MINISTRY OF EDUCATION AND TRAINING - MINISTRY OF AGRICULTURE AND RURAL DEVELOPMENT

VIETNAM ACADEMY FOR WATER RESOURCES

SOUTHERN INSTITUTE FOR WATER RESOURCES RESEARCH

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STUDYING OF HYDRODYNAMIC AND SEDIMENT TRANSPORT MECHANISM IN THE COASTAL AREA OF TRAVINH PROVINCE, PROPOSING A SOLUTION FOR TREATMENT.

Speciality: Technical water construction

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SUMMARY OF TECHNICAL THESIS

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INTRODUCTION

0.1. PRACTICAL MEANING OF THE THESIS

In recent years, the coastline and dyke system has been severely eroded, occurring on a large scale for almost all coastal provinces of the Mekong Delta, significantly affecting the economic development of sectors related to integrated exploitation of coastal strips. Characteristics of the coastal strip tend to vary depending on coastal geology, ocean elements, river-impact factors, human impact, etc. An In-depth study of issues of dynamics - sediment transport in the coastal area of Travinh province, for coastal protection and maintenance work is needed to meet the following urgent practical requirements: (i) requirements for landslide prevention; (ii) requirements for protection and development of mangrove forests; (iii) requirements of coastal environmental protection for tourism and ecology; (iv) requirements of new construction solutions for coastal stabilization and protection.

0.2. SCIENTIFIC MEANING OF THE THESIS

Research about coast should focus on three basic characteristics of coastal zone environment: (i) Hydrodynamics (wave, tide and flow); (ii) Transport of sediment (suspended sediment and bottom sediment); (iii) Morphology (deposition and erosion of the coast). These characteristics are the most critical and difficult problems in research related to regulating and constructing coastal protection buildings.

Travinh coast is located between two large estuaries of the Mekong River (Cung Hau - Co Chien and Dinh An - Tran De). Factors affecting the operating mechanism of the three basic characteristics in the coastal environment of Tra Vinh are: flows from the Mekong River, flows from the sea, waves, wind, tides, coastal geology, tropical monsoon climate, human impact, climate change, etc.

The thesis uses mathematical modeling method to study the influence of factors on hydrodynamic process, sediment transport and morphological changes, from which to build scientific knowledge bases to adjust treatment and stabilizing the coast of Travinh.

0.3. OBJECTIVES OF THE THESIS

- Simulation of hydrological and hydraulic developments to clarify the motivational factors affecting the shoreline fluctuations and the trend of coastal development in Travinh province.

- Establishing scientific knowledge bases to point out modification solutions for stabilizing coastal areas of Travinh province.

0.4. NEW CONTRIBUTIONS OF THE THESIS

1. The thesis has evaluated, in a synthetic and systematic way, the main motivational factors affecting the morphological changes of Travinh coastal area.

2. The thesis has established a trend of bottom terrain changes over time under the impact of sea level rise and sediment reduction from the river. The thesis has proposed suitable treatment solutions for each area of Travinh coast.

CHAPTER 1. OVERVIEW OF RESEARCH ON COASTAL EROSION AND PROTECTION SOLUTIONS

1.1. GLOBAL STUDIES ON COASTAL EROSION

1.1.1. Causes and erosion/sedimentation mechanisms of mangrove mud shoreline

a) Motivational factors affecting the coast

Overview of the research works of domestic and international scientists on coastal hydrodynamic factors, can be categorized as the following five issues:

- Studying the effects of waves on shoreline developments,

- Studying the impact of tides on coastal developments,
- Studying the effects of sea level rise on coastal changes,
- Studying the impact of the flow of the river in the flood season and the dry season to the shoreline, and
- Studying the impact of the Coriolis force on sea currents.

b) Coastal sediment transport process

In terms of movement: sediment transport on the coast can be divided into two categories - perpendicular sediment transport (onshore and offshore) and Longshore sediment transport. perpendicular sediment transport causes short-term morphological changes, while Longshore sediment transport causes long-term changes in the morphology of a coastal area.

In terms of grain properties, it is possible to divide coastal sediments into two types:

- Cohesive sediment (*mud* with particle size < 0.063mm): mainly transported in suspended state. In saline water (estuarine area), there is a process of flocculation into blocks (flocs).

- Non-cohesive sediment (*sand* with particle size > 0.063mm): discrete in all states, sand transport line is mainly moving on the bottom.

c) Causes and erosion/sedimentation mechanisms of mangrove mud shoreline

The main cause of erosion is "sediment imbalance". The process of "sediment imbalance" occurs as a "continuation loop", from the impact of social development impacts, to efforts to restore mangroves by hard construction solutions (coastal squeeze),...(Gegar Prasetya, 2006), (Winterwerp, 2013).

1.1.2. Coastal protection works

The anti-erosion and coastal protection works include:

- *Longshore structures* (seawalls, dikes, embankments) protect the coast or dunes against erosion caused by currents and waves.

- *Cross-shore structures* (groins) are used to interrupt the Longshore sediment transport.

1.2. EROSION STUDIES IN THE MEKONG DELTA OF VIETNAM

1.2.1. Some research by foreign authors

The studies on dynamics, waves... cover the entire South East Sea: K. Wyrtki (1961), K.T Bogdanov (1963), U. N Xecgayev (1964), Robinson (1983), T. Yanagi and Takao (1997), Duan Yi-hong Qin Zeng-hao, Li Yong-ping (1997) and Yu et al. (2006).

1.2.2. Combined studies by foreign and Vietnamese authors

The study of the changes in hydrodynamic and sediment transport factors, coastal changes in the Mekong Delta: Wolanski, Nguyen Huu Nhan (1998, 2005), Japan International Cooperation Agency (JICA – 2012).

Research on the long-term changes of the coastline of Tra Vinh through many periods (Toru Tamura – Japanese).

Nguyen Trung Thanh (2011) studied of coastal flow dynamics and showed that the dominance of the coastal current in the southwest in the winter under the influence of the northeast monsoon, thereby confirmed the dominance of the transport process Longshore sediments to the southwest in this season.

The EU-AFD project, in 2017, is a research project on the erosion process of coastal areas in the Mekong Delta and focuses on the coastal areas of Go Cong and U Minh.

1.2.3. Vietnamese research results

Nguyen Dich Dy (2010) studied geology-geomorphology of river mouths and coastal areas of 4 coastal provinces in the Mekong Delta, and showed that the top (latest) sediments of coastal waters of Tra Vinh originated mainly from rivers and seas

Vu Duy Vinh (2014) studied and evaluated topographic changes in the Mekong Delta coastal area of the current situation and under the influence of sea level rise.

Nguyen Huu Nhan (2015) used model Mike 21C F/M to study the causes and mechanisms of the formation of Camau mudflats.

1.3. THE RESEARCH WORKS ON COASTAL EROSION IN TRAVINH

1.3.1. Research results of foreign authors

Research on short-term changes (accretion or erosion changes) of the coast of Tra Vinh (Anthony, Dussouillez, 2017).

