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Downstream propagation of water and sediment hydrographs due to the hypothetical failure of a real earthen dam

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The most catastrophic flood events are often associated with dam failures. Indeed, the reservoir upstream of a dam can store a huge amount of water, up to billions of m^3. In case of earthen dams, the failure consists of a progressive erosion of the dam body induced by a water flow which progressively increases, reaching the maximum value at a certain time and then decreasing. This phenomenon is usually referred to as “dam-breach”. Even if the maximum discharge is released after a certain time, the duration of a dam-breach is always very short, if considering the huge amount of water that is released. This premise suggests that the flood wave induced by a dam-breach phenomenon can lead to huge damage in the valley areas. Furthermore, it is expected that the discharge from such an event would also induce very drastic changes in bed morphology, given the impulsive features of the related flood waves.

The numerical modelling of dam-breach events is quite challenging, due to the great amount of parameters involved, that introduce a certain degree of uncertainty in the calculation. In the dam-breach modelling, the generation of the breach outflow hydrograph and its downstream propagation are tasks that can be reasonably addressed separately.

As regards the first task, various types of models are available in the literature for the calculation of the breach outflow hydrograph. Among these models, the simplified physically based ones are particularly valuable, as they give accurate results if compared to observed data and, at the same time, are quite easy and fast to apply, being thus quite suitable for emergency situations. However, these models are quite simplified in their schematization of the breach, which is considered to have a certain regular shape, such as triangular, trapezoidal, parabolic, and so on. In some cases, this assumption can lead to an uncertain calculation, influencing significantly the calculated peak discharge.

As regards the second task, that is the numerical modelling of the downstream propagation of the breach flood wave, the numerical resolution of the Shallow Water Equations is usually adopted. It is not clear whether the uncertainties related to the calculation of the discharge hydrograph influence also the numerical modelling of the flood wave propagation. In previous works, it has been demonstrated that, with the same total released water volume, peak discharges associated to different breach shape scenarios become more and more similar proceeding downstream. This suggests that, in some cases, the values of the water depth, flow velocity and flood hazard class affecting the valley area could be not influenced much by the upstream boundary condition. However, there could be situations in which this downstream convergence of the results could not be achieved due, for instance, to high longitudinal slopes which delay the downstream attenuation or to proximity of the interest point to the dam. Therefore, this aspect should be more in depth investigated. Likewise, if a morphodynamic model is used, it is not clear whether the predicted changes in bed morphology are affected by the breach outflow hydrograph or not.

In light of the above, the proposed work intends to investigate the downstream propagation of water and sediment hydrographs due to the hypothetical failure of a real earthen dam according to different breach shape scenarios. To carry out the propagation simulations, the freeware Basement version 4.0.1 is adopted, assuming a fixed bed over the computational domain. In particular, the BASEHPC module is used in order to run the simulations on the Graphics Processing Unit (GPU) and thus carry out very quick calculations. A sensitivity analysis of the results to the bedload transport formula is also proposed, by changing the pre-factor of the Meyer-Peter and Muller formula. The results are shown to be more sensitive to the bedload pre-factor than to the breach shape scenario.