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Tamshui River Estuary Impact Investigation of Induced Topographic Changes from Discharge Changes

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ABSTRACT

This study investigated the mechanism of topographic change of Tamsui River estuary which is affected by the typhoon. The flow rates of tributaries of Tamshui River are used as the upstream boundary condition for the tide-affected estuary. MIKE21 hydraulic model is adopted to simulate the whole process of the effects of the typhoon. This model takes driving forces of topographic change of estuaries into accounts, and those forces include tide, wave, and near-shore currents. The results of simulated and measured meet great agreements. In short, the process of this analysis helps to better understand the mechanism of topographic change of Tamsui River estuary due to discharge change.

KEY WORDS: Tamsui River; Typhoon; MIKE21; Topographical change; Discharge.

INTRODUCTION

Tamsui River is Taiwan's third-largest river, and there are 3 tributaries namely, Xindian River, Keelung River, and Daihan River. The total length of Tamsui River is about 160 km with a watershed of 2,700 km^2. Statistics show that the average annual discharge of Tamsui River is 6.59 billion m3/year and the average annual sediment discharge is 11.45 million tons/year (1950-2000) (Lee, 2004). The discharge and sediment discharge affects the topographical change of the estuary.

There are two reservoirs in the Tamshui River watershed, namely, Shihmen Reservoir (established in 1964) and Feitsui Reservoir (established in 1986). The two reservoirs block the sediments upstream to flush downstream. Comparing aerial photos of 1948, 1978, and 1992, it is found that the coastline is scoured 330 m inland in the coastal area of Bali. From 1978 to 1986, the coastline of in the south of the estuary is scoured about 100 m inland, and the coastline around the estuary is scoured about 200 m inland. From 1986 to 1990, the trend of erosion is found in this time slot, but some depositions were also found. The trend of erosion is milder than that of before (Hsu, 1991).

According to the report of Harbor and Marine Technology Center (HMTC, 2007), the north breakwater of Taipei Port (orange circle in Fig. 1)is protruding 1.6 km from it. The breakwater may easily prevent the sediment from moving south which forces the sediment to fall in the area between the north breakwater and the estuary. The satellite image of the estuary is shown in Fig. 1.

Fig. 1 Tamsui River estuary (Source: Google earth)

Based on the analysis of surveyed topographic changes of the estuary of Tamsui River of Luo (1994), the right bank of Tamsui River erode and deposited alternatively near the estuary and that of the left bank almost eroded. In recent decades, erosion-and-deposition trend was found in Waziwei (yellow circle in Fig. 1) and in its beaches. Waziwei is located on the left bank of Tamsui River and is very near the estuary. With the measurement of total station, high-resolution terrain data of every month of 2009 is gotten. After Typhoon Sinlaku’s striking (2009), the beach of Waziwei was eroding, and the sand bar of Waziwei was recovering to its status before the typhoon’s striking and continued depositing. It shows the short-term recovery ability of Waziwei.

Hsu (2005) investigated the coast from the north of Taipei Port to the left bank of Tamshui River, and he found that the deposition is significant due to sand drifting along the coast and the jetty. Breaking down to the whole year, the deposition occurs in summer, and the erosion occurs in winter.

Wen et al. (2015) conducted the research focusing on the topographical change of Tamshui River estuary due to effects of the typhoon. The deposition is in the main channel of Tamshui River due to typhoons and flood. Cross section narrowed in the estuary which made the water speed increase, and contraction scouring is found in those areas. The areas around the estuary were scouring due to the high speed in the main channel, increasing speed induced by ebbing, and added discharge brought by the upstream reservoir.

This study focused on the role of the typhoon which increases the discharge in Tamshui River that changes the topography near the estuary. The discharge of the whole watershed of Tamshui River including the three tributaries' is considered. MIKE 21 takes different phases of the typhoon, and forces of tide, wave, and current are taking accounts in it. With boundary condition of the tidal river and that of the outer region, the effects of the typhoon on the topography near the estuary can be accurately represented. The simulated results and surveyed data show a high degree of consistency. The analysis flow chart proposed in this study can help better to understand the mechanisms of topographical change near estuary affected by the discharge of typhoons.

METHOD

In this study, MIKE21 hydrodynamic module (Hydro Dynamic, HD), wave module (Spectra Wave, SW) and sediment transport module (Sediment Transport, ST) are used for investigation of the estuary of Tamshui River. On-site sand sampling and hydrodynamic conditions are gathered, and coastlines of different years are retrieved from satellite images. DHI MIKE-21 FM modules adapt the finite volume method on the computation of fluid dynamics which automatically satisfy the continuity equation, and it has better adaptability for irregular boundaries by using irregular meshes than that of finite difference method by using rectangular grids.

