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River Bifurcations

Abstract

Bifurcation is one of the fundamental building blocks of a braided network; it is the process that determines the distribution of flow and sediments along the downstream branches. Braiding is a complex and highly dynamical system, whose evolution is at present predictable only on a short time scale; in this context bifurcations are the crucial process that control the adjustment of braiding intensity, being one of the main causes of the system continuous evolution. A complete description of river bifurcations is still lacking in the literature, though their importance for the onset of braiding is clearly recognized. Moreover, the physical quantitative description of river bifurcation appears as one of the main limitation of the most effective predictive models available at present, i.e. the branches or object-based models.

In the first part of the work the attention has been focused on the quantitative description of the evolution of a single laterally unconstrained channel until the occurrence of the first bifurcation. The analyses has been carried out performing four different sets of experimental runs with both uniform and graded sediments. An objective criterion for the occurrence of the bifurcation has been established, using the data provided by the Fourier analysis of the evolving bank profiles; the procedure enabled to characterise the morphodynamic sequence leading to flow and channel bifurcation and to point out the importance of the mutual interactions between the bed deformation and the planimetric configuration of the channel.

Along with the characterisation of the onset of bifurcations, it is crucial to investigate their further evolution, that has been pursued starting from the theoretical findings of Bolla Pittaluga et al. (2003), concerning their possible equilibrium configurations. Two sets of experiments has been carried out on a "Y-shaped" symmetrical configuration, in which the upstream channel diverge into two branches. The experimental results show the existence of an unbalanced configuration, when the Shields stress reaches relatively low values and the width to depth ratio is large enough. This asymmetrical configuration is characterised by different values of water and sediment discharges in the downstream branches and by a different bed elevation at their inlet, the channel carrying the lowest discharge showing a higher elevation. Experimental runs characterised by the presence of migrating alternate bars displayed an oscillating behaviour, generally leading to a more unbalanced configuration and, in some cases, to the abandonment of one of the branches. Experimental findings can be interpreted in the light of the morphodynamic influence theory (Zolezzi & Seminara, 2001): the distance of the flow from the resonant value of the aspect ratio seems to be a good parameter to represent such phenomenon.

The dynamics of river bifurcation were also analysed in the field. Two field campaign were performed on the Ridanna Creek, Italy and on the Sunwapta River, Canada, joining an international research group. The detailed and repeated measurements allowed to point out the common features showed by the bifurcations, namely the unbalanced water distribution, the difference in bed elevation and the lateral shift of the main flow toward the external bank of the main downstream channel. The monitoring activity on the Ridanna Creek provided also the description of the planimetric and altimetric configurations of the study reach, employing both traditional survey techniques and digital photogrammetry together with the complete characterisation of morphological and hydraulic patterns. Moreover, the analysis of the long term evolution of the network pointed out the existence of three regions in the braided reach, with different morphological features and highlighted the crucial role of bifurcations in controlling braiding evolution.

Theoretical analysis, laboratory and field investigations have allowed a much deeper insight in the bifurcation process, giving a quantitative detailed description of the phenomenon. The investigation now provides a suitable description of the bifurcation process that can readily be implemented in predictive models for braiding evolution, for which the adoption of physically based nodal point conditions would be highly desirable and represent the main sought outcome of the present analysis.