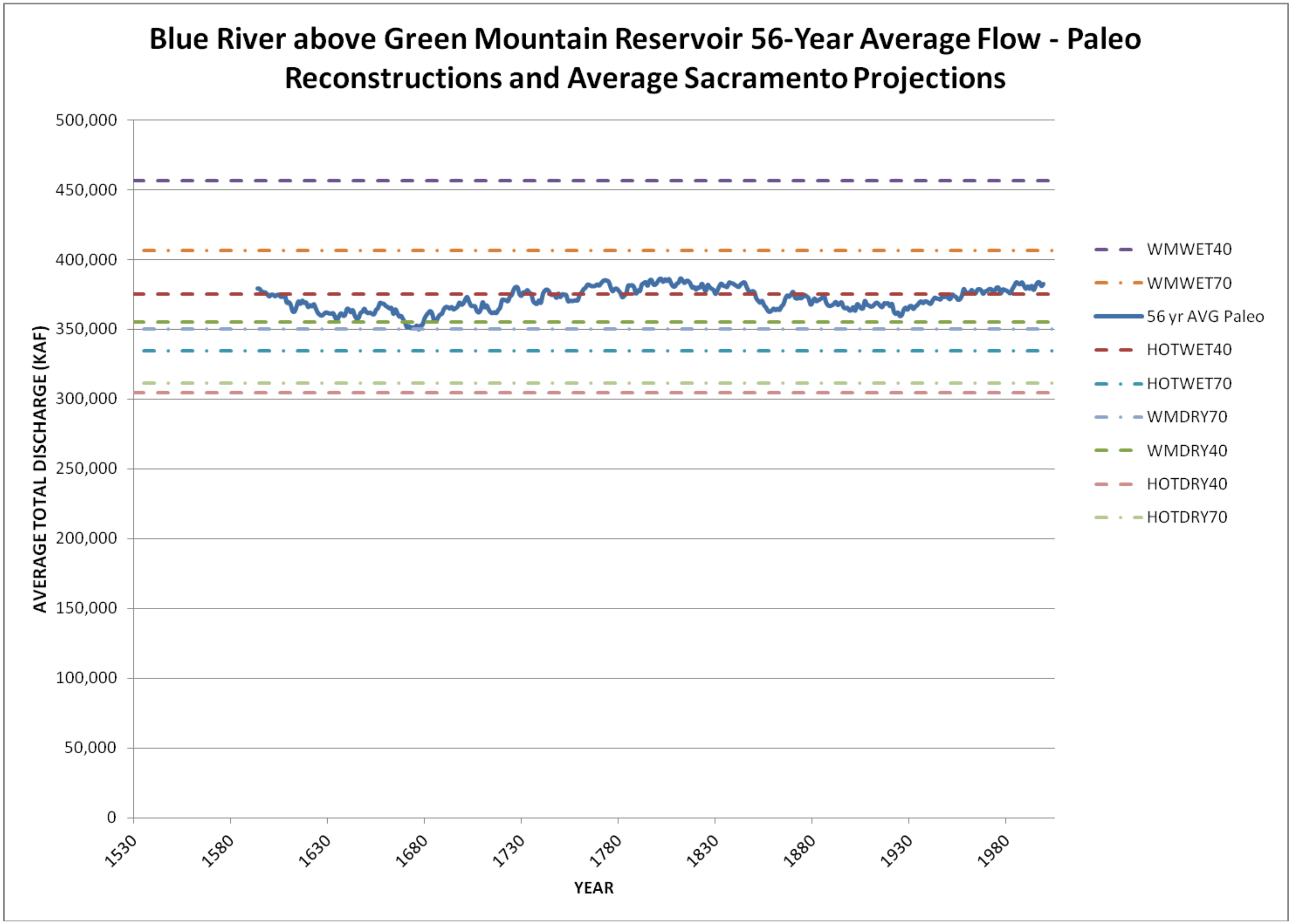


Big Thompson R 56-Year Average Flow - Paleo Reconstructions and Average Sacramento Projections
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
AVERAGE TOTAL DISCHARGE (KAF)
1550
1600
1650
1700
1750
1800
1850
1900
1950
2000
YEAR
WMWET40
WMWET70
56 yr AVG Paleo
HOTWET40
HOTWET70
WMDRY70
WMDRY40
HOTDRY40
HOTDRY70

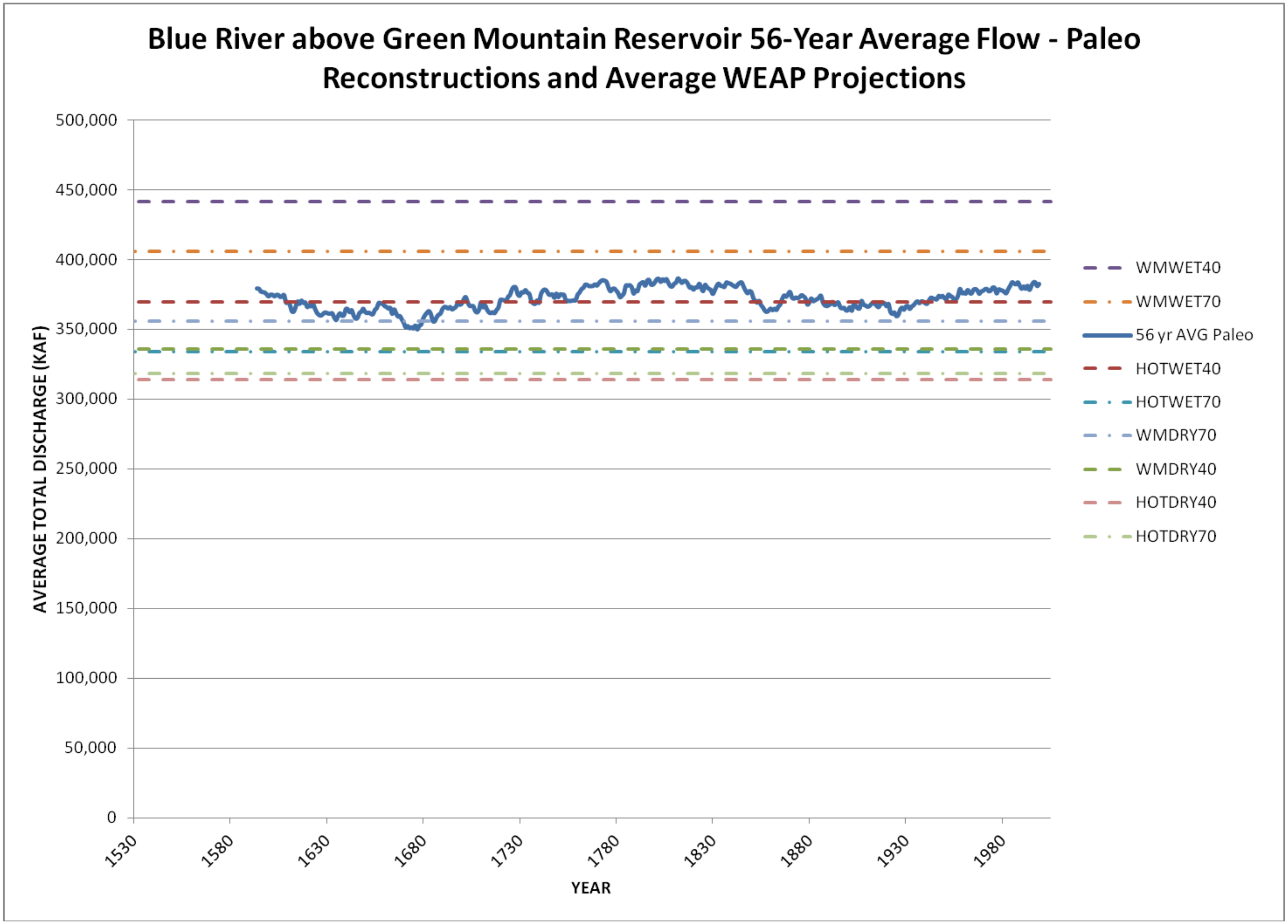


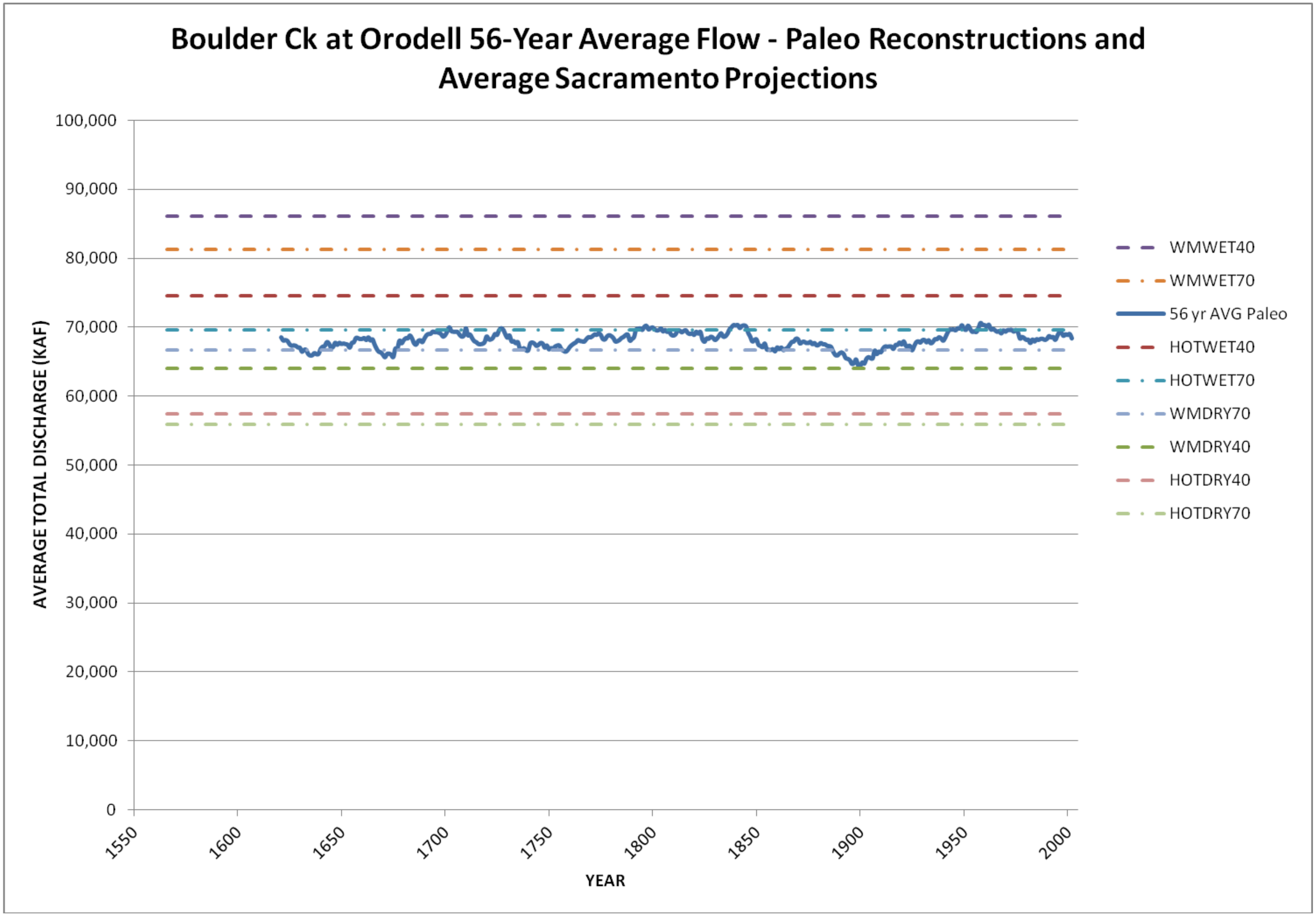
Big Thompson R 56-Year Average Flow - Paleo Reconstructions and Average WEAP Projections
AVERAGE TOTAL DISCHARGE (KAF)
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
1550
1600
1650
1700
1750
1800
1850
1900
1950
2000
YEAR
WMWET40
WMWET70
56 yr AVG Paleo
HOTWET40
HOTWET70
WMDRY70
WMDRY40
HOTDRY40
HOTDRY70


Blue River above Green Mountain Reservoir 56-Year Average Flow - Paleo Reconstructions and Average CRWAS Projections
AVERAGE TOTAL DISCHARGE (KAF)
500,000
450,000
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
1530
1580
1630
1680
1730
1780
1830
1880
1930
1980
YEAR
WMWET40
WMWET70
56 yr AVG Paleo
HOTWET40
HOTWET70
WMDRY70
WMDRY40
HOTDRY40
HOTDRY70

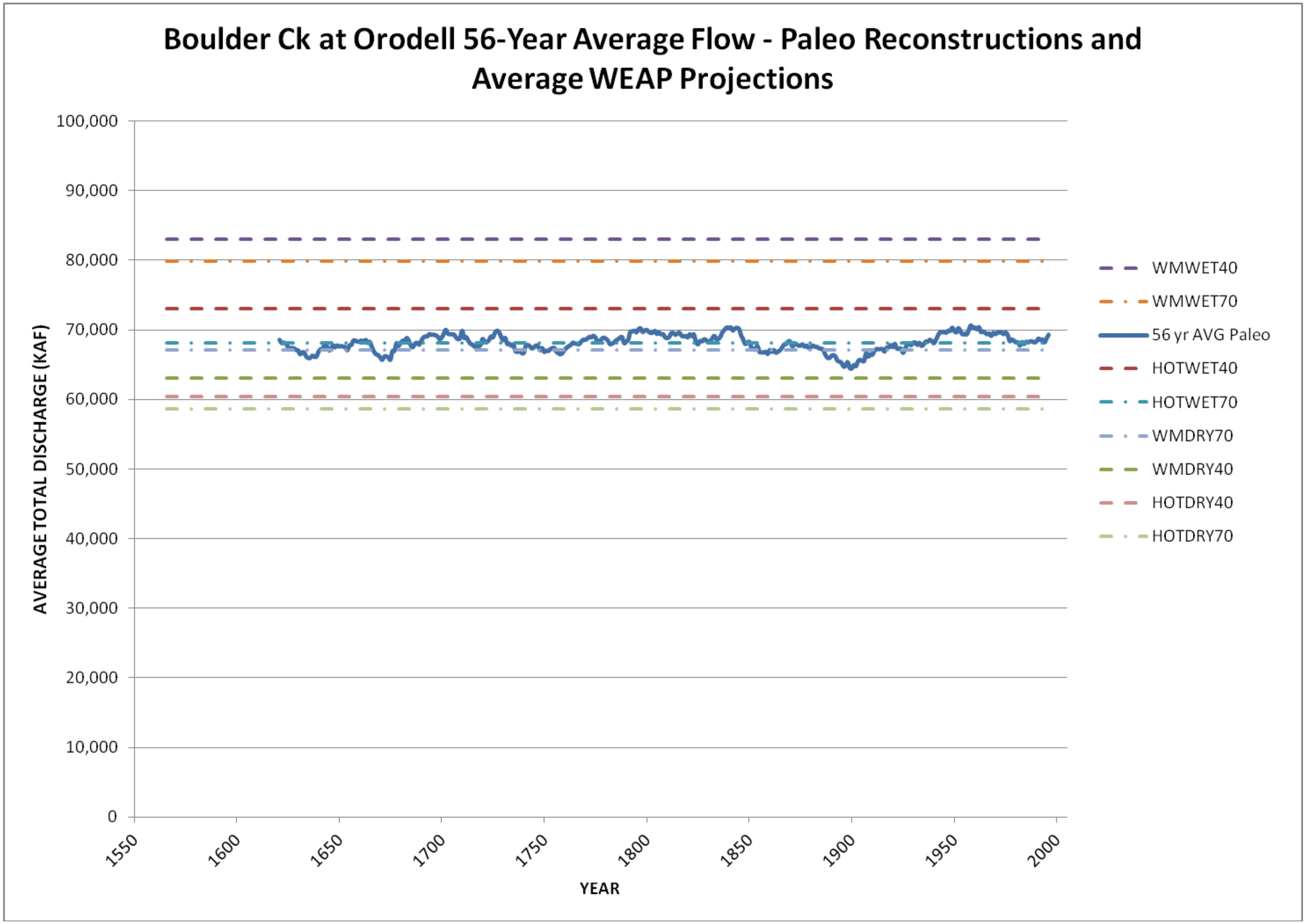


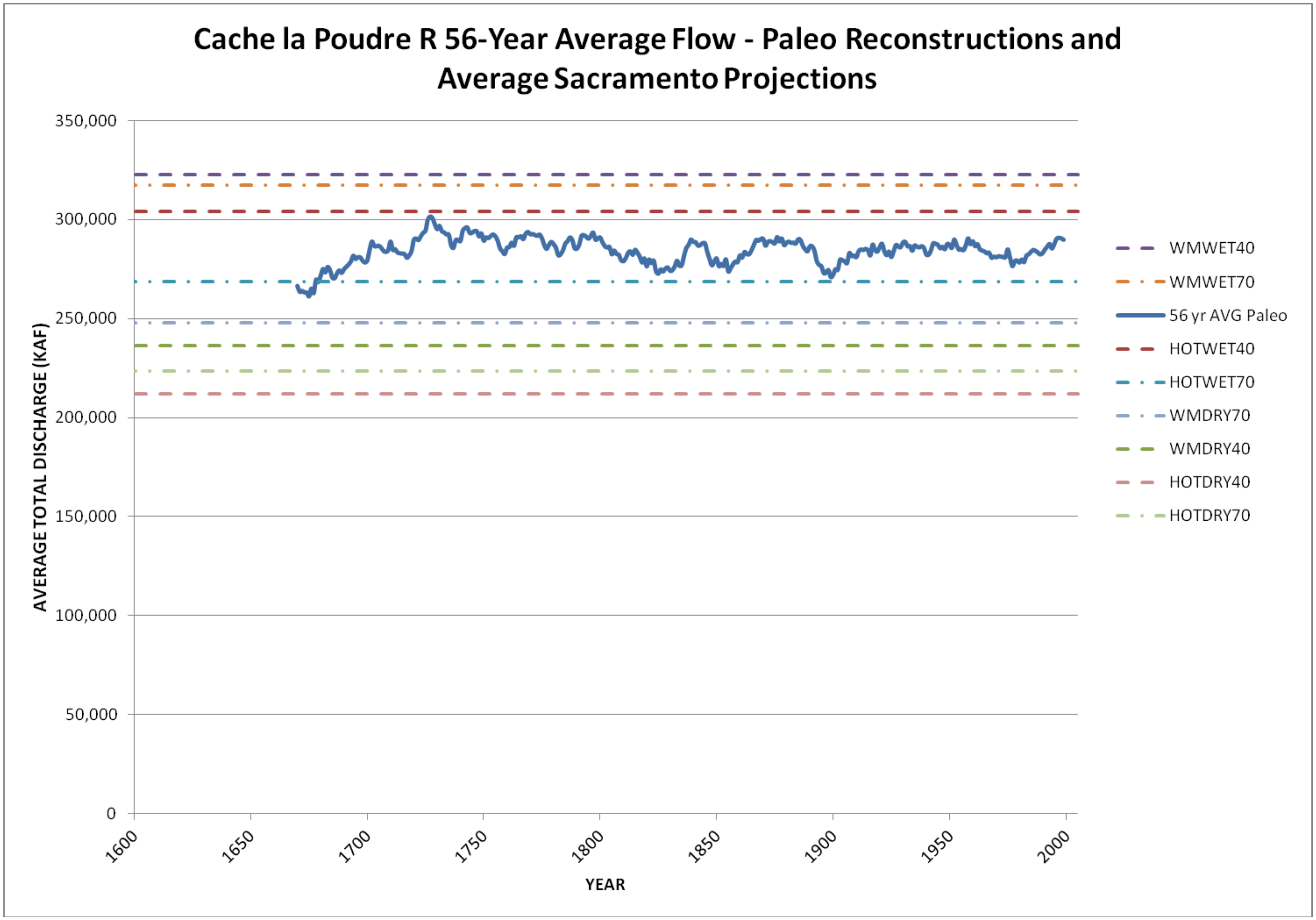
Blue River above Green Mountain Reservoir 56-Year Average Flow - Paleo Reconstructions and Average Sacramento Projections
AVERAGE TOTAL DISCHARGE (KAF)
500,000
450,000
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
1530
1580
1630
1680
1730
1780
1830
1880
1930
1980
YEAR
WMWET40
WMWET70
56 yr AVG Paleo
HOTWET40
HOTWET70
WMDRY70
WMDRY40
HOTDRY40
HOTDRY70

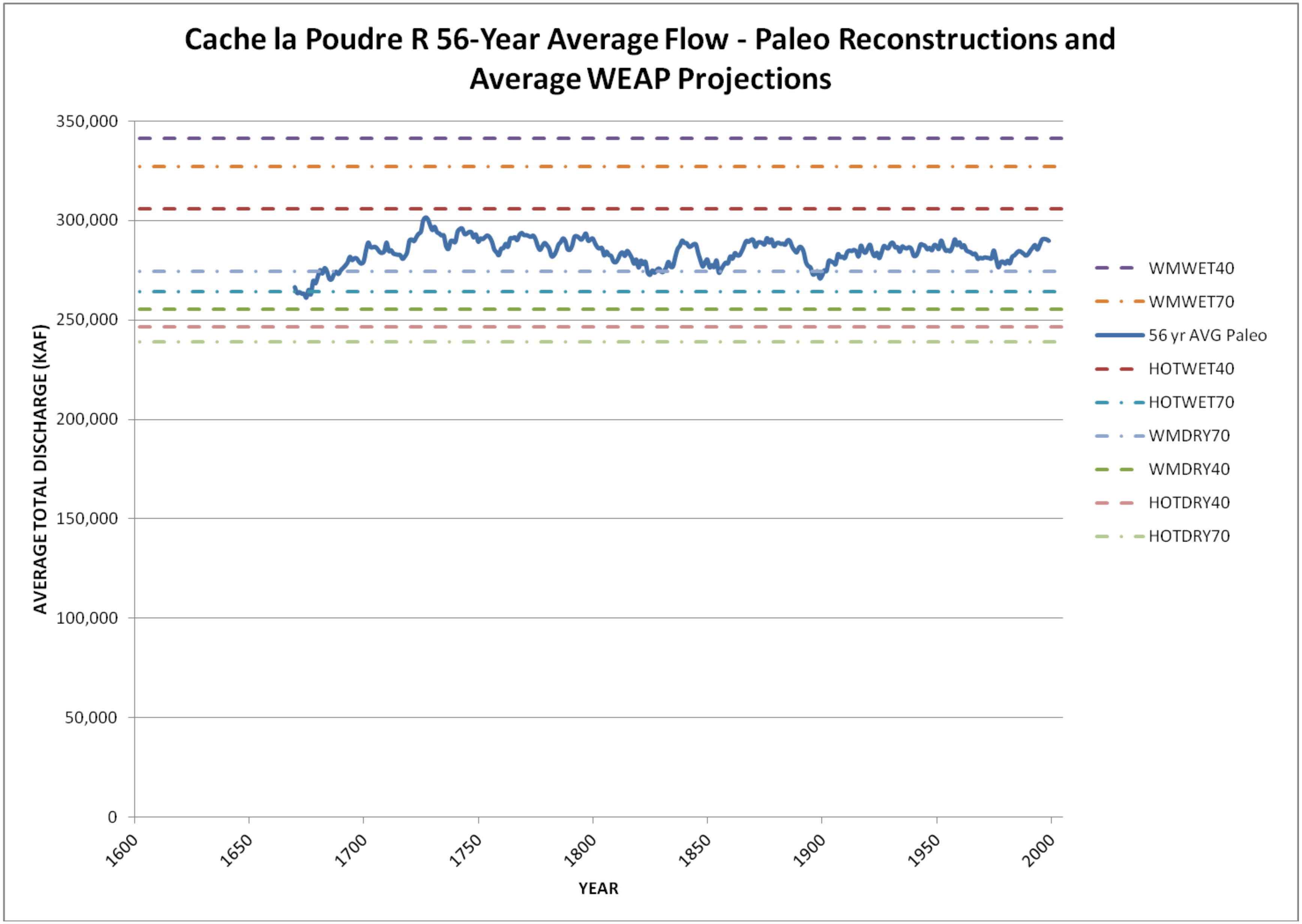

Blue River above Green Mountain Reservoir 56-Year Average Flow - Paleo Reconstructions and Average WEAP Projections
AVERAGE TOTAL DISCHARGE (KAF)
500,000
450,000
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
1530
1580
1630
1680
1730
1780
1830
1880
1930
1980
YEAR
WMWET40
WMWET70
56 yr AVG Paleo
HOTWET40
HOTWET70
WMDRY70
WMDRY40
HOTDRY40
HOTDRY70



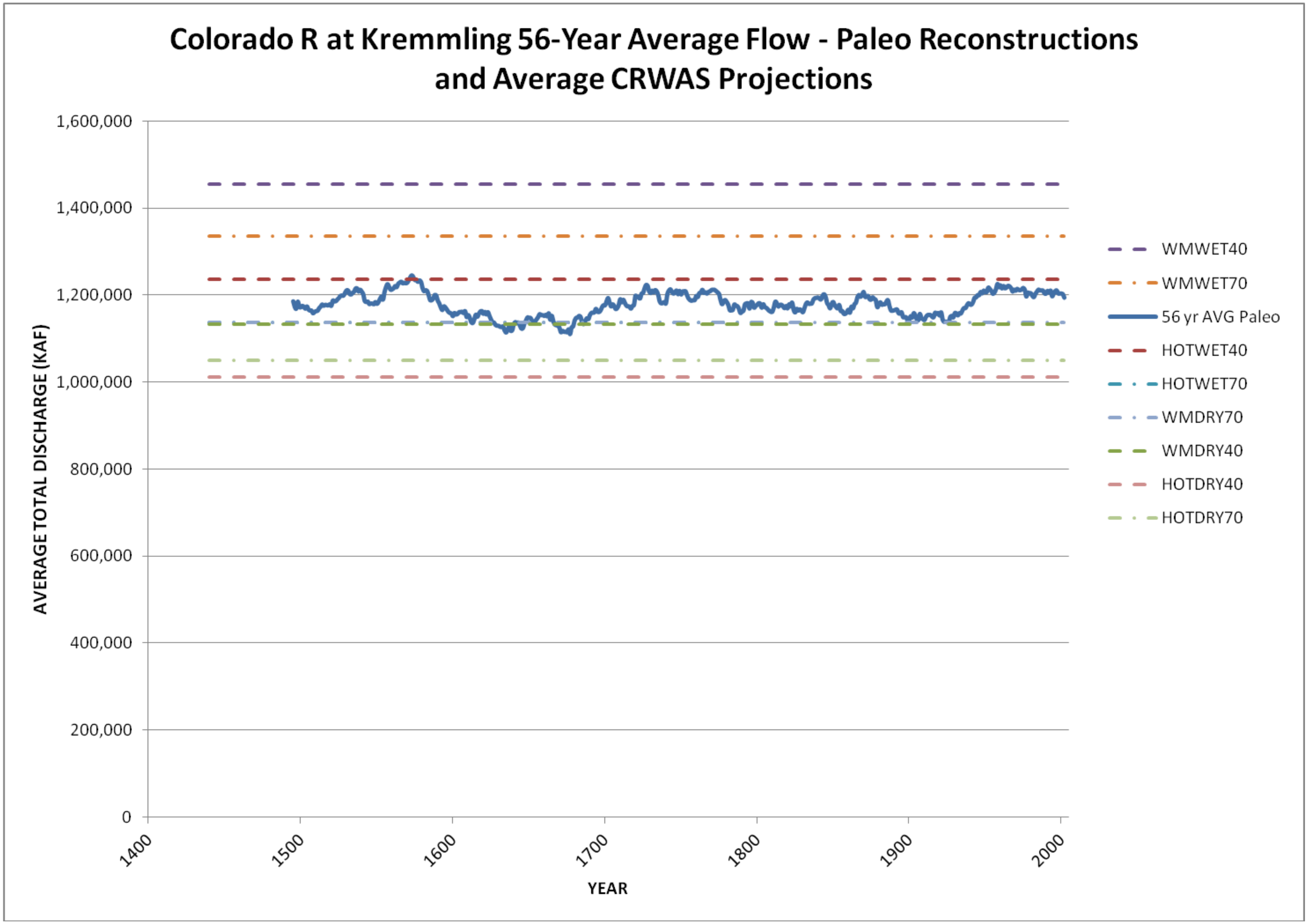
Boulder Ck at Orodell 56-Year Average Flow - Paleo Reconstructions and Average Sacramento Projections
AVERAGE TOTAL DISCHARGE (KAF)
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
1550
1600
1650
1700
1750
1800
1850
1900
1950
2000
YEAR
WMWET40
WMWET70
56 yr AVG Paleo
HOTWET40
HOTWET70
WMDRY70
WMDRY40
HOTDRY40
HOTDRY70


