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Depth-Averaged Modelling of Erosion and Sediment Transport in Free-Surface Flows

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Abstract : A fast finite volume solver for multi-layered shallow water flows with mass exchange and an erodible bed is developed. This enables the user to solve a number of complex sediment-based problems including (but not limited to), dam-break over an erodible bed, recirculation currents and bed evolution as well as levy and dyke failure. This research develops methodologies crucial to the under-standing of multi-sediment fluvial mechanics and waterway design. In this model mass exchange between the layers is allowed and, in contrast to previous models, sediment and fluid are able to transfer between layers. In the current study we use a two-step finite volume method to avoid the solution of the Riemann problem. Entrainment and deposition rates are calculated for the first time in a model of this nature. In the first step the governing equations are rewritten in a non-conservative form and the intermediate solutions are calculated using the method of characteristics. In the second stage, the numerical fluxes are reconstructed in conservative form and are used to calculate a solution that satisfies the conservation property. This method is found to be considerably faster than other comparative finite volume methods, it also exhibits good shock capturing. For most entrainment and deposition equations a bed level concentration factor is used. This leads to inaccuracies in both near bed level concentration and total scour. To account for diffusion, as no vertical velocities are calculated, a capacity limited diffusion coefficient is used. The additional advantage of this multilayer approach is that there is a variation (from single layer models) in bottom layer fluid velocity: this dramatically reduces erosion, which is often overestimated in simulations of this nature using single layer flows. The model is used to simulate a standard dam break. In the dam break simulation, as expected, the number of fluid layers utilised creates variation in the resultant bed profile, with more layers offering a higher deviation in fluid velocity . These results showed a marked variation in erosion profiles from standard models. The overall the model provides new insight into the problems presented at minimal computational cost.

Keywords : erosion, finite volume method, sediment transport, shallow water equations
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