Studying impacts of hard breakwaters and sandbars at Phu-Tan using MIKE21 Model

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1. Introduction

This report presents the simulation of hydrodynamics and morphology impacts by protection measures at Phu Tan area, (west coast of Ca Mau province).

The protection measures are proposed based on the review of existing protection measures applied in the LMDCZ and suggestion of possible measures. Field surveys were carried out to examine the concrete breakwaters which were applied in West coast of Ca Mau. From that, a porous breakwater was proposed. From experiences of the same natural conditions in Demak, North Java, Indonesia a Building with Nature measure, the sandbar was proposed. Both porous breakwater and sandbar were testing their funtions in the Flume of SIWRR. These proposed protection measures will be studied their efficiency and impacts by numerical modeling, the MIKE21FM.

2. Objectives

- To select shore protection measures for the coastal zones of Phu Tan. Selected measures should be suitable to the economic and tourist conditions of the coastal zones of Phu Tan.
- To check the efficiency of the selected shore protection measures for the coastal zones of Phu Tan.
- To check the impact of the selected shore protection measures to the neighbouring of Phu Tan

3. Methodology

With nesting approach, MIKE21FM has been calibrated well from the Regional model to Local Model (Figure 3-1) with water levels, discharges, tides, waves and currents, sediment transport and morphology especially the validation results based on the in-situ data of the LMDCZ project in October 2016 and February-March 2017.

In this WP6 Report of MIKE21 FM in Phu Tan we discuss the efficiency and impacts of protection measures.

The mesh of the study area model is an unstructured mesh with the triangular element occupying most of the sea area but with the quadrilateral part in most of the rivers. To assess the impact of the protection measures in the area of Phu Tan, the net areas are divided very smoothly with a grid step of about 10m ÷ 15m (Figure 3-1).

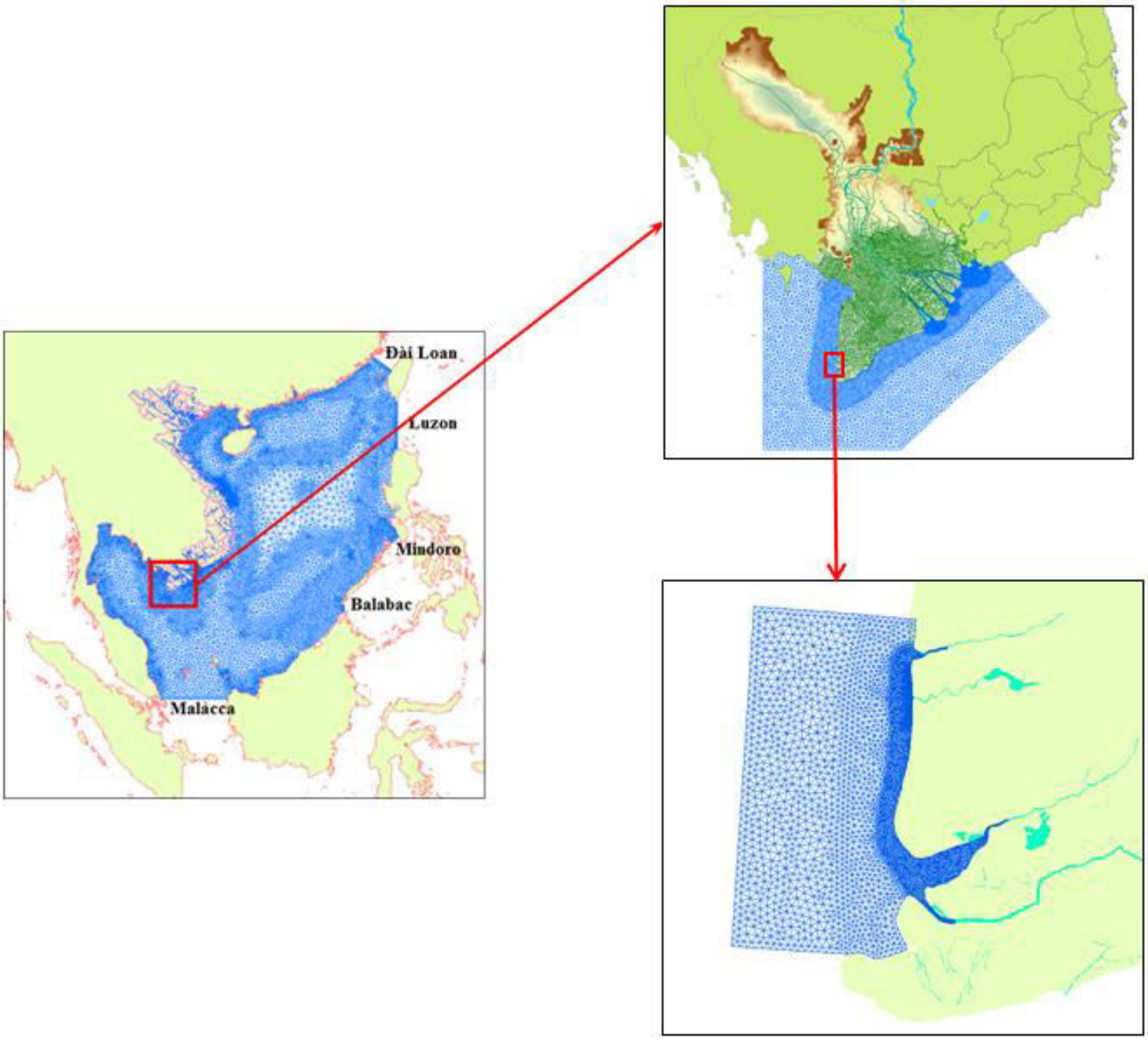


Figure 3-1 Nesting approach for studying protection measure at Phu Tan – Ca Mau

4. Model calibration /validation

The results of calibration and verification of the model with the water level measured at Ong Doc station in October / 2016, February/ 2017 are presented in Figure 4-1 and Figure 4-2.

The results of calibration and verification of the flow at the U Minh fixed station during October 2016 and March 2017 are presented in Figure 4-3 and Figure 4-4.

The results of calibration and verification of the wave at the U Minh fixed station during October 2016 and March 2017 are presented in Figure 4-5 Figure 4-6.

Figure 4-7 Figure 4-8 are the result of calibration and validation of wave in the west coast for mobile stations in the SW and NE monsoon.

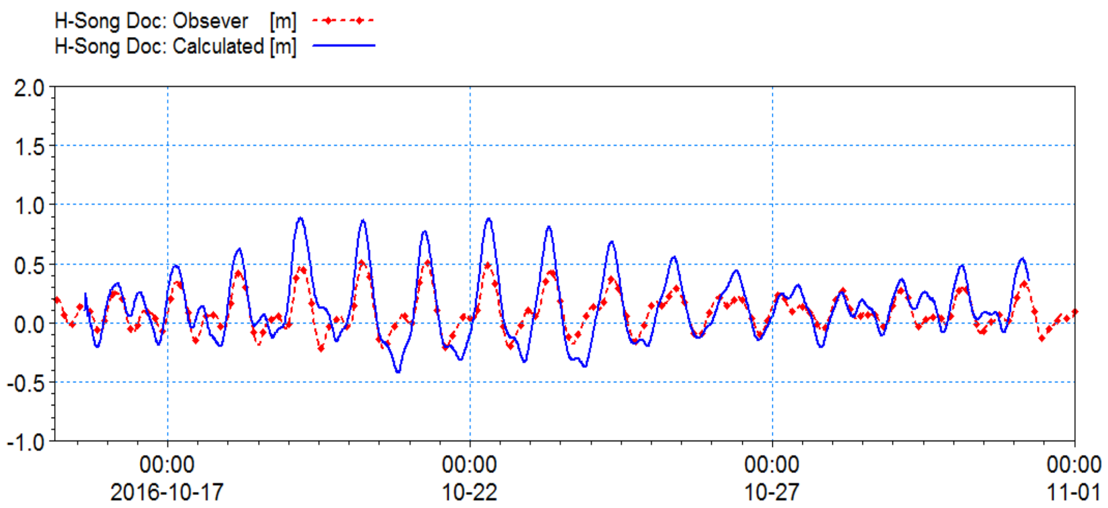


Figure 4-1 Comparison of calculated and measured water levels at Ong Doc station (10/2016)

