COLORADO WATER CENTER
COLORADO STATE UNIVERSITY

COLORADO WATER CENTER

ANNUAL REPORT

FY20

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WHO WE ARE

The Colorado Water Center (CoWC) is one of 54 Water Resources Research Institutes created by the Water Resources Act of 1964, which collectively form the National Institutes for Water Resources. As a division under CSU's Office of Engagement & Extension, the Center aims to connect all water expertise in Colorado's higher education system with research and education needs of Colorado's water managers and users, building on the rich water history at Colorado State University.

The CoWC leads interdisciplinary research, education, and outreach to address complex and evolving water-related challenges in Colorado and beyond. We do so by fostering collaboration between higher education and water stakeholders, synthesizing objective water knowledge to inform decision-making, and inspiring the next generation of water leaders.

OUTREACH & TRANSFER

The CoWC collaborates with CSU Extension to house three water outreach specialists around the state and operates several websites with up-to-date water information that have become a consistent source of knowledge for water professionals and community members alike. Publications available on these sites include: research reports and Colorado Water, a newsletter containing information on current research, water faculty, outreach program updates, climate, water history, Colorado State Forest Service (CSFS) updates, CSU Faculty Grant Program updates, and water-related events and conferences, featuring different research in each issue. The CoWC outreach activities are conducted in conjunction with CSU Extension, the Colorado Agricultural Experiment Station, the CSFS, and the Colorado Climate Center (CCC). Our primary partners include water managers, water providers, and water agencies.

TRAINING

One of the CoWC's primary missions is to facilitate the training and education of university students. To this end, the Center works with the U.S. Geological Survey and the Colorado Water Conservation Board to fund student interns and research grants and manages scholarships on behalf of students. Student researchers work with faculty members and gain valuable water expertise as well as knowledge of the research process.

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Photo by Sonja Wilkinson on Unsplash

MESSAGE FROM THE DIRECTOR

The Colorado Water Center (CoWC) at CSU completed another successful year in FY20 as our state struggled through drought, fires, pandemic, budget shortfalls, the closure of the CSU campus and many businesses and public places. The retirement of CSU Vice President Lou Swanson led to my serving last fall in an interim Vice President role until Blake Naughton joined CSU as the new Vice President of Engagement and Extension. In spite of a challenging year, the Colorado Water Center continued to serve its statutory mission working with all of higher education in Colorado as part of a network of 54 university-based water centers and institutes across the nation serving under the federal Water Resources Research Act.

Significant efforts were dedicated in 2020 toward the development of the program and building plans for the new Water Building at the National Western, in partnership with Denver Water. One major component of the NW Water Center is a planned Western Water Policy Institute that CoWC will have a major role in helping to foster dialogue and study of water policy issues. One component of the Policy Institute will be an online graduate certificate and Master's of Water and Climate Policy, slated to begin offerings in 2022.

Several of our outreach and education projects are highlighted in this annual report, including work in the Cache la Poudre, Arkansas, Yampa, White, South Platte, Republican and Colorado River Basins. The 2020 drought put additional pressure on our CSU Regional Extension Water Specialists, Joel Schneekloth, Blake Osborn and Perry Cabot, to advance water conservation and efficiency information and related drought and fire programs for the benefit of agricultural and urban stakeholders. Work on climate smart agriculture initiatives continued under the leadership of Brad Udall and retired State Climatologist, Nolan Doesken. Julie Kallenberger, CoWC Water Education Specialist, took over responsibility for our Water Literate Leaders program, the Poudre Runs Through It collaborative, and the Regional Water Dialogue, in addition to her other duties at the Center. Angelique Giraud assumed responsibility for internal CSU faculty and student programs and our social media. Jennifer Gimble continued her work on the Colorado River in addition to teaching the Graduate Water Seminar. Nora Flynn joined our staff this year to work on critical agricultural water issues, including drought, ATMs and salinity.

This year's annual report showcases the faculty and student projects funded by the CoWC to address the complex water issues facing Colorado and beyond. Most of these projects were funded with CWCB severance tax funds, US Geological Survey funds, as well as internal CSU funds. Unfortunately, state budget shortfalls resulted in the curtailment of CWCB research funding for FY21, causing us to put these projects on hold for at least a year. Further budget cuts and hiring freezes loom but we are confident that CSU remains committed to the CoWC, and we gratefully acknowledge the support from our state and federal partners. I am pleased to report this year that the Center continues to benefit from a committed staff, excellent support from CSU upper administration, and the guidance of an outstanding advisory committee. More information on the CoWC can be found at **watercenter.colostate.edu**

Reagan Waskom

Reagan Waskom

FY21 NEW RESEARCH

USGS

Advancing Water-Supply Prediction Capacity in the Upper Colorado River Basin During Drought and Non-Stationary Climate
Stephanie Kampf et al., Colorado State University

Assessment and Management of Groundwater and Salinity in the South Platte River Basin under Changes in Population, Climate, and Land Use
Ryan Bailey et al., Colorado State University

Urban Street and Stream Flooding: Harnessing Monitoring Data to Inform Forecasts
Aditi Bhaskar et al., Colorado State University

Machine Learning Algorithms To Predict And Prevent Harmful Algal Blooms
Terri Hogue et al., Colorado School of Mines

CWCB

Impacts of Extreme Events on Forest Recovery and Streamflow Across Colorado's Forest-Dominated Ecosystems
Miranda Redmond & Stephanie Kampf, Colorado State University

Quantification of Industrial Hemp CU Rates, THC Levels, Weed Pressure, and Disease Effects under Irrigated Conditions in Western Colorado
Perry Cabot et al., Colorado Water Center

Relationship Between Irrigation Return Flows, Riparian Vegetation Water Use, and Soluble Pollutant Removal in the Lower Arkansas River Basin (Phase II)
Ryan Morrison, Tim Gates, et al., Colorado State University

Linking the Topology of Forest Disturbance to Water Quality to Enhance Forest and Water Resource Management in Colorado
Tim Covino & Matt Ross, Colorado State University

Watershed Conditions, Climate and Post-Fire Mitigation for Two Wildfires in Southwest Colorado and their Influence on Forest Health and Watershed Recovery
Julie Korb, Heidi Steltzer, & Michael Remke, Fort Lewis College

Aquatic Ecosystem Impacts & Recovery After Wildfire: Can Forest Health be an Indicator of Recovery
Terri Hogue, Ashley Rust, and Scott Roberts, Colorado School of Mines

Reproductive Ecology of Invasive Northern Pike Informs Management Actions to Reduce their Abundance
Kevin Bestgen, Colorado State University

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Subscribe to our e-newsletter, *The Current*, or our print newsletter, *Colorado Water*, for updates on research, water-related news, jobs, funding, scholarships, and more!

watercenter.colostate.edu

CSU Faculty Grant Program

Toward Understanding the Global Impacts of Human Activities on Floodplain Integrity
Ryan Morrison, Colorado State University

Integrating Low-Tech, Process-based Restoration Techniques to a Degraded Perennial Stream System: A Community Driven Research Model
Blake Osborn, Colorado State University

Building a Long-Term Watershed Research Site at CSU Mountain Campus
Sara Rathburn et al., Colorado State University

Beaver-Generated Wetlands as Ecosystem Control Points for Post-Fire Transport of Sediment, Carbon, Nutrients, and Toxic Metals into Rocky Mountain Headwaters
Michael Wilkins et al., Colorado State University

RESEARCH HIGHLIGHTS

STUDENT RESEARCH

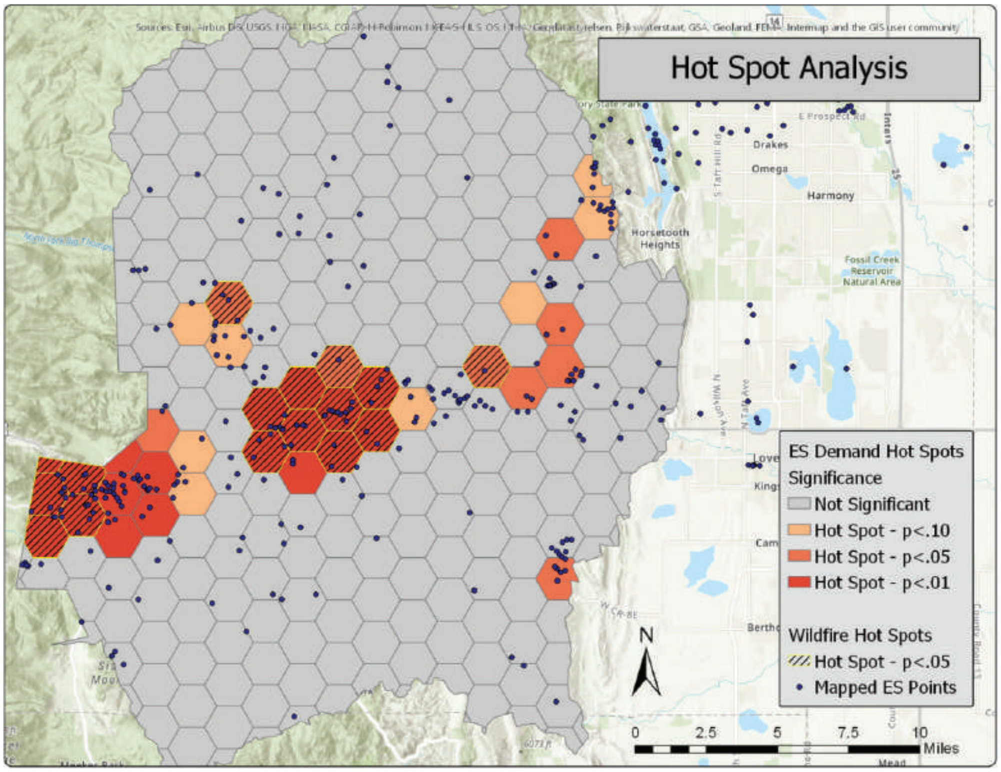
PARTICIPATORY MAPPING OF ECOSYSTEM SERVICE VALUES IN THE BIG THOMPSON WATERSHED

Luke Chamberlain & Kelly Jones, Colorado State University

The concept of ecosystem services came into popularity with the Millennium Ecosystem Assessment (MA), where they were defined simply as “the benefits people obtain from ecosystems.” Ecosystem services create tradeoffs in decision-making. For example, a forest provides services like habitat, biodiversity enhancement, carbon storage, and climate regulation.

In Colorado, people enjoy many benefits from the ecosystems here. But as more people move to the Front Range, an increased demand for ecosystem services is accompanied by an increased threat to those services from development, overuse, and wildfire. More people, more values, and more threats combine to create a complicated, dynamic web of interactions between ecosystems, benefits, and beneficiaries.

Therefore, we set out to better understand the ecosystem service perceptions and preferences of the beneficiaries of one of Colorado’s important watersheds: The Big Thompson. We elected for a participatory mapping approach for describing ecosystem service values in the Big Thompson watershed. People within the watershed boundary and people



living in municipalities that receive water from the Big Thompson River were targeted for a random household survey.

Participants were asked to map the location of their home and the locations of ecosystem services that they value, and were given a list of 13 services to select — including things like recreation, social interaction, food, aesthetics, and spiritual value. They were also asked to assign a hypothetical dollar value out of a possible $100 for the protection of each of the 13 ecosystem services in question. Through identification of service value hot spots, overlaid by hotspots of wildfire risk, we found ecosystem service values that are most threatened by wildfire.

In total, 98 respondents mapped 415 points (5.93 points per respondent). The presence of water was a strong predictor for demand value on the landscape ($p=.007$). Accessibility was the strongest predictor with proximity to roads ($p=.008$), buildings ($p=.006$) and developed areas ($p=.014$) all being significantly correlated with ecosystem service demand. Elevation ($p=.038$) and forest land cover, interestingly, were both negatively correlated ($p=.002$).

We hope that this will spark interest in more participatory research along the Front Range, and that we can use these spatial tools to increase the connection between science, the environment, and those that can benefit most from having their voices heard.

As more people move to the Front Range, an increased demand for ecosystem services is accompanied by an increased threat to those services from development, overuse, and wildfire. Photo of the 2012 Waldo Canyon fire by Airforce Master Sgt. Jeremy Lock.

FLOODPLAIN FOREST ESTABLISHMENT AND LEGACY SEDIMENT WITHIN THE YAMPA RIVER BASIN, NORTHERN COLORADO

John Kemper & Sara Rathburn, Colorado State University

This study took advantage of the opportune assemblage of watershed characteristics to investigate the hypothesis that downstream cottonwood floodplain forests are a direct result of extreme erosion in the headwaters that deposited a large volume of legacy sediment along the Yampa from the late 19th to early 20th century.

The Yampa River is the last largely unregulated major tributary in the Colorado River system, and is an essential water source for agriculture, power generation, and municipalities.

In order to date the observed past arroyo incision, historical documents and photographs were compiled, including General Land Office (GLO) survey notes and maps. Initial and resurvey GLO notes and maps date to 1882 and 1906 in Sand Wash, respectively, to 1883 and 1915 in Sand Creek, and to 1881 and 1916 in Muddy Creek. Aerial photographs for each tributary basin were

John Kemper cores a cottonwood tree, Deerlodge Park, Dinosaur National Monument. Photo courtesy of John Kemper.

obtained from the United States National Archives and USGS Earth Explorer. Earliest photographs date to 1938 for all three basins. Comparison between initial and re-survey notes and the 1938 photographs enabled arroyo incision to be bracketed to certain periods of time.

To determine the area-age dates of the floodplain forest, we constructed polygons of the current forest using 2017 aerial imagery and generated 50 random points within the constructed forest polygons. In the field, we then used an increment borer to collect a core from the tree nearest the randomly generated points, in order to obtain samples that represented 2% of the forest. Because cottonwoods preferentially establish on new, bare floodplain surfaces (Scott et al., 1996), this method additionally allowed for estimation of the age of the surfaces on which the trees established. Using this assumption, along with historical aerial photographic analysis and interpretation of current tree size from modern NAIP imagery, we constructed a map of floodplain age within Deerlodge Park.

Inspection of historical documents and aerial photographs suggests that Sand Wash and Muddy Creek, two key tributaries of the Yampa, underwent significant historical erosion via arroyo incision in the late 19th to early 20th century. We thus propose that there was a period from roughly 1880-1940 where one or both tributary watersheds were actively incising, which in turn suggests floods on the Little Snake and Yampa during this time were charged with sediment from active erosion in the tributaries.

We propose that the demonstrable link between headwater erosion and distal downstream ecological processes (e.g. forest establishment) shown here validates the idea that upstream watershed dynamics play a key role in governing ecological processes such as riparian forest establishment and growth. From these results, two important management implications arise: 1) cottonwood forests along the Yampa River will likely decline regardless of the maintenance of the current flows, and 2) management of upstream sediment loads and flows are fundamental to the long-term health of Yampa River forests. Overall, results of this study suggest that holistic, basin-scale management of watershed resources – land, sediment, and water – is essential for floodplain forest and ecosystem health.

The Yampa River. Photo by Flickr user Doc Searls.

TEMPORAL AND SPATIAL EFFECTS OF SNOW DEPTH ON SNOW SURFACE ROUGHNESS THROUGHOUT THE WHITE RIVER WATERSHED

Jessica Sanow & Steven Fassnacht, Colorado State University

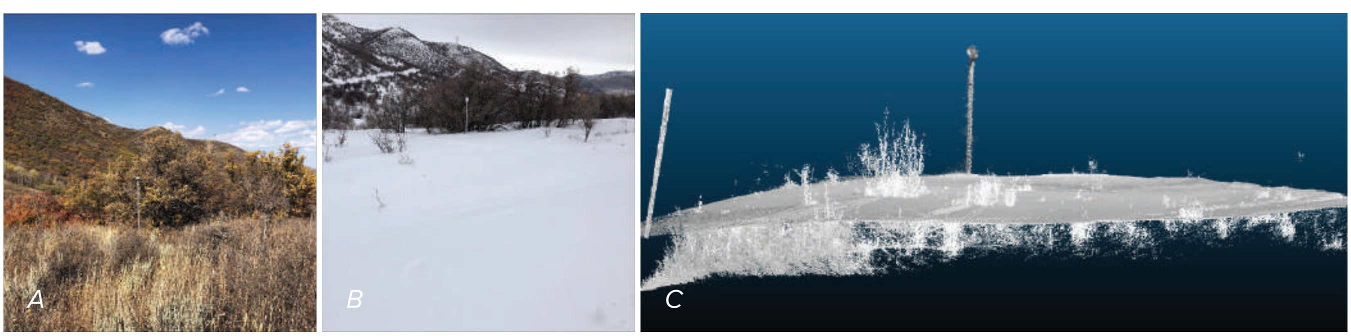
This research aimed to better understand the relationship between snow surface roughness (z_0) and snow depth (d_s) throughout the entire winter season, to improve estimations of snowpack characteristics. Since snow is a critical component of the hydrologic cycle, and meltwater provides drinking water for over 60 million people in the western United States (Bales et al., 2006), accurate measurements of the snowpack and resulting snowmelt are crucial for water management, especially within a changing climate and an overall decrease in snowpack (Mote et al., 2017).

