73rd Annual Meeting
Rocky Mountain Hydrologic Research Center

Friday, 16 November, 2018: 9 a.m. to 3:45 p.m.

Presbyterian Community Church of the Rockies
1700 Brodie Avenue, Estes Park, CO 80517

Purpose: This meeting provides an opportunity for scientists and students working in the Rocky Mountain region to discuss their research in a relaxed, yet scientifically stimulating atmosphere. The meeting encourages interdisciplinary communication among professionals and students in the fields of ecology, engineering, environmental science, geology, hydrology, meteorology, and water resources. The theme for this year's meeting is stream restoration. However, we welcome presentations on any topic related to hydrology. The RMHRC Board meeting will follow the technical session.

Registration fee: $10 for students, $25 for professionals, payable at the meeting.

Lunch: Included in the meeting fee. Menu includes curried butternut squash soup, salad, grilled cheese with garlic and chutney, cider, and dessert.

Annual Membership: Separate annual membership fee of $20 will be accepted for those wishing to join or renew.

The Rocky Mountain Hydrologic Research Center welcomes the members of the Estes Park High School AP Environmental Science class taught by Mr. Alexander Harris.



Restoration on Left Hand Creek, Boulder County.

Photos courtesy of LWOG (www.lwog.org).

PROGRAM

73rd Annual Meeting of the Rocky Mountain Hydrologic Research Center (RMHRC)

Friday, November 16, 2018

9:00 am – 9:30 am	**Registration**
9:30 am – 9:40 am	**Welcoming remarks** Glenn Patterson, President, RMHRC
Poster	**Ecological approaches to stream restoration** Niah Venable/AloTerra Restoration Services
9:40 am – 10:05 am	**Riparian cottonwood dieback and mortality after streamflow diversion, Great Basin National Park** Derek Schook
10:05 am – 10:30 am	**Innovating water diversion for resiliency** Julie Ash
10:30 am - 10:55 am	**An evaluation of debris-flow runout model accuracy and complexity in Montecito, CA: Towards a framework for regional inundation-hazard forecasting** Erin Bessette-Kirton, Jason Kean, Jeffrey Coe, Francis Rengers, Dennis Staley
10:55 am – 11:10 am	**BREAK**
11:10 am – 11:35 am	**Investigating the effects of fine sediment infiltration into gravel on heat exchange: a flume experiment using distributed temperature sensing** Paul Kinzel, Jonathan Nelson, Martin Briggs
11:35 am – noon	**Trout Unlimited 2018 Evans Gulch Restoration Project** Lauren Duncan
Noon – 12:25 pm	**A reflection on the Water Year of 2018 and where we go from here** Peter Goble
12:25 pm – 1:20 pm	**LUNCH**
1:20 pm – 1:45 pm	**Left Hand Creek restoration** Yana Sorokin
1:45 pm – 2:10 pm	**Communicating fluvial geomorphic process and risk to homeowners: Restoration of Left Hand Creek at Streamcrest** Kevin Pilgrim
2:10 – 2:35 pm	**Building fluvial features** John Moody
2:35 pm – 3:00 pm	**Measured Channel resistance at mountain rivers during flood** Yuko Asano
3:00 pm – 3:25 pm	**Some concerns in the development of flushing flow criteria** Robert Milhous
3:25 pm – 3:45 pm	**Discussion, closing remarks, adjourn** **Meeting of the RMHRC Board to follow**

ABSTRACTS

Measured channel resistance at mountain rivers during flood

Yuko Asano

The University of Tokyo (now visiting Colorado State University)