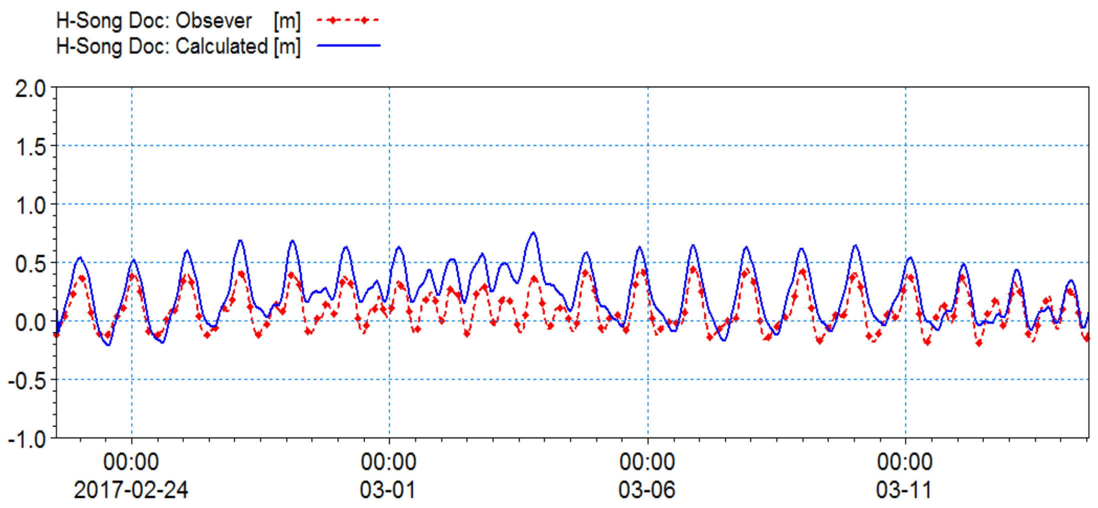


Figure 4-2 Comparison of calculated and measured water levels at Ong Doc station (2/2017)

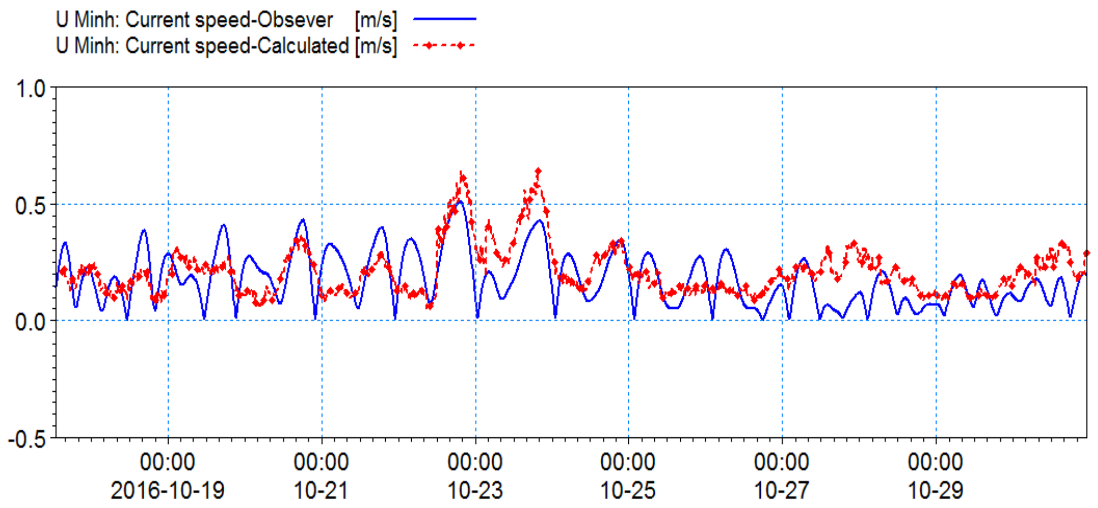


Figure 4-3 Comparison of flow at U Minh fixed station during the southwest monsoon

