Vulnerability, Consequences, and Adaptation Planning Scenarios (VCAPS)

Spanish Valley/Moab Region Drought and Climate Workshop Report

October 2019

Submitted by:

Western Water Assessment
Cooperative Institute for Research in Environmental Sciences
University of Colorado Boulder
University of Utah

In partnership with:

Environmental Dispute Resolution Program
Wallace Stegner Center
University of Utah

WESTERN WATER ASSESSMENT
A NOAA RISA TEAM

About the Western Water Assessment

Western Water Assessment (WWA) is a university-based applied research program that addresses societal vulnerabilities to climate variability and change, particularly those related to water resources. While we are based in Boulder, Colorado and Salt Lake City, Utah, we work across Colorado, Utah, and Wyoming. Our mission is to conduct innovative research in partnership with decision makers, helping them make the best use of science to manage for climate impacts. WWA is part of the Cooperative Institute for Research in Environmental Sciences (CIRES) at the University of Colorado Boulder and affiliated with the Global Change and Sustainability Center at the University of Utah. Our primary source of funding is NOAA's Regional Integrated Sciences and Assessments (RISA) Program, and we are one of 11 RISA programs operating across the United States.

About the Environmental Dispute Resolution Program

The University of Utah's Environmental Dispute Resolution (EDR) Program promotes collaboration, mediation, stakeholder engagement, and other alternative dispute resolution (ADR) processes as a means to address environmental and public policy challenges in Utah and the Mountain West. The program does so by providing process design, facilitation, mediation, stakeholder engagement, public education, and capacity building services, as well as through academic instruction and research.

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Acknowledgements

Thank you to all participants of the Spanish Valley/Moab Region VCAPS workshop for your enthusiasm in this process and thoughtful feedback on this report. Thank you, especially, to Arne Hultquist for his support in pre-workshop planning, encouraging participation, and providing refreshments. Thank you to Dana Van Horn and the Grand Water and Sewer Service Agency (GWSSA) for providing a venue and refreshments for the meeting. Thank you as well to Kirstin Dow, Jess Whitehead, and Seth Tuler from the Carolina Integrated Sciences and Assessment (CISA), North Carolina Sea Grant, and the Social and Environmental Research Institute (SERI), the creators of VCAPS, for training us, answering our questions, and providing valuable support as we prepared for this process.

Recommended Citation

Arens, S., Z. McAlear and D. Rumore (2019). Final Workshop Report for Vulnerability Consequences and Adaptation Planning Scenarios (VCAPS) for Spanish Valley and the Moab Region. Western Water Assessment: Salt Lake City, UT.

Note

This material is based upon work supported by the National Oceanic and Atmospheric Administration (NOAA). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of NOAA.

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1. Introduction

The City of Moab is located in southeastern Utah, near the southern border of Grand County and just to the north of San Juan County. Moab is a gateway community to both Arches and Canyonlands National Parks. Moab had a population of 5,046 as of the 2010 U.S. Census and has grown slightly to an estimated 2017 population of 5,250. Grand County has an estimated population of 10,000 across 3,684 mi^2 and San Juan County has an estimated population of 15,000 across 7,933 mi^2.

Figure 1. Moab and the Spanish Valley

The City of Moab (Moab), residents of Grand County and residents of San Juan County domestic, industrial, and agricultural/secondary water from springs, wells, and surface water from Mill and Pack Creek. Municipal water providers are Moab, Grand Water and Sewer Service Agency (GWSSA) and San Juan Spanish Valley Special Service District (SJSVSSD) and the Moab Irrigation Company (MIC) provide the majority of the municipal, industrial, and secondary/agricultural water for Spanish Valley residents. Moab City provides water to its residents for municipal and industrial uses from springs and wells. GWSSA supplies municipal and industrial water from wells to the unincorporated areas of Grand County. GWSSA also provides secondary water to some of its customers with surface water that is diverted from Mill Creek into Ken's Lake. The SJSVSSD is currently overseeing the construction of a water supply system in the southern Spanish Valley; this system will draw from groundwater, but no water has been withdrawn as of July 2019. Therefore, at this time San Juan County residents currently use groundwater from private wells for culinary and most secondary/agricultural uses. A small portion of secondary/agricultural water used in San Juan County is diverted from Pack Creek. The MIC provides agricultural/secondary water mostly to residents of Moab who own shares of this private irrigation company. Of the four institutional water providers, MIC has the most senior rights, Moab has the second most senior water rights, followed by Grand Water Conservancy District (GWSSA uses these rights for their water), and lastly SJSVSSD. The region has experienced drought in the past, such as the severe drought in 2018 but, historically, total water availability for the region has exceeded demand even in drought years.

On July 18-19, 2019, representatives from the City of Moab, Grand County, and San Juan County, as well as other regional stakeholders, participated in a Vulnerability, Consequences, and Adaptation Planning Scenarios (VCAPS) workshop. VCAPS is a facilitation technique designed to support organizations in building resilience to weather and climate impacts. The workshop was organized by Western Water Assessment (WWA), an applied research program based at the University of Colorado Boulder, with facilitation support provided by staff from the University of Utah's Environmental Dispute Resolution (EDR) Program. WWA and EDR Program staff (the WWA Team) worked with Arne Hultquist, who facilitates the Moab Area Watershed Partnership (MAWP), to identify and convene representatives directly involved with water supply and water quality management in the Moab region (see Appendix C for a list of workshop participants).

In advance of the workshop, WWA staff conducted phone interviews with thirteen workshop participants in order to collect background information on key concerns and local knowledge associated with climate and weather hazards. Conversations with Arne Hultquist, two meetings with the Moab Area Watershed Partnership, and the pre-workshop interviews identified water supply (specifically groundwater supply) as the primary management concern for the workshop. The WWA Team determined, with this input, that the focus of the workshop would be on how drought, climate change, and extreme precipitation impact water supply management in the Spanish Valley. Goals for this workshop included: developing a shared understanding between all participants regarding the most current climate information for the region, specifying short- and long-term management actions to respond to current and future challenges of water supply and its related consequences, and increasing coordination between the three entities.

During the workshop, which consisted of two half-day meetings, WWA staff gave a brief presentation on the observed and projected impacts of climate change in southeastern Utah. The WWA Team then led the group in a participatory diagramming exercise in which participants mapped out the causal structure of a drought event, identified gaps in knowledge, and brainstormed strategic short- and long-term actions for mitigating and adapting to an increasing probability of drought and its related climate risks (see Appendix B for the workshop agenda). The remainder of this report will summarize key aspects of the VCAPS process, highlight themes that emerged during the workshop discussions, and synthesize actions identified by workshop participants.

2. Local climate and weather hazards in the Moab region: concerns and existing initiatives (from pre-workshop interviews)

According to participants in the VCAPS workshop who were interviewed as part of the pre-workshop research process, the Spanish Valley/Moab Region is exposed to a number of climate- and weather-related risks. Workshop participants were primarily concerned with drought and a reduced water supply, but recognized other related climate risks, mainly the potential for increased number and severity of wildfires; the impact of increasing temperatures and decreasing precipitation on flora, fauna, and soil; and the potential for high temperatures to affect water quality and air quality.

Drought and a reduced water supply are particular concerns in the Spanish Valley/Moab Region, in part because there is uncertainty in terms of the quantity of water available in the region's groundwater. There have been multiple studies done to quantify this, but studies disagree on the exact amount of available groundwater; the United States Geological Survey released a new report in the fall of 2019. Additionally, precipitation patterns tend to vary from year to year, increasing uncertainty among water supply providers in terms of the management actions that they should take in the long term. Most recently, the region experienced a historic drought in 2018, but 2019 was an extremely wet year, with a large winter snowpack, cool temperatures, and precipitation extending into early June.

According to interviewees, water supply providers have had to respond to drought in the past, such as in 2018 when there was extremely low snowfall, which resulted in a reduction of runoff, surface water, and aquifer recharge. Irrigation supply for GWSSA customers is limited by divertible amounts of water in Mill Creek. There is a 3 cubic feet per second minimum flow requirement below the Shelly Diversion that must be maintained for Mill Creek's ecological health[1]. However, in 2018, the flow in Mill Creek was actually less than that which prohibited diversions for a significant portion of the irrigation season. These times of low water put stress on Ken's Lake and require pumping groundwater to satisfy secondary water user's irrigation requirements. During times of drought GWSSA also puts restrictions on secondary water by shortening the season or limiting quantities.

To address limited water supplies, water supply providers have also focused efforts on water conservation education and the introduction of various incentive programs for individual property-owners, businesses, and the agricultural sector. Interviewees expressed a strong desire to create more solutions for water storage in order to take advantage of the heavy water flows outside of when they most often occur in the spring season.

Interviewees commonly expressed a concern that the Moab region has experienced rapid development in recent decades, particularly in the tourism sector, due to its location near numerous outdoor recreation areas. Most recently, this resulted in the signing of 180-day moratoria on construction of new overnight accommodations in Grand County and the City of Moab to give each of the jurisdictions time to reevaluate the regional land use code; these will end in mid-August 2019. Concern about new development is related to both the increased development of overnight rentals, without an increase in residential homes, and uncertainty about current water supply. Additionally, the extent and precise location of population growth in the Spanish Valley remains uncertain. According to interviewees, local entities are currently responding to this development through building requirements focused on water conservation,

[1] Personal communication: Ann Marie Aubrey, District hydrologist for the Bureau of Land Management Moab Field Office, 9/17/19.

such as requiring a secondary system for outdoor irrigation, promoting xeriscaping and rain catchment and greywater systems either as mandatory, pilots or best practices.

3. Local weather and climate impacts: recent trends and future projections for the Moab region of southeastern Utah

A. The water budget and drought

Before describing the observed climate trends and projected future climate for the Moab region, it will be helpful to review the basic water budget (Figure 2). Over the course of the year, precipitation minus evapotranspiration (ET) roughly equals runoff (or streamflow). Evapotranspiration (ET) is the combined loss of water vapor to the atmosphere from the soil, water, snowpack, and vegetation—and it has a profound influence on water availability. In a typical water year (October – September), high elevations of Mill Creek in the La Sal Mountains receive about 33" of precipitation[2]. This precipitation comes as snow during November – April and rain during other months, especially during the late summer and fall monsoon. Moab receives about 9" of precipitation, on average[3], significantly less than high elevations of the La Sal Mountains. About 60% of precipitation will return to the atmosphere on a typical year without reaching creeks or recharging aquifers (Figure 2). The remaining 40% will run off or recharge aquifers and be available for use by people. Water not used is discharged to the Colorado River mostly through creeks

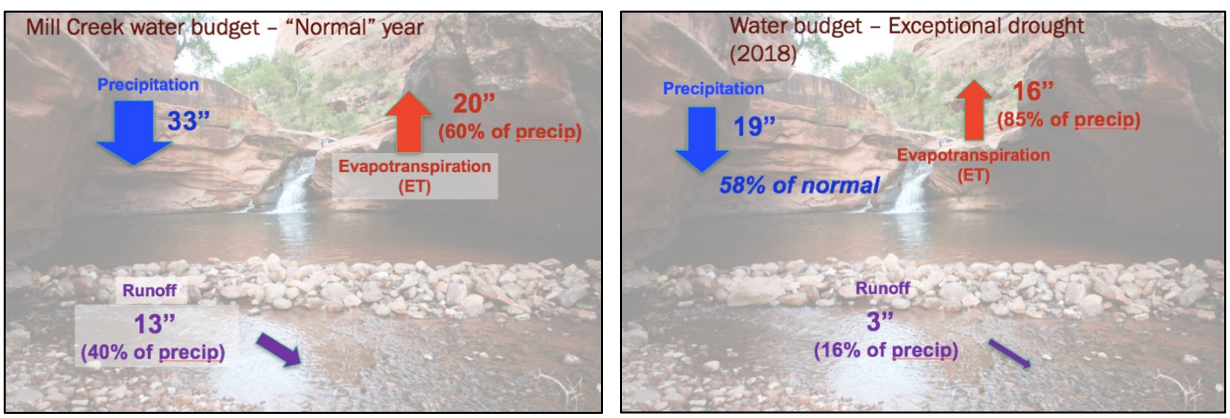

Figure 2. Schematic of Mill Creek water budget during a normal precipitation year (left) and in 2018, an exceptional drought year (right). During severe drought years, such as in 2018, less precipitation falls, *and* the fraction of precipitation lost to the atmosphere (evapotranspiration or ET) goes up, so runoff is disproportionately reduced compared to precipitation.

