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Oil Spill Modeling Study of Montara WHP Blowout using Software MoTuM

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Abstract. The Blowout at the Montara Well Head Platform (WHP) had released significant amount oil to Timor Gap and adjacent area. The release of oil started on the 21st August 2009 and stopped at November 2nd 2009. The spatial extent of oil spill, fates, and exposure occurrence were simulated using software MoTuM. The paper present the methodology and application of integrated three dimensional non-orthogonal boundary fitted ocean hydrodynamics and oil spill models in Geographic Information System (GIS). The ocean hydrodynamics model was calibrated and validated using available observation data. The spatial extents of the oil were compared with satellites image and flight observation. The agreement between results of simulation and observation are excellent

Keywords: *Oil Spill, Ocean Hydrodynamics, Non-Orthogonal Boundary Fitted, Geographic Information System, MoTuM, Model.*

1 Introduction

Oil spill modeling was performed to simulate in the event of a release of oil due to an blowout at the Montara Well Head Platform (Latitude 12o 40' 20.5" South, Longitude 124^{o} 32' 22.3" East). The area of study is presented in Figure 1. The water depth was approximately from 80 to 100 meters in Sahul Shelf and range from 2,000 to 3,500 meter in Timor Gap.

The paper presents the methology of modeling and results of simulation for Montara WHP Blowout. A lagrangian trajectory modeling system was implemented to simulate oil movement. The spillet were driven by simulated surface currents and wind. The hourly time varying current was obtained directly from three dimensional ocean hydrodynamics model. The path of simulated surface oil trajectories were compared to the satellite observations. There is no re-initialized in the modeling effort to match the satellite images data.

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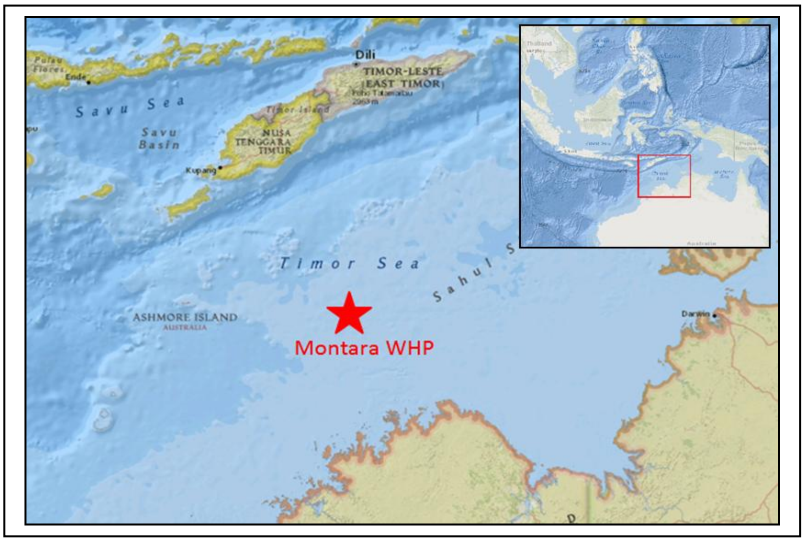

Figure 1 Area of Study, Timor Sea Australia - Indonesia.

The release of oil started on the 21st August 2009 and continued leaking until 2rd November 2009, with a leak rate estimated at 400 barrels of Montara Crude oil per day (APASA, 2010). MoTuM calculated the spatial extent of the oil released the thickness of the surface oil and probability of oil exposure occurrence. The key success of the simulation is because the integration of three dimensional hydrodynamics model in simulation. Direct linkages to 3D hydrodynamic models are extremely important. The multi wind data was obtained from NOAA.

