Journal of Environmental Science and Technology

ISSN 1994-7887

science alert

ANSInet
an open access publisher
http://ansinet.com

OPEN ACCESS Journal of Environmental Science and Technology

ISSN 1994-7887
DOI: 10.3923/jest.2016.437.445

Research Article
Hydrodynamics Modelling at Setiu Wetland, Terengganu

[1]A. Norzilah, [1]M.F. Ahmad, [1]A. Jusoh, [2]N. Tofany, [2]R. Yaacob and [3]A.M. Muslim

[1]School of Ocean Engineering,
[2]School of Marine Science and Environment,
[3]Institute of Oceanography and Environment, University Malaysia Terengganu, Malaysia

Abstract

Background and Objective: A Setiu Wetland located in Terengganu, Malaysia is well modelled using a commercial software so called the MIKE 3 DHI which the two-dimensional model of flow model was used in this study to simulate the hydrodynamic causes by the event of flood and ebb cycles at the inlet of estuary. **Methodology:** The area of the study was model as according to actual situation and with appropriate initial and boundary condition were used in order to run the simulation. In ensuring the computational model is successful, the results obtained from computational model are compared with actual data. It observes that the model performed well with the actual data of the surface elevation where root mean square error ranges between 0.1716-0.3797 m and the bias ranges between -0.2979 to 0.097. **Results:** The simulation results show that the highest current velocities found on June, 2014 due to interchanges of Southwest monsoon into Northeast monsoon but on November, 2014 the current velocities were very low and during February, 2015 the current velocities getting stronger back at the end of Northeast monsoon season. **Conclusion:** The modelling outcome from this study could be further explore for investigating such as the sediment transport and water quality since the models are intergrated in the MIKE 3 HD model. The set-up model could be useful for the planning purposes to enhance the ecosystem of the Setiu Wetland.

Key words: Setiu Wetland, hydrodynamics, MIKE 3DHI, sediment transport

Received: April 12, 2016 Accepted: August 05, 2016 Published: October 15, 2016

Citation: A. Norzilah, M.F. Ahmad, A. Jusoh, N. Tofany, R. Yaacob and A.M. Muslim, 2016. Hydrodynamics modelling at Setiu Wetland, Terengganu. J. Environ. Sci. Technol., 9: 437-445.

Corresponding Author: M.F. Ahmad, School of Ocean Engineering, University Malaysia Terengganu, Malaysia

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Present day development in coastal areas and land use change in recent history have resulted in the requirement for robust numerical modelling packages to enable the calculation of flood risk, impact of engineering works and impact in ecological environment. Due to the wide variation in physical forcing, geometry, hydrodynamics and circulation of estuarine systems, a wide range of numerical have been develop, specialised for differing purposes. Several notable numerical studies are presented here. Moeini and Etemad-Shahidi[1] compared two numerical models, SWAN and MIKE 21 SW for hindcasting of wave parameters in Lake Erie. It was found that MIKE 21 SW results were slightly more accurate than SWAN. Panda *et al.*[2] conducted a numerical study using MIKE 21 on geomorphological changes of a tidal inlet of the Chilika lagoon, India which are governed by complex interactions of tidal currents, waves and sediment. Marsooli *et al.*[3] studied the effects of vegetation on mitigation of storm tides by coastal wetlands using the Stevens Institute of Technology Estuarine and Coastal Ocean Model (sECOM).

Different from the aforementioned studies, the present study is to set-up a numerical model with approriate manner for future to investigate the hydrodynamic patterns and sediment transport in relation to spatial and temporal at focus area Setiu Wetland. Understanding the hydrodynamic and the sediment distribution are important to survey the current movement towards Setiu Wetland that become the habitat of animal especially the mud crab. Expectantly, the scientific data gained from the study will provide the guidance for feature studies and also aim to provide more accurate and latest data to be observed. In addition, the Setiu Wetland meets all the criteria to become a State Part, its rich wetland resources offer a playground for studies and has the potential as an ecotourism destination that can generate economic opportunities for the locals. The Setiu Wetlands harbours natural features comprising a diverse array of freshwater, brackish and marine ecosystems including unique habitats and a 14 km lagoon stretching parallel to the coastline. Lack of comprehensive plan to guide the integrated and sustainable management of the Setiu Wetlands such as changes in land use resulting in degradation and reduced size of the different wetlands habitats indirectly will disturb the economic value for the local people. Other cases that can be seen at Setiu Wetland is erosion and deposition (Fig. 1). Cannot be denied one of the factor to this is monsoon but the anthropogenic activities also one of the contributors towards this matter. Human activities should reduce upon the coastal zone but this task is very difficult to do because that area is the most productive area because it is known for its fishing area and there are many activities occur there.

