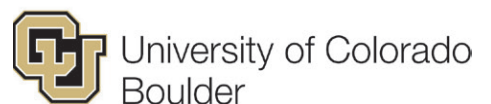


Western Water Assessment

Building Climate Resilience by Design



2019 - 2020 ANNUAL REPORT





WESTERN WATER ASSESSMENT

A NOAA RISA TEAM

WESTERN WATER ASSESSMENT

Cooperative Institute for Research in Environmental Sciences
University of Colorado Boulder

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Performance period covered in this report: June 1, 2019–May 31, 2020

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Cover photo: Lake Isabelle in the Brainard Lake Recreation Area, Colorado. Photo: Jeff Lukas.



University of Colorado **Boulder**



WWA ANNUAL REPORT

June 1, 2019 - May 31, 2020

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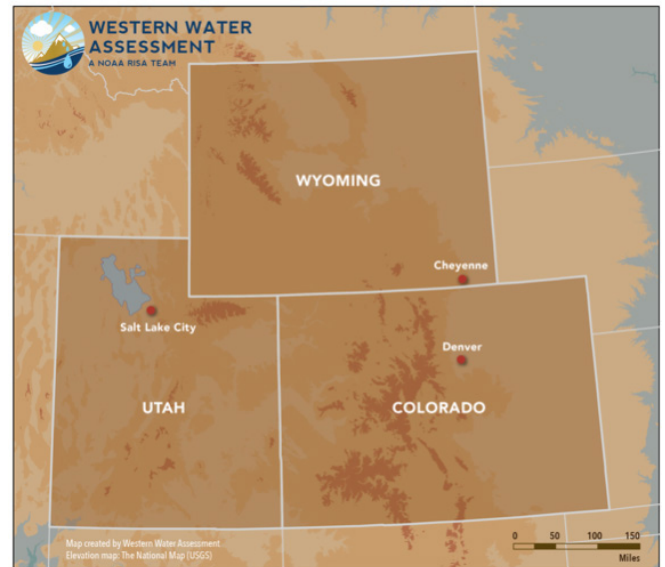
INTRODUCTION

MISSION AND THEMES

The mission of Western Water Assessment (WWA) is to conduct innovative research in partnership with decision makers in the Rocky Mountain West, helping them make the best use of science to manage for climate impacts. Using multidisciplinary teams of experts in climate, hydrology, social sciences, ecology, and policy, WWA works with decision makers across Colorado, Utah, and Wyoming to produce policy-relevant information about climate variability and change. By building relationships with networks of decision makers, our team is able to develop practical research programs and useful information products. WWA focuses its work on four overarching themes:

1. Climate Vulnerability and Adaptive Capacity in the WWA Region
2. Extremes and Climate Risk Management
3. Designing Organizations and Networks for Usable Science
4. Understanding and Monitoring Drought in the WWA Region

WWA is formally part of the Cooperative Institute for Research in Environmental Sciences (CIRES) at the University of Colorado Boulder (CU Boulder), and our researchers and partners come from universities and government institutions across our region.



OUR TEAM

WWA has seven core staff members who focus on program management, research development and synthesis, and coordination of stakeholder interactions. During the past year, Dr. Lineke Woelders joined the team as a postdoctoral researcher, bringing expertise in paleoclimatology, climate change, hydrology, and GIS. WWA also hired Ethan Knight as an undergraduate student assistant, and he has gained experience in usable science while supporting the rest of the team across a variety of projects. In May 2020, Christa Torrens was awarded the first WWA Summer Graduate Fellowship. She conducted a research project exploring opportunities in Wyoming with the team during the summer of 2020.

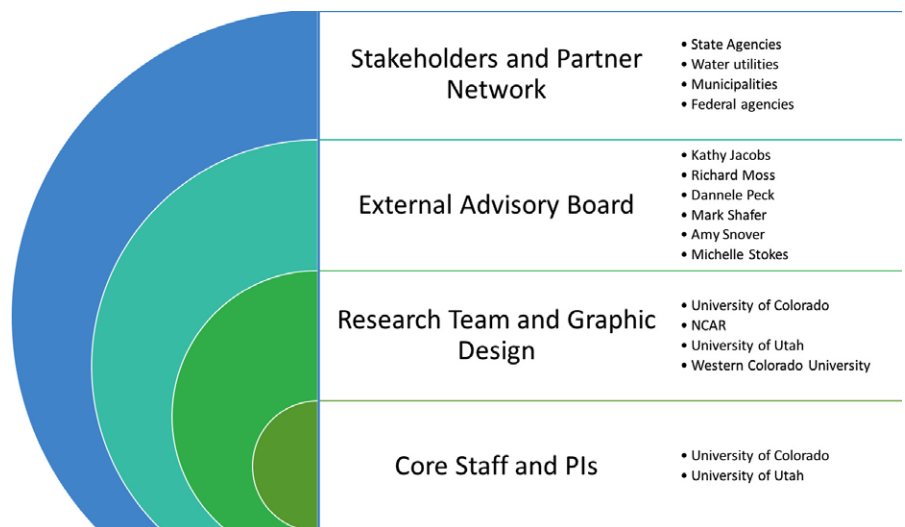
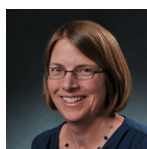


Figure 1. The Western Water Assessment Team and Network.

WWA's broader research team includes physical and social scientists at the University of Colorado, the University of Utah, NOAA, and the National Center for Atmospheric Research (NCAR). The WWA External Advisory Board consists of national experts from across the science-policy landscape, and provides programmatic guidance to the core staff and PIs. Taken together, this network represents a broad base of expertise that enables the program to successfully engage decision makers, building relationships that enable WWA to meet stakeholder needs and advance scientific understanding.

Photo to the left: Painted Rock, Black Canyon of the Gunnison National Park. Photo: Benét Duncan.

