On numerical modeling of the river flows with validation on the measurement data

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Mathematical modeling of the river flows in the natural complex geometries is a challenging problem for the environmental mechanics. Recently the numerical simulations of the river flows is mostly based on the diffusive wave approximation of the Saint-Venant equations which are derived by integration over the river depth of the Reynolds averaged Navier-Stokes equations [1]. It is accepted, the variations in the river morphology are small, and the empirical flow resistance distributions are accounted for. These equations are hyperbolic and capable of studying some extreme conditions like the dam breaks. The diffusive wave approximation of the Saint-Venant equations is parabolic and is obtained by neglecting the inertial terms, so they are restricted to subcritical flow conditions. The diffusive wave shallow water equation is

$$\frac{\partial h}{\partial t} + div(\vec{q}) = q_c, \tag{1}$$

where $h = H + z$ is the hydrological head, H is the river depth, z is the coordinate of the river surface, q_c are sources of water along the river bed, $\vec{q} = -kK\nabla h$ is the flux, $k = H^{5/3}$ is the conductivity, $K = m^{-1}\sqrt{S}$ is the resistivity of the river bed, $S = \left((\partial h/\partial x)^2 + (\partial h/\partial z)^2\right)^{1/2}$ is the friction slope, m is the Manning coefficient. The reliability of the approximation (1) for the runoff simulations has been shown in a series of research papers [1]. Here the model (1) has been used for the numerical computations of the velocity, pressure, and vortexes distributions in a segment of the Seversky Donets River near Kharkiv city. The results of the FEM computations on the model has been compared to the measurement data in dynamics during the 2015 – 2018 years. The flow-based bottom modifications are explained by the mechanical forces and the ratio between the areas of the moving waters and stagnant waters has been proposed for the prognosis of evolution of the river basin.

[1] Thermo-Hydro-Mechanical-Chemical Processes in Porous Media: Benchmarks and Examples. /Ed. by O. Kolditz, U.-J. Grke, H. Shao, W. Wang. Springer Science Business Media, – 2012. – 399pp.