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[2] Average water year precipitation was obtained from the La Sal Mountain SNOTEL site at 9,578' (1982 – 2018). https://wcc.sc.egov.usda.gov/nwcc/site?sitenum=572

[3] Moab, Utah climate summary, Desert Research Institute. https://wrcc.dri.edu/cgi-bin/cliMAIN.pl?ut5733

In drought years like 2018, precipitation in the high elevations of the La Sal Mountains was nearly 40% lower than normal. Because dry weather patterns are also associated with warmer temperatures, severe drought years are typically hotter than normal and are accompanied by greater solar radiation and lower humidity. All of these factors tend to increase ET—the atmosphere is "thirstier" during a drought. The fraction of precipitation going to ET increases to as much as 85% and thus runoff is disproportionately reduced to less than half of normal (Figure 2, right). As such, the smaller snowpack, lower streamflow, and parched soils and vegetation associated with severe droughts result from both reduced precipitation *and* greater moisture loss through ET.

B. Observed precipitation: High variability, no long-term trend

Since 1896, annual precipitation, averaged across all of Grand County (not just the La Sal Mountains), has been extremely variable from year-to-year; some decades are wet while others are dry. This *natural variability* is caused by fluctuations in both the prevailing tracks of storms in winter that bring moisture from the Pacific Ocean and late summer monsoonal rains. Average annual precipitation across all of Grand County is about 12"; during dry years, about 8" and wet years around 20" of precipitation (Figure 3a and 3b). Variability from an average year is greater during wet years compared to dry years. The two wettest years and two of the five driest years on record in Grand County all occurred since 2000. In 2002 and 2018, only 8" of precipitation fell; just three years later, in 2005, a record 24.4" of precipitation was recorded across Grand County. The second wettest year on record was 2011[4].

[4] WestMap Climate Analysis and Mapping Toolbox; https://cefa.dri.edu/Westmap/

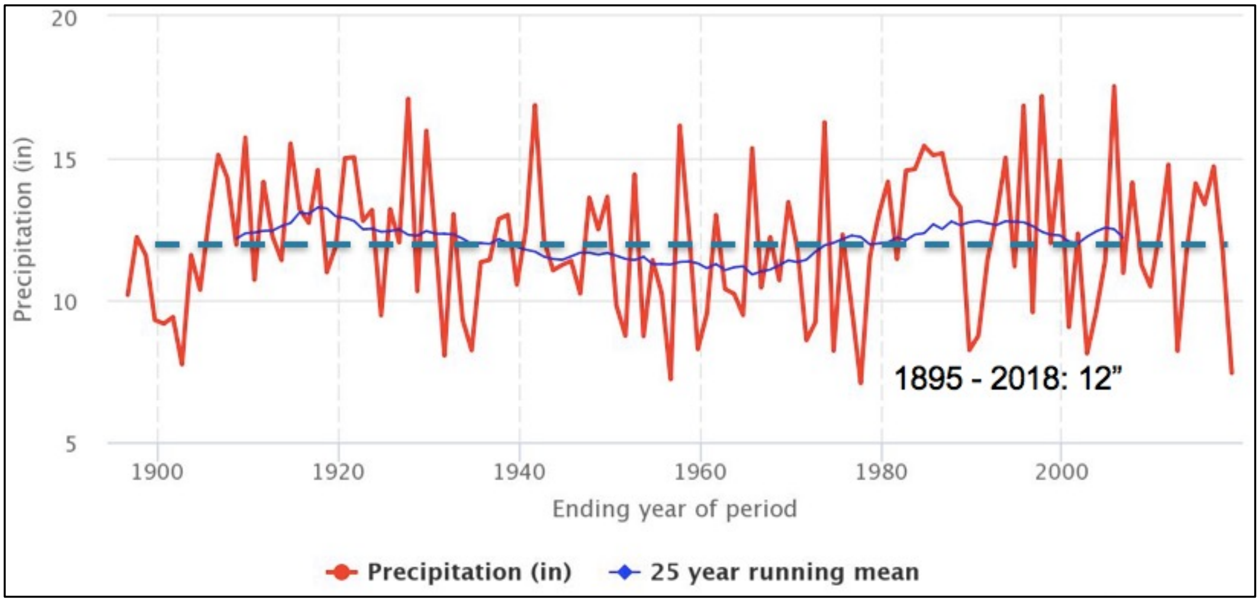

Figure 3a. Average annual water year (October – September) precipitation for Grand County.
https://cefa.dri.edu/Westmap/

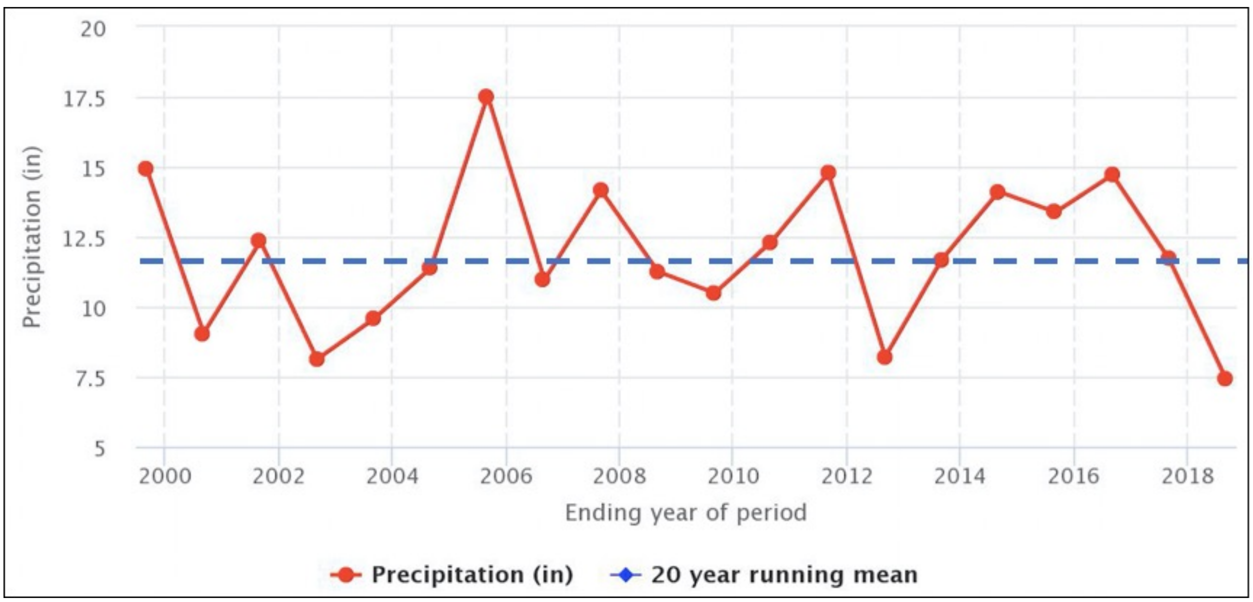

Figure 3b. Average annual water year (October – September) precipitation for Grand County from 1999-2018.
https://cefa.dri.edu/Westmap/

Precipitation patterns, especially winter precipitation, at many locations in the western United States are strongly influenced by El Niño and La Niña or ENSO (El Niño Southern Oscillation). During an El Niño year, the southwestern United States typically receives above average precipitation and the Northwest receives below average precipitation; this pattern is reversed during a La Niña year. There is a geographic zone between the northwestern and southwestern United States where ENSO phase (El Niño, La Niña, or neither) is not correlated with precipitation amount. Much of northern and central Utah falls within this zone where there is an “equal chance” of an above- or below-normal precipitation year during an El Niño or La Niña year. This pattern is true in the Wasatch Mountains of northern Utah, where ENSO phase does not impact winter precipitation amount.

In the Moab area, there is not a statistically significant correlation between ENSO phase and precipitation. Although Moab is geographically part of the Southwest, years with an El Niño do not significantly correlate with above average precipitation. To assess the relationship between ENSO phase and precipitation in Moab, annual water year (October – September) precipitation in Grand County was compared to ENSO phase from 1895 to 2018. Although there was not a significant correlation between ENSO phase and precipitation, 67% of the years with a La Niña event experienced below average precipitation. By contrast, only 48% of El Niño years experienced above average precipitation.

C. Observed temperatures: A strong recent warming trend

Over the course of the 20th century, there was no trend in annual average temperatures for Grand County and annual temperature varied between 46°F (1918) and 54°F (1934). However, temperatures since 2000 in Grand County were 1.9°F warmer than the 20th century average annual temperature and three of the five hottest years have occurred since 2000. By themselves, warmer temperatures have an overall *drying effect*: evapotranspiration tends to increase as a fraction of precipitation, snowpack and streamflow tend to decrease, snowmelt and runoff occur earlier, and soils become drier in the summer.[5]

[5] WestMap Climate Analysis and Mapping Toolbox; https://cefa.dri.edu/Westmap/

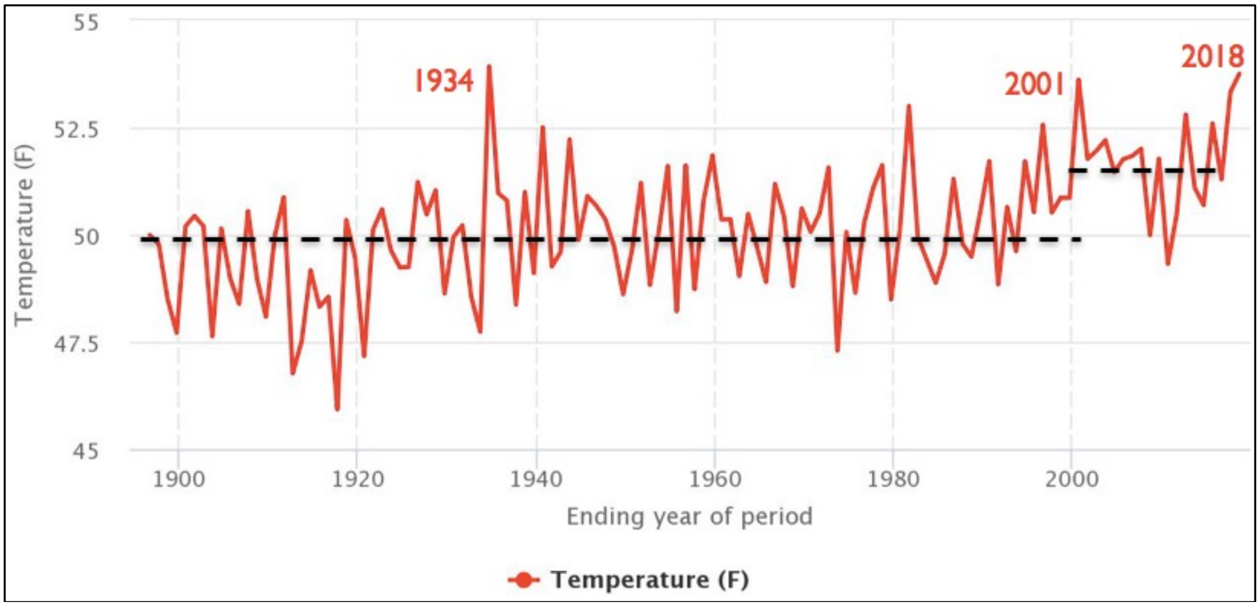

Figure 4. Annual (water year) average temperature for Grand County, 1896-2018. Temperatures since 2000 have been nearly 2°F warmer. (WRCC/DRI; https://cefa.dri.edu/Westmap/)