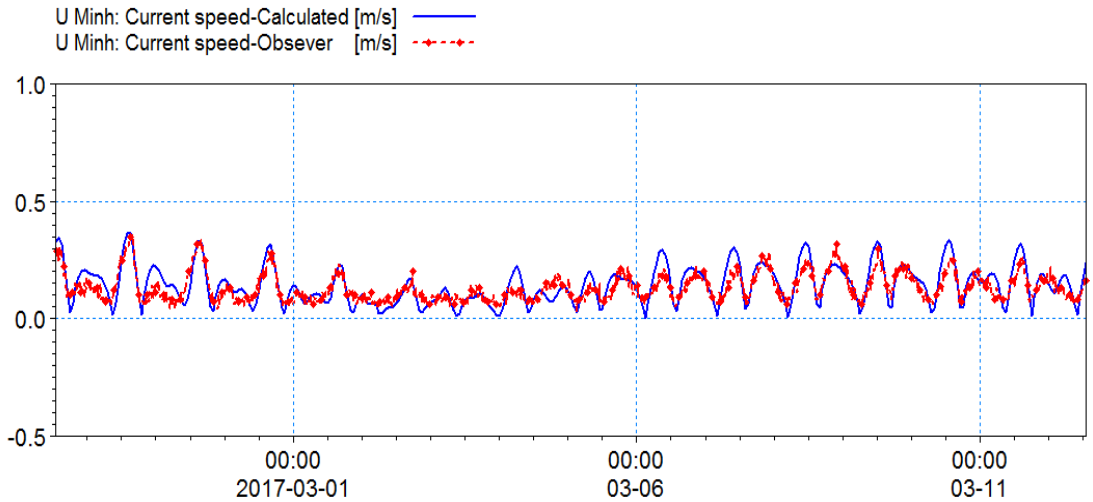


Figure 4-4 Comparison of flow at U Minh fixed station during the NE monsoon

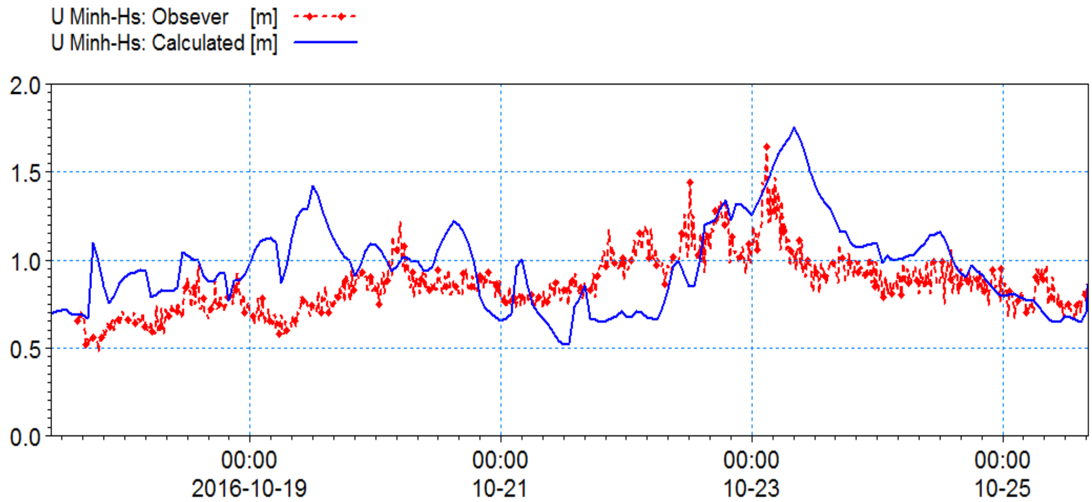


Figure 4-5 Comparison of wave at U Minh fixed station during the SW monsoon

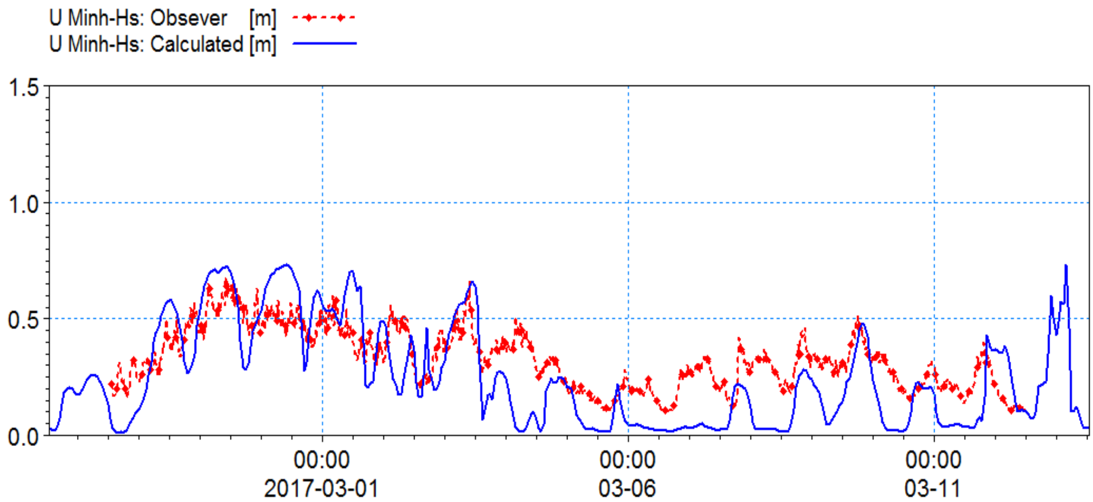


Figure 4-6 Comparison of wave at U Minh fixed station during the NE monsoon

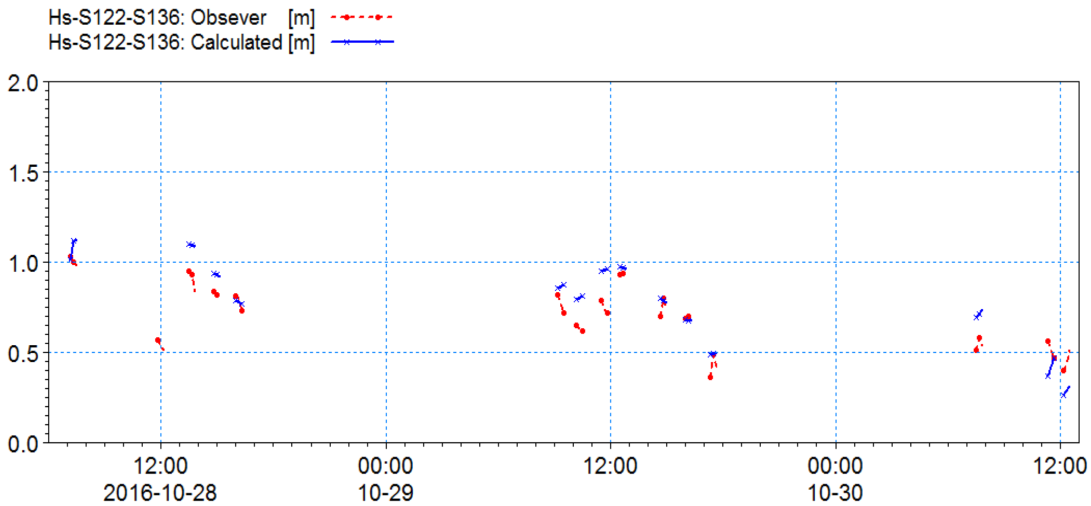


Figure 4-7 Comparison of wave at west coast mobile stations during the SW monsoon

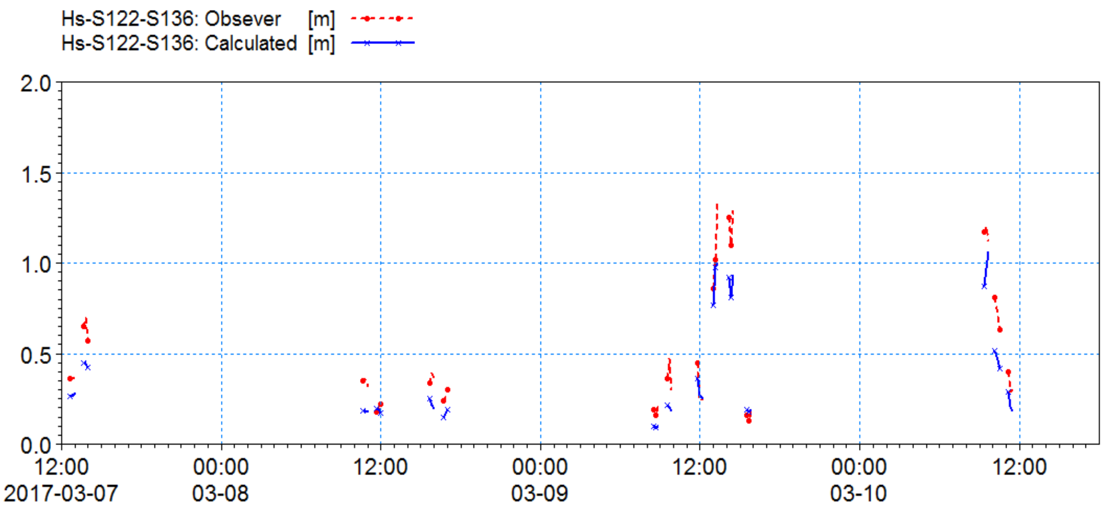


Figure 4-8 Comparison of wave at west coast mobile stations during the NE monsoon

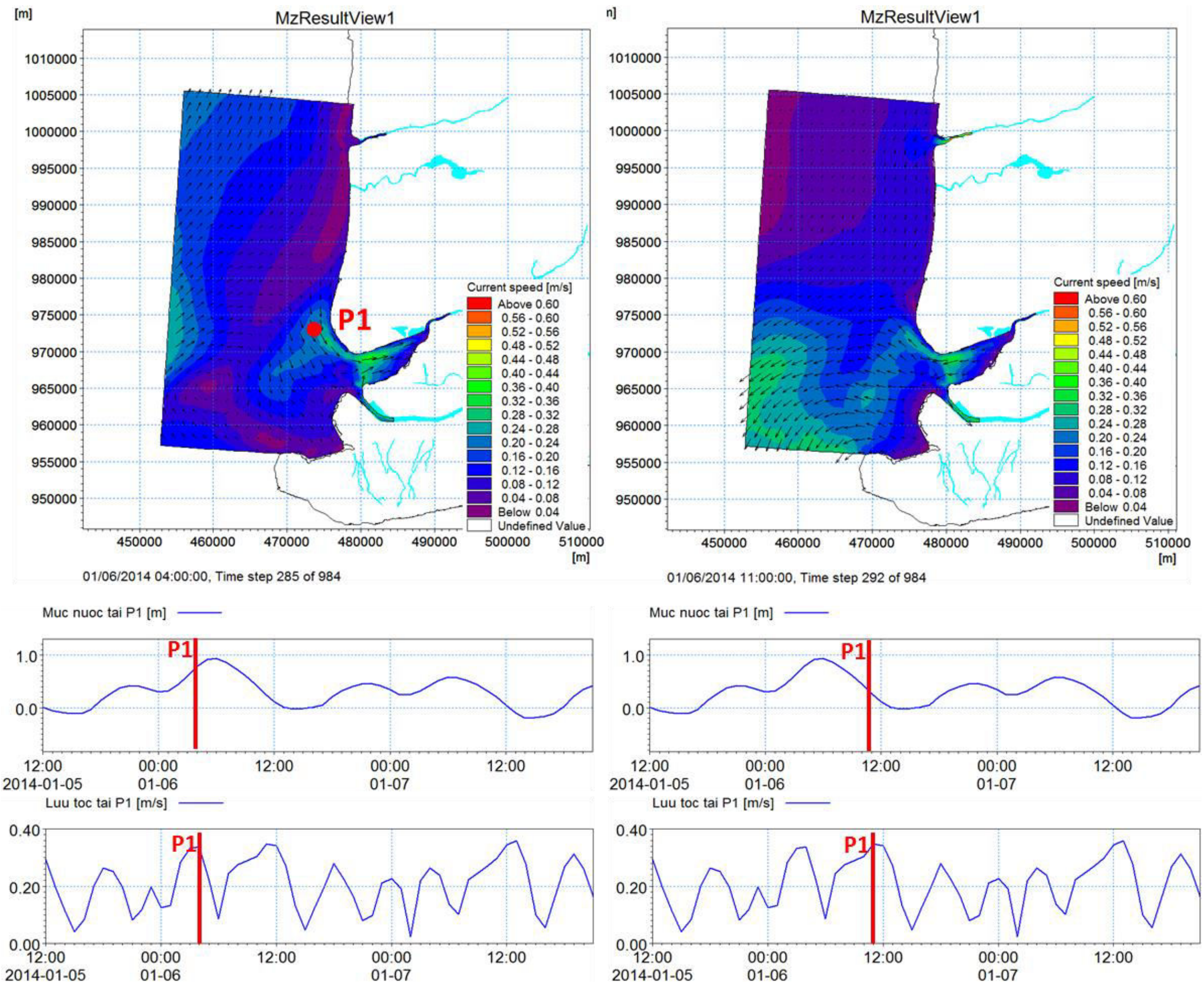
5. Simulation results of the non-structure measure

5.1 Flow regime

The study area is less affected by the hydrodynamic regime of the Mekong River system therefore tidal currents from the sea dominate. Tidal regime in the West Sea is dominated by the diurnal tide regime, with a tidal range much lower than the East Sea tide, is only 0.7 ÷ 1.0 m. The highest coastal flow is 0.36 m/s at rising tide and 0.38 m/s at falling tide

Figure 5-1 indicates the flow field at rising and falling tide at 4 and 11 o'clock of January 6th, 2014. Figure 5-2 expresses the extract locations for detail analysis.

The current roses at the locations P1 ÷ P4 is shown in Figure 5-3 and Figure 5-4. The currents along the coast of Phu Tan direction is mainly south to north in the NE monsoon and north to south in the SW monsoon.



