Experimental study of flow dynamics of movable bed open-channel confluences

PhD student
Olga Birjukova Canelas

PhD program
Civil Engineering (IST, University of Lisbon)

Supervisor
António Heleno Cardoso (CERIS, IST, University of Lisbon)

Co-supervisors
Rui Ferreira (CERIS, IST, University of Lisbon) and Lúcia Couto (LNEC)

Period
2014-2019

Funding
FCT scholarship (SFRH/BD/52482/2014)

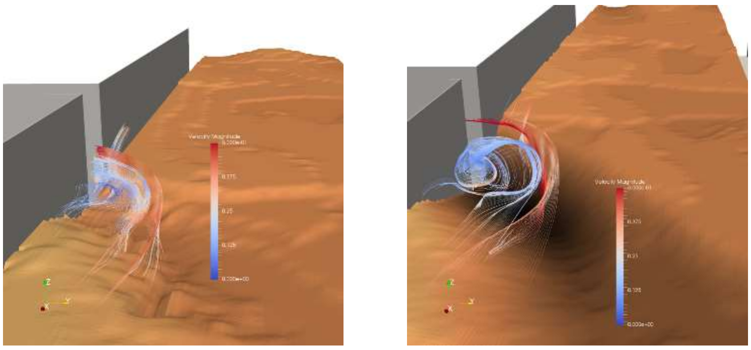
Summary

Research of confluence hydro- and morphodynamics is one of the subjects representing great interest in fluvial hydraulics in the last decades. Nevertheless, the understanding of basic mechanisms is still relatively poor. The knowledge gap is especially strong in issues that differ from the well-studied simplified concepts, such as concordant open-channel confluences with fixed geometries. For instance, bed discordance, i.e, uneven bed elevation between the two channels, was found to enhance secondary motion downstream of the junction and to modify the layout of the mixing interface of two confluent flows. However, the exact mechanisms behind these processes remain a matter of controversy among the researchers. In this context, the present research study aims to deepen the knowledge on the hydro- and morphodynamics of open-channel confluences inspired by those with the pronounced bed discordance and dominant sediment supply provided by the tributary.

For that purpose, eight laboratory experiments were conducted covering a wide range of configurations: (i) three flow discharge ratios ($Q_r = Q_t/Q_{pc}$ =0.08, 0.11 and 0.14), (ii) two junction angles (α = 70° and 90°), and (iii) two sediment discharge ratios ($Q_{Sr} = Q_{St}/Q_{Spc}$ = 0.7 and 1.0). Two experiments were created as a reference scenario to assess the influence of bed discordance on the mean and turbulent flow-field at confluences with rigid rough bed and two configurations of the tributary mouth: with and without bed discordance. The remaining six were performed under movable bed conditions and with continuous sediment supply either to both flumes, or solely into the tributary. Herein, the influence of the three control parameters, i.e., Q_r, Q_{Sr} and α, was analyzed. Experimental procedure implied systematic surveys of bed topography until the equilibrium stage was acquired. Once at equilibrium, the confluence flow field was evaluated on the basis of three-dimensional (3-D) velocity measurements performed by the Acoustic Doppler Velocimeter (ADV) at a very dense mesh. The acquired results were complemented by the mapping of free surface elevation, also at equilibrium. In the experiment with fixed discordant bed, flow separation at the tributary mouth and the shedding of negative cross-wise vorticity by the tilted axis of the highly accelerated jet-like flow coming from the tributary resulted in the formation of a streamwise oriented secondary cell downstream of the junction. The observed secondary motion was found to be influenced by the skewness of the internal shear layer and was classified as Prandtl's first kind. In the experiments with movable bed, aside from the detailed analysis on the influence of the selected control parameters on the bed morphology and flow patterns at the studied confluences, the mechanism behind the formation and propagation of the secondary circulation observed in tests with fixed discordant bed was similarly confirmed. However, in view of the acquired bed morphology at equilibrium, the secondary circulation was found to modify its direction of circulation with respect to the existing bed topography. In summary, this investigation contributes to deepening the existing knowledge on the flow dynamics of this type of confluences and provides a reliable and exhaustive data-set for numerical models.

Keywords

Open-channel confluences, discharge ratio, junction angle, sediment discharge ratio, confluence hydro-morphodynamics.



Secondary flow observed at equilibrium bed topography for two different scenarios.