



# STREAM NOTES

To Aid In Securing Favorable Conditions of Water Flows

Rocky Mountain Research Station

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## Attributes of Bedrock Sierra Nevada River Ecosystems

by Scott McBain and Bill Trush

Most Sierra Nevada rivers I.C. Russell (1902) visited and studied as a geomorphologist more than 100 years ago are now regulated by dams. Reduced flows, disrupted bed material supply, and invasive exotic fish species have significantly altered these bedrock river ecosystems. This raises the questions: What do bedrock river ecosystems require to maintain their integrity? Can regulated bedrock rivers be better managed to help recover river ecosystem integrity?

To begin addressing these issues, we propose a set of seven attributes characterizing basic requirements of bedrock Sierra Nevada river ecosystems based on field observations from two tributaries to the Tuolumne River. These attributes expand on a set of 10 attributes previously developed for alluvial rivers by the authors (Trush et al. 2000) and summarized in the January 2000 issue of **Stream Notes** (Trush and McBain 2000). The bedrock river attributes are an integration of scientific literature, experimental measurement, and field observation. Every river, whether mostly alluvial or bedrock, is unique. The alluvial and bedrock attributes cannot be expected

to adequately address all individual river needs, issues, and/or constraints, nor are the attributes intended for river classification. In working with river management agencies, we have found that the process of developing the attributes for a given river synthesizes geomorphic and ecological understanding into a management framework effective for prescribing annual flow regimes and sediment management practices on regulated rivers.

A significant gap exists between the science and management of bedrock rivers. The science of bedrock rivers tends to focus on landscape-scale processes and geological timescales (Tinkler and Wohl 1998) which are usually too large and too long than required for most contemporary river management issues. A tremendous need exists for new tools to help prescribe flow and sediment regulations, assess corresponding ecological impacts, and recommend restoration strategies for regulated bedrock rivers.

A common perception is that bedrock channel morphology is static compared to alluvial channels, and therefore, relatively insensitive to flow and

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John Potyondy, Program Manager

The *PRIMARY AIM* is to exchange technical ideas and transfer technology among scientists working with wildland stream systems.

*CONTRIBUTIONS* are voluntary and will be accepted at any time. They should be typewritten, single-spaced, and limited to two pages. Graphics and tables are encouraged.  
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### IN THIS ISSUE

- **Attributes of Bedrock Sierra Nevada River Ecosystems**
- **A Historical Perspective on Regional Channel Geometry Curves**
- **Fire and Riparian Ecosystems of the Western USA**

sediment supply changes. But bedrock channels are often highly dynamic depositional environments. Deposition occurs within a confining, rigid bedrock boundary, and therefore these channels are not “alluvial” in the classic sense. If all deposition could be stripped from a bedrock Sierra Nevada river, including the largest boulders, there would still be a bedrock template of pools and riffles.

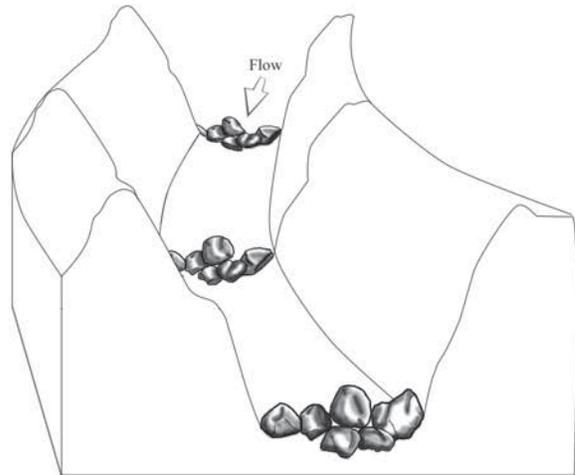
This bedrock template functions as an intricate complex of hydraulic controls that creates diverse nested depositional features ranging from aggregates of large boulders to fine sand deposits. The richness of biological expression in Sierra Nevada river ecosystems depends on the structural complexity created by highly dynamic depositional features and processes. Our timeframe for the bedrock attributes leans more toward the biological than geological and therefore focuses on the next 50 to few hundred years rather than many thousands of years.

