

Simulation of parapet walls' benefits in local area of U-Minh

1. Introduction

Coastal monitoring data for U Minh reveals that erosion has increased in recent years. To mitigate this negative impact, many of the construction measures have been developed by the local authorities. Among these types of structures are parapet walls using various types of materials and structures that have been constructed along the shore. Monitoring data on the effect of these types of structures have been reported in recent years, which show that successes and failures are different from place to place depending on the location of the building. This study aims to simulate the effect of hardened parapet walls on the coast protection of the U Minh.



Figure 1: A typical form of parapet walls for coast protection

In order to study this erosion process, various numerical models are used simultaneously including Telemac2D (hydrodynamic), Tomawac (wave) and Sisyphe (sediment transport). The detailed computing mesh including parapet wall structure will focus on the zone from the Bay-Hap to Ong Doc River.

2. Study area and boundary conditions

The local area of interest is the western coastal area of the Mekong Delta, which is confined to the south, abutting the Gulf of Thailand. The average width is 40 km from the coast and 126 km from Ca Mau Cape to the north. This study area is characterized by 87 thousand unstructured triangle elements of which the largest mesh is up to 2000m (offshore elements) and the smallest is 8m (or 3m in case of built-in wavefronts) for the coastal zone. The wall location is approximately 400m from the shore, extends $L = 7000\text{m}$ and has a crest elevation above the highest water level in the area. The walls are installed almost parallel to the shore.

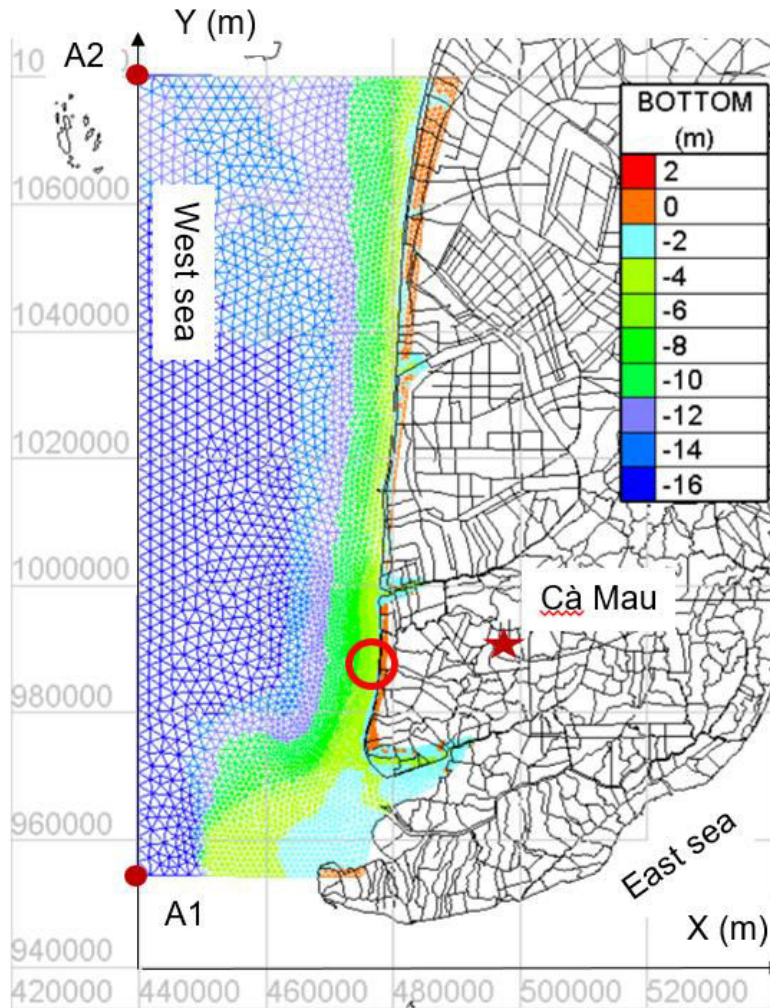


Figure 2.1a: Local study area

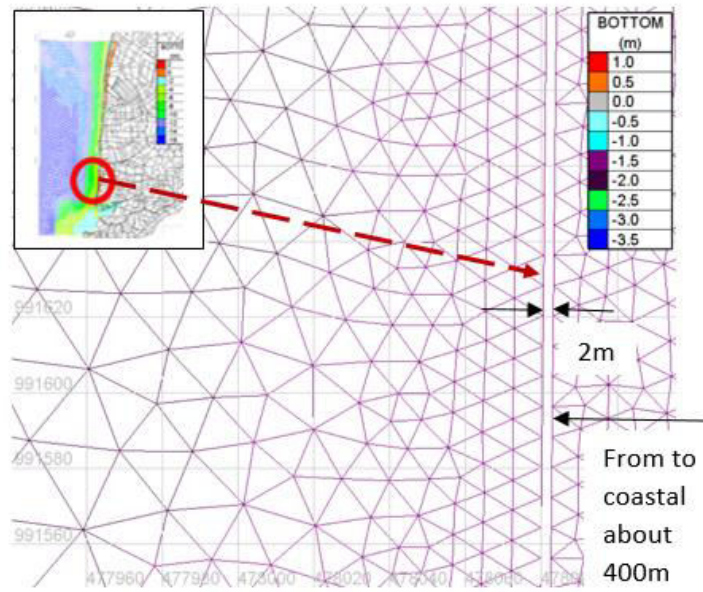


Figure 2.1b: Simulation of parapet walls in study area

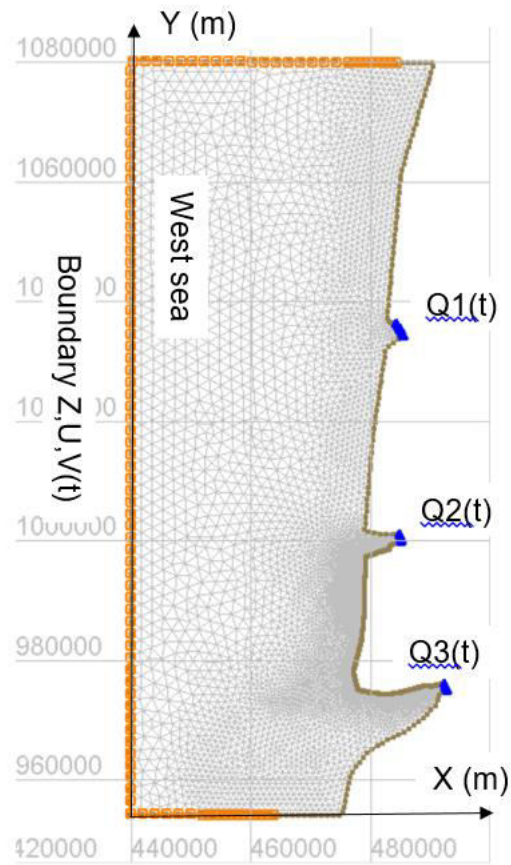


Figure 2.2: Boundary conditions

Tidal: The open boundary at offshore is determined from astronomical tide extracted from TPXO database during the study period.

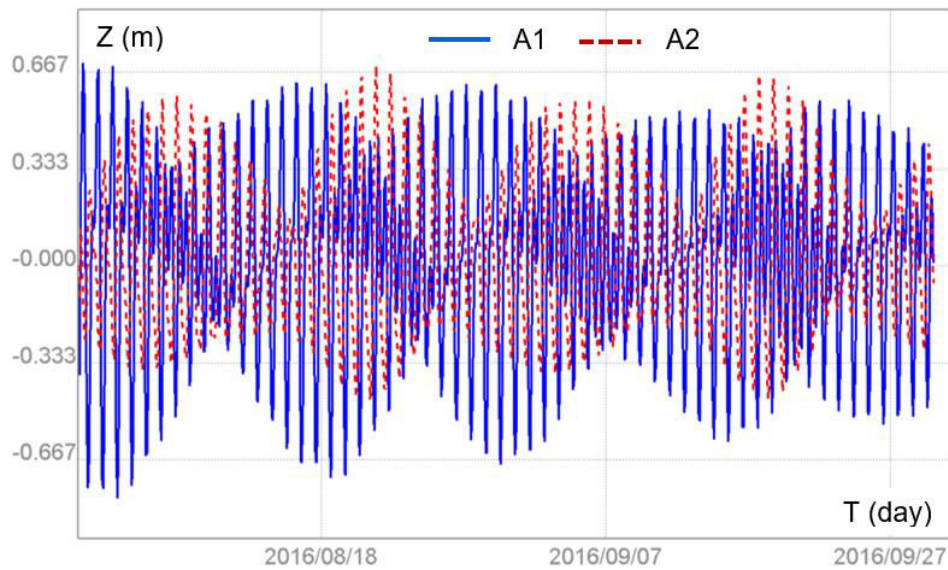


Figure 2.3: Tidal boundary at typical positions A1 and A2 during Aug. & Sep 2016

Wave: At the open boundary, wave data is determined from a global database of wind and wave effects on the surface domain determined from NOAA for the boundary conditions of the Tomawac model.

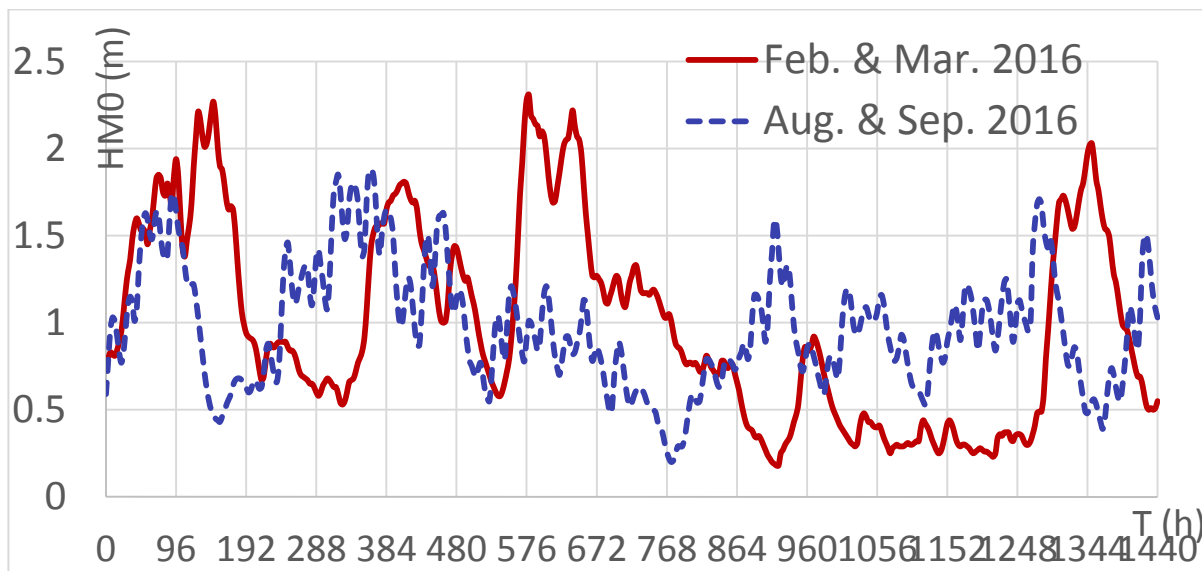


Figure 2.4a: Wave height HMO from NOAA at coordinates (334682.9 ; 884599.1)

