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River Restoration: Effect of Local River Widening and Seigyu on the Bedload Transport in the Context of Sediment Replenishment

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Introduction

Over the past centuries, rivers worldwide have been extensively channelized, straightened, and regulated for water and sediment exploitation. As a result, only about 37% of the world's large rivers remain free-flowing (Grill et al., 2019). Downstream of dams in particular, rivers in bedload deficit experience excess transport capacity during morphodynamic floods, leading to riverbed degradation, incision, scouring, and bank erosion. Such systems are commonly referred to as *hungry waters* (Kondolf, 1997). The ecological consequences of sediment deficit are severe. Bed armoring (Dietrich et al., 1989), grain coarsening, and bedload deficit degrade habitats, e.g., the spawning ground for fish populations (Merz et al., 2006).

In response, river restoration efforts targeting sediment transport continuity downstream of dams

Figure 1: Sediment replenishment stockpile on Naka River, Japan (2025)

have gained increasing attention. In Japan, for instance, sediment replenishment techniques such as sediment stockpiles are widely applied (Katano et al., 2021; Wei et al., 2026) (Fig. 1).

Although sediment replenishment stockpiles overall succeed in replenishing the target reaches (Brousse et al., 2021; Miwa & Parker, 2012), sediment pulses were observed to be washed out of the target reaches rapidly (Sklar et al., 2009) and sediment deficit conditions reemerged (Chardon et al., 2021). To address this limitation, Chardon et al. (2025) suggested implementing local river widenings downstream of sediment replenishment stockpiles in order to reduce sediment transport capacity and increase sediment residence time.

Figure 2: Local river widening established 2021 on the Dranse River, Switzerland

Local river widening (LRW) (Fig. 2) is a river restoration method where levees are set back, or bank protection is removed, allowing the river to laterally erode and develop toward a state close to its natural one (Rohde et al., 2004). This measure serves multiple purposes, including riverbed stabilization as an alternative to sills (Hunzinger, 1998), flood risk mitigation by locally reducing the water depth during high flow (Song et al., 2025), and restoring the riverine morphology, creating diverse habitat structures (Martín et al., 2018; Rachelly et al., 2021, 2022; Rohde, 2005). Experimental and field studies highlight the complex response of widened reaches to varying sediment supply. For example, a widened reach in France developed braided channels and successfully stored sediment following sediment replenishment downstream of a dam (Brousse et al., 2021). Flume experiments of a unilateral LRW conducted Rachelly et al. (2022), showed bedload deposition for equilibrium bedload transport, but erosion under unsteady discharge and low bedload supply However, the effect of bilateral LRW on the overall bedload budget is not yet sufficiently understood.

Beyond modifying transport capacity, river training structures can promote deposition and erosion of bedload by altering flow velocity patterns. A traditional Japanese river training structure, the *Seigyu* (Fig. 3), originally used to divert flow away from the riverbanks, has been studied in its capability to initiate flow migration (Fujii, 2025) and its capability to create diverse river morphology (Fujii et al., 2024; Kobayashi et al., 2022). The results suggest that Seigyus induce pond formation through local scouring and bar formation during high-flow events (Fujii, 2025). However, the effect of Seigyu on the bedload budget has not been explicitly studied.

Figure 3: Seigyu structure at Ujigawa Open Laboratory, University of Kyoto

Objectives

Following the above stated research gaps, the present study aims to assess the short-term effect of bilateral LRW and Siegyus, both individually and in combination, on the bedload budget. The main goal is to determine their potential to enhance sediment retention and thereby support the effectiveness of sediment replenishment.

Methods

LRW and Seigyu structures are investigated using numerical simulations with Delft3D Flow FM and tested under a range of discharge and sediment supply conditions. The LRW model is based on a flume experiment conducted at the Hydraulic Construction Platform at EPFL, Switzerland (Van Mol et al., unpublished), representing a conceptual gravel-bed river typical of Swiss alpine forelands. The flume as a slope of S = 0.007, a median grain diameter of D50 = 0.006m, and a geometric scale of λ = 30 – 40. The morphological development and the flow depth measurements of this flume experiment are used for calibration and validation (Fig. 5). Seigyus are represented numerically by testing two different hydraulic structures in Delft3D: a fixed weir and bridge piers.

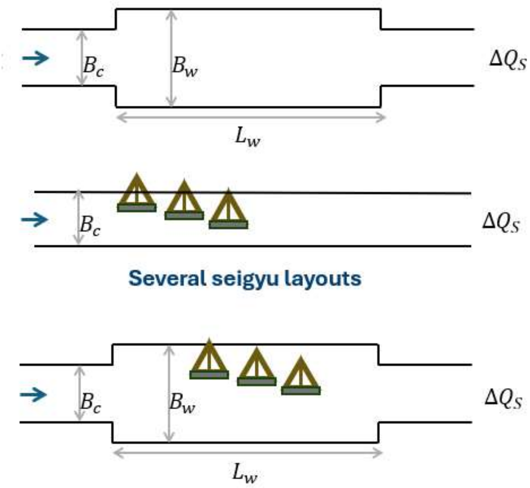

Figure 4: Overview of the three geometries to be tested

Simulations are conducted for three dimensionless shear stress levels (θ = 0.075, 0.10, and 0.125). Corresponding discharge conditions are derived, and the bedload transport is set to 50 – 80% of the transport capacity to represent the sediment release from sediment replenishment stockpiles.

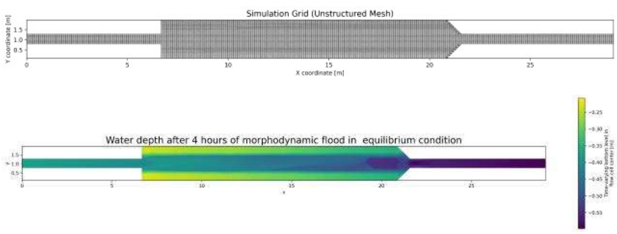

Figure 5: Above: Grid of the simulated flume experiment. Below: Morphology after 4 hours of simulation.