INSIGHTS GAINED ON AGRICULTURAL WATER CONSERVATION FOR WATER SECURITY IN THE UPPER COLORADO RIVER BASIN

Report by Hannah Holm

Introduction

A series of hot, dry years in the Upper Colorado River Basin has led to increasing concern about the security of water supplies at region-wide and local scales for the following purposes and sectors:

- Maintaining compact compliance and preventing Lake Powell's water level from dropping too low to generate power.
- Maintaining agricultural production and the vitality of rural communities.
- Maintaining municipal and industrial water security.
- Maintaining river ecosystems.

Without a strategic, collaborative approach to addressing these issues, there is a risk that individual entities will act independently to secure their water supplies against climate and legal uncertainties. This could lead to more permanent transfers from agriculture, with detrimental impacts on rural communities and unpredictable impacts on river ecosystems.

Over the past several years, there have been numerous explorations into new approaches to meeting community and environmental needs in the Upper Basin, including deliberate, temporary, and compensated reductions in water use in order to help balance supply and demand in the Colorado River system, share water supplies between agriculture and cities, and aid troubled streams.

This report distills insights from these explorations that can help illuminate how

such deliberate, temporary reductions in water use could play a role in:

- Enhancing long-term water security for farms, municipalities, industries and rivers in the Upper Basin (upstream objectives).
- Compact compliance and protection of power generation capacity in Lake Powell (downstream objectives).

In this report, the term "strategic conservation" will be used to describe these deliberate reductions in water use to meet specific goals.

The insights covered in this report focus on the following topics:

- Water user interest
- Agronomic impacts of reducing water use
- Monitoring and verification of saved water
- Shepherding and conveyance of conserved water
- Pricing considerations
- Environmental considerations
- Additional considerations

For each topic, key insights and remaining uncertainties are highlighted and illustrative research, experiences and resources are described. Links to documentation are provided wherever possible.

Introduction

Water User Interest

With outreach and the right conditions, water users are willing to participate.

Prior to the 2015-2018 System Conservation Pilot Project (SCPP), which tested the concept of paying water users to temporarily reduce their water use in order to protect water levels in Lake Powell, there was uncertainty about whether water users would be interested in reducing their water use in exchange for payment.

Insights

- Water users will participate, if they deem the terms to be beneficial.
- Targeted outreach by trusted intermediaries is essential for recruiting participants.
- Flexible options for water management make programs more appealing.
- Long-term programs, as opposed to year-to-year, would be more appealing, because they would enable irrigators to factor periodic irrigation reductions into business and agricultural plans.
- Protecting their water rights is very important to potential participants.
- The purpose for agricultural water conservation matters to potential participants, with preventing compact curtailment and reducing local streamflow and irrigation shortages valued highly.
- Concern about potential injury to other water users, negative perceptions by others, and ditch

company bylaws and other regulations can be impediments to participation.

Remaining Uncertainties

- It took a long time for intermediaries doing outreach on the SCPP to gain producers' trust and generate interest in the program. It is unclear how easily interest in strategic conservation will transfer into new areas where proponents of such programs have not yet developed strong relationships.
- Improved understanding of the longterm costs of fallowing and more precise estimates of potential consumptive use savings could change the cost-benefit calculations of participation.

Studies, Experiences and Resources

System Conservation Pilot Program Reports

The Upper Colorado River Commission reports on the SCPP (<u>UCRC Staff, Wilson Water Group, 2018</u>) contain detailed descriptions of how SCPP operated and lessons learned, including the factors affecting potential cooperators' interest and ability to participate in the program.

The Bureau of Reclamation conducted its own review of the SCPP (Reclamation, 2021), with a section focused on the Upper Basin program. The report also includes detailed background information and information on the Lower Basin SCPP.

Water User Interest 2

Grand Valley, CO Conserved Consumptive Use Pilots

The Grand Valley Water Users Association participated in the SCPP and conducted an extensive review of the project (<u>J-U-B</u> <u>Engineers and Grand Valley Water Users Association, 2019</u>), including surveying participants afterwards.