Boulder Ck at Orodell 56-Year Average Flow - Paleo Reconstructions and Average WEAP Projections
AVERAGE TOTAL DISCHARGE (KAF)
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
1550
1600
1650
1700
1750
1800
1850
1900
1950
2000
YEAR
WMWET40
WMWET70
56 yr AVG Paleo
HOTWET40
HOTWET70
WMDRY70
WMDRY40
HOTDRY40
HOTDRY70

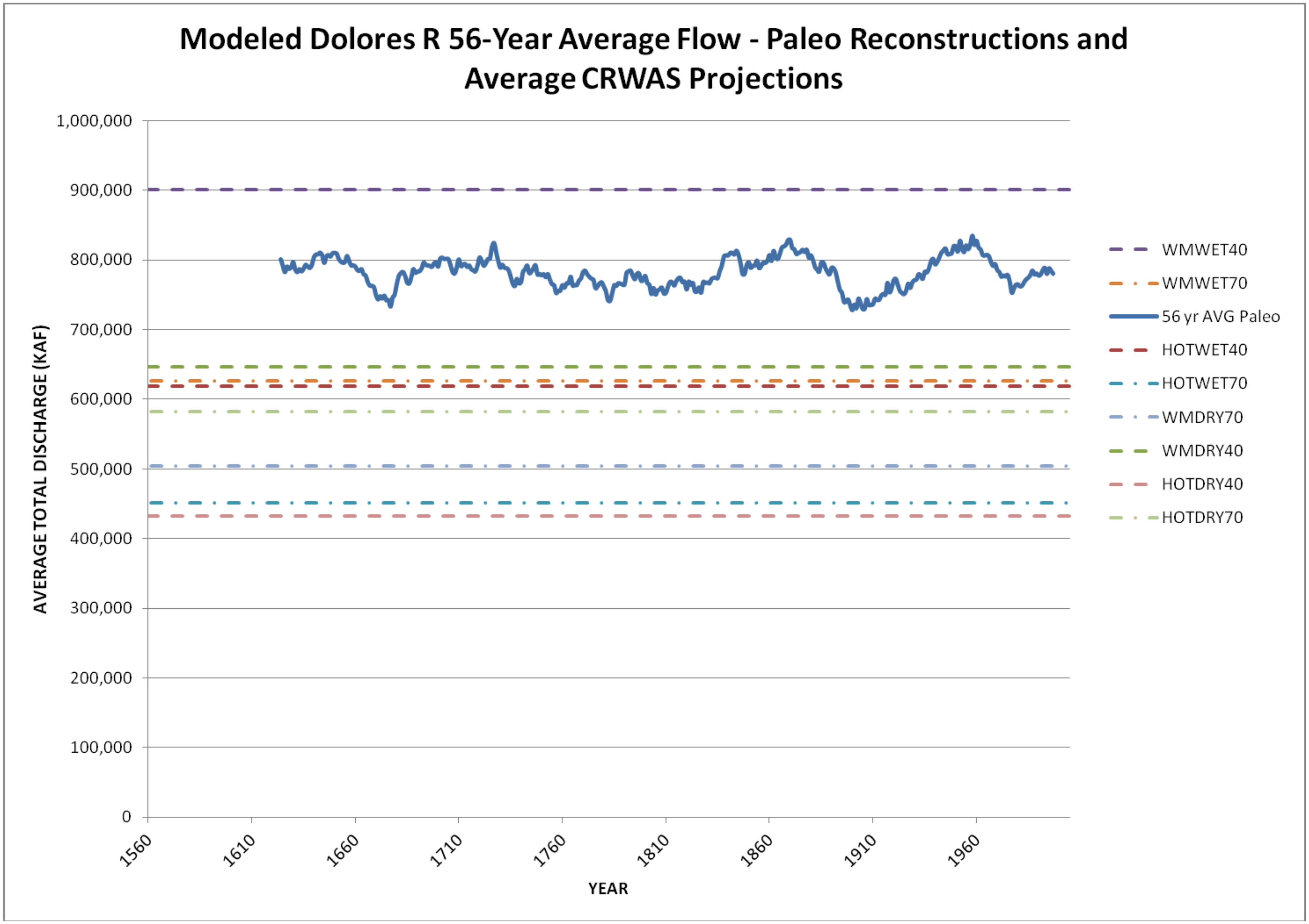

Cache la Poudre R 56-Year Average Flow - Paleo Reconstructions and Average Sacramento Projections
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
AVERAGE TOTAL DISCHARGE (KAF)
1600
1650
1700
1750
1800
1850
1900
1950
2000
YEAR
WMWET40
WMWET70
56 yr AVG Paleo
HOTWET40
HOTWET70
WMDRY70
WMDRY40
HOTDRY40
HOTDRY70

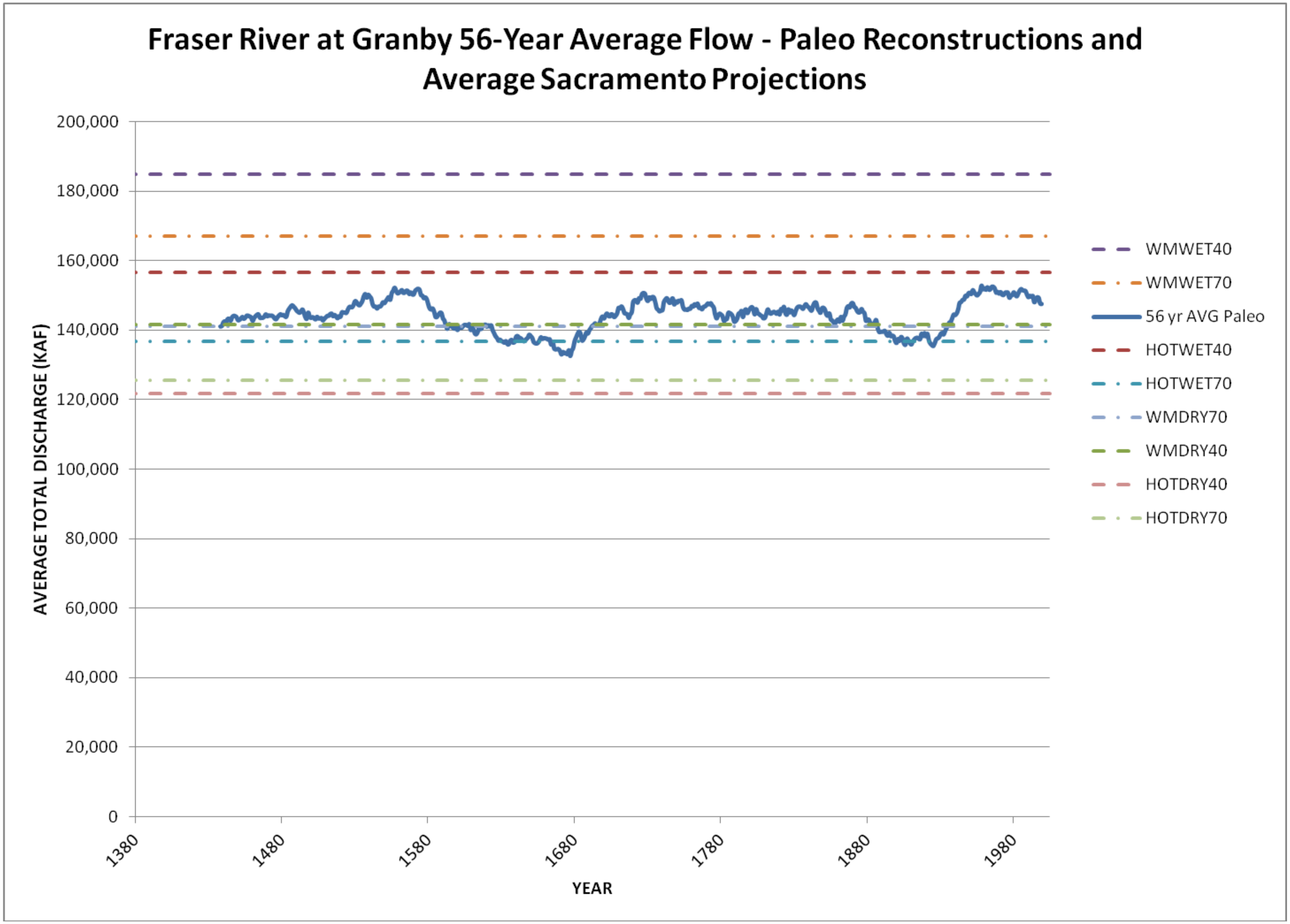


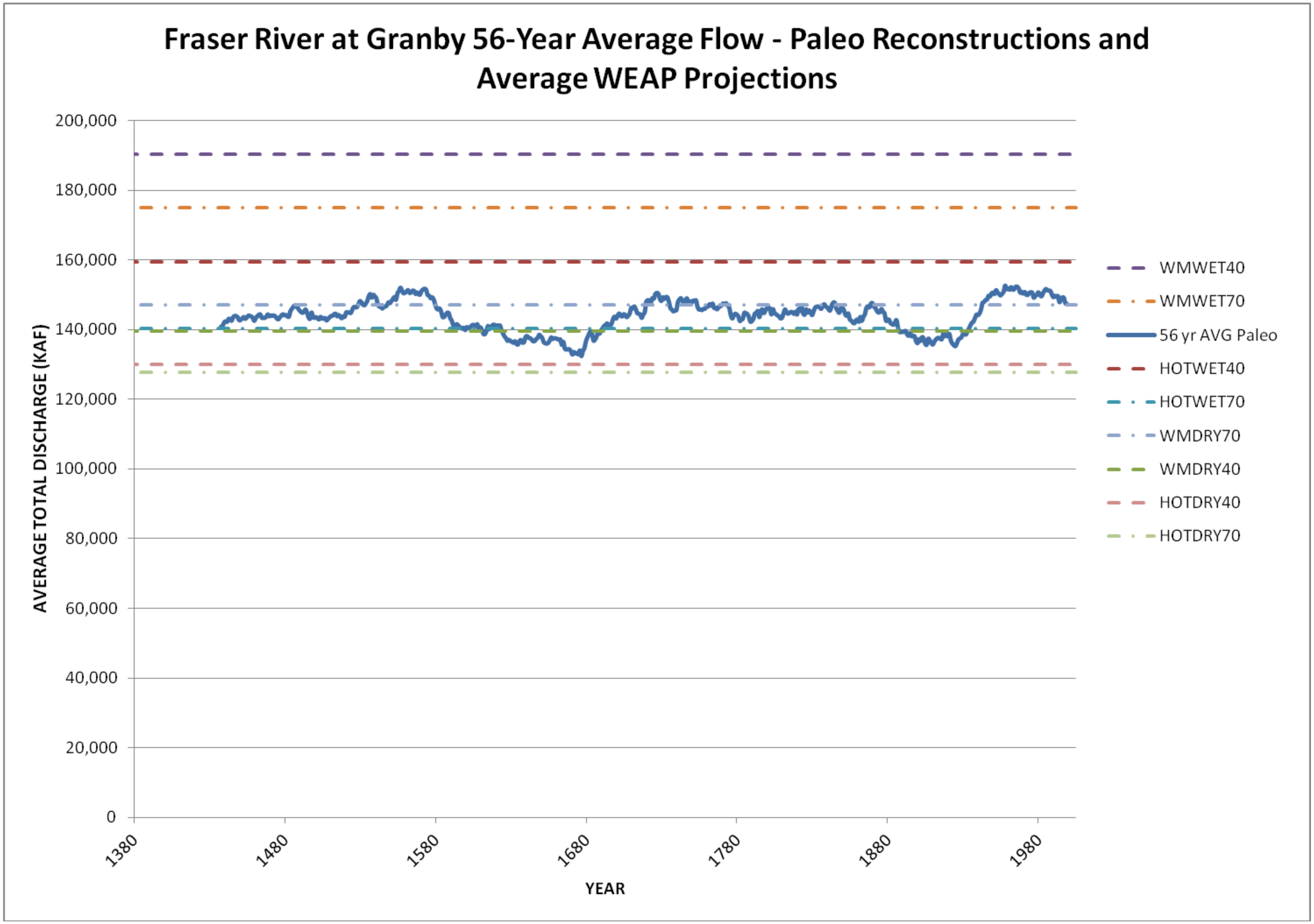
Cache la Poudre R 56-Year Average Flow - Paleo Reconstructions and Average WEAP Projections
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
AVERAGE TOTAL DISCHARGE (KAF)
1600
1650
1700
1750
1800
1850
1900
1950
2000
YEAR
WMWET40
WMWET70
56 yr AVG Paleo
HOTWET40
HOTWET70
WMDRY70
WMDRY40
HOTDRY40
HOTDRY70

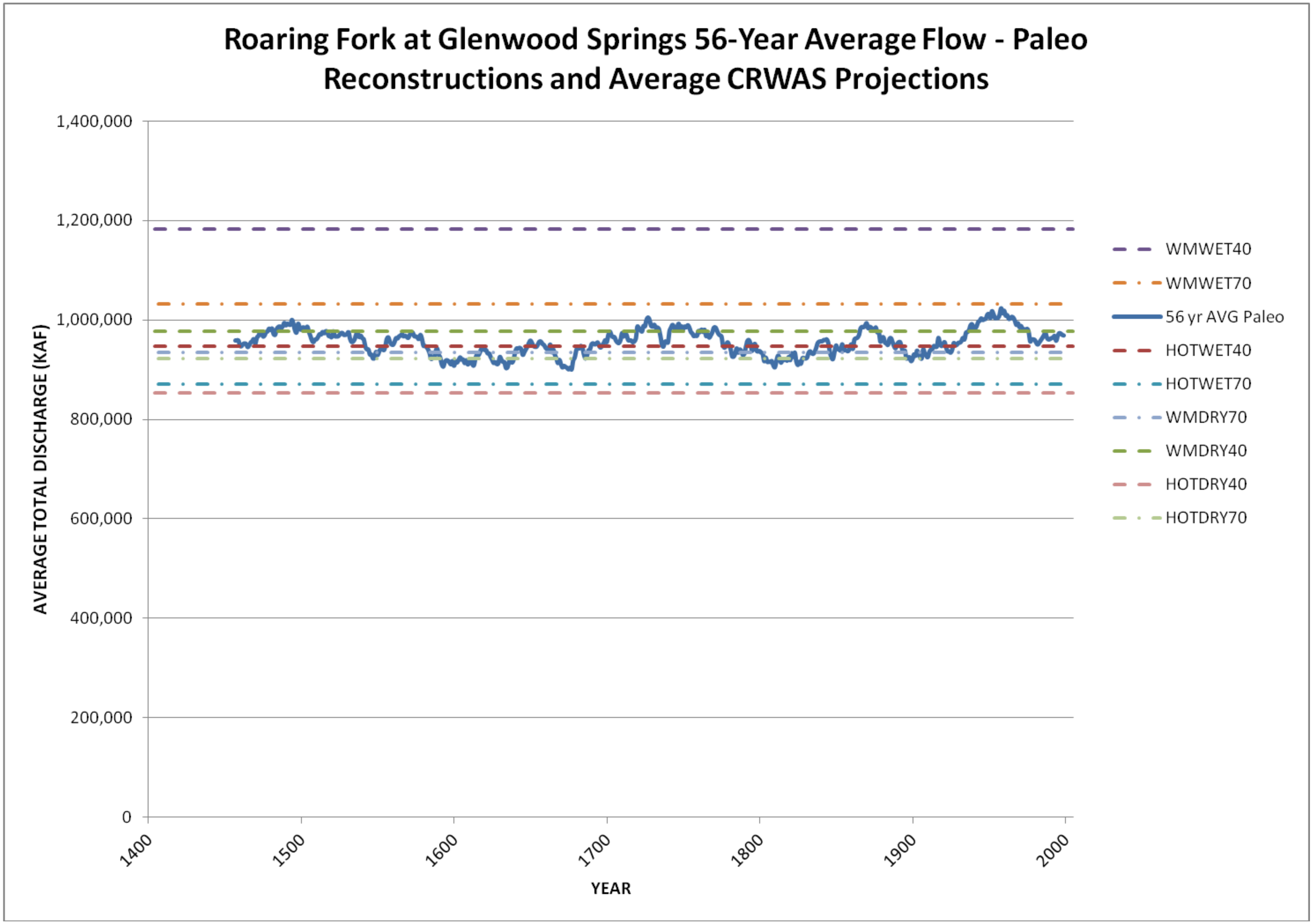


Colorado R at Kremmling 56-Year Average Flow - Paleo Reconstructions and Average CRWAS Projections
1,600,000
1,400,000
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
AVERAGE TOTAL DISCHARGE (KAF)
1400
1500
1600
1700
1800
1900
2000
YEAR
WMWET40
WMWET70
56 yr AVG Paleo
HOTWET40
HOTWET70
WMDRY70
WMDRY40
HOTDRY40
HOTDRY70

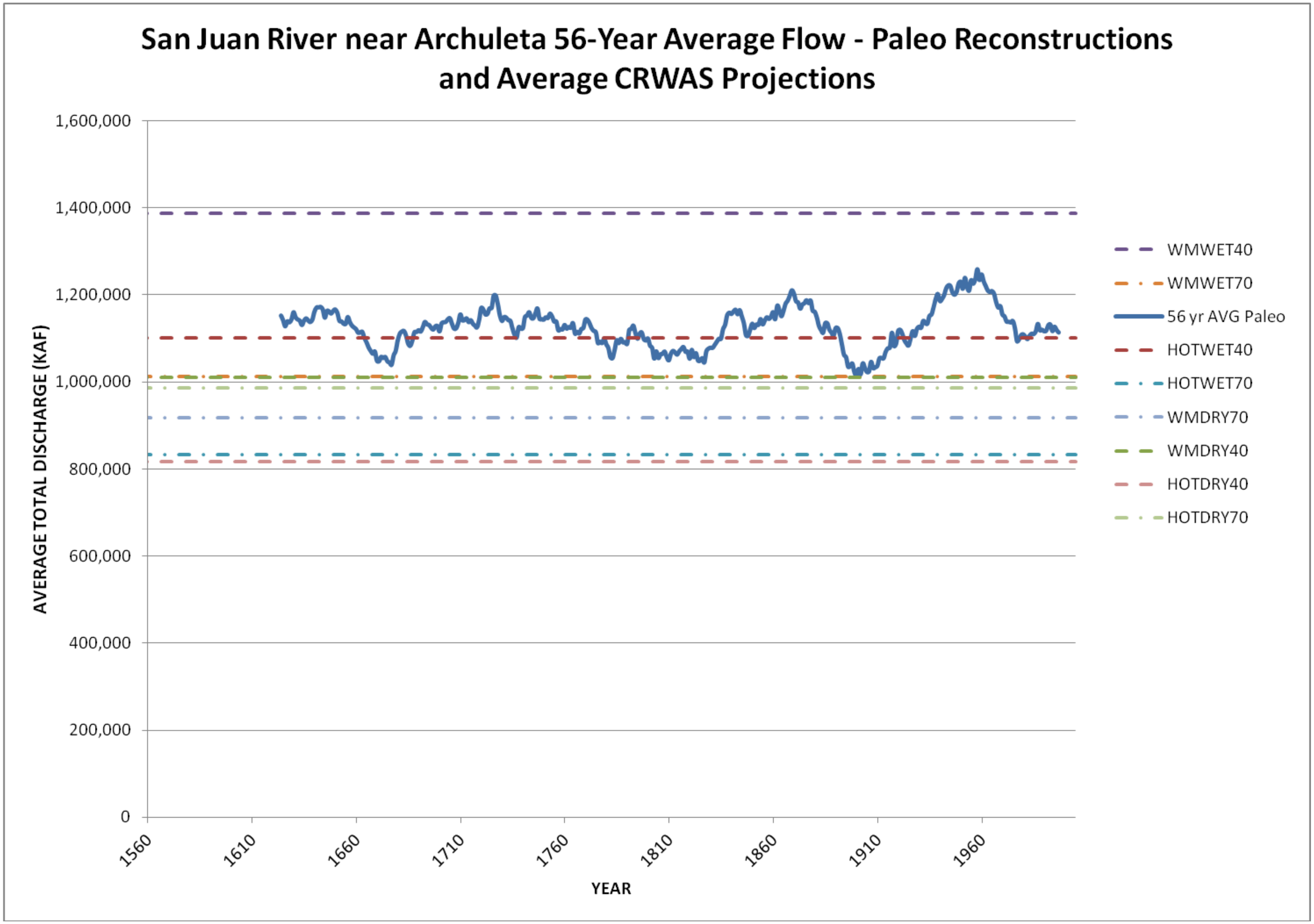

Modeled Dolores R 56-Year Average Flow - Paleo Reconstructions and Average CRWAS Projections
1,000,000
900,000
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
AVERAGE TOTAL DISCHARGE (KAF)
1560
1610
1660
1710
1760
1810
1860
1910
1960
YEAR
WMWET40
WMWET70
56 yr AVG Paleo
HOTWET40
HOTWET70
WMDRY70
WMDRY40
HOTDRY40
HOTDRY70

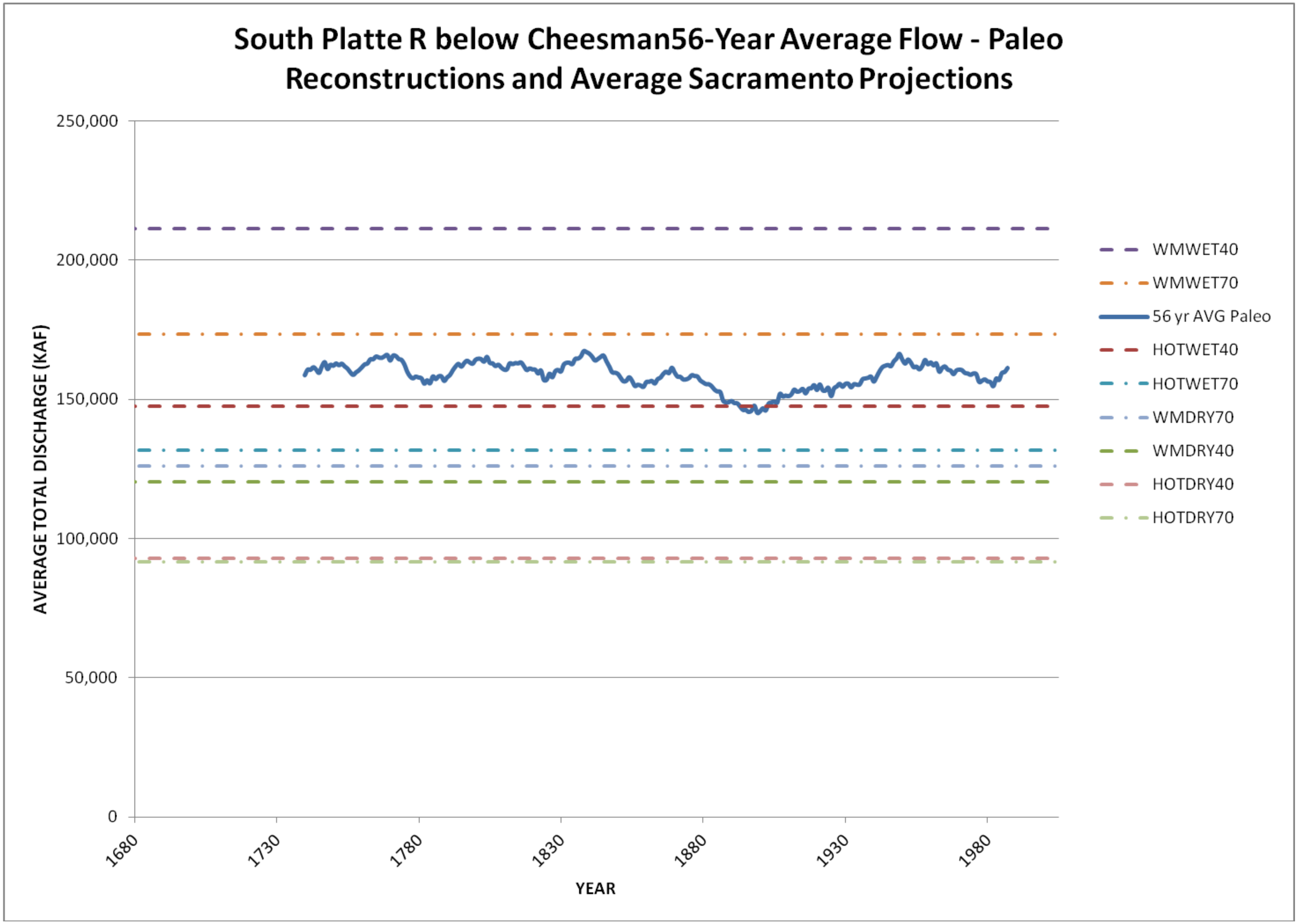

Fraser River at Granby 56-Year Average Flow - Paleo Reconstructions and Average Sacramento Projections
AVERAGE TOTAL DISCHARGE (KAF)
200,000
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
1380
1480
1580
1680
1780
1880
1980
YEAR
WMWET40
WMWET70
56 yr AVG Paleo
HOTWET40
HOTWET70
WMDRY70
WMDRY40
HOTDRY40
HOTDRY70

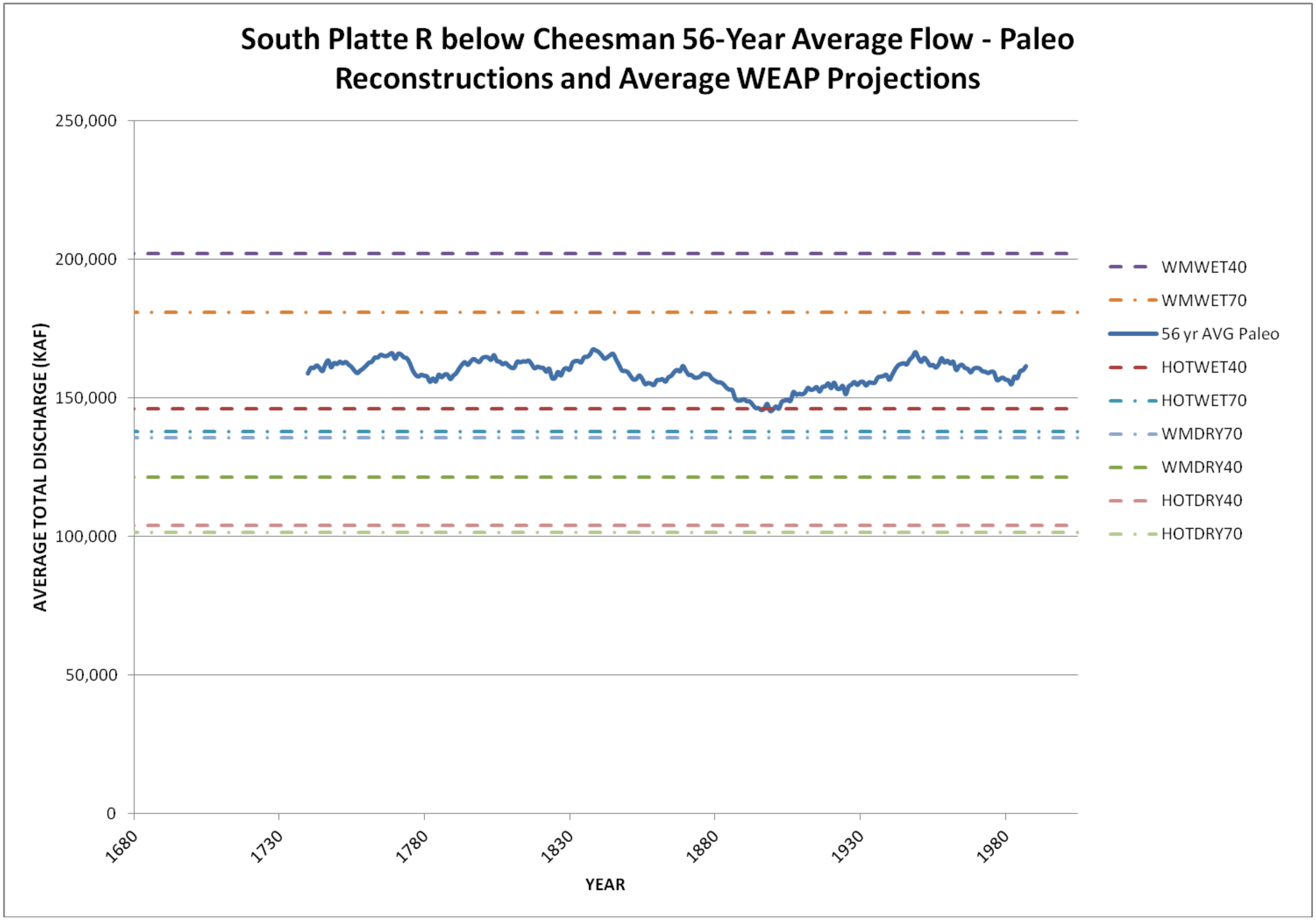

Fraser River at Granby 56-Year Average Flow - Paleo Reconstructions and Average WEAP Projections
AVERAGE TOTAL DISCHARGE (KAF)
200,000
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
1380
1480
1580
1680
1780
1880
1980
YEAR
WMWET40
WMWET70
56 yr AVG Paleo
HOTWET40
HOTWET70
WMDRY70
WMDRY40
HOTDRY40
HOTDRY70

