Simulation of hydraulic regime and sediment transport in the Mekong delta coast

1. Introduction

Coastal erosion in the Mekong Delta has been recorded in recent years and the erosion rate has been increasing rapidly. Understanding the causes and erosion process is an important step in finding the suitable short-term and long-term solution. For this purpose, the hydrodynamic regime and the sediment transport in Mekong Delta will be studied using the numerical modeling method. The theoretical hydrodynamics (with the Telemac2D model), the wave problem (with the Tomawac model) and the morphological change problem (with the Sisyphe model) will be applied. All these modules were developed by Electricité de France with the collaboration of European and American laboratories. They are open source code and are widely used in the world.

2. STUDY AREA AND INPUT DATA

a. Computing mesh

The local area of interest includes the system of downstream rivers in the Mekong Delta and an extension of about 100 km coastline from the sea; extending from Vung Tau through the Gulf of Thailand to Rach-Gia. The area is about 87923 km^2. The study area is characterized by 123 thousand unstructured triangles with the largest mesh up to 10000m for offshore elements and smallest mesh only 200m for the coastal zone.

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Figure 1: Regional (Zone 1) and local (zone 2) study area

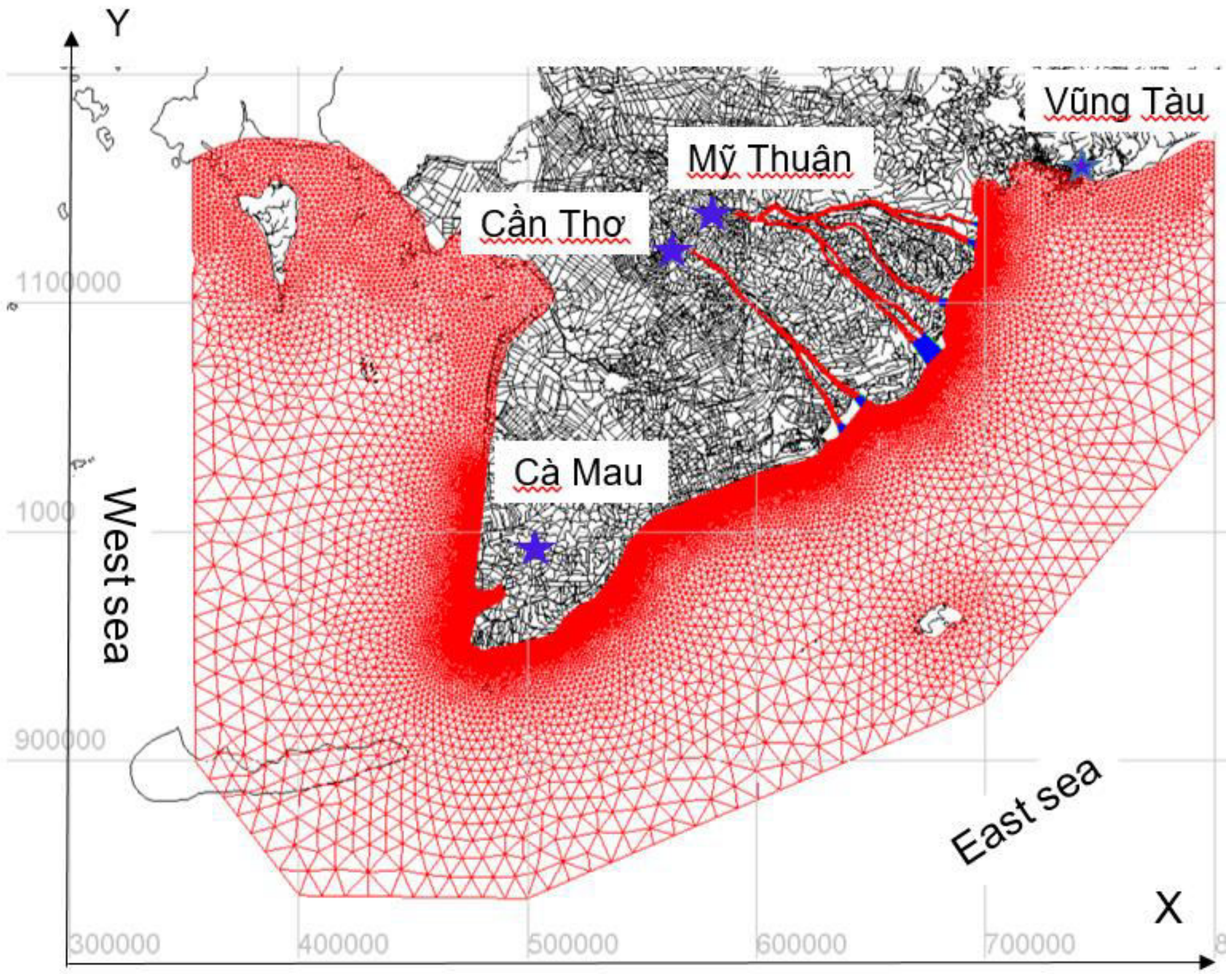

Figure 2.1: Computing mesh (Zone 1)

b. Input data

Bathymetry: Bathymetry data for the coastal study area was provided by from the first package work of project. Offshore terrain data is supplemented by GEBCO database with a density of about 900m. Terrain data is transferred to the WGS84 UTM system, piece 48. In addition, some extra data describing coastal and riverine areas are also used. With the above data, the entire grid area has been established. The following figure shows the sea bed data used for interpolation of mesh level in the model.

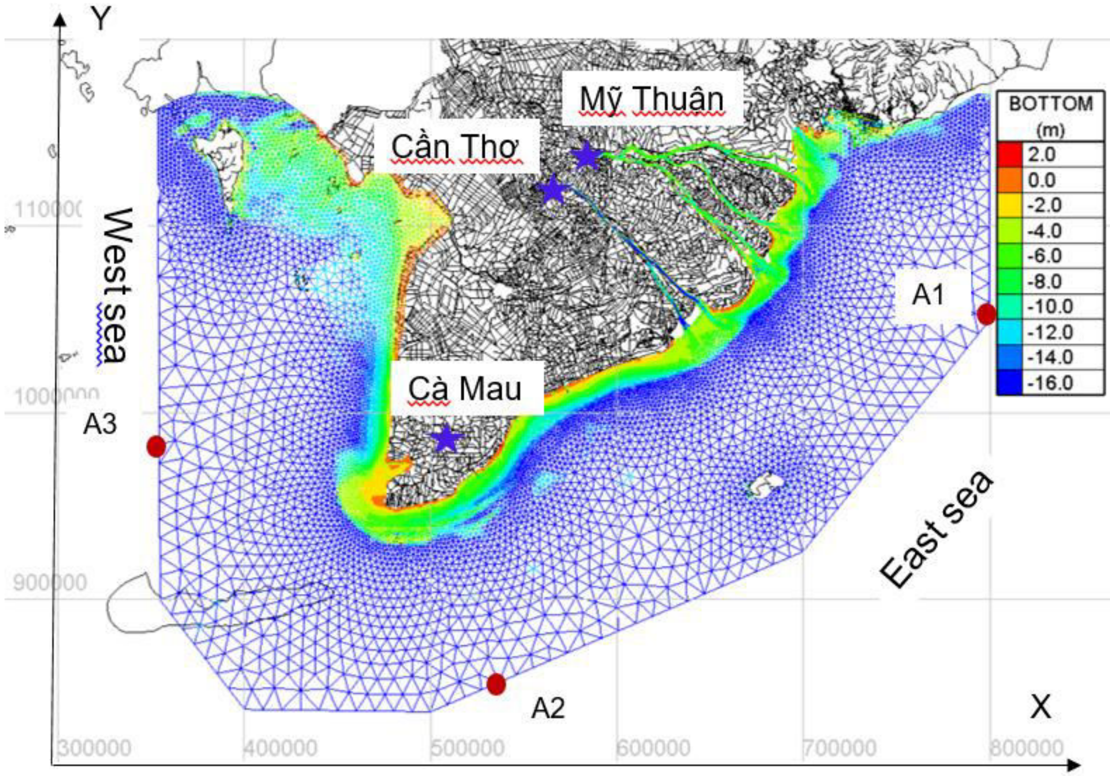

Figure 2.2: Bathymetry of study area

Discharge: The study area consists of two discharge boundaries on the two main upstream tributaries of Can-Tho and My-Thuan. The value of discharge at these two rivers shows that this area is affected by tides (reflected by the temporal change in value).

