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Unraveling the effects of climate change and flow abstraction on an aggrading Alpine river

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Widespread temperature increase has been observed in the Swiss Alps and is most pronounced at high elevations. Alpine rivers are very susceptible to such change where large amounts of sediments are released from melting (peri)glacial environments and potentially become available for transport. These rivers are also impacted on a large scale by hydropower exploitation, where flow is commonly abstracted and transferred to a hydropower scheme. Whilst water is diverted, sediment is trapped at the intake and intermittently flushed down the river during short duration purges. Thus, these rivers are impacted upon by both climate and human forcing. In this study we quantify their relative and combined impacts upon the morphological evolution of an aggrading Alpine river.

Our study focusses on the development of a sequence of braided reaches of the Borgne River (tributary of the Rhône) in south-west Switzerland. A unique dataset forms the basis for determining sediment deposition and transfer: (1) a set of high resolution Digital Elevation Models (DEMs) of the reaches was derived through applying Structure from Motion (SfM) photogrammetry to archival aerial photographs available for the period 1959-2014; (2) flow intake management data, provided by Grande Dixence SA, allowed the reconstruction of (up- and downstream) discharge and sediment supply since 1977. Subsequently we used climate data and transport capacity calculations to assess their relative impact on the system evolution over the last 25 years.

Not surprisingly, considerable aggradation of the river bed (up to 5 meters) has taken place since the onset of flow abstraction in 1963: the abstraction of flow has substantially reduced sediment transport capacity whilst the sediment supply to the river was maintained. Although there was an initial response of the system to the start of abstraction in the 1960s, it was not before the onset of glacial retreat and the dry and warm years in the late 1980s and early 1990's that sediment supply increased and extensive sedimentation took place. The river reaches showed a common, synchronous development, steepening in response to altered flow sediment supply conditions. In the years thereafter sedimentation rates decreased (locally incision occurred) and the reaches showed a more phased and sequential development that propagated in the downstream direction. Besides being conditioned by variations in upstream sediment supply, sediment transfer was also affected by changes in the timing and duration of purges, associated with the management and capacity hydropower system, and the evolving river bed morphology (and local river engineering).

In the Borgne River we find that despite the considerable impact of flow abstraction, it is still possible to identify a climate change signal that propagates through the system and drives river morphological response. This signal is associated with a critical climate control upon upstream sediment supply coupled with the effects of combined climate and human impact on the operation of the hydroelectric power scheme.