FINAL PROGRAM

ROCKY MOUNTAIN HYDROLOGIC RESEARCH CENTER
52ND ANNUAL MEETING
YMCA CAMP OF THE ROCKIES; ESTES PARK, COLORADO

5 SEPTEMBER 1997

ENVIRONMENTAL HYDRAULICS OF MOUNTAIN AND PLAINS WATERSHEDS AND RIVERS

FRIDAY - 5 SEPTEMBER 1997 - BOARD OF TRUSTEES MEETING

08:00 Meeting the board of trustees: Attendees are welcome at the meeting.

FRIDAY - 5 SEPTEMBER 1997 - MORNING SESSION
Session Chair - Donald Frevert, U.S. Bureau of Reclamation.

WATERSHEDS (5 papers)

09:05 **Water and Sediment Response for Two Watersheds Following a Wildland Fire.** John A.Moody and Deborah A. Martin. U.S. Geological Survey, NRP, Denver, CO.

09:35 **Hydrogeologic Effects of Wildfire: A case study of Buffalo Creek, Colorado, focused on hillslope processes.** Deborah A.Martin and John A. Moody. U.S. Geological Survey, NRP, Denver, CO.

10:05 **The Middle Saint Vrain Creek: Headwaters to Confluence with the South Saint Vrain.** Nikki Marchman. University of Northern Colorado, Greeley, CO.

10:35 **Spatial and Temporal Variation of Bulk Snow Chemistry Samples in an Alpine/Subalpine Watershed, Rocky Mountain National Park.** Sarah Clements, Colorado State University, Fort Collins, CO.; Kathy Tonnessen, Air Quality Division, National Park Service, Denver, CO; Donald Campbell, Water Resources Division, U.S. Geological Survey; and Kelly Elder, Colorado State University. Fort Collins, CO.

11:05 **Application of GIS in Environmental Analysis of Watersheds.** Mishra, S.K., D. Olson, and B. Kim. Department of Civil Engineering, Colorado State University, Fort Collins, CO.

11:35 - 1:00 Lunch break. Continuation of Trustees meeting (if required).

FRIDAY - 5 SEPTEMBER 1997 - FIRST AFTERNOON SESSION
Session Chair - Robert T. Milhous, U.S. Geological Survey.

PALEOHYDROLOGY (2 papers)

1:00 **Estimating Ancient Runoff.** Kenneth R. Wright. Wright Water Engineers. Denver, CO.

1:30 **Dendroclimatic Reconstructions in the Colorado Front Range: Overview and Potential.** Connie Woodhouse. NOAA Paleclimatology Program. Boulder, CO.

FRIDAY - 5 SEPTEMBER 1997 - SECOND AFTERNOON SESSION
Session Chair -

RIVERS AND STREAMS (5 papers)

2:00 **Grande Ronde Valley Oregon Flood Control, Fish Habitat Enhancement, and Stream Rehabilitation Study.** Douglas J. Trieste. Flow Technologies. Lakewood, CO.

2:30 **Spatial Variability of Algae in a Mountain Stream.** Valentina V. Vavilova and William M. Lewis, Jr. Center for Limnology. University of Colorado. Boulder, CO.

3:00 Break

3:30 **Specific Weight of the Bed Material of Gravel/Cobble Bed Rivers.** Robert T. Milhous. U.S. Geological Survey. Fort Collins, CO.

4:00 **Development and Field Testing of a Bedload Trap for Sand and Fine Gravels in Mountain Gravel-bed Streams (South Fork Cache la Pounde Creek, CO).** Kristin Bunte. Engineering Research Center. Colorado State University. Fort Collins, CO.

4:30 **Modified Log-Wake in Open-Channel Flows.** Junke Guo and P.Y. Julien. Department of Civil Engineering. Colorado State University. Fort Collins, CO.