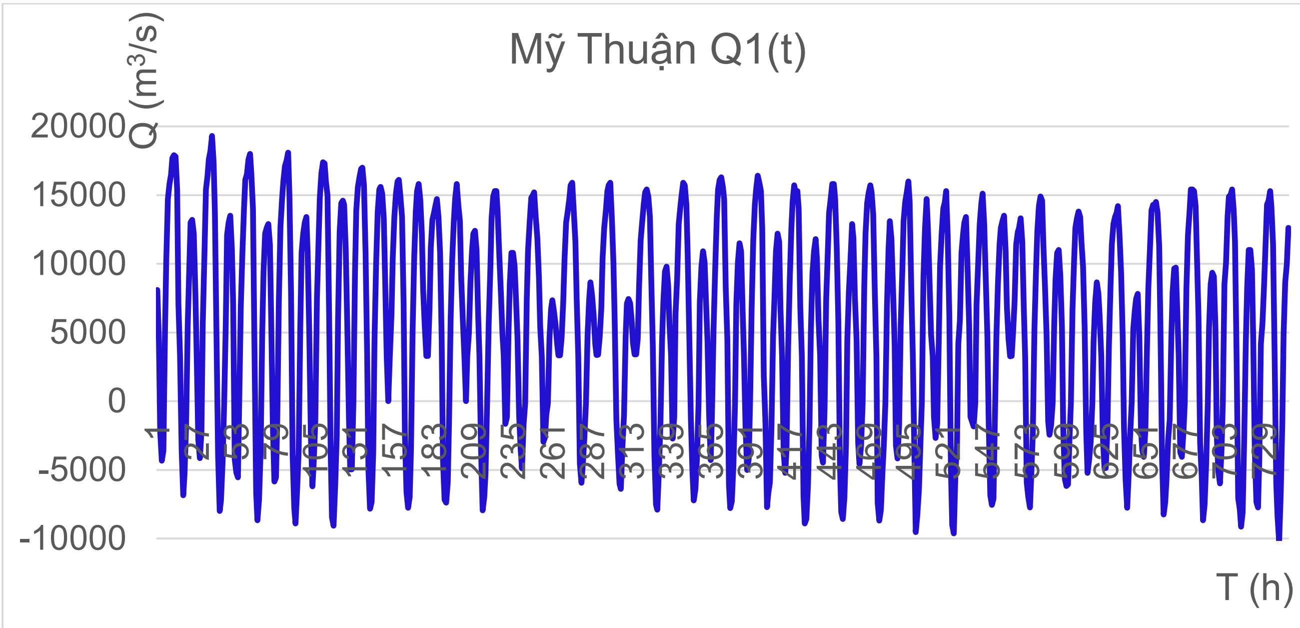

Figure 2.3: Discharge at My-Thuan in 1/2014

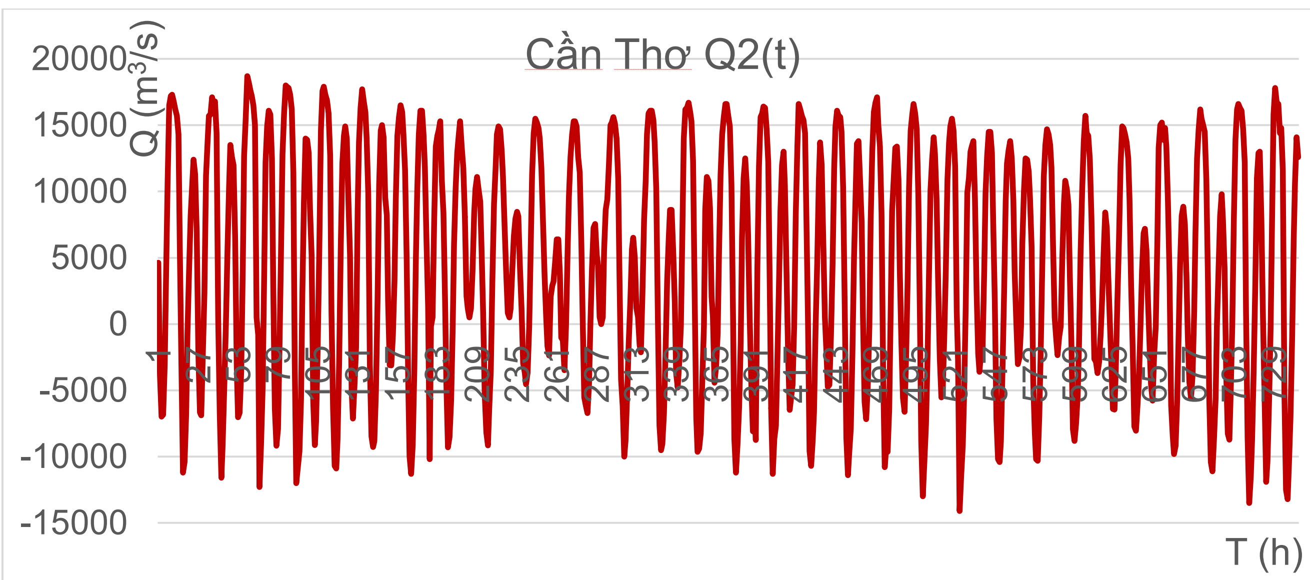

Figure 2.4: Discharge at Can-Tho in 1/2014

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 Direclet 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.

Tide level: The tide levels at the offshore open boundaries are set as astronomical tide under the same period with nine main waves (S2, N2, K2, M2, K1, O1, P1, Q1 and M4) from the OTIS database with a resolution of $1/30^0$.

