Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 154 (2016) 441 – 449

Procedia Engineering

www.elsevier.com/locate/procedia

12th International Conference on Hydroinformatics, HIC 2016

Effects of morphological change on fluvial flood patterns evaluated by a Hydro-geomorphological model

Jingming Hou[a,b,]*, Zhanbin Li[a], Qiuhua Liang[b], Guodong Li[a], Wen Cheng[a], Wen Wang[a], Run Wang[a]

[a]*School of Water Resources and Hydro-power Engineering, Xi'an University of Technology, NO.5 Jinhuan Road, Xi'an, Shaanxi, 710048, China*
[b]*School of Civil Engineering and Geosciences, Newcastle University, Newcastle upon Tyne, NE1 7RU, UK*

Abstract

High aggradation and degradation in a river induced by last flood event will respectively raise and decrease the risk of an upcoming flood event. However, this point is likely to be ignored or is not fully considered in some 2D fluvial flood models. To address this problem, this work develops a 2D high-resolution hydrodynamic model coupled with the sediment transport and the river bed evolution models. The modelling system is within the framework of a Godunov-type finite volume scheme. GPU technique is applied to accelerate the computation by more than 10 times, comparing to the CPU counterpart. After being validated against an experimental benchmark test, the model is applied to simulate the effects of the morphological change on flood patterns for the Bayangaole Reach of Yellow River, China. The results indicate that the effect of perturbed bed could be of significance for the fluvial flood over movable bed. It is therefore suggested to take into account when evaluating the flood risk in this case.

Peer-review under responsibility of the organizing committee of HIC 2016

Keywords: Sediment transport model; Morphological change; Fluvial flood; Shallow water equations; GPU

* Corresponding author. Tel.: +86-15809283371; fax: +86-029-83239907
E-mail address: jingming.hou@xaut.edu.cn

Peer-review under responsibility of the organizing committee of HIC 2016
doi:10.1016/j.proeng.2016.07.536

1. Introduction

Morphological change is of importance for fluvial flood, especially for the rivers with relatively high sediment concentration and movable bed, e.g. the Yellow River in China. The aggraded flood plain could raise the flood risk, causing immeasurable losses to the lives and property. On the contrary, the degraded river bed is likely decrease the water surface level and reduce the flood risk. To reliably predict the flood risk, the morphological effects should be considered. Hydrodynamic models play a significant role in quantitatively evaluate the flood risk, e.g. those in [1-3]. The models are able to model the flood propagation and inundation, however, the river bed evolution is not taken into account. Guan et al. [4] developed a coupled hydro-geomorphological model which could compute the complex solid-fluid interaction process. The model combined with shallow water theory and a non-equilibrium assumption for sediment transport, aiming at simulating the morphological change caused by sediment-laden flows with various sediment transport modes. The modelling concept is applied in this work to develop a GPU based hydro-geomorphological model. The proposed model is validated against an experiment and then adopted to evaluate the morphological effects on the flood propagation and inundation, in order to show the flood pattern may be very different with that of a previous flood with a similar hydrograph, due to the perturbed topography.

2. Governing Equation and Numerical Schemes

The numerical model is governed by the shallow water equations coupled with the sediment transport and bed evolution equations:

$$\frac{\partial \boldsymbol{q}}{\partial t}+\frac{\partial \boldsymbol{f}}{\partial x}+\frac{\partial \boldsymbol{g}}{\partial y}=\boldsymbol{S},$$

$$\boldsymbol{q}=\begin{bmatrix}\eta\\ q_x\\ q_y\\ hC_s\\ hC_b\\ zb\end{bmatrix},\boldsymbol{f}=\begin{bmatrix}q_x\\ uq_x+gh^2/2\\ uq_y\\ q_xC_s\\ \beta q_xC_b\\ 0\end{bmatrix},\boldsymbol{g}=\begin{bmatrix}q_y\\ vq_x\\ vq_y+gh^2/2\\ q_yC_s\\ \beta q_yC_b\\ 0\end{bmatrix},$$

$$\boldsymbol{S}=\begin{bmatrix}0\\ S_{bx}+S_{fx}\\ S_{by}+S_{fy}\\ E_s-D_s\\ E_b-D_b\\ \dfrac{D-E}{1-p}\end{bmatrix}=\begin{bmatrix}0\\ -\dfrac{gh\partial z_b}{\partial x}-C_f u\sqrt{u^2+v^2}\\ -\dfrac{gh\partial z_b}{\partial y}-C_f v\sqrt{u^2+v^2}\\ \varpi_0(C_{sae}-C_{sa})\\ -\dfrac{(q_xC_b-\beta q^*)}{L}\\ \dfrac{1}{1-p}\left[\alpha\left(\dfrac{q_xC_b-q^*}{\beta L}\right)+\varpi_0(1-\alpha)(C_{sa}-C_{sae})\right]\end{bmatrix}.$$

Where, $\boldsymbol{q}$ is the variable vector consisting of the water level η , q_x and q_y (unit-width discharges in the x- and y-direction) , hC_s and hC_b (conservative concentration of suspended load and bed load, respectively) and bed elevation z_b; h denotes the water depth following the relationship of $\eta = z_b + h$; $\boldsymbol{f}$ and $\boldsymbol{g}$ are the flux vectors in the x- and y-directions, respectively; u and v are the velocity components in the two Cartesian directions and $q_x = uh$, $q_y = vh$; g represents the gravity acceleration with a value of 9:81 m/s^2; $\boldsymbol{S}$ is the source vector; S_b and S_f are the source term of bed and friction, respectively; D and E denote the deposition and entrainment rates, respectively, and the subscripts s and b are suspended load and bed load, respectively; C_f is the bed roughness coefficient controlled by the Manning coefficient n and water depth in the form of $C_f = gn^2/h^{1/3}$. Regarding the sediment parameters, ϖ_0 is the settling velocity of single sediment particles; C_{sa} means the near-bed concentration at the reference level