An Upwind Cell Center Finite Volume Solver for Simulation of Erosion and Deposition of Fine Non-Cohesive Sediments

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Abstract

The details of an upwind cell center finite volume free surface flow solver are described in this paper. The model solves two dimensional convection-diffusion equation of suspended sediment transport as well as depth-averaged shallow water flow and *k-ε* turbulence model equations in a coupled manner; which includes a new and effective relation to estimate the critical shear stress. Validation of the sediment transport module is performed through simulation of two test cases in the straight channels. Comparison of the numerical results with the experimental measurements shows very good and acceptable agreement between the simulated results and measured data.

Keywords: Upwind, Finite Volume, Turbulence, Sediment Transport, Non-Cohesive.

1. INTRODUCTION

Due to considerable effects of the sedimentation on the river eco-system, the capacity of dams reservoir and efficient performance of hydraulic structures, prediction of flow and sediment transport in rivers and dams reservoir is of major interest in many practical hydraulic engineering applications and the transport of suspended sediment is an important area of research in fluvial hydraulics. Despite the intensive researches, both numerical and empirical in the last few decades, the transport mechanisms have remained far from a complete physical or analytical description. Numerous 2D and 3D mathematical models for sediment transport have been developed until now to predict the rivers regime and riverbeds deformation. But among these numerical models the results of those which have been simulated by finite volume method, and some of them can be found in the works of *Olsen* [1], *Spasojevic & Holly* [2], *Wu* [3] and *Yeh & Hsu* [4], are more considerable; because the equation of sediment transport is basically a conservative equation and the most suitable method for numerical modeling of conservative equations is finite volume method [5].

In this paper the numerical modeling of suspended sediment transport is presented. To model the suspended sediment transport process by the fluid flow in contact with the sediment concentration, a coupled model on the basis of depth-averaged equations of shallow water flow to study the fluid movement, *k-ε* turbulent model to simulate the eddies due to sediments roughness and suspended sediment transport for modeling the bed morphology is codified. In addition this paper focuses on the validation of the modules for computation of the erosion, transport and deposition of non-cohesive fine sediments which is added to an accurate and efficient upwind finite volume solver for depth averaged turbulent flow. The governing equations for open channel flow and sediment transport simulations are developed and discretised by the *Roe*'s scheme with second order accuracy in space.

2. GOVERNING EQUATIONS

2.1. Governing Equations of Shallow Water Flows

Under the assumptions of an incompressible fluid flow, hydrostatic pressure distribution along the vertical direction, constant pressure distribution on the free-surface and neglecting wind and Coriolis forces, the depth integrated form of shallow water equations for description of free-surface flows are expressed as:

$$\frac{\partial h}{\partial t}+\frac{\partial q_x}{\partial x}+\frac{\partial q_y}{\partial y}=0 \qquad (1)$$