The bedrock attributes were first considered during a 1993 study of the Clavey River and Cherry Creek in the Sierra Nevada funded by the USDA Forest Service, Pacific Southwest Research Station (IRE 1993). The Clavey River, tributary to the Tuolumne River, is the longest unregulated river in the Sierra Nevada. Cherry Creek, also a tributary to the Tuolumne River and of similar drainage area, has been highly regulated since 1956. Both are snowmelt-driven bedrock rivers. The Stream Systems Technology Center supported revisiting both sites in 2001. These visits and subsequent analysis contrasting the regulated and unregulated systems resulted in this list of bedrock river attributes.

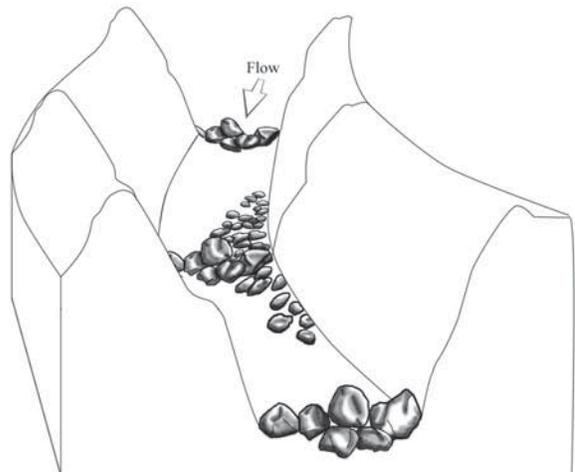
**ATTRIBUTE No. 1. Bedrock Rivers Exhibit Nested Depositional Features.**

*Bedrock channels, though principally erosional, exhibit abundant depositional features. Large geomorphically derived hydraulic controls, such as valley width constrictions or expansions and resistant bedrock outcrops, define an overall limit for coarse sediment deposition in each segment of the bedrock channel. These geomorphic controls induce coarse depositional features that in turn perform as smaller hydraulic controls inducing finer secondary depositional features. Transverse boulder “ribs” are prominent depositional alluvial features (i.e., self-formed) in bedrock Sierra*

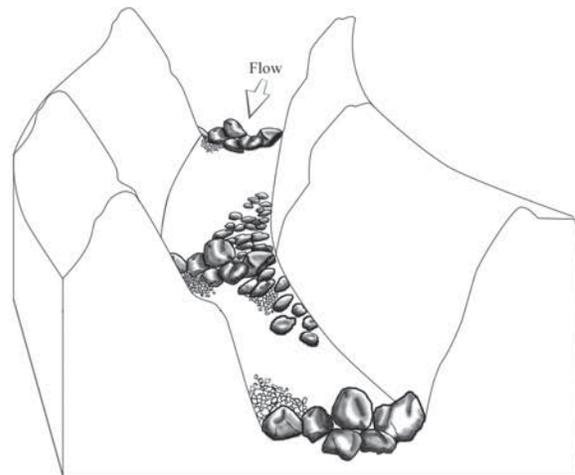
**Large scale depositional and roughness features:**  
Large boulders “fluvially arranged” as boulder ribs.



**Medium scale depositional features:**  
Valley wall curvature and/or expansion cause cobble and boulder bars to form among boulder ribs.



**Small scale depositional features:**  
Sand, gravel, and cobble deposits form as lee deposits and/or obstruction deposits associated with medium and large scale depositional features.



