APPENDIX B DISCHARGE MODELLING REPORT

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FINAL REPORT

Oil Spill, Produced Water, Drilling Mud and Drill Cuttings Discharge Modeling, Ghana

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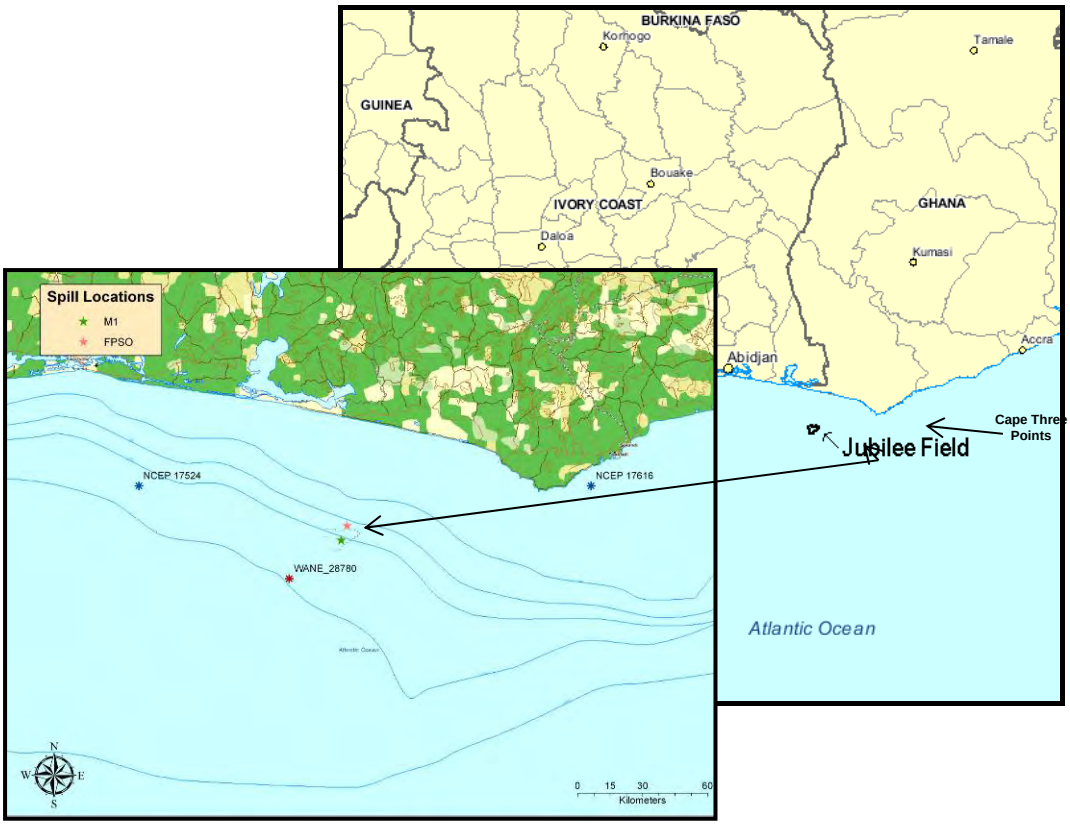

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Executive Summary

ERM contracted with Applied Science Associates, Inc. (ASA) to assess potential marine gasoil and crude oil spills, produced water discharges, and drilling mud (drilling fluid) and cuttings discharges from the Jubilee Field within the Deepwater Tano and West Cape Three Points Blocks off the coast of Ghana.

Wind data based on wind hindcast models were obtained for the Ghana offshore region from NOAA's NCEP atmospheric model reanalysis, and WANE (**W**est **A**frica (Met-Ocean) **N**ormals and **E**xtremes) predicted winds. Both datasets exhibit the same predominant southwestern wind direction, with very little variation over the course of the year. Regional currents were assessed from ADCP (Acoustic Doppler Current Profiler) collected data and WANE predicted currents.

OILMAP's stochastic model was applied to eleven potential surface spill scenarios using WANE winds and currents. Spills were assumed to originate at the FPSO or Well Mahogany 1. For all scenarios the predominant transport of spilled oil is to the east. The footprint for the area of potential impact varies with spill size, with the maximum length of the footprint ranging from 40 km for a marine gasoil spill of 10 Tonnes to more than 600 km for crude oil spills of 1000 Tonnes or more. Spilled oil could reach the Ghana shoreline in a minimum time of 1-1.25 days although the average time to reach shore is 2.5-4.5 days. Roughly 200-300 km of shoreline is at risk for oiling with the larger spill sizes having the potential for more shoreline impact. The shoreline with the highest probability of being oiled is the 100 km west of Cape Three Points. East of Cape Three Points a longer reach of shoreline could potentially be oiled, but the probability of oiling is generally less than 10 percent.

A trajectory/fate simulation was done for the ten spill scenarios with shoreline impacts, using the same simulation start date for each. The simulation start time was selected to encompass a period of winds and currents that resulted in a greater transport of oil to shore than most other time periods. For these scenarios, the results showed that the first oil reached shore 45 hours after the spill began. The extent of shoreline oiling was directly related to the duration of the oil release. An instantaneous or 2-hour duration spill resulted in 10-12 km of shoreline impacted. Longer duration spills contribute to wider spreading of the surface oil due to variations in the wind direction. For the 48-hour release 75 km of shoreline were impacted, for the 168-hour release 125 km were oiled. The mass balance indicated 20-30% of the crude oil and approximately 60% of the marine gasoil evaporated before reaching shore.

Produced water discharges were simulated using ADCP current data as input to ASA's MUDMAP modeling system. Westward and eastward flow conditions were considered for maximum possible (80 MSTB/D), and maximum (18.4 MSTB/D) and average (6 MSTB/D) predicted discharge rates. Based on a continuous surface discharge for 30 days, elevated hydrocarbon concentrations were found to be confined within a fairly short distance of the release location for the maximum and average predicted discharges. The maximum distance from the

discharge point to the 0.005 ppm contour is 2000-2200 m for the maximum possible discharge, 600-700 m for the maximum predicted discharge rate, and 300-400 m for the average predicted discharge rate. The vertical extent of the effluent remains within 5 m of the surface for the predicted discharge rates, and within 7-8 m of the surface for the maximum possible discharge.

The results of the mud/cuttings discharge simulations show that water column concentrations are primarily due to mud solids, while seabed deposition is primarily due to cutting discharges. The majority of deposition occurs close to the discharge site due to the relatively low current velocity at depths greater than 50 m. The maximum horizontal extent of the discharge plume with a concentration greater than 0.5 mg/l is approximately 0.015 km^2 and extends 100-200 m from the well depending on the current direction. The larger size particles of the cutting discharges are deposited in the immediate vicinity of the well site, slightly oriented towards the north and east. The maximum deposition thickness is 73-79 mm within 25 m of the drilling site; the area covered by deposits more than 1 mm thick is approximately 0.053 km^2.

1. Introduction and Scope of Work

ERM contracted with Applied Science Associates, Inc. (ASA) to perform the impact assessment of several operational and potential pollutants from the Jubilee Field in the Deepwater Tano and the West Cape Three Points Blocks off the coast of Ghana.

ASA was requested to undertake the following numerical model simulations:

- Dispersion of potential surface crude and marine gasoil spills from the FPSO and Well Mahogany 1 (M1).
- Dispersion of the produced water from the FPSO
- Dispersion of the drilling discharges from Well M1, in order to estimate the actual seabed deposition of the bulk material and maximum water column concentration.

Several modeling scenarios were defined to represent different wind and current conditions encountered in the study area, as well as to consider different discharge conditions.

Meteorological and oceanographic descriptions of the area of interest were provided by Tullow Ghana Ltd. for use as model input. In addition, ASA performed the following tasks prior to performing the requested simulations:

- A climatologic analysis of the meteorological and oceanographic conditions
- A characterization of the mud and cuttings discharges (volume, size distribution)

The following models were applied:

- ASA's MUDMAP modeling system (Appendix A) to simulate the dispersion of produced water, and mud and drill cuttings discharges, and
- ASA's OILMAP (Appendix B) to simulate potential surface crude and marine gasoil spill from the FPSO and Well M1 locations.

Input data for the models is described in Section 2, including the study location, and the characterization of modeling scenarios. The results of the simulations are described in Sections 3, 4 and 5. Conclusions are in Section 6, and References in Section 7. The appendices include brief descriptions of the models used, and additional details on the oil spill scenarios.

2. Location and Model Setup

2.1. Study Location

The study area is located in the Jubilee Field in the Deep Water Tano and West Cape Three Points Blocks approximately 60 km south of Ghana, West Africa.

This modeling study addresses different operational discharges and potential pollutant spills from Well M1 and FPSO locations, as shown in Figure 1 and Table 1. The well site is located in water approximately 1200 m deep.

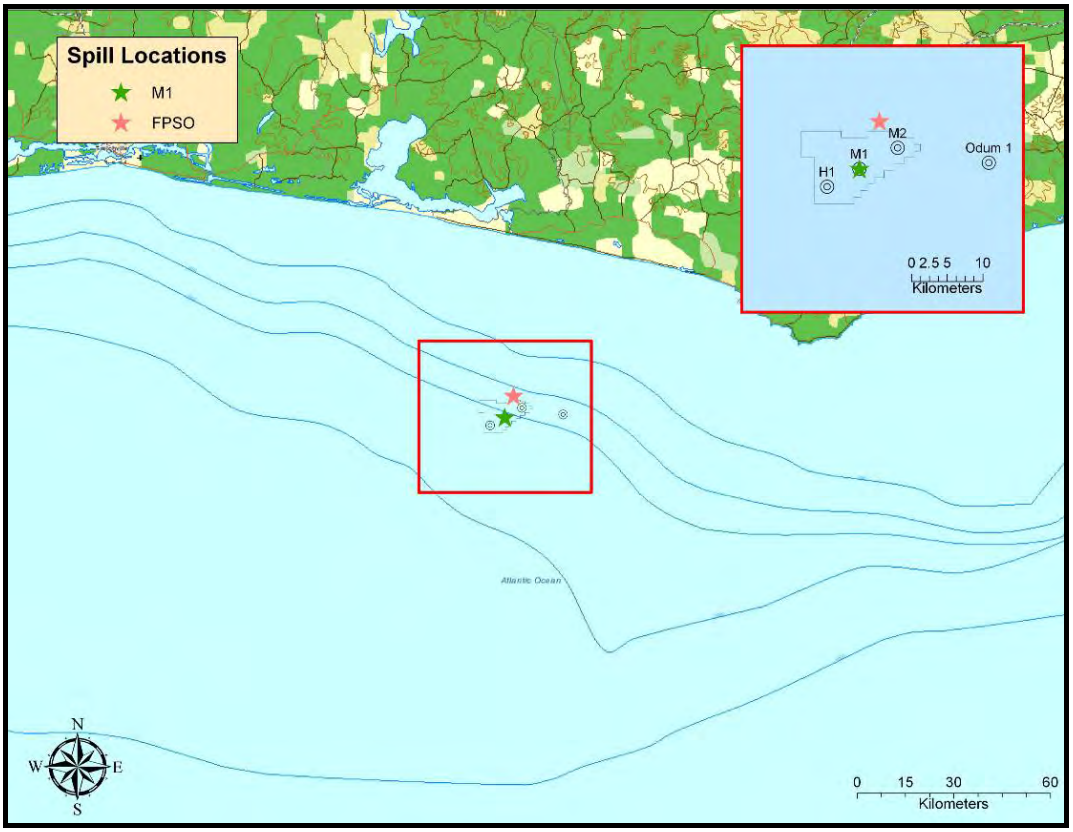


Figure 1. Area of study, showing Well M1, FPSO, bathymetric contours, and local geographic points of reference offshore Ghana.

Table 1. Spill locations

Location	Latitude	Longitude	Datum
FPSO	4.595927º N	2.884601º W	WGS 84
Well M1	4.535758º N	2.909648º W	WGS 84

2.2. General Overview of the Main Dynamics in the Area

Ghana is located within the Inter-tropical Convergence Zone (ITCZ). The ITCZ is a zone of low pressure that migrates from south to north and back again over the course of the year; this shift affects the seasonal patterns. During November-

April the ITCZ is in its southern position when dry winds blow in from the Sahara. During May-October the ITCZ is in its northern position; during this time the year-round southwest trade winds gain a more southeasterly direction due to the Coriolis force.

The wind direction and speed is fairly consistent all year. Winds are primarily from the southwest quadrant with maximum non-squall observed wind speed of 10 m/s. Squall events, caused by thunderstorm cells, generate extreme wind conditions. There are approximately 15-30 events per year. The squall events have a short duration and therefore generate weak currents and low wave heights.

2.3. Wind Data Input

Wind data at a 10 m height were obtained for the Ghana offshore region from NOAA's NCEP atmospheric model reanalysis. Two stations (NCEP point 17524 and NCEP point 17616) are located in the general study area and provide winds for the time period of 1985 to 2009. In addition the WANE (**W**est **A**frica (Met-Ocean) **N**ormals and **E**xtremes) wind file (WANE 28780) was assessed. These three data locations are displayed in Figure 2.

For each data set average monthly wind roses were generated (Figure 3 - Figure 5). All three datasets show the same predominant southwestern wind direction, with average wind speeds of 3.7-4.0 m/s and maximum winds speeds of 8.8-10.8 m/s. There is very little difference in wind speeds and directions over the course of the year. Both data sources (WANE and NCEP) are based on wind hindcast models; such data typically under-represents actual extreme values (i.e., squalls).

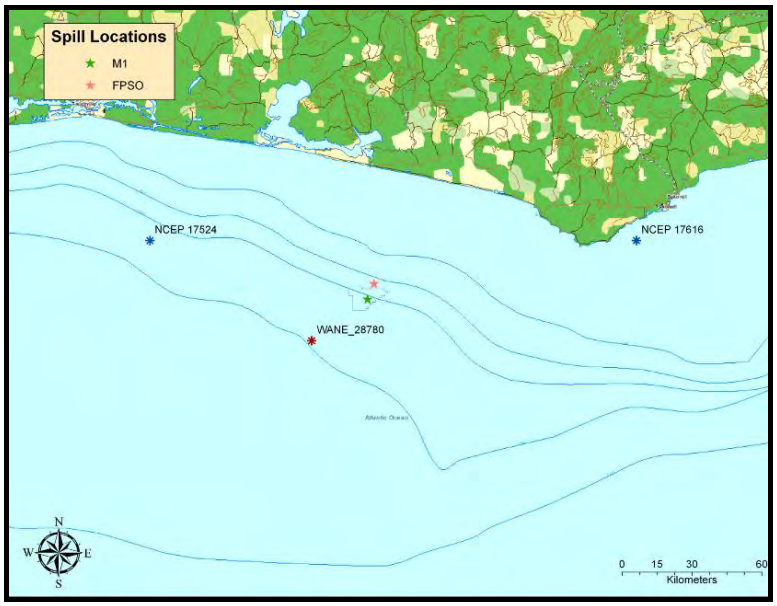


Figure 2. Locations of wind data stations: NCEP 17524, NCEP 17616 and WANE 28780

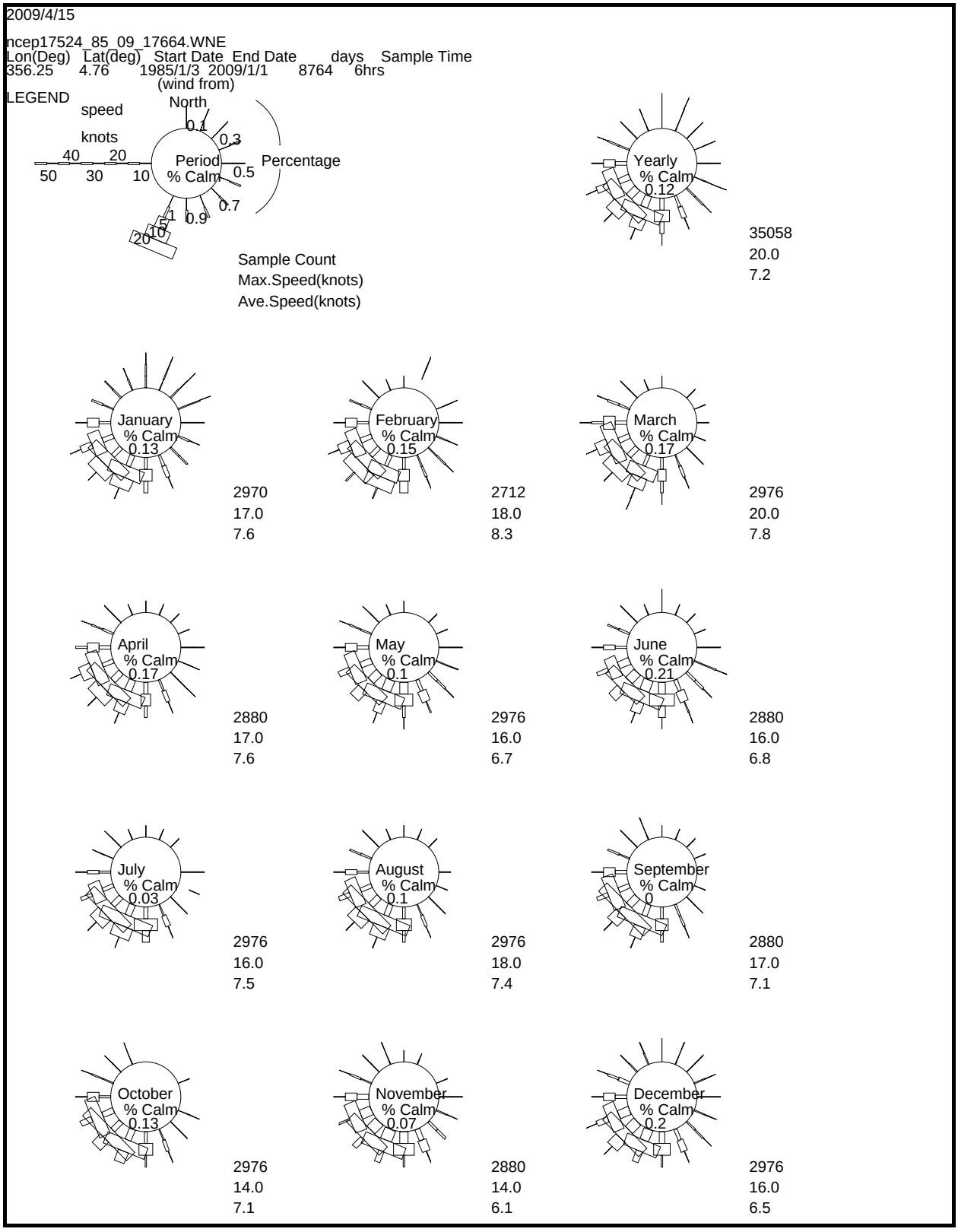


Figure 3. Wind rose of monthly averaged NCEP wind data offshore Ghana, NCEP 17524

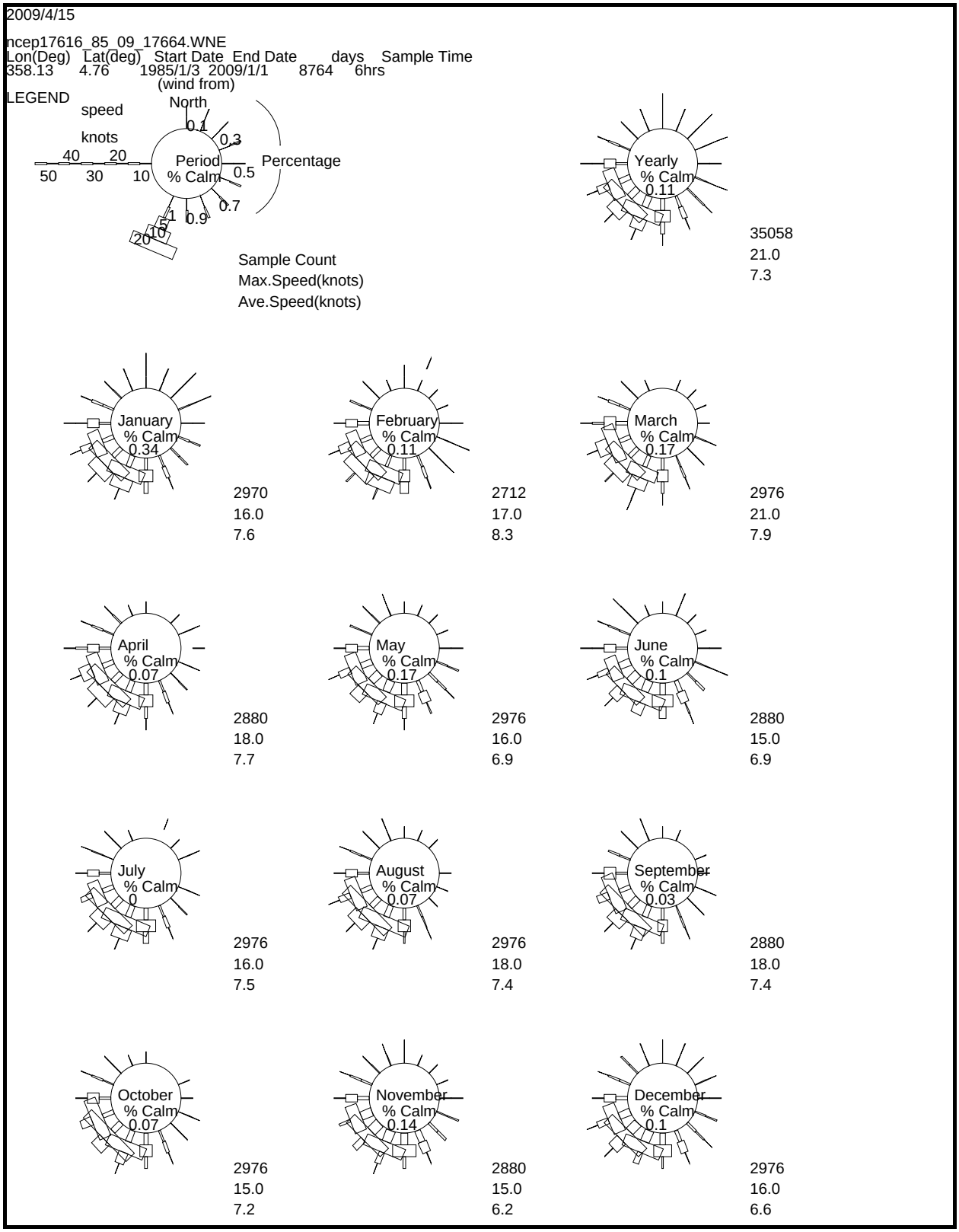


Figure 4. Wind rose of monthly averaged NCEP wind data offshore Ghana, NCEP 17616

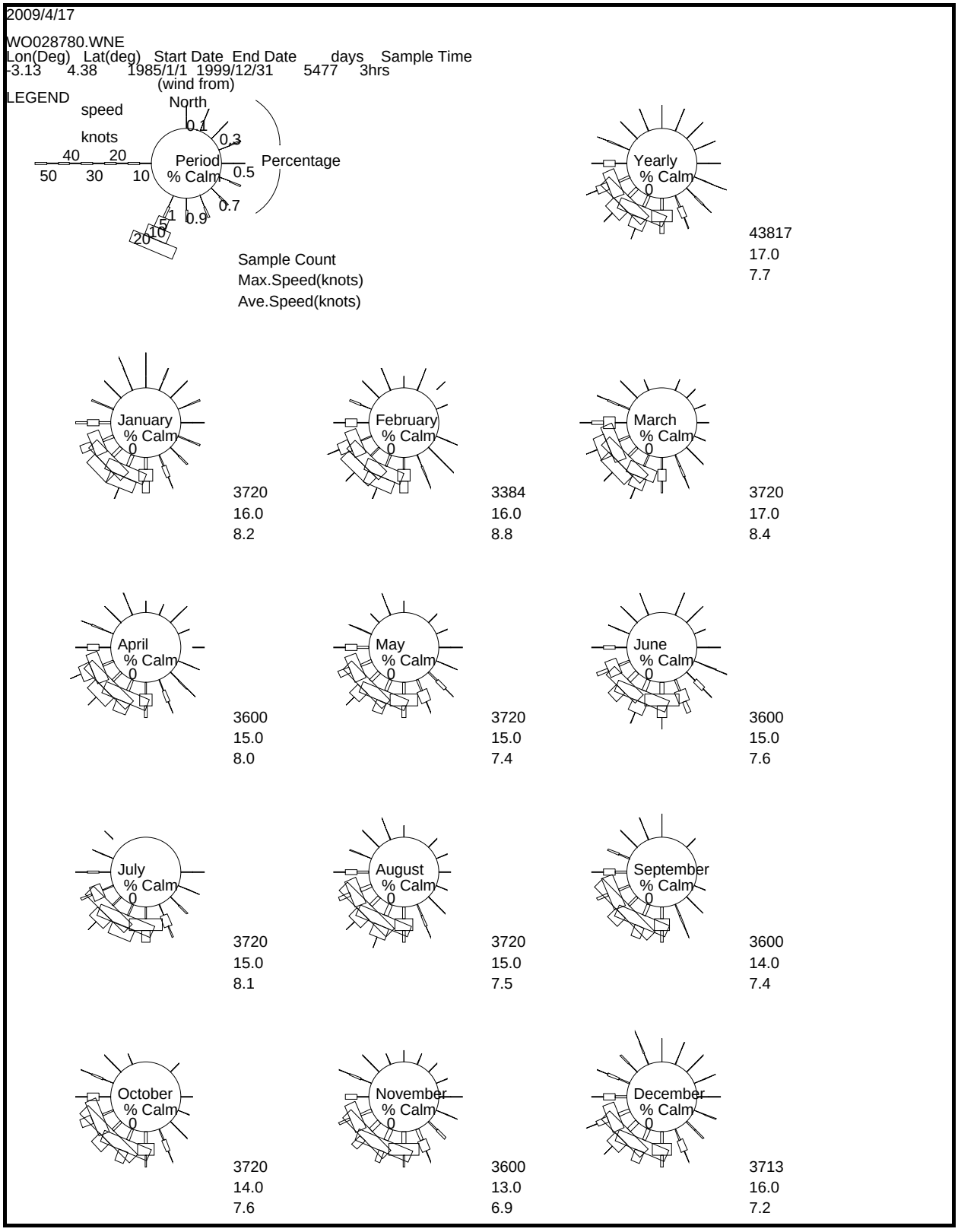


Figure 5. Wind rose of monthly averaged WANE wind data offshore Ghana, WANE 28780

2.4. Current Data Input

Regional currents were assessed from ADCP (Acoustic Doppler Current Profiler) collected data and WANE (**W**est **A**frica (Met-Ocean) **N**ormals and **E**xtremes) predicted currents. Figure 6 shows the location of the current data stations in relation to the Jubilee Field.

ADCP files

Current data was collected at two moorings (M1 and M2, labeled E&H M1 and E&H M2, respectively, in Figure 6). The data files (Evans-Hamilton, Inc., 2008, 2009) are organized in two deployment periods, covering one continuous time span of approximately six months from September 2008 to March 2009. At each mooring, multiple instruments sampled at ~2 m intervals. For use in this study, the data were compiled and sub-sampled at standard NODC depths in the vertical and at hourly time intervals. Figures 7 and 8 present stick vectors representing the currents at standard NODC depths over the deployment period for moorings M1 and M2, respectively.

Observations near the surface are only available for mooring M1. For the first half of the observation period (September – November), surface currents exhibit a strong westward component. Beginning in December the surface currents become generally weaker and have a more eastward orientation. Currents at depths greater than 50 m are weaker than surface currents and do not display any consistent directional trends. The exception to this is the strong NNE-SSW orientation of currents near the bottom, particularly noticeable at mooring M1. These anomalous observations may be related to tidal signals in the deep waters (900, 1000, and 1100 m at M1 and 1200 m at M2).