1.3.2. Vietnamese research results

Hoang Van Huan (2008, 2013, 2014) conducted in-depth studies for the coastal area of Tra Vinh on hydrodynamics, sedimentation / erosion and proposed solutions to prevent erosion.

1.4. COASTAL DEVELOPMENT RESEARCH METHODS

- Research methods based on realworld models.

- Statistical method
- Physical modeling method
- Mathematical modeling method
- Remote sensing image analysis method
- Radioactive marking method

CHAPTER 2. THEORETICAL BASIS AND RESEARCH METHOD

2.1. ANALYSIS AND SELECTION OF CALCULATION MODELS

The thesis selected Mike 21/3 FM model to formulate research problems.

2.2. THEORETICAL BASIS OF CALCULATION MODEL

2.2.1. Simulation of shallow water flow

The shallow water flow, in the 2-dimensional model, is described by the following equation system:

- Continuous equations describing the law of conservation of materials:

$$\frac{\partial h}{\partial t}+\frac{\partial h\bar{u}}{\partial x}+\frac{\partial h\bar{v}}{\partial y}=hS \tag{2.1}$$

- Motion equations describing the law of conservation of momentum according to the x-axis:

$$\frac{\partial h\bar{u}}{\partial t}+\frac{\partial h\bar{u}^2}{\partial x}+\frac{\partial h\bar{v}\bar{u}}{\partial y}=f\bar{v}h-gh\frac{\partial \eta}{\partial x}-\frac{h}{\rho_0}\frac{\partial P_a}{\partial x}-\frac{gh^2}{2\rho_0}\frac{\partial \rho}{\partial x}+\frac{1}{\rho_0}(\tau_{sx}-\tau_{bx})$$
$$-\frac{1}{\rho_0}\left(\frac{\partial s_{xx}}{\partial x}+\frac{\partial s_{xy}}{\partial y}\right)+\frac{\partial}{\partial x}(hT_{xx})+\frac{\partial}{\partial y}(hT_{xy})+hu_sS \tag{2.2}$$

- The momentum equation by y axis:

$$\frac{\partial h\bar{v}}{\partial t}+\frac{\partial h\bar{u}\bar{v}}{\partial x}+\frac{\partial h\bar{v}^2}{\partial y}=-f\bar{u}h-gh\frac{\partial \eta}{\partial y}-\frac{h}{\rho_0}\frac{\partial P_a}{\partial y}-\frac{gh^2}{2\rho_0}\frac{\partial \rho}{\partial y}+\frac{1}{\rho_0}(\tau_{sy}-\tau_{by})$$
$$-\frac{1}{\rho_0}\left(\frac{\partial s_{yx}}{\partial x}+\frac{\partial s_{yy}}{\partial y}\right)+\frac{\partial}{\partial x}(hT_{xy})+\frac{\partial}{\partial y}(hT_{yy})+hv_sS \tag{2.3}$$

Where t is the time (s); x, y are the Cartesian co-ordinates (m); u,v are the velocity components in the x,y direction (m/s); f is the Coriolis parameter (s^{-1}); g is the gravitational acceleration (m/s^2); η is the surface elevation (m); d is the still water depth; $h = \eta + d$ is the total water depth; ρ_0 is the density of water (kg/m^3); P_a is atmospheric pressure (Pa/m); S is the magnitude of the discharge due to point sources (m^3/s); $S_{xx}, S_{xy}, S_{yx}, S_{yy}$ are components of the radiation stress tensor (N/m^2); A is the horizontal eddy viscosity; (τ_{sx}, τ_{sy}) and (τ_{bx}, τ_{by}) are the x and y components of the surface wind and bottom stresses (N/m^2); T_{xx}, T_{xy}, T_{yy} are the lateral stresses, includinge viscous friction, turbulent friction and differential advection (N/m^2).

2.2.2. Wave calculation

In horizontal Cartesian co-ordinates, the conservation equation for wave action can be written as

$$\frac{\partial N}{\partial t} + \nabla \cdot \left(\vec{v} \cdot N \right) = \frac{S}{\sigma} \qquad (2.4)$$

where $N(\vec{x}, \sigma, \theta, t)$ is the action density; t is the time (s); $\vec{x} = (x, y)$ is the Cartesian coordinates (m); $\vec{v} = (c_x, c_y, c_\sigma, c_\theta)$ is the propagation velocity of a wave group in the four-dimensional phase space (x, y, σ, θ) (m/s); S is the source term for the energy balance equation; ∇ is the four-dimensional differential operator.

2.2.3. Simulation of sediment transport process and morphological changes

a) Mud transport

The mud transport module solves the so-called advection-dispersion equation:

$$\frac{\partial \bar{c}}{\partial t} + u\frac{\partial \bar{c}}{\partial x} + v\frac{\partial \bar{c}}{\partial y} = \frac{1}{h}\frac{\partial}{\partial x}\left(hD_x \frac{\partial \bar{c}}{\partial x} \right) + \frac{1}{h}\frac{\partial}{\partial y}\left(hD_y \frac{\partial \bar{c}}{\partial y} \right) + Q_L C_L \frac{1}{h} - S \qquad (2.5)$$

Where t: is the time (s); x,y are the Cartesian co-ordinates (m); u,v are the velocity components in the x,y direction (m/s); h is the total water depth (m); S is the deposition/erosion term ($kg/m^3/s$); $\bar{c}$ is the depth averaged concentration (kg/m^3); Q_L is the source discharge per unit horizontal area ($m^3/s/m^2$); C_L is the concentration of the source discharge (kg/m^3); Dx, Dy are the dispersion coefficients (m^2/s).

b) Sand transport

The sediment (sand) transport is calculated as:

$$q_t = q_b + q_s = S$$

Where q_t is the total sediment transport, q_b is the bed load transport and q_s is the sediment transport in suspension.

Equations 2.1, 2.2, 2.3, 2.4 and 2.5 cannot be solved by analytical methods. Therefore, people have tried to solve these equations by numerical method with finite difference or finite volume scheme by dividing the domain into grid cells and must ensure stable condition is CFL ≤1 (Courant – Friedrichs – Lewy).

2.2.4. Method of building a map

This method is used for the purpose of building a hydrodynamic and sediment transport diagram. The results of flow direction, direction of coastal sediment transport, sediment distribution, wave flower,... were extracted from the model and inputted into specialized software to create map layers. The Arcgis software is used as a tool.

2.3. BUILD CALCULATION MODEL

2.3.1. Data base

Topographic data: was taken from (i) actual results of research projects and basic surveys carried out by the Southern Institute of Water Resources Research (2010) and Institute of coastal and offshore engineering (2009, 2011, 2014), (ii) 1 / 100,000 scale map of the Navy published in 1982, (iii) from GEBCO of the British Oceanographic Data Center.

Wind field data: was taken from the results of the Environmental Prediction Center of the NCEP/NOAA.