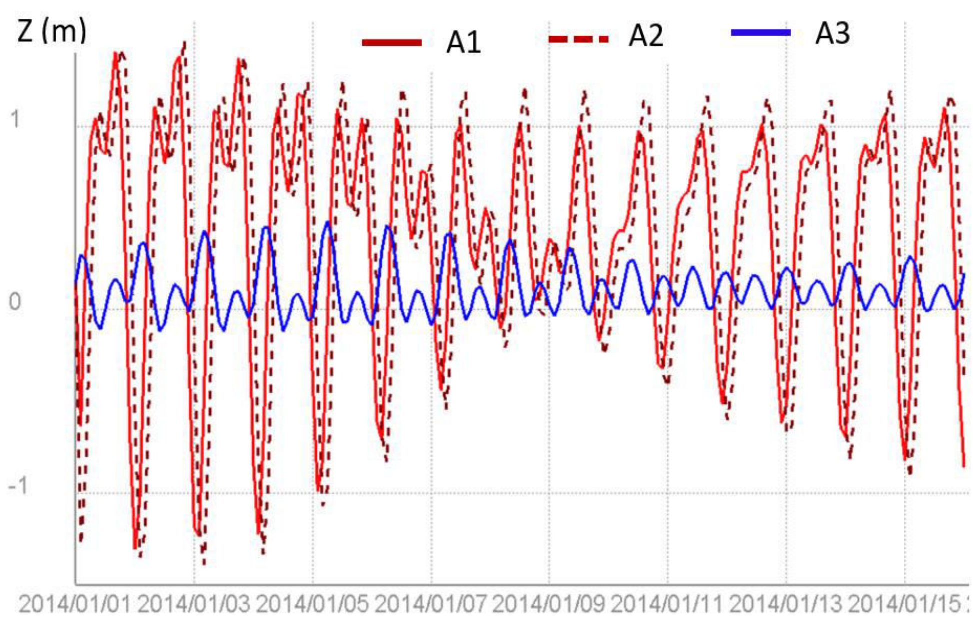

Figure 2.5: Tide level at typical positions in offshore boundary

Wave: Coastal wave data in the same period were taken from the NOAA database. Due to the change in wind direction, the monitoring data shows that in January, the wave heights in East Sea are higher than those in August. Meanwhile, in the West Sea one can observe the reversed phenomena. In August, the waves in the East Sea are generally much higher than in the West Sea.

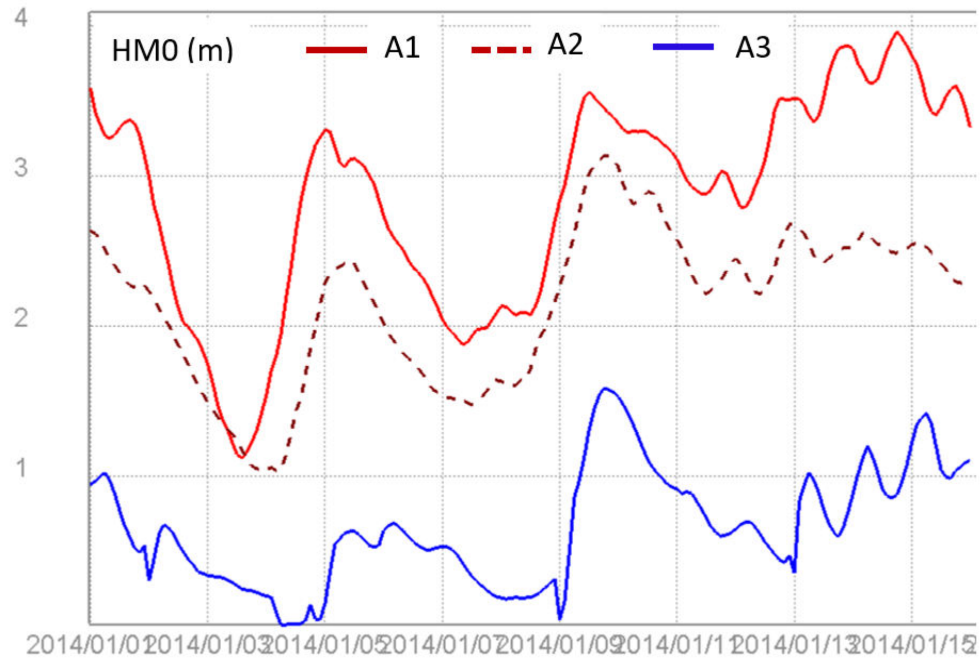

Figure 2.6: Wave height HM0 at typical positions in offshore boundary during period from 1/1/14 to 15/1/2014

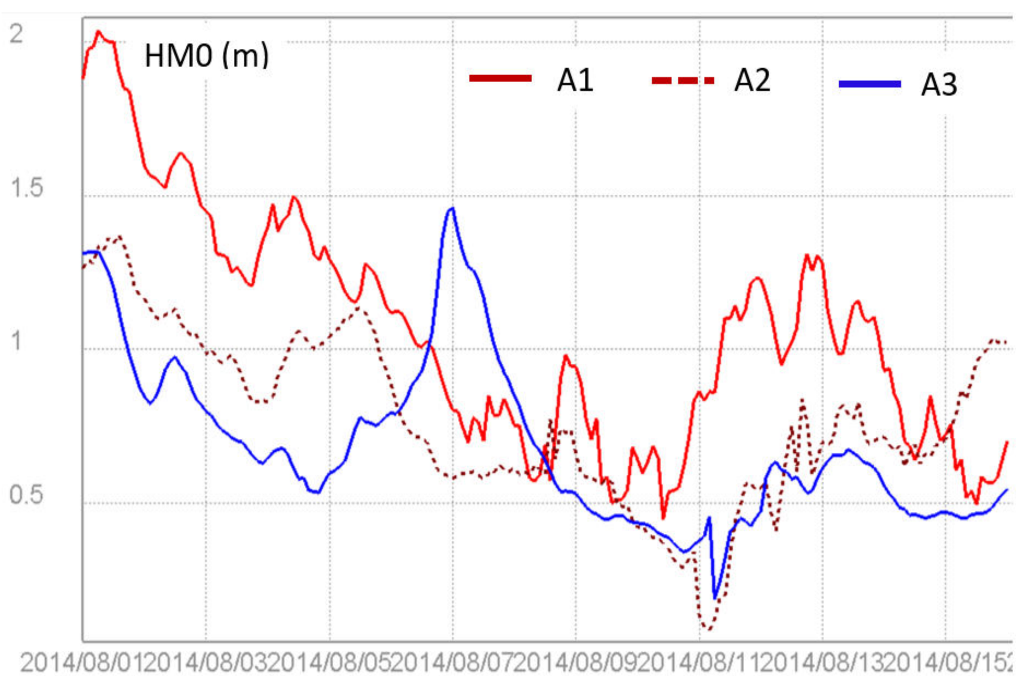

Figure 2.7: Wave height HM0 at typical positions in offshore boundary during period from 1/8/14 to 15/8/2014

Wind: The effects of wind (varying in space and time) on the flow are also taken into account. The following graphs show the wind chart in two typical seasons in January and August at the Hau river. The results show that in January, the wind mainly blows from the northeast. Meanwhile, in August, the main wind blows from the southwest.

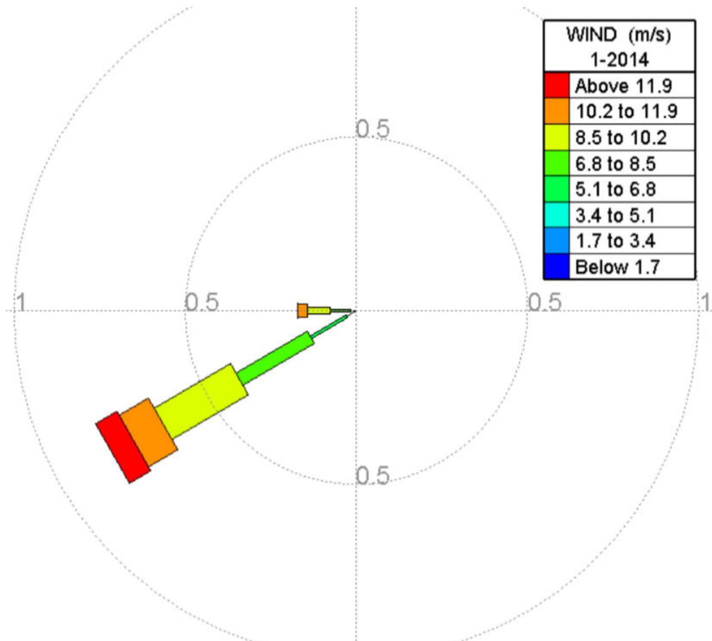

Figure 2.8: Wind rose diagram in 1/2014.

