COUPLING SURFACE FLOW PHENOMENA WITH DYNAMICS IN THE UNSATURATED AND SATURATED ZONES

Jongho Kim, April Warnock, Valeriy Ivanov, and Nikolaos Katopodes, Department of Civil and Environmental Engineering, University of Michigan

Abstract In a lot of hydrologic and hydraulic engineering applications flood routing can be regarded as propagation of shallow water waves. This process can be mathematically investigated with the Saint-Venant equations (dynamic wave) or with their simplified versions, e.g., the kinematic and diffusive approximations. The dynamic wave model requires detailed topographical data and channel cross sections as well as poses several serious numerical challenges to solve when continuously applied over the storm-interstorm period. Therefore, researchers and engineers have historically developed methods based on the kinematic wave model that can be applicable for problems of flood wave propagation in steep terrain due to its computational efficiency. However, the simplified model has several limitations for applications to flow over flat slopes, flow into large reservoirs, strong backwater conditions, flow reversals and flows with boundary conditions. This study develops a new coupled model that integrates a physically-based watershed hydrological model and an open flow hydrodynamic model based on the dynamic routing method.

The hydrology model with the kinematic approximation is based on the existing tRIBS, TIN-Based Real Time Integrated Basin Simulator. This numerical model employs a multiple resolution mesh by using triangulated irregular network (TIN) to resolve watershed and has the ability to explicitly utilize a variety of data such as topography, soil type, land use and vegetation. tRIBS input in terms of hydrometeorological forcing include precipitation, radiation, temperature, atmospheric turbulence, etc. The spatial and temporal variability of runoff, interception, surface soil moisture, evaporative flux, infiltration, and groundwater table position are simulated. The computed runoff is used as input to the hydrodynamic open flow model.

The hydrodynamic open flow model (OFM) with the dynamic approximation utilizes the two-dimensional Saint-Venant equations with a finite volume method in order to predict various flow patterns. OFM is able to compute the depth of flow, velocity field, the location and elevation of the free surface, turbulent characteristics and shear stresses near the bottom. In particular, OFM can accurately calculate whether the regions simulated are wet or dry, for a variety of boundary conditions and flat slopes. This information can be provided as input data to obtain sediment transport flux, which makes feasible studies of the impacts of watershed hydrology on bed morphology.

In this study, the integrated model will be employed to simulate various hydrological processes including the runoff generation mechanisms and the surface water-groundwater interactions. The study highlights the effects of catchment topography and interaction of surface flows with dynamics in partially- and fully- saturated soil. This fully-distributed model permits for a continuous analysis of the watershed hydrologic response.