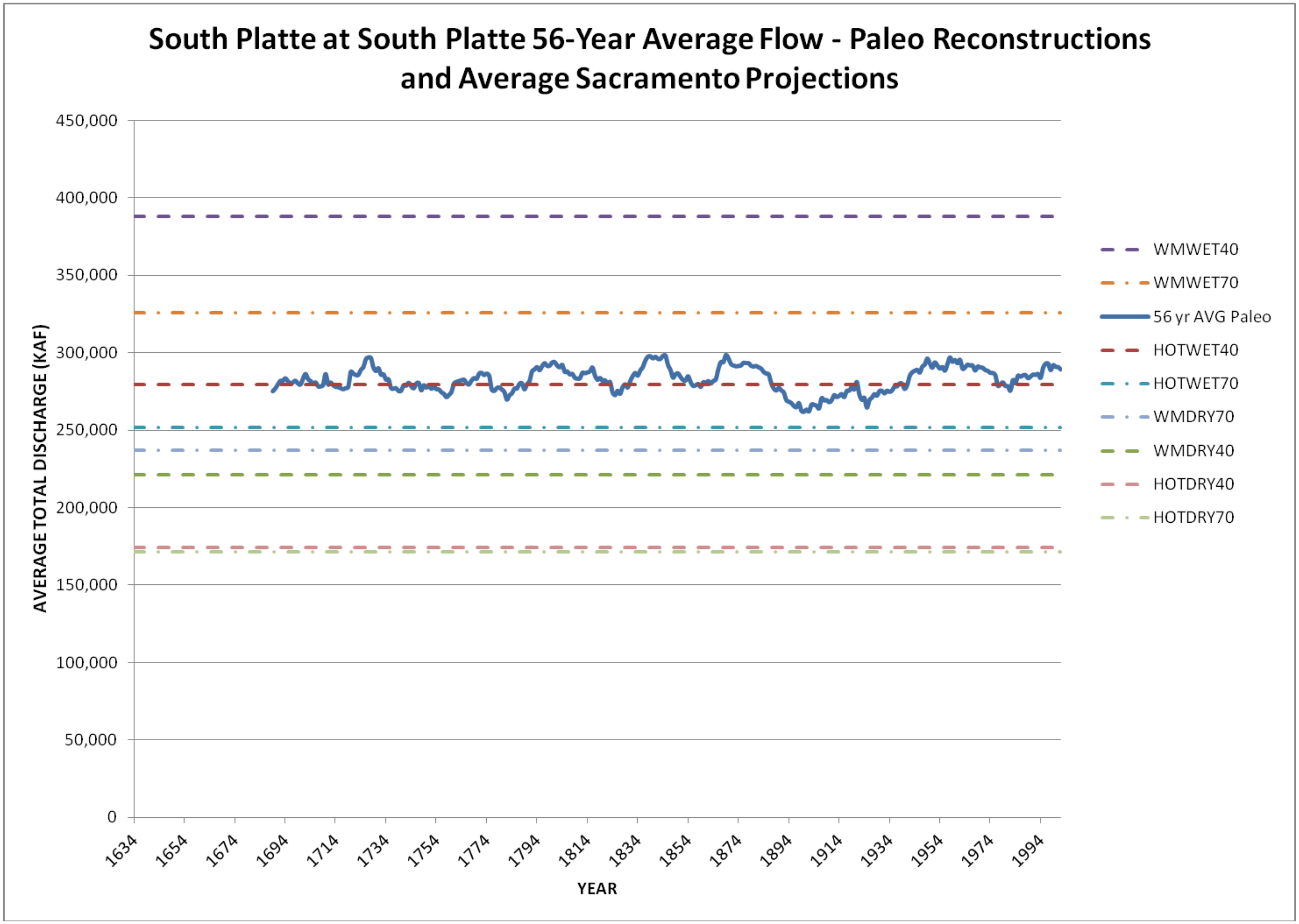


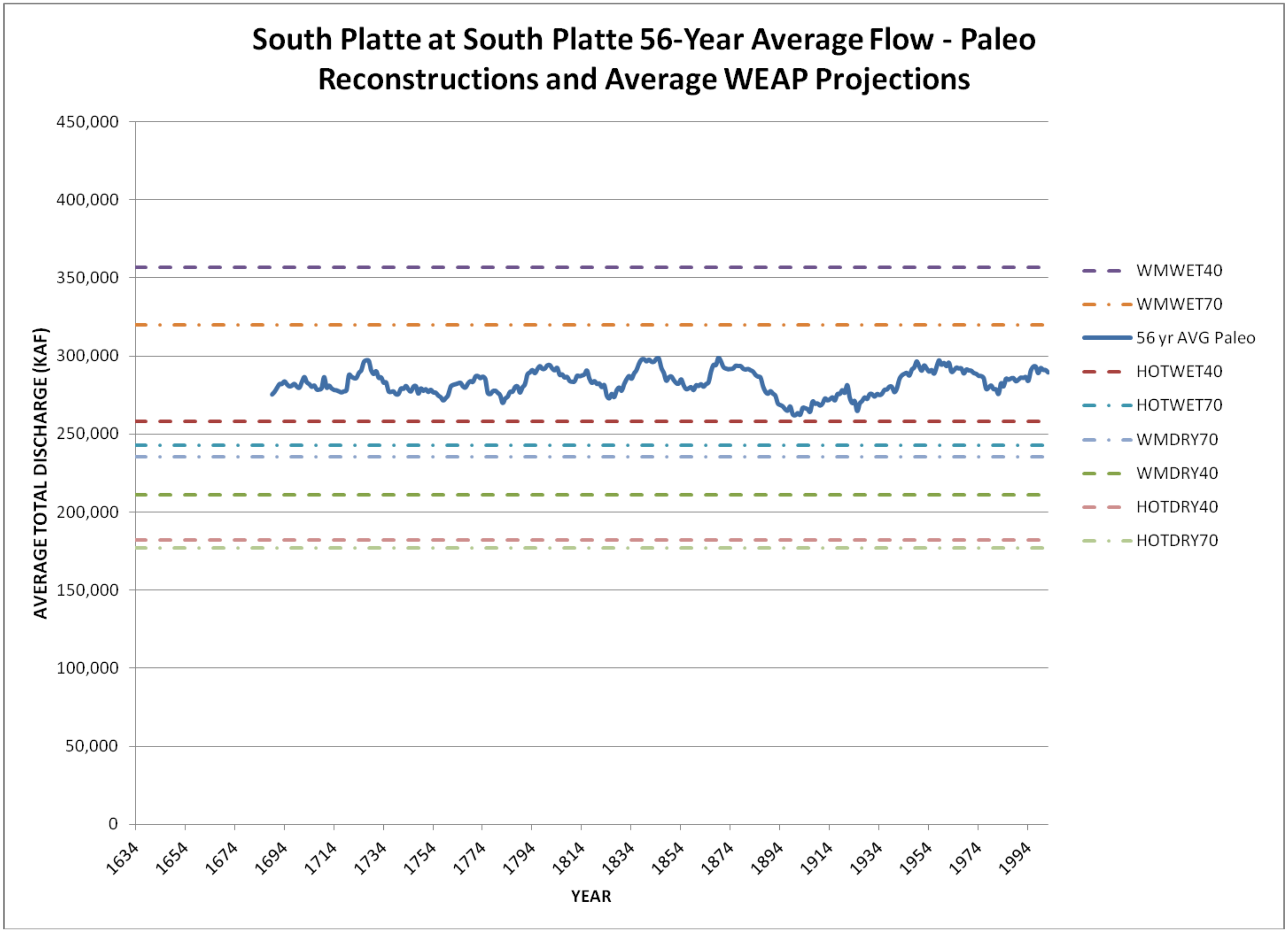
Roaring Fork at Glenwood Springs 56-Year Average Flow - Paleo Reconstructions and Average CRWAS Projections
AVERAGE TOTAL DISCHARGE (KAF)
1,400,000
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
1400
1500
1600
1700
1800
1900
2000
YEAR
WMWET40
WMWET70
56 yr AVG Paleo
HOTWET40
HOTWET70
WMDRY70
WMDRY40
HOTDRY40
HOTDRY70

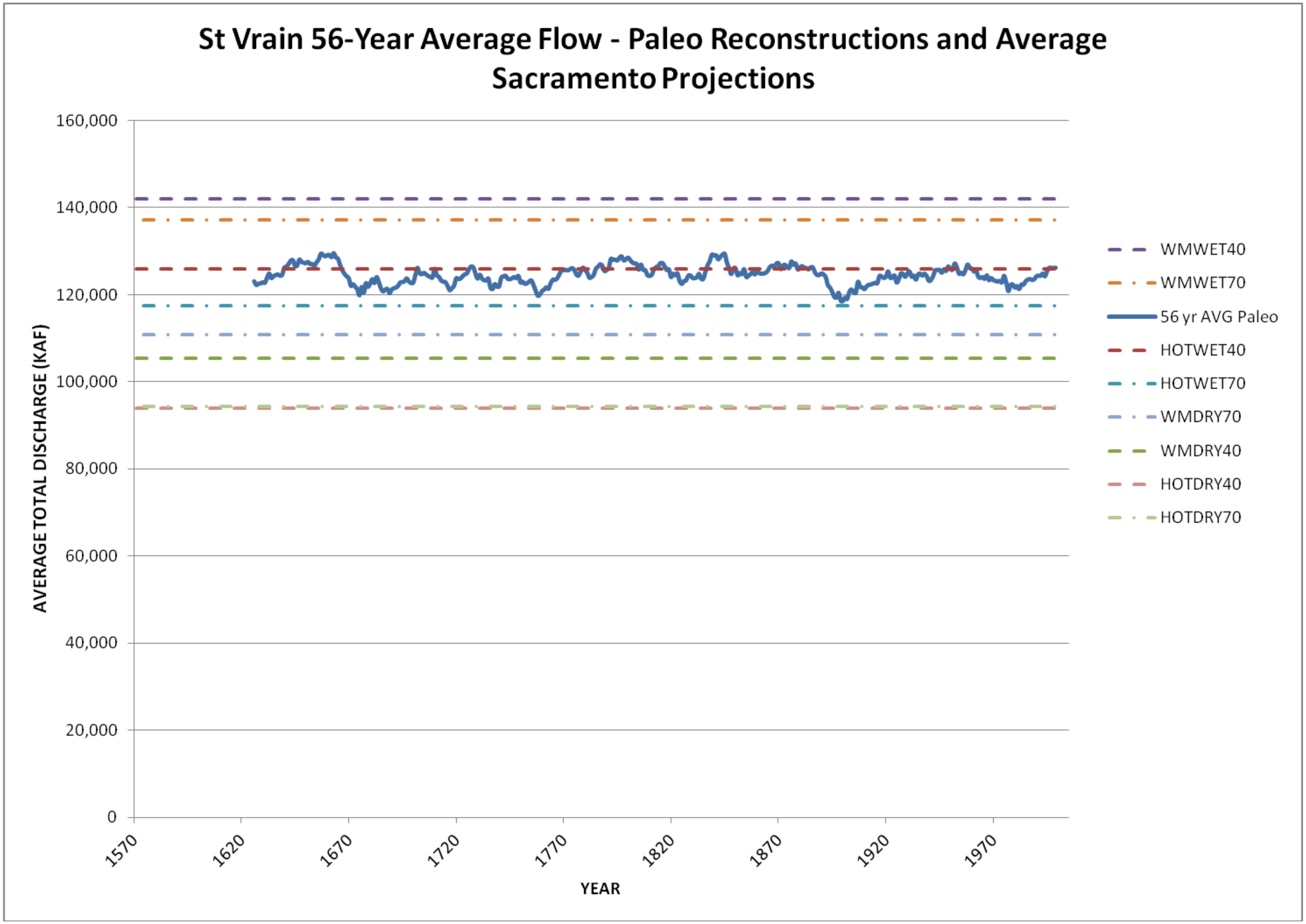

San Juan River near Archuleta 56-Year Average Flow - Paleo Reconstructions and Average CRWAS Projections
AVERAGE TOTAL DISCHARGE (KAF)
1,600,000
1,400,000
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
1560
1610
1660
1710
1760
1810
1860
1910
1960
YEAR
WMWET40
WMWET70
56 yr AVG Paleo
HOTWET40
HOTWET70
WMDRY70
WMDRY40
HOTDRY40
HOTDRY70


South Platte R below Cheesman56-Year Average Flow - Paleo Reconstructions and Average Sacramento Projections
250,000
200,000
150,000
100,000
50,000
0
AVERAGE TOTAL DISCHARGE (KAF)
1680
1730
1780
1830
1880
1930
1980
YEAR
WMWET40
WMWET70
56 yr AVG Paleo
HOTWET40
HOTWET70
WMDRY70
WMDRY40
HOTDRY40
HOTDRY70

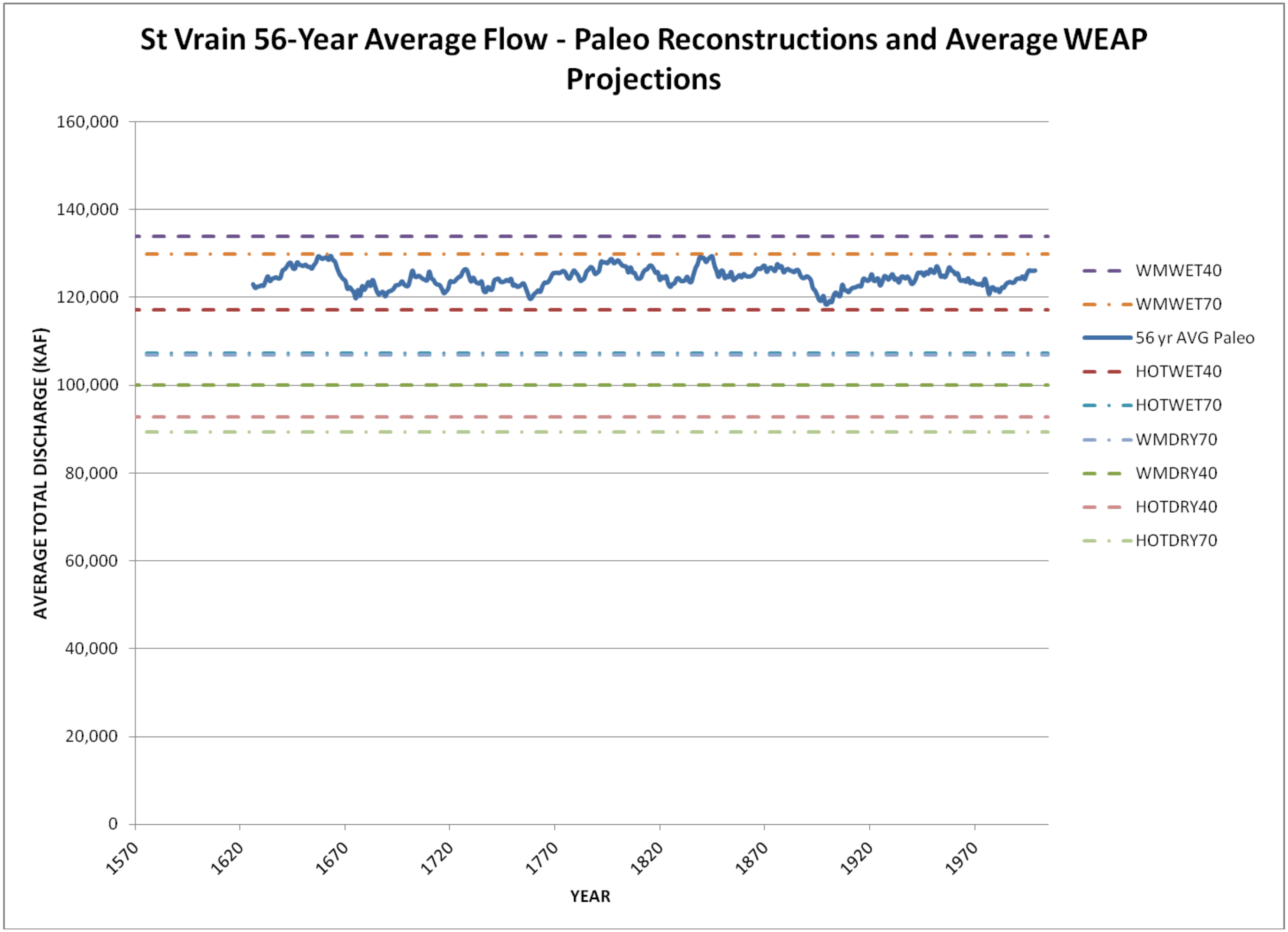

South Platte R below Cheesman 56-Year Average Flow - Paleo Reconstructions and Average WEAP Projections
AVERAGE TOTAL DISCHARGE (KAF)
250,000
200,000
150,000
100,000
50,000
0
1680
1730
1780
1830
1880
1930
1980
YEAR
WMWET40
WMWET70
56 yr AVG Paleo
HOTWET40
HOTWET70
WMDRY70
WMDRY40
HOTDRY40
HOTDRY70

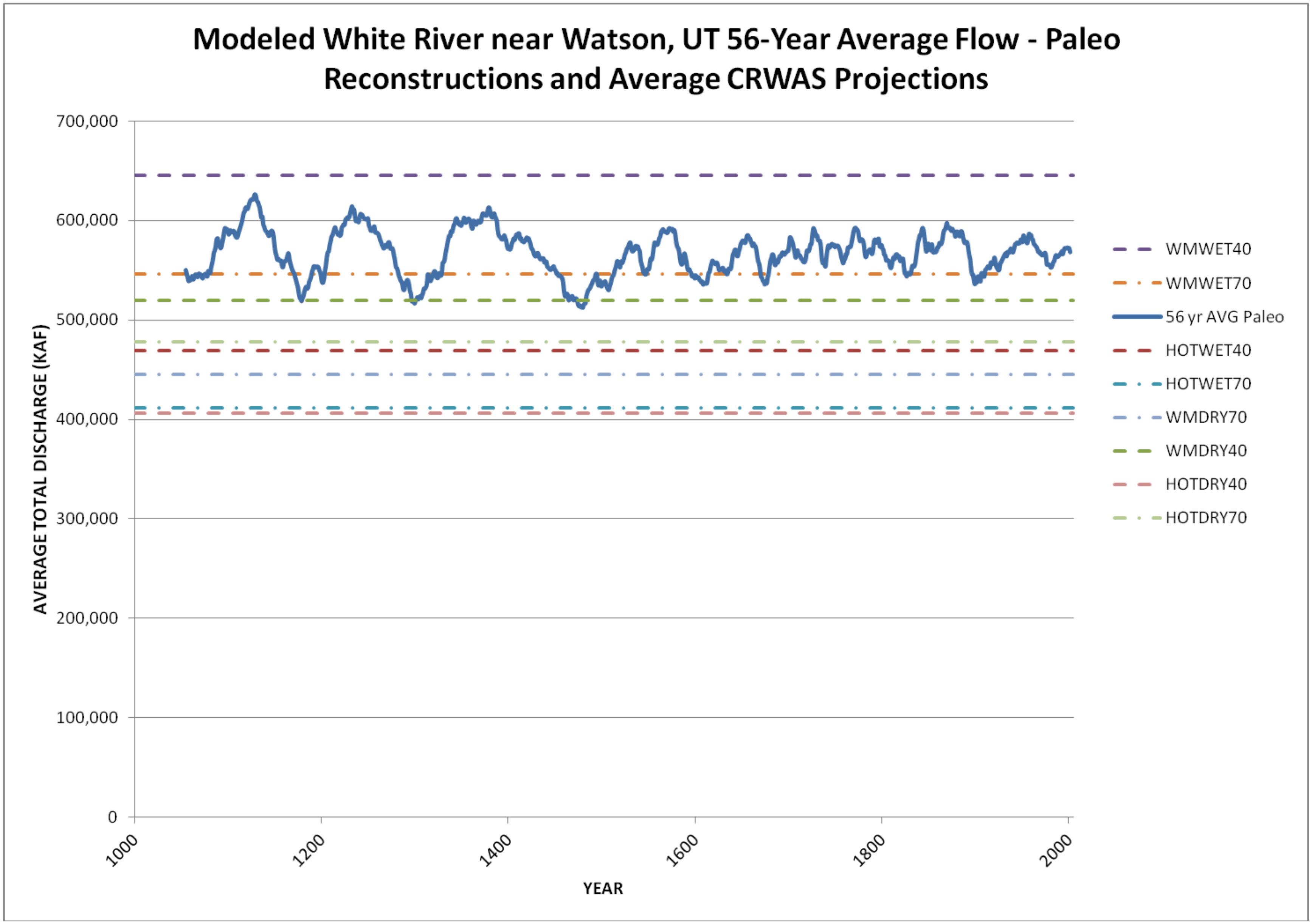

South Platte at South Platte 56-Year Average Flow - Paleo Reconstructions and Average Sacramento Projections
AVERAGE TOTAL DISCHARGE (KAF)
450,000
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
1634
1654
1674
1694
1714
1734
1754
1774
1794
1814
1834
1854
1874
1894
1914
1934
1954
1974
1994
YEAR
WMWET40
WMWET70
56 yr AVG Paleo
HOTWET40
HOTWET70
WMDRY70
WMDRY40
HOTDRY40
HOTDRY70

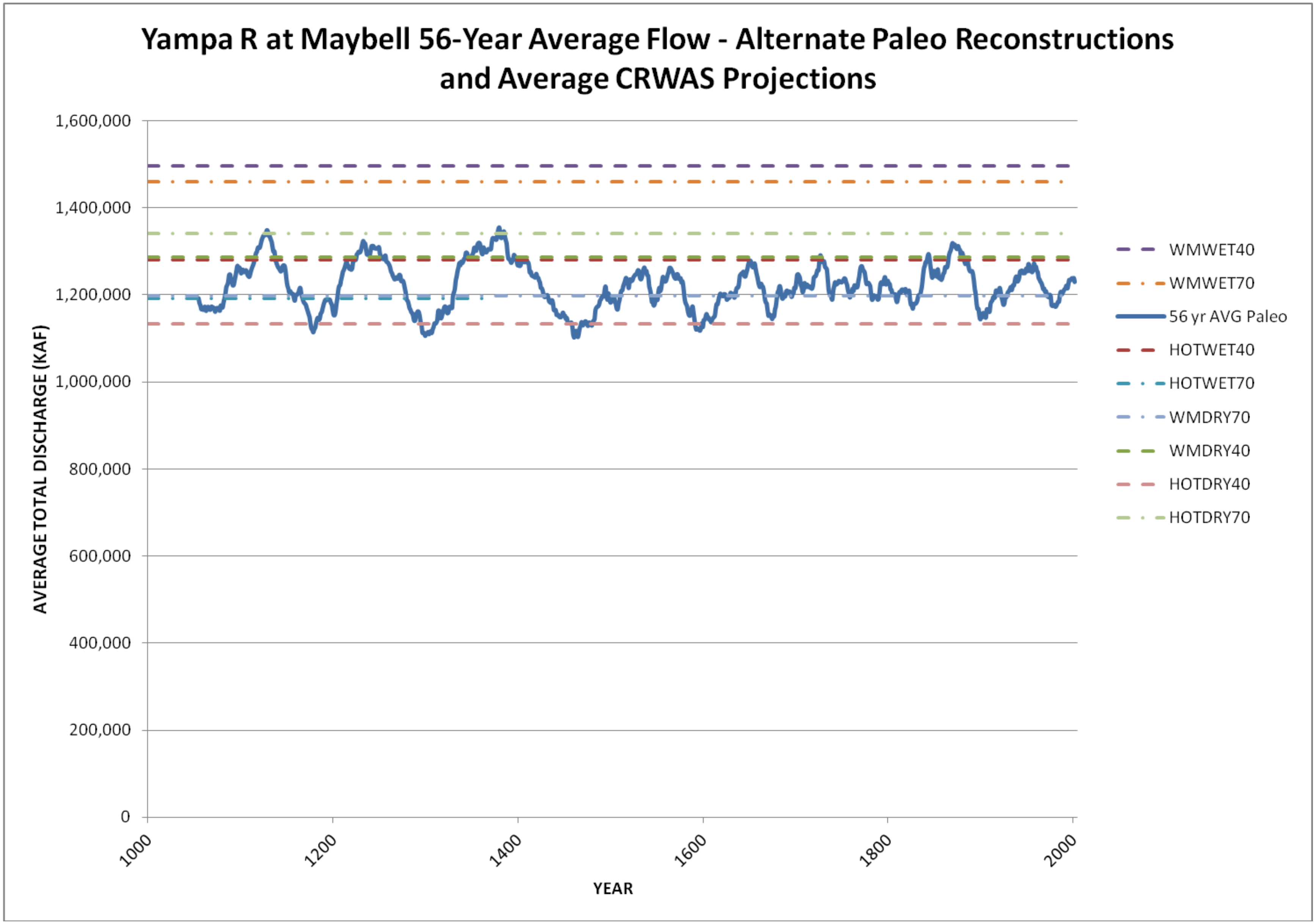

South Platte at South Platte 56-Year Average Flow - Paleo Reconstructions and Average WEAP Projections
AVERAGE TOTAL DISCHARGE (KAF)
450,000
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
1634
1654
1674
1694
1714
1734
1754
1774
1794
1814
1834
1854
1874
1894
1914
1934
1954
1974
1994
YEAR
WMWET40
WMWET70
56 yr AVG Paleo
HOTWET40
HOTWET70
WMDRY70
WMDRY40
HOTDRY40
HOTDRY70



St Vrain 56-Year Average Flow - Paleo Reconstructions and Average Sacramento Projections
AVERAGE TOTAL DISCHARGE (KAF)
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
1570
1620
1670
1720
1770
1820
1870
1920
1970
YEAR
WMWET40
WMWET70
56 yr AVG Paleo
HOTWET40
HOTWET70
WMDRY70
WMDRY40
HOTDRY40
HOTDRY70


St Vrain 56-Year Average Flow - Paleo Reconstructions and Average WEAP Projections
AVERAGE TOTAL DISCHARGE (KAF)
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
1570
1620
1670
1720
1770
1820
1870
1920
1970
YEAR
WMWET40
WMWET70
56 yr AVG Paleo
HOTWET40
HOTWET70
WMDRY70
WMDRY40
HOTDRY40
HOTDRY70


Modeled White River near Watson, UT 56-Year Average Flow - Paleo Reconstructions and Average CRWAS Projections
AVERAGE TOTAL DISCHARGE (KAF)
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
1000
1200
1400
1600
1800
2000
YEAR
WMWET40
WMWET70
56 yr AVG Paleo
HOTWET40
HOTWET70
WMDRY70
WMDRY40
HOTDRY40
HOTDRY70



Yampa R at Maybell 56-Year Average Flow - Alternate Paleo Reconstructions and Average CRWAS Projections
AVERAGE TOTAL DISCHARGE (KAF)
1,600,000
1,400,000
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
1000
1200
1400
1600
1800
2000
YEAR
WMWET40
WMWET70
56 yr AVG Paleo
HOTWET40
HOTWET70
WMDRY70
WMDRY40
HOTDRY40
HOTDRY70

# 6 References


Barnett, T. P., et al. 2008. Human-induced changes in the hydrology of the western United States. *Science* 319 (2).

