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Measurements of flow and sediment transport in a steep, rough stream

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The majority of the total channel length in mountainous watersheds occurs in steep (gradients of 3-20%), rough channels. Sediment mobilized on hillslopes must first pass through these channels before reaching lower-gradient streams. However, we currently cannot accurately predict flow and sediment transport through steep streams. Traditional sediment transport equations typically over-predict flux in these channels by several orders of magnitude. We have developed a transport equation that differentiates between seasonally and rarely mobile sediment, and accounts for the stress borne by large, relatively immobile grains. The proportion of the bed covered by the mobile fraction serves a proxy for the local sediment supply. To further develop and test our theory we require detailed field measurements of flow hydraulics, sediment transport rates, and mobile and immobile grain properties.

Sediment transport rates (above a threshold value) and discharge have been recorded at minute intervals in the Erlenbach torrent (Switzerland) since 1986. Here, calibrated hydrophones (acoustic sensors) measure the sediment flux from the number of grain impacts in a cross-section. We supplemented this dataset with measurements of flow and bed conditions for four events during the summer of 2004. In a short (45 m long), steep (gradient of 10%) reach just upstream of the hydrophones we measured the bed topography, height and spacing of boulder steps, and area, location, and grain size of sediment patches. We installed and surveyed 575 tracers that ranged in size from 11 to 128 mm. Tracers were placed in a variety of locations to determine the influence of immobile particles on the initial motion of sediment. During transport events we measured the flow depth at four cross-sections and the reach-average velocity every 10 minutes. After events we made a photo-survey of the entire bed, re-measured patch elevations and grain sizes, and surveyed new tracer positions. We also sampled the transported grain sizes from a sediment retention basin below the hydrophones.

Although the smallest event (peak discharge of 0.54 m^3/s) mobilized tracers, it did not cause measurable transport by the hydrophones. This flow is similar to the critical discharge determined from hydrophone measurements in 2003 and 2004. The largest event (peak discharge of 1.50 m^3/s) mobilized tracers of all sizes and transported approximately 4 m^3 of bedload material. Preliminary results show that some patches shrank or swelled (in area and thickness) with changes in sediment flux and discharge, while others remained relatively fixed. These observations demonstrate that patches of mobile sediment may dynamically respond to changes in sediment supply. The mobile tracer size was highly dependent on flow and position on the channel bed. We are currently using this unique dataset to test and develop our theory for sediment transport.