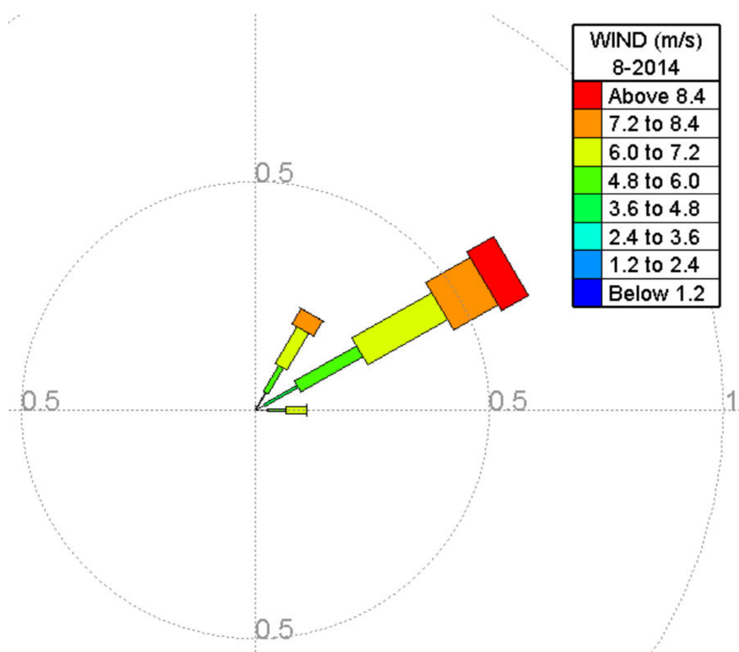

Figure 2.9: Wind rose diagram in 8/2014.

3. HYDRAULIC REGIME OF COASTAL AREA IN MEKONG DELTA

a. Introduction

Based on the available data, simulations were made for two typical seasons in the year, one with the main wind direction coming from the northeast (in January) and one with the main wind direction coming from the southwest (in August). Specific simulation is done for two cases as follows:

- Case 1: From 1/2/2014 to 1/4/2014
- Case 2: From 1/8/2014 to 1/10/2014

b. Boundary conditions

Based on the calibrated and validated model (presented in the First report) simulation of hydraulic regime and sediment transport in main rivers and coastal areas of the Mekong Delta are performed, using 3 modules: Telemac2D, Tomawac and Sisyphe. Hydraulic boundary conditions consist of two discharges in Can-Tho and My-Thuan, with monitoring data during study periods. The open boundary of water levels and velocities are applied to offshore boundary and were extracted from from the TPXO database.

c. Results

Velocity field: Under the effects of tides and waves in the East Sea as well as the discharge from the upstream of the Mekong Delta, a specific hydraulic regime in the study area is formed. Some typical results are shown in the following graphs and figures:

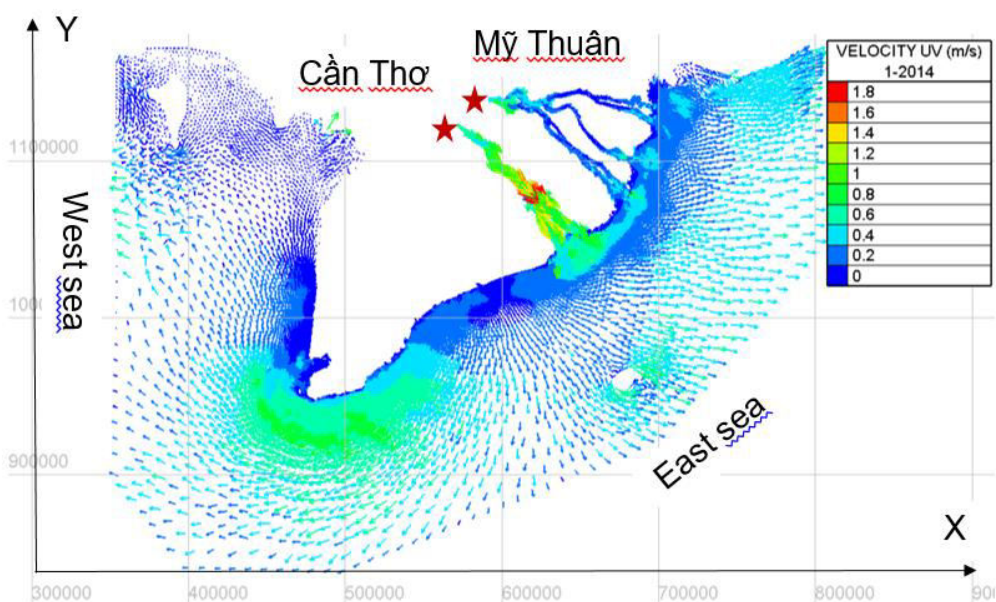

Figure 3.1: Instantenous velocity field at 0h, 18/2/2014

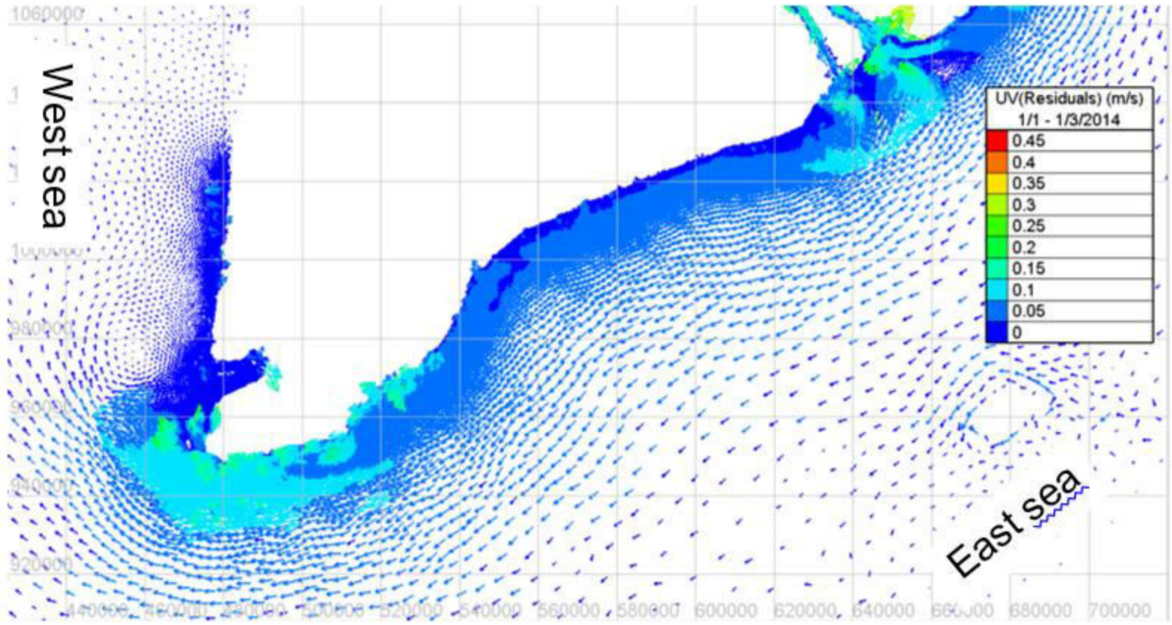

Figure 3.2: Average velocity field from 1/1/2014 to 1/3/2014

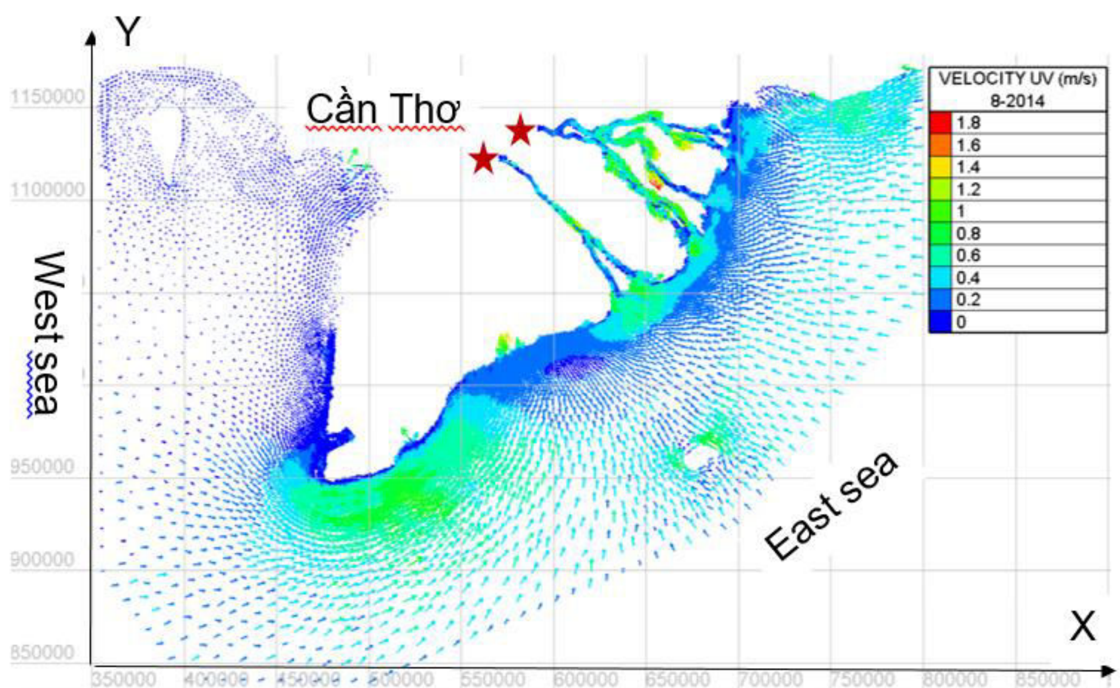

Figure 3.3: Typical velocity at 6h, 12/9/2014

Under the effect of tides and waves as well as the discharge from the upstream Mekong River, some comments on the velocity field in the domain are as follows:

- Under the effects of tides and winds, velocity field is formed with spatial and temporal change in direction. At the offshore, the main trend of flow is going parallel to the shore.
- The area in rivers, estuaries and Ca Mau cape, the instantenous velocities are relatively much higher than in other regions.
- An average flow along the coast, from the southeast and divert into the Gulf of Thailand is formed. The average velocity in January can reach 0.25m/s in the Ca Mau cape (Fig.3.2). This is an important factor in assessing the trend of sediment transport in the Mekong Delta.

Wave field: Monitoring data and modeling show that the waves in the East Sea have a greater amplitude in the West Sea. This might due to the geographic condition of the West Sea as a Gulf with relatively deep sea compared to the East Sea.