Colorado: West Slope Perceptions

In 2019, Kelsea MacIlroy explored sociocultural perceptions of issues related to Demand Management on Colorado's Western Slope (MacIlroy, 2019).

In 2021, the Colorado River District released a report from a stakeholder advisory committee it established on Demand Management (Colorado River District, 2021).

Tools for Protecting Agricultural Water Rights While Enabling Temporary Transfers

Tools for protecting agricultural water rights while enabling temporary transfers for other purposes include:

- Utah's Water Banking Pilot Program
- Utah's new Instream Flow legislation
- Various tools in Colorado outlined in a white paper by the Colorado Water Trust (Colorado Water Trust, 2020):
- Alternative Transfer Methods in Colorado
- New Mexico's <u>Active Water Resource</u> <u>Management options</u>, including shortage sharing agreements and water banking



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Water User Interest

Agronomic Impacts of Curtailing or Reducing Irrigation

Impacts are very location-specific, but both grass and alfalfa can bounce back.

The impact temporary reductions in irrigation may have on future agricultural productivity is an important consideration for potential participants in strategic conservation programs. Uncertainties regarding impacts on perennial grasses has been of particular concern, given the high portion of Upper Basin water use dedicated to irrigated grass hay and pasture (MWH, 2012).

Insights

- High elevation grasses can (but don't always) experience significant productivity reductions in the first year of full irrigation after a year of fallowing but tend to recover almost completely in the second year.
- In some locations, species diversity in grass hayfields and pastures can change significantly in the first year of full irrigation following a year of fallowing. Both beneficial and detrimental changes have been observed.
- Alfalfa production tends to rebound to full production more quickly than grasses after fallowing, but under hot, dry conditions with shallow or sandy soils, it may completely die under fallowing and require reseeding.
- Bringing a field back under irrigation after fallowing can be difficult and take

extra time, due to the loss of soil moisture.

Remaining Uncertainties

- The duration of species diversity changes in grass fields following fallowing is unclear, as is the effectiveness of seeding with different legumes and other species to increase resilience.
- The specific factors that influence differing long-term impacts of fallowing in different locations need more investigation.

Studies, Experiences and Resources

Literature Review

A literature review of agronomic impacts of reduced irrigation in the Upper Colorado River Basin conducted in 2019 by Culp & Kelly (Culp & Kelly, 2019) reviewed impacts to a wide variety of crops from different degrees of deficit irrigation.

Colorado West Slope Water Bank Studies

A study of the impacts of full and partial curtailment of irrigation on grass and alfalfa fields on Colorado's West Slope for the Colorado River Water Bank Work Group (Jones, 2015) found that for grass hay, the year after fallowing, fields still produced only 49% of the volume produced on the fields that had not been fallowed, but had fully recovered by the second year after fallowing.

A separate paper on the same project found that alfalfa yields generally improved in a fully-irrigated year following a year of stress due to deficit irrigation (<u>Cabot, Brummer, Gautam, Jones, & Hansen, 2017</u>).

Grand County, CO Project

The "Evaluating Conserved Consumptive Use in the Upper Colorado" project in Colorado's Grand County, which began in 2020 and will continue through 2023, is assessing the recovery of high elevation grasses following a year of fallowing. Preliminary accounts from project participants indicate that the grasses recovered completely in the first year after fallowing. A November 2021 report on the project, completed before recovery had been completely analyzed, can be found here.

Upper Gunnison Basin, CO Project

At the request of the Upper Gunnison River Water Conservancy District, Trout Unlimited staff and CSU researchers developed a study on grass field recovery after a year of fallowing, beginning in 2019. Preliminary results indicate that in the year following fallowing, yields were similar, but species diversity was much lower and less desirable than in non-fallowed control fields.

Price River, UT SCPP Project

Alfalfa fields in the Price River, UT area that were fallowed for a year as part of the SCPP did not see stand recovery after fallowing,

despite the fact that the crop is generally considered to be drought resilient. Interviewees associated with the project attributed the plant mortality to the exceptionally hot, dry conditions and shallow soils in the area.

