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The influence of climate change on bedload transport in glaciated alpine catchments

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Climate change affects atmospheric circulation and thus may change local precipitation rates. Combined with rising temperatures that accelerate glacial melting, this is expected to have a considerable impact on erosion and sediment supplied to stream channels in high altitudes. In the European Alps, water discharged from glaciated catchments is often exploited in hydropower production. Bedload transported in these alpine streams can affect production efficiency mainly in three ways: (i) sediment deposited in reservoirs reduces storage volume, (ii) higher sediment transport at water intakes may increase maintenance through flushing operations, and (iii) high bedload transport rates during floods can damage water intakes, turbines and other infrastructure. In this study a conceptual model of the interaction of controlling processes and sediment sinks in the sediment transfer system glacier-hillslope-channel-reservoir was developed. The impacts of climate change on high alpine regions were evaluated from published investigations with a view to the relevance of its components in future sediment transfer. Approximately until the middle of the century we assume an augmentation of fluvial erosion and transport due to increasing runoff coming from accelerating glacial melt, recently exposed glacial debris and thawing of stabilising permafrost. A decreasing importance of glacial erosion and transport processes and sinks and uncertain trends in physical weathering and rock fall are expected.

The future development of bedload yield is illustrated with a field study in the Turtmann valley, Swiss Alps, where a reservoir is located beneath the glacier. The potentially erodible sediment volume in the glacier forefield was estimated from digital elevation data. Future sediment yields were determined on the basis of two simple discharge scenarios, focusing on changes in glacial/snow melt assuming temperature rise by 2.1°C on average for 2050 and 3°C for 2100 respectively and precipitation projections at seasonal resolution from published research. To compute annual sediment volumes, we used conventional sediment transport equations calibrated with historical sedimentation measurements of the reservoir. In the first scenario a rise of the annual discharge of 50 % was assumed, while its distribution over the year remains the same. Under these assumptions, an increase of bed load transport by 70 % is expected in the year 2050. In the second scenario the total annual discharge is assumed to be unchanged in 2100, while the discharge regime shifts from glacial to nival-alpine. In this case delivered bedload volume slightly decreases. Whereas currently most of the sediment yield is delivered within the months June to August with occasional transport over a total period of five months, the transport season stretches to a length of nine months by the end of the century. This goes along with an accelerated relevance of base flow and a decreasing contribution of the main discharge months. The estimated available sediment volumes should be sufficient to meet the potential transport capacity. Until the middle of this century, increased bedload and therewith sediment yields can be expected in high alpine glaciated catchments as a consequence of global warming. This will decrease reservoir lifetime, increase maintenance and require extended protective infrastructure. Subsequently, precipitation-driven discharge will become more important than glacial melting. Thus, the operation of hydro-power production will become less predictable in high alpine regions.