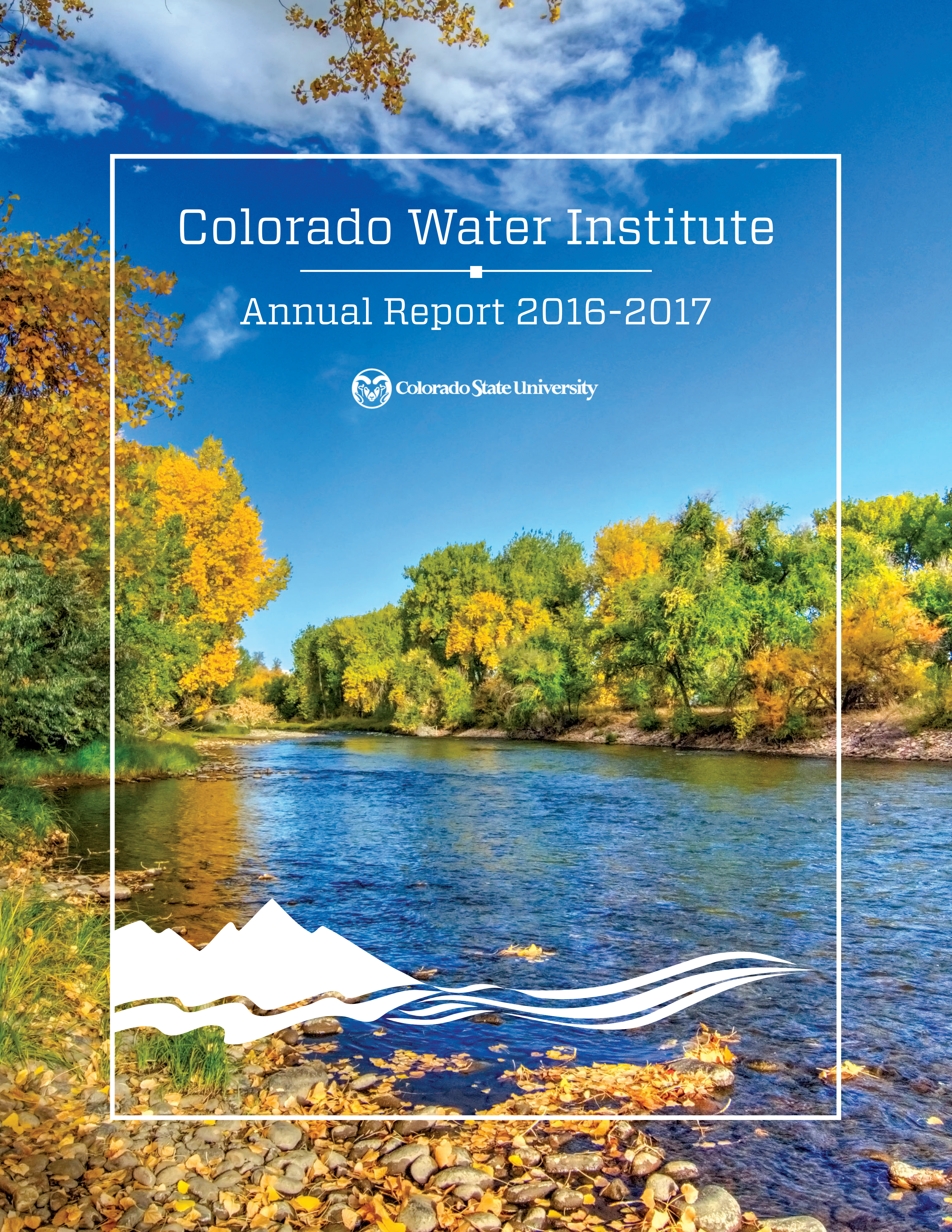
Colorado Water Institute

Annual Report 2016-2017

Colorado State University



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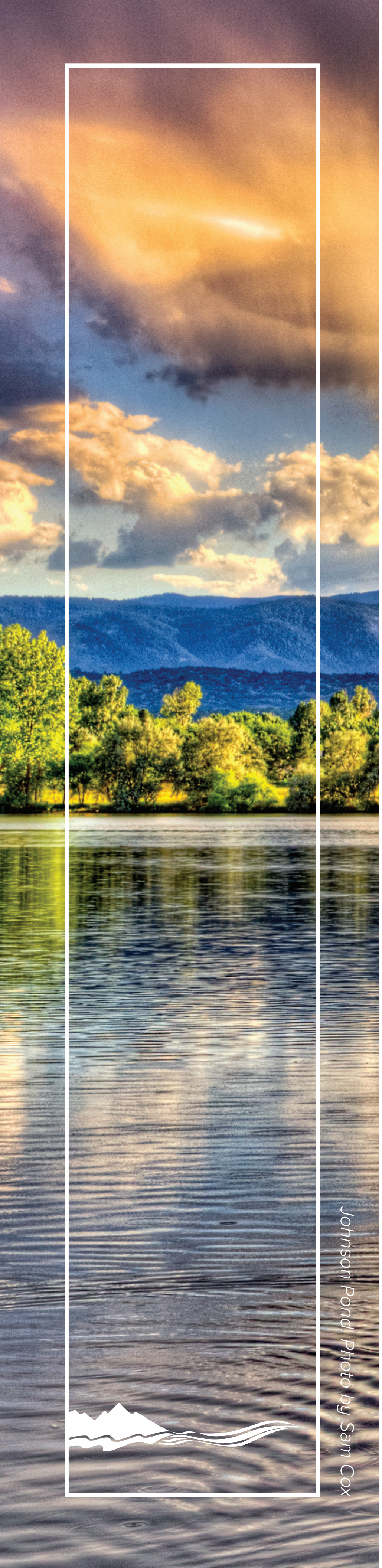
(On the cover) The Arkansas River running through Canon City, Colorado. Photo by Daniel Dyer
(Above) The Animas River Canyon. Photo by Jerry and Pat Donaho

Message from the Director

During the past year, the Colorado Water Institute (CWI) at CSU has continued to serve its research, outreach, and training mission for Colorado through a variety of research projects and student training in cooperation with the Colorado Water Conservation Board and the U.S. Geological Survey. Several of our projects are highlighted in this annual report, including our work in the Cache la Poudre, Arkansas, South Platte and Colorado River Basins, and the Ogallala Aquifer. CWI staff worked this year to advance frameworks for an Upper Basin Water Bank, develop a new water leaders program for Northern Colorado, establish a water and climate focused experiment station at Fruita, provide educational programming on climate smart agriculture for Extension agents, host a conference on aquifer storage and recovery, develop a new irrigation technology center, conduct trainings on rainwater harvesting, and evaluate alternatives to agricultural buy and dry. Additional work on hydraulic fracturing in the South Platte and agricultural conservation in the Ogallala put CWI in the middle of currently controversial water topics in Colorado. Jennifer Gimbel joined the CWI this year to work on Colorado River issues after returning from her position at the Department of Interior. Retired State Climatologist, Nolan Doesken, joins us on a part-time basis to continue connecting Colorado's climate to the management and understanding of our water resources.

Several years ago, CSU President Tony Frank initiated a process to strengthen and better coordinate water programs at CSU, given the importance of water to the University's mission. CSU has recently been evaluating merging the CWI and the CSU Water Center to reduce external and internal confusion and any redundancies. Unlike the CSU Water Center, the CWI has a federal and state authorization requiring us to work with faculty and students from all of Colorado's public institutions of higher education to provide water managers and users with new information to improve decision-making. While it is likely we will bring these two units together with a single budget, staff, web presence, etc., CWI will continue to work with all of higher education in Colorado on the important effort of training the next generation of water managers through research project funding and internships. As CWI director, I am pleased to report this year that the institute continues to benefit from a committed staff, excellent support from CSU upper administration, and the guidance of an outstanding advisory committee. This 2017 annual report contains only the highlights of our activities and impacts in service to Colorado this past year. More information on CWI can be found at www.cwi.colostate.edu. ■



Johnson Pond. Photo by Sam Cox

About CWI

CWI, an affiliate of Colorado State University (CSU), exists for the express purpose of focusing the water expertise of higher education on the evolving water concerns and problems being faced by Colorado citizens. CWI coordinates research efforts with local, state, and national agencies and organizations. CWI works closely with researchers, scientists, and the private sector to develop sound science that assists and informs Colorado water managers and users. CWI accomplishes this by facilitating the transfer of new water knowledge and assisting in educating the next generation of Colorado water professionals by working with all of Colorado's public institutions of higher education.

Outreach & Information Transfer

CWI collaborates with CSU Extension to house three water outreach specialists around the state. CWI 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 bimonthly newsletter containing information on current research, water faculty, outreach program updates, climate, water history, Colorado State Forest Service updates, and water-related events and conferences, featuring a different research in each issue.

CWI outreach activities are conducted in conjunction with the CSU Water Center, CSU Extension, the Colorado Agricultural Experiment Station, the Colorado State Forest Service, and the Colorado Climate Center. Our primary partners include water managers, water providers, and water agencies.

Training

One of CWI's primary missions is to facilitate the training and education of university students. To this end, the Institute 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.

CWCB FY18 Funded Projects

- Constructing and Testing a Refined Groundwater Flow Model for the LaSalle/Gilcrest Area
  Ryan Bailey, Colorado State University
- Bark Beetle Impacts on Remotely Sensed Evapotranspiration in the Colorado Rocky Mountains
  John Knowles and Noah Molotoch, University of Colorado Boulder
- Automated Non-Telemetered Snow Depth Monitoring for Water Supply Forecasting by Improved Basin-Wide Snowpack Water Storage Estimation
  Steven Fassnacht, Colorado State University
- Water Yield Sensitivity to Snow Loss in Colorado Headwater Streams
  Gigi Richard and Stephanie Kampf, Colorado Mesa University
- Mountain Basin Hydrologic Response Study
  Jeffrey Niemann, Colorado State University

Externally Funded Research

- Hydrodynamic-Enhancement of Nitrate Attenuation by Integrating Reactive Biobarriers into Shallow, Open Water Treatment Wetlands
  John McCray and Josh Sharp, Colorado School of Mines; USGS 104G
- Alternatives to Permanent Fallowing Research Synthesis and Workshops
  Brad Udall, Colorado State University; Walton Family Foundation
- SRN: Routes to Sustainability for Natural Gas Development and Water and Air Resources in the Rocky Mountain Region
  Reagan Waskom, University of Colorado; National Science Foundation
- Colorado River Basin Policy With Emphasis on Upper Colorado River Contingency Planning
  Jennifer Gimbel, Colorado State University; Walton Family Foundation
- Moving Forward on Agricultural Water Conservation in the Colorado River Basin
  Reagan Waskom, Colorado State University; USDA
- Sustaining Agriculture through Adaptve Management to Preserve the Ogallala Aquifer Under a Changing Climate
  Meagan Schipanski, Colorado State University; USDA-NIFA
- Water Yield Sensitivity to Snow Loss in Colorado Headwater Streams
  Gigi Richard, Colorado Mesa University; USGS 104B

(Above) The Animas River Canyon. Photo by Jerry and Pat Donaho

USGS Funded Student Research

- Effects of Snow Persistence on Soil Water Nitrogen Along the Colorado Front Range
  Alyssa Anenberg and Stephanie Kampf, Colorado State University

- Effects of Water Velocity on Algal-Nutrient Interactions in Streams of the Poudre Watershed, Colorado
  Whitney Beck and Leroy Poff, Colorado State University

- Diagnosing the Role of External Forcings on Steamflow Variablity
  Leah Bensching and Ben Livneh, University of Colorado at Boulder

- The Effect of Wastewater Effluent on Soil and Water Chemistry Along the South Platte River
  Daniel Clark and Sarah Schliemann, Metropolitan State College of Denver

- Understanding Post-Flood Channel Adjustments and Reservoir Sedimentation to Inform Water Management Practices
  Johanna Eidmann and Sara Rathburn, Colorado State University

- Estimating Agricultural Consumptive Use for Grass and Hay Pasture Fields on Colorado's Western Slope
  Christopher Pack, Gigi Richard, and Perry Cabot, Colorado Mesa University

USGS Internships

- Water, Energy, and Biogeochemical Budgets NIWR-USGS Student Internship Program
  Edward Stets

- Modeling of Watershed Systems NIWR-USGS Student Internship II
  Steve Regan

- Modeling of Watershed Systems NIWR-USGS Student Internship III
  Roland Viger

- National Domain Water Budgets NIWR-USGS Student Internship Program
  William Farmer and Reagan Waskom

CSU Water Center FY18 Projects

- From Information to Prices: What Drives Residential and Commercial Water Demand?
  Jesse Burkhardt, Agriculture and Resource Economics

- Integrating Green Infrastructure within Land-Use and Water Planning
  Kelly Curl, Agricultural and Resource Economics

- Stream Fish Conservation in Extreme Habitats
  Yoichiro Kanno, Fish, Wildlife and Conservation Biology

- A Systems Modeling Approach to Quantify Forest Fuel Treatment Effects on Wildfire Severity and Post-Fire Erosion
  Tony Cheng, Forest & Rangeland Stewardship

- Developing a Comprehensive Understanding of Metal Impacts on Stream Ecosystems in Colorado
  Will Clements, Fish, Wildlife and Conservation Biology

- Biotreatment of Pharmaceuticals and Personal Care Products during Water Treatment for Reuse: Ensuring Human Safety at the Food-Water Nexus
  Susan DeLong, Civil and Environmental Engineering

- Quantifying the Scope and Impact of Permanent Agricultural Dry-Up Due to Rural to Urban Water Transfers
  Michael Falkowski, Ecosystem Science and Sustainability

Student Research

Highlights

A. *John Hammond, Alyssa Anenberg, Stephanie Kampf and Chenchen Ma on an October 2016 field visit to the Michigan River watershed. Photo by John Hammond*
B. *Ellen Daugherty helping with a wood jam survey on the South Fork of the Poudre River. Photo by Dan Scott*
C. *Student Allen Gilbert with a LiDAR unit. Photo by Allen Gilbert*

D. *Collecting biofilm samples at the upper Arkansas River. Photo by Sam Duggan*
E. *Craig Moore taking notes during a soil moisture survey at the transitional Grand Mesa site. Photo by Gigi Richard*
F. *Matt Sparacino and Sara Rathburn measure discharge during 2015 high flow on the Upper Colorado River, Rocky Mountain National Park. Photo by Rick Aster*
G. *Student Haley Sir running samples on the ICP-MS for analysis at Metropolitan State University of Denver. Photo by Sarah Schliemann*

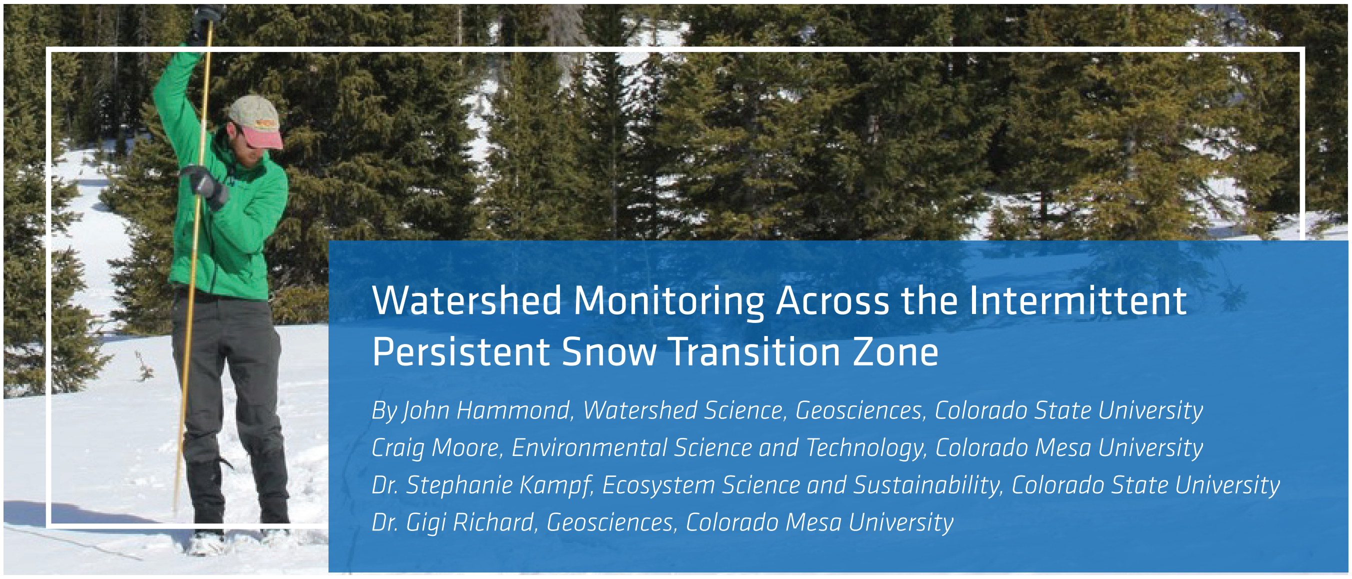


Photo by Emily Chavez

Watershed Monitoring Across the Intermittent Persistent Snow Transition Zone

By John Hammond, Watershed Science, Geosciences, Colorado State University
Craig Moore, Environmental Science and Technology, Colorado Mesa University
Dr. Stephanie Kampf, Ecosystem Science and Sustainability, Colorado State University
Dr. Gigi Richard, Geosciences, Colorado Mesa University

Monitoring the Snow Transition

In mountainous regions, snowpack studies suggest that snowpacks are sensitive to drought and temperature at lower elevations. In Colorado, high elevations have snow throughout the winter, whereas low elevations have intermittent snow over the winter. Most watershed monitoring in Colorado does not include areas where the snowpack transitions between intermittent and persistent. This study established hydrologic monitoring of watersheds in intermittent, transitional, and persistent snow zones of the Southern Rocky Mountains in Colorado. Six watersheds were monitored that drain intermittent, transitional, and persistent snow zones. Instrument failures at some of the Grand Mesa sites lead to some data loss, so we focus on summarizing the 2016 water year at the Front Range sites.