Grand Valley, CO SCPP Project

Participants in the Grand Valley Conserved Consumptive Use Project reported that returning fields to full irrigation after a period of fallowing was challenging (J-U-B Engineers and Grand Valley Water Users Association, 2019).



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Monitoring and Verification of Saved Water

Remote sensing shows promise.

One technical hurdle for any program that pays water users to reduce their use and/or transfer (temporarily or permanently) their rights to another use requires some method for 1) quantifying how much water was being consumed historically, and 2) verifying that it is no longer being consumed. With temporary transfers, there is the added necessity of ensuring that the water was physically and legally available during the agreed-upon period of non-use.

Each of the Upper Basin states currently has a different system for estimating historic consumptive use (Reclamation, 2021) (UCRC Staff, Wilson Water Group, 2018). For implementation of strategic conservation programs at any scale, it is beneficial to have a system that is timely, not too cumbersome and expensive, and can account for consumptive use reductions less drastic than complete fallowing, such as partial season fallowing, deficit irrigation or switching to crops that use less water.

One technology with the potential to address these challenges is remote sensing using satellite imagery, which is becoming increasingly publicly accessible through the "OpenET" platform. Remote sensing doesn't require detailed diversion data and avoids errors in CU estimates related to retained soil moisture or a high water table, which a Utah State University study found led to over-estimates of CU savings from irrigation curtailment when other methods were used (Allen & Torres-Rua, 2018). Another benefit

of OpenET is consistency across all of the states and transparency: it allows irrigators and other parties access to information that was previously only available to those with the resources to hire an engineering firm to produce the data. Additionally, remote sensing methods estimate actual ET as opposed to crop coefficient-based methods of ET estimation. Crop coefficient methods estimate a potential ET that may require a reduction for when irrigation water supplies are limited. This reduction is usually challenging to do accurately.

Insights

- Estimates of CU generated by remote sensing using the OpenET platform have been very similar to estimates generated by ground-based instrumentation, indicating that remote sensing is a scalable and transferable tool.
- Remote sensing can work in concert with other tools, such as Colorado's lease-fallow tool, to estimate impacts of changed irrigation practices to return flows.
- Drone monitoring can provide higher resolution data for CU calculation accuracy, crop condition, and fill gaps in OpenET data. However, drone flights can be costly.
- In the context of split season or deficit irrigation, when forage is hayed plays a role in CU reduction. If forage is left standing after irrigation is curtailed, soil moisture remains and more leaf mass enables more ET from the plants. This was noted in the Tomichi Water

- Conservation Program and identified using METRIC (Kruthaupt, 2019).
- While water saved through fallowing in one year may leave behind dry soils that will require the application of more water than usual to make fields productive when normal irrigation resumes, the change in consumptive use will depend on the crop response, not the time it takes to restore soil moisture.

Remaining Uncertainties

- It remains unclear which models most accurately process remotely-sensed data across the Upper Basin. The Upper Colorado River Commission is sponsoring an in-depth study that addresses this question.
- Determining a baseline CU for the project fields will be necessary for determining the amount of CU that is conserved through strategic conservation measures. Options for calculating conserved CU on fields with strategic conservation measures include comparing to previous years' consumptive use or CU on reference fields; which method to use will require further investigation and decision making.
- Separating CU from irrigation versus
 CU due to precipitation is a challenge,
 which the OpenET platform is working
 with stakeholders to address.

Studies, Experiences and Resources

Analysis of SCPP Water Conservation Efforts

An analysis of water conservation from SCPP projects by Utah State University researchers (Allen & Torres-Rua, 2018) described several reasons the projects tended to overestimate water savings.

OpenET

The <u>OpenET</u> platform provides easily accessible estimates of evapo-transpiration from satellite data.