Collecting meteorological data at the Trout Farm field site. Photo courtesy of Jessica Sanow.

To account for the differences in the underlying terrain, and thus possible variation in surface roughness throughout a watershed, nine snow sites were chosen throughout the White River Watershed. These sites varied based on elevation, location, underlying topography, and land cover type.

Terrestrial-based LIDAR scans using the FARO Focus3D X 130 model were taken on daily to bi-monthly intervals at each of the sites, depending on distance and weather conditions. Photographs, air temperature, and snow depth at each snow stake were also recorded at every site visit. Specialized software, including Cloud Compare and Golden Software Surfer, were used to analyze scans, in order to identify and measure individual roughness elements. These were then used to estimate z_0 based on geometry.

Results indicate that the various topographic and vegetation heights influenced the z_0 of the study sites, and those roughness features were further influenced by the addition of a spatially and temporally heterogeneous snowpack. All sites revealed similar results, indicating that that as the snow depth changes, the z_0 is also changing throughout the winter season.



Yellow Jacket Pass, A) photo of the initial site set up, the t-post shown is to the north; B) photo during peak snow depth of 78 cm, this was taken from a slightly different angle than A, however the t-post is the same one in both photos; C) a screen shot of the point clouds from the snow free scan and the scan taken on 2-26-2020 showing the vegetation and snow pack depth, the t-post is the same as the within the other photos.

FINE SCALE DATA COLLECTION FOR FUTURE SNOWMELT MODELING NEAR SILVERTON, COLORADO

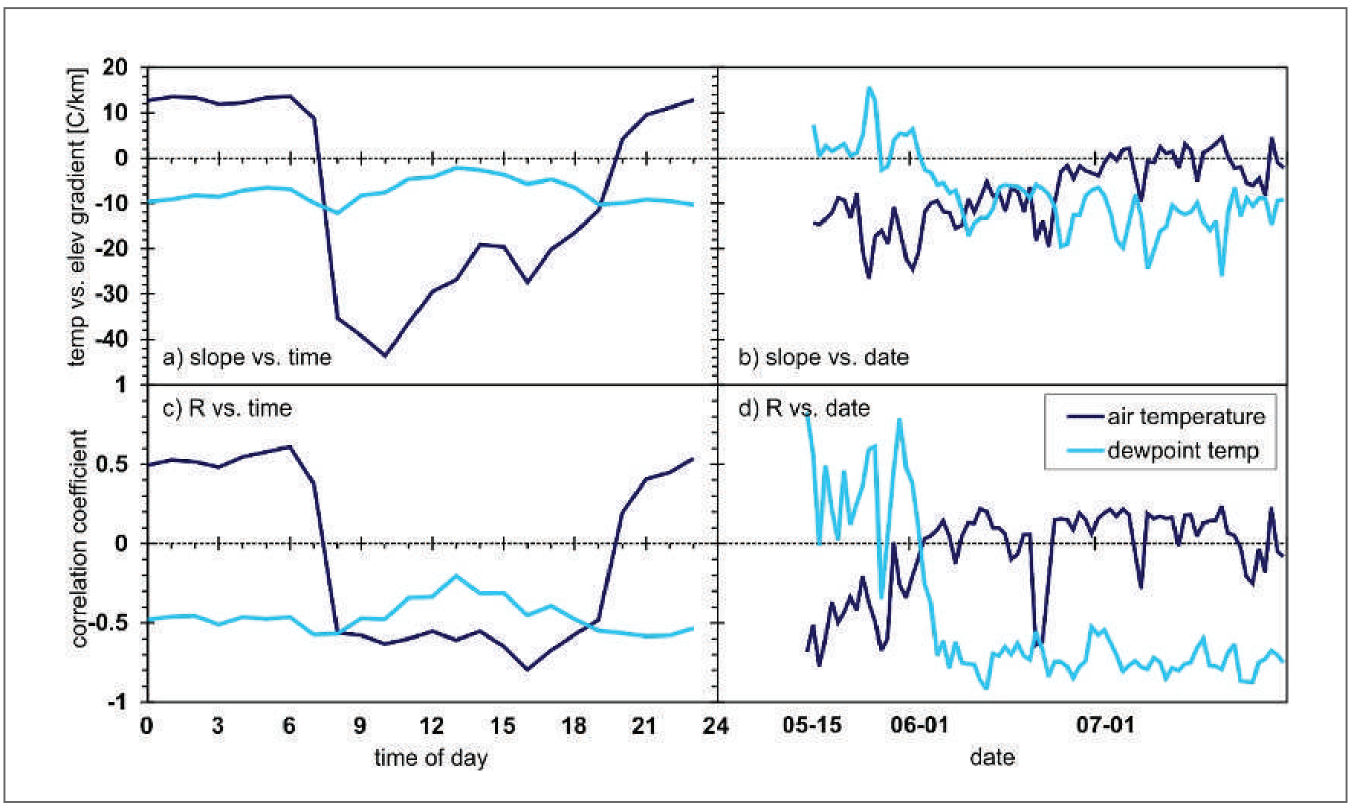
Alison Kingston & Steven Fassnacht, Colorado State University; Jeff Derry, Center for Snow and Avalanche Studies

The purpose of this study was to acquire and understand the impact of fine resolution inputs on snowmelt in Southern Colorado, specifically Senator Beck Basin. Modeling of snowmelt is key to providing useful new information for water resources management, especially in southern Colorado, which has been in drought for much of the past two decades. This field work collected temperature (T) and relative humidity (RH) data along a transect in Senator Beck Basin, near Silverton, CO, using iButton sensors.

Sensors were installed in October 2018, and that winter saw southern Colorado's deepest snowpack in two decades. Unfortunately, due to logistics and sensor memory limitations, data were only available from late February 2019 through August 2019. Analysis was focused on the snowmelt period from mid-May to the end of July. The beginning of snowmelt was estimated using snow water equivalent (SWE) data from the nearby Red Mountain Pass (RMP) SNOTEL station.

On average, dewpoint temperature-elevation gradients (TEG) were more consistent over the day than air TEG. Dewpoint TEG varied from -12.1 C/km at 8am to -2.2 C/km at 1pm, while air TEG varied from 13.6 C/km at 6am to -43.6 C/km at 10am.

The mean daily dewpoint TEG was initially positive, then became consistently negative after June 1st. For air TEG, it was initially a large negative and then became smaller; after July 4th it began to fluctuate between mean positive and negative values. The regression correlation was strongest when TEG was largest, both positive and negative.



Mean temperature-elevation gradient or slope for a) time of day, and b) date, and correlation coefficient for the corresponding c) time of day, and d) date, over the study melt season.

The variation in temperature and relative humidity, as we move up in elevation along a transect, can be substantial, even in a relatively small study area. These results highlight the importance of considering fine scale variability for snowmelt modeling. Future research will use these results to downscale meteorological data from the Weather Research and Forecast model. SnowModel can then be used for understanding melt characteristics and runoff patterns.

Alison Kingston (right) conducting field work. Photo by Ashlee Clarke.

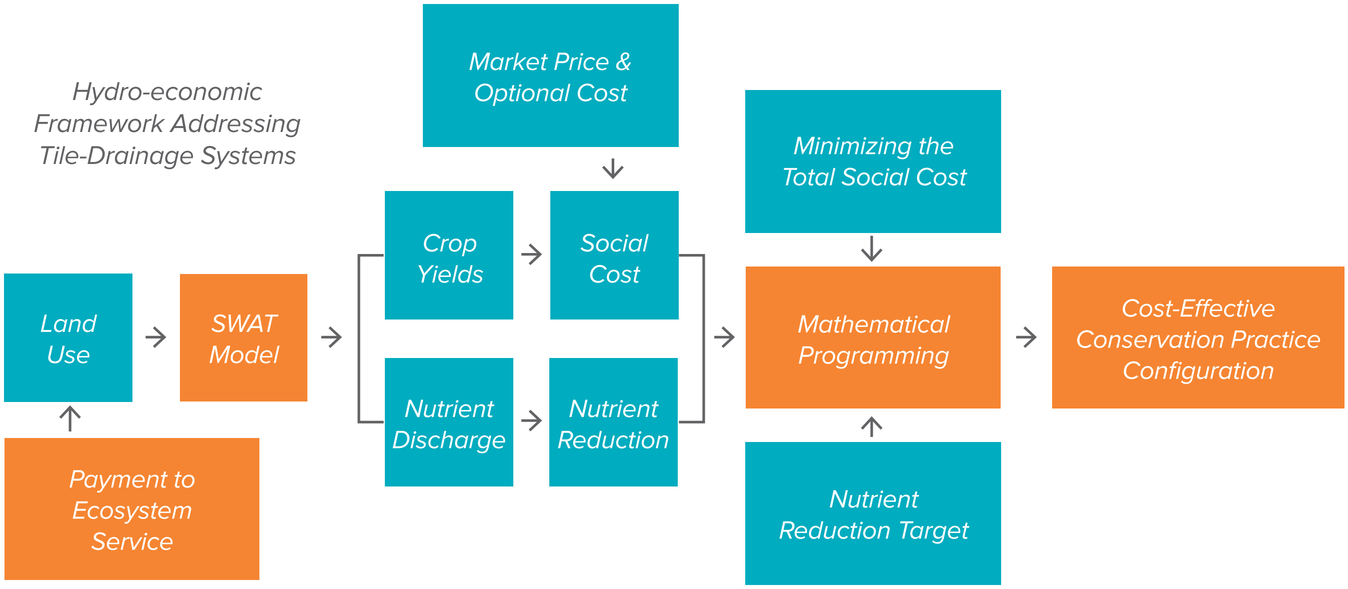
COST-EFFECTIVE WATER QUALITY MANAGEMENT WITH TILE-DRAINAGE SYSTEM

Di Sheng & Jordan Suter, Colorado State University

Our study incorporates spatial information of tile-drainage systems (TDSs) and adopts a hydro-economic framework to address the economic impact and policy implications of TDSs on water quality improvements. Agriculture serves as a major polluter of non-point source nutrients, and agricultural conservation is a popular approach to improve water quality. This research aims to assess the policy implications of agricultural tile-drainage systems in water quality management.

Agricultural TDSs, pervasively installed in the US Midwest, primarily aim to transport excess water from the soil, which also transports nutrients dissolved in water from fertilizer and livestock production into waterways. Studies reveal that TDSs increase the speed of nutrient transportation from agricultural land to nearby waterways and likely increase the nutrient density of a waterbody. It is therefore critical to in-

Student Di Sheng presenting research at AAEA 2019. Photo courtesy of Di Sheng.



clude information on the spatial location of TDSs into conservation policy design.

The results indicate that (1) incorporating TDSs into the PES design can significantly reduce the total cost of achieving a given nutrient reduction target; (2) the underlying distributions of conservation cost and nutrient reduction variables affect how much benefit TDSs information generate; (3) when the geographical scope of the problem expands, water quality trading among areas can also serve as a cost-effective water quality management tool.

In this study, we assume a PES program aiming to improve water quality (reduce nitrate loading). Land owners choose to enroll in the program and adopt a conservation practice (turn cropland into pasture land) if the payment is no less than the opportunity cost of conservation (net benefit of production).

In addition, to assess the benefit of introducing water quality trading between neighboring sub-basins, we compare the optimal enrollment configuration of achieving reduction targets by each sub-basin individually and that of jointly achieving the reduction target by two sub-basins, when paying each parcel with its opportunity cost of conservation.

We found that incorporating the TDSs information into the PES design can significantly reduce the cost of nitrate loading reduction. Incorporating TDSs have decent efficiency improvement with moderate targets.

CoWC FUNDING OPPORTUNITIES

The Colorado Water Center (CoWC) is one of the 54 Water Resources Research Institutes created by the Water Resources Act of 1964, which collectively form the National Institutes for Water Resources (NIWR).

The CoWC brings together interdisciplinary research to address complex and evolving water-related challenges in Colorado and beyond. We do so by supporting with funding and building collaborative networks between higher education and water stakeholders.

Learn more at watercenter.colostate.edu/research

CWCB FY20 PROJECTS

INVESTIGATING THE IMPACT OF RECHARGE PONDS, PUMPING, AND A DROUGHT ON GROUNDWATER LEVELS AND RETURN FLOWS IN THE LASALLE/GILCREST AREA DURING 2013-2018 (YEAR 2)

Ryan Bailey et al., Colorado State University

The LaSalle/Gilcrest area in the South Platte River Basin of Colorado has experienced extremely high groundwater levels during the past six years. This has resulted in flooded basements, waterlogged crop fields, and damages to the Gilcrest wastewater treatment plant ponds.

The area, which lies on alluvial deposits interspersed with pockets of clay, relies on both surface water and pumped groundwater to sustain irrigation practices.

Work on creating a groundwater model for the LaSalle/Gilcrest area commenced in July 2016 and has led to a calibrated and tested MODFLOW model for the area. Modeling results have indicated that recharge from surface water irrigation and canal seepage are the main controls on water table elevation, and therefore may be the cause of the high water table.

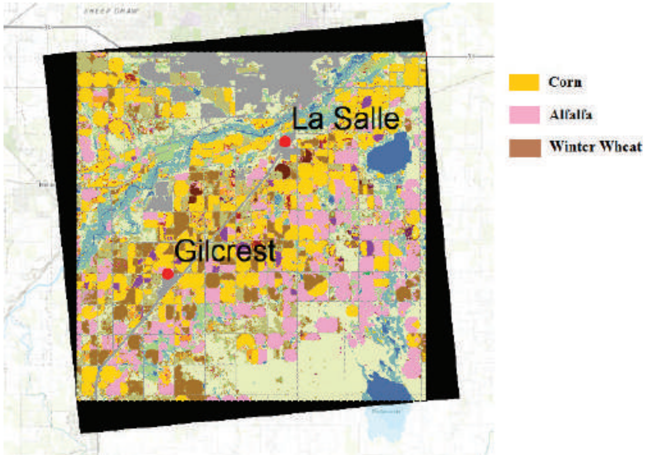
However, the influence of constructed recharge ponds on water table elevation has not been properly assessed, since the majority of recharge ponds in the LaSalle/Gilcrest area have been constructed since 2013, and the model only runs through 2012.

This project extended the refined LaSalle/Gilcrest MODFLOW model to the 2013-2018 time period to assess the influence of the recharge ponds on:

1. water table elevation in the LaSalle/Gilcrest area, and
2. volumes of groundwater discharging to the South Platte River along the LaSalle/Gilcrest alluvial corridor

A tested MODFLOW model for the LaSalle/Gilcrest area was used to quantify the impact of recharge ponds on water table elevation and groundwater return flows to the South Platte River. Results of simulations show that:

- 6-7 feet of water table elevation decrease can be achieved by eliminating all recharge ponds. However, most recharge ponds have negligible influence on water table elevation. One recharge pond (Western D Haren recharge area) has most of the influence on water table elevation, with 5-6 feet of water table elevation decrease achieved if it is the only recharge pond removed from the region.
- 3-4 feet of water table elevation decrease can be achieved by decreasing recharge pond seepage by half throughout the region; once again, most of this decrease in water table elevation can occur if the Western D Haren recharge area seepage is decreased by half.
- Removing recharge ponds from the region decrease the regional groundwater gradient, leading to a reduction in groundwater return



USDA CropScape raster plot showing crop type for each field in one of the years in the 2013-2018 time period.

flows to the South Platte River. Although the Western D Haren recharge area has the strongest influence on return flows amongst all recharge ponds, the overall effect on the South Platte River is minimal.