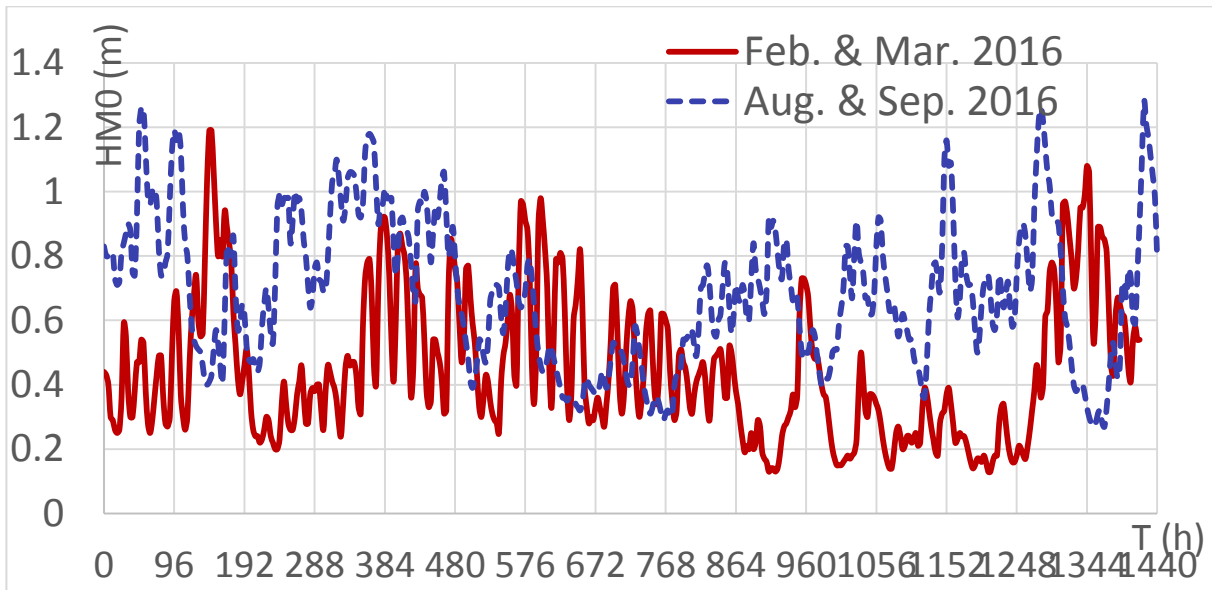


Figure 2.4b: Wave height HM0 from NOAA at coordinates (335343.7 ; 1050487.3)

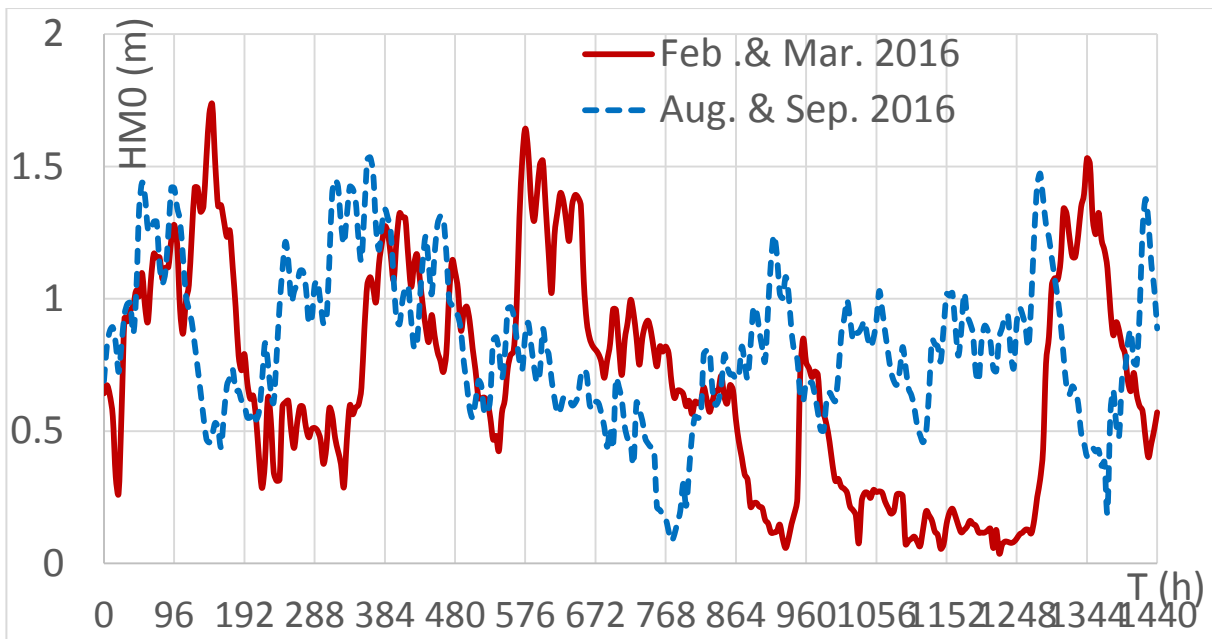


Figure 2.4c: Wave height HM0 from NOAA at position A1 of coordinates (439869.6 ; 954419.1)

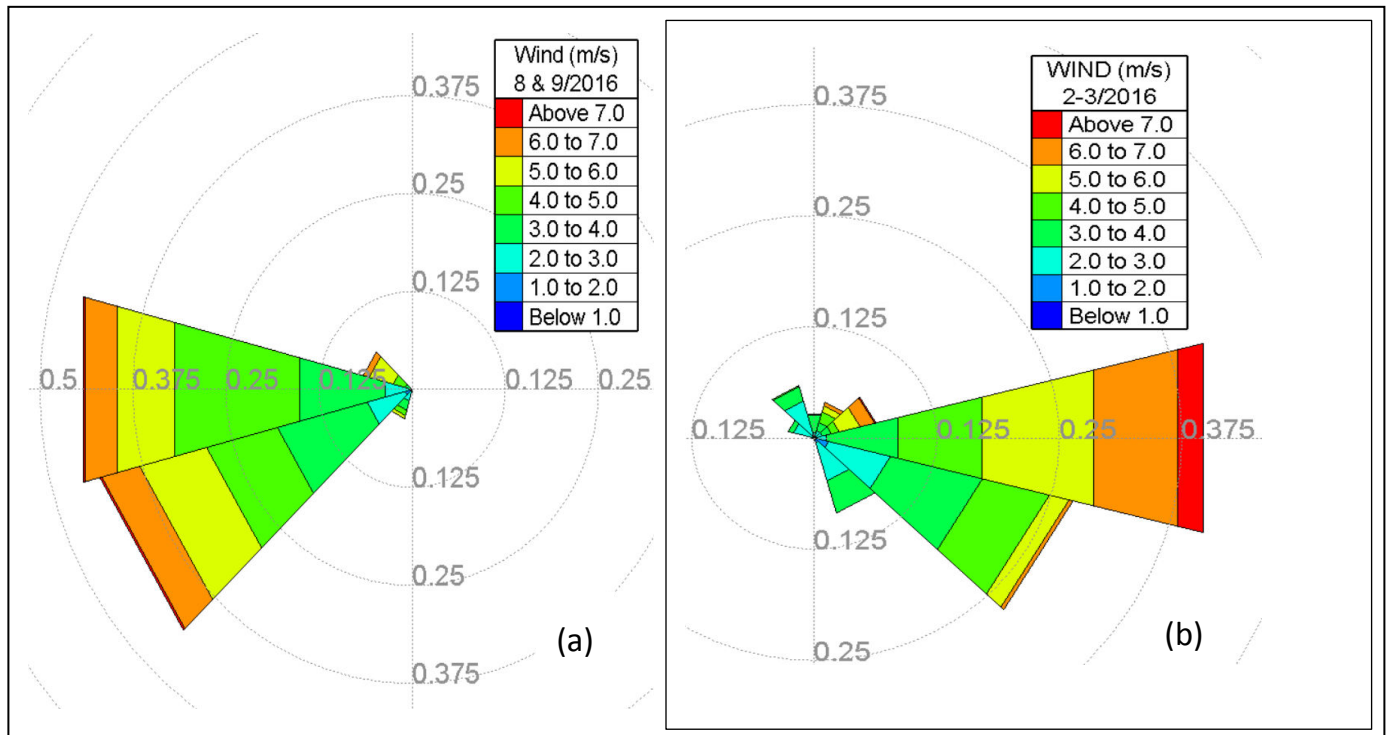


Figure 2.5: Typical wind rose in U-Minh coast in: (a) 8-9 /2016 and (b) 2-3/2016

The results from the wind rose show that these are two distinctly monsoonal periods. In the months of January & February, the winds are relatively intense compared to August and September. Wind direction in January & February is mainly from the East, while in August and September; it is mainly in the west and southwest.

Discharge: Discharge in Ong-Doc river are taken as follow:

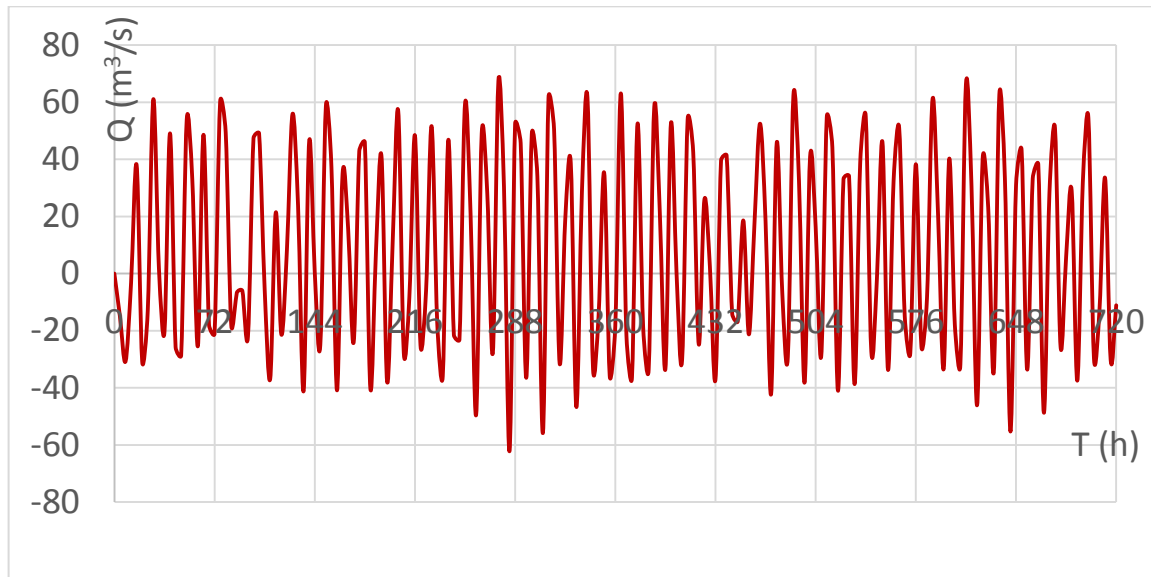


Figure 2.6: Discharge in Aug 2016 at Ong-Doc river

Sediment

Simulation of sediment transport in the area is considered as non-cohesive transport. The distribution of sand is assumed to be uniform throughout the study area. From the monitoring data of granular, the particle size is divided into four representative sizes: 0.06mm, 0.125mm, 1.0 mm, 1.5mm; with the initial rates of 40%, 30%, 20% and 10%.