Grand County, CO Project

The "Evaluating Conserved Consumptive Use in the Upper Colorado" project in Grand County, CO is, in addition to assessing forage recovery after fallowing, comparing different methods of consumptive use estimation on normally irrigated, partially irrigated and fallowed high-elevation hay meadows. The 2021 interim report on the project (Cabot, Derwingson, & Torres-Rua, 2021) found that estimates of consumptive use generated by remote sensing using the Open ET platform were very close to estimates generated using ground-based eddy covariance instrumentation, indicating that remote sensing is a scalable and transferrable tool.

Colorado's Lease-fallow Tool

Colorado's <u>Lease-fallow tool</u> was developed to simplify and streamline the evaluation of historical consumptive use, depletions, and return flows from irrigation.

Wyoming Experience with Remote Sensing

Wyoming has used the METRIC remote sensing model developed by the University of Idaho for a number of years to get a better understanding of consumptive use (Wyoming State Engineer, 2020).

According to interviewees, remote sensing provides a near real-time, relatively cost-effective method of estimating consumptive use, particularly in areas where water diversions are not measured.

Utah Review of Depletion Accounting Methods

Utah's Agricultural Optimization Task Force sponsored a review of potential agricultural depletion accounting methods that was completed in June 2020 (Jacobs, 2020). The report was based on discussions among a panel of experts and compared the strengths and weaknesses of different ground-based and remote sensing methods for estimating consumptive use, recommending different methods for different purposes. The report noted the advantages of remote sensing methods for providing basin-wide estimates of consumptive use, as well as for providing a low-cost alternative for individual water users to using ground-based methods. The report recommended that the state begin

by using the well-established METRIC model while comparing its results with other models also available on the Open ET platform. The report recommended a Case Study to validate its recommendations, which is due to be completed in 2022.

According to the Task Force's 2021 Annual Report, preliminary results from the case study indicate that water depletion accounting is feasible in Utah (<u>Utah</u> Department of Natural Resources, 2021).

Tomichi Creek Water Conservation Project

A project on Tomichi Creek in the Upper Gunnison Basin paid irrigators to stop irrigating early in 2018 and measured the impacts on streamflows. The final report on the project (Kruthaupt, 2019) noted the impact of the timing of haying on CU for a partial season curtailment of irrigation, as well as some discrepancies between remotely sensed ET and more localized measurement.



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Shepherding and Conveyance of Conserved Water

More measurement and instrumentation would be helpful, but models can fill the gap.

For any program that seeks to conserve water in one location in order for it to be used or stored in another, ensuring that the conserved water actually reaches its destination is fundamental to the program's success. Legal shepherding is a mechanism for protecting the delivery of water to its final destination and is practiced routinely across the Upper Basin in the administration of direct-flow water rights and in the delivery of stored water. Conveyance losses, or how much that water "shrinks" due to natural processes along the way to its intended destination, is accounted for in diverse ways, with varying degrees of precision, depending on particular conditions and the technology available for measuring and monitoring flows, as well as past experience with moving water between particular locations.

Insights

- Various legal tools already exist in the Upper Basin states to shepherd strategically conserved water for basin-wide and more local purposes.
- Shepherding is easier when multiple parties on a tributary participate in a strategic conservation program.
- Shepherding strategically conserved water is easier if it can be released

- under high flow, "free river" conditions or outside of the irrigation season.
- Conveyance losses depend on numerous local and seasonal factors, including stream volume, flow rate, streambed characteristics, streambank vegetation and temperatures.
- It is easier to measure the conveyance of water from foregone deliveries or reservoir releases on small tributaries, where they make up a larger share of the total volume, than in mainstem rivers, where they may constitute a very small portion of the flows.
- Where the direct measurement of conveyed water is difficult, models and administrative tools can provide some assurance of successful delivery.
- At a local level, detailed measurement and monitoring of how water flows through a system can improve management and reduce conflict.

Remaining Uncertainties

- The applicability of existing tools for shepherding water from strategic conservation to protect water levels in Lake Powell and compact compliance is not completely clear in Wyoming and Colorado, although both have histories of curtailing and shepherding water as part of standard water rights administration.
- Additional stream gages and pilot projects would improve understanding of conveyance losses when transferring water between uses.

