

Numerical modelling for quantitative environmental risk assessment for the disposal of drill cuttings and mud

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Abstract. To investigate the fate of drilling waste and their impacts towards surrounding environment, numerical models were generated using an environmental software; MIKE by DHI. These numerical models were used to study the transportation of suspended drill waste plumes in the water column and its deposition on seabed in South China Sea (SCS). A random disposal site with the model area of 50 km x 25 km was selected near the Madalene Shoal in SCS and the ambient currents as well as other meteorological conditions were simulated in details at the proposed location. This paper was focusing on sensitivity study of different drill waste particle characteristics on impacts towards marine receiving environment. The drilling scenarios were obtained and adapted from the oil producer well at offshore Sabah (Case 1) and data from actual exploration drilling case at Pumbaa location (PL 469) in the Norwegian Sea (Case 2). The two cases were compared to study the effect of different drilling particle characteristics and their behavior in marine receiving environment after discharged. Using the Hydrodynamic and Sediment Transport models simulated in MIKE by DHI, the variation of currents and the behavior of the drilling waste particles can be analyzed and evaluated in terms of multiple degree zones of impacts.

1. Introduction

Conservation of environment was part of consideration that needed to be taken into account in oil and gas businesses. Nowadays, many countries which operating the oil and gas activities encouraged the service companies to do the assessment on environmental impacts to conserve and protect the ecological habitants of surrounding environments. The author in collaboration with DHI Water & Environment (M) SDN BHD undertaken a study to determine the fate of drilling waste disposal (drill cuttings and mud) for two (2) different cases in terms of suspended drill waste particles in water column and its deposition on seabed based on degree zone of impacts using numerical modelling. Impact of the drill waste particles can be observed within the framework of their effect towards benthic communities such as corals, either through burial or chemical toxicity [2][3]. The deposition of the drill waste on seabed might also resulted in smothering of benthic organism regardless of the type of drilling mud used [1]. Uncontrolled discharge of the drill waste will affect the marine habitants in terms of elevated suspended sediment concentration in water column that can reduced the light penetration from the sea surface in which subsequently affects the photosynthesis process for the surrounding corals. In addition, excess sedimentation of the drill waste on seabed can also clog the filter mechanism of the benthic organism.



The proposed disposal site was located near Madalene Shoal, 8.3 km; 7.57° NW of Bintulu, Sarawak. The project duration will be categorized into three (3) different monsoon scenarios: a) North-East (NE) monsoon periods. b) Inter-monsoon (IM) periods. c) South-West (SW) monsoon periods.

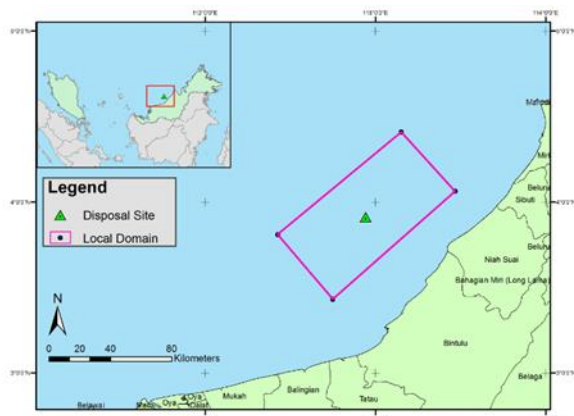


Figure 1. Location of the disposal site and the local domain within the study area.

There were also few limitations in this project such as the impact assessment criteria used were based on the general tolerance of the corals against the suspended sediment and its deposition. No actual coral positioning data at the study area were used due to limitation and confidentiality of the data. However, considerable amount of past researches had been done on studying the environmental impact from the effects of the operational drilling waste, particularly in United States and in Europe [2]. The drilling scenarios and the drill waste particle characteristics were also obtained from past researches and adapted from the actual data mostly from Norwegian Sea. Thus, different particle characteristics may affect the simulated results of the numerical models generated later on. Only two different cases (Case 1 and Case 2) were chosen to study the sensitivity of different particle characteristics towards its behaviour after discharge to open sea due to limitation of data.

2. Research methodology

2.1 Modelling Strategy

This project will focus on generation of hydrodynamic (HD) model and sediment transport model using environmental software, MIKE by DHI. The generation of numerical models were followed according to standard DHI modelling techniques. The process of generating the numerical models started with the generation of regional HD model for South China Sea (SCS) to see the regional variations of the ambient conditions as well as other meteorological conditions in SCS.