Persistent Snow Zone

The Michigan River watershed retained snow from the onset of accumulation to snow disappearance. Peak snow depth was the highest at this site. North-facing slopes and valley bottoms retained snow from the onset of snow to melt, while south-facing slopes and ridgetops experienced snow melting out several times. Soil moisture values were elevated during and following snowmelt. Snowmelt generated saturation excess overland flow in the late spring. The hydrograph of Michigan River is dominated by the spring snowmelt signal without substantial increases in discharge in response to summer rainfall.

Transitional Snow Zone

The Lazy D watershed retained snow from the onset of accumulation to the date of snow disappearance. Soil moisture response was considerably muted. Stream stage at Lazy D exhibited a clear snowmelt signal but with the additional input of spring rain during snowmelt. The hydrograph at this site was less flashy than at the persistent site, because wetland areas adjacent to the stream dampened the hydrograph.

Intermittent Snow Zone

At the Mill Creek watershed, snow fully melted several times mid-winter. The stream responses to snow accumulation and melt was similar in magnitude to the response to summer rainfall. The effects of slope-aspect at this site were most apparent, with snow completely disappearing on south-facing slopes. Soil moisture responded rapidly to rain and snowmelt. Mid-winter snowmelt events at Mill Creek were large enough to generate streamflow and stream stage peaked when the antecedent soil moisture was already high from snowmelt and rainfall inputs. Summer rainfall after June 15 no longer generated runoff in Mill Creek because of lower soil moisture. This was the only Front Range site to completely stop flowing.

Lessons Learned and the Path Ahead

We have made broad assessments on differences in hydrologic response between snow zones and the west and east slopes of the Southern Rocky Mountains. We see more mid-winter melt on the Grand Mesa and shorter duration of snowpack. The persistent site in the Front Range accumulates more snow, does not get much mid-winter melt, and has little mid-winter infiltration. The persistent site on the Grand Mesa does have mid-winter infiltration. With our ongoing watershed monitoring across a range of snow conditions in Colorado, we continue to learn about the factors that alter streamflow in the headwater streams. ■

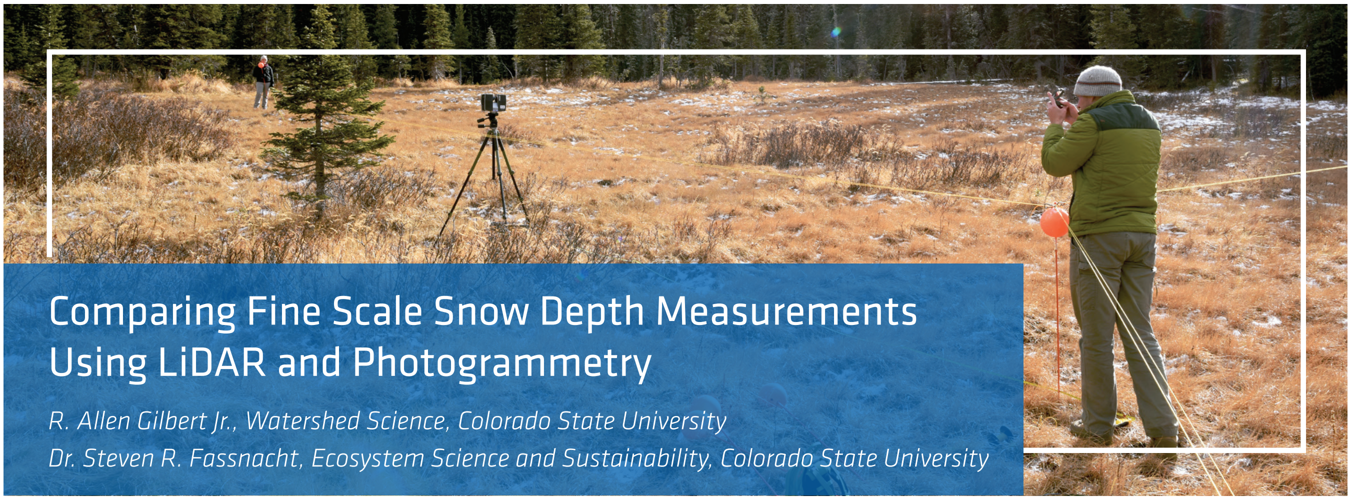


Photo by Allen Gilbert

Comparing Fine Scale Snow Depth Measurements Using LiDAR and Photogrammetry

R. Allen Gilbert Jr., Watershed Science, Colorado State University
Dr. Steven R. Fassnacht, Ecosystem Science and Sustainability, Colorado State University

Introduction

Snow is important to several interests in Colorado and techniques to measure it are technologically limited. Until the late 1970s, snow measurements were accomplished through periodic manual point measurements of snow depth and snow water equivalent. The Intermountain West is now populated by the automated snow telemetry (SNOTEL) network of remote stations to provide daily snowpack measurements, but the network is still at a coarse resolution.

Light detection and ranging (LiDAR) is a technology that provides sub-meter snow depth data. Current aerial and terrestrial LiDAR products require equipment and practices that are expensive. Recent efforts to measure snow depth on low relief areas using aerial photogrammetry have shown promise in providing results similar to using LiDAR but at reduced cost. This study quantifies vertical differences between photogrammetric methods and terrestrial LiDAR scanned surfaces using commercial photographic equipment and processing software.

Research Design

Two sites were selected to provide variety in terrain and data collection variables. A nearly 3,000 m^2 site was selected at the CSU Agricultural Research Development and Education Center's southern area (ARDEC-South). A 900 m^2 plot near the Joe Wright SNOTEL (# 551) station was chosen to represent montane conditions.

Data collection for this study occurred during the 2016 – 2017 snow season. Each site was scanned using a FARO Focus3D LiDAR, and a series of evenly spaced camera stills using a Nikon D810 digital single lens reflex (DSLR) camera with a Nikkor 24-mm fixed focal-length lens were taken along each of the plot's edges. Snow on the images were captured as bracketed sets.

Spherical reference points were set at each corner, approximately 1-m above the surface and were used to align point clouds. LiDAR scans were processed using CloudCompare. Images were processed using the Agisoft Photoscan software and imported into CloudCompare and aligned to LiDAR point clouds. Digital surface models (DSM) were created at 1-m and 10-cm resolutions.

Discussion and Recommendations

Photogrammetry can substantially reduce the cost of equipment and data acquisition without substantial reduction in data quality. This study recommends three metrics be used when comparing these methods:

1. LiDAR results in better vertical accuracy and finer resolved precision, but geographic accuracy is more reliant on the quality of ground control and influences both techniques. Imaging equipment should be considered part of the entire package which, combined with a survey grade GPS, can create highly accurate products.
2. Photographic equipment is more affordable than LiDAR equipment. Data collection time for each technique is substantially different, wherein LiDAR required approximately an hour to record a moderate resolution point cloud but photographic images were recorded in fifteen minutes.
3. Each method has its learning curve and both may be automated to some degree. Photogrammetry's ability to use most images allows an agencies existing infrastructure to be included as potential data collection assets.

This study described a means of implementing photogrammetric snow measurement into existing operational workflows. The core elements of this study comparing LiDAR and photogrammetric techniques and outputs should remain relevant beyond technological advances. ■

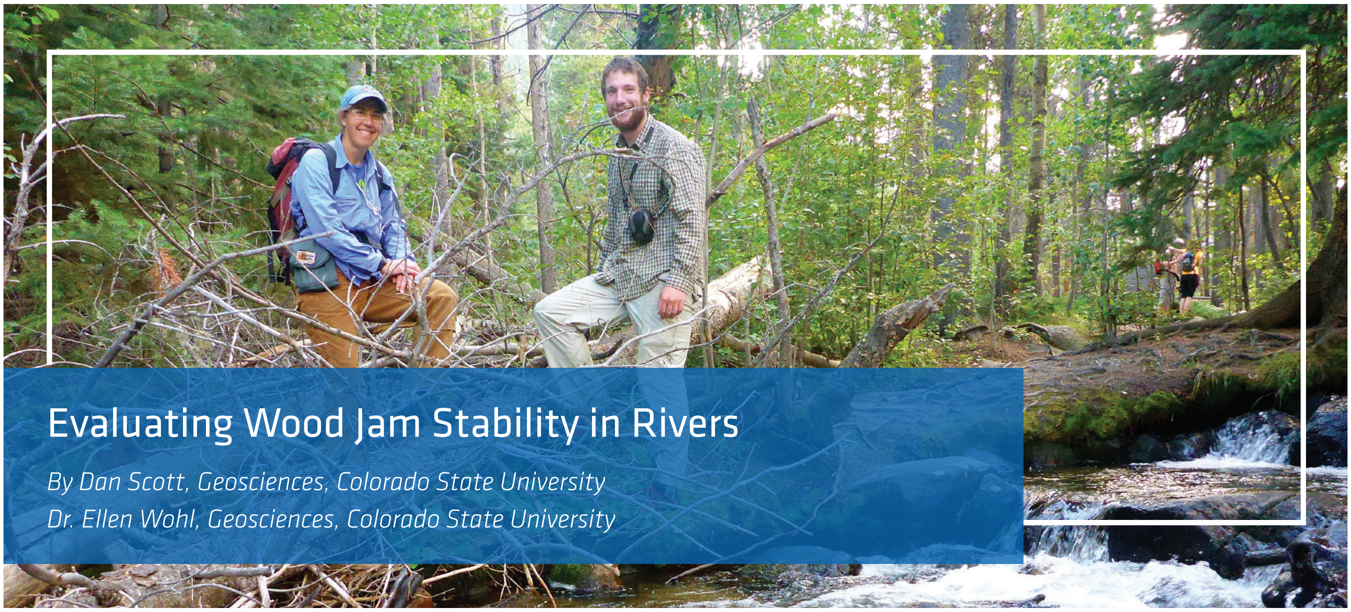


Photo by Dan Scott

Evaluating Wood Jam Stability in Rivers

By Dan Scott, Geosciences, Colorado State University
Dr. Ellen Wohl, Geosciences, Colorado State University

Background

Management of instream and floodplain wood in Colorado has been focused on wood removal. Rivers on the Colorado Front Range are wood-impoverished (Wohl et al., 2015) due to human removal of wood. Despite the abundance of wood mobilized and deposited into streams in the Colorado Front Range during the September 2013 flooding, most rivers have been stripped of wood. This trend has been the national standard, with most wood removed from rivers and floodplains (Wohl, 2014). This has led to a widespread misconception that wood is unnatural in rivers and a lack of understanding regarding the benefits of wood (Chin et al., 2008). Wood provides riverine habitat and nutrients to fish and insects, stabilizes highly erosive systems, and maintains nutrient and water delivery to riparian ecosystems (Gurnell et al., 2005; Wohl, 2013).

Wohl et al. (2015) presents a management strategy for determining whether to remove wood in a river or on a floodplain. This strategy is designed to evaluate the benefits and risks of wood. However, these guidelines are limited in their applicability to entire wood jams. City, state, and national organizations have begun to adapt the guidelines. Many of these organizations have contacted Dr. Wohl about applying the guidelines to wood jams, which motivated the proposed research. Dr. Wohl's communication with these organizations has demonstrated the immediate need for an expanded set of guidelines. Our goal for this project is to develop an understanding of the hydrologic, morphologic, and biotic conditions that impact the stability of wood jams in rivers.

Methods

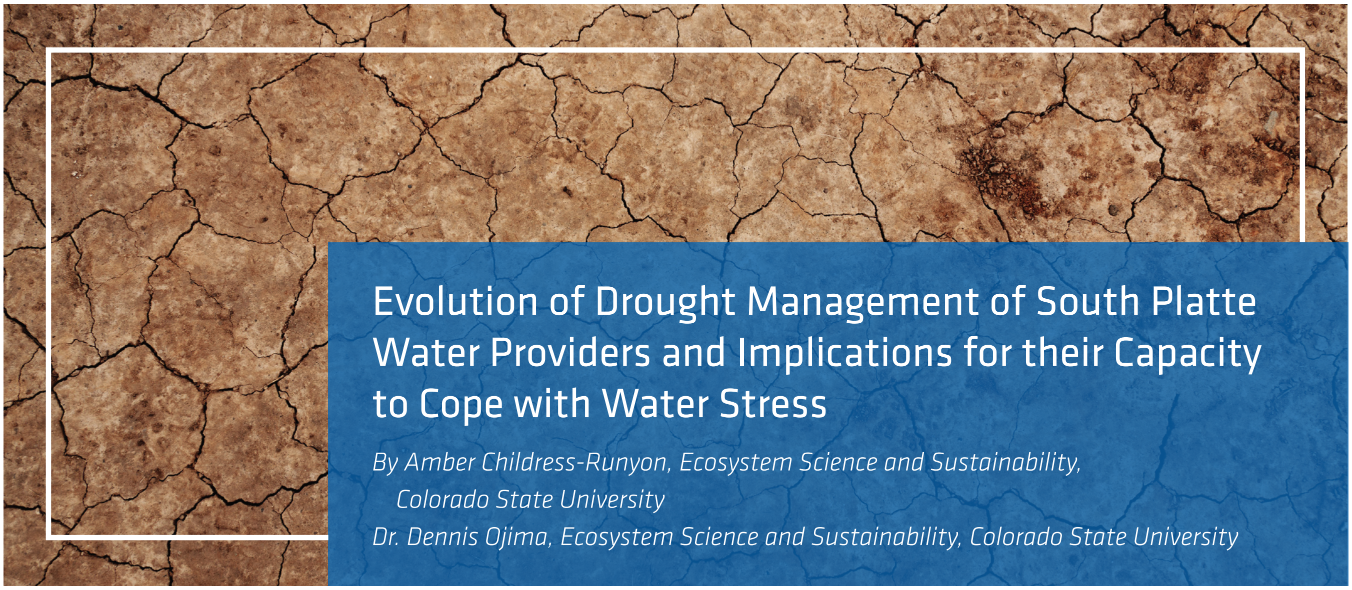
Our approach involved surveying individual wood jams across the Colorado Front Range and in the Cascade Range of Washington State. We measured wood jam geometry, channel geometry, bed material size, and wood jam characteristics across 38 jams. We placed time lapse cameras near 18 jams to observe the high flow season. We returned to each jam after high flow to record whether the jam significantly changed, unchanged, or was transported downstream.

