Program and Abstracts
for the
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of the
Rocky Mountain Hydrologic Research Center

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Wild Basin Lodge
Allenspark, Colorado

Rocky Mountain Hydrologic Research Center

The forerunner of the Rocky Mountain Hydrologic Research Center was the Rocky Mountain Hydraulic Laboratory organized under the laws of the State of Colorado on September 5, 1945. Chesley Posey found a site for the laboratory on the North St. Vrain Creek below Highway 7 near Allenspark, Colorado. At this 20-acre site alongside the North St. Vrain Creek, several hydraulic flumes were constructed and portions of those flumes can be seen today. Research was focused on bridge scour and open channel hydraulics. About 1960, the hydraulic research activity declined but the site has been used for more diverse research in recent years.

In 1991, the name was changed to the Rocky Mountain Hydrologic Research Center to reflect new research goals of conducting a broad range of hydrologic and environmental science investigations in this headwater area of the Rocky Mountains. The site has had little disturbance in the last 50 years. The site is still available for research and anyone interested need only contact any one of the Trustees of the Rocky Mountain Hydrologic Research Center listed below.

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Cover: Copeland Mountain above North St. Vrain Creek
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The Future of Water Resources Worldwide

Maurice Albertson and Robert Kerr

It is extremely important that we plan now for how we can meet our water resource requirements in the future—both in the immediate future and in the distant future. This is especially true for the state of Colorado—but it is also true for water requirements throughout the world.

This is an outline of the studies that need to be carried out—including the engineering aspects, the legal aspects and the energy aspects. There is an unlimited supply of both water and energy. It is just a matter of how to capture and use these in order to accomplish the needs and requirements for water throughout the world.

A series of studies need to be conducted to determine how best to meet the water needs for all places on the earth.

Water Requirements

Worldwide, water is becoming more and more scarce in many crucial areas. This is due to the increase in population in water-scarce places and it is also due to the warming of the earth and less precipitation worldwide.

At the same time, there are vast quantities of salt-water in the oceans and vast quantities of renewable energy available that can be used to desalt the seawater.

As a first step, the present and future water requirements need to be documented for various places on the Earth. At the same time there is a need to document the present and estimated future availability of water for these same places.

Energy Requirements

There are also vast amounts of energy available from the sun, the wind and ocean thermal. Estimates need to be made of the amount of energy needed to provide both the quantity and quality to meet the needs of water for all areas around the earth.

Conclusion

This paper is a study of how to put these water and energy facts together to make water available as needed for domestic, industrial, agricultural and other uses worldwide.

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Fate of Emerging Contaminants in the Boulder Creek Watershed and Their Impact on the Aquatic Ecosystem

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The Boulder Creek Watershed is an ideal field laboratory to study the flux of natural and anthropogenic chemicals because it comprises a climatic, topographic, hydrologic, geologic, and land use gradient. This talk will focus on the fate and effects of organic wastewater contaminants, including pharmaceuticals.

Helley-Smith Bedload Sampler Deployed on Gravel Beds Collects Too Much, Particularly at Low Transport and on Fine-grained Beds

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A Helley-Smith type (HS) sampler is often used for measuring bedload transport in gravel-bed streams; however, sampling results might be biased. If the sampler is placed directly on the bed, it may be perched on top of large cobbles and not collect particles transported below it. If in contact with finer gravel, the sampler may dislocate and scoop those particles or suck them into the sampler due to its hydraulic efficiency >1. These interactions between sampler and bed sediment lead to transport rates that are either too high or too low. This study examined whether setting the sampler onto ground plates (that act as temporary sills and eliminate direct contact between the sampler and the bed) improves sampling accuracy.

Paired bedload samples were collected (either simultaneously or immediately following each other) with a 3-inch, thin-walled HS sampler in two mountain gravel-bed streams. One set of samples was collected conventionally by placing the sampler for 2 minutes each onto 15 evenly spaced locations across the stream directly on the bed. The other set was collected by placing the sampler for 5 minutes each onto 6 metal ground-plates installed flush with the streambed at about even intervals across the stream, i.e., eliminating direct bed contact. The time of ground contact per cross-section (15 x 2 min vs. 6 x 5 min) was the same for both sets of samples. Additional measurements were made at two locations with particularly coarse and fine bed material.