The flow chart of coupled computation is shown in Fig. 2. The new bed elevation is updated by this coupled computation. In other words, the new bed elevation (t+Δt) calculated at the current time is based on the old bed elevation at a previous time (t) and the sedimentation during this time step (Δt).

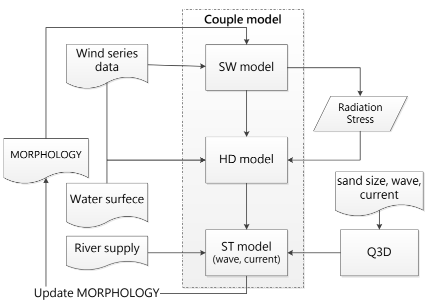

Fig. 2 MIKE21 Flow chart of coupled models

Settings of model

SW module is first performed, then HD, and ST at last. The boundary and parameters of SW module and HD module are set first. The wave-current interactions are coupled in this simulation, and the sediment transport due to effects of the typhoon are included in this paper.

The computation domain of SW module can be divided two scales: large-scale and regional scale. The boundary conditions of the regional scale domain are provided by the computation results of the large-scale domain. The main goal of large-scale is to use the wind as a source for waves generation, and then the wave field of the whole domain can be gotten. For regional computation, large-scale computation results are used for regional boundary conditions. Parameters of SW can refer to Chang et al. (2014).

Two options of the simulation are offered in ST module. One is pure water simulation, and the other is wave-current interaction. The former is usually adopted in sediment transport simulation in the river, and the latter is adopted in the sand drifting in the ocean. This study focused on the coastline so wave-current interaction is chosen. Possible hydrodynamic conditions and their corresponding sediment transport rate are listed in a table ST module. The median diameter of this study is 0.15 mm~0.228 mm. The wave boundary condition of the regional domain is retrieved from the large-scale domain at the same location. The verification of this module can be found in Chang et al. (2014).

DISCHARGE AFFECTED by TYPHOONS

To investigate discharge induced by typhoons which have effects on the topographical change of Tamshui River estuary three typhoons are chosen, namely Typhoon Soulik (2013), Typhoon Trami (2013), and Typhoon Aere (2004). The discharges upstream of Guandu Bridge and their corresponding water surface level at the estuary of respective typhoons are discussed below.

Typhoon Soulik (2013)

The discharge upstream Guandu Bridge during Typhoon Soulik is shown in Fig. 3, and it showed larger discharge occurring from 2013/07/13 to 2013/07/14. The corresponding tide status for the maximum discharge is low tide, and the second largest discharge is low tide.

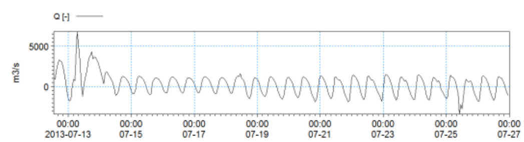

Fig. 3 Discharge at Guandu Bridge-Typhoon Soulik

The flow field of the lowest low tide is shown in Fig. 4 and it can be found that larger discharge occurring upstream of Guandu Bridge which made higher flow speed in the channel. On the contrary, the flow speed is decreasing in the open sea.

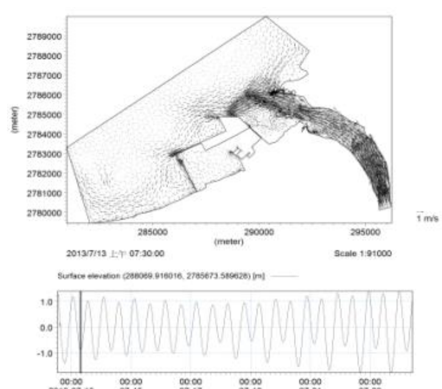

Fig. 4 Tamshui River near the estuary (2013/07/13 07:30) and W.S.L. in the estuary -Typhoon Soulik

Typhoon Trami

The discharge upstream Guandu Bridge during Typhoon Trami are shown in Fig. 5 and it showed larger discharge occurring from 2013/08/22 to 2013/08/23. The discharge during this period is above the average discharge for about 1,000 cms. The corresponding tide status for the maximum discharge is high tide.

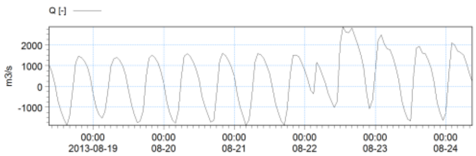

Fig. 5 Discharge at Guandu Bridge-Typhoon Trami

The flow field of the highest high tide turning to low tide shown in Fig. 6 and it can be found that the flow field in the channel of Tamshui River is affected by the discharge released from upstream reservoirs and effects of ebbing. The flow started flowing from channel to open ocean. At this time, the flow velocity is very low.

