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Flow Resistance in Step-Pool Streams: New Insight From an Analysis of Field and Experimental Data

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Alluvial mountain channels with gradients between about 2% and 20% are often characterised by a staircase-like morphology known as step-pools. A tumbling flow regime of alternating subcritical and supercritical flow, in which hydraulic jumps dissipate energy that would otherwise be available to transport sediment, exists in flows up to at least the median annual flood. Step-pools therefore increase flow resistance and stabilise the bed. Several studies have produced empirical flow resistance formulae for step-pool streams, but the success of these equations in collapsing flow resistance data has been limited, and their physical basis is questionable. Furthermore, given that an important function of step-pools is their role in stabilising otherwise erodible sediments, it seems likely that that a proper understanding of the flow resistance of step-pools can only be achieved through a study of flows that destabilise their beds and cause rotational degradation and subsequent restabilisation at an equilibrium slope under the control of step-pool development. None of the flow resistance formulae for step-pool channels published to date have been developed using such flows. However, three experimental studies provide flow resistance data for step-pools at formative flows and equilibrium slopes. In addition, several field studies have measured flow resistance in natural step-pools at less-than-formative flows. An analysis of the morphological and flow resistance characteristics of these step-pools provides new insight into the controls on flow resistance. An innovative method is used to non-dimensionalise the morphological variables of the natural step-pools to allow comparison with the experimental data. Flow resistance varies as a power law function of dimensionless step height. The value of the power in this function varies between field and laboratory data, indicating that flow resistance follows different trends depending on whether it is measured in a flow in which the bed stabilised under the development of step-pools, or in a less-than-formative flow with respect to the step-pools. The power law flow resistance functions are asymptotic with grain resistance estimated using the Keulegan equation based on the D84 grain size of surface material. This suggests the possibility of partitioning flow rsistance in step-pool channels between spill and grain resistance.