Results from both streams showed that the HS sampler deployed on ground-plates measured smaller transport rates than the one deployed directly on the bed. The difference was most pronounced for the lowest flows and more pronounced for gravel than for sand bedload. At 50% of bankfull flow, gravel transport rates obtained when the sampler was deployed on the bed was 3 times greater than on the ground-plates at one stream and 150 times greater at the other. At near bankfull flow, transport rates from both deployments yielded similar results. The difference in sampling results can be explained as a function of transport rates. Both deployment versions yielded similar results for transport rates larger than 10 g/m·s because bed interactions contribute only a minor amount to the total sample volume. At low transport rates, these interactions dominate the sampling outcome, such that at rates of 1 and 0.1 g/m·s, the HS deployed on the bed yielded transport rates 1 and 3 orders of magnitude above those collected with the HS sampler deployed on ground-plates. Results from the two sampling locations on coarse and fine beds showed that a highly erodible, fine gravel bed greatly exacerbates the difference between the two deployment versions.

A review of the 2007 Water Year in Colorado

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This presentation will summarizes climatic conditions during the 2007 water year in Colorado (October 2006 - September 2007). Following the hot, dry summer of 2006 over northeast Colorado, October brought significant and beneficial rains. One of the hardest winters in years then followed, particularly for the eastern half of the state, with deep, long-lasting winter snow cover. Very cold air settled into the South Platte Valley producing much below average temperatures in January and February, particularly in valley-bottom locations like Greeley. Spring conditions were generally warm and dry, with fewer spring storms than usual, and earlier mountain snowmelt. Snow melt from the winter storms provided adequate spring soil moisture in many areas east of the mountains. Summer temperatures were warmer than average, but high humidity from late July into early September fueled frequent and locally heavy rainfall amounts. Water year snowpack, precipitation totals and temperature patterns will be shown with respect to longterm averages. "Walking Through the Water Year," a new weather and water education initiative in Colorado will also be described.

A Multi-Party Evaluation of Droughts and Runoff Frequency in the Colorado River Basin

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Evaluation of drought and runoff frequency in the Colorado River Basin has been a subject of great interest to hydrologists, water resource engineers, meteorologists and scientists in other related fields for a number of years – but never quite so much as today with the drought of record plaguing the basin.

The severity of the current drought – especially when compared to the "dust bowl" years (1929-34) and other major droughts of the past – has led many managers and technical experts in the water resources community to wonder how common an event like this might actually be and the related question – how likely is it that we could see something even worse in the near future.

A technical work group composed of experts from government, the academic community and the private sector has come together to focus on these questions – particularly in the context of how the reservoirs of the Colorado River system might most effectively be managed under extreme drought.

Methodology employed includes parametric and non-parametric stochastic hydrology and tree ring analysis. These studies are aimed at evaluating possible streamflow scenarios that may occur in the future, determining the variability of critical droughts, and the risk that severe droughts may occur during specific planning horizons. The presentation will illustrate some results obtained to date.

Synthesis of Post-wildland Fire Sediment Yields in Different Rainfall Regimes in the western United States

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A variety of methods have been used to measure post-fire erosion across the western United States. We grouped these measurements into four methods: (1) point measurements on hillslopes, (2) hillslope plot measurements, (3) suspended-sediment and bed load sampling in channels, and (4) channel volume measurements of erosion or deposition. We classified features identified as "incised tributaries" or "gullies" as channel erosion. Only measurements made within two years of a fire were included in the synthesis. The measurement methods were stratified into seven different rainfall regimes based on seasonal rainfall type and rainfall intensities within each seasonal type.

Post-wildfire sediment yields varied over five orders of magnitude for the different rainfall regimes. While differences in sediment yields exist across different rainfall regimes, a major source of variance is a result of the different methods used to measure post-fire erosion. Furthermore, the timescale of the measurements does not consider storage of sediment eroded from one source before the sediment is delivered to another storage reservoir on the landscape, for example the storage of sediment derived from hillslopes in often stored lower on the hillslope or in adjacent channels. A median sediment yield value for each measurement method was calculated. The average median sediment yield based on the channel volume method of 190 T ha^{-1} was greater than the sediment yields based on point measurements on hillslopes (29 T ha^{-1}), on hillslope plot measurements (14 T ha^{-1}), and on channel suspended-sediment and bed load sampling (2.5 T ha^{-1}) methods. This suggests that the channels are more important than the hillslope as sources of available sediment after wildfire. The lack of correlation of sediment yields with topographic slope and soil erodibility suggests that sediment availability may be more important than slope or erodibility in determining the sediment yield after wildfire.

