SEDIMENT TRANSPORT IN STREAM RESTORATION: ROLLING THE DICE

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Abstract

It is commonly acknowledged that sediment transport is not effectively incorporated in typical stream restoration design. Some projects seem to perform acceptably. Others fail, sometimes spectacularly. Is stream restoration design simply a game of chance, best left to those with a strong nerve or a deep faith? Can we predict sediment supply and transport capacity with enough accuracy that we can confidently forecast channel behavior? Uncertainty clearly plays a role (whether explicitly considered or not), because it is not possible to precisely forecast future future water and sediment supply. What is a designer to do? What tools and strategies are available? Can we identify conditions under which sediment supply is a significant design issue? Can we accommodate or finesse uncertainties in both sediment supply and transport capacity? This paper presents tools from recent sediment transport research that can help a channel designer incorporate sediment transport and its uncertainty in stream channel design.

Much uncertainty in transport calculations arises from uncertainty in the necessary input. The choice of transport model can sometimes be an issue, but many transport formulations are based on a common set of data and produce similar predictions when applied to appropriately specified conditions. In contrast, because sediment transport is strongly nonlinear, even modest uncertainty in the input can produce large uncertainty in the calculated output. In most cases, uncertainty in the input can be characterized and used to estimate uncertainty in the calculated output. A computational tool for estimating uncertainty in transport calculations will be presented.

Quantification of uncertainty does little good in the absence of a strategy for incorporating that uncertainty in channel design. In addition to providing tools for estimating uncertainty, we need approaches that support intelligent application of that uncertainty.

The first question to address is whether the rate of sediment supply is sufficient that channel performance will depend on an accurate estimate of sediment supply and the channel's transport capacity. At small sediment supply rates, channel performance is relatively insensitive to uncertainty in sediment supply. At large sediment supply rates, the potential for storing or evacuating 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. The same transport model is available in HEC-RAS for evaluation of alternatives during the design phase.

If the sediment supply rate is judged to be small, indicating a small potential for significant sediment accumulation, a threshold channel design can be used. In this case, the conservative choice in channel design is relatively clear: the channel must be *at least* strong enough to withstand the range of flows it will experience without undergoing significant sediment entrainment and incision. One can accommodate uncertainty by building a stronger channel or by designing a channel with smaller stresses. But how much stronger? What kind of stress reduction is appropriate? These choices affect cost and impact other design considerations such as appearance, ecological behavior, and floodplain connection. We will show how explicit estimates of prediction uncertainty can be used to develop a probabilistic assessment of risk, such that tradeoffs between design choices, cost, and failure risk can be evaluated. There is currently little guidance for such assessments.

Different design choices emerge if the sediment supply rate is judged to be large, such that a significant risk of sediment accumulation exists. One approach is to design an alluvial channel, which requires a balance between the channel's transport capacity and the rate of sediment supply. This balance will never be exact over the range of flows that a channel will experience, so some sediment accumulation and evacuation must be tolerated in any channel design. An estimate of the uncertainty in both supply and capacity can be used to select a channel design that is robust in light of uncertainty in the transport. A second approach that is commonly used (although rarely stated explicitly) is to design a semi-alluvial channel. In this case, the conservative choice in channel design is again clear: the transport capacity of the channel is designed to be *at least* that of the sediment supply while the channel bed is also designed with grade control structures. Thus, the chance of sediment accumulation is reduced by designing for a transport capacity that exceeds supply and the chance of sediment evacuation and incision is reduced by building a channel that is strong enough to withstand the range of flows it will experience without undergoing significant incision. Although such a design does not match the natural dynamic channel that is advocated by many in the stream restoration business, it is a prudent response to uncertainty in the transport. Again, the questions remain: how strong should the bed and banks be and by how much should the transport capacity exceed the supply? What are the tradeoffs between risk, uncertainty, cost and other design factors? Explicit estimates of prediction uncertainty can be used to develop a probabilistic assessment of risk, such that tradeoffs between design choices, cost, and failure risk can be evaluated.