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Preliminary Modelling Assessment of Hydrodynamic Simulation due to Terengganu Airport Runway Extension

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Abstract. Coastal erosion is a naturally phenomenon occurring result of the coastal hydrodynamic process. It is referring to the process of diminution, crafting and unloading of materials in coastal areas by agents such as waves, wind and tides. Erosion process becomes faster when there is activity on the waterfront development. To identify potential erosion caused by development, a study was conducted at the Terengganu Airport Runway extension. In this study, numerical modelling analyses were conducted to represent hydrodynamics using MIKE-21 software. The MIKE-21 is a comprehensive coastal modelling of software that simulates hydrodynamic, wave action, wind and tides. Modelling data input were obtained from National Hydraulics Research Institute Malaysia (NAHRIM) for the period of November 2009. Collected marine data were used as base for model calibration. Model calibration is with-in the acceptable confident level. Then, the calibrated model is used to predict the potential impact due to the Kuala Terengganu Airport runway extension.

1. Introduction

In order to accommodate the growing capacity of Kuala Terengganu and its economy growth, the Federal Government had decided upgrade public infrastructures to meet the demands. One of the first boosts for Kuala Terengganu is the upgrading of the Sultan Mahmud Shah Airport from a domestic airport into an international airport. The open door policy will of state government to invite more investors and tourist to visit state and boost is economic factor. Tourism is one of the important main economic contributors for state of Terengganu.

Kuala Terengganu (Sultan Mahmud) Airport was first built in 1948 as a grass landing strip. It was subsequently upgraded in the mid 1960’s to accommodate larger classes of aircraft. Later, with the discovery of offshore oil and gas reserves and the subsequent development of the local economy, the airport was again upgraded in the late 1970’s to accommodate Boeing 737 class aircraft.

On July 1, 1984, the first Boeing 737 aircraft landed at the airport. The increase in air passenger volume and the need to accomodate larger aircrafts has made it necessary to further upgrade the existing airports failities. Currently two main domestic carriers (MAS and Air Asia) are operating daily from the airport. Kuala Terengganu (Sultan Mahmud) Airport is currently operating with an airstrip length of 1,810m.

Separate airport upgrade works are being undertaken, which commenced late in 2005. The upgrading works include the extension of western end of the runway to a total runway length of 2,800m (opposite end to the proposed project), construction of new facilities and other associated airport infrastructure. The proposed project will further commence to extend the runway length from 2800m to a total length of 3480m to accomodate the operation of the Boeing 747-400 class aircraft at the airport.

According to Gopikrishna and Deo, (2017), the wave is the main agent causing changes in morphology of the coastal. The shorelines will keep changing its shape and position because of the environmental conditions (Salghunaa and Aravind, 2015). The impacts due to any changes in shorelines also is mainly influenced from the waves, tides, winds, periodic storms, sea-level change, sea geomorphic processes of erosion and human activities.

According to Muslim also mentioned that the shoreline at Terengganu has been categorized as critical. It is because of the physical process such as changes in sea levels and also human activities that contribute to this highly erosion occurred. Monitoring of this area or along the shoreline is necessary to identify the most affected location.

Belibassakis and Karathanasi (2017) also mentioned in the studied that environmental pressures from natural processes at coastal zones will influence problems such as raising of sea-levels compare the inland area. Modelling simulation showed that coastline changes along the shorelines because of the major contributions of sediment transport which if formed by the wave and current (Kaergaard and Fredsoe, 2012). Due to this high wave, it is contributed to the erosion occurred along the shorelines.

In 2008, Kuala Terengganu airport runway extension is completed, and some erosion problem occur and visible. In April 2009, NAHRIM engineers monitored erosion problems extend up to 8m of the coastline. The measured erosion distance was increased to 24m by September in the same year. Therefore, further research has been carried out by NAHRIM. The erosion phenomena were extended to be worst up to 46 m in March 2010.

2. Study Area

Kuala Terengganu airport is located about 6 km north of Kuala Terengganu rivermouth. The expansion of the Kuala Terengganu Sultan Mahmud Airport involve land reclamation of the coastal area fronting the existing runway or present airport boundary. The existing runway was further extended seawards on this new land to be created.

The southern coastline of the airport is orientated at 61.5^{0}N and merged into the stramlined of Kuala Terengganu breakwater located further south. North of the airport, the angle of the coastline turns more northward and becomes 47^{0}N. The proposed airport runway extension intersects the coastline at a point known as an inflexion point which is a point with zero net transport and where the net sediment transport is moving southward south of the point and northward north of the point on an open coast with moderate changes in the coastline orientation, the position of the inflexion point is not fixed rather it moves up and down the coast as a result of the inherent seasonal variablity in the wave climate. A beach with an inflexion point will typically erode as sediment is transported away from the inflexion point and sand is lost continuosly.

Post extension of the airport runway start to withness several erosion phenomenon at the north and southern part of the airport. MIKE-21 numerical modelling software as a tool to model and analyze the physical impact of the ocean such as the wave, wind and tidal pattern during the monsoon impact which contributed by North East Monsoon season to simulate a hydrodynamic behaviour due to implication of extension of airport runway.