Current Findings

Three of our surveyed jams experienced significant change, probably due to relatively mild high flow seasons. This has limited our ability to develop our statistical model. However, we have gleaned important observations from our time lapse data. Diurnal flow fluctuations in snowmelt systems cause a repeated dilation and contraction of wood jams during peak flow, which we hypothesize has a cumulative effect in destabilizing jams over time.

Future Directions

We plan to expand our dataset to over 100 wood jams in the Colorado Front Range and deploy 12-time lapse cameras. We are revising our field methods to minimize variability between different people taking measurements. This will allow for more reliable, widespread use of our methods. We also plan to expand our field sites to include small ephemeral streams, a larger multi-thread river, and a low gradient plains river. We hope to achieve a dataset of at least 200 jams through one peak flow season before making the model available to the public. We hope these resources will assist others in understanding wood jams. ■



Evolution of Drought Management of South Platte Water Providers and Implications for their Capacity to Cope with Water Stress

By Amber Childress-Runyon, Ecosystem Science and Sustainability, Colorado State University
Dr. Dennis Ojima, Ecosystem Science and Sustainability, Colorado State University

Introduction

Droughts in the western U.S. are common (Dai, 2013; Cook et al., 2015). Water management in Colorado has developed based on lessons learned and refinements made to water policy and management strategies during and after droughts. Water providers often bear the responsibility of mitigating drought risk for water users. Studies conducted by the State (Colorado Water Conservation Board, 2013) suggest that actions taken as a result of the 2002 drought increased the adaptive capacity of many water providers. However, because the results were aggregated by basin, the differences between providers' capacities and factors that contribute to increased adaptiveness were not investigated. Therefore, the objective of this study was to evaluate the variance in the capacity of water providers in the South Platte River Basin (SPRB) to meet their demand obligations that affect their capacity to respond to droughts.

Methods

This study used an analogue approach, looking at past drought periods to understand future droughts. There were two recent major droughts in the SPRB, in 2002 and 2012 and were different temporally and in severity. The 2002 drought lasted longer than the 2012 drought, but the 2012 drought was more severe. An event history calendar (EHC) was used to collect data from managers in the SPRB. The EHC collects time-series data of water providers' management strategies and functioning through time. The EHC collected information including: 1.) strategies water provides used and variations in the strategies, and 2.) their capacity to meet water delivery requirements (capacity). To measure capacity in the EHC, 25 participants were asked to rank from 0 to 3 their ability to meet their water delivery requirements over the time period.

Results

This study asked providers to rank for their capacity to meet water delivery demands, which served as a proxy for their capacity to cope with conditions over time. Results indicated that capacity was reduced from normal levels during the 2002 drought, but not during the 2012 drought. Capacity scores were higher in the second drought than the other non-drought periods, suggesting an increase in adaptive capacity. This was supported by interviews with water managers who said that lessons from the 2002 drought caused them to be more proactive during the 2012 drought. The severity of drought effects on water providers and drought-mitigation techniques available to them are determined by characteristics unique to each water provider (e.g. their source of water supply, seniority of rights, the type of community they serve, population growth rates, etc.).

Discussion

The increase of capacity for all water providers suggests that periodic droughts actually can increase the resilience of water managers if they improve upon lessons learned. Because they were caught off guard and systems were impaired in 2002, water managers used the period after the drought to reorganize and develop new policies and/or update their systems. Then in 2012, when the signs of drought first appeared, water managers had established protocols in place. This analysis provides a better understanding of how water providers manage drought and their motivations for future adaptation. ■

Photo by Sam Duggan

Microbial Community Responses to Metals Contamination

Mechanisms of Metals Exposure and Bioaccumulation in a Stream Food Web

By Brian Wolff, Ecology, Colorado State University
Dr. William Clements, Fish, Wildlife and Conservation Biology, Colorado State University
Dr. Ed Hall, Ecosystem Science and Sustainability, Colorado State University

Introduction

Mining has generated 45 billion metric tons of waste and impaired 8,000 km of streams in the U.S. and widespread in Colorado. With the accidental release of metals from historical mining into the Animas River in 2015, the impacts will continue to be an important issue. Our research focused on the upper Arkansas River that has been impacted by mining.

The EPA added California Gulch into the upper Arkansas River, to the National Priorities List. It was found that metals contamination caused a shift in stream benthic insect community composition, with more 'sensitive' taxa at upstream reference sites (no metals contamination) and more 'tolerant' taxa at contaminated sites downstream of California Gulch. Much of the upper Arkansas River has since been remediated to remove most metals sources.

Research Questions and Methods

We addressed the following research questions: (1) are metals concentrations greater within benthic biofilms than in seston at downstream (impacted) sites?; (2) are there differences in upstream and downstream resource composition and dietary quality (i.e. nutrient content)?; and (3) what are the effects of exposure to metal-contaminated biofilm and seston on aquatic insect consumers?

To determine if metals are determinants of microbial communities, ceramic tiles were deployed upstream (reference) of the metals contamination source (California Gulch) and downstream (impacted). Biofilm and seston were collected. Samples were then analyzed for metals (Cd, Cu, and Zn). We measured C:N from sites upstream (reference) and downstream of California Gulch (impacted). We also measured metal concentrations and C:N of upstream and downstream aquatic insects including: benthic biofilm grazing mayflies, and seston filter-feeding caddisflies.

Results

Our analysis suggests that seston and biofilms downstream of California Gulch have higher metals concentrations than at upstream reference sites. Metals concentrations in biofilms were greater than in the seston samples. We found that mayflies at upstream reference sites had higher metals concentrations than in the caddisflies. Despite higher metals concentrations in downstream biofilms, we found higher chlorophyll-a, suggesting that metals do not have a negative effect of algal biomass. The reference sites had greater abundance of diatoms and green algae, but the impacted site had greater abundance of cyanobacteria. Results from our C:N ratios suggest that metals may influence resource quality. Biofilm C:N ratios were lower in the reference sites, implying greater nitrogen or less carbon availability; however, seston C:N ratios were not different between sites. Mayfly C:N ratios remained relatively unchanged between reference and impacted sites despite the observed changes in C:N ratios of their diet.

Discussion

Our results show that the effects of metals on stream ecosystems are complex. Metals accumulation in caddisflies did not change between reference and impacted sites suggesting that these insects may have the capacity to regulate metals. Metals also created a shift in algal biomass at impacted sites and the shifts resulted in changes in resource quality. Resource quality only changed between reference and impacted site biofilms, but not seston C:N. Metals in combination with a shift in resource quality, may be more stressful to insect scrapers than filterers. ■

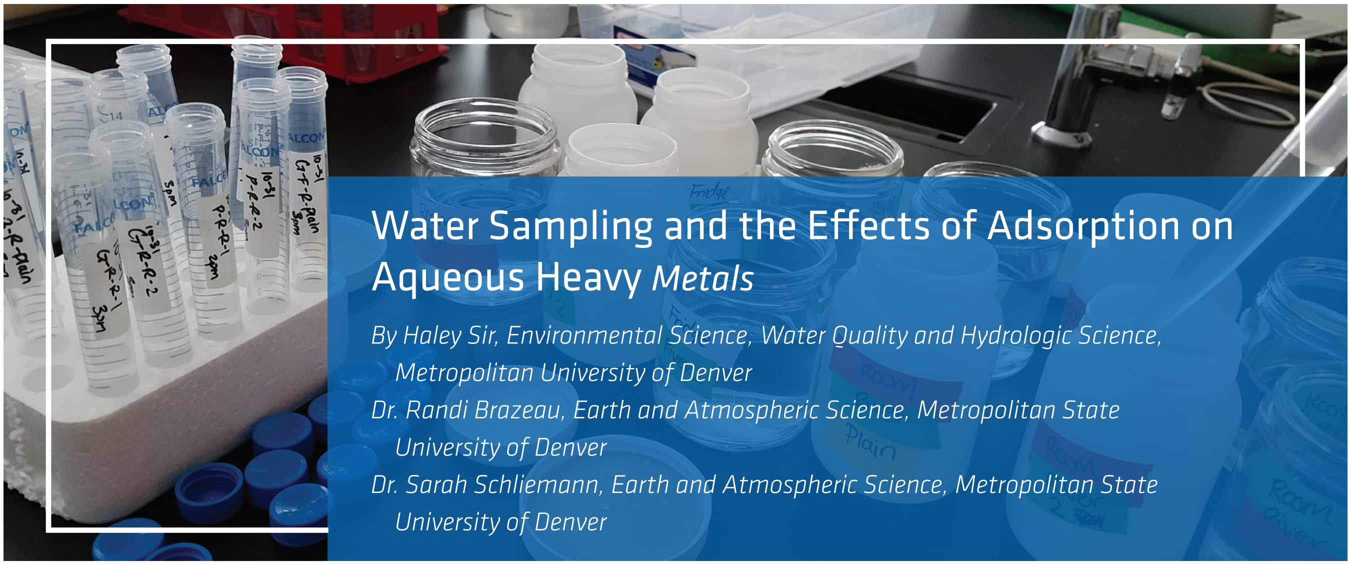


Photo by Haley Sir

Water Sampling and the Effects of Adsorption on Aqueous Heavy *Metals*

By Haley Sir, Environmental Science, Water Quality and Hydrologic Science, Metropolitan University of Denver

Dr. Randi Brazeau, Earth and Atmospheric Science, Metropolitan State University of Denver

Dr. Sarah Schliemann, Earth and Atmospheric Science, Metropolitan State University of Denver

Background

Sampling techniques can strongly influence the results of a study. This study investigated the concentrations of aqueous heavy metals in sampling containers spiked with lead and cadmium. The study aimed to mimic water samples that would have been collected in August of 2015 after the Gold King Mine Spill in Silverton, Colorado.

The Gold King Mine has been out of commission since 1923, but it has posed an environmental threat due to tailings that release heavy metals into soil, sediment, and surrounding surface waters. The Las Animas Spill in 2015 dumped concentrations of lead, arsenic, and cadmium into the waterway causing harm to drinking water treatment facilities (Environmental Protection Agency, 2015).

Research has concluded that during the collection, transport, and storage of water samples, various constituents may be removed from the aqueous solution as they become adsorbed to the bottle (Spangenberg, 2012). These studies support the hypothesis that plastics may play a role in metal adsorption and a significant factor in inaccurate data for water samples. This study aimed to investigate the effect that sampling techniques may have on aqueous metal adsorption.

Methods

Twelve samples were observed including four controls. Water samples were taken from the Arkansas River upstream from Buena Vista and spiked with standards of cadmium and lead. Spiked concentrations were below those in the Las Animas River spill due to detection limits. From each plastic and glass sample group, half were stored at a refrigerated temperature and half were stored at room temperature. The four control samples included the two sampling bottles (plastic and glass); two containing natural river water (and two with distilled water spiked with the metal standards of concern. Concentrations of cadmium and lead were measured every hour for four hours on the first day. On the second day, they were measured 20 hours after the initial sample and then 22 hours after the initial sampling.

Results

A consistant downward trend in concentration can be seen in all of the samples. There did not seem to be an overwhleming difference between the glass and plastic sampling containers, nor was there a significant difference in samples kept at the refrigerated temperature and at room temperature. For all four samples, lead decreased slightly faster than cadmium. Lead had an average decrease of 21% while cadmium only decreased by an average of 13% for all four samples.

Discussion and Conclusions

A steady decrease of both elements was observed, suggesting adsorption of aqueous heavy metals to the sampling containers. However, there did not appear to be a difference due to bottle type (plastic vs. glass) or temperature. The results from this research suggest that there should be some consideration taken when analyzing water samples for heavy metal contamination. Water samples should be analyzed as soon as possible after sampling to minimize adsorption. Samples stored for long periods of time may produce low readings. We suggest that studies analyzing heavy metal concentrations in water should report the time elapsed between collection and analysis to account for possible adsorption. ■

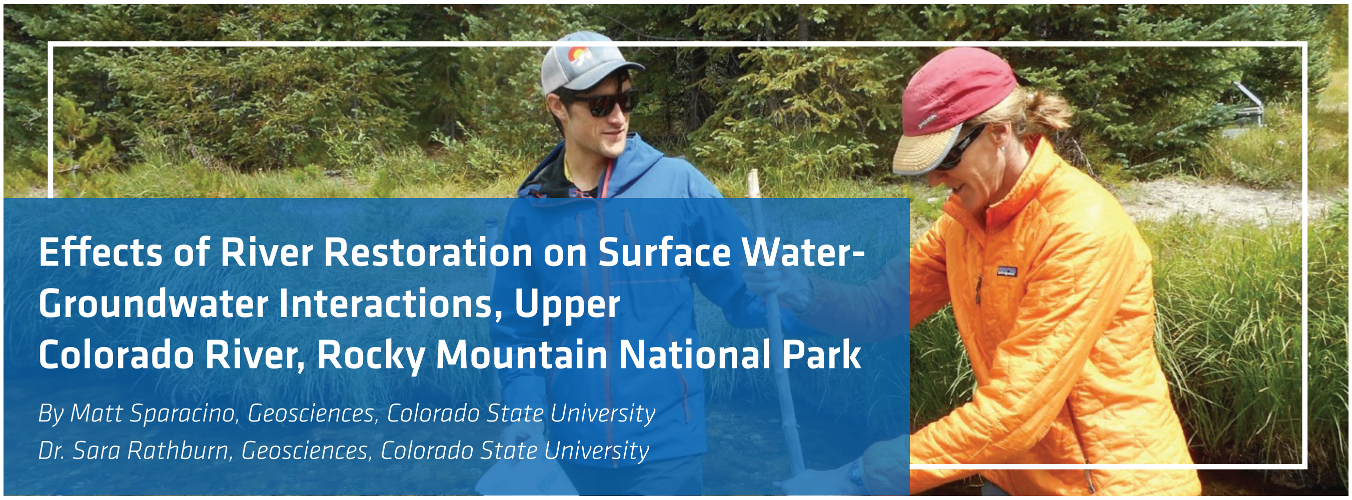


Photo by Dave Dust

Effects of River Restoration on Surface Water-Groundwater Interactions, Upper Colorado River, Rocky Mountain National Park

By Matt Sparacino, Geosciences, Colorado State University
Dr. Sara Rathburn, Geosciences, Colorado State University

Introduction

Wetlands provide valuable ecosystem services. During the past 200 years, increased human activity and land use changes have reduced total wetland area in the U.S. In RMNP, a 2003 debris flow eroded sediment from the hillslope below Grand Ditch, an earthen water diversion structure. The debris flow scoured channels, deposited sediment at the head of Lulu City wetland, and altered the Colorado River. In 2015, RMNP completed restoration work to realign a portion of the Colorado River. The main goal of the research was to assess the effects of the channel restoration on a variety of channel and wetland hydrogeomorphic functions.

Methods

Replicate measurements were collected under similar environmental conditions in 2015 (pre-restoration) and 2016 (post-restoration) to assess the effects of the channel realignment. Hydrographs were used to characterize changes in flow redistribution and a salt tracer injection test was paired with continuous surface conductivity measurements to quantify changes in surface water-groundwater interactions. Average daily flow rates were extracted from hydrographs and a daily discharge flux was calculated too. A salt solution, injected at the upstream site was used to elevate the conductivity of surface water above background concentrations. Measurements of surface water conductivity were also collected. Mass recovery through time, as represented by breakthrough curves, was used to evaluate the exchange behavior between surface water and groundwater.