Barnett, T. P., and D. W. Pierce. 2008. When will Lake Mead go dry? *Water Resources Research* 44.

CCSP. 2008. 4.3 The effects of climate change on agriculture, land resources, water resources, and biodiversity in the United States. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research.

Christensen, N. S., et al. 2004. The Effects of climate change on the hydrology and water resources of the Colorado River Basin. *Climate Change* 62.

Colorado Water Conservation Board. 2008. Climate Change in Colorado; A Synthesis to Support Water Resources Management and Adaptation.

Colorado Water Conservation Board. 2012. Colorado River Water Availability Study, Phase I final report.

Colorado Water Conservation Board. 2012a. Colorado River Water Availability Study, Phase I final report, Appendices.

Gleick, P. H., and E. L. Chalecki. 1999. The impacts of climate change for water resources of the Colorado and Sacramento-San Joaquin River Basins. *Journal of the American Water Resources Association* 35 (6).

Harding, B. L., Wood, A. W. and Prairie, J. B., 2012. The implications of climate change scenario selection for future streamflow projection in the upper Colorado River basin, Hyd. Earth Sys. Sci. http://www.hydrol-earth-syst-sci.net/16/3989/2012/.

IPCC. 2001. Climate change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report for the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK and New York, NY.

IPCC. 2007. Climate Change 2007: The Physical Science Basis, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge UK and New York, NY.

Karl, T. R., and W. E. Riebsame. 1989. The impact of decadal fluctuation in mean precipitation and temperature on runoff: a sensitivity study over the United States. *Climate Change* 15.

Knowles, N., M. D. Dettinger, and D. R. Cayan. 2006 Trends in snowfall versus rainfall in the western United States. *Journal of Climate* 19.

Milly, P. C. D., et al. 2008. Stationarity is dead: whither water management? *Science* 319 (2).

Mote, P. W. 2006. Climate-driven variability in trends in mountain snowpack in western North America. *American Meterological Society*.

Mote, P. W., et al. 2005. Declining mountain snowpack in western North America. *Bulletin of the American Meteorological Society*.

Nash, L. L., and P. H. Gleick. 1990. Sensitivity of streamflow in the Colorado basin to climate changes. *Journal of Hydrology* 125 (10).

NOAA. 2009. The potential consequences of climate change for Boulder Colorado's water supplies.

NOAA. 2013. Treeflow web site. http://treeflow.info/index.html Last accessed, June 22, 2013.

Stewart, I. T., D. R. Cayan, and M. D. Dettinger. 2004. Changes toward earlier streamflow timing across western North America. *Journal of Climate* 18 (7).

Suanders, S., and M. Maxwell. 2005. Less snow, less water: climate disruption in the west. In *A Clear the Air Report*.

Udall, B., and G. Bates. 2007. Climate and Hydrologic Trends in the Western U. S.: A review of Recent Peer-Reviewed Research. *In Intermountain West Climate Summary*.

Water Research Foundation, 2012. Joint Front Range Climate Change Vulnerability Study. Denver, Colorado, 2012.

Woodhouse, C., and J. Lukas. 2006. Streamflow Reconstructions for Boulder Creek, South Boulder Creek, and the Colorado River. Report to City of Boulder and Hydrosphere Resource Consultants, January 2006.

# DROUGHT MONITORING INDICES

ANNEX D TO THE DROUGHT MITIGATION AND RESPONSE PLAN

August 2013

Prepared Pursuant to
Disaster Mitigation Act 2000 & Section 409, PL 93-288

Prepared by
Colorado Water Conservation Board
Department of Natural Resources
in Cooperation with
the Department of Local Affairs
Division of Emergency Management

# Table of Contents

1 Introduction ........ 1

2 Surface Water Supply Index Modernization for Colorado ........ 1

3 2010 Analysis of the Palmer Drought Severity Index for Colorado Drought Monitoring ..... 5

3.1 Background ........ 5

3.2 Index Documentation ........ 6

4 References ........ 22

# 1 Introduction

The Surface Water Supply Index (SWSI) has been used, along with the Palmer Drought Severity Index (PDSI) and the Standardized Precipitation Index (SPI), as the basis for making decisions for the activation and deactivation of the Colorado Drought Response Plan (Plan). This annex discusses an evaluation and integration of these drought monitoring indices and their role and use in Colorado's Drought Mitigation and Response Plan. This evaluation project was led by the Colorado Climate Center in the Department of Atmospheric Science at Colorado State University during November 2009–September 2010 as a parallel effort to the Plan revision. During the same time frame the Natural Resources Conservation Service (NRCS) modernized the SWSI for Colorado. The results of these efforts have been integrated into the Base Plan and Annex A and are discussed in greater detail in this annex.

# 2 Surface Water Supply Index Modernization for Colorado

The original SWSI was developed in Colorado in 1981 by the Soil Conservation Service (now named the Natural Resources Conservation Service) and the Colorado Division of Water Resources. The purpose of the index was to describe drought severity for areas relying primarily on surface water supplies (direct streamflow and water stored in reservoirs) where water availability is driven by winter snow accumulation and subsequent melt, typical in the western U.S. During the winter months (December–May) the index uses snowpack, water year precipitation and reservoir storage. In summer and fall (June–November), the index switches to streamflow, previous month's precipitation, and reservoir storage. The index is computed by determining each variable’s nonexeedance probability, then multiplying by a subjective weighting factor that relates approximately to the contribution of each component to the total water surface water supply. The variables are summed and converted to an index of generally +4 (abundant supplies) to -4 (exceptional drought). The +4 to -4 range was used to mimic the historic and widely used PDSI.

In the early 1990s, the NRCS refined the SWSI calculation to improve upon the known deficiencies of the existing SWSI procedures that had evolved in many western states.[1] It had long been recognized that one of the primary deficiencies of the SWSI formulation is the use of weighting factors which are a subjective assessment of water availability in the basin in an attempt to index surface water supplies. Substituting streamflow forecasts for these variables is a more objective, statistical assessment of the data relating to snowmelt runoff. Streamflow forecasts are optimized from the data for the hydrologic components and implicitly contain optimal weighting of the components.

[1] Garen, D. C. (1993). Revised surface water supply index for western United States. Journal of Water Resources Planning and Management, American Society of Civil Engineers, 119(4), 437-454.

Additionally, the result of a weighted sum of nonexeedance probabilities does not behave statistically like a nonexeedance probability itself. A preferable method in this application is to base the index on a single aggregated variable designed to describe surface water supply (the water supply forecast plus available reservoir storage). By doing this, only one nonexeedance probability is used, and the index will have the appropriate statistical behavior.

Adopted as part of the 2010 state drought plan revision, the revised technique for calculating SWSI provide a more stable month to month transition which should eliminate some of the illogical shifts in index values, which the existing SWSI sometimes produces as the variables change throughout the year. The revised SWSI will use the following variables as an index of available water supplies:

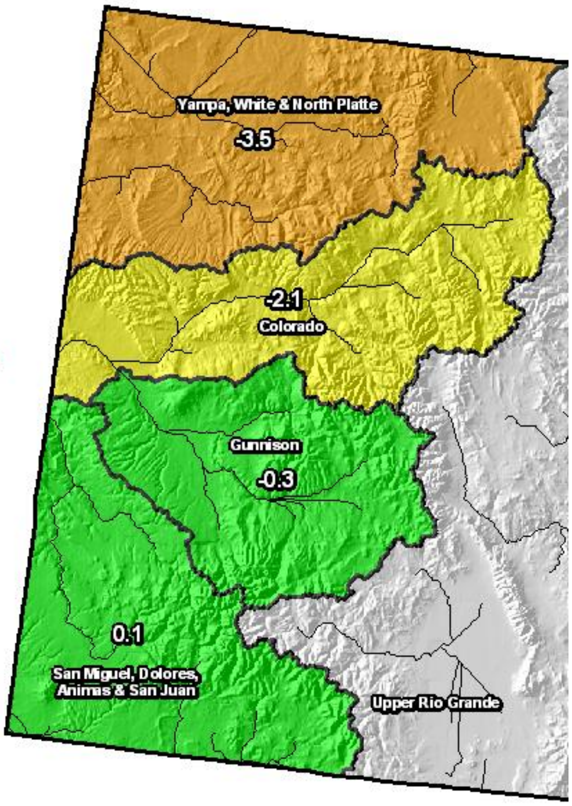
| **Time Period** | **Variables** |
|---|---|
| January – June | Forecasted Runoff + Reservoir Storage |
| July – September | Previous Month's Streamflow + Reservoir Storage |
| October - December | Reservoir Storage |

During the January through June period, SWSI values are based on forecasted runoff plus reservoir storage. Forecasted runoff values are issued each month jointly by the NRCS and River Forecast Centers (RFC) of the National Weather Service. These forecasts incorporate an objective, statistical assessment of the data for the components relating to snowmelt runoff (snowpack, precipitation, streamflow).

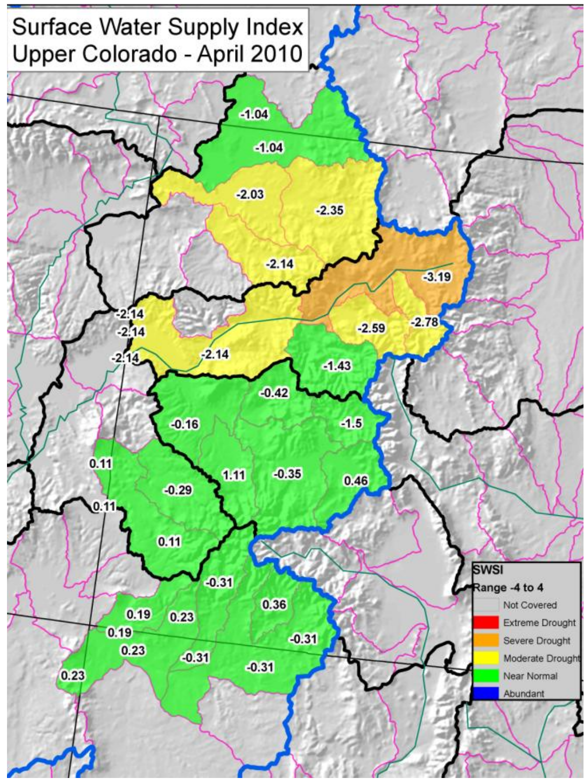
Both Utah and Wyoming have adopted SWSI procedures similar to this revised SWSI procedure and the transition to this technique in Colorado will improve cross-state comparisons of drought severity. This consistency would assist with the coordination of drought categories used in the US Drought Monitor. Another improvement includes an increase of the spatial detail to approximately 30 watersheds instead of the seven major basins previously covered, which is shown in Figure 1.Watersheds in the Upper Colorado River Basin began using the revised SWSI in April 2010, with the first results presented at the Colorado WATF meeting on May 21, 2010. The transition for the rest of the state was completed in 2012. Upon completion, NRCS assumed full responsibility for issuing monthly SWSI values for 38 eight-digit Hydrologic Units in Colorado. Figure 2 provides on example of the SWSI index applied statewide in January 2013. A comparison between the traditional SWSI and the revised SWSI will be performed to evaluate the performance of the revised SWSI procedure.

## Figure 1 Comparison of Old and New Surface Water Supply Index

**Old Method**

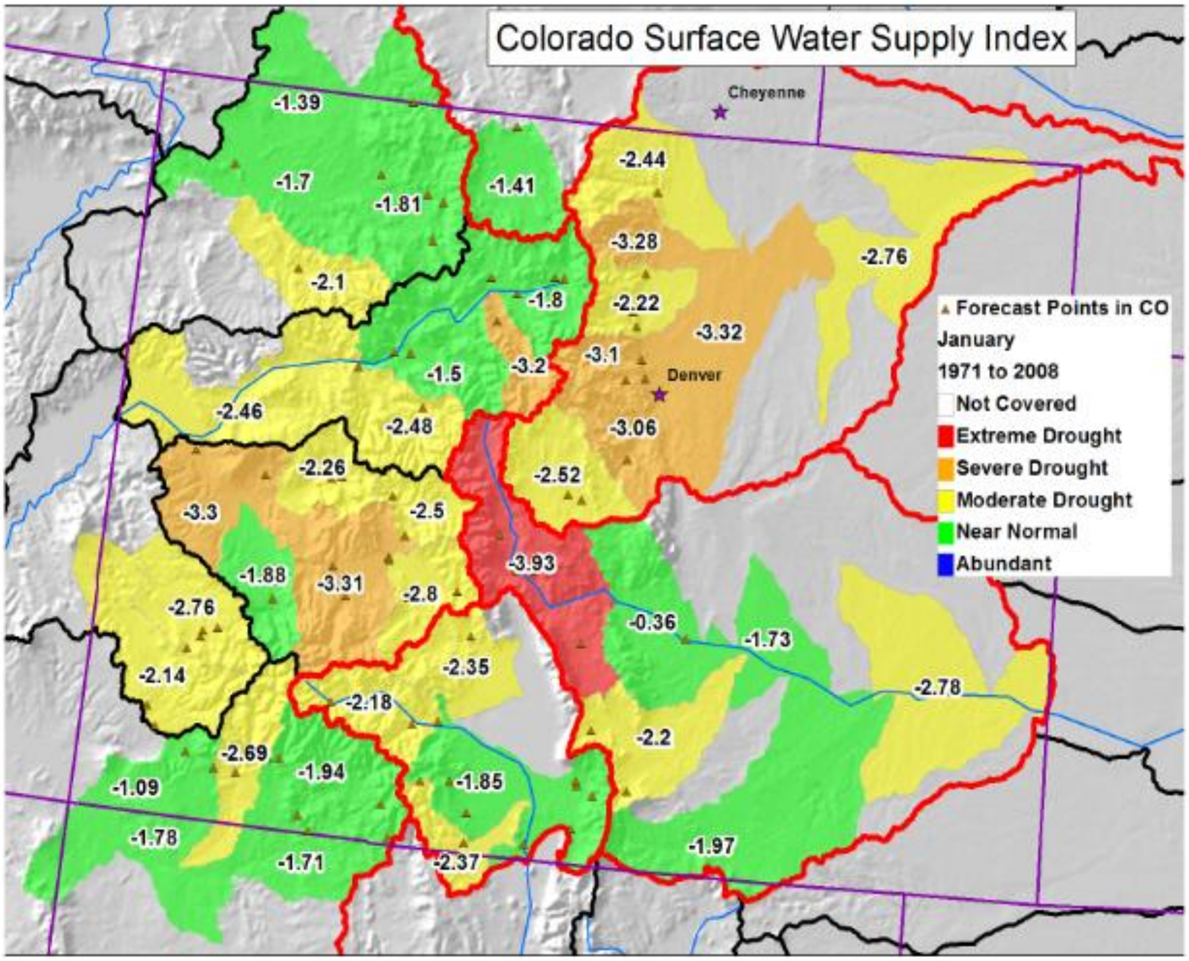



**New Method**




Source: USDA – Natural Resources Conservation Service

## Figure 2 SWSI Index for Colorado – Example from January 2013



# 3 2010 Analysis of the Palmer Drought Severity Index for Colorado Drought Monitoring

## 3.1 Background

The Colorado Climate Center (CCC) Department of Atmospheric Science at Colorado State University conducted an analysis of drought monitoring indices as part of the 2010 Plan revision. The CCC has played an active role in climate observation, drought monitoring, data integration, and decision support since its establishment in 1974. Starting with the intense winter drought of 1976–1977, the CCC has helped develop and evaluate tools for monitoring and communicating drought information. Since the first Colorado State Drought Response Plan was implemented in 1981, the CCC has worked through the Colorado Water Availability Task Force to propose and evaluate several drought indices to simplify the communication of drought severity. These included the Colorado Modified Palmer Drought Severity Index (CMPDSI) and the standardized precipitation index (SPI). The CCC was also a participant in the development, evaluation and implementation of the Surface Water Supply Index (SWSI). The selection of the Upper Colorado River as the first pilot project for the National Integrated Drought Information System (NIDIS) provided an unprecedented opportunity for Colorado to look closely at hydrometeorological observations and their role in drought monitoring and early warning. The NIDIS pilot project basin-focused activities and resources were leveraged and assisted with the re-evaluation of traditional Colorado drought monitoring statewide.

The CCC performed the following tasks to evaluate and improve the use of drought thresholds and indices in the revised State of Colorado Drought Mitigation and Response Plan:

1) Development of brief documentation for the computation and input data for the SPI. Evaluate the pros and cons of the SPI and provide recommendations on how to best utilize this index in statewide drought monitoring.

2) Development of brief documentation of the CMPDSI including a description of the index and its computation and required input data. Evaluate the pros and cons of the CMPDSI and provide recommendations on how to best utilize this index in statewide drought monitoring.

3) Assessment of climate data requirements and data continuity used in the development and production of the CMPDSI and SPI. Reselect, as needed, the long-term climate data inputs for drought index computation. This included computation of drought index time series for the period 1951-2009.

4) Comparison and contrast of the CMPDSI and SPI (at several different time scales – 3, 6, 9, 12, 24, and 48 month) values for 25 specific regions of Colorado (Western Slope, mountain regions, interior high valleys, Front Range, Eastern Plains) using the new drought index time series. This included statistical determination of fundamental similarities and differences of indices and their relative predictive and diagnostic capabilities. These results were presented

at the April 30 Drought Mitigation and Response Planning Committee meeting with the specific goal of determining, by consensus of drought information providers and drought response decision makers, if the CMPDSI is sufficiently different and skillful (diagnostically or predicatively) to justify its continued use.

5) Work with the Water Availability Task Force to determine if either CMPDSI or the SPI should be computed and displayed as index values for predetermined "climate divisions" (regions and subregions) or computed and displayed as individual data points with sufficient long-term data.

6) Development of best-practices strategies for use of indices in drought documentation, prediction, early warning, and public dissemination.

7) Work with the CWCB drought plan revision consultant to illustrate and evaluate the historical use of drought index thresholds and trigger points. Then, in context with improvements, enhancements and inherent limitations of "Triggers and Indices", provide a rationale for incorporation of individual and/or combined index values in the activation and deactivation of State Drought Plan response steps. Provide experience-based input to the consultant on response steps in the existing State Drought Plan including recommendations for changes.

The key results of these efforts have been integrated where applicable into the Base Plan and Annex A. The following discussion captures additional details and recommendations from the study, including technical information.

## 3.2 Index Documentation

***Standardized Precipitation Index (SPI)***

The SPI was developed at the Colorado Climate Center (McKee et al. 1993) as a tool for defining and monitoring drought. This relatively simple index can be used in any location or region to compare wet and dry periods as long as there are weather stations with a reasonably long (i.e., ideally 30 years or longer) period of consistent data. The SPI is ideally suited for examining dryness on a variety of different time scales such as the past month, the past three months, the past year, or even longer periods. Precipitation is the only input data requirement for the SPI calculation. Please refer to Edwards and McKee 1997 for a complete description of the SPI methodology.

To begin the SPI calculation precipitation sums of varying length (i.e., 3-month, 6-month, 12-month, etc.) are calculated where "n" can be any length of consecutive months, but is typically 3, 6, 9, 12, 24 and 48 months..This distribution of empirical data, depending on the selected time scale, may not be normally distributed (i.e., a bell-shaped curve). To simplify the statistical analysis of the data, the distribution of raw data are fit with a smooth curve. Gamma distributions (Thom 1966) are well suited for describing the shapes of the distributions of monthly and seasonal precipitation totals. The shape and scale parameters of the gamma distribution are estimated for each individual station or region for each time scale for each month of the year using the empirical probabilities of the precipitation data (Thom 1966). The running precipitation sums are converted to nonexceedance probabilities using the incomplete gamma function (Figure 3). The nonexceedance probabilities are then converted to an index value using the inverse normal function shown in the equations below. This transforms the data from a skewed distribution to a standard normal distribution with a mean of zero and variance of one (i.e., the bell-shaped curve) using the methodology of Abramowitz and Stegun (1965). In this form, the SPI becomes essentially the number of standard deviations an event is above or below the mean value. Table 1 provides the relationship of the SPI values to condition descriptors and percentile rankings.

$$Z = \text{SPI} = -\left(t - \frac{c_0 + c_1 t + c_2 t^2}{1 + d_1 t + d_2 t^2 + d_3 t^3}\right) \quad \text{for } 0 < \text{H(x)} \le 0.5$$

$$Z = \text{SPI} = +\left(t - \frac{c_0 + c_1 t + c_2 t^2}{1 + d_1 t + d_2 t^2 + d_3 t^3}\right) \quad \text{for } 0.5 < \text{H(x)} < 1.0$$

where:

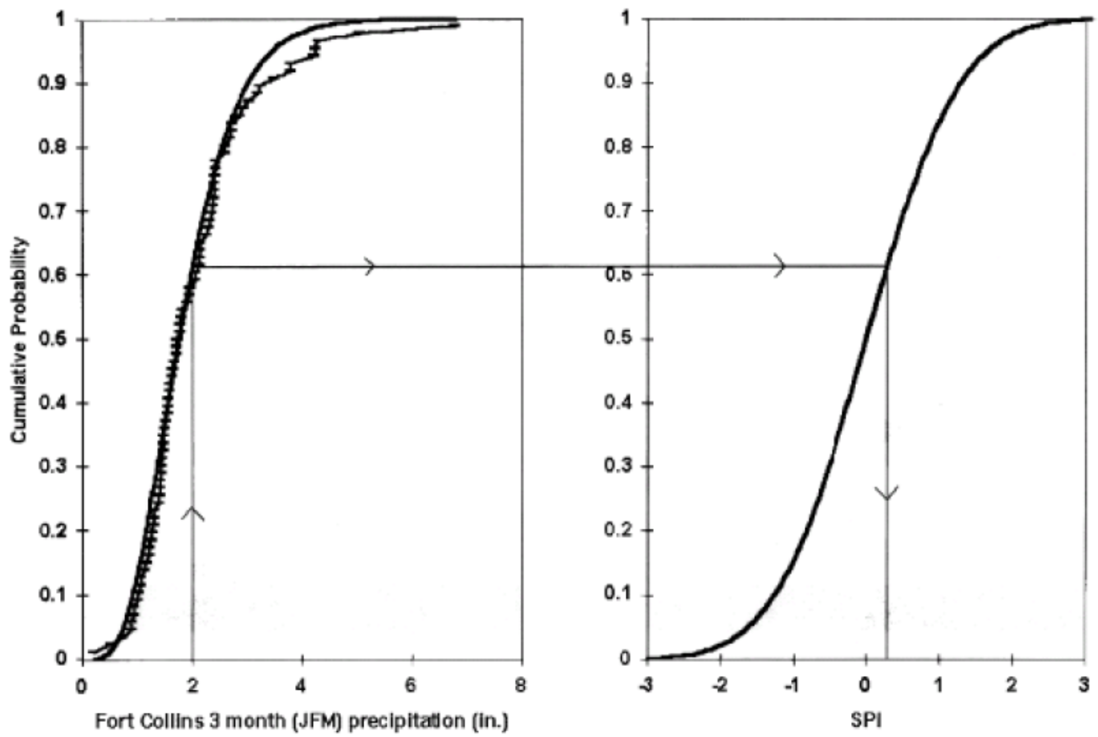
*H(x)* = non-exceedance probabilities from the incomplete gamma function.

$$t = \sqrt{\ln\left(\frac{1}{(H(x))^2}\right)} \qquad \text{for } 0 < \text{H(x)} \le 0.5$$

$$t = \sqrt{\ln\left(\frac{1}{(1.0 - H(x))^2}\right)} \qquad \text{for } 0.5 < \text{H(x)} < 1.0$$

$c_0 = 2.515517$
$c_1 = 0.802853$
$c_2 = 0.010328$
$d_1 = 1.432788$
$d_2 = 0.189269$
$d_3 = 0.001308$

## Figure 3 Cumulative Probability Transformation from the Gamma (left) to Standard Normal Distribution (right)




Source: Edwards and McKee 1997

## Table 1 SPI and Corresponding Percentile Rank and Character of Index

| SPI | Percentile Rank | Character |
|---|---|---|
| -3 | 0.14% | Extremely Dry |
| -2.5 | 0.62% | Extremely Dry |
| -2 | 2.28% | Extremely Dry |
| -1.5 | 6.68% | Severely Dry |
| -1 | 15.87% | Moderately Dry |
| -0.5 | 30.85% | Dry but Near Normal |
| 0 | 50.00% | Near Normal |
| 0.5 | 69.15% | Wet but Near Normal |
| 1 | 84.13% | Moderately Wet |
| 1.5 | 93.32% | Very Wet |
| 2 | 97.72% | Extremely Wet |
| 2.5 | 99.38% | Extremely Wet |
| 3 | 99.86% | Extremely Wet |

Source: Recreated from McKee, et al. 1993

The cumulative probability of precipitation events for any given month or time scale (i.e., 3, 6, 9, 12, 24, 48 months) can be calculated. The time scale used will affect the frequency of drought, the duration and the magnitude of precipitation deficit (McKee, et al. 1999). The longer the time scale analyzed, the fewer dry and wet periods will be identified, however the duration of those dry and wet periods are longer than if shorter time scales are analyzed (McKee et al. 1999).

### *Colorado Modified Palmer Drought Severity Index (CMPDSI)*

In 1965, Wayne C. Palmer developed the Palmer Drought Severity Index (PDSI) in the paper “Meteorological Drought” (Palmer 1965). This method uses a simple water balance approach to identify prolonged unusually wet or dry periods. The data requirements include: precipitation and temperature data by week or month and also latitude. Temperature is used to estimate evapotranspiration (Palmer and Havens 1958). In order to calculate runoff and soil moisture recharge and complete the water accounting procedure, assumptions must be made regarding soil available water capacity (awc). For each area, climatically dependant coefficients must be determined. Table 2 provides the types of coefficients used and their description. These coefficients are used to determine the long-term normal for a specific time of year. Departures from these “normals” are then used to identify wet or dry periods.

**Table 2 PDSI Coefficients and Descriptions**

| Coefficient | Description |
|---|---|
| Coefficient of Evapotranspiration | Average ET/Potential ET |
| Coefficient of Recharge | Average Recharge/Potential Recharge |
| Coefficient of Runoff | Average Runoff/Potential Runoff |
| Coefficient of Moisture Depletion | Average Depletion/Potential Depletion |

The final coefficient is a weighting factor termed the “climatic characteristic.” The climatic characteristic transforms the hydrologic accounting procedures into an index that can be compared across varying water balances. The index ranges from -6 in extreme drought to +6 for extremely wet periods, but is normally between +4 and -4. This is what is known as the Palmer Drought Severity Index. The PDSI values and corresponding conditions are shown in Table 3.