2.1. Marine Data Collection
Essential data for model input were obtained from the primary data measured by National Hydraulic Research Institute of Malaysia (NAHRIM). Base data for model input are bathymetry, current speed, current direction, water level and bed sample analysis are incorporated in data collection campaign. This marine data collection was executed from 3 November 2009 to 25 November 2009 which covered a cycle of spring to neap tide which is base minimum simulation period requirement.

2.2 Bathymetry
Model domain and bathymetry generation for modelling is shown at Figure 1. Primary bathymetry data are surveyed at the field throughout the survey duration. Offshore bathymetry data was optimized from DHI C-map source which is derived from world electronic navigation chart. All the bathy data was incorporated with mesh triagulation and interpolation process before generate the model domain of bathymetry as base fundamental for hydrodynamic (HD) and spectral wave (SW) model. Model domain intepolation was established base on the Mean Sea level (MSL). Datum which is base from Jabatan Ukur dan Pemetaan Malaysia (JUPEM). Water level data measured during the bathymetric survey and tied with MSL datum to sync with model domain datum. The difference between MSL datum and Admiralty Chart Datum is about 1.45m reffering to JUPEM observation shown in Table 3.

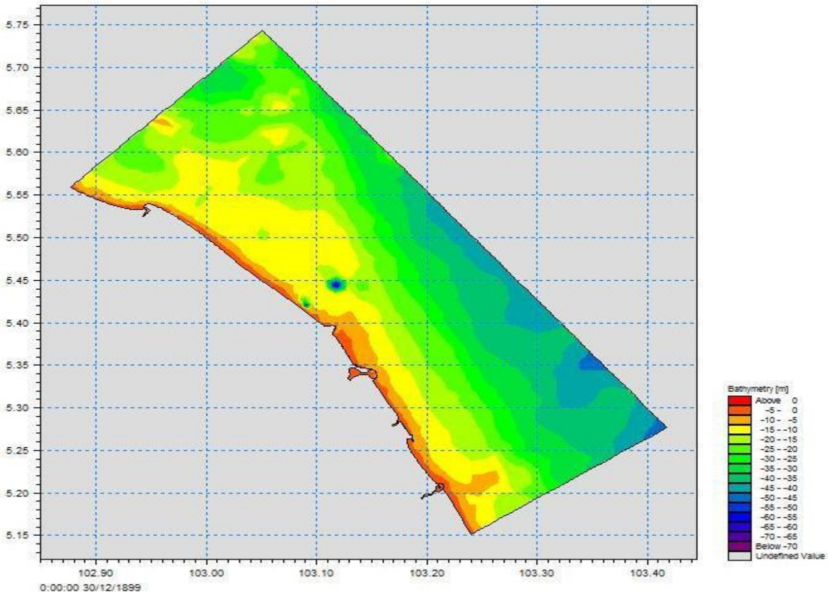

Figure 1. Model Doamin with Mean Sea Level Bathymetry Datum

2.3 Location of Data Measurements
In order to study the potential impact of the proposed breakwater in the study area, it is important to establish the baseline conditions so that once the impacts are quantified it is possible to evaluate the relative changes to the existing water environment. Prior to the modelling work, current, water level and bathymetry data were measured. The measurements are described in the sub-sections below and the location of the Acoustic Doppler Current Profiler (ADCP) and water level/tide gauge (TG) measurements is shown in Figure 2.Water level measurement stations and ADCPs locations deployed are as per stated in Table 1 and Table 2:

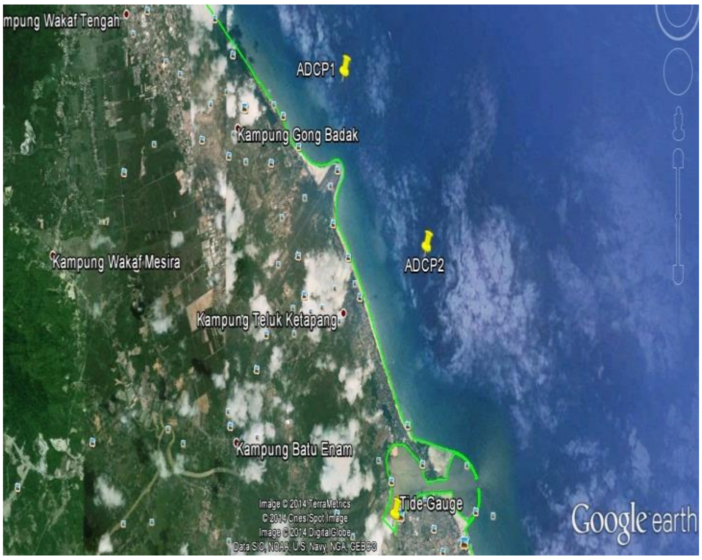

Figure 2. ADCP and Tide Gauge deployment location

Table 1. Location of ADCP-1 and ADCP-2.

Station	(East) Longitude (X)	(North) Latitude (Y)
ADCP-1	103.1168°	5.41044°
ADCP-2	103.1401°	5.37924°

Table 2. Location of tide gauge.