Western Water Assessment Core Staff



Lisa Dilling, Director
ldilling@colorado.edu
 Expertise: Climate information, Adaptation



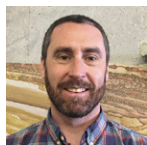
Liz Payton, Colorado River Basin Assessment Specialist
elizabeth.payton@colorado.edu
 Expertise: Hydrology; Water system modeling



Benét Duncan, Managing Director
benet.duncan@colorado.edu
 Expertise: Assessments; Climate indicators; Science policy



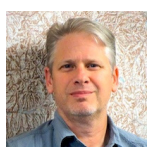
Lineke Woelders, Postdoctoral Researcher
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 Expertise: Hydrology; Climate change



Seth Arens, Research Integration Specialist, Utah
www.arensgmail.com
 Expertise: Eco-hydrology, air quality



Ethan Knight, Undergraduate Student Assistant
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 Expertise: Environmental science



Jeff Lukas, Research Integration Specialist, Colorado
lukas@colorado.edu
 Expertise: Climate variability and climate change, paleoclimatology

WWA PIs

Name	Title	Expertise
Lisa Dilling	Lead PI and Director, WWA; Associate Professor, Environmental Studies, Univ. of Colorado; Fellow, CIRES	Climate information; Adaptation
Joseph Barsugli	Research Scientist, CIRES, Univ. of Colorado	Climate dynamics
Ben Livneh	Assistant Professor, Civil Engineering, Univ. of Colorado; Fellow, CIRES	Hydrology; Land surface modeling; Climate impacts
Noah Molotch	Director, CWEST; Fellow, INSTAAR; Associate Professor, Geography, Univ. of Colorado	Snow hydrology
William Travis	Associate Professor and Department Chair, Geography, Univ. of Colorado	Natural hazards; Climate impacts; Adaptation

WWA External Advisory Board

Name	Title	Expertise
Kathy Jacobs, Chair	Director, Center for Climate Adaptation Science and Solutions, University of Arizona	Climate adaptation; Climate assessment
Richard Moss	Visiting Researcher, Andlinger Center for Energy and the Environment, Princeton University; Senior Scientist, Joint Global Change Research Institute (on leave)	Climate assessment
Dannele Peck	Director, USDA Northern Plains Climate Hub	Agricultural economics
Mark Shafer	Director, Southern Climate Impacts Planning Program (SCIPP); Associate State Climatologist, Oklahoma	Climatology; Climate adaptation; Hazard preparedness
Amy Snover	Director, Climate Impacts Group; University Director, NW Climate Adaptation Science Center; Affiliate Associate Professor, Marine and Environmental Affairs, University of Washington	Climate adaptation and decision-making; Climate dynamics; Vulnerability assessment
Michelle Stokes	Hydrologist in Charge, NOAA Colorado Basin River Forecast Center; Co-Team Lead, NOAA Western Region Collaboration Team	Hydrology

WWA Research Team and Partners

Team Member	Title	Expertise
John Berggren	Western Resource Advocates (Formerly Univ. of Colorado graduate student)	Colorado River water policy
Paul Brooks	University of Utah	Hydrology; Ecohydrology
Steve Burian	University of Utah/Utah Water Center	Hydrology
Katie Clifford	USGS North Central and National Climate Adaptation Science Centers (Formerly Univ. of Colorado graduate student)	Conservation decision making
Jeff Deems	Research Scientist, CIRES, Univ. of Colorado	Climate and snow modeling
Jen Henderson	Univ. of Colorado (Formerly CIRES/WWA postdoctoral fellow)	Weather and society
Joe Kasprzyk	Univ. of Colorado	Multi-objective analysis for water management
Corrie Knapp	University of Wyoming	Climate change adaptation
Leanne Lestak	Univ. of Colorado	GIS; Remote sensing
Kelly Mahoney	NOAA ESRL Physical Sciences Division	Hydrometeorology; Extreme precipitation
Toby Minear	Univ. of Colorado	Hydrology
Rebecca Morss	National Center for Atmospheric Research	Socioeconomic and policy impacts of weather
Ami Nacu-Schmidt	Univ. of Colorado	Social media; Design
Rebecca Page	Formerly Univ. of Colorado graduate student	Decisions in natural resources
Luca Palasti	Univ. of Colorado graduate student	Environmental economics; decision-making
Imtiaz Rangwala	North Central Climate Adaptation Science Center, Univ. of Colorado	Regional climate change; High elevation climate
Andrea Ray	NOAA ESRL Physical Sciences Division	Climate-society interactions; Water management
David Rosenberg	Utah State University	Systems analysis for water and resource management
Danya Rumore	University of Utah	Decision-making
Court Strong	University of Utah	Climatology
Christa Torrens	WWA Summer Graduate Fellow; Univ. of Colorado graduate student	Hydroecology; Climate change
Olga Wilhelmi	National Center for Atmospheric Research	Vulnerability and adaptation to weather and climate
Travis Williams	Univ. of Colorado (Formerly Univ. of Colorado graduate student)	Climate risk management; Agriculture
Klaus Wolter	Univ. of Colorado and NOAA ESRL (Retired)	Climatology and meteorology
Heather Yocum	North Central Climate Adaptation Science Center, Univ. of Colorado	Climate and social systems