Wave data: The study area model needs wave data at 3 margins opening to the East Sea of the calculation domain. This data is extracted from the calculation model for the entire East Sea (research results were built, tested and published in the second article in the List of published works of this thesis).

Hydrological data: Flow data at My Thuan, Can Tho hydrological stations and water level data at Nha Be and The Vai stations (Figure 2.1) are real data measured every hour. The water level data at the 3 boundaries opening to the East Sea of the calculation domain is extracted from the global tide forecast software. The data of water level and flow at the Co Chien station (measured in 2011) and coastal water level measurement station in 2014 were used for calibration and verification of models.

Sediment data: the suspended sediment data at My Thuan, Can Tho, Nha Be and Thi Vai stations (Figure 2.1) is measured data, serving as the input boundary for the model. The data of suspended sediments, bottom sediments observed at the 2011 and 2014 sampling points of the Institute of Marine Engineering is used for calibration and verification of models.

2.3.2. Set up in numerical modeling

The domain scope is shown in Figure 2.1.

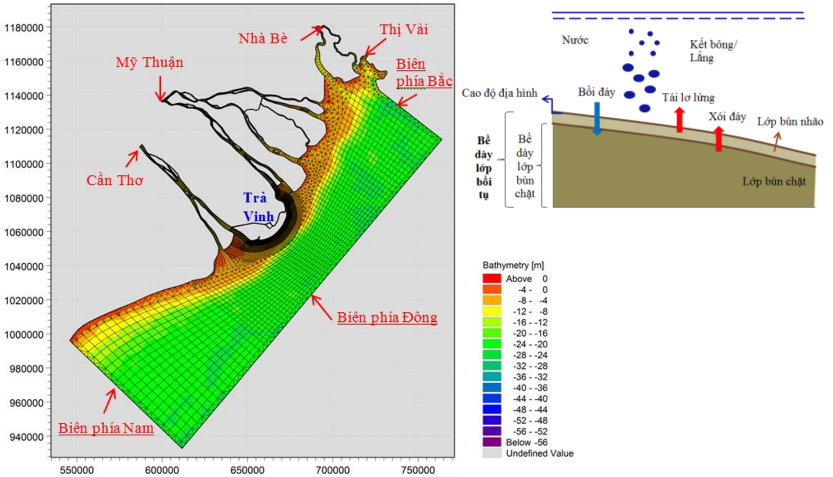


Figure 2. 1: Calculated net, seabed topography of the region (left side) and bottom deposition / erosion process in the "multi-layer deposition" model (right side)

Modules used simultaneously in the MIKE 21/3 Coupled model FM model include: (i) Hydrodynamic module for determining the flow field and water level field; (ii) Spectral Wave module for determining wave field and wave scattering stress; (iii) Mud transport module for simulating the process of morphological changes due to smooth sediment transport; (iv) Sand transport module for simulating the morphological process due to the transport of loose sand.

2.3.3. Results of model calibration and verification

The established research area has been calibrated with detailed parameters and achieved the following criteria: (i) CFL parameter ≤ 1 in all calculation cases; (ii) The model is calibrated and verified by comparing the calculated value with the measured value of water level, flow rate, flow velocity, significant wave height, wave period, and suspended sediment concentration. Real measured data were obtained from the basic survey project as well as from a number of projects chaired by Hoang Van Huan in 2011 (from September 13, 2011 to September 16, 2011) and 2014 (from August 11, 2014 to August 14, 2014).

2.3.4. Calculation scenarios

The thesis builds 05 scenarios as follows:

Scenario 1: Calculation for prediction of hydrodynamic regime (flow, wave) and erosion accretion for the current situation.

Scenario 2: Calculation for prediction of hydrodynamic regime (flow, wave) and erosion accretion with consideration of SLR factor of 13cm.

Scenario 3: Calculation for prediction of hydrodynamic regime (flow, wave) and erosion accretion with consideration of SLR factor of 23cm.

Scenario 4: Calculation for prediction of hydrodynamic regime (flow, wave) and erosion accretion with consideration to the reduction of Mekong sediment content by 20% (compared to 2011).

Scenario 5: Calculation for prediction of hydrodynamic regime (flow, wave) and erosion accretion with consideration to the reduction of Mekong sediment content by 30% (compared to 2011).

CHAPTER 3: RESULTS OF RESEARCH ON A HYDRODYNAMIC REGIME FOR ADJUSTING OF TRAVINH COAST

3.1. STUDY OF HYDRODYNAMIC MECHANISM AND COASTAL SEDIMENT TRANSPORT

3.1.1. Impact factor from the Mekong River

The results of the flow and sediment flow at the mouths of the Mekong River are shown in Figure 3.1 and Figure 3.2.

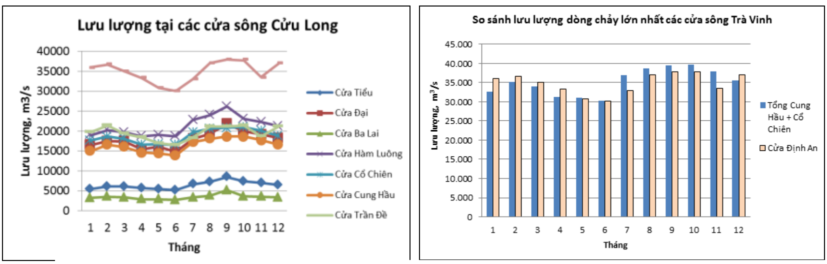


Figure 3.1: Maximum flow in the Mekong estuaries for 12 months (left figure) and a chart comparing the maximum flow at Dinhan and Cunghau - Cochien (right figure)

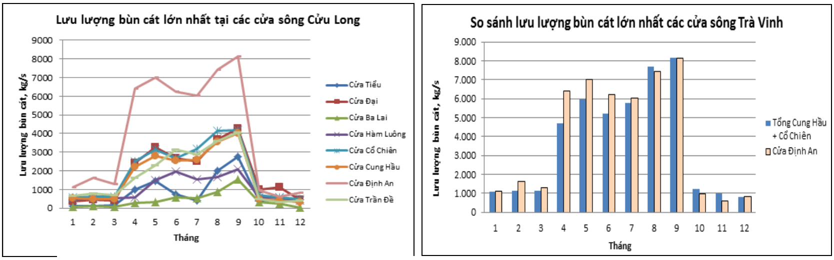


Figure 3.2: Maximum sediment flow in the Mekong estuaries for 12 months (left figure) and a chart comparing the largest sediment flow at Dinhan and Cunghau - Cochien (right figure)

The diagram shows that the flow and sediment flow through Dinh An estuary is always the largest compared to the remaining estuaries. The coast of Tra Vinh province is located between two large river mouths of the Mekong, Dinh An and Cung Hau - Co Chien. When comparing the flow and sediment flow of sand combined by 2 mouths of Cung Hau - Co Chien and the flow at Dinh An estuary, it shows the similarity in values. Thus, it can be seen that the amount of water and sediment of the Mekong River flowing to the coast of Tra Vinh is always more dominant than the surrounding coastal areas (Tien Giang, Ben Tre and Soc Trang).