In general, recharge ponds have a significant impact on local water table elevation, particularly for large recharge areas such as the Western D Haren recharge areas. Although the decrease in groundwater return flow volumes is small compared to original return flows, they may be significant when analyzing water right cases and accounting for augmentation plan credits.

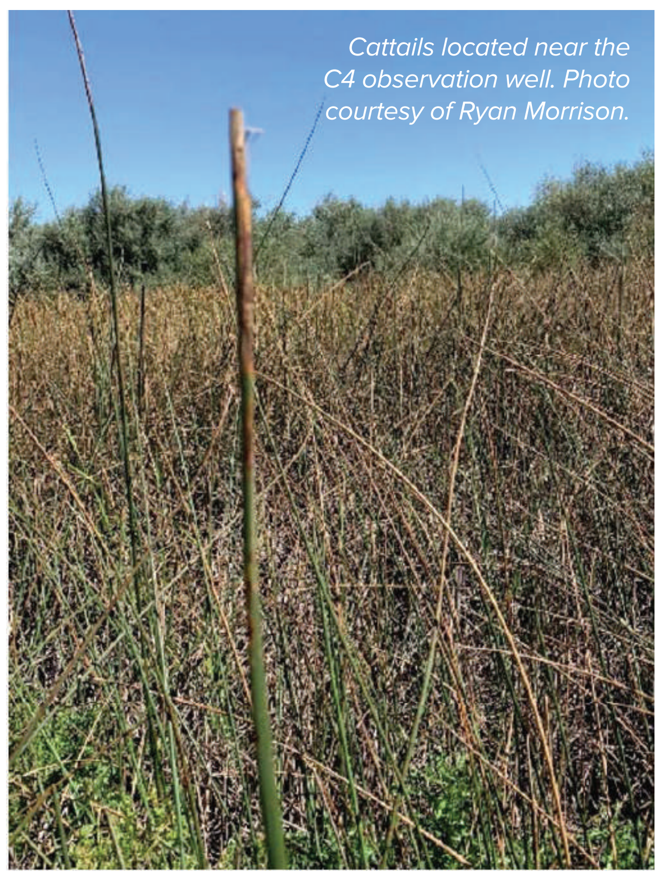
RELATIONSHIP BETWEEN IRRIGATION RETURN FLOWS, RIPARIAN VEGETATION WATER USE, AND SOLUBLE POLLUTANT REMOVAL IN THE LOWER ARKANSAS RIVER BASIN

Ryan Morrison et al., Colorado State University

The Lower Arkansas River Valley (LARV) in Colorado has an extensive history of agricultural production which has resulted in a number of challenges caused by heavy irrigation, including elevated water tables, high salinity concentrations, and large groundwater return flows to Arkansas River and its tributaries. In addition, elevated concentrations of nitrate (NO_3), sulfate (SO_4), selenium (Se), and uranium (U) in groundwater sources have prompted a search for innovate methods to improve water quality in the LARV while protecting natural ecosystem functions. Since one of the best management practices under consideration in the LARV is management of riparian buffer zones surrounding the Arkansas River (Shultz et al 2018), it is important to further understand the role of riparian zones in reducing non-point source pollution and improving water quality.

This project builds off previous work led primarily by Drs. Gates and Bailey at Colorado State University, and seeks to better represent and understand the role of riparian vegetation in reducing solute concentrations in the LARV. We worked to meet the following research objectives:

1. Improve estimates of groundwater flow partitioning within the riparian region of the LARV, and
2. Assess nitrate (NO_3), Se, and U removal within the riparian corridor with varying irrigation return flow volumes and vegetation characteristics.



Cattails located near the C4 observation well. Photo courtesy of Ryan Morrison.

Despite setbacks caused by COVID-19, the outcomes of this project include:

1. A MODFLOW-UZF2 model that we are continuing to improve and calibrate as part of an ongoing MS degree for Naveen Kumar.
2. New water quality data for sodium (Na), potassium (P), calcium (C), magnesium (Mg), chloride (Cl), carbonate (CO_3), bicarbonate (HCO_3), dissolved organic carbon, total organic carbon, boron (B), nitrate (NO_3-N), nitrite (NO_2-N), sulfate (SO_4-S), selenite (SeO_3), total dissolved Se and U concentrations.
3. Initial field assessments indicating the possible lack of riparian vegetation necessary for selenium volatilization.
4. An initial MODFLOW-RT3D model that is continuing to be developed for the ongoing PhD research for Semin Barlak.

QUANTIFYING IMPACTS OF HYDROLOGIC PARAMETER UNCERTAINTY ON DAM SAFETY ANALYSIS

Jeffrey Niemann et al., Colorado State University

Accurate hydrologic models play an important role in ensuring the safety of Colorado's dams. These models are used to determine the flow a dam must pass without overtopping or failing.

The purpose of this study is to implement three simplifications of the Woolridge et al. (2020) model and to determine the errors these simplifications introduce in the streamflow hydrographs. These simplifications are: (1) merging NFS and SFS sub-basin elements, (2) using the HEC-HMS default dimensionless time-area curve, and (3) obtaining the time of concentration and storage coefficient without in-depth GIS analysis. These simplifications are tested for the same five Front Range basins and storm events that Woolridge et al. (2020) considered.


Bear Creek scenery. Photo by PDTillman, Wikimedia Commons

For the historical events, the results from the simplified models are compared to both the observed streamflow and the results from Woolridge et al. (2020). For the design storms, the results of the simplified models are compared to the results from Woolridge et al. (2020). Each simplification is introduced sequentially into the models until all simplifications are considered.

Key conclusions from the study are as follows:

- Merging sub-basin elements produces relatively small differences from the Woolridge et al. (2020) results for the historical storms. In most cases, the merged models underestimate peak flow compared to the Woolridge et al. (2020) models.
- Merging sub-basin elements can change the streamflow production mechanisms. The altering of runoff mechanism produced the largest disagreements between the two models.
- All studied basins, except the North Fork of the Big Thompson River, have sub-basins with skewed time-area curves. For these sub-basins, a few locations have very long travel times to the sub-basin outlet. Such locations are most commonly associated with alpine lakes.

- Changing the dimensionless time-area curves to the HEC-HMS default curve without adjusting time of concentration or the storage coefficient causes small changes for the historic storms but large peak flow errors for the design storms. Specifically, the peak flows are typically underestimated compared to Woolridge et al. (2020).
- By using the HEC-HMS default time-area curve and the time of concentration equation recommended by Sabol (2008), and a storage coefficient from the ratio method, the few locations with very long travel times are neglected in a consistent manner throughout the model.
- The models with all three proposed simplifications perform very similar to the Woolridge et al. (2020) models for the historic storms.

Overall, the simplifications considered in this report require less time to implement, rely less on complex GIS procedures, and produce similar results to the Woolridge et al. (2020) models. Although the results differ case to case, the proposed simplifications typically produce more conservative results than the Woolridge et al. (2020) model. In multiple basins, the Woolridge et al. (2020) models underestimate peak flow for the historic storms whereas the simplified models better estimate peak flow or slightly overestimate peak flow.

ALTERNATIVE TRANSFER METHOD (ATM) STRATEGIC PLAN DEVELOPMENT

Nora Flynn, Colorado State University

As part of the update to the Colorado Water Plan, the Colorado Water Conservation Board commissioned a project to assess progress made to date on Alternative Transfer Methods (ATMs), and to develop a framework for moving the ATM program forward.

The ATM Support Project was funded by the Colorado Water Conservation Board (CWCB) and was a collaborative effort involving Colorado Water Center staff in Fort Collins, Pueblo, and Grand Junction, staff at WestWater Research, LLC, , J-U-B Engineers, Inc., and Fischer, Brown, Bartlett & Gunn, PC., and CWCB staff.

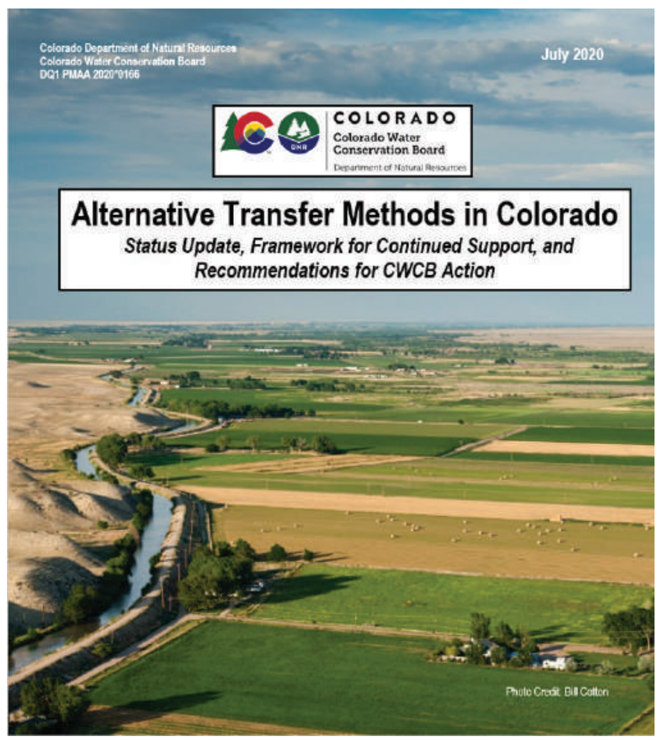
METHODS

The status of ATMs was evaluated in two parts:

1. the volume of ATM projects relative to the 2015 Water Plan goal of 50,000 acre-feet, and
2. progress in overcoming well-known barriers to ATM adoption

The team analyzed water transaction data and gathered input on ATMs through Basin Roundtable meetings, consulted with an ATM Advisory Committee, and interviewed municipal water providers and past participants in ATM projects.

More information is available in CoWC Special Report #34 at: **watercenter.colostate.edu/publicationsdatabase**



NEXT STEPS

The framework for continued analysis of ATMs provides metrics for tracking progress in terms of Water Plan goals, incentives and benefits of ATMs, and policy changes.

TOOLS FOR IMPROVING KNOWLEDGE OF RESERVOIR WATER QUALITY IN THE FRONT RANGE OF COLORADO

Matthew Ross, Colorado State University

This project was funded to develop a method for detecting algae blooms with satellite imagery based on field data, and data collected by municipalities along the Front Range (Pueblo, Denver, Fort Collins, Northern Water, and others). These field data provide direct knowledge on algal biomass (through a proxy measurement of chlorophyll A, a photosynthetically active pigment that tinges water green).

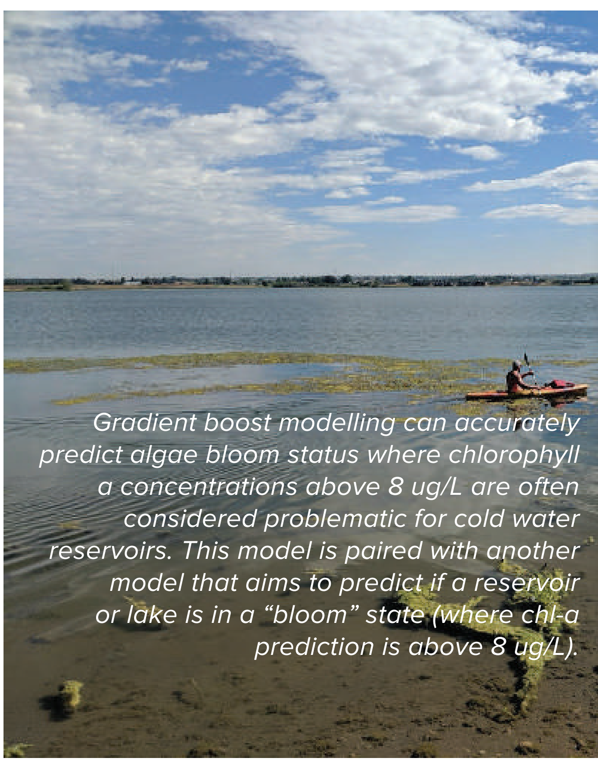
During the summer of 2019 (from June to September), two students, Miles Austin and Casey Barby, sampled nine reservoirs along the Front Range of Colorado, with on-dates coinciding with satellite overpass time for the reservoir. For each reservoir site, two water samples were collected for chlorophyll analysis and secchi depth measurement. (At spatially variable reservoirs like Horsetooth, multiple testing sites were selected.) The nine reservoirs were sampled over nine days, for a combined total of 102 chlorophyll A (chl-a) concentration values.

These field samples, paired with additional data from federal and municipal databases, were used to build and validate machine learning models that convert satellite imagery into continuous predictions of chl-a. Using Google Earth to extract average lake and reservoir color, we developed a dataset of more than 5,000 lakes and reservoirs in Colorado, with at least five observations per year, per reservoir, since 1984.

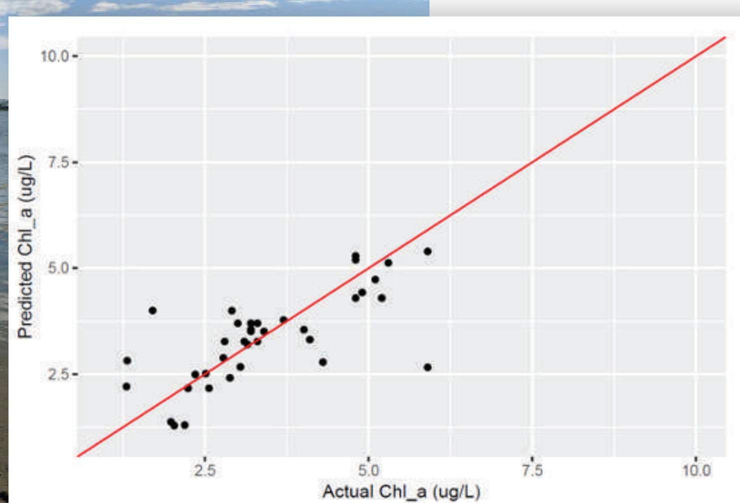
After aggregating our field data, municipal data, and federal data on chlorophyll A, we had more than 500 matchups where a satellite image was taken on the same day that a chl-a sample was taken. This dataset — the largest assembled for the state — provides an ideal dataset for building and testing models for predicting water quality from satellite imagery.

While we are still working on this modelling approach, we have promising initial results from using a machine learning approach called “gradient boost modelling.” This model can accurately predict algae bloom status where chlorophyll A concentrations above 8 ug/L are often considered problematic for cold-water reservoirs.

This model is 90% accurate, and we expect to turn it into a tool allowing managers to use satellite imagery to examine the likelihood of a bloom — a tool that is especially useful in reservoirs with little or



Miles Austin field sampling. Photo courtesy of Matthew Ross.



Gradient boost modelling can accurately predict algae bloom status where chlorophyll a concentrations above 8 ug/L are often considered problematic for cold water reservoirs. This model is paired with another model that aims to predict if a reservoir or lake is in a “bloom” state (where chl-a prediction is above 8 ug/L).

no data. We are planning to use these models to look at how algae blooms have changed over time, but this work is not yet completed.

We anticipate delivering additional future products from this research, including:

1. A short paper describing the available in-situ datasets, and how inadequate they are for understanding long-term change in algae dynamics.
2. A second paper describing our modelling approach, and analyzing long-term variation in Colorado reservoirs and lakes, with a particular focus on water-supply reservoirs.
3. A tool for managers to download our predictions, and to see data on the latest satellite imagery.