Water and Sediment Response for Two Watersheds Following a Wildland Fire

John A. Moody and Deborah A. Martin, U. S. Geological Survey

The evolution of hydrogeological processes in burned watersheds is not well understood. A wildland fire (May 18-20, 1996) that burned 2700 hectares in the Buffalo Creek and 2100 hectares in the Spring Creek watersheds adjacent to the urban/wildland corridor southwest of Denver, Colorado has provided an opportunity to study the water and sediment response of two burned watersheds. Several thunderstorms yielding up to 125 mm of rain occurred after the fire in both watersheds, and eroded sediment from hillslopes and stream channels. During the subsequent floods, mostly coarse sand and gravel were deposited and completely filled existing stream channels while mostly fine sand, silt, and clay were deposited in a water-supply reservoir farther downstream. Buffalo and Spring Creek watersheds are both within the Pikes Peaks granite batholith which characteristically has shallow soils on easily eroded grus but the watersheds have different slopes, water discharges, and stored sediment. Buffalo Creek watershed slopes are 10-20% while Spring Creek watershed slopes are 20-40%. Buffalo Creek is a perennial stream with an average stream gradient of 0.01 and Spring Creek was probably an ephemeral stream before the fire but after the fire burned about 79% of the watershed it appears now to be a perennial but intermittent stream with an average stream gradient of 0.04. The Spring Creek watershed probably has more sediment available in the stream channel for potential transport. Ground and aerial surveys (1:3,000) have been made after each significant geomorphic change in study reaches starting at the mouth of each stream and extending upstream for 480 m along Buffalo Creek and 1370 m along Spring Creek are part of a study of the processes affecting sediment storage and mobilization. Bedload and suspended load measurements have been made at both ends of each study reach and have been combined with water discharge measurements to develop sediment budgets for each watershed. In addition to direct measurements of sediment and water discharge, water level in Spring and Buffalo Creeks and precipitation are being measured every 15 minutes near the upstream end of each study reach and additional precipitation measurements are being collected in the upper part of each burned watershed to monitor the evolution of the hydrologic response of both watersheds.

Initial ground surveys of both stream channels indicate reaches of scour and reaches of deposition exist during baseflow conditions in Spring Creek but that the reaches of scour fill in when the discharge increases. Similar reaches of deposition have not been observed in Buffalo Creek during baseflow conditions--instead the eroded sediment is transported continuously downstream in Buffalo Creek into the North Fork of the South Platte River. During greater discharge, sediment is deposited in reaches of scour which existed at baseflow conditions. Initial bedload discharge measurements in Buffalo Creek have ranged from 0.12 to 0.94 kg/s corresponding to 0.18 to 0.51 m^3/s and bedload measurements in Spring Creek have ranged from 0.015 to 0.10 kg/s corresponding to 0.0079 to 0.0201 m^3/s. Although bedload discharge from Spring Creek is less than Buffalo Creek, the sediment discharge per unit water discharge for Spring Creek is about 2.8 times that of Buffalo Creek. The water discharge response of both watersheds depends on rainfall from summer thunderstorms and on antecedent soil moisture conditions. Bed- and suspended-sediment discharge also depend on antecedent condition. For example, the peak discharge response of Spring Creek watershed to about 6.3 mm of rain after an approximately 3 weeks of warm, sunny, dry weather, was about 0.07 m^3/s, but increased to about 0.4 m^3/s with an additional 7.5 mm of rain on the second day, and finally to about 4 m^3/s, with 10.1 mm of rain on the third day. The bedload discharge in Spring Creek was essential zero (0.0002 kg/s) during baseflow conditions of about 0.006 m^3/s because the 3 weeks of warm, sunny, dry weather had produced algal mats that stabilized the bed material, however, after the rainfall and subsequent higher discharges, the bedload and suspended load were observed to increase significantly as the algal mats were removed and stored silt and ash material were mobilized.

Hydrogeological Effects of Wildfire: A case study of Buffalo Creek, Colorado focused on hillslope processes

Deborah A. Martin and John A. Moody, U. S. Geological Survey

We are interested in the short- and long-term responses of watersheds to wildfire and prescribed fire. A local wildfire in 1996 has presented the opportunity to study these responses in detail. A swift-moving, severe wildfire burned approximately 4820 hectares of national forest southwest of Denver, Colorado. Two months after the fire, a 100-year plus rainstorm caused a greater than 500-year runoff event which killed two people and resulted in extensive erosion and sedimentation. The same amount of rainfall in adjacent unburned watersheds did not produce erosion and flooding. Concern continues that the burned watersheds may still contribute to flash flooding. A water-supply reservoir downstream from the fire area has in one year received sediment equivalent to several "normal" years of accumulation.