3.1.2. The tide factor of the East Sea

Tra Vinh coast is dominated by irregular semi-diurnal regime, the fluctuation range of tide is from 2m ÷ 4m during the day. The up and down rule of the tide is characterized by five main modes of vibration with a period of ½ day, 1 day, ½ month, 6 months and 12 months. The average water level of the low tide is (-) 1.3m. The average water level of the high tide is (+) 1.8m. This is a high tide amplitude. There for the influence of tide on the hydraulic regime in the coastal waters of Tra Vinh is very large. The flow rate at the time of tidal rise and low tide will be analyzed in 3.1.3 section (coastal flow).

3.1.3. Flow factor

a) Synthetic flow

The coastal area of Tra Vinh province is located in the area of tropical monsoon climate, so it is dominated by the monsoon with the main directions being Northeast, Southwest every year.

In the northeast monsoon season (NEMS) (from November to April), the flow rate in coastal locations during the high tide phase is higher during the ebb tide phase. The flow rate at locations near the river mouth when tides rise and fall are almost equal (about 1m/s). When the sea currents come from the Northeast, combined with the flood tide (especially when there is a stormy wind), there will be powerful destruction of the coast. Therefore, the northeast monsoon flow when the flood tide is considered to play a dominant role in fluctuating the coast of Tra Vinh in this season.

During the southwest monsoon season (SWMS) the flow rate during flood tide (about 1m/s) is much smaller than the flow at low tide (about > 1m/s). At low tide, the flow rate at estuaries is from 3 to 4 times higher than coastal locations. With an abundance of sediment, the small coastal flow rate has created a trend of deposition mainly for coastal waters of Tra Vinh in the southwest monsoon season (only the coastline of Hiep Thanh and Truong Long Hoa communes remains eroded). Therefore, it can be considered that the flow from the river when combined with the ebb - tide is the main flow, which influences the fluctuation of Tra Vinh coast in this season.

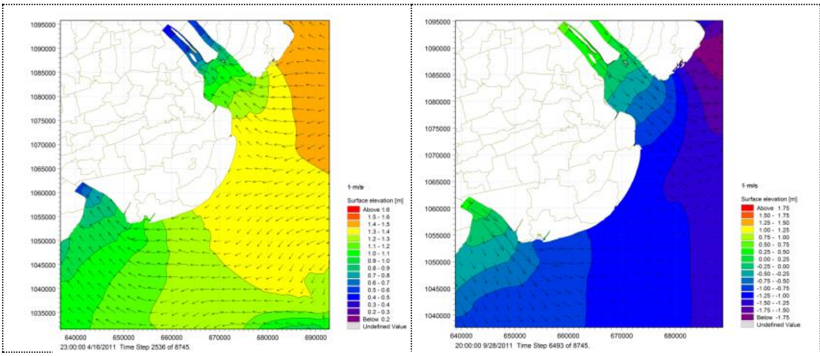


Figure 3.3: Water flow and surface elevation in NEMS during flood tide (left figure) and enter SWMS during ebb tide (right figure)

b) Coastal currents due to waves and wind

During the northeast monsoon season, the tidal current rises from the northeast to southwest along with the coastal current flowing from the northeast to southwest, leading to a synthetic flow that increases during high tide and decreases at low tide.

In the southwest monsoon season, the tidal current from the northeast to southwest is opposite to the coastal current flowing from the southwest to northeast, leading to a synthesis flow decreasing at high tide and increasing at low tide.

3.1.4. Wave factor

The study noted a significant reversal of wave direction during the northeast and southwest wind seasons. The direction of the ocean wave coincides with the northeast and southwest wind directions. Due to the wave refractive effect, when entering shallow water, the wave direction tends to orthogonal to the contour line. The wave height in the southwest monsoon is about ½ of the wave height during the northeast monsoon season. Due to the wave breaking effect, the wave height decreases from offshore to onshore area.

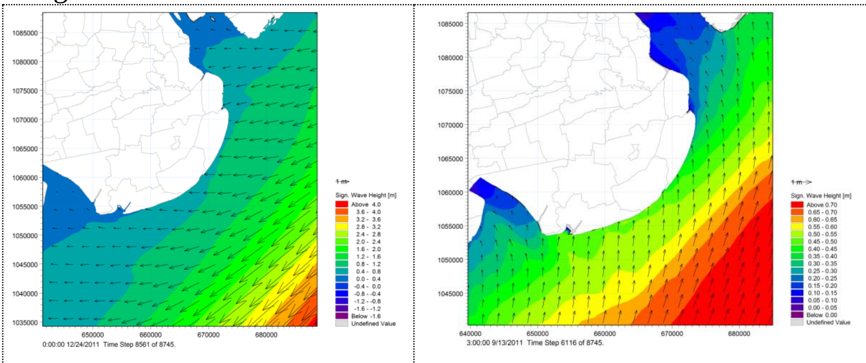


Figure 3.4: Wave of northeast monsoon (left side) and southwest monsoon (right side)

3.1.5. Sediment transport regime and reserves

a) Longshore sediment transport

In order to evaluate the Longshore sediment transport process in the coastal area of Tra Vinh, the study extracted the sediment transport results at 03 coastal sections MC 1, MC 2 and MC 3, the width of each section is 2km from the shore to the sea (Figure 3.5 – left side). At section MC2 (Figure 3.5 – right side), there is a difference in the trend of coastal sediment transport between the northeast and southwest wind season. During the northeast monsoon season, the Longshore sediment transport to the southwest is clearly dominant.

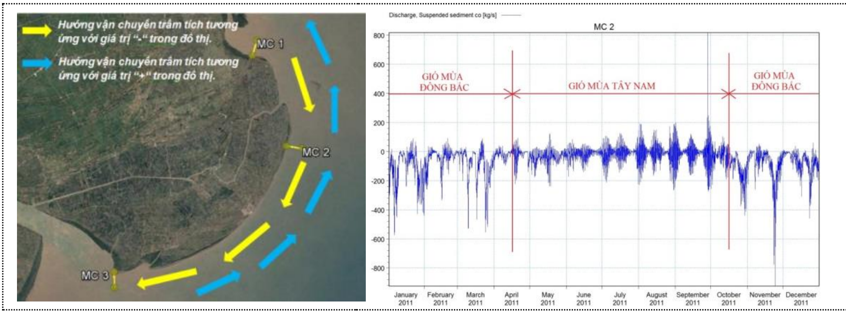
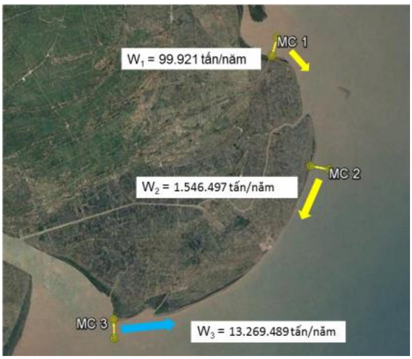


Figure 3.5: Position of sections (left) and suspended sediment flow at section MC 2 (right)

Table 3.1: Results of calculation of Longshore sediment through cross sections (Unit: ton / year)

Sections	**Longshore sediment through cross sections** (The width of each section is 2km) - *Tính cho năm 2011*		
	Northeast monsoon	**Southwest monsoon**	**A whole year**
MC1	$W1_{\text{ĐB}}$ = 70.368	$W1_{\text{TN}}$ = -170.289	W1 = - 99.921
MC2	$W2_{\text{ĐB}}$ = -1.251.666	$W2_{\text{TN}}$ = -294.831	W2 = - 1.546.497
MC3	$W3_{\text{ĐB}}$ = -875.859	$W3_{\text{TN}}$ = 14.145.348	W3 = 13.269.489



Values of W1 and W2 with the "-" sign show that the sediment transport process prevails to the southwest on the coastal section between section MC 1 and MC2.