(a) (b)

Figure 5-1 Distribution of current field at the coastal studied area at the rising tide (a) and at the falling tide (b) (belows are the water level and current at P1 at extracting time and corresponding to current field above)

Figure 5-2 Extraction location in the study area for analysis

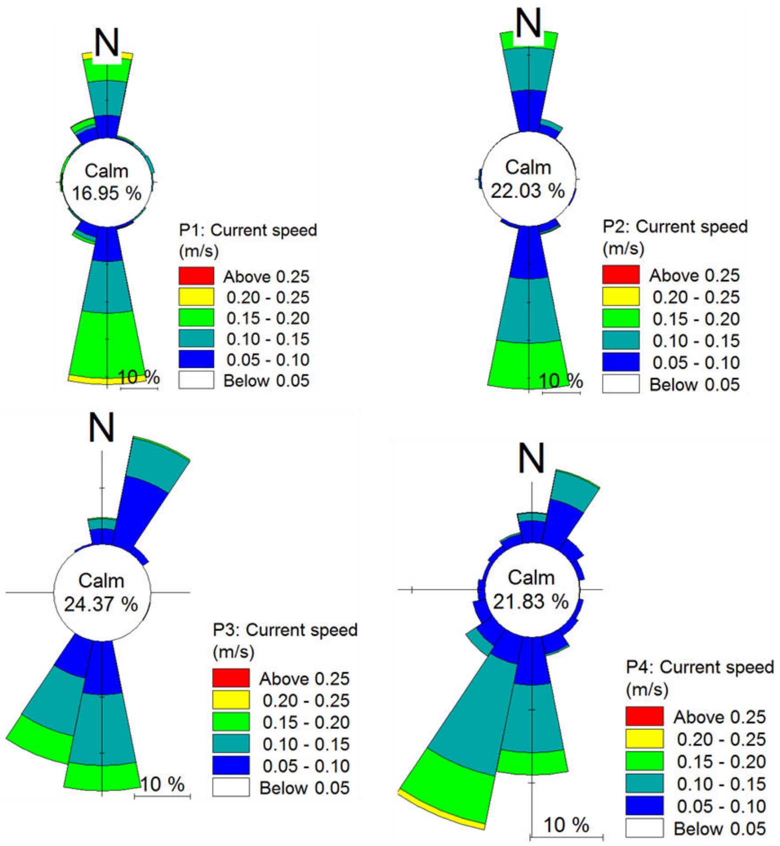


Figure 5-3 Current roses at positions P1 ÷ P4 with computational time period is from 25/12/2013 to 5/2/2014 (NE monsoon)

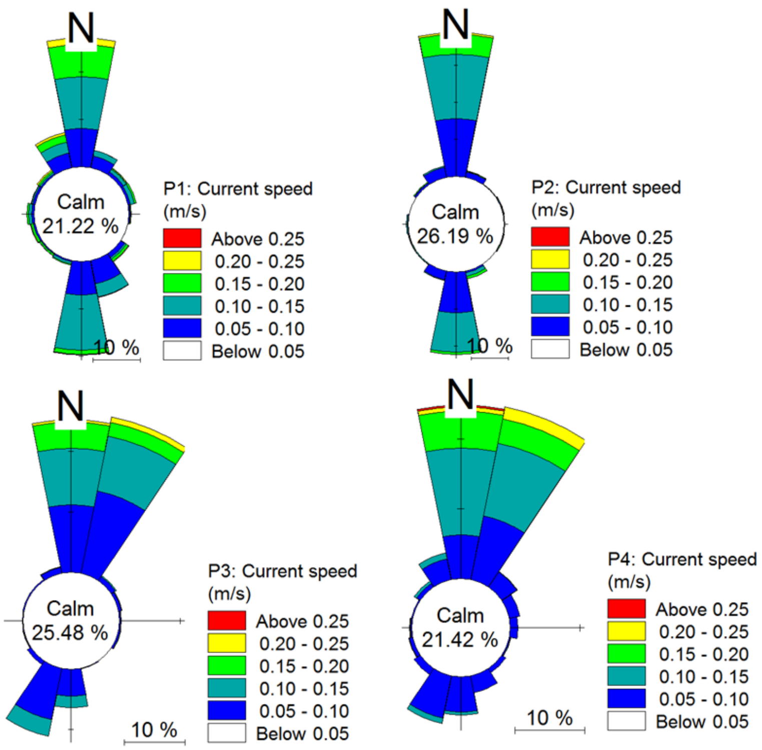


Figure 5-4 Current roses at positions P1 ÷ P4 with computational time period is from 25/8/2014 to 5/10/2014 (SW monsoon)

5.2 Wave regimes

Figure 5-5 indicate wave climate in the SW and the NE mosoon of the study area.

Figure 5-6 and Figure 5-7 shows the results of wave roses calculated at positions P1 ÷ P4 in the SW monsoon and NE monsoon. This result shows that the wave height during the SW monsoon is much higher than the one in the NE monsoon.

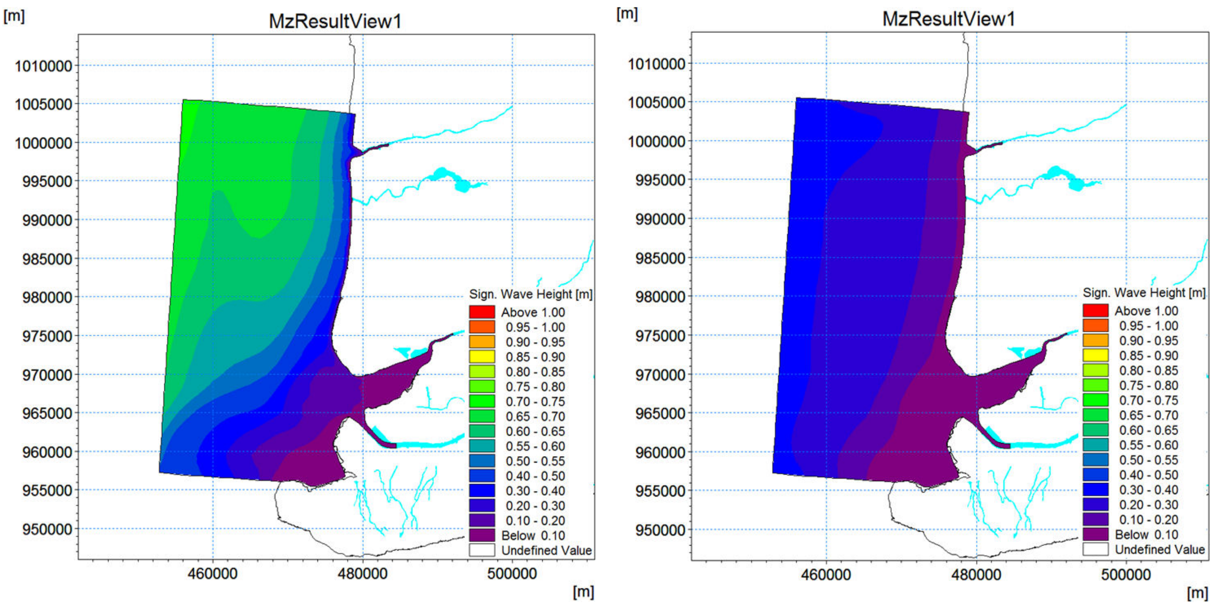


Figure 5-5 Wave climate in the SW monsoon (September 2014) (left) and NE monsoon (January 2014) (right)

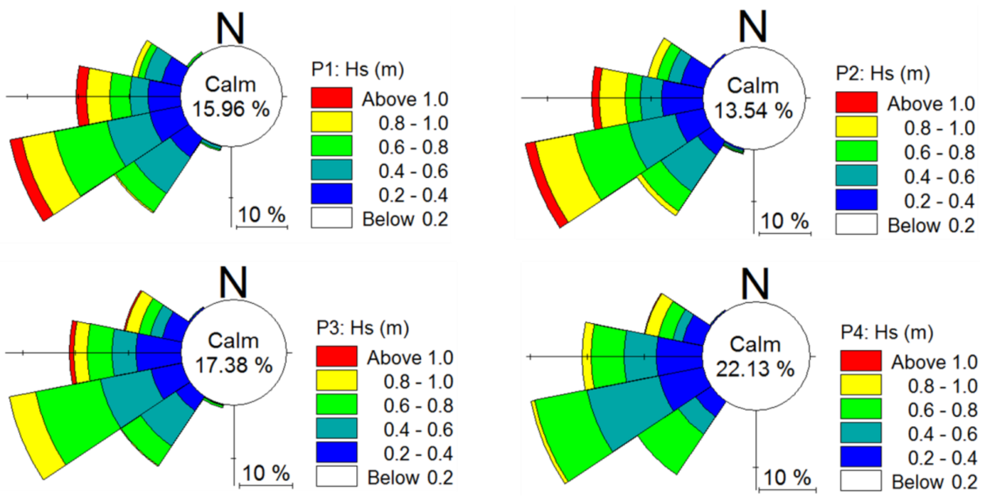


Figure 5-6 Wave roses at P1, P2, P3 and P4 in the SW monsoon (September 2014)

