THE INFLUENCE OF RIVER FLOODS ON COASTAL INLET MORPHOLOGY

N. T. LAM[1], M. J. F. STIVE[2], H. J. VERHAGEN[2], Z. B. WANG[2,3]
[1]*Faculty of Ocean and Coastal Engineering, Water Resources University, 175 Tay Son, Hanoi, Vietnam*
[2]*Faculty of Civil Engineering and Geosciences, Delft University of Technology P.O. Box 5048, 2600 GA Delft, The Netherlands*
[3]*WL | Delft Hydraulics, P.O. Box 177, 2600 MH Delft, The Netherlands*

Abstract. The influence of river flood on the coastal inlet morphology is investigated with the aid of process-based state-of-the-art numerical models. Hydrodynamics of tidal inlets during a severe flood situation and behavior of the inlets are described and explained.

1. Introduction

The central region of Vietnam is characterized as a narrow coastal strip, highly steeping topography, harsh climate and typhoon prone. Rivers and their basins in the region are generally short and steep sloping. Torrential rainfall frequently floods the lowland areas. River floods also make serious change in coastal morphology. In early November 1999, a torrential rain with the maximum intensity of 120mm/hour has produced a serious flooding of the central coastal provinces of Vietnam that killed 324 people and caused an economic loss of more than 100 million US dollars (Huynh et al., 1999). The flood scoured tidal inlet channels and caused dramatic changes to tidal inlets of the Tam Giang-Cau Hai lagoon in Thua Thien-Hue province: the Thuan An, Hoa Duan and Tu Hien inlets (Figure 1). The cross-sectional area of the Thuan An inlet has increased from 3250 m² to 6200 m², and the cross-sectional area of the Tu Hien inlet has been scoured from to 600 m² to 1800 m². The Thuan An inlet channel has not only been enlarged in cross-section but also been reoriented from SE-NW to SW-NE direction (Figure 2). High flood water level initiated overflow and breached the sand barrier at its weakest point at Hoa Duan to create a new inlet with a width of 600 m and a cross sectional area of 1750 m². The new inlet opened at Hoa Duan caused many socio-economic and environmental problems. The breach not only swept away dozens of houses on the barrier but also isolated a large number of people living on the area. It also causes the existing inlet to decline that affects the navigation to the Thuan An port and the access to a sheltering area inside the lagoon.

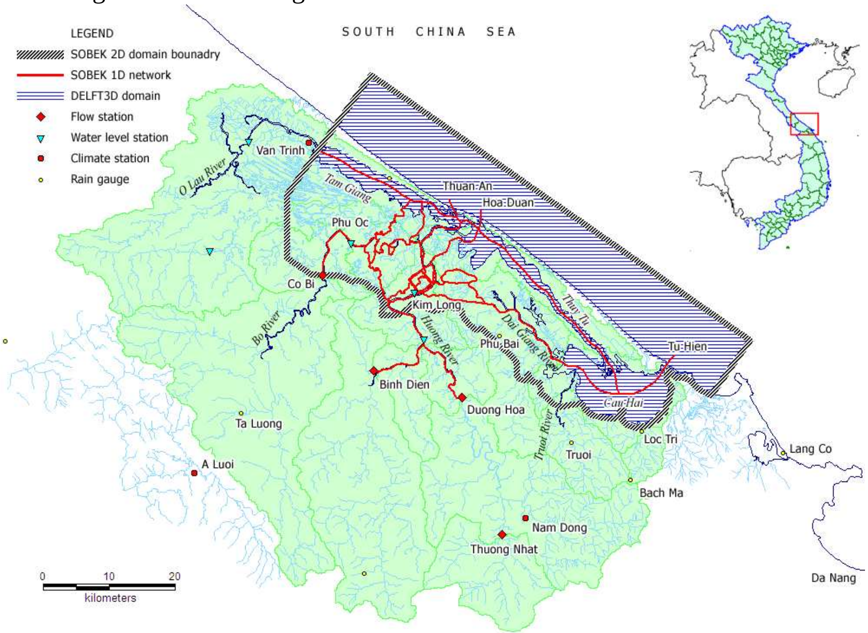

Figure 1. The system of lagoon, tidal inlets and river basin in Thua Thien-Hue province and the numerical model domains

The influence of fluvial processes as an important factor for inlet flushing and opening has been recently recognized (Escoffier and Walton, 1979; Kjerfve and Magill, 1989; Elwany et al., 1998; FitzGerald et al., 2002). However, the mechanisms and the behavior of tidal inlets which are strongly influenced by severe episodic river floods like the tidal inlets of Thua Thien-Hue are not fully understood. To provide more insight into the influence of river floods on tidal inlet morphology, this study has been conducted with an application of numerical models.