Meanwhile, the value of W3 with the "+" sign indicates that through the MC3 cross-section, every year the coast of Tra Vinh includes an enormous additional amount of coastal sediment (13,269,489 tons / year).

Figure 3.6: Annual Longshore sediment flux through sections

b) Longshore, cross-shore sediment transport and reserves

Because the coast is a large area, which is subject to the multi - dimensional impact of hydrodynamic factors, the direction of sediment transport is also very complicated, in which the two main directions are Longshore and coastal perpendicular sediment transport. The thesis divides the coast of Tra Vinh into two areas of analysis: Hiep Thanh area and Truong Long Hoa - Dong Hai area.

Table 3. 2: Analysis of sediment reserves in Hiep Thanh area (Unit: ton / year)

TT	Areas	Reserves come in	Reserves come out	Balance reserves	Conclude
1	Zone 1	99.922	3.838.621	-3.738.699	Strong erosion
2	Zone 2	1.702.938	1.257.421	445.516	Accretion
3	Zone 3	937.048	723.709	213.339	Accretion

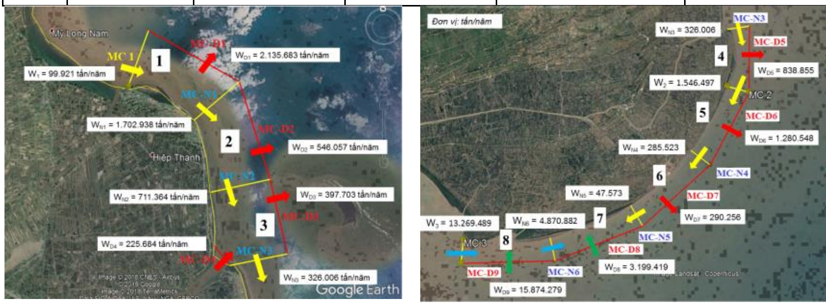


Figure 3. 7: Range of sediment balance cells in Hiep Thanh and Truong Long Hoa - Dong Hai areas

Table 3. 3: Analysis of sediment reserves in Truong Long Hoa - Dong Hai (Unit: ton / year)

TT	Areas	Reserves come in	Reserves come out	Balance reserves	Conclude
1	Zone 4	326.006	2.385.352	-2.059.346	Erosion
2	Zone 5	1.546.497	1.566.071	-19.574	Erosion
3	Zone 6	285.523	337.829	-52.307	Erosion
4	Zone 7	8.117.875	-	8.117.875	Accretion
5	Zone 8	29.143.768	4.870.882	24.272.886	Accretion

3.1.6. Hydrodynamic regime and coastal sediment transport

Summarizing the above research results, it is possible to draw conclusions about hydrodynamic and sediment transport mechanism in Tra Vinh coastal area as follows: During the southwest monsoon season, the flow of the Mekong provides sediment for the Tra Vinh coastline; then, in the northeast monsoon season, this amount of sediment under the influence of waves of higher height is suspended again. Most of this suspended sediment flows along the coastal currents to the south. The rest is brought back into the estuaries by the tidal stream and causes sedimentation at the river mouths.

3.1.7. Hydrodynamic diagram and sediment transport in the coastal area of Tra Vinh

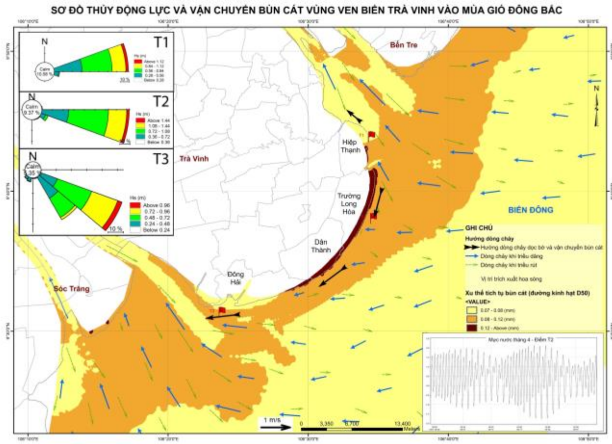


Figure 3.8: Hydrodynamic and sediment transport diagram in the coastal area of Tra Vinh during the northeast monsoon

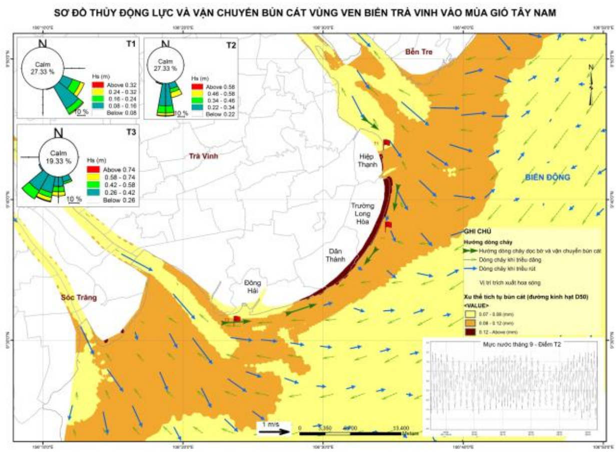


Figure 3.9: Hydrodynamic and sediment transport diagram in the coastal area of Tra Vinh during the southwest monsoon

3.2. STUDY THE MORPHOLOGY OF THE COAST OF TRAVINH

3.2.1. Characteristics of the coast of Tra Vinh

a. The cross-section of the coast

Diagram showing the cross-section of the coast of Tra Vinh (Figure 3.10) was built from the information calculated in the previous section such as: The coastal terrain of Tra Vinh under water; Site of terrestrial topographic survey and representative sections; The average water level of the low tide is (-) 1,3m, the average high tide level is (+) 1,8m; The waves of the East Sea with a height> 3m often break in the distance of 6→10 km (contour line - 8m).