Flow resistance coefficients, such as Manning's roughness coefficient were developed for conditions of steady uniform flow, however, they have been used in many mountain channels. It is because properties of flow resistance at steep mountain streams are difficult to quantify thus not well understood. We have documented that channel resistance dramatically decreases with an increase of discharge but once the water surface was above most of the boulders in the bed, the coefficient then changed little with increasing water depth in a confined cascade pool channel. If this can be a common phenomenon, prediction of flood flows can be possible using resistance equation that assumed resistance does not change with water depth even at mountain channel. We collected existing data from literature that documenting changes in flow resistance during flood and (1) examined the relationships between relative water depth and channel resistance for each channel, (2) extracted the smallest resistance from each channel and demonstrated the measured ranges of resistance according to channel morphology, and (3) investigated the effect of slope, catchment area and grain size on flood flow resistance. We collected data from 76 channels with bed slope over 1/100. They were classified as cascade, step-pool, plane-bed and pool-riffle morphology. Manning's n decreased with increasing relative water depth, and for most of channels, resistance changed little with increasing water depth on higher water levels. Measured minimum Manning's n, that should represent the resistance during flood, ranged from 0.03 to 0.35. Minimum Manning's n increased with slope and grain size for plane-bed and pool-riffle channels, while no such relationships can be found for cascade and step-pool channels. These results suggested that for the prediction of the large flood flows (but not too large that can change bedform), constant resistant values can be used also for mountain channels. The prediction accuracy of channel resistance during flood can be improved using slope and grain size distribution for plane-bed and pool-riffle channels but not for cascade and step-pool channels. For better prediction of resistance for cascade and step-pool channels, we may need more information that should contribute to channel resistance, such as bedform.

Key words: cascade, channel morphology, Manning's roughness coefficient, small stream, step-pool

Innovating Water Diversion for Resiliency

Julie E. Ash

Colorado WNR Technical Director

One of the great stories of flood recovery is the collaboration between ditch companies (tasked with ensuring water delivery and minimizing maintenance costs) and watershed advocates (tasked with increasing resiliency, including river health and function). These seemingly disparate goals have been brought together by our common goal of performing better in our next big flood. We can all get behind reduced infrastructure damage, faster and cheaper post-flood recovery, reduced maintenance, and increased river health and function. It isn’t easy – solutions are expected to reduce potential flood damage, reduce sediment transport disruptions, improve maintenance requirements, enhance riparian ecosystems, and/or provide fish and safe recreational passage, while absolutely guaranteeing the full decree of water. This talk presents example innovations, covering the critical lessons they are offering and the new ideas that are coming out to help us clear the myriad hurdles that go with these challenging and rewarding projects.

An evaluation of debris-flow runout model accuracy and complexity in Montecito, CA: Towards a framework for regional inundation-hazard forecasting

Erin K. Bessette-Kirton, Jason W. Kean, Jeffrey A. Coe, Francis K. Rengers, and Dennis M. Staley

U.S. Geological Survey, Box 25046, MS 966, Denver, CO 80401, USA

Numerous debris-flow inundation models have been applied retroactively to significant events around the world. While such studies can be useful in identifying controlling factors, calibrating model parameters, and assessing future hazards in specific study areas, model parameters tailored to specific events can be difficult to apply to regional inundation assessments. The advancement of debris-flow modeling applications from post-event model validation of individual case studies to pre-event forecasting that can be implemented rapidly and at regional scales is critical in light of the fatalities and extensive infrastructure damage caused by debris flows that inundated a developed fan in Montecito, CA following heavy rain on 9 January 2018. In this study, we began to evaluate the tradeoffs between model accuracy, simplicity, and reproducibility in the context of the need for a framework that can be used in conjunction with initiation models and storm predictions for rapid, large-scale inundation hazard mapping as a component of post-fire debris-flow hazard assessments. We used numerical (FLO-2D) and empirical (LAHARZ) models to simulate debris flows from one of the drainages upstream of Montecito that was burned in the Thomas Fire in December 2017 and compared model results with field observations and building damage assessments collected immediately following the event. Initial testing demonstrated that LAHARZ can simulate channelized flow but is not able to replicate flow bifurcations or avulsions, which are a critical aspect of flows travelling over populated fans. FLO-2D simulations matched well with observed inundation area data, but variably under and overpredicted inundation height, deposit depth, and velocity in different areas. ROC analyses showed that FLO-2D and LAHARZ had true positive rates of 0.84 and 0.6, respectively, while both models had similar false positive rates (0.3 and 0.35, respectively). We established a comprehensive model evaluation framework that allowed us to compare model results with detailed field observations and should serve as a platform for more extensive model testing in the future.

Trout Unlimited 2018 Evans Gulch Restoration Project

Lauren Duncan
Abandoned Mine Restoration Project Manager

In the summer of 2018, Trout Unlimited (TU) completed the Evans Gulch Restoration Project. Evans Gulch is a five-mile-long segment of the Upper Arkansas River basin in the historic mountainous "mineral belt" located near Leadville, Colorado. Evans Gulch is the primary water source for Parkville Water District which serves over 5,000 Leadville and Lake County customers.