### Table 3 PDSI Values with Corresponding Conditions

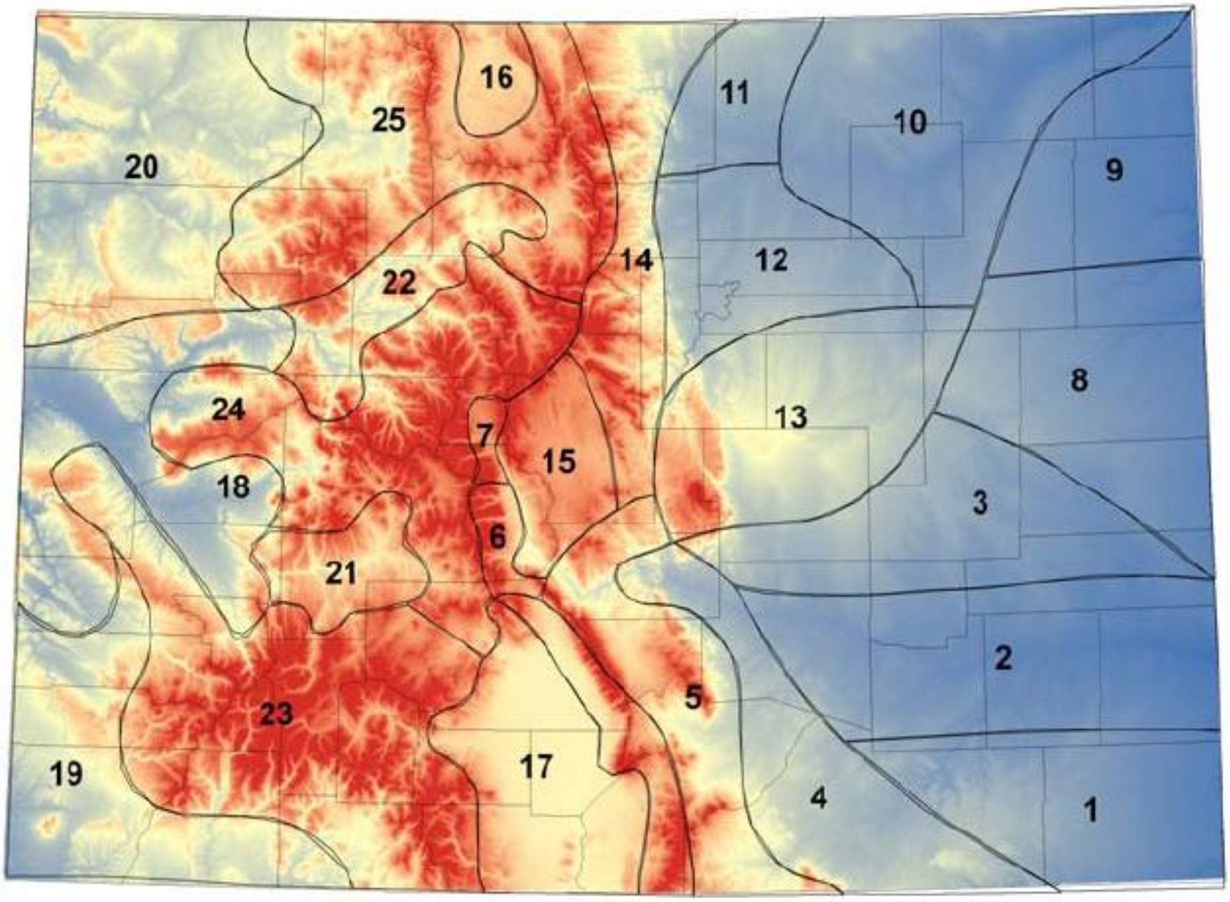
| Palmer Classifications | |
|---|---|
| 4.0 or more | extremely wet |
| 3.0 to 3.99 | very wet |
| 2.0 to 2.99 | moderately wet |
| 1.0 to 1.99 | slightly wet |
| 0.5 to 0.99 | incipient wet spell |
| 0.49 to -0.49 | near normal |
| -0.5 to -0.99 | incipient dry spell |
| -1.0 to -1.99 | mild drought |
| -2.0 to -2.99 | moderate drought |
| -3.0 to -3.99 | severe drought |
| -4.0 or less | extreme drought |

Limitations of the Palmer Index have been identified. Many studies have identified the problems with spatial comparability of the PDSI: (Karl 1983, 1986), (Alley 1984), (Heddinghaus and Sabol, 1991), (Guttman et al. 1992) and (Wells et al. 2004). Alley (1984) noted that the PDSI addresses two critical components of drought, the intensity and duration, but the index uses arbitrary rules in quantifying these properties. Guttman (1998) suggests the SPI to be a better index than the Palmer because it is simple, spatially consistent in interpretation, probabilistic for use in risk and decision analysis, and can be tailored to a time period of interest. He notes alternatively that the PDSI is complex, spatially variant, difficult to interpret, and temporally fixed.

Originally, the National Climatic Data Center began calculating the PDSI for the entire country. However, Colorado was only broken into five drainage areas: Platte, Kansas, Arkansas, Rio Grande, and the Colorado. Due to extreme terrain variations of Colorado, the state has diverse climatic characteristics and consequently these broad regions are not particularly useful.

In an effort to improve the utility of the Palmer index in Colorado, (Doesken et al. 1983), created the CMPDSI. The CMPDSI creates 25 geographical subregions of the state that are more climatically similar than the original five regions calculated on the national scale. The CMPDSI regions are shown on the map in Figure 4 and regional descriptions are given in Table 4.

## Figure 4 CMPDSI Regions



## Table 4 Table 4: CMPDSI Regional Basin Descriptions

| Region | Basin/Description |
|---|---|
| **ARKANSAS DRAINAGE** | |
| 1 | Plateau South of Valley |
| 2 | Valley Bottom |
| 3 | North of Valley |
| 4 | Mesas |
| 5 | Foothills |
| 6 | Collegiate Valley |
| 7 | Upper Valley |
| **KANSAS DRAINAGE (Republican River Basin** | |
| 8 | South Plains |
| 9 | North Plains |
| **PLATTE DRAINAGE** | |
| 10 | Lower Plains |
| 11 | North Front Range |
| 12 | South Front Range |
| 13 | Pikes Peak |
| 14 | Front Range Foothills |
| 15 | South Park |
| 16 | North Park |
| **RIO GRANDE DRAINAGE** | |
| 17 | San Luis Valley |
| 18 | Sangre De Cristo |
| **COLORADO DRAINAGE** | |
| 19 | Lower Valleys |
| 20 | San Juan, Dolores, Animas |
| 21 | Yampa-White |
| 22 | Upper Gunnison |
| 23 | Upper Valley |
| 24 | San Juans |
| 25 | Central Mountains |
| 26 | Northern Mountains |

The procedure for calculating the CMPDSI is the same method as described by Palmer (1965), only the regions were modified and different coefficients were developed. Please refer to Palmer (1965) for a complete description of how the index is calculated.

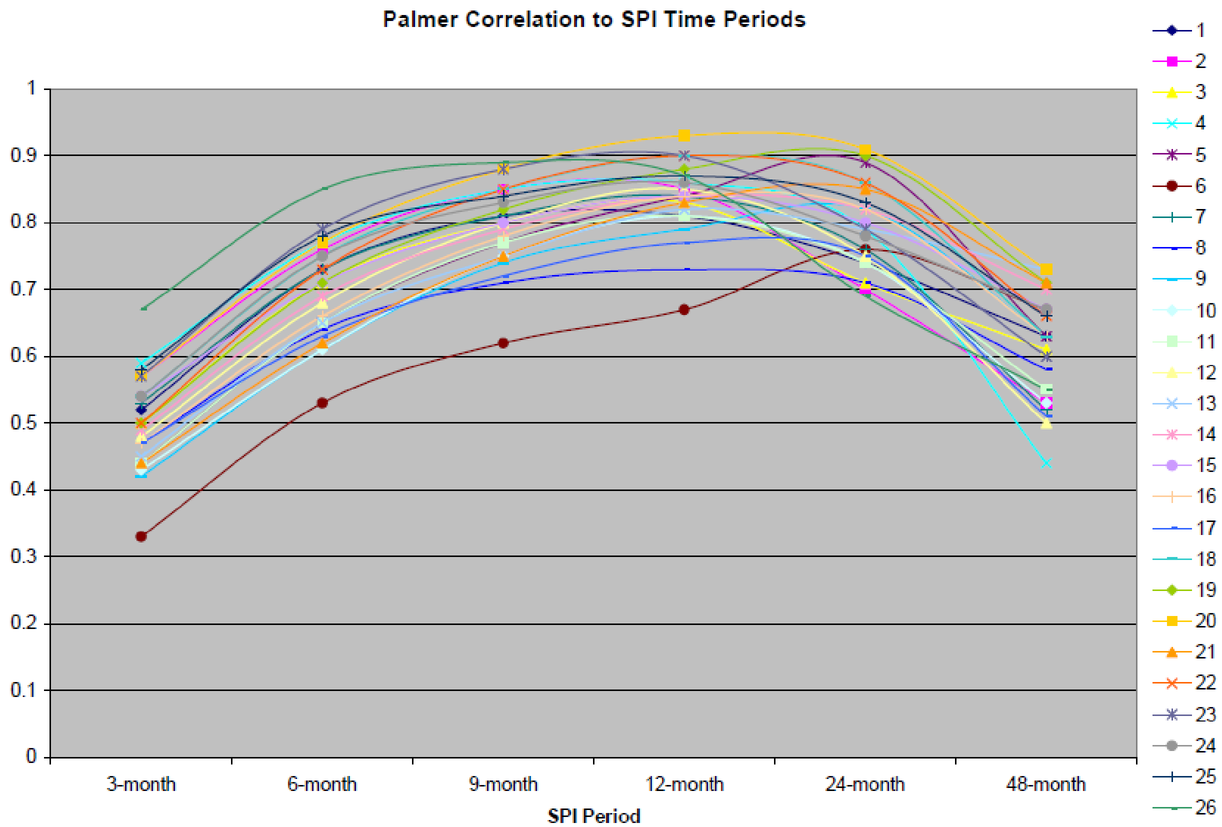
### *Current Work*

As part of the Colorado Water Conservation Board revision to the State Drought Mitigation and Response Plan, the data inputs for the above indices have been updated. Previously, the indices used the base period 1961–1980. In an effort to modernize the index calculations, station lists were updated to remove discontinued stations and add in new stations that have been added in recent decades and that now have at least 25 years of data. Once the station lists were updated, new station averages were created for the period 1980–2009 for both temperature and precipitation. From these station averages, new regional averages for the CMPDSI were calculated. Additionally, for the CMPDSI new water balance coefficients (see Table 2) were calculated using the revised base period.

### *Index Time Series Description*

The time series of Palmer and SPI indices were calculated for the period 1980-2009. Figure 5 shows the relationship of the Palmer Index to different time-scale SPI indices. This graph in no way implies that any one index is "better" than another. It simply shows how well each SPI time scale correlates with the Palmer Index. It is important to note that the Palmer is most highly correlated (depending on region) to the 12 and 24 month time period suggesting that these indices are not very responsive to recent short wet and/or dry periods. Longer time scales (12 months or more) tend to be best suited for retrospective assessment of drought severity while shorter intervals may be better to point out developing and worsening drought conditions.

**Figure 5 Palmer Index Correlation to SPI Time Scales by region**




### *Index Evaluation*

In an effort to characterize the utility of the indices for drought evaluation, independent variables that relate to drought impacts were correlated with each index. For the Eastern Plains and Yampa/White basin, non-irrigated winter wheat yields were correlated to monthly index values. Winter wheat (planted in the fall and harvested in early summer) is a major crop grown in several parts of Colorado. Wheat can be grown in semiarid regions provided that sufficient precipitation and soil moisture is available at critical times in the growth cycle. In other areas where wheat is not grown, water year total streamflow was correlated to monthly indices. The graphics below show the regions that are being evaluated and the seasonal patterns in index correlation.

### Non-irrigated Winter Wheat

Figure 6 through Figure 8 below show results from three regions of Colorado for the 3, 6, 9 and 12 month SPI and the CMPDSI. In Baca County, extreme SE Colorado (Figure 6) both the Palmer index and 6-month SPI indices are strongly correlated to wheat yield during the spring months with correlations peaking in May about a month before harvest. Even though correlations are strongest in May, the 3-month SPI has some predictive power starting in December and then rapidly declines after May when the crop is near fully established. This would indicate that fall and winter precipitation are important for crop yields. Correlations of index values to wheat yield were highest in this part of Colorado probably because of the high natural variability of year to year precipitation and the large variations in wheat yield in this area.

Figure 7 shows the correlations for Phillips/Yuma Counties (NE Colorado), an area that grows large quantities of wheat and enjoys somewhat more reliable yields than SE Colorado. In this region, the correlations are not as strong especially during the fall and winter months, but increase rapidly during the spring months indicating the great importance of spring precipitation for wheat production. The fact that correlations with wheat yield are poorer here than in Baca County may relate to the fact that a 2-county average was used for regional wheat yields and also that other factors such as disease, pests, and winterkill, may also be significant contributing factors. The 6-month SPI in May shows the strongest correlation to wheat yield.

**Figure 6 Region 1 – Baca County Index Correlation to Non-irrigated Winter Wheat Yields**

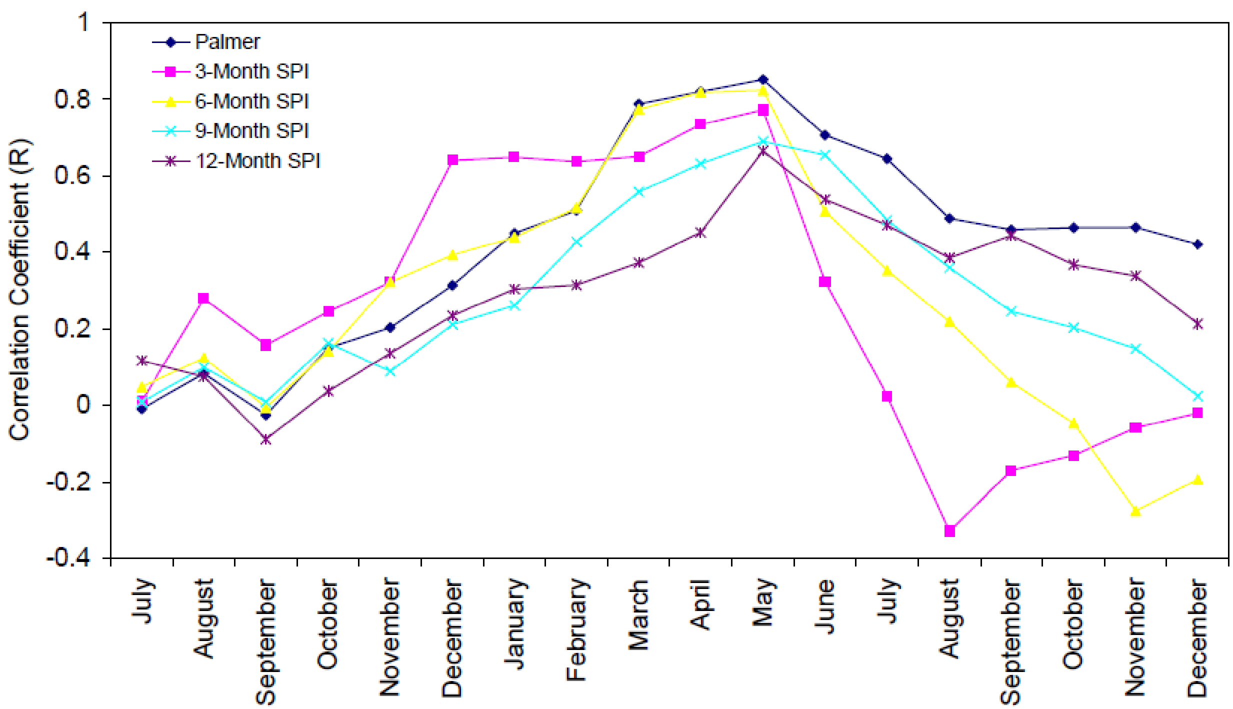


**Figure 7 Region 9 – Phillips/Yuma Counties Index Correlation to Non-irrigated Winter Wheat Yields**

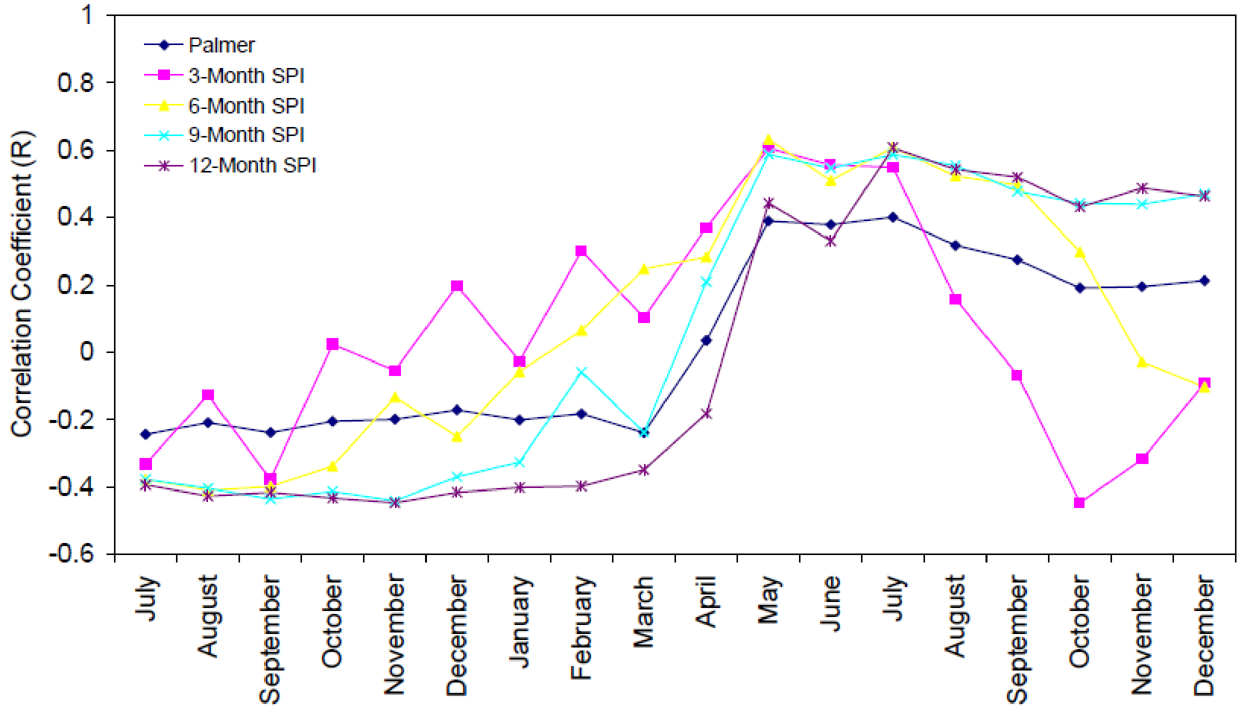


**Figure 8 Region 20 – Routt/Moffat Counties Index Correlation to Non-irrigated Winter Wheat Yields**

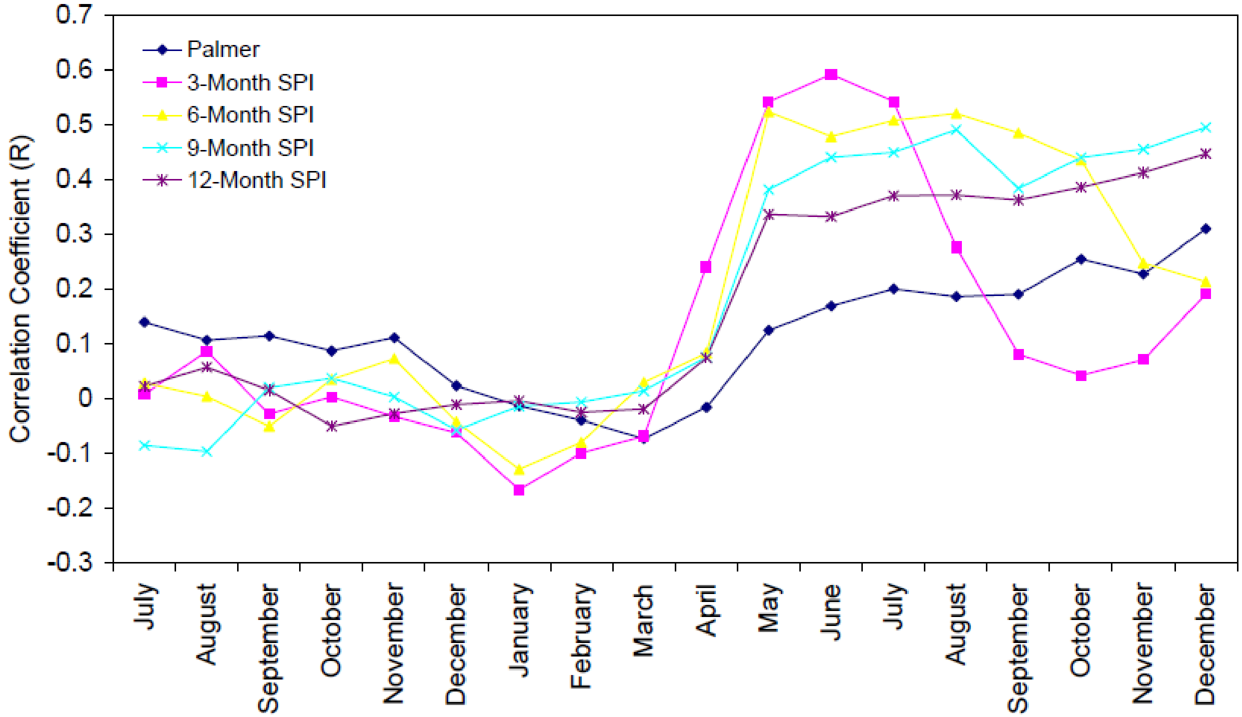



Figure 8 shows winter wheat correlations for the northwest corner of the state where the climate is much different. Here, water is less of a limiting factor during fall and winter, wheat harvest is completed later in the summer and wheat production is a minor part of the local economy. Results from those correlations show the 3-month SPI in June with the highest predictive power for wheat yields, with May and July also showing a good relationship. The 6-month SPI is also well correlated. For this region, the CMPDSI is not a good predictor of wheat yield.

## Water Year Streamflow

In an effort to evaluate an additional external and somewhat independent drought impact, total water year streamflow was evaluated in several basins and correlated with the same set of drought indices performed above. Figure 9 illustrates that the May Palmer index, based on the water balance, is highly predictive of the total water year streamflow at Glenwood Springs, Colorado. Additionally, longer time scales (12–24 months) of the SPI are also highly predictive of streamflow. This indicates that the water in our rivers on any given year retains a memory of the previous year streamflow as well as the present year conditions.

**Figure 9 Region 22 – Upper Colorado Drainage Correlation to Water Year Streamflow at Glenwood Springs, CO**

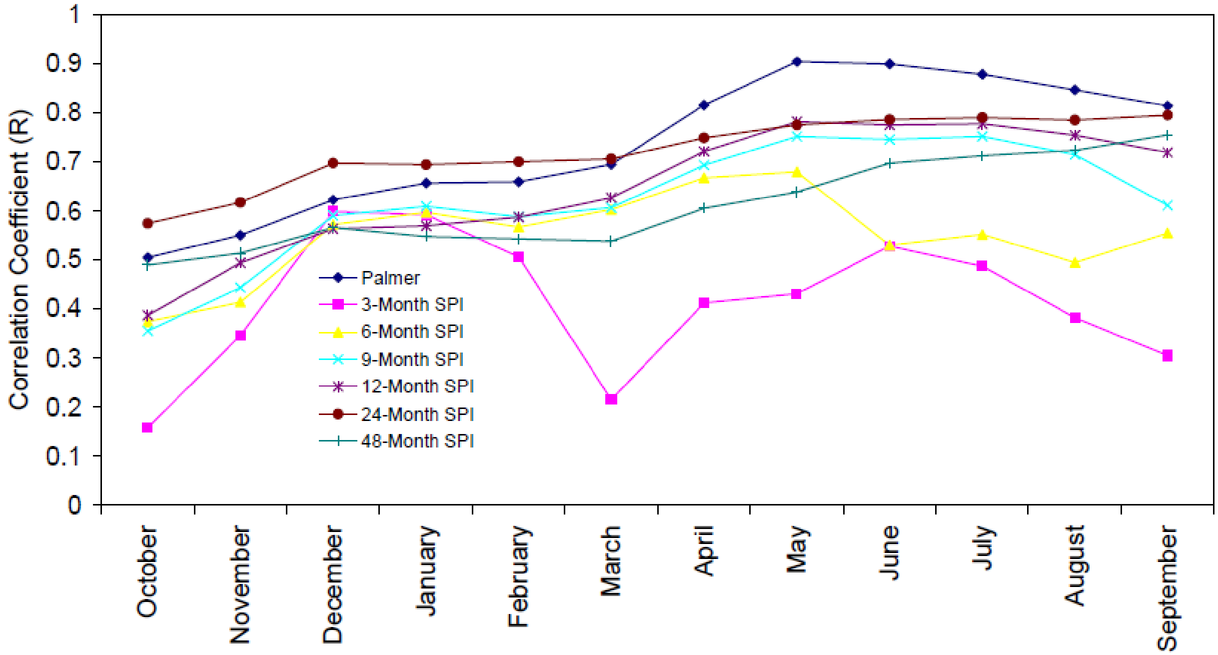



Figure 10 shows the same relationship for the water year streamflow for the Cache la Poudre drainage. Again, the Palmer index shows the highest correlation to water year streamflow, but the correlations do not peak until July. This means that the Palmer is more of a diagnostic and less of a predictive tool than in other watersheds. But nevertheless, the Palmer shows the best correlations in most every month.

**Figure 10 Region 25 - Cache la Poudre Drainage Correlation to Water Year Streamflow at the Mouth of the Canyon**

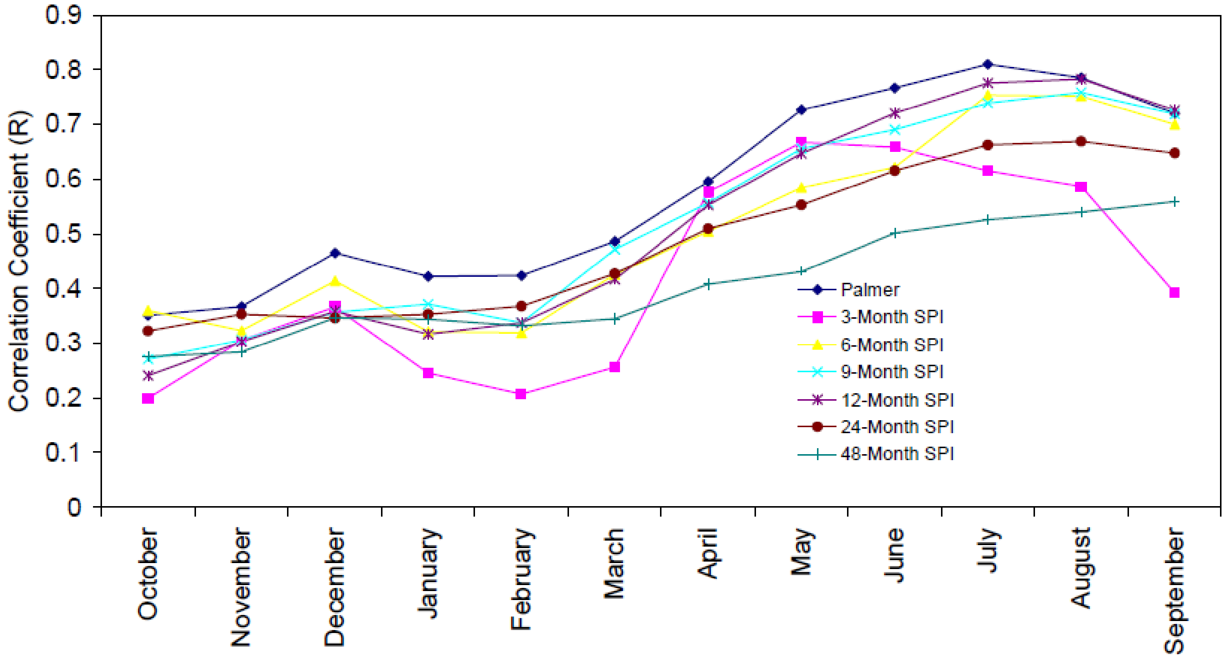



**Figure 11 Region 25 – Yampa Drainage Correlation to Water Year Streamflow at Craig, CO**

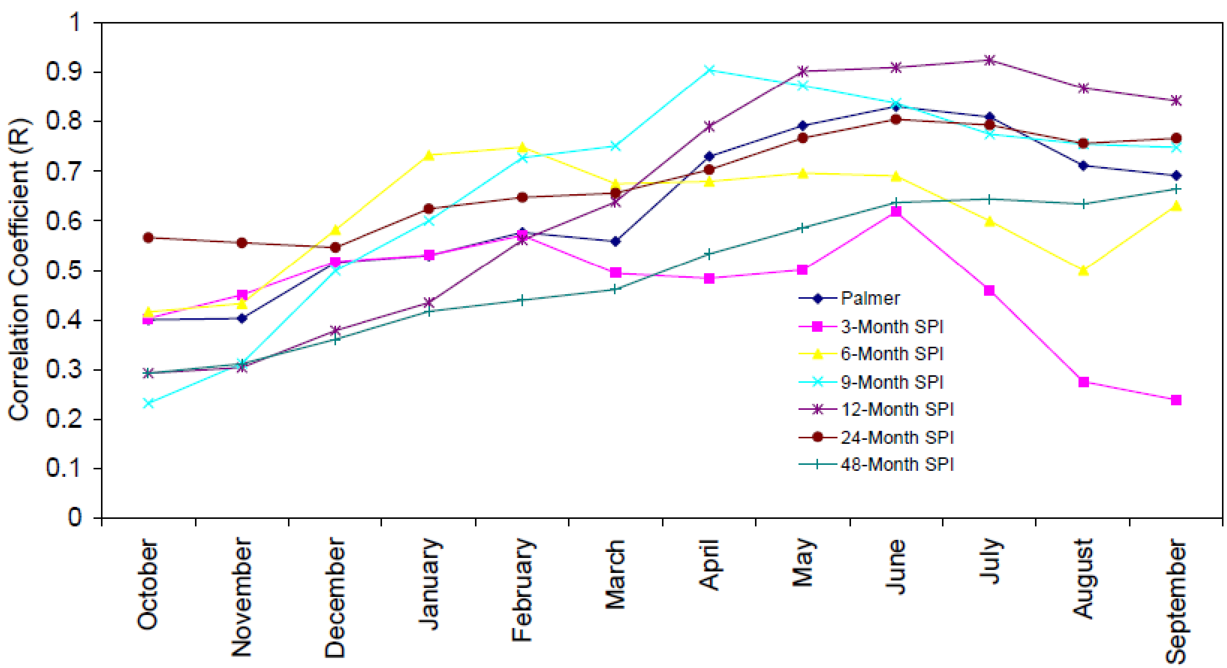


Figure 11 uses the same Palmer region 25 for the correlation with streamflow in the Yampa basin measured at Craig, Colorado. In this basin, the 9-month SPI in April has the best correlation to water year streamflow. The 12-month SPI also shows a good relationship but with less lead time starting in May. Although the Palmer is not as strongly correlated as the 9- and 12-month SPI, it still shows a strong relationship with streamflow beginning in April and peaking in June. It is unclear why the Palmer does not do as well for this basin as it does for the others.