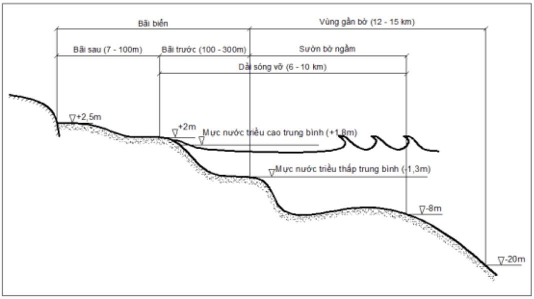


Figure 3. 10: Sketch of the cross section of the coast of Tra Vinh

b. Coast plane

The calculation results of hydrodynamic and sediment transport regimes show that:

- The two estuaries of Cung Hau - Co Chien and Dinh An have the same flow and sediment flow as the largest of all the Mekong estuaries. The coast of Tra Vinh province located between these two estuaries should be influenced by the Mekong River more strongly than the surrounding coastal areas (see 3.1.1 section).

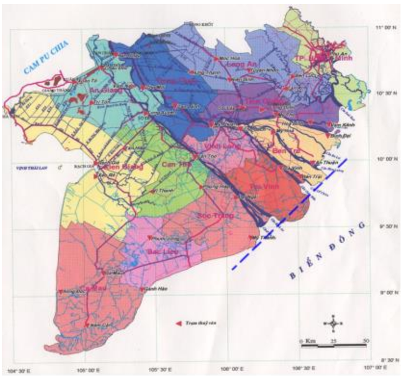


Figure 3. 11: Map of the Mekong Delta

- According to the general trend of the coastal areas of the Mekong Delta, the Longshore sediment transport to the southwest dominates during the northeast monsoon season. However, in terms of the whole year regime, the Tra Vinh coast is annually accreted with a large amount of sediment from the Mekong River, especially through Dinh An estuary (see 3.2.1 section).

These explain a part of the phenomenon: the coast of Travinh is particularly prone to protrude out of the East Sea than the surrounding coastal areas (see Figure 3.11). However, this issue needs further research.

3.2.2. Results of simulation of deposition/erosion regime in Travinh coastal area for scenarios

Results of simulation of deposition / erosion regime in Tra Vinh coastal area for the scenarios were calculated. For a more thorough analysis of the difference of the sedimentation rates between the scenarios, the thesis extracted the results of the change in the thickness of the depositional layer of three typical points for comparison (Sx- erosion, Sb- deposition, So- Stability).

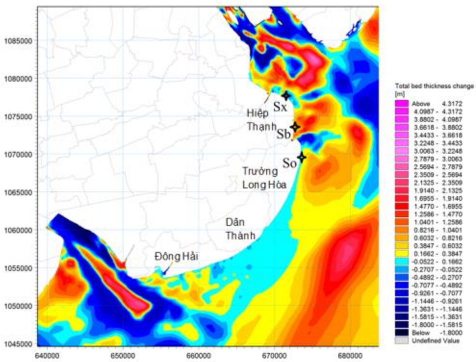


Figure 3. 12: Erosion evolution after 1 year - Current scenario and location of results extraction points

3.2.3. Building a relationship line about the thickness of sediment over time in some typical areas of the coast of Tra Vinh

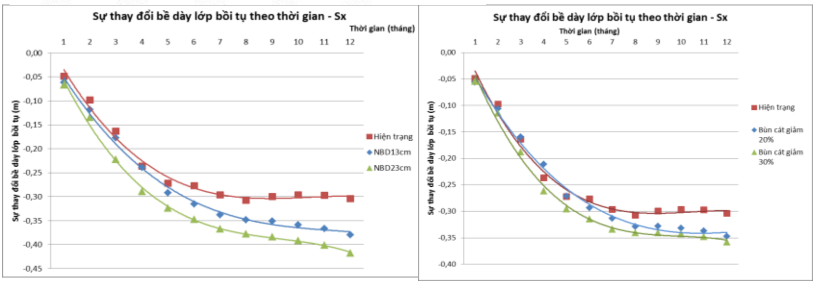


Figure 3. 13: Change of depositional thickness at Sx point

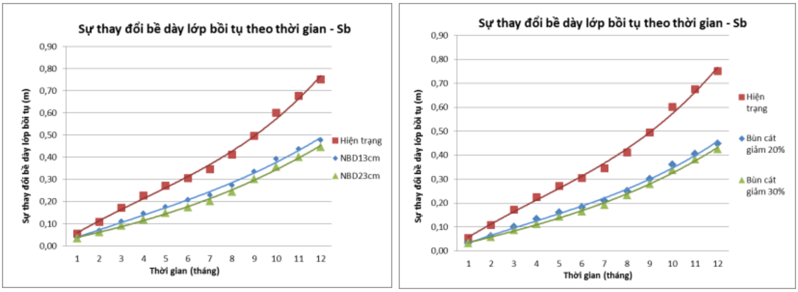


Figure 3. 14: Change of depositional thickness at Sb point

The graphs show the trend of increasing erosion (or reducing deposition) in the coastal area of Tra Vinh under the impact of sea level rise due to climate change and the sediment reduction of the Mekong River due to construction of upstream projects.

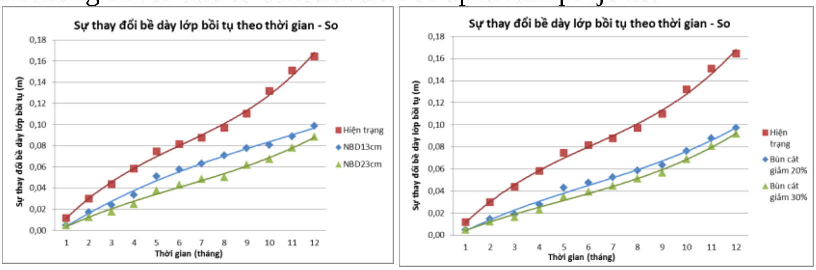


Figure 3. 15: Change of depositional thickness at So point

Table 3. 4: Change of depositional layer thickness compared to the current scenario (%)

The average value (%)						
Points	Sea level rise 13 cm	Sea level rise 23 cm	Estimate - Sea level rise 10 cm	Sediment reduction 20%	Sediment reduction 30%	Estimate - Sediment reduction 10%
Sx	-3,7	-6,9	-2,9	-1,6	-3,3	-0,9
Sb	-12,7	-15,3	-8,2	-14,7	-16,4	-6,4
So	-3,1	-4,2	-2,1	-3,7	-4,3	-1,7

3.3. STUDY SCIENTIFIC BASIS FOR PROPOSING PROTECTION SOLUTIONS

3.3.1. Erosion processes

- *Determining the oceanic area related to erosion:* The analysis in the upper part of the thesis on the characteristics of bottom terrain, wave breaking range, distribution of coastal sediments and the process of exchanging sediments shore shows that erosion is the result of the re-suspension due to waves and the sediment transport flow under the impact of wind occurs on a shallow clinoform along the coast (about 6 to 10 km across the shore) instead of the limit in shallow coastal waters (less 1 kilometer).