STREAMFLOW ESTIMATION IN COLORADO UNGAGED BASINS

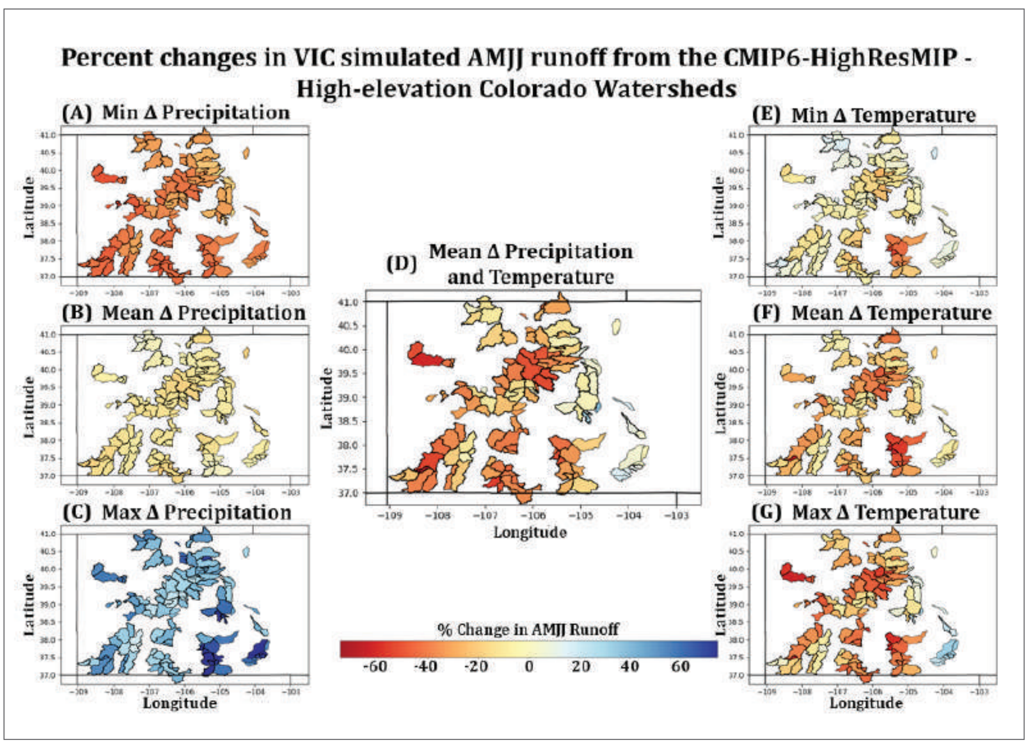
Stephanie Kampf, Colorado State University

Colorado has over 600 active stream gages, representing only a small fraction of the >100,000 miles of stream length in the state. Water managers often need to estimate flow on ungaged streams to determine water supply availability and aquatic habitat, or to manage flood risk, but existing tools for doing this can have high uncertainty and may not be appropriate for all stream types.

This project is a continuation of a project funded by CWCB via the Colorado Water Center for FY18 with a focus on two objectives: (1) validate performance of streamflow estimation methods in reference gaged basins, and (2) build and maintain a new stream monitoring network of small watersheds that span the wide range of snow zones and land cover types in the state. Our latest work expanded to include study of the effects of diversions, reservoirs, land cover changes, and climate on streamflow.

METHODS

We developed models for predicting mean annual and mean monthly streamflow and compared these



Percent changes in AMJJ streamflow generated from the gridded VIC simulations forced with projected changes in meteorology. Color scale for precipitation only delta simulations (A-C) ranges from -75% to +75% change in streamflow compared to the simulation forced with historical meteorology. Color scale for all other simulations (D-G) range from -40% to +40% change in runoff compared to the simulation forced with historical meteorology.

to the USGS regional regression equations and to the variable infiltration capacity (VIC) model.

Sensitivity of streamflow to the range of projected changes in climate (2015-2050) were evaluated using an ensemble of high-resolution (25-50 km) global climate model (GCM) projections from the CMIP6 HighResMIP[1] ensemble and the most recent version of the Variable Infiltration Capacity[2,3] (VIC5) hydrologic model. VIC5 simulations were run for each member of the representative ensemble using the same protocol by which the historical-control simulation was generated.

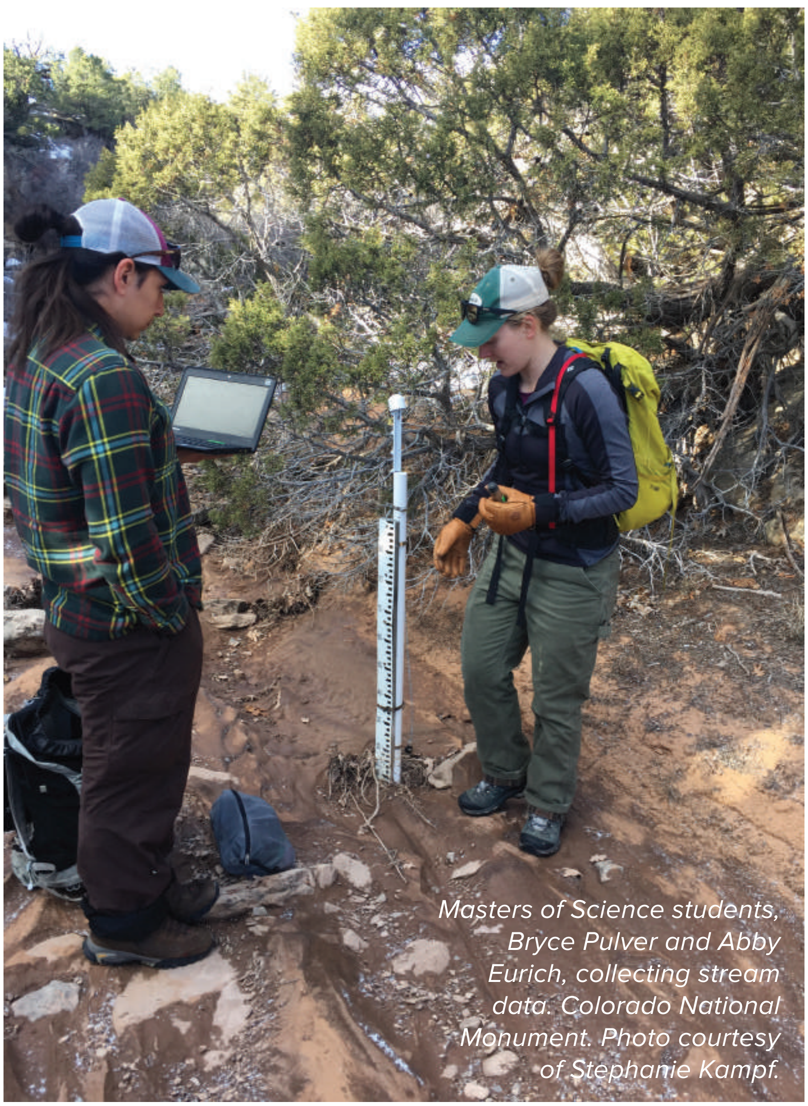
We have built up a small watershed monitoring network on the Front Range, Grand Valley, and San Juans. In each region we monitor watersheds in each of three snow zones: persistent, transitional, and intermittent. We monitor snow depth, snow water equivalent, precipitation, soil moisture, temperature, and stream stage/discharge. We also track flow presence/absence in intermittent streams along the drives to field locations; this allows us to see how our detailed monitoring sites relate to other streams in each region.

CONCLUSIONS

Researcher Abby Eurich found that transbasin diversions had the largest effect on mean annual streamflow, reducing flow by an average of 20% in watersheds with transbasin diversions out of the basin — and increasing flow by an average of 221% in watersheds with transbasin diversions into the watersheds. Urbanized watersheds also had greatly increased streamflow. The effects of forest disturbance were less pronounced, with only 25% of watersheds with forest disturbance showing a significant change in streamflow.

We find that streamflow is much more sensitive to the projected range in precipitation, with large decreases (increases) in streamflow for the most negative (positive) change in precipitation. The simulation forced with the ensemble mean projected changes in precipitation and temperature predicts mostly declines in streamflow across the gaged watersheds in Colorado, with the exception of a few watersheds on the eastern plains.

Most of the temperature change scenarios show declining streamflow as well, with the largest declines for the highest temperature scenario.



Masters of Science students, Bryce Pulver and Abby Eurich, collecting stream data. Colorado National Monument. Photo courtesy of Stephanie Kampf.

NEXT STEPS

Because streamflow sensitivity to precipitation change is large compared to sensitivity to temperature change, predictions of future flows will benefit from future work on constraining uncertainty in projected precipitation change.

We are preparing the data from our small watershed sites for public release through Hydroshare, and are working on a publication analyzing the hydrologic characteristics of the field sites and comparing them to regional patterns at long-term stream gages.

Photo courtesy of Stephanie Kampf.

EXPLORING THE POTENTIAL OF IMPROVED SOIL MANAGEMENT PRACTICES TO SUPPORT SOIL HEALTH AND WATER CONSERVATION IN IRRIGATED CORN SYSTEMS OF EASTERN COLORADO

Steven Fonte, Colorado State University

As part of the Colorado Water Plan, soil health plays a vital role in water conservation as this directly impacts agriculture and rural livelihoods across the state. However, little information is available on soil health and associated impacts on water conservation in irrigated production of Colorado. In many parts of the state, the livestock industry is an important driver of irrigated production. In these systems, intensive tillage and continual removal of corn residue (from either stover or silage harvest) often have significant negative impacts on a range of soil functions and productivity. Thus, there is an urgent need to restore and/or maintain soil health in irrigated farming systems of Colorado to help ensure the efficient capture, storage and use of water, and the long-term sustainability of these systems.

To better understand how tillage and residue management impact soil functions and water conservation, we utilized an established field trial near Akron, CO where conventional tillage and no-tillage together with residue retention and harvest have been manipulated for six years. A wide range of soil properties that encompass soil physical, chemical and biological properties were measured at two soil depths (topsoil, 0-10 cm and subsoil, 10-20 cm).

We found that the greatest differences between the management approaches was seen in the topsoil particularly for the soil physical and chemical properties measured. Soil water content, soil carbon, soil aggregate stability and other soil physical and chemical properties were best enhanced under no-till combined with residue retention management followed by conventional tillage with residue retention. While no-till and residue retention had more impact on the topsoil, conventional tillage with residue retention had the most impact on the subsoil. Soil biological diversity including macrofauna (earthworms, beetles, spiders and other soil insects), fungi and bacteria was also greatly enhanced under residue retention management at both soil depths regardless of tillage mode employed. Positive correlations were observed between soil water content and earthworm presence.

Our findings demonstrate that residue retention practices after six years of establishment in semi-arid Eastern Colorado can greatly enhance soil water conservation and other soil biological, physical and chemical properties with the greatest effects observed in the topsoil layer (0-10 cm).

RESEARCH HIGHLIGHTS

CSU FACULTY GRANT PROGRAM

KIDS POETRY ON WATER – CREATING K-12 CURRICULUM INTEGRATING WATER SCIENCE AND POETRY

Steven Fassnacht, Colorado State University

This Water Education and Engagement project developed a new K-12 program using the creative writing skill-building of literature courses to introduce students to the subject of water science. The goals of this project are to:

- engage K-12 students in exploring nature
- combine the creativity of writing poetry with the exploration of nature
- provide hands-on experiences with water
- provide early exposure to water science

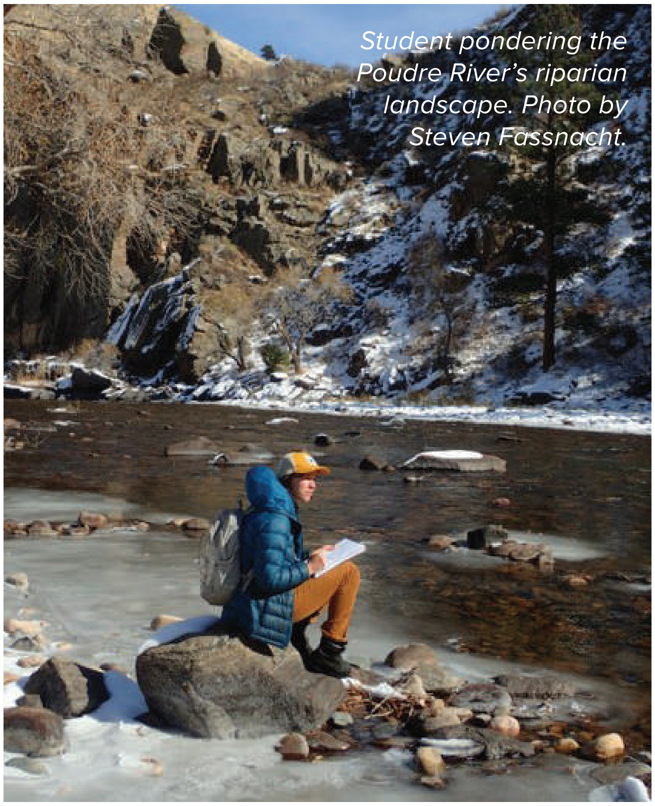
METHODS

To fulfill the goal of kids writing poetry on water, the project team partnered with Jim Glenn, an English Language Arts (ELA) instructor at Rocky Mountain High School (RMHS). As part of his U.S. Literature and Poetry class, a three-part lesson plan was implemented at the end of October and beginning of November 2019.

First, students were provided with select scientific papers to explore key words and descriptors that scientists use to write about rivers. Students were asked to write a poem using these key words as metaphors.

Second, students were taken on a field trip to Picnic Rock on the Cache la Poudre River to experience the river and its landscape. There they wrote a poem using personification of the river.

Third, printed scientific papers were provided for students to use to create a found poem by highlighting words, blacking out other words, and linking the selections together.

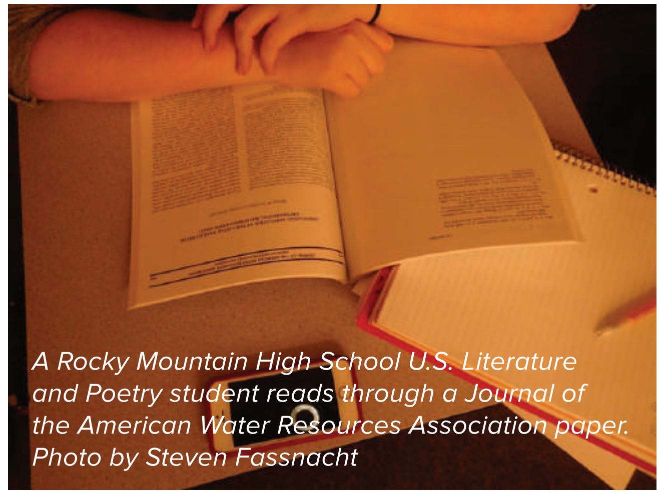


Student pondering the Poudre River's riparian landscape. Photo by Steven Fassnacht.

RESULTS

There were 23 students who participated in the class, and all submitted some of the poems. Some were unable to attend the field trip, but those who did, stated that they enjoyed the experience. This project was deemed a useful exercise and will form the basis of future work.

All four goals that motivated this work benefit the broader water community. It is important to inspire the next generations to think about water, art, and nature. With such experiences, the project team hopes to provide future decision-makers and non-scientists with an understanding of the role of water in society and as part of the human experience.



A Rocky Mountain High School U.S. Literature and Poetry student reads through a Journal of the American Water Resources Association paper. Photo by Steven Fassnacht

NEXT STEPS

The Education and Engagement project team plans to continue this Kids Poetry on Water partnership with Jim Glenn and expand it across the Poudre School District, and into other areas, such as the San Luis Valley.

Considerations for future plans include visiting the Poudre River in Fort Collins to explore the portion of the river upstream of the new Poudre River Whitewater Park. This would also enable students to explore human-altered river flow characteristics. An alternative is to access the Ross Natural Area on Spring Creek which is closer to RMHS.