Studies, Experiences and Resources

Existing Tools for Acquisition and Shepherding of Strategically Conserved Water for other Purposes

New Mexico's <u>Strategic Water Reserve</u>
<u>Program</u> allows the New Mexico Interstate
Stream Commission to acquire water rights
by purchase, lease or donation in order to
comply with interstate obligations or benefit
threatened and endangered species.

Utah's <u>Water Banking Pilot Program</u> allows for water rights to be placed in a bank for temporary, voluntary and locally directed water leasing.

Utah's legislature passed new instream flow legislation in 2022 (<u>HB 33</u>) that enables water right holders to permanently or temporarily dedicate water rights for instream flow purposes, specifying where the water will be used.

Colorado water laws enabling "Alternative Transfer Methods," or temporary water transfers, are summarized in a report from the Environmental Defense Fund (Environmental Defense Fund; WestWater Research, 2016).

Colorado mechanisms specifically for instream flows, with some applicability for other uses, are described in a 2020 Colorado Water Trust white paper (Colorado Water Trust, 2020).

Shepherding Challenges

A 2017 paper from University of Colorado researchers discussed issues raised under Colorado water law with shepherding

appropriated water to Lake Powell to protect water levels and provide compact security (MacDonnell & Castle, 2017).

Tracking the Homestake Release

Through a voluntary effort conceived by Front range water users, a 1,666.9 acre-foot release was made over the course of several days in September of 2020 from the Homestake Reservoir on a tributary to the Eagle River, itself a tributary to the Colorado River. The water released would have otherwise been transported across the Continental Divide for urban water use. In a comprehensive review of the release (Colorado Division of Water Resources, 2021), the Colorado Division of Water Resources found that it was able to legally shepherd the additional water to the state line using existing administrative tools. Tracking the released water in the stream was fairly straightforward in Homestake Creek and the Eagle River, where the release was a large portion of the total stream volume, but was not possible in the Colorado mainstem to the state line because the amount released was dwarfed by the total water volume in the river, interactions with a complex set of upstream and downstream water management actions, and insufficient instrumentation to measure all influences on streamflow. However, given that administrative actions prevented the diversion of additional water downstream from the release, it can reasonably be assumed that the water made it to the Colorado-Utah state line.

Emery County, UT Real Time Monitoring and Control

In Emery County, a Real Time Monitoring and Control System (RTMCS) was installed beginning in 1993 with gauging stations on the San Rafael River and its tributaries as well as canals and springs and has grown into an extensive network with automated control structures and data viewable on a public website. A review of the program (Green, Hansen, Narayanan, & Green, 2020) credits the system with reducing diversions required to serve irrigators, improving conveyance efficiency, and improving transparency and trust among water users.



Photo © Perry Cabot

Pricing Considerations

The lowest price may not always yield the most benefit over the long term.

Finding the right price to pay for strategic conservation involves navigating the tension between keeping the price low enough for it to be affordable for the funder(s) and high enough to make it worthwhile and sustainable for a sufficient number of participants and their water systems.

Insights

- The SCPP was able to develop a standardized price over the course of the program.
- Most SCPP participants appeared to be satisfied with the prices they received for participation; however, several potential participants backed out of the process claiming the standardized price could not cover the cost of lost production. These tended to be irrigators that generally have a full water supply and higher production.
- The administrative burden for ditch systems to manage programs needs to be factored in for their participation to be sustainable.
- The value of water to a producer may vary, depending on how general water availability in the region affects crop prices. For example, in dry years, hay prices tend to be higher, making the economic value of water higher for those with good water access.

Remaining Uncertainties

- More accurate estimates of conserved consumptive use due to fallowing may lead to lower estimates of water made available by program participation, potentially exerting downward pressure on the compensation offered.
- More accurate accounting of the costs of participation, factoring in long term impacts on field productivity, could exert upward pressure on compensation requested.

Studies, Experiences and Resources

System Conservation Pilot Program Final Report

The Upper Colorado River Commission's final report (<u>UCRC Staff, Wilson Water Group, 2018</u>) on the SCPP includes a discussion of issues related to pricing.

