STREAM SYSTEMS TECHNOLOGY CENTER

STREAM NOTES

To Aid in Securing Favorable Conditions of Water Flows

April, 1994

THE HYDROLOGY AND FORM OF SPRING-DOMINATED STREAMS

In certain geologic settings, such as areas underlain by carbonate or volcanic rocks, conditions are favorable for groundwater to emerge at the surface as springs. These springs can exsurge large volumes of water and give rise to relatively large streams. In some cases, the spring may actually represent the re-emergence (or resurgence) of a former surface-stream.

While some research has been published on the hydrographs of springs (for example: White, 1988; White and Reich, 1970), few studies consider the nature of the form and associated alluvial deposits of channels which begin at springs. Here we explore some of the characteristics of streams that begin at springs, herein referred to a spring-dominated streams. How do they compare to streams which receive their water from direct surface runoff (herein referred to as runoff-dominated springs)?

We are interested in those spring-dominated streams in which the banks are composed of alluvium (as opposed to bedrock) and therefore will adjust more easily to changes in discharge. In particular, we will discuss the form and character of Browns Creek, a spring-dominated stream in Oregon (Figure 1) in which the parent spring is exsurging from fractured basalt. Browns Creek is located in the southwest corner of the Columbia Plateaus physiographic province (Fenneman, 1931) and is one of about ten spring-dominated springs in Idaho, Montana and Oregon that we visited in October of 1993 as part of reconnaissance research on such streams (Whiting and Stamm, 1994).

Description of Browns Creek, Oregon

Browns Creek is located in the SW $^1/_4$ of the NE $^1/_4$ of Section 30, T.21S., R.8E., of the Davis Mountain 7.5-minute series quadrangle. The springs are at an elevation of about 1350 m (4440 ft) and a gaging station is located approximately 1 km downstream of the springs. The gage has been operating since 1939 and is one of the few gages on spring-dominated channels of which we are aware. Using data from this gage, we

STREAM NOTES *is produced quarterly by the Stream Systems Technology Center, Fort Collins, Colorado.*

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

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

Ideas and opinions expressed are not necessarily Forest Service Policy. Trade names do not constitute endorsement by the Forest Service.

Phone: (303) 498-1731
FAX: (303) 498-2306
DG: STREAM:S28A

IN THIS ISSUE

- **Hydrology & Form of Spring-dominated Streams**
- **Stream Channel & Riparian Reference Areas**
- **Flow Resistance & Manning's Equation**