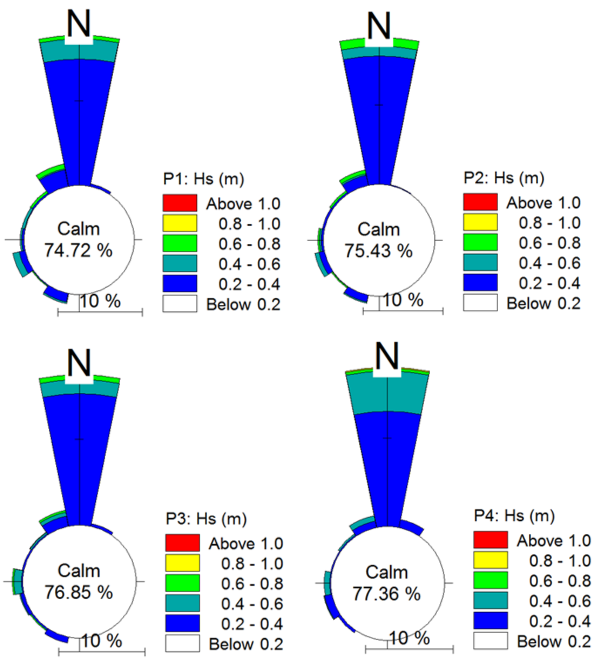


Figure 5-7 Wave roses at P1, P2, P3 and P4 in the NE monsoon (January / 2014)

6. Impacts of breakwater

6.1 Breakwater scenarios

The breakwater and its configuration is presented in Figure 6-1 and Table 6-1. As lession learned from the Go Cong study area, the different impacts of difference gaps of two breakwaters (Lg) are not much, therefore only KB2 is considered. From the impacts of hard concrete breakwater in Ca Mau, there is no need to have T shape but only I shape instead.

Table 6-1 Protection measure configurations

No	SCENARIOS	Senario description	BREAKWATER CONFIGURATION			
			Lengh (Ls) (m)	Distance from shoreline (Y)(m)	Gap between two breakwater (Lg) (m)	Crest elevation of breakwater (m)
1	KB0	Baseline				
2	KB3	Breakwaters	600	300	70	1.1

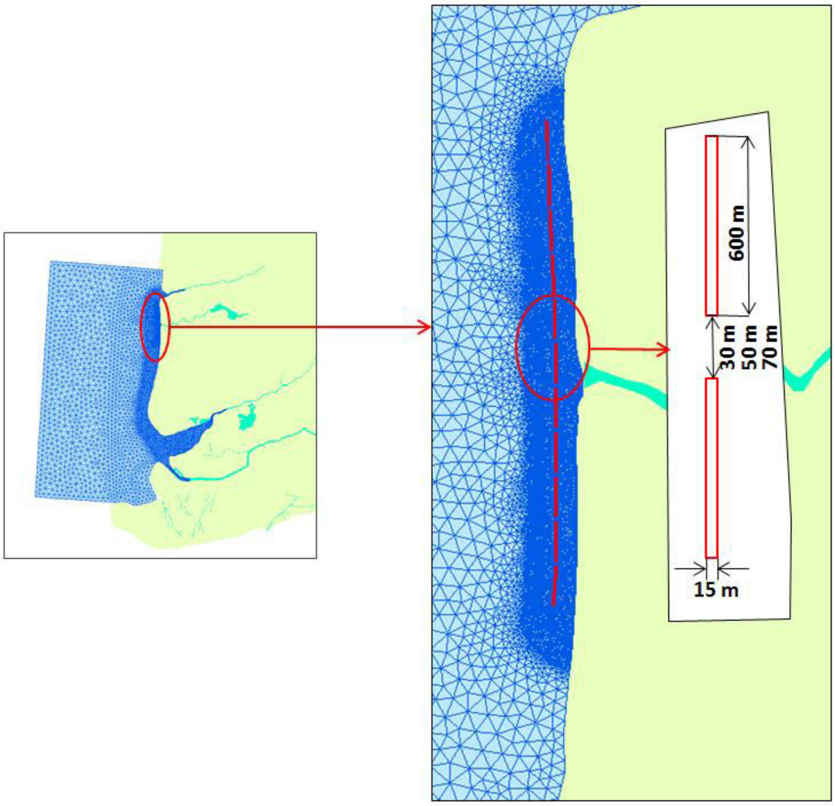


Figure 6-1 Detail meshes and protection measure of T shape breakwaters

6.2 Impact of breakwater in flows, waves

The beakwaters can reduce flow and wave in the same principle of the effect of breakwaters in Go Cong area and are not presented for detail.

6.3 Impact on morphology

The morphological change in KB0 and KB2 scenarios after 1 month of simulation of the NE monsoon (25/12/2013 ÷ 5/2/2014) and SW monsoon were presented in Figure 6-11 and Figure 6-12. During the NE monsoon, the breakwater impacts are not significant due to low wave as well as low SSC in the area. In the SW monsoon, due to high wave and high SSC, the impact of breakwaters are much more comparing to the NE monsoon.

To study the morphological impact in more detail, an area 1 from the shoreline to 2 km offshore and the length of 7 units of breakwater (length of 4.6 km) is considered the erosion and accretion volumes, maximum erosion depth (at gap site) and average erosion/accretion thickness.

The calculation results of erosion and accretion volume, after 1 month in the NE and SW monsoon are presented in Table 6-2 and Table 6-3 respectively. Table 6-4 combined the NE and SW monsoon results. It can be seen from Table 6-4 that after 2 months of typical monsoon seasons, the breakwaters can trap sediment of an average of 0.7 cm for the area from the shoreline to 2 km offshore. However, the breakwater also caused toe's erosion to the maximum of 0.5 m for 2 typical months.

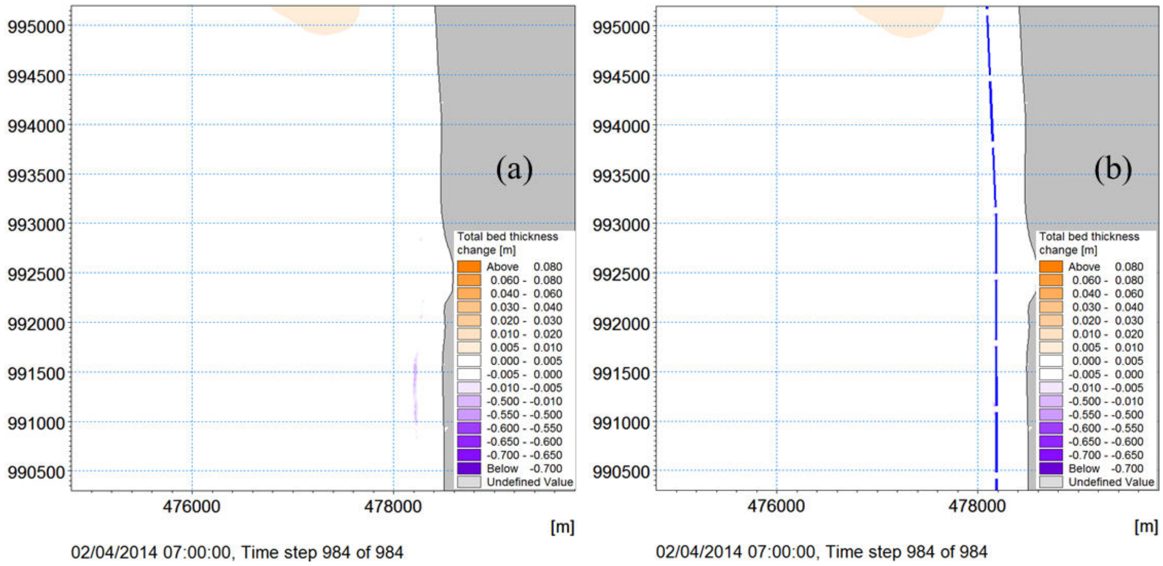


Figure 6-11 Distribution of erosion and accretion after one monthof NE monsoon (January 2014)of scenarios (KB0 (a) KB3 (b))

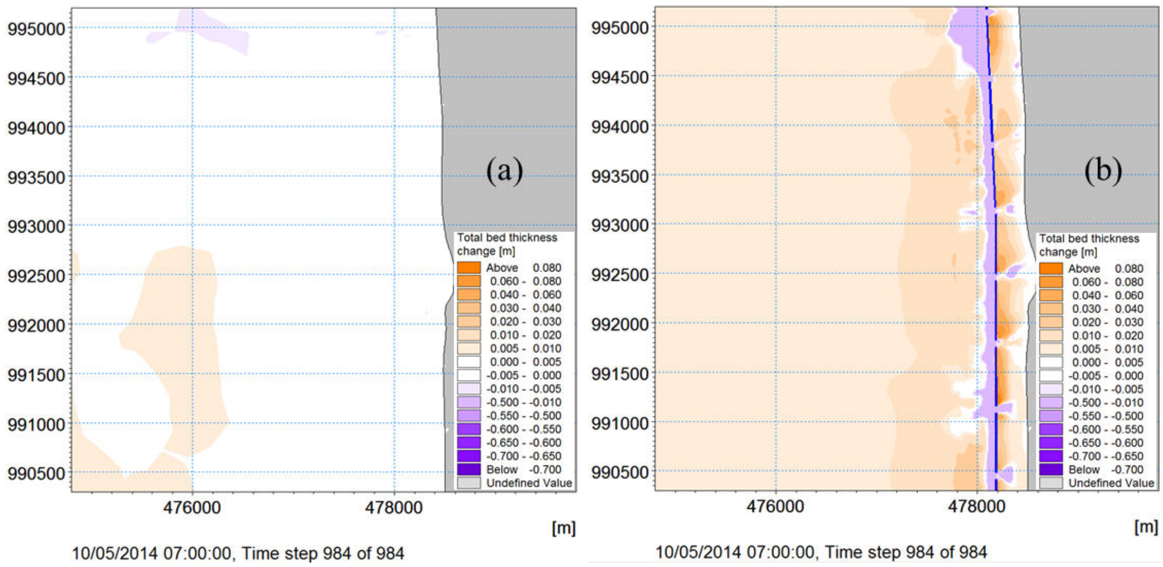


Figure 6-12 Distribution of erosion and accretion after one month of SW monsoon (September 2014)of scenarios (KB0 (a) KB3 (b))

