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New bed load trap design in order to allow sediment transfer during morphological floods

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Problem statement

Bed load traps are edifices which are situated in steep mountainous areas. They consist of a check dam and mostly also of a retention basin in front of the latter. The purpose is the protection of urban settlements.

Figure 1: Boulders in a river bed of a typical mountain torrent in the Bavarian Alps (Germany)

Once the discharges of a river increase, check dams retain transported sediments and the reservoirs are backfilled. This may be unfavorable for different reasons. On the one hand, the reservoirs have to be emptied artificially and regularly. These maintenance works are cost-intensive for municipalities. On the other hand, the continuity of sediment transport is interrupted. From an ecological and morphological point of view, it is important that organic and inorganic matter are continuously transported. The inorganic material, i.e. gravel or boulders, are important for the equilibrium of erosion and deposition processes along the river. An interruption of transport may cause severe erosion processes downstream. Fishes and other organisms of the river habitat are dependent on the nutrition transported by the river in terms of sediments, including driftwood.

Figure 2: Check dam at the Jenbach in the Bavarian Alps (Germany)

Objectives

It is important to prevent hazardous floods from entering into urban areas. But not all floods are hazardous. Morphological floods, from a hydrological view, by definition do not leave the river bed. The stream power of morphological floods is sufficient for the erosion of the top layer of the river bed and therefore important for the formation of the latter. This is also why these floods are described by “morphological”: the river morphology is shaped.

The reservoirs in front of check dams have already been the subject of compound theoretical studies and systematic laboratory experiments in terms of their shape and dimensions. Also the check dams were approached in many scientific articles and models. However, the purely theoretical approach based on mass and momentum theorems as well as models did not answer the question for an optimum design of the check dams satisfactorily. A good design is especially with respect to the openings of the check dam, where the river is considered to pass unhindered up to morphological floods.

This optimum design is the objective of this research project. The new design is intended to improve the river continuity at check dams with respect to ecological, morphological and hydraulic aspects. Aquatic biota, sediments and water ought to pass undisturbed up to morphological floods.

The activation of check dams is characterized by the occurrence of backwater effects. The latter are intended to appear since the discharges of a flood can be claimed to be hazardous. A thumb rule describes such floods by return periods of about 3 to 5 years.

Methodology

In the first phase, the work was focused on literature review, with particular interest on sediment transport, river morphology and bed load transport. Actually, another emphasis is put on the creation of a data base including geometric (river width, bed slope, etc.), sediment related (grain sizes) and hydrologic (flood discharges) information about mountain torrents.

On the one hand, the data serve for the design of the laboratory model, where it is intended to respect geometric relations such as the ratio between river width and reservoir width. On the other hand, the later description of design criteria will be governed by key parameters of real rivers.

Once the model is set up in the laboratory, different variants of check dams will be investigated. For all shapes of check dams and their openings the upstream river slope will be varied, as well as scenarios with and without reservoir in front of the dam will be tested.

During an experiment, distinct discharges are introduced and the solid discharges are injected by means of theoretic formulae.

Results

The experiments will output information about the moment when backwater effects occur. This moment is intended to be synchronized with floods larger than morphological ones. A design which fulfils this requirement has to be valid also for different slopes of the upstream channel. The layouts of the check dam model which are found to be satisfactory will be described by non-dimensional design criteria as some function of river data, namely discharges series, sediment granulometry as well as channel slope and width.