Results and Discussion

The channel restoration effectively rerouted all but the highest flows through the center channel. Under the pre-restoration condition, the cumulative discharge flux indicated water was retained in storage or lost to evapotranspiration. The discharge flux calculated over the same post-restoration time indicated a gain of water. These results indicate that less water was retained in the wetland through storage or lost to evapotranspiration because of channel restoration. Less storage means water was routed through the wetland more quickly, thereby limiting the beneficial ecosystem processes that require stored water. The change in discharge flux through between 2015 and 2016 can be explained by channel changes. The channel realignment altered channel complexity through the wetland. The center channel facilitates less exchange between surface water and groundwater. Breakthrough curves from the wetland outlet indicate that there was more surface water-groundwater exchange in 2015 than 2016. Inflections on the rising and falling limbs of the 2015 wetland outlet breakthrough curve are absent from the 2016 curve.

Management Implications

The construction of a shorter, straighter, and less geomorphically-complex flow path that consolidated flow into the historic center channel with lower substrate permeability resulted in less surface water retained within the wetland. This loss of surface water-groundwater exchange pathways between the river and adjacent wetland is an important, and unintended, side-effect of a project that prioritized the restoration of form over function.

After one year, this restoration project was effective at drying the west side of Lulu City wetland. If this drying continues, the lowering of water tables will facilitate the encroachment of upland vegetation on the west side of the wetland and inhibit the growth of desired wetland vegetation. ■

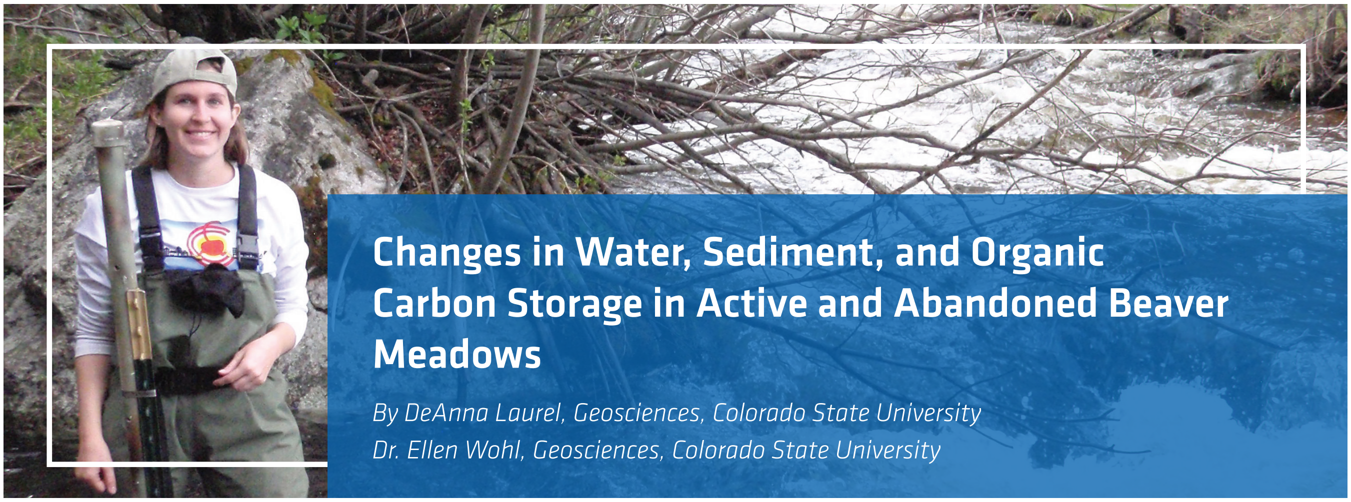


Photo by Ellen Wohl

Changes in Water, Sediment, and Organic Carbon Storage in Active and Abandoned Beaver Meadows

By DeAnna Laurel, Geosciences, Colorado State University
Dr. Ellen Wohl, Geosciences, Colorado State University

Introduction

In the Colorado mountains, streams are steep and narrow, confined by valley walls. The exceptions are unconfined, lower gradient. Compared to the confined river segments, the unconfined meadows have less efficient downstream transport, greater storage, and attenuation of fluxes of water, sediment, and organic carbon. Beaver favor the unconfined meadows.

Fur trapping almost eradicated beavers. In the last few decades, beaver populations in Colorado have been recovering. Beaver manipulate their environments to suit their needs. This study aims to quantify the alteration in storage and attenuation of three fluxes: water, sediment, and organic carbon, which result from the simplification of channel and floodplain geomorphology after beavers have left a meadow.

Study Area

The study area is central and northern Colorado within and near Rocky Mountain National Park. The active (North St. Vrain, Glacier Creek and Hollowell Park) and abandoned (Cow Creek, Hidden Valley, Upper Beaver Meadows and Moraine Park) beaver meadows on each stream are wide flat-bottomed valley features in steep, mountain streams.

Methods

Geomorphic complexity of each meadow was measured by conducting surveys in multiple transects across each meadow. A geomorphic survey of the channel cross-section geometry was conducted for each instrument site and surveys of the flow velocity. The velocity, stage data, the channel discharge were calculated and a mathematical relationship developed to convert the stage data into flow discharge data. Attenuation of streamflow in each meadow was quantified. Organic carbon stocks were calculated, soil samples were collected, and the organic carbon concentration was measured. Bulk density of the soil samples was calculated as well as the soil organic carbon stocks.

Results and Discussion

Active beaver meadows showed greater complexity than the abandoned meadows. Complexity appears to be related to the presence or absence of beaver, the level of beaver activity, and the length of time since beaver abandoned the environment. North St. Vrain is a highly active multithread channel meadow that supports multiple beaver colonies. Upper Beaver Meadows has been abandoned for upwards of 3 decades and has a single channel. The other sites, whether active or abandoned, fall somewhere in-between.

Mill Creek was a sink at high streamflow, but a source at low streamflow. Glacier Creek did not show any attenuation of streamflow even though it has current beaver activity. For the abandoned meadows, Cow Creek and Hidden Valley both became a sink at high streamflow and a source at low streamflows. Although these meadows are abandoned and have lower overall morphologic complexity, they retain remnant beaver dam and pond features that may still be affecting the hydrology even though the beaver have left.

The organic carbon analysis includes North St. Vrain (active meadow) and Moraine Park (abandoned). The percent organic carbon (OC) in the soil samples is not statistically different between the active and abandoned meadows. Moraine Park has greater soil OC stocks than the active meadow, but the difference is not statistically significant. These preliminary results indicate that beaver activity may not play a role in soil OC storage in Colorado mountain meadows. ■

CWCB | FY17 Project Highlights

Near South Park, Colorado. Photo by Alan Szalwinski

Quantifying Pumping-Induced Streamflow Depletion in the South Platte River Corridor

Ryan T. Bailey, Civil and Environmental Engineering, Colorado State University
Luke Flores, Civil and Environmental Engineering, Colorado State University

Background

To gain further insight and understanding into stream-aquifer interactions with regard to pumping induced streamflow depletion, a study has been conducted along a short reach of the South Platte River located in South Suburban Park, Littleton, Colorado. The reach is located just downstream of Chatfield Dam and is adjacent to a well field consisting of four alluvial pumping wells operated by the Centennial Water and Sanitation District.

Methods

The study was primarily conducted from December 2016 to March 2017. Field measurements included streamflow at an upstream and downstream site to determine streamflow depletion, and groundwater levels. To monitor groundwater heads in the alluvium, 11 monitoring wells were drilled at five different locations.

The purpose of the nested wells was to try and detect a strong vertical gradient near the river (as was the case at Locations A and B), which would provide insight into the direction of flow near the streambed.

Results

There are two trends worth recognizing. The first and most prominent is that there is a strong correlation between upstream flowrate and the total loss (Q). The two most likely contributors to this relationship relate to the geometry of the flow. In general, a higher flowrate corresponds to a larger stream depth, and if for a given head under the streambed, it is known that the volumetric seepage from the river is linearly proportional this difference (assuming hydraulically connected conditions). The second contributor to having more loss with more upstream flow relates to bank storage and the width of the river increasing with a larger flowrate. Again, in general, a larger flowrate will lead to a wider stream. While it is clear that there exists a relationship between upstream flowrate and total loss (regardless of pumping effects), the data suggests that pumping causes even more loss.

MODFLOW

A MODFLOW model has been developed to better understand groundwater flow and groundwater-surface water interactions in the study area. During the next year this model will be refined and calibrated to better capture aquifer-river interactions. ■

Section of the South Platte River in the study region.

Luke Flores (MS student) measuring streamflow discharge, January 2017.

Developing a Refined Groundwater Flow Model for the LaSalle/Gilcrest Area

Ryan T. Bailey, Civil and Environmental Engineering, Colorado State University
Chenda Deng, Civil and Environmental Engineering, Colorado State University

Installation of Groundwater Monitoring Wells in the Gilcrest area, performed by Drilling Engineers, Inc.

In recent years, the Gilcrest/LaSalle area has experienced high groundwater levels. The source of water for the aquifer includes infiltration and recharge from surface water irrigation, groundwater irrigation, and rainfall; pumping for agricultural use and M&I use; infiltration from recharge ponds; canal seepage; groundwater lateral flow from surrounding areas; and upflux from the underlying bedrock aquifer. The principal objective for this project is to assess the impact of these individual contributions on water table elevation fluctuation. This report describes the development of a new MODFLOW model for the area and preliminary testing results.

Various entities have drilled 445 boreholes in the alluvial aquifer of the study area. The borehole data were used to create a bedrock elevation contour map using the base elevation recorded for each borehole. The borehole data also were used to create maps of hydraulic conductivity. The variogram models are used for the 3-D Kriging interpolation. The groundwater stress data for the model consist of pumping, recharge (rainfall, irrigation), recharge pond infiltration, canal seepage, lateral groundwater flow, and bedrock upflux.

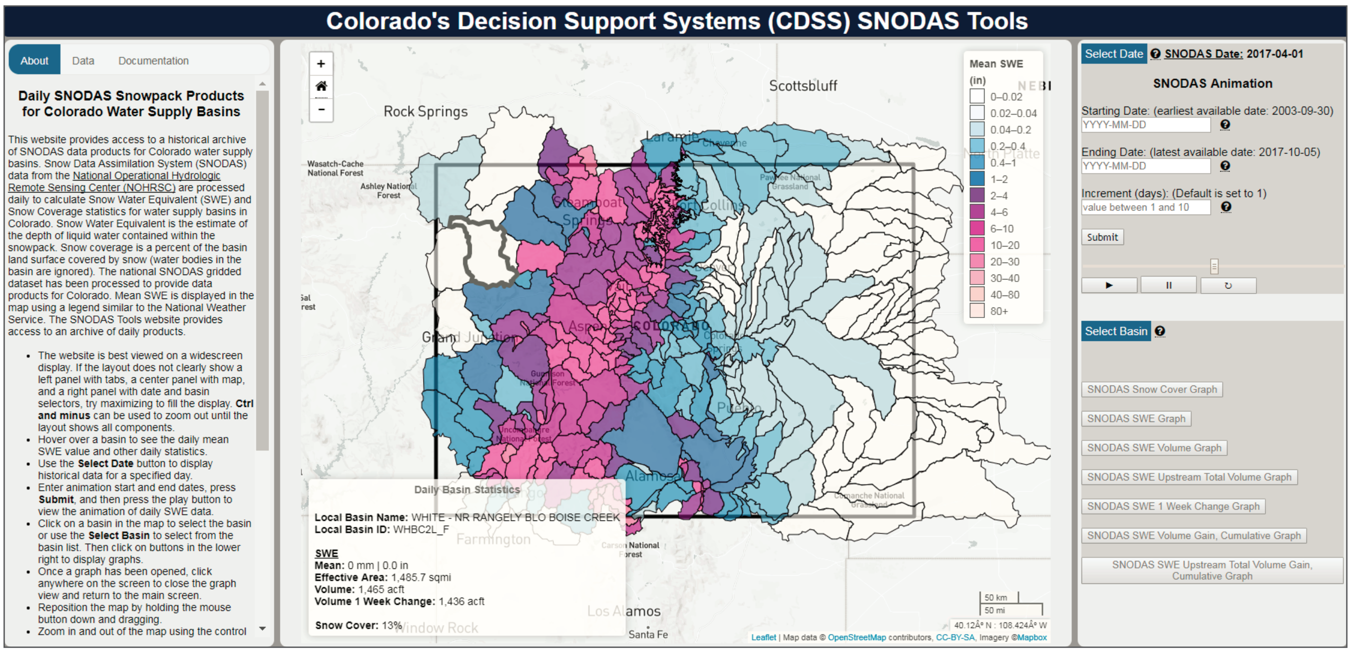
A steady state simulation was performed first to verify the initial working of the MODFLOW model. The results indicated that the groundwater flow from southwest to northeast, with groundwater discharging into the South Platte River. The simulation result was also compared with the observed depth to the water table data in 1967. The high water table simulated by the model matches the observed values along the South Platte River and the Beebe Draw reach in the eastern part of the region. However, the model was not able to capture the observed high water table in the Gilcrest area.

A transient simulation was then run using the stresses included in the SPDSS model. The simulation period is from 1950 to 2012 with a 3-day time step. The results were compared with to the observed groundwater levels from 2012. Overall, the simulated groundwater levels match the observed levels, with a high groundwater level along the South Platte River, along Beebe Draw, and in the Gilcrest area. The next steps for model testing included comparing groundwater levels at the observation well locations (i.e. compare time series of head values). Once tested, the model will be used in a sensitivity analysis to determine the effect of each stress (pumping, recharge pond, canal seepage, irrigation) on groundwater levels through the modeled area.

This report provides results of the following information: 1) creating hydraulic conductivity maps for Gilcrest using an extensive set of borehole data; 2) creating a refined MODFLOW model for the Gilcrest/LaSalle area; and 3) preliminary model testing using both steady-state and transient simulations. For the transient simulations, groundwater source/sink data were extracted from the SPDSS MODFLOW model, modified by Brown and Caldwell in 2016. Preliminary model results match reasonably well with the observation groundwater levels, particularly along the South Platte River, along Beebe Draw, and in the Gilcrest area. The next phase for this project is to calibrate the MODFLOW model using monitoring well data. A sensitivity analysis will be done to assess the impact of the individual contributions of all groundwater stresses (pumping, recharge pond, canal seepage, irrigation) on water table elevation fluctuation. ■

Enhanced Open Data for Colorado's Water Resources

Steve Malers, Open Water Foundation



Snowpack Data Visualization.

The "Enhanced Open Data for Colorado Water Resources" project was a collaborative effort between Colorado State University (CSU) and the Open Water Foundation (OWF) to improve access to water resources data through implementation of open data and visualization technologies. This collaboration continues an ongoing effort to integrate the State of Colorado data and tools with CSU education and research, while also providing applied experience to students. OWF performed a comprehensive review of recent Colorado Water Conservation Board (CWCB) studies, including Colorado Water Plan, Statewide Water Supply Initiative, and Basin Implementation Plans to identify important water datasets and potential visualizations that would improve understanding of Colorado water issues. A subset of visualizations was selected for further attention including data related to urban, agricultural, and environmental water use. Visualization techniques and tools were evaluated and were applied to specific examples. CSU students Kory Clark (Computer Science) and Justin Rentie (Applied Computing Technology) developed several software tools to process and visualize water resources data using open source web technologies, including tools to visualize data spatially and illustrate temporal trends. For example, urban water use data were visualized to illustrate trends, and mapping tools were implemented to visualize basin water plans and population growth. Recommendations were provided to the State for tool implementation and improved open data access. The results of the project are being used on a number of ongoing CWCB projects such as the Statewide Water Supply Initiative and will be applied and enhanced on future projects to support the CWCB. Software components were also leveraged to create tools to visualize water supply data including snowpack. Clark and Rentie continue to develop water resources software tools as interns at OWF. ■

Colorado Irrigation Center Design and Concept Development

By José L. Chávez, Civil and Environmental Engineering, Colorado State University
Reagan Waskom, Colorado Water Institute
Stephen W. Smith, Wade Water LLC

Purpose of the Research
Current pressures on available water supplies in the western U.S. are creating unprecedented political, sociological, engineering, and management issues for practitioners in the irrigation sectors (both agricultural and landscape) irrigation. Climate change, extended drought periods, and population forecasts portend significant future water shortages. The western U.S. has experienced severe drought and competition has increased for these limited water resources. The irrigation industry is the primary target for change and improvements as water becomes increasingly scarce. Technology and management schemes currently exist that can significantly upgrade irrigation system efficiency, but they have not yet been widely implemented. In particular, the Colorado Division of Water Resources has specifically noted the need of an irrigation center in Colorado.