*Nevada rivers and function as hydraulic controls for diverse secondary, and even tertiary, depositional features. The occurrence of smaller hydraulic controls within larger hydraulic controls gives rise to a complex, nested depositional channel morphology that provides diverse aquatic and riparian habitats.*

### **ATTRIBUTE No. 2. Bedrock River Ecosystems Require Variable Annual Hydrographs.**

*Annual hydrographs can be partitioned into discrete hydrograph components (including winter storm events, winter and summer baseflows, spring snowmelt peaks, and spring-summer snowmelt recession limbs). Each is a discrete, repeatable portion of the annual hydrograph that varies in magnitude, duration, frequency, and timing within and among different types of water years. Annual hydrograph components uniquely:*

- (a) contribute to geomorphic processes that shape and maintain depositional features,*
- (b) sustain varied life history and habitat requirements for plant and animal species native to bedrock Sierra Nevada river ecosystems, and*
- (c) perpetuate early-successional woody riparian communities. Seasonally dependent life history requirements, such as the short timespan when riparian plants disperse viable seeds (often as short as two weeks), have evolved to the natural timing and frequency of annual hydrograph components.*

### **ATTRIBUTE No. 3. Episodic Sediment Delivery Enhances Spatial Complexity.**

*Hillslope mass wasting, such as rock falls and bedrock shearing from canyon walls, episodically deliver colluvium of sufficient volume and/or caliber that create large depositional features in the channel or function as large-scale hydraulic controls capable of generating other prominent depositional features.*

### **ATTRIBUTE No. 4. Bedrock Channel Maintenance Requires Multiple Flow Thresholds.**

*Multiple flow thresholds are required to initiate diverse depositional and erosional processes essential to maintaining the erosional and depositional features of bedrock channels.*

*Infrequent large “re-setting” floods (approximately 25-yr annual maximum floods and greater) are needed to:*

- (a) significantly scour and redeposit large depositional features such as entire lateral bars,*
- (b) reposition and aggregate large boulders into depositional features such as transverse boulder ribs,*
- (c) periodically remove mature woody vegetation from bars and along channel margins,*
- (d) encourage avulsions in broader channel reaches,*
- (e) prevent steepening of riffles due to excessive boulder accumulation, and*
- (f) sweep-out boulders accumulating in bedrock pools.*

*More frequent, lower magnitude floods (10-yr to 20-yr annual maximum floods) are needed to:*

- (a) significantly mobilize surface layers of large coarse-grained bars in part to minimize woody riparian encroachment,*
- (b) deposit smaller coarse depositional features associated with transverse boulder ribs and/or individual large boulders and bedrock outcrops, and*
- (c) deposit silt and sand on floodplains and low terraces.*

*Frequent snowmelt flood hydrographs (up to 5-yr annual maximum floods having relatively small peak discharges) are needed to:*

- (a) maintain a high turnover of fine-grained depositional features (composed of small cobbles and finer particles) often associated with secondary hydraulic controls of bars and transverse boulder ribs, but also in gravel deposits of bedrock pool tails (e.g., spawning habitat for salmonids), and*
- (b) build few and highly localized floodplains.*

### **ATTRIBUTE No. 5. Maintenance of depositional features is partially independent of the coarse bedload transport capacity.**

*Bedrock rivers have a huge, and generally unfulfilled, potential transport capacity for coarse sediment but a low temporary storage capacity of coarse and fine sediment. Hydraulic complexity and channel form, expressed as nested hydraulic controls in a variable flow regime, exert the greatest control on storage capacity. The annual coarse bedload transported may*



*fluctuate significantly without significantly affecting the volume of coarse sediment stored in a channel segment. Although storage capacity is low, the ecological implications for maintaining limited depositional features can be great.*

**ATTRIBUTE No. 6. Biological Hotspots Occur at Highly Depositional Channel Reaches.**

*Biological hotspots, short channel segments supporting unique and/or more diverse aquatic and riparian communities, typically occur where the local river corridor or major episodic geomorphic events exert large-scale hydraulic control over deposition. These atypical channel segments exhibit prominent depositional features, and even alluvial tendencies such as a meandering channel morphology and limited floodplains that are highly dependent on snowmelt flood and recession annual hydrograph components. This alluvial tendency promotes smaller particle size, abundant riparian habitat, off-channel amphibian habitat, and higher overall biological diversity. Biological hotspots are the offspring of other attributes and are reminders that nature is attracted to novelty.*