We have collected several cores from this reservoir and instrumented several small subwatersheds to characterize the amount and type of sediment transported after the fire by precipitation events. We have focused on quantifying the material moving down the slopes adjacent to main channel and out of minor tributaries. Gerlach troughs have been installed to quantify the runoff, sediment yield, and the particle distribution of material produced from the hillslopes. Each cluster of four Gerlach troughs will have a rain gage. The initial sampling design includes measurement of water and sediment yield from north- and south-facing 30-degree slopes in severely burned and unburned areas of the Spring Creek watershed. Precipitation, runoff, and sediment measurements have been collected for events during the summer thunderstorm period of 1997. We will be monitoring soil moisture conditions and will be experimenting with a drop-former infiltrometer to examine infiltration response in the burned and unburned study areas. Remote sensing, photogrammetry, and GIS methods will be used to monitor the effect of revegetation on infiltration and runoff.

Honors Thesis Proposal
Nikki Marchman

1. Title: "Downstream Changes in the Middle Saint Vrain River: Headwaters to Confluence With the South Saint Vrain River"

2. Statement of the Problem: The objective of this research project is to study the Middle Saint Vrain River and how it changes as it moves downstream. The river will be studied from spring runoff through the summer season and through the early part of the winter season. From its beginning near the Continental Divide in Boulder County, Colorado to the point where it joins the South Saint Vrain River just upstream of Lyons, Colorado, this river passes through many different settings. It is the thesis of this study that the biological, chemical, and geological settings through which the river flows will have an effect on the water. This project will test the water at various points along the river to see if the aforementioned factors impact water quality. The scope of this study will limit itself to description of changes rather than exact causes of those changes; several years of observations and additional tests would be required to identify the probable causes.

The Middle Saint Vrain begins its journey near the Continental Divide where there is little human activity or chance for unnatural pollution. In the town of Peaceful Valley, however, the river passes through its first area of human settlement. There are more than fifteen houses less than thirty feet from the river in addition to a Guest ranch that keeps its horses and stables within forty feet of the river during the summer. Downstream, there are two little towns that consist of between 40 and 60 houses within one hundred feet of the river. They are very close together and many are close enough to the river that their owners worry year after year about rising levels of water during spring runoff. This proximity to the flowing water has the possibility of creating more problems than flooded basements or garages. Because the houses are close to the river, so are the wells and propane tanks. The risks of contamination escalate as the river flows downstream and more houses are close to the river.

3. Approach/Methodology: The Middle Saint Vrain River will be studied using a portable water testing kit manufactured by Hach. The kit contains many chemicals needed to perform tests for dissolved oxygen, phosphates, nitrates, pH, temperature, alkalinity, carbon dioxide, and other parameters.. Testing will be done a few times in the spring before major runoff starts and will continue approximately every other week after spring runoff begins. Collection of data will be done between May and September 1997.

4. Project Significance: This project encompasses many of the principles included in the Earth Sciences major: Oceanography, Geology, and Meteorology. It will provide the researcher with valuable knowledge of field work and water quality testing. In addition to benefits to the researcher, this research will provide baseline data for this particular river which is not one that is typically studied by UNC research groups as is the Poudre or Big Thompson.

SPATIAL AND TEMPORAL VARIATIONS OF BULK SNOW PROPERTIES IN AN ALPINE/SUBALPINE WATERSHED, ROCKY MOUNTAIN NATIONAL PARK

Sarah Clements, Department of Earth Resources, Colorado State University; Kathy Tonnessen, Air Quality Division, National Park Service; Donald Campbell, Water Resources, U. S. Geological Service; and Kelly Elder, Department of Earth Resources, Colorado State University

ABSTRACT

Chemical deposition, generally known as acid deposition, is a concern in high elevation snowpacks due to the elution of cations and anions in a mass flush during spring melt. The focus of this research project is to better understand spatial and temporal trends and variations in snow chemical concentrations related to snow distribution and spring snowmelt patterns in a high elevation alpine/subalpine watershed in the Colorado Rockies. This research is important in determining the amount of excess nitrogen and sulfur that may be eluted from snowpacks to alpine and subalpine ecosystems that may be linked to air emissions from urban areas and power plants.