The boundary conditions are:

- The open offshore boundary is free and balance condition.
- In the upstream areas, the boundary conditions are specified of Dirichlet type with the monitoring level.

The main parameters of simulation are as follows:

- The law of friction according to Nicuradse
- The bottom sediment transport model according to Soulsby - Van Rijn
- The settling velocity is determined by the Van Rijn, depending on the characteristic of the sediment layer.
- The value of the Shield taken by the Rijn Valves depends on the dimensionless dimension of the sediment classe.

3. Simulation results

Simulations are made for two representative seasons: the southwest monsoon season and the northeast monsoon season. Each simulation season lasts for 2 months:

- West-South monsoon season: 8-9 / 2016
- East - North monsoon season: 2-3 / 2016

a. Hydrodynamic

The results show that the flow tends to go from Ca-Mau cap to the north. Simulation results for the local area indicate a trend of mainstream going from the East Sea to the West Sea.

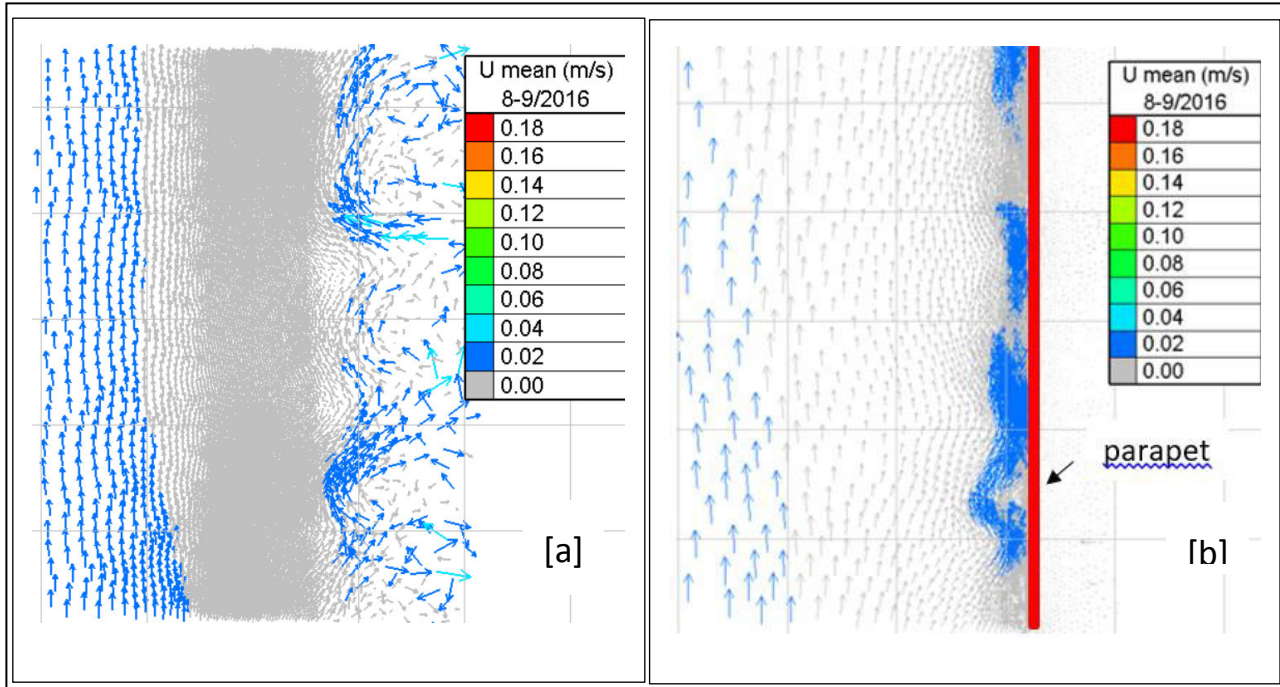


Figure 3.1: Field of average velocity in 8-9/2016 at coast.

(a) without parapet; (b) with parapet.

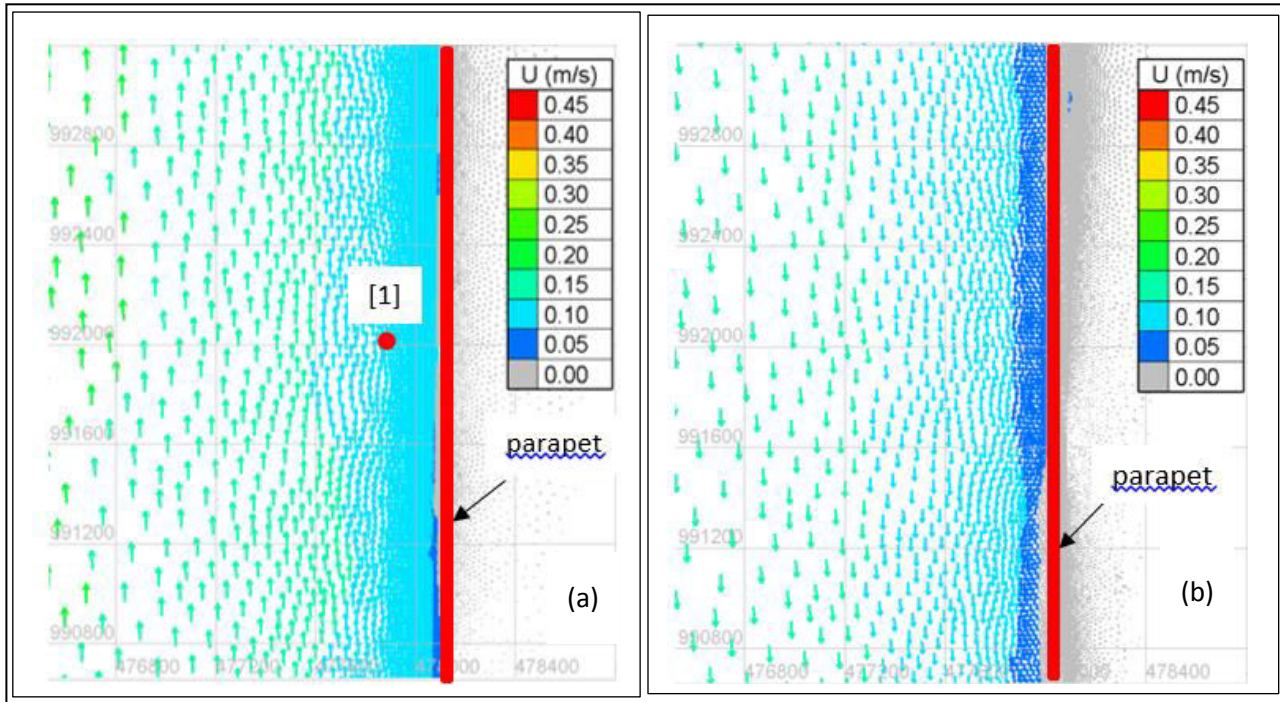


Figure 3.2: Field of instantaneous velocity at typical coastal position.

(a) at 10h, 17/9/2016; (b) at 18h, 17/9/2016.

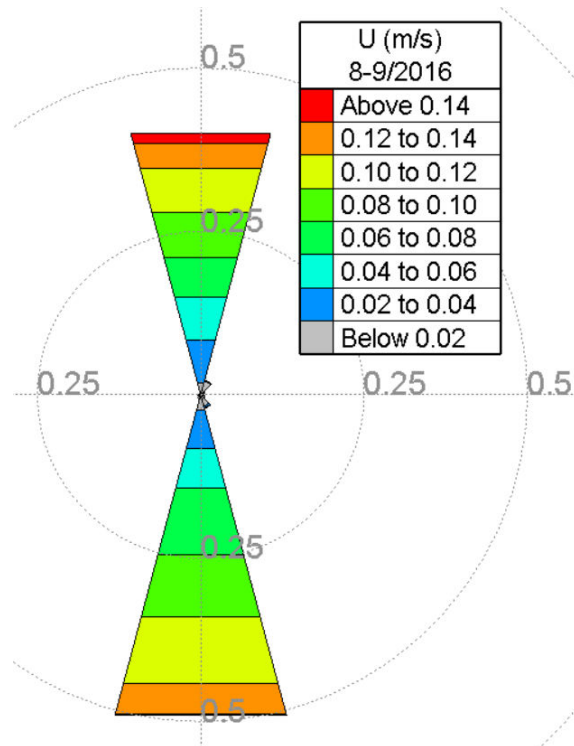


Figure 3.3: Distribution of flow velocity in 8-9/2016 at typical coastal position [1].

Comments on field of average velocity are as follow:

- The average field velocity in both cases with walls and without walls did not change much in the area outside the wall (Figure 3.1).
- The instantaneous velocity field in the domain varies in two main directions, North and South, which are closely related to tidal fluctuations in the region (Figure 3.2).
- With the presence of walls, the coastal flow almost disappeared inside of the wall. The main flows in the coast follow the north and south direction (Figure 3.3). This result does not change with and without walls.

b. Waves

Waves in the local model are described from boundary conditions in the West Sea extracted from the NOAA global wave data. In addition, the waves are also created by the effects of the wind on the surface of the domain. Wind data is also collected from NOAA. In this model, these wave and wind data are changed over time and space.