Therefore, this study is to provide once mechanism through numerical model with testifying, it's robustness to ensure the accuracy for future uses in prediciting the current intensity, current pattern and sediment movement. The guidance for stakeholder on how to manage and plan towards sustainabiliy of the ecosystem could be made.

MATERIALS AND METHODS

The study area was conducted in Setiu Wetland which is situated in the East coast of Peninsular Malaysia. The area was a coast parallel estuary-lagoon system separated from the South China Sea by a narrow barrier island has been chosen as the study area (Fig. 2). The methods of the study were field study and simulation works.

Fig. 1: Erosion occurs at the river mouth of Setiu Wetland

Field study: In the field study, the wave gauge was deployed at two point as shown in the Fig. 2. Two pressure sensors were deployed at 2 study sites (Fig. 2) to record pressure and water level during June, 2014, November, 2014 and February, 2015 for duration of 2 full tidal cycles. Locations were taken with a handheld Global Positioning System (GPS), which is accurate to 3-5 m at the site (Table 1). The wave gauge was set–up for interval of 1 min for a period of 1 week to get at least minimum 2 full tidal cycle. In addition, the field study of bathymetry survey was also carried out using site scan sonar to get the bottom bed profile of the wetland. Figure 3 shows that the site sonar pathway with green and yellow line during the bathymetry survey using boat and while the red line shows the boundary of the survey area.

Simulation study: The hydrodynamic study was carried out by using the commercial software so called MIKE 3. The three-dimensional flow model was governed by conservation of mass and momentum equations in Eq. 1 and 2, respectively shows as:

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}=0 \quad (1)$$

$$\frac{\partial u}{\partial x}+\frac{\partial u^2}{\partial x}+\frac{\partial uv}{\partial y}+\frac{\partial uw}{\partial z}=\frac{-1}{\rho}\frac{\partial p}{\partial x}+v\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}+\frac{\partial^2 u}{\partial z^2}\right) \quad (2)$$

$$\frac{\partial v}{\partial t}+\frac{\partial uv}{\partial x}+\frac{\partial v^2}{\partial y}+\frac{\partial vw}{\partial z}=\frac{-1}{\rho}\frac{\partial p}{\partial y}+v\left(\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}+\frac{\partial^2 v}{\partial z^2}\right) \quad (3)$$

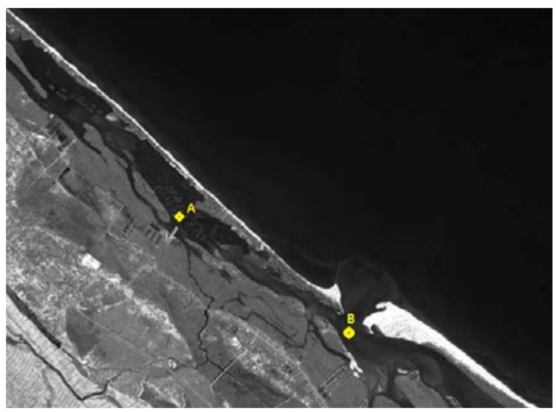

Fig. 2: Study area and locations of instrument deployment in the Setiu Wetland, pressure sensors were located near point A and B

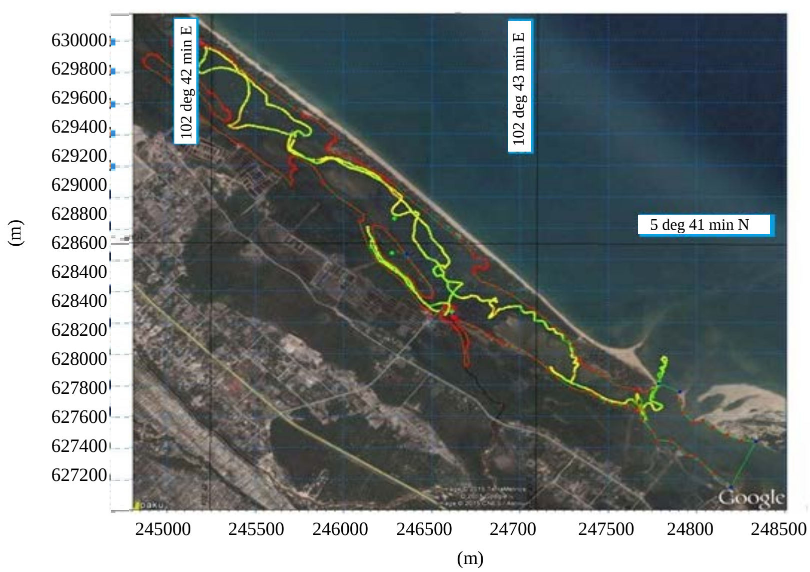

Fig. 3: Site scan sonar pathway using the boat

Table 1: Pressure sensor deployment locations, locations are given in Universal Transverse Mercator (UTM)