Based on the directional trends of the surface currents at mooring M1, the ADCP currents are considered to represent periods of eastward or westward flow for the produced water and drill cuttings and mud discharge simulations discussed in Sections 4 and 5, respectively.

WANE product files

Data for three WANE current locations (labeled wc_1114, wc_1148 and wc_1149 in Figure 6) were provided by Tullow Ghana Ltd. Two of the stations are located in waters deeper than the potential well site. The triangle symbols in Figure 6 indicate additional WANE current locations (the original distribution) for which data could potentially be obtained if necessary.

WANE currents cover the period from 1985 to 1999. A representative time series of currents at location wc_1149 is shown in Figure 9. For comparison, Figure 10 displays the ADCP data at the same depths as the WANE data in Figure 9. The two figures cover the same months but in different years since the time periods covered by the two data sets do not overlap. The WANE currents exhibit a strong easterly component near the surface and do not show the westward trend in the surface currents noted in the ADCP data. Similar to the ADCP currents, the WANE currents also show decreasing speed with depth. However, the WANE

data exhibits more coherent/consistent directional patterns at greater depths, reflecting its source as model-generated data.

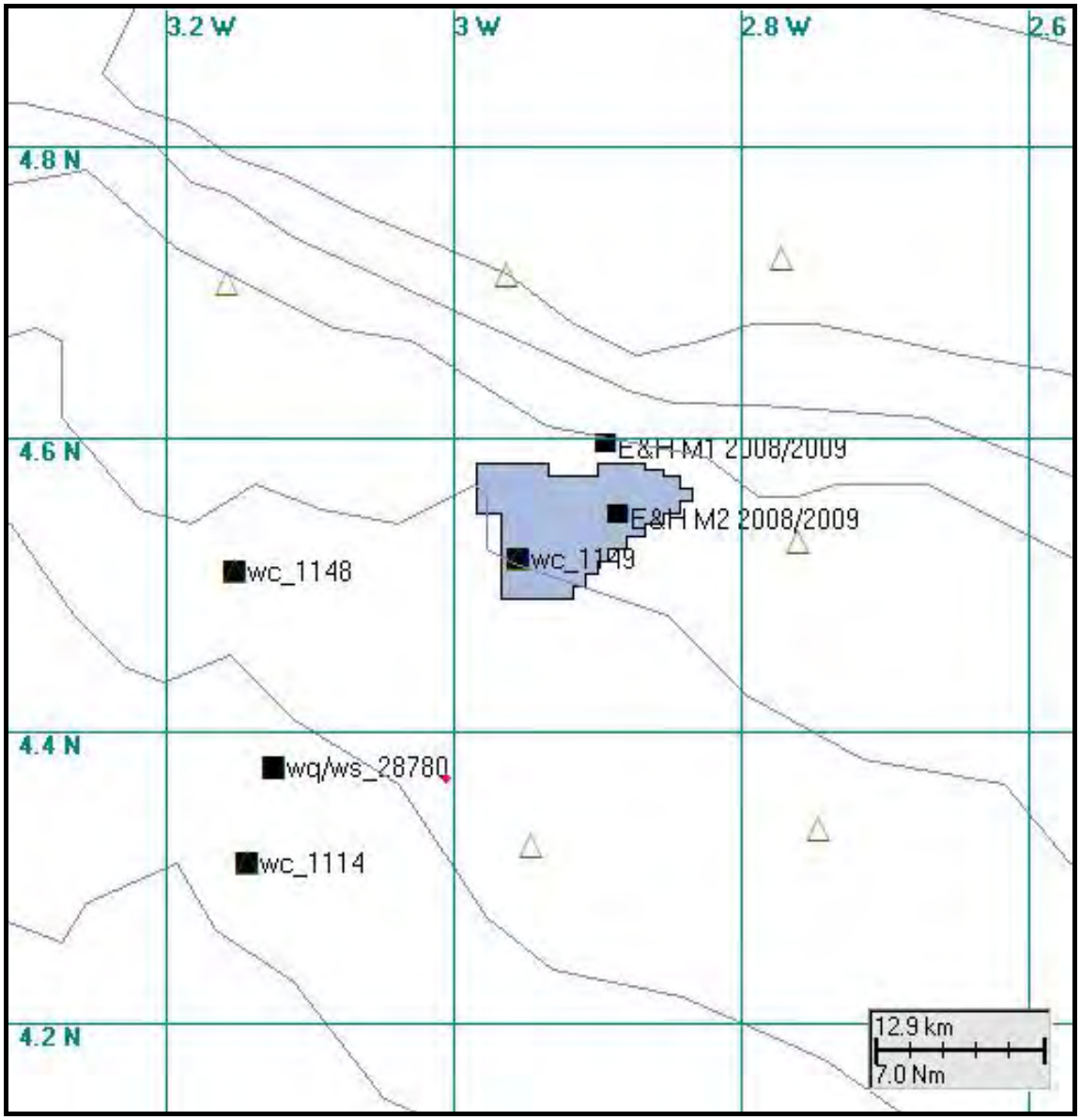


Figure 6. Location of current data

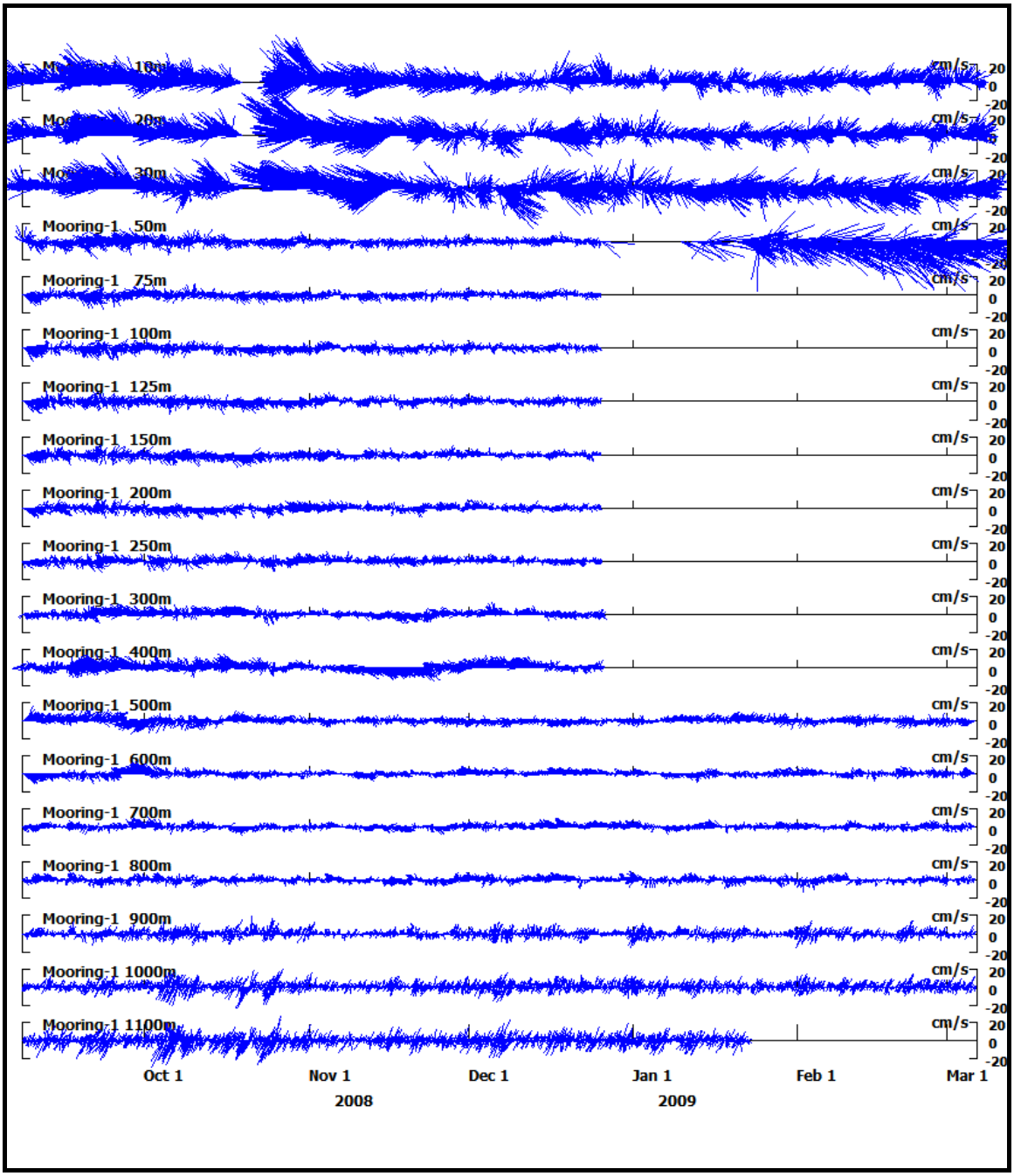


Figure 7. Current vectors at selected depths for Evans-Hamilton ADCP Mooring 1

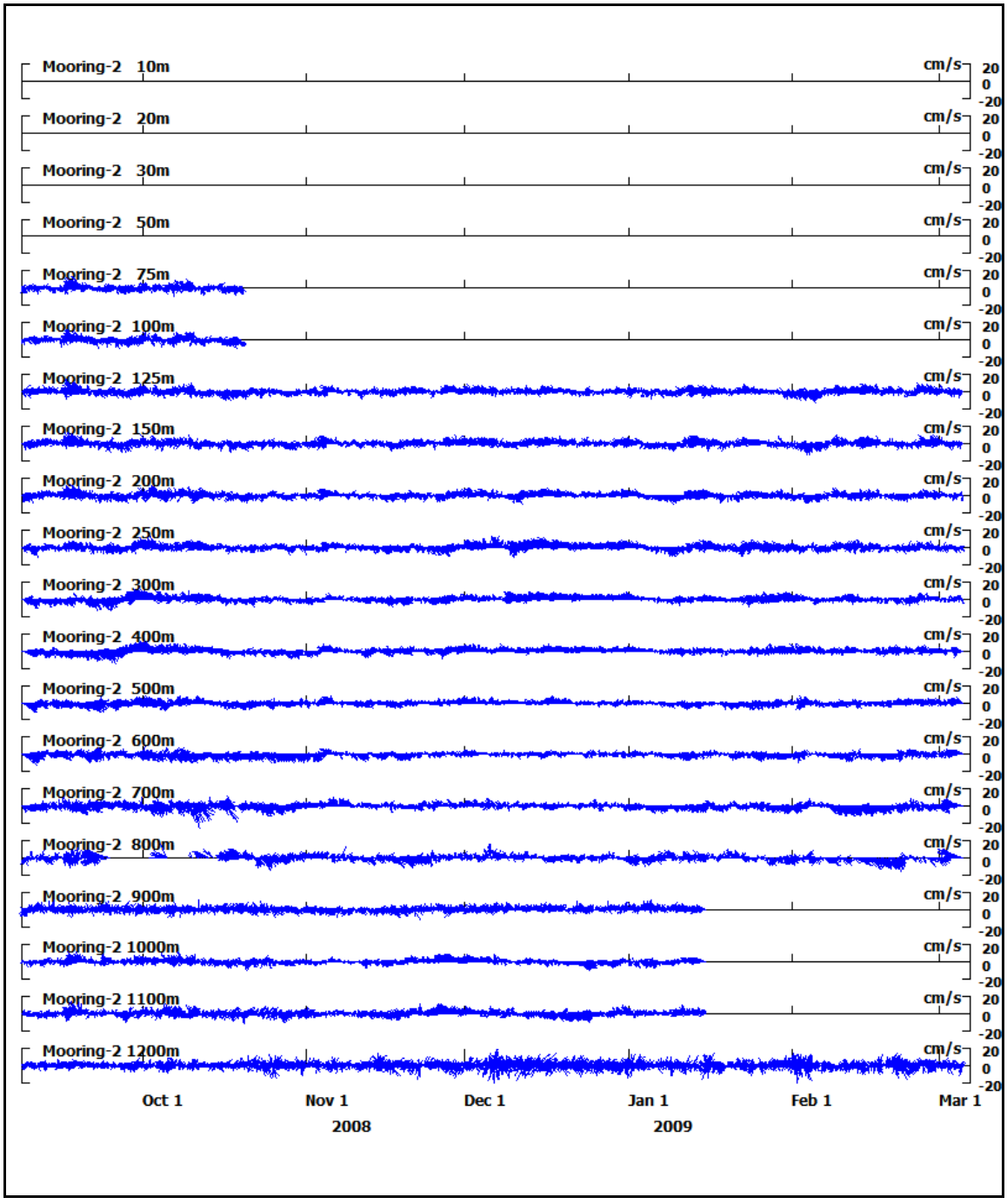


Figure 8. Current vectors at selected depths for Evans-Hamilton ADCP Mooring 2

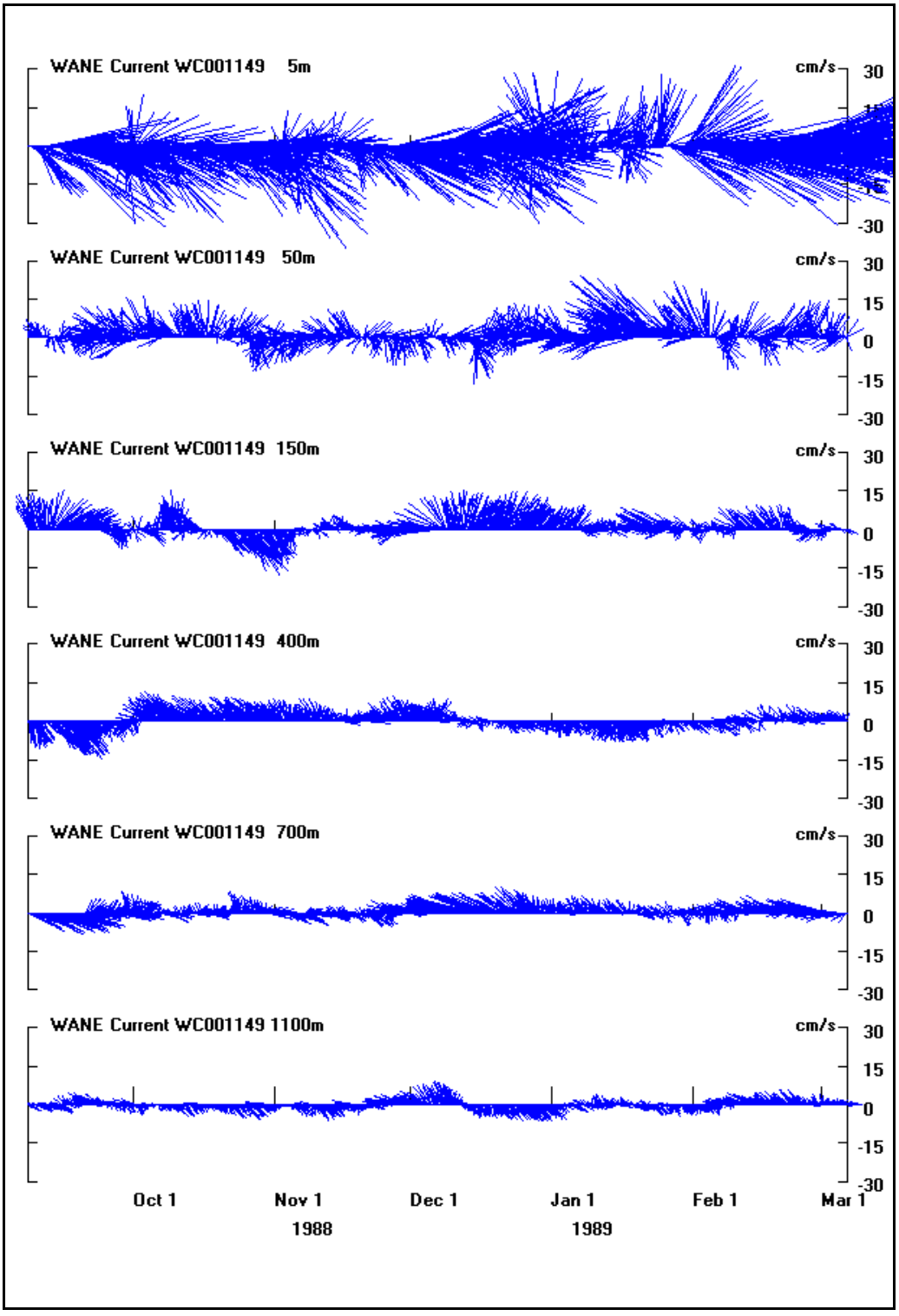


Figure 9. Current vectors at selected depths for WANE data location wc_1149

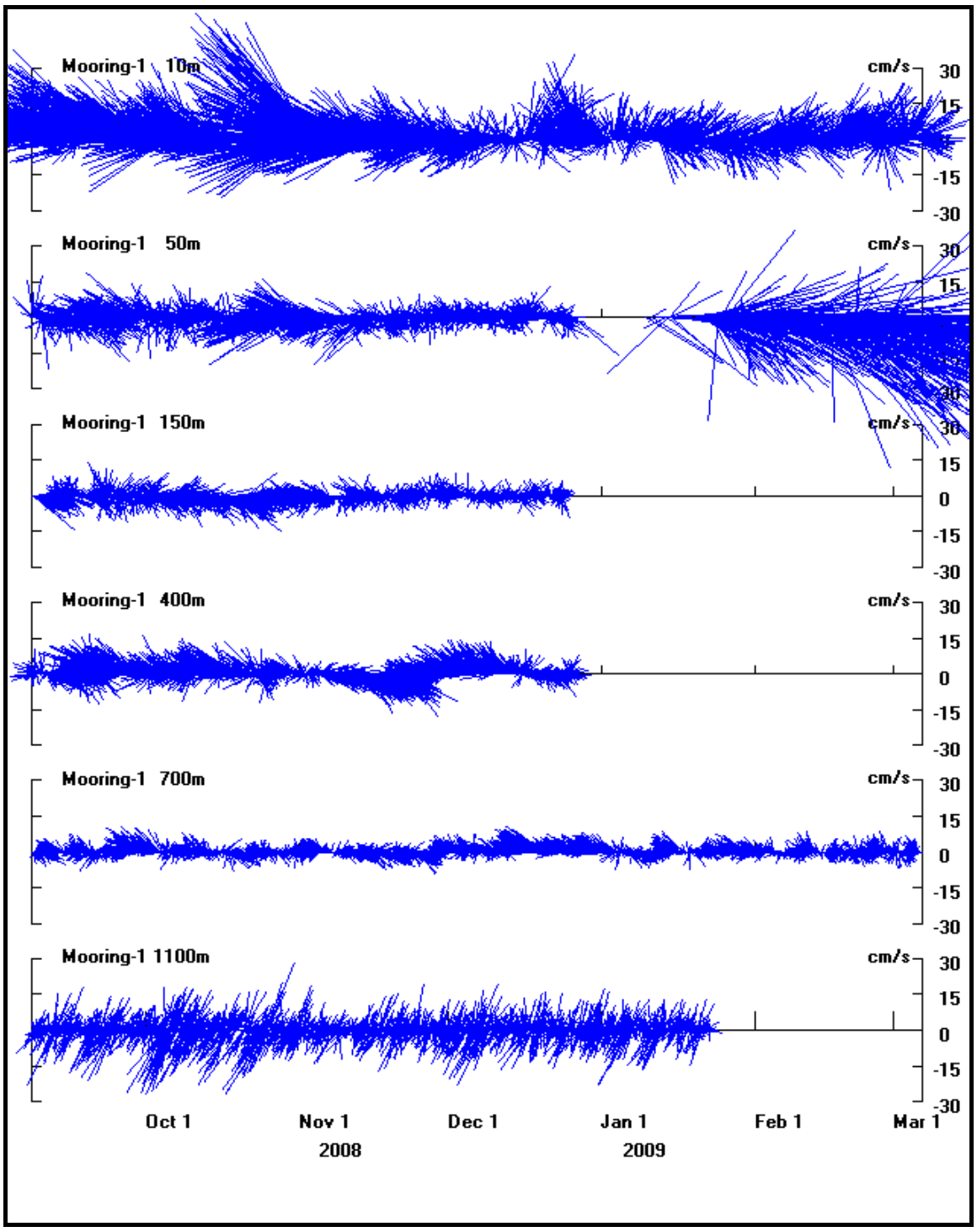


Figure 10. Current vectors for Evans-Hamilton ADCP Mooring 1, at the same water depths as WANE currents in Figure 9.

3. Surface Oil Spill Simulations

3.1. Surface Release Scenarios

Eleven spill scenarios (Table 2) were simulated to represent potential spill consequences. The full list of selected spill scenarios and the representative surface spill modeling scenarios are given in Appendix C. All spill scenarios assumed a surface release and were simulated for 14 days.

Table 2. Surface spill modeling scenarios

Scenario	Location	Oil Type	Release Duration (hours)	Spill Volume (tonnes)
1	Well M1	Crude	Instantaneous	10
2	FPSO	Marine Gasoil	Instantaneous	10
3	Well M1	Crude	Instantaneous	100
3a	FPSO	Crude	Instantaneous	100
4	FPSO	Marine Gasoil	Instantaneous	100
5	Well M1	Crude	48	1000
5a	FPSO	Crude	2	1000
6	Well M1	Crude	48	5000
7	Well M1	Crude	168	20000
8	Well M1	Crude	48	28000
8a	FPSO	Crude	2	28000

3.2. Oil Characterization

The characteristics of the oils used in the simulations are given in Table 3. Evaporation characteristics were assumed based on representative oils with similar density and viscosity.

Table 3. Oil characterization summary

Oil Type	Density @ 15°C (gm/cm^3)	Viscosity @ 25°C (cP)
Marine Gasoil	0.8564	4.8
Crude	0.8783	33

3.3. Stochastic Model Predictions

The OILMAP stochastic model was applied to predict sea surface probabilities of oiling due to potential oil spills during drilling, production and transfer from Jubilee Field Well M1 and FPSO locations. The stochastic simulations provide insight into the probable behavior of potential oil spills under the met-ocean conditions expected to occur in the study area. Two types of statistics are generated: 1) sea surface areas that might be oiled and the associated probability of oiling, and 2) the shortest time required for oil to reach any point in the areas predicted to be

oiled. The stochastic analysis is based on a large number of individual simulations, each with a different start time within the selected season.

OILMAP's stochastic model was applied to the eleven potential surface spill scenarios. WANE winds and currents were used as input to the oil spill simulations due to their long data record. Since wind conditions remain very consistent year-round, only one "season" was considered for selecting the start times of individual simulations. Five hundred simulations were run to generate the stochastic statistics for each scenario.

The following figures (Figure 11-21) depict water surface probabilities of oiling, and travel time contours. The plots define the area in which sea surface oiling may be expected and the probability of oil reaching the area, based on the ensemble of trajectories from the 500 independent simulations run for each scenario. They do not imply that the entire colored surface presented would be covered with oil in the event of a spill. The plots do not provide any information on the quantity of oil in a given area (water surface or shoreline); they only show the probability that some oil reaches the area.

All simulations show the predominant transport of spilled oil is to the east. This transport is due to the influence of consistent winds from the southwest quadrant and the WANE currents with a strong easterly component. The footprint for the area of potential impact varies with spill size, with the maximum length of the footprint ranging from 40 km for a marine gasoil spill of 10 Tonnes to more than 600 km for crude oil spills of 1000 Tonnes or more. Shoreline oiling is possible for all scenarios except the marine gasoil spill of 10 Tonnes.

The simulations show that the minimum time in which spilled oil could reach the Ghana shoreline is 1-1.25 days although the average time to reach shore is 2.5-4.5 days. Roughly 200-300 km of shoreline is at risk for oiling with the larger spill sizes having the potential for more shoreline impact. The shoreline with the highest probability of being oiled is the 100 km west of Cape Three Points. East of Cape Three Points a longer reach of shoreline could potentially be oiled, but the probability of oiling is generally less than 10 percent. The shoreline east of Cape Three Points has the highest probability of oiling due to a 168-hour release of 20,000 Tonnes of crude oil from Well M1. For this scenario some areas have up to a 15 percent probability of being oiled.

Table 4 summarizes the results of the eleven stochastic scenarios in terms of shoreline impacts. The table shows that 45-82 percent of the 500 simulations run for each scenario resulted in oil reaching shore by the end of the simulation. For those simulations with oil reaching shore, the table also indicates the minimum and average time for oil to reach shore, the maximum and average mass of oil that reaches shore, and the length of shoreline that has greater than a 10 percent probability of being oiled.

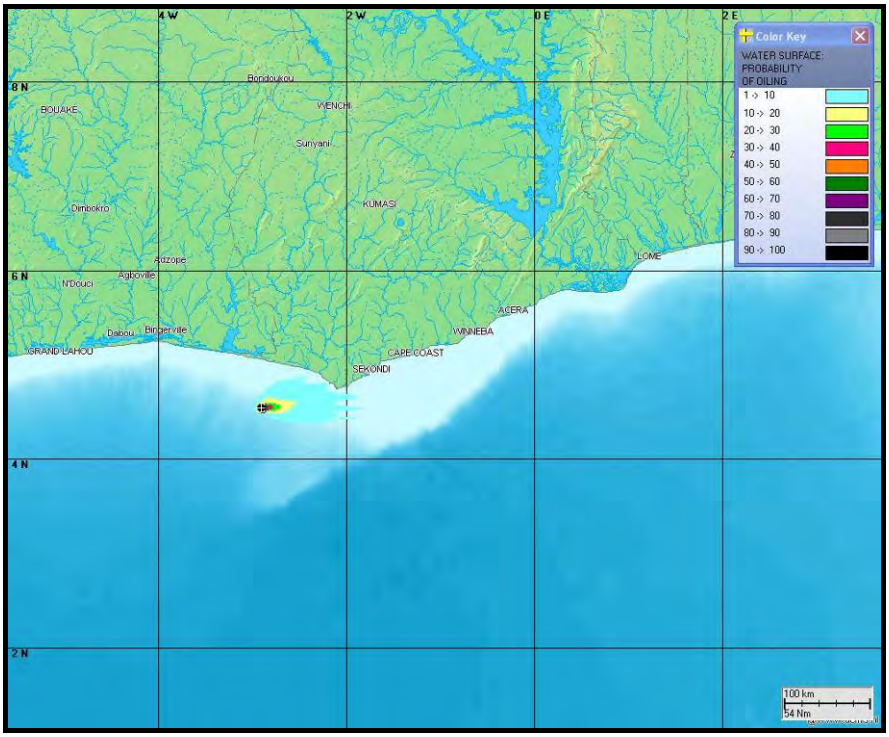
It should be noted that the stochastic simulations use winds and currents generated by model hindcasts. Such data is valuable for providing long time series of environmental conditions and is accurate in a statistical sense. However model-generated data may not replicate the very short-term or anomalous

behavior that is often seen in observations. This is evident in the comparison of WANE (modeled) and ADCP (observed) currents (Section 2.4); the WANE data does not reproduce the westward flowing surface currents measured by the ADCP. By using modeled environmental data, the stochastic model predictions do not reflect anomalous wind or current patterns. Such anomalous conditions represent a very low probability of occurrence and may not be reflected in the oil spill results.