YEAR IN REVIEW: WWA ACCOMPLISHMENTS

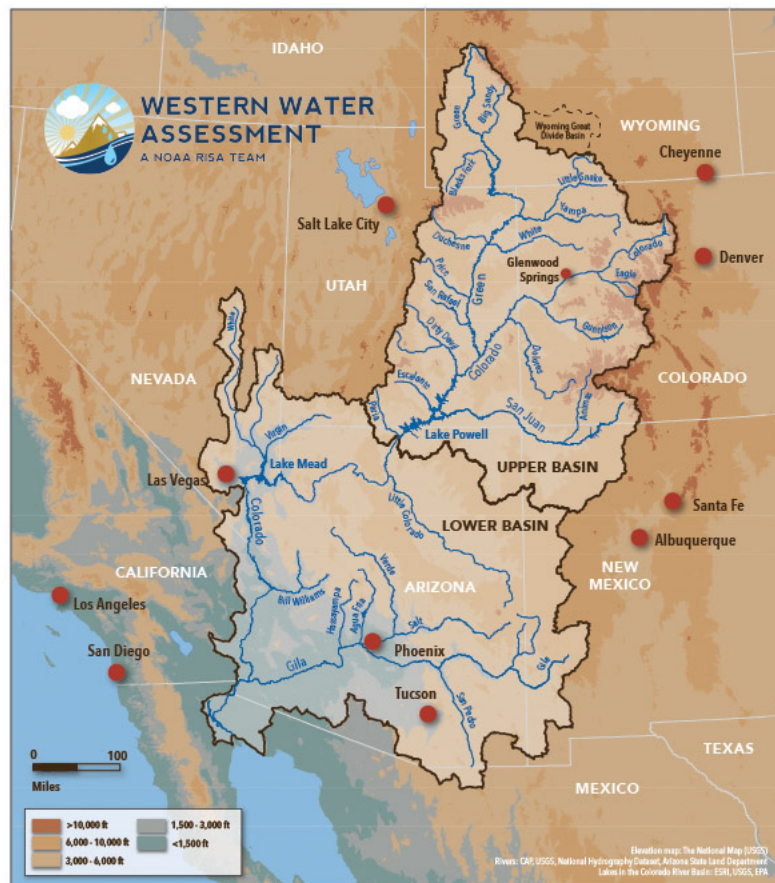
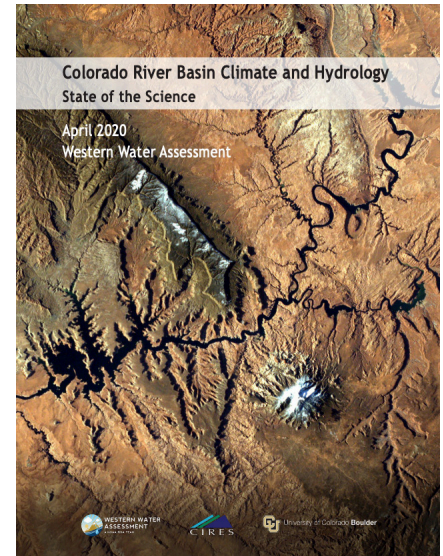
KEY ACCOMPLISHMENT

In recent decades, increasing water demand, dry conditions, and warming temperatures have impacted the Colorado River, creating greater uncertainty about the future of the basin's water supply. With support and guidance from over a dozen federal, state, and local water agencies, WWA researchers teamed up with leading experts to integrate nearly 800 peer-reviewed studies, agency reports, and other sources to assess the state of the science and technical practice relevant to water resources in the Colorado River Basin.

Released in April 2020, *Colorado River Basin Climate and Hydrology: State of the Science* creates a shared understanding of the physical setting and the latest data, tools, and research underpinning the management of Colorado River water resources. In identifying both challenges and opportunities, the report guides water resource managers and researchers in efforts to improve the short-term and mid-term forecasts and long-term projections for the basin's water system.

WWA's **Jeff Lukas** and **Liz Payton** served as co-lead authors and co-editors of the report, while **Lineke Woelders**, **Ethan Knight**, and **Benét Duncan** contributed to the text and provided support and coordination. An additional 13 experts contributed content as co-authors.

WWA has received overwhelmingly positive feedback from water agencies and other stakeholders. Terry Fulp, Regional Director of the Lower Colorado River Basin for the Bureau of Reclamation, stated, "It will provide an invaluable foundation for future research, planning and management in the Basin. The relationships between scientists, stakeholders, and Federal agencies that made this Report possible are critical to Reclamation's ongoing commitment to using sound science in its management of the Colorado River."



FUNDING PARTNERS AND COLLABORATORS

-  Arizona Department of Water Resources
-  California's Six Agency Committee
-  Central Arizona Water Conservation District
-  Colorado River Water Conservation District
-  Colorado Water Conservation Board
-  Denver Water
-  Metropolitan Water District of Southern California
-  New Mexico Interstate Stream Commission
-  Southern Nevada Water Authority
-  Utah Division of Water Resources
-  Wyoming State Engineer's Office
-  U.S. Bureau of Reclamation

Photo to the Left: Rabbit Mountain Open Space in Longmont, Colorado. Photo: Liz Payton.

NEW AREAS OF FOCUS OR PARTNERSHIP

Deepening Partnerships in Utah

Since moving to the **University of Utah's Global Change and Sustainability Center** in 2017, WWA's **Seth Arens** has focused on deepening the program's relationships with researchers at the University of Utah and beyond. This year, he established a partnership with the **U Water Center**, which focuses on interdisciplinary research on water challenges and solutions, and collaborated with the **University of Utah Environmental Dispute Resolution Program**. As a U Water Center affiliated scientist, he is working to identify opportunities for collaborative research at the intersection of climate science, hydrology, and water management.

In October 2019, Arens organized and led a faculty research retreat to raft **Cataract Canyon** of the Colorado River, which extends for 100 miles from Moab to Lake Powell. Low Lake Powell levels due to drought in the 2000's exposed rapids and land that had once been inundated; eight rapids have returned since 2007 and ecosystems are recovering. The trip brought together researchers from WWA, University of Utah, University of Alaska, USGS, National Park Service, Utah Geological Survey, and American Rivers. The retreat had three core goals: to foster connection and collaboration between regional researchers; to collect preliminary data for future research and funding; and to discuss opportunities for education and experiential learning in Cataract Canyon. During the retreat, each participant delivered mini-lectures about their work, in between stops to collect data and explore the canyon. Since then, participants have begun to pursue collaborative research opportunities.

Evaluating the Value of Grass-Cast

WWA has a close relationship with the **USDA Northern Plains Climate Hub**, including 'Three Centers Retreats' held twice a year with the Hub and the **North Central Climate Adaptation Science Center (NC CASC)**. These retreats provide an important opportunity to identify collaborative projects and to coordinate efforts in the region. One such collaborative project is an effort to determine the value of the Northern Plains Climate Hub's Grass-Cast tool, which provides a grassland

Research retreat rafting the Cataract Canyon of the Colorado River in October 2019. Photo: Seth Arens/WWA.



productivity forecast for ranchers in the Western US. WWA helped to support CU Boulder graduate student **Luca Palasti's** project, under the supervision of **WWA Co-PI Bill Travis**. The **National Drought Mitigation Center** (NDMC) also provided support for this effort.

Inaugural WWA Summer Fellowship

In the spring and summer of 2020, WWA launched the WWA Summer Graduate Fellowship with the generous support of a private donor. This fellowship is designed to support a CU Boulder graduate student during the summer months, as they conduct research in support of WWA's mission. WWA selected Christa Torrens, a PhD candidate in the CU Boulder Environmental Studies department, as the inaugural WWA Summer Fellow. She plans to spend the summer exploring adaptation planning opportunities in Wyoming.