- *Lacking of sediment supply from the river:* The increase in erosion is much less than the decrease in the supply of sediment from the river and this increase is not large compared to the erosion caused by the hydrodynamic regime (the erosion is about 30cm / year).

- *Sea level rise due to climate change:* Global warming may not be significant in the current situation because its impact is still very low compared to the erosion caused by the existing hydrodynamic regime.

- *Near-shore hydrodynamics:* Waves are the most important factor in shallow marine motivational factors, wave characteristics and flows generated by waves have the greatest effect on the evolution of the coast. Two big wave areas are Hiep Thanh and Truong Long Hoa.

- *Long-shore and cross-shore sediment transport:* The main processes are the combination of sedimentation of the rivers in the summer, re-suspended sediments due to waves (to tidal participation) in the winter and suspended sediment transported to the south under the influence of wind. In areas with large tidal amplitudes, such as the east coast of the Mekong Delta, the influence of tidal currents is very significant. Although the amount of water flowing towards the shore at high tide is equivalent to the outflow of water at low tide, but tidal currents tend to promote sediment transport to the seaside and accretion while waves tend to cause erosion.

- *Impact of hard construction (coastal squeeze) is built around the water's edge:* First of all, coastal squeeze structures are impossible to limit the sediment transport of cross-shore, Longshore or sedimentations, and further they aggravate coastal erosion.

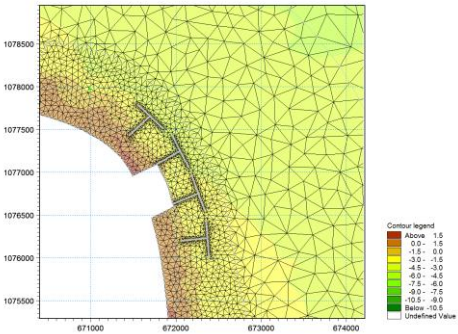
Figure 3. 16: Diagram of orientation of coastal protection structures

3.3.2. Propose coastal protection solutions

The Travinh's coast has a few areas of serious landslides that require protection solutions in Hiep Thanh, Truong Long Hoa and Dan Thanh communes as shown in Figure 3.16.

3.4. SOLUTION TO PROTECT THE COAST OF TRAVINH IN HIEPTHANH AREA

3.4.1. Introduction of coastal area of Hiepthanh commune



The coastal section of Hiepthanh commune has coordinates from A (669448-E, 1078472-N) to F (672203-E, 1072363-N).

3.4.2. Selected construction plan

Figure 3.17: Diagram of coastal protection works in Hiep Thanh commune

Table 3.5: Construction scenarios

Scenario's name	Describe the scenario	Distance from dike to shore X (m)	Length of dike L (m)	Distance between 2 dikes G (m)	Elevation of the dike crest (m)
HT	current	(Calculated in section 3.1)			
KB1	4 T-dykes	300	400	130	+2.0
KB2		300	400	80	+2.0
KB3		300	400	50	+2.0

3.4.3. Analyzing the effectiveness of the treatment system

a) Effectively reducing flow velocity in coastal areas

Flow roses extracted at position P for 4 calculated scenarios as shown in Figure 3.17. The T- dyke has reduced the velocity at point P significantly in terms of both the intensity and the time to maintain the high velocity. The distance between the dykes is smaller so the effective reduction of flow velocity is better.

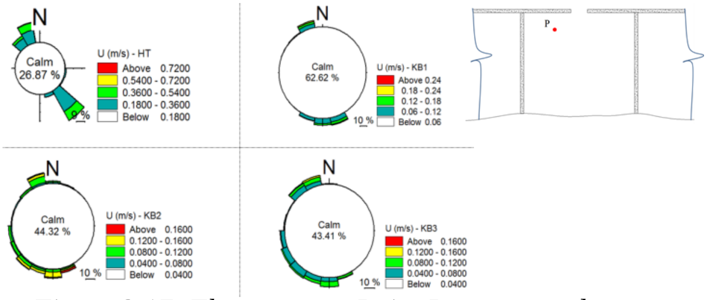


Figure 3.17: Flow roses at Point P corresponds to scenarios HT, KB1, KB2, KB3 in the Northeast monsoon (1/1/2011÷ 27/1/2011)

b) Effectively reducing wave height

The wave height diagram in section 3, 4 during the northeast monsoon period between the options is shown in Figure 3.18. Wave height at both sections after construction is significantly reduced compared to the time when the construction has not constructed. The smaller the distance between the dykes (G), the higher the wave reduction effect.

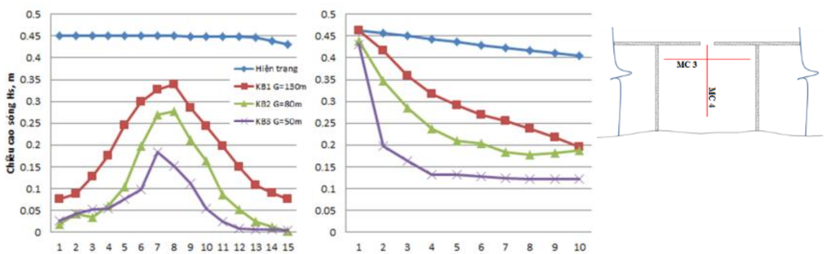


Figure 3.18: Wave height at section 3 (left) and section 4 (right) at 19:00 on January 18, 2011 (Northeast season)

c) Effective reduction of Longshore sediment transport

Calculation results show that T-dykes significantly reduce Longshore sediment transport.

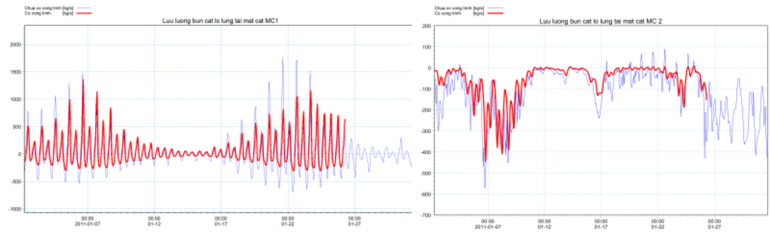


Figure 3.19: Comparison of suspended sediment flow at cross-section MC1 and MC2 between 2 alternatives: with construction and no construction

d) Morphological developments

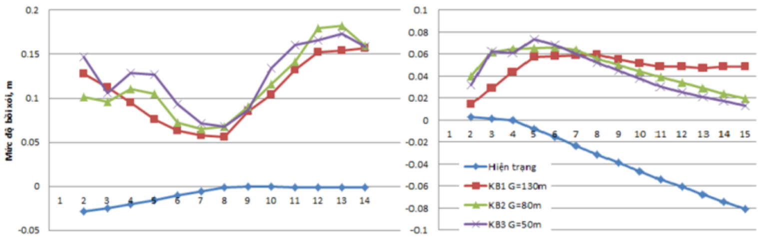


Figure 3.20: Deposition level at MC3 (left) and MC4 (right) after 1 month

THE CONCLUSIONS AND RECOMMENDATIONS

The conclusions:

1. The thesis has studied the factors affecting hydrodynamics and sediment transport in coastal areas of Tra Vinh. The calculation results indicate that:

- Waves: (i) The northern half-shore area is more severely affected than the southern half by the impact of large waves during the northeast monsoon season; (ii) The underground wall reduces the wave at the distance from the shore from about 6 (mid-shore) - 10km (north and south banks); (iii) Wave height at locations near the river mouth is always lower than the mid-shore points due to the bottom topography and the impact of the flow of the river.