D. Observed snowpack and streamflow: A little earlier, a little less

The timing and type of precipitation is very important to water supply in the Mill Creek basin and the Spanish Valley, both for surface runoff and aquifer recharge. Since 1982, peak snow water equivalent (SWE) at 9500' in the La Sal Mountains varied from 6" (1999) to 26.6" (1983) and averaged 14" (Figure 5). In 2018, total precipitation in the La Sal Mountains was the lowest since 1982, but peak SWE was higher compared to other drought years. On average, about half the precipitation in an average year falls as snow in the La Sal Mountains with as little as 30% of precipitation falling as snow in some years and as much as 60% in other years. No trends in SWE were observed from 1982 to 2019, but there was a trend towards earlier peak SWE. Average time of peak SWE was nine days earlier (March 26th) from 2000-2019 compared to 1982 – 2000 (April 3rd).[6]

[6] NRCS SNOTEL, La Sal Mountain SNOTEL site; https://wcc.sc.egov.usda.gov/nwcc/site?sitenum=572

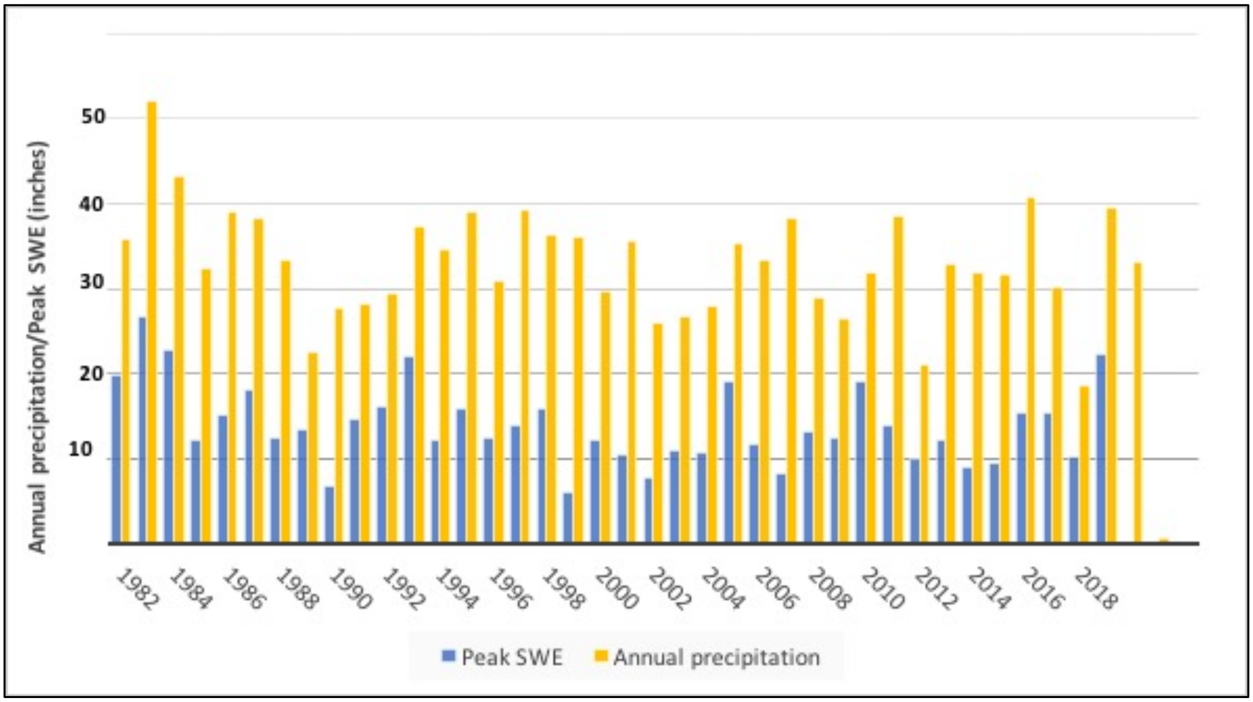

Figure 5. Peak snow water equivalent (SWE) and annual precipitation at the La Sal Mountain SNOTEL site (9578') from 1982 – 2018.

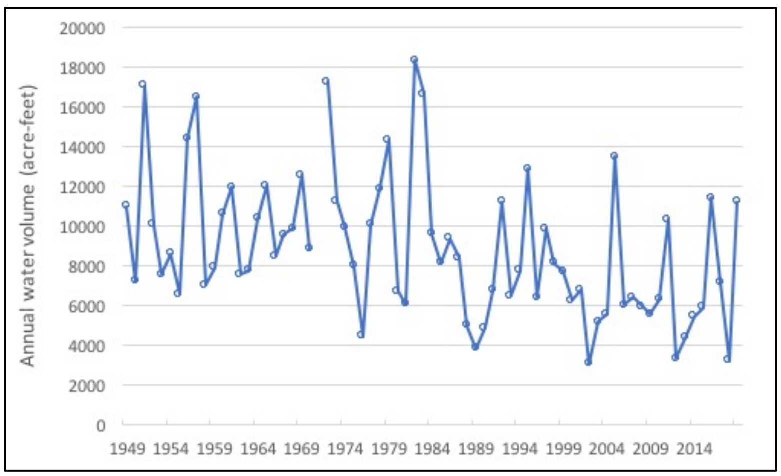

Figure 6. Annual water volume in acre-feet for Mill Creek from 1949 – 2018. Data is for water year (October – September).

Since 1949, annual water volume, which is measured in acre-feet (af), varied from a maximum of over 18,000 af in 1982 to a minimum of 3,100 af in 2002. The 2018 water year produced only slightly more water than 2002 with an annual water volume of 3,250 af. Figure 6 shows annual water volume (October – September) from 1949 – 2018. The stream gage on Mill Creek was moved to an upstream location in 1993; annual water volume data before 1993 is not directly comparable to data after 1993.

The recent warming observed in the Moab region and across Utah is part of broader warming trends documented regionally, nationally, and globally. This unusual and widespread warming is attributed to increasing levels of greenhouse gases, such as carbon dioxide (CO_2), in the atmosphere; CO_2 is now at its highest level in at least a million years, according to evidence from Greenland and Antarctic ice cores.

How much will the climate change in the future, and in what ways? Global climate models (GCMs) give us our best view of the future climate. GCMs are computer-based tools that incorporate fundamental laws of atmospheric physics, weather observations, and knowledge of the Earth system to project future climate given assumptions about greenhouse gas emissions. Figure 7 shows temperature projections from 20 different climate models run forward for the 21st century under two such assumptions: a higher-emissions scenario (Representative Concentration Pathway or RCP 8.5), with no global efforts to restrain emissions, and a lower-emissions scenario (RCP 4.5), which assumes that annual global emissions are reduced by two-thirds after 2040.

E. Future temperatures: Even warmer, and into uncharted territory

All climate models indicate that the climate of the Moab region will continue to warm well into the 21st century. Figure 7 shows modeled (gray shading) and observed (gray bars) historic temperature and future temperature projections for a low emission scenario (blue line and shading) and a high emission scenario (red line and shading). For future temperature projections, the shaded area represents the range of 20 model projections of future temperature and the line represents the median of 20 model projections. Under the lower-emissions scenario, by 2050, average temperatures in Grand County are projected to be 5°F warmer than the late-20th century average, and 6°F warmer by 2080. Under the higher-emissions scenario, warming will be even greater, with temperatures projected to increase 6°F by 2050 and increase 9°F by 2080. By 2050, under both emissions scenarios, the typical year in Grand County will be warmer than the hottest years of the 20th century. Returning to the water budget as described previously, a much warmer future climate would create mild drought conditions even during years of average precipitation by increasing evapotranspiration.

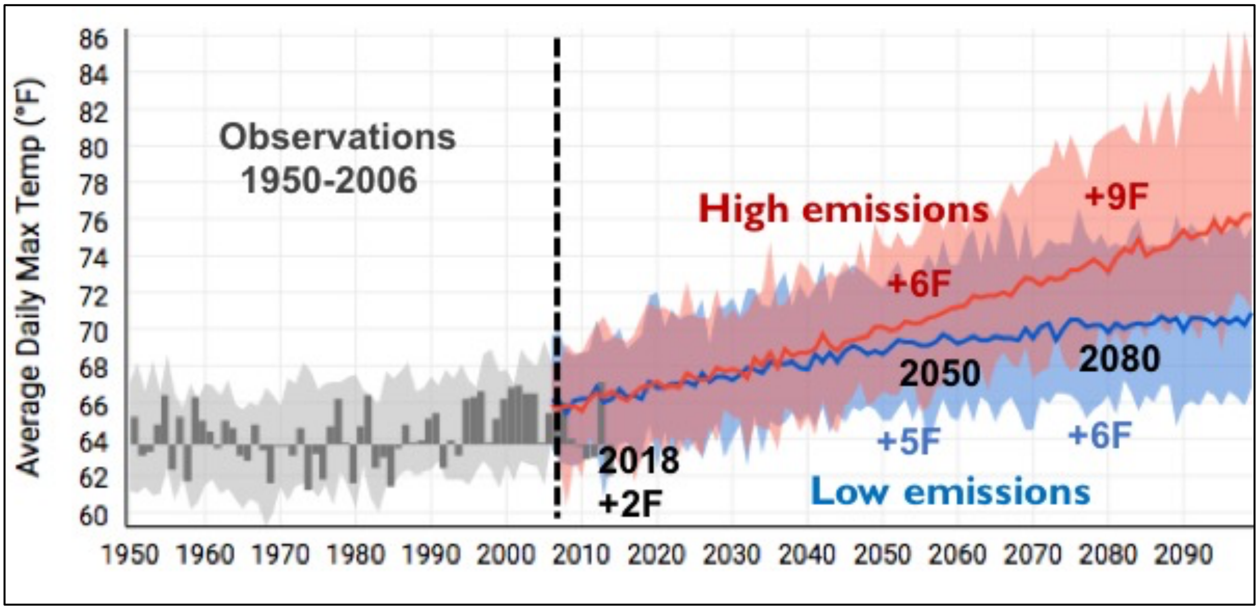

Figure 7. Projected annually-averaged daily maximum temperatures for Grand County for 2007 – 2099 from 20 climate models under high (RCP 8.5) and low (RCP4.5) emissions scenarios, compared to observed temperatures, 1950 – 2006. (Source: NOAA Climate Explorer; http://https//crt-climate-exporer.nemac.org)

Extreme heat (temperatures above 90°F) can impact water resources, ecosystems, and potentially tourism. Historically, temperatures do not exceed 105°F in Grand County (temperatures in Moab do exceed 105°F occasionally, but maximum temperatures averaged over the entire county do not exceed 105°F). By the end of the century, climate models project ten days that exceed 105°F under a low emissions scenario; under a high emissions scenario, 40 days will exceed 105°F by the end of the century. While 90°F is not considered extreme heat in Moab, it is projected that the number of days that exceed 90°F by 2100 will double from 60 days to 120 days under the high emission scenario. Under a low emissions scenario, the number of 90°F days is expected to increase to 90 days by 2100 in Grand County.[7]

F. Future precipitation: Unclear changes, but large variability will continue

In contrast with the near-certainty of future warming, it is unclear how annual precipitation will change in the Moab region, relative to the late 20th century. Regionally, precipitation in the Desert Southwest is projected to decrease. However, in the Moab region, some climate models show modest increases in annual precipitation (up to 18%), some models show modest decreases (up to -13%), and some models show precipitation remaining about the same. All models show continuation—if not enhancement—of the large year-to-year variability in annual precipitation. The mean of 20 downscaled climate models shows that precipitation for Moab is projected to increase by about 5% by mid-century under both high and low emissions scenarios.[8] It is

[7] NOAA Climate Explorer; https://crt-climate-explorer.nemac.org/

[8] MACA downscaled climate dataset, Scatterplot Visualization of Future Projections; https://climate.northwestknowledge.net/MACA/vis_scatterplot.php

important to recognize that a mean of 20 climate models showing a 5% increase in precipitation is no more likely to occur than any individual climate model projections.