Station	(East) Longitude (X)	(North) Latitude (Y)
Tide Gauge	103.1307°	5.33309°

The water level and currents measurements were recorded from 3 November 2009 to 25 November 2009. Observed tidal range is recorded to be about 2.53 m during this measurement period. The tidal level relationship for Kuala Terengganu coast derived from harmonic constituent which is established from minimal of 30 days of water level measurementsfor Kuala Terengganu station information as extracted from Jabatan Ukur dan Pemetaan Malaysia (JUPEM). Tide table as shown in Table 3.

Table 3. Tidal levels and elevation for Kuala Terengganu.
(Source : JUPEM- Tide Table 2008)

Tidal Levels	Elevation (m ACD)
Highest Astronomical Tide (HAT)	+ 3.02
Mean Higher High Water (MHHW)	+ 2.47
Mean Lower High Water (MLHW)	+ 1.93
Mean Sea Level (MSL)	+ 1.45
Mean Higher Low Water (MHLW)	+ 0.97
Mean Lower Low Water (MLLW)	+ 0.43
Lowest Astronomical Tide (LAT)	0.00

2.4 Wind Data

East coast of Peninsular Malaysia is experiencing two monsoon seasons. The Northeast (NE) monsoon from November to March is dominant contributor compare to the Southwest (SW) monsoon from May to September. Historical wind data of Terengganu was collected from Malaysian Meteorological Department (MMD) for the duration from 2000 to 2009. Data covers the times series of wind speed and corresponding direction. The percentage frequency of various directions and speeds of wind from the collected data series is prepared for wind rose. Wind rose in Figure 3 represents pattern of annual wind speed at Kuala Terengganu meteorology station that is located at Kuala Terengganu Sultan Ismail Airport itself.

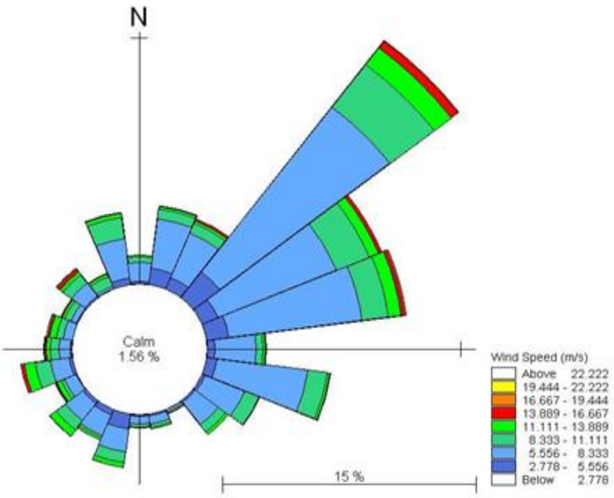

Figure 3. Pattern of wind direction and wind speed from 2000-2009.
(Source : MMD)

2.5 Hydrodynamic Model

Coastal processes are very dynamic and unique by presents of natural processes such as tide, wave, wind and morphological changes as well. According to the Rohit (2013) the coastal process which comprises of wave propagation, transformation and dissipation, wave induced water level changes and long-shore while the cross-shore currents due to wave, wind and tidal actions refers to the part of coastal hydrodynamics. Hydraulic modelling is a proven and tested technology as a tool which can be applied for any kind of hydraulic study either for river or sea. An effectively calibrated and validated hydrodynamic model is the pre-requisite for other models such as hydrodynamic model, wave model, morphological model etc. In this study, hydrodynamic model has been developed as a pre-requisite of wave and morphological model. MIKE-21 modelling system has been applied for hydraulic modelling. MIKE-21 is a user-friendly, fully dynamic, two-dimensional modelling tool for the detailed hydraulic analysis.

Figure 4 showed area which used as a boundary of the model. In order to create the model domain, triangulation mesh approach was applied before incorporated with the bathymetry values ahown in Figure 5. Model domain bathymetry bed resistence Manning adjested to be 45 after few simulation process which is best suited for the Kuala Terengganu coastal area.

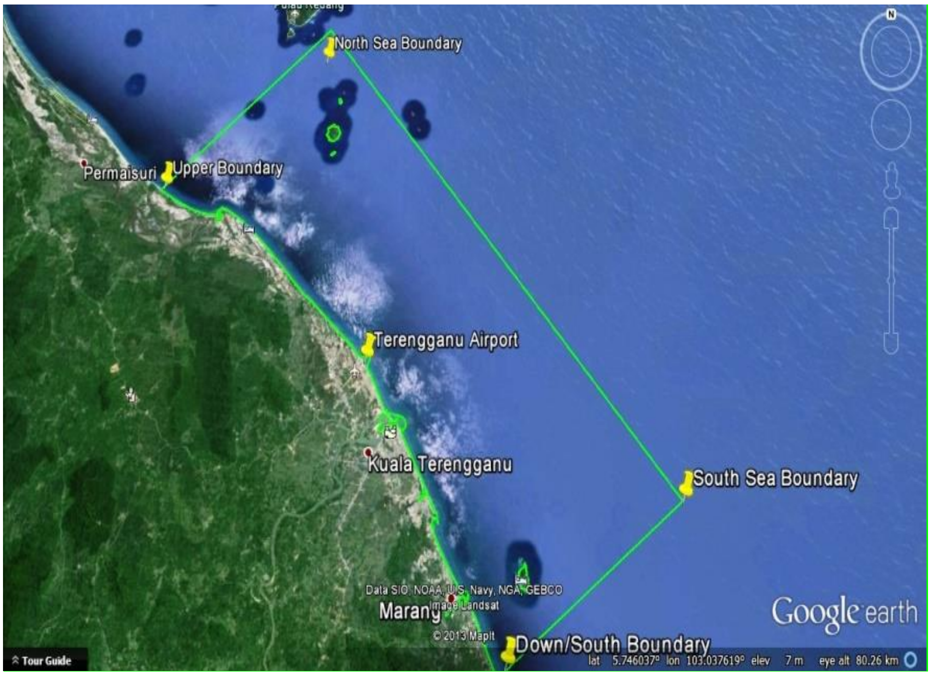

Figure 4. Domain for the model.

