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Assessing the Impact of Inundation Preventing Construction on River Morphology of Can Giuoc River in Long An Province

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Abstract. To attend to inundation prevention in Ho Chi Minh city, the Prime Minister approved the irrigation plan to prevent inundation in which there is a solution of constructing Thu Bo tidal drainage in Long An province. Thu Bo drainage is expected to have a total width of 200m, including 120m with drainage threshold -8m and 80m with drainage threshold -4,0m. Thu Bo drainage will be constructed on Can Giuoc River which is a national waterway that has been planned (two level 3 waterways from Ho Chi Minh city to Kien Luong and to Ca Mau). The article presents the result of MIKE 21 model study to assess the impact of inundation preventing construction on river morphology of Can Giuoc River in Long An province. The result indicates that the location of the drainage has caused local erosion due to narrow riverbed, flow velocity here increases, hence there are erosions in front of and behind the drainage. The sphere of erosion influence causes riverbed modification towards the upstream and downstream about 180 – 200m, especially in the time of drainage operation, there are significant differences between the upstream and downstream water level, which causes local erosion, therefore it is essential to have riverbed and river bank strengthening reinforcement measures to stabilize riverbed.

1. Introduction

According to Decision 1547/QD-TTg on irrigation planning approved by Prime Minister on October 28, 2008 of proposing irrigation solutions to control flood in Ho Chi Minh City implementing phase 1 of projects for the right bank of Saigon River - Nha Be, it includes:

Stage 1: Construction of 6 large culverts at the canal gates of Phu Xuan, Muong Chuoi, Kinh river, Kinh Lo, Thu Bo, Hang canal and small culverts at other canals; construction of dikes connecting the culverts; dredging the drainage canal in the city center to the south.

Stage 2: Construction of two large sluices Rach Tra, Vam Thuat and other small culverts with irrigation subprojects on the right bank of the Saigon River; dredging the Rach Tra - An Ha - Saigon; Vam Thuat - Tham Luong - Ben Cat – Nuoc Len.

Stage 3: Construction of 4 two-end sluice gates at Doi - Te - Cho Dem canal in Ben Nghe, Tan Thuan, Ben Luc, Xang Lon; expanding the existed An Ha sluice, completing constuction of the embankment dike and other small culverts under the dyke.

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The construction of these tidal barriers will less or more affect the river flow and river morphology on Dong Nai - Saigon. river system.

This paper will cite the results of the application of the MIKE21FM mathematical model to evaluate the efficiency of the riverbed's stability protection after the construction of the tidal prevention sluice gates for Ho Chi Minh City area.

2. Study area

The Thu Bo tide control sluice is located on the Can Giuoc River, a branch of the Soai Rap River in Ho Chi Minh City. This sluice is located on the part of Can Giuoc River belonging to the planning route of the III-level waterway, with the traffic from Ho Chi Minh City to the Mekong Delta provinces and vice versa (the section from Rach Co Cay T-junction to the confluence of Soai Rap River); its north area located in Long An Commune, West area in Tan Lan Commune & Can Duoc District, East area in Long Phung and Dong Thanh Commune of Can Gio District, South area in Phuoc Dong commune in Can Duoc district. Thu Bo sluice's admistrative boundary lies in Can Giuoc district and Can Duoc district, Long An province (Vu Thanh Te and nnk 2011).