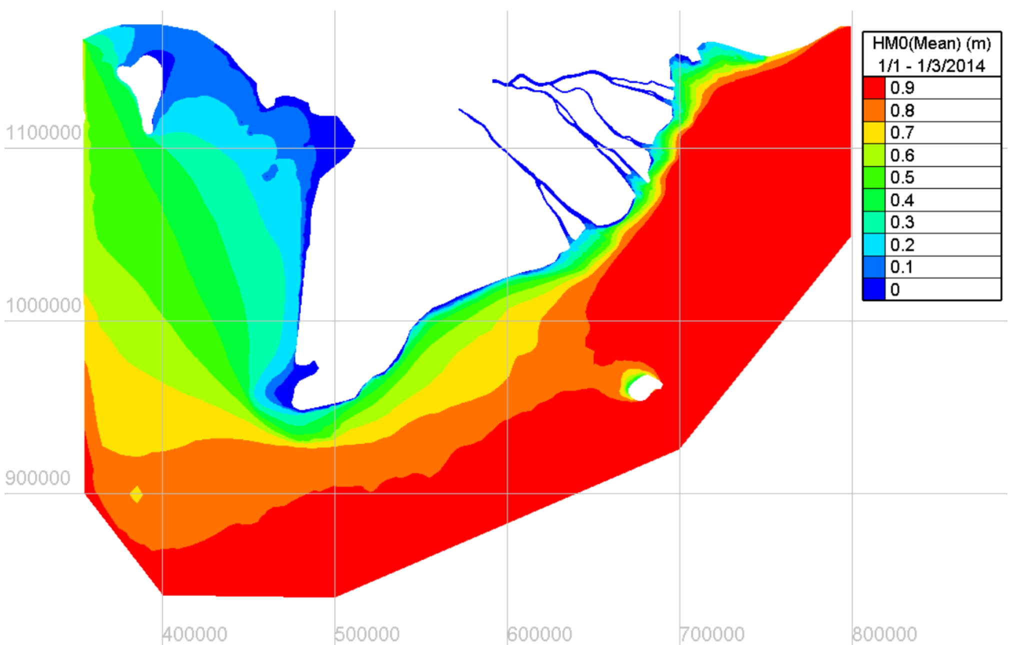

Figure 3.4: Average wave height HM0 from 1/1/2014 to 1/3/2014

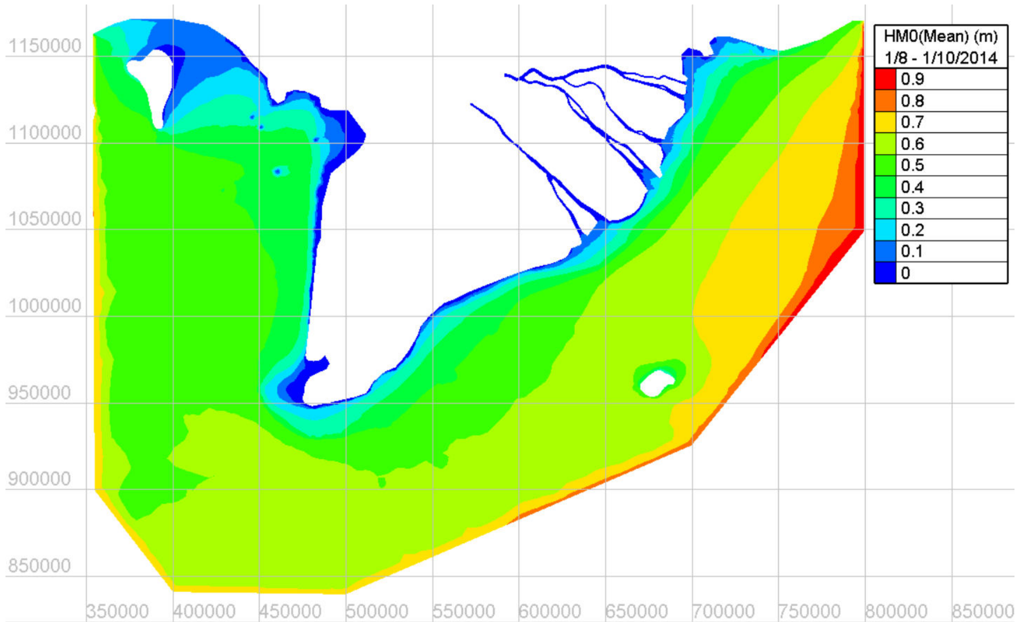

Figure 3.5: Average wave height HM0 from 1/8/2014 to 1/10/2014

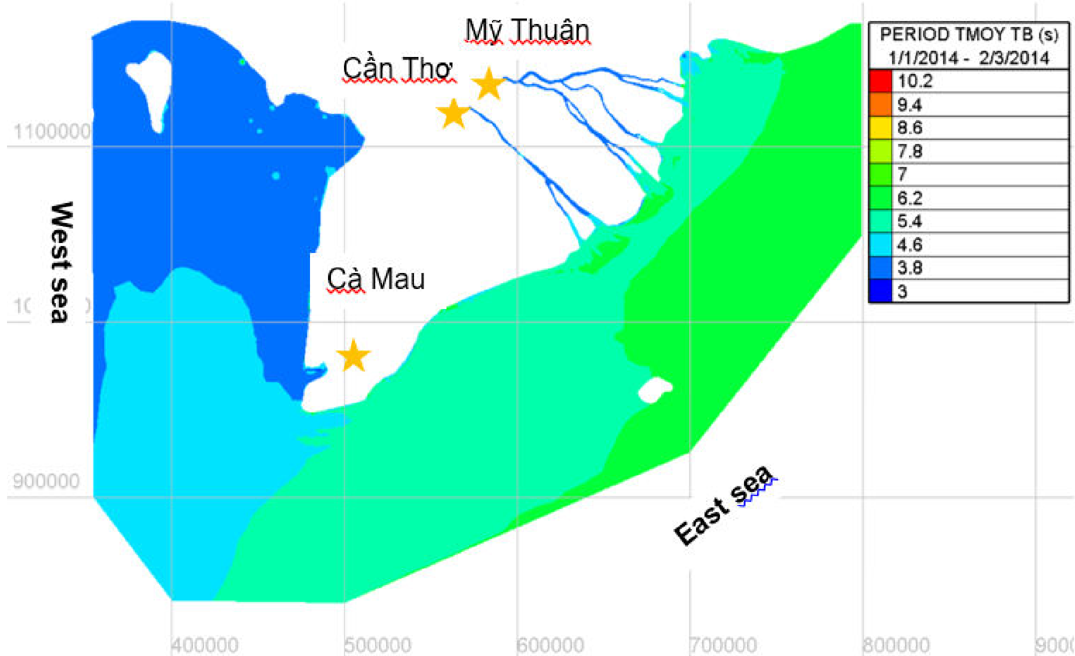

Figure 3.6: Average wave period from 1/1/2014 to 2/3/2014

Figure 3.7: Average wave period from 1/8/2014 to 30/9/2014

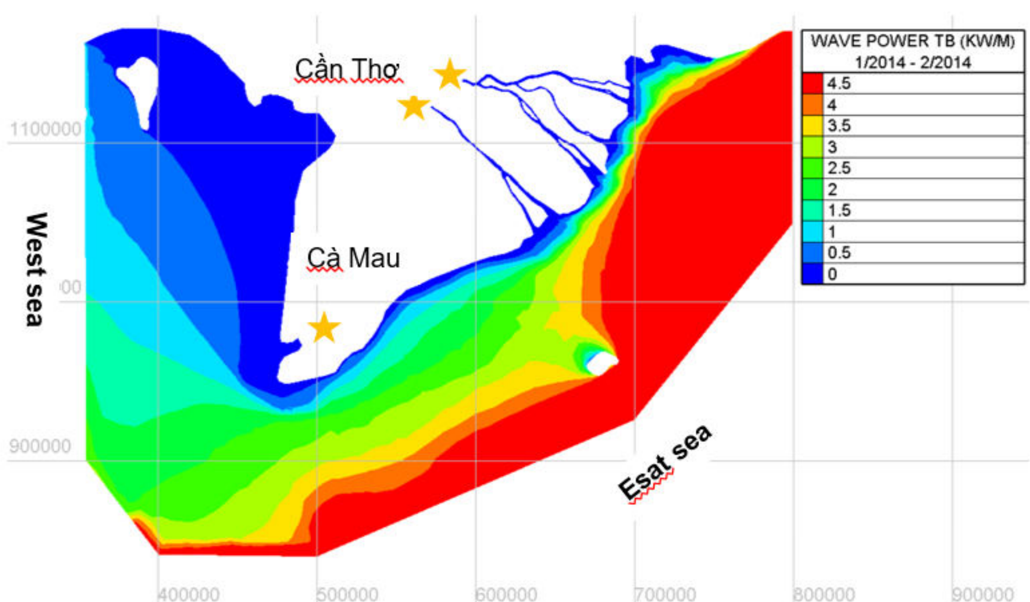

Figure 3.8: Average wave power from 1/1/2014 to 2/3/2014

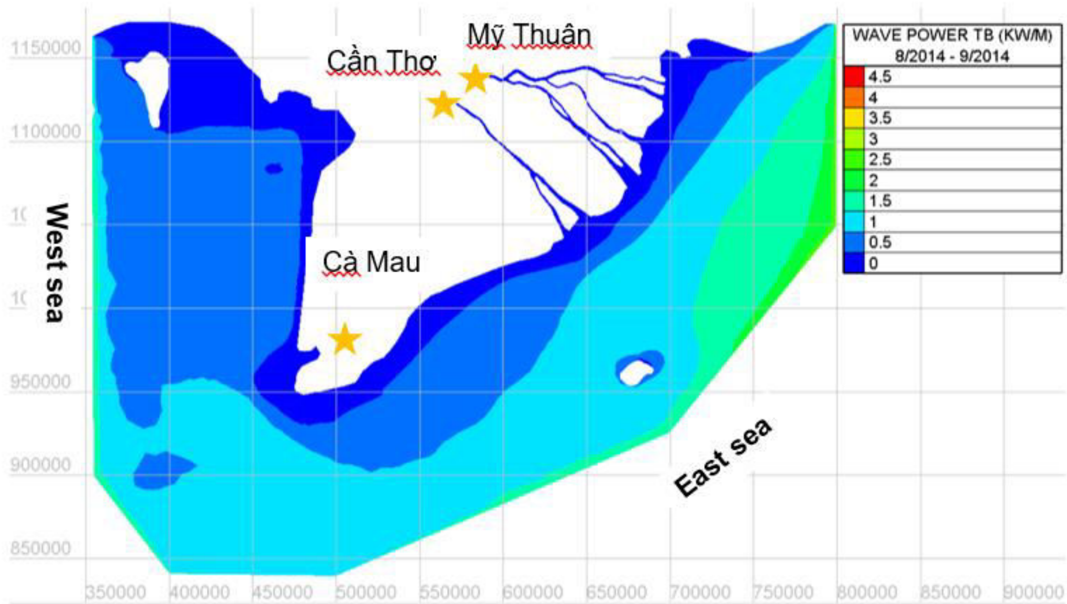

Figure 3.9: Average wave power from 1/8/2014 to 30/9/2014

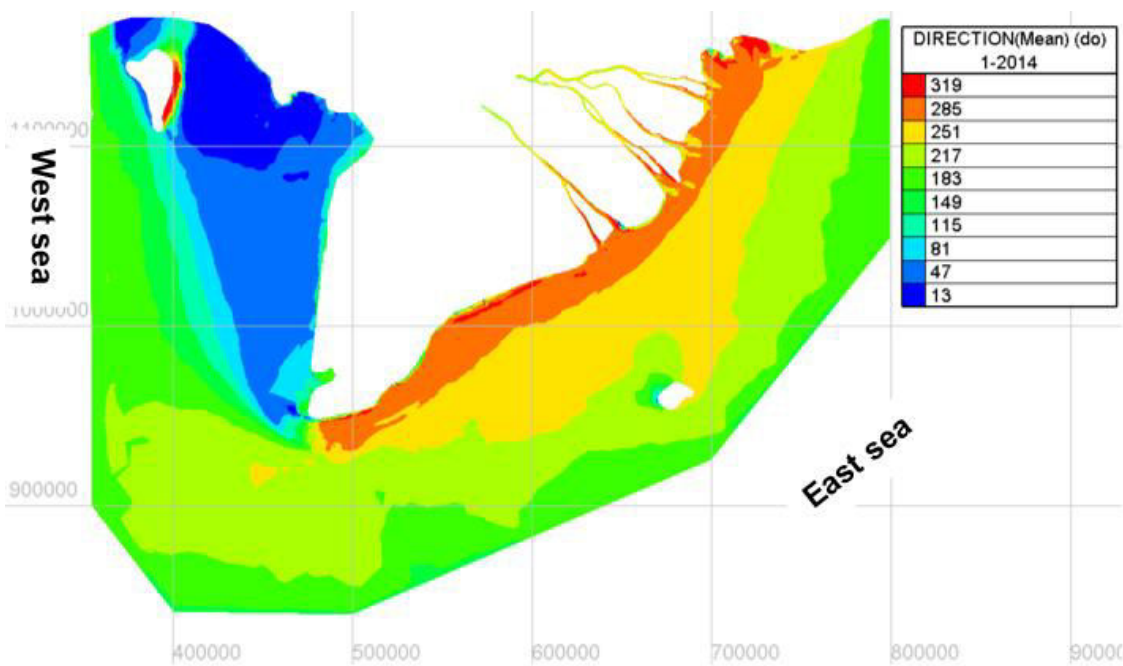

Figure 3.10: Average wave direction (compared to the north) from 1/8/2014 to 1/10/2014

Comparison of average wave height HM0 in January and in August gives the following comments:

- In the East Sea, the wave in January is much higher than in August (North-East monsoon) while in the West Sea, the wave in January is smaller than that in August (southwest monsoon).
- In coastal area, the mean waves are similar in August.
- The waves in East Sea are relatively larger than those in the West Sea, as noted above.
- During the monsoon season in January, wave in the West Sea tends to decrease rapidly as it goes into the Gulf of Thailand. In August, with the southwest monsoon, waves on the west coast are almost the same and did not diminish as they reached the Gulf of Thailand. This phenomenon can be explained from the trend of winds blowing towards the west coast of the respective season.
- Most waves in January have average period of 3 seconds to 7 seconds. Large-scale waves occur mostly offshore of the East Sea and their periods reduce gradually as going inshore. In the West Sea, much of the wave occurs with smaller period than in the east coast. Meanwhile, in August the waves appear to have a period of less than 3s to 5.5s. The wave period trend is relatively the same for both East and West seas.
- The wave is always straight when it comes to shore.

Sediment transport: The sediment transport is under the influence of hydraulic and wave regime in the area. As the monitoring data of sediments at the boundary is not sufficient, this study will use the sediment balance condition in these locations. Sediment sources defined in the study area will play an important role in this physical phenomenon. The following graphs show some of the main results of sediment transport for the two periods: in January 2014 and in August 2014.

