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TRAJECTORY MODELING OF MARINE OIL SPILLS: CASE STUDY OF LACH HUYEN PORT, VIETNAM

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ABSTRACT: In 2011, an oil spill occurred off Lach Huyen port in the Northeast of Vietnam, due to vessels collision. The results of collision caused pollution on wide area and surrounding areas. This paper was used MIKE 21 SA model to simulate oil spill transport with five scenarios. The results of simulation showed that spill trajectory and slick area depend on analysis hydraulic regime, wind direction and wave in the study area. This paper presents the model application for simulation spill scenarios. It helps in selecting eco-sensitive regions for preparedness and planning suitable response strategies whenever spill incident occurred.

Keywords: Oil spill, MIKE 21 SA model, Lach Huyen port, spill trajectory, hydrodynamics, spectral wind-wave.

INTRODUCTION

Half the world' production of crude oil is transported by sea (Clark, 1992). 48% of marine oil pollution is due to fuels and 29% due to crude oil. A significant amount of oil is spilled into the sea from operational discharge, collision, pipeline-breaks, blow-outs and human error.

In 2011, an oil spill occurred off Lach Huyen port due to vessels collision, far from the center of Hai Phong city 25 km in Northeast of Vietnam (Fig. 1). The quantity of spilled diesel oil was assumed 2,000 tones overflow during 10 consecutive days at one of two positions SL1, SL2. Hypothetical two spill locations are illustrated in Fig. 1. One oil spill accident from Duc Tri ship occurred on March 02nd, 2008 in Binh Thuan (1,700 tons of diesel oil).

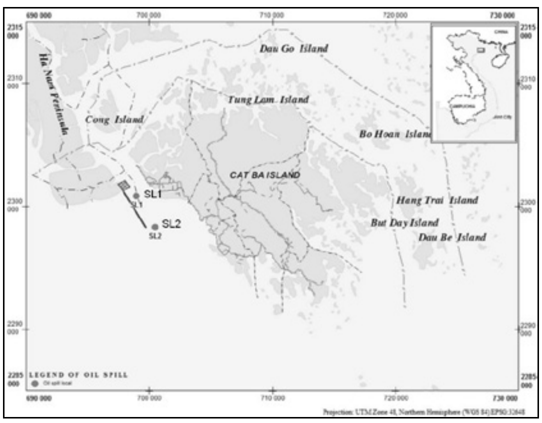

Fig. 1 Study location area

Hai Phong International gateway port was built in the south of Lach Huyen River. This project is the cooperation between Vietnam Government and Japan in the period 2010 – 2015. This is a project to construct one of the largest ports in the North of Vietnam. Lach Huyen port has a very important position in the socio-economic and tourism development. In case of oil spills at the beach or near-shore zone will directly affect the economy, ecosystem and tourism activities near the port, Island and the surrounding places.

If a spill were to occur today, the "best guess" would probably be a compilation of outputs from different models (Daniel et al. 2002) or even from the same model if using different boundary conditions and data choices. More than one model may be used because a particular model may perform better in certain situations. Performance varies because the mathematical equations describing oil movement are complex, making an analytical solution impossible. Therefore, one model's simulation of a particular aspect of an oil spill's fate and behavior may be rigorous, but it is likely to be weaker in other aspects. Discussions of the strengths and weaknesses of the current state-of-the-art oil spill models can be found in (Yapa and Shen 1994, Yapa et al. 1994), (Anon 1996), (Cekirge and Palmer 2001), and (French-McCay 2004).

Spill modeling is important to predict the trajectories and oil fate for devising suitable combating mechanism. MIKE 21 Spill Analysis (SA) model was used to simulate trajectories. The objectives of this study were: (i) to simulate Spectral Wind Wave (SW) of these

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boundaries calculation; (ii) to simulate Hydrodynamics (HD) of the coastal water off Lach Huyen; (iii) to simulate trajectories Spill Analysis (SA) for the oil spill. A flowchart of research procedure is constructed as shown in Fig. 2.

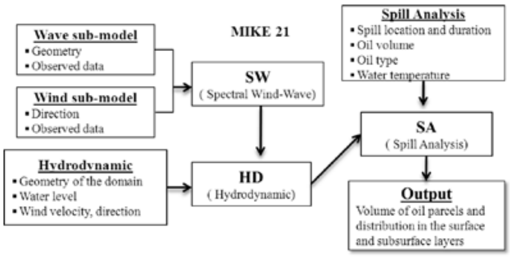


Fig. 2 The flowchart of study procedures

MATERIAL AND METHODS

Data collection

Wind is relatively calm in study area except in storm season beginning from June to November. The wind direction is mostly from East to South (about 45%) and North (13%) based on wind monitoring data in 3 years from 2006 to 2008. Wind speeds above 15m/s rarely appeared. Wind speed occurs mostly in wet season from on March to September. Tropical storm generates wind speed about 40-50m/s. The highest wind speed reached 52m/s. As the previous study, wind regime in the study area is relatively stable. Thus, this study can take the wind at Bach Long Vi station to calculate the wind for all study area. According to the statistic data at Bach Long Vi station from 1960 to 2007, average wind velocity showed as follows (Table 1).

Table 1 Average wind data at Bach Long Vi station

Script	Wind			
	Direction	Average velocity (m/s)	Frequency	Period time
Scenario 1	North East	8.3	39%	12 – 22 December 2011
Scenario 2	East	4.7	16%	12 – 22 November 2011
Scenario 3	South East	4.5	9%	12 – 22 May 2011
Scenario 4	South	7.7	23%	12 – 22 July 2011
Scenario 5	South West	6	4%	12 – 22 August 2011

The flow at the estuary of Hai Phong coastal site is affected by the flows of Cam River, Bach Dang River and Chanh River and tidal level. Therefore, the flow regime is very complicated. There is an interaction among several factors including water level, topography of the river bottom, wave, wind and tide. The flow is mainly affected by tide-flow and water level differences. The wind wave data observed in Hon Dau station in three years from 2006 to 2008 describes the wave characteristics generated by wind. The wave data observed at Hon Dau station in 20 years from 1988 to 2008 are used to calculate the maximum height of wave based on the Gumbel and Weibull distribution method.

Mike 21 model was used to study the impact of the constructions on flow model in the study area. The input is the wave and wind scenarios based on analysis of observation data at Bach Long Vi oceanographic stations. Computation mesh used for oil spill calculation for Lach Huyen port with unstructured grids (Fig. 3). Minimum computation mesh size is set as 60m in order to express the geometry of sea route and port berth. The mesh size is bigger in offshore area based on the unstructured grids method, and the biggest mesh size is 3,000m at Bach Long Vi station. Tides are given at Hon Dau oceanographic station. Choosing period time simulates for calibration and validation SW module from July 12th, 2007 until July 22nd, 2007 and HD module from July 13th, 2006 until July 23rd, 2006 for calibration, July 13th, 2007 until July 23rd, 2007 for validation. The period's time simulations for SA module are shown in Table 1.

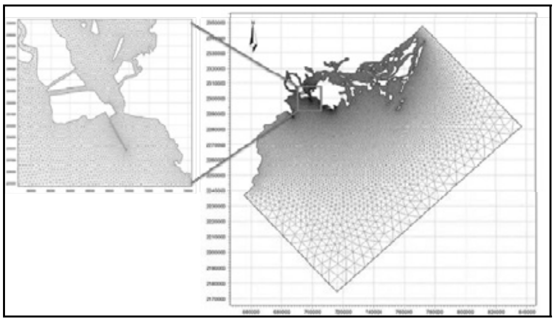


Fig. 3 2-D visualisation of computational mesh

Spill modeling system

Several oil spill models have been developed based on transport and weathering processes (Mackay et al. 1980, Huang 1983, Kolluru et al. 1994, Li and Mead 1999, Brebbia 2002 & 2004).The Oil Weathering Model, OWM (Daling and Strøm 1999) and the Oil Spill Contingency and Response model system, OSCAR (Aamo et al. 1997) are used in contingency planning. The spill model, SINTEF OWM has been field tested extensively in laboratory and experimental spill (Daling and Strøm 1999, Daling et al. 2003). (Wanga 2005) used a Lagrangian discrete particle algorithm to simulate transport of oil slick, assuming the slick as a large number of small particles.

In the present study, we used a two-dimensional MIKE 21 Spill Analysis (SA) developed by the Danish Hydraulic Institute (DHI), Denmark to simulate spill trajectories (Anonymous 2004). MIKE 21 Spectral Wind Wave (SW) is a 3rd generation spectral wave model that simulates the growth, decay and transformation of wind-generated waves and swells in offshore and coastal areas. The model includes wave growth by action of wind, non-linear wave-wave interaction, dissipation by white-capping, dissipation by wave breaking, dissipation due to bottom friction, refraction due to depth variations, and wave-current interaction. Equilibrium equation wave impact was built for both Cartesian coordinate system and Spherical coordinate system (Komen et al. 1994 and Young 1999). (Janssen et al. 1989) and (Janssen 1991) have demonstrated that the growth rate of waves generated by the wind depends on the wave periods, because it involves sea states.

