Field Study of Coastal Processes near Hualien River

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Abstract

This project is based on the national economic development plan "Modernization of Hydrographic Survey Technology for Taiwan". One major task is to realization the goal set up in the plan, which is to study the distribution of the current hydro-monitoring network and come up with suggestions for improvement. This plan integrate field study, remote sensing and numerical modeling to investigate the wave, tide, current, bathymetry and sediment transportation in the coastal area adjacent to the opening of river systems, and predict the potential changes.

1 Introduction

The coast along the estuary of Mei-Luen river to Hua-Lein river is the most beautiful and essence in Hua-Lein city, but the topography is steeper and tend to be easily erosive. There are about 100~200 meters wide beach before the dyke was constructed in 1954. However, after the west breakwater of Hua-Lien port constructed, the coastal at Bei-Ben shrunk back. The topography change
presented more significant when the east breakwater of the port was prolonged to 800 meters in 1987.

To achieve the purpose of sustainable development, it has to perform field measurements and numerical simulation of the sediment transport in the estuary of Hua-Lein river to clarify long-term trend of beach evolution in this area to make a plan for beach protection. Hence, to understand the complex characteristic of topography on Hua-Lien coast, survey of beach topography, wave, current and tide has been being carried out in 2005. The results this study includes: (1) survey data integration and analysis for the target site. (2) collection of marine meteorology, wave and tide currents, bathy and sediment transportation. (3) forecast how different conditions (headstream rainfall rate, source of river sediment, monsoon and typhoons) affecting the change of coast line in the target area. Based on the historical data and the data collected in the project and the, we come up a general description of how the coast line will change for the target site under different weather conditions like monsoon or typhoons. We also predict possible change for the short term to long term in the future. In summery, we suggest dredging the river channel which will be invaded by flood, and move the bed pebble to supplement the coastline south to the Hua-Lien River. This prevents the supply of river sediment being transported out to the deeper waters.

2 Outline the Field Measurements

2-1 The Surveyed Area

Figure 1 shows the area of the Hua-Lien River surrounding the area under survey. The scope of the area takes the opening of the Hua-Lian River as the center, extending north to the Mei-Luen River which is just by the south of Hua-Liang Port, south to the Yen-Laio River, east to the nine-meter isobaths, and west to the man-made features by the coastline such as high ways. The Hua-Lian River supplies relatively large volumes of sediment during flood.

2-2 Method

Three observation stations shown in Figure 2 were established to monitor the wave and currents within water depths of 20m to 110m. To continuously monitor hydrodynamics, we conducted continuous measurement at the main station. The main station was located at the deep water outside the Hua-Lian River and about 110 m depth. The main station was used to collect data throughout the term of the project. The other two short-term stations were set up at the shallower water for cross-check. The areas of the bathymetry survey around the Hua-Lian River are near coast waters, river channels, tidal zone and man-made structures. It was carried once in summer and winter respectively. It was investigated based on aerial photographs, LiDAR, GPS and single-beam instrument measuring the water depth.
3 Observed Results and Discussion

3-1 Temporal Variation of Wind and Ocean Environment

The winter seasonal wind blows from October to February and the wind directions are NNE~NE. The summer seasonal wind blows from June to August and the wind directions are SW~WSW. There are usually several typhoons passing Taiwan every year, typically in summer and autumn. Upon the intrusion of a typhoon, a flood in the river and a large wind-driven current are occasionally produced and it will cause severe erosion of the coast. There were seven typhoons, including LONWANG, DAMREY, KHAHUN, TALIM, SANVU, MATSA, and HAITANG, hitting the land area or passing through the vicinity of ocean area.

Figure 3 shows the measured time series of wave, tide, and current at main station during the typhoon period and the records of the significant wave height and period during the typhoon period are listed in Table 1. It shows that the maximum wave height can reach up to 11.34 m during period of the typhoon LONWANG. It also shows that the wave heights in southern station are higher than the main and
northern stations during the period of investigating time. This could be attributed to the geomorphology shown as Figure 4 of the Hua-Lian River. Depending on the trend of the bottom contours, the waves can be either focused, Figure 5(a), or defocused, Figure 5(b) (Kinsman, 1965). It is simply a matter of crowding the wave energy into a smaller area or of spreading it out. This is the typical wave refraction effect. The direction taken by the waves can be altered and lens effects produced by varying water depths. The southern station measuring the wave and current was located at a submarine bridge, a focal place for waves from some directions, so that it is common to have the highest waves. The main and northern stations are located at the submarine valley where defocusing so reduces the wave heights. The northern station is also influenced by the diffraction effect of the Hua-Liang Port, so that it has the smallest wave heights in this area.