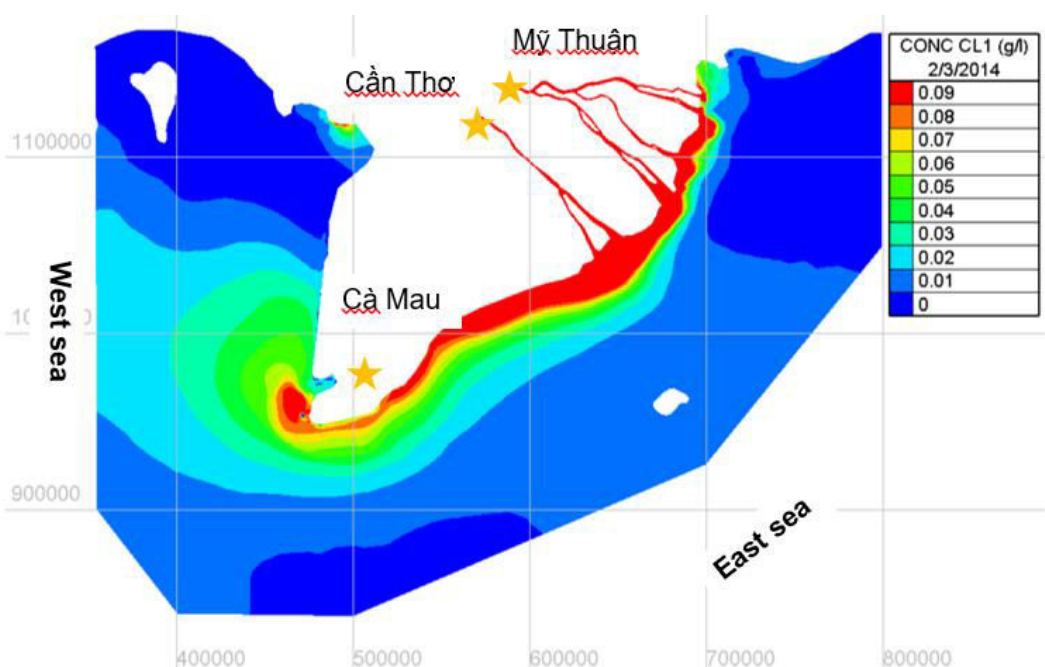

Figure 3.11: Sediment concentration at 0h, 2/3/2014

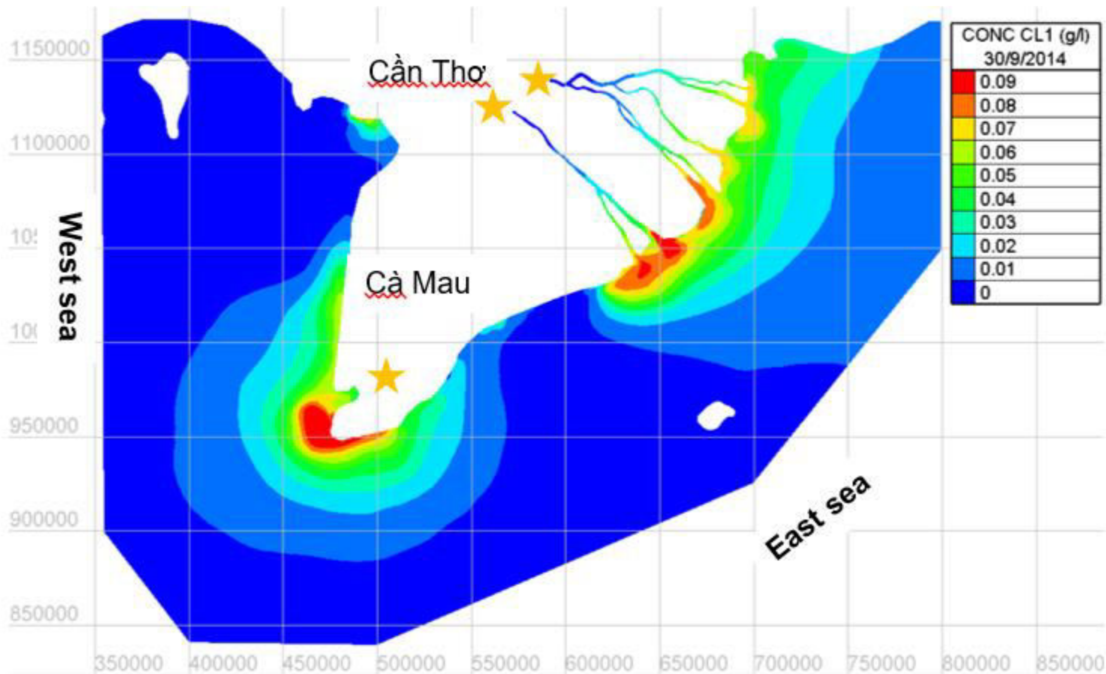

Figure 3.12: Sediment concentration at 0h, 30/9/2014

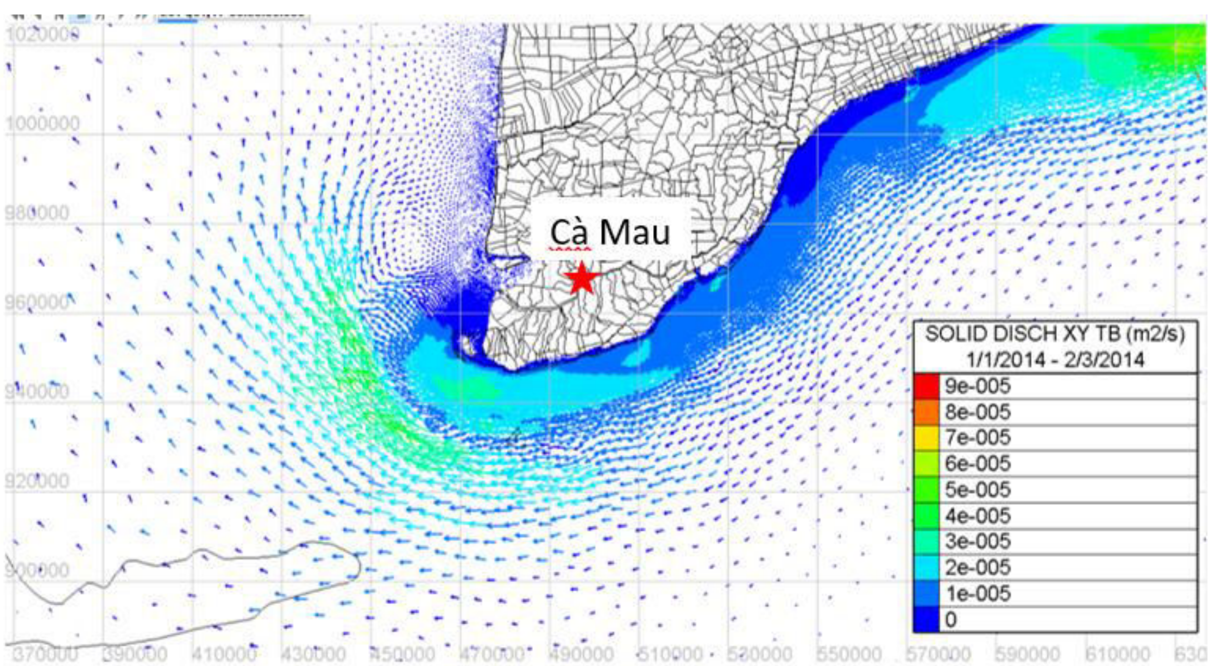

Figure 3.13: Sediment transport rate from 1/1/2014 to 2/3/2014

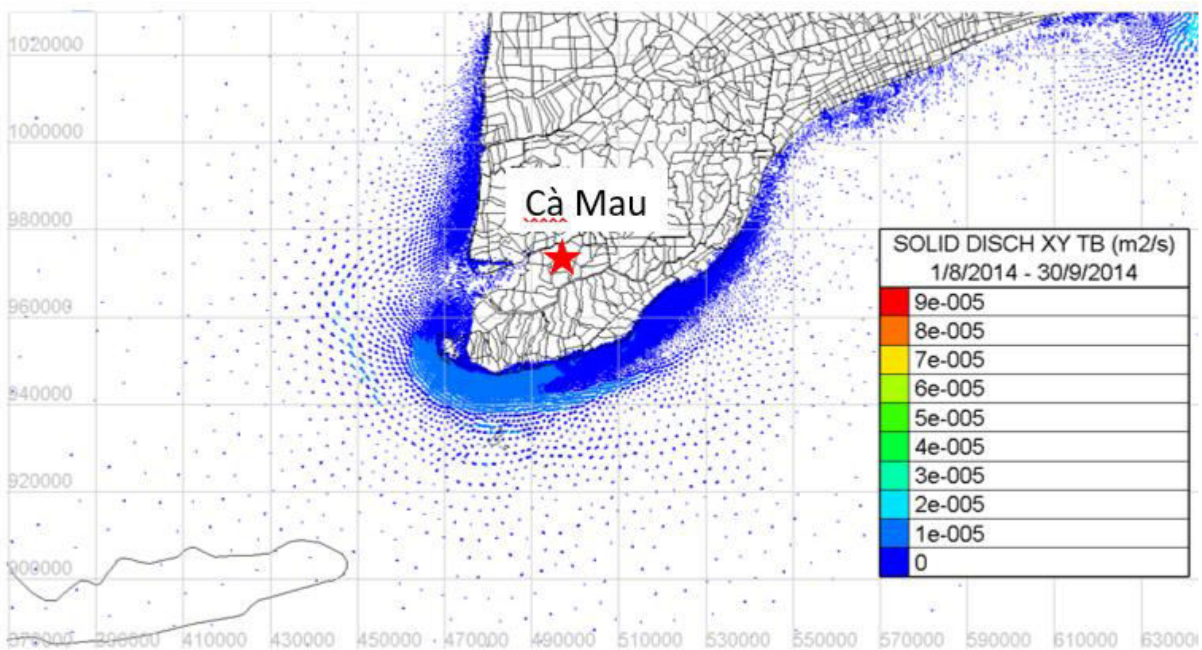

Figure 3.14: Sediment transport rate from 1/8/2014 to 30/9/2014

4. CONCLUSION

- The simulation results show that the coastal erosion rate in the North is more serious than in the South. This is consistent with the observation in recent years.
- Significant erosion occurs in the northern coast near Cua-Dai estuary and gradually decreases as far north.
- Waves play an important role in coastal erosion.
- Mainstream current trends caused by tides and waves are toward the south direction.
- Formation of many local vortices on the north coast due to the change in shoreline shape. This factor will create more adverse conditions for the area in terms of erosion.

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