**ATTRIBUTE No. 7. Hydraulic Pathways in the River Corridor Fluctuate Seasonally and Annually.**

*Variable hydrograph components, particularly the snowmelt recession limb and baseflows, sustain surface and subsurface hydraulic pathways throughout the river corridor.*

**Discussion**

The bedrock attributes provide a means for recognizing the complex needs of Sierra Nevada river ecosystems, and offer a geomorphic foundation to begin managing potential flow and sediment related impacts to bedrock river ecosystems. When considering other bedrock rivers, the attributes should be re-evaluated, added to, and/or modified based on the unique nature of individual river ecosystems.

For the Sierra Nevada rivers used to develop the above attributes, the first three attributes, which set the stage for how flowing water sorts sediment in bedrock channels, are integrated by Attribute No. 4. It takes the nested hydraulic controls of Attribute No. 1, exposes these controls to variable flows through Attribute No. 2, and supplies the unpredictable (but certain to occur) wild-card of episodic sediment delivery of Attribute

No. 3. All three are needed to meet the physical demands of a complex bedrock channel morphology. Flow thresholds linked to physical processes addressed in Attribute No. 1 and Attribute No. 4 can then be implemented through discrete hydrograph flow components described by Attribute No. 2. Attribute No. 3 (episodic sediment delivery), Attribute No. 6 (biological hotspots), and Attribute No. 7 (seasonal and annual fluctuations) are reminders that the norm does not exist in nature, and therefore simplistic flow recommendations cannot address ecosystem needs outside an arbitrary norm.

A prevailing attitude towards managing bedrock Sierra Nevada river ecosystems has been that they require considerably less than natural annual flow regimes to sustain ecological integrity. We argue that only by managing bedrock rivers as highly dynamic depositional environments can ecological beneficial uses be restored and/or sustained.

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# A Historical Perspective on Regional Channel Geometry Curves

William W. Emmett

Regional channel geometry curves are now being developed in many parts of the United States and some understanding of the early data used to develop the original curves may be useful. Channel geometry and bankfull discharge concepts had their origin in the 1950s. A little background from the era when bankfull discharge was first being determined and bankfull values of hydraulic and channel geometry were first being utilized, is helpful in understanding what early data may be useful in the preparation of present day “regional curves.”

As a general rule, because channels are constantly changing to maintain equilibrium with the water and sediment being supplied to them, historical data may have limited utility in developing regional curves. For example, in relatively stable environments with slow climate change, 30-year-old data may be useful, while in environments with rapid land-use change, 3-year-old data may be useless.

In the late 1950s, Luna Leopold, then Chief Hydrologist of the U.S. Geological Survey, requested that some USGS Districts conduct bankfull channel-geometry surveys. A total of 13 surveys were made, from Tennessee and Kentucky to Massachusetts and the Dakotas. Referred to as the “original 13 surveys,” these sites provided data for the dimensionless rating curve first published in Emmett and Leopold (1963), repeated as Figure 7-10 in Leopold, Wolman, and Miler (1964) where the data are captioned as “eastern half of United States,” and repeated as Figure 16-37 in Dunne and Leopold (1978) where the data are captioned as “eastern United States.” A listing of the gaging stations is provided in Emmett and Leopold (1963), an internal USGS publication, but these data were not further used in preparation of distinct “regional curves,” so this reference to Eastern United States has no connection to Eastern United States as used in some regional curves. In the early 1960s, some USGS personnel provided site-inspection data of bankfull stage (published as Table 7-13 in Leopold, Wolman, and Miller [1964]), but these data were not further used in preparation of distinct “regional curves.”

The first comprehensive set of bankfull values of hydraulic and channel geometry is the early 1970s data provided in Emmett’s 1975 publication, “The Channels and Waters of the Upper Salmon River Area.” These data are almost always referred as “Idaho,” “Upper Salmon River, Idaho,” or “Emmett, 1975”. Because much of this area is pristine, these data should still be valid.