Evaluating Engagement in the WWA Region

WWA has placed a strong emphasis on evaluating the results of our recent engagement with communities in the region and identifying opportunities for future efforts. This has included a full program evaluation ([see page 14](#)), an evaluation of our 2018-2019 community adaptation VCAPS (Vulnerability, Consequences, and Adaptation Planning Scenarios) workshops ([see page 17](#)), and upcoming work by the WWA Summer Fellow and a WWA summer intern to assess opportunities in Wyoming.

SIGNIFICANT OUTPUTS

During the reporting period, WWA produced a wide range of outputs, including products, communications, tools, and other technical assistance. Our most significant outputs are listed below:

Region & National

- *Colorado River Basin Climate and Hydrology: State of the Science*, released on April 9, 2020, is used by federal, state, and local water agencies, including the Bureau of Reclamation, Colorado Water Conservation Board, Southern Nevada Water Authority, and Denver Water to inform management of the Colorado River and support improvements in short- and mid-term forecasts and long-term projections for the basin's water system. This is particularly timely given the expected renegotiation of the Colorado River Basin interim guidelines.
- *Intermountain West Spatial Snow-Water Equivalent (SWE) Reports*, released for March 17, April 1, April 14, and May 1, were used by water managers, snow scientists, streamflow forecasters, and climate service providers as supplemental information to guide water resources planning. The reports were also highlighted at a meeting of the Colorado Water Availability Task Force.
- *WWA Intermountain West Climate Dashboard* is used by WWA stakeholders to better understand climate conditions in the Intermountain West region. The dashboard has the highest traffic on the WWA website, with over 26,000 pageviews from 2015-2018. In WWA's program evaluation (currently underway, [see page 14](#)), over 88% of respondents reported having used and/or recommended the dashboard to others. One noted, "I visit and use [the dashboard] at least monthly if not more frequently. I highlight [it] as a resource to colleagues and stakeholders at least a dozen times a year at various meetings/conferences/etc.!" Another respondent shared, "We are pushing for contractors working on studies to access and utilize these resources [in the dashboard] in their evaluation of water supply and demand modeling moving forward to begin to move our plans forward with potential changes of climate change."
- *Learning from Success in Climate-Informed Decision-Making: Case Studies Across Three U.S. Regions* was published in September 2019. This cross-RISA collaborative report provides case studies of local programs that are using or producing climate information in an ongoing way. The report was produced by sustained assessment specialists at WWA, the Pacific RISA, and the Southern Climate Impacts Planning Program (SCIPP). The authors identify common themes that contributed to the success of each case study. The report is a reference for programs within the RISA network and beyond.
- *Weber Basin Climate Vulnerability Assessment*, expected to be released soon, is a climate vulnerability assessment that focuses on the Weber River Basin. Weber Basin Water Conservancy District is a wholesale water provider in northern Utah with over 600,000 customers, and it is the first water provider in Utah to address climate change in this manner. The report will be used to inform water management decisions in the region.

Local

- *Report from a Vulnerability, Consequences, and Adaptation Planning Scenarios (VCAPS) Community Workshop in Moab, UT* was used by stakeholders in Moab, including municipal decision makers, to document results of workshop discussions and diagrams; kickstart engagement with municipal leadership and citizens; and support municipal planning to increase resilience to drought and extreme precipitation.

MOST SIGNIFICANT PUBLICATIONS

WWA researchers published a number of publications, which range from peer-reviewed research articles to grey literature and general reports. For a full list of publications from the reporting period, see Appendix A. Three significant publications are:

- Lukas, Jeff, and Elizabeth Payton, eds. 2020. *Colorado River Basin Climate and Hydrology: State of the Science*. Western Water Assessment, University of Colorado Boulder. DOI: <https://doi.org/10.25810/3hcv-w477>.

This report provides an assessment of the state of the science and technical practice relevant to water resources in the Colorado River Basin. Topics covered include observations, modeling, and forecasting of hydrology, weather, and climate; historical hydrology; paleohydrology; and climate change-informed hydrology.

- Livneh, B., Badger, A.M. *Drought less predictable under declining future snowpack*. *Nature Climate Change*. 10, 452–458 (2020). <https://doi.org/10.1038/s41558-020-0754-8>.

In this paper, WWA Co-PI **Ben Livneh** and co-author use downscaled hydrologic simulations from 28 climate model projections to evaluate the predictability of drought in snowmelt dominated systems in the Western US. They find that snow will be less able to predict seasonal drought in 69% of these systems by mid-century, and in 83% of these systems by late century.

- Page, R., Dilling, L. *How experiences of climate extremes motivate adaptation among water managers*. *Climatic Change* 161, 499–516 (2020). <https://doi.org/10.1007/s10584-020-02712-7>.

Former WWA graduate student Rebecca Page and WWA PI Lisa Dilling evaluated what motivated five smaller water systems in Western Colorado to implement adaptive measures in the wake of significant droughts in 2002 and 2012. They found that systems did not uniformly take adaptive measures, and that organizational worldviews affected whether or not post-drought organizational changes occurred. Pressures from residents and peer systems also had an impact on the adoption of adaptive measures.

OUTREACH: ENGAGEMENT WITH COMMUNITIES AND RESOURCE MANAGERS

WWA is committed to engaging with communities and decision makers across our region, and with the broader scientific community. During the reporting period, we conducted a broad range of outreach. Following are highlights from this work:

Continued Engagement and Evaluation of VCAPS Workshops

In the summer and fall of 2018, WWA kicked off the VCAPS (Vulnerability, Consequences, and Adaptation Planning Scenarios) pilot project in five communities in Colorado and Utah. The summer of 2019 marked the final workshop in the pilot project in Moab, UT. Following completion of the pilot workshops, we conducted outreach with participants from all six of the communities that participated in VCAPS, as part of a project evaluation. Former graduate student **Katie Clifford** conducted phone interviews with key stakeholders from each VCAPS community, and collaborated with **Lisa Dilling** and **Benét Duncan** to conduct an online survey of all participants.