These examples above point out that appropriate use and interpretation of drought indices may require an understanding of the underlying climatic conditions and the specific application. Not all time scales of the SPI are equally suited for all applications. The PDSI is obviously still a valuable tool for relating drought conditions with certain impacts, but the shorter accumulation period SPIs are more responsive to seasonal changes.

### *Recommendations*

Although many studies have found the Palmer Drought Index problematic for a number of statistical and physical reasons when comparing index values between climatically diverse regions, this study shows clearly that when computed for relatively small climate divisions using consistent input data, the Palmer Index relates surprisingly well to both winter wheat yields and water year streamflow. It is recommended that the Palmer Index be retained as a monitoring tool. Further evaluation of where and when to use the CMPDSI index is still needed for other applications such as municipal water supplies. The long memory of the Palmer Index (time scale of 9-24 months) means that it will not respond quickly to rapidly changing conditions so will not be an ideal index in some situations.

The SPI is a very useful index that is relatively easy to understand, straightforward to calculate, and relates directly to percentile rankings, which is how the majority of drought monitoring is evaluated. It is recommended that both indices be calculated and that further investigation is conducted to identify seasons, regions, and time scales where each index is most applicable.

The previous recommendation has been incorporated into the Drought Response Plan Summary Action Table (Table 1) in Annex A Drought Response Plan in coordination with the DMRPC. This table also reflects the revised SWSI. A new addition to the table includes the incorporation of U.S. Drought Monitor ranges and indicator blend percentiles, as well as a summary of potential impacts associated with the drought phases defined in the table. Another recommendation that came from the Plan revision process was to move away from the term “triggers” in relation to the drought indices, which implies that drought response actions automatically occur when thresholds are exceeded. Severity indices are intended to provide a general framework and by themselves do not initiate response actions. Further data analysis may be required to fully understand impacts of abnormally dry conditions suggested by the indicators. Recommendations for action may also be dependent on timing, location, extent, water supply, and subjective considerations, and recognize that different parts of the state may be in different phases at different times.

Drought severity (i.e., duration, intensity, and area) all influence drought impacts.  The CCC is able to produce ongoing time series of the percent of area within Colorado experiencing drought to graphically depict drought impacts. Opportunities for further study may include the need to assess and evaluate what percent of Colorado's is experiencing drought at any given time and for how long.

# 4 References


Abramowitz, M., and I. A. Stegun (eds.), 1965: *Handbook of Mathematical Functions with Formulas, Graphs, and Mathematical Tables*. Dover Publications, Inc., New York, NewYork 1046 pp.

Alley, William M., April, 1984: The Palmer Drought Severity Index: Limitations and Assumptions. Volume 23, Journal of Climate and Applied Meteorology.

Doesken, N. J., T. B. McKee, and J. Kleist, 1983: Use of the Palmer Index and Other Water Supply Indexes for Drought Monitoring in Colorado. Climatology Report No. 83-3. Department of Atmospheric Science, Colorado State University, March, 1983.

Garen, D. C. (1993). Revised surface water supply index for western United States. Journal of Water Resources Planning and Management, American Society of Civil Engineers, 119(4), 437-454.

Guttman, N. B., J. R. Wallis, and J. R. M. Hosking, 1992: Spatial comparability of the Palmer Drought Severity Index. *Water Resour. Bull*, 28:1111–1119.

Guttman, N. B., February, 1998: Comparing the Palmer Drought Index and The Standardized Precipitation Index. Volume 34, No.1, Journal of the American Water Resources Association. American Water Resources Association, February, 1998.

Heddinghaus, T. R. and P. Sabol, 1991: A review of the Palmer Drought Severity Index and where do we go from here? Preprints, *Seventh Conf. on Applied Climatology*, Dallas, TX, Amer. Meteor. Soc., 242–246.

Karl, T. R., 1983: Some spatial characteristics of drought duration in the United States. J. *Climate Appl. Meteor*, 22:1356–1366.

Karl, T. R., 1986: The sensitivity of the Palmer Drought Severity Index and Palmer's Z-index to their calibration coefficients including potential evapotranspiration. J. *Climate Appl. Meteor*, 25:77–86.

McKee, T. B., N. J. Doesken, and J. Kleist, 1993: The Relationship of Drought Frequency and Duration to Time Scales. Preprints, 8th Conference on Applied Climatology, 17-22 January, Anaheim, California, American Meteorological Society, 179-184.

McKee, Thomas B, Nolan J. Doesken, and John Kleist, 1999: Historical Dry and Wet Periods in Colorado, *Climatology Report 99-1, Part A: Technical Report, Part B: Appendices*, Dept. of Atmos. Sci., CSU, Fort Collins, CO, July, 1999.

Palmer, W. C., 1965: Meteorological Drought. U.S. Department of Commerce, Office of Climatology, U.S. Weather Bureau. *Research Paper No. 45*. Washington, D. C. February 1965.

Palmer, W.C. and A.V. Havens. 1958. A graphical technique for determining evapotranspiration by the Thornthwaite method. *U.S. Weather Bureau. Mon. Weather Rev*. 86:123-128.

Thom, H. C. S., 1966: Some Methods of Climatological Analysis. WMO Technical Note Number 81, Secretariat of the World Meteorological Organization, Geneva, Switzerland, 53 pp.

Wells, N., S. Goddard and Hayes, M. 2004. A Self-Calibrating Palmer Drought Severity Index. *Journal of Climate*, 17: 2335-235 1

# Appendix A DROUGHT MITIGATION AND RESPONSE PLANNING COMMITTEE

## Table A.1 DMRPC Contact List

| AGENCY | CONTACT | PHONE | E-MAIL | ITF or Sector |
|---|---|---|---|---|
| Colorado Department of Agriculture | Ron Carleton | (303) 239 - 4104 | ron.carleton@ag.state.co.us | Agriculture ITF |
| Colorado Department of Agriculture | Cindy Lair | (303) 239-4111 | cindy.lair@ag.state.co.us | Agriculture ITF |
| Colorado State University - Water Resource Institute | Reagan Waskom | (970) 491-6308 | Reagan.waskom@colostate.edu | Agricultural ITF |
| Office of State Planning and Budgeting | Mattie Albert | (303) 866-3177 | mattie.albert@state.co.us | Drought Task Force |
| Department of Local Affairs | Barry Cress | (303) 866-2352 | barry.cress@state.co.us | Municipal Water ITF |
| Colorado Department of Public Health | Dick Parachini | (303) 692-3516 | dick.parachini@state.co.us | Municipal Water ITF |
| CO Parks and Wildlife | Jay Skinner | (303) 291-7260 | jay.skinner@state.co.us | Wildlife ITF |
| Colorado Water Conservation Board | Taryn Finnessey | (303) 866-3441 X3231 | taryn.finnessey@state.co.us | Water Availability TF et al.; plan lead |
| Colorado Water Conservation Board | Kevin Reidy | (303) 866-3441 X3252 | kevin.reidy@state.co.us | Water Availability TF |
| Office of Emergency Management | Marilyn Gally | (720) 852-6694 | Marilyn.gally@state.co.us | Water Availability TF |
| Office of Emergency Management | Ken Brink | (720) 947-9729 | kenneth.brink@state.co.us | Water Availability TF |
| Office of Emergency Management | Kerry Kimble | (720) 852-6604 | Kerry.kimble@state.co.us | Water Availability TF |
| Department of Corrections | John Gillogley | | john.gillogley@state.co.us | State Assets sector |

| AGENCY | CONTACT | PHONE | E-MAIL | ITF or Sector |
|---|---|---|---|---|
| Division of Water Resources - SEO | Kevin Rein | (303) 866-3581 X8239 | Kevin.rein@state.co.us | Water Availability TF |
| Division of Water Resources - SEO - WATF Co-Chair | Tracy Kosloff | (303) 866-3581 ext 8211 | tracy.kosloff@state.co.us | Water Availability TF |
| CSU - Colorado Climate Center | Wendy Ryan | (970) 491-8506 | wendy.ryan@colostate.edu | Water Availability TF |
| CSU - Colorado Climate Center | Nolan Doesken | (970) 491-3690 | nolan@atmos.colostate.edu | Water Availability TF |
| Colorado School of Mines – Colorado Geological Survey | Annette Moore | (303) 866 2611 | Annete.moore@state.co.us | Municipal Water ITF |
| Natural Resource Conservation Service | Mage Hulstrand | (720) 544-2855 | mage.hulstrand@co.usda.gov | Water Availability TF |
| National Integrated Drought Information System - NOAA | Chad McNutt | (303) 497-5481 | chad.mcnutt@noaa.gov | Water Availability TF |
| National Integrated Drought Information System - NOAA | Veva Deheza | (303) 497-3431 | veva.deheza@noaa.gov | Water Availability TF |
| Cooperative Institute for Research in Environmental Sciences - NOAA | Klaus Wolter | (303) 497-6340 | Klaus.wolter@noaa.gov | Water Availability TF |
| DPS – Division of Fire Safety | Rocco Snart | (970) 491-7538 | Rocco.snart@state.co.us | Wildfire |
| Colorado State University | Chris Goemans | | chris.goemans@colostate.edu | Ag |
| Colorado Energy Office | Cabell Hodge | (303) 866-2204 | cabell.hodge@state.co.us | Energy ITF |
| DORA- PUC | Larry Duran | (303) 894-2538 | lawrence.duran@state.co.us | Energy ITF |

| AGENCY | CONTACT | PHONE | E-MAIL | ITF or Sector |
|---|---|---|---|---|
| Office of Economic Development - Tourism Office | Kim McNulty | (303) 892-3885 | kim.mcnulty@state.co.us | Tourism |
| Denver Water | Marc Waage | (303) 628-6572 | marc.waage@denverwater.org | Municipal Water ITF |
| Denver Water | Sarah Dominick | (303)  628-6000 | sarah.dominick@denverwater.org | Municipal Water ITF |
| Aurora | Alfredo Rodriguez | (303) 739-7334 | drodrigu@auroragov.org | Municipal Water ITF |
| Thornton | John Orr | | john.orr@cityofthornton.net | Municipal Water ITF |
| NCWCD | Katie Melander | (970) -622-2357 | kmelander@ncwcd.org | Municipal Water ITF |
| Colorado Springs Utilities | Leon Basdekas | (719) 668-4063 | lbasdekas@csu.org | Municipal Water ITF |
| National Drought Mitigation Center | Mike Hayes | (402) 472-4271 | mhayes2@unl.edu | Stakeholder |
| National Drought Mitigation Center | Cody Knutson | (402) 472-6707 | cknutson@unlnotes.unl.edu | Stakeholder |
| National Drought Mitigation Center | Melissa Widhalm | (402) 472-6707 | mwidhalm3@unlnotes.unl.edu | Stakeholder |
| National Drought Mitigation Center | Deborah Bathke | (402) 472-6707 | dbathke2@unlnotes.unl.edu | Stakeholder |
| AMEC | Graeme Aggett | (303) 443-7839 | Graeme.Aggett@amec.com | Consultant |
| AMEC | Jeff Brislawn | (303) 443-7839 | Jeff.Brislawn@amec.com | Consultant |
| AMEC | Luke Swan | (303) 443-7839 | Luke.Swan@amec.com | Consultant |
| AMEC | Courtney Black | (303) 443-7839 | Courtney.Black@amec.com | Consultant |
| AMEC | Hanna Sloan | (303) 443-7839 | Hanna.Sloan@amec.com | Consultant |

# Appendix B ACTIONS TAKEN TO REDUCE DROUGHT IMPACTS IN PREVIOUS DROUGHTS

This appendix includes information on actions taken by the State during previous droughts. Information was taken from multiple sources including: "Recently Impacted States Historical Drought Information" by the Western Drought Coordination Council Drought Response Working Group in 1999; the 2003 Drought Impact and Mitigation Report prepared by the Colorado Water Availability Task Force following the 2002 drought; agency input during the 2010 and 2013 Plan revisions; Drought of 2012 in Colorado Climatology Report 13-01; and a summary of "Colorado Parks and Wildlife 2012 Drought Impacts Highlights." This appendix is intended to serve as a reference in future droughts for the various Impact Task Forces that have the responsibility of tracking impacts and recommending mitigation and response actions (See Annex A Drought Response Plan). The table is organized by Impact Task Force. Refer to Annex B Drought Vulnerability Assessment Technical Information for additional information on State actions in past droughts and recommendations for adaptive capacities for future droughts.

### Table B.1 Previous Actions Taken

| Past Impact | Response Action Taken | Related Task Force |
|---|---|---|
| Crop/livestock losses (agriculture) [2] | USDA Secretarial Disaster Declaration | AITF |
| Reduced forage/water for livestock (agriculture) [2] | Conservation Reserve Program – emergency grazing; list of water haulers to livestock producers; Hay Hotline | AITF |
| Tax implications of herd reductions (agriculture) [2] | Workshop re: tax implementation and information re: available drought assistance | AITF |
| Water supply reduction/watershed restoration[2] | Thin/remove trees | AITF |
| Various Agricultural impacts[2] | State/federal aid; monitor legislation for benefits to agriculture; communicate with legislature re: drought impacts | AITF |
| Lack of water storage[2] | Assess legislation to provide for more stored water and to support temporary transfers of agricultural water to cities during drought | AITF |
| Increase cost of cattle production (e.g., feed, shipping, lease) (Agriculture) [1] | Offset cost of feed to rancher<br>- Setup 800# to locate feed<br>- Ship cattle to areas with feed<br>- Reduce size of herds<br>- Reserve stocks | AITF |

| Past Impact | Response Action Taken | Related Task Force |
|---|---|---|
| Loss of livestock production (Agriculture) [1] | Offset agricultural impact<br>- Emergency Farm Loans<br>- Livestock Indemnity Program<br>- Emergency Conservation Program<br>- Water Conservation and Enhancement Measures including wells, springs, pipelines, troughs, etc. | AITF |
| Agricultural contamination of groundwater (Environmental) [1] | Development of new database to focus on groundwater quality | AITF, MWITF |
| Need for public information dissemination (Social) [1] | Conduct workshops in affected areas | DTF |
| In rural communities, municipal water restrictions resulting from 1956 drought caused many schools to close (Social)[1] | Information on State response not available | DTF |
| Need for enhanced monitoring of water availability, blowing soils and agriculture, wildlife, and tourism (Social)[1] | Activation of State coordinating team | DTF |
| Transportation hazards – highway visibility reduced to ten feet at times (Social) [1] | Coordination with State Patrol | DTF |
| Loss of energy production[2] | Review suppliers for ability to maintain supply; monitor snowpack/runoff; predict hydroelectric generation reductions; update contingency plans/improve communications; ensure adequate cooling water for plants | EITF |
| Public water system operational problems[2] | Update list; provide impacted systems with technical/financial assistance information; update information on available funding sources for drought mitigation; develop technical/financial assistance plan for each system with problems based on prioritized needs | HITF |
| Risks associated with operational problems[2] | Work with impacted systems to develop bottled water/ boil water advisories; approve new water supply sources | HITF |
| In-stream water quality problems (environmental) [2] | Identify potential problems in key segments; assess low-flow-related fish kill impacts | HITF |
| Risks associated with body contact uses[2] | Increase public awareness/education | HITF |
| Interrelated wastewater/drinking water treatment concerns[2] | Identify potential problems caused by upstream wastewater discharges on downstream drinking water plants | HITF |
| Risks associated with intersystem impacts[2] | Work with impacted systems to develop bottled water/ boil water advisories | HITF |
| Need for technical assistance to site new municipal wells (Economic) [1] | Technical assistance from universities | MWITF |

| Past Impact | Response Action Taken | Related Task Force |
|---|---|---|
| Greater reliance on water from wastewater treatment plant discharges (Environmental) [1] | Administration of “effluent bank” | MWITF |
| Possible water and wastewater treatment plan non-compliance due to increased salinity caused by inadequate streamflows. (Environmental) [1] | Additional Water Quality Control Division and enforcement activity | MWITF |
| Need ground and surface water management for drought protection (Social) [1] | Conjunctive use management | MWITF |
| Insufficient water supply for system[2] | Identify systems with needs; potential funding sources; encourage water conservation planning/education; create incentives for those with less reliable sources to connect/consolidate with others with more reliable sources; support additional storage reservoirs | MWITF |
| Insufficient water system revenue due to reduced water sales[2] | Identify ways to generate additional revenue to offset revenue losses; technical assistance | MWITF |
| Mechanical and process failures related to reduced water supplies, higher contaminant levels and high temperatures[2] | Outreach to identify and assist needy systems; continued funding of emergency and long-term mitigation and infrastructure projects; assess President’s Healthy Forests Initiative to mitigate wildfire impacts on water quality/supply | MWITF |
| Lack of funding for municipal and wildlife related drought mitigation activities (Economic) [1] | Provide assistance in accessing grants and other resources | MWITF, WITF |
| Assessing downturn in tourism industry (Tourism) [1] | Financial analysis of impacts on local government tax revenues; analysis of credit needs at resort areas | TITF |
| Economic loss to recreation and tourism industries[2] | Develop Local Community Mitigation and Response Plans; public outreach and education | TITF |
| Rafting industry impacts[2, 4] | Public education/outreach, maintain river flows wherever possible through coordination with multiple entities; keep river corridors open for commercial outfitters, In 2012 CPW along with many other municipalities, water districts and agencies worked together to maintain a flow of 350 cfs on the Arkansas River. Although this was half of the agreed upon flow, this helped to reduce impacts. | TITF |
| Golf industry impacts[2] | Water conservation; public outreach/education | TITF |
| Ski industry impacts[2] | Public outreach/education | TITF |
| State Parks impacts[2, 4] | Public outreach/education; lengthen boat ramps; fire bans | TITF |
| Local parks & recreation area impacts[2] | Limit field access/practice hours in spring; close fields during periods of extreme duress;  public outreach education; water conservation; BMPs | TITF |
| Campground industry[2] | Public outreach/education; fire bans | TITF |

| Past Impact | Response Action Taken | Related Task Force |
|---|---|---|
| Fishing/hunting impacts[2] | Public outreach/education; offset hatchery/fishery locations to provide best stocking coverage during drought events; monitor instream flows and reservoir levels for fish kill potential | TITF |
| Lodging industry impacts[2] | Planning sessions with member properties; water conservation; public education/outreach | TITF |
| Food service industry impacts[2] | Public outreach/education; reduced water usage | TITF |
| Competing Interest could require suspension of current water rights system[1] | Emergency water proclamation drafted to suspend statutes and rules regulating distribution of water in the state | WATF |
| Need to maximize supplies and minimize effects of drought on water users (Social) [1] | Aid in local water resources planning | WATF |
| Need for “Water Bank” to help water users buy water supplies and improve protection of fish and wildlife (Environmental) [1] | Administration of water bank, increase public awareness | WATF, WITF |
| Catastrophic Fires (Wildfire) [1] | Increased preparedness for fire suppression | Wildfire/ Forest Health |
| Loss of Fire Fighters (Wildfire) [1] | Research and improved fire fighting equipment and tactics | Wildfire/ Forest Health |
| Fear of losing one’s home (Wildfire) [1] | - Information on what can be done to protect homes from wildfire<br>- Urban wildland interface programs for targeted high risk areas | Wildfire/ Forest Health |
| Increased potential for wildfires in wildland interface areas[2] | Technical/cost-sharing assistance for county Fire Management Plans; provide for wildland-urban interface management needs and fuels mitigation cost-sharing program; mechanism for State contributions to Emergency Fire Fund; statewide wildfire risk assessment; update roles in Colorado interagency Cooperative Fire Protection Agreement; expanded state support to zone dispatch center and extended attack; coordinate funding efforts for various programs; public education/outreach | WITF |

| Past Impact | Response Action Taken | Related Task Force |
|---|---|---|
| Low streamflow, low reservoir, high water temperatures, anoxic conditions, sediment impacts from wildfire and flash floods on fish have resulted in stress and fish kills[2, 3, 4] | Identify critical reaches, monitor, implement emergency habitat improvements; communication network; emergency instream flow protection; drought emergency closures; fishing restrictions; fish salvage operations; advance stocking; inform anglers to monitor water temperatures. CPW's management response to fisheries impacts from the Hayman Fire of 2002 included: 1) Increased stocking fingerling and sub-catchable size (5 to 8 inch) trout in some areas in order to replace year class losses to offset natural reproduction declines 2) Worked closely with water providers within the South Platte Basin to implement sediment trap areas on tributaries of the South Platte River, increasing opportunities for flushing flows to move the sediment bed load downstream, and 3) Worked on other stream and riparian habitat enhancements to restore watershed function. As of 2010, the CPW is still experiencing the residual impacts of the increased sediment load resulting from the Hayman fire, yet to a lesser extent than in 2002 as the ecosystem and watershed recovers slowly over time. In 2012, emergency releases were made from Lake Avery to maintain in-stream flows and protect cold water fish in the White River.<br>In 2012, the Colorado Water Trust launched the "Request for Water 2012" program and was able to purchase temporary water rights that were unclaimed in Stagecoach Reservoir. These rights were purchased within the Colorado water rights framework and used as in-stream flow to keep water flowing through the Yampa River near Steamboat Springs, CO during the summer recreation season. [.5] | WITF |
| Decrease in recreational angling[2] | Public education/information activities | WITF |
| Reduced hatchery production[2] | Monitor hatchery water levels/stocking conditions; modify production levels and stocking procedures | WITF |
| Reduction in quality habitat for wildlife including reductions in supplies of food, water and cover [2,4] | Identify priority areas; monitor impacts on T&E species; implement emergency habitat improvements; application of good herd management | WITF |
| Increases in predator/human/livestock interaction[2, 4] | Identify/assess impacts; public education; issuing public advisories on black bear activity and need for good public hygiene practices on food and garbage management | WITF |
| Increased impacts to big game including game damage and habitat reduction from drought stressed lands; higher risk of starvation, predation and survival of the young[2,4] | Evaluate compensating private landowners; reduce herd sizes via drought mitigation hunting licenses | WITF |
| Changes in migratory bird patterns and waterfowl production rates; reduction in chick survival, increased predation; declines in nesting and brood rearing habitat for some species[2, 4] | Monitor/identify impacts; develop emergency habitat improvements | WITF |

| Past Impact | Response Action Taken | Related Task Force |
|---|---|---|
| Fish migration impacts due to low flows[3] | Due to the extremely low flows in the Gunnison River during late summer of 2002, the kokanee salmon run wasn't able to get beyond a barrier west of the town of Gunnison. As a result, CPW staff netted the trapped fish and transported them manually to the Roaring Judy Fish Hatchery on the East River for spawning operations. Kokanee salmon is a high value sport fishery in Colorado and the spawning run on the Gunnison River is a critical component of maintaining this high value fishery. Further, a long-term solution was implemented as the concrete barrier was removed, re-designed, and re-constructed under the direction of a CPW aquatic biologist in order to allow fish passage. | WITF |
| 2011-2013 Drought impacts in southeast Colorado | Agricultural Impact Task Force Activation<br>The agricultural impact task force met for much of 2012, bringing together Farm Service Agency personnel and state water managers to report failed and prevented planting acreages, updates on CRP (Conservation Reserve Program) grazing availability as well as emergency loan status and disaster declarations status by county. Reports were also given on (although hard numbers were rarely available) cattle being sold, which mainly occurred in the Arkansas basin. These reports were integral for understanding impacts in different regions of the state.[5] | AITF |
| 2013 Drought - Municipal water impacts | Municipal Water Impact Task Force Activation | MWITF |

[1] 1999 Western Drought Coordination Council Drought Response Working Group
[2] 2003 Drought Impact and Mitigation Report
[3] 2010 state agency input
[4] 2013 Colorado Parks and Wildlife 2012 Drought Impacts Highlights
[5] Ryan, Wendy, and Nolan Doesken, 2013: Drought of 2012 in Colorado. Climatology Report 13-01. Dept. of Atmos. Sci., CSU, Fort Collins, CO. June, 2013.

