Available online at www.sciencedirect.com
ScienceDirect
Journal of Hydrodynamics
2011,23(3):273-281
DOI: 10.1016/S1001-6058(10)60113-8
www.sciencedirect.com/
science/journal/10016058

A COUPLED MORPHODYNAMIC MODEL FOR APPLICATIONS INVOLVING WETTING AND DRYING*

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(Received April 22, 2011, Revised May 23, 2011)

Abstract: This work presents a new finite volume Godunov-type model for predicting morphological changes under the rapidly varying flood conditions with wetting and drying. The model solves the coupled shallow water and Exner equations, with the interface fluxes evaluated by an Harten-Lax-van Leer-Contact (HLLC) approximate Riemann solver. Well-balanced solution is achieved using the surface gradient method and wetting and drying are handled by a non-negative reconstruction approach. The new model is validated against several theoretical benchmark tests and promising results are obtained.

Key words: morphodynamic model, Exner equation, shallow water equations, Godunov-type method, wetting and drying, well-balanced scheme

Introduction

Morphodynamics concerns the evolution of the channel bathymetry in response to sediment activities driven by flows. It may have great impacts on local habitats, affect river conveyance and hence have implications for flooding during storm events. An understanding of morphodynamics and the relevant processes is therefore vital for river management systems. In the past few decades, with the rapid development of computer technology, computer modelling has become a common practice in assessing river morphodynamics although it may not entirely replace the laboratory studies for understanding the relevant processes[1].

A morphodynamic modelling system is typically consisted of a hydrodynamic component that describes the flow hydrodynamics and a sediment transport/morphological component that accounts for the bed evolution[2]. Conventionally, morphodynamic modelling is carried out in a decoupled way where the flow hydrodynamics is first obtained and then used to drive sediment transport and update the channel bed change[2-4]. Ignoring the unsteady hydrodynamic effects, this approach has been recognized to be more appropriate for slow-varying flows or quasi-steady processes[5]. For a rapidly-varying flow (e.g., dam breaks, floods, etc.) where the flow unsteadiness can strongly impact the sediment transport, a coupled model, in which the flow hydrodynamics and morphodynamics are solved instantaneously, is desirable and may lead to more reliable predictions[5]. A number of coupled models that solve the integrated shallow water and Exner equations have been reported in recent years for simulating morphodynamics. For example, Liu et al.[6] presented a Roe's approximate Riemann solver based finite volume Godunov-type morphodynamic model on unstructured grids with applications to coastal waters. They also compared the results with those produced by the quasi-steady approach and confirmed the necessity of using a coupled approach for a problem involving strong fluid-sediment interactions. Benkhaldoun et al.[7] reported an alternative finite volume Godunov-type model combined with the Roe's approximate Riemann solver on adaptive triangular grids. The authors also compared the performance of the coupled and decoupled methods and indicated that the coupled approach out-performed the quasi-steady approach when the bed-load rapidly interacts with the hydrodynamics.

* Project supported by the UK Engineering and Physical Sciences Research Council (Grant No. EP/F030177/1).
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