The governing equation in MIKE 21 SW is the wave action balance equation formulated in either Cartesian or spherical co-ordinates. The conservation equation for wave action reads:

$$\frac{\partial N}{\partial t} + \nabla.\left(\bar{v}N\right) = \frac{S}{\sigma} \quad (1)$$

where $N\left(\bar{x}, \sigma, \theta, t\right)$ is the action density, t is the time, $\bar{x} = \left(x, y\right)$ is the Cartesian co-ordinates, $\bar{v} = \left(c_x, c_y, c_\sigma, c_\theta\right)$ is the propagation velocity of a wave group in the four-dimensional phase space $\bar{x}, \sigma$ and θ. S is the source term for energy balance equation. ∇ is the four-dimensional differential operator in the $\bar{x}, \sigma, \theta-space$.

$$\sigma = \sqrt{gk \tanh\left(kd\right)} = \omega - \bar{k}.\bar{U} \quad (2)$$

where g is the acceleration of gravity, d is the water depth and $\bar{U}$ is the current velocity vector and $\bar{k}$ is the wave number vector with magnitude k and direction θ.

The characteristic propagation speeds are given by the linear kinematic relationships.

$$\left(c_x, c_y\right) = \frac{\bar{dx}}{dt} = \bar{c}_g + \bar{U} = \frac{1}{2}\left(1 + \frac{2kd}{\sinh\left(2kd\right)}\right)\frac{\sigma}{k} + \bar{U}$$
$$c_\sigma = \frac{d\sigma}{dt} = \frac{\partial\sigma}{\partial d}\left[\frac{\partial d}{\partial t} + \bar{U}.\nabla_{\bar{x}}d\right] - c_g\bar{k}.\frac{\partial\bar{U}}{\partial s} \quad (3)$$
$$c_\theta = \frac{d\theta}{dt} = -\frac{1}{k}\left[\frac{\partial\sigma}{\partial d}\frac{\partial d}{\partial m} + \bar{k}.\frac{\partial\bar{U}}{\partial m}\right]$$

where s is the space co-ordinate in wave direction θ and m is a co-ordinate perpendicular to s. $\nabla_{\bar{x}}$ is the two-dimensional differential operator in the $\bar{x}-space$.

The source function term, S, on the right hand side of the wave action conservation equation is given by

$$S = S_{in} + S_{nl} + S_{ds} + S_{bot} + S_{surf} \quad (4)$$

where S_{in} represents the momentum transfer of wind energy to wave generation, S_{nl} energy transfer due non-linear wave-wave interaction, S_{ds} the dissipation of wave energy due to white capping, S_{bot} the dissipation due to bottom friction and S_{surf} the dissipation of wave energy due to depth-induced breaking. The default source functions S_{in}, S_{nl} and S_{ds} in MIKE 21 SW are similar to the source functions implemented in the WAM Cycle 4 model (Komen et al. 1994)

The wind input is based on (Janssen's 1989, 1991) quasi-linear theory of wind-wave generation, where the momentum transferred from the wind to the sea not only depends on the wind stress, but also the sea state itself. The non-linear energy transfer is approximated by the DIA approach (Hasselmann et al. 1985). The source function describing the dissipation due to white-capping is based on the theory of (Hasselmann 1974) and (Janssen 1989). The bottom friction dissipation is modeled by using the approach by (Johnson et al. 2000), which depends on the wave and sediment properties. The source function describing the bottom-induced wave breaking is based on the well-proven approach of (Battjes and Janssen 1978) and (Eldeberky and Battjes 1996).

MIKE 21 Flow Model is applicable to the simulation of hydraulic and environmental phenomena in lakes, estuaries, bays, coastal areas and seas. The hydrodynamic (HD) module is the basic module in the MIKE 21 Flow Model (MIKE 2007). The model domain (Fig. 6) is bounded by 653,510.9m Latitudes and 838,614.7m Longitudes on UTM-48 coordinate system.

RESULTS AND DISCUSSION

SW module

Boundary condition

At the land boundary, full slip boundary conditions are applied. The throughput components coming are attributed zero. There is no boundary condition for the throughput components come out. At the open boundary, the energy spectrum is determined by wave characteristics. In this study, wave and wind data at Bach Long Vi oceanographic station are used as open boundary condition for computational domain (Table 1 and Table 2).

Table 2 Average wave data at Bach Long Vi station

Script	Direction	Wave	
		Average wave height (m)	Frequency
Scenario 1	North East	1.2	35%
Scenario 2	East	0.8	10%
Scenario 3	South East	0.9	6%
Scenario 4	South	1.2	19%
Scenario 5	South West	0.9	3%

Validation SW module

Calculation results of the calibration and validation process model obtained stable parameters for calculating wave field in these scenarios. The calibration and validation process obtained the model parameters as follows: the impact force of wind is determined by the formula of Karman et al; wave breaking parameter γ = 0.79; the friction parameter k_N = 0.043m. The comparisons between calculated and measured wave height at Hon Dau station showed a good fit (Fig. 5). This is a good basis to calculate the wave stress field with these given scenarios. That is the input data fields to serve flow fields in the study site when calculating the impact of waves. Fig. 6 showed the calculated wave field from July 15 to 18, 2007.

Hydrodynamic module

Topography condition, domain and mesh

Bathymetry of model domain for the model MIKE 21 is obtained from the measurements of Navy's High Command from the seabed topographic map at a rate which is different from the rate of 1:10,000 to 1:1,000,000 (Fig. 4).

Initial condition, boundary condition

Water level boundaries are taken according to the harmonic constant coefficient from tidal simulations on a global scale. There are tools available in the toolbox of MIKE 21 model. After the terrain is input in the toolkit of MIKE 21 with the coordinates and depth values, the tool automatically defines the boundary. Initial conditions of model are determined by the running method before model a certain time period to stabilize the model. The initial water level value is taken following the results of this calculation.

Validation and calibration of hydrodynamic model

Calibration model used tide analysis at Hon Dau oceanographic station to compare with the results of calculation from model in the period from July 13th, 2006 to July 23rd, 2006. By editing Nash-Sutcliffe criterion (Nash and Sutcliffe 1970) we have a result of water level calibration at Hon Dau (Fig. 7). The results of calculation from Fig. 7 above showed a high conformity about phase and water amplitude between calculated and measured water level data with Nash-Sutcliffe criterion equal 0.97. It means that MIKE 21 was edited well with hydraulic parameters. These parameters are used as the basic for validation model and calculate oil spill pollution.

Validation model used water level data at Hon Dau location in the period from July 13th, 2007 to July 23rd, 2007. The results revealed that in the validation case, the water level between calculated and measured have a high conformity about phase and water amplitude with Nash-Sutcliffe criterion equal 0.93 (Fig. 8). Wave regime, wind combined with the strong tidal changes will affect the results of oil spill simulation in the next section. The results of validation and calibration model showed that MIKE 21 model can simulate well the hydrodynamic process in this study site. Model can be used to calculate and simulate the oil transmission. The hydraulic parameters of model are used to run the oil spread.