AITF – Agricultural Impact Task Force
DTF – Drought Task Force
EITF – Economic Impact Task Force
HITF – Former Health Impact Task Force (no longer exists as of 2010)
MWITF – Municipal Water Impact Task Force
TITF – Former Tourism Impact Task Force (no longer exists as of 2013)
WATF – Water Availability Task Force
WITF – Wildlife Impact Task Force

# Appendix C DROUGHT MITIGATION CAPABILITIES SUMMARY

| Title | Lead Agency | Statute | Description | Pre-disaster | Post Disaster | Impact Sector* | Effect on Loss Reduction | | | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Supports | Facilitates | Needs Improvement | |
| **Socioeconomic** | | | | | | | | | | |
| Colorado Disaster Emergency Act of 1992 | Office of the Governor | CRS 24-32-2101 March 12, 1992 | Part 21 shall be known and may be cited as the "Colorado Disaster Emergency Act of 1992" | x | x | All | x | | | No funding associated with the establishment of the "Act" |
| Colorado Disaster Emergency Act of 1992 - Purpose | Office of the Governor | CRS 24-32-2102 March 12, 1992 | (a) Reduce vulnerability of people and communities of this state to damage, injury, and loss of life and property resulting from natural catastrophes or catastrophes of human origin, civil disturbance, or hostile military or paramilitary actions. (b) Prepare for prompt and efficient search, rescue, recovery, care and treatment of persons lost, entrapped, victimized, or threatened by disasters or emergencies. (c) Provide for a rapid and orderly start of restoration and rehabilitation of persons and property affected. (d) Clarify and strengthen roles or the governor, state agencies, and local governments in prevention of, preparation for, response to and recovery from disasters. (e) Authorize and provide for cooperation in disaster prevention, preparedness, response and recovery. (f) Authorize and provide for coordination of activities relating to disaster prevention, preparedness, response and recovery by agencies and officers of this state... | x | x | All | x | | | At the discretion of the Governor |
| Definitions | Department of Public Safety | CRS 24-33.5-701 July 1, 2012 | "Disasters" means the occurrence or imminent threat of widespread or severe damage, injury, or loss of life or property resulting from any natural cause or cause of human origin, including but not limited to fire, flood, earthquake, wind, storm, wave action, hazardous substance incident, oil spill or other water contamination requiring emergency action to avert danger or damage, volcanic activity, epidemic, air pollution, blight, drought, infestation, explosion, civil disturbance, hostile military or paramilitary action, or a condition of riot, insurrection, or invasion existing in the state or in any county, city, town, or district in the state. | | | All | x | | | Drought has equal status with other natural and man-made hazards |
| The Governor and Disaster Emergencies | Department of Public Safety | CRS 24-33.5-702 July 1, 2012 | Suspend provisions of any regulatory statute prescribing the procedures of conduct of state business or the orders, rules, and regulations of any state agency. | | x | All | x | | | |

| Title | Lead Agency | Statute | Description | Pre-disaster | Post Disaster | Impact Sector* | Effect on Loss Reduction | | | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Supports | Facilitates | Needs Improvement | |
| Governor's Disaster Emergency Council | Department of Public Safety | CRS 24-33.5-704(3)(a) July 1, 2012 | "Council" consisting of not less than six nor more than nine members. The attorney general, the adjutant general and the executive directors of Personnel, Transportation, Public Safety, Natural Resources. Additional members shall be appointed by the governor from among the executive directors of the other departments. | x | x | All | x | | | The "Council" has not been utilized to its fullest potential in the past to serve its purpose for creation. |
| Office of Emergency Management | Department of Public Safety | CRS 24-33.5-705(2) July 1, 2012 | OEM shall prepare and maintain a state disaster plan which complies with all applicable federal and state regulations and shall keep such a plan current. | x | x | All | x | | | State agencies have made significant progress in developing disaster response and recovery plans relative to their area of expertise. State Hazard Mitigation Funds for mitigation plans and projects. |
| Disaster Emergency Fund | Office of the Governor | CRS 24-32-2106.(2)(a)(I) March 12, 1992 amended June 3, 2009 | Disaster Emergency Fund established. The General Assembly declares that funds to meet disaster emergencies shall always be available. | x | x | All | x | | | The amount designated for each disaster varies based on damage assessment and unmet needs. Appropriated by the General Assembly. If demands are unreasonably great, the Governor, with concurrence of the council may transfer and expend moneys appropriated for other purposes. |
| Disaster Prevention | Department of Public Safety | CRS 24-335-710 | The Governor shall consider steps that could be taken on a continuing basis to prevent or reduce the harmful consequences of disasters. | x | | All | x | | | Programs established depending on disaster circumstances. |

| Title | Lead Agency | Statute | Description | Pre-disaster | Post Disaster | Impact Sector* | Effect on Loss Reduction | | | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Supports | Facilitates | Needs Improvement | |
| National Guard | Department of Public Safety | CRS 28-3-104 | Governor can activate resources of the State National Guard. | | x | All | x | | | The Guard is reimbursed with funds from the Disaster Emergency Fund. |
| Natural Hazards Mitigation Council | Office of the Governor | Executive Order B044-89 | Council established by Governor's Executive Order to address Natural Hazard Mitigation. | x | x | All | x | | | EO had a sunset date of 1999. No longer an active Council but some subcommittees still active on a periodic basis (e.g. Earthquake Subcommittee). |
| | | CRS 24-33.5-710 July 1, 2012 | | | | | | | | |
| The Governor and Disaster Emergencies | | CRS 24-33.5-704 (4) July 1, 2012 | An executive order will be disseminated promptly to bring its contents to the attention of the general public. | x | x | All | x | | | |
| **Environment (includes Water Quality)** | | | | | | | | | | |
| Concerning the Establishment of Community Wildfire Protection Plans (CWPP) by County Governments | County Sheriffs, Board of County Commissioners | CRS 23-31-Part 3(VI)(b) SB09-001 August 4, 2009 | By enacting this section, the general assembly intends to facilitate and encourage the development of CWPPs in counties with fire hazard areas in their territorial boundaries… | x | | All | x | | | Grant funding from other agencies and private organizations available to local governments and fire protection districts. |
| Responsibility of Responding to Wildland Fires | Colorado State Forest Service | CRS 29-22.5-101(d) SB09-020 April 30, 2009 | The development of a county wild land fire plan, in cooperation among the sheriff, the fire chiefs, the board of county commissioners of the county based on the resource capabilities specific to the county will assist in clarifying the roles and responsibilities of local emergency response agencies, in the management of wild land fire incidents, and for these reasons the development of such a plan is encouraged. | | x | All | x | | | |
| County Wildfire Preparedness Plan | County Sheriff | CRS 29-22.5-104(1) | The Sheriff of each county may develop and update as necessary a wildfire preparedness plan for the unincorporated area of the county in cooperation with any fire district with jurisdiction over such unincorporated area. | x | x | E,S | | x | | |

| Title | Lead Agency | Statute | Description | Pre-disaster | Post Disaster | Impact Sector* | Effect on Loss Reduction: Supports | Effect on Loss Reduction: Facilitates | Effect on Loss Reduction: Needs Improvement | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| Fire Planning Authority | County Government, Board of County Commissioners | CRS 30-11-124 HB 00-1283 Section added; May 26, 2000 | The Board of County Commissioners of each county in the state, subject to the requirements of section 25-7-123 CRS (Open Burning - Penalties) may prepare, adopt and implement a county fire management plan that details individual county policies on fire management on prescribed burns, fuels management, or natural ignition burns on lands owned by the state or county. Such plans will be in coordination with the County Sheriff, the Colorado State Forest Service and the appropriate state and local governmental entities. | x | | All | | x | | |
| Wildfire Emergency Response Fund | Colorado State Forest Service | CRS 23-31-309 August 3, 2007 amended August 5, 2009 | Administered by CSFS and all moneys that may be appropriated, all private and public moneys received through gifts, grants, reimbursements, or donations are authorized to be used for wildfire emergency response. | | x | All | x | | | Reimbursement funding for first aerial tanker flight or the first hour of firefighting helicopter to a wildfire at the request of any county sheriff, municipal fire department or fire protection district. |
| Wildfire Preparedness Fund | Colorado State Forest Service | CRS 23-31-309(4)(a) | All moneys that may be appropriated, all private and public moneys received through gifts, grants, reimbursements, or donations transferred to be used for wildfire preparedness activities. | x | | All | x | | | Funding for wildfire preparedness activities |
| State Emergency Fire Suppression Fund | Colorado State Forest Service | CRS 24-33.5-1207.6 | Trust fund managed by State Forest Service. Can be used to offset the cost of fire suppression. | | x | All | x | | | Funding for assistance to local governments within the first suppression period (usually 12 hours). |
| Fire Bans | County Sheriff's | CRS 23-30-308 | Authorized by Governor, bans on open burning in designated areas. | x | x | All | x | | | |
| Federal "Healthy Forest Restoration Act of 2003" PL 108-148 | Colorado State Forest Service and County Governments | CRS 23-31-312 August 5, 2009 | Facilitate and encourage the development of CWPP's in counties with fire hazard areas and to provide more statewide uniformity and consistency with respect to the content of CWPP's. The State Forester, in collaboration with representatives of the USFS, the Colorado DNR, county governments, municipal governments, local fire departments or fire protection districts, electric, gas, and water utility providers shall provide guidelines and criteria for counties to consider in preparing their own CWPP's | x | x | All | x | | | |
| Determination of Fire Hazard Area - Community Wildfire Protection Plans - Adoption - Legislative Declaration - Definitions. | Board of County Commissioners of Each County | CRS 30-15-401.7 (3)(a) | No later than January 1, 2011, the board of county commissioners of each county, with the assistance of the state forester, shall determine whether there are fire hazard areas within the unincorporated areas of the county. Not later than 180 days after determining there are fire hazard areas within the unincorporated portion of a county, the board of county commissioners, in collaboration with the representatives of the organizations or entities enumerated in section 23-31-312(3) that established the guidelines and criteria, shall prepare a CWPP for the purpose of addressing wildfires in fire hazard areas...In preparing the CWPP, the board shall consider the guidelines and criteria established by the state forester.. | x | | E, S, R | | | | Technical Assistance from the State Forester |

| Title | Lead Agency | Statute | Description | Pre-disaster | Post Disaster | Impact Sector* | Effect on Loss Reduction: Supports | Effect on Loss Reduction: Facilitates | Effect on Loss Reduction: Needs Improvement | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| Wildlife Cash Fund | Division of Parks and Wildlife | CRS 33-1-112 | Can be used to fund both response and mitigation actions affecting wildlife during drought periods. | x | x | E, S, | x | | | |
| Income Tax Imposed on Individuals, Estates, and Trusts - Single Rate - Definitions - Repeal | Colorado State Forest Service | CRS 39-22-104(4)(n)(I)(A) HB08-1110 | Tax relief for landowners who conduct wildfire mitigation measures on their property up to $2,500. | x | | E, S | | | | 2009–2014 - up to $2,500 federal tax deduction for land owners for conducting wildland urban interface wildfire mitigation measures meeting the Colorado State Forest Service standards. |
| Economic Development | Office of Economic Development and International Trade | CRS 24-46-101 through 106 July 8, 1987; Section added July 1, 1998 | The purpose of this article is to bring together people representing a broad spectrum of interests, including higher education, agriculture, advanced technologies, finance and banking, venture capital, energy and industry to review the economic condition of Colorado, to develop and implement programs for the promotion of economic development in Colorado. | x | x | S | x | | | |
| U. S. Department of Commerce | EDA Denver Region | Economic Development Administration and Reauthorization Act 2004 (P.L. 108-373) | Economic Development Administration (EDA) is an agency within the U.S. Department of Commerce that partners with distressed communities throughout the United States to foster job creation, collaboration and innovation | | x | S | x | | | Job losses from natural disaster Economic Adjustment Program $25,000 to $2 million. |
| Drinking Water Revolving Fund (DWRF) | Colorado Water Quality Control Division (WQCD), Division of Local Government (DLG), Water Resources and Power Development Authority (CWRPDA) | CRS 37-95-107.8 | Loans: If the project will help the water system maintain compliance with drinking water standards, or will further the health protection of goals of the Safe Drinking Water Act. Small grants (up to $10,000) are available for system planning and design. | x | x | PHS | x | | | |
| Owner may loan agricultural water right (loans to CWCB for instream flows) | CWCB | CRS 37-38-105 | Enables entities in collaboration with CWCB to lease water for streams on short notice to protect the environment. This tool has been available since 2003 however it was first utilized by the Colorado Water Trust in 2012 to maintain water flows in at-risk stream reaches during the drought. | X | X | E | X | | | |

| Title | Lead Agency | Statute | Description | Pre-disaster | Post Disaster | Impact Sector* | Effect on Loss Reduction | | | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Supports | Facilitates | Needs Improvement | |
| Water Pollution Control Revolving Fund (WPCRF) | Colorado Water Quality Control Division (WQCD), Division of Local Government (DLG), Water Resources and Power Development Authority (CWRPDA) | CRS 37-95-107.6 | Loans: If the project will help the waste water system maintain compliance with sewer discharge permit requirements, or will further the health and environment protection of goals of the Clean Water Act. Small grants (up to $10,000) are available for system planning and design. | x | x | PHS | x | | | Annual funding through EPA as well as revenues generated by the program |
| Colorado Water Institute - Creation | Colorado State University | CRS 23-31-801 Section amended March 20, 2008 | Conducting scientific research and policy analysis in areas of drought planning and mitigation. Establish and maintain a clearinghouse and archive of water research, water quality, and climate projection data. | X | | All | x | | | State funds granted |
| Colorado Noxious Weed Act | CSFS and CDA | CRS 35-5.5-101 through 119 | In enacting this article the general assembly finds and declares that there is a need to ensure that all the lands of the state of Colorado, whether in private or public ownership, are protected by and subject to the jurisdiction of a local government empowered to manage undesirable plants as designated by the state of Colorado and the local governing body. In making such determination the general assembly hereby finds and declares that certain undesirable plants constitute a present threat to the continued economic and environmental value of the lands of the state and if present in any area of the state must be managed. It is the intent of the general assembly that the advisory commissions appointed by counties and municipalities under this article, in developing undesirable plant management plans, consider the elements of integrated management as defined in this article, as well as all appropriate and available control and management methods, seeking those methods which are least environmentally damaging and which are practical and economically reasonable. | x | | E | x | | | 1. Restore stream channel capacity and reduce flood hazards 2. Provide habitat for aquatic and terrestrial species 3. Intensive restoration of riparian areas 4. Reduce erosion 5. Improve water quality 6. Enhance recreational access, and 7. Increase the capacity to utilize water through demonstrated reductions in the non-beneficial consumption of water by TRO. |
| **Water Suppliers (Water Quantity)** | | | | | | | | | | |
| Local Government Land Use Control Enabling Act of 1974 | Local Governments | CRS 29-20-101 through 205 1974 | Grants counties and municipalities broad authority to plan for and regulate the use of land with no specific procedures proscribed for local governments to follow. | x | x | All | | | x | |
| Land Use Planning Subdivision regulations (County) | County Government, Board of County Commissioners | CRS 20-28-133 1972 | Requires counties to adopt subdivision regulations, including "adequate evidence that a water supply that is sufficient in terms of quality, quantity, and dependability will be available", subject to state review. Evidence includes: ownership or use of water right, estimated yield of water right, amenability to change in use, etc. (Takes into account dry year yield.) The Department of Water Resources reviews this evidence and provides comments regarding the reliability and potential water rights | x | x | E, S WS | | x | | |

| Title | Lead Agency | Statute | Description | Pre-disaster | Post Disaster | Impact Sector* | Effect on Loss Reduction | | | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Supports | Facilitates | Needs Improvement | |
| | | | injury for the proposed water supply. | | | | | | | |
| Local Government Land Use Control Enabling Act - Adequate Water Supply (Curry Bill, HB08-1141) | Local Governments | HB08-1141 | Requires a local government to make a determination as to whether an applicant for a development in excess of 50 units or a single-family equivalents, or fewer as determined by the local government, has demonstrated that the proposed water supply is adequate to serve the proposed development | x | x | S, WS | x | | | |
| Local Government Land Use Control Enabling Act - Adequate Water Supply (Curry Bill, HB08-1141) | Local Governments | CRS 24-65.1-101 HB08-1141 Powers | Allows local government to identify, designate, and regulate (through a permitting process) 21 statutorily defined "areas of state interest" including: site selection and construction or major new water and sewage treatment systems; major extensions of existing domestic water and sewage treatment systems. Allows some local control over matters of statewide interest. The State Engineer's Office does not implement Act. | x | x | S, WS, | x | | | |
| Land Use Planning | Local Governments | CRS 30-28-106; CRS 31-23-206 1939 through 2007 | Counties and municipalities meeting certain growth standards are required to adopt a master plan (comprehensive plan) for the physical development of their jurisdictions; MUST include a recreation and tourism element; extraction commercial mineral deposits. May include a "water supply element." If included, the county or municipality needs to coordinate with the local water supply entities. | x | x | E, S, WS | x | | | |
| Land Use Planning | Subdivision Notification | CRS 30-28-136 | Requires counties to submit a copy of preliminary plans for subdivisions to affected governments, including school districts, special and other districts, counties and municipalities located within two miles of the proposal and other agencies. | x | x | All | x | | | |
| Land Use Planning | Local Governments | CRS 29-20-104.5 | Grants broad impact fee authority to counties and statutory municipalities to have new development pay for certain costs associated with growth; home rule municipalities always had this authority through their constitutional home rule powers. Nearly half of Colorado's cities have implemented impact fees. The most commonly used fee is for water 40% and sewer 27%. (CML 2004b) Impact fees may only be used to offset the impacts of new development on existing infrastructure and capital improvements and may not be used to pay for improvements needed to correct existing deficiencies in levels of service. | x | x | All | x | | | |
| Waterworks | Municipal Governments | CRS 31-15-707 | Allows municipalities to construct waterworks outside its boundaries and protect the waterworks and water supply from pollution up to five miles above the point from which the water is taken. | x | x | All | x | | | |
| Weather Modification Operations | Colorado Water Conservation Board | CRS 36-20-101 through 127 | CRS 36-20-108(4)(b) The Director may direct the State and assist counties, municipalities and public agencies in contracting in commercial operators for the performance of weather modification or cloud seeding operations. | x | x | All | x | | | See Non Reimbursable Investment |
| The Colorado Water Conservation Act of 1991 HB91-1154 | Colorado Water Conservation Board | CRS 37-60 124 and CRS 37-60-126 | Creates the Office of Water Conservation and Drought Planning under the Colorado Water Conservation Board to promote water conservation and drought mitigation planning | x | x | All | x | | | |

| Title | Lead Agency | Statute | Description | Pre-disaster | Post Disaster | Impact Sector* | Effect on Loss Reduction | | | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Supports | Facilitates | Needs Improvement | |
| Water Conservation Board and Compacts | Colorado Water Conservation Board | CRS 37-60-101 to 210 | Provides voluntary guidelines for use by water utilities and funding for water conservation projects for those who have a plan. | x | x | All | x | | | |
| Duties of the Board | Colorado Water Conservation Board | CRS 37-60-106(1)(c) & (d) | Authorizes CWCB to formulate plans for bringing about the greater utilization of the waters of the state. | x | | All | x | | | |
| Water Studies | Colorado Water Conservation Board | CRS 37-60-115 | Authorizes CWCB to study water resources toward a unified and harmonious development of all waters for beneficial use in Colorado to the fullest extent possible under the law including studies regarding interbasin transfers. | x | | All | x | | | |
| Colorado Water Conservation Board Construction Fund | Colorado Water Conservation Board | CRS 37-60-121 | Funds projects dealing with Water resources, instream flows, etc. The CWCB Loan Program provides low interest loans to agricultural, municipal and commercial borrowers for the development of water resource projects in Colorado. | x | x | A, E, S, WS | x | | | |
| Flood and Drought Response Fund | Colorado Water Conservation Board | CRS 37-60-123.2 | Transfers up to $300,000 from CWCB's construction fund to support flood and drought preparedness in addition to response and recovery activities following flood or drought events. | x | x | All | x | | | |
| Agricultural Emergency Drought Response | Colorado Water Conservation Board | CRS 37-60-123.5 | Appropriates funds to CWCB for use in making loans and grants to agricultural organizations for emergency drought related water augmentation purposes. | | x | A | x | | | up to $1 million |
| Water Conservation and Drought Planning - Programs - Relationship to State Assistance for Water Facilities - Guidelines - Water Efficiency Grant Program | Colorado Water Conservation Board | CRS 37-60-126 | Defines the requirements that cover water conservation and drought mitigation planning. Creates the water efficiency grant program for purposes of providing state funding to aid in the development and implementation of water conservation plan, and drought mitigation plans in addition to efforts for water resource conservation public education and outreach. Funds are continuously appropriated to the CWCB for this purpose, to be available until the programs financed by the grants have been completed. CWCB has also developed M&I drought and conservation guidance documents and sample plans for the purposes of assisting water providers in developing such plans in addition to various stakeholder outreach efforts to encourage drought planning throughout the State. | x | x | S | x | | | |

| Title | Lead Agency | Statute | Description | Pre-disaster | Post Disaster | Impact Sector* | Effect on Loss Reduction | | | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Supports | Facilitates | Needs Improvement | |
| Water Conservation and Drought Planning - Programs - Relationship to State Assistance for Water Facilities - guidelines - Water Efficiency Grant Program | Colorado Water Conservation Board | CRS 37-60-126.4 | Minimum water conservation plan elements for an entity that seeks financial assistance from either the CWCB or Colorado Water Resources and Power Development Authority. (I) Water-efficient fixtures and appliances, including toilets, urinals, showerheads, and faucets. (II) Low water use landscapes, drought-resistant vegetation, removal of phreatophytes, and efficient irrigation. (III) Water-efficient industrial and commercial water-using processes. (IV) Water reuse systems; (V) Distribution system leak identification and repair; (VI) Dissemination of information regarding water use efficiency measures, including by public education, customer water use audits, and water-saving demonstrations; (VII) Water rate structures and billing systems designed to encourage water use efficiency in a fiscally responsible manner; (VIII) The department of local affairs may provide technical assistance to covered entities that are local governments to implement water billing systems that show customer water usage and that implement tiered billing systems; (IX) Regulatory measures designed to encourage water conservation; (X) Incentives to implement water conservation techniques, including rebates to customers to encourage the installation of water conservation measures; (b) A section stating the covered entity's best judgment of the role of water conservation plans in the covered entity's water supply planning; (c) The steps the covered entity used to develop, and will use to implement, monitor, review, and revise, its water conservation plan; (d) The time period, not to exceed seven years, after which the covered entity will review and update its adopted plan; and (e) Either as a percentage or in acre-foot increments, an estimate of the amount of water that has been saved through a previously implemented conservation plan and an estimate of the amount of the water that will be saved through conservation when the plan is implemented. | x | | S | x | | | |
| Drought Mitigation Planning - Programs - Relationship to State Assistance | Colorado Water Conservation Board | CRS 37-60-126.5 | Regulates drought mitigation planning programs and the relationship to State assistance to manage water supplies and water demand appropriately. | x | | | x | | | |
| Drought Mitigation Planning - Programs - Relationship to State Assistance | Colorado Water Conservation Board | CRS 37-60-126(11)(a) | Homeowners associations cannot enforce restrictive covenants that prohibit or limit xeriscape, installation or use of drought-tolerant vegetative landscapes, or require cultivated vegetation to consist exclusively or primarily of turf grass. | x | x | S | x | | | |

| Title | Lead Agency | Statute | Description | Pre-disaster | Post Disaster | Impact Sector* | Effect on Loss Reduction | | | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Supports | Facilitates | Needs Improvement | |
| Water Availability Task Force - drought condition recommendations - legislative declaration - repeal. | Colorado Water Conservation Board | CRS 24-32-2105.5 | Encourages Water Availability Task Force to continue to monitor drought conditions to recommend legislation addressing drought emergencies. | x | x | All | x | | | |
| Reservoirs and Ditches May Exchange | Colorado Water Conservation Board | CRS 37-83-104 | Allows water users to release stored water to the stream or ditch and in exchange divert an equal amount of water from a point higher upstream without adjudicating an exchange. Such exchanges are subject to the no injury rule and a water user undertaking such an exchange may be required by the State Engineer to release additional water from storage to make up for delivery losses. | | x | WS | x | | | |
| Owner may loan agricultural water right - loans to Colorado water conservation board for instream flows. | Colorado Water Conservation Board | CRS 37-83-105 | Allowing persons taking water from the same stream or ditch to exchange or loan water to one another for a limited time for the purpose of saving crops or using water in a more economical manner without requiring an adjudication of a change of water rights. Recently amended to allow temporary loans of water to CWCB for instream flow purposes. | x | x | WS | x | | | Ongoing |
| Authority of political subdivisions to lease or exchange water. | Colorado Water Conservation Board | CRS 37-83-106 | Allowing water conservancy and conservation districts to enter into cooperative agreements with other political subdivisions for the lease or exchange of water outside district boundaries. | x | x | S | x | | | |
| Interruptible water supply agreements - special review procedures - rules - water adjudication cash fund - legislative declaration. | Colorado Water Conservation Board | CRS 37-92-309 | This section, adopted during last legislative session. Gives State Engineer authority to approve temporary, interruptible water supply agreements, between water users providing for the temporary transfer of historic consumptive use credit to another type and or place of use without requiring adjudication of a change of water rights. Subject to approval by State Engineer upon a finding of non-injury to other water users. And non-interference with interstate compact requirements and will only be approved for operation during a calendar year in which a drought or other emergency has been declared by the Governor and the first full calendar after the declared emergency terminates. | x | x | WS | x | | | |
| Water Conservation in State Landscaping | Colorado Water Conservation Board | CRS 37-96-101 to 103 1989; amended 1991, 99 | Requirements of public project landscaping to promote water efficiency and conservation. Any governmental or quasi-governmental agency of the state and political subdivision of the state that receives State financing for a project or facility is subject to the requirements. | x | x | | x | | | |

| Title | Lead Agency | Statute | Description | Pre-disaster | Post Disaster | Impact Sector* | Effect on Loss Reduction | | | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Supports | Facilitates | Needs Improvement | |
| Water Metering Act | Colorado Water Conservation Board | CRS 37-97-101 to 103<br>July 1, 1990; 2004 | Every water service supplier providing water to over 600 taps in this state shall provide a metered water delivery and billing service to its customers - residential, commercial and industrial. New construction will have meters installed at the time of construction. Existing construction are to have had meters installed by January 1, 2009. | x | x | PHS | x | | | |
| Colorado Water Resources and Power Development Authority Act | Not an agency of State Government, but a body corporate and a political subdivision of the state | CRS 37-95 July 1, 1981 | To preserve, protect, upgrade, conserve, develop, utilize and manage the water resources of the state. | x | | All, PH S | x | | | |
| Local Government Energy and Mineral Impact Assistance Fund | Department of Local Affairs | CRS 34-63-102, CRS 39-29-110 | To assist political subdivisions that are socially and/or economically impacted by the development, processing, or energy conversion of minerals and mineral fuels. | x | | | x | | | |
| Community Development Block Grant | Department of Local Affairs | | Benefit persons of low and moderate income, prevent or eliminate slums or blight, and address other urgent needs. | x | x | | x | | | |
| Water Resources Review Committee | CWCB | CRS 37-98-102 | Creates a water resources review committee to monitor the conservation and development of water resources in Colorado. | x | x | All | x | | | |
| State Engineer | State Engineer's Office | CRS 37-80, CRS 24-1-124, CRS 24-33-104 | Reservoir, streamflow, and water resources data collection dissemination. Real time satellite stream gauge system: river basin simulation models, production of surface water supply index. | x | x | WS | x | | | |
| County Control of Reservoirs | County Commissioners | CRS 37-88-109(2) | Shall maintain and keep reservoirs in good condition and provide for the storage of water and for distribution of water under the direction of the division engineer for the district in which the reservoir is situated and should be replenished for agricultural purposes during water scarcity. | x | | PHS | x | | | |

| Title | Lead Agency | Statute | Description | Pre-disaster | Post Disaster | Impact Sector* | Effect on Loss Reduction | | | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Supports | Facilitates | Needs Improvement | |
| Arkansas River Water Bank Pilot Program | State Engineer | CRS 37-80.5-106 | To authorize the creation of water banks within each water division to be operated under strict parameters established by rules approved by the water court. Accordingly, this article provides for the promulgation of rules concerning water banks and requires the water court to approve the rules and the state engineer to report to the general assembly regarding the operation of the banks. The water bank program created by this article is intended to simplify and improve the approval of water leases, loans, and exchanges, including interruptible supply agreements, of stored water within each river basin, reduce the costs associated with such transactions, and increase the availability of water-related information. It is also the purpose of the water banks to assist farmers and ranchers by developing a mechanism to realize the value of their water rights assets without forcing the permanent severance of those water rights from the land. | x | x | WS | x | | | |
| Substitute Water Supply Plans | State Engineer | CRS 37-92-308(7) HB 02-1414 | The State Engineer may approve such a plan if it is needed to address an emergency situation meaning "affecting public health or safety". | | x | PHS | x | | | Allows 90 days of operation with no notice requirement. |
| Substitute Water Supply Plans | State Engineer | CRS 37-92-308(5) | SWSP allows one year of operation but only in situations where the depletions from the operation will not go out for a duration of more than five years. For this SWSP, no water court application is required as a prerequisite but the applicant must still give notice through the SWSP Notification List and allow 30 days for comments. | | x | PHS, Ag | x | | | |
| Substitute Water Supply Plans | State Engineer | CRS 37-92-308(4) | Allows for temporary operation of a plan for augmentation that has been filed in water court but has not received judicial approval. The applicant must have an active application in water court. The SWSP must not allow more than that which has been applied for in water court and the applicant must give notice to objectors to the water court application. | | x | PHS, Ag | x | | | |
| Colorado Healthy Rivers Fund | Colorado Water Conservation Board | CRS 39-22-2403 2002; title amended in 2008 | Creates a fund to be added to the Colorado Individual Income Tax Refund Check-off Program to give taxpayers the opportunity to voluntarily contribute to watershed protection efforts in Colorado. Moneys in the fund are available through a grant program jointly established by the CWCB and the Water Quality Control Commission, and the Colorado Watershed Assembly. Two categories of grants: 1) Project grants that support the improvement and/or protection of the condition of the watershed. 2) Planning grants to support development of plans for restoration or protection projects. | x | x | E | x | | | Provides additional contribution for a variety of funds. |
| The Construction Fund | Colorado Water Conservation Board (1971) | CRS 37-60-121 | This fund provides low-interest loans for water projects. The fund has financed up to 90% of engineering and construction costs for more than 370 locally sponsored water projects. The fund may also provide non reimbursable investments. The Construction Fund is a revolving loan fund that allows the CWCB to be self-supporting and operate without money from the General Fund. | x | x | WS | | | | Revenues come from interest earned on outstanding loans and on the fund's cash balance in the state treasury, and royalty distributions from federal mineral leases |