Ojectives and Methods
The main objective of this project is to develop a business plan to create and operate a Colorado Irrigation Technology Center (ITC) within CSU. A partnership is proposed between private business and the public sector to create a new center of excellence in irrigation methods, automation, SCADA, modernization, evaluation, management, training to enhance the economic and environmental opportunities for water sharing arrangements in CO, the U.S. and across the globe. In Colorado, this need has been identified specifically by the Colorado Division of Water Resources staff and dovetails nicely with the needs of the State Water Plan.


An irrigation structure on the I-25 and Prospect site, CSU.

Related Sub-Objectives of this Proposal
1) Establish a consortium of interested parties that will help develop a business plan for the ITC,
2) Design the center's physical layout (e.g., buildings, equipment), and
3) Identify entities and obtain commitments to support the creation of the ITC.

Results
Activities carried out addressing the sub-objectives
Regarding Sub-Objective 1:

- A group was formed to help develop the ITC business plan.
- We visited Fresno State's Center for Irrigation Technology to learn about their equipment, services, and business plan.
- A list of desired equipment and instruments for the ITC was initially identified.

Regarding Sub-Objective 2:

- A local irrigation engineering company was hired to assist in the design of the ITC
- A location was identified and confirmed for the ITC. The location is the land at the south-west quadrant of the intersection of I-25 and Prospect (I25P).

Regarding Sub-Objective 3:

- Dr. Stephen Smith presented the ITC concept to the Irrigation Association and Irrigation Foundation board and through the Spring of 2017 seeking pledges for acquiring cash investment, irrigation equipment, instruments, sensors, teaching/training/testing materials, and other needed support. ■

Fountain Formation - Potential for Subsurface Water Storage

Tom Sale, Civil and Environmental Engineering, Colorado State University

Growth in Colorado continues to drive a need for new Front Range water storage. A key driver for future water storage development will be the ability to take advantage of water available during periods of high streamflow to sustainably address water needs for municipal water supply, agriculture, and industry. In this study, we evaluated subsurface water storage in the Fountain Formation. The study included a review of relevant literature, a compilation of data from the Colorado Division of Water Resources AquaMap database, data from visual inspection of outcrops, data from rock and well water samples, and recommendations for further research.

The 1091 existing Fountain Formation wells identified are dominantly designated as either household or domestic wells. Two neighboring quadrangles about halfway between the Wyoming and New Mexico state lines, Mount Deception Quadrangle and Woodland Park Quadrangle, account for 30% of the Fountain Formation wells. Another 26% of the Fountain wells are in the six quadrangles along the northern Colorado Front Range between Fort Collins (Horsetooth Reservoir Quadrangle) and Boulder (Boulder Quadrangle), with an additional 12% accounted for near the southern end by three neighboring quadrangles, Cooper Mountain, Phantom Canyon, and Mount Pittsburg. One quadrangle, Littleton, hosts only monitoring wells in the Fountain Formation.

The degree of variability in numbers of Fountain Formation wells within and between quadrangles likely reflects several factors, one being variation in hydrogeologic parameters. In addition, some areas have relatively limited access to the Fountain as a potential aquifer because of faulting or variation in the dip of bedding affecting the volume of Fountain sandstones accessible at appropriate depths beneath the surface. Two other factors that may affect the number of wells drilled into the Fountain are related to groundwater demand; localities with access to good aquifers overlying the Fountain are less likely to tap the Fountain and rural localities with low population density may drill fewer total groundwater wells.

High yield values suggest that permeability is high enough to permit adequate flow rates to support ASR. Low yield values, however, may be related to multiple factors, including low permeability or low demand placed upon a well. The compiled data suggest that there are multiple localities along the length of the study area that have existing wells with high yields and high specific capacities, supporting the view that the Fountain Formation has the potential to be a good ASR target. There are some characteristics of the Fountain Formation that are clearly positive in this assessment, although there are also some potential constraints that will require additional consideration. Additional testing will be necessary to verify that the Fountain aquifer is a good ASR target. ■

Fountain Formation exposures in northern Colorado. (A): permeable coarse-grained gravelly channel-fill surrounded by finer-grained sandstone. (B): permeable conglomeratic sandstone typical of some horizons within the Fountain Formation. (C): fine-grained, low-permeability paleosol mudstone (dark red horizon) sandwiched between sandstone layers (gray above, nottled gray-red below).

Determination of Consumptive Water Use of Winter Wheat in the Arkansas Valley of Colorado

(Year 2: 2016-2017)

By Allan A. Andales, Soil and Crop Sciences, Colorado State University
Lane H. Simmons, Arkansas Valley Research Center, Colorado State University
Michael E. Bartolo, Arkansas Valley Research Center, Colorado State University

Accurate calculations of crop consumptive water use or crop evapotranspiration (ETc) of irrigated winter wheat (Triticum aestivum L.) are needed in the Arkansas Valley of Colorado. A locally-derived crop coefficient (Kcr) curve for winter wheat is needed to convert alfalfa reference crop ETrs calculated from the ASCE standardized equation to non-stressed winter wheat ETc at different stages of crop development. The objective of this study was to measure the seasonal ETc of winter wheat and develop a preliminary Kcr curve using data collected in 2016 – 2017. A precision weighing lysimeter at Rocky Ford, Colorado was used to measure daily ETc of furrow-irrigated winter wheat grown under local weather and environmental conditions. The mass of an undisturbed soil monolith with an actively-growing winter wheat crop contained in a steel tank (1.5 m x 1.5 m area; 2.4 m deep) was continuously monitored with a calibrated load cell to determine wheat ETc. Winter wheat (TAM-113 variety) was planted on the monolith and surrounding field (3.5 ha) on 9/20/2016. Crop height and soil water content were monitored weekly during the growing season. Fifteen-minute average measurements of solar radiation, air temperature, wind speed, and humidity were used to calculate hourly and daily ASCE standardized ETrs values. Daily Kcr values for winter wheat were calculated as ETc/ETrs. Total season winter wheat ETc (9/21/2016 – 7/9//2017) was 809.5 mm. Average daily ETc was 2.8 mm d-1. The seasonal winter wheat Kcr curve was adequately represented (R2 = 0.84) by a fifth order polynomial equation, with Kcr as a function of days after planting. Winter wheat grain water use efficiency (WUE) was 0.561 kg m-3, which was in the lower range of published values. ■

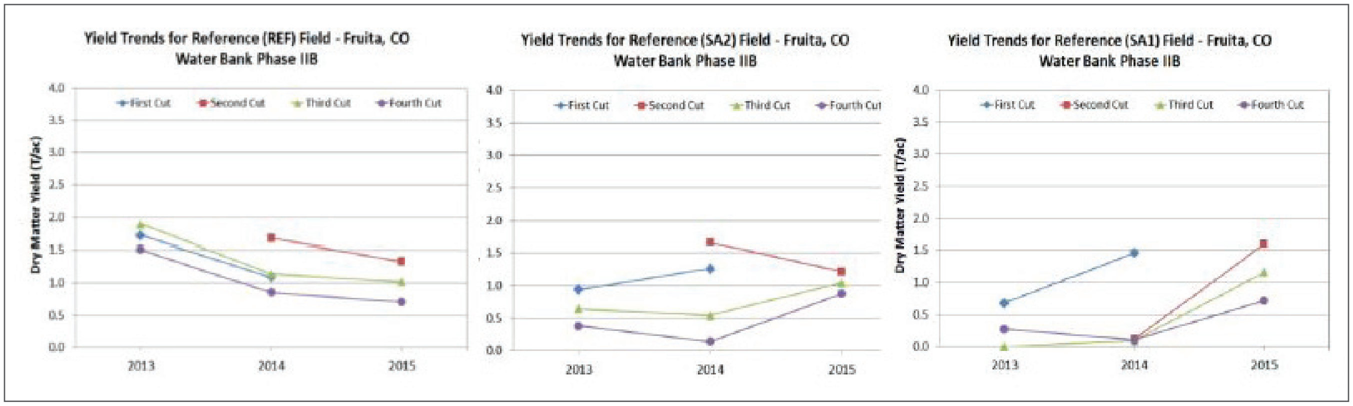
The inner tank with soil being lowered into the containment tank of the lysimeter. The manhole for accessing the underground weighing scale is on the right.

View of the lysimeter looking to the southeast. The net radiometer, infrared thermometer, and temperature/humidity sensor are shown mounted above the lysimeter.

Agronomic Responses to Partial and Full Season Irrigation of Alfalfa and Grass Hayfields

By Perry E. Cabot, Research Scientist and Extension Specialist, Colorado Water Institute
Joe Brummer, Soil and Crop Sciences, Colorado State University
Sumit Gautam, Civil and Environmental Engineering, Colorado State University

Trends for the Eckert and Fruita alfalfa fields are shown below.



The following discussion provides a brief overview of the reportable findings from an additional $5,000 that was granted to support continual research under the CWI Project entitled "Agronomic Responses to Partial and Full Season Fallowing of Alfalfa and Grass Hayfields" originally supervised by Joe Brummer.

The recovery of the forage crops from the work of the project has been of interest. It has been observed that "fully irrigated" reference (REF) plots in some cases have exhibited diminished yields through the life of the study, whereas some of the fields on which irrigation has been curtailed, have unaffected or improved yields

- **Summary of Field Sites**. Established alfalfa fields were subjected to irrigation treatments including normal irrigation (control), irrigation stopped after the 1st cutting (SA1), and irrigation stopped after the 2nd cutting (SA2) for two consecutive years. These plots were returned to full irrigation in 2015. One of the plots (Eckert, Colorado) was also maintained in alfalfa through 2016.

- **Summary of Yield Data**. It is evident that yields across the reference (REF) plots generally declined during the 3 or 4 years of the study. On the other hand, the fields on which irrigation was stopped after the first or second cutting (SA1, SA2) exhibited stable and in some cases increasing yields.

- **Explanations for Yield Responses.** Although this study did not evaluate the causes underlying the performance of the forage crops, there are only a select number of possible explanations.

1. **Oxygen Deprivation**. Lack of oxygen can cause death or damage to rooting systems. As such, it is possible that the reduced irrigation regimes led to increased oxygen levels.

2. **Death of Fine Root Hairs**. Fine root hairs are critical for nutrient and water uptake and can be damaged during waterlogging.

3. **Root Pruning**. Saturated sub-surface layers can damage roots below that level, and also may deposits salts when capillary action recedes.

4. **Micronutrient Availability**. Low oxygen conditions can lead to iron (Fe) and other micronutrients unavailable for plant growth. It is possible that the reduced irrigation regimes led to increased micronutrient levels.

5. **Disease and Pests**. Phytophthora and stem nematodes that can weaken alfalfa are more pronounced in waterlogged soils.

6. **Total Nonstructural Carbohydrate (TNC)**. Plants exposed to periods of drought may have rapid initial regrowth upon alleviation of these stresses because high amounts of total nonstructural carbohydrates (e.g., glucose, fructose, sucrose) may have accumulated in their storage organs during stress (Busso, Richards and Chatterton, 1989). ■

What’s New?

Rocky Mountain National Park. Photo by Anne Dirkse

South Platte Phreatophyte Study

CWI Special Report 30

Colorado Water, January/February 2017

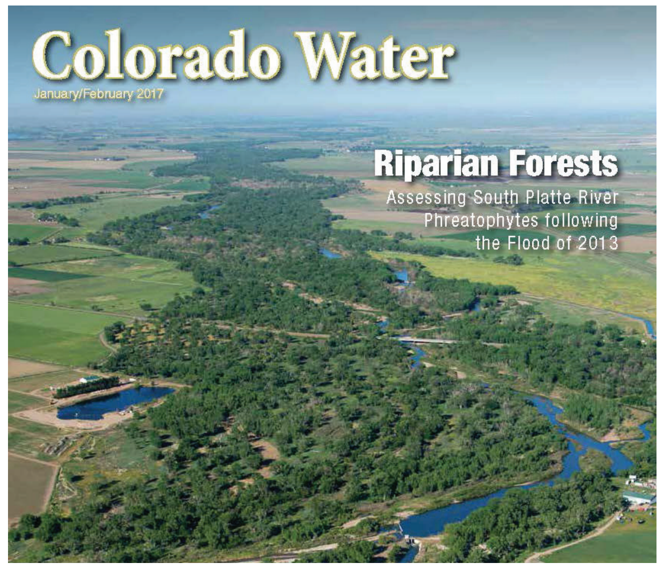
By Reagan Waskom, Director, Colorado Water Institute

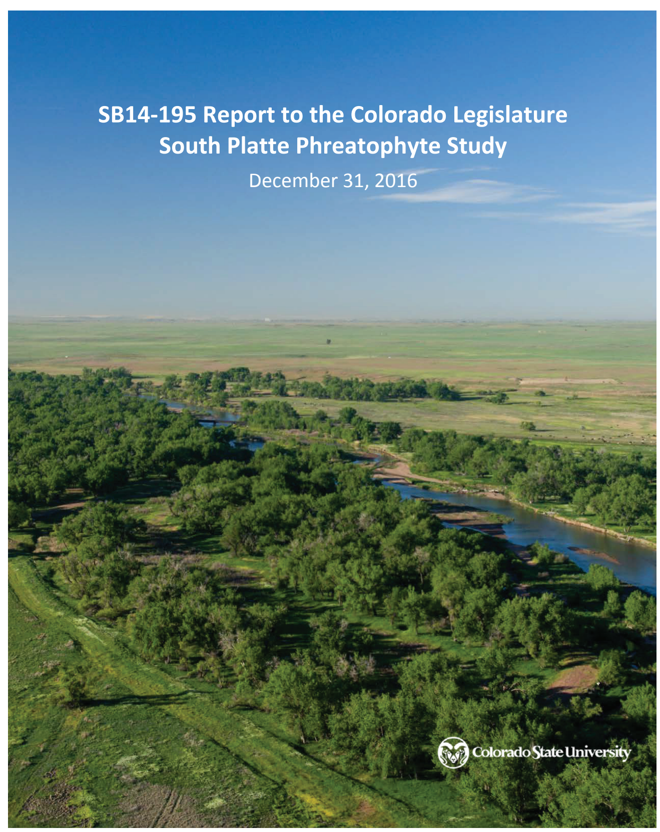
Phreatophytes, those deep-rooted water loving trees such as cottonwoods or willows, are seen by some as water thieves, by others as critical components of healthy riparian ecosystems. Riparian forest composition and extent in Colorado have likely been under significant and continuous change since water development began in the mid-19th Century. We now know that this process is largely driven by both short- and long-term patterns of river discharge within the system. Phreatophytes are associated with all riparian corridors to various degrees, but non-native and invasive phreatophytes are a source of particular concern for both water users and environmental interests.

The September 2013 flood on the Colorado Front Range occurred due to an unusually heavy and prolonged rainfall event over a large area of the foothills, resulting in an exceptional flood event on the South Platte River. The flood inundated large stretches of the floodplain from communities along the Front Range all the way to Nebraska.