Table 4. Summary of shoreline statistics for stochastic simulations

Scenario	Volume (Tonnes)	Spill Duration	Oil Type	Spill Location	Percent of Simulations Reaching Shore	Minimum Time to Reach Shore (Hours)	Average Time to Reach Shore (Hours)	Maximum Amount of Oil Ashore (Tonnes)	Average Amount of Oil Ashore (Tonnes)	Length of Shoreline with Greater than 10% Probability of Oiling (km)
1	**10**	**Instantaneous**	**Crude**	**Well M1**	45	31	73	7	6	40
2	**10**	**Instantaneous**	**Marine Gasoil**	**FPSO**	NA*	NA	NA	NA	NA	NA
3	**100**	**Instantaneous**	**Crude**	**Well M1**	64	28	96	66	60	60
3a	**100**	**Instantaneous**	**Crude**	**FPSO**	69	24	90	66	60	65
4	**100**	**Instantaneous**	**Marine Gasoil**	**FPSO**	72	25	85	64	58	55
5	**1000**	**48 hours**	**Crude**	**Well M1**	66	31	102	684	559	115
5a	**1000**	**2 hours**	**Crude**	**FPSO**	73	22	84	689	583	70
6	**5000**	**48 hours**	**Crude**	**Well M1**	74	28	97	3,530	2,746	110
7	**20,000**	**168 hours**	**Crude**	**Well M1**	82	29	109	14,817	9,341	170
8	**28,000**	**48 hours**	**Crude**	**Well M1**	72	27	99	21,053	16,372	100
8a	**28,000**	**2 hours**	**Crude**	**FPSO**	70	21	88	21,193	18,849	55

*NA – Not Applicable.



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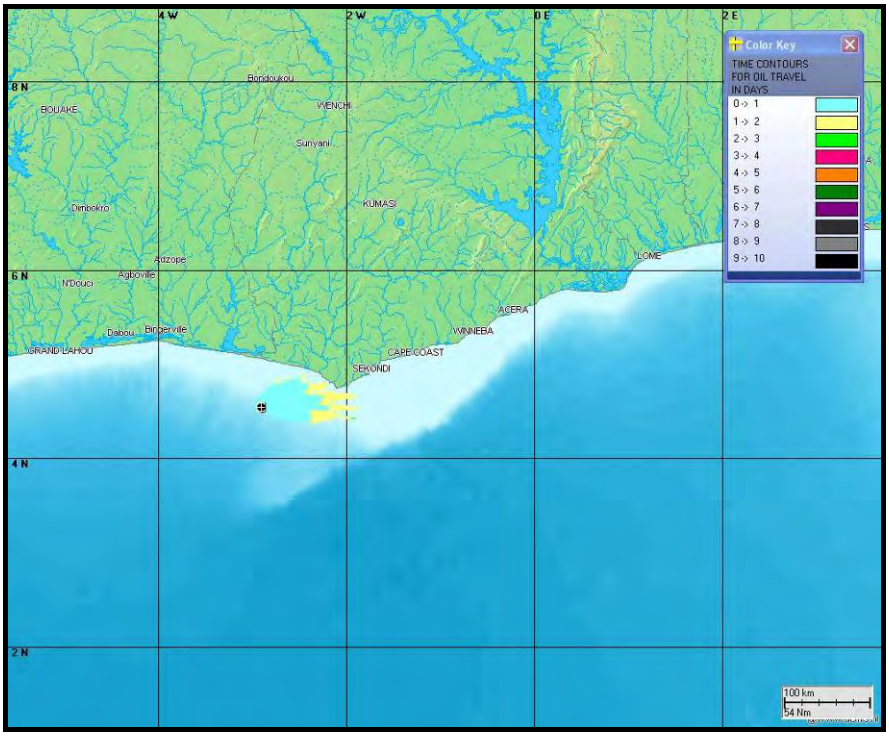

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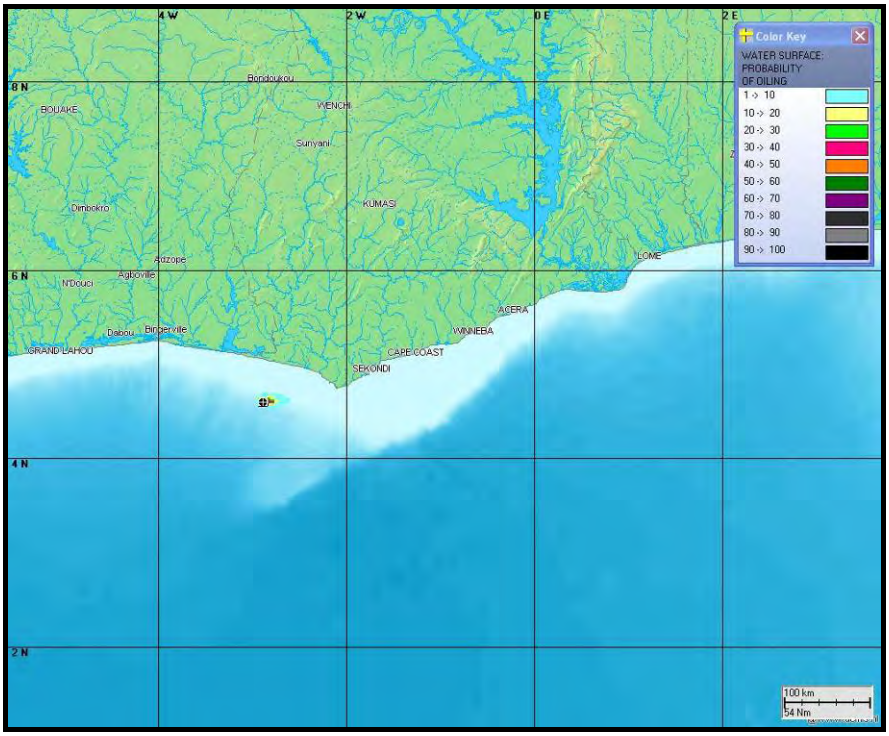
Figure 11. Crude spill of 10 Tonnes at Well M1, a) water surface probabilities of oiling; b) travel time contours.



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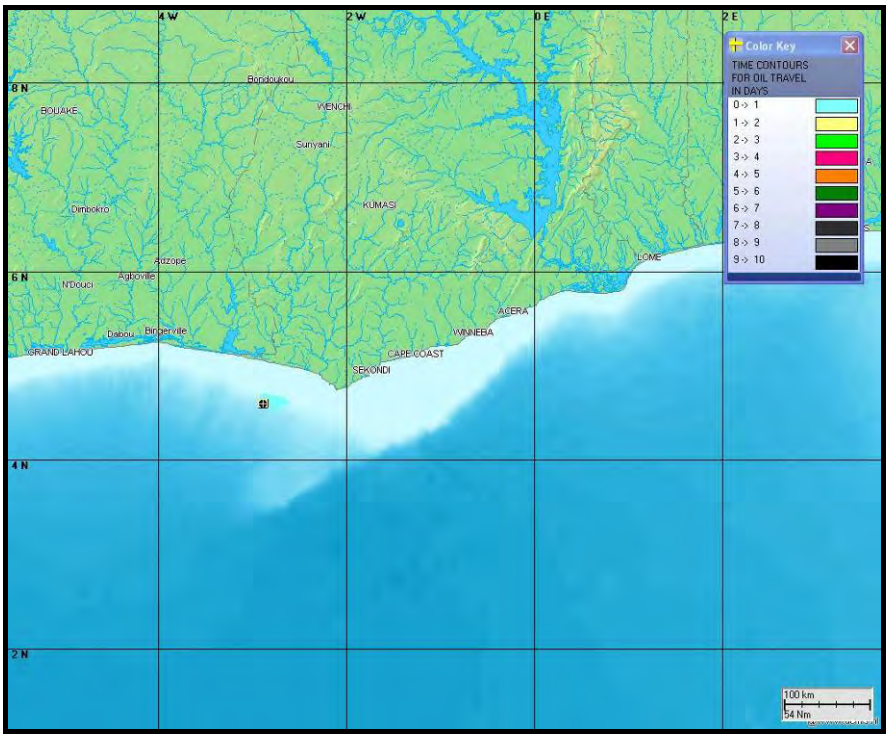

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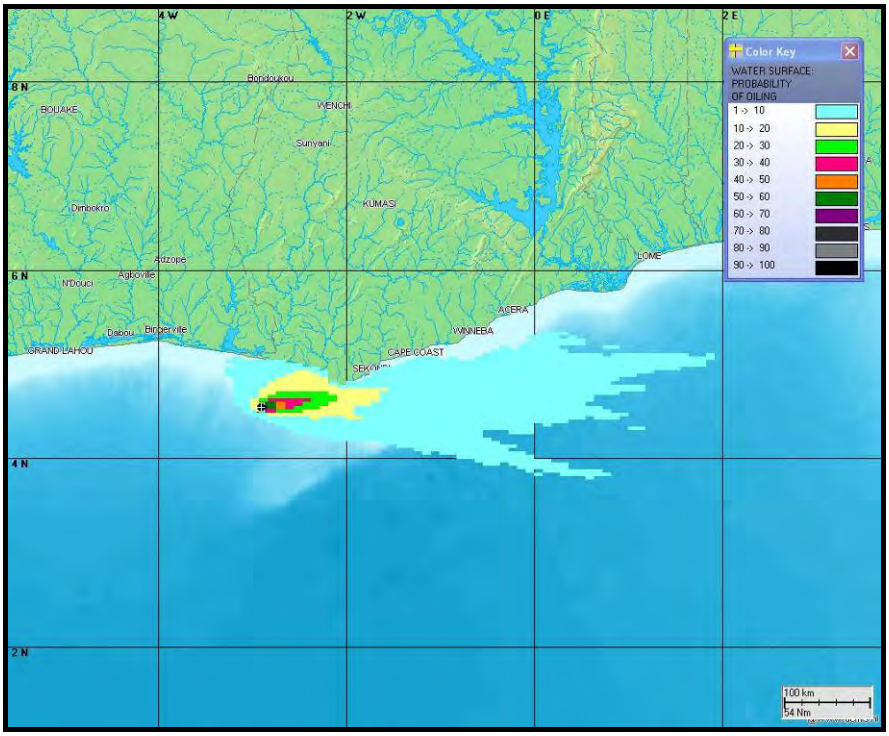
Figure 12. Marine gasoil spill of 10 Tonnes at the FPSO, a) water surface probabilities of oiling; b) travel time contours.



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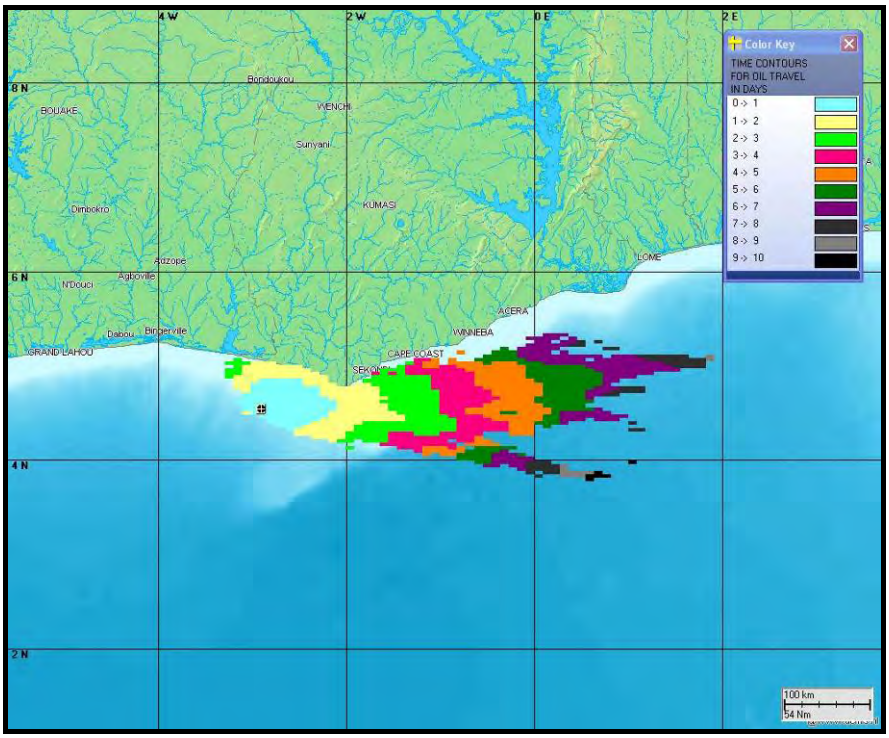
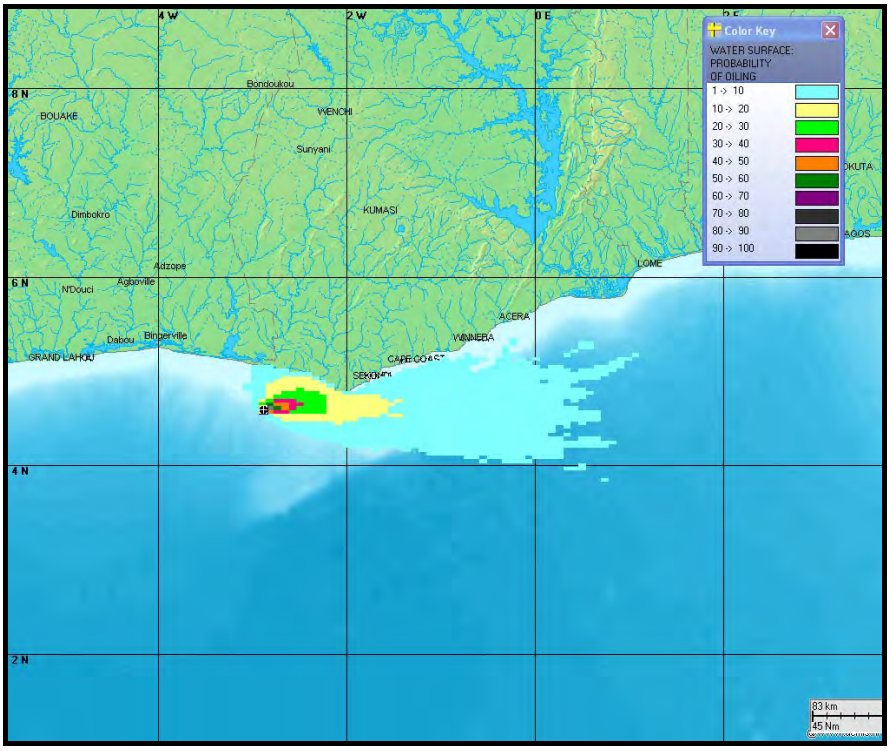


b)

Figure 13. Crude spill of 100 Tonnes at Well M1, a) water surface probabilities of oiling; b) travel time contours.



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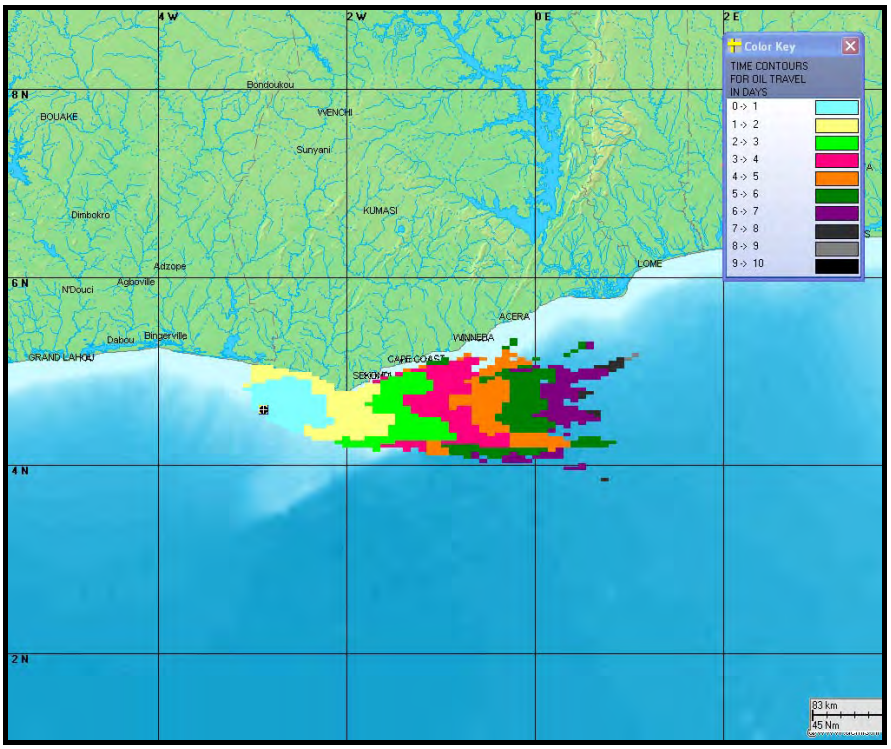
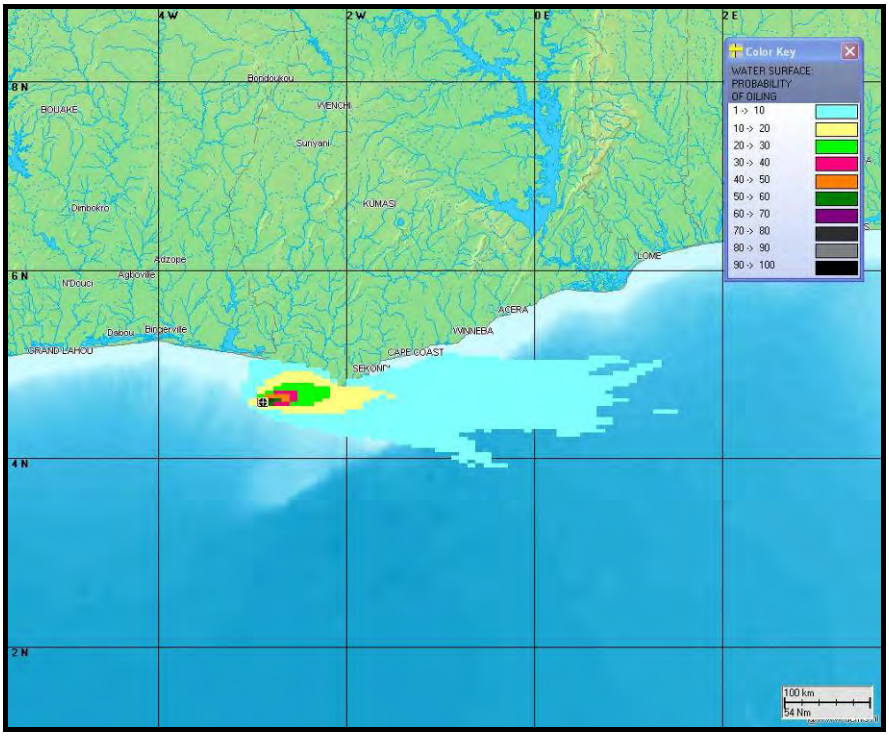


b)

Figure 14. Crude spill of 100 Tonnes at the FPSO, a) water surface probabilities of oiling; b) travel time contours.



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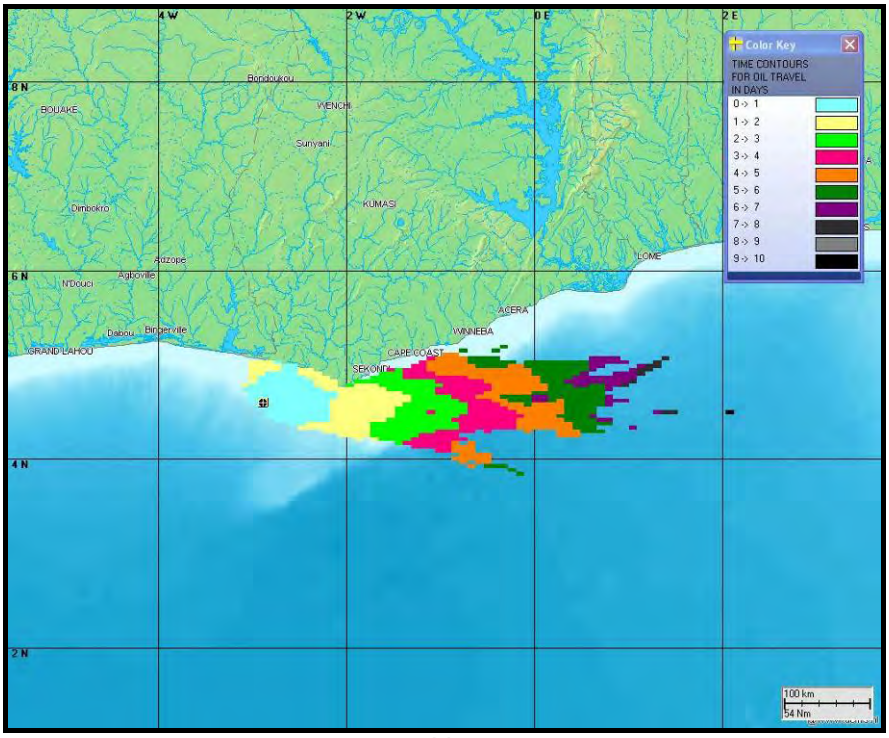
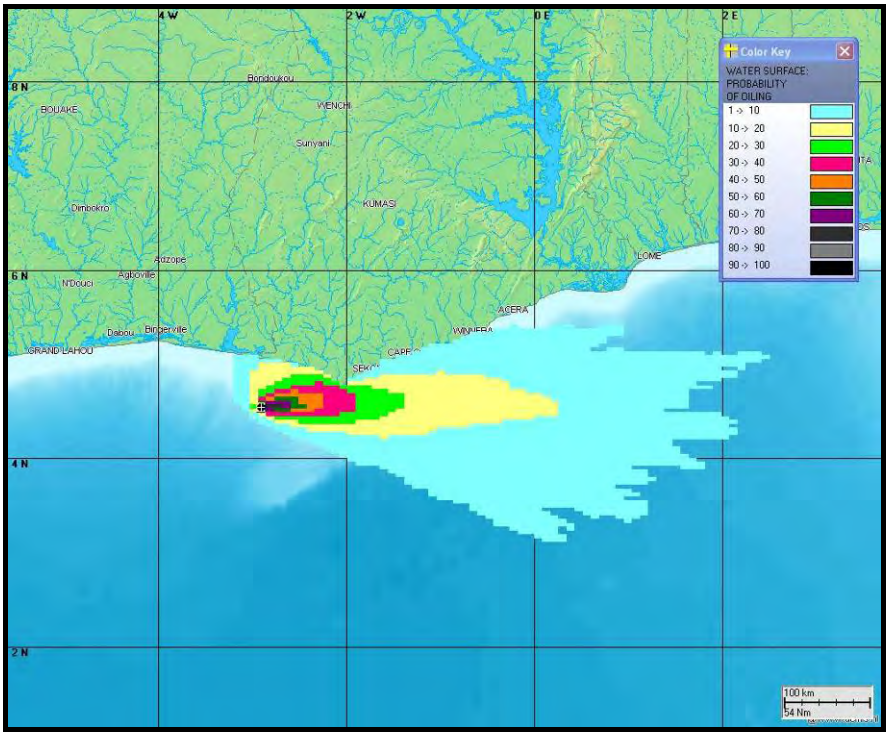


b)

Figure 15. Marine gasoil spill of 100 Tonnes at the FPSO, a) water surface probabilities of oiling; b) travel time contours.



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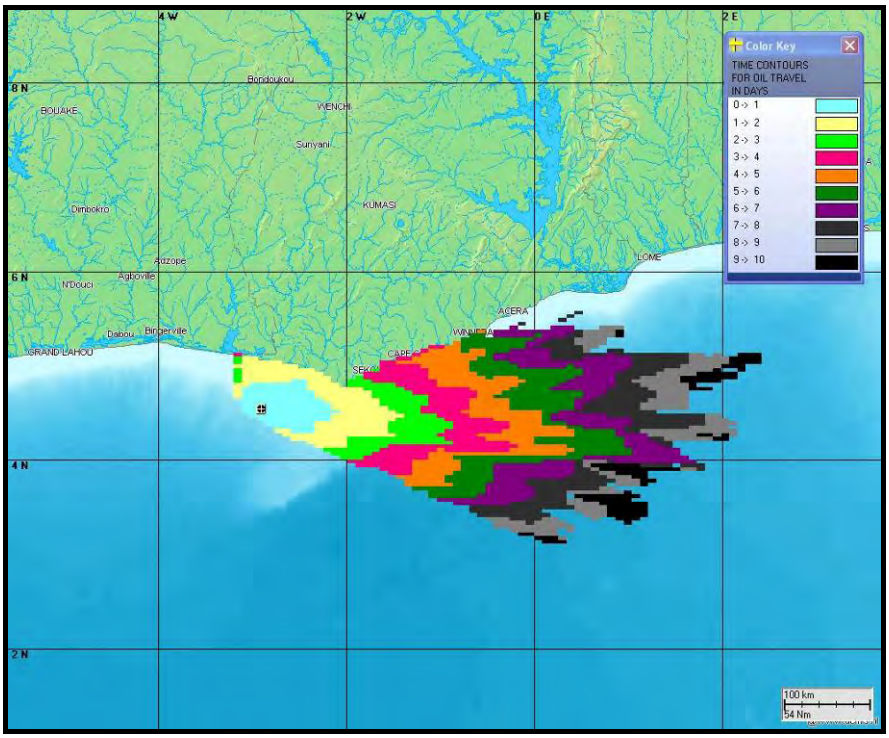
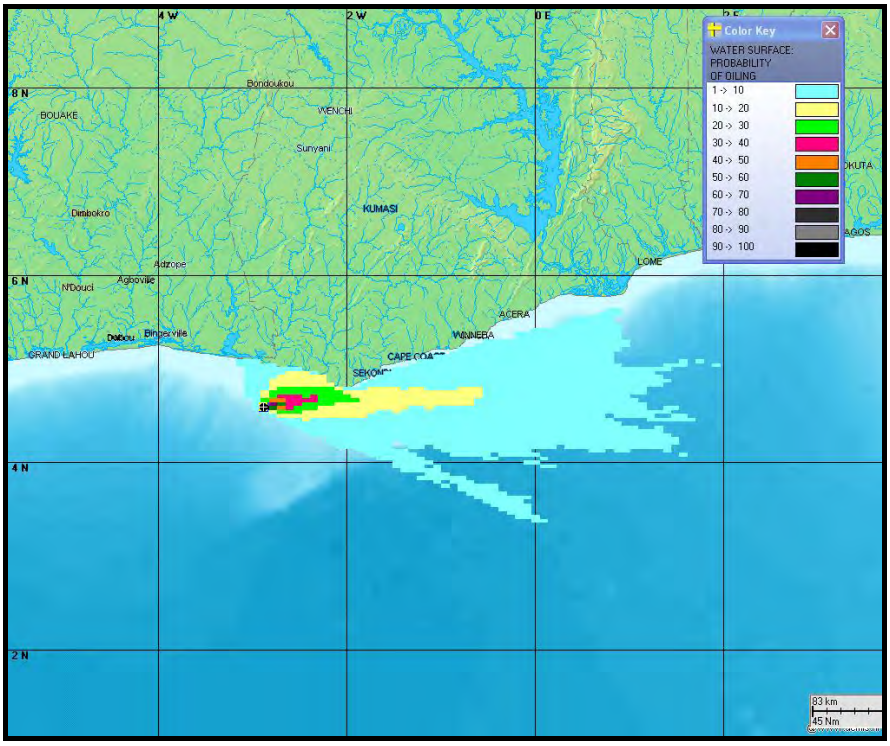
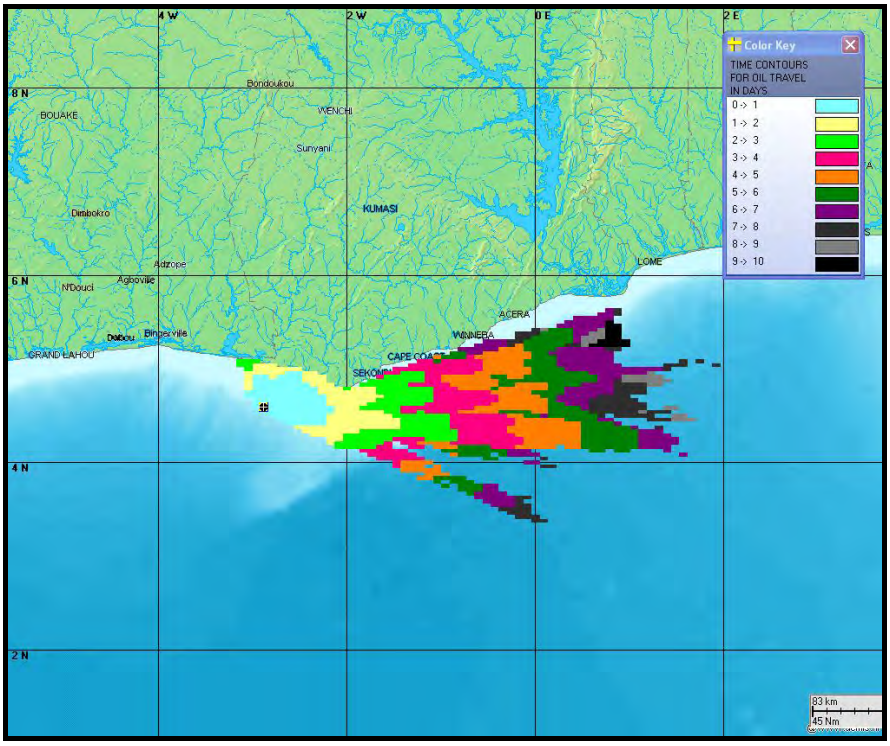


b)

Figure 16. Crude spill of 1000 Tonnes at Well M1, a) water surface probabilities of oiling; b) travel time contours.

