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Sedimentological downstream effects of dam failure and the role of sediment connectivity: a case study from the Bohemian Massif, Austria

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Introduction and Objectives

Sediment connectivity describes the potential for sediment transport through catchment systems, further defining locality and characteristics of sedimentation. (BRACKEN et al., 2015) Dams generally decrease sediment connectivity and act as temporary sediment sinks. (PÖPPL et al., 2012) When dams are removed these sediments are being reworked and released downstream. In December 2015 a dam failure led to the entrainment of several tons of fine-grained reservoir sediments entering and depositing in the downstream channel reaches of the Kajabach, Nationalpark Thayatal. After excavation-works, the National Park Authority decided to initiate a flushing event in April 2016, aiming to remove the remnant deposits.

The aim of this study was to investigate the effects of dam failure-induced fine sediment release and reservoir flushing on downstream bed sediment characteristics, further discussing the role of in channel sediment connectivity.

Study Area

The Thayatal National Park is located in the Bohemian Massif, Lower Austria. The Kaja River is a mixed-load single-thread perennial wadable tributary of the Thaya River. The climate in this region is temperate, with an average temperature around 8°C and 500 – 600 mm average annual precipitation. In the upper reaches of the Kaja the landscape is characterized by wide open valleys draining a sedimentary arable environment, while in the lower reaches steep forested valleys in crystalline rocks are predominant.

Data and Methods

Geomorphological Mapping was done along the river course, recording all fine sediment bars, its size and volume as well as log jams. These features were GPS-tagged and further processed in ESRI ArcMap to retrace the movement of sediment within the channel.

For granulometry analysis, two freeze cores were taken at three spots in March an October respectively and subdivided in 10 cm layers. The first sampling point (K1) was near the broken dam, right before the inflow of a small tributary, the Merkersdorfer Bach. K2 was next to the estuary of the Kaja. The third sampling point (M) was taken in Merkersdorfer Bach as a reference point. All in all, 12 cores were taken. The analysis of the 10 cm sections was done following ÖNORM with a focus on the grain sizes sand (2 mm – 63 µm), silt (63 µm – 2 µm) and clay (< 2 µm) to determine the distribution of all grain sizes within the core.

Results

The results of Geomorphological Mapping illustrate the overall decrease of fine sediment regarding deposition area as well as volume: in March, shortly after the dam failure event, a total of 17.95 m3 of fine-grained sediments had accumulated as in-channel sediment bars, while in October, 6.85 m3 were left, forming a tenuous layer within the channel. The results further indicate a downstream migration of the fine sediment deposits (Fig. 1). Both in March and October fine sediment bars as well as fine sediment blankets were primarily formed in zones of low flow velocity and decreased longitudinal connectivity (i.e. in backwater areas of woody debris jams, or at slip-off bank locations).

Sedimentological analysis of the freeze core samples exhibited that most bed sediment layers show a significant increase of clay and/ or silt particles from October to March (Fig. 1), indicating a clogging of the hyporheic zone.

In river systems, the hyporheic interstitial vertically controls the exchange of matter, energy and oxygen between the groundwater body and the overland flow. Additionally, it is an important habitat for fishes and macroinvertebrates and helps buffering the effects of floods or pollutants. While small amounts of jetted fine grained sediment can easily be reworked, entrained clay, silt and sand particles are clogging up the channel bed (i.e. colmation), thereby decreasing vertical connectivity.

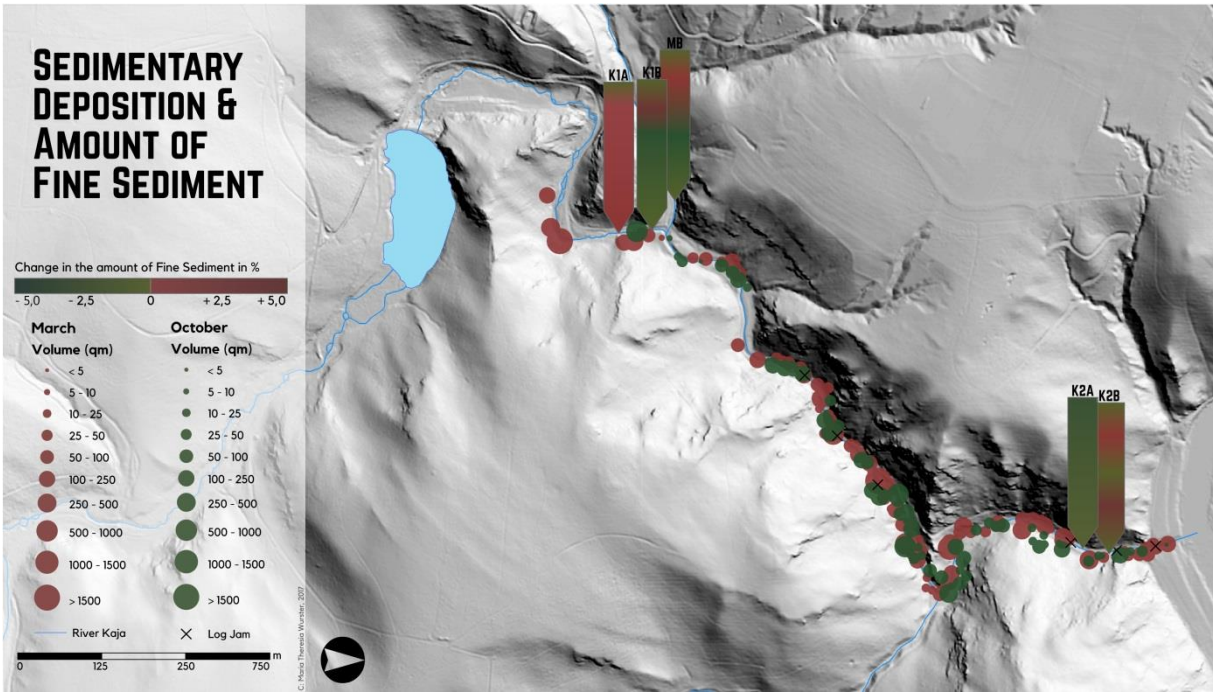

Figure 1

Conclusion and Outlook

Investigations of the consequences of dam failure-induced fine sediment release have shown that the flushing event had an improving effect, removing nearly 60% of the material. The remaining material infiltrated into lower soil horizons and, affected by geomorphological setting (narrow valley reaches) or log jams, formed tenuous layers in-channel. These layers of clay and silt decrease vertical connectivity and oxygen availability, further inducing oxidation of the upper bed sediment layers and putting strain on the overall functionality of the hyporheic interstitial. Additionally, effects on chemical conditions and invertebrate community have been observed. These observations also indicate a significant influence of vertical connectivity conditions on in-channel fine sediment storage. Overall, the effects of dam failure-induced fine sediment release and reservoir flushing on downstream bed sediment characteristics were differentiated. I could clearly be seen, that geomorphological setting was most important for sediment depostition and strongly influenced in-channel sediment connectivity.

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