An extensive snow survey complete with sequential aerial photography was executed in the Loch Vale watershed, Rocky Mountain National Park in 1996. Thirteen sampling sites were selected to represent the variability in slope, aspect, topography, and elevation in this watershed. Snow depth and density measurements, and bulk snow chemistry samples were taken during four sampling periods in April through June and compared for spatial and temporal trends and variations. Questions of interest were whether spatial variability of depth, density, and chemical concentrations were greater within sampling sites or between sampling sites.

The snow depth, density, and snow water equivalence (SWE) measurements indicated that there is a significant basin or zone difference between Andrews Creek subbasin and the remainder of the Loch Vale watershed. Elevation was first used to divide the sampling sites into two zones since the deepest snow depths were found at the highest elevation. The difference in mean SWE values for the low elevation zone was 0.93 m compared to 1.75 m for the high elevation zone. Statistical tests showed that the three sites in Upper Andrews Creek are significantly different than all other sites in snow depth, density, and SWE; the variability of the mean for these variables was greater between sites and zones than within sites and zones. Preliminary results of snow chemical data show trends of pH values increasing at all sites over time from the April to June. Major cations (Ca, Mg, Na, NH4, and K) and anions (Cl, SO4, and NO3) show trends with less spatial variability within a site than between sites.

APPLICATION OF GIS IN ENVIRONMENTAL ANALYSIS OF WATERSHEDS

By Subhendu K. Mishra[1], Derek Olson[2], and Brandon Kim[3]

The Wallercreek watershed discharges at its confluence with the Colorado River near Austin, Texas. This watershed is home to a rare species, Texas Map Turtle (scientific name: Graptemys versa). This turtle can only be found in this part of the world.

The breeding season for the turtle coincides with the rainy season for the area. The Texas Map Turtles lay their eggs just inland from the creek bed. Turtle eggs are porous, so that oxygen may diffuse to them. If the eggs were to become covered with water, the embryonic process will cease, and the turtles would not hatch. The problem of concern is if the area were to receive a major storm, the knowledge of the extent of flooding, could be important information to the survival of the species.

The purpose of this study is to develop a GIS model to route storm water through the creek and find out the effects of a major storm on the breeding grounds for the turtles. This paper will explain a methodology used to create the above model. This methodology could be used in any watershed for a variety of purposes. A discussion of the findings will be presented. Finally, with this information a plan will be developed to protect the breeding grounds for the turtles from the flooding.

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Abstract for Rocky Mountain Hydrologic Research Center 52nd Annual Meeting—Environmental Hydraulics of Mountain and Plains Watersheds and Rivers, September 1997

Estimating Ancient Runoff

By Kenneth R. Wright, Wright Water Engineers, Inc. Denver, CO

Rainfall-runoff curve numbers were estimated for Morefield Canyon of Mesa Verde National Park for the Anasazi occupational period using estimated ground cover conditions for 950 - 1100 AD. Annual rainfall totals were developed from tree ring analyses and individual rainstorm patterns were developed using modern records. It was determined that the ancient inhabitants of the canyon would have been able to rely on 4 to 5 runoff events each year. Present canyon conditions result in a once in 5 year runoff event of practically 0 cfs based on a survey of canyon floor geomorphological evidence.

Ancient rainfall records based on ice core chronologies or tree ring dendro-chronologies can be coupled with paleohydrological field studies and present day rainfall-runoff techniques to determine the likely hydrology of drainage basins in ancient times. Such information is useful to archaeologists and anthropologists in their studies of ancient cultures and likely reasons for their demise.

Dendroclimatic Reconstructions in the Colorado Front Range: Overview and Potential

Connie A. Woodhouse, NOAA Paleoclimatology Program, National Geophysical Data Center, Boulder, CO (woodhous@ngdc.noaa.gov)

The history of dendroclimatology in the Colorado Front Range dates back to the 1940s when Edmund Schulman collected three tree-ring chronologies from the headwaters of the S. Platte River with the goal of reconstructing runoff in the S. Platte River basin. Since then, more than 60 tree-ring chronologies have been developed for the central and northern Colorado Rocky Mountains. Although many of the chronologies were collected for the purpose of climate analysis, most of the dendrochronological studies in this region have focussed on forest ecology. A number of Front Range chronologies have been collected as part of large networks of climatically-sensitive chronologies that have been used to successfully reconstruct large scale patterns of climate variability in the western U.S. and drought in the Great Plains. Several studies have looked at the response of tree growth to climate with regard to elevational gradient, species, and topography, but to date, no climate reconstructions for the Colorado Front Range have been generated.