The upper and lower portions of Evans Gulch are included in one of the 12 units created through the California Gulch Superfund listing. Evans Gulch was originally listed in 1998 on Colorado's 303(d) list of impaired waterways for dissolved zinc. The State of Colorado completed a Total Maximum Daily Load (TMDL) for Evans Gulch in 2009, noting that the gulch exceeded standards for zinc in May, July, and August. Although the main pollutant of concern in the watershed is dissolved zinc, cadmium has shown to exhibit levels above chronic or acute hardness-based concentrations at sites within the watershed during seasonal variations. As is associated with other historic mine sites containing seeps and mine waste piles, low pH and low dissolved oxygen concentrations have also been observed through field sampling.

TU and project partners began water quality monitoring in the Evans Gulch watershed in 2014. Preliminary observations and the seasonality of table value standard exceedances attributed the main sources of loading to waste rock piles, seeps, or mine tailings. Through the 2014-15 water quality sampling efforts and subsequent data investigation, the Streamside and Valley Mine tailings/waste piles were identified as primary non-point source loaders in the watershed.

To address these non-point sources, TU contracted with H2 Enterprises to grade, amend and revegetate the Streamside and Valley waste piles and install grading, stormwater and erosion controls at an adjacent private site. TU worked with our contractor to revegetate the "dead zone" below the Valley pile with natively harvested willows and install rootwads to stabilize the banks adjacent to the Streamside pile. This collaborative project is expected to reduce non-point source loading into Evans Gulch and improve downstream water quality in the watershed.

A Reflection on the Water Year of 2018 and Where We Go from Here

Peter Goble

Colorado Climate Center

Tracking deviations in Colorado's weather and water balance remains both an imperative and fascinating subject of study. In this presentation, we'll take a look back at the weather and water patterns from Water Year (WY) 2018 in Colorado. Focal points are as follows:

1. WY 2018 tied for the warmest water year on record for Colorado, and was the second driest year on record for Colorado dating back to 1895. We'll take a closer look at how this happened.
2. The deep dive into drought in WY 2018 will be examined with a focus on the west slopes. This will include discussion on dwindling reservoir supplies, and the conditions needed to pull the region back out of drought.
3. Despite being a dry year, WY 2018 still managed to be an above average hail year on the eastern plains and urban corridor. This report will review some of the damaging hail events from WY 2018.
4. A look forward: whenever El Niño works its way into the seasonal forecast this generates a great deal of buzz in the media, but is it just that? Buzz. We'll examine what El Niño, in tandem with our overall anthropogenic climate warming trend mean for WY 2019, and our odds of a water supply recovery.

Investigating the effects of fine sediment infiltration into gravel on heat exchange: a flume experiment using distributed temperature sensing

