To investigate the proposition that step-pool streams adjust their form to maximize resistance to flow, three sets of experiments were conducted in a flume 4.88 m long and 0.15 m wide. These experiments were performed on four slopes, 0.05, 0.10, 0.15, and 0.20, which are typical of streams containing step pools. A layer of gravel with D50 = 0.00486 m was glued to the floor of the flume. During the experiments, discharge was held constant, and regularly spaced steps were constructed within the flume using wooden weirs as step risers and filling the space behind the weirs with gravel identical in size to that glued to the flume floor. Step spacing ranged from 0.05 to 0.60 m for 0.03-m-high weirs, from 0.10 to 1.00 m for 0.06-m-high weirs, and from 0.10 to 0.80 m for 0.11-m-high weirs. During the experiments employing the 0.03-m and 0.06-m weirs, the flume floor was exposed at the longer step spacings. However, during the experiments using the 0.11-m weirs, the flume floor was never exposed. Flow velocity was measured by electronically timing the passage of a salt plume down the flume. Graphs of friction factor against step length are convex-upward for each slope and each weir height. The ratio of step height to step length H/L measured at the step length where friction factor is maximized varies with slope S in such a manner tat $S \leq H/L \leq 2S$.

Thus, the flume studies of step pools establish that friction factor is maximized when $S \leq H/L \leq 2S$. The question is: Do natural step-pool streams have the same geometry? To investigation this question, 18 mountain stream reaches were selected for study in the Adirondack Mountains, New York, and the Lake District, England. Stream gradient S, mean step height H, and mean step length L were calculated from surveyed long profiles, and in all cases, it was found that $S \leq H/L \leq 2S$. This finding provides strong evidence that natural step-pool streams adjust their morphology to maximize resistance to flow.

A General Theory of Channel Adjustment in High Gradient Streams

Gordon E. Grant[1]

Abstract

Ever since Mackin first proposed the idea of the graded stream, geomorphologists have been attempting to characterize the physical principles underlying the mutual adjustments of channel slope, morphology, hydraulics, and sediment transport. Many theories have been proposed to explain observed patterns of morphology and process in alluvial channels, including minimum variance, entropy production, unit stream power, and energy dissipation rate and maximum resistance. While these theories provide insight into the tendency of stream channels to organize themselves into characteristic forms, they often lack physical mechanisms to explain how such forms arise.

In this paper, a simple theory is presented here which argues that given sufficient energy, stream channels will adjust their dimensions and flow hydraulics so as to maintain critical flow over their length. In this context, sufficient energy is defined by two conditions: 1) critical flow is possible at a given slope; and 2) flow is competent to transport the bedload and adjust channel boundaries; hence total boundary shear stress τ_o exceeds critical shear stress τ_{cr}. This theory is consistent with Yang's theory of minimum energy dissipation rate but focuses on the hydraulic and morphologic mechanisms involved.

Empirical evidence in support of this theory comes from field studies in high-gradient sand-bed streams that exhibit regular pulsating flow around with an average Froude number of approximately 1.0. The mechanism responsible for this involves the dynamic interaction between bed deformation induced by the hydraulics of flow at high Froude numbers, resistance offered to the flow by those bedforms, and the resultant effects on local scour and fill and bedload transport rates. Other examples derived from field studies and

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the literature include measurements made in braided gravel outwash rivers, bedrock canyons, step-pool channels, and rivers flowing at bankfull discharges over a range of channel slopes.

Step Pool Geometry and Flow Characteristics in Low-Sediment-Storage Channel Beds

Tamir Grodek[1], Moshe Inbar[2], Asher P. Schick[1]

Abstract

Data from two small ephemeral streams in Israel indicate that step pool geometry in bedrock channels is similar, in its salient features, to that in alluvial channels. For steep (>0.10) bedrock channels the average step length is quasi-constant. Well developed steps found in very small, lithologically homogeneous channels suggest that low magnitude high frequency events play a role in their formation. In Nahal Meshushim (drainage area 14 km^2) the water surface reconstructed from the highest flood marks indicates that all steps, though partly submerged, retain clear discontinuities between moderately sloping segments.

Introduction

Step pools, commonly observed in steep (slope > 0.02) mountain river channels, are associated with the dissipation of excessive energy. They represent a mechanism of self-adjustment to the most efficient rate of energy expenditure in least time (Yang 1971). Step pool sequences are more common in gravel bed rivers that in bedrock channels. In gravel bed rivers the steps have a staircase-like structure, and groups of large bed elements span both sides of the channel and act like weirs as the water plunges into a small pool below these elements (Whittaker 1987). A step pool unit, also classified as a channel unit sequence (Grant et al. 1990), is a sequence of steps followed by a pool

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