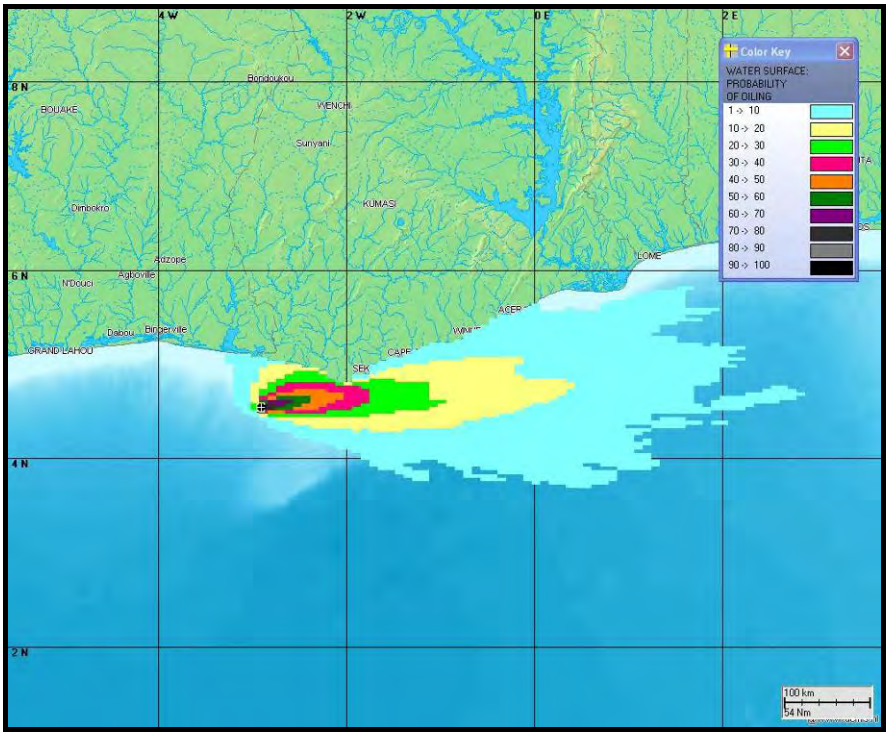


a)

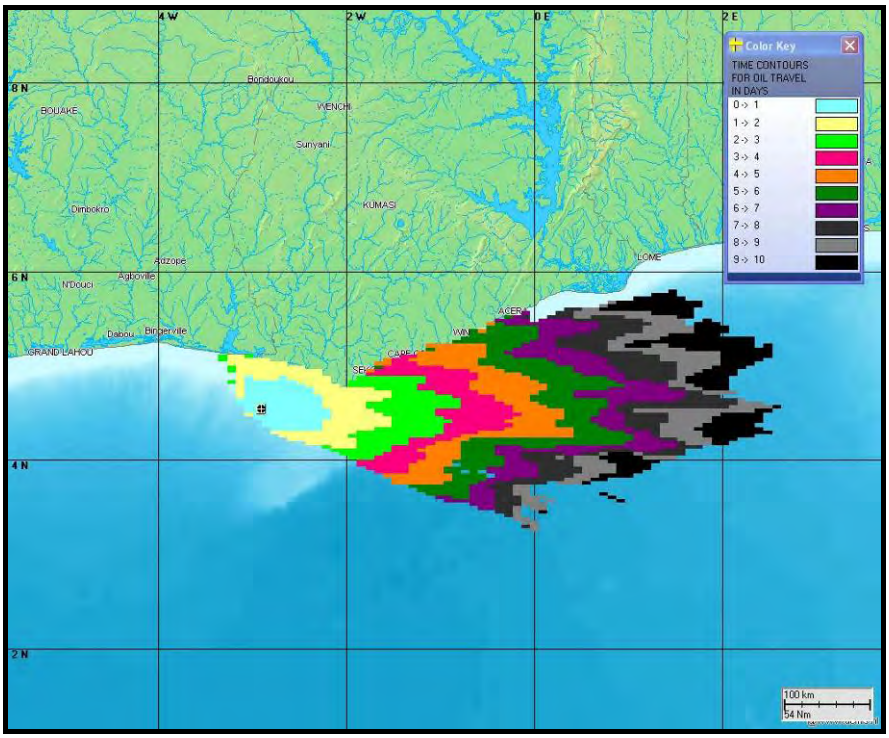


b)

Figure 17. Crude spill of 1000 Tonnes at the FPSO, a) water surface probabilities of oiling; b) travel time contours.

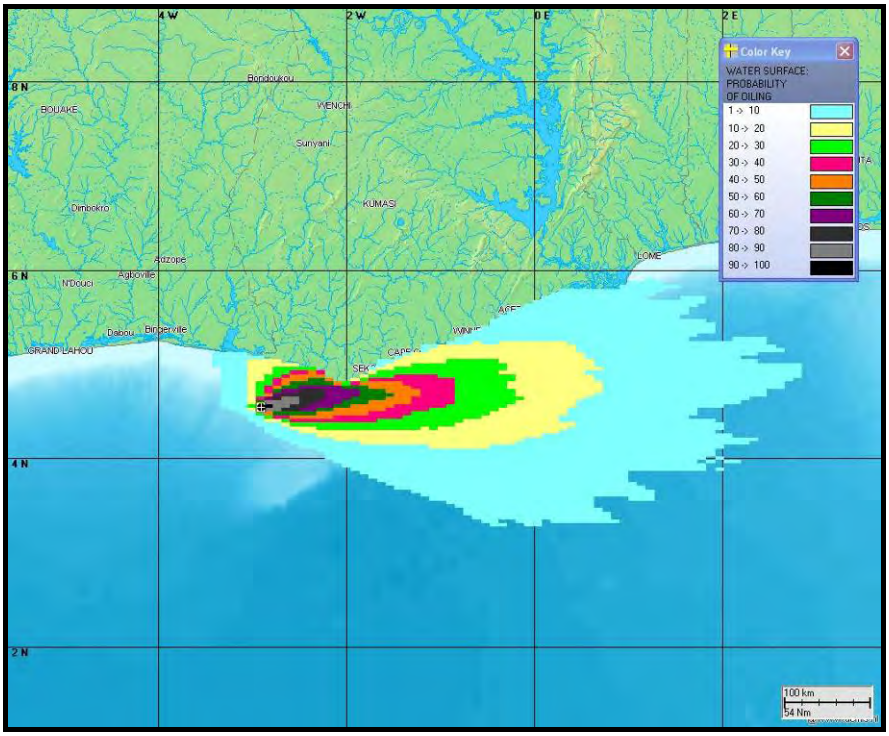


a)

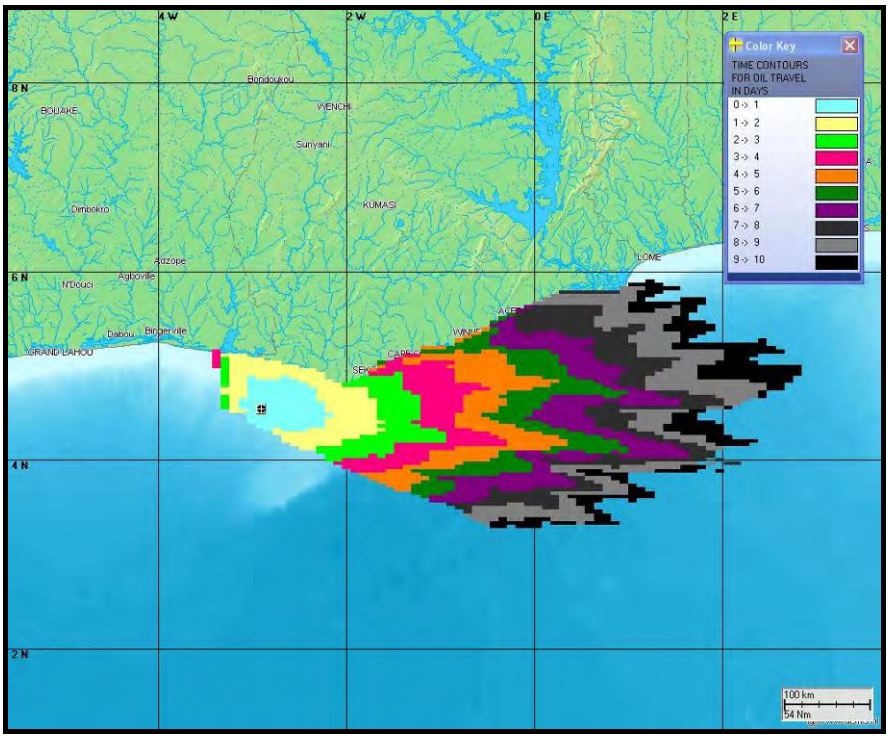


b)

Figure 18. Crude spill of 5000 Tonnes at Well M1, a) water surface probabilities of oiling; b) travel time contours.

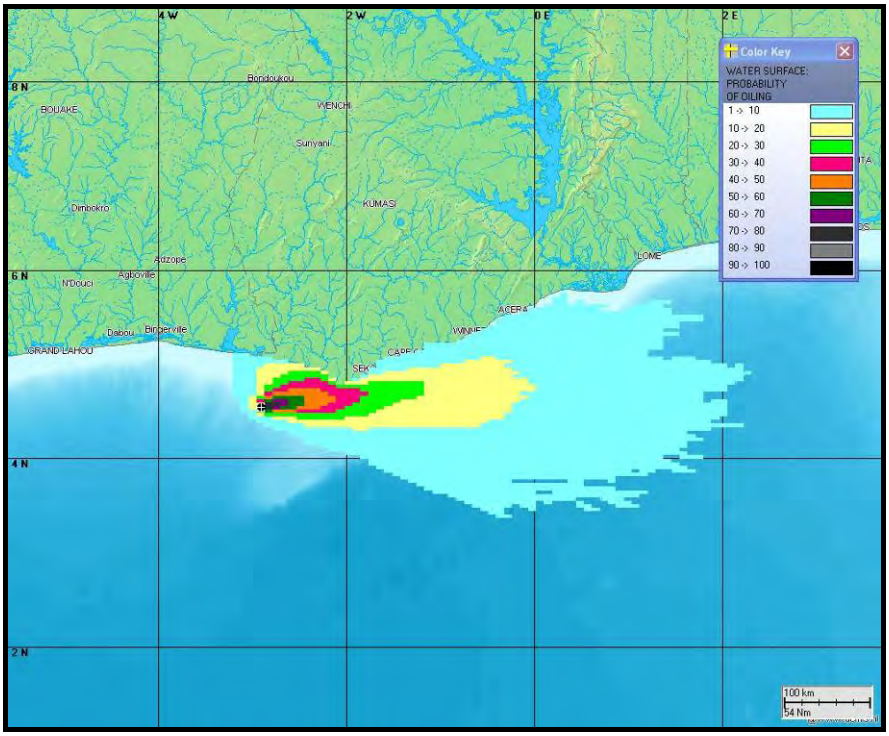


a)

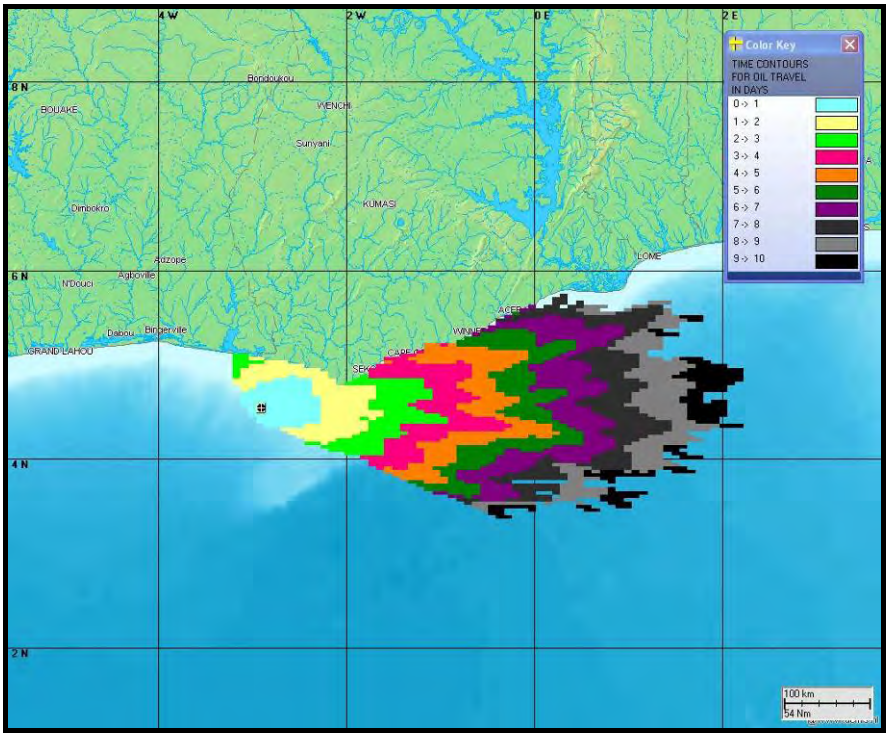


b)

Figure 19. Crude spill of 20,000 Tonnes at Well M1, a) water surface probabilities of oiling; b) travel time contours.

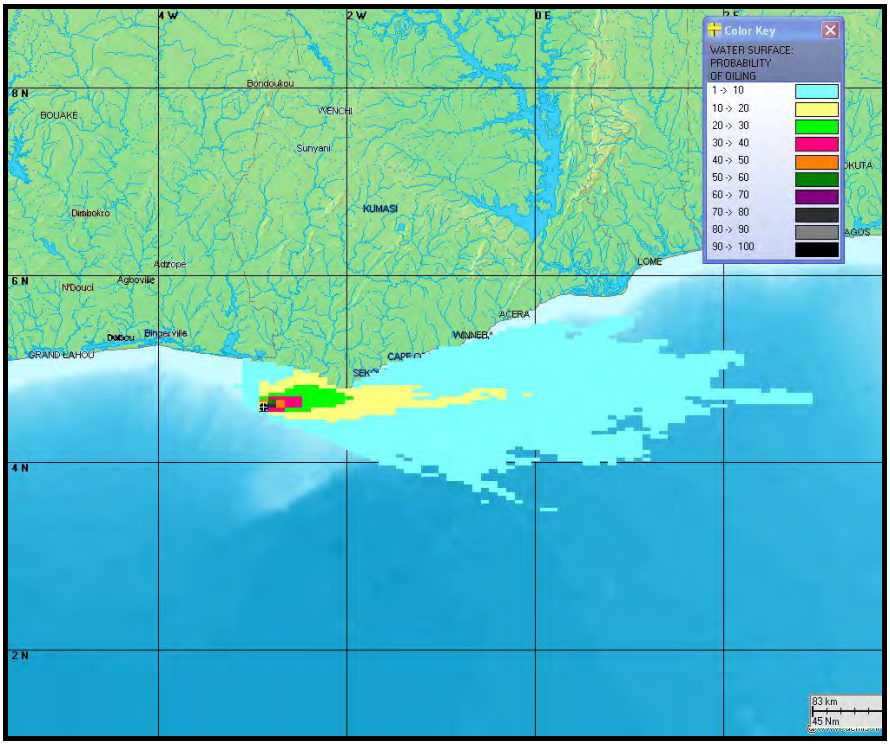


a)

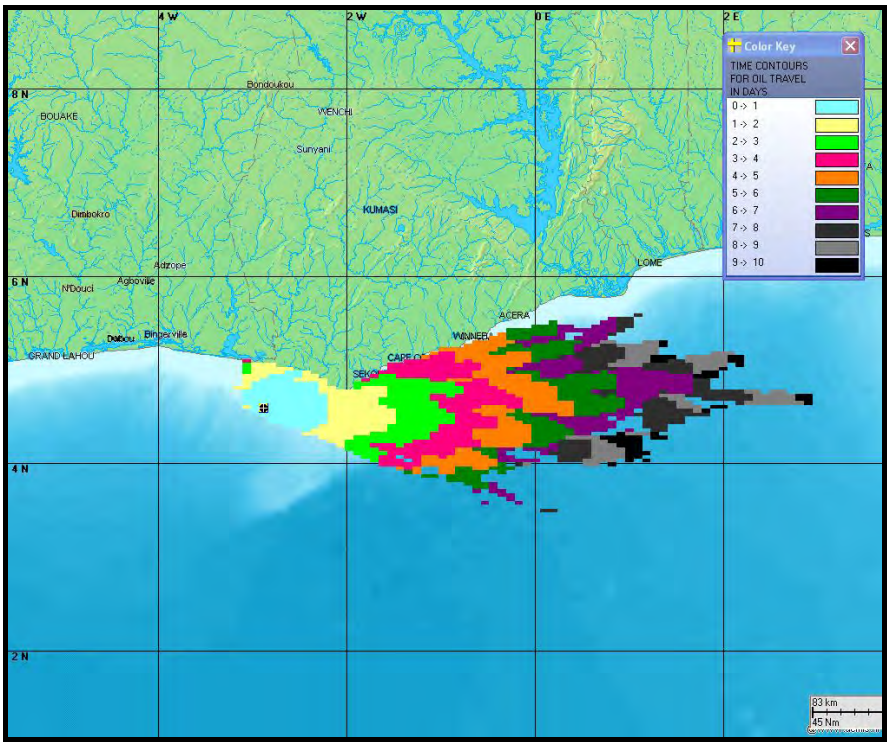


b)

Figure 20. Crude spill of 28,000 Tonnes at Well M1, a) water surface probabilities of oiling; b) travel time contours.



a)



b)

Figure 21. Crude spill of 28000 Tonnes at the FPSO, a) water surface probabilities of oiling; b) travel time contours.

3.4. Deterministic Model Predictions

A deterministic trajectory/fate simulation was performed for a simulation resulting in significant shoreline impacts identified in the stochastic analysis. Deterministic simulations provide a time history of oil weathering over the duration of the simulation, expressed as the percentage of spilled oil on the water surface, on the shore, evaporated, and entrained in the water column.

The simulation with significant impacts can be defined in many ways: as the simulation that predicts the shortest time for oil to reach shore, the simulation with the most oil ashore, the simulation with the greatest length of shoreline oiled, or based on some other criterion. For this study, due to the consistency of the wind record and the similarity of the stochastic predictions for the eleven scenarios considered, a single start time was selected to be used for all trajectory/fate simulations. The simulation time was chosen to encompass a period in which the winds and currents resulted in a greater transport of oil to shore than most other time periods. Winds are primarily from the south, transporting the first oil onshore 45 hours after the spill begins. The time for the first oil to reach shore is approximately half the average time for oil to reach shore determined by the stochastic simulations (see Table 4).

Trajectory/fates simulations were run for all scenarios except the marine gasoil spill of 10 Tonnes at the FPSO. Results are shown in Figures 22-41. Two figures are given for each scenario: the first shows the predicted footprint of the spilled oil (in gray) and the shoreline impacted (in red), the second shows the oil mass balance over time.

The footprint of the instantaneous spills of 10 or 100 Tonnes is almost exactly the same for the crude and marine gasoil spills at Well M1 and the FPSO (Figures 22, 24, 26, and 28) with the same shoreline area being oiled. The mass balance figures show the difference due to the type of oil: due to the lower evaporation rate of the crude, 70-75% of the crude oil is still on the water surface when the spill reaches land (Figures 23, 25 and 27). In contrast, evaporation has removed approximately 60% of the marine gasoil prior to landfall (Figure 29).

Similarly the footprints for the 2-hour duration crude oil spills of 1000 and 28,000 Tonnes (Figures 32 and 40) are nearly identical to those of the instantaneous 100 Tonne spills (Figures 24 and 26) and the trend of the mass balance is also similar (Figures 33 and 41 versus Figures 25 and 27). For the larger spills, there is a slight decrease in the percentage evaporated and correspondingly slight increase in the percentage of oil in the water or on shore throughout the duration of the simulation.

The 48-hour duration spills of 1000, 5000 and 28,000 Tonnes at Well M1 (Figures 30, 34 and 38, respectively) have very similar footprints and extent of shoreline oiling. The effect of a 48-hour spill, compared to an instantaneous spill (Figures 24, 26 and 28), is to spread the oil over a wider area due to the winds shifting while the oil is being released. For these scenarios approximately 75 km of shoreline are oiled. The mass balances (Figures 31, 35, and 39) are also similar

for these scenarios, with approximately 80% of the oil on the water surface when oil first reaches shore and oil going ashore over a period of just over two days.

The 168-hour duration spill (Figure 36) shows the largest oiled footprint of all the scenarios due to winds shifting over the long duration of the release. Approximately 125 km of shoreline are impacted by the spill. Oil reaches shore while oil is being released at the well site; the mass balance (Figure 37) shows that roughly 20% of the released oil has evaporated by the time it first reaches shore.

A few generalizations can be made based on the results of the trajectory/fates simulations. Most obvious is that the length of shoreline impacted depends on the duration of the spill release. As oil is released over a longer period, variations in winds and currents carry the spilled oil in different directions so that when it finally reaches shore, it is spread over a wider area. For the short duration spills (instantaneous to 2 hours) 10-12 km of shoreline are impacted. A spill duration of 48 hours results in 75 km of shoreline oiled, while a 168-hour release impacts more than 125 km of shoreline. Note that all these simulations are run under the same environmental conditions.

Also evident from the oil mass balance results is that the amount of oil that strands onshore is reduced by the extent of evaporation that occurs before the oil reaches shore. The longer it takes for oil to reach shore, the more time is available for evaporation to reduce the surface water mass. Evaporation is also affected by oil type, water temperature and wind speed. The typically high water temperatures in the study area increase the rate and amount of evaporation over what would occur in temperate regions.

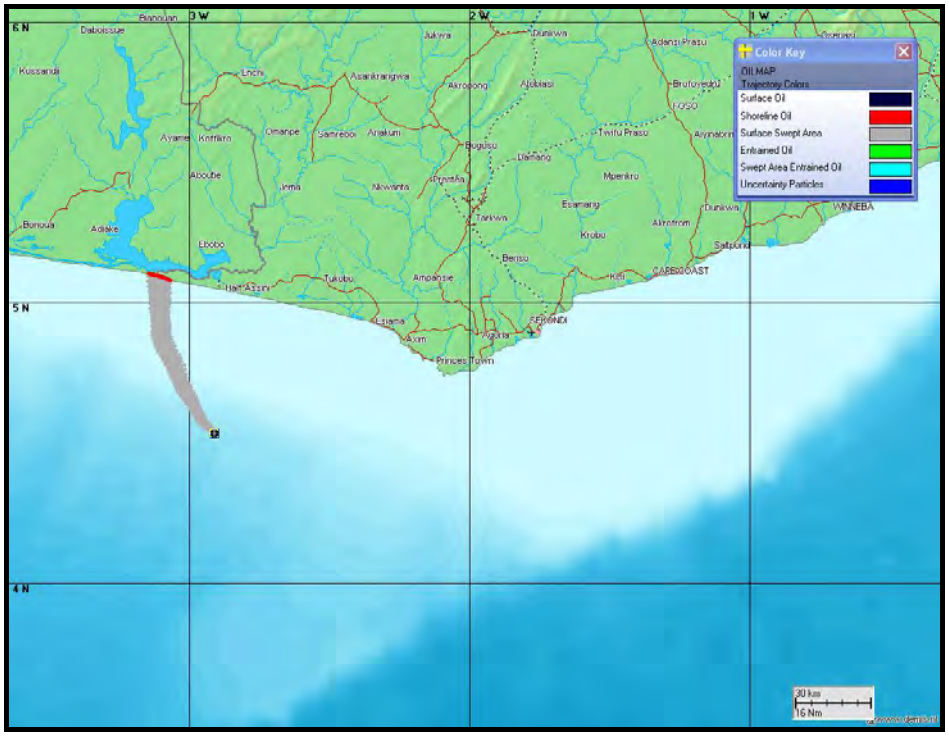


Figure 22. Instantaneous spill of 10 Tonnes crude at Well M1: model predicted water surface signature of the significant impacts spill.

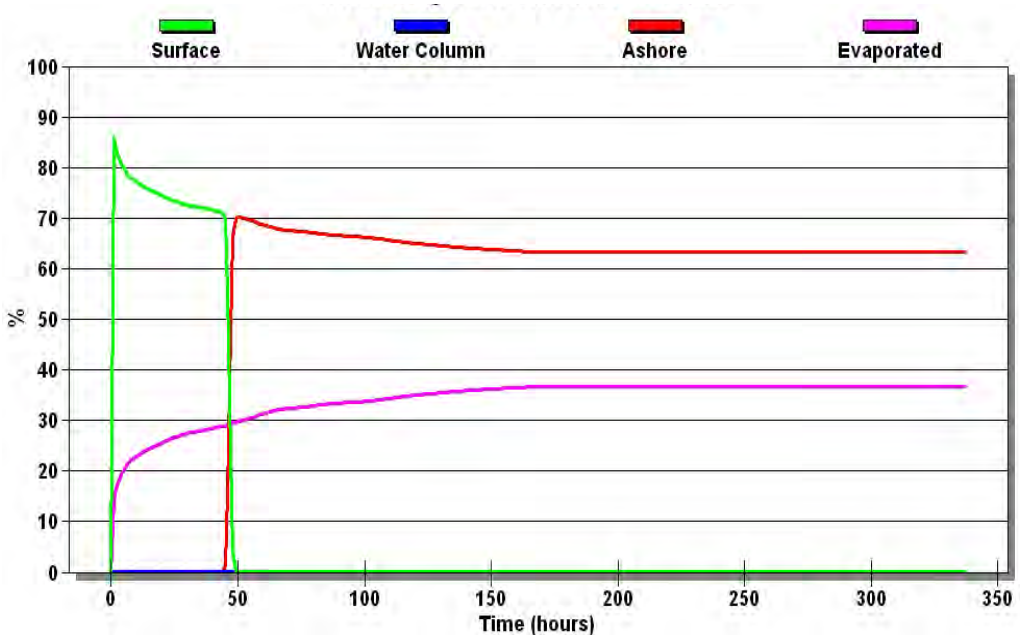


Figure 23. Instantaneous spill of 10 Tonnes crude at Well M1: model predicted mass balance of the significant impacts spill.

