Application of a 1-D numerical model to estimate the sediment transported along a river

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Introduction: Natural rivers tend to adjust their plane shape and longitudinal profile in order to assume a configuration compatible with the changing hydraulic and man-made constraints. The causes of these bed variations are related to changes in independent river channel variables (increase in water discharge, decrease in sediment discharge, etc..) or to changes in river slope [3]. River bed degradation and aggradation, often occurring as result of river morphological changes, modify the longitudinal bed profile of the river and the amount of sediment transported along the river until to reach the outlet. As an example, the costruction of river dams produces large morphological consequences [2, 4]: when the stream passes through a large capacity reservoir much of the incoming sediment is trapped and pratically clear water flows out. Hence the amount of sediment load entering the river reach downstream of a dam is less than the amount of sediment going out of that reach downstream. Thus the bed degradation occurs in the river reach mentioned. If the banks are erodible, material can be picked up from the banks and widening of the stream will also result.

The computation of the evolution in time of the river bed variations is rather complex since it is influenced by many interrelated factors. The size and composition of bed material and the dimensions of bed forms affect significantly the nature and magnitude of bed variation. Because of erosion process, supposing a constant river width [5], the bed slope gradually decreases and, consequently, the flow depth increases, modifying the value of the average bottom shear stress. Furthermore, river beds are composed mainly of no-uniform materials and, for a given flow, not all the sediments are in motion. Thus, the decrease in bed slope and in average bottom shear stress during the progress of the degradation, produces a variation of grain size distribution of bed materials until the formation of the so-called armour layer, that inhibits further erosion [1].

In this work, a 1-D numerical model recently developed [5] is applied in order to to simulate the bed longitudinal profile variations and to quantitatively estimate the material transported by the flow at each river section as far as the outlet. For the application, data collected both in testing river reaches and in laboratory channels have been considered.

Methods: The proposed one-dimensional approach analyses bedload transport of non-uniform sediment mixtures, taking into account both sorting and armouring processes. It is hypothesized that the amount and the size distribution of the eroded material depend on both sediment properties and flow properties. The key parameter to analyze the evolution of the process is the friction factor, that reflects both flow and sediment properties. A simple one active layer is assumed to schematize the interchange between the sediment bed and the flow over it, during bed load transport. The system of equations for water and sediment movement is reduced to a differential equation, called bed variation equation, that expresses the variation of longitudinal bed profile in function of friction factor. The methodology allows to estimate the variation of grain size distribution curve of sediments on the bed during the evolution of process. The variation of the dimensions of bed forms is also considered.

Results: The model's performance to estimate the variations of bed material size distribution has been assessed by comparison with both experimental and field data available in literature. For all the applications considered the comparisons are reasonable.

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