Sediment Transport in River Channel Design

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Abstract. Reliable predictions of sediment transport face a difficult problem of scale. Bed material transport is intrinsically local and can be well characterized at the scale of individual grains to patches. Formulas for predicting sediment transport in rivers are generally applied at the cross-section to reach scale and necessarily average flow and bed properties. Because transport is stochastic and strongly nonlinear, calculations using spatially averaged input can only approximate the integrated result of mechanisms controlled at the grain-to-patch scale. Estimates of bed material transport should be understood to provide (when combined with hydraulic relations) an approximate correlation between section-averaged rates of transport and water discharge. The approximate nature of section-to-reach scale transport estimates requires that closer attention be paid to uncertainty in transport prediction. For useful application, it is not sufficient to merely characterize uncertainty. Some basis is needed to incorporate that uncertainty in the analysis and design of stream channels. This presentation focuses on the elements of this problem: characterizing the local, nonlinear nature of transport, estimating the uncertainty in transport estimates, developing an effective definition of stream channel behavior, and presenting a strategy to accommodate uncertainty in analyzing and designing stream channels. We will argue that the uncertainty in transport calculations is better defined in terms of uncertainty in the necessary input, rather than the choice of transport formula. Explicit characterization of input uncertainty allows uncertainty in the calculated output to be estimated. A computational tool for estimating uncertainty will be presented within a strategy for incorporating sediment transport in channel design. The strategy builds on the classic definitions of threshold and alluvial channels. A threshold channel is one for which the bed material is immobile at a specified discharge. An alluvial channel is one whose transport capacity must be balanced against the rate of sediment supply. It is useful to define a third type of channel that combines the first two – over-capacity threshold – in which transport capacity exceeds supply but design flows do not exceed threshold limits for channel erosion. This type of channel is more common than often realized and is, in fact, unintentionally designed in many cases. It offers both advantages and disadvantages that can only be weighed if the combined objectives are specifically defined. Using these three channel types, we develop a basis for evaluating the significance of sediment supply to the performance of a design channel. At small sediment supply rates, channel performance is relatively insensitive to uncertainty in sediment supply and may be designed as a threshold channel using principles of stream competence. At large sediment supply rates, the potential for storing or evacuating channel-changing quantities of sediment is much larger. A computational tool will be presented that assists in estimating the sensitivity of channel performance to uncertainty in sediment supply. The tool includes river state diagrams useful for reconnaissance evaluation and channel stability diagrams useful at the planning stage.