2 Software MoTuM Description

MoTuM was developed to meet the need for an extremely user friendly and verified modeling system to predict oil spill. MoTuM consists of three principal parts:

- 3D Ocean Hydrodynamics Model
- Oil Spill Model
  - Trajectory
  - Fates
  - Stochastic
  - Backtracking
- Geographic Information System (GIS)

The software was developed in Microsoft Windows System. The software is also designed to operate on low cost computers and user friendly. The environmental data was stored in GIS Database. The wind forcing can be specified as constant or time varying for all computational domains. The model extrapolates the wind forcing for each computational cell if multi-wind data is available. The ocean hydrodynamics and oil spill model are coupled. Time varying ocean current as main driving force of oil dispersion was obtained directly from three dimensional ocean hydrodynamics non-orthogonal curvilinear technique or boundary fitted model (Muin, 1993; Muin and Spaulding, 1996-1997). The integration of ocean hydrodynamics model into oil spill model makes the software easier to use and more accurate. Therefore, it is important to calibrate the model for each area of application. Figure 2 show the scheme of MoTuM.

MoTuM is used by oil industry in Indonesia (Total Indonesie, Chevron, CNOOC, Exxons Mobile, Pertamina, BOB Jambi Merang, BOB Pertamina-Siak, EMP, Premier Oil, Citics-Seram, Conocco Phillip Indonesia, and BPTangguh). Software MoTuM has been adapted by Ministry of Environment Indonesia (MOE) and Upstream Oil and Gas Executive Agency (BPMigas) as primary response tool.

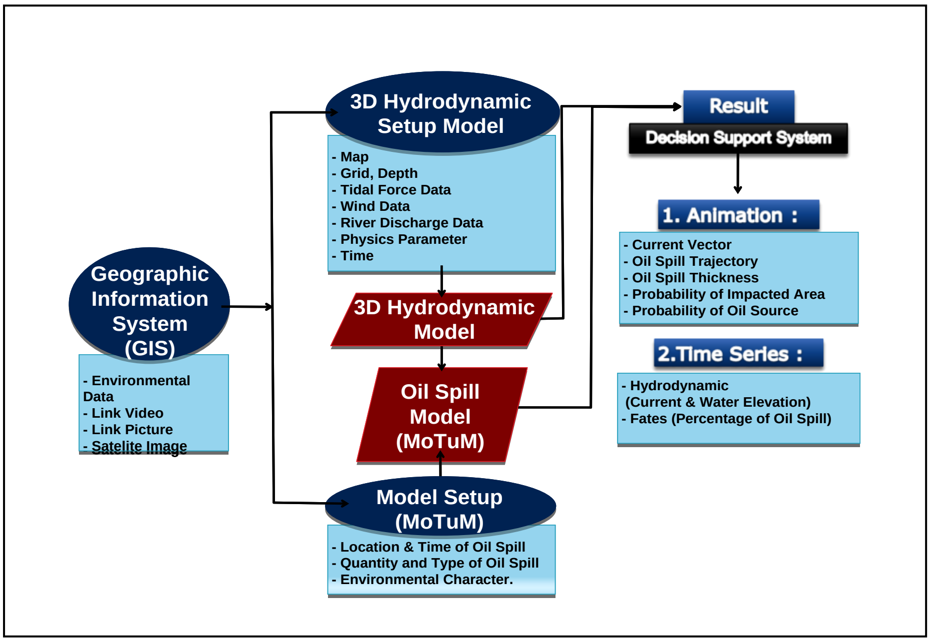

Figure 2 Software MoTuM Scheme

3 Model Setup

The computational Non-Orthogonal Boundary Fitted Grid System is shown in Figure 3. It consists of 5850 water cell. Bathymetry was obtained from the US NOAA GEODAS.

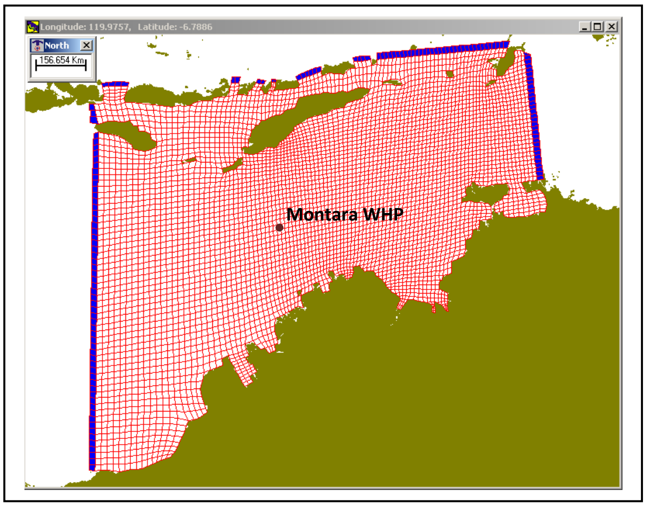

Figure 3 Non-Orthogonal Boundary Fitted Grid System.