WWA's VCAPS pilot project was also the focus of a research effort conducted by **Zoë McAlear**, a graduate student at MIT. For her master's thesis, McAlear conducted an evaluation of the impacts of the 2018-2019 VCAPS workshops. She found that the majority of workshop participants felt that the workshops had supported adaptation planning in their community, and identified opportunities to increase the efficacy of future workshops ([see page 17](#)).

Colorado River Basin Climate and Hydrology Outreach

The release of the *Colorado River Basin Climate and Hydrology: State of the Science* was accompanied by extensive outreach with water managers, researchers, other stakeholders, and the general public. WWA worked closely with

communications experts at CIRES to produce a “press packet” containing key outreach materials for the report, including a two-pager, quotes from partner organizations, a website, and other supporting materials. Communications staff from partner organizations used the press packet contents to inform their own outreach efforts, which encouraged consistent communication about the report.

WWA’s **Liz Payton** is coordinating a webinar series about the report. She and **Jeff Lukas** are also coordinating presentations about the report with sponsors, including a series with **Southern Nevada Water Authority**. They have already delivered a presentation to Colorado River stakeholders in Utah organized by the **Central Utah Water Conservancy District**, and to stakeholders in California organized by the **Colorado River Board of California**.

Connecting Communities with Climate Information

WWA remains firmly committed to supporting adaptation and resilience-building by connecting communities with usable climate information. During the reporting period, **Seth Arens** led the sixth and final workshop of our VCAPS pilot project, this time in Moab, UT. The workshop was a collaboration between WWA and the University of Utah Environmental Dispute Resolution Program. Held in July 2019, the workshop focused on the impacts of severe drought on water supply in Moab. **Benét Duncan** convened and moderated a session at the **Colorado Municipal League’s Annual Conference** in June 2019 focused on connecting Colorado’s communities with weather and climate information. The session featured talks from key community partners that helped to convene VCAPS workshops in Cortez, CO and Carbondale, CO. Duncan also continues to collaborate with researchers at **Aspen Global Change Institute** on a NOAA SARP-funded project to explore how network-building can support adaptation in the Intermountain West. As part of this project, she co-organized a virtual workshop in March 2020 with communities in the broader Intermountain West region to explore how they use and access information, and how networks can support those activities in the future.

Lineke Woelders, Seth Arens, and Benét Duncan are also planning a workshop focused on water planning for small-to-medium utilities in Colorado, Utah, and Wyoming. This workshop is sponsored by NOAA CPO in collaboration with the Water Research Foundation, and it is part of a series of workshops across the country that will connect water managers with tools like the **NOAA Water Resources Dashboard**. Results from the workshop will inform decisions about improvements in the Water Resources Dashboard, and help WWA to plan engagement in the future. We are fortunate to be working with a planning committee that includes representatives from **Aspen Global Change Institute, Denver Water/Water Utilities Climate Alliance**, and the **Water Research Foundation** to organize the workshop. Due to the ongoing COVID-19 pandemic, we have pivoted to hosting a virtual workshop. We believe that this shift from an in-person to an online workshop will also allow us to engage more utilities from across the entire WWA region, rather than the relatively limited number of utilities that would have been able to participate in person prior to the pandemic.



WWA’s Seth Arens talking to a group during a research retreat rafting the Cataract Canyon of the Colorado River. Photo: Seth Arens.

Research Integration Specialist Ongoing Outreach

As Research Integration Specialists, WWA's **Seth Arens** and **Jeff Lukas** continue to maintain existing relationships and cultivate new ones with resource managers at federal, state, and regional agencies; utilities; municipalities; and other entities. They delivered over 14 presentations during the reporting period, including at the Colorado Water Conservation Board's C9 Conference (Lukas), the Colorado River District Annual Summit (Lukas), the Southwest Drought Learning Network Conference (Arens), and the Salt Lake City Association of Municipal Governments (Arens). They also engaged regularly with members of the media to provide scientific expertise in news stories about weather and climate impacts in the Mountain West.

Engaging with the Academic Community

As a NOAA RISA team, WWA places a strong emphasis on contributing to the broader base of knowledge about the impacts of climate variability and change, and advancing adaptation science. An important component of this is regular engagement with the academic community -- such engagement helps us to identify opportunities to conduct research that both advances scientific understanding and meets stakeholder needs.

During the performance period, WWA staff engaged with the academic community in a number of ways. **Seth Arens** led a research and team-building trip on Cataract Canyon in Utah that included faculty from the University of Utah and agency researchers from USGS and the National Park Service (see page 7). The trip provided an opportunity for him to more deeply connect WWA's work with the Utah academic community and identify potential future collaborations. He also delivered guest lectures at graduate seminars at the University of Utah, and was an invited speaker at Weber State University. **Benét Duncan** also engaged with students as a guest lecturer for a large undergraduate course and a speaker in a career seminar series at the University of Colorado Boulder, and as an invited panelist at the student-organized ComSciCon Rocky Mountain West conference.

Beyond the university setting, WWA staff spoke at academic meetings and conferences. For example, together with Pacific RISA's Zena Grecni, Benét Duncan gave a presentation about the work of RISA network sustained assessment specialists, including *Learning from Success in Climate-Informed Decision-Making: Case Studies Across Three U.S. Regions* (see page 8). She also delivered two presentations at the December 2019 AGU Fall Meeting, including an invited talk about WWA's work in the Mountain West region and a talk about the VCAPS pilot project (see page 9).

WWA also has a close relationship with the USGS North Central Climate Adaptation Science Center and the USDA Northern Plains Climate Hub. We meet twice a year at "Three Centers Retreats," which provide opportunities for us to coordinate and collaborate across our programs. This often includes presentations about existing research projects; discussions about how to leverage our existing work to meet stakeholder needs; and identification of opportunities to conduct new collaborative projects that help to advance scientific knowledge in stakeholder-relevant ways. The evaluation of Grass-Cast currently underway by Bill Travis and Luca Palasti is an example of one such project to emerge from this collaboration (see page 7). Due to the COVID-19 pandemic, the summer 2020 Three Centers Retreat was held virtually over multiple days.

