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Hydrodynamics of 90^o concordant beds' confluences of straight-channels with unequal channel widths

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With the exception of confluences of large alluvial rivers, tributary channel is usually narrower that the channel of the main-river. hydrodynamics of confluences of equal width channels has been thoroughly studied using 3D numerical models and to a certain extent it was studied in laboratory confluences. Hydrodynamics and morphodynamics of confluences with unequal channel widths were recently studied experimentally for mountainous rivers, and there are limited experimental data on hydrodynamic characteristics for horizontal bed confluences.

This study aims at analysing hydrodynamics of alluvial river confluences with unequal channel widths and concordant beds. They are analysed for the three typical hydrological scenarios at the confluence (defined by the discharge ratio $D_R = Q_{MR}$ / $(Q_{MR} + Q_T)$): 1) the dominance of the tributary flow (D_R = 0.250), 2) equal contributions of the combining flows (D_R = 0.583) and 3) the dominance of the main-river flow (D_R = 0.750). A confluence with the 90^o junction angle is chosen for the study, since this angle allows for the development of all six subzones within the confluence hydrodynamics zone that were recognised by Best in 1980s. Two values of the channel-width-ratio of the tributary ("T") and main-channels ("MR") (B_T / B_{MR} = {0.75, 0.50}) are analysed in addition to the case of equal width channels (B_T / B_{MR} = 1.00).

As it was expected, the flow deflection on the horizontal plane (defined by the flow angle δ = arc tg (v/ u)) reduced with the narrowing of the tributary channel, due to increase in the value of the momentum-flux ratio. For D_R=0.250, the momentum-flux ratio increases by 22 and 73% for B_T/B_{MR} = {0.75, 0.50}, respectively, whereas for D_R= 0.583 and D_R = 0.750, this increase ranges between 10 and 40%. The greatest effect on the reduction of the flow deflection (increase in the average flow angle (δ_{av})) is achieved in the case when the main-river flow dominates. The increase is between 28 and 33% for B_T/B_{MR} = {0.75, 0.50}, respectively. The reduced flow deflection results in deeper penetration of the tributary flow into the main channel and consequent widening of the recirculation zone (RZ) in the post-confluence channel. The maximal RZ width is increased by 50% for B_T/B_{MR} = 0.75 and it is almost doubled for B_T / B_{MR} = 0.50 when D_R = 0.250. The increase does not exceed 50% for D_R=0.583, whereas for D_R = 0.750, it reaches 35% when B_T/B_{MR} = 0.75 and it is again doubled for B_T / B_{MR} = 0.50. The maximal increase in the stream-wise velocity magnitude of almost 45% is attained for B_T / B_{MR} = 0.50 when D_R = 0.250. The RZ widening and the increase in the stream-wise velocity magnitude result in the increased transport capacity within the maximal velocity and flow recovery zones. An indicator of this increase is the value of non-dimensional bed shear stress (τ_0 / $\tau_{0,cr}$) for the grain of certain size. For example, τ_0 / $\tau_{0,cr}$ for the sand grain of 1 mm size increases approximately 4.5 times in the confluence with B_T / B_{MR} = 0.50 when the tributary flow dominates. Under the remaining two scenarios, the rise in τ_0 / $\tau_{0,cr}$ is significantly smaller regardless of the B_T / B_{MR} -value, i.e. it does not exceed 30%.