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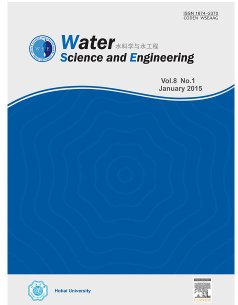


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# Influence of bed elevation discordance on flow patterns and head losses in an open-channel confluence

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**Abstract**

Confluences play a major role in the dynamics of networks of natural and manmade open channels. Since field measurements on river confluences reveal that discordance in bed elevation is common, schematized confluences with a step at the interface between the tributary and the main channel bed have been studied, revealing that the bed elevation discordance is an important additional control for the confluence hydrodynamics. This study aimed to improve understanding of the influence of bed elevation discordance on the flow patterns and head losses in a right-angled confluence of an open channel with rectangular cross-sections. A large eddy simulation (LES)-based numerical model was set up and validated with experiments by others. Four configurations with different bed discordance ratios were investigated. The results confirm that an increase in bed elevation discordance yields a reduced deviation from the geometrical confluence angle of the tributary streamlines at the interface, a reduced extent of the recirculation zone (RZ), a reduced ratio of the water depth upstream to that downstream of the confluence, and a reduced water level depression. The bed elevation discordance also leads to the development of a large-scale structure in the lee of the step. Despite the appearance of the large-scale structure, the reduced extent of the RZ and associated changes in flow deflection/contraction yield a decrease in total head losses experienced by the main channel with an increase of the bed discordance ratio. It turns out that the bed elevation discordance results in an increased efficiency of converting the lateral momentum from the tributary into streamwise momentum in the main channel.

*Keywords:* Open channel confluence; Bed elevation discordance; Three-dimensional numerical modelling; Large eddy simulation; Recirculation zone

## 1. Introduction

Stream confluences play an important role in networks of natural or artificial open channels, as they regulate water elevations and the transport of sediments, nutrients, and pollutants. Therefore, confluence hydrodynamics have been the subject of many field studies, laboratory experiments, and numerical simulations (Rice et al., 2008; Konsoer and Rhoads, 2014; Gualtieri et al., 2018; Yuan et al., 2017, 2018; Umar et al., 2018; Lewis and Rhoads, 2018). Bathymetric surveys in river confluences often reveal the existence of a difference in bed elevation between the tributary and main open channel (Kennedy, 1983; Kennedy, 1984; Biron et al., 1996a). Moreover, the flow patterns of discordant bed confluences are found to be profoundly different from those of concordant bed confluences (Biron et al., 1996a,1996b; Bradbrook et al., 2001). Field studies such as De Serres et al. (1999) and Boyer et al. (2006) indicate that a strong secondary circulation may develop in the lee of a bed elevation discordance in the confluence hydrodynamic zone (CHZ). This feature may not only be relevant to mixing and scouring processes, but its interaction with the other features of the open-channel confluence may be important for the head losses, hence the backwater effects induced by the confluence. Also, laboratory experiments have revealed significant differences in flow and turbulence characteristics between discordant and concordant bed confluences (Biron et al.,1996a, 1996b).

Detailed laboratory (e.g., Weber et al., 2001; Creëlle et al., 2017; Yuan et al., 2018) and numerical studies (e.g., Constantinescu et al., 2012, 2014; Luo, 2017) of the hydrodynamics of asymmetric confluences of open channels with equal width often make use of geometrically schematized configurations with sharp-edged confluence corners. In the case of concordant beds, such confluences are characterized by complex hydrodynamic patterns (Fig. 1(a), which is adapted from Best (1987)), including a zone of flow stagnation at the upstream confluence corner, a mixing layer between the merging flows, a separation zone of flow from the downstream confluence corner (Hager, 1987), and an ensuing shear layer (Best, 1987). Those patterns are predominantly influenced by parameters, such as the geometrical confluence angle, the momentum flux ratio, the cross-sectional shape, and the Froude number ( $Fr$ ) for the downstream

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