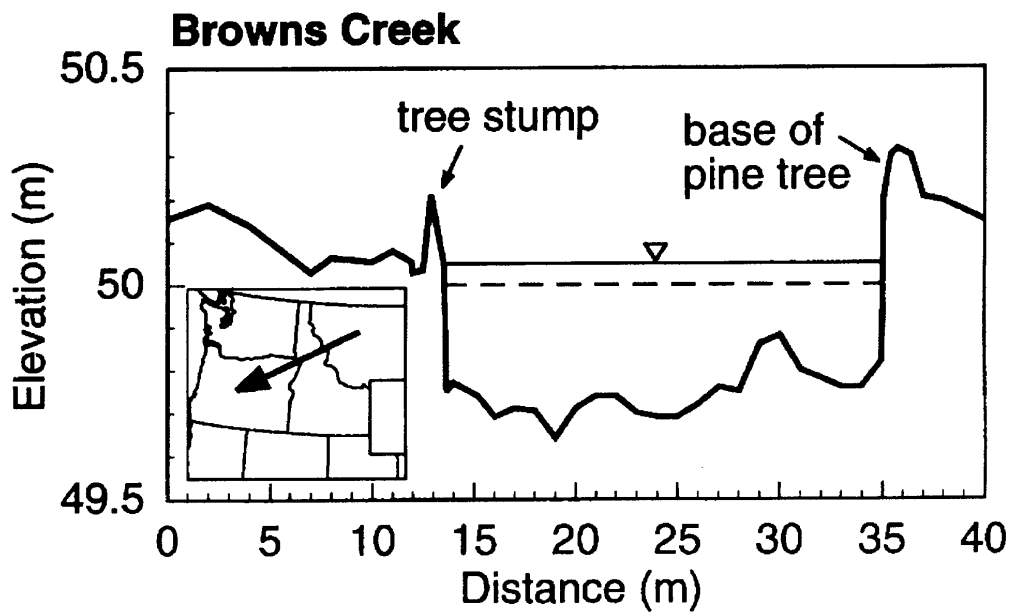


Figure 1. Cross-section of Browns Creek, Oregon. Triangle marks estimated bankfull stage. Elevations are with respect to an arbitrary datum. Inset map shows the northwest U.S. and the approximate location of Browns Creek.

constructed a flow-duration curve for Browns Creek. Bankfull, mean annual, and baseflow discharges are 1.36 m^3/s (48 cfs), 1.07 m^3/s (38 cfs), and 0.88m^3/s (31 cfs), respectively. The bankfull discharge has a recurrence interval of 1.67 years. The 100-year-flood discharge is 2.86 m^3/s (101 cfs). The largest flood on record was 2.95 m^3/s (104 cfs on August 4, 1956) and has a recurrence interval of slightly greater than 100 years. Water levels in Browns Creek exceed bankfull 22% of the time (approximately 80 days a year). Water levels are high enough to keep the floodplain moist for long periods.

Browns Creek is a perennial stream that flows eastward through a broad pine-covered valley. The valley is underlain by recently extruded volcanic material. The springs at the head of Browns Creek issue from the northwest side of the valley. The creek flows eastward, along the base of the southern flank of Browns Mountain, towards the Deschutes River. A small tributary stream enters Browns Creek about one kilometer upstream of the gaging station and adds about 40 km^2 to its drainage area. This tributary has springs at its headwaters and drains a marshy area to the south of Browns Creek that is probably fed by springs.

The bed of the channel is composed of sand- and gravel-sized particles that are loose and free of mud or algal coatings. Also, the water was very clear on the day of our survey. There are fallen logs within the channel that show no evidence of rotation by the stream's current. Overall, the channel has a rectangular geometry with minor variations in depth and poorly-defined bars. The channel appears to be migrating laterally and, at the survey site, eroding a terrace on its right bank. The left bank of the channel is a mat of vegetation that was only about 5 cm above the water level on the day of the survey.

We surveyed the stream at a location that was

about 100 m downstream of the springs. The cross-section of Browns Creek at this site, showing relative elevations of the floodplain, channel, water surface and estimated bankfull stage, is shown in Figure 1. On the day we surveyed the stream, it had a discharge of 0.99 m^3/s (35 cfs). The channel has a slope of about 0.0055. At bankfull, the channel was about 22 m wide and 0.35 m deep. The channel is therefore 63 times wider than it is deep at the survey site.

The apparent drainage area (based on topographic maps) upstream of the survey site is about 45 km^2 -- the largest drainage area of the spring-dominated streams studied (Whiting and Stamm, 1994). Mean annual precipitation at nearby Wickiup Dam, 10 km to the southeast, is 51.6 cm (20.3 in). For comparison, the mean annual discharge of Browns Creek corresponds to a 75 cm depth of water over a 45 km^2 area. This indicates that precipitation over this drainage area is insufficient to sustain the discharges in Browns Creek -- water must be supplied from a larger area. In addition, highest precipitation at Wickiup Dam occurs in the winter months but Browns Creek floods in late summer and fall. This suggests a lag between recharge and runoff of at least three months.

Attributes of Spring-dominated Streams

Browns Creek is a good example of a spring-dominated stream. While spring-dominated streams share many characteristics of runoff-dominated streams, there are attributes that make them distinct from runoff-dominated streams. These attributes are summarized below.

• **Channel Form**:

Channels of spring-dominated streams are generally rectangular in form with little variation in depth. Changes in depth are mostly due to flow around large organic debris, such as fallen logs. In general, spring-dominated streams do not have a well-defined thalweg nor do they have bars, which are typically found in runoff-dominated streams (see, for example, Bloom, 1991, Chapter 9). Channel material is usually clear of mud and algal growth.