Table 6-2 Total accretion and erosion in study area after one month in the NE monsoon (25/12/2013 ÷ 5/2/2014) of scenarios

January - 2014							
Scenarios	**Area 1**						
	Vol. (10^6 m3)		**Aveg THK (m)**		**Net Vol. (Mm3)**	**Max Ero. depth (m)**	**Everage thickness (m)**
	Accr.	**Ero.**	**Accr.**	**Ero.**			
KB0	0.0128	-0.0009	0.0014	-0.0001	0.012	-0.028	0.0013
G70(KB3)	0.0126	-0.0004	0.0014	0.0000	0.012	-0.112	0.0013

Table 6-3 Total accretion and erosion in study area after one month in the SW monsoon (25/8/2014 ÷ 5/10/2014)

September - 2014							
Scenarios	Area 1						
	Vol. (10^6 m3)		Aveg THK (m)		Net Vol. (Mm3)	Max Ero. THK (m)	Everage thickness (m)
	Accr.	Ero.	Accr.	Ero.			
KB0	0.0045	-0.0053	0.0005	-0.0011	-0.001	-0.011	-0.0001
G70(KB3)	0.1037	-0.0384	0.0112	-0.0041	0.065	-0.500	0.0070

Table 6-4 Net volume (Mm3) and maximum erosion thickness (m) with various scenarios

Scenarios	Area 1				Combined January and September 2014 of Area 1		
	Jan.2014		Sep.2014		Vol. (Mm3)		Everage thickness (m)
	Net Vol. (Mm3)	Max Ero. Thickness (m)	Net Vol. (Mm3)	Max Ero. Thickness (m)	Net Vol. (Mm3)	Max Ero. depth (m)	
KB0 (Baseline)	0.012	-0.028	-0.001	-0.011	0.011	-0.028	0.001
G70(KB3)	0.013	-0.167	0.031	-0.500	0.077	-0.500	0.007

7. Impact of sandbars

7.1 Methodology

Due to the MIKE21 model cannot run cohesive and non-cohesive sediment in one scenarios, we treated them in two steps.

The first step we run the model of sand transport assuming that the morphological changes in the vicinity area are negligible, then only the sandbar deformation is considered. Fortunately the deformation of sandbar is not high so that we can go to the second step. Otherwise, the sandbar scenarios are not considered further.

The second step we run the model of mud transport, assuming that the average cross section of the deformation sandbar in the first step are unchanged. That means the sandbars now become "concrete" breakwater when morphological changes are considered the impact of sandbars.

7.2 Sandbar scenarios

Sandbar scenario was studied as expressed in Table 7-1 and Figure 7-1.

Table 7-1 Sandbar configuration for Go Cong study area

No	Scenarios	Description	Sandbar configuration/dimensions (m)				
			Leng	Distance of 2 units	Distance from shoreline	Width of sandbar	Top elevation
2	KB2	Sandbar was made from 500 m from the shoreline offshore	1000	200	500	120	0.0

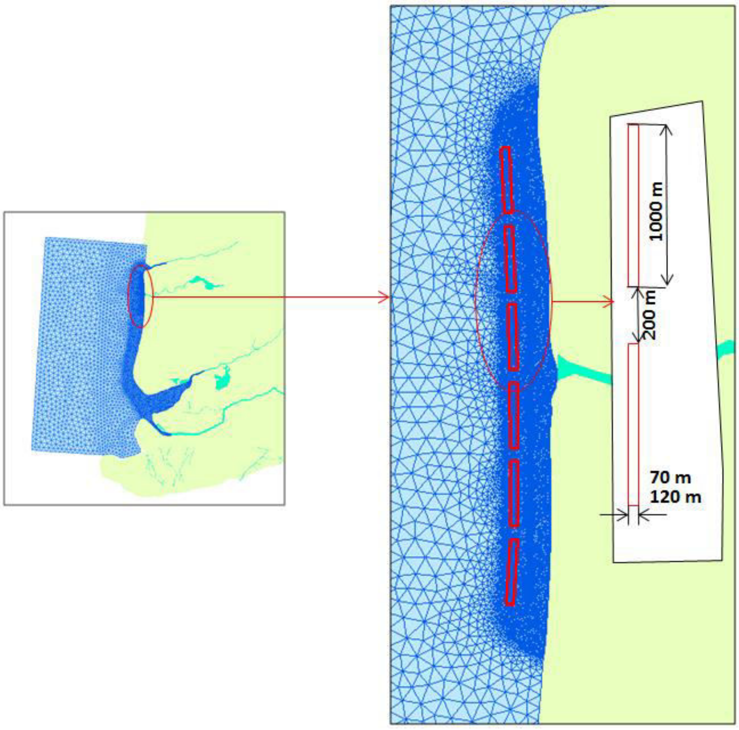


Figure 7-1 Sandbars in the study model at Phu Tan, Ca Mau province

7.3 Calibrate the sandbar deformation in 21FM (HD&SW&ST) model

The deformation of sandbars in the physical models were presented the result of physical model test. In this section, numerical sand transport model is set up to calibrate sandbars deformation. Model set up is expressed in Figure 7-2. The smallest grid size is 2 m.

In general, the deformation rates of the numerical model and physical model were similar. One scenario, for example presented in Table 7-2 and Figure 7-3.

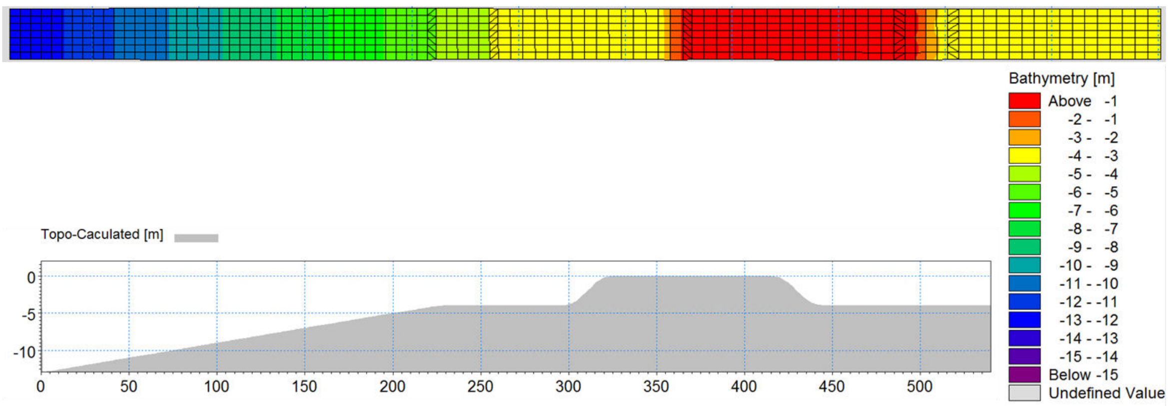


Figure 7-2 Numerical model 21FM (HD&SW&ST) set up for sandbar deformation calibration

Table 7-2 Typical scenario for 21FM (HD&SW&ST) model calibrate

Tên kịch bản	MODEL					PROTOTYPE				
	B (m)	Rc (m)	Hm0 (m)	Tp (s)	Dura (min)	B (m)	Rc (m)	Hm0 (m)	Tp (s)	Dura (hrs)
WP6-NOU-B5-R15-JSW2	5	-0.15	0.1	1.53	80	100	-3	2	6.84	9.32