As the regional and global climate warms, the frequency and severity of extreme precipitation events will increase. Historically, extreme precipitation events associated with monsoonal rains are a relatively common occurrence in the Moab region; warmer temperatures in the atmosphere will likely cause an increase in the amount of precipitation that falls in a short duration (≤ one hour), resulting in high-intensity events such as monsoonal thunderstorms. The atmosphere holds more water at higher temperatures; for every degree-Celsius (i.e., 1.6°F) of warming, precipitation amounts are projected to increase by 7% during events like monsoonal thunderstorms.[9] The concept of increasing precipitation amounts as temperature warms can be applied to projecting the amount of rain that falls in a one-hour, "100-year" rainfall event under climate change scenarios for the Moab region. Figure 8 shows how much the amount of precipitation that falls during a one-hour, 100-year precipitation event will increase by 2050 and 2085 under a high emissions scenario. Historically, a 100-year precipitation event has involved 1.36" of rain falling in an hour. By 2050, that amount is projected to increase by 21% to 1.64" of rain falling in an hour. By 2085, a 35% increase is projected, equating to 1.84" of rain falling in an hour.

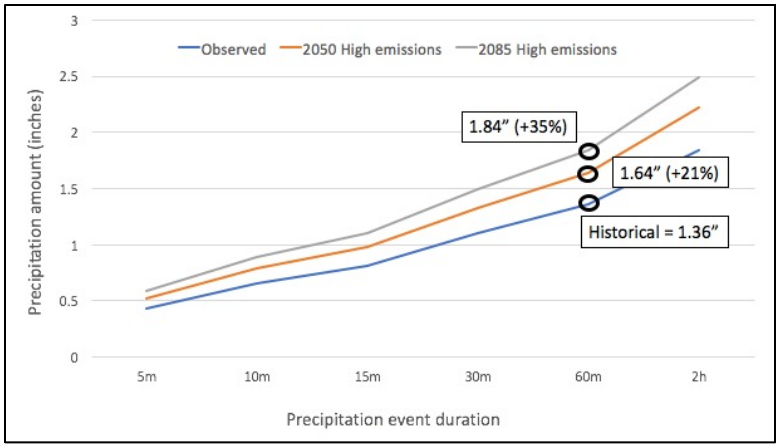

Figure 8. Historic and projected changes in the amount of precipitation falling during a one-hour, 100-year event. Historic data is from the NOAA ATLAS-14 database; (https://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html?bkmrk=pa).

Figure 9 shows the historic recurrence interval of hourly precipitation events of different amounts (blue line) and projected changes in the recurrence interval of hourly precipitation events (red line) based on a high emissions

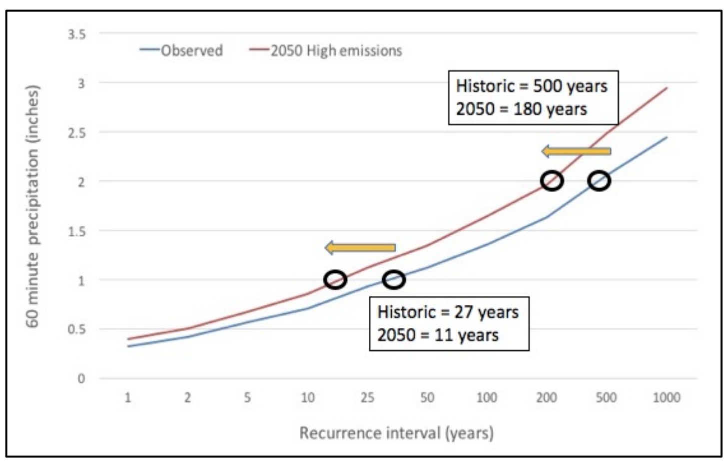

Figure 9. Historic and projected recurrence interval of a one-hour precipitation event of different amounts for Moab. Historic data is from the NOAA ATLAS-14 database; (https://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html?bkmrk=pa).

[9] Prein, A.F., R.M. Rasmussen, K. Ikeda, C. Liu, M.P. Clark and G.J. Holland. 2016. "The future intensification of hourly precipitation." *Nature Climate Change*. doi:10.1038/nclimate3168

scenario for 2060. Historically, a 1" in one-hour rainfall event occurs once every 12 years. Assuming 3.6°F of warming, a 1" in one-hour rainfall event is projected to occur every five years. The historic recurrence interval of a 2" in one-hour rain event is 180 years; by 2060, that recurrence interval is projected to decrease to 52 years. While extreme precipitation is a difficult climate parameter to project into the future, this technique gives an estimation of both frequency and intensity of future extreme precipitation events for the Moab region.

4. VCAPS workshop: Highlights and themes

A. Description of the workshop process

During the workshop in Moab on July 18 – 19, 2019, participants took part in a diagramming exercise and discussion focused on examining the impact of drought and reduced water availability on water supply management in the Spanish Valley. During the discussion, one WWA Team member facilitated the group discussion while another team member diagrammed the conversation in real-time, using discrete "building blocks" (Figure 10). The WWA Team built the diagram on a computer and projected it onto a screen so that participants could see the diagram being populated with ideas as they were being generated.

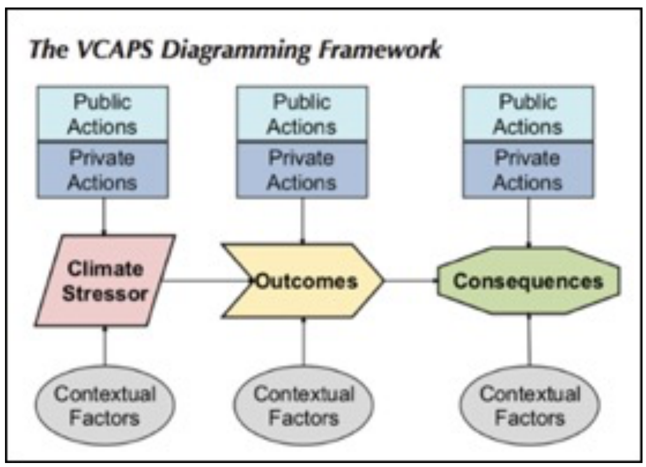

Figure 10. VCAPS building blocks, from www.seri-us.org

During the diagramming exercise, the facilitator led the group through the process of mapping out the causal structure of the hazardous event – starting with a ***management concern*** (e.g., reduced water supply) and ***climate stressor*** (e.g., increased temperature or decreased precipitation), and then identifying the physical and social ***outcomes*** and ***consequences*** that stem from the relevant climate stressors. The facilitator asked questions such as "Why do we care about drought?" to guide the group to identify the potential outcomes that could be problematic or concerning for the community. The causal structure of the hazard was completed when the outcomes being generated by the discussion started to be related to loss or harm to things the community cares about, such as people, assets, and ecosystems.

Throughout the process, WWA Team staff listened for mention of ***contextual factors***, or factors unique to the Moab region's specific management or community context that influence its ability to cope with a particular outcome or consequence. Once the causal structure was completed, the facilitator then led the group in a discussion of potential ***actions*** that the region could take to address different outcomes and consequences.

The final versions of the diagram, broken out by theme, are embedded in the following text. A table listing the management actions for the scenario is included in Appendix D. **All diagrams are a reflection of the opinions of the participants, *not* WWA Team staff.**

B. Discussion of drought and reduced water supply scenario

During the diagramming exercise, participants focused on water supply management as the management concern to frame the overarching discussion. The diagrams generated through the group discussion were separated into five issue areas by the WWA Team, although these themes overlapped in the discussion: 1) groundwater depletion, 2) extreme precipitation, 3) wildfire risk, 4) flora and wildlife risk, and 5) water quality and extreme heat. The WWA/EDR team grouped diagrams into these five themes in order to provide structure to the report and to create diagrams that were manageable in size and complexity. The following sections present a detailed examination of each of these five themes, using the diagrams as a basis for the discussion.

i. Groundwater depletion

During drought, the primary climate stressors that impact groundwater resources are reduced precipitation and increased temperature, which can lead to earlier snowmelt (Figure 11). During drought, higher temperatures, more clear days, and increased solar radiation cause an increase in evapotranspiration which leaves less water available for runoff and groundwater recharge. The combination of these climate stressors during a period of drought lead to earlier and/or reduced runoff, which stresses groundwater resources through decreased aquifer recharge and increased demand for water to maintain outdoor landscapes and agricultural production. Drought conditions can lead to increased mobilization of dust by high winds; when dust is deposited on snow, the dark color of the dust increases the amount of solar radiation absorbed by snowpack and can also lead to earlier snowmelt.

The City of Moab currently relies primarily on groundwater for its water supply (from both springs and wells), and SJSVSSD will rely on groundwater once its water supply system is complete. GWSSA primarily uses surface water diverted to Ken's Lake from Mill Creek to provide irrigation water and groundwater to provide drinking water to its customers. During times of drought when Ken's Lake has insufficient water, groundwater resources can be stressed due to increased pumping to provide irrigation water.

Groundwater resources are also stressed during times of drought due to increased groundwater pumping; more ground water is pumped due to decreased spring flows, decreased aquifer recharge, increased evapotranspiration and increased demand for outdoor water usage and the periodic need to pump groundwater to fill Ken's Lake. Persistent drought accompanied by increased groundwater pumping and severely reduced aquifer recharge could lead to a decline in the aquifer or, in an extreme scenario, aquifer collapse. However, there is no evidence of significant aquifer decline at present; a report on the state of groundwater resources in the Spanish Valley should be published by the US Geological Survey by fall 2019. Reduced surface water also has consequences for recreation, both for local residents and tourists, for riparian ecosystems, and for local agricultural producers who may be subject to irrigation restrictions. An important contextual factor is that a flow of three cfs must be left in Mill Creek, which affects the amount of water that can be diverted to Ken's Lake during times of low flow, but protects riparian areas along the creek.