Site	Easting	Northing	Site description
Point A	246609.580602	628360.252697	Near main jetty and fish cages
Point B	247678.621433	627668.490272	Near river mouth and mangrove area

Table 2: Overview of input data in Mike 3 HD

Parameter	Value
Module	Hydrodynamic only
Simulation period	25-28 June, 2014
	9-11 November, 2014
	24-28 February, 2015
Time step	Every 60 Sec
Initial surface level	1 m
Boundary formulation	Water level
Eddy viscosity	Smagorinsky formulation, velocity based 0.8 m^2 sec^{-1}
Bed resistance	Manning number coefficient 38 $m^{1/3}$ sec^{-1}
Wave radiation	No wave
Wind condition	Enable

$$\frac{\partial w}{\partial t}+\frac{\partial uw}{\partial x}+\frac{\partial vw}{\partial y}+\frac{\partial w^2}{\partial z}=\frac{-1}{\rho}\frac{\partial p}{\partial y}+v\left(\frac{\partial^2 w}{\partial x^2}+\frac{\partial^2 w}{\partial y^2}+\frac{\partial^2 w}{\partial z^2}\right)-g \quad (4)$$

The boundary condition for the free surface is expressed by the following equation:

$$w=\frac{\partial u\tau}{\partial t}+u\frac{\partial \zeta}{\partial x}+\frac{\partial \zeta}{\partial y} \text{ for } z=\zeta(x, y, z) \quad (5)$$

While bottom boundary condition is defined as follows:

$$u = v = w = 0 \text{ at } z = -h \quad (6)$$

where, x, y, z denote the space coordinates, u, v, w represent the three components of the velocity, r is the density and p is the pressure.

Model set-up for simulation study: The 1st part of model set-up was inserted the map of Setiu Wetland and sectional bathymetry data in computitional domain. The datum for the bathymetric data was taken from Mike C-Map, which specifies a mean sea level of 1.21 m. Then data consists of wind speed, water level and other input parameters were specified as initial boundary conditions and these are presented in Table 2. The 2nd part was the model calibration where the bed roughness considered as fine tuning parameter was used until the numerical model results and the field measurements within an acceptable tolerance[4]. This study used surface elevation in model calibration because the effect of the roughness changes on the water surface elevations. This step was taken because the water level reflects on horizontal movement. The final part was modelled tidal speed and direction were vector-averaged over 2 tidal cycles during high tide conditions.

Analysis of error: In validating the results obtained, the output from the simulation was compared with field measurement data. The bias of model and Root Mean Square Error (RMSE) were calculated to determine the accuracies and differences of the data, respectively. The bias was calculated using Eq. 7 and RMSE was calculated using Eq. 8. The results of hydrodynamic model were validated with pressure sensor recorded at 2 point inside the estuary as shown in Fig. 2. The pressure sensor measurements are available in 60 sec intervals covering a period of 3 days on each month during June, 2014, November, 2014 and February, 2015:

$$\text{Bias}=\sum_{i=1}^{n}\frac{\left(X_{obs_i i}-X_{model_i i}\right)}{n} \quad (7)$$

where, X_{obs} is measured data and X_{modet} is modelled data at time/place i:

$$\text{RMSE}=\sqrt{\frac{\sum_{i=1}^{n}\left(X_{obs_i i}-X_{model_i i}\right)^2}{n}} \quad (8)$$

where, X_{obs} is measured data and X_{modet} is modelled data at time/place i.

RESULTS AND DISCUSSION

The first part of the simulation is discritized the mapped and inserted the cross-sectional values of the bottom sea bed profile as shown in Fig. 4. The result indicates that the deepest and very shallow water level is between 3.0-2.8 m and above 0.8 m, respectively. The deepest water level is located at the opening of the estuary whereas the very shallowest is always at the remote area of the wetland. However, the average of the sea bed profile below the chart datum is in the range of 1.6-2.2 m. The sea bed profile changes of the wetland occur with minimum over time due to sediment transport but at the opening of the estuary is very significant. The ocean wave and long shore sediment transport is a major contribution to the sediment being transported at the opening of the estuary and weak velocity of water flushing out from the water body of estuary[5].