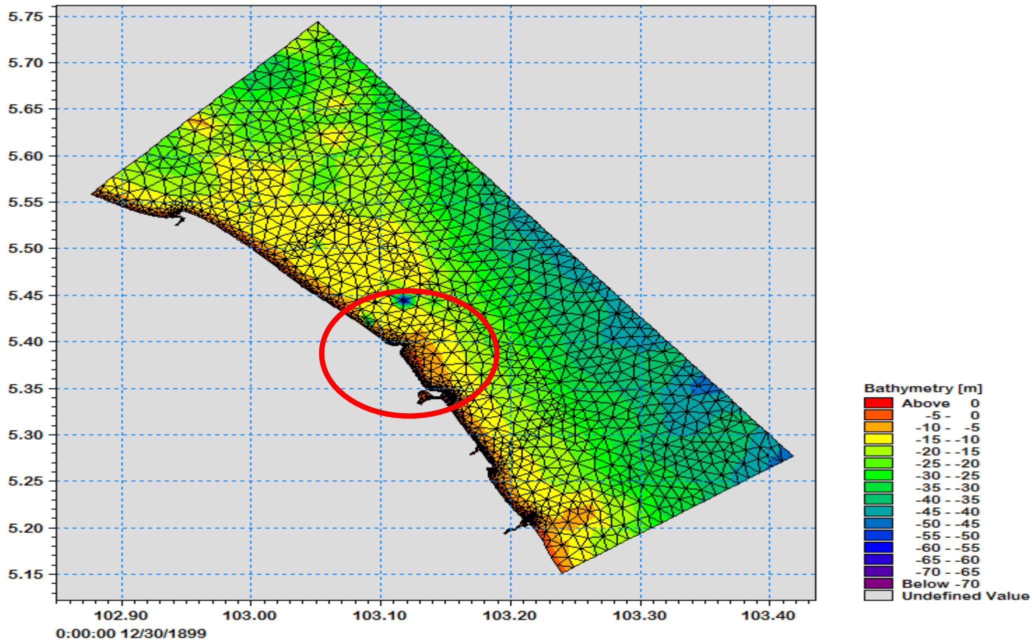

Figure 5. Bathymetry Model Domain with Triangulation mesh.

2.6 Model Calibration and Validation

All the developed numerical model calibrated with the collected marine data. Two main hydrodynamic element is calibated to ensure our simulation is valid. Current Speed and Water Level are the main calibrated elements. The tolerants in calibration process are varies by features which are 20% for the current speed and 10% for water level between the measured data and simulated model. Calibrated model domain is integrated with the constructed airport run way extension to predict the post construction model.

The hydrodynamic model has been calibrated against one measured water level and two current speed at both the ADCPs. Water level calibrations are shown in Figure 6 and current speed calibrations are shown in the Figure 7 and Figure 8. Both calibaration pattern suited well with the measured data shown in the following figures below.