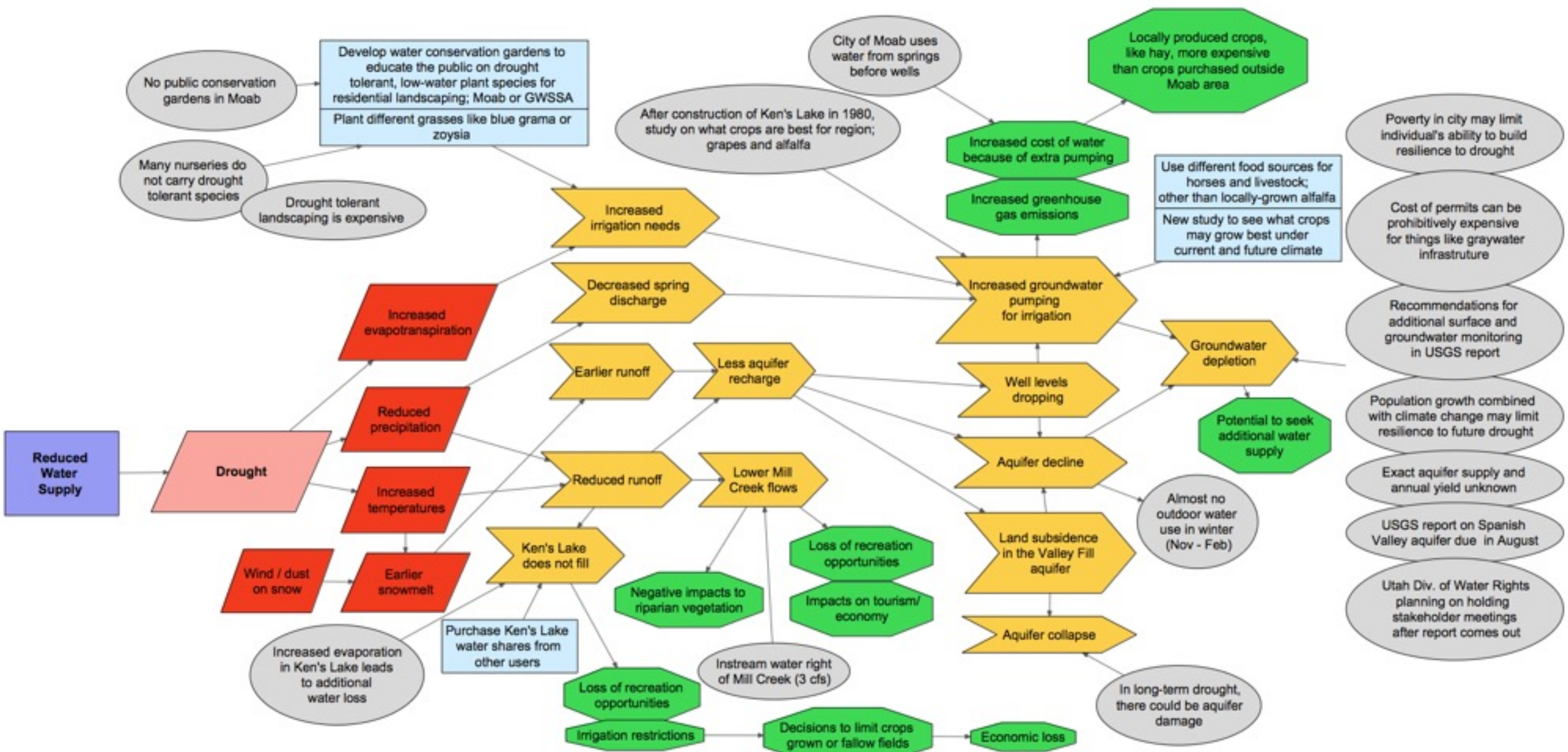

Figure 11. Diagram for groundwater depletion. See Figure 12 for additional management actions.

Participants discussed management actions primarily focused on two broader solutions: actions to reduce groundwater depletion and actions to seek additional sources of water supply. In order to reduce groundwater depletion, participants discussed development and landscaping strategies to improve water capture and retention, strategies for water conservation, and the importance of the upcoming Spanish Valley groundwater management plan. In terms of seeking additional sources of water supply, participants discussed developing more water storage, reusing storm water and wastewater as secondary water sources, and selling water rights from agricultural producers to other users. Other management actions mentioned were related to increased irrigation needs due to increased evapotranspiration, including educational efforts to introduce drought-tolerant species to the public through pilot water conservation gardens on public properties.

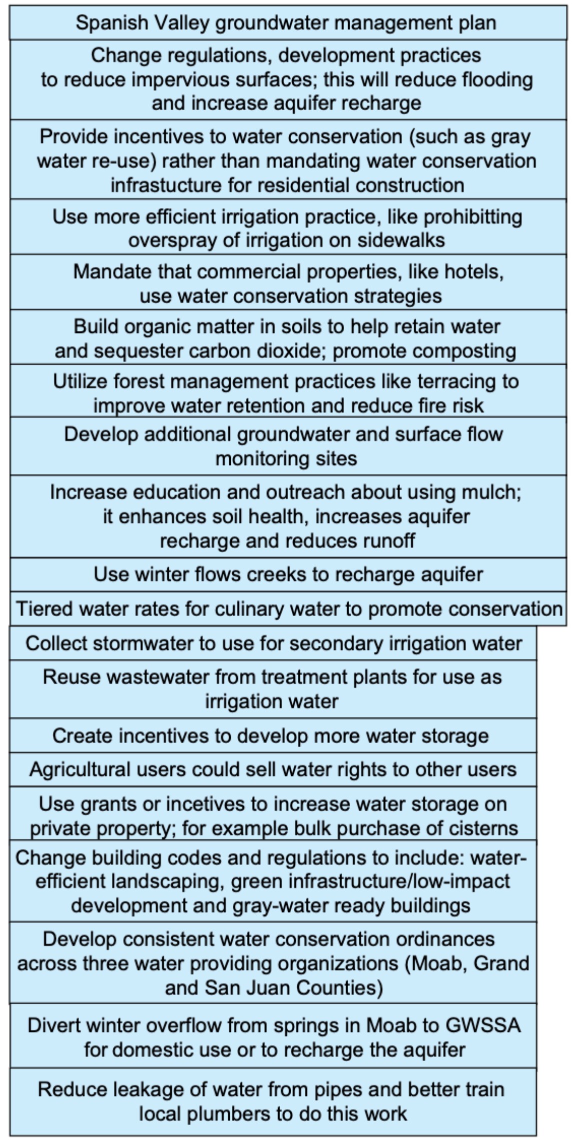

Figure 12. Management actions for the groundwater depletion diagram.

ii. Extreme precipitation

Extreme precipitation events are more likely to occur
in the future and these events will likely bring greater amounts of precipitation in very short durations. Warmer temperatures in winter and spring due to drought or climate change can cause early and rapid snowmelt from the La Sal Mountains. Both extreme precipitation events or early and faster snowmelt can cause rapid runoff. This rapid runoff has two main consequences. First, it can lead to flooding events, which cause infrastructure damage when existing infrastructure cannot handle such high levels of runoff. This results in property loss and increased costs to the City of Moab and other entities. Second, rapid runoff also results in less infiltration, which reduces aquifer recharge (Figure 13). For more information on the consequences of groundwater depletion, refer back to Figure 11. A contextual factor of extreme precipitation is that this rapid runoff is difficult to capture in the existing reservoir of Ken's Lake and limited additional infrastructure exists to store extreme precipitation or runoff. Additionally, increasing urban

development in the region leads to increased impervious surfaces, which results in more runoff that is difficult to capture and store.

Participants identified two sets of management actions for addressing the risk of rapid runoff. The first included using small scale dams to slow the flow of water, incorporating landscape management techniques to increase water retention and reduce erosion, and developing infrastructure that will capture water and reduce sedimentation. The other set of management actions focused on reducing damage to infrastructure through assessing existing infrastructure and identifying and investing in priority improvement needs, and more frequently cleaning sediment and debris from stormwater conveyance pipes and systems.

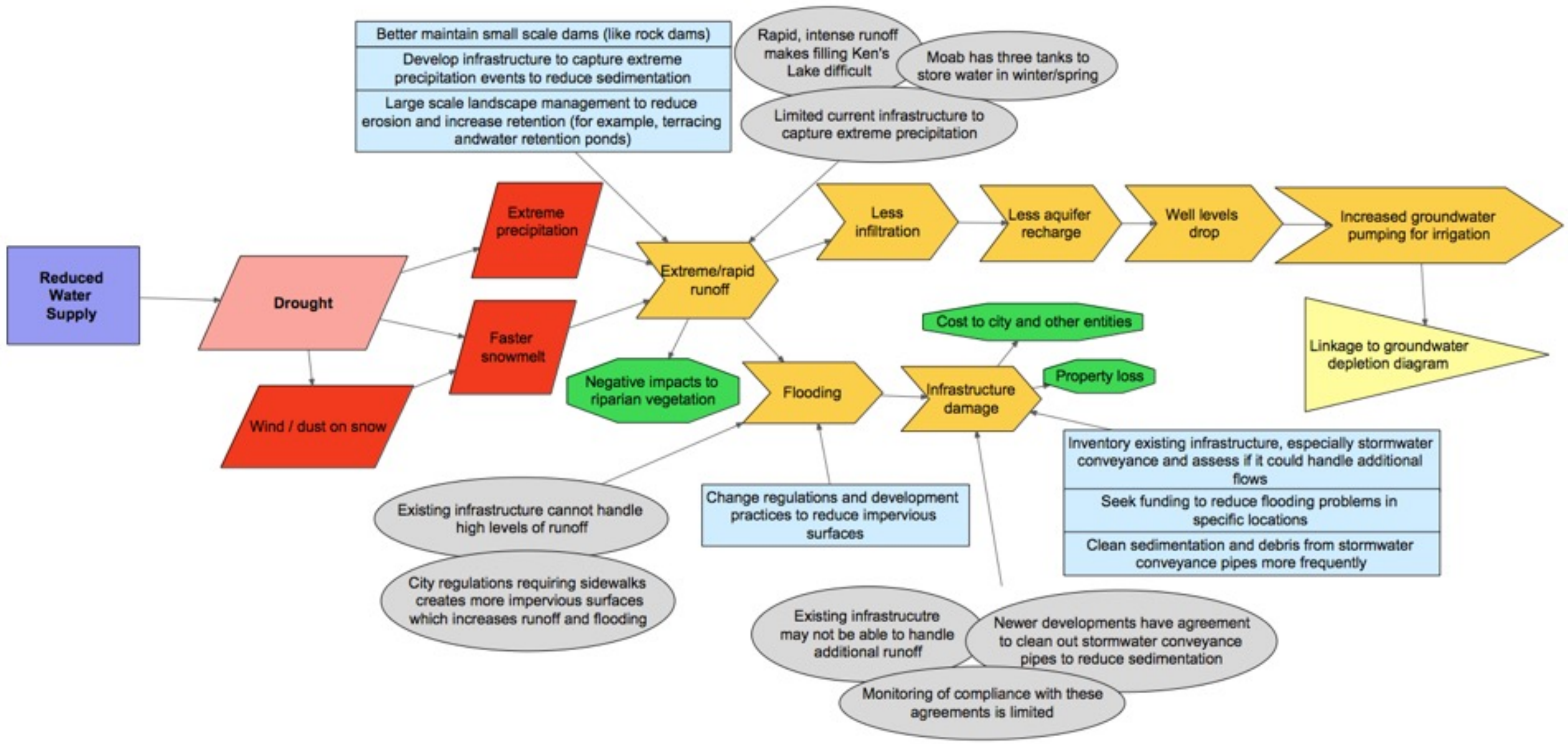

Figure 13. Diagram and management actions for extreme precipitation.

iii. Wildfire risk

Drought is often associated with reduced precipitation and/or increased temperatures, either of which can increase both the incidence and severity of wildfire. High temperatures and below average precipitation cause lower soil moisture and drier fuels for wildfire. Participants discussed two primary outcomes of increased wildfire that affect water supply. One, an increase in demand for water to fight wildfires and, two, that burned landscapes are less effective at retaining water and recharging the aquifer (Figure 14). When rain falls on recently burned landscapes, or "burn scars," runoff is greatly increased and very little of the precipitation is retained in the soils for aquifer recharge. The increased runoff that occurs in burn scars typically carries extremely high loads of sediment. Extreme precipitation events that occur in recently-burned landscapes can trigger rock and mudslides, further increasing sediment transport. (Section 4.B.ii discusses the impacts of extreme precipitation and rapid runoff on water supply). Participants expressed a concern about wildfire and increased sediment transport around Ken's Lake. If a wildfire were to burn in the watershed directly surrounding Ken's Lake, high sediment loads from ensuing runoff could begin to fill the reservoir with sediment and reduce its capacity to store water. If a wildfire occurs in the Mill Creek watershed, high sediment loads in runoff during post-fire precipitation events could limit GWSSA's ability to divert water from Mill Creek into Ken's Lake and would certainly cause problems by clogging irrigation diversions and piping with sediment and debris. Consequences of increased wildfire risk include increased cost of fighting wildfires, competition for water during times of actively burning fires, damage to irrigation systems, and both economic and recreational impacts if Ken's Lake were affected by sedimentation.