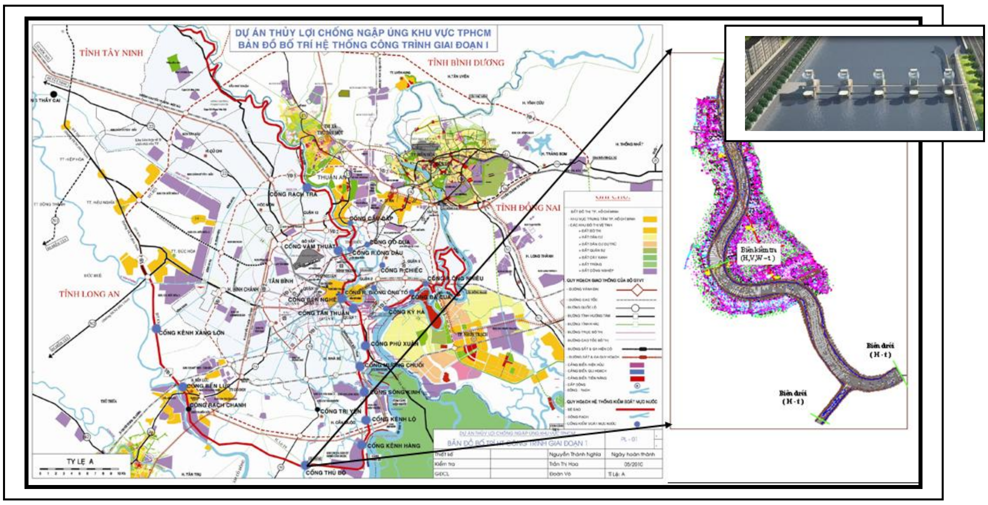

Figure 1. Location of Thu Bo Sluice.

The expected area of Thu Bo sluice is in lowland, relatively flat and low terrain, divided by a tangled river network. The ground level varies from 0.3 to 1.0m, average from 0.5 to 0.8m, dominated by the semi-diurnal regime of rivers and canals, and is very convenient to use the tide to drain water, using for drainage and soil improvement. The riverbed area is expected to be constructed in the section of curved river section with terrain depth ranging from -1.0 to -11.0m, the terrain of the river bed is smooth from riverbank to riverbed without any terrain changes.

Thu Bo sluice is invested and built to achieve the following objectives: - The most important goal is to work with other tidal control projects and tide control embankments to keep water levels within the canal in the area, not exceed the permissible level of + 1.00m, ensure that the city is not flooded due to tide during the dry season, support rainfall and tidal drainage in the rainy season for socio-economic development. - Secondly, in collaboration with other projects contributing to improve the water environment, to create a one-way flow for a certain time, and to receive fresh water from the Saigon River and drain the water to the South, out of Can Giuoc River. - Thirdly, improve road traffic conditions in the area and restrict impacts on inter-regional traffic, including national waterways.

3. Materials and Conditions

3.1. Hydrodynamic model

MIKE 21 Coupled Model FM is a dynamic model system that can be applied to coastal and estuarine environments. It includes the Mud Transport (Mike 21 MT), Sand Transport, the Particle Tracking models, the Hydrodynamic Module (Mike 21 HD), and the Spectral Wave Module (Mike 21 SW). Several of these models were used in order to research the morphological evolution of the Ham Luong Estuary, such as, Mike 21 HD, Mike 21 SW, and Mike 21 MT. Mike 21 Hydrodynamic module in Mike 21 is based on the numerical solution of the two dimensional incompressible Reynolds averaged Navier-Stokes equations with the assumptions of Boussinesq and of hydrostatic pressure. It comprises continuity, momentum, temperature, salinity, and density equations. The wind may be specified as a constant value for the entire area, or temporally and spatially varied values. The wind friction, Manning number and viscosity coefficient may be used as calibration parameters in the modeling.

Simulation of hydrodynamics has been carried out by solving 2D shallow water equations of mass and momentum thanks to the HD model of MIKE 21FM. To solve these equations using finite volume numerical methods, unstructured grids were used to define the topography of the study area. Simulations generate unsteady two-dimensional flows in one layer fluids (vertically homogeneous). Flow and water level variations are described by the Saint-Venant equations (the conservation of mass and momentum integrated over the vertical) which are the following:

$$\frac{\partial h}{\partial t} + \frac{\partial p}{\partial x} + \frac{\partial q}{\partial y} = w \tag{1}$$

$$\frac{\partial p}{\partial t} + \frac{\partial}{\partial x}\left(\frac{p^2}{h}\right) + \frac{\partial}{\partial y}\left(\frac{pq}{h}\right) + gh\frac{\partial z}{\partial x} + gp\frac{\sqrt{p^2+q^2}}{C^2h^2} - \frac{1}{\rho_w}\left[\frac{\partial}{\partial x}(h\tau_{xx}) + \frac{\partial}{\partial y}(h\tau_{xy})\right] + \frac{h}{\rho_w}\left(\frac{\partial p_a}{\partial x}\right) = 0 \tag{2}$$

$$\frac{\partial q}{\partial t} + \frac{\partial}{\partial y}\left(\frac{q^2}{h}\right) + \frac{\partial}{\partial x}\left(\frac{pq}{h}\right) + gh\frac{\partial z}{\partial y} + gq\frac{\sqrt{p^2+q^2}}{C^2h^2} - \frac{1}{\rho_w}\left[\frac{\partial}{\partial y}(h\tau_{yy}) + \frac{\partial}{\partial x}(h\tau_{xy})\right] + \frac{h}{\rho_w}\left(\frac{\partial p_a}{\partial y}\right) = 0 \tag{3}$$