2.2 Disposal Method

For this project, the disposal method chosen would be the offshore discharge method. The drill cutting and mud were brought up to the platform and undergo the cleaning processes. The drilling fluid (mud) recovered from the cleaning processes will be re-used. However, the remaining drill cuttings and mud stain which known as drill waste were discharge to the marine receiving environment [1].

2.3 Drilling Scenario and Drill Waste Characteristics

This project was a sensitivity study to investigate the effect of different drill waste characteristics towards the behaviour of the drilling discharge in the marine receiving environment. Two different cases representing the different drill waste characteristics (Case 1 and Case 2) were selected with the same amount of total volume discharge. The differences in term of the drill waste particle sizes, drilling scenario, rate of discharges as well as other drill waste characteristic were determined for this study.

The drilling scenario and drill waste characteristics were obtained and adapted from past researches regarding waste disposal mostly from the Norwegian Sea for both Case 1 and Case 2. The drilling scenarios and particle size characteristics for both cases were described in the tables below:

Table 1. Drilling scenario for Case 1 and Case 2.

Case 1

Well Section	Hole Size (Inch)	Section Length (ft)	Drilling Time (hr)	Volume (bbls)	Weight (MT)	Drill Cuttings and Mud Discharge (kg/s)
1	13.38	227	19.2	240.1	91.5	1.584
2	12.25	3083	60.0	449.4	171.2	0.948
3	8.50	1487	40.8	104.4	39.8	0.324
Total		4797	120.0	793.9	302.5	2.868

Case 2

Well Section	Hole Size (Inch)	Section Length (m)	Drilling Time (hr)	Weight (MT)	Drill Cuttings and Mud Discharge (kg/s)
1	36	83 + 2 Batch	14	2103	41.726
2	8.5	339 + 1 Batch	19.75	2899.45	40.78
3	17.5	335 + 2 Batch	37	5389.63	40.463
Total			70.75	10392.08	245.938

Table 2. Drill waste characteristics for Case 1 and Case 2 used for simulating the sediment transport model.

Case 1

Fraction	Average Size (mm)	Contribution (%)	Settling Velocity (mm/s)	Density (g/cm ³)
1	2.073	5	1333.22413	2.65
2	1.225	15	528.12161	2.65
3	0.855	24	291.068519	2.65
4	0.345	12	71.9839585	2.65
5	0.094	8	8.51686484	2.65
6	0.061	8	3.7781812	2.65
7	0.031	20	1.0066431	2.65
8	0.002	8	0.0042481	2.65

Case 2

Fraction	Average Size (mm)	Contribution (%)	Settling Velocity (mm/s)	Density (g/cm ³)
1	2.203	11	1790.1831	3.0
2	1.625	10	1031.8218	3.0
3	1.330	2	725.5673	3.0
4	0.995	23	442.9635	3.0
5	0.462	8	131.5793	3.0
6	0.069	21	4.3542	2.5
7	0.043	10	1.7424	2.5
8	0.031	15	0.9146	2.5

2.4 Impact Assessment Criteria

The following tolerance limits and impact thresholds for corals habitats (Table 3 and Table 4) have been developed by DHI through a combination of literature reviews and previous experience from environmental mitigation and monitoring plans. The impact assessment criteria for both suspended sediments in water column and sediment deposition on seabed were tabulated as follows:

Table 3. Threshold values for suspended particles in water column

Zone of Impact	Criteria	Percentage
Zone of High Impact	> 25 mg/l	> 7 %
EPO: Total mortality allowed	> 10 mg/l	> 19 %
	> 5 mg/l	> 40 %
Zone of Moderate Impact	> 25 mg/l	2.5 - 7 %
EPO: <30% mortality	> 10 mg/l	10 - 19 %
	> 5 mg/l	25 - 40 %
Zone of Influence (Low Impact)	> 25 mg/l	0.5 % - 2.5 %
EPO: 0% mortality	> 10 mg/l	0.5 % - 10 %
	> 5 mg/l	2.5 % - 25 %
No Impact	> 25 mg/l	< 0.5 %
	> 10 mg/l	< 0.5 %
	> 5 mg/l	< 2.5 %

Table 4. Threshold values for sediment deposition on seabed.