The time series of wind data in the computational domain is obtained from the US National Oceanic and Atmospheric Administration (NOAA). The version used in the study is NCEP Reanalysis 2, NOAA/NCDC blended daily in surface wind, provides global coverage with a horizontal resolution of 1°.

The global ocean current Indonesia Through Flow (ITF) is very important in the Timor Passage. Figures 4 show the observation data at depth 50 meter from surface in Longitude 122.9598° E and Latitude 11.3683° S. The data show that the surface water current along Timor Passage is very dynamics. The time varying of speed and direction of the surface current was caused by tidal and wind forcing. It can be seen that the surface water may flow to the Northern direction or to the Indonesia Coastline. Clearly, the tidal current cannot be ignored. At the surface the net flow or ITF along Timor Passage is about 0.35 m/s. The net or residual current of ITF is assumed as constant flow. The model input for ITF in the domain of Timor Passage is 7.6 Sv. The vertical Eddy

Viscosity in the ocean hydrodynamics model is tuned to match the net surface current 0.35 m/s at the observation station.

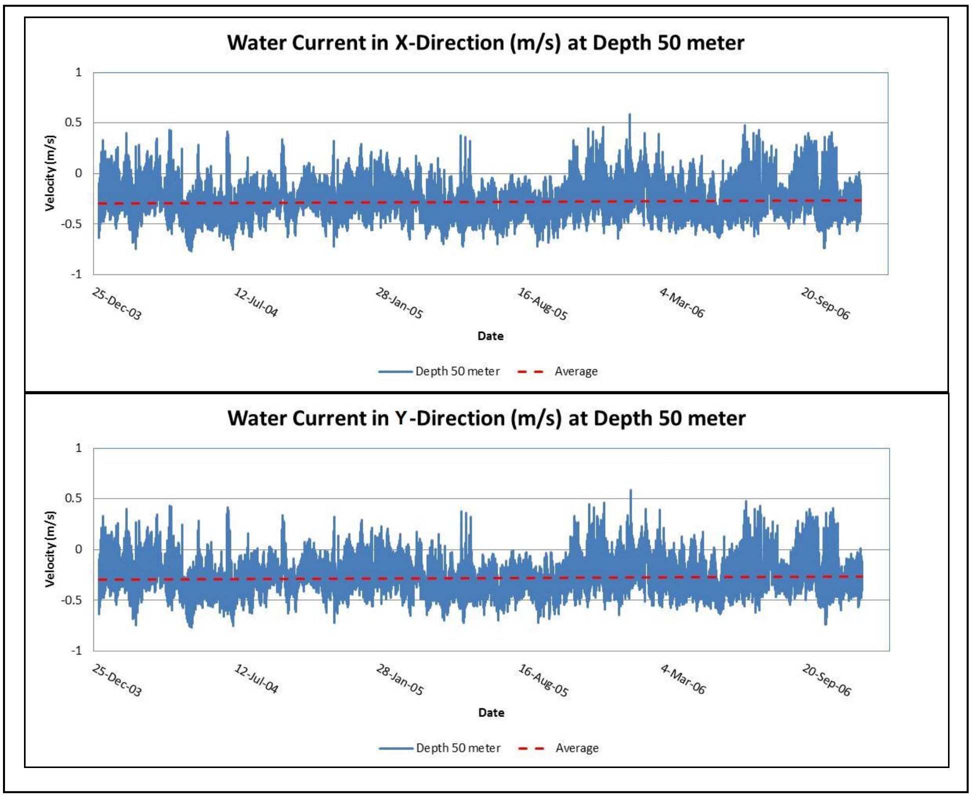

Figure 4 Ocean current observation data in E-W and N-S directions.