where, h is the water depth [m], w = R – l is the net incoming flow rate [m/s], z is the surface elevation [m], (p,q) = (hu,hv) are the flux densities in directions x and y respectively [m²/s], C is the Chezy resistant [m1/2/s], g is the gravitational gravity [m/s²], ρ_a is the atmospheric pressure [kg/m/s²], ρ_w is the density of water [kg/m3] and τ_{xx}, τ_{yy}, τ_{xy}, are the components of effective shear stress. The aim of hydrodynamic part is to compare suitable way to build a 2D surface flow model in the Thu Bo area with MIKE 21FM. Focus is given in the implementation of hydraulic structures, which are directly included in the topography or specified by an empirical law.

3.1.1.Sediment transport model

Simulation of bed evolution has been carried out with Sand Transport module in Mike 21FM which calculates the sediment transport capacity, the initial rates of bed level changes and the morphological changes for non-cohesive sediment due to currents. The sediment transport computation is based on hydrodynamics conditions and sediment properties. ST model takes in account bed load and suspended load. The first one is controlled by shear stress or stream power per unit and reacts instantaneously with the flow. The second one is characterized by a phase-lag in the transport compared to the flow. Bed load does not need advection-dispersion modelling, but two important effects must be taken into account: the deviation of the direction of the bed shear stress and the effect

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of a slopping river bed. On the other hand, modelling of non-cohesive suspended sediment in a fluid can be described by a transport equation for the volumetric sediment concentration. Van-Rijn model has been used for the sediment transport model.

3.2. Input data

The study area of the model is the Can Giuoc section of the upstream section of Thu Bon Bridge to downstream of about 7km.

The calculated area of the model is controlled by the left and right topographic trails including the dyke embankments and the upper and lower boundary limits of the model as following.

The upper boundary is the process of actual flow measurement and the lower boundary is the actual water level measurement from September 8, 2009 to September 23, 2009 (figure 3).

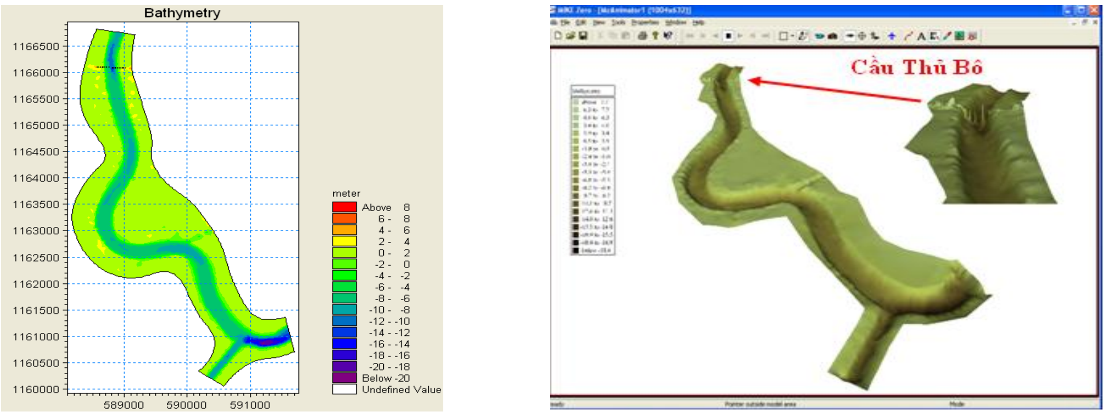

Figure 2. The topography of the tributary drainage area of Thu Bo.

3.2.1. Model Calibration

Computed water level and velocity result and observed (OBS) data as following figure:

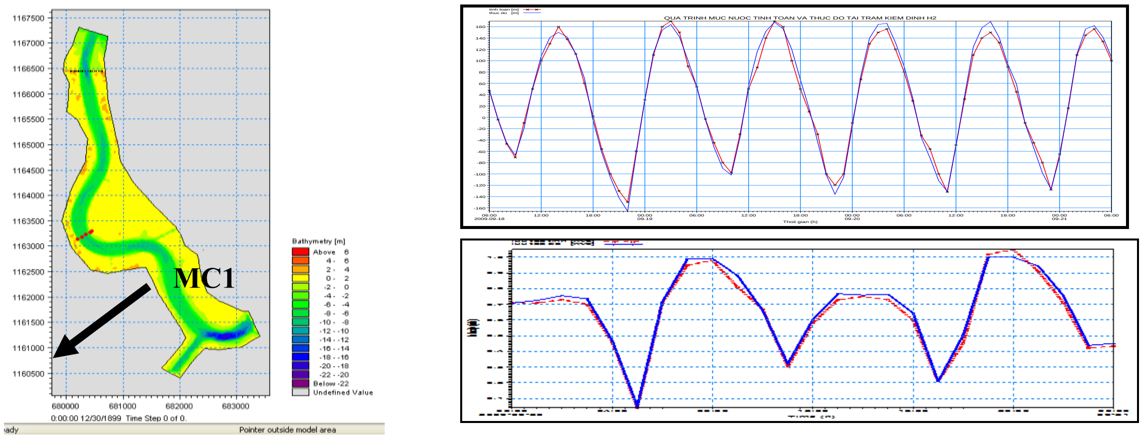

Figure 3. Computed water level and velocity result and observed (OBS) data.

The computed water level result had very little deviation (smaller 5%) compared with measured data at MC1 positon, see in Figure 4. Figure 4 indicated that the two series of data (at MC1) had similar fluctuations with the amplitude of variation of the simulated results being unremarkable and trace smaller than that of measured water level. During that, the computed velocity results also received a good agreement with observed velocity data at the survey point, and Figure 4 delineated the same order between computed results and observed data in current field. Resulting the modifier for the NASH was at 82%, offset between the water and accounting is allowed in limit.

4. Result and Discussion

4.1. Before constructing Thu Bo sluice

The area under significant influence of the tide, at the calculated time at 6pm September 19, 2009, the transporting speed was 0,82 m/s at the confluence area of the salt-water channel corresponding with the discharge of rising tide was 1125m^3/s whereas starting velocity of sediment in this area was 0,6m/s, hence the topography of this area's bed fluctuated sharply, the ability to transport drifting sediment with rising tidal discharge of -1125 m^3/s was average at 775-800g/m^3, the level of river morphology at the end of simulation was 0.62m in the area near Thu Bo bridge as in this place the water flow was narrowing which lead to local increase of flow velocity.

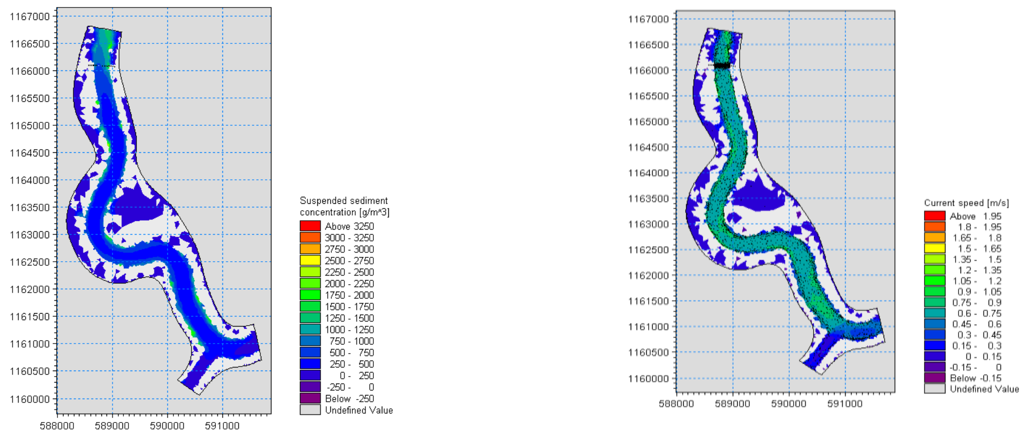

Figure 4. Current speed and suspended sediment concentration at 6pm on 19/9/2009.