LOOKING FORWARD: NEXT STEPS

During the coming year, WWA will continue to advance scientific understanding in ways that decision makers need and can use, and to expand our connections with stakeholders in the region. Three of our initiatives are highlighted below:

Engaging with Small- and Medium-Size Communities and Utilities

WWA has placed a strong emphasis on building relationships with small- and medium-sized communities and water utilities in the Mountain West, to support their continued resilience-building and climate planning efforts. These relationships have made it clear that such communities and utilities have a real need for continued engagement and usable scientific information about climate impacts.

We plan to continue these efforts in the coming year through new engagement opportunities and initiatives. WWA's **Lineke Woelders**, **Seth Arens**, and **Benét Duncan** will engage with new communities and utilities about snowpack, drought, water supply, and available tools in a virtual workshop, which will be part of a series of workshops across the country sponsored by the **NOAA Climate Program Office and the Water Research Foundation** (see page 10). The WWA team will also expand the VCAPS pilot project to include one to two communities in Wyoming, drawing on findings from the recently-completed VCAPS evaluation (see page 17) to maximize the effectiveness and impacts of the workshops. We expect to work closely with partners at the **USDA Northern Plains Climate Hub** and the **USGS North Central Climate Adaptation Science Center** on this effort.



Due to the COVID-19 pandemic, the summer 2020 Three Centers Retreat was held virtually over multiple days in 2020.

Cross-RISA Collaborative Efforts

WWA is excited to launch two new cross-RISA collaborative efforts during the coming year. These projects take advantage of one of the key strengths of being a NOAA RISA program: the ability to learn across RISA teams and apply methodologies in new ways and regions.

In one collaborative project with the **Great Lakes Integrated Sciences and Assessments (GLISA)** team, WWA's **Lisa Dilling**, **Liz Payton**, and **Lineke Woelders** and GLISA researchers will conduct pilot work to test and co-develop a usable spatially explicit model of urban development in the context of flood patterns and existing socio-political variables for small and mid-sized cities across our two regions. The overarching goal is to provide a tool that will help urban decision makers make better informed decisions and consider tradeoffs in the face of changing demographics, patterns of socio-economic growth, and flood risk, in the course of planning and decision making.

In another project, WWA's **Seth Arens** and **Benét Duncan** will collaborate with researchers at the **Southern Climate Impacts Planning Program (SCIPP)** RISA team to build the capacity of state and local hazard mitigation efforts to incorporate climate into their natural hazards planning efforts, and to use those planning efforts to support actionable climate adaptation. In this project, we will pilot SCIPP's Simple Planning Tool in the WWA region and support the transition from hazard mitigation planning to actionable climate adaptation at multiple scales in both the SCIPP and WWA regions.

Advancing Adaptation Research

WWA PIs and research team members remain committed to conducting innovative research to advance understanding of how communities and agencies adapt in the Mountain West. Over the coming year, we will draw on this recent scholarship to expand our adaptation research. As part of this focal area, WWA PI **Lisa Dilling** and incoming Graduate Research Assistant **Natalie Bennett**, with collaborator **Olga Wilhelmi**, will use GIS and social science techniques to develop a regional understanding of 'hotspots of vulnerability' and how they are viewed from different perspectives. In a complementary research effort, WWA PI **Ben Livneh** and a Graduate Research Assistant will identify hotspots of increased drought risk under climate change and characterize the uncertainty in those risks. WWA PI **Noah Molotch** and a Graduate Research Assistant will also work to advance this research track, with a project to integrate the new modeled spatial Snow Water Equivalent product ([see page 8](#)) into forecasting operations at Denver Water.



WWA Goals and Metrics

Goal 1: Building Relationships and Enhancing Networks

Building relationships is key to WWA achieving its mission, and literature and practice show strong relationships are necessary for producing usable science. We are interested in tracking various aspects of relationships: the type of relationship (new or ongoing), the types of organizations involved, and what activities are occurring through the relationship. A key way that WWA acts to improve the usability of information for decision-making is to enhance networks by convening researchers and decision makers throughout the region. Here, WWA wants to measure the connections we help to foster among others, in addition to the relationships between WWA and its stakeholders.

Metrics:

- Track stakeholder interactions, including who we engage with and what organizations they are from; referrals to and from WWA; one-on-one conversations; and attendees at WWA events
- Track how relationship building and maintenance lead to bigger, formal projects, including through reports

Goal 2: Having Influence in the Region

WWA should be seen as a trusted (non-partisan, non-advocacy) voice for information that helps stakeholders do their job and make decisions, and that provides valuable services in the region.

Metrics:

- Track stakeholder interactions, including the number of people and organizations that attend WWA events; the types and diversity of entities with which we work; requests for presentations, training, and inclusion on boards; and the type of information people seek from WWA and its use
- Track media mentions
- Survey stakeholders to assess the impact of our work

Goal 3: Building Resilience in our Region

Building resilience in the Colorado, Utah, and Wyoming region is a core goal of WWA's work, but it is very difficult to measure. WWA provides information and activities that help decision makers in their effort to increase resilience. We can convene groups to work through what resilience means in their region or sector given what we know about current and future climate.

There are also overall changes in our region that point to progress on resilience. For example, increasing uptake of relevant science into decision-making can help decision makers more clearly see risks and vulnerability in their systems. Another example of regional change is the growth of capacity to incorporate climate knowledge in other organizations. WWA cannot claim sole credit when this occurs, but we should see increased capacity in partners as a sign that we are doing our job well. We can trace our interactions with organizations that helped to make the case that climate was important for them to consider.

Magnolia Mill overlooking Montgomery Reservoir in Alma, Colorado. Photo: Ami Nacu-Schmidt.



Metrics:

- Survey stakeholders and the broader RISA network to learn about conceptual, justification, and instrumental use of WWA-provided information
- Identify cases in which scientific information is added to policies or referenced in justification for adaptation actions
- Track where WWA personnel go next in their careers
- Analyze the climate capacity of our stakeholders over time, both in terms of positions created and stakeholder use of climate information
- Analyze the change in climate capacity in Utah and Colorado, and compare those changes

Goal 4: Piloting New or Underutilized Tools

RISAs are meant to be a place to try out new tools, datasets, and other experimental information. WWA has several examples of tools at various stages, so progress on this goal can be documented on a project basis.