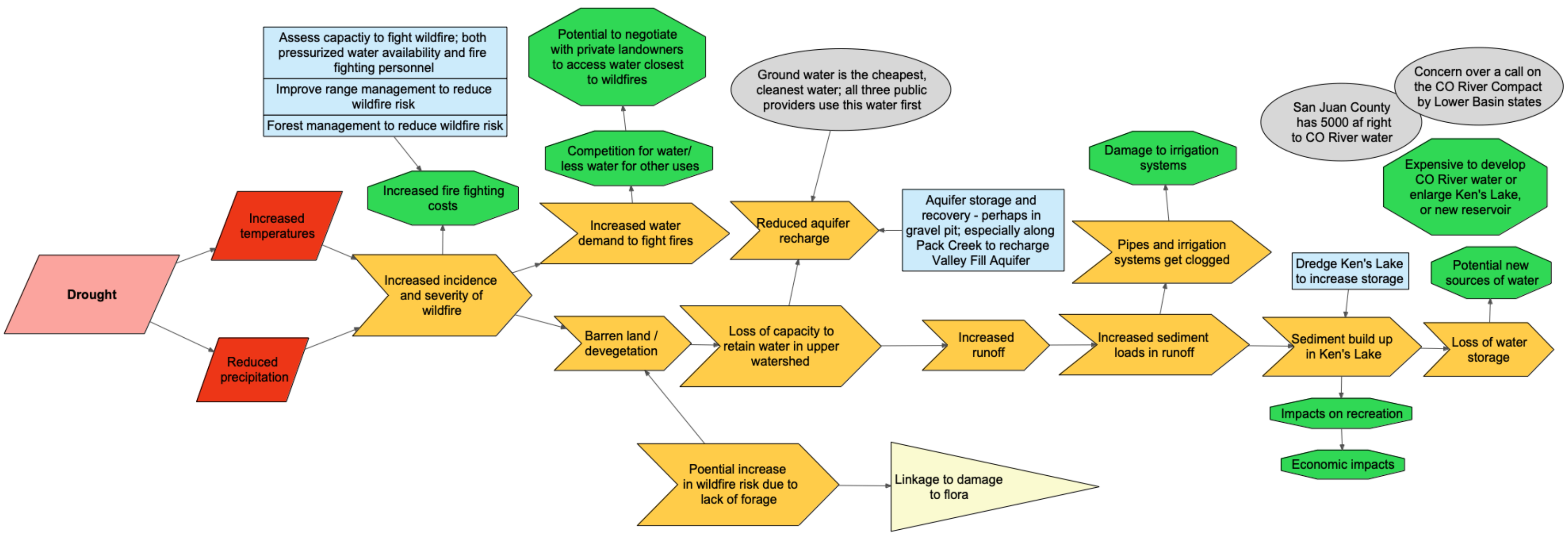

Figure 14. Diagram for wildfire risk. See Figure 15 for additional management actions.

Management actions directly related to the increased risk of wildfires included using forest and range management techniques to reduce the fire risk and assessing the capacity of pressurized water and personnel to fight fires. Discussion about the potential for post-fire sedimentation of Ken's Lake sparked a conversation about the possibilities for increasing water supply in Spanish Valley. Management actions suggested to increase water supply in this section also pertain to stresses on water resources potentially created by groundwater depletion and population growth. Ideas for expanding water supply in the Spanish Valley include, in no particular order: developing Colorado River water, raising the earthen dam of Ken's Lake, developing a second reservoir, and utilizing landscape strategies to increase water retention and conservation.

Saving money to have reserves to apply for grants to evelop CO River water that require matching money
Use available water in different parts of valley; Ken's Lake in south, Valley Fill aquifer in central, CO River water in north
Utilize Colorado River water
Use Pack Creek to fill Ken's Lake - perhaps relevant on a drought year
Aquifer storage and recovery - perhaps in gravel pit; especially along Pack Creek to recharge Valley Fill Aquifer
Develop a second reservoir in the Moab area
Raise dam on Ken's Lake to increase storage
Large scale effort by Civilian Conservation Corp to rehabilitate ecosystems to increase aquifer recharge, slow flow of water
Promote construction of green infrastructure
Roof top storage of water; small scale treatments over a large area
Change building and zoning codes to enhance water conservation and therefore water supply
Change direction of city/county code away from water detention to water retention

Figure 15. Management actions for wildfire risks.

iv. Flora and wildlife risk

Workshop participants recognized that increased temperatures and reduced precipitation will also put stress on flora and wildlife in the area. Figure 16 shows the outcomes, consequences, and management actions pertaining to the impact of drought on flora and wildlife. Stress on flora will affect local ecosystems and native vegetation, result in economic losses for property owners due to damage of their vegetation, and cause decreased agricultural production, including of alfalfa which is used as livestock feed in the area. Additionally, the effect of this stress on local ecosystems may cause increased wildfires because of the vegetation changes, including an increase in the abundance of invasive species. Increased entrenchment of riparian corridors is caused partly by invasive species such as Russian olive and tamarisk, and tends to decrease the water storage in the system. Entrenchment of the riparian corridor may cause streams to lose connectivity with their historic floodplain and negatively impact native species, such as cottonwood trees. Local wildlife will also be affected by the two climate stressors, particularly resulting in changing grazing habits, for both wildlife and livestock. During times of drought, when forage in natural ecosystems is limited, wildlife abundance in irrigated landscapes of the Spanish Valley may increase. This expansion of the grazing area could potentially impact natural ecosystems, cause more human-wildlife and livestock-wildlife interactions, and damage residential and agricultural vegetation.

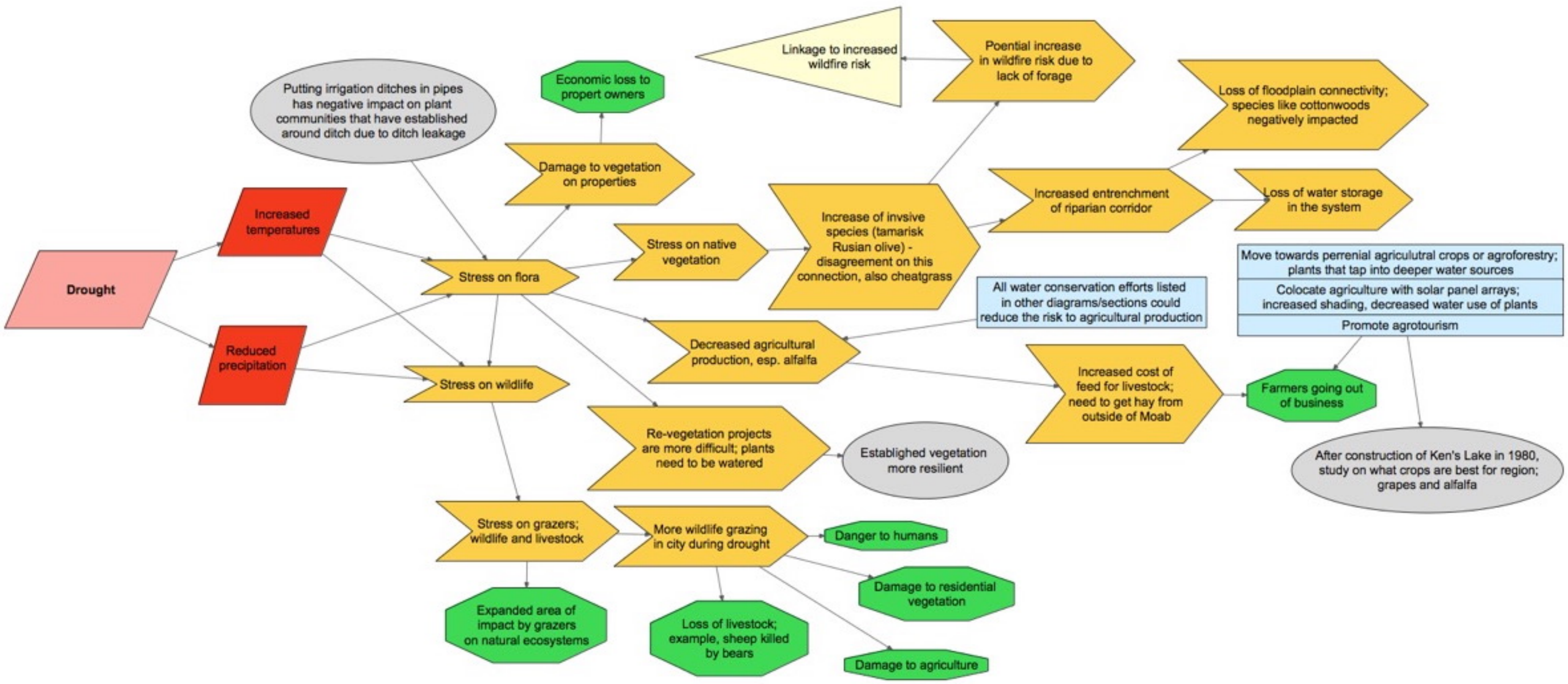

Figure 16. Diagram and management actions for flora and wildlife risk.

Management actions to reduce the impact of drought on flora and wildlife focused on reducing the strain on local agriculture by introducing water conservation practices (as identified in other diagrams), adopting new agricultural practices including alternative crops, agroforestry, and the introduction of solar arrays, and expanding agritourism in the region.

v. Water quality and extreme heat

Increased temperatures and reduced precipitation will increase the risk of water quality degradation in Mill Creek, Pack Creek, and Ken’s Lake. Higher temperatures will increase the incidence of extreme heat events and extend the period of the year with high temperatures. Decreases in water quality and increased extreme heat will potentially reduce the quality of life for residents and the quality of experiences for tourists (Figure 17). The coincidence of higher temperatures and reduced precipitation and streamflow during drought will result in increased surface water temperatures. Increased water temperatures tend to decrease water quality in two manners. One, high stream temperatures negatively impact the health of some fish species that are adapted to cooler temperatures and warmer water holds less dissolved oxygen, which also negatively impacts fish health. Two, high stream and lake temperatures increase the likelihood of algal blooms, some of which may contain toxic cyanobacteria. This will impact residents and tourism through decreased recreation on algal bloom-impacted water bodies. One management action proposed by participants was to focus on investing in green infrastructure projects that will help to improve water quality.

Increased temperatures and extreme heat events may result in the region becoming too hot for tourists to visit during certain times of the year. High summer temperatures will increase cooling costs for both residential and commercial sectors. Extreme or prolonged heat events may negatively impact the local economy, by causing decreased revenue for the tourism and service sectors. An important contextual factor is that as urban development increases in the region, the urban heat island effect will likely increase as well, further enhancing high local temperatures. Management actions to respond to these consequences focused on providing alternative activities to tourists, including indoor activities such as museums and more water-based, cooling activities.