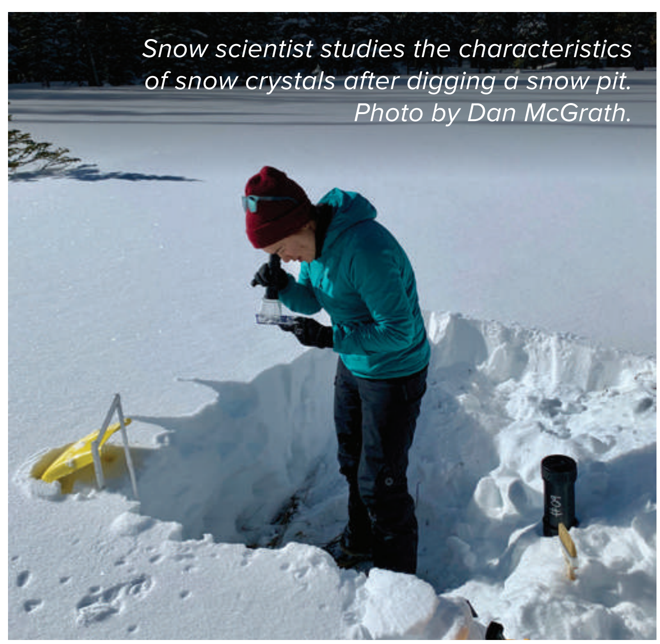
Alternate virtual experiences may include the VR simulation of the Ebro River in Spain which is currently being created and there are plans to create videos of portions of the Poudre River. The team plans to use this project as the Broader Impacts component of a National Science Foundation and/or National Endowment for the Humanities proposal.

THE CURRENT AND FUTURE STATE OF WATER RESOURCES FOR THE COLORADO ROCKY MOUNTAINS

Kristen Rasmussen et al., Colorado State University

Streamflow in the western U.S. is largely derived from seasonal mountain snow that accumulates during the winter and spring and melts during the spring and summer each year. Mountain snowpacks are experiencing climate-induced changes that include earlier snowmelt, declining snow-covered area, and decreases in the fraction of precipitation falling as snow. These changes pose a major risk to future water availability in the western U.S., yet there is uncertainty about future snow dynamics given its complex interactions with the atmosphere, land cover, and terrain.

While recent advances in the field of atmospheric science have resulted in high-resolution regional climate models, these have not previously been coupled to snow hydrology models. There is a need for models to rigorously evaluate how snow processes will respond to projected climate change, and specifically



Snow scientist studies the characteristics of snow crystals after digging a snow pit. Photo by Dan McGrath.

how water availability will be altered by changes to snow dynamics. This research targets this gap, to investigate how predicted changes in climate will modify the snow hydrology of the Colorado Rocky Mountains.

METHODS

Research team member, Glen Liston, has developed SnowModel, a suite of spatially-distributed snow-evolution modeling tools designed for application in all landscapes, climates, and conditions where snow occurs. SnowModel can be thought of as a detailed process suite that takes the understanding of snow physics and converts basic meteorology such as air temperature, humidity, precipitation, wind, and radiation, into the evolution of complex snow variables such as depth and density.

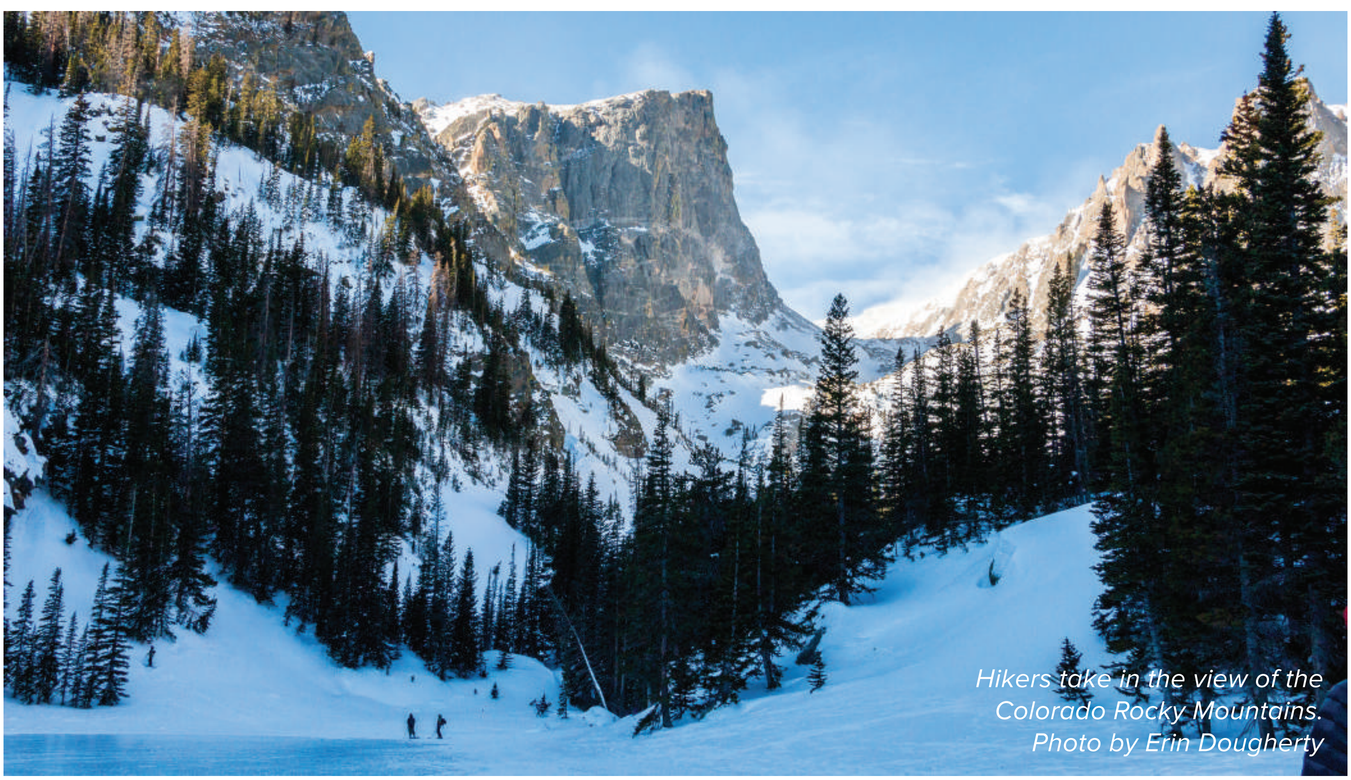
The research team downscaled the contiguous U.S. Weather Research and Forecasting Model (WRF CONUS) simulations to a domain centered on the northern Colorado Rocky Mountains for input conditions to SnowModel. The model was run at 100-m resolution over this region over two intervals: a historic (2000-2013) and future (2080-2093) period. For each year in the simulations, the start of the snow season is defined as the initial rise in snow water equivalent (SWE) and the end is once the SWE melted.

RESULTS

Future changes in SWE over the northern Colorado Rocky Mountains indicate a shorter snowpack duration with less overall SWE in all thirteen years of the simulation. In general, the snow season starts later and ends earlier in a future climate. Analysis of the length of the snow season shows that the future snowpack may be approximately 50 days shorter in each of the simulation years. The implications of these changes are significant and widely relevant to water managers, agricultural stakeholders, and outdoor sports enthusiasts in Colorado.

COLLABORATIVE IMPACT

By nature, collaboration includes three departments at CSU including atmosphere and earth system processes and the USGS Colorado Water Science Center. This type of broad and interdisciplinary work combines the expertise of all team members to use cutting-edge models to estimate snowpack changes. Through these efforts, the Water Research Team has contributed to interdisciplinary research at CSU, and has provided new information to the community about how climate change will impact Colorado's water resources.

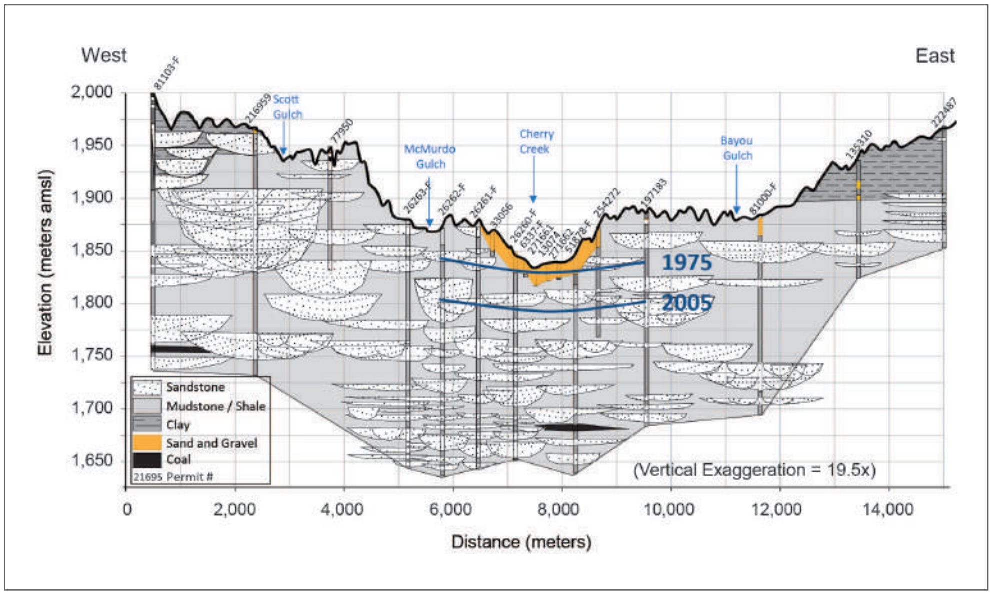


Hikers take in the view of the Colorado Rocky Mountains. Photo by Erin Dougherty

NUMERICAL MODELING OF EVOLVING RECHARGE-DISCHARGE SOURCES IN A MULTI-AQUIFER SYSTEM

Michael Ronayne, Colorado State University

Many aquifer systems worldwide are stressed by groundwater pumping. In addition to depleting aquifer storage, long-term pumping eventually affects the aquifer water budget, including the rates and potentially the sources and mechanisms of aquifer recharge and discharge. Accurate characterization of water budgets is critical for the effective management of groundwater resources.



Hydrogeologic cross-section in the vicinity of Cherry Creek, Douglas County, Colorado. Water levels from state well records are plotted for the bedrock aquifer and indicate hydraulic head declines of roughly 50 meters since 1975.

This project focused on the Douglas County region of the Denver Basin Aquifer System (DBAS) in Colorado. Several decades of groundwater pumping in the DBAS have resulted in a substantial decline of the water level, which has the potential to change aquifer water budgets. In particular, the exchange of groundwater between alluvial and bedrock aquifers is dependent on hydraulic heads within each aquifer, and the heterogeneous distribution of hydraulic properties. This research explored quantitative methods to evaluate how aquifer recharge and discharge respond to long-term pumping.

Specific questions addressed in the research include the following:

- How does geologic heterogeneity impact the alluvial-bedrock groundwater exchange?
- What hydrogeologic conditions give rise to unsaturated zones between the alluvium and bedrock?
- When do the aquifers become “disconnected,” such that further declines in the bedrock water table no longer affect seepage losses from the overlying alluvium?

METHODS

The research team conducted a detailed review of historical water level data, well logs of geologic descriptions, and borehole geophysical logs to refine the conceptual model. These data were used to constrain geostatistical simulations of the aquifer architecture. The simulations incorporate the style of heterogeneity reflected in the conceptual model: channelized sandstones embedded within a less permeable matrix of mudstone and shale.

Numerical groundwater flow models were developed based on the detailed heterogeneity for the stream-alluvium-bedrock aquifer sequence. The interacting stream, alluvial aquifer, and bedrock aquifer were modeled and evaluated for expected long-term changes in inter-aquifer exchange with pumping-induced water level declines. Numerous 2D cross-sections were evaluated using a variably-saturated flow simulator which allowed for the development of unsaturated conditions within the bedrock aquifer.

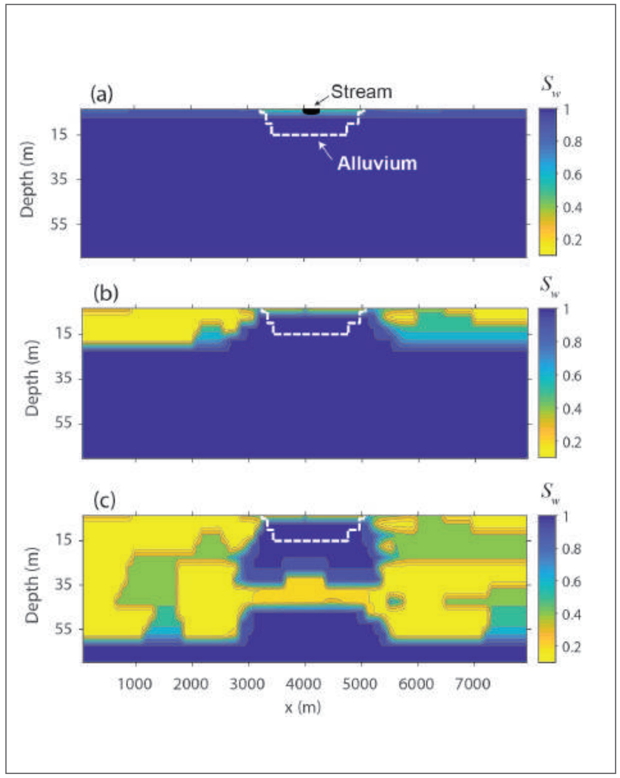
Predictive scenarios were constrained by the observed historical water level changes in Douglas

County. The focus was on the evolution of bedrock aquifer recharge, which is fundamentally important for long-term management of groundwater resources in the Denver Basin and similar multi-aquifer systems.

CONCLUSIONS & RESULTS

Study results illustrate the importance of geologic heterogeneity in controlling alluvial-bedrock aquifer exchange. When the regional water table declines, recharge to the bedrock aquifer increases. However, the rate of increase, and the potential for long-term stabilization of recharge, is critically dependent on the heterogeneity.

In areas where sandstone is separated from the alluvial aquifer by low-permeability mudstone, there is a greater tendency for the two aquifers to "disconnect," leading to an eventual leveling off of recharge. In areas where the alluvial aquifer is in direct contact with sandstone units, there is a reduced potential for disconnection, and bedrock aquifer recharge continues to increase with further lowering of the regional water table. These results show that an accurate description of aquifer structure is important for making long-term water budget assessments.



Modeled water saturations (S_w) for three scenarios with progressively lower (a → b → c) water-table positions in the bedrock aquifer.

Dawson Formation sandstone in Castlewood Canyon State Park. Photo by Kristen Cognac.

DEVELOPMENT AND LAUNCH OF A "MASTER IRRIGATOR" EDUCATION AND TRAINING PROGRAM IN NORTHEASTERN COLORADO

Amy Kremen, Colorado State University

This Water Education and Engagement project, funded by the CSU Water Center, supported the development and program delivery of a new, four-day, 32-hour in-person advanced water management training course called Colorado Master Irrigator (**comasterirrigator.org**).

This program was designed for producers and farm managers irrigating in northeastern Colorado's Republican River Basin. Colorado Master Irrigator's main goals are to:

- equip producers and others with the information they need, and a community of practice that is necessary to catalyze broader adoption of advanced, water and energy conservation-oriented technologies, tools, and strategies
- track program graduates' success in integrating these tools to save water and energy while remaining productive and profitable

Across the nation, only a small percentage of producers have extensively adopted proven tools and strategies to increase water and energy conservation and efficiency in irrigated agricultural systems. For example, on average, just over one-tenth of producers nationwide employ soil moisture sensor data to support their irrigation decisions; it's more typical for producers to rely on hand feel of soil, gauging by eye if their crops look water-stressed, and checking to see if their neighbors are irrigating (NASS, 2019).

A complex combination of practical, economical, and social factors limits broader use of advanced, conservation-oriented practices and tools. Finding ways to reduce consumptive energy use can also lead to reducing water use, which is urgently needed in groundwater-dependent regions, such as in eastern Colorado.

METHODS

Brandi Baquera, Colorado Master Irrigator program coordinator, led the multifaceted effort to adapt the Master Irrigator program developed by the North Plains Groundwater Conservation District to specifically suit the needs of Republican River Basin producers, supported closely by Amy Kremen, PI for the Colorado Water Center award.

The Colorado Master Irrigator course curriculum was designed by a 30-member program advisory committee (PAC) of volunteers. This diverse PAC was comprised of several local producers, Groundwater Management District leaders, technical service providers, state and federal agency personnel, CSU Extension representatives, and others.