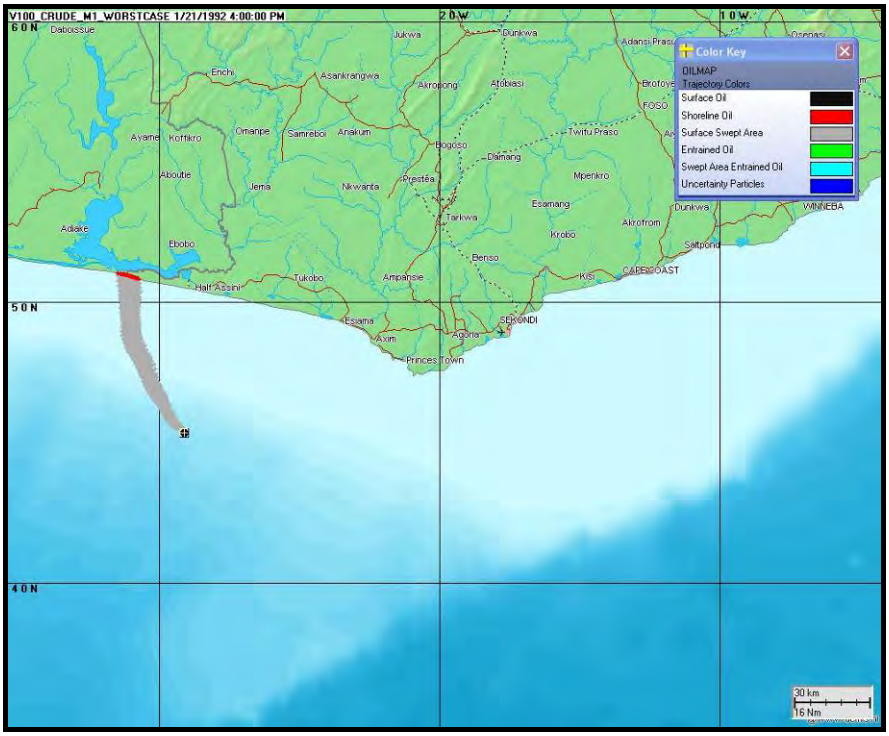


Figure 24. Instantaneous spill of 100 Tonnes crude at Well M1: model predicted water surface signature of the significant impacts spill.

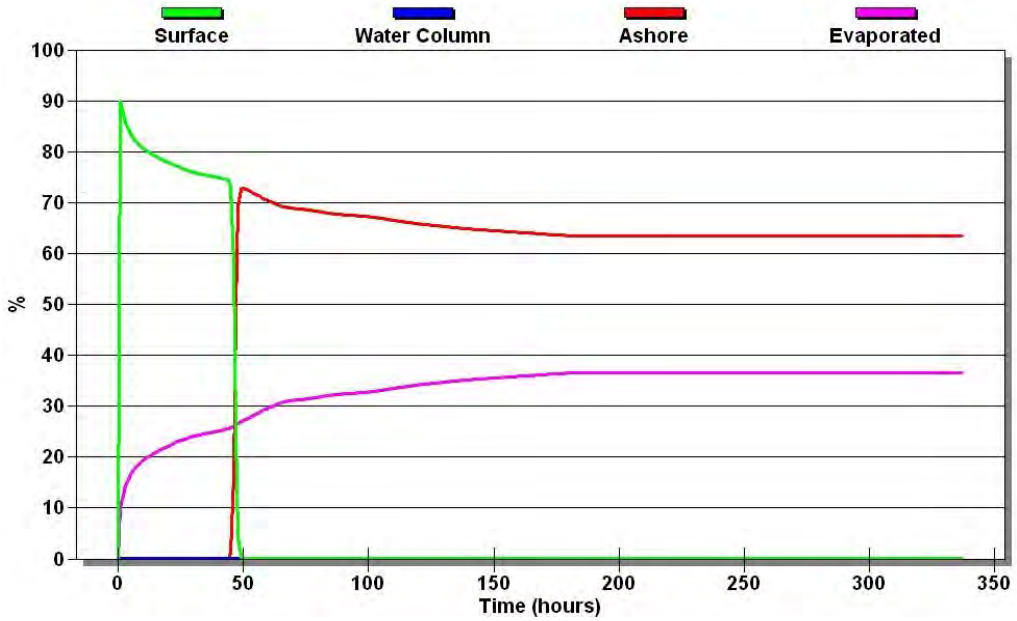


Figure 25. Instantaneous spill of 100 Tonnes crude at Well M1: model predicted mass balance of the significant impacts spill.

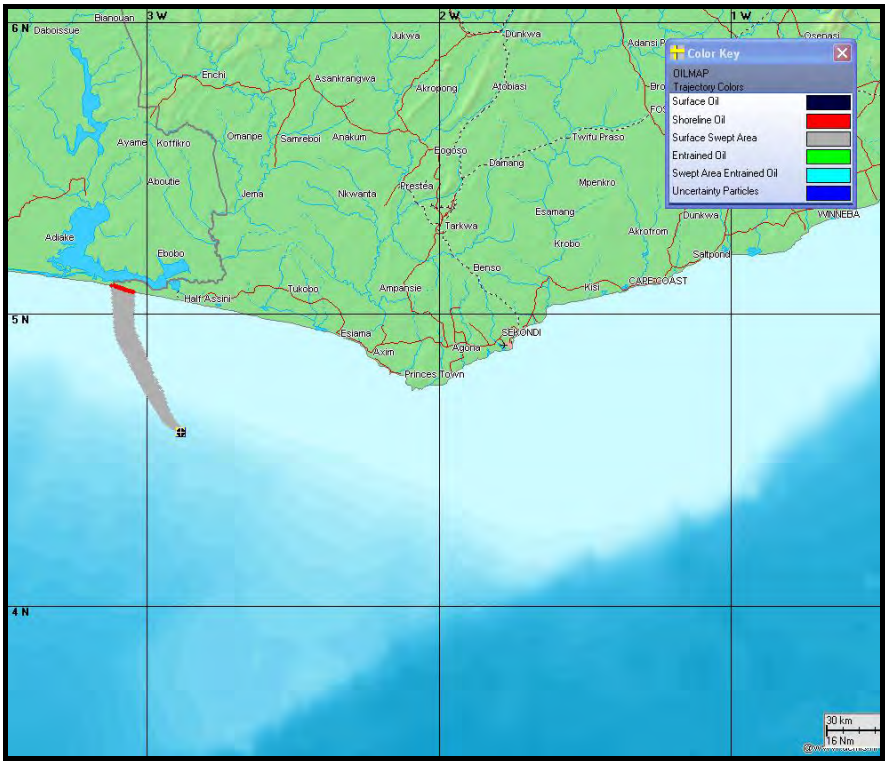


Figure 26. Instantaneous spill of 100 Tonnes crude at the FPSO: model predicted water surface signature of the significant impacts spill.

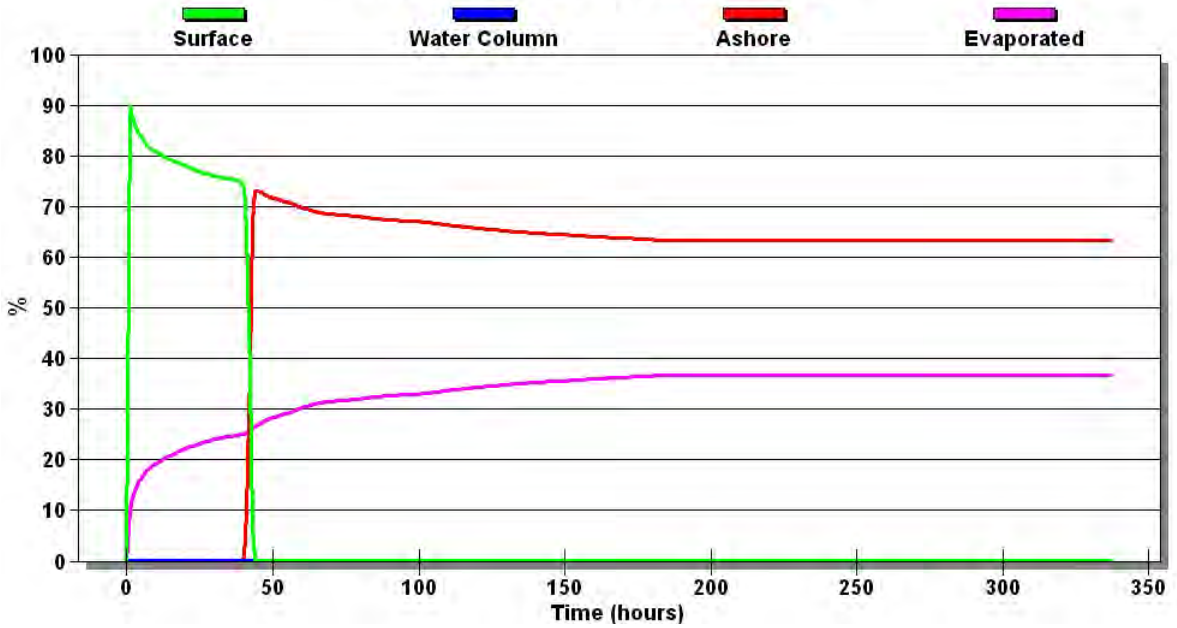


Figure 27. Instantaneous spill of 100 Tonnes crude at the FPSO: model predicted mass balance of the significant impacts spill.

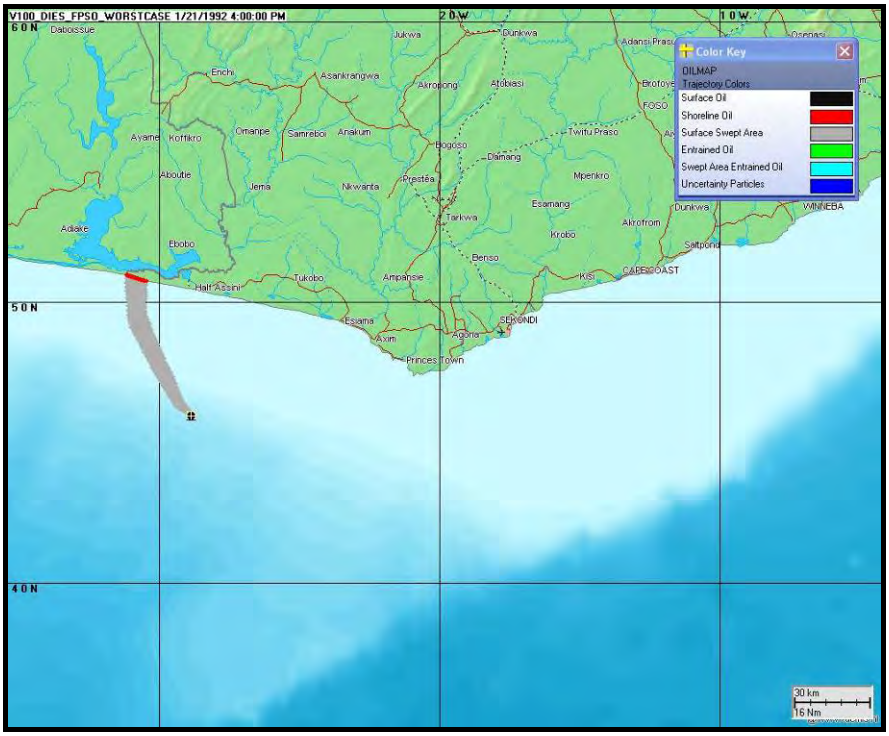


Figure 28. Instantaneous spill of 100 Tonnes marine gasoil at the FPSO: model predicted water surface signature of the significant impacts spill.

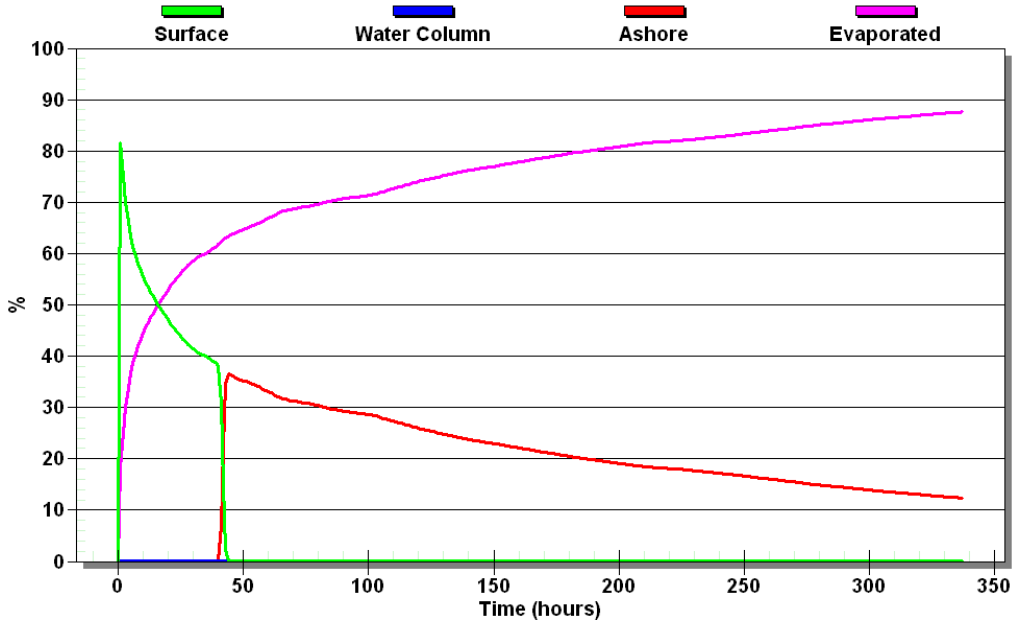


Figure 29. Instantaneous spill of 100 Tonnes marine gasoil at the FPSO: model predicted mass balance of the significant impacts spill.

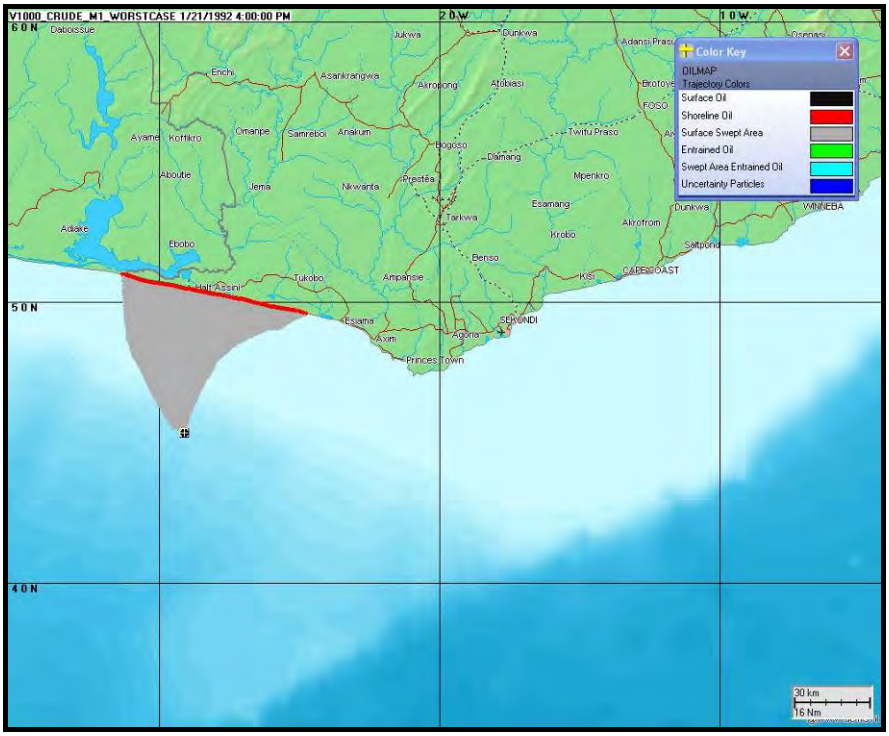


Figure 30. 48-hour spill of 1000 Tonnes crude at Well M1: model predicted water surface signature of the significant impacts spill.

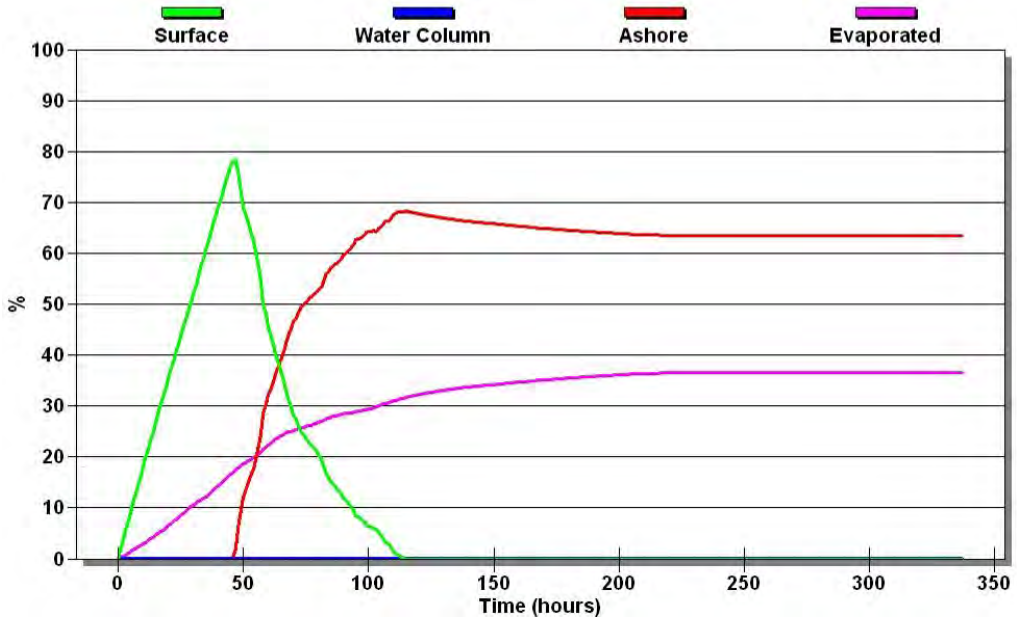


Figure 31. 48-hour spill of 1000 Tonnes crude at Well M1: model predicted mass balance of the significant impacts spill.

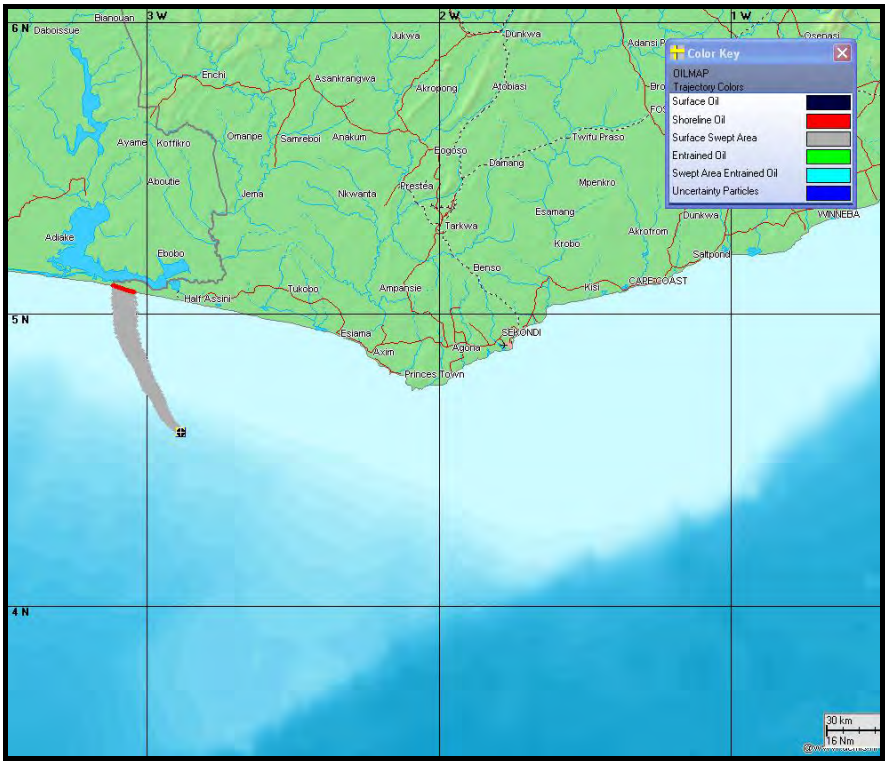


Figure 32. 2-hour spill of 1000 Tonnes crude at the FPSO: model predicted water surface signature of the significant impacts spill.

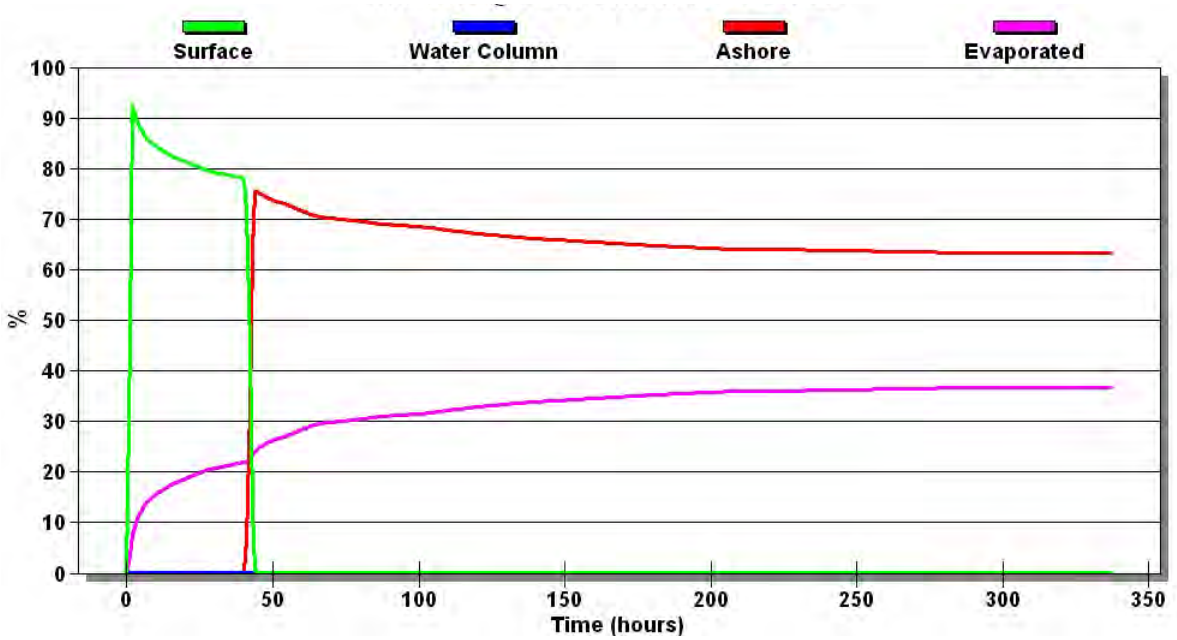


Figure 33. 2-hour spill of 1000 Tonnes crude at the FPSO: model predicted mass balance of the significant impacts spill.

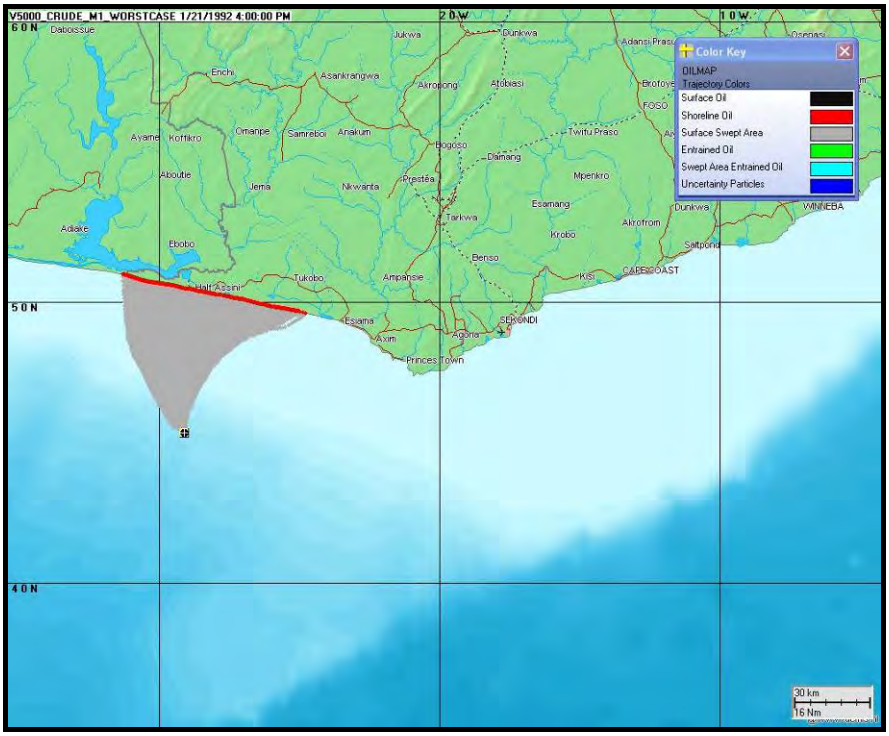


Figure 34. 48-hour spill of 5000 Tonnes crude at Well M1: model predicted water surface signature of the significant impacts spill.

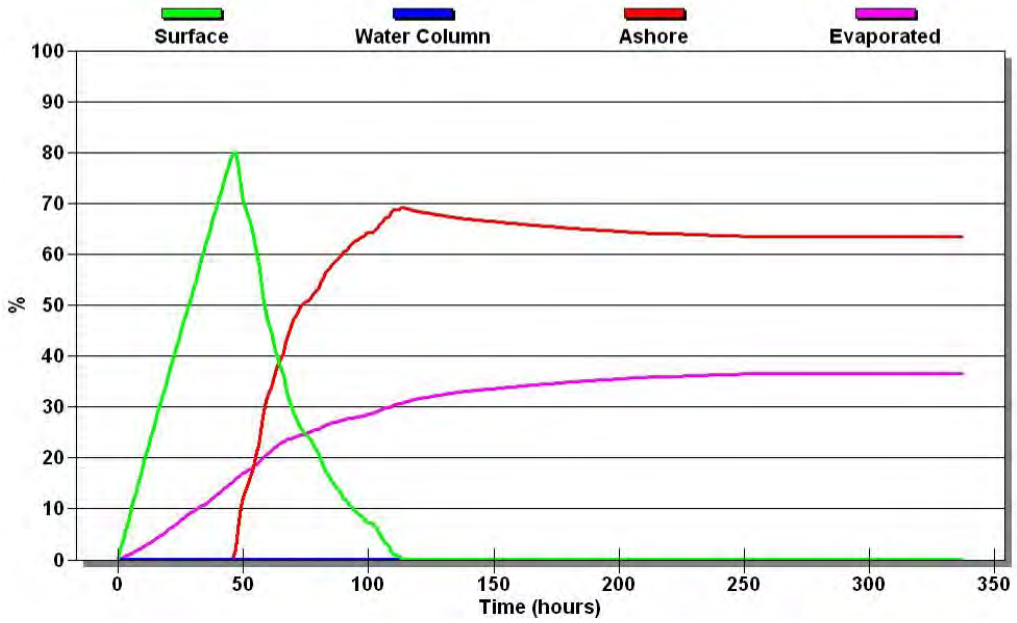


Figure 35. 48-hour spill of 5000 Tonnes crude at Well M1: model predicted mass balance of the significant impacts spill.