The importance objective of this study is to obtain the simulation results as close as possible with the field data. Once

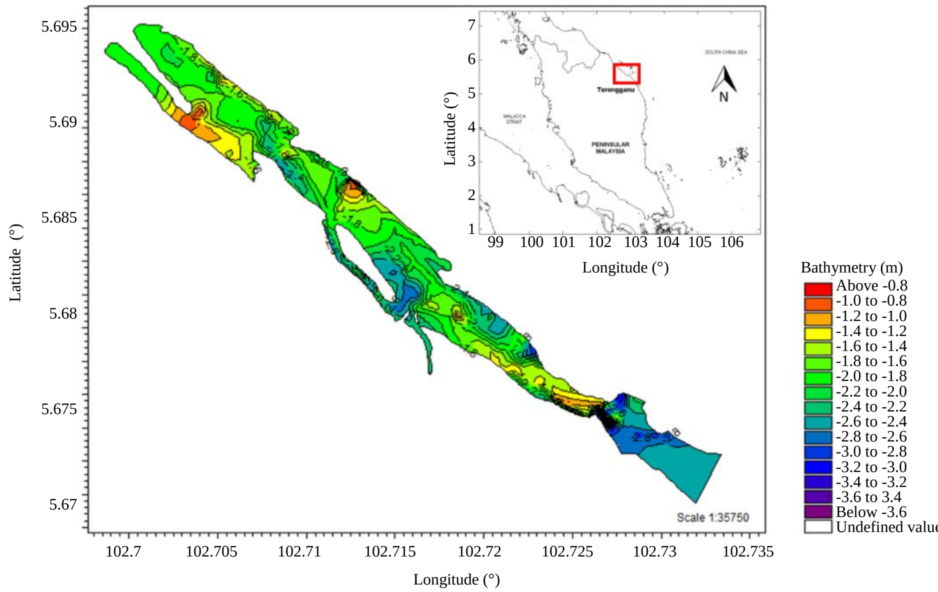

Fig. 4: Discritizing map and bathymetry profile of Setiu Wetland

this objective is achieved, it can be used to predict the current and sediment movement and velocity of the water. Therefore, the proposed model set-up is observe the Water Surface Elevation (WSE) at point A and B. For easy interpretation, it is only shown the comparisons for the period 2 full tidal cycle on June, 2014, November and February, 2015. The tedious process of calibrating the model should be carried out. From the study carry out, the best fit of modelled and measured surface elevation was obtained with manning number of 38 $m^{1/3}$ sec^{-1} and an eddy viscosity of 0.8 m^2 sec^{-1} and show in Fig. 5. The condition of flood and ebb flows are common phenomena occur at the estuary. During the flood event the current speed or water level shows positive value while negative values indicate the ebb flow. On June 2014, point A had the maximum error of $\pm$0.70 m while point B with $\pm$0.3 m maximum error. The highest and lowest surface elevation recorded at point A was 0.754 and -0.062 m, respectively. While, at point B the highest and lowest surface elevation recorded was 0.825 and -0.514 m, respectively. On November 2014, point A had the maximum error of $\pm$0.3 m while point B with $\pm$0.01 m maximum error. The highest and lowest surface elevation recorded at point A was 1.037 and -1.148 m, respectively. While at point B the highest and lowest surface elevation recorded was 0.843 and -0.803 m, respectively. According to Mohamad *et al.*[6], the average of tidal range is about 2.04 m above the sea level and more than 3 m wave height occur during this month which are measured along the coast. On February, 2015, point A and B had the closest maximum error of $\pm$0.2 m. The highest and lowest surface elevation recorded at point A was 0.371 and -0.460 m, respectively. While, point B the highest and lowest surface recorded was 0.302 and -0.363 m, respectively.

Table 3: Statistical evaluation of model performance for water surface elevation (m)

Variable/station	RMSE		Bias	
	Point A	Point B	Point A	Point B
Water surface elevation (m)				
June, 2014	0.219	0.379	-0.003	-0.106
November, 2014	0.317	0.361	0.097	-0.298
February, 2015	0.185	0.172	0.038	0.079

Generally, based on the scatter plots, model performed reasonably well in simulating the surface elevation.

Statistical analysis: The data from computational and observe from two stations A and B performed a statistical analysis of root mean square error and biasness is shown in Table 3. For most tracks, the simulated surface elevation matches the observed with the RMSE ranges between 0.1716-0.3797 m and the bias ranges between -0.2979 to 0.097 (Table 3). The values of RMSE are nearly zero and they are acceptable due to the complexity of the situation of the water body. Many processes and interaction occur in reality which it is beyond the capability of the computational model to produce the zero value of error. The biasness of the values are very small as compared between the simulated and observe values, leads to acceptability to the tuning parameter of bed roughness of the Setiu Wetland in general.