Photo by Susan Hutton

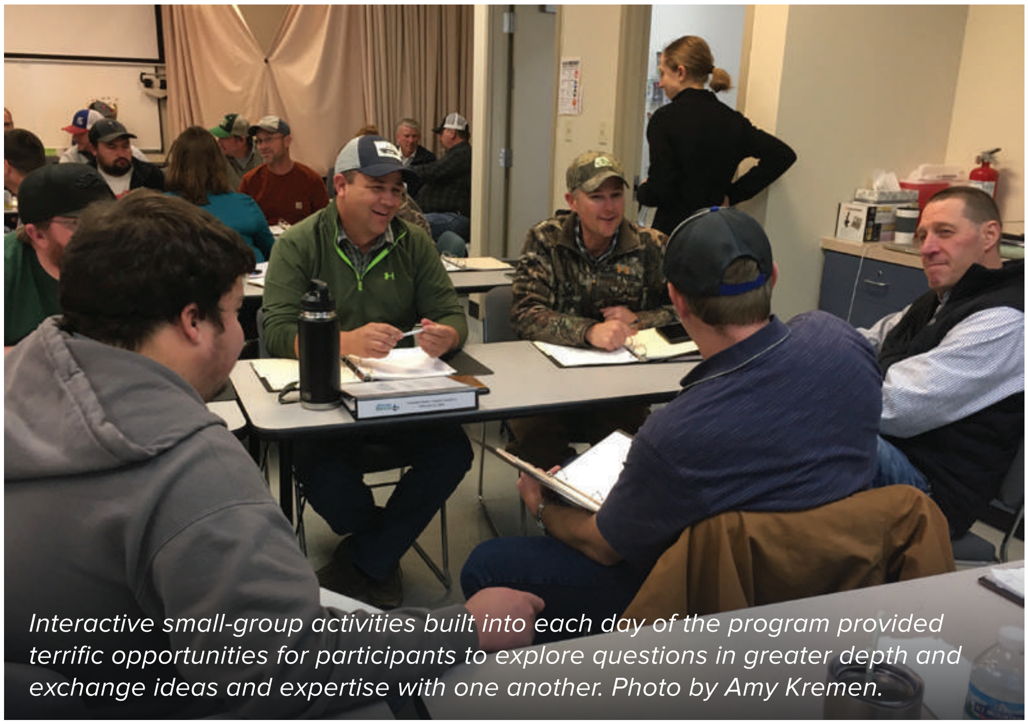
CONCLUSIONS

Notably, the inaugural class of 22 producers and farm managers represent all eight Groundwater Management Districts located in the Republican River Basin. Collectively, the group has a wide range of soil types and typical well depths/capacities of the region, operation sizes and types (crops only vs. crops and livestock, all irrigated vs irrigated & dryland), and experience (highly or less experienced) with regard to implementing and using conservation-oriented tools and practices.

Participants indicated that the program helped them gain a better understanding of different tools, practices, services, and strategies for their operations. The program also helped some learn about local hydrogeology, regional water policy, and financial opportunities that they didn't know of, or as much about, prior to participating in the class.

NEXT STEPS

Overall, this project achieved its goals of effectively developing, advertising, and launching this program as well as building a successful track record within the Republican River Basin community from its inception. The program has been able to use several small grants, including local investment in the program, to leverage additional financial support that will support the program over the next two years.



Interactive small-group activities built into each day of the program provided terrific opportunities for participants to explore questions in greater depth and exchange ideas and expertise with one another. Photo by Amy Kremen.

ASSESSING GENE FLOW OF INVASIVE BROOK TROUT TO RESTORE A META-POPULATION OF THREATENED GREENBACK CUTTHROAT TROUT IN THE UPPER POUDRE RIVER BASIN

Yoichiro Kanno, Colorado State University

This Water Fellow project occurs at the interface of altered hydrology, invasive species management, native species conservation, and population genetics. The greenback cutthroat trout is currently listed as Threatened under the Endangered Species Act. A large-scale greenback cutthroat trout reclamation effort is taking place in the Long Draw region of the Upper Poudre River between 2018 and 2033. This effort is intended to re-establish a greenback cutthroat trout meta-population in a 60-km stream network. Self-reproducing populations of greenback cutthroat trout currently occupy only 14.5 km of stream and 4 ha of lake habitats in their formerly broad South Platte River Basin range. Successful implementation of the project would result in a fivefold increase in their habitat.

Currently, a scientific uncertainty exists regarding the spatial population structure and movement of trout in the upper Poudre River, now dominated by invasive brook trout. Future management actions include basin-wide removal of brook trout prior to reintroduction of greenback cutthroat trout and construction of movement barriers to prevent re-invasion of brook trout.

METHODS

Dr. Kanno and colleagues investigated gene flow and population structure of non-native brook trout as a surrogate species in the ongoing effort to restore a meta-population of native greenback cutthroat trout in the upper Poudre River basin. In 2019, they collected genetic samples from 1,391 brook trout individuals at 20 sites, and randomly chose 796 individuals for genetic analysis using microsatellite markers.

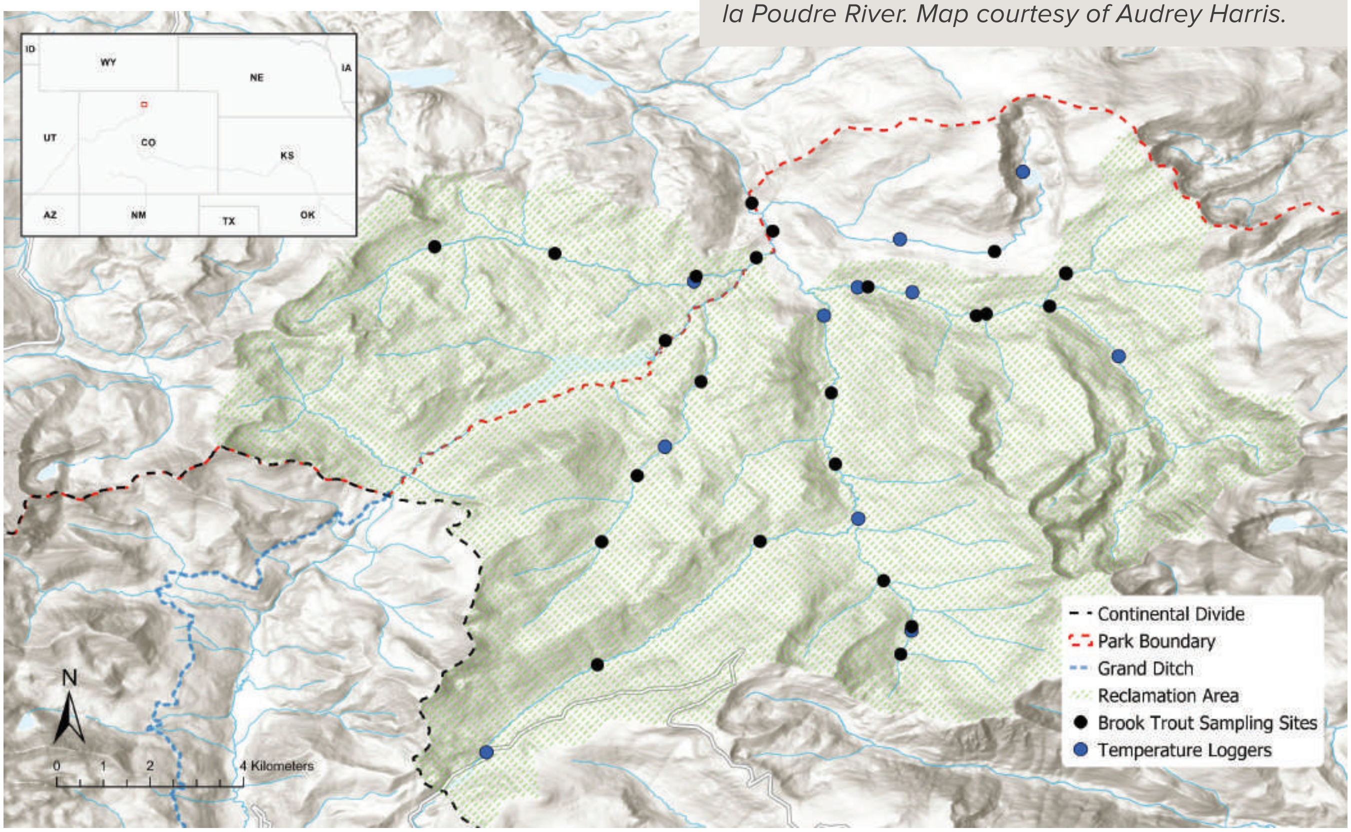
RESULTS, IMPLICATIONS, & CONCLUSIONS

Based on a preliminary analysis of existing data, it appears that samples are spatially structured by major tributary, meaning individuals can be assigned to each major tributary using genetic data with high confidence. Gene flow was observed among tributaries, meaning that brook trout move across a large headstream network. Additional analysis is warranted when the full genetic data set becomes available. A key implication, if this preliminary result holds true, is that the study area can harbor a “trout” meta-population, which had been an untested assumption in the reclamation effort of the ongoing greenback cutthroat trout restoration project.

FUTURE RESEARCH

This genetic research has led to an additional project and funding to assess cutthroat trout movement through the Grand Ditch over the Continental Divide. The Long Draw area has a hydrologic connection to the west side of the Continental Divide, which harbors a different strain of cutthroat trout. A management concern is that movement of fish through the Ditch may hamper the effort to restore and protect genetically distinct strains of cutthroat trout species. Pending a molecular study, management actions may need to be taken, such as constructing additional fish movement barriers.

Research team collecting brook trout by using backpack electrofishing units and dip nets. Photo by Kate Hansen.



Brook trout study area located in the upper Cache la Poudre River. Map courtesy of Audrey Harris.

HARNESSING THE POWER OF THE CROWD TO MONITOR URBAN STREET FLOODING

Aditi Bhaskar et al., Colorado State University

Cities in Colorado and throughout the U.S. face increasing costs to the economy and threats to the health and safety of communities caused by flooded streets. This multi-disciplinary Water Research Team addressed the problem of urban flooding. Using the watershed of Harvard Gulch located in Denver, Colorado as a case study, the team compared the experiences reported by residents with the modeled flooding.

Two types of urban flooding occur in Colorado:

1. fluvial flooding caused when streams overtop their banks
2. pluvial flooding when precipitation intensity exceeds the capacity of natural and engineered drainage systems and flooding inundates streets and structures

Green stormwater infrastructure (GSI) offers one method to mitigate street flooding, such as bioretention cells which reduce the amount of water entering the subsurface stormwater network. The team investigated how GSI affects street flooding depth and extent in Harvard Gulch, an 8.26 km^2 watershed.

METHODS

A dual drainage model was developed to model the interactions between overland flow and the subsurface stormwater network. The model was used to simulate the response to a storm from 15:45 MDT to 23:45 MDT on June 24, 2015, during which a total rainfall of 20.07 mm fell. There were 1,067 municipal service requests reporting street flooding from 2000-2019 in Denver with uneven distribution across the city. The location

Photo via floodtracker.org

of these complaints was compared with model results. Four GSI scenarios were evaluated.

RESULTS

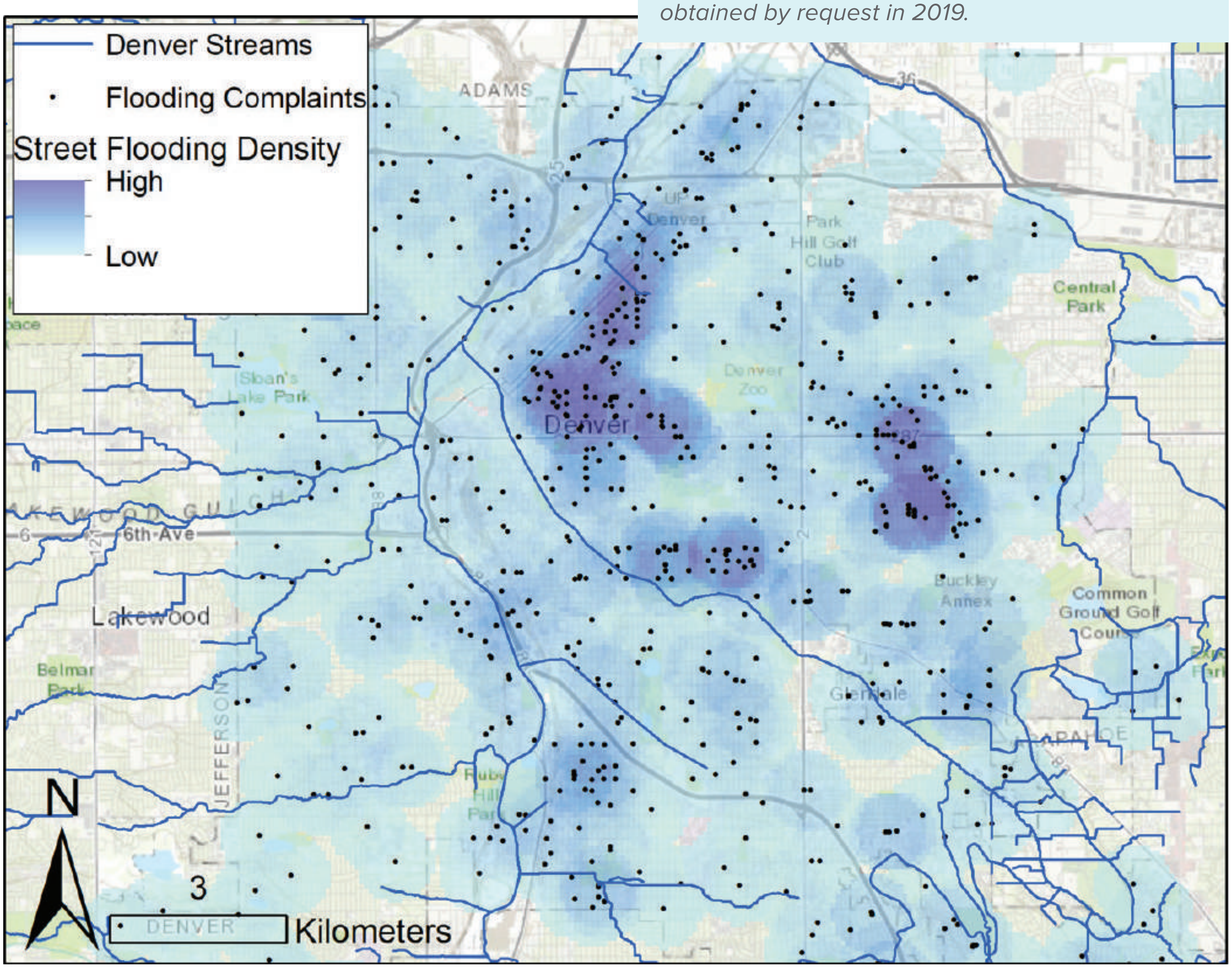
Generally, the model showed flooding in locations where residents reported recurring flooding to the Denver Department of Public Works. There are areas at the downstream (western) edge of the study area with flood depths near 1m (3.28 ft) with no occurrence of co-located resident reports. However, there were flooding complaints from this storm which did not note the location of the report.

The extent of stormwater street flooding was smaller in GSI scenarios compared to the baseline (Pre GSI) scenario. As more DCIA was converted to GSI, street flooding extent decreased as did the mean street depth. However, the most efficient scenario to reduce the extent of street flooding was the scenario with 2.5% GSI conversion from DCIA. In contrast, the largest reduction in mean street flood depth occurred for the scenario with 1% GSI conversion to DCIA, and the efficiency decreased as the percentage of DCIA converted increased.

NEXT STEPS

To improve the prediction and mitigation of street flooding, more widespread observations are needed. Flood Tracker (floodtracker.org), a crowdsourced citizen science app, was created by CSU researchers to fill this gap. Users submit locations of street flooding, with optional information on flooding depth (below or above curb), flooding extent (number of lanes affected), and photos. This project sets the groundwork for developing future research and engagement on street flooding monitoring, modeling, and mitigation in urban areas in Colorado.

Street flooding complaints and density from municipal service requests to Department of Public Works, City and County of Denver, obtained by request in 2019.