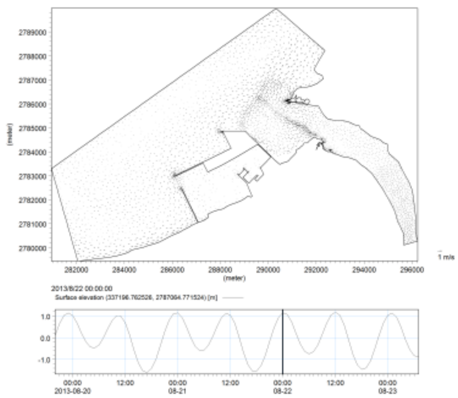

Fig. 6 Tamshui River near the estuary (2013/08/22 00:00) and W.S.L. in the estuary -Typhoon Trami

Typhoon Aere

The discharge upstream Guandu Bridge during Typhoon Aere is shown in Fig. 7 and it showed larger discharge occurring from 2004/08/24 to 2004/08/25. The maximum discharge during this period is about 10,000 cms. The corresponding tide status for the maximum discharge is high tide.

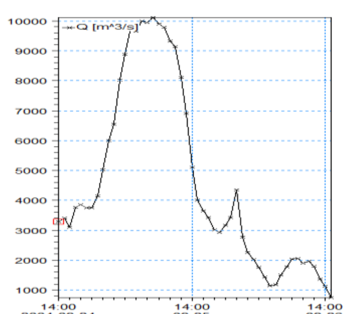

Fig. 7 Discharge at Guandu Bridge-Typhoon Aere

The flow field of the highest high tide turning to low tide shown in Fig. 8 and it can be found that the flow field in the channel of Tamshui River is affected by the discharge released from upstream reservoirs and effects of ebbing. The flow started flowing from channel to open ocean. The discharge upstream of Guandu Bridge was significant increased which also increased flow velocity in the channel. And it flew toward open sea more significantly than that of Typhoon Trami due to higher discharge induced by Typhoon Aere.

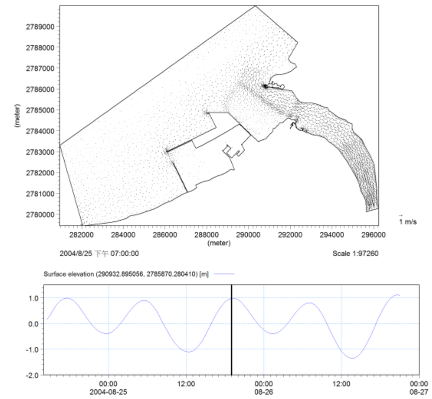

Fig. 8 Tamshui River near the estuary (004/08/25 19:00) and W.S.L. in the estuary -Typhoon Aere

INVESTIGATION OF TOPOGRAPHICAL CHANGES

To investigate the impacts of topographical change of the estuary due to discharge induced by typhoons and tidal elevation, Typhoon Soulik, Typhoon Trami, and Typhoon Aere were selected. The locations of topographical change of the estuary for analysis (Area 1-Area 4) is shown in Fig. 9. The topographical changes of the estuary of respective typhoons are shown in Fig. 10-Fig.12. For Typhoon Soulik, the maximum discharge of Guandu Bridge occurred when low tide turning to high tide. For Typhoon Trami and Typhoon Aere, the maximum discharge of Guandu Bridge of occurred when high tide turning to low tide.

Right Bank of Estuary (Area 1)

For Typhoon Soulik, deposition and erosion were shown in river mouth. For Typhoon Trami, deposition was shown in Area 1. For Typhoon Aere, erosion was shown in Area 1. As a result, if the maximum flow of Guandu Bridge occurred (water flowing from river channel into open ocean) when low tide turning to high tide (water flowing from out of estuary into river channel), deposition and erosion occurred in the estuary. The main explanation is that two opposite forces are acting on the water body of the estuary.

During Typhoon Trami's striking, maximum discharge of Guandu Bridge occurred when high tide turning to low tide. The directions of river water and tide area in the same direction, and significant deposition was found in the estuary. The location of deposition is closed to the estuary.

As for Typhoon Aere, the directions of tide and river water are the same. The discharge of Typhoon Aere is larger than that of Typhoon Trami. With this larger discharge, the deposition was more significant. The location of deposition is closed to the estuary and is closer to that of Typhoon Trami.