4.2. After building Thu Bo sluice

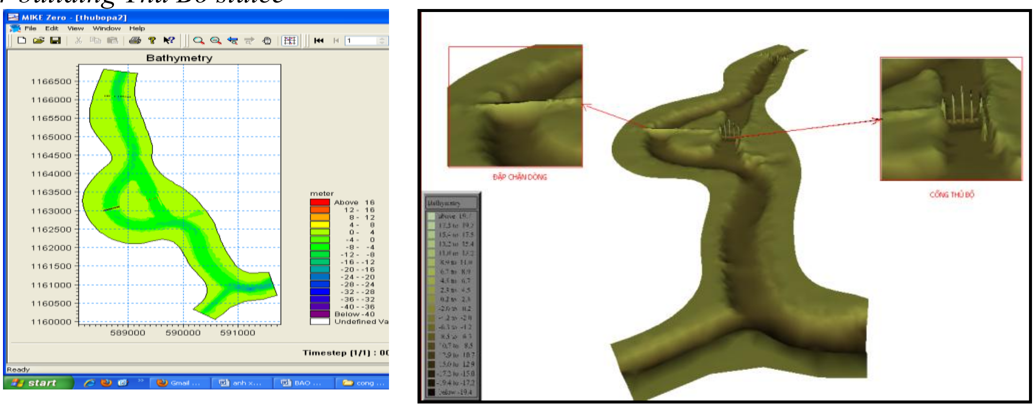

Figure 5. Location of the region with Thubo Sluice.

At the starting point of the river stream's curve, because of decreasing water level, increasing flow velocity, increasing ability to carry sediment, this section has riverbed and river bank erosion. At calculated time at 2am on September 19th, 2009, the discharged observed at the location about 500m to the upstream of the bridge was 1367 m^3/s, flow velocity at the same time was 0.87m/s, therefore when the permissible erosion velocity of this area is about 0.6m/s, erosion is possible to occur. The ability to transport drifting sediment here fluctuated from 724g/m^3-735g/m^3 corresponding with the discharge at the same time in the location around 500m from Thu Bo bridge is -1367m^3/s.

At the sluice where the local erosion occurs due to riverbed narrowing, flow velocity here increased, flow velocity in the middle of the sluice was from 1.2m/s to 1.3m/s corresponding with calculated time at 2am September 19th, 2009, when the discharged observed at the location about 500m to the upstream of the bridge was -1367 m3/s. The ability to transport drifting sediment here fluctuated from 689g/m3-702g/m3 corresponding with the discharge at the same time in the location around 500m from Thu Bo bridge is +1092m3/s. Because of the impacts of tide and flow narrowing when constructing sluice, flow velocity increased compared to prior to the sluice construct, therefore there were erosion ahead and behind the sluice. Consolidation of constructions in the upstream and downstream depended on the sphere of influence of constructing sluice to the upstream and downstream of riverbed. Calculating local erosion at the constructing location is important foundation to determine the depth of sluice burying safely and economically. To prevent erosion in the upstream, especially in the downstream of sluice when tide lower, it is essential to consolidate riverbed in the upstream and downstream. The sphere of influence of erosion that caused riverbed morphology about was 180 – 200m to the upstream and downstream, in particular in sluice operation time, the water level difference between upstream and downstream is big, causing local erosion, therefore we need riverbed and riverbank consolidation measures to stabilize riverbed.

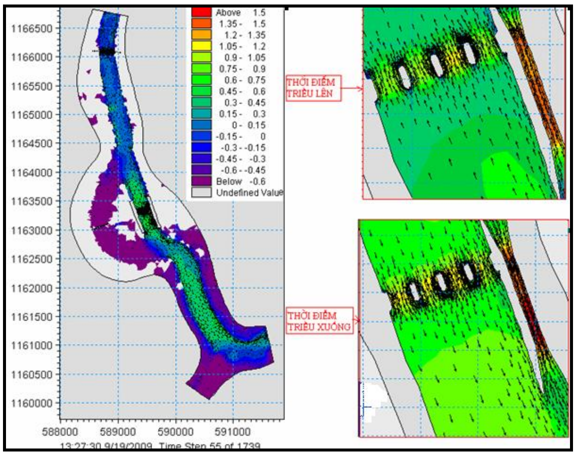

Figure 6. The current speed at Thu Bo sluice area.

5. Conclusion

This research focuses on the application of a numerical model to the morphology evolution of Thu Bo Sluice in Can Giuoc River. The result of this research identified the key factors of the Can Giuoc morphology evolution. Sediment transport model has been built with discretization extracted from the hydrodynamic model. Sedimentation area will be characteristics of sealing area for the exchange between river and sluice.

6. References

[1] V T Te and P T H Lan 2011 *Study on forecasting sedimentation and erosion of Dong Nai - Saigon river under the impact of the system of works against flooding and environmental improvement for Ho Chi Minh City area*
[2] Prime Minister of Vietnam *Decision No. 1547 / QD-TTg on irrigation planning*

Acknowledgement

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