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A numerical study about the influence of channel-scale secondary circulation on mixing processes at Kama/Vishera confluence

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Confluences are common components of all riverine systems, and are characterized by converging flow streamlines and mixing of separate flows, which can take some significant distance to be complete. Whilst turbulent diffusion and Taylor dispersion are expected to affect mixing in any open channel flow, the analysis of mixing at river confluences should also consider some peculiar processes, which could be divided between near-field processes and far-field processes. The former, which have been well studied, are those operating at the junction itself and lead to rapid mixing only if some form of asymmetry (geometry, discordance, momentum, density difference) between the tributaries exists. The latter are advective processes, such as secondary circulation, that can enhance mixing to degrees greater than those associated with turbulent diffusion or Taylor dispersion combined. These processes, which have received less attention, were investigated using a three-dimensional computation of the Reynolds averaged Navier-Stokes equations combined with a Reynolds stress turbulence model for the confluence of the Kama river and Vishera rivers in the Russian Urals. To test the hypothesis that far-field mixing can be both enhanced and reduced by the type of secondary circulation that develops, numerical simulations on an idealized configuration (rectangular channel with no curvature) and on the real configuration with the natural planform and/or bathymetry were carried out to isolate the relative impacts of real planform and bathymetry on secondary circulation and mixing for different combinations of momentum/discharge ratio. Results show that if the rivers are represented as an idealized junction, the initial vortices that form due to channel-scale pressure gradients decline rapidly with distance downstream. Mixing is slow and incomplete at more than 10 multiples of channel width downstream from the junction corner. On the other side, if the real configuration is introduced, rates of mixing increase dramatically. This is related to both increase intensity of secondary circulation at the junction and the formation of a single channel-scale vortex downstream of the junction. The latter appears to be aided by curvature of the post-junction channel. This effect is strongest when the discharge of the tributary that has the same direction of curvature as the post junction channel is greatest.

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