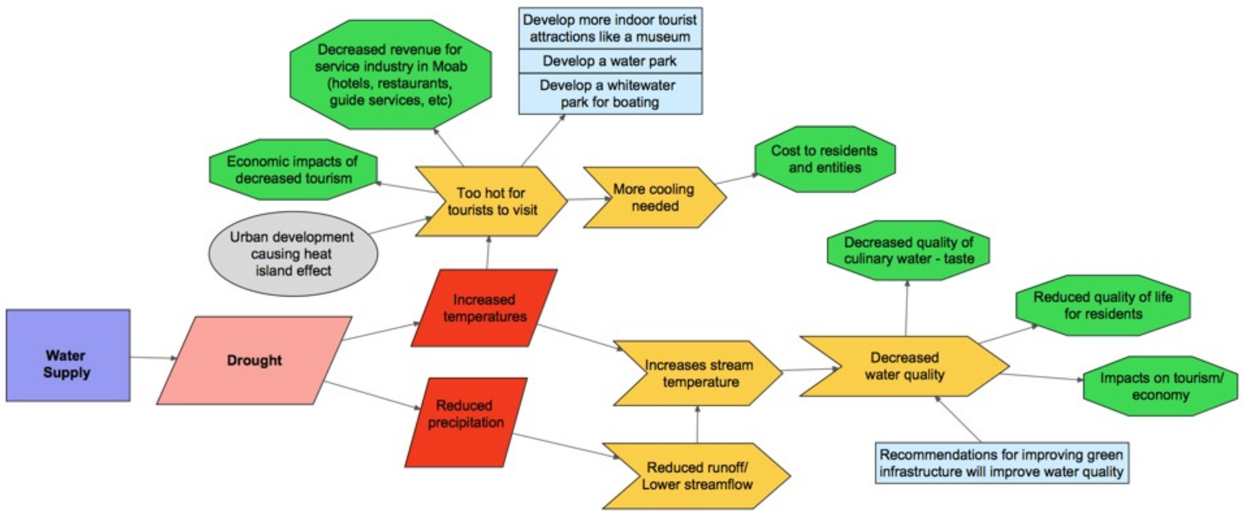

Figure 17. Diagram and management actions for water quality and extreme heat.

C. Cross-cutting themes: planning, coordination, education, and landscape management

Each diagram in the sections above focuses on a particular topic of water supply management that participants discussed during the VCAPS workshop. However, there are broad themes that cut across all of these topics and provide a framework for thinking about and addressing these issues. The primary themes identified by the WWA/EDR team are presented below:

- *Planning:* Two large-scale efforts related to water supply in the region will be introduced to the public this fall: the release of the United States Geological Survey's report on available water in the region and the initial stage of the Utah Division of Water Right's Spanish Valley groundwater management plan. Also, the six-month moratoria on the construction of hotels in Moab and Grand County is set to expire in August 2019. Participants recognized the importance of learning from and participating in these large-scale planning efforts, alongside their agency's individual work. It was also noted that collaborative planning efforts between the entities might need to go beyond these existing plans to produce a more detail-oriented response, such as through the creation of a drought contingency plan.

- *Coordination:* Increased coordination between the three main water supply entities in the region (Moab, GWSSA, MIC and SJSVSSD) was mentioned as an important next step for improving region-wide response to drought and reduction in water supply. Participants proposed that in the short-term this could look like expanding the reach of MAWP to encourage the participation of stakeholders that have not joined in the past, as well as to focus more on actions related to water quantity. Ideas were also discussed to promote collaboration amongst water management agencies in the long-term, including the development of an overarching regional agency. Coordination is important in order to fully take advantage of all of the different potential sources of water in the region by thinking about sharing the cost of their allocation on a regional level in order to use them in the most efficient and cost-effective way possible.

- *Education:* Participants identified education of the public as an important step in promoting water conservation strategies in the region. Ideas for this included sharing information on water catchment and retention systems for individual properties and increasing the visibility of City subsidies for infrastructure and materials that will help to increase water conservation for private homes. Participants also discussed how incentives can be an important way to create change in individual property owners, agricultural producers, and high water-consuming businesses. Lastly, participants discussed the importance of using pilots on public properties to demonstrate landscape techniques, including low-water plantings, that can be used as examples for the education of the public.

- *Landscape Management:* The importance of various landscape management techniques, from the watershed scale to the individual property, were discussed in relation to all themes and potential actions. Landscape management strategies could be used to mitigate the effects of extreme precipitation, including protecting current infrastructure, and as a strategy for water conservation. Participants recognized that certain landscape management decisions, such as increasing urban development and impervious surfaces, work in opposition to the collective goal of increasing regional water supply. In addition, the group discussed many landscape management strategies that would enhance regional water supply, including green infrastructure projects, water catchment and retention systems, and landscape alterations in the upper parts of the watershed.

5. Participant reflections and next steps

During the final session of the workshop, participants shared reflections on the two-day process. Participants found the following aspects of the process to be valuable:

- It engaged new voices outside of those who regularly participate in MAWP in the conversation about water supply
- It provided a step forward in efforts to unify the three water suppliers in the region
- It created an opportunity for regional entities to discuss and work together to identify actionable strategies for addressing water supply

- It provided a reminder about how much local talent and leadership there is focused on this issue in the region

Participants also shared the following next steps they would like to take themselves or see the group take:

- Participate in the upcoming Spanish Valley groundwater management planning process
- Share information between entities to ensure consistency on water conservation ordinances
- Develop better groundwater monitoring strategies in the region
- Increase community education on water collection/retention methods
- Coordinate a bulk order of water cisterns for water catchment on individual properties
- Increase trees and landscaping in new parking lots through secondary water usage
- Codify best practices in water-efficient landscaping, green infrastructure/low-impact development, and gray water-ready buildings
- Conduct a neighborhood campaign in Moab to increase the usage of free City-provided mulch on individual properties
- Incorporate water conservation into San Juan County ordinances as they are being written
- Ensure storm drain design is sufficient for projected precipitation numbers
- Fix leaks throughout water supply systems and focus on maintenance of infrastructure
- Increase outreach about irrigation and aerator rebates

6. Conclusion

The VCAPS facilitation method used in the Spanish Valley/Moab Region Drought and Climate Workshop is one of many approaches available to empower adaptation to changes in local climate and weather through structured, deliberate dialogue. Over the course of two half-day meetings, the City of Moab, GWSSA, SJSVSSD, and other key water supply stakeholders worked together to systematically examine and document local climate concerns; experienced and anticipated impacts of climate hazards; knowledge of past, current, and planned efforts to mitigate climate risks; and potential new solutions to address risk across regional operations. Nearly all workshop participants expressed the need to continue these discussions. We hope that this report and the diagrams generated from the meetings can support this group to continue the conversation and generate a plan for examining the broad range of vulnerabilities, questions, existing assets, and new ideas that emerged through this process.

7. Appendices

Appendix A: Interview Summary

Seth Arens and Zoë McAlear conducted phone interviews with workshop participants during May and June of 2019. The WWA Team conducted interviews in order to better understand the water management issues in the Spanish Valley and the roles of all the organizations and individuals participating in the workshop. Additionally, the interviews explored which climate risks, in regards to water supply management, most concerned participants in order to determine what climate information to present to the group during the workshop. This interview summary presents basic professional information about the participants interviewed, the goals of the workshop as understood from the interviews, and a summary of interview responses organized into climate-related concerns, climate information needs, and local dynamics/political concerns.

Participants and Their Role in Water Supply Management:

Convener:

Arne Hultquist - Grand and San Juan County Watershed Coordinator at Southeast Utah Health Department (focused on improving water quality and funded by the Utah Division of Water Quality); facilitates the Moab Area Watershed Partnership (MAWP); member of Moab Water Conservation and Drought Management Advisory Board

Participants:

Organization	Participant	Title	Specific Role(s)
City of Moab	Mike Duncan	City Council Member (also member of the GWSSA and MIC boards)	City Council Member for 1.5 years; member of MAWP, GWWSSA Board, Moab Water Conservation and Drought Management Advisory Board, and Moab Irrigation Company Board.
	Rosemarie Russo	Director of Sustainability	Completed 10-year Sustainability Action Plan for Moab – works on accelerating renewable energy use, sustainability for businesses, water conservation, etc.
Grand County	Bob O'Brien	County Planning Commission	Also on the Castle Valley Town Council, a member of the Canyonlands Watershed Council, and working on a land management plan for the La Sal Mts. with the USFS.
	Kenny Gordon	Planning and Zoning Administrator	Focuses on development and acts as a liaison between developers and other agencies.

	Terry Morse	County Council Member	Conveys information from Moab to the County and County Commission to better understand water resources.
Grand Water and Sewer Service Agency (GWSSA)	Dana Van Horn	Agency Manager	Water supply for unincorporated areas of Grand County – focuses on protecting public health, managing surface water into Ken's Lake, and deciding which wells to operate.
	Dale Weiss	Board Member	On the Operating Committee: involved in hiring, and acquiring new sewer system in Moab. Also farms on a small scale.
San Juan Spanish Valley Special Service District (SJSVSSD)	Kerry Behunin	Board Member	Concerned with taking care of customers and ensuring water is available for them through the new water supply system in San Juan County.
	Ben Musselman	Public Works Director	Overseeing the construction of water supply system in southern Spanish Valley and will be the system operator until it is running smoothly.
Utah Division of Water Rights (UDWRi)	Marc Stilson	Regional Engineer	Based in Price and administrator of all water rights in SE Utah.
Canyonlands Watershed Council (CWC)	Jeff Adams	Executive Director	Focused on policy advocacy, research, and supporting decision-makers related to protecting and preserving the waters/watersheds of SE Utah.
Bureau of Land Management Moab Field Office	Ann Marie Aubry	District Hydrologist	Provides expertise and information to BLM staff and others on water resources in SE Utah.
U.S. Forest Service, Manti-La Sal National Forest	Michael Diem	District Ranger	Provides expertise on all management issues pertaining to the US Forest Service.

Participant Goals/Hopes for the Workshop:
Three main themes emerged concerning participants' hopes for the workshop (in no particular order):

1. Learn from other participants:
    a. Many interviewees expressed a desire to hear from other local stakeholders about what they know and what they plan for regarding drought and water supply in order to learn from each other and collectively move forward.

2. Increase coordination between participants:
    a. Many interviewees described wanting to create a dialogue between the different entities in order to increase coordination, especially by discussing what each plan to do if there is a drought, how they plan to coordinate with other entities, how they plan to manage their water rights, and how they can mitigate the effects of drought.
    b. Going further, one interviewee expressed a desire to agree on conservation measures and another interviewee would like to see commitment from water providers on funding and action related to establishing a monitoring program.
3. Understand the current water situation, and what to expect in the future, in order to make specific plans:
    a. Interviewees hope to learn more about issues (such as drought and water supply) in order to inform their own work and bring information back to their organization/board to share, including specifics on how climate change may impact water supply, what sort of "bank account" is necessary in case of drought, and what are current water usage patterns. Interviewees also expressed the need for guidance on establishing drought contingency plans.