Left Shoal of Estuary (Area 2, Area 3)

Area 2 is located in the left shoal estuary, and this area is affected by the topography of estuary. Part of water flows through this area and converges with the water in the main channel. After converging, the combined water flows upstream of Tamshui River.

This area is tide affected, and the radiation stress affects the flow here. The topographical change of the three typhoons is erosion and deposition. Area 3 is located in the shoal area between Area 2 and Area 1. In this area, the direction of flow is opposite to that of current. Erosion and deposition were found in Typhoon Soulik. As for Typhoon Trami and Typhoon Aere, deposition was found here.

Estuary (Area 4).

Area 4 is closed to . The discharge and sediment yield from reservoirs upstream which makes the river water speed in the main channel, and that force interact the tidal force. The two main forces change the topography of the estuary.

For Typhoon Soulik, erosion and deposition were found in this area. The direction of the tide was opposite to that of the flow of maximum discharge which makes the flow field more complex in the area. The frontal area of Fisherman's Wharf is deposition, and the left bank of Tamshui River erode and deposited.

For Typhoon Trami, the trend of deposition is similar to that of Typhoon Soulik. For Typhoon Aere, deposition was also found in the frontal area of Fisherman's Wharf, and the area of deposition is larger than that of Typhoon Soulik and Typhoon Aere. The possible reason of deposition in this area may be due to the river channel and the effects of harbor structure. But the main reason may be accounted to the tide and peak flow interaction which makes deposition more obvious. The sediment in the river channel was brought to the estuary and then to the open sea.

Overall, the right bank of Tamsui River estuary was scouring and the left bank of it was deepening. The left beaches of the estuary had a large amount of deposition.

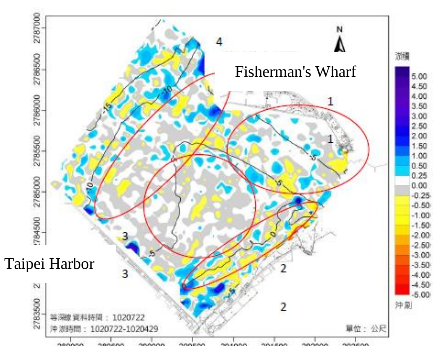

Fig. 9 Location of Area 1-Area 4

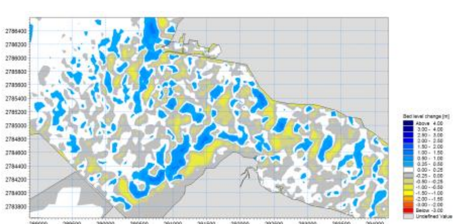
Fig. 10 Topographical change of the estuary-Typhoon Soulik

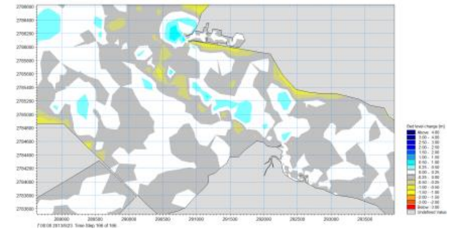
Fig. 11 Topographical change of the estuary-Typhoon Trami

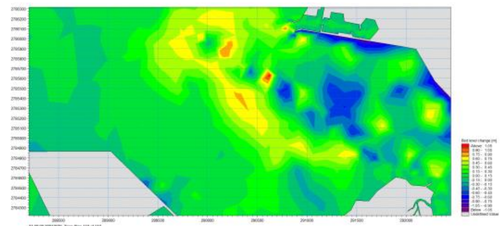
Fig. 12 Topographical change of the estuary-Typhoon Aere

CONCLUSIONS

This study investigates the topographical change of the estuary of Tamshui River under different conditions of three typhoons of Typhoon Soulik, Typhoon Trami, and Typhoon Aere. The tidal effect and discharge induced by the typhoon are considered in this study. Conclusions are drawn as below:

1. The beaches of the left bank of Tamshui River estuary is affected by the discharge of it, the waves of the open sea, tidal current, and near-shore current. Those forces make the beaches near the river channel deposit or erode.
2. The changes of the terrain of Tamshui River estuary corresponds to the time of peak flow and its status of tide (high tide, low tide, and etc.). Different changes can be found in different statuses. When peak flow occurs at the time of low tide turning to high tide, derision and deposition can be found. When peak flow occurs at the time of high tide turning to low tide, deposition can be found. The location of deposition is affected by the discharge upstream.
3. When the peak flow is small, deposition is easily induced in the river channel. When the peak flow is large, deposition is easily induced in the estuary and the shape of deposition is banded.

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