Following the September 2013 flood, there was concern that new sediment deposits, elevated groundwater levels, and altered stream banks would result in an increase the abundance of invasive non-native species, including woody phreatophytes and State of Colorado-listed noxious weeds. In 2014, the Colorado legislature passed SB14-195, directing the Colorado Water Conservation Board to study the effects of the September 2013 South Platte flood on phreatophyte spread and the feasibility of removing non-native phreatophytes from the South Platte River corridor. The CWCB subsequently contracted with Colorado State University and the Tamarisk Coalition to conduct the required studies. Both 2014 and 2015 were also high water years with some flooding on the South Platte, no doubt further impacting the trajectory of channel morphology, phreatophyte recruitment and survival.

The study, led by CSU Professor Andrew Norton, documented that the riparian forest along the South Platte River is dominated by Plains cottonwood, while the second most common mature tree species is the Peachleaf willow. Currently, the most common non-native phreatophytes in the study area are Russian olive and Siberian elm. They estimated that non-native phreatophytes make up between 4 and 10% of the riparian





forest on a per-area basis. It was also estimated the 2013 flood and subsequent high water years in 2014 and 2015 caused the mortality of 8.5% of the forest, on an area basis. The flood opened up new areas for cottonwood seedling germination and establishment that occurred during 2014 and 2015 but it is not yet know whether these seedlings will survive to become saplings or mature trees. Estimated total costs for removing 20% of phreatophytes from reaches along the South Platte below Denver range from $870,700 for one-time removal only, to $45,524,846 for removal plus weed control, seeding, and shrub planting. Continued monitoring will be needed to assess long-term trends in riparian forest spatial extent, dynamics of cottonwood regeneration, and successional trajectories for species composition within aging forest stands. A key question that remains from the work is how frequently cottonwood seedlings successfully recruit to the sapling stage within this system.

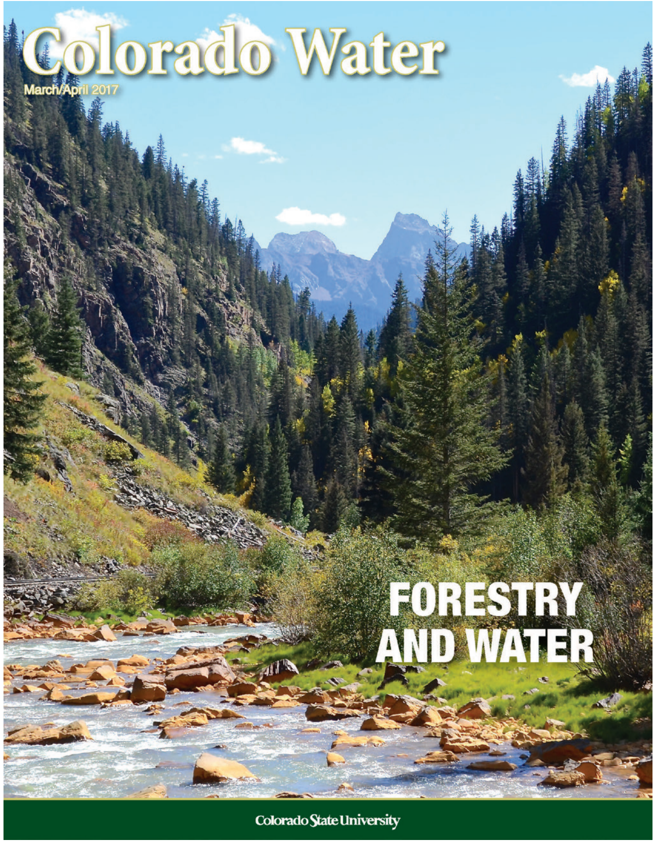
This edition of Colorado Water newsletter provides an overview of findings and recommendations related to effects of the 2013 flood on the riparian forest of the South Platte River in northeast Colorado. For supporting documentation and a more detailed summation, please see full report found online at http://www.cwi.colostate.edu/publications/SR/30.pdf and to view the newsletter please visit http://wsnet2.colostate.edu/cwis31/ColoradoWater/Images/Newsletters/2017/CW_34_1.pdf ■

Achieving Healthier Forests for Cleaner Water

Colorado Water, March/April 2017

By Michael B. Lester State Forester and Director, Colorado State Forest Service

Colorado's headwaters play a crucial role in meeting our nation's need for fresh water. Colorado's Water Plan indicates that approximately 80 percent of our population depends on forested watersheds for municipal water supplies. But these watersheds suffer the same fate as the forests. When forest health declines, so may the quality of the water yield flowing through those forests. These forests can set the stage for potentially devastating wildfires or insect and disease outbreaks. The theme of the March/April issue of Colorado Water was focused on of the link between healthy forests and clean, reliable water supplies.



How Forests Impact Water

Intense Colorado wildfires often lead to severe runoff and soil erosion during storms. The resulting high rates of runoff and erosion during post-fire weather events can greatly lower water quality in nearby streams, and clog reservoirs downstream with sediment, impacting urban and agricultural interests.

Protecting Water Through Forest Management

The High Park Fire provides a good example of the effectiveness of forest management to later reduce wildfire risk. During that event, high-severity fire was prevented within previous fuels treatment areas in

Lory State Park, where stand thinning occurred. As a result, the watershed for Horsetooth Reservoir was not as seriously threatened by post-fire runoff.

It is the role of agencies like the CSFS to ensure that private landowners have the tools they need to address forest and watershed health, including wildfire risk. Every year, the CSFS helps treat more than 17,000 targeted acres of forestland and assists approximately 2,000 landowners to improve forest health and reduce risks to watersheds.

Partnerships, Legislative Support Vital for Success

CSFS partnerships with other federal and state agencies, including the U.S. Forest Service (USFS), Colorado Parks and Wildlife, and with water providers like Denver Water and Northern Water, allow stakeholders and land managers to work together to make the greatest possible impacts in the health of the forestlands that supply our water.

Colorado's forested watersheds face many challenges. But these can be addressed through targeted forest management, legislative and public support, and by strengthening key partnerships that have a common goal of ensuring clean, stable water supplies.

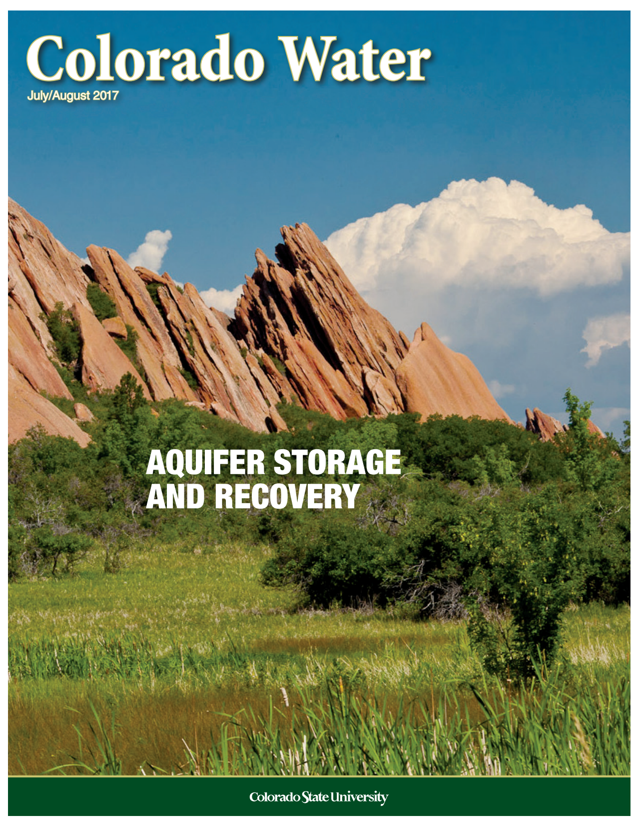
To view this issue of the *Colorado Water* newsletter, please visit: http://wsnet2.colostate.edu/cwis31/ColoradoWater/Images/Newsletters/2017/CW_34_2.pdf ■

Subsurface Water Storage Symposium Overview

Colorado Water, July/August 2017

By Tom Sale, Civil and Environmental Engineering, Colorado State University

A one-and-a-half-day symposium addressing subsurface water storage was held at Colorado State University (CSU) on November 15 and 16, 2016. The focus of the meeting was to share emerging knowledge, collaboratively debate critical issues, and prioritize future work to address key water management challenges of using aquifers for storage of available surface water.



Focus

Per the 2016 White House Water Summit, "...there is a need to shine a spotlight on the importance of cross-cutting, creative solutions to solving the water problems." Similar themes can be found in the State of Colorado's 2016 Water Plan, including "storage as we conserve" and in the commitments, being made by water districts across Colorado and the western U.S.

An emerging "cross-cutting, creative solution" is the use of subsurface water storage in conjunction with existing surface water systems. Subsurface water storage projects can simplify permitting for new storage, provide an economical alternative to surface storage, minimize environmental impacts of new water storage, enhance the resiliency of water systems, and conserve water by reducing seepage and evaporative losses.

Scope
David Pyne was the keynote speaker and guiding participant in the symposium. Pyne is an internationally recognized leader in the field of subsurface water storage and is the widely acclaimed author of Groundwater Recharge and Wells: A Guide to Aquifer Storage Recovery (1995) and Aquifer Storage Recovery: A Guide to Groundwater Recharge (2005). Critical elements of the agenda for the first day included: 1) current best practices for subsurface water storage, 2) exploring water rights and permitting issues, 3) introducing new enabling technologies including research tools developed at CSU, and 4) sharing insights from active subsurface water storage projects. On the second day, participants convened in the morning for a lively review of findings, evaluations of constraints, and debate of areas for future investment.

Outcomes
The symposium was a great success. New collaborations were built, critical knowledge was shared, and vision for the future of subsurface water storage in Colorado was advanced. Meeting notes including meeting presentations are available at: http://www.engr.colostate.edu/CCH/2016_SWS_Symposium_Notes.docx. Furthermore, the July/August issue of Colorado Water focused on aquifer storage recovery (ASR) and highlighted the SWS Symposium and topics discussed at this event. To access this issue of Colorado Water, please visit http://wsnet2.colostate.edu/cwis31/ColoradoWater/Images/Newsletters/2017/CW_34_4.pdf. ■

Reports and Newsletters

Completion Reports http://cwi.colostate.edu/publications.asp?pubs=cr

CR230 Management of Large Wood in Streams of Colorado's Front Range: A Risk Analysis Based on Physical, Biological, and Social Factors
Ellen Wohl, Kevin Bestgen, Brian Bledsoe, Kurt Fausch, Mike Gooseff and Natalie Kramer

CR231 Using Remote Sensing Assessments to Document Consumptive Use (CU) on Alfalfa and Grass Hayfields Managed Under Reduced and Full Irrigation Regimes
Perry E. Cabot, Aman Vashisht and José L. Chávez

Special Reports http://cwi.colostate.edu/publications.asp?pubs=sr

SR30 Report to the Colorado Legislature South Platte Phreatophyte Study
Andrew Norton, Gabrielle Katz, Ahmed Eldeiry, Reagan Waskom and Tom Holtzer

SR31 Where now with Alternative Transfer Methods—ATMs—in Colorado?
Anne Castle, MaryLou Smith, John Stulp, Brad Udall and Reagan Waskom

John Fetcher Upper Yampa Water Conservancy District Scholarship Recipient

Jacob Park

Hometown:
Grand Junction

University:
Colorado Mesa University

Areas of Study:
Junior, Environmental Science and Technology, Watershed Science

Newsletters http://cwi.colostate.edu/publications.asp?pubs=sr

V33, I5 November/December 2016, CSU Water Center 2016 Projects

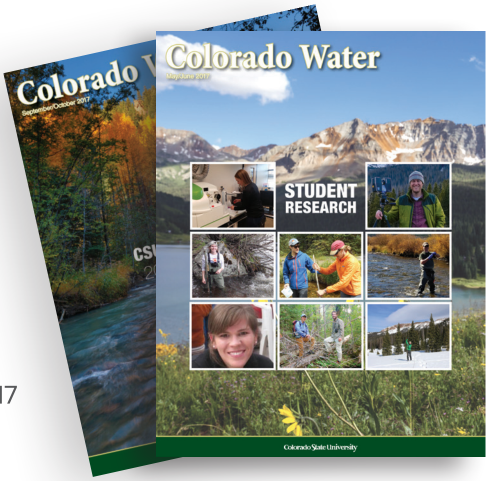
V34, I1 January/February 2017 Riparian Forests

V34, I2 March/April 2017 Forestry and Water

V34, I3 May/June 2017 Student Research

V34, I4 July/August 2017 Aquifer Storage and Recovery

V34, I2 September/October 2017 CSU Water Center 2017 Projects



CWI Staff Highlights

Clear Creek, Colorado. Photo by Grant Bishop

Jennifer Gimbel, Senior Water Policy Scholar, Colorado Water Institute

Upon returning from Washington D.C., where she was Principal Deputy Assistant Secretary for Water and Science, Jennifer began her work with the Colorado Water Institute (CWI) in November 2016. Her work is funded by a Walton Family Foundation (WFF) grant to work on Colorado River policy issues, focusing on the Upper Basin and a potential Upper Basin compact bank. She developed an internal policy evaluation tool to guide work on a compact bank over the next few years. Her analysis of possible governance structures for a Compact Bank was shared with the Upper Basin Commissioners and staff members. She participates and coordinates her work with the Upper Colorado River Compact Commission (UCRC), individual state commissioners and their staff, Colorado Natural Resource Law Center at Colorado University Law School, Colorado Water Conservation Board, Colorado Water Bank Working Group and non-governmental entities, including The Nature Conservancy and Trout Unlimited.

During the fall semester of 2017, Jennifer is leading a graduate seminar (GRAD592) on water management in Colorado. The class consists of graduate students and upper classmen who have varied majors. The focus of the class is to delve into some of the data bases used in managing water.

Emcee Jennifer Gimbel welcomed the audience to the Western Water Symposium and Barbecue. Photo courtesy of CSU Libraries

Over her time at CWI, Jennifer has emceed the Western Water Symposium and Barbeque supporting the Water Resources Archive. She was invited to speak at the Martz Summer Conference, where she discussed the negotiations around Minute 319. At the biennial Water Education Foundation's Colorado River Symposium, she moderated a panel consisting of Mike Connor, former Deputy Secretary of the Department of the Interior (DOI), and Bennett Raley, former Assistant Secretary for Water and Science at DOI. She was the keynote speaker at a Rio Grande Law Conference in Santa Fe and participated on a panel on Indian Water Law at the annual ABA Water Law Conference. ■

MaryLou Smith, Policy and Collaboration Specialist, Colorado Water Institute

Convening stakeholders for dialogue and action regarding complex water policy issues is one of the Colorado Water Institute's key activities. Our USDA project Moving Forward on Ag Water Conservation in the Colorado River Basin has given us many opportunities this year to convene and facilitate stakeholder dialogue, much of it as part of Ag workshops around the state put on by Colorado Ag Water Alliance. We have also continued our facilitation of the Poudre Runs Through It Study/Action Work Group, which this year staged its fourth annual Poudre River Forum. We moved down the river to Greeley for the Forum, gaining enthusiasm and assistance from both Greeley Water and Sewer and University of Northern Colorado.

In 2016, a notable accomplishment was bringing together stakeholders statewide to work with Colorado's State Engineer to dig into the issue of "use is or lose it"—to clarify what's myth and what's reality when this frequently used phrase is thrown around. That effort resulted in our Special Report 25: How Diversion and Beneficial Use of Water Affect the Value and Measure of a Water Right Is "Use It or Lose It" an Absolute? Most recently, the new State Engineer, Kevin Rein, asked for a set of "waste rules" to give those administering water law in the field, guidance to help when questions come up about whether an irrigator is diverting in excess of need.

Somehow, we managed to find time to take on two entirely new efforts in 2017, each of them for the purpose of drawing new constituencies into an understanding of water issues and decision making.