4 Model Calibration and Validation

The success of any model application depends on the credibility of the model predictions. This credibility is gained by careful comparison of model predictions with observations. The purpose of calibration is to select model coefficient to best match observation data. The following sections present the model calibration and validation

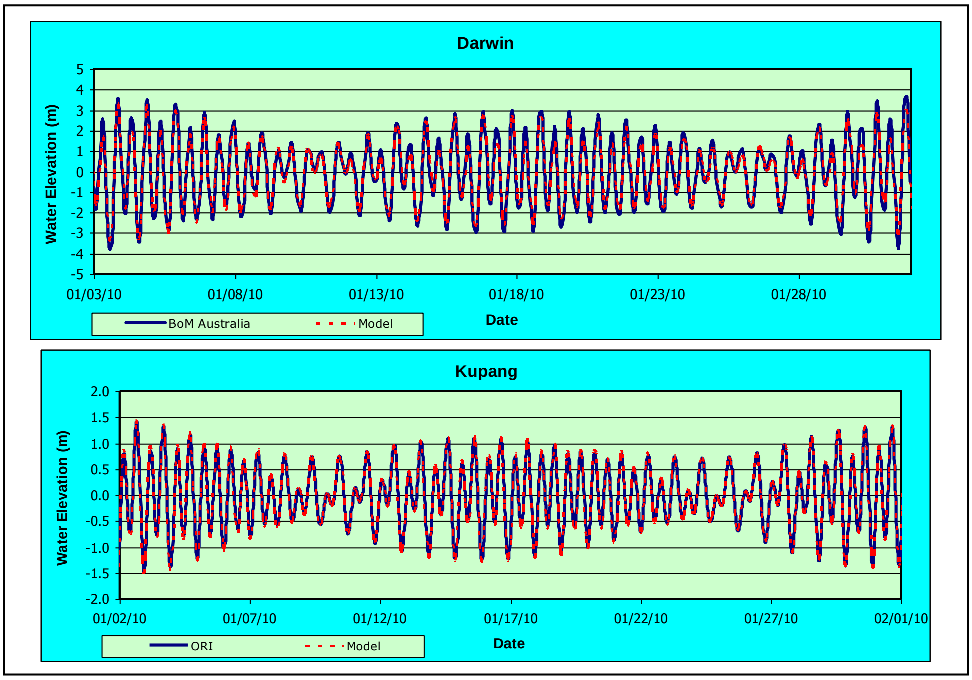

Figure 5 Water elevation comparison between model and observations.

The bottom frictions in the main water body were tuned to match the water elevation data. It was found coefficient of bottom friction is 0.002. The comparison between the predicted and observed water elevations are presented in Figures 5. The agreement between the prediction and observations are excellent.

The results of ocean hydrodynamics model were also validated by comparing the Tracking Buoy Data collection by AMSA. The Buoy was deployed on 14^{th} October 2009 and latest position data on 22^{nd} October 2009. Figure 6 presents the comparison between tracking line of buoy data and model prediction. It can be seen that the agreement is very good. The ITF is simulated very well.

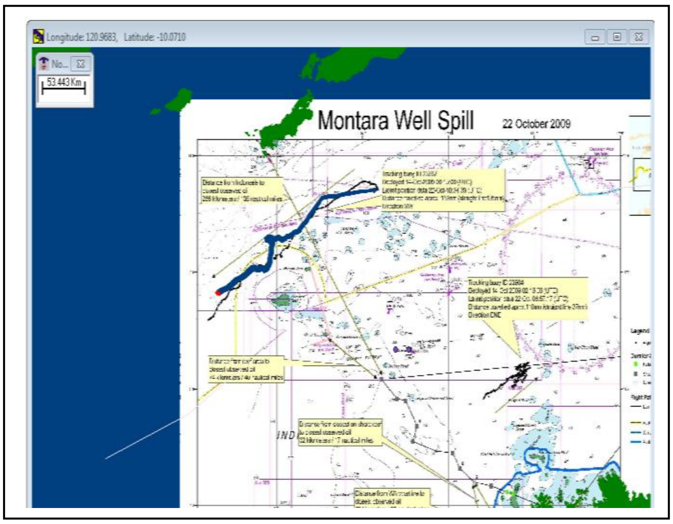

Figure 6 The Comparison between Tracking Line of Buoy Data (AMSA, 2009) and MoTuM Prediction (blue line).