Although previous work has indicated that Front Range trees are sensitive to climate and may be suitable for regional reconstructions of climate, several factors may have contributed to the lack of reconstructions for this area. Many of the trees in the Colorado Front Range do not contain the strong linear relationships between climate and tree growth found in the drought-stressed trees of the Southwest. Front Range trees at higher elevations may have a more complex response to climate that includes sensitivity to both to winter/spring moisture conditions and summer temperatures. However, preliminary work in this area suggests that the most climatically-sensitive trees are ponderosa pine and Douglas fir at lower forest borders. These trees are stressed mostly by drought and are likely responding to variations in seasonal moisture. Another factor deterring dendroclimatic research in the Front Range may be related to the widespread notion that the area was clear-cut near the turn of the century, leaving few or no old trees suitable for long-term climate reconstructions. Although there is evidence for extensive clear cutting, isolated pockets of old trees have been located by a number of researchers.

The Front Range has good potential for dendroclimatic reconstruction. An assessment of all chronologies available through the International Tree-ring Data Bank and from several private collections has identified key species and locations that are particularly suitable for dendroclimate reconstructions. Careful attention to site and species selection can maximize the climate reconstruction potential. Searches have turned up a surprising number of old trees (dating back to at least 1600), and the under-utilized technique of combining remnant material with living samples has proven useful in extending chronologies back several centuries or more. Work is presently underway to reconstruct moisture-related variables such as precipitation, streamflow, and maximum snowpack for the S. Platte River drainage, and initial results appear promising. Such reconstructions will provide important information about natural climate variability for past centuries, providing a broader temporal context from which to evaluate present variations in climate.

GRANDE RONDE VALLEY OREGON

FLOOD CONTROL, FISH HABITAT ENHANCEMENT,

AND

STREAM REHABILITATION STUDY

by

Douglas J. Trieste, P.H.

Flow Technologies
Lakewood, Colorado

ABSTRACT

Flooding in the Grande Ronde Valley, Oregon has been a major part of the ecosystem for millions of years. Such flooding in the very flat valley recharged groundwater, replenished soils, made for a healthy riparian ecosystem, filtered sediment from streams, decreased flood peaks, improved fish habitat, etc. However, around 100 years ago, local farmers, in an attempt to "reclaim" as much land as possible, began altering the river system. That included cutting off about 33 miles of the original meandering Grande Ronde River by diverting that reach of river into a four-mile-long man-made channel, called State Ditch, about 5 ft wide, and 3 ft deep. State Ditch eventually eroded to its present dimensions averaging around 150 ft to 175 ft wide at the bank and 25 ft to 30 ft deep, and actually compounded flooding in the lower part of the valley. Other flood control efforts included building levees and cutting off meanders.

In spite of efforts to control flooding, it is still a major problem to farmers and occurs almost annually. Farmers would like as much of the river contained as possible thereby keeping more land for farming. However, impacts of flooding to farming is no longer the only concern. In these environmentally sensitive times, other issues have arisen that are not only concerns, but, conflict with farmers needs.

Attempts at flood control have resulted in a deteriorated riverine ecosystem and conflicting interests in the Grande Ronde Valley. The levee system follows the river channel in very close proximity to the river banks in most reaches, and as a result pinches it. Such pinching decreases hydraulic capacity, increases velocities during flood events, limits river/floodplain interaction, and increases bank erosion. Consequently, riparian vegetation has been destroyed and/or limited, and fish habitat severely deteriorated.

Although almost all of the river passes through private land, most farmers don't have capital for flood control. Thus, outside funding is desired, but, would mainly be funding allocated for fish habitat, wetlands, and riparian improvement. That money could be justified for flood control only if other concerns are primary. That is, the main focus would be the overall riverine ecosystem such as having a river/floodplain interaction, riparian vegetation improvement, erosion and sedimentation reduction, and improved habitat complexity.