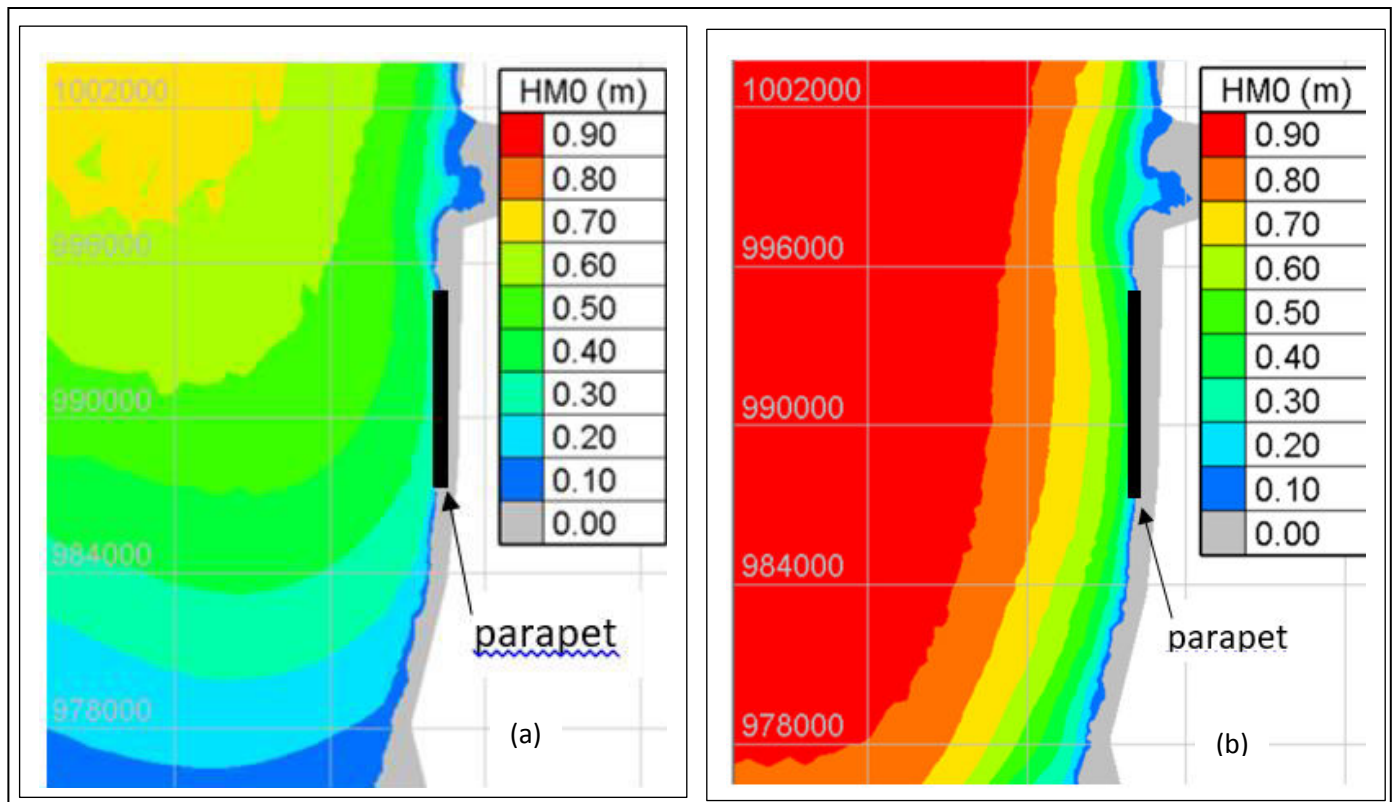


Figure 3.4: Instantaneous wave height HMO (m): (a) at 12h, 19/9/2016; (b) at 12h, 21/9/2016

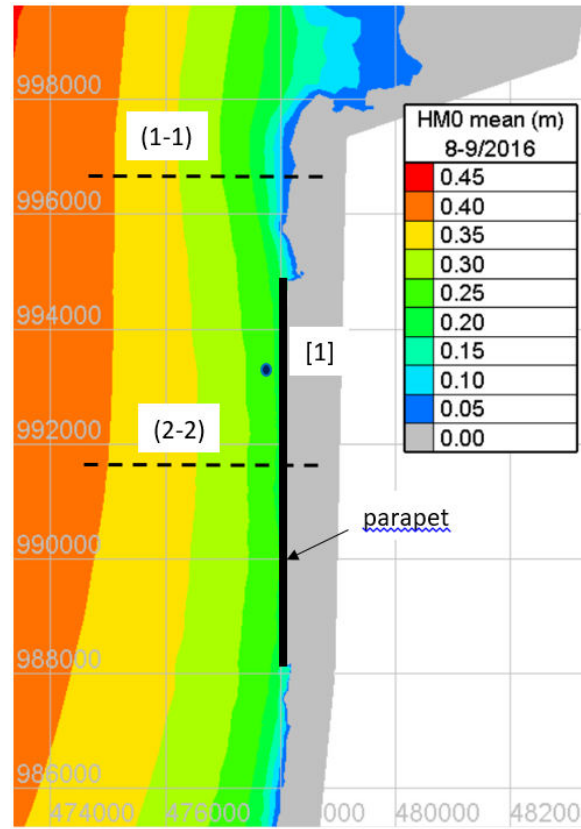


Figure 3.5: Average wave height HM0 (m) in 8-9/2016

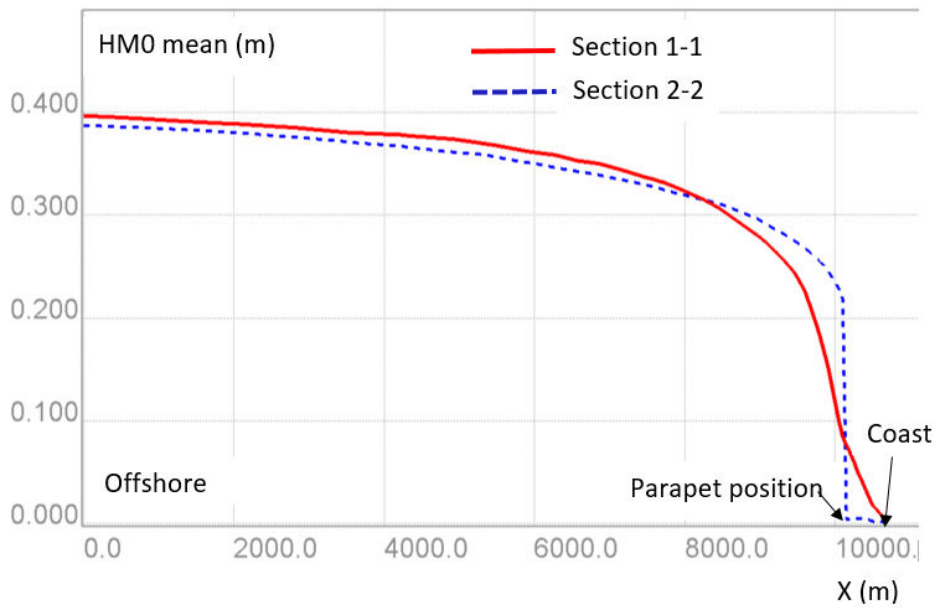


Figure 3.6: Variation of average wave height HM0 (m) in 8-9/2016 at sections 1-1 & 2-2

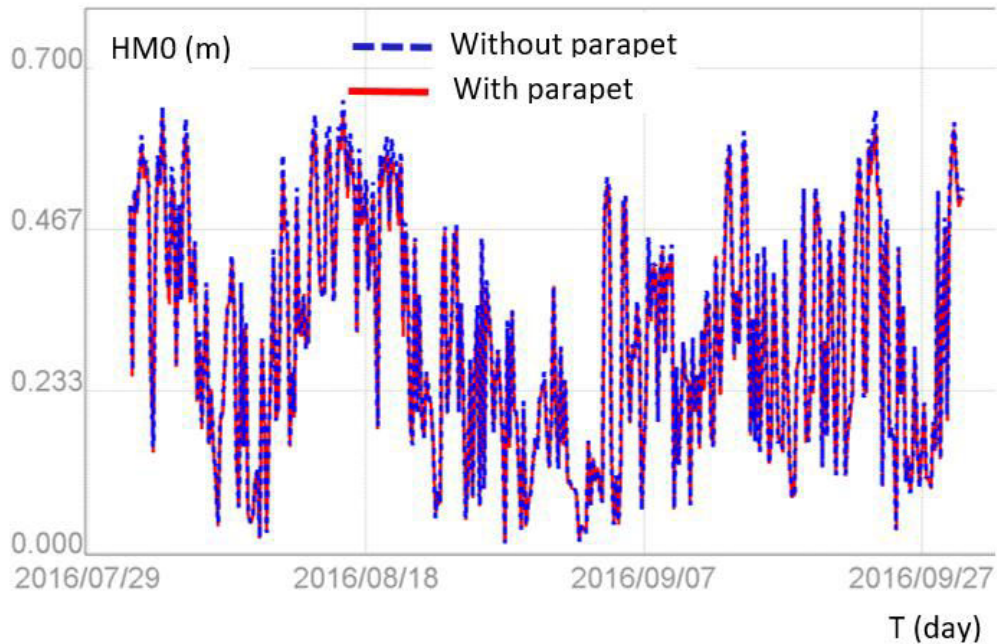


Figure 3.7: Variation of wave height $HMO(t)$ over time at typical positions [1] in two cases: with (continuous red line) and without (dashed blue lines) walls.

Some general comments about waves in the domain area are as follows:

- With the construction of wall structures with crest above the sea level, the effect of blocking waves approaching the coastal area is radical. The erosion phenomenon due to this factor is therefore also excluded (Figure 3.4).
- The wave reduction effect of parapet is described in Fig. 3.6. The waves are almost eliminated behind the wall.
- Waves at the front of the wall are almost unchanged in case with and without walls (position [1] in Figure 3.7).

c. Sediment transport

The results of sediment transport are determined from the combination of three equations, including hydrodynamics, waves, and morphological change. The sediment boundary at the sea is considered as a free zone for the movement of bed load and suspended sediment. Due to the limit of field data (bathymetry and sediments), this model only considers the confluences Bay Hap and Ong Doc. Concentration of suspended sediment is set at 150 mg / l.

Under the influence of the hydrological regime and U Minh coastal shores, satellite data for suspended sediments for the month were recorded as follows:

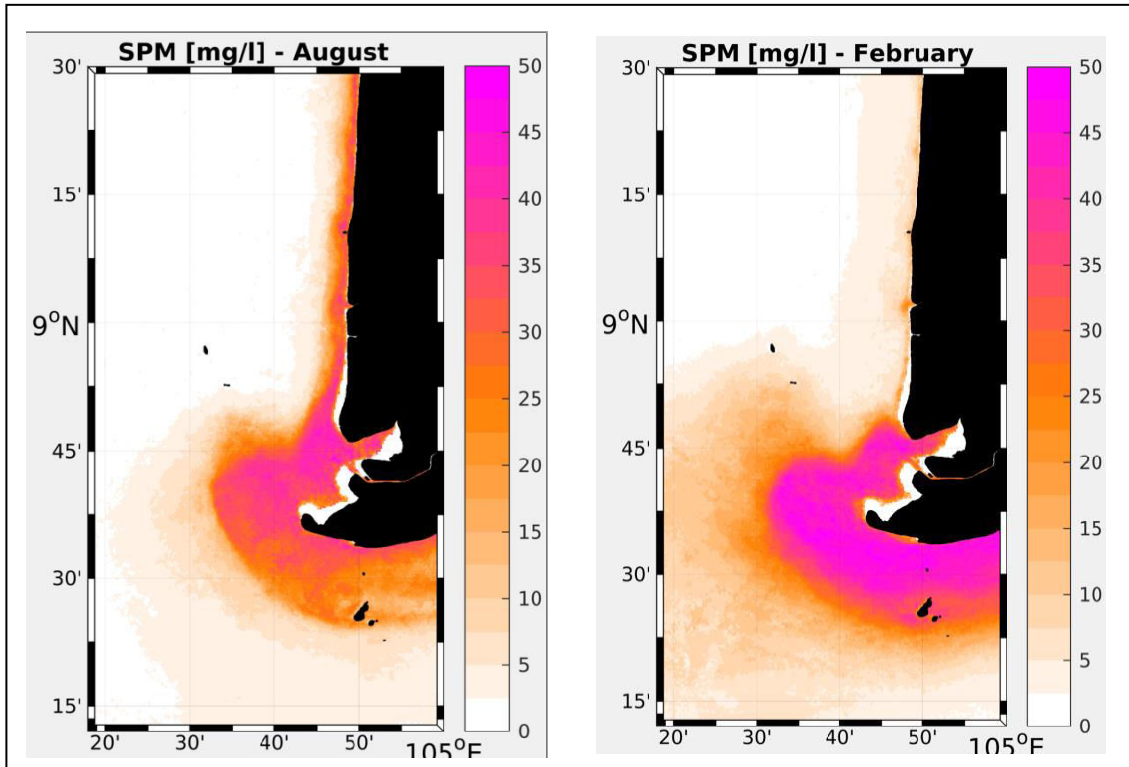


Figure 3.8: The typical average concentration of suspended sediment in August and February 2016 from the satellite data

The above graph shows the effect of coastal waves on the concentration of suspended sediment in the area. The following charts and graphs summarize the simulation results of sediment transport in the area.