The comparison between the satellite image and model prediction are presented from Figures 7 to 10. The scale of oil thickness in the model prediction is based on experience at sea, the majority of the oil slick area shown in the satellite images are more than 100 microns (>0.1 mm). The oil thickness less than 50 microns cannot be observed by Satellites Image.

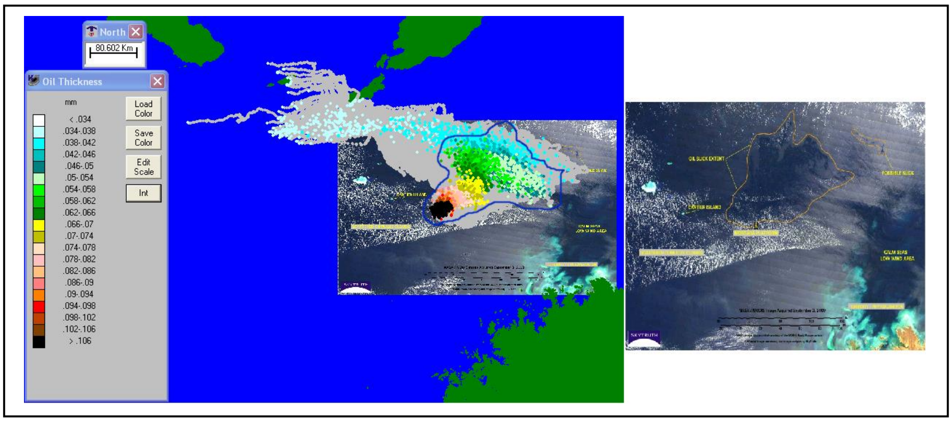

Figure 7 Comparison of the MODIS satellite images (right) with the model prediction (left) on the 03rdSeptember 2009. Note: yellow polygons in the satellite image encircle identified visible oil patches and colored spots and blue polygon in the modeled image represent modeled oil patches.

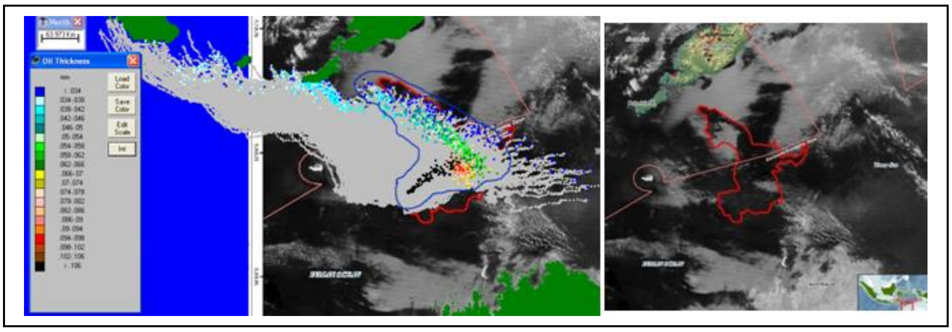

Figure 8 Comparison of the LAPAN satellite images (right) with the model prediction (left) on the 10thSeptember 2009. Note: red polygons in the satellite image encircle identified visible oil patches and colored spots and blue polygon in the modeled image represent modeled oil patches

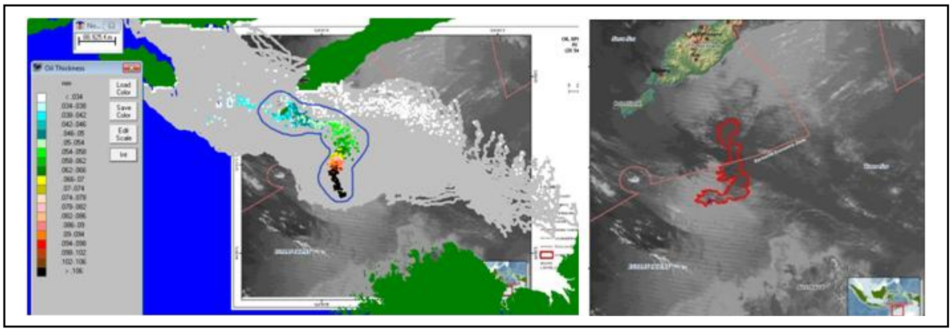

Figure 9 Comparison of the LAPAN satellite images (right) with the model prediction (left) on the 26thSeptember 2009. Note: red polygons in the satellite image encircle identified visible oil patches and colored spots and blue polygon in the modeled image represent modeled oil patches.