An Adaptive Assessment of the Flushing Flow Needs of the Lower Poudre River, Colorado: First Evaluation

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Adaptive assessment of a riverine system is a continual learning process and probably never reaches the state of full knowledge. Adaptive assessment also includes the principle that continuous adaptation of improved knowledge to the work at hand is the normal state of affairs. The application of adaptive assessment presented in this paper is a first assessment in an adaptive process. The first evaluation is made using readily available discharge measurement summary data available for some gaging stations to determine the flushing flow needs of a river. The process presented is useful 1) when little money is available for a flushing flow study and 2) in guiding more extensive studies that might be done later in the adaptive process when additional and more detailed information may be needed. In this paper, discharge measurement summary data and limited field data were used to develop a relation between a substrate movement parameter and the discharge for a USGS gage on the Poudre River above Boxelder Creek just downstream from Fort Collins, Colorado. The relation was combined with a value of the substrate movement parameter critical for movement of sand and fines to find the discharge in the Poudre River in the Fort Collins reach required to flush fines and sand from the river. The discharge - sediment transport parameter relation determined from the analysis is $\beta = 0.000320\ Q\ ^{\wedge}\ 0.549$ where Q is the discharge and β is the substrate movement parameter. From previous studies, the critical value of the substrate movement parameter is 0.021. The flushing flow was calculated to be 2050 cfs. There are 32 years of record at the Fort Collins gage with 12 years where the channel was flushed and a current run of at least 7 years without flushing of the channel. Downstream at Greeley there have been 15 flushing years between 1924 and 2006 and a run of 22 years starting in 1925 and ending in 1946 without flushing.

Effects of Topography on Convective Rainfall Characteristics in the Colorado Front Range

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Summer convective rainfall is frequently the driver for floods in steep mountainous terrain. Along the Colorado Front Range, these storms generally form near the Continental Divide and propagate from the divide eastward across variable topography to the plains. Nine recording tipping-bucket rain gages were deployed from 17 June through 31 August 2007 along part of the same 35-km east-to-west transect occupied in 2006. Four of the rain gages were deployed along another transect across Deer Ridge (trending approximately from northwest to southeast) to determine the effect of topography on total rainfall and rainfall intensity. All rain gages recorded the time of each 0.254 mm of rainfall and these data were used to calculate the rainfall intensity and to determine the relation between the elevation and rainfall intensities associated with convective storms.

The results of this year's study along the east-to-west transect were similar to the results in 2006. However, there were fewer convective storms (those lasting longer than 5 minutes) in 2007 than in 2006. The duration of the storms and the maximum 30-minute rainfall intensity increased with elevation along the east-to-west transect. The data from the additional transect across Deer Ridge showed that the ridge had no significant effect on the average total rainfall from 20 storms. However, the ridge did appear to affect the rainfall intensity. The effect was to produce (for 14 storms with 30-minute intensity at all locations) significantly less intense rain on the western side of the ridge, more intense rain on the top of the ridge, and possibly less intense rain on the eastern side of the ridge.

Some observations on National Park Service water quality monitoring in Rocky Mountain National Park, and on the protection status of Upper North St. Vrain Creek

Glenn Patterson

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The National Park Service is in the process of implementing, on a national scale, an ambitious resource monitoring program. Known as the Vital Signs Monitoring Program, this effort represents the monitoring part of the Inventory and Monitoring Program, and follows on the heels of watershed condition assessments done as part of the resource inventories. The monitoring program seeks to improve understanding of the status of physical and biological indicators of stream ecosystem health, trends in those indicators as conditions change, and their relation to various drivers and stressors. Plans for implementing this monitoring program in Rocky Mountain National Park will be described.

On another topic, Upper North St. Vrain Creek has for decades been the focus of plans and debates regarding water-supply issues, dams, and protection of free-flowing reaches. A brief description will be given of the work done by the Upper North St. Vrain Creek Landowners Association during 1988-1996 on both sides of these issues, and the resulting legislation promoted by Congressman David Skaggs.

