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Morphodynamics of semi-alluvial streams in northern Fennoscandia: a flume experiment to determine bedform self-organization

Lina Polvi
Umeå University, Department of Ecology and Environmental Science, Umeå, Sweden (lina.polvi@umu.se)

Streams in northern Fennoscandia have two characteristics that complicate a process-based understanding of sediment transport affecting channel form: (1) they are typically semi-alluvial, in that they contain coarse glacial legacy sediment, and (2) numerous mainstem lakes buffer sediment and water fluxes. Systematic studies of these streams are complicated because natural reference sites are lacking due to over a century of widespread channel simplification to aid timber-floating. This research is part of a larger project to determine controls on channel geometry and sediment transport at: (1) the catchment scale, examining downstream hydraulic geometry, (2) the reach scale, examining sediment transport, and (3) the bedform scale, examining the potential for predictable bedform formation. The objective of the current study, targeting the bedform scale, was to use a flume experiment to determine whether sediment self-organizes and creates bedforms in semi-alluvial channels. The prototype channels, tributaries to the unregulated Vindel River in northern Sweden that are being restored after timber-floating, contain coarse sediment (D16: 55 mm, D50:250 mm, D84:620 mm) with moderately steep slopes (2-5%) and typically experience snowmelt-flooding and flooding due to ice jams. Using a scaling factor of 8 for Froude number similitude, an 8-m long, 1.1 m wide fixed-bed flume was set up at the Colorado State University Engineering Research Center with a scaled-down sediment distribution analogous to the prototype channels. For two flume setups, with bed slopes of 2% and 5%, four runs were conducted with flows analogous to QBF, Q2, Q10 and Q50 flows in the prototype channels until equilibrium conditions were reached. Digital elevation models (DEMs) of bed topography were constructed before and after each run using structure-from-motion photogrammetry. To examine self-organization of sediment, DEMs of difference between pre-flow conditions and after each flow were created; scour and deposition in relation to large immobile clasts were examined.
Preliminary results show that at high flows at the lower slope (2%), fine sediment was deposited above immobile clasts and scour was common below. High flows at the higher slope (5%) caused scour above and occasionally directly below immobile clasts, with fine sediment deposited nearby scour zones above immobile clasts. These results indicate that these channels experience a shielding effect by large immobile clasts, inhibiting bedload transport and creating pockets of fine sediment upstream of large boulders. Additionally, pools downstream of immobile boulders may experience velocity reversals, causing scour instead of deposition in low-velocity zones. In addition, the combined aggradation and degradation between the Q50 and Q10 flows was less than between the Q10 and Q2 flows. This is most likely because the snowmelt-dominated flow regime of northern Sweden with buffering capacity of lakes precludes extremely high flows, causing a small difference in intermediate- and high-recurrence interval flow magnitudes. Therefore, flows with an intermediate recurrence interval likely do the most geomorphic work, but major sediment self-organization as seen in alluvial mountain streams is unlikely barring an extreme event. In conclusion, classical slope-dependent bedform relationships found in alluvial gravel-bed streams may not be applicable in semi-alluvial channels in northern Fennoscandia.