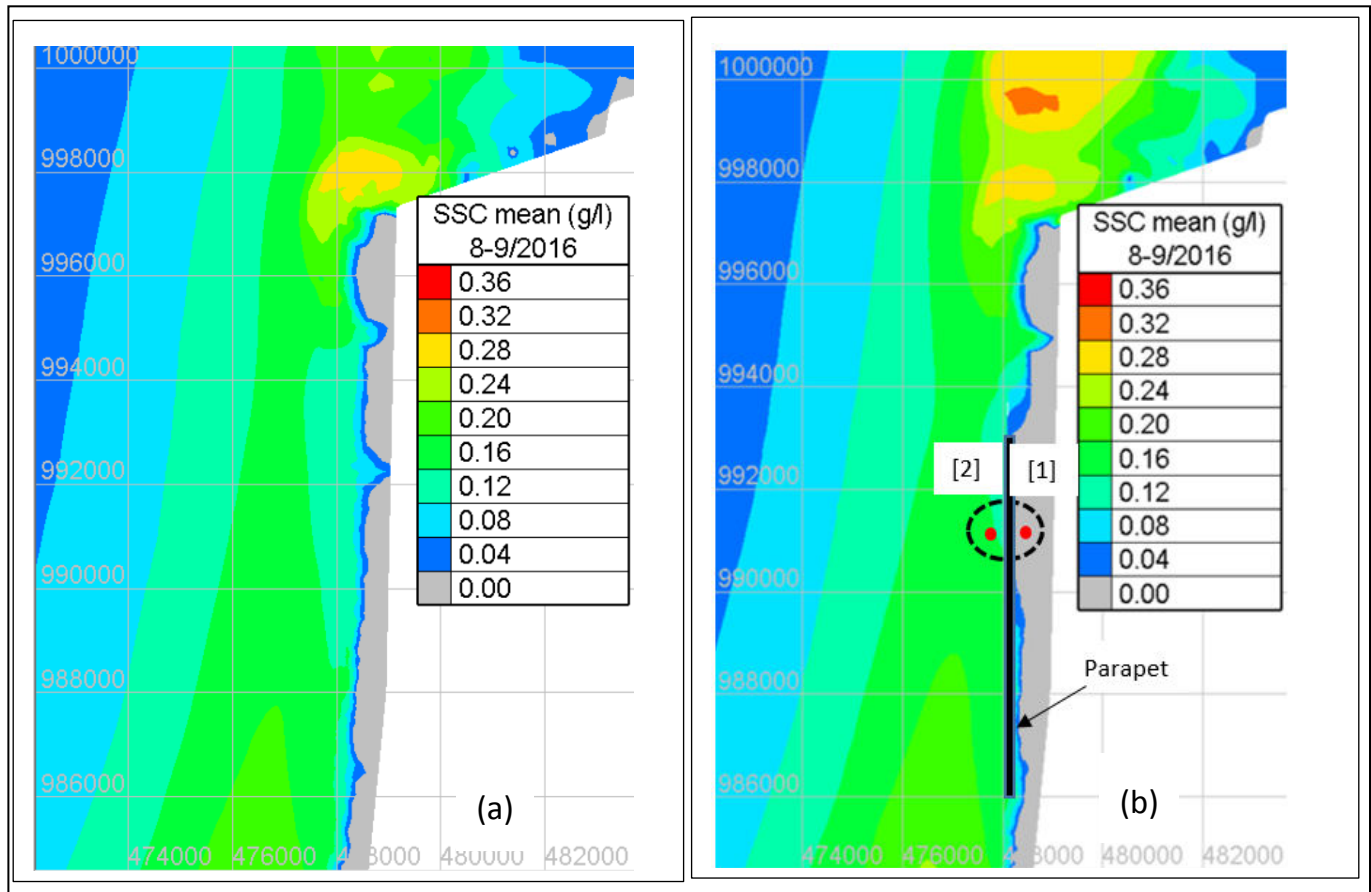


Figure 3.9: Average suspended sand concentration in 8-9/2016 : (a) without walls; (b) with walls

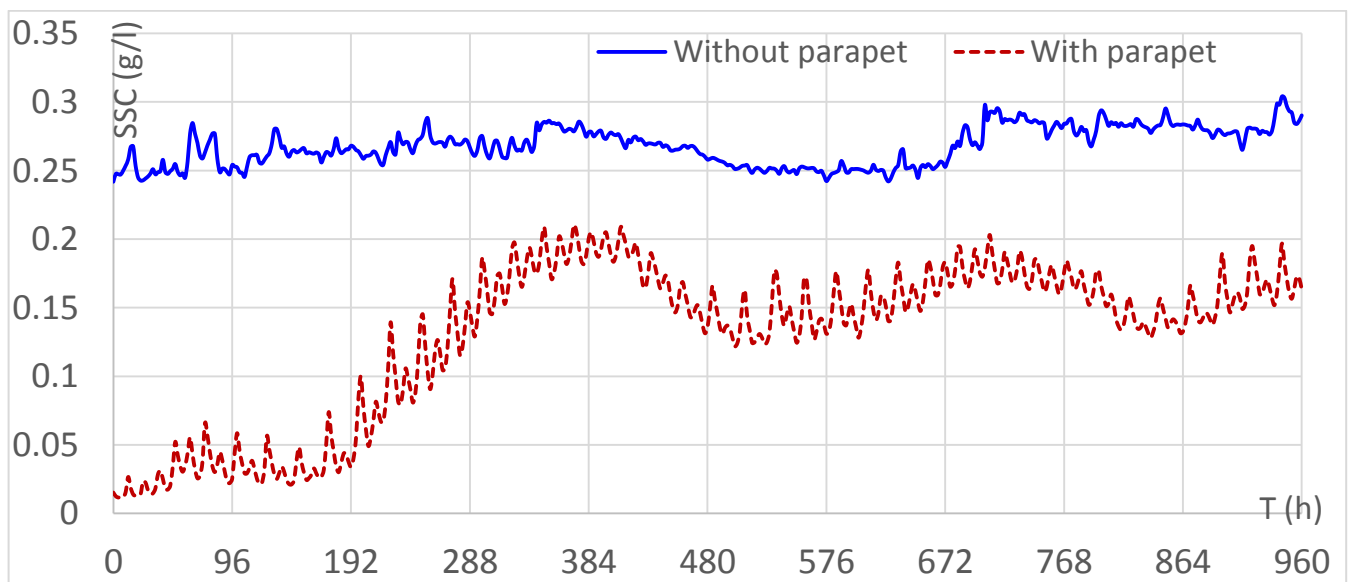


Figure 3.10: Instantaneous suspended sand concentration over time at position [1], behind walls

(a): without walls (dashed red lines); (b) with walls (continuous blue line).

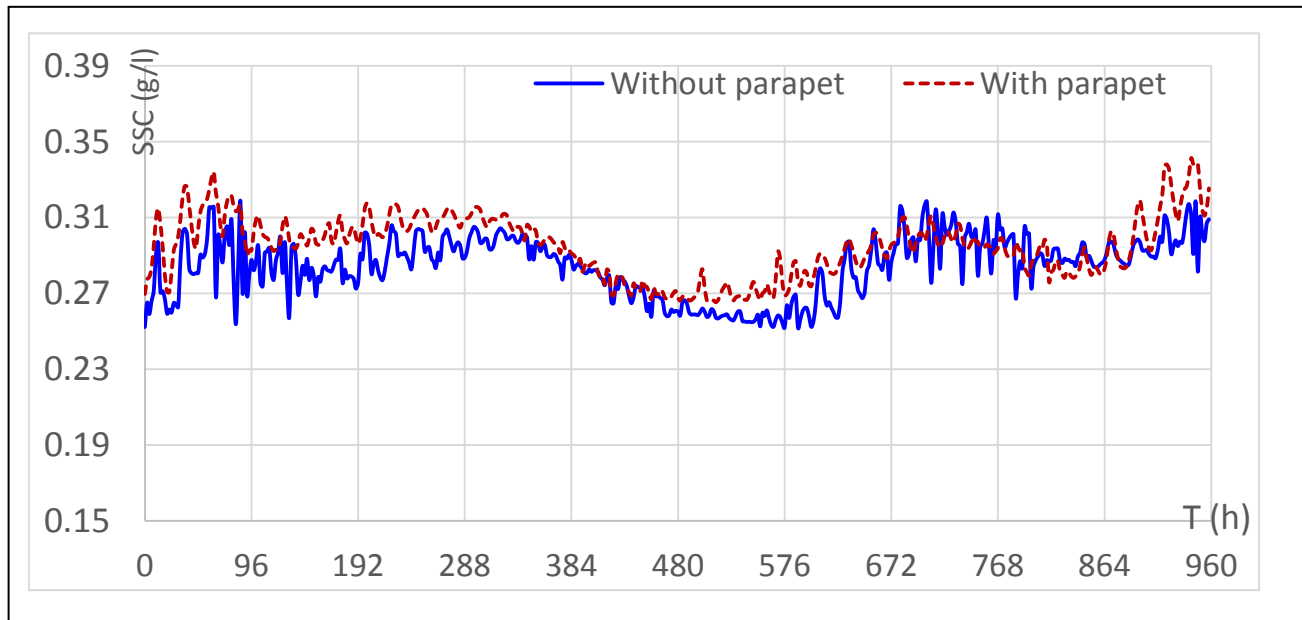


Figure 3.11: Average suspended sand concentration over time at position [2], in front of walls

(a): without walls (dashed red lines); (b) with walls (continuous blue line).

Comparing the results from the graphs gives the following conclusions:

- Coastal waves greatly affect the concentration of suspended sediment. This result was recorded from satellite imagery data and was explained by physical phenomena in which coastal breaking waves increase the concentration of suspended sediment under the effect of high intensity turbulent flows in this area.
- One can observe clearly that the parapet wall reduces the concentration of sediment, especially behind the wall, within the wall construction. In Figure 3.10, almost all of the shoreline is protected by parapet wall with a lower average sediment concentration than in other locations. This result may explain the wave attenuate effect and thus reduce the turbidity in this area.
- Figure 3.11 also shows that the suspended sediment concentration at a typical location in front of the wall in case of with and without walls does not change much comparing to back wall.