Climatological Observations from Allenspark

William C. Rense

This paper examines some of the climatological observations that have been kept by me and my father in Allenspark since January of 1960. Annual precipitation averages 22.49 inches (571 mm) and has shown little change over the 47-year record. However, there have been seasonal and monthly shifts, some of them, such as May, being quite dramatic. Temperatures also show some changes. Minimum winter temperatures have increased over the period of record while summer average temperatures have increased by about four degrees Fahrenheit. Observations of the melt dates of two prominent snowfields in the area, the “Lower Meeker Drift” and the “Eye” of Chiefs Head, show a two week shift earlier in the season. Thus, there is definite evidence of “global warming” in the Allenspark area.

Documenting changes in channel form and process following Mountain Pine Beetle Outbreak in Subalpine Watersheds, Fraser Experimental Forest, Colorado

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Many lodgepole pine (*Pinus contorta*) forests in North-Central Colorado have undergone recent widespread infestation by mountain pine beetle (*Dendroctous ponderosae*), causing high levels of mortality over substantial areas. The reach of this epidemic, thought to be related to increased temperatures and sustained drought conditions, continues into previously unaffected watersheds, including areas of the Fraser Experimental Forest (FEF), CO. Widespread forest loss from beetle outbreak may potentially increase water yield and rates of sedimentation from steep hillslopes. Several watersheds within FEF have extensive records of water and sediment yield, providing an opportunity to evaluate changes in flow and sedimentation following the outbreak. The most immediate impact to streams will likely be increased instream wood loading as beetle-killed trees begin to fall from steep hillslopes. Many of the small streams on FEF are directly adjacent to steep hillslopes and up to one third of current load of instream wood can be traced to hillslope origins. Baseline information on volumes, sources, and geomorphic influences of large wood in these systems indicate that much of the wood is relatively immobile and often becomes incorporated into the channel form (e.g., steps, banks, and small falls) rather than being transported. Large wood in streams can both increase and decrease local channel stability so the net effect of increases in wood loading are uncertain.

Response of Beaver Dams on Headwater Tributaries of East Plum Creek to the 1965 Flood

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The resistance of beaver dams to breaching or removal by floods is important hydrologically, geomorphically, and ecologically. If these dams hold back the floodwaters in the tributaries, then the peak flows are likely to be delayed significantly and differently in each tributary resulting in a decreased flood peak downstream. The decreased height of the peak flow means that the downstream channel is less likely to be dramatically modified sedimentologically, geomorphically, and ecologically. Moreover, the beaver ponds provide a refuge for aquatic organisms during the flood, and, if the stream morphology is not severely altered, the downstream aquatic habitats are likely to be preserved.

During the 1965 flood-of-record on Plum Creek (located just south of Denver, Colorado), beaver dams on the headwater tributaries responded to the flood in direct correspondence to the density and distribution of riparian shrubs upstream. In cases where shrubs (predominantly sandbar willow) were absent for two or more pond widths directly upstream, the beaver dams were washed out. This occurred (1) where the original channel was straight, (2) where prolonged occupancy of sequences of old beaver ponds left the area depleted of willows, and (3) where the floodplain was predominantly covered with grass that was maintained from willow encroachment by grazing. In contrast, in cases where the individual beaver ponds were bordered on the upstream side by extensive willow thickets, the beaver dams survived intact. Between these two cases were situations where the shrub density upstream of the pond was insufficient to provide protection across the entire dam. In these situations, the dams were breached by narrow gaps but maintained a high stage in the upstream ponds during the period of peak flow. These ponds drained as the floodwaters receded, and it is likely that the beaver were able to repair these narrow breaches in a few hours after the pond drained to a low level.

Reconstruction of the flow during the flood, using a fully predictive model that explicitly accounts for the form drag on bed features (such as dunes) and the stems and branches of the shrubs, permits determination of the forces on the dams as a function of upstream shrub density and discharge (determined from rainfall rates and drainage area). Calculations using this model show that the form drag from a succession of beaver dams across a channel is very small compared to that resulting from a mature stand of sandbar willow or a combination of a beaver pond and an upstream stand of sandbar willow that covers the same area as the pond. Applying the model to the field site also shows that these beaver dams remained intact until the shear stress on the bed of the channel exceeded the critical shear stress for the sand on the channel bottom. This result suggests that breaches in the beaver dams resulted from under cutting of the bases of the dams by the shooting flows and hydraulic jumps that formed downstream of their crests, not by the direct force of the flow on them.