• **Floodplain and Banks**:

The floodplains of spring-dominated streams are rich in organic matter and were a few centimeters above the water level at the time of our reconnaissance. The surface of the floodplain was wet, and probably remains so for most of the year. As a result of the wet floodplain soils, some streams flow through a treeless corridor. Logs are often found to be spanning the channel, and in some streams, with a frequency of one or more per meter.

• **Flow Characteristics**:

First-order, runoff-dominated streams in the western United States receive much of their water from snowmelt in the spring and summer. Once the snow has melted, these streams are nearly dry. In contrast, streams that have springs at their headwaters are perennial and can be important source of water for wildlife.

Figure 2 shows the flow-duration curve for Browns Creek and, for comparison, the curve for the upper Salmon River, Idaho. These curves indicate that spring-dominated streams, such as Browns Creek, have a narrower range of discharges and a higher frequency of flooding than runoff-dominated streams, such as in the upper Salmon River. The mean annual flow on Browns Creek, normalized by the bankfull discharge, is 0.80, whereas the ratio for the upper Salmon River drainages is 0.25. In eight Wyoming streams, the ratio of mean annual flow to bankfull discharge is 0.14 (Dunne and Leopold, 1978). The ratio of baseflow to bankfull flow at Browns Creek is 0.65, whereas the ratio for the upper Salmon River drainages is usually less than 0.10.

Bankfull discharges occur on Browns Creek with a recurrence interval of 1.67 years. This is nearly indistinguishable from the recurrence interval of 1.5 years, thought to be typical of runoff-

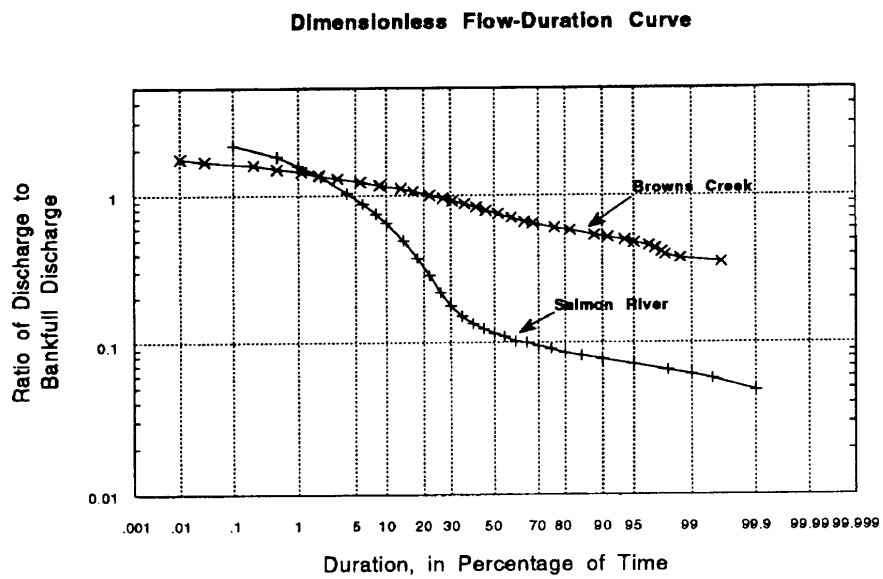


Figure 2. Flow-duration curve for Browns Creek and the upper Salmon River. Data for the upper Salmon River are from Emmett (1975, Table 17).

dominated streams (Wolman and Leopold, 1957; Emmett, 1975). However, the timing of high floods in late summer and fall timing is somewhat unusual. Seasonal growth of vegetation, such as watercress, may effect stream stages by changing the roughness of the channel.

The 100-year flood on Browns Creek has a discharge 2.1 times greater than bankfull, whereas this event in the upper Salmon River drainages has a discharge 2.9 greater than bankfull. Bankfull and greater discharges occur an incredible 22 percent of the time in Browns Creek. For comparison, the corresponding figure for the upper Salmon River drainages is 4 percent (Emmett, 1975). In eight Wyoming streams, the channel is out of its banks 2.1 percent of the time (Dunne and Leopold, 1978).