In the mid-1970s, Leopold assembled bankfull values of hydraulic and channel geometry near his residence at Pinedale, Wyoming; these data are referred as “Upper Green River, Wyoming,” generally cited as Dunne and Leopold (1978), and these data should still be valid. Some site information of the Upper Green River data is provided in Dunne and Leopold (1978) and use of both the Upper Salmon River data and the Upper Green River data is sprinkled liberally throughout the book.

Leopold also assembled other data sets; these were used in Dunne and Leopold (1978) as (a) “San Francisco Bay region” and (b) either “Eastern United States,” “Southeastern Pennsylvania,” or “Pennsylvania.” Data for San Francisco Bay were from near Leopold’s residence in Berkeley (a listing of sites was not separately maintained), and data variously labeled as for Eastern United States or Pennsylvania came from our channel-geometry files compiled from eastern sites while we were residents of Washington, D.C., and from data from the Brandywine area of Pennsylvania (an exact listing of sites was not maintained).

These west and east coast sites from Dunne and Leopold (1978) are very insightful, giving a comparison of rainfall-runoff channels to the snowmelt-runoff channels of Idaho and Wyoming. Because of the lack of specificity of sites, the west and east coast sites cannot be further used in preparation of present-day regional curves, however the published curves should show similarity to curves developed for sites in the generalized west or east coast areas.



The most important criteria in developing any type of bankfull relations are the correct field identification of bankfull (floodplain) and the surveying procedure for determining bankfull stage. It has long been recognized that a single cross section is inadequate in determining the floodplain elevation. That's why the original USGS channel-geometry instructions (USGS, 1959), Leopold, Wolman, and Miller's classic 1964 book on fluvial processes, the first detailed field work (pages 35-36, (Emmett, 1975), and the oft-cited procedure (pages 653-655, Dunne and Leopold, 1978), all state the necessity of a longitudinal profile of the floodplain.

Where the longitudinal profile passes a given cross-section, that's the elevation of bankfull at the section; better yet when there's a gage, where the long profile passes the gage section, the stage reading of the longitudinal profile is bankfull stage. Absent a longitudinal profile, each cross section is likely to have a unique value of bankfull discharge. And we know that when we have many cross sections, we really have but one bankfull discharge, not a different one for each section.

The use of a single cross section became so pervasive that it led to mentioning techniques of channel-geometry surveys in two important Forest Service publications: (1) "Stream Channel Reference Sites: An Illustrated Guide to Field Techniques" (Harrelson et. al. 1994), and (2) "A Guide to Field Identification of Bankfull Stage in the Western United States" (USFS 1994). I played a role in both of these efforts, largely to ensure that we begin to do things consistently.

Proper identification of bankfull stage is critical to the development of channel geometry curves. Bankfull stage is that stage at which stream water just begins to overtop the floodplain; the floodplain is defined as that relatively flat, depositional surface adjacent to the stream that is being built and rebuilt by the stream in the present hydrologic regime. This definition separates the floodplain from within-channel bars and berms, and from nearby terraces. Bankfull identification is further complicated when there's improper use of so-called "bankfull indicators." I am not enamored with the often used phrase "...indicators to take the place of the

floodplain," but am not opposed to the phrase "... indicators which help us find the floodplain."

A river channel is formed by a range of flows. The bankfull discharge is a surrogate for this range of flows. The recent video by the U.S. Forest Service (2003), "Identifying Bankfull Stage in Forested Streams in the Eastern United States," in which I was the technical coordinator, emphasizes these latter points. Copies are available from the Stream Systems Technology Center upon request. Use it in your endeavor to correctly identify bankfull stage in the field and to develop meaningful regional channel geometry curves.