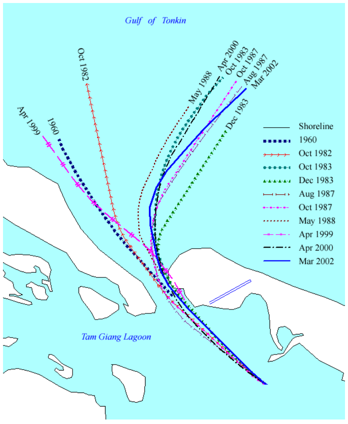

Figure 2. Historical development of Thuan An inlet channel

2. Numerical models

2.1. *River flow*

The Tam Giang-Cau Hai lagoon receives water from a drainage basin of 4400 km^2. Severe river floods on the river basin are mainly generated by the torrential rain on a very steep topography. Therefore, flood water flows rapidly to downstream and inundates the coastal lowland area. Flood water not only flows in the river channel network but also overflow on the floodplain with the water depth up to 5.6 m. For this situation, a numerical model which incorporates 1D-2D flow in SOBEK-RURAL has been used. The 2D module of the model is used for simulating overland flow on the floodplain. It covers all the areas of the lagoon and the coastal lowland with a DEM of 200 m resolution. The 1D module of the model is used for presenting flow in the river channel network. It does not only superpose the DEM but also extends 45 – 65 km upstream to include the flow and water level stations so that the observations at these stations can be used for the upstream boundary conditions as well as for model calibration and verification (Figure 1). Upstream boundary conditions of the models are flow discharges at these observation stations. Downstream boundary conditions of the model are tidal water levels off the inlets. The model has been calibrated and validated for some flood events including the floods of November 1999 and October 1983.

2.2. *Inlet morphodynamics*

Morphological change at the inlets is simulated using DELFT3D modeling suite. During the floods, the inlets are river dominated and the influence of short period waves can be neglected. Therefore, only DELFT3D-FLOW and DELFT3D-MOR modules are used for the simulation of hydrodynamics, sediment transport and bottom changes. The model domain has been setup as in Figure 1. Boundary conditions of the model on the landward side are the results of flow discharge from SOBEK model. Sea boundary conditions of the model are tidal water levels. Model results of bottom changes during the flood of November 1999 are compared with the topographic data surveyed before and after the flood in April 1999 and March 2002, respectively.

3. Results and discussions

3.1. *River floods*

Base on model simulations for river floods, hydrodynamics in the situation of the historical flood in November 1999 is discussed. Figure 3 shows computed water levels in the lagoon and flow velocities in Thuan An and Tu Hien inlets. Peaks of lagoon water levels near the inlets are very high. These values at Thuan An and Tu Hien are 2.6 m and 2.8 m above the datum (MSL), respectively. This due to too much flood water flows to the lagoon and lowland area in a short time period which the inlet cross sectional area could not have enough capability to discharge into the sea.

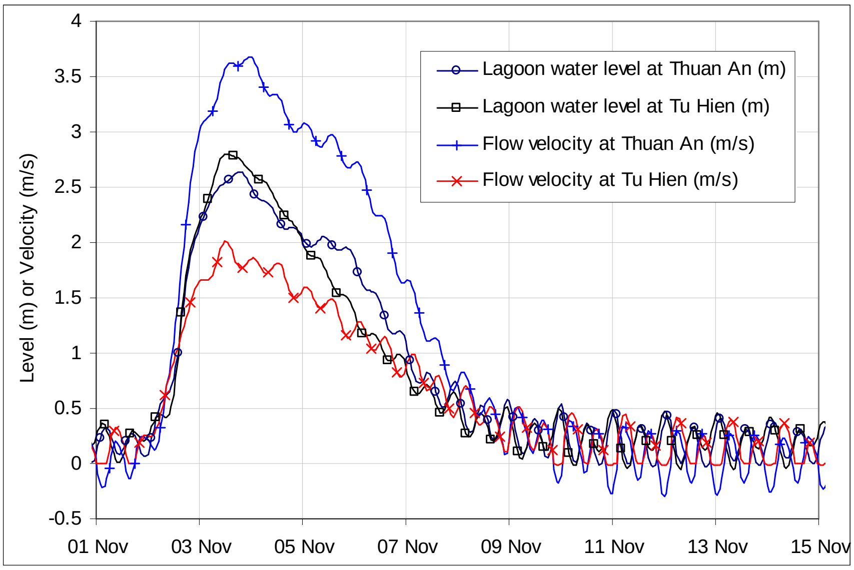

Figure 3. Computed lagoon water level and inlet flow velocity at Thuan An and Tu Hien

The maximum water level differences between the lagoon and the sea at the Thuan An and Tu Hien are 2.5 m and 2.8 m, respectively. These produce extreme flow velocities in the inlets of 3.7 m/s and 2.0 m/s at Thuan An and Tu Hien, respectively. Although the water level difference at Tu Hien is bigger but due to its length is longer, its cross section is smaller and the resistant is higher so the flow velocity at this inlet is smaller.