• Drainage Basin Characteristics:

The drainage-basin areas of spring-dominated streams are small in proportion to the discharges of the streams. Clearly, these streams receive water from other sources than the surface expression of their drainage basin. Also, there appears to be a lag, which may be on the order of several months, between precipitation in the area and flooding.

Summary and Conclusions

Runoff-dominated streams in the western U.S. typically receive most of their recharge from spring snowmelt over a well-defined drainage area. Channels often exhibit bars and a well-defined thalweg. Flooding is infrequent, but can be extreme.

In contrast, there can be a significant lag (on the order of months to years) between a recharge event and the response of spring-dominated streams. The recharge area is often difficult to define using topographic maps. The spring-dominated channels have poorly-defined bars and thalwegs (or inner berms): features which may be typical of runoff-dominated channels. Spring-dominated streams flood their banks frequently, but the magnitude of floods is less extreme. Also, there is a small range between bankfull, mean annual and bankfull discharge.

In conclusion, we suggest that hydrologists evaluate the importance of springs in contributing water to streams that they may be studying. If springs are an important source of recharge to the stream, the distinctions discussed above should be considered in evaluating the gross hydrology of the stream. Rules-of-thumb and procedures used for runoff-dominated streams, such as assuming that baseflow is on the order of 10 percent of the mean annual flow, may be based on assumptions that are not strictly valid for spring-dominated streams.

References

Bloom, A.L., 1991, Geomorphology, A Systematic Analysis of Late-Cenozoic Landforms, Second Edition: Prentice Hall, New Jersey, 532 p.

Dunne, T. and Leopold, L.B., 1978, Water in Environmental Planning: W.H. Freeman and Co., San Francisco, 818 p.

Emmett, W.W., 1975, The channels and waters of the Upper Salmon River area, Idaho: U.S. Geological Survey Professional Paper 870-A, 116 p.

Fenneman, N.M., 1931, Physiography of Western United States, First Edition, Fifth Impression: McGraw-Hill Book Company, Inc., New York, 534 p. plus map

Whiting, P.J. and Stamm, J.F., 1994, Channel form and process in spring-dominated channels: Geomorphology, in review

White, E.L. and Reich, B.M., 1970, Behavior of annual floods in limestone basins in Pennsylvania: Journal of Hydrology, Vol. 10, pp. 193-198

White, W.B., 1988, Geomorphology and Hydrology of Karst Terrain: Oxford University Press, New York, 464 p.

Wolman, M.G. and Leopold, L.B., 1957, River flood plains, some observations on their formation: U.S. Geological Survey Professional Paper 282-C, pp. 86-109.

This article was prepared by **John F. Stamm**, Hydrologist and Post-doctoral Researcher, and **Peter J. Whiting**, Geomorphologist and Assistant Professor, Case Western Reserve University, Department of Geological Sciences, Cleveland, Ohio.

STREAM CHANNEL & RIPARIAN REFERENCE AREAS

The Stream Systems Technology Center is developing a partnership with the University of Arizona to develop an inventory of undisturbed or recovered channel and riparian reference sites on public lands within the Interior West, specifically the Four Corners States and Nevada. We seek to locate a wide array of distinctive channel and riparian areas which represent desirable future stream and riparian conditions to serve as reference sites for evaluating scientific concepts. The primary interest of this effort focuses on documenting, describing, and measuring physical channel characteristics and the influence riparian vegetation has on channel dimensions.

This effort will build an important source of knowledge for use in ecosystem management. We need your assistance to identify candidate areas.

The project will be conducted by Dr. Richard "Pete" Hawkins, University of Arizona, School of Renewable Natural Resources, Watershed Resources Program. Dr. Hawkins will personally visit each candidate site to evaluate it for inclusion in this study and a future STREAM handbook.