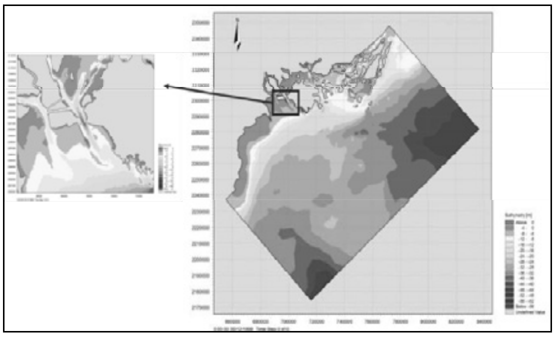


Fig. 4 Bathymetry of model domain

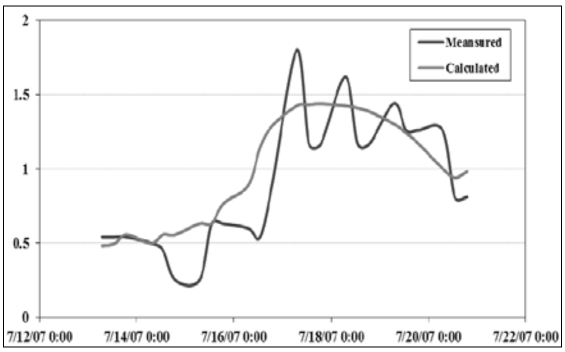


Fig. 5 Validation of wave height measured and calculated at HonDau

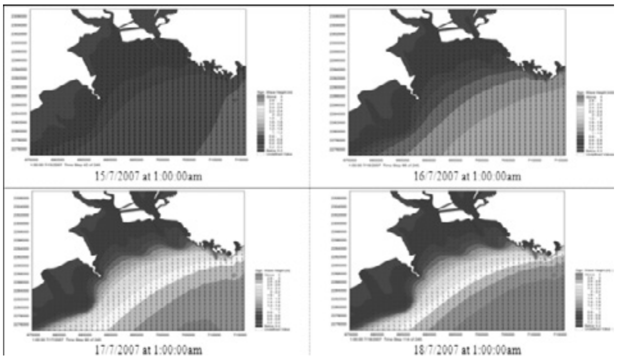


Fig. 6 The calculated wave field from July 15 to 18, 2007

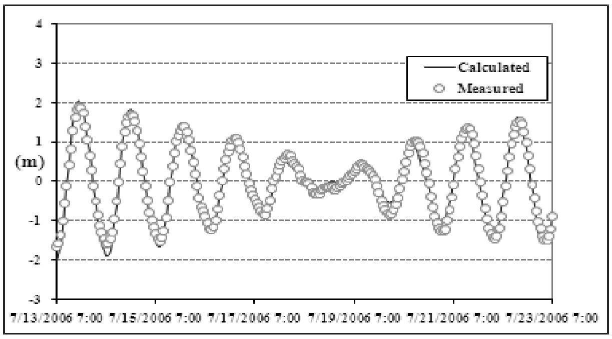


Fig. 7 Calibration of water level at Hon Dau

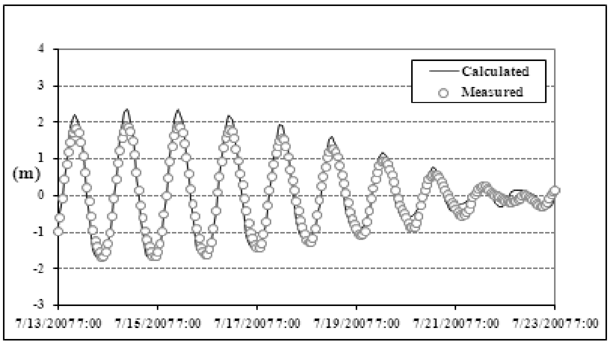


Fig. 8 Validation of water level at Hon Dau

Spill Analysis module

The analysis was made under the scenario that oil overflows with 2,000 tons in 10 consecutive days in one of two positions SL1, SL2. SL1 position located at the head of the creek with UTM-48 coordinates (700095, 2298279). SL2 position located at the end of the creek with UTM-48 coordinates (701655, 2296119). Based on the input data from SW, Wind, HD, there are five scenarios oil spill calculating; each scenario has two options at the two positions SL1, SL2. Hypothetical oil spill occurs in each scenario with wind direction, average velocity of wind and period time in 2011. The details of five scenarios are presented in next section.

Flow field at study site

Fig. 9 and Fig. 10 show simulation results of flow field in five scenarios corresponding with rising tide and falling tide. The simulation results of flow field showed that in the creeks area, flow rate of rising tide is usually greater than falling tide. Fig. 9 and Fig. 10 showed that tidal factor decides the flow direction of the study area. Flowing at Lach Huyen port is quite complicated due to the influence of topography with many small islands; bank beach appears at falling tide and submerged at rising tide.

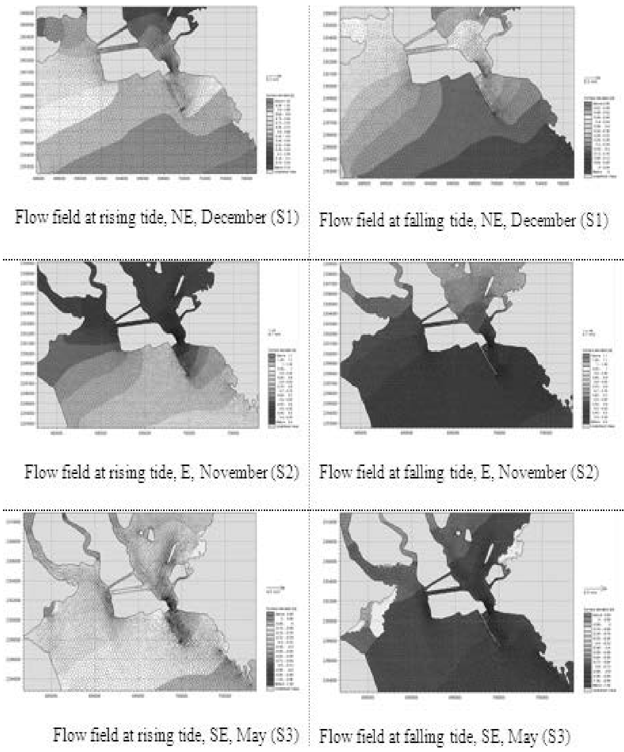


Fig. 9 Flow field at rising and falling tide

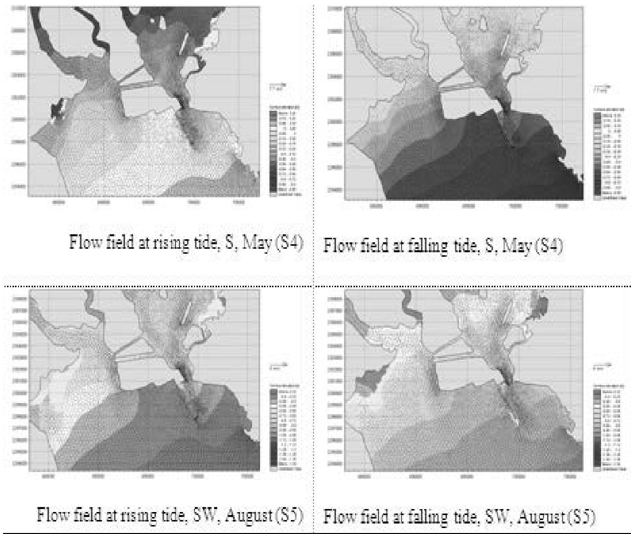


Fig. 10 Flow field at rising and falling tide

Calculation results of Oil Spill

Calculation results of oil spread with five scenarios showed as follows:

Scenario 1: Hypothetical oil spills occurred at 0h00' on December 12th 2011 in one of two locations SL1 and SL2. The wind blew in northeast direction with the constant value of 8.3 m/s.

(1) Spill location 1 (SL1): 12hours to 24hours, oil washed ashore near port and pollutes coastal port. After 48 hours due to the tidal current, an oil slick washed outwards, spilled over the sea towards the Northwest. After 10 days, the volume of oil washed out on the shore of port which polluted to the around area and a part of oil drifted coastal through the Hon Dau (Fig. 11).

(2) Spill location 2 (SL2): the oil slick spreads along the northeast coast. Overflow at location about 30km from the shore so oil did not affect coastal areas as well as the creek. After a day, the oil slick was brought about 20km away from the source. After 48 hours, an oil slick washed along the northwest direction about 50 km. In the next 5 days, oil slick washed to Do Son Peninsula and affected to Do Son beach. In 10 days, with oil 2,000 tons, the oil slick spread about 100km away. (Fig. 12).

Scenario 2: hypothetical oil pills occurred on November 12th 2011. The wind blew in east direction with the constant value of 4.7 m/s.

(1) Spill location 1 (SL1): after 12hours oil washed ashore of the harbor. After 24 hours, due to the rising tidal, oil was putted into the river by the Lach Huyen estuary and washed to Ha Nam channel which affected to Bach Dang estuary. After 48 hours, the oil polluted in coastal areas from Bach Dang to Cua Cam estuaries and a part of oil overtopping a sand dike which washed up on the shore near Do Son Peninsula. After 10 days, oil slick spread outwards to the sea in the Southwest (Fig. 13).

(2) Spill location 2 (SL2): Calculation results showed that from 6 -12 hours falling tide phase coincides oil slick went out of the sea in the southeast. 12hours to 24hours with rising tide phase the oil slick from oil source into the Cat Hai channel in the Northwest to Cong Island and a part of spread on the port and banks. After 48 hours, the oil slick caused pollution Cat Hai coastal, Bach Dang estuary and small channels around. After 10 days, oil slick spread over 50km and drifted into the Hon Dau station (Fig. 14).

Scenario 3: hypothetical oil spill occurred on May 12th 2011. The wind blew in Southeast direction with the constant value of 4.5 m/s.