| Title | Lead Agency | Statute | Description | Pre-disaster | Post Disaster | Impact Sector* | Effect on Loss Reduction: Supports | Effect on Loss Reduction: Facilitates | Effect on Loss Reduction: Needs Improvement | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | (FML). The Construction Fund's ability to support CWCB's operations and programmatic activities was significantly impacted by a $10 million general fund transfer in FY08/09. |
| Severance Tax Trust Fund | Colorado Water Conservation Board (1997) | CRS 39-29-109 | Creates the water supply reserve account in the severance tax trust fund. CWCB oversees the fund and makes loans or grants for water activities approved by a basin roundtable, including: Competitive grants for environmental compliance and feasibility studies; Technical assistance regarding permitting, feasibility studies, and environmental compliance; Studies or analysis of structural, nonstructural, consumptive, and non-consumptive water needs, projects, or activities; and Structural and nonstructural water projects or activities. | x | x | S, WS | x | | | $10 million each year |
| Recommended Non Reimbursable Investments | Colorado Water Conservation Board (1997) | | Projects or studies of statewide impact or importance. Feasibility studies and projects designed to address statewide, region-wide, or basin-wide issues. The Board examines whether such studies will result in new loans. CWCB can approve loans up to $10 million without legislative approval. | x | | | x | | | |
| Colorado Water Quality Control Act | Colorado Department of Public Health and Environment | CRS 25-8-101 through 703 1963; repealed and reenacted 1981 | In order to foster the health, welfare, and safety of the inhabitants of the state of Colorado and to facilitate the enjoyment and use of the scenic and natural resources of the state, it is declared to be the policy of this state to prevent injury to beneficial uses made of state waters, to maximize the beneficial uses of water, and to develop waters to which Colorado and its citizens are entitled and, within this context, to achieve the maximum practical degree of water quality in the waters of the state consistent with the welfare of the state. | x | | E | | | | Principal funding comes from the taxes paid by the producers of gas, oil, coal and other minerals. Also used for water supply projects. Loan rates are 2.75% for agriculture loans, 4% to 5.25% for municipal loans, and 6.25% for commercial loans (adjusted annually). |

| Title | Lead Agency | Statute | Description | Pre-disaster | Post Disaster | Impact Sector* | Effect on Loss Reduction | | | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Supports | Facilitates | Needs Improvement | |
| Regional Wastewater Management Plans | Colorado Department of Public Health and Environment | CRS 25-8-105 1963; repealed and reenacted 1981 | Wastewater management plans guidelines; creates water quality control commission to ensure provision of continuously safe drinking water by public water systems; permit system for pollutant discharge; violation, remedies, penalties; construction of domestic wastewater treatment works. Covered governmental entities include "any regional commission, county, metropolitan district offering sanitation service, sanitation district, water and sanitation district, water conservancy district, city town, Indian tribe or authorized Indian tribal organization or any two or more of them which are acting jointly in connection with a sewage treatment works." | x | x | S, WS | x | | | |
| Colorado Water Resources Research Institute | Colorado State University | CRS 23-35-101 moved to Part 8 of Article 31 | Program provides for funding of water resources related research and dissemination of findings, including drought as well as the dissemination of information of a water policy nature. | x | x | A, E, W | x | | | |
| **Power and Mining** | | | | | | | | | | |
| Colorado Energy Assurance Emergency Plan Recovery Act - | Colorado Energy Office | CRS 24-38.5-101 through 103 | Establishment of the Energy Office to fulfill the offices mission to lead Colorado to a new energy economy by advancing energy efficiency and renewable, clean energy resources. | x | x | All | x | | | Enhances State government energy assurance capabilities and planning ; multiple grant programs |
| Colorado Renewable Energy Standard | Colorado Energy Office | HB 1001 | The new law requires utilities to supply at least 12% of their retail electric sales from such sources from 2011 to 2014, 20% from 2015 to 2019, and 30% for 2020 and thereafter. Those requirements apply to all providers of retail electric service in the state, with the exception of municipal utilities serving 40,000 customers or fewer. In-state power facilities receive extra credit towards the requirements. More rooftop solar, community wind farms and other distributed resources such as small hydro, biomass, and geothermal will enhance the stability of the electric grid and create predictability in the renewable market, allowing us to bring more clean resources onto the system. | | | | | | | Increases the Renewable Energy Standard to 30% of retail electric sales (from 20%) by 2020 for Investor-Owned Utilities (Xcel Energy and Black Hills Corp.) Creates a minimum requirement for renewable distributed generation of at least 3% of total retail electric sales by 2020. Sets a standard for solar photovoltaic system installations. Keeps in statute the existing standard for rural electric associations (REAs). |
| **Recreation & Tourism** | | | | | | | | | | |
| Creation of Colorado Tourism Office | Colorado Tourism Office | CRS 24-49.7-101 through 109 May 22, 2000 | Tourism and travel industries are vital to the general welfare, economic well-being, and employment opportunities of the state and its communities and citizens and that the continued health and expansion of these industries requires a long-term and continuing investment by the State in the planning promotion, coordination and | | x | All | x | | | Colorado Travel and Tourism Promotion Fund |

| Title | Lead Agency | Statute | Description | Pre-disaster | Post Disaster | Impact Sector* | Effect on Loss Reduction | | | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Supports | Facilitates | Needs Improvement | |
| | | | development of Colorado as a quality national and international tourist and travel destination. | | | | | | | |
| Colorado Office of Economic Development | Office of Economic Development and International Trade | CRS 24-46-Part 1 | Declares that the commission encourages, promotes, and stimulates economic development and employment in Colorado by awarding economic development incentives to employers in the form of grants, loans, and performance-based incentives. The general assembly further finds that it is in the best interest of the people of the state to ensure that United States citizens and others lawfully present in the state are the beneficiaries of employment opportunities that are made possible through moneys awarded to employers. | x | x | All | x | | | Colorado Economic Development Fund |
| Colorado Regional Tourism Act | Office of Economic Development and International Trade | CRS 24-46- Part 3 June 4, 2009 | The health, safety, and welfare of the people of the state of Colorado are enhanced by a diverse revenue stream, and the people of the state would benefit from an expansion of opportunities for investment in large-scale regional tourism projects that will attract significant investment and revenue from outside the state. | x | | All | x | | | Funds for regional tourism projects |
| **Agriculture** | | | | | | | | | | |
| Colorado Agriculture Extension Service. Public Information Technical Assistance | | CRS 22-34-101 | Program provides for dissemination in a timely manner to the agriculture community of drought related information and provision of technical assistance to deal with drought impacts. | x | x | A | x | | | |

| Title | Lead Agency | Statute | Description | Pre-disaster | Post Disaster | Impact Sector* | Effect on Loss Reduction | | | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Supports | Facilitates | Needs Improvement | |
| Agriculture | FMA, FCA, FSA, FEMA, SBA, | Title 7 CFR Part 1945 Subpart A | This subpart describes and explains the types of incidents which can result in an area being determined a disaster area, thereby making qualified farmers in such areas eligible for Farmers Home Administration (FmHA) or its successor agency under Public Law 103–354 Emergency (EM) loans. With respect to natural disasters, it sets forth the responsibility of the Secretary of Agriculture; the factors used in making a natural disaster determination; the relationship between FmHA or its successor agency under Public Law 103–354 and the Federal Emergency Management Agency (FEMA); the method for establishing and using Emergency Loan Support Teams (ELST) and Emergency Loan Assessment Teams (ELAT); the training of FmHA or its successor agency under Public Law 103–354 personnel; and disaster related public information functions. The natural disaster determinations/notifications made under this subpart do not apply to any program other than the FmHA or its successor agency under Public Law 103–354 EM loan program. FmHA or its successor agency under Public Law 103–354's policy is to make EM loans to any otherwise qualified applicant without regard to race, color, religion, sex, national origin, marital status, age, or physical/mental handicap (provided the applicant can execute a legal contract) as provided by law. | | x | A, S | x | | | Secretary of Agriculture activates programs |
| Credit for income eligible to be deferred on sale of livestock due to weather-related conditions | Taxation | CRS 39-22-128 HB 02S-1010 August 12, 2002 | Allows qualified livestock producers to defer taxes on livestock sold due to drought (with four years to replace livestock without reporting gains). | | x | A | x | | | Tax benefit to the agricultural community |
| Colorado Noxious Weed Act | Department of Agriculture | CRS 35-5.5-1-2 | This "Act" declares that certain undesirable plants constitute a present threat to the continued economic and environmental value of the lands of the state and if present in any area of the state must be managed. It is the intent of the general assembly that the advisory commissions appointed by counties and municipalities under this article, in developing undesirable plant management plans. | | | | x | | | Noxious Weed Management Fund under the State Treasurer |

*A=Agriculture
*E=Environment
*PHS=Public Health and Safety
*R=Recreation
*S=Socioeconomic
*WS=Water Supply

# Appendix D REFERENCES

*American Experience - Surviving the Dust Bowl*. WGBH Boston. Distributed by the Public Broadcasting System. 1998.

Associated Press. 2013“Insurance cost of Waldo Canyon fire: $453 million.” June 21.

J. Brahney, A.P. Ballantyne, C. Sievers, J.C. Neff. 2013. Increasing $Ca^{2+}$ deposition in the western US: the role of mineral aerosols. *Aeolian Research*, http://dx.doi.org/10.1016/j.aeolia.2013.04.003.

Board of Land Commissioners. 2011. Colorado State Board of Land commissioners Annual Report Fiscal Year 2010-11.

Colorado Department of Local Affairs – State Demography Office. 2010.

Colorado Dust-on-Snow Program (CODOS), http://snowstudies.org/dust/index.html.

Colorado Office of the State Engineer – Colorado Division of Water Resources. 2003. Colorado Historic Average Annual Stream Flows.

Colorado Parks and Wildlife (CPW). 2013. 2013 Fact Sheet.

Colorado State Land Board. 2008.

Colorado Water Conservation Board (CWCB). 2012. Colorado River Water Availability Study, Phase I Report. March.

CWCB. 2010. Colorado River Water Availability Study, Phase I draft report.

CWCB. 2008. Climate Change in Colorado; a Synthesis to Support Water Resources Management and Adaptation.

CWCB. 2007. Drought and Water Supply Assessment.

CWCB. 2004. Drought and Water Supply Assessment.

CWCB. 2003. Technical Assistance to Covered Entities: Review of Conservation Planning Policies and Practices. (R. Pinkham, prepared for the CWCB, May 2003).

Congressional Research Service. 2013. Drought in the United States: Causes and Issues for Congress. #7-5700. April 22.

Denver Post. 2013a. Drought turns plains to dust. June 9.

Denver Post. 2013b. – Good news of deep snow in Colorado foiled by dust that will speed melt, April 18.

Doesken, N. J., T. B. McKee, and J. Kleist, 1983: Use of the Palmer Index and Other Water Supply Indexes for Drought Monitoring in Colorado. Climatology Report No. 83-3. Department of Atmospheric Science, Colorado State University, March, 1983.

Doesken, N. J., T. B. McKee, and J. Kleist, 2000. A History of Drought in Colorado: Lessons Learned and What Lies Ahead. *Colorado Water* newsletter, No. 9 - Second Edition. Department of Atmospheric Science, Colorado State University, February 2000.

Durango Herald. 2013. Dust storms hasten snowmelt. April 21.

El Paso County Sheriff's Office. 2013. Black Forest Fire Residences.pdf. June 21.

FEMA. 2001. Understanding Your Risks: Identifying Hazards and Estimating Losses.

Gunter, Allison, Goemans, Christopher, Pritchett, James, and Dawn Thilmany. 2012. *The economic impact of the 2011 drought on southern Colorado: A combined input-output and EDMP analysis.* Department of Agricultural and Resource Economics, Colorado State University. July, 2012.

Hall, J. 2002. Sources of water for irrigation along the South Platte during a drought, *Streamlines: Quarterly Newsletter of the Office of the State Engineer*, 16, pp. 2–3.

Intergovernmental Panel on Climate Change (IPCC) (2007). Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

IPCC. 2001. Climate change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report for the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK and New York, NY.

Knowles, N., M. D. Dettinger, and D. R. Cayan. 2006 Trends in snowfall versus rainfall in the western United States. *Journal of Climate* 19.

McKee, T. B., N. J. Doesken, and J. Kleist, 1993: The Relationship of Drought Frequency and Duration to Time Scales. Preprints, 8th Conference on Applied Climatology, 17-22 January, Anaheim, California, American Meteorological Society, pp. 179-184.

McKee, Thomas B, Nolan J. Doesken, and John Kleist, 1999: Historical Dry and Wet Periods in Colorado, *Climatology Report 99-1, Part A: Technical Report, Part B: Appendices*, Dept. of Atmos. Sci., CSU, Fort Collins, CO, July, 1999.

Mote, P. W. 2006. Climate-driven variability in trends in mountain snowpack in western North America. *American Meteorological Society*.

National Drought Mitigation Center. 2010. Drought Impact Reporter. Last accessed April 22, 2010. http://droughtreporter.unl.edu/.

National Drought Mitigation Center. 2010. U.S. Drought Monitor. Last Accessed July 20, 2010. http://www.drought.unl.edu/dm/monitor.html.

National Drought Mitigation Center. 2010. Understanding and Defining Drought. Last accessed on August 20, 2010. http://drought.unl.edu/whatis/concept.htm.

National Drought Mitigation Center. 2003. North American Drought: A Paleo Perspective. Last accessed on July 22, 2010. http://www.ncdc.noaa.gov/paleo/drought/drght_home.html.

NOAA. 2010. U.S. Standardized Precipitation Index. Last accessed August 20, 2010. http://lwf.ncdc.noaa.gov/oa/climate/research/prelim/drought/spi.html.

NOAA. 2010. U.S. Seasonal Drought Outlook. Last accessed July 20, 2010. http://www.cpc.ncep.noaa.gov/products/expert_assessment/seasonal_drought.html.

Painter, T. H., J. Deems, J. Belnap, A. Hamlet, C. C. Landry, and B. Udall. 2010., Response of Colorado River runoff to dust radiative forcing in snow, *Proceedings of the National Academy of Sciences*, published ahead of print September 20, 2010,doi:10.1073/pnas.0913139107.

Palmer, W. C., 1965: Meteorological Drought. U.S. Department of Commerce, Office of Climatology, U.S. Weather Bureau. *Research Paper No. 45*. Washington, D. C. February 1965.

Pielke, Sr, R. A., Doesken, N. & Bliss, O. 2003. Climate of Colorado. *Climatology Report* 60, Department of Atmospheric Science, Colorado State University, Fort Collins, CO.

Prior-Magee, J.S., K.G. Boykin, D.F. Bradford, W.G. Kepner, J.H. Lowry, D.L. Schrupp, K.A. Thomas, and B.C. Thompson, Editors. 2007. Southwest Regional Gap Analysis Project Final Report.

Ryan, Wendy, and Doesken, Nolan. 2013: Drought of 2012 in Colorado. *Climatology Report* 13-01. Dept. of Atmos. Sci., CSU, Fort Collins, CO. June, 2013.

Schuck, Eric C., Frasier, W. Marshall, Webb, Robert S., Ellingson, Lindsey J., and Umberger, Wendy J. 2005. Adoption of More Technically Efficient Irrigation Systems as a Drought Response. *Water Resources Development*, Vol. 21, No. 4, pp. 651–662, December 2005.

Suanders, S., and M. Maxwell. 2005. Less snow, less water: climate disruption in the west. In *A Clear the Air Report*.

The Gazette. 2012. Waldo Canyon Fire: Tally of destruction remains imprecise. Septemter 21.

Thomas, Deborah, and Olga Wilhelmi. 2012. *Drought Assessment for recreation & Tourism: Southwestern Colorado report.* The Colorado Water Conservation Board.

Tronstad, R. & Feuz, D. (2002) Impacts of the 2002 drought on western ranches and public land policies. Western Economics Forum, 1, pp. 19–24.

Udall, B., and G. Bates. 2007. Climate and Hydrologic Trends in the Western U. S: A review of Recent Peer-Reviewed Research. *In Intermountain West Climate Summary*.

United States Department of Agriculture – Farm Services Agency. 2010. Secretarial Disaster Declarations from Drought. Data collected and provided by the Colorado Farm Services Agency. Lakewood, CO.

United States Department of Agriculture – Risk Management Agency. 2010.

Western Water Assessment (WWA). 2011. Colorado Climate Preparedness Project, Final Report

# Appendix E DEFINITIONS AND ACRONYMS

## Definitions

**Drought Types**

*Meteorological drought* – a period of below-average precipitation.

*Agricultural drought* – a period of inadequate water supply to meet the needs of the state's crops and other agricultural operations such as livestock.

*Hydrological drought* – deficiencies in surface and subsurface water supplies. Generally measured as streamflow, snowpack, and as lake, reservoir, and groundwater levels.

*Socioeconomic drought* – occurs when drought impacts health, well-being, and quality of life, or when a drought starts to have an adverse economic impact on a region.

**Drought Stages**

Drought severity levels generally differentiated by pre-defined trigger points or thresholds.

**Drought Indices**

Assimilation of data on rainfall, snowpack, streamflow, and other water supply measurements into a comprehensible picture (NDMC website, "What Is Drought: Drought Indices," Michael Hayes). Some examples of common drought indices are: Palmer Drought Severity Index, Crop Moisture Index, Surface Water Supply Index, and the Standardized Precipitation Index.

**Drought Management Planning**

Drought management planning includes drought mitigation and drought response planning. The main objective of drought management planning is to preserve essential public services and minimize the adverse effects of a water supply emergency on public health and safety, economic activity, environmental resources and individual lifestyles.

**Impact**

Measured or observed affect of drought that could include social, economic, and environmental sectors.

**Mitigation**

Drought mitigation refers to actions taken in advance of a drought that reduce potential drought-related impacts when the event occurs. Measures taken in advance of a disaster aimed at decreasing or eliminating its impact on society and environment (U.N. 1992, 4). Examples of drought mitigation steps include community drought response plans, mutual aid

| | |
|---|---|
| | agreements, and drought legislation. Advances in technology often result in improved mitigation strategies, such as increasingly efficient techniques for irrigating crops. |
| **Response Planning** | Drought response planning addresses the conditions under which a drought induced water supply shortage occurs and specifies the actions that should be taken in response. |
| **Response Action** | Actions that will be carried out during a drought as various drought trigger points are reached. Response strategies can include anything from short-term emergency aid to government assistance programs and media relations. |
| **Risk** | A combination of hazard, vulnerability, and exposure. The impact a hazard would have on people, services, facilities, and structures in a community and refers to the likelihood of a hazard event resulting in an adverse condition that causes injury or damage. |
| **Vulnerability** | Being open to damage or attack (as defined by FEMA's risk assessment guidance (FEMA 386-2). The likelihood that an area or sector will be negatively affected by environmental hazards (Bolin and Stanford, 1998). |

## Acronyms

| | |
|---|---|
| AF | Acre-feet |
| AGO | Attorney General's Office |
| AUM | Animal Unit Month |
| BIA | Bureau of Indian Affairs |
| BLM | Bureau of Land Management |
| CAA | Community Agriculture Alliance |
| CAH | Climate-Adjusted Hydrology |
| CAIC | Colorado Avalanche Information Center |
| CASA | Carnegie-Ames-Stanford Approach |
| C-BT | Colorado Big Thompson |
| CCA | Colorado Cattlemen's Association |
| CCC | Colorado Climate Center |

| | |
|---|---|
| CDA | Colorado Department of Agriculture |
| CDBG | Community Development Block Grant |
| CDC | Center for Disease Control |
| CDOC | Colorado Department of Corrections |
| CDPHE | Colorado Department of Public Health and Environment |
| CEAEP | Colorado Energy Assurance Emergency Plan |
| CEDMP | Colorado Equilibrium Displacement Mathematical Programming Model |
| CEO | Colorado Energy Office |
| CFWE | Colorado Foundation for Water Education |
| CGS | Colorado Geological Society |
| CIR | Crop Irrigation Requirement |
| CMPDI | Colorado Modified Palmer Drought Index |
| CO WWC | CO Water Wise Council |
| CODOS | Colorado Dust-on-Snow program |
| COGCC | Colorado Oil and Gas Conservation Commission |
| COMaP | Colorado Ownership, Management, and Protection |
| CPW | Colorado Parks and Wildlife |
| CROA | Colorado River Outfitters Association |
| CRP | Conservation Reserve Program |
| CRMI | Colorado Resource Monitoring Initiative |
| CRWA | Colorado Rural Water Association |
| CRWAS | Colorado River Water Availability Study |
| CSAS | Center for Snow and Avalanche Studies |

| | |
|---|---|
| CSCUSA | Colorado Ski Country USA |
| CSFS | Colorado State Forest Service |
| CSU Coop Ext | Colorado State University Cooperative Extension |
| CSU | Colorado State University |
| CSU-WRI | Colorado State University Water Research Institute |
| CU | University of Colorado |
| CWCB | Colorado Water Conservation Board |
| CWPP | Community Wildfire Protection Plan |
| CWR&PDA | Colorado Water Resources and Power Development Authority |
| DARE-CSU | Department of Agricultural and Resource Economics at Colorado State University |
| DART | Drought Assessment and Response Tools or Drought Assessment for Recreation and Tourism |
| DHSEM | Colorado Division of Homeland Security and Emergency Management |
| DMA | Disaster Mitigation Act |
| DMRPC | Drought Mitigation and Response Planning Committee |
| DNR | Department of Natural Resources |
| DOI | Department of the Interior |
| DOLA | Department of Local Affairs |
| DORA-PUC | Department of Regulatory Agencies Public Utilities Commission |
| DOW | Division of Wildlife (merged with Colorado State Parks in 2012; currently Colorado Parks and Wildlife (CPW)) |
| DPS | Department of Public Safety |

| | |
|---|---|
| DRMS | Division of Reclamation and Mining Safety |
| DWR | Division of Water Resources |
| DWSA | Drought and Water Supply Assessment |
| DWSU | Drought and Water Supply Update |
| EDA | Economic Development Administration |
| EHH | Extended Historical Hydrology |
| EHSB | Environmental Health Services Branch |
| EIA | Energy Information Administration |
| EMAP | Emergency Management Accreditation Program |
| EMPG | Emergency Management Program Grant |
| EPA | Environmental Protection Agency |
| EQIP | Environmental Quality Incentives Program |
| FEMA | Federal Emergency Management Agency |
| FSA | Farm Services Agency |
| FWS | Fish and Wildlife Service |
| GAR | Governor’s Appointed Representative |
| GCM | Global Climate Model; General Circulation Model |
| GCSAA | Golf Course Superintendents Association of America |
| GIS | Geographic Information Systems |
| GOCO | Great Outdoors Colorado |
| GreenCo | Green Industries of Colorado |
| GW | Groundwater |
| HMA | Hazard Mitigation Assistance grant program |
| HMGP | Hazard Mitigation Grant Program |

| | |
|---|---|
| HSIP | Homeland Security Infrastructure Program |
| HSPA | Health Professional Shortage Area |
| HVAC | Heating, Ventilating and Air Conditioning |
| IP&Ps | Identified Projects and Processes |
| IPCC | International Panel on Climate Change |
| IRP | Integrated Resource Planning |
| ISFDSS | Instream Flow Decision Support System |
| ITF | Impact Task Force |
| JFRCCVS | Joint Front Range Climate Change Vulnerability Study |
| LMIC | Livestock Marketing Information Center |
| L-PDM | Legislative Pre-Disaster Mitigation Program |
| M&I | Municipal and Industrial |
| MODIS | Moderate Resolution Imaging Spectroradiometer |
| MWTF | Municipal Water Task Force |
| NASA | National Aeronautics and Space Administration |
| NASS | National Agriculture Statistics Service |
| NCAR | National Center for Atmospheric Research |
| NCNA | Non-Consumptive Needs Assessment |
| NCWCD | Northern Colorado Water Conservancy District |
| NDIS | Natural Diversity Information Source |
| NDMC | National Drought Mitigation Center |
| NETL | National Energy Technology Laboratory |
| NHD | National Hydrography Dataset |
| NHMP | Natural Hazard Mitigation Plan |

| | |
|---|---|
| NIDIS | National Integrated Drought Information System |
| NIDIS | Natural Diversity Information Source |
| NIMS | National Incident Management System |
| NIMSCAST | National Incident Management System Capability Assessment Support Tool |
| NLCD | National Land Cover Database |
| NOAA | National Oceanic and Atmospheric Agency |
| NPS | National Park Service |
| NRCS | National Resource Conservation Service |
| NREL | Natural Resource Ecology Laboratory |
| NRF | National Response Framework |
| NSAA | National Ski Areas Association |
| Ntu | Nephelometric Turbidity Units |
| NWS | National Weather Service |
| OEDIT | Office of Economic Development and International Trade |
| OEM | Office of Emergency Management |
| OSPB | Governor's Office of State Planning and Budgeting |
| OWDCP | Office of Water Conservation and Drought Planning |
| PA | Public Assistance |
| PDM | Pre-Disaster Mitigation Program |
| PR | Public Relations |
| RAD | EPA's Reach Address Database |
| RMA | Risk Management Agency |
| RW | Reservoir Water |

| | |
|---|---|
| SAP | Simplified Acquisition Procedures |
| SBA | Small Business Administration |
| SCS | Soil Conservation Service |
| SEO | State Engineer's Office |
| SHMO | State Hazard Mitigation Officer |
| SLB | State Land Board |
| SM | Soil Moisture |
| SN | Snowpack |
| SNOTEL | Snow Telemetry Network |
| SPI | Standardized Precipitation Index |
| ST | Streamflow |
| SWSI 2010 update | Statewide Water Supply Initiative 2010 update |
| SWSI | Statewide Water Supply Initiative |
| SWSI | Surface Water Supply Index |
| TABOR | Taxpayer Bill of Rights |
| THM | Trihalomethane |
| TMDL | Total maximum daily load |
| TNC | The Nature Conservancy |
| TRT | Technical Roundtable |
| UCAR | University Corporation for Atmospheric Research |
| UCRB | Upper Colorado River Basin |
| USACE | United States Army Corps of Engineers |
| USBR | United States Bureau of Reclamation |
| USDA | United States Department of Agriculture |

| | |
|---|---|
| USDM | United States Drought Monitor |
| USDOI | United States Department of Interior |
| USDOT | United States Department of Transportation |
| USFS | United State Forest Service |
| USFWS | United States Fish and Wildlife Service |
| USGS | United States Geological Survey |
| VAT | Vulnerability Assessment Tool |
| VIC | Variable Infiltration Capacity |
| WATF | Water Availability Task Force |
| WECC | Western Electricity Coordinating Council |
| WPA | Western Area Power Authority |
| WPCRF | Water Pollution Control Revolving Fund |
| WQCC | Water Quality Control Commission |
| WQCD | Water Quality Control Division |
| WRA | Western Resource Advocates |
| WRF | Water Research Foundation |
| WWA | Western Water Assessment |