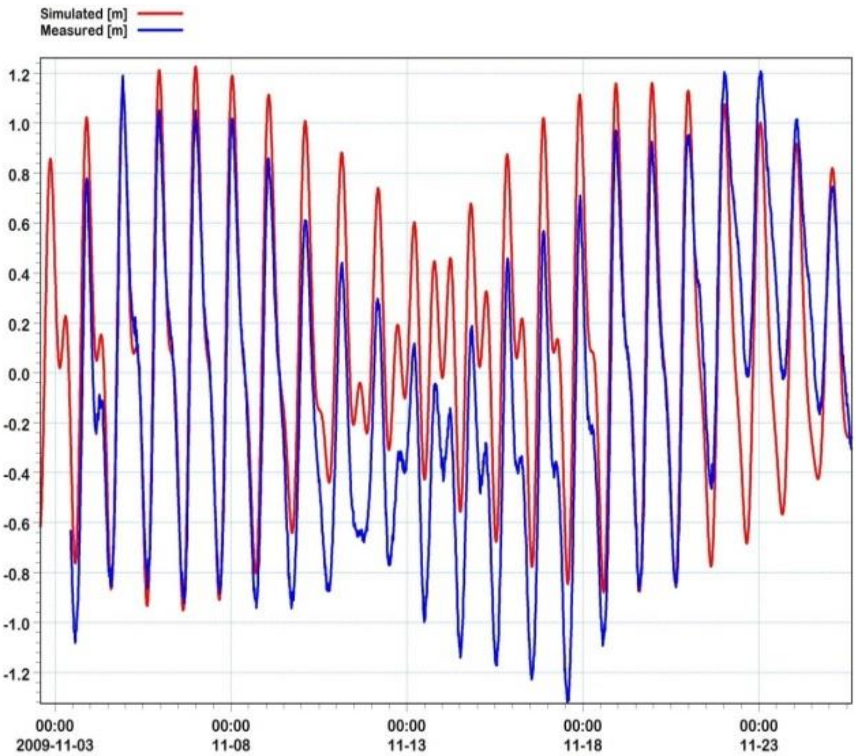

Figure 6. Calibration of water level at tide gauge

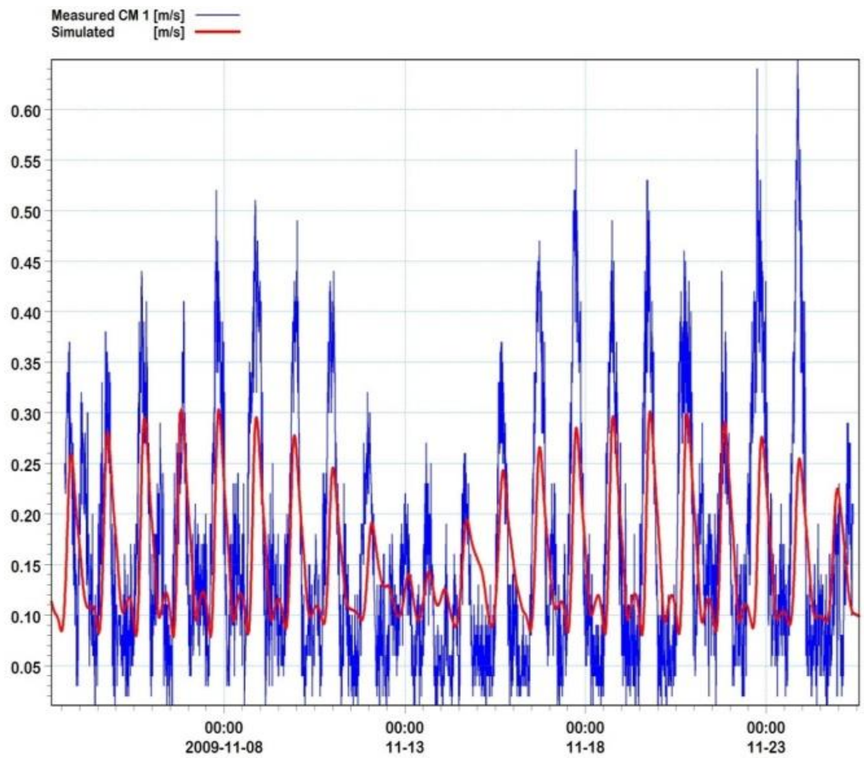

Figure 7. Calibration of current speed at ADCP-1.

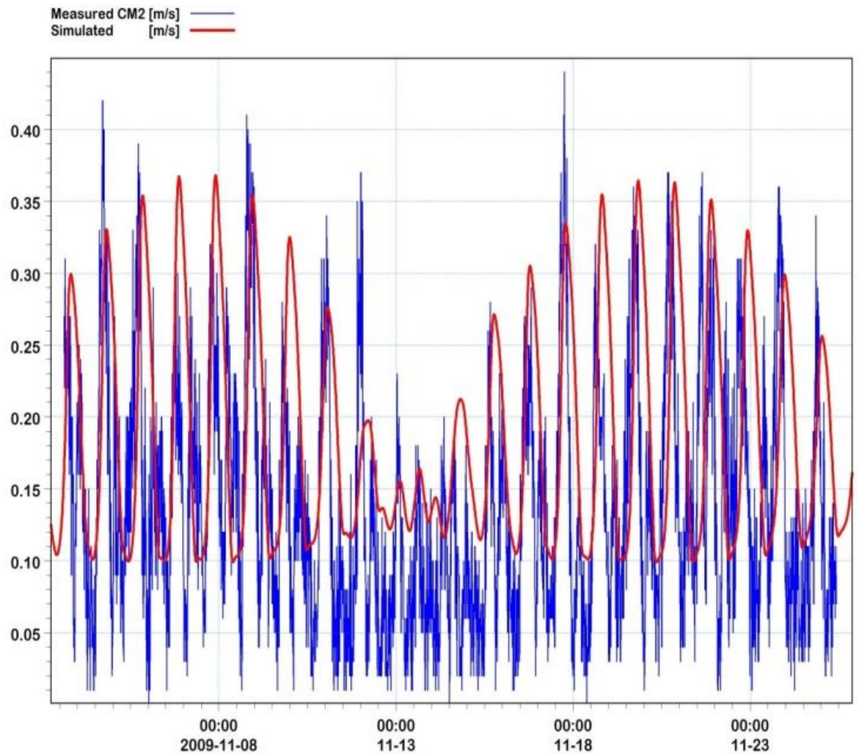

Figure 8. Calibration of current speed at ADCP-2.