Effects of Coal-Bed Methane Discharge Waters on Soils and Vegetation

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Coal bed methane co-produced discharge waters in the Powder River Basin of Wyoming, resulting from extraction of methane from coal seams, have become a priority for chemical, hydrological and biological research during the last few years. Soil and vegetation samples were taken from impacted and reference sites (upland elevations and wetted gully) to investigate impacts of CBM discharge waters on soil physical and chemical properties and on native and introduced vegetation richness and diversity. Results indicate a significant increase of salinity and sodicity within local soil ecosystems at sites directly exposed to CBM discharge waters. Elevated concentrations of sodium in the soil appear to be due to consistent exposure to CBM waters. Clay-loam soils in the study area, which have a much larger specific surface area than the sandy soils, readily allow sodium ions to adsorb quickly to exchange sites. There was no significant relation between increasing water SAR values and increasing sediment SAR values downstream; however, soils exposed to the CBM water ranged from the moderate to severe SAR hazard index. Native vegetation species richness was highest at the reference (upland and gully) and impacted upland sites. The impacted gully had the greatest percent composition of introduced vegetation species. Salt-tolerant species had the greatest richness at the impacted gully, implicating a potential threat of invasion and competition to established native vegetation. CBM waters could have detrimental impacts to the local ecosystem, causing dispersion of soils and making it difficult for native vegetation to exist. These waters could also have a negative effect on agricultural production and long-term water quality.

Erosional Consequences of Saltcedar Removal

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Managers of riparian lands are increasingly removing invasive trees such as saltcedar (*Tamarix* spp.), to reduce water lost to evapotranspiration, improve wildlife habitat, or restore native vegetation. In the United States this activity is accelerating in part because of the passage in 2006 of the *Saltcedar and Russian Olive Control Act* (Public Law 109-320), which authorized spending of $80,000,000 to control the third and fourth most frequently occurring riparian woody species in the interior western United States (Friedman et al. 2005). Removing the dominant vegetation along hundreds of miles of river, however, could have unintended consequences, including increased erosion. Stabilizing sediment was a primary rationale for the original introduction of saltcedar in the western United States (Bryan and Post 1927). Removal of this vegetation could cause substantial sediment erosion and transport, potentially increasing flood hazards for communities downstream and accelerating the filling of reservoirs with sediment. A recent saltcedar removal effort along the Rio Puerco, New Mexico, constitutes a natural experiment testing the importance of riparian vegetation on bank stability.

Efforts to eradicate saltcedar through a 12 km valley reach (17.3 km river reach) of the Rio Puerco arroyo by widespread spraying with an herbicide in 2003 were followed by a large flood in August 2006. Although the target of the control effort was saltcedar, the herbicide killed most of the woody vegetation on the floodplain and channel banks. We documented erosion and sediment transport that followed saltcedar control and subsequent flooding in two long river reaches, an 18.5 km reach upstream from Hwy 6 and a 13.2 km reach downstream from Hwy 6. The upstream reach includes a 1-km long segment upstream from the eradication area. Average channel width within the eradication reach almost doubled, while channel width upstream and downstream, where woody vegetation remained healthy and intact, remained unchanged or narrowed. The flood deposited large volumes of sediment on the floodplain through both long river reaches, and data indicate the majority of sand eroded from the channel banks was deposited on the floodplain within 5 to 10 km downstream.

Observed Temperature Trends in Colorado

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Colorado ranges from around 1200m in elevation to well over 4000m. While many of the original high-elevation mining camps also recorded temperature and moisture as early as a century ago, continuous station records rarely precede the 1930s, or 'Dust Bowl' era. This analysis documents the temperature trends of those stations that are deemed most reliable by the Colorado State Climatologist' Office, stratified by new 'Climate Division', by season, by varying base periods (from 30- to 100-year), by statistical significance, and by elevation. While recent warming trends are large and alarming (especially in spring), longer-term trends are not always upwards, highlighting the need to understand the warmth of the 1930s in particular.