Current prediction: The model has highlighted a number of interactions of hydrodynamic conditions within

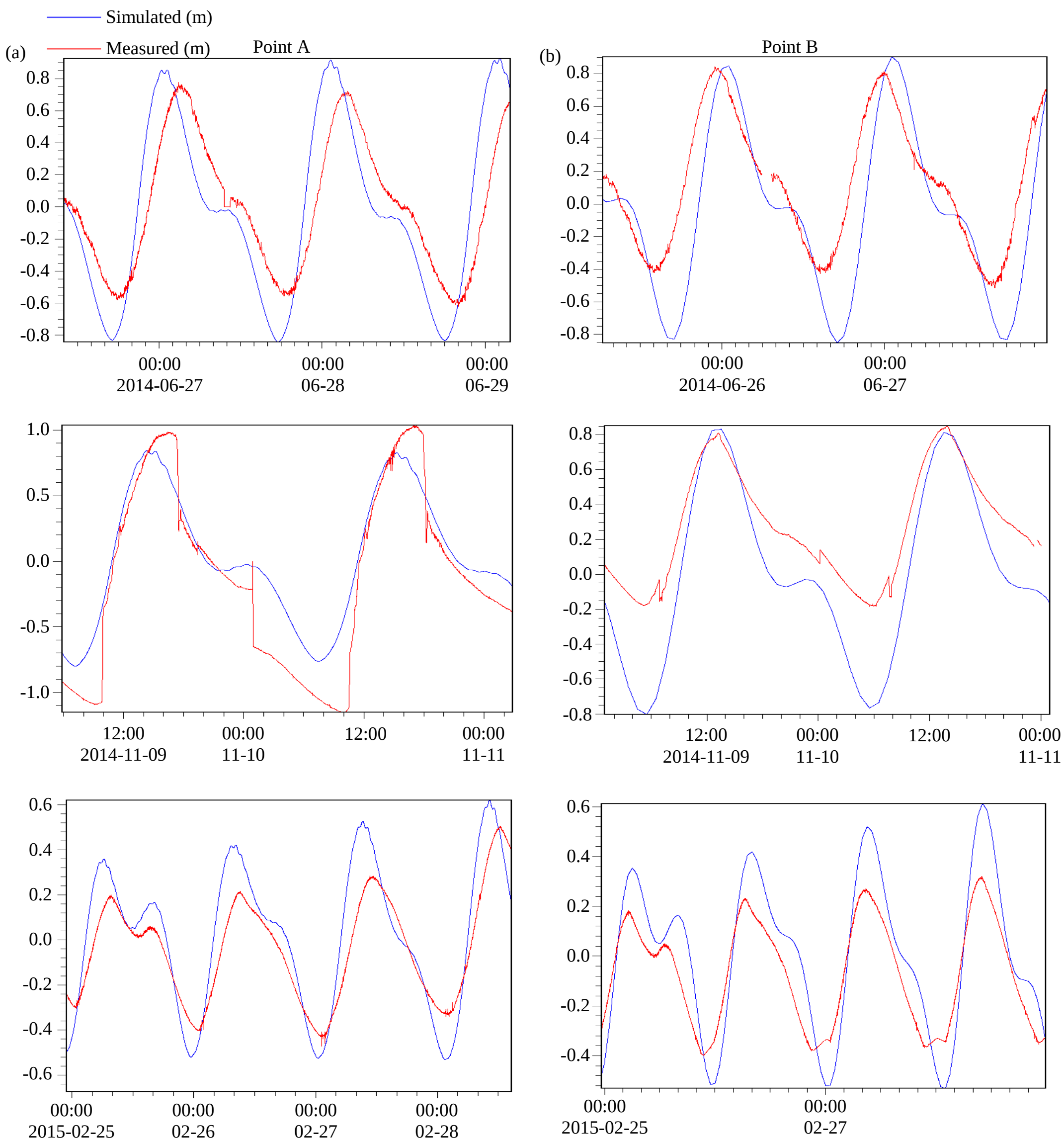

Fig. 5(a-b): Comparison of measured (red line) and simulated (blue line) water surface elevations at (a) Point A and (b) Point B

Setiu Wetland. An image of flood cycle and ebb tidal cycle (Fig. 6-8) for each month shows the fastest flow occurs in the point B (river mouth) and across the ebb delta, then dissipates as its enters near point A (Jetty). Based on simulation results on June, 2014, the peak flows in the main channel reached velocities upto 0.82 m sec^{-1} at point A and 0.87 m sec^{-1} at point B during flooding conditions and slightly lower velocities under ebbing conditions. A decrease of maximum current velocities was found on November, 2014 which is 0.17 m sec^{-1} at point A and 0.37 m sec^{-1} at point B. But on February, 2015 the current velocities increase to 0.28 m sec^{-1} at point A and 0.58 m sec^{-1} at point B. The simulation results shows that the highest current velocities found on June, 2014 due to interchanges of Southwest monsoon into Northeast monsoon but on November, 2014 the current velocities were very low and during February, 2015 the current velocities getting stronger back which is at the end of Northeast monsoon season (Table 4). The East part of Peninsular Malaysia is subjected to Northeast monsoon occurs from November to March. During the monsoon seasons, the current velocity could be achieved the maximum depending the intensity of the wind blow. Furthermore, the net sediment transport is moving to the North due to the current flow direction where the average of wave angle is 60-70° from the North[7].