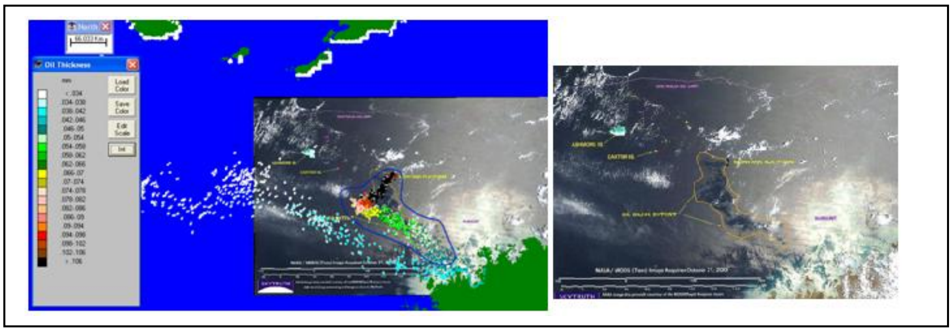

Figure 10 Comparison of the MODIS (Terra) satellite images (left) with the model prediction (right) on the 21stOctober 2009. Note: yellow polygons in the satellite image encircle identified visible oil patches and colored spots and blue polygon in the modeled image represent modeled oil patches.

5 Results of Simulation

5.1 Oil Spill Trajectory and Thickness

The model indicates that the released oil started to enter Indonesia Coastal Water on August 30th 2009 (Figure 11). The age of oil that had reached Indonesia Coastlines is mostly older than nine days. The color legends represent the age or the duration of each oil spillet which had been exposed in the surface water.

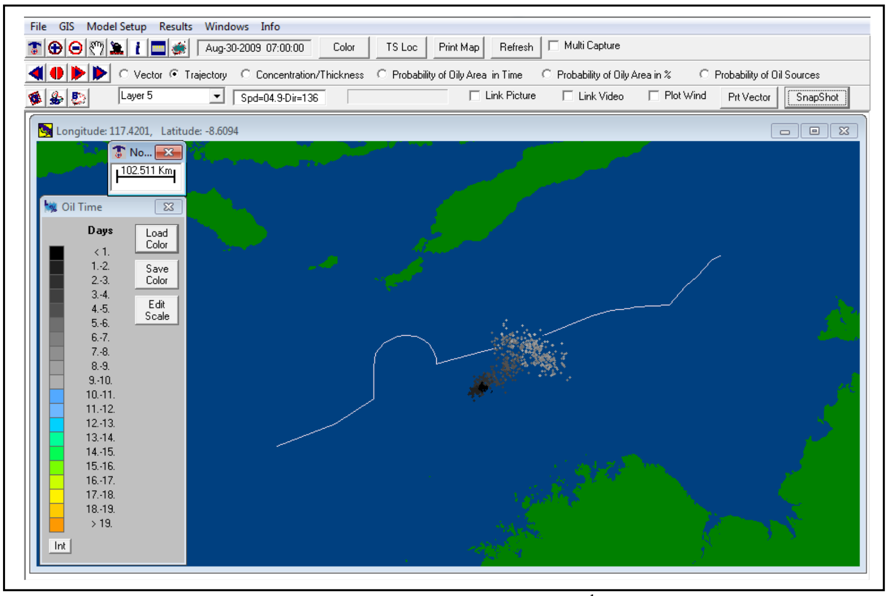

Figure 11 The Oil Spill Trajectory on 30th August 2009.

From 6th September to 26th October 2009, the model indicated that the oil are exposed in the Indonesia Coastal Water. On 13th October 2009, the oil was observed to be moving from its initial northerly position towards Australia as shown in Figure 10. However, the residual oil in offshore remains in Indonesia Coastal Water until 26th October 2009.