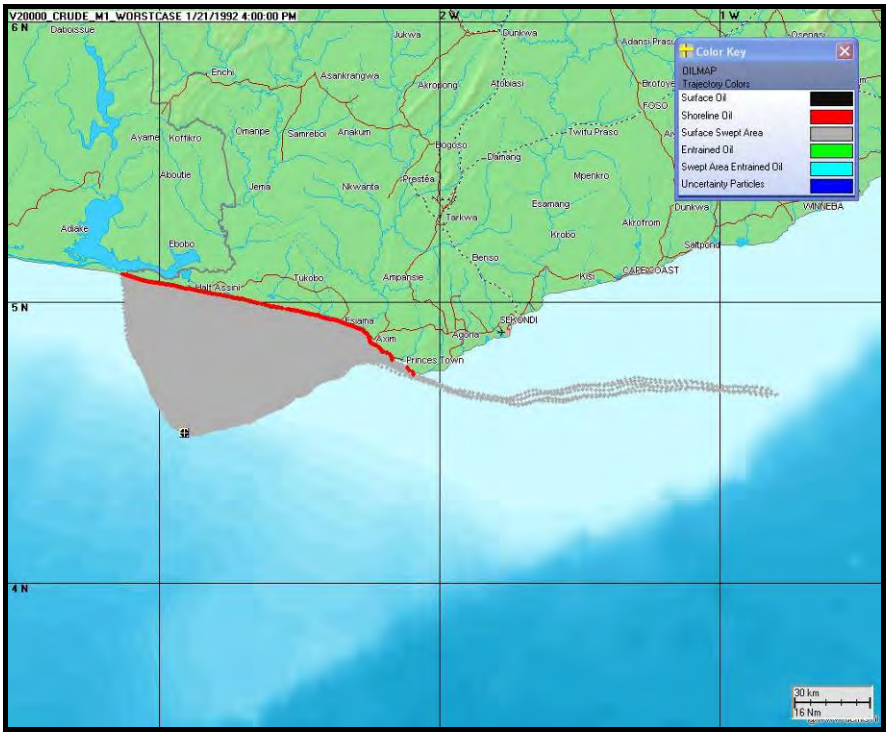


Figure 36. 168-hour spill of 20,000 Tonnes crude at Well M1: model predicted water surface signature of the significant impacts spill.

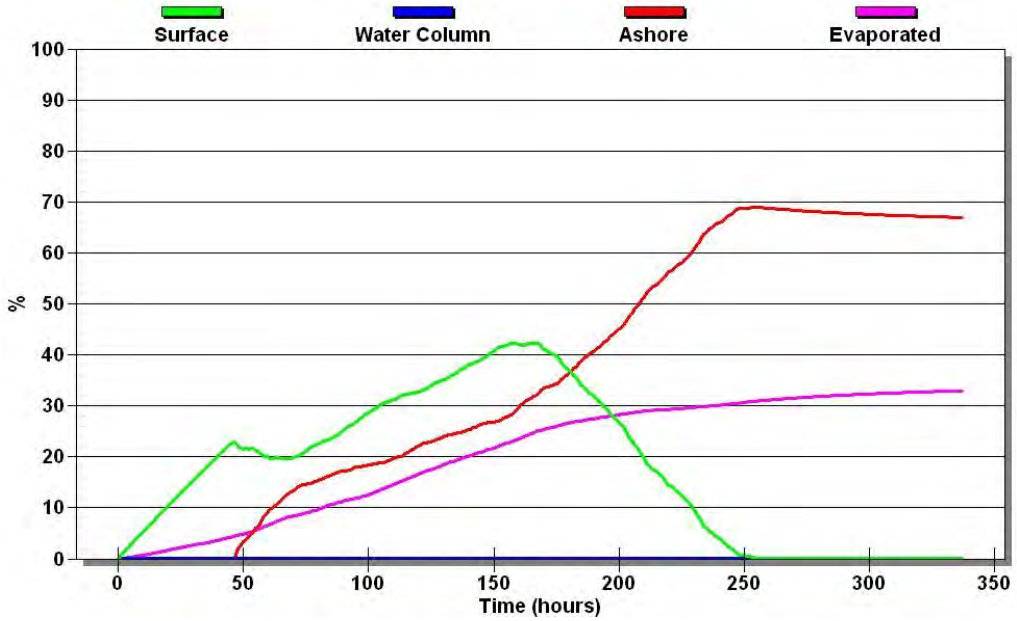


Figure 37. 168-hour spill of 20,000 Tonnes crude at Well M1: model predicted mass balance of the significant impacts spill.

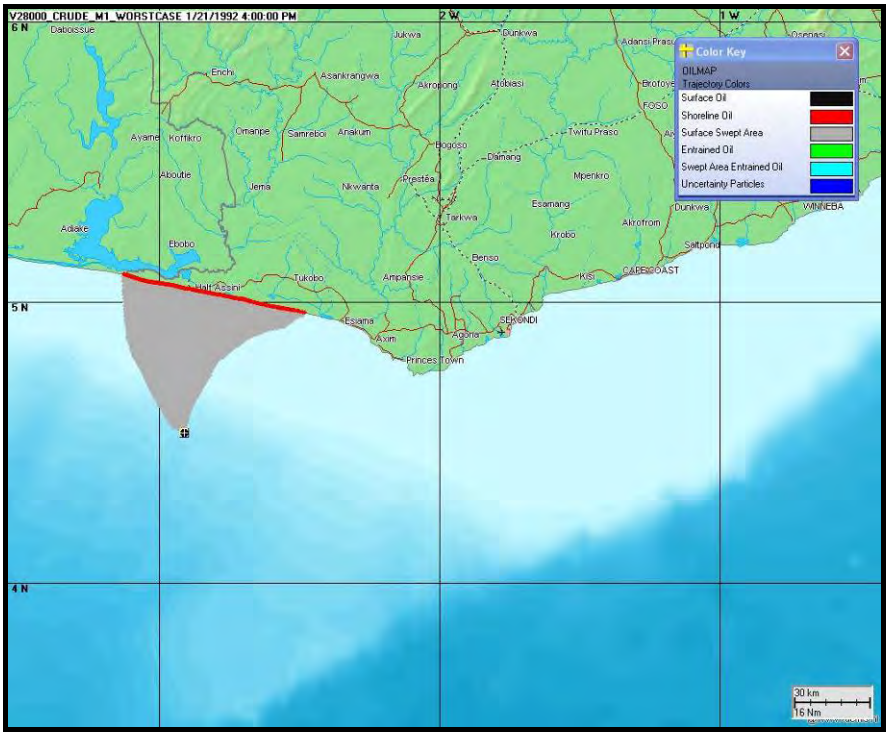


Figure 38. 48-hour spill of 28,000 Tonnes crude at Well M1: model predicted water surface signature of the significant impacts spill.

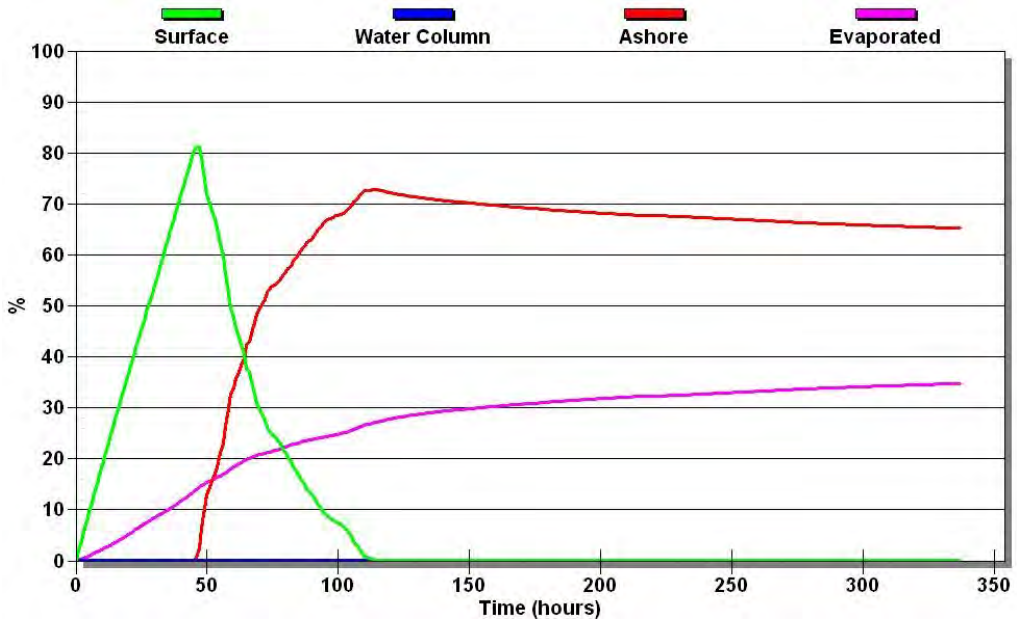


Figure 39. 48-hour spill of 28,000 Tonnes crude at Well M1: model predicted mass balance of the significant impacts spill.

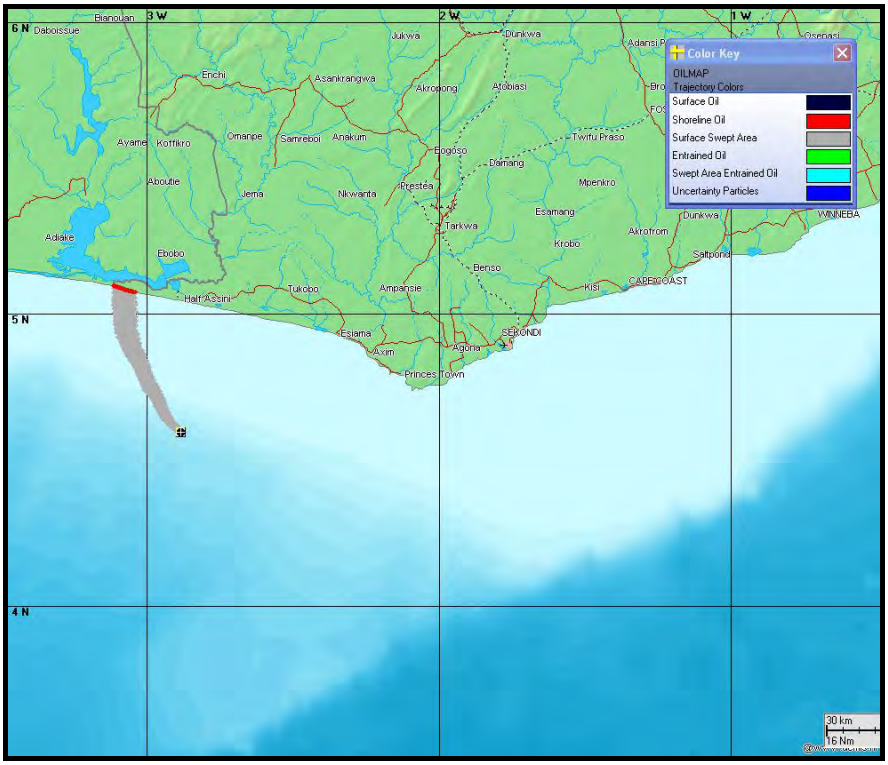


Figure 40. 2-hour spill of 28,000 Tonnes crude at the FPSO: model predicted water surface signature of the significant impacts spill.

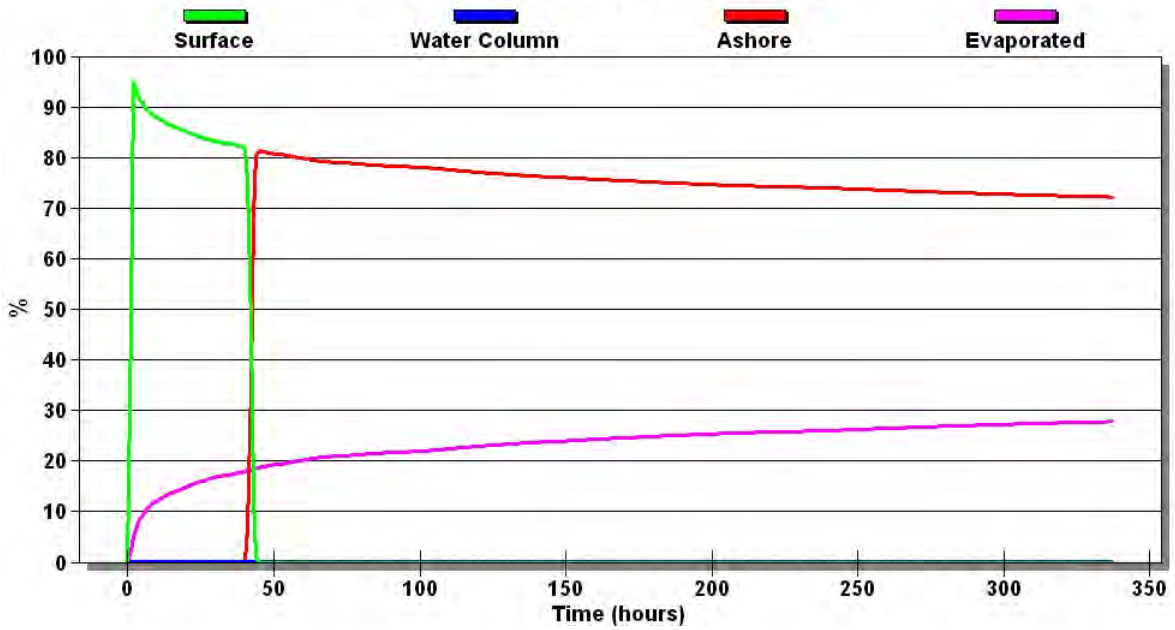


Figure 41. 2-hour spill of 28,000 Tonnes crude at the FPSO: model predicted mass balance of the significant impacts spill.

4. Produced Water Simulations

Produced water discharges were simulated using ASA's MUDMAP modeling system with ADCP current data input. Based on the operational production forecast (provided by the client), three discharge rates were chosen: 80, 18.4 and 6 Million Standard Barrels per Day (MSTB/D). These values represent the maximum the FPSO can process in a day, and maximum and average predicted discharges, respectively. Produced waters with a hydrocarbon concentration of 42 ppm are assumed to be discharged at the water surface at the FPSO. As previously described, the regional circulation is characterized by two periods: westward and eastward surface flows. These combinations lead to six simulations as defined in Table 5.

Table 5. Summary of produced water simulations

Simulation number	Discharge rate (MSTB/D)	Hydrocarbon concentration (ppm)	Flow direction
1	80	42	westward
2	18.4	42	westward
3	6.0	42	westward
4	80	42	eastward
5	18.4	42	eastward
6	6.0	42	eastward

In each simulation, produced water is discharged continuously for 30 days, a period sufficiently long to capture variations of current speed and direction. Figures 44-49 show simulated 30 day average hydrocarbon distributions for the six scenarios listed in Table 5. Each figure shows both the horizontal and vertical extent of elevated hydrocarbon concentrations. Hydrocarbons rapidly disperse within a short distance and the vertical extent of the effluent is limited to less than 5 m for the predicted discharges and 7-8 m for the maximum possible discharge. In response to the westward currents, the hydrocarbon plume is transported to the northwest (Figures 42-44), whereas the eastward currents transport the plume to the east (Figures 45-47). The outermost concentration contour on the figures represents 0.005 ppm. This concentration represents a conservative estimate of the threshold for toxic effects to sensitive biota (French-McCay, 2002). The maximum distance from the discharge point to the 0.005 ppm contour is 2000-2200 m for the 80 MSTB/D discharge, 600-700 m for the 18.4 MSTB/D discharge, and 300-400 m for the 6.0 MSTB/D discharge.

The results shown in Figures 42-47 assume a hydrocarbon concentration of 42 ppm in the produced water discharge. The contours scale linearly with the discharge hydrocarbon concentration. Thus if the produced water hydrocarbon concentration is 30 ppm, the contours are 71% of the values shown for 42 ppm; and for 20 ppm the contours are 48% of the values shown. For example, for a 30 ppm discharge, the 0.005 ppm contour shown in the figures represents 0.0036 ppm, the 0.01 ppm contour represents 0.007 ppm, the 0.02 ppm contour represents 0.014 ppm, et cetera. The area impacted by concentrations greater than 0.005 ppm is reduced for discharge concentrations of 30 or 20 ppm, but does not necessarily scale linearly with the 42 ppm discharge results.

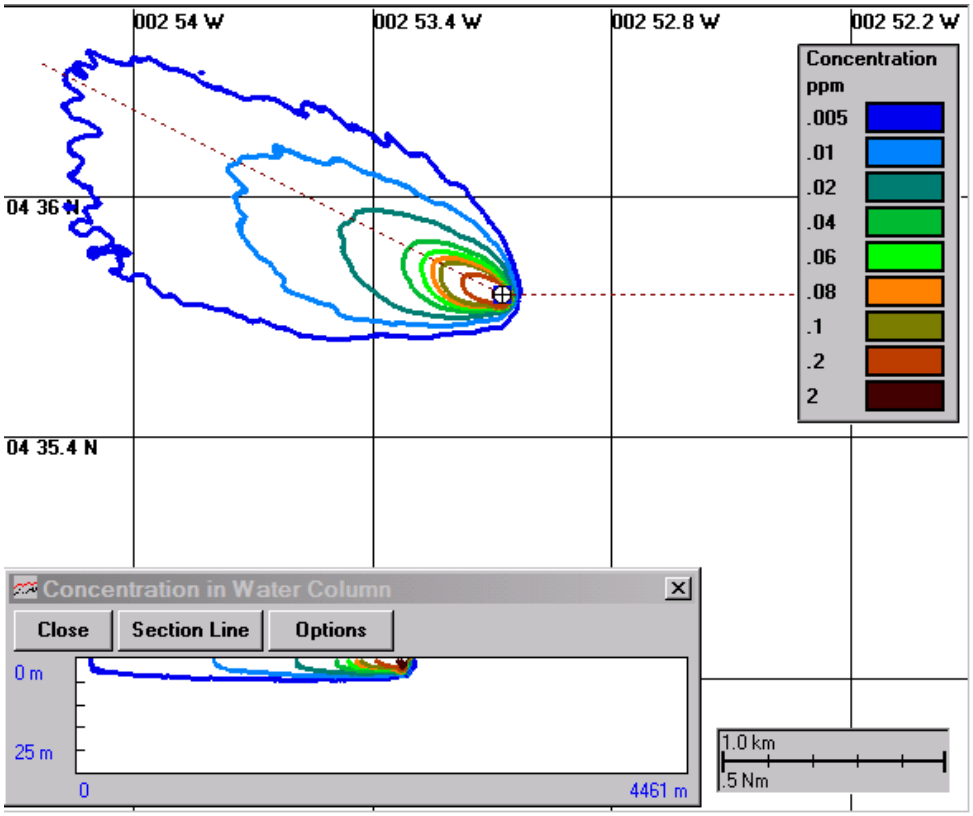


Figure 42. Simulated hydrocarbon distribution with discharge conditions of 80 MSTB/D, 42 ppm, and westward flow.

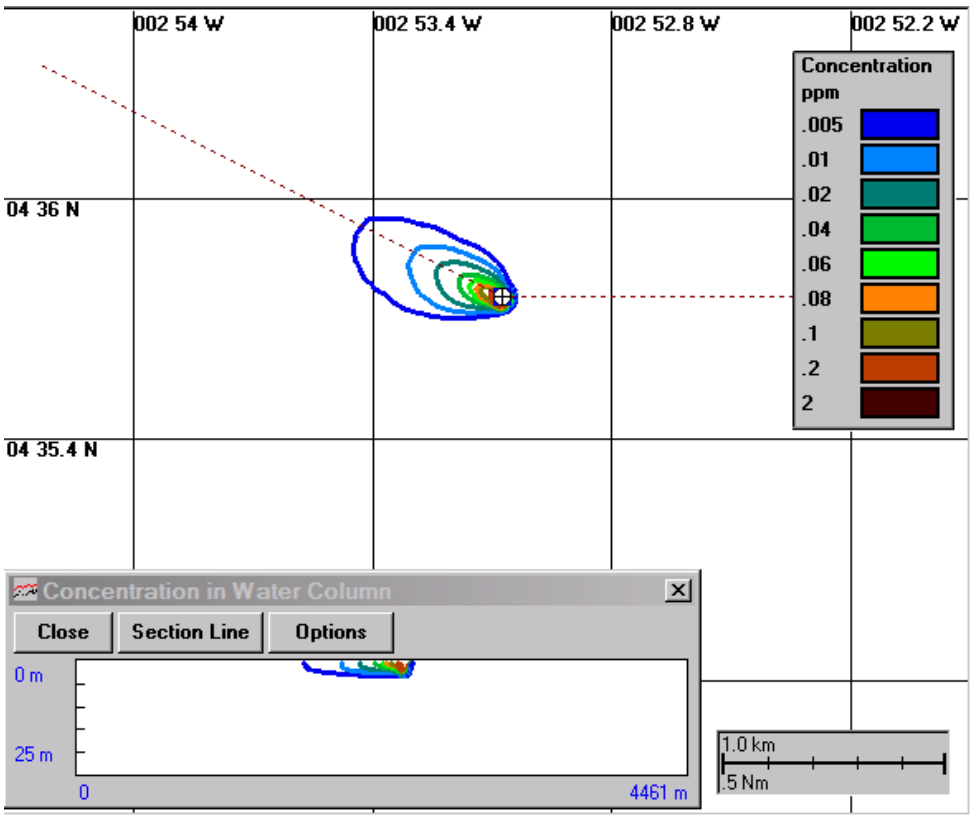


Figure 43. Simulated hydrocarbon distribution with discharge conditions of 18.4 MSTB/D, 42 ppm, and westward flow.

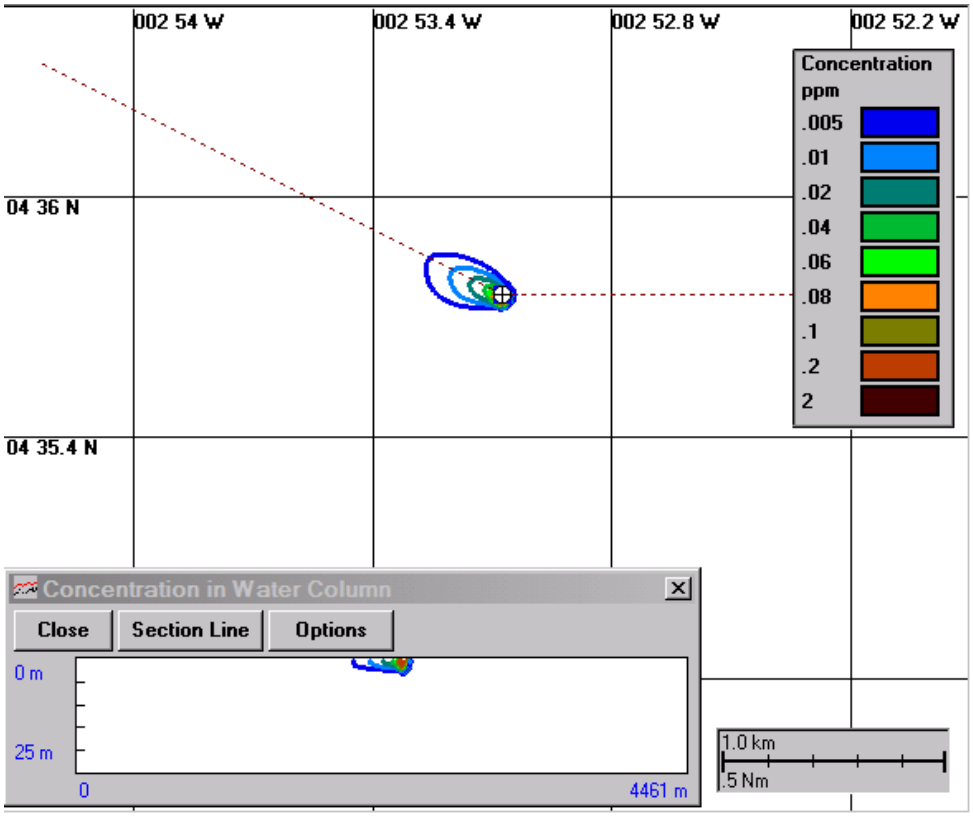


Figure 44. Simulated hydrocarbon distribution with discharge conditions of 6.0 MSTB/D, 42 ppm, and westward flow.

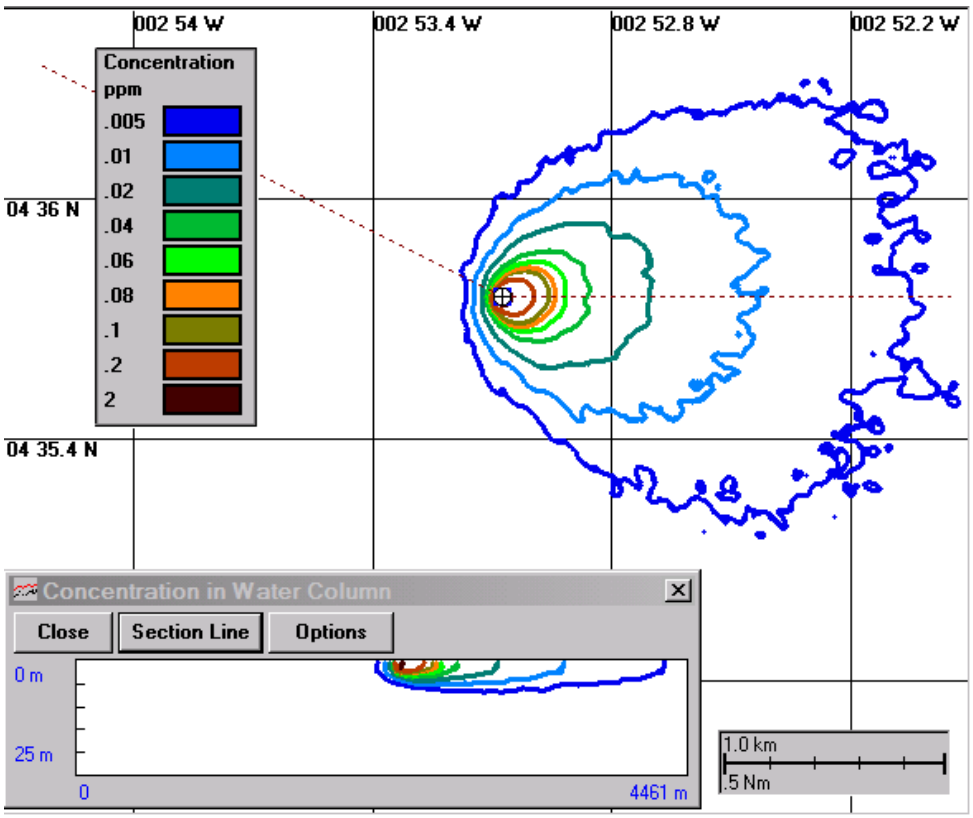


Figure 45. Simulated hydrocarbon distribution with discharge conditions of 80 MSTB/D, 42 ppm, and eastward flow.