Metrics:

- Track tools that WWA pilots, and analyze each tool's status and use by stakeholders

Goal 5: Providing Feedback to NOAA

One important goal of WWA is to provide feedback to NOAA about the use of their informational and operational products. In addition to organizing meetings with stakeholders to solicit feedback that can inform NOAA, we submit an annual report to the RISA program at NOAA CPO. We also organize and lead sessions at RISA annual meetings and present project findings on RISA monthly calls.

Metrics:

- Track workshops and other meetings with stakeholders regarding NOAA products
- Track contributions to NOAA regular reporting systems, including RISA monthly calls

Goal 6: Contributing to the Literature and Providing Lessons Learned

WWA is committed to contributing to the literature and providing lessons learned across organizations that aim to do similar work. Activities under this goal include sharing best practices; writing papers and reports; participating in cross-RISA, regional, or national dialogues for connecting knowledge to decision-making; and building the capacity of the network beyond our region, including to other academics and groups like the USGS Climate Adaptation Science Centers (CASCs) and the USDA Climate Hubs.

Metrics:

- Track papers and reports published
- Track presentations delivered and participation on panels
- Track workshops organized
- Participate in semi-annual retreats with the North Central CASC and the USDA Northern Plains Climate Hub

SOCIETAL IMPACT

Through our user-driven projects, WWA has made an impact on stakeholders at scales ranging from federal and state agencies to smaller utilities and communities. Our work has helped to support decision makers to manage for climate impacts on risks like drought, water supply, flooding, and other hazards.

The COVID-19 pandemic has shifted our activities to virtual modes of engagement, which has been a big change from our previous focus on in-person meetings and workshops. While virtual engagement has its own challenges, it has provided unexpected opportunities to connect with a broader range of stakeholders, many of whom may have been less able to travel to in-person events. Through our in-person and virtual events over the past year, WWA has maintained its role as a go-to entity for climate, drought, and resilience information in our region.

In early 2019, **Seth Arens** worked with the Utah Division of Emergency Management to provide content and input for the 2019 revision of the Utah State Hazard Mitigation Plan. The 2019 Utah Hazard Mitigation Plan was one of the first state planning documents that explicitly acknowledged the future risks of climate change. In December of 2019, WWA was again approached by Utah DEM for assistance in beginning an effort to develop a climate adaptation plan for natural hazards. This ongoing interest in climate change planning represents a shift in climate planning in the state.

The following case studies provide additional examples of tangible impacts of WWA's recent work in the Mountain West:

Case Study: Incorporating Climate in Colorado River Basin Management

The release of the *Colorado River Basin Climate and Hydrology: State of the Science* report in April 2020 (see page 6) was a major achievement that has already impacted decision makers in the Colorado River Basin. Members of the workgroup of agencies that supported development of the report and other key stakeholders in the basin gave testimonials that demonstrate its value. Colby Pellegrino, the Director of Water Resources for Southern Nevada Water Authority stated, "Not only does this report analyze in extraordinary detail the latest data, discoveries, and decision support tools that are used in the basin, but it also lists a series of opportunities for using science and technology to help improve our understanding of current and future hydrologic conditions." Brad Udall, Senior Water and Climate Research Scientist at the Colorado Water Center noted, "This is by far the most comprehensive scientific report ever produced about the Southwest's iconic river. Scientists summarize what they think about the past, present and future of the river and also provide challenges and opportunities for improving science to assist decision making in the 21st century."

WWA's **Ethan Knight** conducted a survey of the report sponsors to better understand how they expect to use the report. Nearly all of the respondents indicated that they have already used the report to broaden their understanding of the Colorado River Basin, to educate users and the public, and to get up-to-date information on climate and hydrology research in the basin. Within weeks of the report's release, one respondent indicated that they had already begun developing a research project to address an opportunity identified in the report. In the future, nearly all survey respondents indicated that they plan to use the report to educate their boards or other decision makers, and to inform planning and decision-making. One respondent noted, "Our organization plans to use the report to help inform funding priorities, at the very least."

Case Study: Impact on Municipal Decision-Making through VCAPS Workshops

As noted earlier in this report, graduate student Zoë McAlear focused her research on evaluating the impact of WWA's 2018-2019 VCAPS Pilot Project (see page 9) on six communities in Colorado and Utah. Her research drew on a written survey open to all VCAPS workshop participants (35 out of 51 participated); phone interviews conducted by Katie Clifford with seven champions that had helped us to convene the workshops in each community; and additional interviews with 16 additional workshop participants from each community.

The majority (94%) of survey participants found the VCAPS workshops to be very or somewhat useful, and 80% indicated that the workshop had increased their motivation to take action to address the hazards discussed at the workshop. In the evaluation interviews and survey, many participants also noted that the workshops increased the motivation of elected officials in attendance to take action to increase resilience to climate impacts. In Carbondale, one interviewee said that the workshop had "helped focus budgeting on certain [identified actions]," and another shared that the VCAPS process added "legitimacy" to budget requests, making it easier to request that elected officials prioritize funding for specific actions. An interviewee in Durango shared that they had heard an elected official cite VCAPS when advancing actions and making specific decisions.

Interviews and survey responses also revealed that all six workshops contributed to tangible outcomes and follow-up actions in their respective communities. Zoë's evaluation identified both process-related outcomes like follow-up meetings or public communication of workshop discussions, and adaptation-related projects and planning like incorporation of workshop findings into municipal budgeting and planning, changes in local ordinances, and public education campaigns. More specifically, the communities of Durango, CO, Routt County, CO, Cortez, CO, Zion, UT, and Moab, UT all are incorporating VCAPS workshop findings into the development of new municipal plans. Participants from Carbondale, CO prioritized actions identified in VCAPS in their municipal budgeting process and are integrating findings into the town's water management plan. The City of Cortez, CO also invested budgetary resources in a new water conservation program that was launched after the VCAPS workshop, called Water is Our Future.

Given the long list of tangible societal impacts in the six communities that participated in the VCAPS Pilot Project, we are excited to move forward with planning an additional one to two workshops in Wyoming in the coming year. WWA also continues to engage with all of the communities who participated in the pilot project to support continued adaptation and resilience-building.