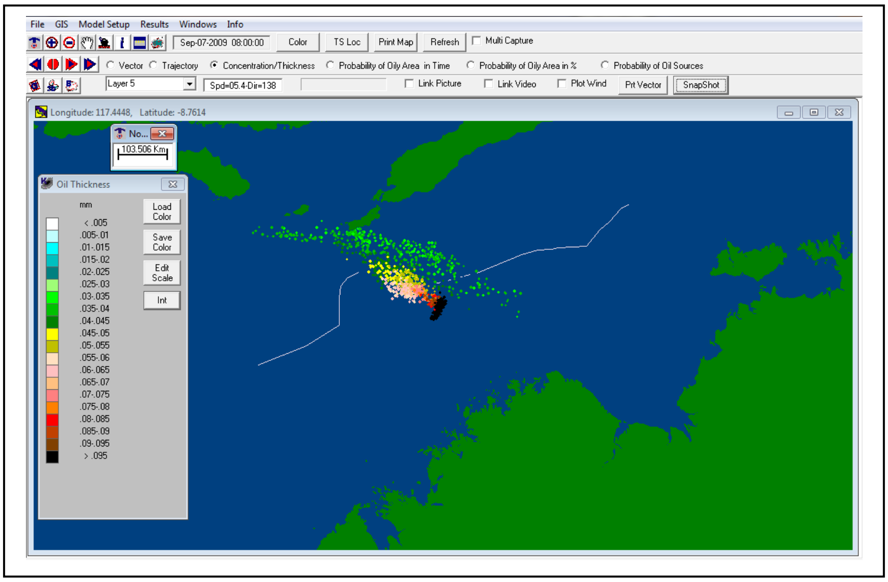

Figure 12 Oil Spill Thickness on 7th September 2009.

It can be seen that the thickness of oil enter Indonesia Coastal Water and trapped along coastline exceed the minimum thickness threshold 0.1 µm. Therefore, the oil spill will impact the marine environment in that area.

The thickness of oil higher than 0.1 mm is shown in black colors which represent fresh oil. The thickness of oil had entered Indonesia Coastal Water are mostly less than 0.1 mm.

5.2 Mass Balance

Mass balance plots describe the fate of the oil as time-varying percentages of the total mass for the three primary phases: the offshore, stranded on shorelines, and mass evaporated into the atmosphere.

Figure 13 present the time series of evaporated oil. The model predicts that 8,000 barrels of 29,600 of released oil will be evaporated after 72 days.

The released oil started to reach Indonesia Coastline after 20 days of simulation. The released oil movement change direction away from Indonesia's coastal water after about 50 days of simulation. The results of simulation indicate that the total oil had been stranded in the Indonesia Coastal water is about 10,000 barrels.

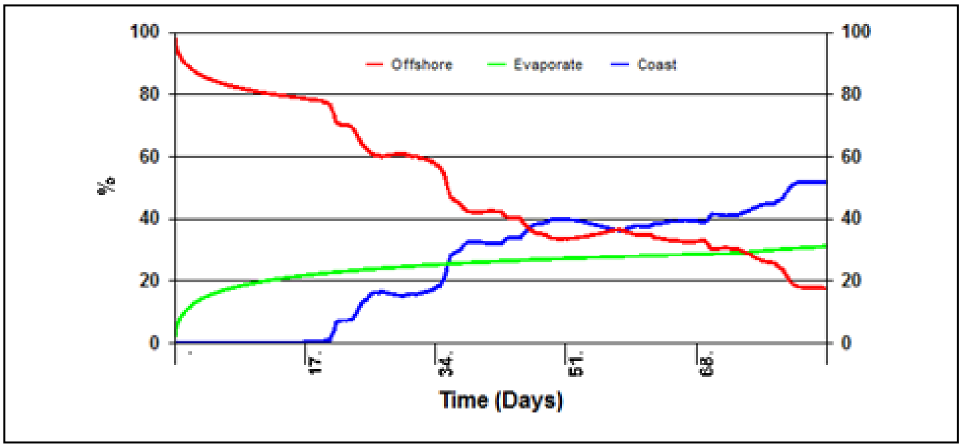

Figure 13 Oil Mass Balance during Montara WHP Spill.