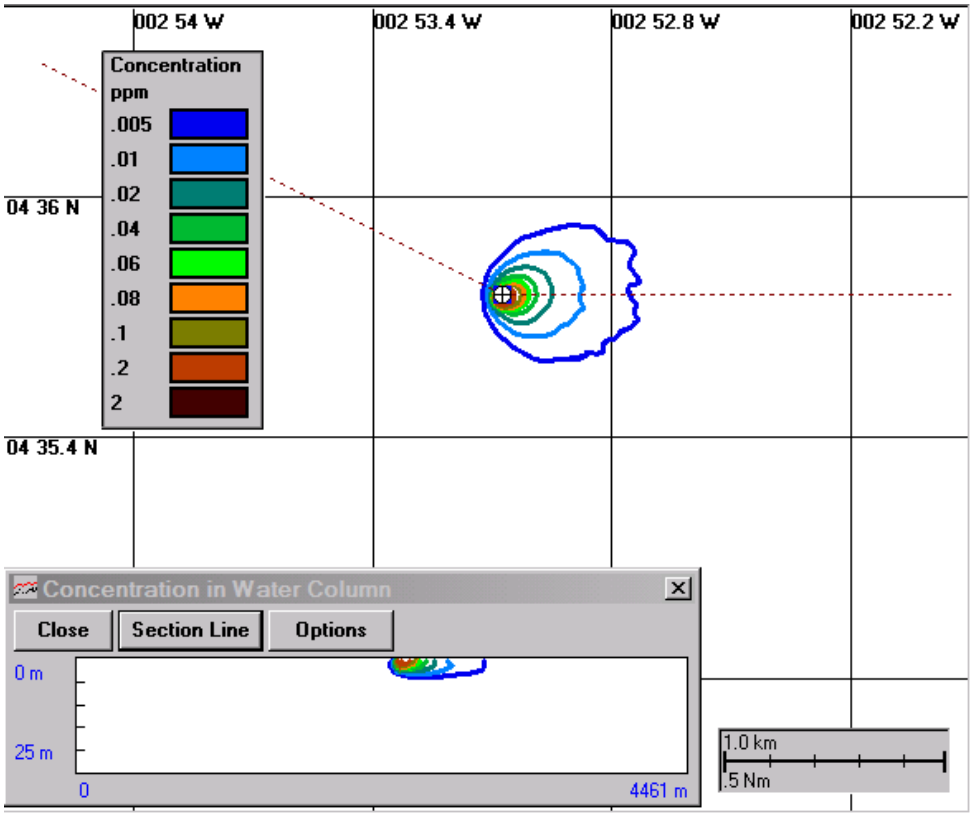


Figure 46. Simulated hydrocarbon distribution with discharge conditions of 18.4 MSTB/D, 42 ppm, and eastward flow.

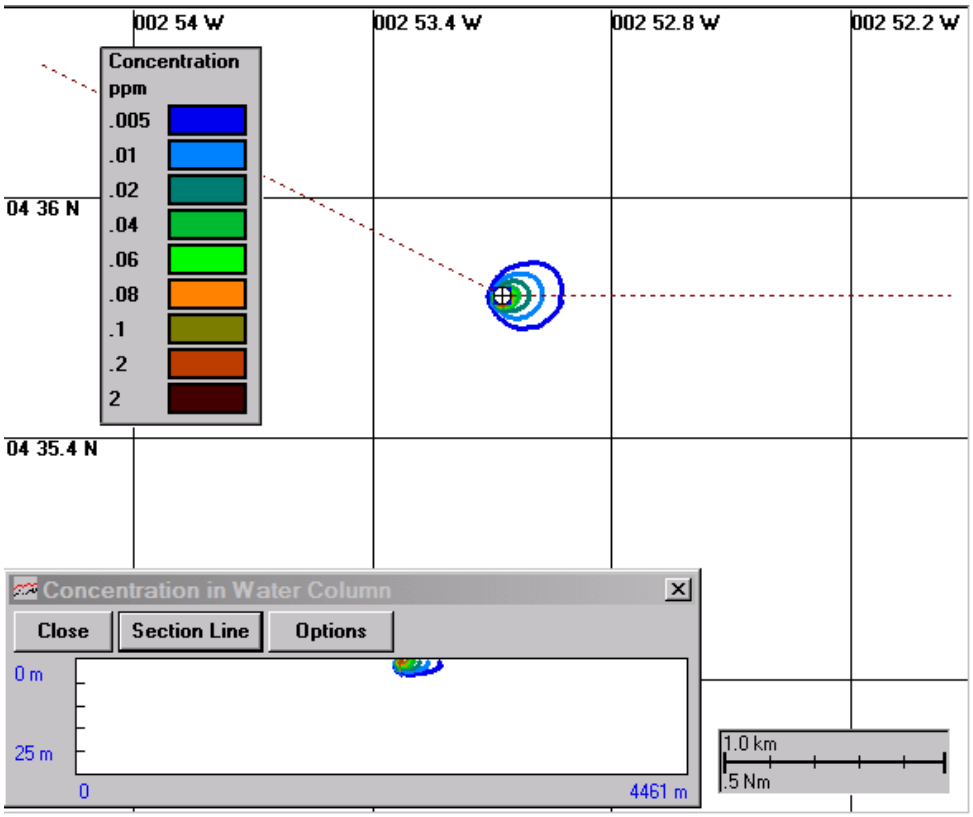


Figure 47. Simulated hydrocarbon distribution with discharge conditions of 6.0 MSTB/D, 42 ppm, and eastward flow.

5. Drill Cuttings and Mud Discharge Simulations

5.1. Discharge Scenarios

Drill cuttings and mud discharge simulations were conducted for Well M1, during both the westward- and eastward-directed current season. Water depth at the well site is 1193 m. The ADCP-observed current data described in Section 2.4 was used for the current input data in these dispersion simulations. A drilling program of up to four different sections was assumed.

Error! Reference source not found.provides scenario specifications for the drill cuttings and mud modeling based on the expected drilling program provided by the client. The table lists the season, and the discharge amount, duration and location for each drilling section.

Table 6. Scenario specifications for the drill cutting scenarios

Season	Section	Diameter (inches)	Mud Discharged (tonnes)	Cuttings Discharged (tonnes)	Start Date	Duration (hours)	Discharge Location
Westward Current Period	1	36	7.3	115.2	2008-Oct-01	24	Seabed
	2	26	185.7	456	2008-Oct-05	93.3	Seabed
	3	17.5	8.8	352.8	2008-Oct-15	33.1	surface*
	4	12.25	5.3	211.2	2008-Oct-21	90.2	surface*
Eastward Current Period	1	36	7.3	115.2	2009-Jan-01	24	Seabed
	2	26	185.7	456	2009-Jan-05	93.3	Seabed
	3	17.5	8.8	352.8	2009-Jan-15	33.1	surface*
	4	12.25	5.3	211.2	2009-Jan-21	90.2	surface*

* Discharge: 15 m below the surface.

The grain size distribution used in this study for the drill cuttings is adapted from Brandsma and Smith (1999), and is given in Table 7. The mud grain size distribution was adapted from Brandsma and Smith (1999), and is given in Table 8. The bulk density of the cuttings and mud are 2,400 kg/m^3 and 1,198 kg/m^3, respectively.

Table 7. Drill cuttings grain size distribution (adapted from Brandsma and Smith, 1999)

Particle Size (microns)	Percent Volume	Typical Settling Velocity (cm/s)
1	8	0.00014
3.5	6	0.00173
12.5	7	0.02233
41.1	3	0.23810
107.7	2	1.47659
217.2	18	4.07169
616.8	16	9.89828
1049.5	15	13.64825
3585.1	25	26.21170

Table 8. Mud grain size distribution for each drilling section (size distribution adapted from Brandsma and Smith, 1999)

Particle Size (microns)	Percent Volume	Typical Settling Velocity (cm/s)
3.7	1	0.0003
5.5	4	0.0006
8.6	19.2	0.0015
12.2	19.2	0.0031
14.8	13.3	0.0045
16	13.3	0.0053
17.9	10	0.0066
20.3	5	0.0085
46.5	8	0.0446
77.2	7	0.1222

5.2. Mud and Drilling Simulation Results

Results of the mud and drill cuttings simulations are presented in terms of maximum predicted water column concentrations (Section 5.2.1) and predicted seabed deposition thickness (Section 5.2.2).

5.2.1. Predicted Water Column Concentration

The water column concentrations of discharged material are a function of the discharge amount and ambient current strength/direction. Predicted water column concentrations were examined to determine maximum concentrations in the horizontal and vertical directions over the duration of the drilling period. The maximum concentrations are presented in Figures 48-51. The minimum water column concentration considered was 0.01 mg/l. This concentration is significantly below the threshold concentration for impacts to biota, but was selected to show the distribution of fine muds in the water column. The water column concentrations are primarily due to mud solids, since these particles have lower settling velocities and remain suspended in the water column for longer periods of time. In contrast, discharged cuttings settle to the seabed very quickly.

Figures 48 and 49 show horizontal and vertical section views, respectively, of the maximum sediment concentrations during the westward current period. The main direction of suspended sediment dispersion is along a northwest-southeast axis following the flow pattern variation over the water column. The northwest plume is composed primarily of mud discharged at the surface during drilling sections 3 and 4, while the southeast plume contains the cuttings and muds discharged at the sea bed while drilling sections 1 and 2. The sediment plume with concentrations greater than 0.5 mg/l (the maximum concentration level shown in the figures) covers an area of approximately 0.015 km^2 and does not extend more than 200 m from the well.

Figures 50 and 51 show horizontal and vertical section views, respectively, of the maximum sediment concentrations for the eastward current period. As expected from the flow pattern, the sediment plume is primarily transported toward the east. The sediment plume with concentrations greater than 0.5 mg/l extends less than 100 m from the drilling position.

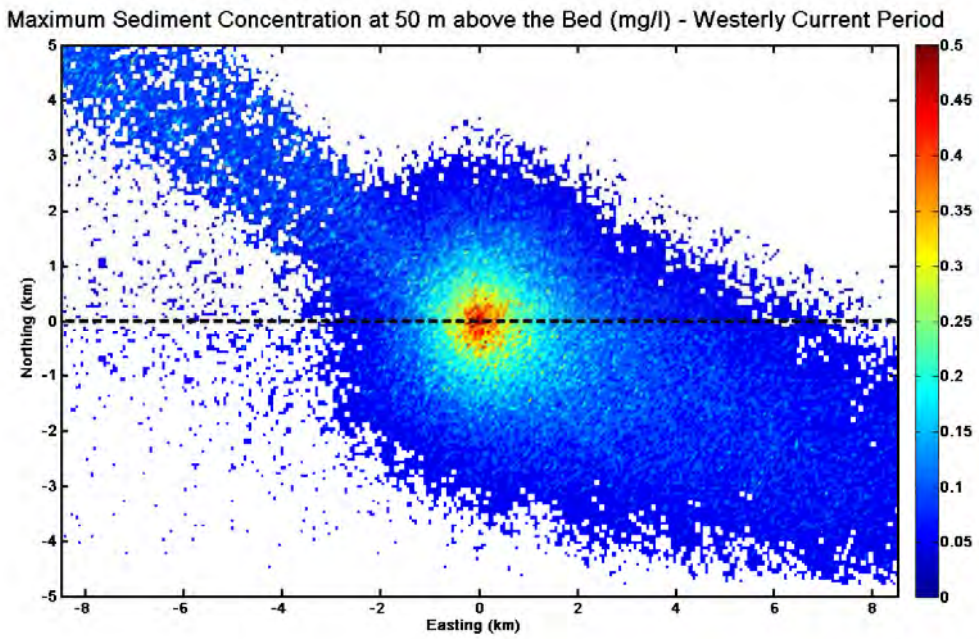


Figure 48. Plan view of predicted maximum water column concentrations 50 m above the seabed after drilling all sections. Concentrations less than 0.01 mg/l are not shown.

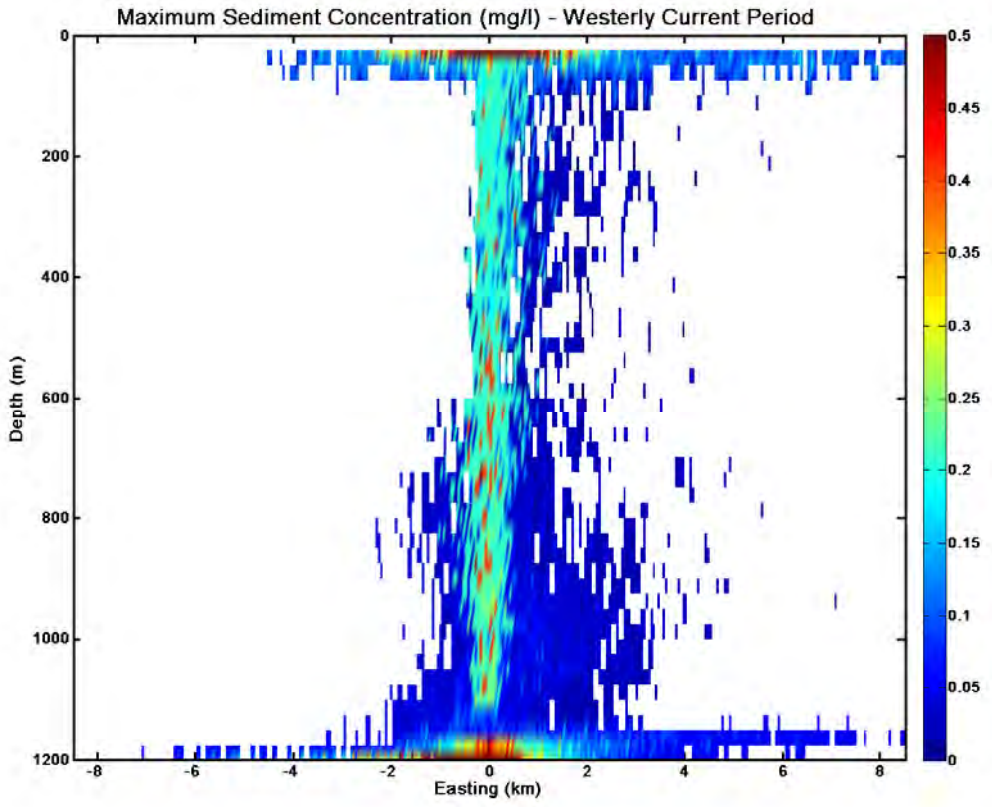


Figure 49. Cross section view of predicted maximum water column concentrations after drilling all sections. Concentrations less than 0.01 mg/l are not shown.

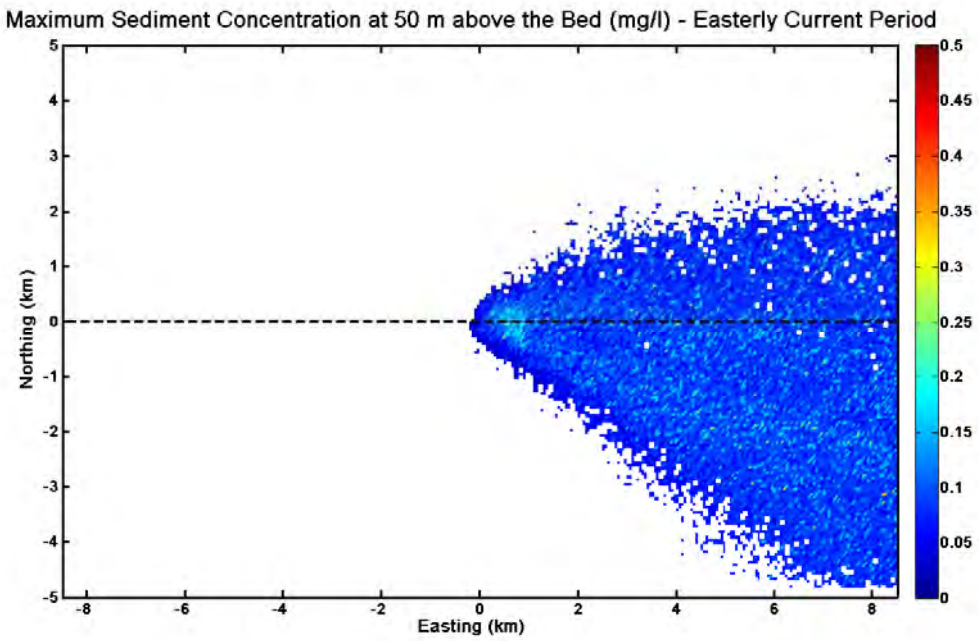


Figure 50. Plan view of predicted maximum water column concentration 50 m above the sea bed after drilling all sections. Concentrations less than 0.01 mg/l are not shown.

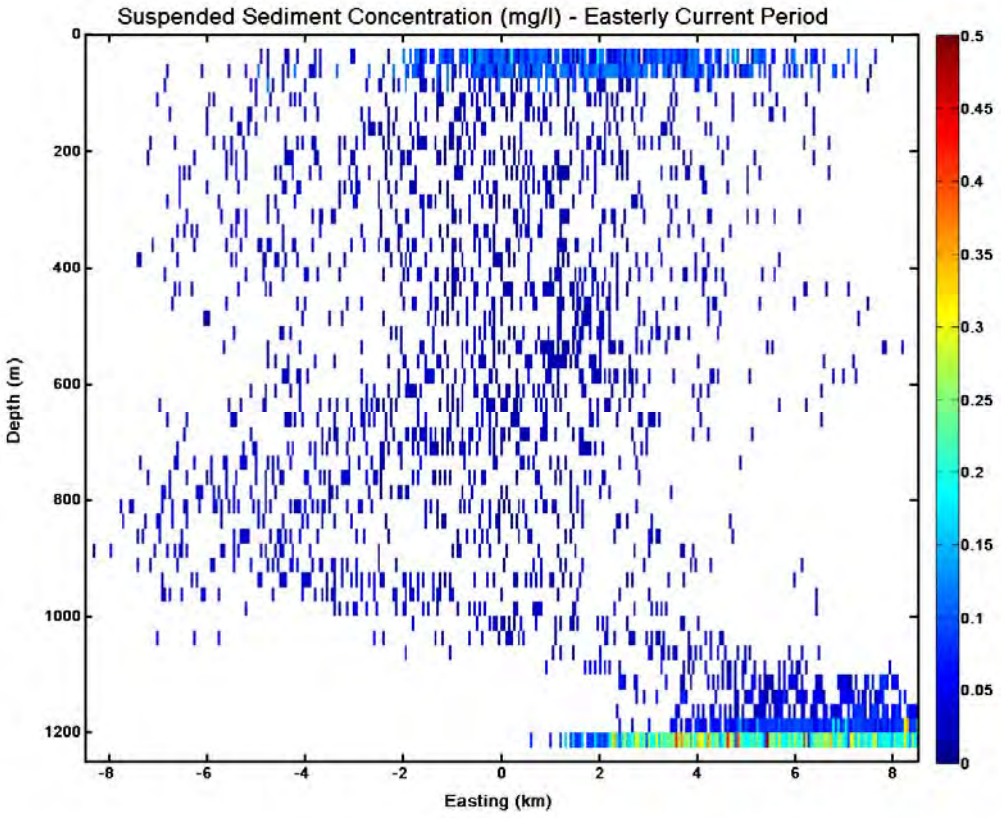


Figure 51. Cross section view of predicted maximum water column concentration after drilling all sections. Concentrations less than 0.01 mg/l are not shown.

5.2.2. Predicted Seabed Deposition Thickness

As a result of the particle settling velocities (Tables 7 and 8), cuttings settle relatively quickly compared to the discharged mud. Simulations were run under both westward and eastward current conditions; the results are similar for both. Table 9 presents the maximum predicted deposition thickness at any location at the end of drilling operations due to the discharge of cuttings and mud. This value represents the cumulative predicted deposition after all well sections have been drilled and the cuttings discharged. It occurs in the immediate vicinity of the well site. Table 9 also shows the percent of the discharged cuttings and mud deposited within the study area.

Table 9. Maximum predicted deposition thickness of drill cuttings and mud and percent deposited after drilling all four sections

Season	Maximum Deposition Thickness (mm)	Percent Deposited
Westward currents	73.2	88.8
Eastward currents	78.9	89.1

Figures 52 and 53 present the predicted deposition of the cuttings and mud released from all well sections during the westward current period. The majority of the deposited material is concentrated around the release location. The deposition pattern is roughly uniform in all directions with a slight bias to the north and east. Deposition is greater than 0.1 mm over an area of approximately 0.353 km^2 and greater than 1 mm over an area of approximately 0.053 km^2 (Table 10). Figure 54 depicts the cumulative mass of cuttings and mud deposited over time (as a percent of the total), showing 88.8 percent deposited.

Figures 55 and 56 present the predicted deposition of the cuttings and mud released from all well sections during the eastward current period. The majority of the deposited material is concentrated near the release location. The deposition pattern is skewed toward the north and east. Deposition is greater than 0.1 mm over an area of approximately 0.343 km^2 and greater than 1 mm over an area of approximately 0.053 km^2 (Table 10). Figure 57 depicts cumulative mass of cuttings and mud deposited over time (as a percent of the total), showing 89.1 percent deposited.

Table 10. Areal extent of seabed deposition by thickness interval.

Thickness (mm)	Area for Westward Current Period (km^2)	Area for Eastward Current Period (km^2)
≤ 0.1	1.0625	1.1000
0.1 - 1.0	0.3000	0.2900
1.0 - 10.0	0.0450	0.0475
≥ 10.0	0.0075	0.0050

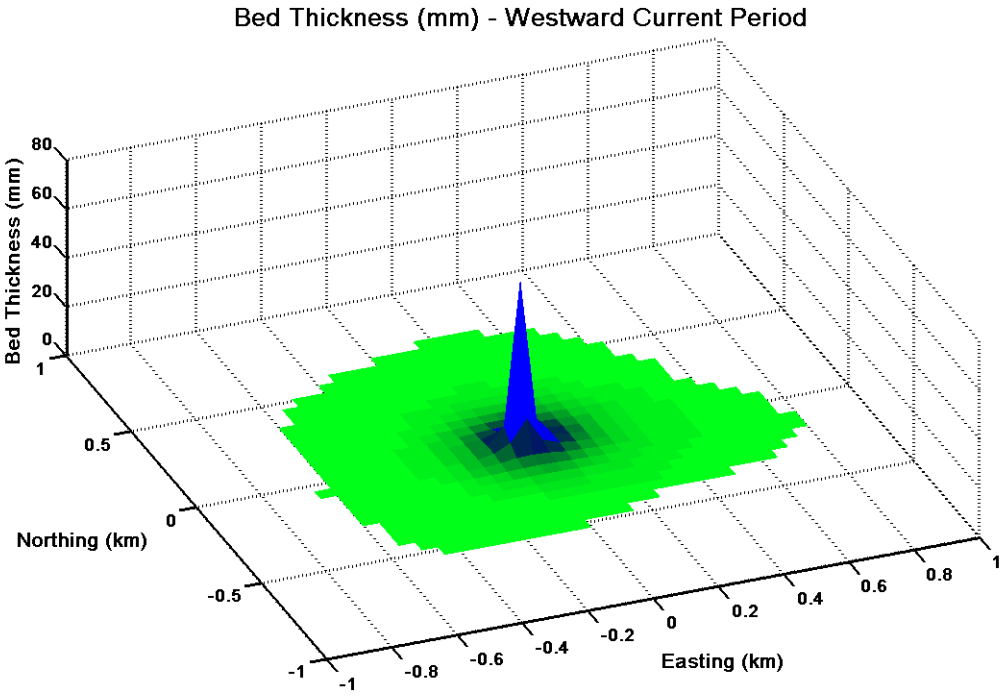


Figure 52. Cumulative sea bed deposition thickness contours of drilling discharges after completion of the four drilling sections during the westward current period. Thicknesses less than 0.01 mm are not shown .

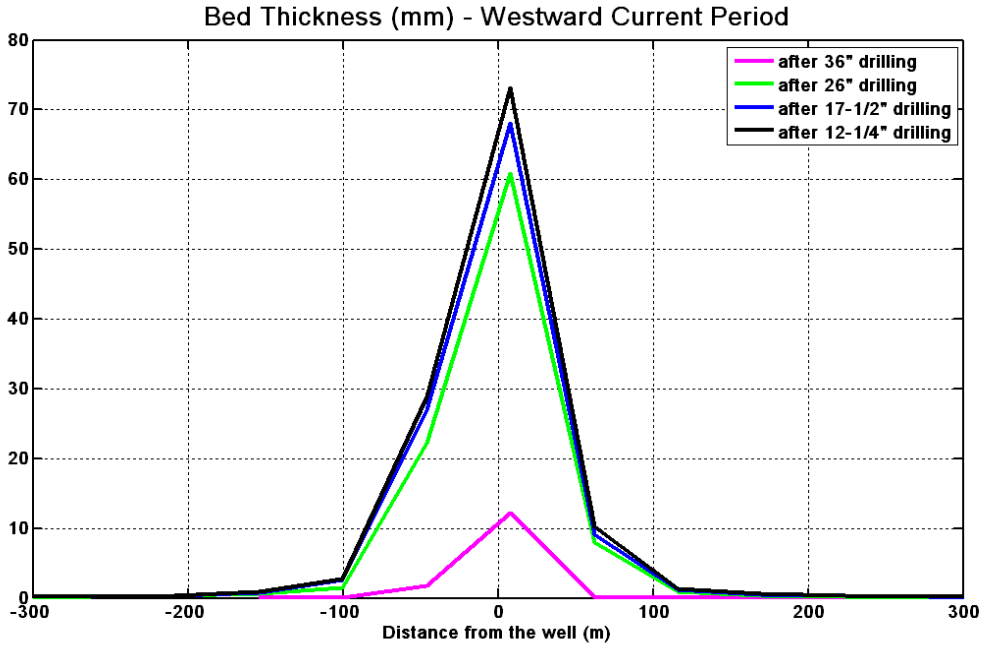


Figure 53. Evolution of sea bed deposition thickness due to drilling discharges after drilling each section during the westward current period.

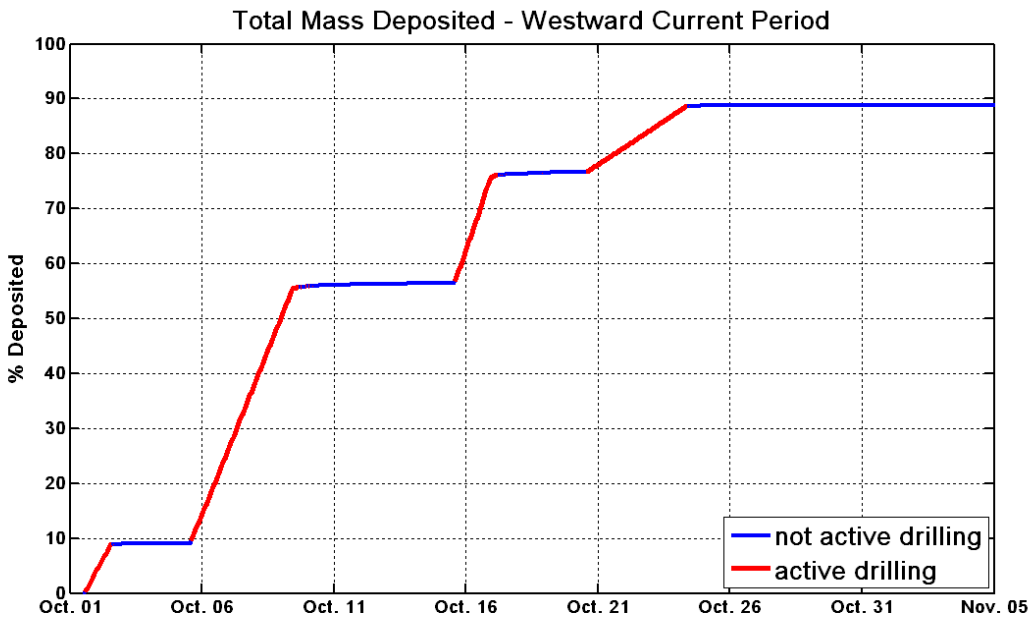


Figure 54. Percent total mass of bulk material deposited over time during the westward current period.