Ideally, from an ecological standpoint, the best solution to restore the riverine ecosystem would be to remove all levees and let the river run free. However, ideally, from a farmers standpoint, the best solution would be to confine the channel to as much as possible and move the water through the valley as fast as possible. A compromise is being sought that includes levees with a floodplain, alternative crops in the floodplain, subsidizing land "lost" to the river, emphasis on benefits such as decreased erosion and a more fertile floodplain, etc. A "win-win" solution should be sought. If not, the riverine ecosystem will continue to deteriorate, and flood protection will be minimal at best - essentially, a "no-win" situation.

SPATIAL VARIABILITY OF ALGAE IN A MOUNTAIN STREAM

Valentina. V. Vavilova and William M. Lewis, Jr.

Center for Limnology
Department of Environmental,
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We studied variability in space of algae in periphyton and suspension on two Rocky Mountain streams - the St.Vrain Creek and the Snake River. Distribution, abundance and biomass were estimated using the multi-scale analysis. The following scales were chosen: 1) from tens of centimeters to first meters, 2) from tens to first hundred of meters and 3) from kilometers to tens of kilometers.

Heterogeneity exists even on small scale. Total cell counts and biovolumes of attached algae varied by an order of magnitude at the rocks located tens of centimeters to one meter apart. The same variability was tracked for single algal groups and species. Coefficients of variation (CV) for different characteristics of algal communities ranged from 64 to 173% for periphyton and from 14 to 167% for suspension on this scale.

On the scale of tens to hundred meters variability was about the same. However, the coefficients of variation were in average lower for the Snake River as compared to the St.Vrain Creek and for high elevations as compared to low elevations. Diatoms exposed the lowest variation (CV=15-75% and 28-44% for periphyton and suspension, correspondingly, compared to CV reached 200% for green and blue-green algae) among the algal groups.

The Ochiai coefficient (OC) was used to estimate variability between algal communities positioned several kilometers apart and at different elevations. It was shown that periphyton algae were more variable in August than in October (OC varied from 0.05 up to 0.8 in August and from 0.7 to 0.9 for in October).

SPECIFIC WEIGHT OF THE BED MATERIEL OF GRAVEL/COBBLE BED RIVERS

ROBERT T. MILHOUS

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ABSTRACT

The bulk density of the bed material of a gravel or cobble river can be important from a variety of environmental reason. One of these is related determining the quantity of metals stored in the stream bed. Another is related to the void space available for the used of aquatic animals. The technique is relatively simple is derived from geotechnical techniques used in the control of embankment construction. The first step is to remove the surface layer (armour) from a stream bed. The second step is to place a template on the bed, measure the volume of the template by covering the stream bed and template with plastic sheeting and placing a measured volume of water in the template until full. The third step is to remove the water and sample the bed material. The fourth step is to repeat the process of measuring the volume of the template - this time with the hole from which the bed-material sample was obtained. The difference in volumes in the volume of the hole. The bulk density of the bed-material is the ratio of the dry weight of the material removed to the volume of the hole from which the sample was obtained. The results of measurements in a number of gravel and cobble rives are presented in the table below.

SPECIFIC WEIGHT OF BED MATERIAL
GRAVEL AND COBBLE BED RIVERS

STREAM	specific weight (lb/ft3)	specific gravity	porosity
Oak Creek, OR	105	2.85	0.41
Soda Butte Creek, WY-MT	106	2.65	0.36
Stanislaus River, CA	123	2.68	0.27
North Platte, WY	151	2.52	0.04
Gunnison River, CO			
1993	163	2.62	0.001
1994	130		0.20
1995	144		0.12

Development and field testing of a bedload trap for sand and fine gravels in mountain gravel-bed streams
(South Fork Cache la Poudre Creek, CO)

Kristin Bunte

Engineering Research Center, CSU

Channel maintenance studies for gravel-bed mountain streams need to know the threshold flows for incipient motion of sand and fine gravels. Results from initial motion computations depend on the equation used and can vary within an order of magnitude. Measuring bedload with a Helley-Smith samplers faces poor bed contact, oversampling fines, short sampling times, and high labor intensity. Using portable bedload traps seemed a viable alternative.

Initial motion traps for fine bedload were developed under the premise that traps should be relatively inexpensive and easy to construct and install, and operable by one or two persons only. 5 traps each about 1 foot in diameter and depth were installed at the South Fork Cache la Poudre Creek, and field tested over a 3-week period during snowmelt high flow with flows between 35 and 100% of bankfull. Sample periods ranged from 0.5 - 50 hours.