Zone of Impact	Sedimentation (mg/cm ²) or (mm/14 days)
Zone of High Impact	> 14 or > 4.9
EPO: Total mortality allowed	
Zone of Moderate Impact	5 - 14 or 1.7 - 4.9
EPO: <30% mortality	
Zone of Influence (Low Impact)	1 - 5 or 0.3 - 1.7
EPO: 0% mortality	
No Impact	< 1 or <0.3

3. Result and discussion

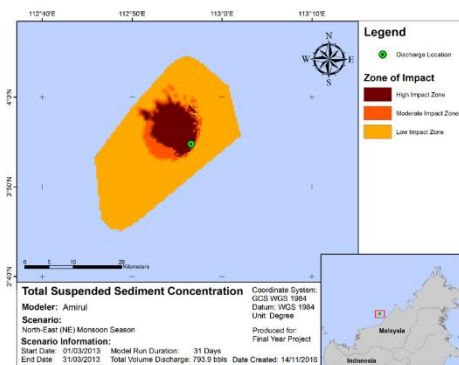
3.1 Impact Assessment

3.1.1 During NE monsoon period

3.1.1.1 Total suspended sediment concentration in water column.

Based on Figure 2, the dark brown color represented the high impact zone while the orange color indicated the area covered by moderate impact zone. The low impact zone were shown by the electron gold color. Major concentration of the suspended particles for low impact zone during NE monsoon in Case 1 were pointing towards SW.

Case 1



Case 2

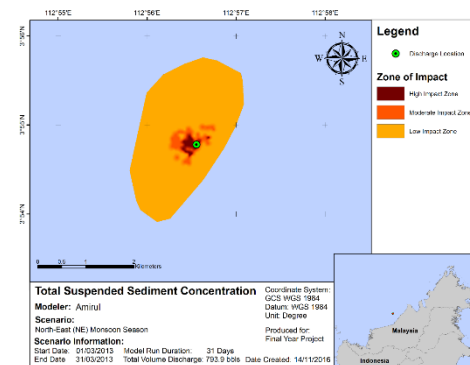
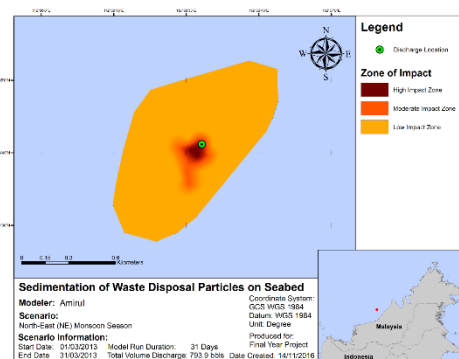


Figure 2. Impact assessment on TSSC model results for Case 1 and Case 2 during NE monsoon.

3.1.1.2 Sediment deposition on seabed

Case 1



Case 2

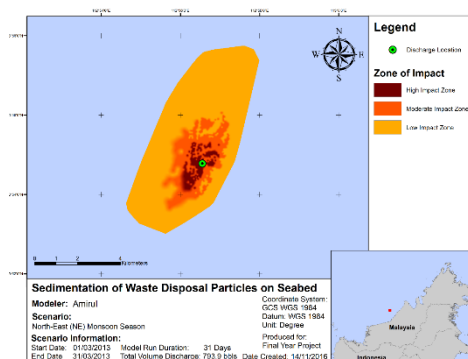


Figure 3. Impact assessment of waste disposal sedimentation on seabed for Case 1 and Case 2 during NE monsoon.

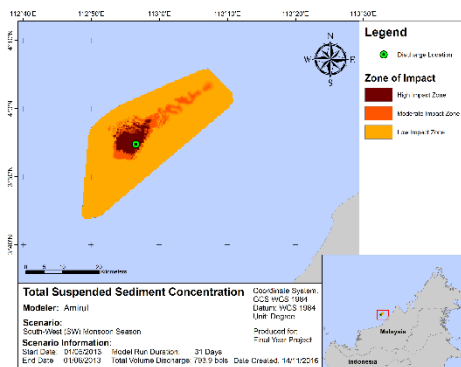
Based on Figure 3, the sedimentation of the particles was likely deposited at the SW direction from the disposal site during NE monsoon. This can be seen by the particles which possessed the high, moderate and low impact zone were mostly accumulated and deposited at the SW direction from the disposal site. For Case 2, the sediment also showed major deposition in SW direction from the disposal site. Minor

deposition towards other directions were mainly due to the minor currents movement throughout NE monsoon period.