(1) Spill location 1 (SL1): in 12hours due to the falling tidal, the oil washed ashore for port with more than 3 km and spread along the sand dikes around 1.5 km. In the next 24hours to 48hours, oil spread along Lach Huyen into the river, spreads into the Ha Nam and Trap channels which deposited here because of two narrow channels and small flows. After 10 days the volume of oil affected the Bach Dang River, Cua Cam River. Oil slick spread to the sea in the Southeast direction and affected Cat Ba town (Fig. 15).

(2) Spill location 2 (SL2): after 12 hours, oil spread toward the creek about 3 km. 12hours to 24hours, an oil slick was wider spread in the southeast about 8 km from the source. After 48 hours, traces of oil continued to spread toward the southeast coastal, an oil slick was measured about 16 km. After 10 days, an oil slick spread toward the southeast and effected on the south of Cat Ba Island. Oil spill polluted a coastal over 10km (Fig. 16).

Scenario 4: hypothetical oil spill occurred on July 12th 2011. The wind blew in South direction with the constant value of 7.7 m/s.

(1) Spill location 1 (SL1): At a location bordering creek and harbor, oil spread along from Cat Ba Island to Hoang Tan and opened to the Tuan Chau Island. 24hours to 48hours, oil washed through Lach Huyen channel into Ha Nam Peninsula which polluted here. In 5 days, oil spread in the Southeast to South of Cat Ba coastal Island which polluted in here. In 10 days, the oil spread further to the Tuan Chau, Dau Go Island in the North and Dau Be, But Day, Hang Trai and Bo Hoan Island in the South and Southeast (Fig. 17).

(2) Spill location 2 (SL2): With wind speed of 7.7 m/s, the amount of oil spill mainly affected coastal areas along the creeks of Cat Ba Island. Oil settled in here, which was relatively large and caused pollution to the coastal islands (Fig. 18).

Scenario 5: hypothetical oil spill occurred on August 12th 2011. The wind blew in the Southwest direction with the constant value of 6 m/s.

(1) Spill location 1 (SL1): After 12 hours, oil spread about nearly 20 km in the South. After 24 hours, the oil diffused widely to the southeast near 40 km, while a part of oil washed ashore of Cat Ba Island. After 48 hours, oil continues spread and tended ashore. After 10 days, oil volume spread in coastal and estuaries which caused serious pollution full Cat Ba Island (Fig. 19).

(2) Spill location 2 (SL2): After 12 hours the oil spread in the southwest nearly 20 km and surrounded the small island on the right side of creek. After 24 hours, oil spills continue spread in the south direction. After 48 hours, oil did not almost diffuse but polluted on the shore of the island. After 10 days, oil slick spread with rising tide phase through the Dau Go and Tuan Chau Island coming to the Southeast of Cat Ba Island. The oil slick spread with falling tide phase through Bau Be, But Day, Hang Trai Island and coming to Northeast of Cat Ba. The oil diffused which caused serious pollution for coastal of Cat Ba Island and surrounding small islands (Fig. 20).

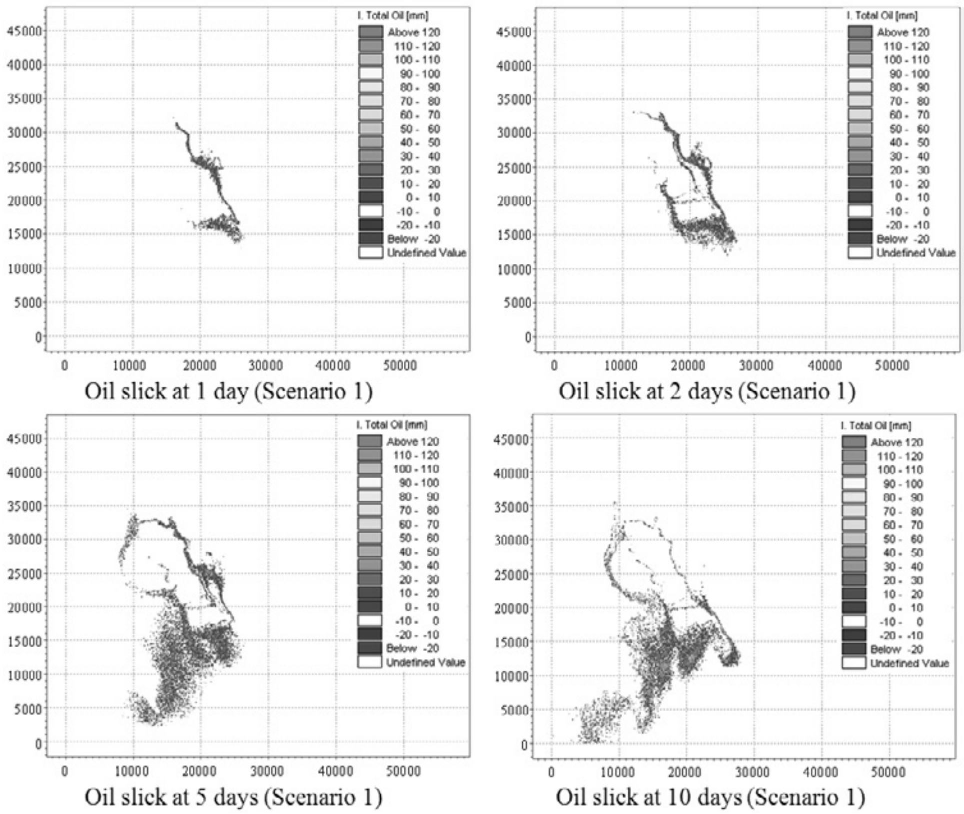


Fig. 11 Spill location 1 (Scenario 1)

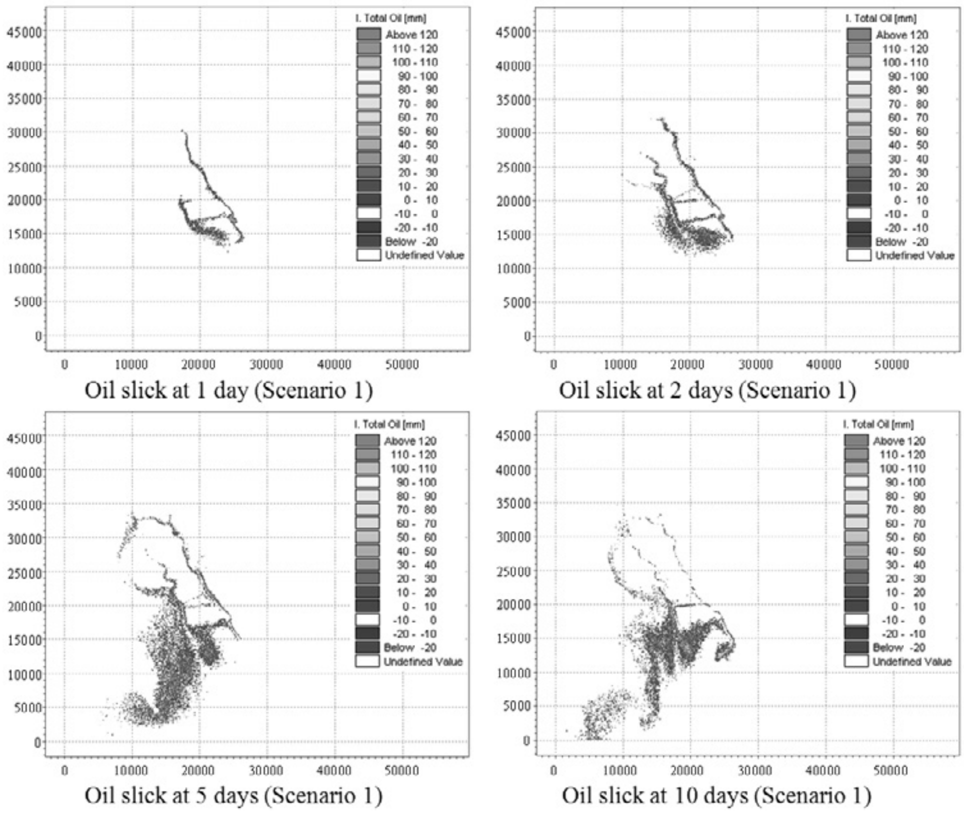


Fig. 12 Spill location 2 (Scenario 1)