Bedload transport rating curves determined from the traps are well defined and extend from 0.01 to 10 g/m·s. Rating curve exponents decrease with the traps' distance from the bank. Near-bank traps received high sediment supply in form of sand streaks, and relatively calm flows ensured a high trap efficiency. Contrarily, highly turbulent flow at mid-riffle probably caused particle jump lengths to exceed trap diameter.

Sampled sediment was mostly sand with average sizes of D_{16}, D_{50}, and D_{84} of 0.5, 1.1, and 2.2 mm. Sediment coarsened with distance from bank on the gravel bar, but fined again towards the bar edge. Direct relations between sediment size and daily waxing and waning flow were not consistent in hourly sample series; trendless, and even inverse relations occurred as well. Similar inconsistencies were found in relations between sediment size and daily low flows. Pooled D_{50} size from all traps was unrelated to flow, while pooled D_{95} size slightly increased with flow.

Traps generally worked satisfactorily, although some trap modifications are desirable. Traps are well suited to sample a wide range of transport rates of *true bedload* (particle jump length < trap diameter), but cannot sample temporarily suspended sediment. Since sand frequently changes its transport mode, *true bedload* samples of sandy sediment do not reflect stream competence, but momentary interactions between sediment (rates and sizes) supplied to the trap, and local turbulence that decreases trap efficiency. Incipient motion studies in mountain gravel-bed streams based on bedload traps require an array of traps positioned at strategic locations in the stream.

Modified Log-Wake Law in Open-Channel Flows

Junke Guo AND P. Y. Julien
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The most advanced knowledge of the velocity profile of an open-channel flow is the log-wake law, i.e.

$$\frac{u}{u_*} = \underbrace{\left(\frac{1}{\kappa}\ln\frac{yu_*}{\nu} + C\right)}_{\text{The law of the wall}} + \underbrace{\frac{2\Pi}{\kappa}\sin^2\frac{\pi\xi}{2}}_{\text{the law of the wake}} \tag{1}$$

or

$$\frac{u_{\max} - u}{u_*} = -\frac{1}{\kappa}\ln\xi + \frac{2\Pi}{\kappa}\cos^2\frac{\pi\xi}{2} \tag{2}$$

in which u is the velocity at distance y from the bed; u_* is the shear velocity; $\kappa = 0.41$ is the von Karman constant; $\Pi \approx 0.2$ is the wake strength coefficient; ξ is the normalized distance y by the flow depth h; and $u_{\max}$ is the water surface velocity.

The log-wake law is originally suggested by Coles (1956) in studying boundary layer flows. Coleman (1981, 1986), Nezu and Rodi (1986), and others examined it in open-channels. Generally speaking, the log-wake law can improve the calculation of the velocity profiles in open-channels. However, like its applications in boundary layer flows (Coles, 1969), it is not valid near water surface because its first derivative is not zero at $\xi = 1$. In particular, the eddy viscosity from the log-wake law is not much different from that of the log law.

To satisfy the boundary condition at $\xi = 1$, i.e., $\left.\frac{du}{dx}\right|_{\xi=1} = 0$, an additional term in (2) must be brought. That is, (2) must be modified as

$$\frac{u_{\max} - u}{u_*} = -\frac{1}{\kappa}\ln\xi + \frac{2\Pi_1}{\kappa}\cos^2\frac{\pi\xi}{2} - \frac{1-\xi}{\kappa} \tag{3}$$

in which the value of Π_1 is not the same as that of Π. Using Muste's (1995) wide flume experiments, the wake strength coefficient Π_1 is determined as about 0.5. Equation (3) reduces to the log law near the bed and is close to the classical parabolic law suggested by Bazin.

The average velocity from (3) is exactly the same as that from the log law. The position of the average velocity is at $\xi = 0.39$. In particular, from (3) one can get a quite good expression of eddy viscosity. That is, near the bed, the eddy viscosity is proportional to ξ; at about $\xi = 0.3$, the eddy viscosity reaches its maximum value; when $\xi \geq 0.5$, the eddy viscosity tends to a constant. Naturally, a sediment concentration profile can be derived for the new eddy viscosity model, which shows that near the bed, the concentration profile obeys a power law; near water surface, the concentration profile obeys an exponential law.