Climate-Related Concerns Beyond Drought:

- Water / Precipitation: multiple interviewees expressed concern with the uncertain shifts in timing of precipitation; extreme precipitation and flooding events; oversupply of surface water during certain times of the year (i.e.: currently ~ 50 f^3/s in Mill Creek), but no storage method
- Snow: concern with the shift in timing and amount of snow and snowmelt, particularly if snowmelt happens earlier and reduces summer base flows
- Wildfires: multiple interviewees expressed concern for wildfires, specifically that drought might cause more fires and the question of water availability to fight wildfires
- Soil: interviewees raised concerns of soil moisture levels and health, as it relates to storm water runoff, soil compaction, and impact on flooding
- Temperature: interviewees raised concerns about rising temperatures and their impact on drought, particularly through increased rates of evapotranspiration
- Flora and Fauna: interviewees raised concerns about the health and well-being of ecosystems, particularly in aquatic and riparian areas due to changing water flows
- Water Quality: one interviewee expressed concern that the higher temperatures found in the streams and surface water often exceeds water quality standards
- Air Quality: interviewees raised the concern of climate change having an impact on air quality, as well as the connected concern of how air quality may impact water quality
- Earthquakes: one interviewee expressed concern for earthquakes shifting the aquifer
- Economy: many interviewees talked about the economy and how drought and water supply will impact the service and recreation industries, development and real estate, and agriculture and grazing

Climate Information Needs:

- Most interviewees stated their primary information need to be **site-specific information** to Moab and the surrounding region, addressing potential future water supply changes.
    - More specifically, interviewees are interested in learning about the **water budget** for Spanish Valley and how climate change might affect it; this relates to question about projections of **temperature** and its effect on **evapotranspiration**; timing and intensity of **precipitation** and **snowmelt**, and their relation to **flooding** and **runoff**; **wildfire** predictions; and the regional effect of **El Niño.**
    - Interviewees also want information to determine the **water storage** needed for the region and to define how much excess capacity should be left in the system in order to be resilient to future drought and account for climate change.
    - Many interviewees also mentioned the different reports on current water supply quantity and would like to know what they measure and why/how they differ.
- Many interviewees stated a desire to know as much as possible about **long-term climate projections**, particularly related to whether or not there will be a long-term drought and/or if they are currently in a pattern of **aridification**, as well as how many years to expect between **wet years**.
- Additionally, interviewees identified the following topics as other areas of interest:
    - Groundwater information: how and why **groundwater levels** fluctuate, including how **aquifers** are recharged, how **snow pack** affects groundwater levels, and an inventory of **springs**, along with how climate change might impact them
    - How climate change will affect **ecosystems**, invasive species, and local **soils**
    - Connection between **air quality** and climate change
    - How to prepare for **flooding/flood management**
    - Clarification on how shifting in the Earth's poles and axis impact climate

Local Dynamics / Potential Tensions / Political Concerns:

- Interviewees mentioned the challenge of three political entities using the same water supply, especially when there is a lack of agreement regarding its current and future quantity.
    - Additionally, one interviewee expressed concern with the long-term strategies of these entities and others: pumping water out of the ground when there is a lack of surface water, with the assumption that it will replenish in a wet year; and holding on to the Colorado River as a fallback, despite the expense and political challenge of developing water supply from there.
    - This connects to the upcoming groundwater management planning process advocated by the DWRi to establish safe yield. In public meetings, DWRi has stated that the community can set that safe yield, but that it needs to be by consensus. One interviewee mentioned the concern that junior water rights users (i.e.: SJSVSSD) will not come to consensus on holding water in reserve for conservation/ecosystems, especially when the Colorado River is still considered to be a backup option by some.
- Related to this, the main tension in the region is around **development and water availability**, particularly now that a third water district (SJSVSSD) has formed with junior water rights and uncertainty remains regarding regional population growth:

    - Most interviewees mentioned the **construction of the new water supply system and potential new development in San Juan County** as a tension, as some stakeholders are against any development (or such expansive development) of water in the southern Spanish Valley, while others say that it is necessary to reduce development pressures in Moab.
    - One interviewee expressed concern that a third water district has formed despite the fact that Moab and Grand County plan on using all of their water rights eventually; this may lead to a scenario in which "first in right, first in time" is invoked, potentially shutting down SJSVSSD's water supply system after immense spending on development.
    - Additionally, an interviewee mentioned DWRi and GWSSA's assumption that irrigated agriculture in the valley will be replaced by houses, so water used for agriculture will be available for development. However, they expressed that certain constituencies want to see agriculture and a rural lifestyle continue in the region.
- Interviewees expressed that stakeholders have **differing views on climate change and its causes**, especially as it relates to Moab's future water supply.
    - One interviewee expressed a hope that workshop dialogue would be based on solid science and water law, not emotions and "non-facts."
- Interviewees expressed that stakeholders have **differing information on/understanding of current water availability**, with interviewees referencing the difference between paper water rights and what actually exists (some think paper water rights are greater than actual water supply and others think vice versa).
    - One interviewee expressed not wanting to discuss water rights in the workshop.
- One interviewee expressed that some long-time residents are skeptical of outsiders and outside knowledge, including scientific studies, because they trust in their own experience.

Appendix B: Workshop Agenda

WESTERN WATER ASSESSMENT
A NOAA RISA TEAM

Workshop Overview & Agenda

Spanish Valley/Moab VCAPS Workshop
Grand Water and Sewer Service Agency (GWSSA) Office
3025 E Spanish Trail Road, Moab
July 18-19, 2019

About VCAPS and Western Water Assessment

Vulnerability, Consequences, and Adaptation Planning Scenarios (VCAPS) is a facilitated workshop designed to help communities be more resilient to weather and climate change. During VCAPS, communities examine a local weather- or climate- related hazards of concern (such as drought or flooding), analyze existing and anticipated community impacts of those hazards, identify gaps in knowledge, and brainstorm strategic short- and long-term solutions for preventing and dealing with impacts of the hazards. While VCAPS is designed as a stand-alone exercise, many communities have used it as part of a larger community-led planning process, including initiating dialogue, developing or updating new local plans, and identifying areas to seek further funding or implementation.

Western Water Assessment (WWA) is a research group based at the University of Colorado that supports decision-makers in the Rocky Mountain West to make the best use of science for management. WWA is partnering with the University of Utah and communities across the Rocky Mountain West to pilot the VCAPS process.

Workshop Goals and Objectives
The VCAPS process for the Moab region aims to:

1. **Raise awareness** and **build expertise** among key stakeholders regarding regional climate trends and future climate scenarios for planning efforts related to water supply in Spanish Valley;
2. Establish a **common understanding** of the anticipated impacts of climate change on regional operations, with respect to water supply;
3. **Take inventory** of current initiatives, concerns, and challenges associated with water supply;
4. **Identify options** for adapting regional operations to mitigate risks associated with drought and climate; and
5. Build relationships for **regional** climate hazard preparedness and response.

Anticipated Participants
Workshop participants: 15 staff from city, county, federal and non-profit agencies.
Workshop facilitation team: 4 staff and scientists from Western Water Assessment and the University of Utah

WESTERN WATER ASSESSMENT
A NOAA RISA TEAM

Workshop Agenda

DAY 1 Afternoon Session 1:00-5:00pm	**DAY 2** Morning Session 8:30am-12:30pm
Introductions, Workshop Goals, VCAPS Overview *Presentation on Local Weather and Climate Impacts* *Q&A on Weather and Climate Impacts* ***Break*** *Overview of VCAPS Diagramming, Ground Rules* *How Does Drought Impact the Moab Region?* ***Break*** *How Does Drought Impact the Moab Region? (cont.)* *Wrap-Up, Go Over Day 2 Agenda*	*Review of Day 1 and Check In* *Actions: How Can the Moab Region Prepare for Drought?* ***Break*** *Next Steps* *Reflections, Wrap-Up*

Appendix C: Workshop Participants

Bureau of Land Management – Moab Field Office	Ann Marie Aubry	District Hydrologist
	Jorge Gonzalez	Hydrotechnician
Canyonlands Watershed Council (CWC)	Jeff Adams	Executive Director
City of Moab	Mike Duncan	City Council Member (and GWSSA Board Member)
	Rosemarie Russo	Director of Sustainability
Grand County	Bob O'Brien	County Planning Commission
	Kenny Gordon	Planning and Zoning Administrator
Grand Water and Sewer Service Agency (GWSSA)	Dana Van Horn	Agency Manager
	Dale Weiss	Board Member
Manti – La Sal National Forest	Michael Diem	District Ranger (Moab/Monticello Ranger Districts)
San Juan Spanish Valley Special Service District (SJSVSSD)	Kerry Behunin	Board Member
	Ben Musselman	Public Works Director
Utah Division of Water Rights (UDWRi)	Marc Stilson	Regional Engineer
Southeastern Utah Health Department/Utah Division of Water Quality	Arne Hultquist	Grand and San Juan County Watershed Coordinator (and Moab Area Watershed Partnership Facilitator)

Appendix D: Scenario Management Actions

Scenario	Issue Area	Action*
Drought Scenario	Groundwater Depletion	Purchase Ken's Lake water shares from other users
		Develop water conservation gardens to educate the public on drought-tolerant, low-water plant species for residential landscaping
		Plant different grasses, like blue grama or zoysia (Wild Landscapes in Moab has a lot of information on this)
		Use different food sources for horses and livestock, other than locally-grown alfalfa
		Conduct a new study to see what crops may grow best under current and future climate
		Work on Spanish Valley groundwater management plan
		Change regulations and development practices to reduce impervious surfaces
		Provide incentives for water conservation (such as gray water re-use) rather than mandating water conservation infrastructure for residential construction
		Use more efficient irrigation practices, such as prohibiting overspray of irrigation on sidewalks
		Mandate that commercial properties, such as hotels, use water conservation strategies
		Build organic matter in soils to help retain water and sequester CO_2; promote composting
		Utilize forest management techniques, such as terracing, to improve water retention and reduce fire risk
		Develop additional groundwater and surface flow monitoring sites
		Increase education and outreach about using mulch; it enhances soil health, increases aquifer recharge, and reduces runoff
		Use winter flows from creeks to recharge aquifer
		Use tiered water rates for culinary water to promote conservation
		Collect stormwater to use for secondary irrigation water
		Reuse wastewater from treatment plants as secondary irrigation water

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Scenario	Issue Area	Action*
	Groundwater Depletion	Create incentives to develop more water storage
		Agricultural users could sell water rights to other users
		Use of grants or incentives to increase water storage on private property; for example, bulk purchase of cisterns
		Change building codes and regulations to include: water-efficient landscaping, green infrastructure/low-impact development, and gray water-ready buildings
		Develop consistent water conservation ordinances across the three water supply entities (City of Moab, Grand County, and San Juan County)
	Extreme Precipitation	Better maintain small scale dams
		Develop infrastructure to better capture extreme precipitation events to reduce sedimentation
		Large-scale landscape management to reduce erosion and increase retention (for example, terracing and water retention ponds)
		Change regulations and development practices to reduce impervious surfaces
		Inventory existing infrastructure, especially stormwater conveyance, and assess if it could handle additional flows
		Seek funding, as City of Moab and Grand County are doing now, to reduce flooding problems in a few specific locations
		Clean sedimentation and debris from stormwater conveyance pipes more frequently
	Wildfire Risk	Assess capacity to fight wildfires, both of pressurized water and fire-fighting personnel
		Improve range management to reduce wildfire risk
		Improve forest management strategies to reduce wildfire risk
		Increase aquifer storage and recovery, such as through gravel pits, especially along Pack Creek to recharge Valley Fill Aquifer
		Dredge Ken's Lake to increase storage

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Scenario	Issue Area	Action*
	Wildfire Risk	Save money in order to have reserves to apply for grants to develop CO River water that require matching funds
		Use available water in different parts of the valley: Ken's Lake in south, Valley Fill Aquifer in center, and CO River water in north
		Utilize CO River water
		Use Pack Creek to fill Ken's Lake, particularly in drought years
		Develop a second reservoir in the Moab area
		Raise dam and walls on Ken's Lake to increase water storage
		Rehabilitate ecosystems, such as through a large-scale effort of the Civilian Conservation Corps, to increase aquifer recharge and slow flow of water
		Promote construction of green infrastructure
		Utilize rooftop storage of water and other small-scale treatments over a large area
		Reduce leakage of water from pipes, and better train local plumbers to do this work
		Change building and zoning codes to enhance water conservation and, therefore, water supply
	Flora and Wildlife Risk	Move towards perennial agricultural crops and agroforestry (i.e., plants that tap into deeper water sources)
		Co-locate agriculture with solar panels to increase shading and decrease water usage by plants
		Develop more agritourism
		(See water conservation strategies in other Issue Areas that would help reduce the risk to agricultural production)
	Water Quality and Extreme Heat	Develop more indoor tourist attractions (such as museums)
		Develop more water-based tourist attractions (such as a water park or more boating opportunities)
		Follow recommendations for increasing/improving green infrastructure in order to effect water quality

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