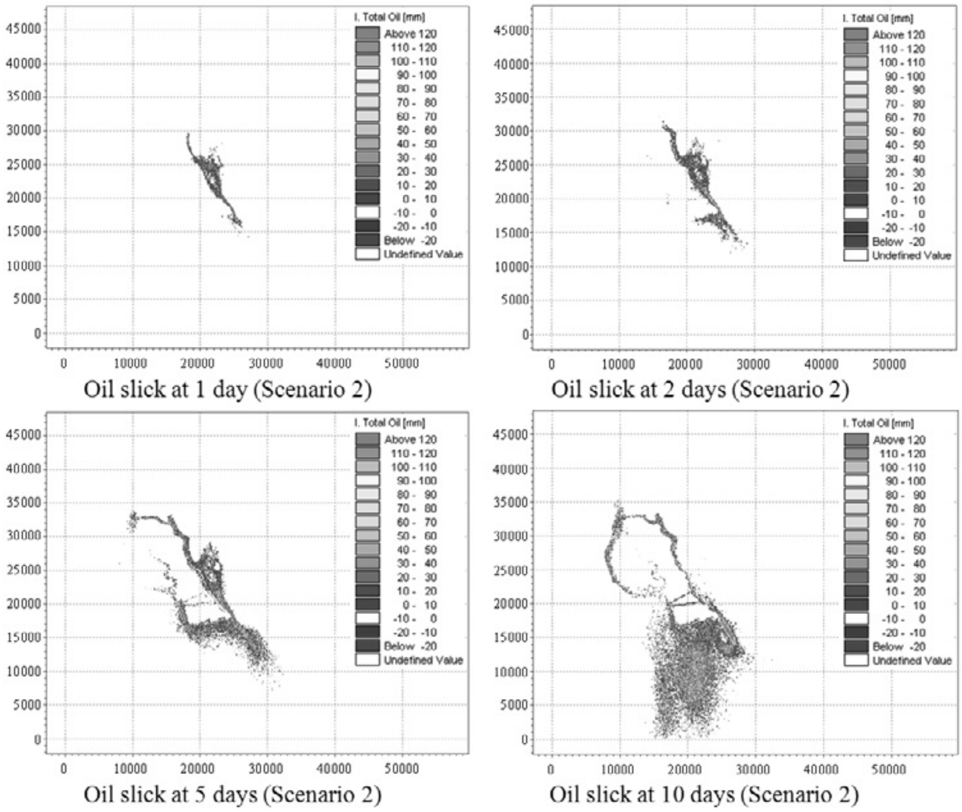


Fig. 13 Spill location 1 (Scenario 2)

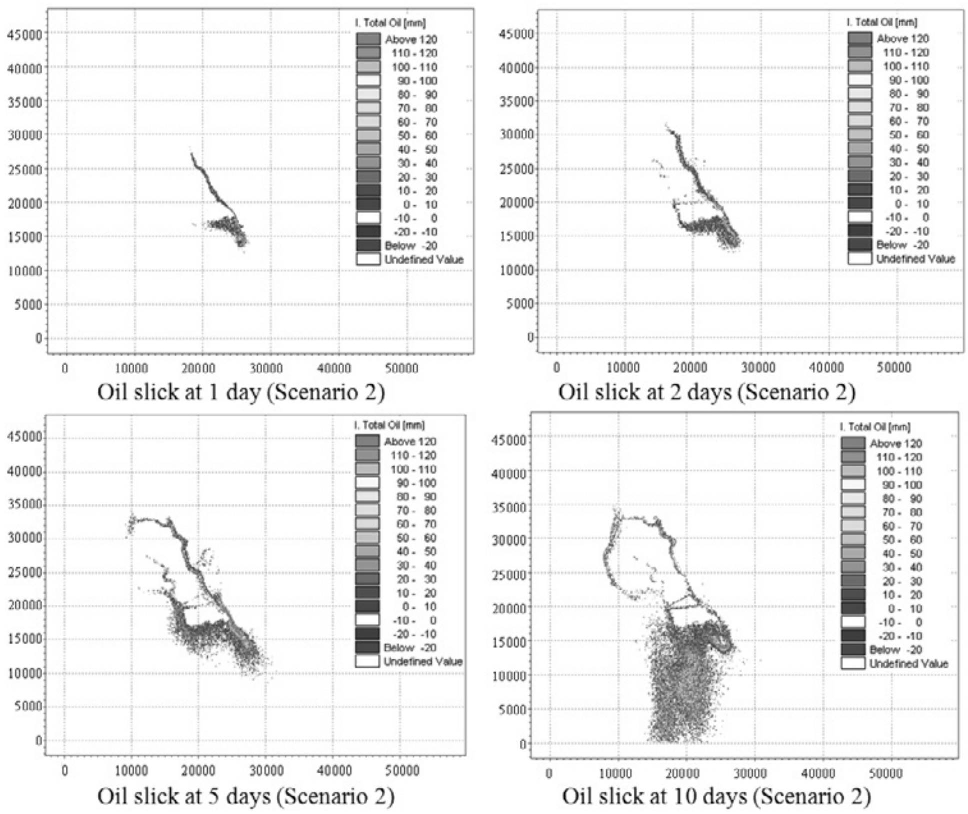
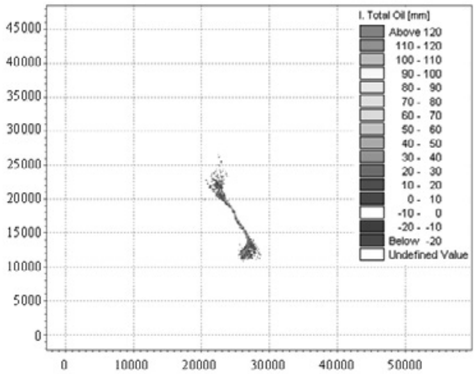
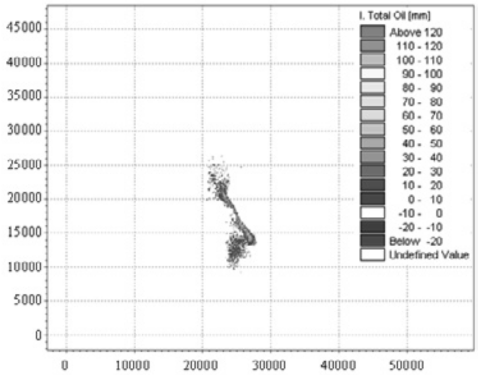


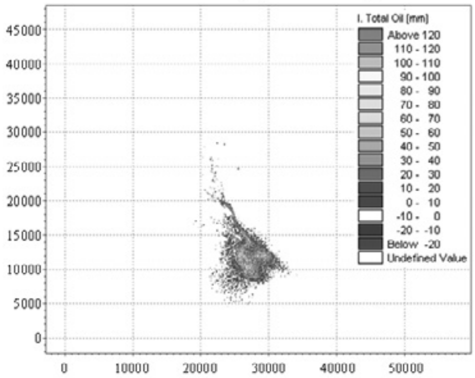
Fig. 14 Spill location 2 (Scenario 2)



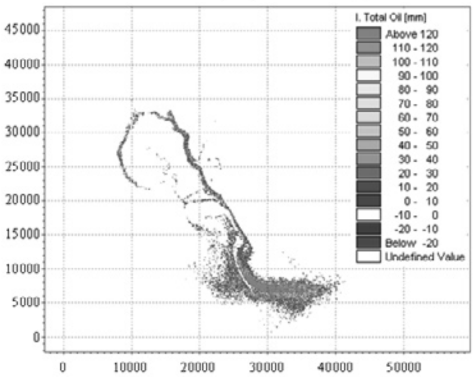
Oil slick at 1 day (Scenario 3)



Oil slick at 2 days (Scenario 3)

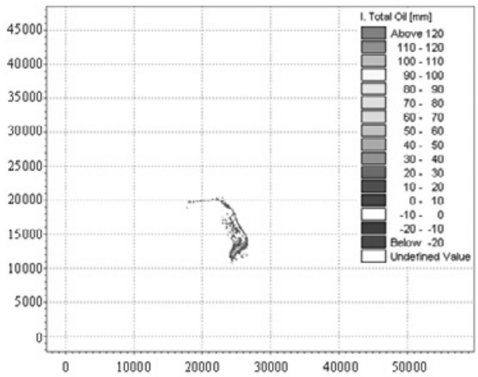


Oil slick at 5 days (Scenario 3)

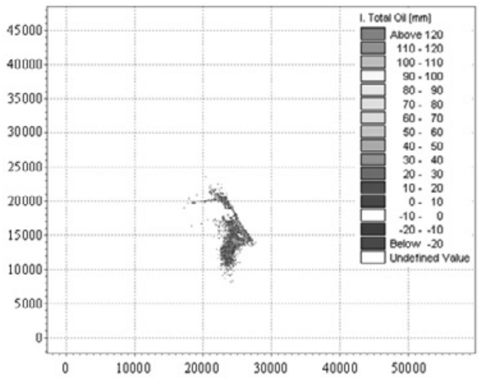


Oil slick at 10 days (Scenario 3)