Paul Kinzel
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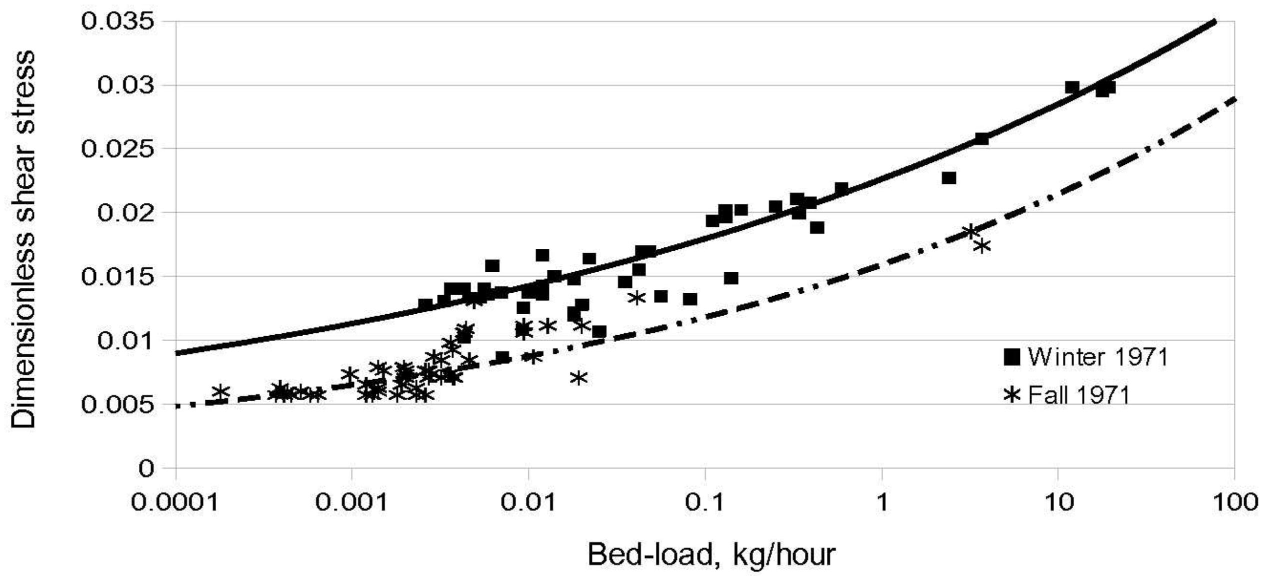
The utility of Fiber Optic Distributed Temperature Sensing (FO-DTS) as a technique for detecting the infiltration of fines into coarser sediment was investigated in a laboratory flume. A 10 m fiber optic cable was placed in the flume with one half of the cable buried in various substrates (gravel, sand, and mixtures of the two) along the length of the flume, while the other half was placed at the sediment/water interface. Water in the tail tank was heated for 12 hr and then the heater was shut off for 12 hr. Water from the tank was circulated through the flume during this cycle and a temperature profile was recorded along the entire FO cable. Our data indicated a small but detectable difference between the temperature measured in the buried half of the cable versus that measured at the interface due to relatively high porosity and thermal diffusivity of the gravel. The temperature difference between the buried and interface cables was more pronounced for the sand substrate due to dampened thermal transmission through the finer media. Mixtures of gravel with incremental volumes of sand produced intermediate responses. Taken together, these experiments suggest that FO-DTS could be used to detect the infiltration of fines into coarser materials and could be applied for continuous monitoring of habitat restoration sites.

Some Concerns in the Development of Flushing Flow Criteria

Robert T Milhous
Hydrologist
Fort Collins, Colorado

Flushing flows are streamflows needed to remove fines and sand from a river that may have a negative impact on the quality of the aquatic ecosystem. Flushing flow criteria are the information needed to calculate the magnitude of the flushing require to maintain the heath of the aquatic ecosystem. One set of criteria is presented in this paper. The criteria is used to calculate the dimensionless shear stress required to remove the sediment not wanted on the surface of the stream-bed. The equation is $\tau^* = 0.0137\ x^{-0.841}$ where x is the ratio of median size of the sediment to be removed to the armour median size and τ^* is the required dimensionless shear stress. The equation was is based on data from a study of bed-load movement in Oak Creek near Corvallis, Oregon. There is a concern associated with the Oak Creek data - the for τ^* less than 0.03 based on the median size of the armour the value required to move a give bed-load was smaller in the fall of 1971 than in the winter (see diagram below).



Much of this paper presents different explanations - none of which are satisfactory. The paper also investigates some concerns associated with the use of measured suspended sediment loads to determine flushing flow needs.

Building Fluvial Features

John A. Moody

U.S. Geological Survey, Water Mission Area, Boulder, CO

Fluvial features such as floodplains and point bars are built by sediment deposition and sculpted by erosion. Long-term measurements (38 years) of channel cross-sections of active floodplains and point bars along the freely-meandering Powder River in southeastern Montana, USA River (mean daily discharge of 12.5 $m^3 s^{-1}$), were used to develop dynamic relations between annual sediment deposition and peak-flood discharge. Five floodplain sections and five point-bar sections were selected from 24 cross sections along a 90-km study reach. At each cross section the sediment deposition volume per unit streamwise distance was computed as the difference between two topographic surveys made in consecutive years.

Snowmelt floods were found to be the dominant annual process. However, other processes such as flash floods, ice breakup floods, autumnal floods, and animals played a role. Dynamic relations were linear for both fluvial features, but had interesting outliers indicating the other processes can be important episodically. The snowmelt deposition-discharge relations showed, in general, that point bars were about two times more efficient at trapping sediment than floodplains. Each relation had a discharge threshold that must be exceeded before sediment was deposited. For Powder River these thresholds were nearly the same (69 and 71 $m^3 s^{-1}$) but were associated with different processes. Thresholds for other rivers will probably differ from those for Powder River because of different channel geometry and sediment characteristics.