2.7 Hydrodynamic Analysis

Figure 9 shows the variation of the current distribution arround the model region. The maximum current variation pattern shows range of 0.8m/s to 1.2m/s. This figure illustrates the visible current speed to be maximum at the reclaimed headland and slowly disperse to the shoreline towards the Northern and southern zones. Medium range of the current pattern are visible dominant at the Northern region. Post construction of the runway shows than some serious erosion phenomenon at the southern region. The slanting shape of the runway revetment drives the current speed travel to the nearshore of the coastal zone. Gradually decreasing the water depth is increase the bed resistance and increases the initial momentum for the non-cohesive sediment to lift from its original place to be travel along with the current.

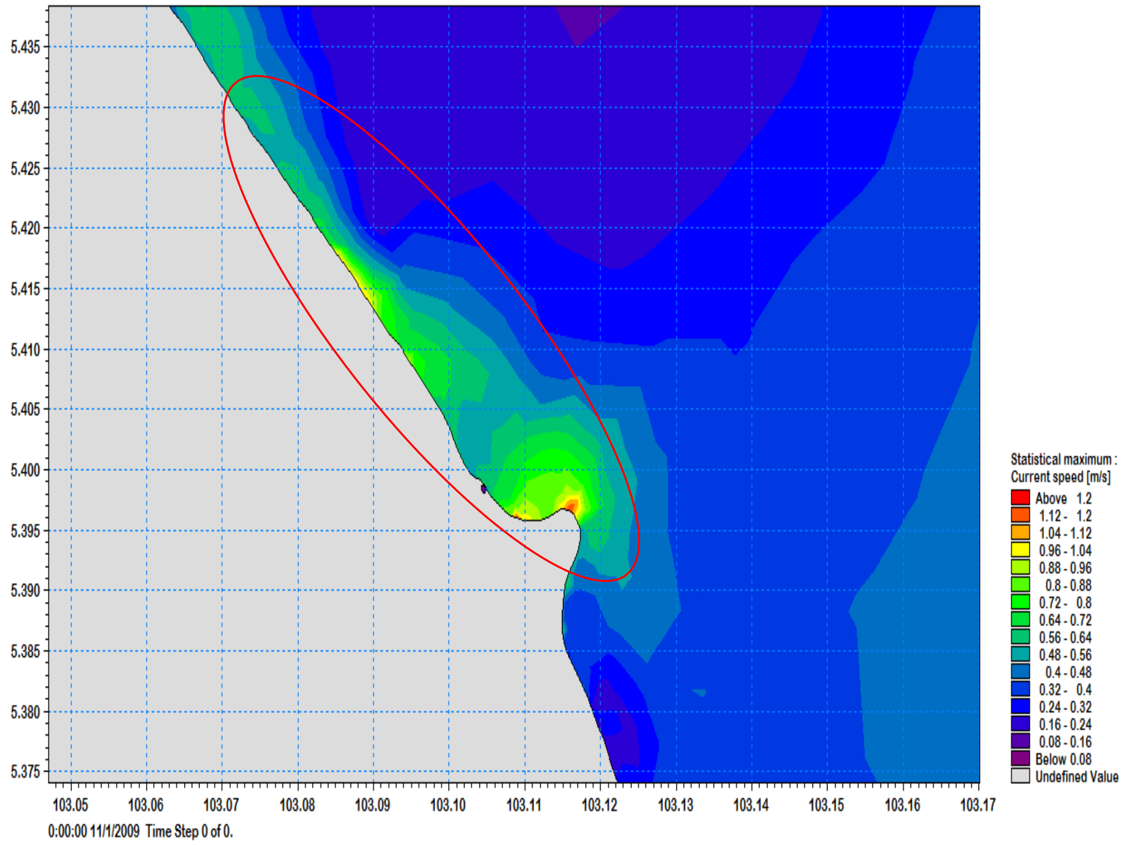

Figure 9. Maximum current analysis from the simulation.

The intensity of current speed from simulation area shows that the current speed density is dispersed at the shore as shown in Figure 10 and Figure 11. Both figures indicate that the water depth influences the current pattern due to the irregular bathymetry elevation. Nearly similar pattern of current flow during ebb tide and flood tide are also seen on both figures. The northern sector of the airport area is known as Tok Jembal village and all the density of current velocity arrows indicate the strongest current flow phenomenon occurs at the particular zone and potentially to face a serious erosion problem.

According to the National Coastal Erosion Study (1985), littoral current for Kuala Terengganu beach is divided into two sections, with a deviation point from Kuala Terengganu River estuary. The littoral current travels northerly from this point which is inclusive our study area. This factor is one of the main contributing factors towards erosion problems. Even though surface or mid-depth currents may be substantial, either alongshore or a cross shore, they generally occur in closed or near-closed loops. Thus, the net movement over a tidal cycle may be very minor. Velocities over this tidal period will vary, with some having the capacity to move material suspended by wave action, but the net effect is likely to be small in Southwest monsoon season. But this sediment movement are large in Northeast monsoon due to the present of the external strong wave and wind.

