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Dividing Flows in Vegetated Open Channel Junctions

C.W. LI and C. ZENG
Department of Civil and Structural Engineering, Hong Kong Polytechnic University, Hong Kong, China

Abstract:

The flow division at an open channel junction is affected by the inflow discharge and the downstream water depths of the junction. The growth of vegetation in a channel system is environmental friendly but its effect on the flow in an open channel junction can be significant. In the design of flood channel network system in which the channels are connected together, one difficult problem is the estimation of the energy loss and the division of flow at channel junctions. An incorrect estimation will lead to the under-estimation of flow at one channel and over-estimation of flow at another channel. Flooding thus may occur in the former channel and wastage of resource may be resulted for the latter channel. Experimental, analytical and numerical methods have been developed in the past to investigate flow at channel junctions. However, the effect of vegetation has not been fully investigated. The existence of vegetation produces a completely different vertical velocity profile in the channel and thus the complicated 3D flow structures at the junction will also be affected.

In this work a 3D RANS (Reynolds Averaged Navier-Stokes equation) model has been implemented to investigate the flow phenomena in channel junctions with or without vegetation. The Spalart-Allmaras model is used for turbulence closure. In the numerical solution the governing equations are first transformed by using a sigma-coordinate to map the physical domain to a uniform transformed space. A split operator method is then used in the solution of the transformed governing equations. At each time interval, the momentum equations are split into three steps: advection, diffusion and pressure propagation. In the advection step the equations are solved by the method of characteristics. In the diffusion step and pressure propagation step the central difference scheme is used in the space discretization. For continuity requirement, the pressure propagation equation is substituted into the continuity equation to obtain the Poisson equation which is solved by a stable and robust conjugate gradient method CGSTAB. The free surface elevation is tracked by an Eulerian-Lagrangian method.

The model is first validated by two cases: flow in an open channel T-junction without vegetation, and flow in a single open channel with vegetation. The model is then applied to simulate flow in an open channel T-junction with varying vegetation density of the branch channel. The computed results show that the increase in vegetation density will direct more flow into the main channel, lead to a decrease in the overall energy loss of the system, and shorten the recirculation zone in the branch channel. The dependence of the degree of flow division on the vegetation density leads to a way of controlling flow diversion using vegetation.

Keywords: open channel, flow diversion, vegetation, 3D flow model