3.1.2 During SW monsoon period.

3.1.2.1 Total suspended sediment concentration in water column

Case 1



Case 2

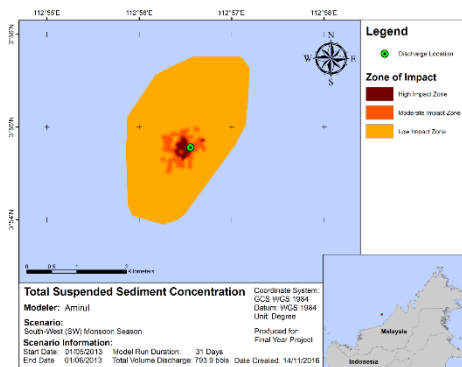
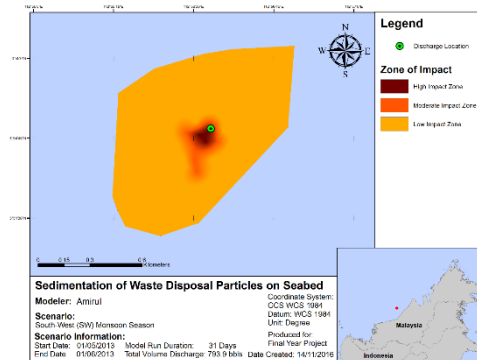


Figure 4. Impact assessment on TSSC model results for Case 1 and Case 2 during SW monsoon.

In terms of SW monsoon scenario, Case 1 showed major concentrations in NE direction for all impact zones. This supported the evidence that during SW monsoon, the major current movements were pointing towards NE direction hence, the concentration of the suspended sediments were likely pointing towards NE direction. Meanwhile, for Case 2; the covered area for low impact zone mostly pointing towards NE direction although there was few covered area in SW direction.

3.1.2.2 Sediment deposition on seabed

Case 1



Case 2

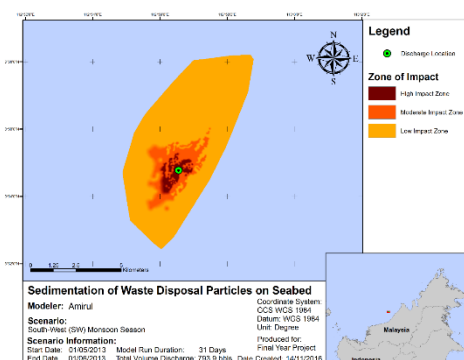


Figure 5. Impact assessment of waste disposal sedimentation on seabed for Case 1 and Case 2 during SW monsoon.

In terms of sediment deposition, Case 1 showed minor deposition towards NE direction for high and moderate impact zone during SW monsoon period. However, deposition of the particles which possessed low impact zone had major deposition towards NE direction compared from previous Inter-monsoon period. Other covered areas for all degree of impact came from previous NE and Inter-monsoon period. However, Case 2 showed major deposition towards NE direction during the SW monsoon period. The low impact zone showed the highest deposition towards NE direction compared to high and moderate impact zone.

4. Conclusion & Recommendation

Based on the hydrodynamic (HD) modelling for the proposed location, it was proven that during NE monsoon, the currents variations were most likely moved towards South-West direction meanwhile during SW monsoon periods, the currents variations were most likely showed dominant movement towards North-East direction. However, during Inter-monsoon period, there were no major direction which dominated the currents movement. Using the drilling scenarios for two (2) different cases (Case 1 and Case 2) as well as the estimated distributions and settling velocities for different particle sizes, transportation and deposition model were generated. Case 1 had the largest area covered for all degree of impacts in terms of suspended sediment concentrations compared to Case 2 scenario. However, in terms of sediment deposition on seabed, Case 2 proved to have largest covered area compared to Case 1. This was due to differences in drill waste characteristics such as settling velocities, density and particle sizes of the drilling discharge.

As for the recommendations on the impacts of drill waste discharge towards surrounding corals, a real time coral data should be applied to validate the degree zone of impact. The detailed modelling for studying the behaviour of each drill waste particle sizes in terms of suspended sediment in water column and also sediment deposition on seabed should be showing the impacts towards surrounding coral. Other factors such as flocculation effects, critical sheer stress for drill waste particles and topography of the seafloor should be included in the future modelling works.

Full Environmental Impact Assessment (EIA) should also be carried out in the near future for the proposed location to determine whether the proposed disposal site could be used as offshore disposal location for drilling discharge or not. If the impacts from the drilling discharges were to be prevented, it was necessary to reduce the volume discharged and discharge rate to allow the suspended sediment from the discharged materials to settle down on seabed. This could prevented the harm towards marine habitants due to abrading of gills of the marine habitants as well as giving the nearby coral time for self-cleaning.

References

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