Communicating fluvial geomorphic process and risk to homeonwers

Restoration of Left Hand Creek at Streamcrest

Kevin Pilgrim

Pilgrim's Places, LLC

The September 2013 rainfall on the Colorado Front Range produced an estimated 50-500 year flood on Left Hand Creek depending on the location. The storm produced numerous debris flows in the steep confined canyon above the Streamcrest neighborhood. Streamcrest lies on an alluvial fan at the mouth of Left Hand Canyon. The estimated discharge at the old stage road above the mouth of the canyon was 3,570 cfs (50-100 year flood) while a typical 2-yr flow is 350 cfs. The flood carved a new channel and deposited feet of sediment throughout the neighborhood. Many home owners experienced the flood event first hand and had to be rescued.

Phase II of the Emergency Watershed Protection (EWP) program began in June 2017 with a design and permit schedule that required completion of the $400,000 design by December. All the homeowners that wished to participate in the program had to approve the %30 design before the project could break ground. Many homeowners just wanted things "back the way they were before the flood." The goals for the EWP Phase II program were to 1) Reduce hazards and protect life, safety and property 2) Use federal and state funding effectively 3) Enhance the health and resilience of stream corridors and their broader watersheds 4) Build the capacity of watershed coalitions 5) Advance a watershed-based approach to flood recovery hazard, hazard identification, and risk communication. It was this fifth goal of hazard identification and risk communication that would prove to be the most challenging and is the focus of the presentation.

Riparian cottonwood dieback and mortality after streamflow diversion, Great Basin National Park

Derek M. Schook

Department of Forest and Rangeland Stewardship, Colorado State University

Water Resources Division, National Park Service

Water is commonly extracted from rivers to support agriculture, but stream diversions endanger riparian ecosystems that are dependent on river flows. The largest drainage basin in Nevada's Great Basin National Park forms Snake Creek, a river that supports diverse microhabitats and biodiversity in an arid landscape. Snake Creek passes through a 5-km section of porous karst, where some surface water is naturally lost to groundwater recharge. To prevent potential irrigation water loss, a water diversion pipeline was built in 1961 to transport water past the karst reach. This action has left most of the diverted reach dry throughout most years. Our research team is using cottonwood dendrochronology to understand the spatial and temporal patterns of riparian forest declines associated with the diversion pipeline by investigating the dewatered and reference reaches. Cottonwoods in the dewatered reach and both Snake Creek reference reaches had 80-95% of trees establish between 1870-1935, revealing low regeneration over the last 80 years. Tree mortality was highest in the dewatered reach (36%) compared to three reference reaches (12-14% mortality at Snake Creek above and below the diversion and at Baker Creek). Cross-dating revealed that 86 of the 110 (78%) standing dead trees in the dewatered reach died after 2005, some 50 years after pipeline installation. Samplable dead trees that had fallen down had death dates from throughout the past half-century. Among the living trees, percent live canopy was lowest in the dewatered reach (45%) compared to the three reference reaches (63-76%). Ring width analyses revealed that basal growth in the dewatered reach did not substantially differ from that of reference trees in the first three decades after the diversion was installed; however, over the last two decades dewatered tree ring widths have declined sharply and diverged from those in reference reaches. After the year 2000, ring widths in the dewatered reach resembled trends seen preceding mortality in dead trees, likely foreshadowing additional mortality. Aerial photography and stable isotope analyses are also under way to complement tree-ring analysis.

Ecological Approaches to Stream Restoration [Poster]

Niah Venable

AloTerra Restoration Services

Traditional engineering approaches to stream and bank erosion control using hard structures such as rip-rap and concrete lined channels are expensive and often environmentally detrimental. Bioengineering approaches however, combine biological, mechanical and ecological concepts to control erosion and restore riparian systems through the use of living and non-living plants and plant-derived products as primary construction and remediation materials. Bioengineering practices provide resiliency for streambanks, enhance wildlife habitat, enhance organic matter inputs to streams, improve water quality, increase floodplain roughness, and heighten landscape aesthetics. With a mission to provide ecological restoration solutions that enhance biological diversity and maintain highly functioning landscapes within the context of community needs and values, AloTerra Restoration Services is working to push the boundaries of applied science in the restoration industry to find the most ecologically and economically sensible approaches. We present recent results of our efforts to employ modern bioengineering approaches that work with existing and desired site ecology to improve and restore riparian systems.