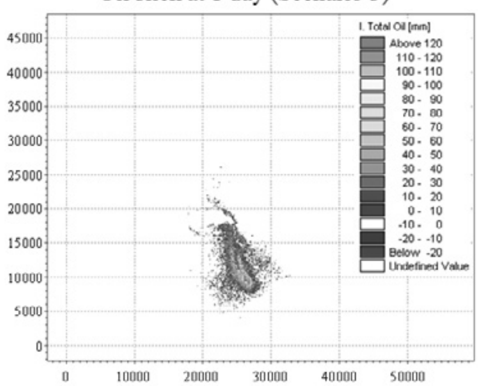
Fig. 15 Spill location 1 (Scenario 3)



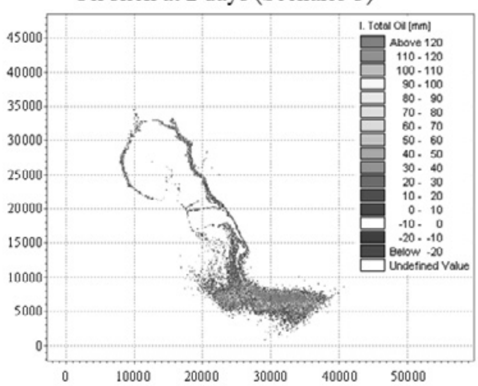
Oil slick at 1 day (Scenario 3)



Oil slick at 2 days (Scenario 3)



Oil slick at 5 days (Scenario 3)



Oil slick at 10 days (Scenario 3)

Fig. 16 Spill location 2 (Scenario 3)

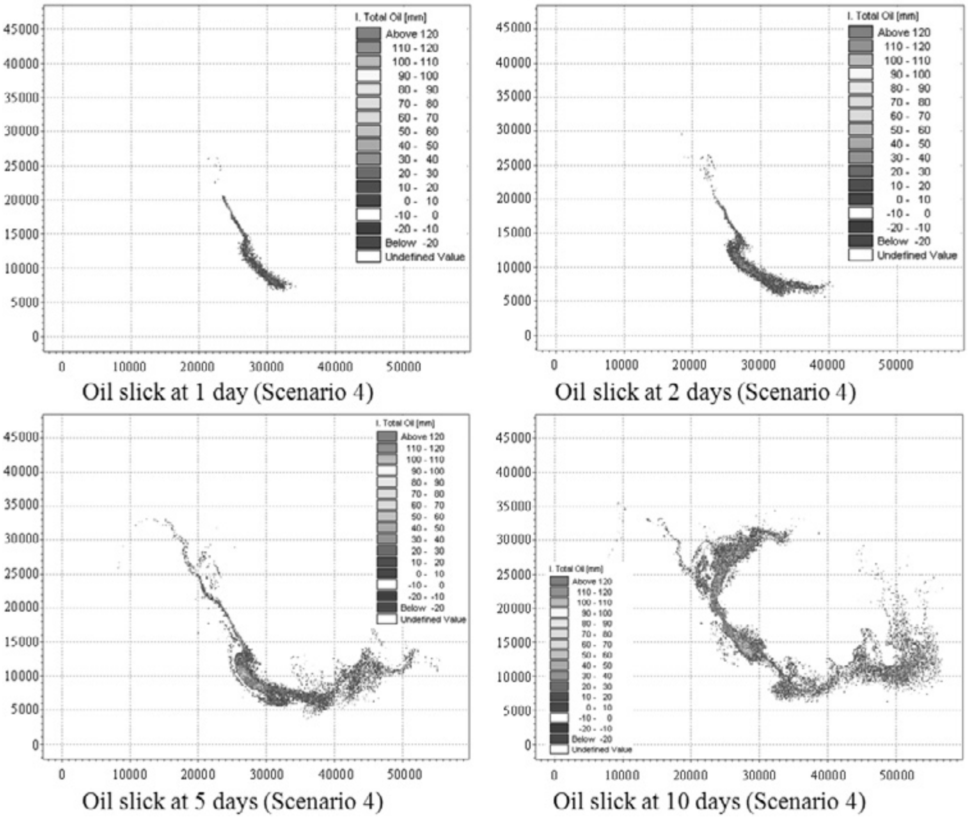


Fig. 17 Spill location 1 (Scenario 4)

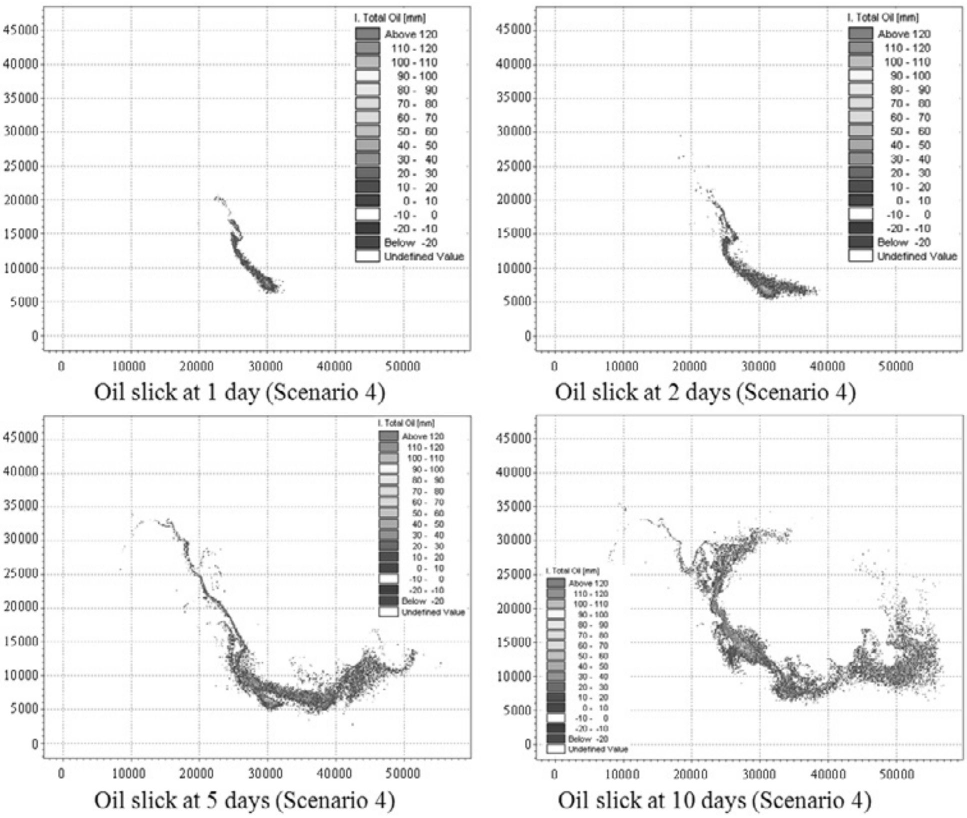


Fig. 18 Spill location 2 (Scenario 4)

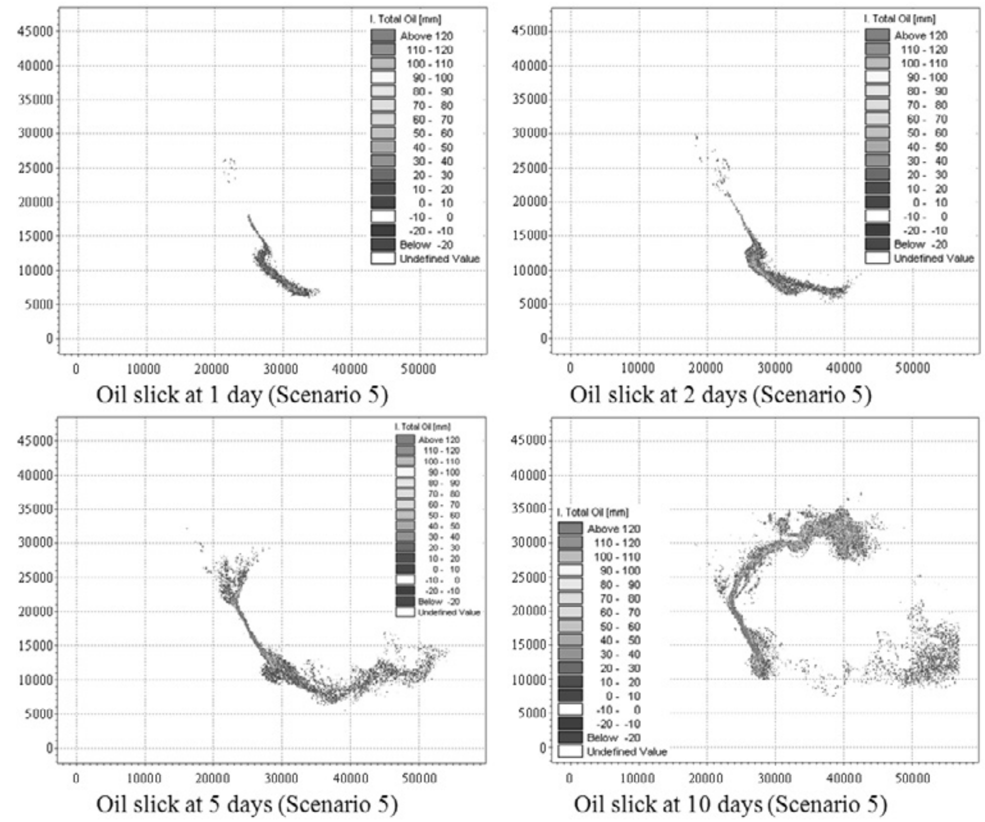


Fig. 19 Spill location 1 (Scenario 5)