Focusing upon the detail of the tidal inlet from that three months simulations some additional trends over the tidal

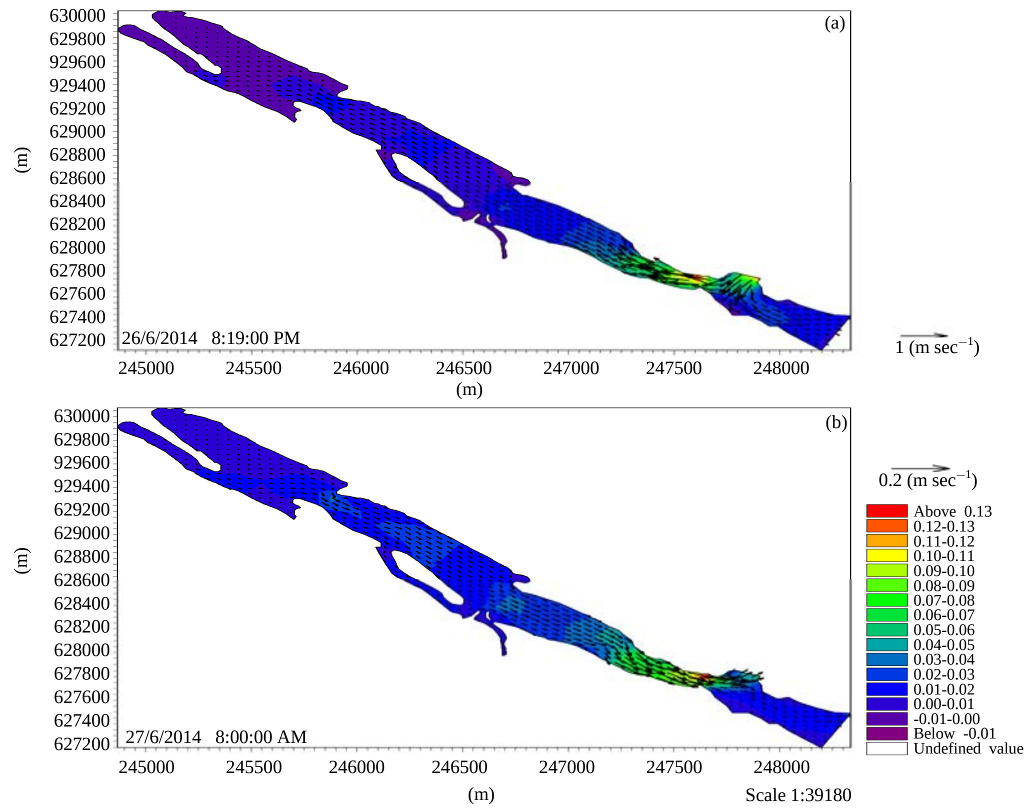

Fig. 6(a-b): Flood (top) and ebb (below) conditions on June, 2014

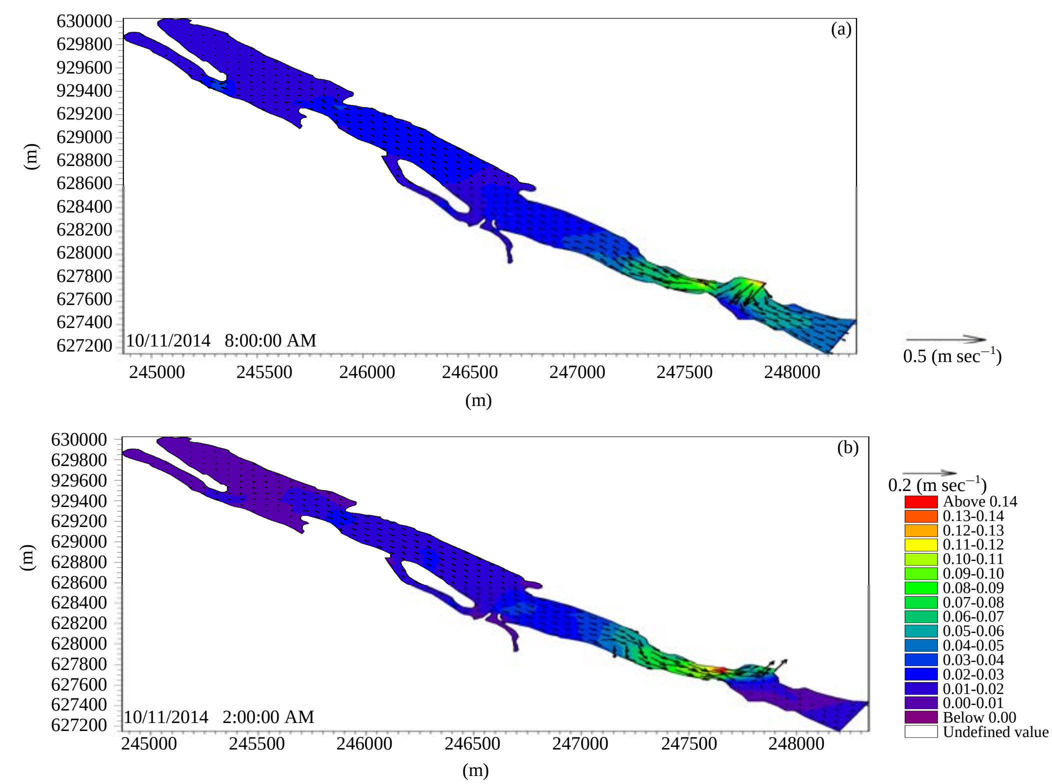

Fig. 7(a-b): Flood (top) and ebb (below) conditions on November, 2014

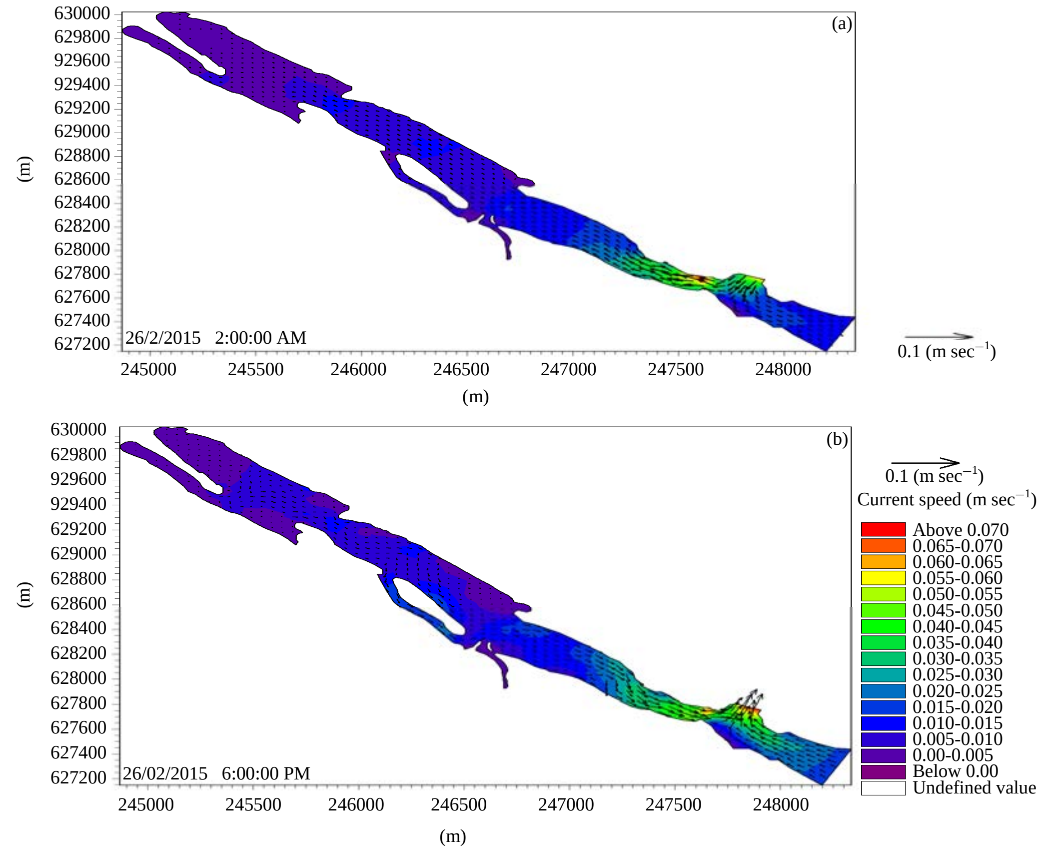

Fig. 8(a-b): Flood (top) and ebb (below) conditions on February, 2015

Table 4: Simulated velocity of Setiu Wetland

	Point A			Point B		
Variable/station	Minimum	Maximum	Mean	Minimum	Maximum	Mean
Simulated velocity (m sec^{-1})						
June, 2014	0.05	0.8224	0.0467	0.25	0.8754	0.0855
November, 2014	0.05	0.1726	0.0459	0.10	0.3787	0.1058
February, 2015	0.04	0.2883	0.0402	0.20	0.5848	0.0854