- Flow: 3 factors that strongly influence the flow regime in the coastal area of Tra Vinh are: The flow of the Mekong River in the rainy and dry seasons, the semi-diurnal tide regime with a tidal range of 2-4m / day, the northeast and southwest monsoon climate regime. There are some basic characteristics:

+ The impact of the flow regime and the sediment content of the Mekong in the rainy and dry seasons for the coast of Tra Vinh can be considered the largest compared to the surrounding coastal areas;

+ The flow velocity is the greatest when the tidal direction coincides with the monsoon direction, more specifically, the flow occurs in the northeast monsoon season when the tide rises and occurs in the southwest monsoon season during the ebb tide phase;

+ The positions near the river mouth always have a higher flow velocity than the mid-shore points;

+ The flow in the high tide phase (especially in the northeast monsoon season) has a significant influence on coastal erosion;

+ The direction of flow during the flood tide in both the northeast and southwest monsoon comes from the northeast, which contributes to the increase of the erosion of the northern half of the coast in both seasons.

- Mechanism of sediment transport: The tendency of Longshore sediment transport to the southwest dominates during the northeast monsoon season. The process of cross-shore sediment transport plays an important role in shoreline development. The amount of sediment from the Mekong River through Dinh An estuary, accreting to the coast of Tra Vinh is very large every year.

- The thesis has built hydrodynamic and sediment transport diagrams in the coastal area of Tra Vinh in the northeast and southwest monsoons.

2. Based on the calculated results of hydrodynamic and topographic terrain in the coastal area, the thesis has developed a sketch of the cross-section of the coast of Tra Vinh. The thesis also identified and gave some initial explanations about the shape of the coast of Tra Vinh, which tends to protrude out to the East Sea than the surrounding coastal areas. However, this issue needs further research.

3. The thesis has calculated the erosion with the current scenario, it shows that the dominant areas of erosion are Hiep Thanh, Truong Long Hoa, Dan Thanh, and the area of deposition is Dong Hai. The results on the change in the thickness of the deposited layer at 3 typical points of the coast of Tra Vinh (Sx-high erosion, Sb - high deposition, So - stable) with different scenarios (current situation, sea level rise 13cm and 23cm, decline sediment in Mekong river 20% and 30% - compared to 2011) were extracted from the model. The thesis

has built the relationship between sedimentary thickness over time. The effects of sea level rise due to climate change and the decline in the sediment load of the Mekong River due to the construction of upstream structures tend to increase the level of erosion (or reduce deposition) in the coastal areas.

4. The thesis provides the approach for selecting the type of works to regulate and stabilize the coastline of Tra Vinh province: (i) Hiep Thanh area using the T-dyke project to reduce wave height from far and limited Longshore sediment transport; (ii) Truong Long Hoa area uses the form of offshore wave dam construction; (iii) Dan Thanh and Dong Hai areas use the form of hollow fence with bamboo or Melaleuca poles.

5. The research results have been applied to arrange the coastal protection of Tra Vinh to Hiep Thanh commune area and determine that the distance between the dykes should be 50m.

The recommendations:

The results in this thesis only consider the actual conditions in the period of 2011 and 2014. Therefore, the above analytical results are only representative of these time periods.

The following research directions are needed:

- The study results of the protrusion of the Tra Vinh coast in the dissertation are just initial explanations, it is necessary to study the process of shoreline formation through many periods using remote sensing images in the future.
- Studying the influence of the canal Tat and the works around the canal Tat mouth after being put into use (2016) to the hydrodynamic and sediment transport regime in the coastal area of Tra Vinh.
- Research on the synthetic impact of construction works on the upper Mekong River and sea level rise on coastal developments in Tra Vinh area.

LIST OF PUBLICATIONS

1. Hoang Van Huan, Nguyen Thi Phuong Thao. *Some basic problems in designing the base structure of wind power stations are located in the coastal areas*. Journal of the Science and Technology of Southern Institute for Water Resources Research, 2012. ISSN: 1859-4255.

2. Hoang Van Huan, Phan Manh Hung, Nguyen Thi Phuong Thao. *Some initial rudiment results on hydrodynamic – wave – deposition/erosion processes in the coastal southern Vietnam*. The 14th Asian Congress of Fluid Mechanics (14 ACFM), Ha Noi, 2013. ISBN: 978-604-913-145-5

3. Hoang Van Huan, Nguyen The Bien, Nguyen Thi Phuong Thao. *Shore fluctuations in coastal areas of Tra Vinh province - the basic causes.* Proceedings of the Scientific Conference on Hydraulic Mechanics, 2013. ISSN: 1859-4182.

4. Hoang Van Huan, Pham Van Tung, Nguyen Thi Phuong Thao. *Causes of flooding in Nha Trang city*. Proceedings of the Scientific Conference on Hydraulic Mechanics, 2013. ISSN: 1859-4182.

5. Nguyen Thi Phuong Thao, Hoang Van Huan. *Application of mathematical models to study hydrodynamics and sediment transport in coastal areas*. Proceedings of the Scientific Conference on Hydraulic Mechanics, 2015. ISSN: 1859-4182.

6. Hoang Van Huan, Nguyen Thi Phuong Thao. *Identify the causes of fluctuations in the hydrodynamic regime in the coastal area of Tra Vinh*. Proceedings of the Scientific Conference on Hydraulic Mechanics, 2016. ISSN: 1859-4182.

7. Nguyen Thi Phuong Thao. *Assessment of economic benefits from floods in the Mekong Delta*. Proceedings the third scientific conference "Effective management of natural resources and environment for green growth", 2016. ISBN: 978-604-73-4719-3.

8. Nguyen Thi Phuong Thao, Hoang Van Huan. *Influence of coastal hydrodynamic regime to morphological characteristics of coastline of Tra Vinh province*. Proceedings of the Scientific Conference on Hydraulic Mechanics, 2017. ISSN: 1859-4182.

9. Nguyen Thi Phuong Thao, Hoang Van Huan. *The relationship between the total bed thickness changes of Travinh's coast with the sediment concentrations of the Mekong River and the sea level rise*. Journal of the Science and Technology of Southern Institute for Water Resources Research, 2018. ISSN 1859–4255.

10. Nguyen Thi Phuong Thao, Ho Trong Tien. *Simulation of sea level rise impact of climate changes on hydrodynamic regime and morphological change in the coastal region of Travinh province.* Vietnam environment administration magazine (VEM), 2018. ISSN 1859–042X.