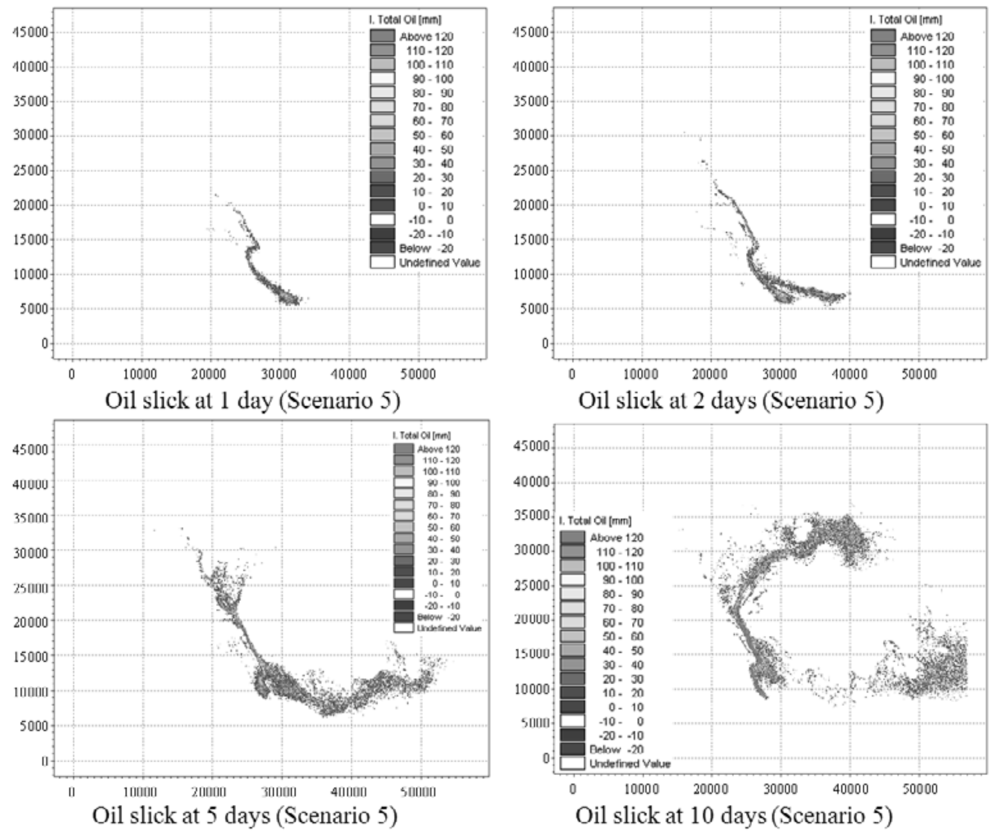


Fig. 20 Spill location 2 (Scenario 5)

Calculation result of oil spill trajectory

The results of simulation with five scenarios showed that oil spill occurs at Lach Huyen port effect on wide area and surrounding areas. An oil slick from 1, 2 scenarios at two SL1, SL2 positions have trajectories far from the port site in Northwest to Southwest (Fig. 21 to Fig. 24). Oil slick affects to Bach Dang, Cua Cam estuaries and small river branch near Lach Huyen. An oil slick in scenario 3 has trajectories to Cat Ba Island in the Southwest (Figs. 25 and 26). Oil slick affects in the North of Lach Huyen port and small islands in the South of Cat Ba. An oil slick in two scenarios 4, 5 showed that spill trajectories affect Cat Ba Island on wide area along the coastal and small islands (Figs. 27-30). Spill trajectories affect Tuan Chau Island in scenario 5 at both two SL1, SL2 positions (Figs. 29-30).

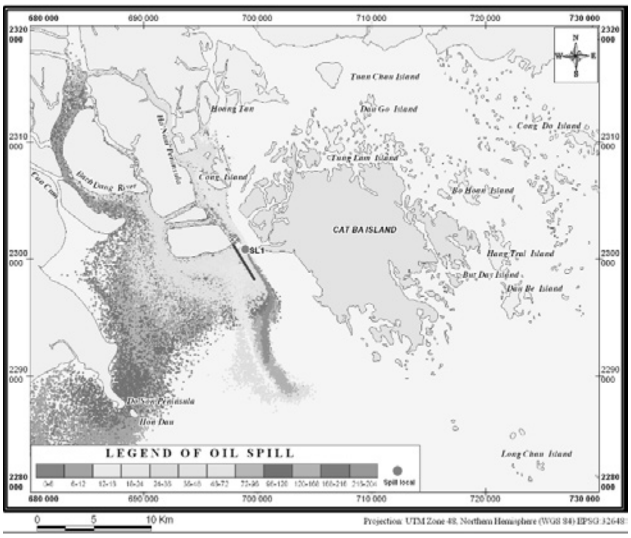


Fig. 21 Spill trajectory at SL1with (Scenario 1)

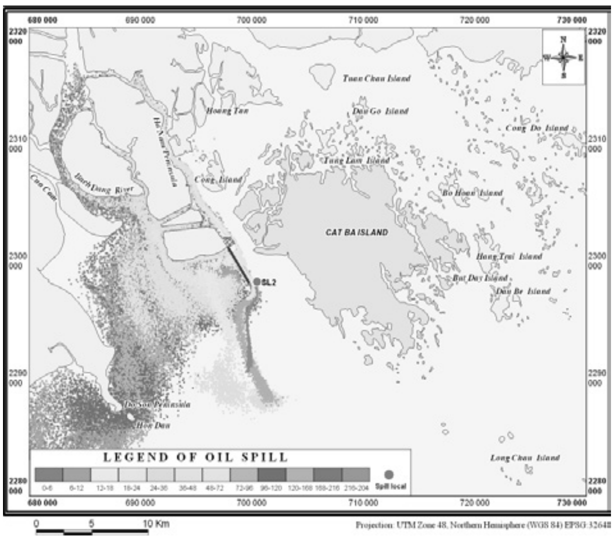


Fig. 22 Spill trajectory at SL2 with (Scenario 1)

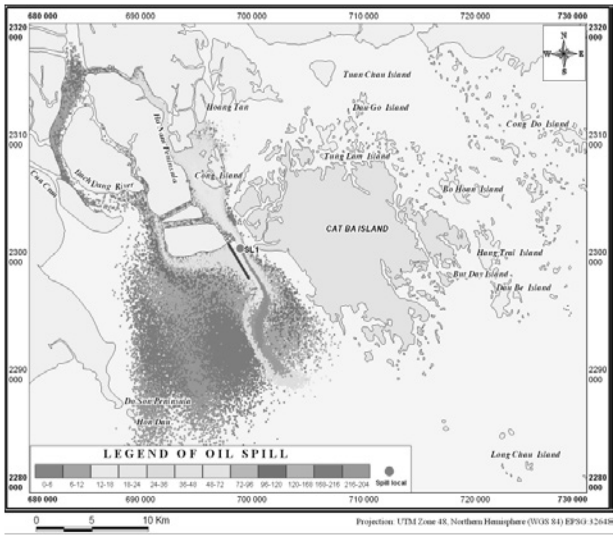


Fig. 23 Spill trajectory at SL1with (Scenario 2)