5.3 Oil Exposure Occurence

The stochastic model was run for 1776 hours. Surface oiling is defined as any oil having a thickness above the minimum thickness threshold, a value that protects aquatic biota from being smothered. This threshold is 0.1 µm, an order of magnitude below a minimum smothering thickness of 1 µm (French et al, 1999; NOAA, 1996). Thicknesses less than the 0.1 µm threshold are typically invisible to the eye (Koops, 1985).

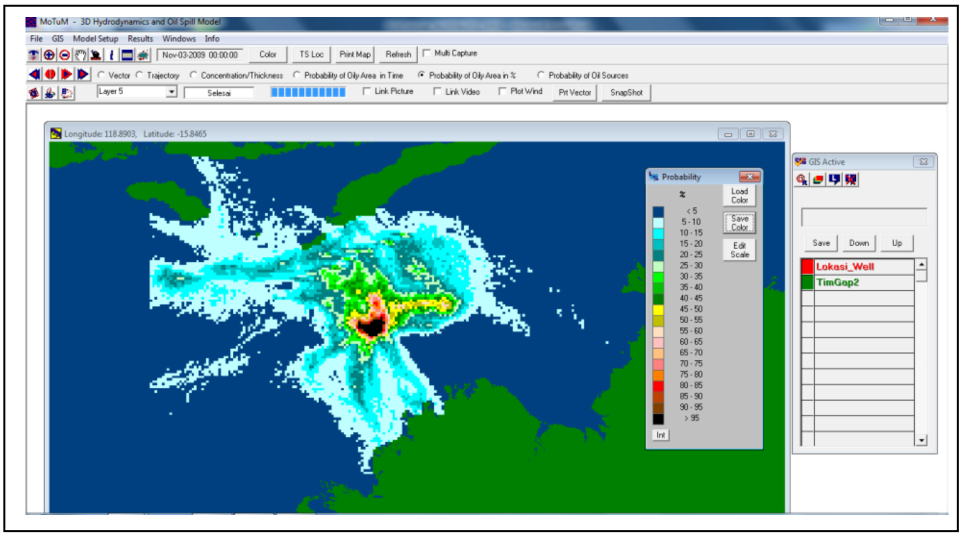

Figure 14 Oil Relative percentage Oil Exposure Occurrence in Offshore.

Figure 14 shows the results of simulation in relative percentage oil exposure occurrence of offshore region. It can be seen that the highest percentage of oil exposure occurs in the region of source released oil or Montara Well Platform. However, the results of simulation indicate that the oil exposure in Indonesia Coastal Water can reach 35% or 622 hours, where the highest exposure is in Rote Island.

The modeling results also show that the risk of the released oil to Indonesia Coastline is higher than to Australia Coastline because the percentage of oil spill occurrence is higher in Indonesia Coastal Water.

6 Conclusion

Direct linkage of ocean hydrodynamics to oil spill model is the key success of oil spill simulation in Montara WHP Blowout. The ocean hydrodynamics model had been calibrated by comparing the results with available data (drogue experiments by AMSA and Bureau of Meteorological Australia). The comparisons are excellent. This indicated that the predicted flow pattern in Timor Passage regions is accurate.

The results of oil spill model had been validated by comparing the model prediction and observations data. The comparison between results of simulation and available data (satellite image) are excellent.

The strong surface water current along Timor Passage was also driven by dynamic local wind forcing which is seasonal. The observational data show that the net water current may flow to North direction. Under the condition of wind blow to Northern direction, the oil will move the oil to Indonesia Coastline.

The results of simulation show that the released oil from Montara WHP (Well Head Platform) has reached Indonesia Coastlines. Approximately 10,000 barrel released oils were stranded along the Indonesia Coastline.

The results of model prediction indicate that the percentage of oil exposure to Indonesia Coastline is higher than that of to Australia Coastline. Therefore, the impact of released oil to Indonesia Coastline is higher than to Australia Coastline.

The simulation results indicate that the released oil had impacted 850 km Indonesia's coastline and 172,000 km^2 coastal water areas.

7 Acknowledgement

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