cycle is evident. The flow moves into Setiu Wetland and decelerates as it flows over the ebb delta due to the shallow nature of the delta, which induced greater friction. Current speed in intertidal areas was relatively low which is including point A. However, results indicated the incidence of considerable currents in low intertidal channels, which feed the intertidal flat on the incoming tide. The low intertidal currents identify these intertidal areas as a potential area of sediment accretion. According to Dyer[8], intertidal flats are a major sink for suspended sediments and deposition of sediment is likely to occur in places where the current moves from high to low velocity or where two opposing currents meet, such as over the ebb delta and river mouth. While, point B has the fastest current speeds compared to point A as the inlet narrows and flow is pushed through. The same area of study was done by Rosnan[9] which to indentify the main hydrodynamics factor influenced the distribution sediment pattern concluded that the current in the lagoon-estuary is mainly a combination of tide and river flow. The influenced become more significant during Northeast monsoon season where stronger wave and wind recorded as compared to normal seasons in other months[10].

CONCLUSION

This study achieved in modelling the Setiu Wetland by setting the approriate initial and boundary condition in junction with the bed roughness as tuning parameter. The results of water surface elevation are used as a benchmark to validate the accuracy by performing the statistical analysis and produce well agreement between observe and computational data. The modelling outcome from this study could be further explore for investigating such as the sediment transport and water quality since the models are intergrated in the MIKE 3 HD model. The set-up model could be useful for the planning purposes to enhance the ecosystem of the Setiu Wetland.

ACKNOWLEDGMENT

Most of this study was undertaken as a part of the project "Improving the Health of Setiu Wetland Ecosystems and Productivity of Crustacean Resources for Livelihood Enhancement", funded by the Niche Research Grant Scheme (NRGS) under vote 53131. The first author gratefully thanks to Associate Professor Dr. Mohammad Fadhli Bin Ahmad for encouragement and kind help.

REFERENCES

1. Moeini, M.H. and A. Etemad-Shahidi, 2007. Application of two numerical models for wave hindcasting in Lake Erie. Applied Ocean Res., 29: 137-145.
2. Panda, U.S., P.K. Mohanty and R.N. Samal, 2013. Impact of tidal inlet and its geomorphological changes on lagoon environment: A numerical model study. Estuarine Coastal Shelf Sci., 116: 29-40.
3. Marsooli, R., P.M. Orton, N. Georgas and A.F. Blumberg, 2016. Three-dimensional hydrodynamic modeling of coastal flood mitigation by wetlands. Coastal Eng., 111: 83-94.
4. Shankar, D., P.N. Vinayachandran and A.S. Unnikrishnan, 2002. The monsoon currents in the north Indian Ocean. Progr. Oceanogr., 52: 63-120.
5. Yaacob, R. and M.Z. Mustapa, 2010. Grain-size distribution and subsurface mapping at the *Setiu* wetlands, Setiu, Terengganu. Environ. Earth Sci. J., 60: 975-984.
6. Mohamad, M.F., N.A. Omar and M.K. Huda, 2012. Physical modeling testing for coastal infrastructure: A prerequisite for marine engineering. Proceedings of the International Conference on Marine Technology, May 28, 2012, Kuala Terengganu.
7. Ahmad, M.F., Subiyanto, R. Yaacob, M. Mamat, A.M. Muslim and M.L. Husain, 2014. Coastline changes in vicinity of runway platform of Sultan Mahmud Airport, Kuala Terengganu: comparative analysis of one-line model versus satellite data. J. Appl. Sci., 14: 2234-2245.
8. Dyer, K.R., 1994. Estuarine Sediment Transport and Deposition. In: Sediment Transport and Depositional Processes, Pye, K. (Ed.)., Blackwell Scientific Publications, Oxford, pp: 193-218.
9. Rosnan, Y., 1988. Geophysical studies in setiu lagoon-estuary system. Masters Thesis, Universiti Pertanian Malaysia.
10. Yaacob, R., M.L. Husain, M. Shazili and N. Azhar, 1995. Grain-size distribution of sediment in the vicinity of Setiu lagoon-estuary system. Pertanika J. Trop. Agric. Sci., 18: 71-76.