COLORADO WATER CENTER

STAFF UPDATES

ENGAGING STAKEHOLDERS AND COMMUNITY LEADERS IN CRITICAL WATER DISCUSSIONS

Julie Kallenberger, Water Education Specialist & SWIM Advisor, Colorado Water Center

Coloradoans again played an active role in discussions, partnerships, decisions, and learning — all of which prove to be essential as our state continues to experience pressures on limited water supplies. Over the past year, the Colorado Water Center (CoWC) continued to serve local communities as an unbiased convener and facilitator. Two of the Center's prominent programs, Water Literate Leaders of Northern Colorado and the Poudre Runs Through It Study Action Work Group, allow time and space for stakeholders to confront tough conversations, tradeoffs, and decisions associated with water.


Poudre River Forum attendees engage in discussion about water quality and the Poudre River. Photo courtesy of Tina Chandler.

WATER LITERATE LEADERS OF NORTHERN COLORADO

Many values are important to the citizens of Northern Colorado, including preserving agricultural land and open space, ensuring high-quality drinking water, healthy rivers and environment, vibrant communities, and robust economies. For local leaders to make sound decisions related to water issues, they seek relationships with other leaders throughout the region as well as reliable, unbiased information from water experts.

Recognizing this need, CoWC developed the Water Literate Leaders of Northern Colorado program, offered

"Within just a few sessions I felt better able to contribute to complex water policy discussions and more fully understood the historic context around a variety of water issues facing Northern Colorado."
Water Literate Leaders Participant

in partnership with the Community Foundation of Northern Colorado. To date, the program has cultivated three cohorts consisting of 63 leaders from all different sectors with the goal of raising the level of dialogue about water to the top decision makers in the region.

2020 marked the close of our third year of the Water Literate Leaders of Northern Colorado Program. A diverse group of 24 community leaders from across the Poudre and Big Thompson river basins engaged in eight months of learning about the many facets of water, discussing tough issues and associated tradeoffs, exchanging ideas, and working towards how Northern Colorado can best achieve its goals for regional water collaboration. Interested in learning more about Water Literate Leaders? Visit **watercenter.colostate.edu/wll**.

Water Literate Leader participants learn about the history of water development in Northern Colorado and how the region receives supplemental water supplies from Colorado's West Slope. Photo by Julie Kallenberger.


Water Literate Leaders learn about the intricacies of water supply, storage, and delivery. Photo by Julie Kallenberger.

THE POUDRE RUNS THROUGH IT STUDY / ACTION WORK GROUP

The Poudre Runs Through It Study/Action Work Group (PRTI), consisting of two dozen experts involved in various communities throughout the Basin, continued to work toward their goal of making the Poudre the best example of a healthy, working river.

A new initiative of PRTI charged a subcommittee of agricultural, urban, environmental, and recreational water users to share current flow conditions and identify opportunities to increase coordination among consumptive and non-consumptive water users. Additionally, PRTI members were instrumental in developing Colorado House Bill 20-1037, passed in early 2020, a step toward allowing owners of certain augmentation water rights to be able to "deposit" water into a new Poudre Bank.

The 8th Annual Poudre River Forum, Quality Collaborations: Coming Together to Ensure Clean Water for a Healthy, Working River, engaged over 350 community members, water managers, professionals, scientists, and students from throughout the Basin to learn about the Poudre River's water quality, discuss challenges, and explore opportunities to collaborate on this salient topic. Thirty-five water organizations and industry partners participated as display hosts. This year's forum was made possible by the generous support of 54 different sponsors. Learn more about the 2021 Poudre River Forum at **poudreforum.com**. Learn more about PRTI at **watercenter.colostate.edu/prti**

WATER RESEARCH AND OUTREACH IN SOUTHERN COLORADO

Blake Osborn, Regional Water & Extension Specialist, Colorado Water Center & CSU Extension

The changes brought by COVID-19 allowed research projects to rise to the top of my "to do" list, as most are in the field and well within the social distancing requirements. I have now concluded two larger research and education projects:

1. The Lower Arkansas River Watershed plan was finalized and submitted last fall. This project was meaningful for its ability to develop a vast stakeholder coalition to help improve water quality in an agriculturally dominated watershed.
2. The Upper Arkansas River Water Balance Study – Phase 2 work wrapped up this past summer. This was important for collecting data and developing crop coefficients for high-altitude grass hay crops that can be used in irrigation scheduling tools for better water management.

The real value in both of these projects was in the lessons that I learned, and the connections they created toward better understanding how our work at the Colorado Water Center — and my position in southern Colorado specifically — is tied into the larger conversations and decision-making within the water community.

For more information, or to read the watershed plan, visit **lowerarkplanjm.com**, or contact me directly. I am also available to provide more information on the grass water-use and crop-coefficient project. I can share data, graphs, summaries, and reports.

Over the past year, I have started new projects in hemp varietal trials, post-wildfire "hydro-assessments," and the nexus of stream restoration, hydrology, and water rights. This work included: Stream Restoration and Water Rights: Hydrology, Policy, and Community Development.

Most of us recognize the need to balance healthy rivers and river ecosystems with flood protection, infrastructure development, water quality conditions, etc. New development continues to re-engineer stream and wetland habitats on larger and smaller scales.

Regardless of approach, little is understood about the hydrological impacts of river and stream restoration, and even less is understood about how stream restoration could impact water rights.

In 2019, I developed a pilot project, along with the help of other stakeholders, with the goal of understanding how novel stream restoration treatments might impact surface-groundwater interactions, and how this could impact water rights holders on the stream system. Our goal is to better understand how low-tech and process-based restoration treatments impact surface-groundwater dynamics, specifically within the alluvium.

I have gathered the support and collaboration from a variety of groups, including municipal and private landowners, and have even worked to develop a local high-school class that uses this research project as its field component. This new class, River Science, is designed to give students practical skills that apply in a water resources career field.

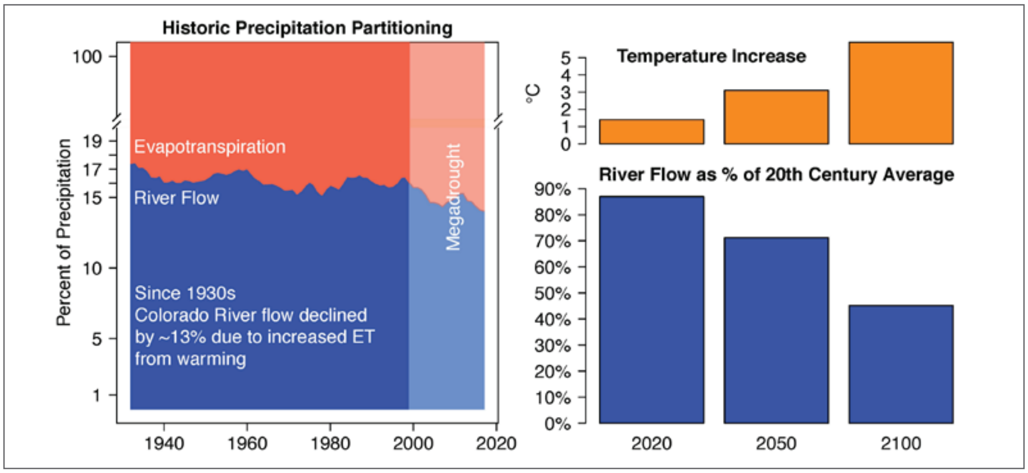
This entire project will be successful if we can use data to further our understanding of surface-groundwater connections in our stream systems, better predict their impacts to downstream water rights, and educate/train the next generation of water professionals.

Photo by Nick Weber

EDUCATING ON THE CONNECTION BETWEEN CLIMATE CHANGE AND WATER SUPPLIES

Brad Udall, Senior Water and Climate Research Scientist / Scholar, Colorado Water Center

During this past year, I continued with my longstanding focus on how climate change has been and will continue to impact our water supplies. My efforts spanned several areas of work.



Climate change is causing the Southwest to aridify. (Left) Since the 1930s, increasing temperatures have caused the percentage of precipitation going to evapotranspiration (ET) to increase at the expense of precipitation going to Colorado River flow, resulting in an unprecedented and still ongoing megadrought (shading) starting in 1999 (8). (Right) Higher temperatures have already reduced Colorado River flow by 13%, and projected additional warming, assuming continued high emissions of greenhouse gases, will increase ET while reducing river flow even more through the 21st century.

OUTREACH & PRESENTATIONS

Presentations and guest-lectures included:

- An overview of the State of Colorado River Science at the Upper Colorado River Commission meeting, which took place as part of the Colorado River Water Users Association Meeting in Las Vegas, in December of 2019.
- Several presentations on climate change and water management at the Society of Environmental Journalists Annual Meeting in Fort Collins
- Sybil Sharvelle's graduate, and Howard Ramsdell's undergraduate classes at CSU
- The Colorado Legislature's Interim Water Committee at the State Capitol in September 2019
- Overview of the Colorado River and Climate Change at the National Judicial College's Dividing the Waters Project

EXPERT REVIEWS

I was asked to provide expert reviews of:

- A chapter of the recently released State of the Science Report on the Colorado River
- The upcoming Intergovernmental Panel on Climate Change chapter on North America, as an invited U.S. Federal reviewer
- Two articles submitted for publication (peer-review)

PUBLICATIONS & DATASETS

In April, along with longtime co-author Jonathan Overpeck, now Dean of the University of Michigan School of Environment and Sustainability, I wrote Climate Change and the Aridification of North America. This invited commentary was in the Proceedings of the National Academy of Sciences, and discusses why flows are declining across North America, including in unexpected, northern basis.

I constructed a series of temperature-adjusted natural flows for the Colorado River for use by decision-makers. These flows provide plausible but very low flows that might occur with increased warming during the 21st century.

I've engaged with scientists at Utah State University on the Colorado River Futures Project, and we've just released an extensive whitepaper on Colorado River hydrology — including another set of plausible future low flows for use by decision-makers as they grapple with renegotiations over Colorado River interstate management.

PRESS CONTACTS

I assisted with the Washington Post's August 2020 article on the climate warming hotspot in Grand Junction. I also worked with reporters from Politico, the Denver Post, the Arizona Daily Star, Colorado Public Radio, and the New York Times, among others.

ONGOING WORK

My current work includes investigations into why runoff in recent years has been so low relative to precipitation, including the connection to declines in soil moisture.

Additionally, along with Julie Vano of the Aspen Global Change Institute, I am building a wiki website, **coloradoriverscience.org**, to provide decision-makers with continuing updates on new scientific developments in the Colorado River. The website will cover data, science, projects, models, tools, and all other appropriate scientific endeavors in a wiki-like format. This is funded by the DOI Southwest Climate Adaptation Science Center.

I continue to support the activities of the Northern Plains Climate Hub, and also work with Denver Water and CSU employees to design the Western Water Policy Institute to be housed at CSU's new SPUR Campus in Denver. I've also been designing a course on Climate Policy for use there.

COLORADO MASTER IRRIGATOR PROGRAM

Joel Schneekloth, Regional Water Specialist, Colorado Water Center & CSU Extension

In 2019, local producers and agencies within the Republican Basin decided to duplicate a program from Northern Texas called the Master Irrigator Program. The intent is to educate irrigated producers on technology and management practices to increase their efficiency, and help them make better decisions. The anticipated result is increased water-use efficiency and/or decreased water use within the Basin.

TRAINING TOPICS

Topics covered the use of soil moisture probes, remote sensing and imagery, as well as impacts of management practices on soil water and yields.

Much of 2019 saw planning meetings to develop objectives, outcomes, and relevant topics that would help producers understand key Basin issues, and management practices relevant to the Basin. Grants

The inaugural Colorado Master Irrigator class of 22 producers and farm managers are involved in the management of approximately 20,000 irrigated acres located across the Republican River Basin, within all eight of the Basin's groundwater management districts. Photo by Hannah Moshay.

totaling more than $300,000 were obtained to support the training, and to help implement conservation practices for the participants. Presenters were brought in from four states to expand the impact and range of discussion for the attendees.

Unfortunately, the COVID-19 pandemic impacted the ability of participants to engage in a planned, summer-long opportunity to work directly with producers and observe management changes and results.

RESULTS & NEXT STEPS

Participants evaluated the course, and we received overall very positive feedback. Many participants indicated that the knowledge gained from the course would help them improve their irrigation management practices in the future, for a positive impact on water conservation and potentially the economics of their operations.

Additionally, throughout the development of this program, we received a great deal of interest from other basins in expanding the program to their areas.

"[The class] made me realize with little time and money I can probably improve my irrigation applications that will increase efficiency and make it easier to conserve."

"We want to learn more about the technology that will help us provide the precise amount of water that each crop needs at the precise time."

2020 Master Irrigator participant statements:

WESTERN REGION CONSUMPTIVE USE EVALUATIONS

Perry Cabot, Regional Water Specialist, Colorado Water Center & CSU Extension

The Specialist for the Western Region of Colorado Water Center (CoWC) engages with stakeholders spread across the Colorado, Gunnison, Yampa/White/Green and San Juan/Dolores basins. This Region considers the Western Colorado Campus (WCC) in Mesa County as its base, where several applied research and extension projects are underway. The WCC centralizes three Agricultural Experiment Stations, of which one is designated strictly for the purpose of irrigation and water resources research. Priority interests of the Western Region include on-station and off-station consumptive use (CU) evaluations of grass pastures through remote-sensing, applied research on cropping alternatives to traditional forages, technology that more efficiently applies water through drip irrigation, and engagement with stakeholders, water resource management districts and industry partners.

METHODS & NEXT STEPS

Sub-Surface Drip Irrigation System. In 2019, Phase I of construction on a research field dedicated to sub-surface drip irrigation (SDI) system was completed, to allow watering of 22 individual plots (3,600 sf; 0.08 ac), each with separate control valves. As mentioned in last year's report, Phase I also involved installation of the controller, pump, piping, and filtration equipment. In 2020, Phase II was completed, which involved valving and injecting tape for the next 22 plots. Installing the SDI system by ourselves has been frustrating at times, but highly useful for capacity-building. As a result of the knowledge gained during construction and industry partners developed, the CoWC is in a position to better educate farmers on the complexities of SDI, from installation, engineering, operational and financial perspectives.

Consumptive Use of Cannabis Sativa. Two of the SDI plots were used this year to conduct a research project focusing on the measurement of CU rates and associated hemp management practices for hemp (Cannabis sativa) grown for the cannabidiol (CBD) industry. The project was conducted in Mesa and Montezuma counties using hemp clones and seedlings locally sources from industry partners Colorado Hemp Solutions and EcoGen Biosciences. At both sites, drip irrigation was used with metering and monitoring equipment to estimate hemp CU rates for optimally irrigated conditions. Yields and levels of THC in hemp crops are being evaluated under optimally and suboptimally irrigated conditions, along with weed and insect pressures.

Conserved Consumptive Use Evaluations. The CoWC is the lead for a collaborative project partnering with Utah State University, Trout Unlimited, The Nature Conservancy, Colorado Water Conservation Board and OpenET, local farmers in Grand County. The project team is integrating remotely sensed estimations of conserved consumptive use, strategies for reduced consumption, economic considerations, forage yield and quality impact of reduced pasture irrigation, and producer engagement. Multiple project fields totaling over 1,000 acres have been subjected to full season and split season irrigation for this project 2020. Collecting this information has been identified as an important contribution to understanding the impacts and benefits of alternative transfer methods (ATMs) on the Western Slope.

Dr. Perry Cabot taking soil moisture measurements with neutron probe at an irrigated pasture research location in Kremmling, Colorado. Photo courtesy of Perry Cabot.

Large hemp plant with neutron probe measurements being taken using access tube (30 in depth) located next to plant mainstem. Photo courtesy of Perry Cabot.

Drip tape and plastic layers being installed by Greg Litus and Jimmy Fry at the Southwest Colorado Research Center in Yellow Jacket, Colorado. Photo courtesy of Perry Cabot.

YEAR IN REVIEW

GRAD592

The CoWC organizes and conducts a graduate level course offered in the fall at CSU. GRAD592 is taught by Jennifer Gimbel, CoWC's Senior Water Policy Scholar, and hosts interested students in a variety of degree fields and academic ranks.

Described as an interdisciplinary water resources seminar, GRAD592 offers its attendees the opportunity to learn from and engage with distinguished lecturers from a variety of fields on the basis of each semester's theme.

