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Author(s):
Bergami, Gianluca; Molnar, Peter; Burlando, Paolo

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Effects of Flow Regulation on the Surface Water-Groundwater System in an alpine gravel-bed braided River (Maggia)

Gianluca Bergami, Peter Molnar, and Paolo Burlando
Institute of Environmental Engineering, ETH Zürich, Stefano-Franscini-Platz 5, CH-8093 Zürich (bergami@ifu.baug.ethz.ch)

While the importance of renewable energy sources and hydropower is constantly rising, streamflow regulation and abstraction by hydropower plant operation potentially leads to negative impacts in downstream rivers. In many alpine basins, water stored and diverted to produce electricity bypasses long river reaches, potentially affecting their hydrology, sedimentology and ecology. The prediction of short- and long-term impacts of such changes on river morphology, riparian vegetation, groundwater levels and aquatic habitat requires the development of numerical tools which combine high resolution surface and subsurface hydrodynamic simulations with ecosystem models for riparian vegetation growth, aquatic habitat, etc. Furthermore, these tools have to be validated with ground measurements wherever possible.

We developed a coupled model of river-aquifer interactions, suitable for gravel-bed braided river floodplains with large changes in inundated area with rising discharge (Ruf et al., 2008; Shaad, 2015). With this model we predict the response of river and groundwater systems to different environmental flow strategies, i.e. mandatory releases downstream of hydropower systems (e.g. constant releases, seasonal releases, artificial floods), as well as with natural flow. We illustrate here a numerical analysis of pre- and post-dam conditions in the Maggia River, which is highly regulated by a hydropower system and intensively monitored in terms of streamflow and groundwater levels, river bed morphology, riparian vegetation, etc.

The coupled model consists of a two-dimensional shallow water flow simulator (2dMb) iteratively coupled to a groundwater model (MODFLOW) on a high resolution regular grid (12.5 m). Fluctuations in flow and inundated area occur with a very short response time, requiring high resolution simulation and an accurate numerical coupling scheme. The coupled river-aquifer model allows us to estimate surface water properties (inundated areas, flow depth, velocity and shear stress at the bed), level and oscillations of the groundwater table as well as the rates and areas of infiltration/exfiltration along the river system, thereby quantifying river-aquifer connectivity.

Through the application of the coupled model to pre- and post-dam streamflow conditions, we draw conclusions about the impacts of water diversion in the Maggia Valley: streamflow regulation led to a reduction of the average inundated area, flow depth, velocity and shear stress and to a significant drop in the groundwater table. These changes affected aquatic habitat, reduced overall sediment transport potential and adversely influenced water availability for riparian vegetation. In particular, extreme conditions of low flow, which are the most critical for the ecosystem, exhibit a much longer duration.

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