We anticipate that the final set of reference sites will include a variety of stream types in a variety of landscapes (unique combinations of climate, geology, and landform). The aim is to stratify the variation that exists in the field and allow valid comparisons to be made between like channels and riparian areas.

The **Ideal Candidate Site** would be a well-established and well-controlled streamside exclosure on a National Forest, with existing on-site monitoring and well documented written or oral history of land use. The site should be photogenic and clearly demonstrate contrasts between undisturbed and impacted conditions.

Suitable Sites might include:

- Streamside reaches in range reference areas
- Research Natural Areas
- Nature Conservancy holdings
- National Parks
- BLM Areas of Significant Environmental Concern
- Well managed riparian areas.

Vegetation at the site should be relatively "undisturbed" or well into "recovery."

Undisturbed sites are sites with no major human impacts or major fires within the last 25 years of recorded history, and a minimum of ongoing stress in the interim. These sites are conversationally equivalent to "virgin" or pristine." The number of undisturbed sites are expected to be rare, and almost certainly restricted to parks, preserves, wildernesses, or areas isolated by virtue of topography or inaccessibility.

Recovered sites are potential reference sites depending on the extent of their recovery toward the stable, long-term undisturbed condition. By recovery we mean primarily "natural" vegetative recovery from prior disturbance. The disturbance may have been natural or human-caused, such as mining, grazing, roads, etc. Recovery is "natural" to the extent that it is without major structural or cultural works (major earth moving, in-stream channel structures, etc.) Natural recovery would generally be attributed to non-use or the inadvertent protection of an area. Recovery is assumed to be toward the ideal of the prior stable, long-term undisturbed condition or the areas natural potential. Recovery is a subjective evaluation involving judgment, local advice, and comparisons with other areas. Hopefully, vegetative health leads to channel health.

The following additional guidelines apply to candidate streams:

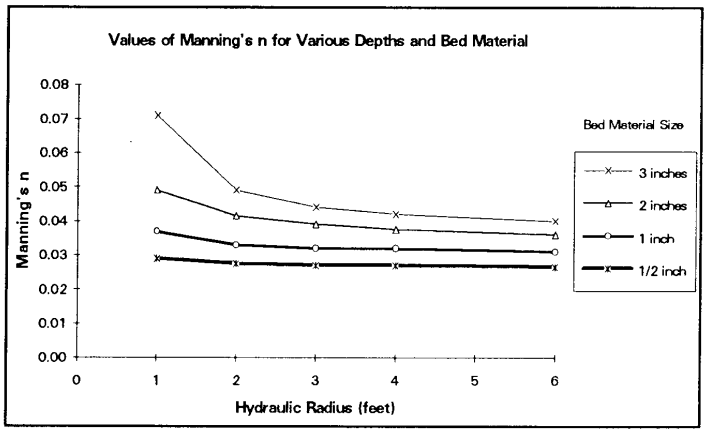
- Streams should have a defined bed, a thriving riparian vegetation component, and some baseflow. (This eliminates intermittent and desert sites.)
- Streams should have a riparian area which reacts with the stream. (This eliminates bedrock channels and incised channels with vegetation well removed from the stream zone via elevation)
- Streams should have no significant regulation (major diversion or reservoir upstream).
- Streams should be of moderate proportion (3rd to 4th order or smaller). This eliminates major rivers and retains streams reasonably influenced by land management and of a size convenient for measurement.
- The stream should have no major quality issues.

Contact Dr. Hawkins with information about stream and riparian areas which meet these criteria. For your convenience, you can contact him by phone, FAX, or E-Mail.

Telephone: (602) 621-7272
FAX: (602) 621-8801
DG (E-Mail): internet!mesquite.srnr.arizona.edu!pete@att:X400

If you know of sites which may fit the above criteria in other parts of the United States, the STREAM TEAM would like to know about their location for future reference.