Grand Valley Water Users Association Conserved Consumptive Use Program

The Grand Valley Water Users Association (GVWUA) in Western Colorado administered an SCPP program for its members through a lottery system. Elements that went into the cost proposed for the program included ensuring that the GVWUA was compensated adequately for the administrative work required to run the program, as well as that the system as a whole would benefit from participating in the program through revenue generated for infrastructure upgrades (J-U-B Engineers and Grand Valley Water Users Association, 2019).

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Tomichi Creek Water Conservation Project

A project on Tomichi Creek in the Upper Gunnison Basin paid irrigators to stop irrigating early in 2018 and measured the impacts on streamflows. The final report on the project (Kruthaupt, 2019) notes that 2018 was a very dry year, which reduced the value of the fallowing payments to participants, because hay and pasture prices go up in dry conditions. The dryness of the year also reduced the total amount of water conserved, since less was available, but it increased the importance of that water for the health of the stream.

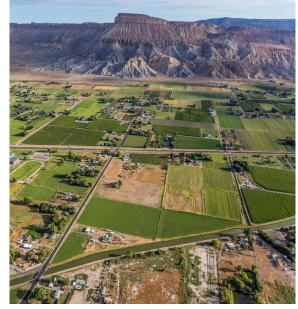


Photo © Ken Geiger

Price River Basin

In the Price River area in Utah, alfalfa stand mortality as a result of fallowing during the SCPP demonstrated that fully accounting for the costs of fallowing can include the cost of reseeding the following year. In addition, producers have indicated a desire to fallow the same fields for multiple years in a row in order to reduce the frequency of reseeding.

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Environmental Considerations

More monitoring is needed to better understand benefits.

It makes intuitive sense that, particularly on streams where ecological values suffer from low flows, agricultural water conservation would benefit the environment. However, despite the existence of various projects to temporarily forego irrigation and leave water in streams, there is little documentation of the resulting environmental benefits from specific projects. Some recent and current projects are attempting to fill that void.

Insights

- Reducing irrigation diversions can have a measurable, positive impacts on flows and fisheries, depending on the amount of reduced irrigation compared to natural streamflow.
- Reducing diversions can also have positive impacts on stream temperatures and other water quality parameters.
- Strategic conservation by multiple
 water users on the same tributary
 increases the impacts on flows, both
 by increasing the amount of water left
 instream and reducing the chances
 that the additional water will be
 diverted by another water user.

Remaining Uncertainties

 In many areas, the connection between streamflow improvements

- and biologic response is not well-understood and needs more work.
- Accounting for streamflow changes throughout the year, to capture potential impacts from reduced return flows, is necessary to capture the full environmental significance of a project.

Studies, Experiences and Resources

Tomichi Creek Water Conservation Project

On Tomichi Creek in Colorado's Upper Gunnison Basin, Trout Unlimited paid several irrigators to reduce their diversions during the drought year of 2018, with extensive monitoring of streamflows as well as consumptive use. Comparing streamflows and fish mortality in 2018 with similar drought years in 2002 and 2012 indicated significantly improved streamflow and trout fishery conditions as a result of the irrigation curtailments (Kruthaupt, 2019).

Fontenelle Creek Project

On Fontenelle Creek in Wyoming's Green River Basin, Trout Unlimited signed non-diversion agreements with several ranchers and commissioned a study (One Fish Engineering, LLC, 2018) of the impacts on flows in Fontenelle Creek and deliveries of water to Fontenelle Reservoir. The study identified significant flow increases in the creek as a result of the non-diversion agreements, when compared with usual irrigation practices.