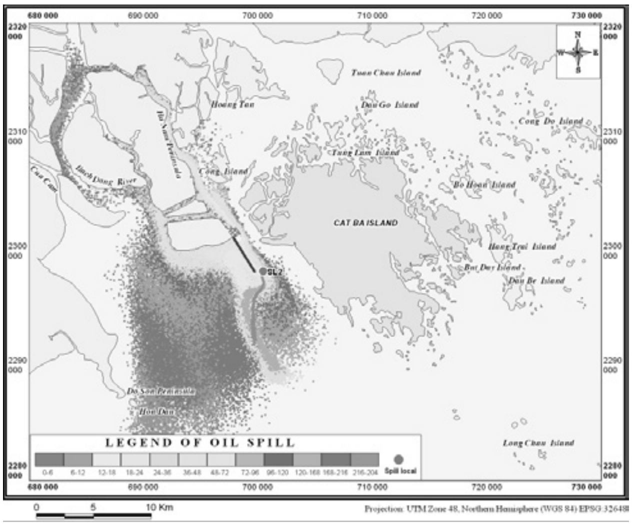


Fig. 24 Spill trajectory at SL2 with (Scenario 2)

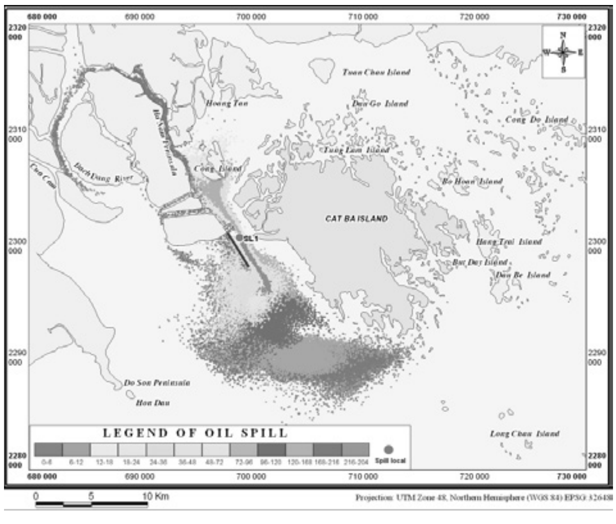


Fig. 25 Spill trajectory at SL1with (scenario 3)

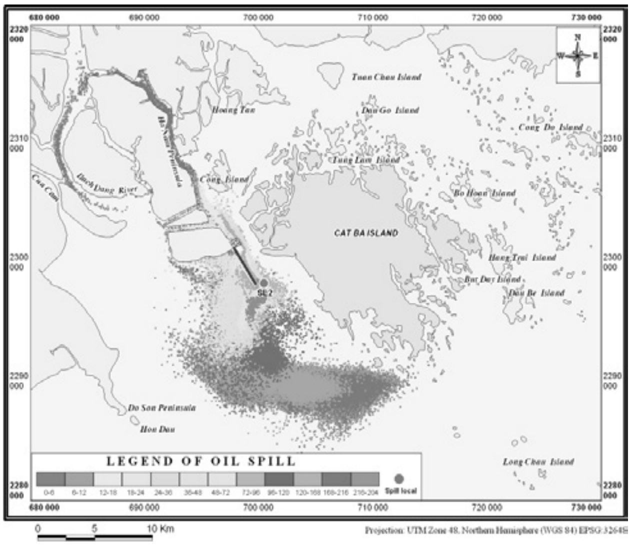


Fig. 26 Spill trajectory at SL2 with (scenario 3)

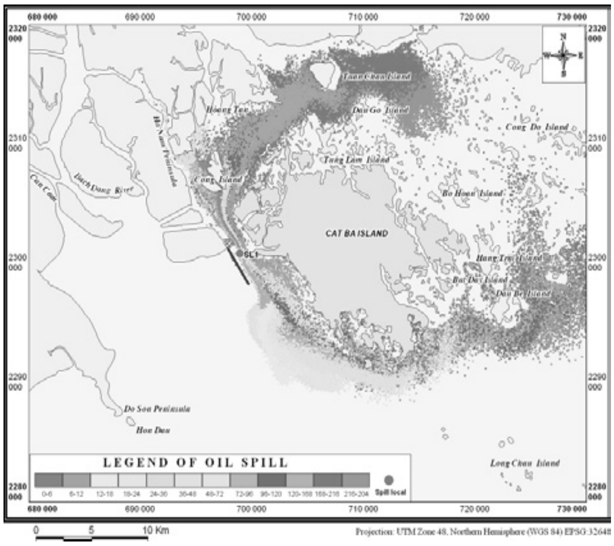


Fig. 29 Spill trajectory at SL1with (scenario 5)

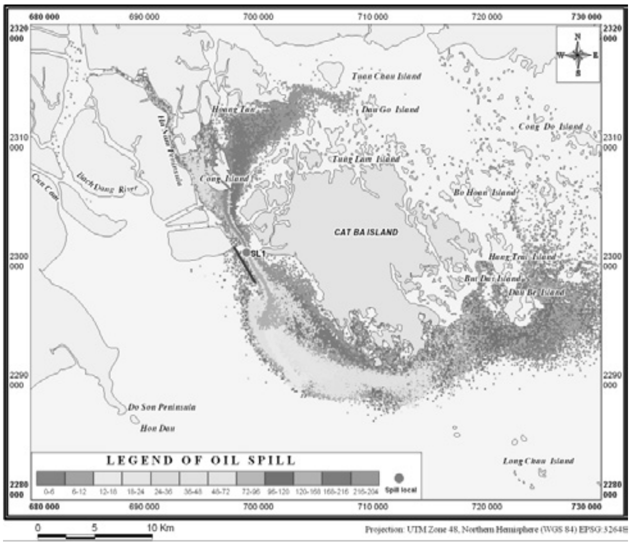


Fig. 27 Spill trajectory at SL1with (scenario 4)

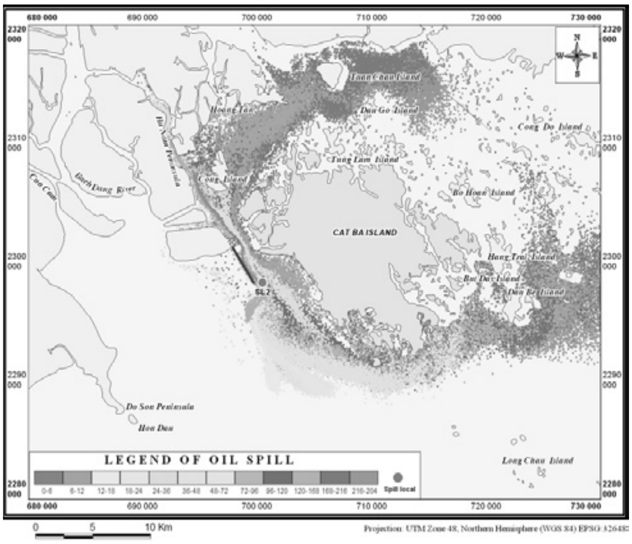


Fig. 30 Spill trajectory at SL2 with (scenario 5)

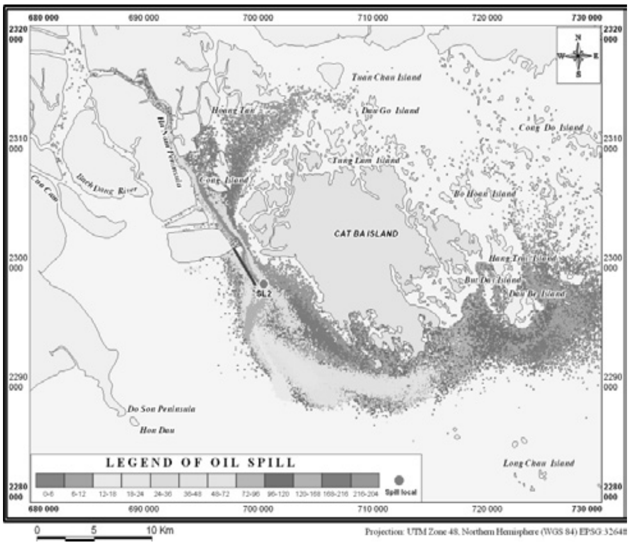


Fig. 28 Spill trajectory at SL2 with (scenario 4)

CONCLUSIONS

This paper presents the calibration and validation model for MIKE 21 SW, MIKE 21 HD. The comparisons between calculated and measured wave height at Hon Dau station showed a good agreement. The results of calculation from HD calibration and validation process above showed a high conformity about phase and water amplitude between calculated and measured water level data with Nash-Sutcliffe criterion equal 0.97 and 0.93. The results of validation and calibration model showed that MIKE 21 model can simulate well the hydrodynamic process in this study site. The simulation results of flow field showed that in the creeks area, flow rate of rising tide usually greater than falling tide. Flowing at Lach Huyen port is quite complicated due to the influence of topography with many small islands; bank beach appears at falling tide and submerged at rising tide. This paper has given us an opportunity to understand the capabilities of the MIKE 21 model, and use this model in simulating spill scenarios. The results of model can help preparedness and planning suitable response strategies.

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