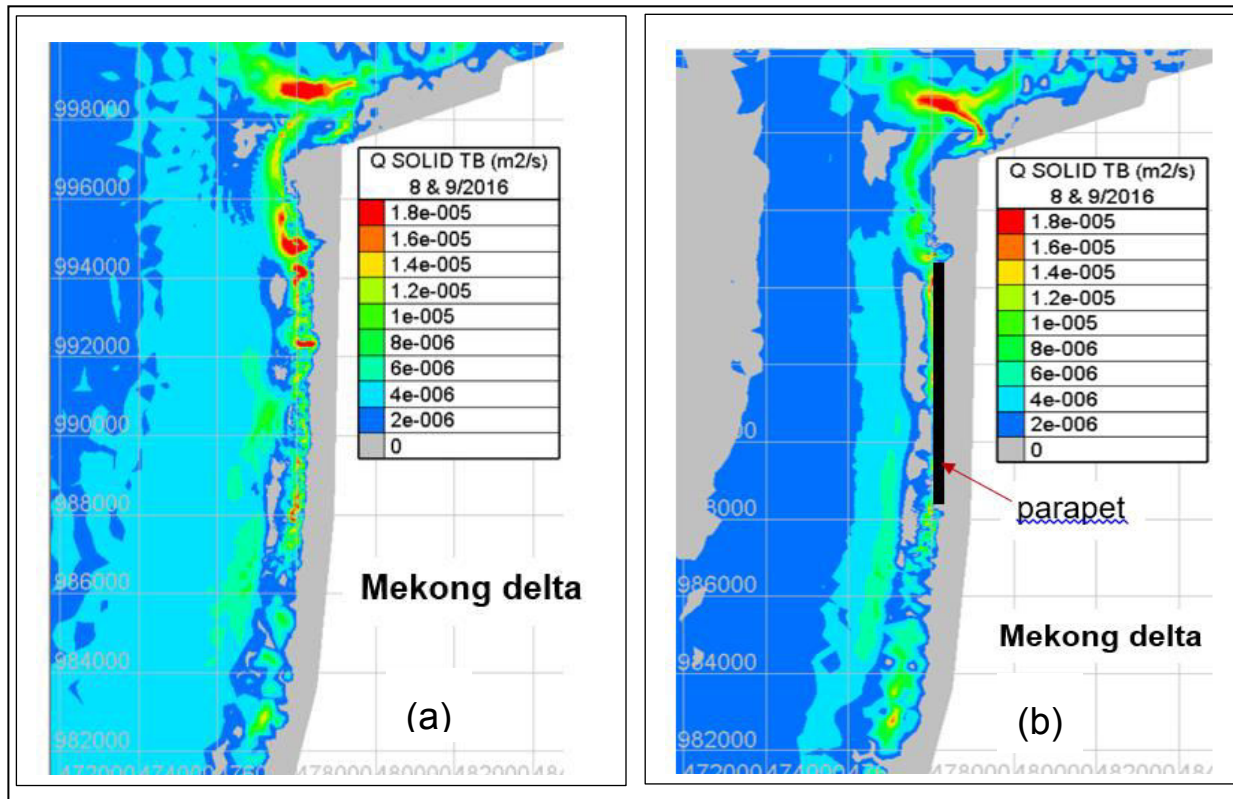


Figure 3.12: Average sediment fluxes in 8-9/2016: (a) without walls; (b) with walls

In order to quantify the sediment transport within the wall construction area, the sediment budget analysis in the front and behind walls will be conducted. The sediment budget analysis in typical area of $B=800m$ in width and $L=7000m$ in length will be conducted (see Figure 3.13).

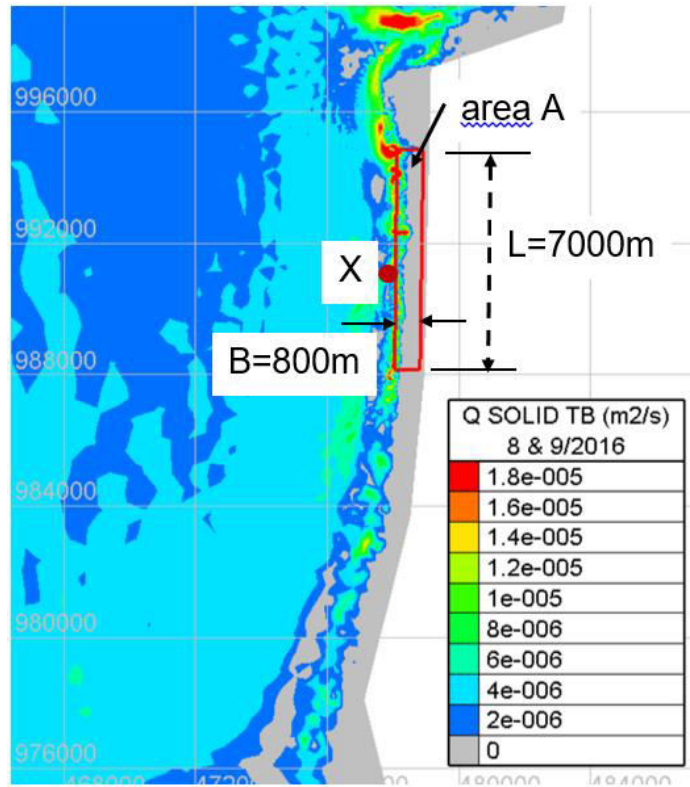


Figure 3.13: Area for sediment budget analysis

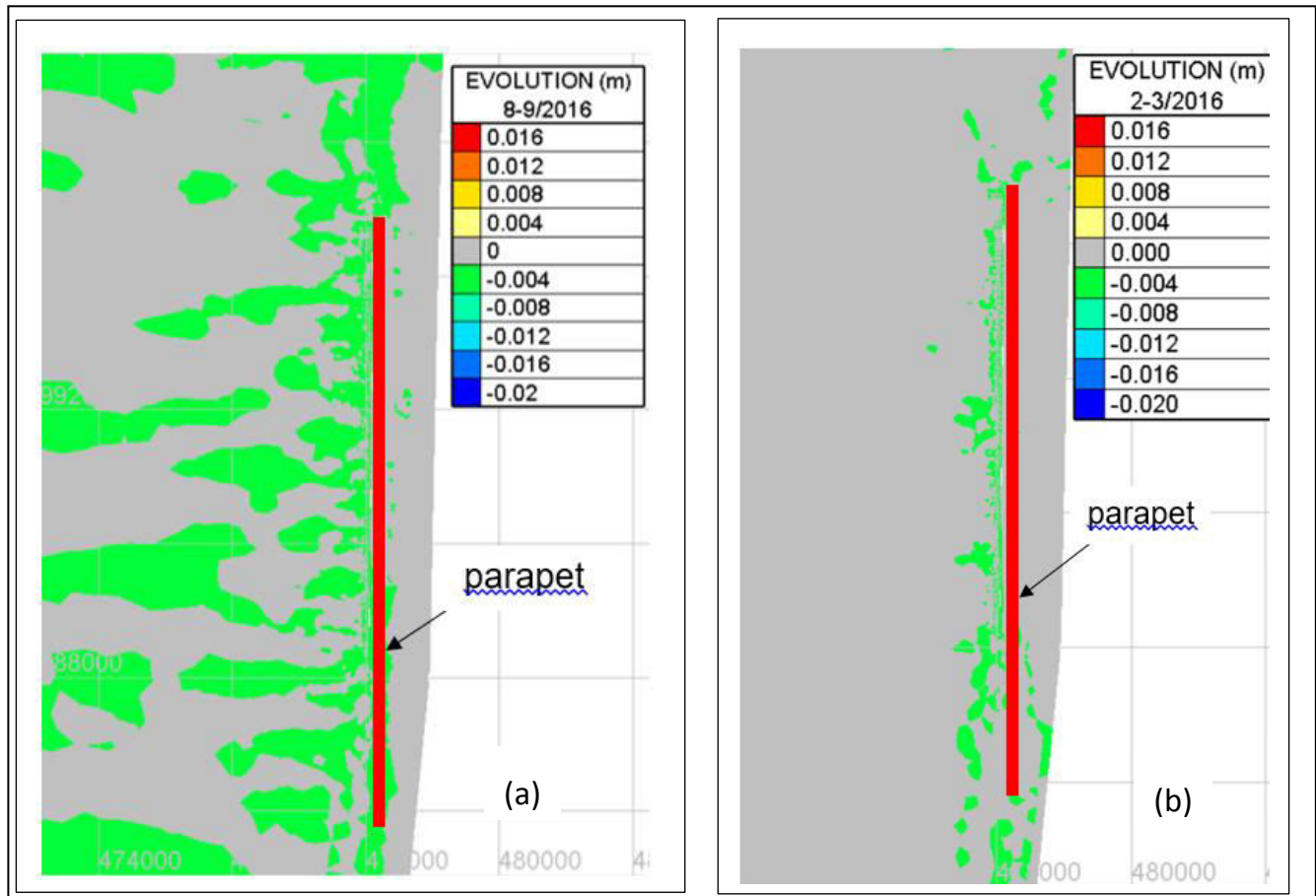


Figure 3.14: Erosion/accretion after 2 months: (a) 8-9/2016; (b) 2-3/2016

Table 3.1: Sediment budget analysis for zone A behind parapet

	In (m ³)	Out (m ³)	(In-Out), m ³	Comments
Tháng 8-9/2016	40.9	15.4	25.5	(+) accretion
Tháng 2-3/2016	149.5	20.1	129.4	(-) erosion

The following results compare the erosion rate in the zone behind the wall to the shore (Area A, Fig. 3.13) for two cases with and without walls.

Table 3.2: Sediment budget analysis for coastal area in 8-9/2016

Case	In (m ³)	Out (m ³)	(In-Out), m ³	Comments
without parapet	94.1	242.3	-148.2	(+) accretion
with parapet	40.9	15.4	25.5	(-) erosion

Table 3.3: Sediment budget analysis for coastal area in 2-3/2016

Case	In (m ³)	Out (m ³)	(In-Out), m ³	Comments
without parapet	302.7	375.6	-72.9	(+) accretion
with parapet	149.5	20.1	129.4	(-) erosion

Comment:

- The erosion in the foot of wall might occur which can be explained by the phenomenon of breaking waves moving to shore and exposing to the wall. A small accretion to the area behind the wall is also noted.
- The wall has positive effect for the accretion of the area behind the wall. This result can be explained by the "absolute" wave breaking effect of the wall for the beach.

4. Simulation results with the T-groyne protection

This section presents the results of protection using T-shaped groynes along the coast. Unlike the wall structure mentioned in the previous section, the structure considered in this section consists of successive T-shaped groynes, as described by the following diagram.