The first is Water Literate Leaders of Northern Colorado. We reached out to the Community Foundation of Northern Colorado to partner with us to identify leaders and emerging leaders in the communities of Greeley, Loveland, Windsor, and Fort Collins. At our first session were participants including a city major, a city manager, several council members from three of the cites, chamber of commerce and real estate folks, an agricultural lender, an architect who does land use planning and a couple from the region's watershed groups. Over a nine-month period, they will be doctrinated in all things water, but most importantly, will be brought into dialogue about the region's critical water issues. Our long-term goal is to spur a regional dialogue about water—something that has been difficult for us to ignite at higher levels up to this point. That goal is behind the funding we received from an anonymous donor.

Our other far reach is to establish CSU's Water Sustainability Fellows and resulting from that, a National Western Center Youth Water Project. We believe that Colorado's water decisions can be improved by bringing in people and ideas from the state's broader ethnic makeup. For instance, 21% of Colorado residents are Latino, yet we see few Latino faces in water meetings. We wanted to see if we could plant a seed to change that. We began by working with CSU's School of Global Environmental Sustainability and CSU's ASSET Program to offer internships to undocumented students interested in learning about water. The ASSET program pays in-state tuition for high achieving undocumented high school students who are seeking legal status, mostly through DACA—Deferred Action for Childhood Arrivals. The eight fellows we chose met monthly and during weekend field trips learning about water and strategizing best ways to engage unrepresented populations in Colorado water dialogue and decisions.

This past summer, five of our CSU Water Sustainability Fellows were subsequently chosen for a National Western Center Summer Youth Project that we developed in cooperation with the emerging National Western Center Project. (For more information about the National Western Center effort being undertaken

Students from CSU and Denver high schools participating in the National Western Center Youth Water Project pause for a photo this summer at Swansea Recreation Center.

Water Literate Leaders of Northern Colorado

Water is emerging as one of the most complex and controversial subjects to be addressed in the 21st century. Water issues are particularly complex, and understanding the nuances is critical for good decision-making. Many who have helped our communities make sound water decisions are nearing retirement age. Northern Colorado needs a new crop of water literate leaders!

The Colorado Water Institute, in cooperation with Community Foundation of Northern Colorado is launching a non-partisan Water Literate Leaders of Northern Colorado program. Modeled after highly successful programs such as Leadership Northern Colorado, this program is for those who hold or aspire to political office, or other roles, including boards and commissions, which can impact regional water policy.

- A colloquium of emerging leaders from Northern Colorado's communities
- Actively learning about Northern Colorado water from all angles including: agriculture, urban, environmental, recreation, and business via presentations, dialogue and field trips
- Interaction and dialogue with regional water leaders to get an inside view of issues affecting Northern Colorado's water future—and participation in visioning activities
- Dates: September 14, October 12, November 9, December 14 of 2017, and January 11, February 8, March 8, April 12, May 10 of 2018, 8 am—1 pm including lunch at Community Foundation offices, 4745 Wheaton Drive, Fort Collins
- $150 fee
- Maximum of 20 participants

Criteria for acceptance:

- Has exemplified leadership in one of the Northern Colorado communities
- Anticipates continued community leadership for the next 15-20 years
- Concerned about the water future of Northern Colorado
- Must make a strong commitment to attend sessions

Applications due August 1
Participants chosen August 15

For more information and to apply: **waterliterateleaders.colostate.edu**

COLORADO WATER INSTITUTE
COLORADO STATE UNIVERSITY

Community Foundation of NORTHERN COLORADO by CSU, the Denver Mayor's Office, Denver Water, and others see https://www.denvergov.org/content/denvergov/en/north-denver-cornerstone-collaborative/national-western-center.html. This ambitious effort intends to expand the current National Western Stock Show complex into a year-round state-of-the art showcase for water and agriculture, with hopes of giving the underserved neighborhoods around the complex jobs, and opportunities to voice their opinions about the expansion. With funding from Denver Water and the Denver Mayor's Office of Economic Development, our five ASSET students received paid internships to work with six high school students from the neighborhoods surrounding the stock show complex, to get them interested in water, motivate them to stay in school, and focus on community action. The student team worked to plan a future Denver Youth Water Summit. See http://source.colostate.edu/csu-high-school-students-plan-denver-youth-water-summit/ for more information. We are currently conceptualizing a continuation of this program by reaching out to potential philanthropic funders whose mission is to expand the involvement of underrepresented individuals and communities in critical natural resources and social issues.

Both of these efforts are making a difference by broadening the interest in water and the constituency of those engaging in dialogue about water. For the complex water decisions ahead, we need these voices that we have not traditionally reached out to! ■

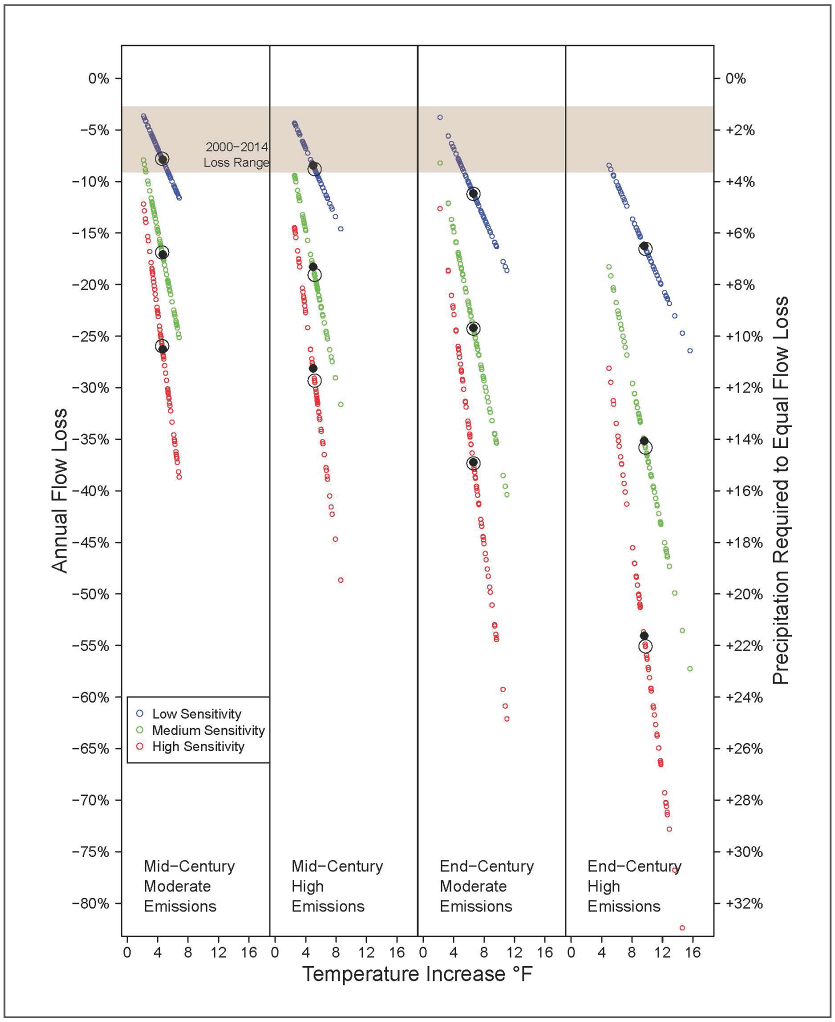
Brad Udall, Senior Water and Climate Research Scientist/Scholar, Colorado Water Institute

Climate-Smart Agriculture Initiative

The Colorado Water Institute, with the support and backing from the Vice President for Engagement Lou Swanson and CSU's President Tony Frank, continues to work on the Climate-Smart Agriculture initiative. We held a session at the Colorado Farm Show on this topic. Over 75 people attended this event. CWI along with other CSU faculty are pursuing a series of short online courses on this topic to be rolled out in late 2017. The USDA North Central Climate Hub, based at CSU, is also a partner in this effort

Western Water and Climate Change Efforts

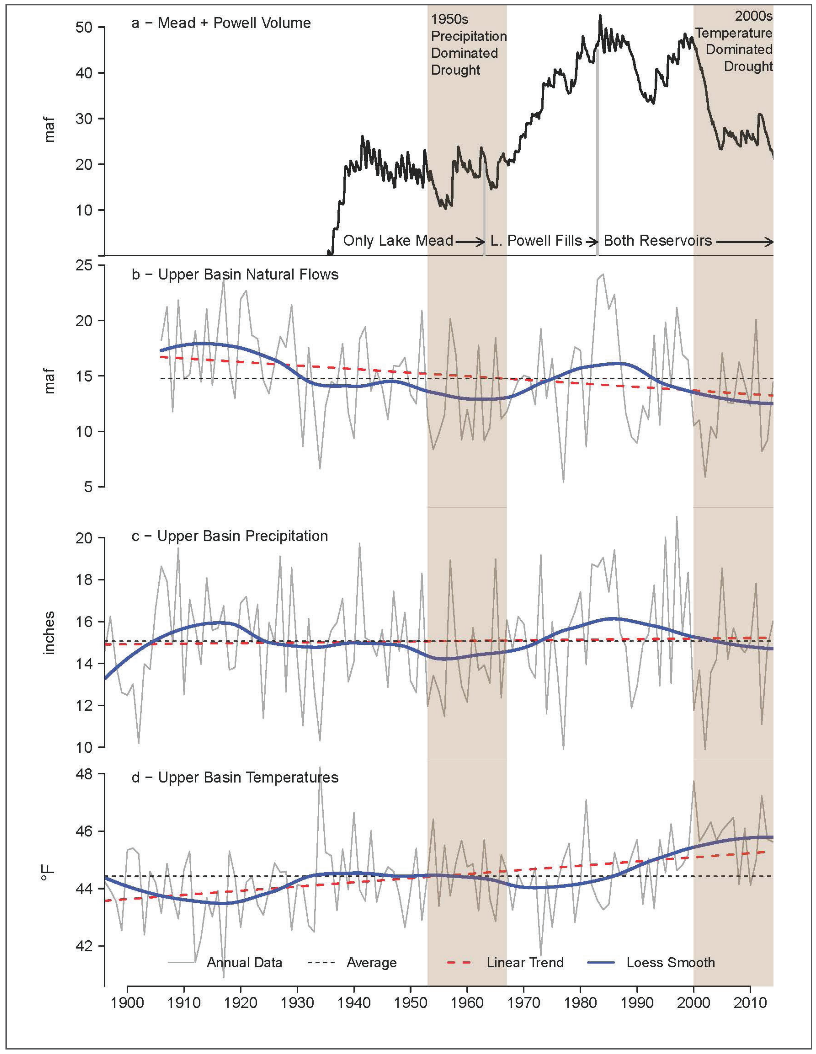
Jonathan Overpeck and I published an article in the Journal Water Resources Research entitled "The twenty-first century Colorado River hot drought and implications for the future". The research article finds that one-third to one-half of the record-setting 19% flow decline from 2000 to 2014 in the Colorado River was caused by higher, human-caused temperatures in the basin. These higher temperatures cause snow to melt earlier which in turn leads to more days for plants to grow, more water use by plants on hot days,



Potential flow reductions in the Colorado River.

more evaporation from soils and water bodies, and now snow can more easily sublimate directly to water vapor. Based on climate model projections, we estimate that by mid-century the Colorado River could lose 20%, and by end of century 35%, of its flow due to these ‘temperature-induced’ effects.

I am a co-author of the 4th National Climate Assessment. This Congressionally-mandated effort summarizes the scientific findings on the impacts of climate change. My focus is on the impacts of climate change on water supplies and demands in the American Southwest. The report will be released in 2018.



Reservoirs, temperatures, precipitation, and flows in Colorado River

Alternatives to Permanent Fallowing Report

My final report with Greg Peterson on the issues with deficit irrigation, crop switching, rotational fallowing, irrigation efficiency and water conservation to procure water for municipal and environmental purposes without permanent fallowing will be available soon. We held workshops to present our findings and to obtain feedback. I presented our findings at the Interbasin Compact Committee.

Talks and Other Activities

I gave a variety of talks on water this past year. I presented at the Colorado Water Congress and opened the University of Utah Law School Wallace Stegner Conference. I attended the Public Policy Institute of California Workshop and in May I presented at the inaugural meeting to establish the Compact of Colorado Communities. I was on a Colorado River panel at the University of Colorado Law school’s annual conference and presented on alternatives to permanent fallowing at the Universities Council on Water Research at CSU. In late August, along with Lou Swanson, Reagan Waskom, and University of Nebraska researchers, we presented on water and climate issues in the American West at World Water Week. ■

Perry Cabot, Research Scientist and Extension Specialist, Colorado Water Institute

Western Colorado Research Center.

The Colorado Water Institute (CWI), Agricultural Experiment Station and CSU Extension (Ext) form a powerful engagement network that can shape agriculture under the new realities of water, soil, and energy management. This integrates demand-driven programming, whereby collaboration arises by listening to stakeholders, securing funding, and designing projects directly targeted to community needs. This collaboration has been formalized under the CSU Western Campus, based in Mesa County, Colorado. In particular, one of the units under this new paradigm – the Western Colorado Research Center at Fruita, Colorado – has been tasked with addressing research needs to deal with the irrigation and water management realities of the Western Region. Engagement under this initiative will utilize the CWI/AES/Ext partnership to support creation, evaluation, demonstration and deployment of technologies that improve agricultural irrigation practices, such as the following:

- Drought-response technologies and programs that match crop water use with climate realities
- Modest improvements (15-20%) of efficiency under traditional furrow and flood irrigation
- Major improvements of efficiency (> 20%) under advanced sprinkler and drip irrigation
- Irrigation scheduling tools to optimize irrigation rates to match crop consumptive use
- Remote-sensing technologies to monitor water stress and evaluate consumptive use
- Agronomy of drought-tolerant varieties and systems for conventional forage and row crops

Pilot System Conservation Program (SCPP)

CWI has continued its partnership with the Pilot System Conservation Program (SCPP) and the Colorado River Water Bank Work Group (CRWBWG). Major accomplishments include documenting the agronomic and consumptive use (CU) impacts to perennial crops under split-season irrigation regimes for perennial crops. The study entitled "Monitoring Consumptive Use and Agronomic Sustainability for Split-Season Irrigation of Alfalfa and Grass Hayfields under the Auspices of a Western Slope Water Bank," 's results demonstrate that alfalfa and grasses are resilient crops, but also demonstrate varying strengths of recovery as a response to irrigation curtailment. In particular, soil conditions and rooting depth appear to be significant factors driving the recovery of crops back to desired production levels.

Resource Conservation Partnership Program (RCPP) Support

Working with No Chico Brush (NCB), the CWI is completing the final year of collaborative projects entitled "No Chico Brush Agricultural Water Research Project" and "A Farmer-Led Initiative to Quantify and Demonstrate Irrigation Efficiencies at Farm-Scales through Instrumented Water Budgeting," funded under the Gunnison Basin WSRA and CWCB ATM programs, respectively. These projects are coordinated with the RCPP effort to promote irrigation efficiency at both farm and regional scales. Results indicate that in the west, a farmer's decision to improve their irrigation system is impacted by constraints that may not be typical to other areas. In particular, field shape irregularities, heavy clay soils, energy costs and profitability margins pose significant impediments to the adoption of improved irrigation systems.

Orchard Mesa, showing the rebound of the field that received limited water (left), and the slow return of the "fully irrigated" field on the right. Taken in the Spring of 2015.

Remote Sensing and Radiometry Tools for Evaluating CU

A report entitled "Using Remote Sensing Assessments to Document Consumptive Use (CU) on Alfalfa and Grass Hayfields Managed Under Reduced and Full Irrigation Regimes" was submitted for publication on the CWI's website. Major accomplishments from this work have been to promote the use of remote sensing and multi-spectral radiometric tools to evaluate actual consumptive use for crops with large leaf area index (LAI), such as alfalfa and grasses. Early results indicate strong relationships between spectral signatures, such as normalized difference vegetation index (NDVI) and actual ET (AET) rates.