High speed flow velocities will scour the inlet channels tremendously. The high water level also exceeds the level of the sand barrier at the weakest point at Hoa Duan which is approximately 2 m high and only 170 m wide. Overflow on the sand barrier at Hoa Duan can explain for the breaching happened at this location in early November 1999 that swept away dozens of houses. Although the beach at this location was eroded during the typhoon Eve 10 days before but the river flood was the main cause of the breaching.

3.2. *Inlet morphology*

Figure 4 shows the topographic change at the Thuan An inlet made by the flood of November 1999 simulated in the model and from data of 1999 and 2002 surveys. The erosion/deposition patterns in the inlet channel and on the ebb tidal delta are very similar. In side the lagoon and in the inlet, flow concentrated as a high speed flow bundle that scours the channel. On the ebb tidal delta, river flood current dominates over the influence of waves and tides. It spreads over the ebb tidal delta and transport sediment to the terminal lob.

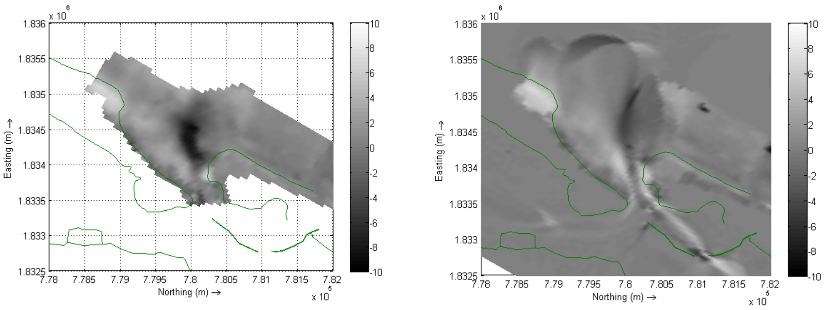

Figure 4. Bottom changes at Thuan An inlet from 1999-2002 surveys (left) and simulation (right)

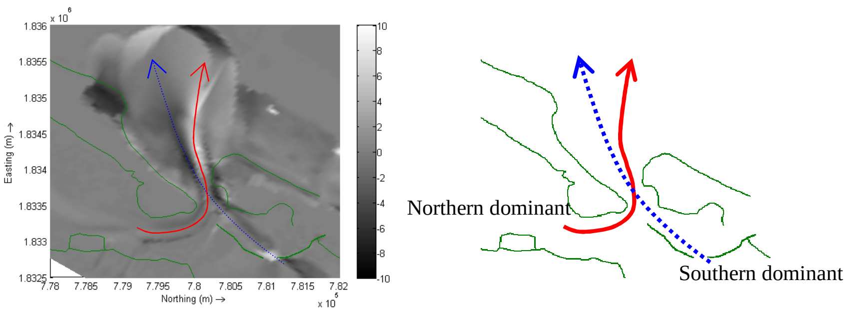

Figure 5. Influence of river floods on Thuan An channel orientation

Several computational scenarios have been conducted for different distributions of flood water from the rivers. Figure 5 shows the erosion/

deposition patterns caused by two distinct scenarios: a) one with most of flood water coming from north rivers of the Thuan An inlet (northern dominant); and b) one with most of flood water coming from south rivers of the inlet (southern dominant). It clearly shows that the direction of the inlet channel depends on the side which the dominant river flood discharge comes from. If the flood water dominantly comes from the southern side of the inlet, i.e. mainly contributed by the rainfall on the Huong River catchment, the flood flow will turn the inlet channel to the same as its direction. If the flood water coming from the northern side is stronger caused by much rainfall happens on the northern catchments of the O Lau and Bo rivers then it will have a tendency of perpendicular to the coast that turns the inlet channel to the northeast direction.

Outside the ebb delta, the flow direction changes according to the tidal currents in the sea in the along shore direction. Sediment is mainly removed in the channel and the ebb delta and transported to the terminal lobe of the ebb tidal delta where the flow velocity decreases significantly.

During the non-river flood periods, because the inlet cross sections were scoured largely, the flow currents in the inlets drop significantly. For instance, the magnitude of flow current in the Thuan An inlet reduces to less than 0.5 m/s just after the flood of November 1999 (Figure 3). With this velocity, the inlet is unable to transport out the sediment deposited in the inlets. There is almost no sediment transported from the inlet into the lagoon and the flood tidal delta can not be formed.

Conclusions

In the central coast of Vietnam, river floods can cause serious morphological change at tidal inlets. River floods can dramatically change inlet channel cross sections and orientation. Channel reorientation is caused by the direction the dominant flood flow. High water level and overflow on the sand barrier are the main cause for barrier breaching. Due to inlet channels are scoured too large by the floods, tidal currents become too weak afterward to transport sediment and build up the flood tidal delta.

References

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