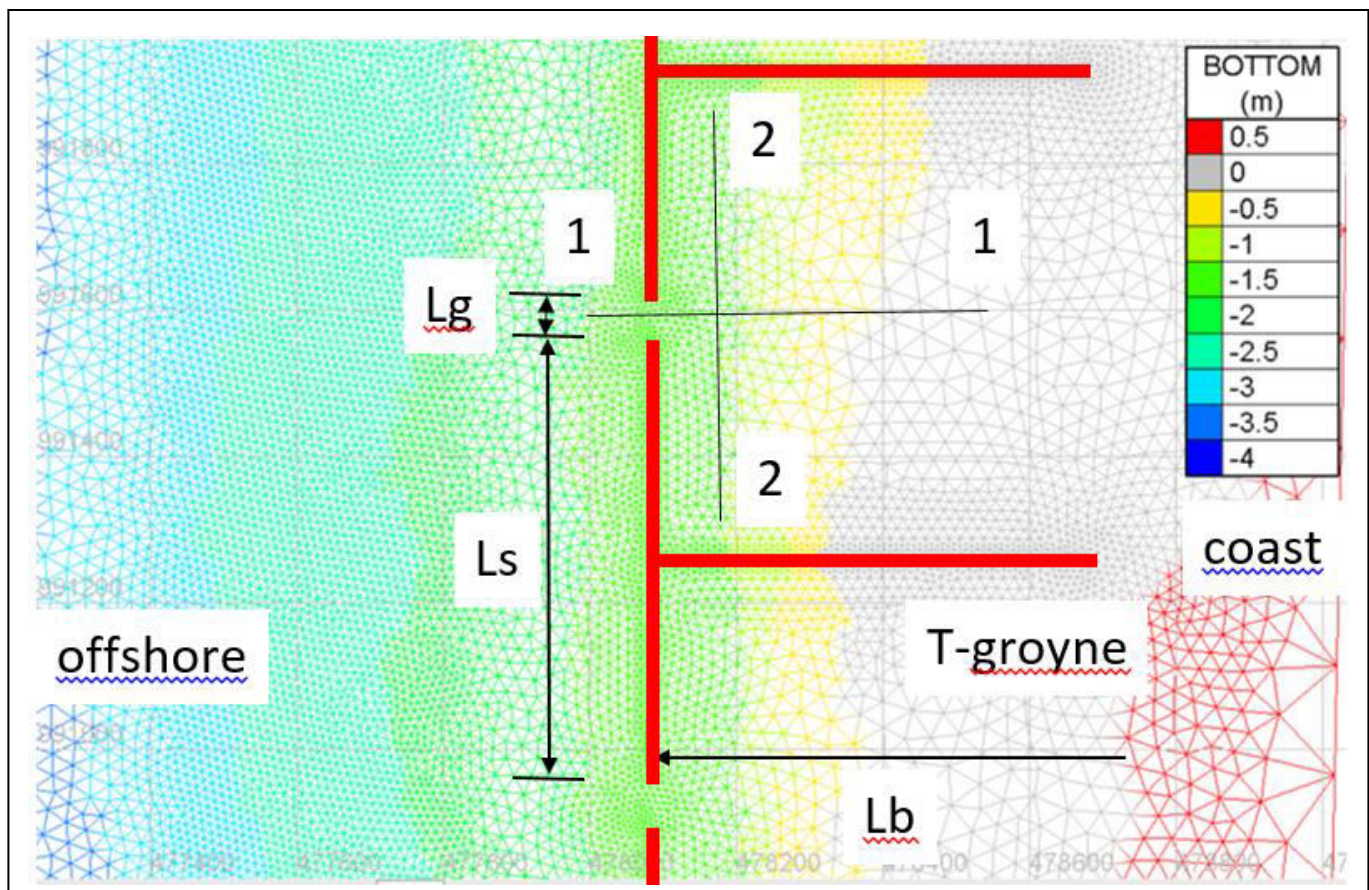


Figure 4.1: Location and size of the T-groyne

Relative position and typical groyne size are as follows:

- Width of groyne's wing $L_s = 600$ m
- Clearance between wings $L_g = 50$ m
- Height of groyne (from wings) $L_b = 400$ m

a. Results of wave simulation

Waves spreading to the shore will encounter the groynes. The wave attenuation of the T-groyne is shown in the following graphs.