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# Fire and Riparian Ecosystems in Landscapes of the Western USA

The paper "Fire and Riparian Ecosystems in Landscapes of the Western USA" is based on a 2001 workshop Dr. Boone Kauffman, then with the Department of Fisheries and Wildlife at Oregon State University, conducted for the Stream Systems Technology Center. Workshop participants included a diverse group of 30 specialists in the fields of fire science, fire management, riparian ecology, hydrology and geomorphology. The group met for three days at the Center for the Management of Information at the University of Arizona and participated in a series of verbal and electronic discussions using GroupSystems® software, a suite of tools designed to facilitate collaboration and information sharing.

The goals of the workshop were to:

- discuss the status of knowledge on the relationships between fire and riparian zones at spatial scales from the riparian area to the entire landscape;
- discuss the role and values that riparian areas have for fire suppression;
- discuss the effects of land and water management on fire regimes (fire frequency, behavior and severity within riparian zones); and on wildfire control and use; and
- identify knowledge gaps and needed research on these subjects.

The 209 page report summarizing discussions from "**The Workshop on Multiple Influences of Riparian/Stream Ecosystems on Fires in Western Forest Landscapes**" can be downloaded from the STREAM Web page ([www.stream.fs.fed.us](http://www.stream.fs.fed.us)) or by going directly to "<http://www.stream.fs.fed.us/publications/documents/Stream.html>" and looking for the file "Riparian Fire Final.pdf."

An abbreviated version of the workshop findings was recently published by **Kathleen A. Dwire**, Research Ecologist with the Rocky Mountain Research Station, and **Boone Kauffmann**, now Research Biologist and Director of the Pacific Southwest Research Station Institute of Pacific Islands Forestry, in *Forest Ecology and Management*.

The article notes that despite the numerous values of riparian areas and the recognition of fire as a critical natural

disturbance, few studies have investigated the behavior, properties, and influences of natural fire in riparian areas of the western USA. Riparian areas frequently differ from adjacent uplands in vegetative composition and structure, geomorphology, hydrology, microclimate, and fuel characteristics and these features contribute to different fire environments, fire regimes, and fire properties in riparian areas relative to uplands.

In certain forested riparian areas, fire frequency has generally been lower, and fire severity has been more moderate than in adjacent uplands, but in other areas, fires have appeared to burn riparian areas with comparable frequency. Impacts of land use and management may strongly influence fire properties and regimes in riparian areas. Fire suppression, livestock grazing, logging, damming and flow regulation, agricultural diversions, channel modifications, and introduction of invasive species have led to shifts in plant composition, structure and distribution of fuel loads, and changes in microclimate and aerial extent of riparian areas. These cumulative impacts of human alterations are likely to exert the most pronounced influence on fire behavior during periods of drought and under conditions of extreme fire weather. Riparian plant species possess adaptations to fluvial disturbances that facilitate survival and reestablishment following fires and this contributes to the rapid recovery of many streamside habitats. However, an improved understanding of fire ecology and effects in riparian areas is needed to prescribe ecologically sound rehabilitation projects flowing fires.

The above abstract is from: Kathleen A. Dwire and J. Boone Kauffman, 2003. Fire and riparian ecosystems in landscapes of the western USA. *Forest Ecology and Management* 178 (2003) 61-74.

The paper by Dwire and Kauffman can be downloaded from [www.sciencedirect.com](http://www.sciencedirect.com). Simply type "Fire and riparian" into the Quick Search box and the title will be listed for retrieval as a pdf file.



# STREAM NOTES

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# STREAM NOTES



## John Potyondy Appointed STREAM Program Manager



**John Potyondy** has been selected as the Program Manager for the National Stream Systems Technology Center and will succeed **Larry Schmidt** who will be retiring early in 2004 after directing the program from its inception in 1992.

John Potyondy has been with the Stream Systems Technology Center since 1992 as a Physical Scientist. Prior to this, he held various positions within the National Forest System including Forest Hydrologist on the Boise National Forest, Assistant to the Regional Hydrologist in the Intermountain Region, and Barometer Watershed Hydrologist on the Wasatch-Cache National Forest. John has a Masters

Degree in Forestry-Forest Hydrology from the University of Minnesota and also spent 3 years doing erosion research in Morocco with the Peace Corps.

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