In Fall 2019, the course theme was "Transboundary Aquifer and River Governance" and covered a multitude of sub-topics including:

- Western Water Law
- Lower Colorado River Issues
- Wyoming Water Issues
- Kansas Water Issues
- International Water Issues with Mexico
- Interstate Water Law
- Politics, Political Will, & Bureaucracy

While offered for school credit at CSU, the course is also open to the public and welcomes anyone who wishes to educate themselves on the issues and challenges that Colorado water managers and users face.

To learn more and watch previously recorded lectures, please visit **watercenter.colostate.edu/grad592**

IMPACT HIGHLIGHTS
FALL 2019

12 students

9 different majors

» Agricultural & Resource Economics

» Atmospheric Science

» Civil Engineering

» Earth Sciences

» Ecology

» Human Dimensions of Natural Resources

» Natural Resources Stewardship

» Soil & Crop Sciences

» Watershed Science

11 guest speakers

GES120

IMPACT HIGHLIGHTS
FALL 2019

is a 100-level course for CSU undergraduates who are interested in exploring and learning about various water-related topics. The curriculum is designed to familiarize students with the role that water plays in supporting different water users, the history of water development, processes and organizations that govern water allocation, tradeoffs that come with limited water supplies, and how to ensure the sustainability of water in an arid region such as the West. Students who complete GES 120 can apply three credits towards the SWIM program. Learn more about this course at **watercenter.colostate.edu/ges120**.

42 students

15 different majors

"Everyone has a right to clean water and I want to make sure that happens." *Jameson Lumpkin, Spring 2020 graduate in Environmental Engineering*

MINOR PROGRAM

Training future water experts

The Sustainable Water Interdisciplinary Minor (SWIM) is open to all majors and provides students with the opportunity to gain deeper knowledge about the many dimensions of water and prepare for a career in water or graduate study. Since the program was revamped in 2015, 43 students representing 14 different majors have graduated with the SWIM, and another 23 are currently enrolled. The program is offered in partnership with the School of Global and Environmental Sustainability at Colorado State University. Learn more about the program at: **watercenter.colostate.edu/swim**.

43 graduates

14 different majors

"I think having the SWIM on my resume helped boost my resume when I was applying and interviewing for my job." *Sara McMahan, Spring 2020 graduate in Civil Engineering*

PUBLISHED REPORTS

Educating the public on recent research

For an archive of publications, please visit **watercenter.colostate.edu/publicationsdatabase**

The Colorado Water Center (CoWC), previously known as the Colorado Water Resources Research Institute and the Colorado Water Institute, has published hundreds of water-related research reports and studies dating back to 1965. CoWC reports for all funded projects is available for public access on CoWC website in addition to its publications ***Colorado Water*** and ***The Current***, which frequently include summaries of research projects and their impacts on Colorado water managers and users. Available reports are organized into the following categories:

- **COMPLETION REPORTS**
- **INFORMATION SERIES**
- **TECHNICAL REPORTS**
- **SPECIAL REPORTS**
- **OPEN FILE REPORTS**
- **ADDITIONAL PUBLICATIONS**
- **WATER IN THE BALANCE**

COLORADO WATER

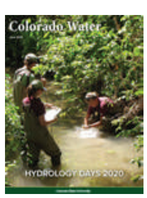
CoWC's Print Newsletter

For an archive of newsletters, please visit **watercenter.colostate.edu/colorado-water-archive**

2,230+ subscribers

17 countries

Map ©Vecteezy



V36, I3 Jul/Aug 2019
Hydrology Days

V37, I1 Jan/Feb 2020
Research Reports

V37, I2 May/Jun 2020
Hydrology Days 2020

SUBSCRIBE to *Colorado Water* to learn about research funded by the Colorado Water Center
tinyurl.com/CoWater-subscribe

THE CURRENT

CoWC's monthly e-newsletter

For an archive of e-newsletters, please visit **watercenter.colostate.edu/the-current-archive**

Water-related research, education, events, jobs, grants, scholarships, and community partner news

The Colorado Water Center (CoWC) connects with the community through our e-news, **The Current**, with a readership of 918 subscribers. Over the past year, CoWC published eight issues that featured water-related updates including outstanding university researchers in Spotlight articles, important events, new data tools, educational resources, funding and scholarship opportunities, and much more.

Eight students and seven faculty and staff were showcased throughout the year for their contributions to water research and teaching. Several of those researchers were funded through the CoWC's grant programs. These conversations shed light on what motivates their cutting-edge science and the impact they are working to achieve. All share a common passion for improving how water resources are managed and conserved. Deeper connections to CoWC were made through these informal interviews, which allowed for sharing more personal experiences beyond the data and research.

We've also had opportunities to spread awareness of new data tools and other resources. Among several new projects shared are **Flood Tracker**, a citizen science app developed by a team at CSU and funded by CoWC; a **Stream Management Plan Resource Library**; the **Delph Carpenter Diaries Project**; and **CSU Spur educational resources**. Exciting current events included the opening of the **CSU Environmental Justice Center** and the **Four Corners Water Resources Center** at Fort Lewis College, celebration of **2020 SWIM graduates**, the **Business for Water Stewardship campaign**, and CSU awards.

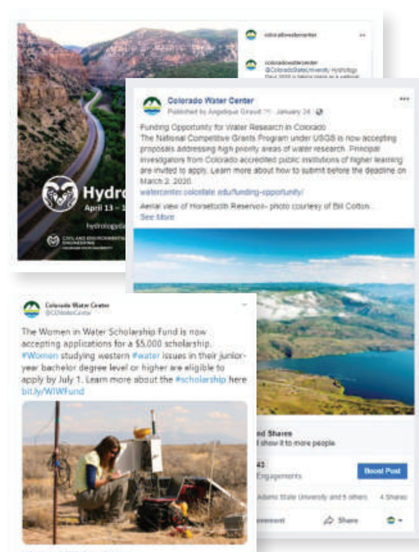
SUBSCRIBE to *The Current* to keep up with the Colorado water community
tinyurl.com/TheCurrent-subscribe

SOCIAL MEDIA

Connecting with Colorado water managers and users

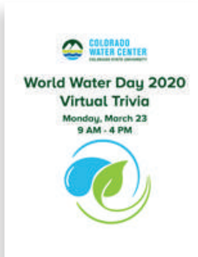
Follow the CoWC on all your favorite platforms: @COWaterCenter @ColoradoWaterCenter

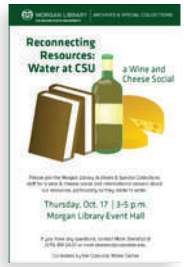
Platform	Total Posts	Engagement (Likes, Comments, etc.)	Audience Increase
Facebook	203	1,551	11%
Twitter	226	2,342	45%
Instagram	99	-	100%



EVENTS

Engaging current & future water leaders





Angelique Giraud, Colorado Water Center

Throughout the past year the Colorado Water Center (CoWC) sponsored, co-hosted, and partnered on more than 16 water-related events. The health precautions prompted by COVID-19 forced the cancellation of several other events, though many were still offered virtually. Events were promoted through social media platforms, CoWC publications, electronic emails, digital and print signs, and by sharing information at other events and meetings.

CoWC co-hosted the Reconnecting Resources event with the CSU Water Resources Archive by inviting partners to display, and getting students, faculty, and staff to attend. The Archive offers a vast collection of content from individuals and organizations on water resource management, engineering, law and legislation, endangered species, and more. The goal of the event was to connect water organizations across campus, and to encourage the CSU community to utilize this unique collection.

CSU brings new and prospective students to campus throughout the year to learn about the resources and programs offered. Together with our partners at the School of Global Environmental Sustainability we promoted the Sustainable Interdisciplinary Water Minor, plus opportunities for undergraduates to engage in water activities at CSU.

Student engagement is highly encouraged at CoWC hosted and partnered events. CoWC regularly supports students to attend events — like the Poudre River Forum and AGU Hydrology Days — by covering their registration fees.

The Hydrology Days event, as well as CSU Earth Week, were both adapted to be held virtually, and CoWC staff worked with organizers to adapt content into compelling virtual programming. Hydrology Days featured 21 presentations over two days, with 14 being from students.

In all, the CoWC hosted, co-hosted, or sponsored these 15 events, in cooperation with campus and community partners.

1. River Voices: The Confluence of Art and Science
2. Pedaling the Poudre
3. Geological Society of America Birdsall-Dreiss Distinguished Lecture
4. Reconnecting Resources: CSU Water Resources Archive
5. Adopt-a-Highway Cleanup
6. Value of Water Campaign's Imagine A Day Without Water
7. CSU Spur Water in the West Symposium
8. Ag Water Summit: Colorado Ag Water Alliance
9. Choose CSU, Discover CSU, and Spring Transfer Student Visit Day Resource Fair
10. 7th Annual Poudre River Forum
11. Confluence 2020: Western Collaborative Conservation Network
12. World Water Day Virtual Trivia Event
13. American Geophysical Union (AGU) Hydrology Days
14. CSU Earth Week: Earth Day Virtual Trivia Game
15. The Greenway Foundation's Gala on the Bridge and Reception on the River

UPPER YAMPA WATER CONSERVANCY DISTRICT JOHN FETCHER SCHOLARSHIP 2019-2020 RECIPIENTS

Allison Altimore, Colorado Water Center

The Upper Yampa Water Conservatory District John Fetcher Scholarship provides financial assistance to a committed and talented student who is pursuing a water-related career in any major at a public university within the state of Colorado. Congratulations to this year's scholarship recipients, Natalie Collar and Claudia Corona.

Collar has a bachelor's and master's degree from the University of California Santa Barbara in biological science, focusing on ecology, evolution and marine biology and water resources science. She is commencing her doctoral work at Colorado School of Mines in the Hydrological Science and Engineering department with her dissertation focusing on post-fire hydrology with an emphasis on impacts to runoff volume. Her last 14 years have been spent studying and working in the realms of water supply and water quality and she is embarking on a PhD that will asses the ways in which fire changes the partitioning of water in the landscape. Prior to going back to school to get her doctorate, Collar worked for three and a half years at Denver's Wright Water Engineers, Inc. as a certified floodplain manager becoming a leader in her company for her peer group. Ideally, her goal is to be instigating change as a program director at a federal agency when her career culminates.

Since beginning at CU Boulder in 2018, Corona joined the steering committee for the Annual Hydrologic Sciences Symposium and has been an integral member of the committee, contributing to many decisions and projects she was involved in, including writing two successful grant applications to the American Geophysical Union. She is also involved with UNAVCO's Research Experiences in Solid Earth Science for Students as a mentor for a disadvantaged undergraduate student studying within the same field. She will work with her assigned student for 10 weeks over the summer to help them achieve the goal of completing an original project they get to present to UNAVCO and their peers. Corona also remains strongly involved with the Mono Lake Committee as an advocate and guest teacher for the Outdoor Experiences Program. The goal for her career is to spearhead projects about what happens to infiltration before it becomes recharge and ultimately have the ability to giver back to the community through volunteering, teaching, and mentoring the next generation of inquiring minds.

University: *Colorado School of Mines*
Major: *Hydrologic Science & Engineering*
Anticipated Graduation: *May 2022*
Area of Interest: *Post-fire modifications to surface and subsurface hydrology*

University: *University of Colorado at Boulder*
Major: *Geological Sciences*
Anticipated Graduation: *May 2022*
Area of Interest: *Extreme precipitation & groundwater response in Colorado*

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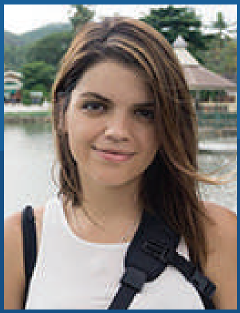

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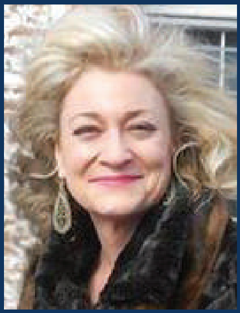

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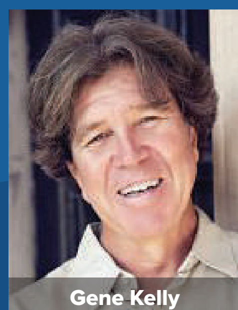
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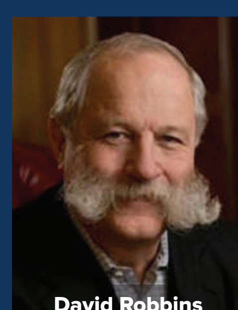
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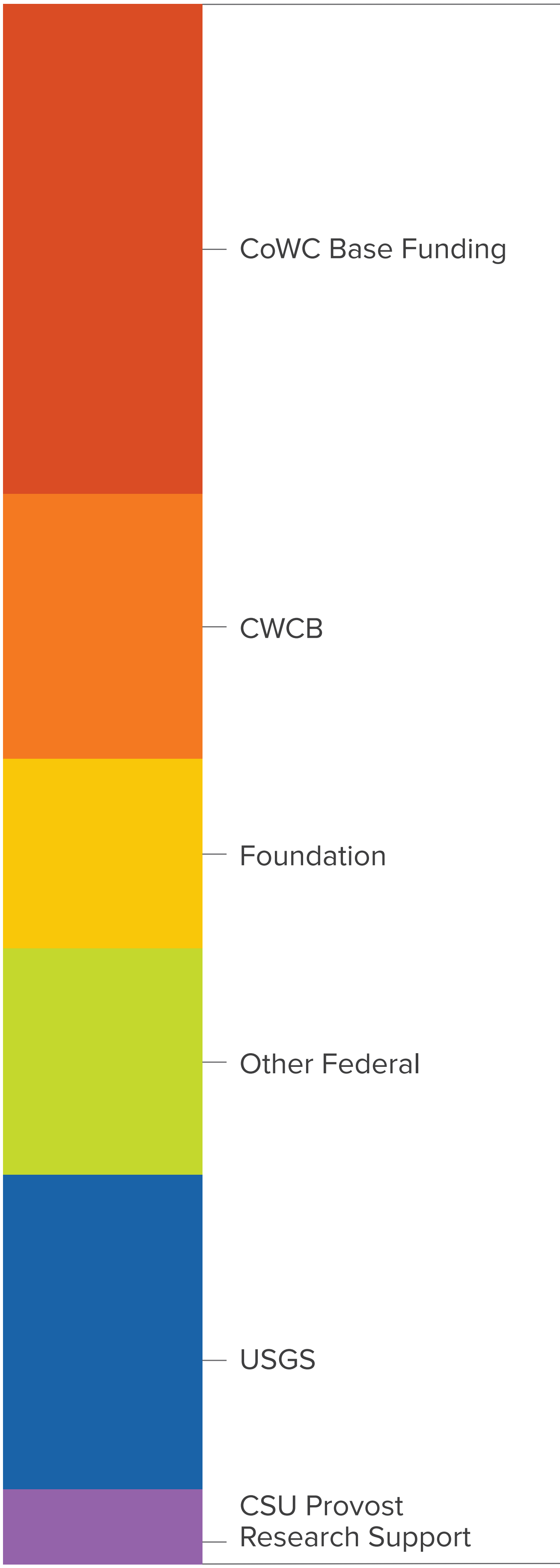
FINANCIAL SUMMARY

Reporting Period: July 1, 2019 - June 30, 2020



SUMMARY BREAKDOWN

CoWC Base Funding	**$ 675,551**

CoWC RESEARCH FUNDING SOURCES	
CWCB	$ 373,319
Foundation	$ 267,656
Other Federal	$ 319,289
USGS	$ 443,188
CSU Provost Research Support	* $ 106,773
Total	** **$ 1,510,225**

ACTIVE PROJECT TYPE

Research	33
Education	1
Outreach	2
Internships	1
Training	1
Total	**38**

STUDENT DEGREE LEVEL ON PROJECTS

Undergraduate	20
Masters	17
Ph.D.	16
Total	**53**

* CSU Provost Research Support of $106,773 is included in FY 20 CoWC Base Funding of $675,551.

** Multiple research projects being conducted during a multi-year timeframe can cause overlap in funding.

ENGAGEMENT
AND EXTENSION
COLORADO STATE UNIVERSITY

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