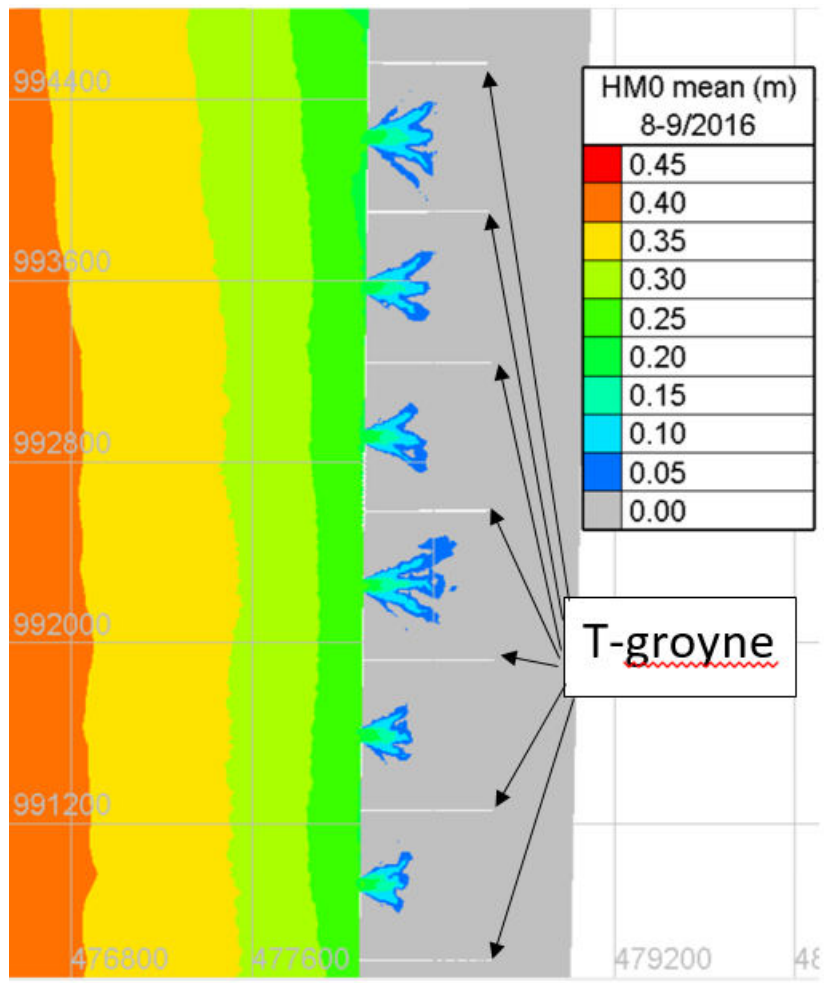


Figure 4.2a: Average wave height HM0 in 8-9/2016 between the T-groynes

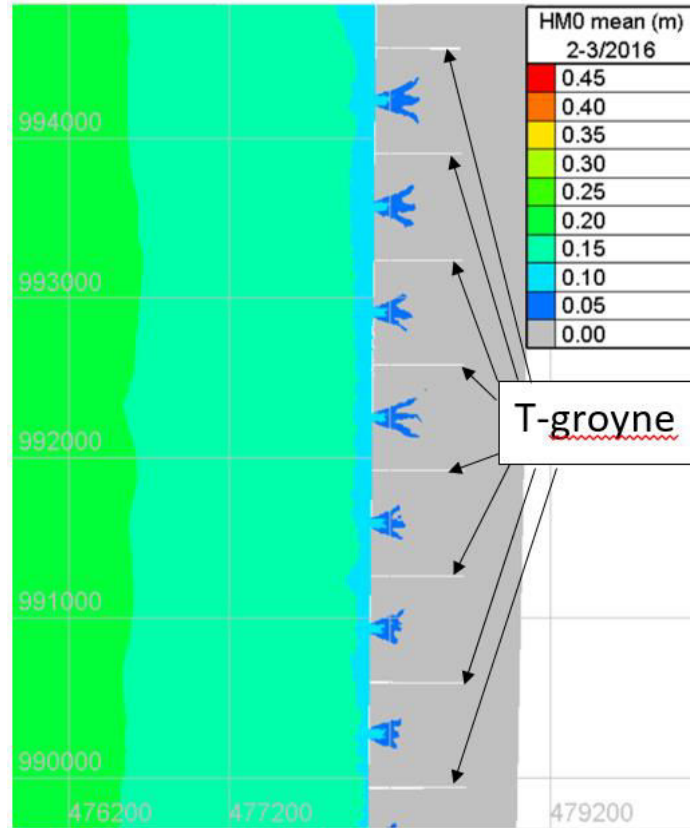


Figure 4.2b: Average wave height HMO in 2-3/2016 between the T-groynes

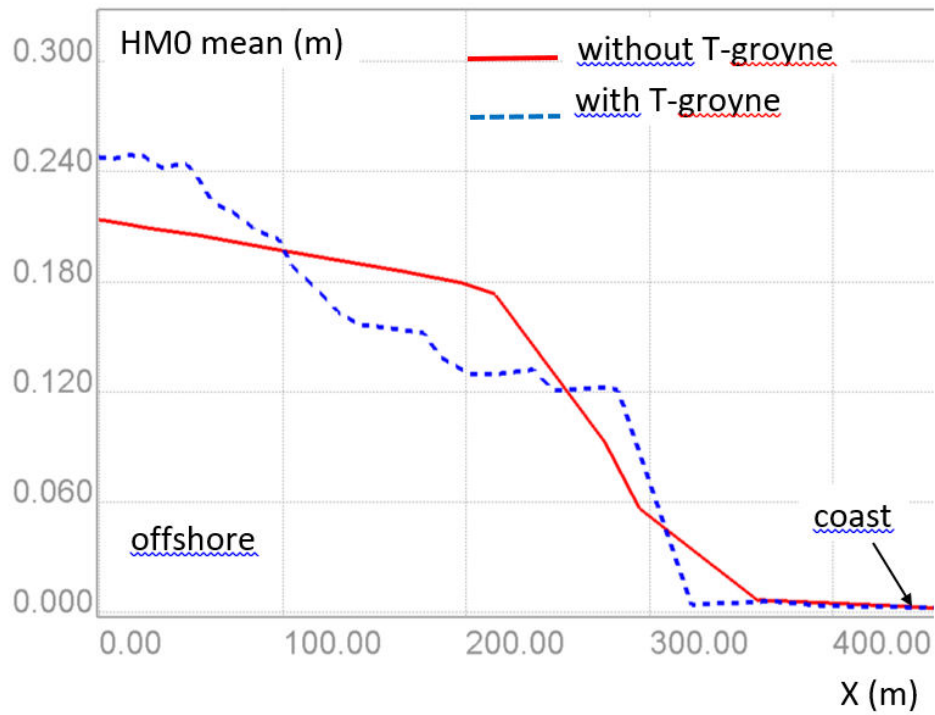


Figure 4.3: Average wave height H_{M0} in 8-9/2016 at section 1-1

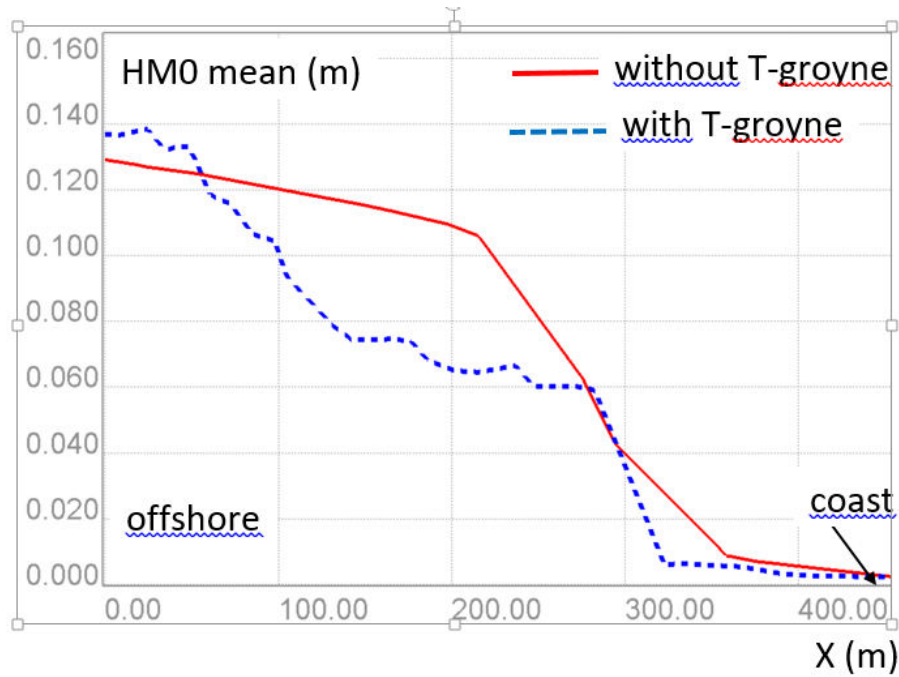


Figure 4.4: Average wave height H_{M0} in 2-3/2016 at section 1-1

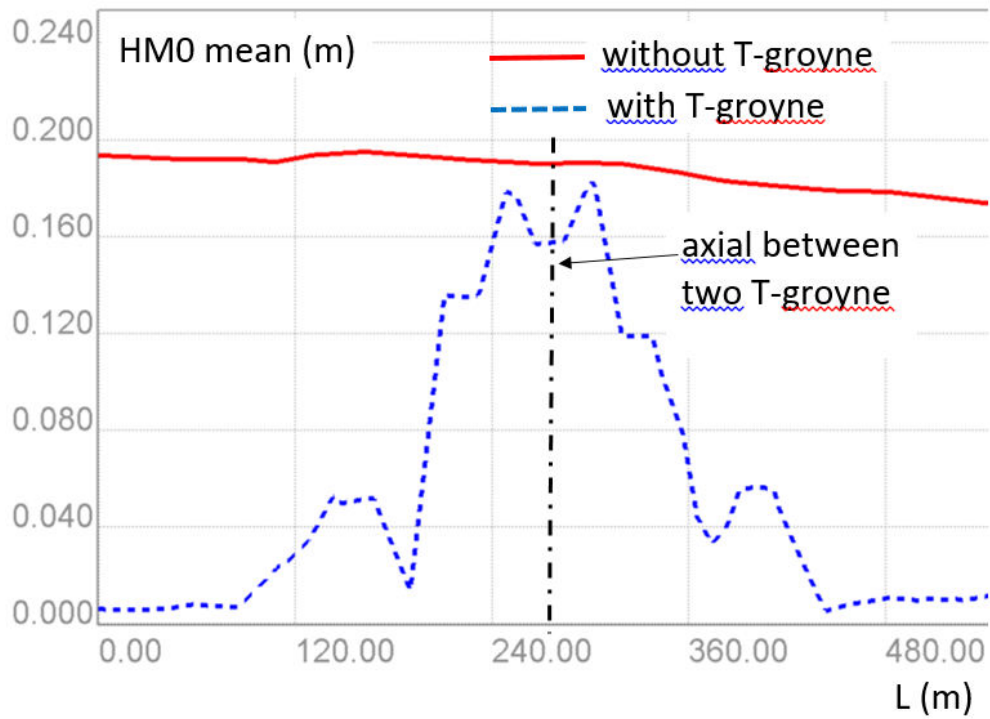


Figure 4.5: Average wave height H_{M0} in 8-9/2016 at section 2-2

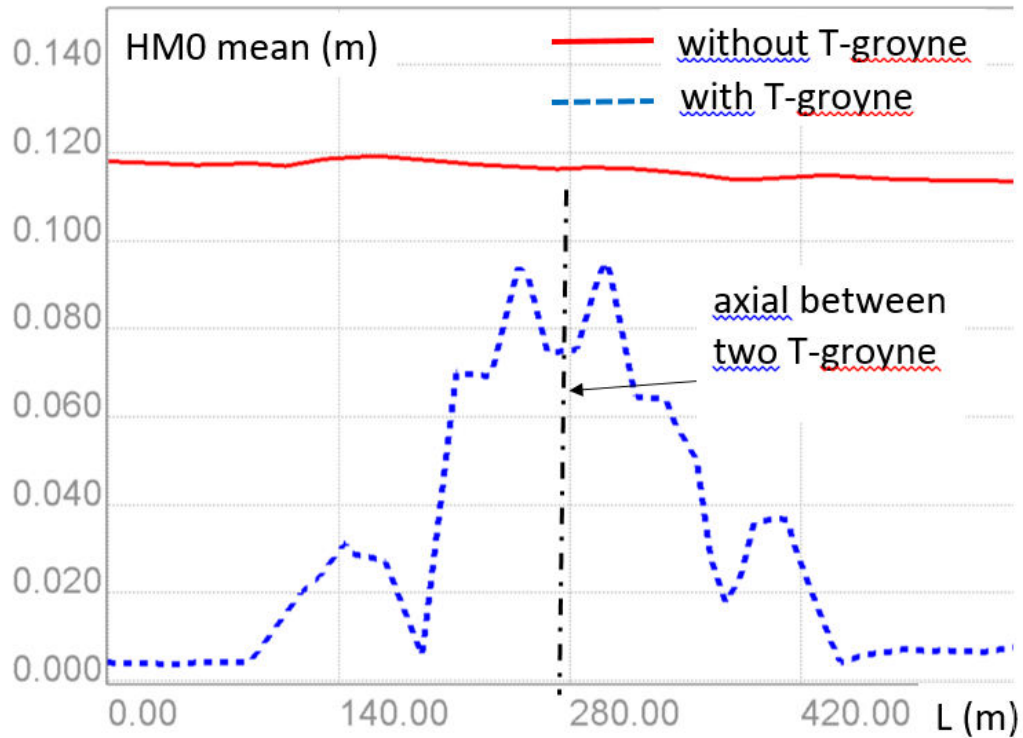


Figure 4.6: Average wave height Hm0 in 2-3/2016 at section 2-2

The results from the above graphs give the following remarks:

- The waves propagating to the T-groyne are almost blocked on the width of Ls.
- In the space between two trenches (L_g gap), waves can still propagate to shore. However, the wave intensity is smaller than in the case of no groyne (see section 1-1).
- The wave passing through the gap between the two groynes has horizontal diffusion (see section 2-2).

b. Simulation results of sediment transport

The following results compare the erosion rates from continuous parapet and T-shaped groynes.

Table 4.1: Sediment budget analysis of coastal area in 8-9/2016

Case	In (m ³)	Out (m ³)	(In - Out), m ³	Comment
Continuous parapet	40.9	15.4	25.5	(+) accretion
T-groyne	7714.2	918.5	6795.7	(-) erosion

Table 4.2: Sediment budget analysis of coastal area in 2-3/2016

Case	In (m ³)	Out (m ³)	(In - Out), m ³	Comment
Continuous parapet	149.5	20.1	129.4	(+) accretion
T-groyne	2754.6	369.3	2385.3	(-) erosion

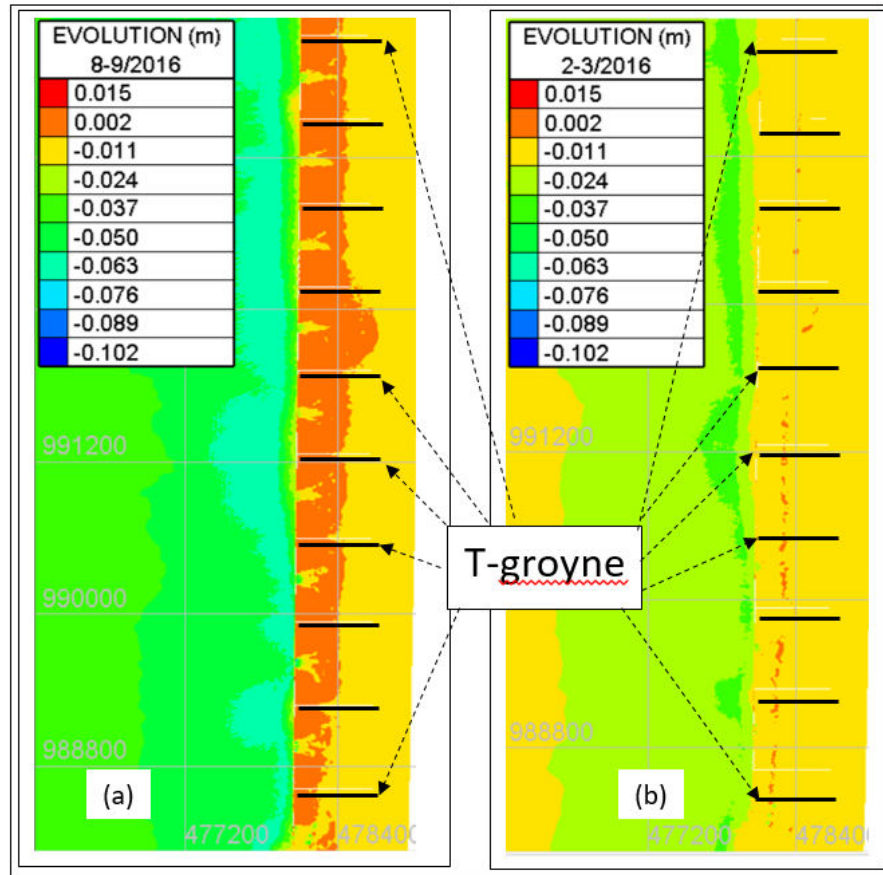


Figure 4.7: Evolution of bathymetry in area with T-groyne protection: (a) in 8-9/2016; (b) in 2-3/2016

The results from the above graphs give following remarks:

- There is slight erosion at the front of the wall. This phenomenon can be explained by the strong turbulence of sediment once the waves impact on the wall surface. The suspended sediment in this area facilitates the erosion rate.
- At the areas between the two groynes, where light erosion is noted. This is due to the fact that waves are still spreading to the shore at these gaps.
- Comparing to continuous parapet, the T-groyne protection is more effective.

5. CONCLUSION

Simulation was made with typical wall structures constructed along a 7000m shoreline (from Bay Hap to Ong Doc Rivers) and 400m offset from the shore. The effect of this structure on the sediment transport in U-Minh coastal areas were studied in two representative periods: 2-3 /2016 and 8-9 / 2016, showing the following main results:

- The analysis of sediment budget in U Minh coast show that this area has a general trend of erosion during the study period.

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- Breaking waves near the coast have a clear effect on the sediment concentration in coastal areas. This is consistent with the data observed by satellites over time.
- The parapet walls attenuate the wave for the coastal area behind the wall.
- The wall structure reduces the concentration of suspended sediment in the construction area.
- The continuous parapet has almost no effect on instantaneous flow as well as average flow. This can be explained by the fact that its direction is almost the same as the velocity fields.
- The results of sediment budget analysis within the construction areas of walls (in the section of Song Hap river to Ong Doc river) shows that the structure of the wall parallel to the shore reduces erosion in the area behind the wall. This means that the corresponding coastal zone is protected. This is a clear positive impact for this type of construction.
- Erosion at the foot of wall may occur due to the effect of breaking waves when exposed to the wall (Figure 4.7).
- T-groyne measure demonstrate the ability of coastal sediment trapping is quite good comparing to other measures.

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