A Step-pool sequence, an environmentally friendly grade control structure as an alternative to old-style-concrete check dams: an application in the Western Italian Alps using Basement as design supporting tool

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The Chisone River is located in the Western Italian Alps and is an orographic left tributary of the Pellice River flowing south of Turin. The studied reach is the upstream part, which flows through the Troncea valley. It is characterized by to parts, the uppermost is 240 m long and approximately 9% steep; the downstream one is 200m long and 5% steep.

In this section there are currently 8 check dams, many of which are in an advanced state of deterioration. One of them has completely failed and another has partially collapsed during maintenance works. The presence of these check dams is therefore critical for several reasons. Firstly the check dams do not fully perform their hydraulic function of preventing the incision of the riverbed, increasing the hydraulic hazard for the downstream residential areas. Their structural stability is already compromised and their maintenance is very expensive. In addition, these check dams interrupt the longitudinal connectivity of fish passage.

For these reasons a restoration project of the Chisone River has been supported by the local Administration. The project consists in removing the central spillway and part of the check dam side wings . To avoid incison phenomena in the steepest reach, the riverbed is stabilized through an artificial step-pool morphology. In the milder sections (approx. 5%), incision processes are less likely to occur because the Chisone River is wider and sediment inputs from the tributaries are consistent. It is therefore sufficient reshaping the river bed by removing the check dams and protecting the banks using large boulders.

A step-pool morphology has been designed for a 100-year flood event, based on a preliminary study carried out by the CIRF (Italian Centre for River Restoration). The design of the step-pool morphology was carried out at unit scale, according to a new modular design framework proposed by Zhang et al (2023), which combines different approaches. The size of the keystone was based on the results obtained from Maager (2022).

The hydraulic proof of the step-pool morphology was carried out using the model BASEMENT v4.0.2 (BASEHPC module). Hydraulic modeling was applied to assess both the hydraulic conditions assumed in Zhang's approach (assumption of critical conditions on the step) and the correct behaviour of the step-pool layout. The computational domain encompasses an area of 4 ha and the mesh is composed of more than 24’000 elements, whose maximum size is 1 m^2 in the riverbed and 20 m^2 in the off-channel areas. The step-pool morphology has been shaped in the computational mesh. In particular the new channel bed morphology has been built directly into the digital terrain model from which the mesh has been sampled. Results were finally used to evaluate the keystone stability and its failure probability, according to the approaches proposed by Zhang et al. (2023) and Maager (2022).

BASEMENT proved to be a useful designing supporting tool to verify the assumptions of the design framework proposed by Zhang et al (2023) and to calculate the hydraulic variables (velocity and water depth) needed to verify the stability of keystones.