Effects of Bar Morphology and Vegetation on Flow Resistance in Gravel-Bed Rivers

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1. Introduction

Gravel-bed rivers are often characterized by complex bed topography, including single- and multiple-row alternate bars, bed undulations associated with channel curvature, riffle andpool sequences, presence of riparian vegetation in the floodplain, etc. The complexity and interaction of these features can produce spatial variation of flow resistance and sediment transport.

The recent work by Francalanci et al. (2012) has shown that alternate bars in a gravel-bed river can strongly enhance bedload transport at low Shields stress. Conversely, they do not seem to alter much the flow resistance.

The present work investigates the additional effect of the vegetation on the development of alternate bars, until the equilibrium conditions of the bed are reached: at the river-reach scale, floodplain vegetation increases water levels and flow resistance, and it could alter the topographic evolution of bed morphology.

2. Eco-Morphodynamic modelling

In the present work, a model coupling river bar dynamics and riparian vegetation evolution was developed. Bar dynamics was simulated with a 2D morphodynamic model, GIAMT2D (Siviglia et al., 2012), which uses a synchronous strategy to solve the shallow water - Exner equations on unstructured triangular grids. The model is capable of treating wetting-and-drying fronts correctly preserving mass.

The riparian vegetation model takes into account the effects of some of the main river processes, e.g. water table oscillations, floods, and sedimentation. A logistic law and an exponential decay were used to model the increase and decrease, respectively, in the biomass in dry areas at low water stages, following the approach proposed by Camporeale and Ridolfi (2006).

The flow resistance was divided into a resistance exerted by the soil and a resistance exerted by the plants (Crosato and Saleh, 2010); in this way it was possible to reproduce both the decrease in bed shear stress, reducing the sediment transport capacity of the flow within the plants, and the increase in hydraulic resistance, reducing the flow velocities.

3. Results

The model has been applied to different test configurations. Starting from a flat bottom, bars developed under formative conditions. Over the resulting morphology, we allowed the vegetation to grow and interact with morphodynamic evolution at lower water stages.

The role of vegetation was investigated with particular focus on bar morphology, e.g. bar length, height and migration. Moreover, the reach-averaged hydraulic resistance and sediment transport regime were evaluated with the aim of deriving 'morphological factors' correcting the classical equations for flow resistance and sediment transport originally developed for 1D flat geometries. The results of the eco-morphodynamic model were compared with the case of self-formed alternate bars without vegetation and with the regime that would prevail where no bars are present. These 'morphological factors' can be easily incorporated in 1D models for hydro-morphodynamic computations.

4. Conclusions

The present work addresses the problem of quantifying the effect of vegetation onbar morphology and hence on flow resistance and sediment transport, by means of a morphodynamic numerical model which couples the evolution of the bed topography with the dynamics of the vegetation.

Numerical simulations have been carried out in order to reproduce the morphological conditions of a straight channel with alternate bars and riparian vegetation growing in the dry emergent areas. Preliminary results suggest the importance of the properties of the vegetation and the role of flood magnitude and timing.

References

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