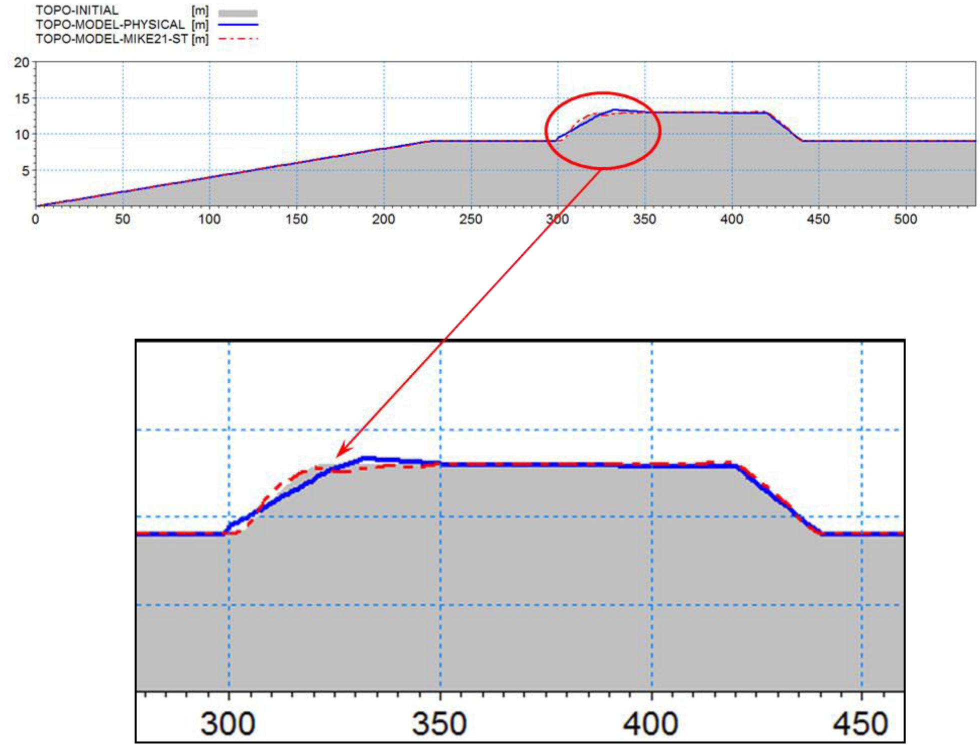


Figure 7-3 Calibration result of 21FM (HD&SW&ST) with typical scenario WP6-NOU-B5-R15-JSW2

7.4 Impact of sandbars

7.4.1 Current impacts

Figure 7-10 and Figure 7-11 compared flow rose of the baseline and KB2 scenarios. It can be seen due to the sandbar installation, both flow in the NE and SW monsoon are significant reduced.

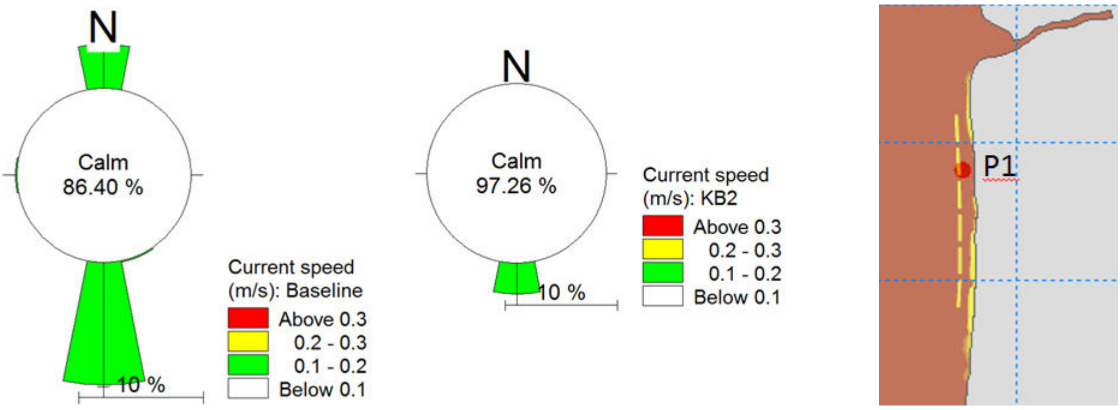


Figure 7-4 Comparison of flow rose at position P1 for baseline and KB2 scenario during NE monsoon (25/12/2013 ÷ 5/2/2014)

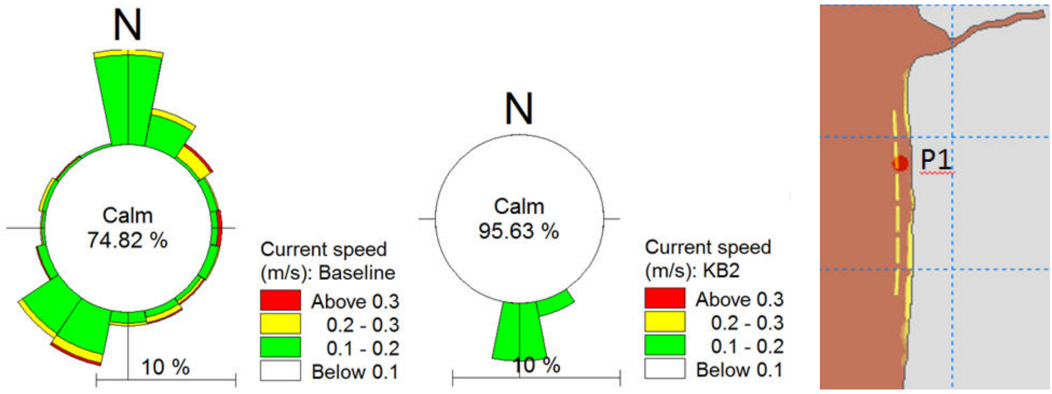


Figure 7-5 Comparison of flow rose at position P1 for baseline and KB2 scenario during SW monsoon (25/8/2014 ÷ 5/10/2014)

7.4.2 Wave impacts

Figure 7-12 and Figure 7-13 compared the wave roses of baseline and KB2 scenarios. It can be seen due to the sandbar installation, both wave in the NE and SW monsoon are significant reduced.

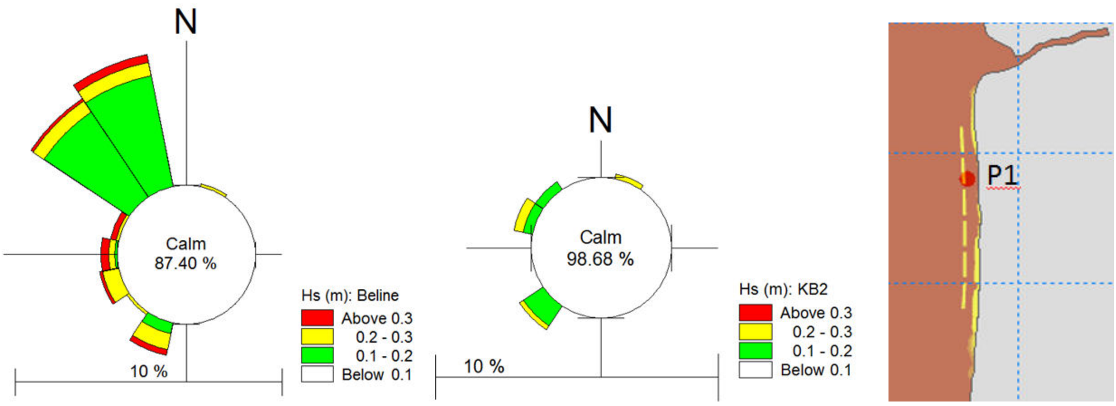


Figure 7-6 Comparison of wave rose at position P1 for baseline and KB2 scenario during NE monsoon

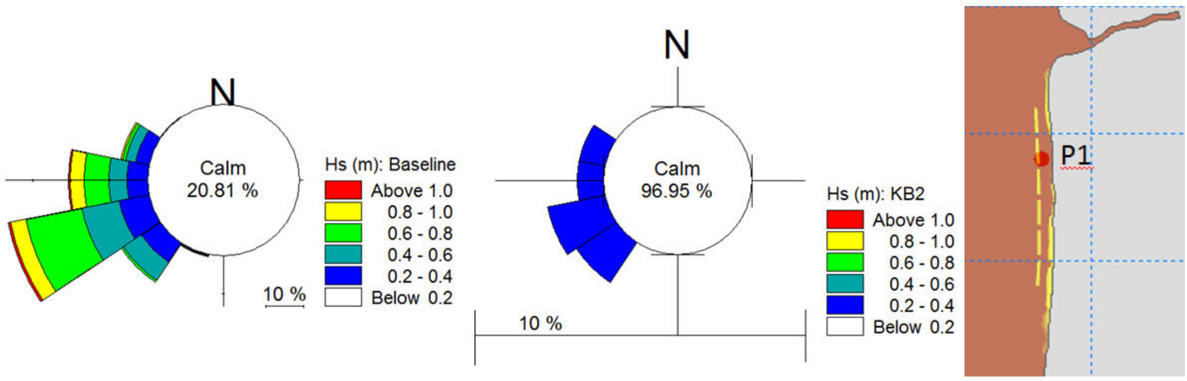


Figure 7-7 Comparison of wave rose at position P1 for baseline and KB2 scenario during SW monsoon

7.4.3 Morphological impacts

This section we discuss the morphological changes of sandbar impacts where sandbars are considered to be "concrete breakwater" and using MIK21FM-MT (as mentioned in part a)).