FLOW RESISTANCE & MANNING'S EQUATION



Manning's n often is stated to vary with the 1/6 power of the depth because of consideration of the dimensions of the Manning equation. However, this is not correct. Manning's n is an empirical approximation to the relative roughness relation. For greater values of relative roughness (hydraulic radius divided by median diameter) Manning's n becomes relatively constant with depth. This can be seen by computing Manning's n for various depths and bed materials. The Darcy-Weisbach resistance can be computed from:

$$1/\sqrt{f} = 0.35 + 2.03 \log (R/D_{50}) \text{ and}$$
$$n = 0.0926\, R^{1/6}/(1/\sqrt{f})$$

where f is the Darcy Weisbach resistance factor, n is Manning's coefficient, R is hydraulic radius in feet and D_{50} is the median diameter of the bed material in feet, which can be determined from a Wolman Pebble Count. A comparison of results from such an analysis is shown in the table below and the figure above.

This shows that for smaller material and large enough depths, Manning's coefficient is approximately constant. Remember that by hydraulic radius approximates average depth in streams which are very wide compared to their depth (width-depth ratios of 20:1 or more). This analysis assumes that all resistance is grain resistance, which is true for most cases for $R/D_{50} > 5$, based on field data (Burkham and Dawdy, 1976).

Burkham, Durl E., and Dawdy, David R., 1976, Resistance Equation for Alluvial-Channel Flow, Proc. ASCE, Vol,. 102, No. HY10.

Contributed by David R. Dawdy, Consulting Hydrologist, San Francisco, CA.

Hydraulic Radius (feet)	D_{50} = 1/2 inch			D_{50} = 1 inch			D_{50} = 2 inches			D_{50} = 3 inches		
	R/D_{50}	$1/\sqrt{f}$	n	R/D_{50}	$1/\sqrt{f}$	n	R/D_{50}	$1/\sqrt{f}$	n	R/D_{50}	$1/\sqrt{f}$	n
1	24	3.15	0.0295	12	2.5	.037	6	1.9	.0490	3	1.3	.071
2	48	3.75	0.0275	24	3.1	.033	12	2.5	.0415	6	1.9	.049
3	72	4.1	0.0270	36	3.5	.032	18	2.9	.0390	12	2.5	.044
4	96	4.4	0.0270	48	3.7	.032	24	3.1	.0375	16	2.8	.042
6	144	4.7	0.0265	72	4.1	.031	36	3.5	.0360	24	3.1	.040

Editorial Policy

To make this newsletter a success, we need **voluntary contributions** of relevant articles or items of general interest. YOU can help by taking the time to share innovative approaches to problem solving that you may have developed.

Please submit typed, single-spaced contributions limited to two pages. Include graphics and photos that help explain ideas.

We reserve editorial judgments regarding appropriate relevance, style, and content to meet our objectives of improving scientific knowledge. Send all contributions to: Stream Systems Technology Center, Attention: STREAM NOTES Editor.

Please share copies of STREAM NOTES with your friends and associates. We mail a copy of the newsletter to each Forest Service hydrologist and fisheries biologist using lists provided by the Regional Offices. You may have noticed a new format for our mailing labels. **Please check your address and notify us of any corrections if you do not like the way your mailing label is addressed.**

Anyone wishing to be added to our mailing list or requiring a change of address should send their name and street mailing address via DG to STREAM:S28A or write to our mailing address at USDA Forest Service, Stream Systems Technology Center, Rocky Mountain Station, 240 West Prospect, Fort Collins, CO 80525.

USDA policy prohibits discrimination because of race, color, national origin, sex, age, religion, or handicapping condition. Any person who believes he or she has been discriminated against in any USDA-related activity should immediately contact the Secretary of Agriculture, Washington, DC 20250.

STREAM NOTES

STREAM SYSTEMS TECHNOLOGY CENTER
USDA Forest Service
Rocky Mountain Station
240 West Prospect
Fort Collins, CO 80525

BULK RATE
POSTAGE & FEES PAID
USDA-FS
Permit No. G-40

IN THIS ISSUE

- **Hydrology & Form of Spring-dominated Streams**
- **Stream Channel & Riparian Reference Areas**
- **Flow Resistance & Manning's Equation**