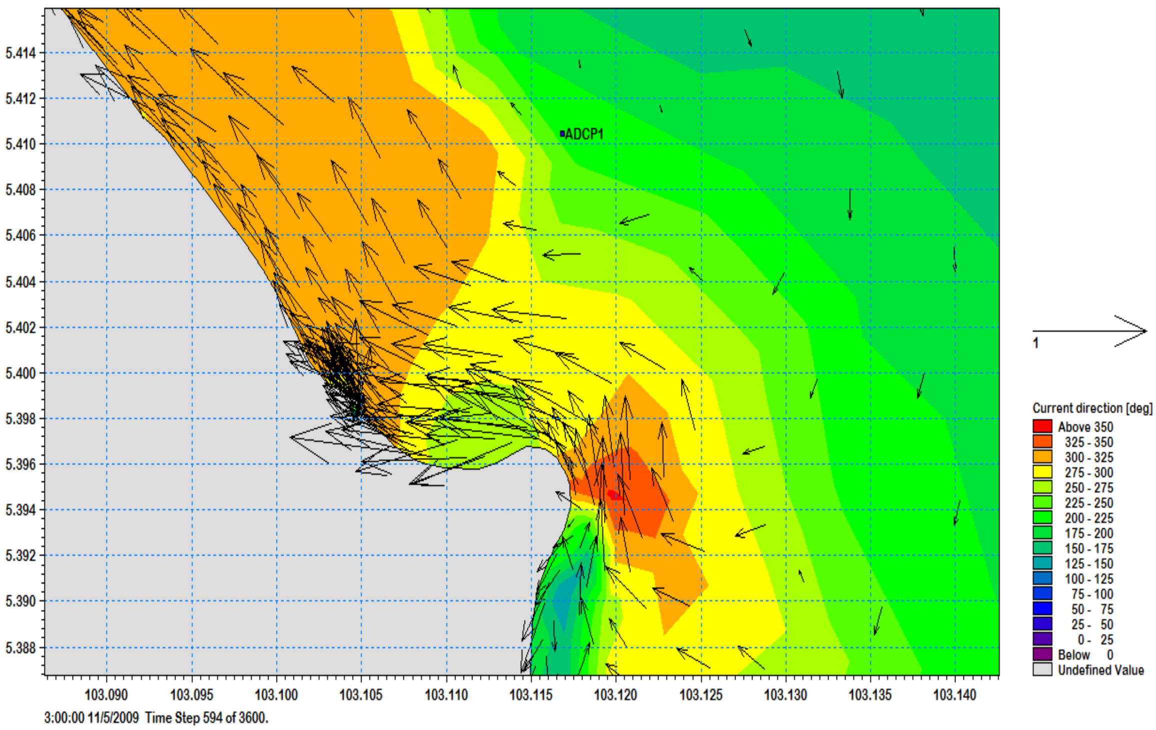

Figure 10 Current flow pattern during flood tide (Spring) at study area.

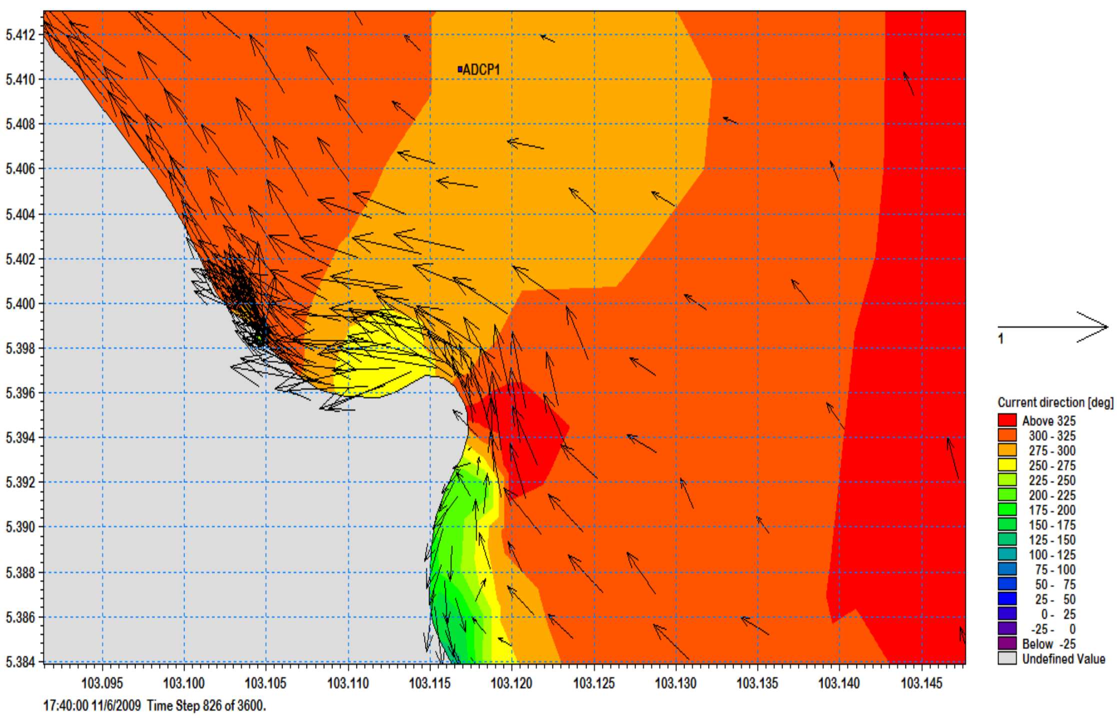

Figure 11. Current flow pattern during ebb tide (Spring) at study area.

