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Standard Deviation of Bed Elevation as a Measure of Hydraulic Roughness for Gravel-bed Streams

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Hydraulic roughness height is a key parameter for velocity prediction. There are not yet firm conclusions about whether characteristic particle size (D_{84}, D_{90}...) or the standard deviation of bed elevation is better indicator for the hydraulic roughness of gravel-bed streams. A data set of 1713 flume experiments and 515 field measurements was used to test whether or the standard deviation was a better predictor of the stream velocity, and to explore possible reasons for the difference between the two roughness measures. Tests were performed using 4 well-known flow resistance equations, based on either flow depth or a dimensionless discharge as independent variables. Results showed that the standard deviation of bed elevation was consistently a better predictor of the velocity than D84 in terms of the root-mean square error. In addition, Ferguson equation with the standard deviation as hydraulic roughness shows best overall performance in velocity prediction. In particular, when using dimensionless discharge as the input variable, logarithmic matching equation with the standard deviation as hydraulic roughness is recommended for its explicit form. The data set was separated into two sub-sets with or without typical bed forms or large wood debris. The results showed that the existence of bed forms and large wood debris could be the reason why the standard deviation outperformed as a measure of hydraulic roughness for velocity predictions. Characteristic size measures the grain roughness only, whilst variations in bed elevation combine the effect of surface roughness and that of some large flow resistance elements such as bed forms and wood debris.