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Sensitivity Study for a Bed-Load Transport Routing Scheme applied to a large Alpine Catchment

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Abstract

The work presented attends to a sensitivity analysis of an event based bed-load transport calculation for an alpine catchment in Tyrol. Within a routing scheme transport capacities are calculated according to an approach from Rickenmann (1990). The comparison of parameter sensitivities is based on relative variations between feasible physical parameter limits. Within the study the variation of sedigraphs from different sub catchments is analysed at different flood flow situations. The investigation involves independent as well as combined parameter variations to assess lower and upper bounds of total bed-loads. The results are furthermore compared by using alternative approaches such as those from Meyer-Peter/Müller and Smart/Jaeggi. It is found that there is a broad spectrum of model results although parameters are varied within reasonable physical ranges. Still, the knowledge of variation is important for practitioners using the given approaches.

Keywords: Bed-Load Transport, Alpine Catchments, Steep Slopes, Sensitivity

1. Main text

The quantity of damage-causing flood events in the last years underlines a growing demand of approved flood simulation models. Current research in hydraulic engineering deals with multidisciplinary process models covering the rainfall-runoff, hydraulics and the associated sediment transport on a spacious scale. An overview of available models can be found in Rinderer et al. (2009). In Gems et al. (2009) the development of an integrated event based modelling concept for flood causing processes is presented. Within the used test case, a large alpine catchment of 890 km² in Tyrol, the hydraulics of steep slopes is a key issue. A hybrid approach linking the hydrological model component for the tributaries and 1D/2D hydraulic models for the main river is used. Discharges are calibrated for three major flood events during the observation period. The associated sediment transport in the torrent catchments as well as in the main receiving water course is computed with a routing scheme. The applied bed-load transport function (Rickenmann (1990)) therefore is based on the results from the hydrological model. Entrainments and drag

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forces caused by coarse bed material and an irregular channel geometry are considered by using approaches from Rickenmann (1990) and Palt (2001). In Figure 1 the sub catchments and the respective routing scheme located above the gauging station in Vent (180 km²) are shown: The torrent catchments with the most decisive bed-load potential are linked to the routing sections along the main river. The applied dynamic transport capacity calculations use a fixed time step at which the bed-load material is routed further downstream. In addition to simple routing routines, detention reservoirs are as well implemented within this scheme.

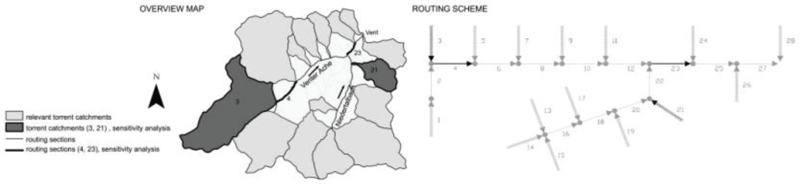

Figure 1 – Schematic overview on torrents and routing scheme upstream the gauge Vent / Tyrol (180 km²)

In the sub catchments physical parameters such as the channel gradient (I), the main channel width (B) and the sediment grain sizes (d_{50}, d_{90}) are used to describe the catchments sediment yield. Since they describe a complete catchment with varying characteristics they are very well subject for calibration. The potential (maximum) available sediment mass defines the limit for balancing deposition and erosion of material. Model output is the amount of bed-load delivered from torrent catchments or routing reaches further downstream.

Since measurements of sediment fluxes are hardly available, the knowledge of the sensitivity of the applied equations is of high value. For the study done here focus is put on the two torrent catchments 3 and 21 (see Figure 1). Thereby the variation of the above mentioned physical parameters and thus the effects on the sediment flux is investigated. Further the numerical approach is tested for different time steps used for the dynamic balancing:

A relative parameter variation within feasible physical ranges is applied to allow the comparison among different parameters (Achleitner et al., 2009). The relative variation of I, B, and d_{50}, d_{90} is based on already verified parameter settings. The sensitivity of the resulting sediment fluxes is analysed for the bias of the total bed-loads and the Nash-Sutcliffe coefficient of the sedigraphs for three flood events with different characteristics. In a first step, these parameters are varied independently from each other. Further the sensitivity analysis is extended varying all parameters combined to obtain the maximum possible variation in the results. For the transport capacities along the receiving water course a comparison of the used equation with approaches from Meyer-Peter/Müller and Smart/Jaeggi is accomplished for the two river sections 4 and 23 (see Figure 1).

The results of the study show a wide range of calculated bed-load rates, strongly depending on the model parameters and on the flow conditions as well. A reasonable setting of the physical parameters supported by field observations is essential to narrow the range of output variation. The comparison of approaches from Rickenmann, Meyer-Peter/Müller and Smart/Jaeggi illustrates spreading results, in particular when considering drag forces in terms of an adapted gradient (I_{char}) within the Rickenmann approach.

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