Case Study: Award-Winning Research on Climate and Dam Safety

WWA's **Jeff Lukas** was recognized as part of a multi-agency, public-private collaboration to estimate probable maximum precipitation (PMP) and the frequency of extreme events above dams in Colorado and New Mexico. This collaborative effort, conducted in partnership with NOAA ESRL physical scientist **Kelly Mahoney** and CIRES Research Scientist **Michael Mueller**, was part of a larger project sponsored by the Colorado Division of Water Resources and the New Mexico Office of the State Engineer to update decades-old PMP estimates used in these states using modern technical methods and



Jeff Lukas (WWA), Kelly Mahoney (NOAA), and Bill McCormick (Colorado Dam Safety Office) accept the 2019 CO-LABS Governor's Award for High-Impact Research from Jill Grano (Director of Community Affairs for Congressman Joe Neguse) and Theresa Szczurek (Colorado Chief Information Officer). They received the award for their work estimating extreme precipitation in the 21st century to enhance dam safety and community resilience. Photo: Benét Duncan.

current scientific understanding. During the previous reporting period, the Colorado Dam Safety Office proposed Rule 7.2.4, which would apply an atmospheric moisture factor (multiplier) of 1.07 to PMP values to account for the expected future warming and associated increases in atmospheric moisture availability from 2020 to 2070. The rule was officially adopted in November 2019.

In recognition of the importance of this work, Jeff Lukas and collaborators Eric James (CIRES), Kelly Mahoney (NOAA), Rob Cifelli (NOAA), Trevor Alcott (NOAA), and Bill McCormick (Colorado Dam Safety Office), were awarded a **2019 CO-LABS Governor's Award for High-Impact Research** under the category of "Pathfinding Partnerships". The award noted that the project will enhance safety and community resilience efforts and inform the Colorado State Engineer and Army Corp of Engineers' priorities and urgent projects.

COPING WITH DROUGHT IN COLORADO AND UTAH

During this reporting period, WWA contributed to the Intermountain West Drought Early Warning System (IMW DEWS) through several activities, some of which are highlighted below and in other sections of this report. In January 2020, the WWA staff met with **Joel Lisonbee**, the new NIDIS IMW DEWS Coordinator to discuss research activities and lay the groundwork for future collaboration between WWA and NIDIS. WWA's **Seth Arens** attended the **Southwest Drought Learning Network** inaugural meeting in El Paso, TX in February 2020, where he gave an invited talk about the production and use of climate information for smaller water providers in rural areas. Following that meeting, Seth has continued to engage with the Learning Network, and he is co-lead of the Learning Network's Water in Utah Working Group. In collaboration with partners that include **Emile Elias** from the **USDA Southwest Climate Hub**, he is helping to scope out the Learning Network's outreach and engagement with managers in Utah in support of drought planning.

WWA Co-PI **Bill Travis** has continued work to advance our understanding of drought decision analyses for adaptation in the agricultural sector. During the previous reporting period, he worked with former Graduate Research Assistants **Travis Williams** and **Trisha Shrum** to combine a drought decision model for ranching with drought impact calculators developed by the USDA Agricultural Research Service (ARS) and an insurance model simulating USDA's Pasture, Rangeland, and Forage (PRF) drought insurance based on a NOAA gridded precipitation product. Williams and Travis continued this work by analyzing a wide range of drought indices in comparison to insurance triggers. A peer-reviewed publication was released in July 2019 to share results with the broader scientific community. Since then, Travis and Williams have created the new **Drought Index Portal (DrIP)**, available at <https://droughtindexportal.colorado.edu>. DrIP is a web analytic resource that allows users to display, compare, and extract time series for various indicators of drought in the contiguous United States. Work on this effort was also supported by the North Central Climate Adaptation Science Center and CU Boulder Earth Lab.



APPENDIX A

2019-2020 WWA PUBLICATIONS

Clifford, K.R., W.R. Travis, and L.T. Nordgren, 2020. A Climate Knowledge Approach to Climate Services. *Climate Services* 18 (April): 100155. <https://doi.org/10.1016/j.cliser.2020.100155>.

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Grecni, Z., L. Shore, and B. Duncan, 2019. *Learning from Success in Climate-Informed Decision-Making: Case Studies Across Three U.S. Regions*. Honolulu: East-West Center. 34pp. Available at <https://www.eastwestcenter.org/climate-case-studies>.

Hobbins, M. and J. Barsugli, 2020. Threatening the Vigor of the Colorado River. *Science* 367 (6483): 1192–93. <https://doi.org/10.1126/science.abb3624>.

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*Page, R. and L. Dilling, 2020. How Experiences of Climate Extremes Motivate Adaptation among Water Managers. *Climatic Change* 161 (3): 499–516. <https://doi.org/10.1007/s10584-020-02712-7>.

Raseman, W.J., J. Jacobson, and J.R. Kasprzyk, 2019. Parasol: An open source, interactive parallel coordinates library for multi-objective decision making. *Environmental Modelling and Software*, vol 116: 153-163.

Smith, R.M., J.R. Kasprzyk, and R. Balaji, 2019. Combining Multivariate Regression Trees and multiobjective tradeoff sets to reveal fundamental insights about water resources systems. *Environmental Modelling and Software*, Vol 120: 104498.

Smith, R., J. Kasprzyk, and L. Dilling, 2019. Testing the Potential of Multiobjective Evolutionary Algorithms (MOEAs) with Colorado Water Managers. *Environmental Modelling & Software* 117 (July): 149–63. <https://doi.org/10.1016/j.envsoft.2019.03.011>.

Steinberg, D., B.K. Mignone, J. Macknick, Y. Sun, K. Eurek, Badger, A.M., B. Livneh, and K.B. Averyt, 2020. Decomposing supply-side and demand-side impacts of climate change on the U.S. electricity system through 2050. *Climatic Change*, <https://doi.org/10.1007/s10584-019-02506-6>.

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Williams, T.M. and W.R. Travis, 2019. Evaluating Alternative Drought Indicators in a Weather Index Insurance Instrument. *Weather, Climate, and Society* 11 (3): 629–49. <https://doi.org/10.1175/WCAS-D-18-0107.1>.

Photo to the left: Easter Pasture on Cataract Canyon, Utah. Photo: Jenn Shah.



WESTERN WATER ASSESSMENT

A NOAA RISA TEAM

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