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2.8 Wave Analysis

Data on significant wave height and dominant wave direction were obtained from the previous study report of National Coastal Erosion Study, 1985. The report describes the pattern of significant wave height and corresponding wave direction through wave rose based on the data from 1949 to 1983 near the project site. Between the month of November to March during year end, the Northeast Monsoon usually occurs. The Southeast Monsoon prevails from June to October. Periods between the monsoons are known as the inter-monsoon periods. The wave climate offshore of the study area consists of locally generated wind and swells propagating from South China Sea. The wave climate is influenced by seasonal variations. Large waves occur during the Northeast Monsoon. Rough wave conditions occur from November to February. The dominant incoming wave direction to the Kuala Terengganu coastal area is obtained from the NCES report as 60° for Northeast Monsoon with wave heights of 4.0 m.

Figure 12 shows the result of simulated wave model. Derived wave result shows that the wave height at the site is estimated to be from 1.2 meter to 4.0 meter during the Northeast monsoon season. The wave energy that induces by the strong wind is not the normal condition event. The Northeastern monsoon will cause a high-water level where the energetic wave will destroy large sand and transport the sand and then be stored and named as a bar. Figure 12 illustrate the nearshore wave action along the project site. The incoming wave heights from offshore decrease in term of the its heights and the wave energy is transform as an energy and disperse at the coastline.

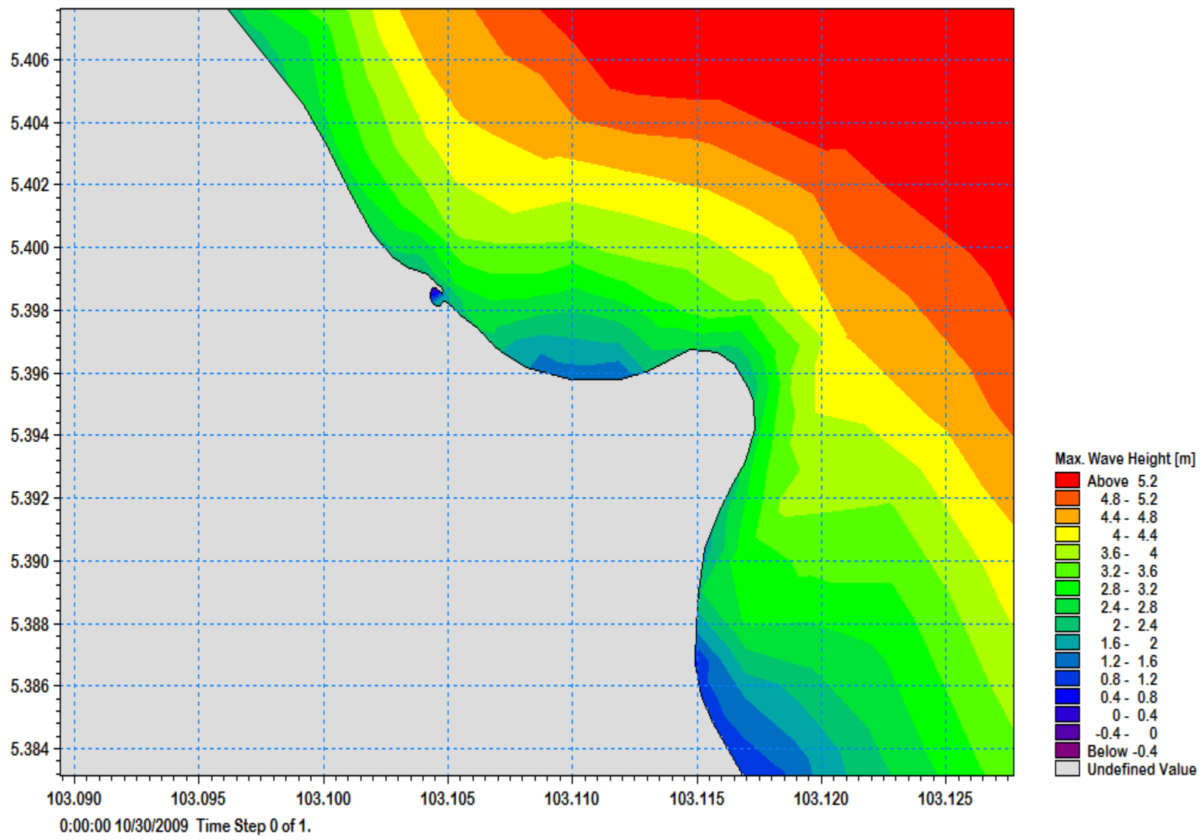

Figure 12 Simulated spectral wave heights model result at Kuala Terengganu Airport coastal area.

3. Conclusions

As a conclusion, we can conclude that the extension of the airport runway to the coastal water changes the hydrodynamics pattern of the area. The model has been calibrated against the measured dataset and within the acceptable error. The hydrodynamics simulation results showed that the north region of the runway extension having very high currents in comparison to the south region. The erosion and deposition patterns observed at this area are believed to occur due to this effect.

Acknowledgement

The Authors are grateful to National Hydraulic Research Institute of Malaysia (NAHRIM) and Aqvaspace Sdn Bhd for the support and assistance in providing data and modelling work in MIKE-21 used in this study.

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