Additional Considerations

Additional important issues related to strategic conservation such as the secondary or community impacts of agricultural water conservation and equity concerns related to program design are not addressed in detail in this report due to the inherently speculative nature of assessing the potential impacts of a program that has not yet been designed vs a "no action" future that remains uncertain. Nonetheless, important work that begins to address these questions has been carried out by BBC Research and Consulting for the Colorado River Water Bank Work Group (BBC Research & Consulting; ERO Resources; Headwaters Corporation, 2020); the University of Wyoming with The Nature Conservancy, Wyoming Stockgrowers Association and University of Wyoming Extension (Hansen, Coupal, Yeatman, & Bennett, 2021); and Harvey Economics for the Upper Gunnison River Water Conservancy District (Harvey Economics, 2020).

Resources

Water Bank Work Group Secondary Impact Study

The Colorado Water Bank Work Group contracted with BBC Research and Consulting to conduct economic analysis and stakeholder focus groups to assess the potential secondary impacts of demand management on communities in Western Colorado river basins (BBC Research & Consulting; ERO Resources; Headwaters Corporation, 2020).

University of Wyoming Economic Assessment

The University of Wyoming Economic Assessment was designed by the University, in partnership with The Nature Conservancy, the Wyoming Stock Growers' Association and University of Wyoming Extension (Hansen, Coupal, Yeatman, & Bennett, 2021). It drew on both agricultural producer surveys and economic modeling.

Upper Gunnison Study

The Upper Gunnison River Water Conservancy District commissioned Harvey Economics to study the potential economic impacts of irrigation water curtailment in the Upper Gunnison Basin under various scenarios (Harvey Economics, 2020).

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Conclusion

This snapshot of insights gained from recent pilot projects, studies and other developments would look very different if it were completed a year from now, or even a few months from now. Many of the remaining uncertainties noted are being addressed by the Upper Colorado River Commission, state agencies and the same research teams involved in the studies highlighted. The pace of learning on how agricultural water conservation can play a role in increasing overall water security is rapid and accelerating.

A recurring theme from this review is that rich learning occurs whenever new approaches to managing water are tried – but this learning is not always welldocumented, which impedes capturing and sharing it. Another theme is the elusiveness of results that will yield precise and generalizable answers to many of the feasibility questions related to strategic conservation for both basin-wide and local objectives. But it is also clear that our current and historical practices of managing and accounting for water are based to a large degree on estimates and models that are imprecise, although they have continued to improve over time. Combined together, these themes indicate that moving forward, policies that are flexible enough to enable experimentation with new approaches, careful documentation of the results, and adaptations to new learning offer the best opportunity to manage diminishing water supplies for enhanced water security at all levels.

Methodology and Acknowledgements

The development of this report began with a review of the key feasibility issues for establishing a demand management program identified by the Upper Colorado River Commission and state agencies, through both available documentation (Upper Colorado River Commission, 2019) (Colorado Water Conservation Board, 2021) and interviews with agency staff. Staff for nongovernmental organizations, agencies and researchers involved in promoting and studying agricultural water conservation programs in the Upper Colorado River Basin were also consulted. The author is deeply grateful to all of the interviewees for their direct insights, as well assistance in locating useful resources and documentation.

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About the Author

Hannah Holm

At the time this report was prepared, Hannah directed the Ruth Powell Hutchins Water Center at Colorado Mesa University, which promotes research, education and dialogue to address the water challenges facing the Upper Colorado River Basin. While working with the Center, which she co-founded in 2011, Hannah organized numerous water conferences and educational seminars and worked with the Colorado and Gunnison Basin Roundtables on educational activities, as well as authored dozens of newspaper columns on current water issues. She also taught classes on water science and policy, with an emphasis on the Colorado River Basin. Hannah previously facilitated the Grand Valley and Lower Gunnison Wise Water Use Council, advocated for stronger drinking water protections with Western Colorado Congress, and served on her local watershed group board in Pennsylvania. Earlier in her career, Hannah worked for the North Carolina General Assembly, where she staffed committees on the Environment, Natural Resources, Sustainable Agriculture and Smart Growth. Hannah has a joint Master's degree in Community & Regional Planning and Latin American Studies from the University of Texas at Austin and a Bachelor's degree in Anthropology from Macalester College in St. Paul, MN.

As she completed this report, Hannah was preparing to leave Colorado Mesa University for a position with American Rivers.

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