Figure 3(a)(b) The time series of wave, tide and current at main station during the period of typhoons
Figure 4 The geomorphology of the Hualien River

Figure 5(a) The refraction of a wave train over a submarine ridge (Kinsman, 1965)
Figure 5(b) The refraction of a wave train over a submarine valley (Kinsman, 1965)
### Table 1 The significant wave height and period during the invasion time of typhoon

<table>
<thead>
<tr>
<th>Typhoon name</th>
<th>Station</th>
<th>The invasion time</th>
<th>$H_{1/3}$(m)</th>
<th>$T_{1/3}$(sec)</th>
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<td>102.15</td>
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</table>

#### 3-2 The Geographical Change in the Circumference of the River Mouth Observed by Survey

The bathymetry survey included the opening of the Hua-Lian River as the center, extending north to the Mei-Luen River which is just by the south of Hua-Liang Port, south to the Yen-Laio River, east to the nine-meter isobaths. Figure 6 shows the topographical map. The contour line basically is parallel to coastline, but the topography still present some change in this area. In Bei-Bin, the average slope on near shore, depth beyond 5m, is around 1/25 to 1/55, and for about 1/50 in offshore area. In Nan-Bin part, the seabed becomes more steeper, its slope beyond 5m is 1/15 to 1/25 in near shore, and is 1/15 to 1/50 depth about 5m to 10m in offshore. In Hau-Ren beach, the average slope steep more extremely about 1/10 to 1/15 beyond 5m depth in near shore, and about 1/15 in offshore where depth is around 5m to 10m.
3-3 Topographical Change around the Hua-Lian River Mouth

Figure 7 shows the change in topography around the mouth of Hua-Lian River based on field surveying. It shows that major sediment supplied from Hua-Lian River be transported to the offshore area and the rest was in the northern direction. According to the meteorological measurements, the seasonal wind, NNE~NE direction in winter and SW~WSW direction in summer, is predominant in this area and there are usually several typhoons passing Taiwan every year causing severe erosion of the coast. The sediment deposited at the river mouth has been transported to the offshore area and to the north due to the flood and the high waves. Furthermore, it is noted that the waves attach the shore with oblique wave incident. In this regard, wave conditions are most unlike those found along coastal shores in general. Due to these current and wave conditions, remarkably active shoreline changes are occurring in the river mouth and the northern area.
3-3-1 Change in Cross-Shore Profile

Field measurement of beach profile has been carried out in the vicinity to the river mouth to understand the process of sediment transport. Figure 8 shows the survey sections and Figure 9(a)–(d) show the longitudinal profiles along Sections 1~16. Accumulation of the coast can be seen along Section 1~5, near the estuary of Mei-Luen river, whereas erosion is remarkable in the southern side of Ziyou street drainage outlet, especially in the Nan-Bin coast. From the longitudinal profiles in each measurement section, the change of the shoreline is calculated shown as figure 10.

3-3-2 Change in Shoreline

Figure 11 show the results of the shoreline fluctuations taken from 1986 to 2005. It shows that the beach became wider near the estuary of Mei-Luen river and the shoreline in the southern side of the Nan-Bin coast is severe back after 1986. The sediment deposition can be observed at Section 1~5 caused by the effect breakwater at Hua-Lian Port. After the construction of detached breakwaters, the shoreline at Nan-Bin and Hau-Ren coast is gradually advances towards offshore about 4.3 m/year and 6.56m/year during 2002~2005. It shows that the offshore breakwaters could effectively reduce the incident wave energy and interrupt the...
sediment transport

Figure 8 The shoreline change and the survey sections

Figure 9(a)~(d) The cross-shore profile along sections 1~16
4 Modeling of Morphological Change Process

Field measurements performed in present study provided useful information for a better understanding of estuarine hydrodynamics and for the model calibration. In addition, long-term data of the rainfalls, waves, currents, water levels, river discharges, sediment grain-sizes and bathymetry were also collected and analyzed. Preliminary results revealed that the major factors related to sand spit erosion at the Hua-Lian river mouth including wave, river discharge, and water level. Their
individual influence on the short-term sand spit erosion processes during the typhoon invasion period was examined through the numerical modeling.

A hybrid two-dimensional depth-averaged numerical model was applied to simulate the sand spit erosion processes due to the combining actions of waves, tides, and river inflows. This model is based on the nonlinear shallow water equations and integrated with short wave module, transport module and bottom change module. The coupled short wave module could either be a Mild-slope model or a Boussinesq-type model according to the requirements, the sediment transport module solves the advection and diffusion equation for the suspended solids and the bottom change module calculates the bottom topographic changes based on the sediment balance and the sediment transport rate (Van Rijn, 1993). This model had been satisfactorily verified by the field observation data in other projects.

Several model runs with different combinations of waves, discharge rates, and water levels had been performed in this study. One set of numerical model input data was plotted in Figure 12. The model simulation time lasted two days to thoroughly cover the entire typhoon invasion period. The simulated current and morphological changes by the numerical model were plotted in Figure 13 and Figure 14. Results indicated that, during the flood with lower discharge rate, the river would keep flowing within the main channel and only the edge of sand spit was scoured. But when the discharge rate increased, the river waters would overflow onto the sand spit and start scouring a new passage. Finally, this passage would get even deeper and separate the sand spit from the left river bank. At this moment, most of the river waters still discharged into the sea from the inherent channel. When the discharge rate increased to 6000 m³/s, the sand spit would totally be flushed away. The eroding spots of the sand spit and the 4-5 meters scour depth predicted by the numerical model and field survey appeared to be reasonable and consistent.
5 Conclusions

This plan integrates field study, remote sensing, and numerical modeling to investigate the wave, tide, current, bathymetry, and sediment transportation in the coastal area adjacent to the opening of Hua-Lien river systems, and predict the potential changes. The results of these tasks provide the basic information of coastal area and marine meteorology for coastal engineering design and construction. It will also be used to estimate the possible change of coastlines, and offers the parameters needed for hydro-model test or numerical simulation. The long term impact will be the completeness of the information necessary for the coastal protection in Hua-Lien area subjected to the influence of monsoon and typhoons, coming up with the appropriate short, mid and long term strategies.

6 References


