The design of a resilient flood protection system in the Klausbach valley

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INTRODUCTION

The catchment of the alpine torrent „Klausbach“ is situated in the National Park „Berchtesgaden“ and represents a complex torrential area. The following features characterize the flood situation in the valley:

- An enormous rock fall poses a bed load source with unlimited potential. Hence the artificial channel (about 4km long) steadily loses capacity.
- The torrent breaks out regularly and blazes its trail back into its abandoned channels in the valley floor.
- The interaction of the torrent and the lake at the bottom of the catchment (fig. 1 left).

TARGETS

The general target is to regain flood safety within the Klausbach catchment. As part of a concept study a sustainable flood protection system was drawn up. This includes strategies to avoid abrupt events like dike breaching in Klausbach and damages to the outlet in Lake Hintersee which happened during the flood event in 2013. Fortunately the worst case scenario of a complete failure of the outlet structure did not occur.

Furthermore the flood protection system is targeted on the following matters:

- To take into account changing boundary conditions (rehabilitation variants should be planned as flexible and resilient as possible).
- To keep the running costs and the interference within the National Park as low as possible.
- No deterioration of the flood situation downstream.

METHODS

A hydrologic model was formed by the State Office for Environment (LfU) that defines the relevant discharge curves. Up to date laser scan data, surveyed profiles, culverts and bridges were the base for a hydrodynamic 2D model that was used to understand the complex processes during flood events and to develop a sustainable protection concept.

At first the transient interaction of Klausbach and Lake Hintersee was investigated on the basis of various reconstruction options for the outlet structure at the lake. These variants were combined with various flood scenarios such as the design flow and a breach of the dike.

The weak points and the hydraulic capacity of Klausbachs artificial channel were analyzed by the use of semi steady-state simulations. The results were utilized to find suitable locations for overflow sections and to define the target profiles used for necessary excavation works in the channel bed.

The critical flow for the beginning of bed load mobilization was estimated by the formulas of Rickenmann (Rickenmann, 1990), while the total volume of bed load material was calculated with the approach by Smart and Jäggi (1983). As the debris source at the bottom of the rock fall is inexhaustible it was assumed that sediment transport is totally limited by the transport capacity of Klausbach. The results were used to dimension possible retention structures.

RESULTS

The particular measures are strongly interdependent. Sufficient flood safety can only be achieved by the implementation of all measures in an integral flood protection concept (fig. 1 right).

The present retention effects of Lake Hintersee play an important role for flood mitigation downstream. As a result the complete deviation via Klausbach or the widening of the existing outlet at Lake Hintersee cause higher flood peaks downstream (loss of retention). In contrast, if the proportion of „lake flow“ is too high - as in dike breach scenarios for instance - the lake capacity can be exceeded. The best results were achieved by keeping the existing outlet combined with controlled flow deduction

from Klausbach via spillway sections in the dike system. The lack of sufficient capacity in Klausbach leads to significant flow over the levees in a number of sections. The required freeboard of 1m is not available at the majority of the channel profiles. Therefore to prevent future dike breaching and to reach an optimal flow distribution, the following measures are necessary:

1. Sustainable bed load management

About 500m downstream of the pick-up area the topography provides favorable conditions to detain bed load. The idea is to create a combined retention system. The wide (~20.000m²) and flat (~2%) area itself is used to detain large material volumes transported in the design event (up to 15.000 m³). In addition there will be a retaining structure in the channel with a defined deposition area that can be cleared easily.

2. Excavation works in the channel

Medium-term, the implementation of the sediment retaining structure does not lead to a higher flow capacity in the channel of Klausbach. Long-term a flushing of the channel could set in, but to provide the necessary flow capacity at the present moment, excavation works are necessary. If possible the extracted material will be used for the restoration of the dikes.

3. Three overflow-sections along Klausbach

To achieve a continuous freeboard of 1m and to achieve the best flow distribution between the torrent and the lake it is planned to create an open dike system. This ensures a high level of reliability concerning extreme events, uncertainties due to tributaries and changing boundary conditions. The overflow-sections show a length of 220m (Nr.1), 200m (Nr.2) and 100m (Nr.3). It is the idea to lower the dam crest in these sections and to replace the current dam material with armourstones.

CONCLUSIONS

The 2D model proved as a strong tool to understand the complex situation and to derive flood protection measures in the Klausbach catchment. However there are uncertainties connected with the used modeling approach. Therefore it is important to set up a monitoring concept and to review the assumptions met in the model. Furthermore it should be taken into consideration to build up a sediment transport model for the Klausbach catchment to check for possible long-term developments in the channel, possible deposition zones and possible effects of the suggested flood protection measures.

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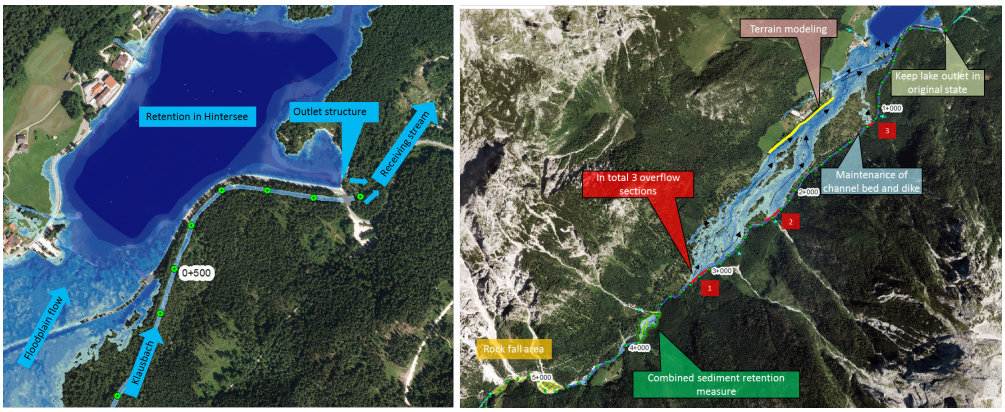

Figure 1. flood situation at the outlet (left) and elements of the protection system (right)

KEYWORDS

2D model; flood study; flood protection; Alpine torrent; sediment transport

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