Extension and Engagement.

The CWI works regularly with Extension agents and other specialists in the Western Region. In 2017, significant effort has been placed on the writing and publication of Extension Fact Sheets, detailing subject matter on a diverse set of water topics including: algae management in residential and commercial ponds, open channel flow measurement structures, and explanation of water share structures. ■

Blake Osborn, Regional Water Specialist, CWI and CSU Extension

Call it good fortune, or just sheer luck. It is likely a combination of both. In my three years as the Southern Colorado Extension Water Resources Specialist, I have witnessed three water years with near-average or above average-precipitation in the Arkansas and Rio Grande River Basins. But even in these relatively well-watered landscapes (at least recently) of southern Colorado, the need for research and outreach around water continues to grow. I have been developing projects to improve water quality and better understand regional water supplies and demands, as described below.

- **Lower Arkansas River Watershed Plan: John Martin Reservoir to the Stateline**
  This project, funded by CDPHE and in partnership with the Colorado Department of Agriculture, is working with local stakeholders below John Martin Reservoir to identify and implement best management practices (BMP's) that will reduce non-point source pollution. This project includes a summary of current water quality conditions, stakeholder outreach, identification of BMP projects and possible funding sources, as well as a final watershed plan that details this work going forward.

- **Upper Arkansas River Water Balance Study**
  In partnership with the USGS and the Upper Arkansas River Water Conservancy District, this project will evaluate agricultural contributions to a regional water balance and help irrigators improve water management. This project monitors water balance fluxes at the field scale location in four high mountain hay fields with varying irrigation methods. The first year of the three-year project involved mostly field work and the installation of the many field sensors. We hope to better understand irrigation efficiency, crop water demands, and irrigation scheduling for this cropping system.

Blake Osborn, CSU Extension Regional Water Specialist

In addition to the projects listed above, I am developing a research project in the San Luis valley to look at water use efficiency of multiple barley varieties. Other outreach and education projects I helped with this past year included: rain barrel workshops, collaborative water sharing workshop, new and beginning farmer trainings, irrigation scheduling trainings, domestic well workshops, and an agricultural hydropower factsheet. ■

Joel Schneekloth, Regional Water Specialist, CWI and CSU Extension

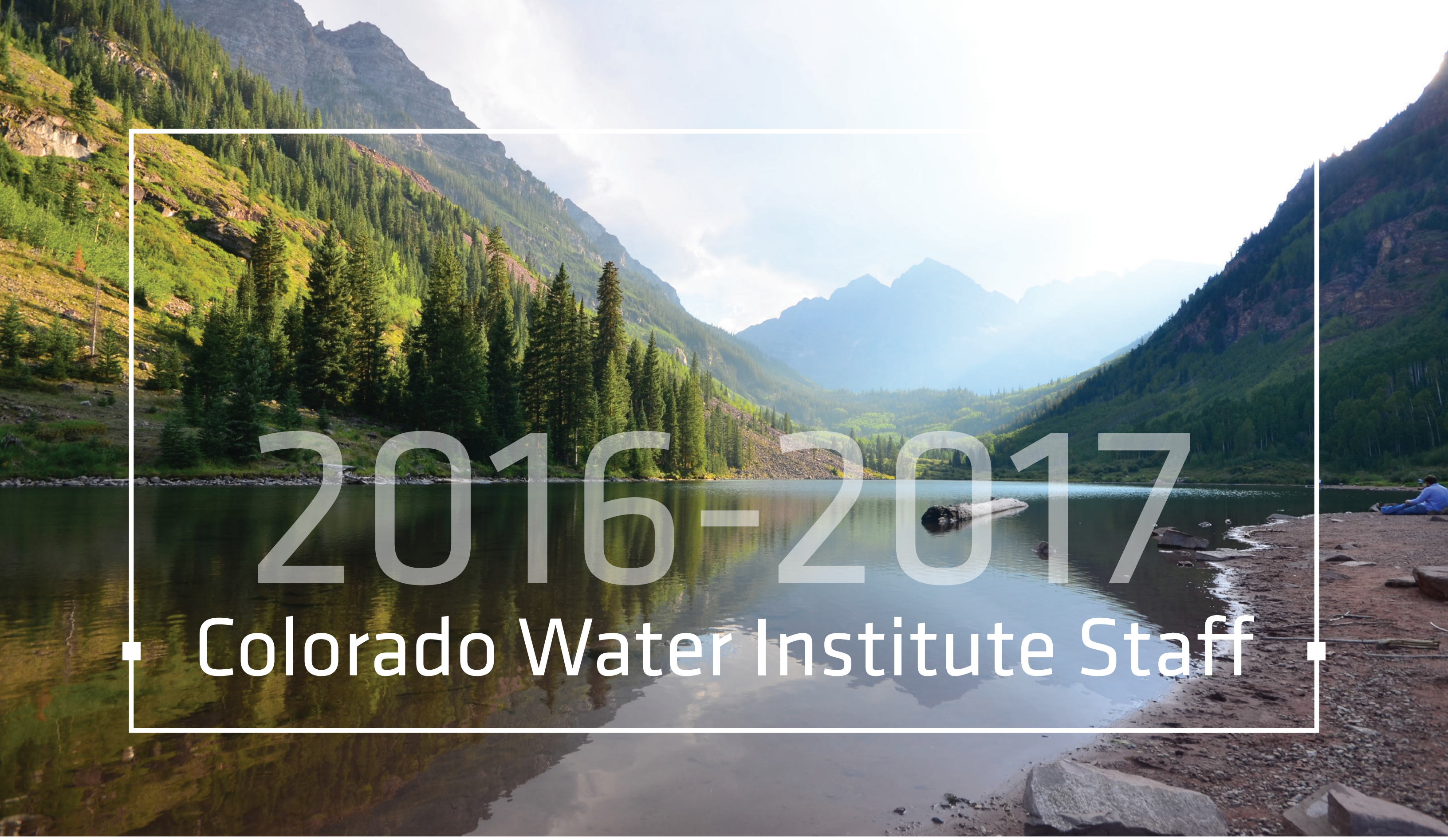
Agricultural Water Management

- Residue and Water Management – Current research is looking at implications of water management, nutrient management, as well as tillage management. Long term data is needed to determine the impacts of residue harvest and tillage management on irrigation management and soil health.
- Limited/Deficit Irrigation Management – As well output declines or water is limited for irrigation by drought, producers have to make decisions on how to manage the water thru either irrigation scheduling or crop management. Research is being conducted on the response of corn to irrigation strategies of timing limited quantities of irrigation availability with crop rotations.
- Ogallala CAP Grant – One of the major new grants is the Ogallala CAP (NIFA). The major objective of this grant is to assess policy and management impacts on the Ogallala Aquifer. It will also look at ways to sustain the aquifer, as well as the transition from irrigated to dryland, or range in areas where sustainability is not achievable.
- Drought Genetics – Improvements in technology are continuing in agriculture. Research with these genetics has shown some promise with corn under some stress. Further research is being conducted as to the potential of the genetics in limiting irrigation at the end of the season.

Extension

- Central Plains Irrigation Association – As a board member of the Central Plains Irrigation Association, we strive to give producers up-to-date research within Colorado, Kansas, and Nebraska.
- South Platte Roundtable –The roundtable structure was developed for individual basins to solve water issues. The past three years have involved development of the “Basin Implementation Plan” which provides options of management to the “gap”.
- Field Days – As a member of the Central Plains Research Station, we host an annual field day to highlight research findings. Irrigation management is a key component of my presentations at this field day. ■

Joel Schneekloth leading a tour with the Colorado Climate Center staff on agricultural issues in Northeast Colorado. They are looking at a CoAgMET weather station near Haxton, CO. (From left to right) Peter Goble, Nolan Doesken, Noah Newman, Dannele Peck, and Joel Schneekloth.



2016-2017 Colorado Water Institute Staff

(Above) The Maroon Bells. Photo by Sayamindu Dasgupta

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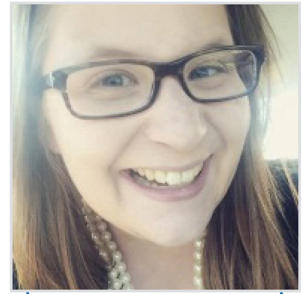

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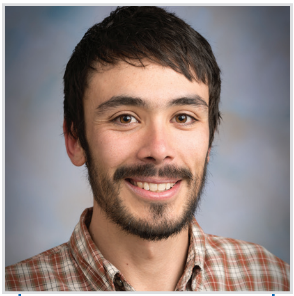

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Financial/Academic Summary

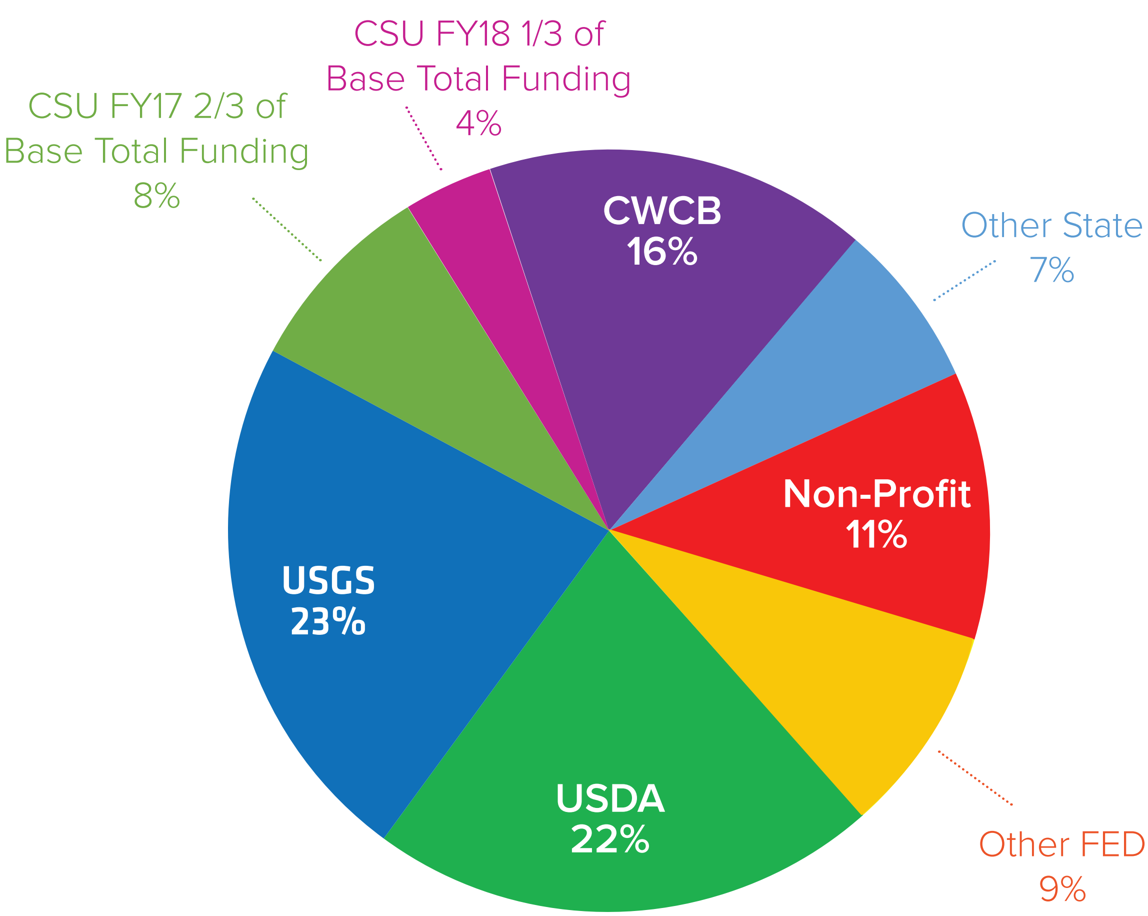
CWI Funding Sources (November 1, 2016 - October 31, 2017)	
CSU Base Funding*	$ 440,498
CWCB	$ 591,553
Other State	$ 255,890
Non-Profit	$ 413,729
Other Federal	$ 319,290
USDA	$ 788,415
USGS	$ 827,778
Total	$ 3,637,153

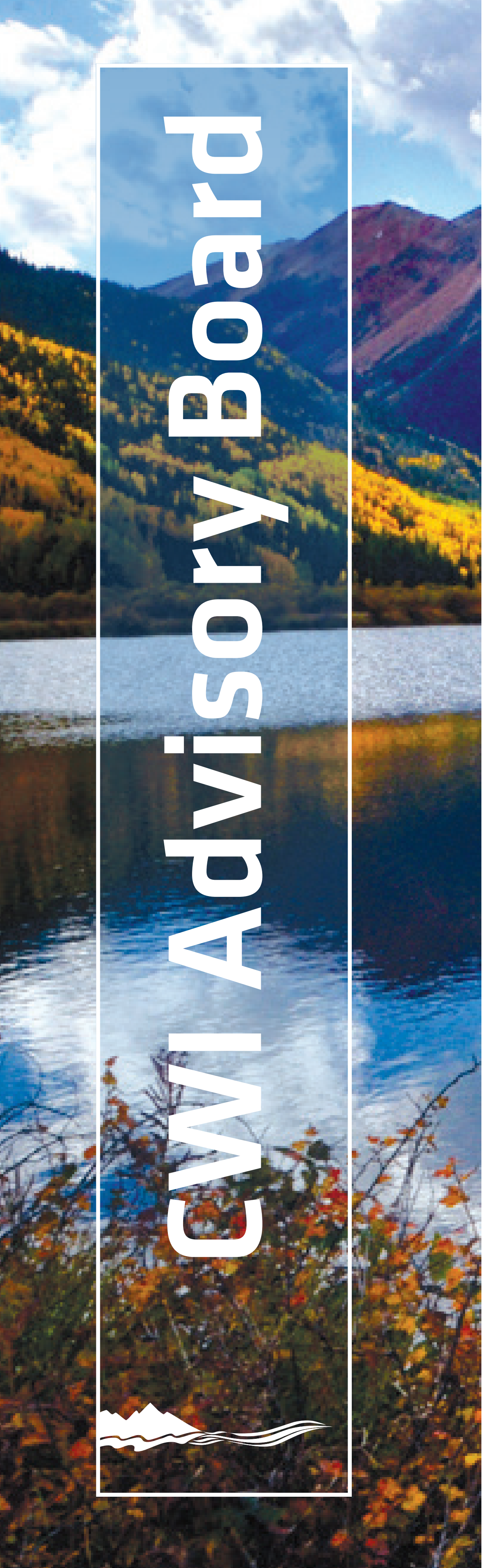
The reporting period above spans CSU fiscal years 17 and 18.

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

Active Project Type	
Research	50
Education	3
Outreach	3
Internships	4
Training	1
Total	61

Student Degree Level on Projects	
Undergraduates	22
Masters	14
Ph.D.	15
Total	51





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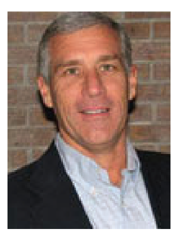

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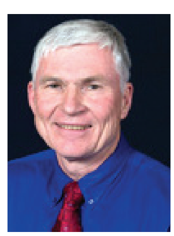

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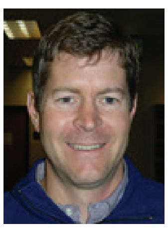

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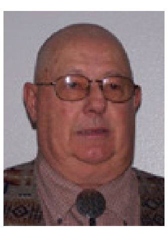

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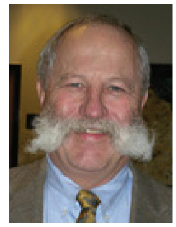

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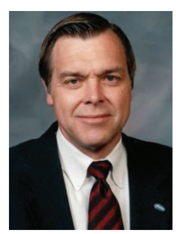

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The Gunnison River.
Photo by Flickr user iuk