Figure 7-8 and Figure 7-9 compared the morphological variation after one month in the NE monsoon (January 2014) and one month in the SW monsoon respectively.

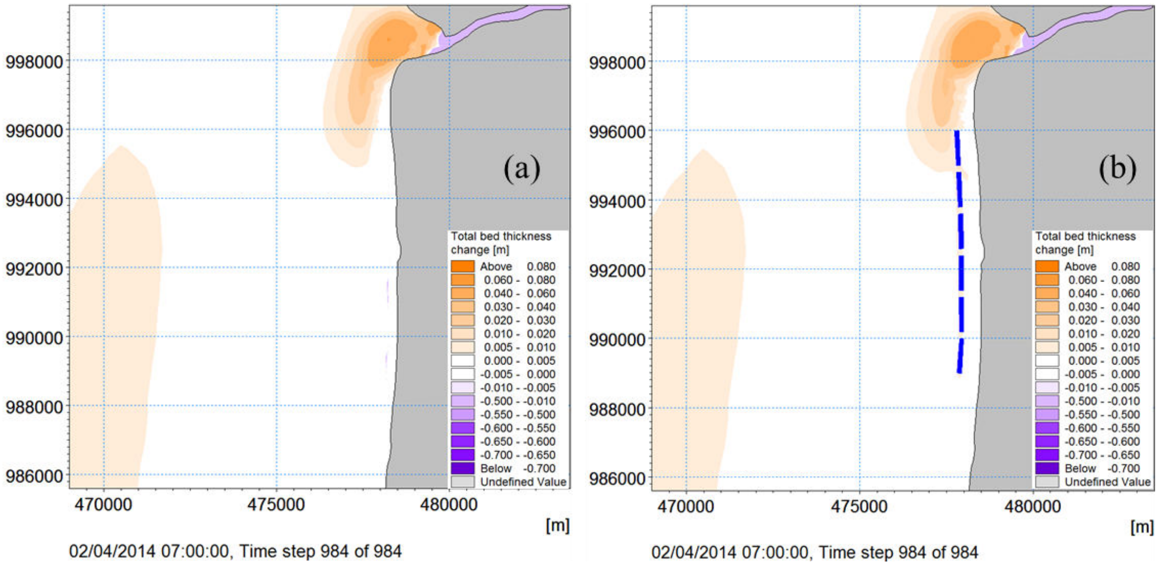


Figure 7-8 Distribution of erosion and accretion after one month of NE monsoon (January 2014) of scenarios (KB0 (a) KB2 (b))

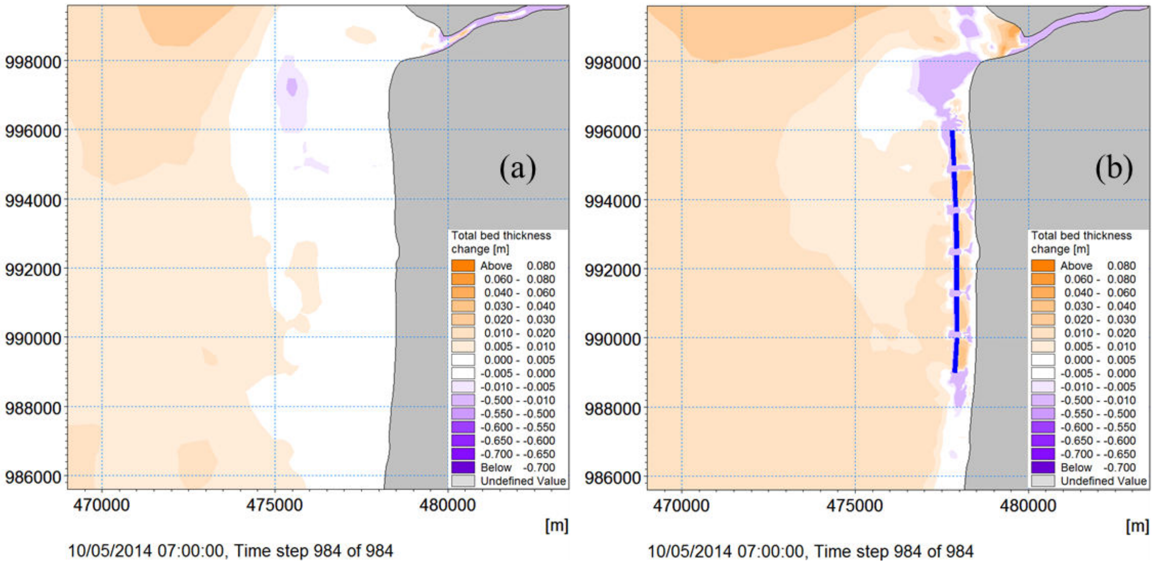


Figure 7-9 Distribution of erosion and accretion after one monthof SW monsoon (September 2014)of scenarios (KB0 (a) KB2 (b))

To study the morphological impact in more detail, an area 1 from the shoreline to 2 km offshore and the length of 4 units of sandbars (length of 4.6 km) is considered the erosion and accretion volumes, maximum erosion depth (at gap site) and average erosion/accretion thickness.

Table 2-5 and Table 2-6 showed the impacts of sandbars (B=120m) in NE and SW monsoon. Table 2-7 combined the NE and SW monsoon results. It can be seen the accretion trend in the NE monsoon and erosion in the SW monsoon (last column of the tables). The sandbar (with of

120 m, crest level of 0.0 m) can trap sediment for 2 months in the NE and SW monsoon of the everage thickness of about 5 mm comparing with 1 mm of non-measure.

Table 7-3 Morphological changes of sandbar impact after one month in the NE monsoon (January 2014)

Jan-2014							
Scenarios	Area 1						
	Vol. (10^6 m3)		Aveg THK (m)		Net Vol. (Mm3)	Max Ero. depth (m)	Everage thickness (m)
	Accr.	Ero.	Accr.	Ero.			
KB0	0.013	-0.001	0.001	-0.0001	0.012	-0.028	0.0013
B120 (KB2)	0.017	-0.005	0.002	-0.0005	0.013	-0.167	0.0014

Table 7-4 Morphological changes of sandbar impact after one month in the SW monsoon (September 2014)

Sep-2014							
Scenarios	Area 1						
	Vol. (10^6 m3)		Aveg THK (m)		Net Vol. (Mm3)	Max Ero. depth (m)	Everage thickness (m)
	Accr.	Ero.	Accr.	Ero.			
KB0	0.005	-0.005	0.0005	-0.001	-0.001	-0.011	-0.0001
B120(KB2)	0.087	-0.055	0.0093	-0.006	0.031	-0.500	0.0034

Table 7-5 Net volume (Mm3) and maximum erosion thickness (m) with sandbar scenarios

Scenarios	Area 1				Combined January and September 2014 of Area 1		
	Jan.2014		Sep.2014		Vol. (Mm3)		Everage thickness (m)
	Net Vol. (Mm3)	Max Ero. Thickness (m)	Net Vol. (Mm3)	Max Ero. Thickness (m)	Net Vol. (Mm3)	Max Ero. depth (m)	
KB0 (Baseline)	0.012	-0.028	-0.001	-0.011	0.011	-0.028	0.001
B120(KB2)	0.013	-0.167	0.031	-0.500	0.044	-0.500	0.005

7.5 Impact comparison of of breakwater and sandbars

Comparing with hard breakwater, the sandbar scenario is less effective with the accretion volume of 0.044 Mm3 whereas the hard breakwater can get 0.077 Mm3 for two typical NE and SW monsoon months of 2014 (see Table 7-6).

Other criteria will be compared such as the impact of sea level rise, changes of waves, sediment reductions from the Mekong river mouths (due to damming upstream countries), environment impacts (to be updated soon).

Table 7-6 Compare between sandbar and breakwater

Scenarios	Area 1				Combined January and September 2014		
	Jan.2014		Sep.2014		Vol. (Mm3)		Everage thickness (m)
	Net Vol. (Mm3)	Max Ero. Thickness (m)	Net Vol. (Mm3)	Max Ero. Thickness (m)	Net Vol. (Mm3)	Max Ero. Thickness (m)	
KB0 (Baseline)	0.012	-0.028	-0.001	-0.011	0.011	-0.028	0.001
Breakwater G70	0.012	-0.112	0.065	-0.500	0.077	-0.500	0.008
Sandbar B120	0.013	-0.167	0.031	-0.500	0.044	-0.500	0.005

8. CONCLUSION

With nesting approach, MIKE21 has been calibrated well from the Regional model to Local Model with water levels, discharges, tides, waves and currents, sediment transports especially the validation results based on the in-situ data of the LMDCZ project in October 2016 and February-March 2017.

These results in the Local model of LMDCZ are ready for creating the boundary conditions for the detail study areas of Phu Tan.

The impacts of hard breakwaters are the reducing of wave, current and increasing accretion in the protection area .

The impact of soft measure, that is the sandbar which is less effective than hard breakwater in trapping sediment (62.5%)

Both scenarios should be considered more in term of economic aspect.

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