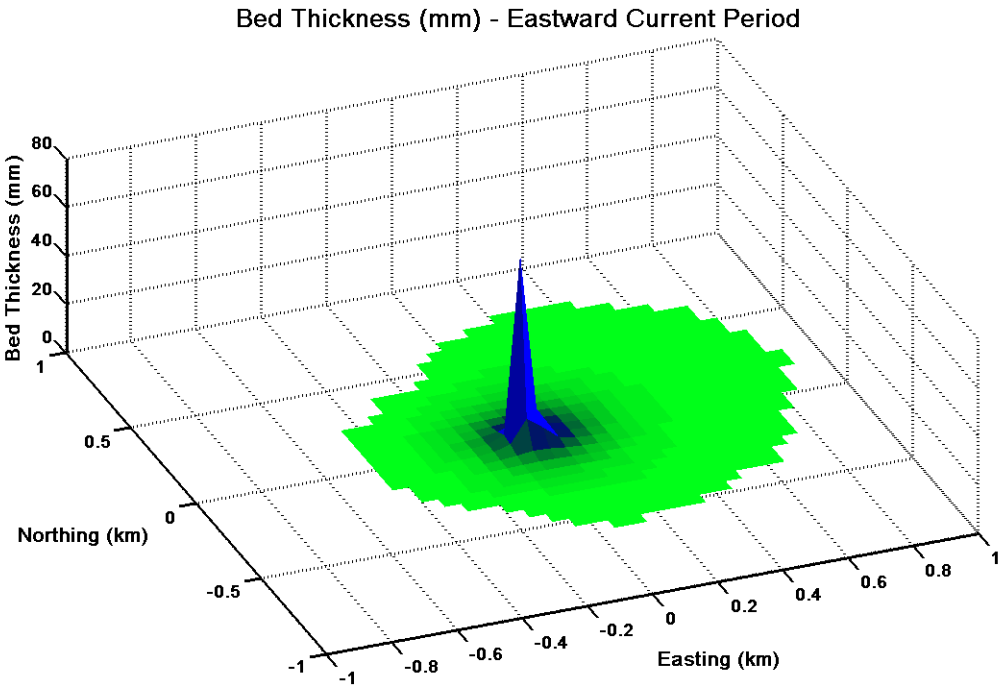


Figure 55. Cumulative sea bed deposition thickness contours of drilling discharges after completion of the four drilling sections during the eastward current period. Thicknesses less than 0.01 mm are not shown .

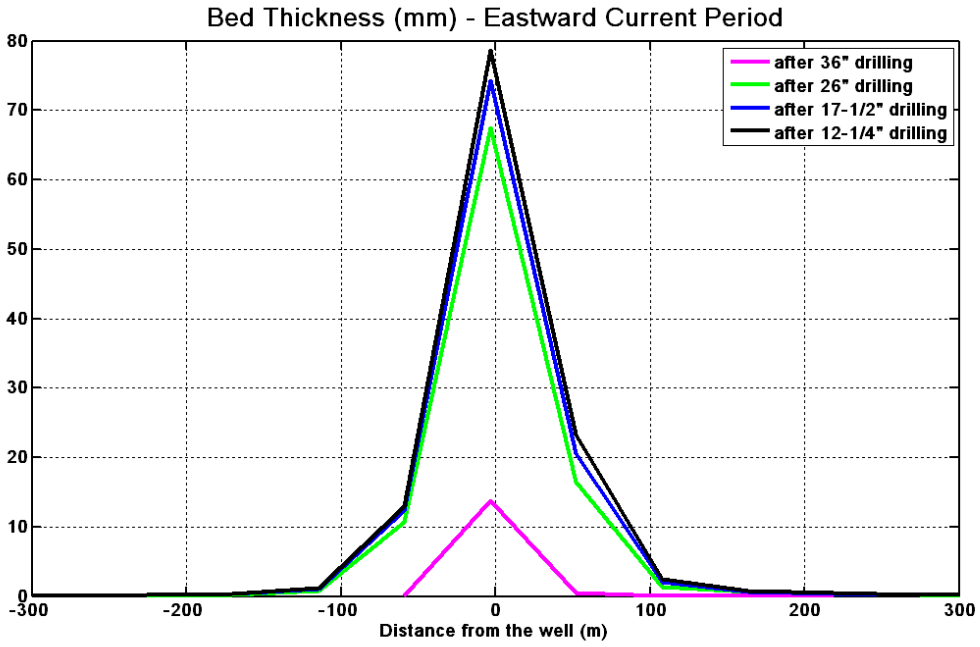


Figure 56. Evolution of sea bed deposition thickness due to drilling discharges after drilling each section during the eastward current period.

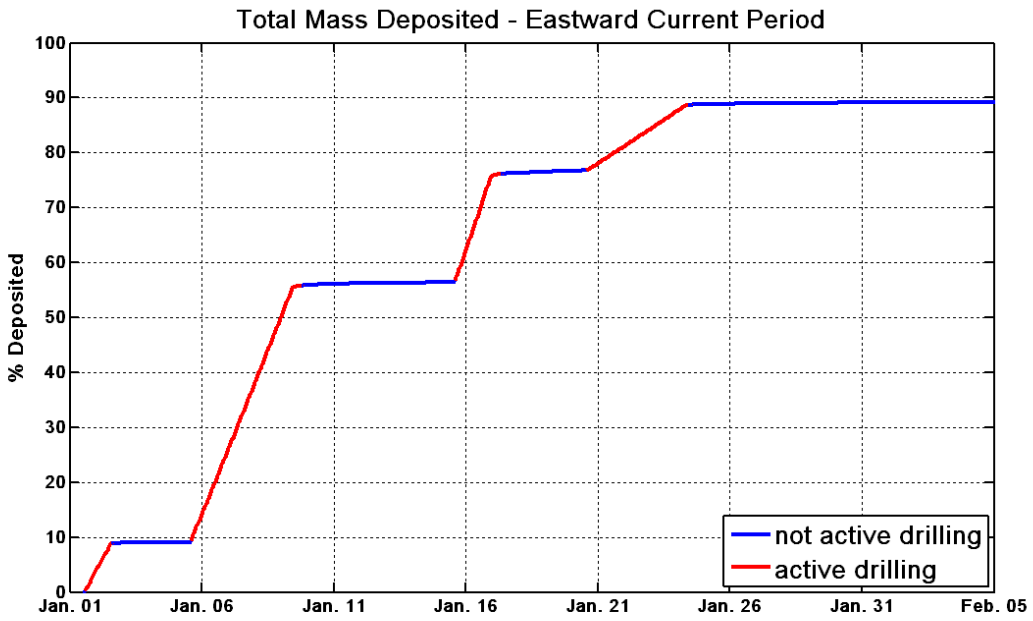


Figure 57. Percent total mass of bulk material deposited over time during the eastward current period.

6. Conclusions

Oil Spill Simulations

OILMAP's stochastic model was applied to eleven potential surface spill scenarios using WANE wind and current data. For all scenarios the predominant transport of spilled oil is to the east. The footprint for the area of potential impact varies with spill size, with the maximum length of the footprint ranging from 40 km for a marine gasoil spill of 10 Tonnes to more than 600 km for crude oil spills of 1000 Tonnes or more. Spilled oil could reach the Ghana shoreline in a minimum of 1-1.25 days although the average time to reach shore is 2.5-4.5 days. Roughly 200-300 km of shoreline is at risk for oiling with the larger spill sizes having the potential for more shoreline impact. The shoreline with the highest probability of being oiled is the 100 km west of Cape Three Points. East of Cape Three Points a longer reach of shoreline could potentially be oiled, but the probability of oiling is generally less than 10 percent. The shoreline east of Cape Three Points has the highest probability of oiling due to a 168-hour release of 20,000 Tonnes of crude oil from Well M1. For this scenario some areas have up to a 15 percent probability of being oiled.

The stochastic simulations use winds and currents generated by model hindcasts. Such data is valuable for providing long time series of environmental conditions and is accurate in a statistical sense. However model-generated data may not replicate the very short-term or anomalous behavior that is often seen in observations. Such anomalous conditions represent a very low probability of occurrence and may not be reflected in the oil spill results.

A trajectory/fate simulation was done for each spill scenario with shoreline impacts using the same simulation start date for each. The simulation time was chosen to encompass a period with winds and currents that result in a greater transport of oil to the shore than most other time periods. For these scenarios, the first oil reached shore, north and slightly west of the spill site, 45 hours after the spill began. The extent of shoreline oiling was directly related to the duration of the oil release. An instantaneous or 2-hour duration spill resulted in a relatively short (10-12 km) length of shoreline impacted. Longer duration spills contribute to wider spreading of surface oil due variations in the wind and current directions. For the 48-hour release 75 km of shoreline were impacted, and for the 168-hour release 125 km were oiled. The mass balance indicated 20-30% of the crude oil and approximately 60% of the marine gasoil evaporated before the oil reached shore.

Produced Water Simulations

Produced water discharges were simulated using ADCP current data as input to ASA's MUDMAP modeling system. Westward and eastward flow conditions were considered for maximum possible, and maximum and average predicted discharge rates. Based on a continuous surface discharge for 30 days, elevated hydrocarbon concentrations were found to be confined within a short distance of the release location for the maximum and average predicted discharges. The

maximum distance from the discharge point to the 0.005 ppm contour is 2000-2200 m for the maximum possible discharge (80 MSTB/D), 600-700 m for the maximum predicted discharge rate (18.4 MSTB/D), and 300-400 m for the average predicted discharge rate (6 MSTB/D). The vertical extent of the effluent remains within 5 m of the surface for the predicted discharge rates, and within 7-8 m of the surface for the maximum possible discharge.

Drilling Discharge Simulations

For the westward and eastward-current periods, four drilling section discharges were simulated. Water column concentrations are primarily due to mud solids, while the accumulated seabed deposition is primarily due to cutting discharges. The majority of deposition occurs close to the discharge site due to the relatively low current velocity.

During the westward current period, the maximum horizontal extent of the discharge plume with a concentration greater than 0.5 mg/l is approximately 0.015 km^2 and extends less than 200 m from the well. The larger size particles of the cutting discharges are deposited in the immediate vicinity of the well site, slightly oriented towards the north and east. The maximum deposition thickness is 73 mm within 25 m of the drilling site; the area covered by deposits more than 1 mm thick is approximately 0.053 km^2.

During the eastward current period, the maximum horizontal extent of the discharge plume with a concentration greater than 0.5 mg/l extends approximately 100 m from the drilling position. The maximum deposition thickness is 79 mm within 25 m of the drilling site, indicating that the majority of the deposited material is concentrated below the release location. The area with deposition greater than 1 mm is predicted to be approximately 0.053 km^2.

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- University of New Hampshire: http://www.grdc.sr.unh.edu/index.html

Appendix A: MUDMAP Model Description

MUDMAP is a personal computer-based model developed by ASA to predict the near and far field transport, dispersion, and bottom deposition of drill muds and cuttings and produced water (Spaulding et al; 1994; Spaulding, 1994). In MUDMAP, the equations governing conservation of mass, momentum, buoyancy, and solid particle flux are formulated using integral plume theory and then solved using a Runge Kutta numerical integration technique. The model includes three stages: convective descent/ascent, dynamic collapse and far field dispersion. It allows the transport and fate of the release to be modeled through all stages of its movement. The initial dilution and spreading of the plume release is predicted in the convective descent/ascent stage. The plume descends if the discharged material is more dense than the local water at the point of release and ascends if the density is lower than that of the receiving water. In the dynamic collapse stage, the dilution and dispersion of the discharge is predicted when the release impacts the surface, bottom, or becomes trapped by vertical density gradients in the water column. The far field stage predicts the transport and fate of the discharge caused by the ambient current and turbulence fields.

MUDMAP is based on the theoretical approach initially developed by Koh and Chang (1973) and refined and extended by Brandsma and Sauer (1983) for the convective descent/ascent and dynamic collapse stages. The far field, passive diffusion stage is based on a particle based random walk model. This is the same random walk model used in ASA's OILMAP spill modeling system (ASA, 1999).

MUDMAP uses a color graphics-based user interface and provides an embedded geographic information system, environmental data management tools, and procedures to input data and to animate model output. The system can be readily applied to any location in the world. Application of MUDMAP to predict the transport and deposition of heavy and light drill fluids off Pt Conception, California and the near field plume dynamics of a laboratory experiment for a multi-component mud discharged into a uniform flowing, stratified water column are presented in Spaulding et al. (1994). King and McAllister (1997, 1998) present the application and extensive verification of the model for a produced water discharge on Australia's northwest shelf. GEMS (1998) presents the application of the model to assess the dispersion and deposition of drilling cuttings released off the northwest coast of Australia.

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Appendix B: OILMAP Modeling System Description

OILMAP is a state-of-the-art, personal computer based oil spill response system applicable to oil spill contingency planning and real time response and applicable for any location in the world (Jayko and Howlett, 1992; Spaulding et al., 1992a,b). OILMAP was designed in a modular fashion so that different types of spill models could be incorporated within the basic system, as well as a suite of sophisticated environmental data management tools, without increasing the complexity of the user interface. The model system employs a Windows based graphics user interface that extensively utilizes point and click and pull down menu operation. OILMAP is configured for operation on standard Pentium PCs and can be run on laptop and notebook computers to facilitate use in the field.

The OILMAP suite includes the following models: a trajectory and fates model for surface and subsurface oil, an oil spill response model, and stochastic and receptor models. The relevant models are described in more detail below.

The trajectory and fates model predicts the transport and weathering of oil from instantaneous or continuous spills. Predictions show the location and concentration of the surface and subsurface oil versus time. The model estimates the temporal variation of the oil's areal coverage, oil thickness, and oil viscosity. The model also predicts the oil mass balance or the amount of oil on the free surface, in the water column, evaporated, on the shore, and outside the study domain versus time. The fate processes in the model include spreading, evaporation, entrainment or natural dispersion, and emulsification. As an option OILMAP can also estimate oil-sediment interaction and associated oil sedimentation. A brief description of each process algorithm is presented here. ASA (1999) provides a more detailed description for the interested reader. The oil sedimentation algorithm is described in French et al. (1994), ASA (1999) and Kirstein et al. (1985). Spreading is represented using the thick slick portion of Mackay et al.'s (1980, 1982) thick-thin approach. Evaporation is based on Mackay's analytic formulation parameterized in terms of evaporative exposure (Mackay et al., 1980, 1982). Entrainment or natural dispersion is modeled using Delvigne and Sweeney's (1988) formulation which explicitly represents oil injection rates into the water column by droplet size. The entrainment coefficient, as a function of oil viscosity, is based on Delvigne and Hulsen (1994). Emulsification of the oil, as function of evaporative losses and changes in water content, is based on Mackay et al. (1980, 1982). Oil-shoreline interaction is modeled based on a simplified version of Reed et al. (1989) which formulates the problem in terms of a shore type dependent holding capacity and exponential removal rate.

For the subsurface component, oil mass injection rates from the surface slick into the water column are performed by oil droplet size class using Delvigne and Sweeney's (1988) entrainment formulation. The subsurface oil concentration field is predicted using a particle based, random walk technique and includes oil droplet rise velocities by size class. The vertical and horizontal dispersion coefficients are specified by the user. Resurfacing of oil droplets due to buoyant effects is explicitly included and generates new surface slicks. If oil is resurfaced in the vicinity of surface spillets the oil is incorporated into the closest surface spillet. A more detailed presentation of the subsurface oil transport and fate algorithm is given in Kolluru et al. (1994).

The basic configuration of the model also includes a variety of graphically based tools that allow the user to specify the spill scenario, animate spill trajectories, currents and winds, import and export environmental data, grid any area within the model operational domain, generate mean and/or tidal current fields, enter and edit oil types in the oil

library, enter and display data into the embedded geographic information system (GIS) and determine resources impacted by the spill. The GIS allows the user to enter, manipulate, and display point, line, poly line, and polygon data geographically referenced to the spill domain. Each object can be assigned attribute data in the form of text descriptions, numeric fields or external link files.

In the stochastic mode spill simulations are performed stochastically varying the environmental data used to transport the oil. Either winds, currents, or both may be stochastically varied. The multiple trajectories are then used to produce contour maps showing the probability of surface and shoreline oiling. The trajectories are also analyzed to give travel time contours for the spill. These oiling probabilities and travel time contours can be determined for user selected spill durations. If resource information is stored in the GIS database a resource hit calculation can be performed to predict the probability of oiling important resources.

OILMAP has been applied to hindcast a variety of spills. These hindcasts validate the performance of the model. Hindcasts of the *Amoco Cadiz*, Ixtoc and Persian Gulf War spills and an experimental spill in the North Sea by Warren Springs Laboratory are reported in Kolluru et al. (1994). Spaulding et al. (1993) also present a hindcast of the Gulf War spill. Spaulding et al. (1994) present the application of the model to the *Braer* spill where subsurface transport of the oil was critical to understanding the oil's movement and impact on the seabed. Spaulding et al. (1996a) describes how the model had been applied to hindcast the surface and subsurface transport and fate of the fuel oil spilled from the *North Cape* barge. Integration of OILMAP with a real time hydrodynamic model and the hindcast of the movement of oil tracking buoys in Narragansett Bay are presented in Spaulding et al (1996b).

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Appendix C: Selected Spill Scenarios

Representative Oil Spill Size	Typical, Representative Production Phase Oil Spill Scenarios				ASA Oil Spill Modeling Scenario
	Drilling Scenarios	**Subsea Scenarios**	**Production/ Topsides Scenarios**	**Offloading/ Transfer Scenarios**	
10 te (~73 bbls)	Well Release	Production Blowout (Small, Isolated)	Turret Leak (Small)	Release From Transfer Hose (Small)	**1 (Crude from M1)**
	Drains Release	Manifold Release (Small, isolated)		Diesel/Marine Fuel Oil Transfer Release (Small, Medium) Vessel release (small) from collision	**2 (Diesel from FPSO)**
	Well Test Release (Small)	Riser Release(Small, Isolated)			
100 te (~730 bbls)	Diesel/Marine Fuel Oil Transfer Release (Large)		Turret Leak (Medium)	Release From Transfer Hose (Medium) Vessel/FPSO release (medium) from collision	**3 (Crude from MI)** **3A (Crude from FPSO)**
	Reservoir Blowout (short duration)		Liquid Carry Over From Flare	Diesel/Marine Fuel Oil Transfer Release (Large)	**4 (Diesel from FPSO)**
1000 te (~7300 bbls)	Reservoir Blowout (48 hrs)		Turret Leak (Large)	Transfer Hose Rupture (Isolated) Vessel/FPSO release (large) from collision	**5 (Crude from MI)** **5A (Crude from FPSO)**
			Crude Oil Tank Explosion		
5000 te (~37,000 bbls)	Reservoir Blowout (48 hrs)	Production Blowout (Small, Unisolated)	Turret Explosion (Escalated)		**6 (Crude from MI)**
		Manifold Release (Small, Unisolated)			
		Riser Release (Small, Unisolated)			
20,000 te (~146,000 bbls	Reservoir Blowout (> 5 days)	Production Blowout (Medium, Large)	Crude Oil Tank Explosion (Escalated)	Transfer Hose Rupture (Unisolated) FPSO release (very large) from collision	**7 (Crude from MI)**
	Well Test Release (Un-isolated)	Manifold Release (Medium, Large, Unisolated)	Turret Leak (Escalated)		
~28,000 te (~210,000 bbls)		Riser Release (Medium, Large, Unisolated)	Escalated FPSO Loss Events		**8 (Crude from MI)** **8A (Crude from FPSO)**

APPENDIX C EMISSIONS CALCULATIONS

EMISSION FACTORS AND ASSUMPTIONS

Well Drilling and Completion

Reciprocating (Crane)

General http://www.epa.gov/ttn/chief/ap42/ch03/final/c03s03.pdf
Use AP42, 3.3 for Gasoline and Diesel Industrial Engines (< 600hp)
All emission rates are in lb/MMBTu

Note 1 The SO2 emission factor is based on the value provided by AP42. Given that the size of the engine is almost at the upper boundary for the recommended engine size (527 hp cf 600 hp), if a more conservative assessment is required, it is recommended to use the SO2 emission factor for the large diesel engines of 2.02.

Note 2 PM-10 = particulate matter less than or equal to 10 :m aerodynamic diameter. All particulate is assumed to be # 1 :m in size.

Note 3 No VOC emission rate is provided therefore the value that has been selected is emissions equal to TOC. This represents a conservative estimate of VOC emissions as not all TOC emissions will be VOCs

Note 4 Assumes 99% conversion of carbon in fuel to CO2 with 87 weight % carbon in diesel, average BSFC of 7,000 Btu/hp-hr, diesel heating value of 19,300 Btu/lb.

Note 5 Assume all VOC emissions are equal to CH4 emissions.This will be a conservative estimation of the emissions of CH4 as all of the TOC has been equated to CH4, thus providing a conservative estimate of the GHG emissions

Reciprocating (Dual, Emergency Shipboard and tanker)

General http://www.epa.gov/ttn/chief/ap42/ch03/final/c03s04.pdf
Use AP42, 3.4 for Large Diesel Engines as these are for engines > 600hp
All emission rates are in lb/MMBTu

Note 1 Is the sum of filterable particulate less than 10 µm aerodynamic diameter and condensable particulate.

Note 2 Assuming 1.0% SO2.

Note 3 For uncontrolled emissions

Note 4 No VOC emission rate is provided therefore this has been selected as being equal to TOC. This represents a conservative estimate of VOC emissions as not all TOC emissions will be VOCs

Note 5 Given as 'TOC as methane'. This will be a conservative estimation of the emissions of CH4 as all of the TOC has been equated to CH4, thus providing a conservative estimate of the GHG emissions

Natural gas turbines

General http://www.epa.gov/ttn/chief/ap42/ch03/final/c03s01.pdf
Use AP42, 3.1 for Stationary Gas Turbines
All emission rates are in lb/MMBTu
Emission factors are based on an average natural gas heating value (HHV) of 1020 Btu/scf at 60oF assuming uncontrolled emissions
EF for high loads >80%

Note 1 VOC emissions are assumed equal to the sum of organic emissions. This will thus be a conservative estimate of the VOC emissions

Note 2 Based on 99.5% conversion of fuel carbon to CO2 for natural gas . CO2 (Natural Gas) [lb/MMBtu] = (0.0036 scf/Btu)(%CON)(C)(D), where %CON = weight percent conversion of fuel carbon to CO2, C = carbon content of fuel by weight, and D = density of fuel. For natural gas, C is assumed at 75%, and D is assumed at 4.1 E+04 lb/106scf.

Flaring

General http://www.eea.europa.eu/publications/EMEPCORINAIR4/B926vs2.2.pdf
Corinair Emission Factors
All emissions are in g/Sm3

Note 1 Instead of using Corinair emission rates for CO2 and CH4, the emissions have been calculated using a mass balance. The Corinair emission rates will depend on the composition of the gases used to determine these rates. As the composition of the gas of interest has been provided, it is more accurate to use a mass balance for these pollutants. A 99% combustion efficiency is assumed for these 2 pollutants

Note 2

Note 3

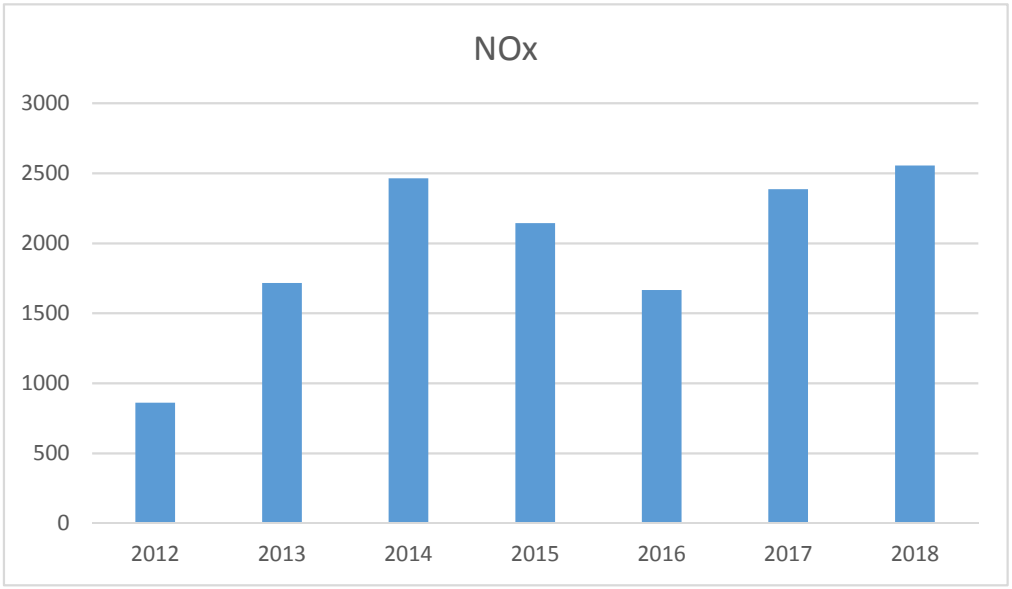
Note 4 No VOC value is provided so NMVOC is used; thus this is likely to underestimate the emissions of VOCs

GHG Emissions

Note 1 Based on CH4 GWP of 23, as in the TAR IPCC, 2001. Climate Change 1995: The Physical Science Basis, Contribution of Working Group I to the Second Assessment Report of the Intergovernmental Panel on Climate Change (IPCC)

Fuel Consumption

	2012		2013		2014		2015		2016		2017		2018	
	Diesel m^3	Gas MMscf	Diesel m^3	Gas MMscf	Diesel m^3	Gas MMscf	Diesel m^3	Gas MMscf	Diesel m^3	Gas MMscf	Diesel m^3	Gas MMscf	Diesel m^3	Gas MMscf
Jan	66.00	306.70	6.00	309.20	170.00	239.20	19.00	243.64	281.00	213.43	955.00	275.20	589.80	234.30
Feb	143.00	232.70	415.00	244.30	119.00	265.10	117.00	238.27	136.00	242.13	883.00	201.60	2,813.00	1.70
Mar	77.00	260.20	276.00	220.70	212.00	261.00	34.00	227.71	768.00	0.00	686.00	245.60	1,931.00	211.40
Apr	323.00	222.40	98.00	242.50	16.00	248.60	24.00	256.67	2,083.00	0.00	658.00	251.90	184.00	269.80
May	68.00	243.50	362.00	242.20	43.00	267.80	68.00	270.93	1,686.00	213.48	926.00	201.40	197.00	278.30
Jun	51.00	273.00	48.00	249.00	8.00	227.70	221.00	274.52	790.00	216.05	595.00	243.00	1,138.00	81.20
Jul	49.00	266.80	216.00	221.80	94.00	224.00	20.00	201.24	836.00	267.30	381.50	249.30	689.00	273.00
Aug	121.00	241.40	239.00	179.00	0.00	281.60	50.00	251.07	651.00	253.63	97.20	240.50	405.60	285.00
Sep	114.00	273.10	287.00	115.20	543.00	244.70	16.00	245.48	583.00	263.54	137.10	223.40	239.00	324.70
Oct	35.00	287.60	140.00	192.40	38.00	272.20	75.00	264.75	821.00	303.98	57.00	217.00	26.00	354.25
Nov	6.00	280.00	178.00	222.00	16.00	407.00	40.00	259.74	799.00	267.36	54.00	199.90	772.00	285.90
Dec	113.00	262.00	206.00	264.50	27.00	279.00	49.00	241.76	804.00	302.48	27.90	239.70	306.00	313.00
Totals	**1,166.00**	**3,149.40**	**2,471.00**	**2,702.80**	**1,286.00**	**3,217.90**	**733.00**	**2,975.78**	**10,238.00**	**2,543.37**	**5,457.70**	**2,788.50**	**9,290.40**	**2,912.55**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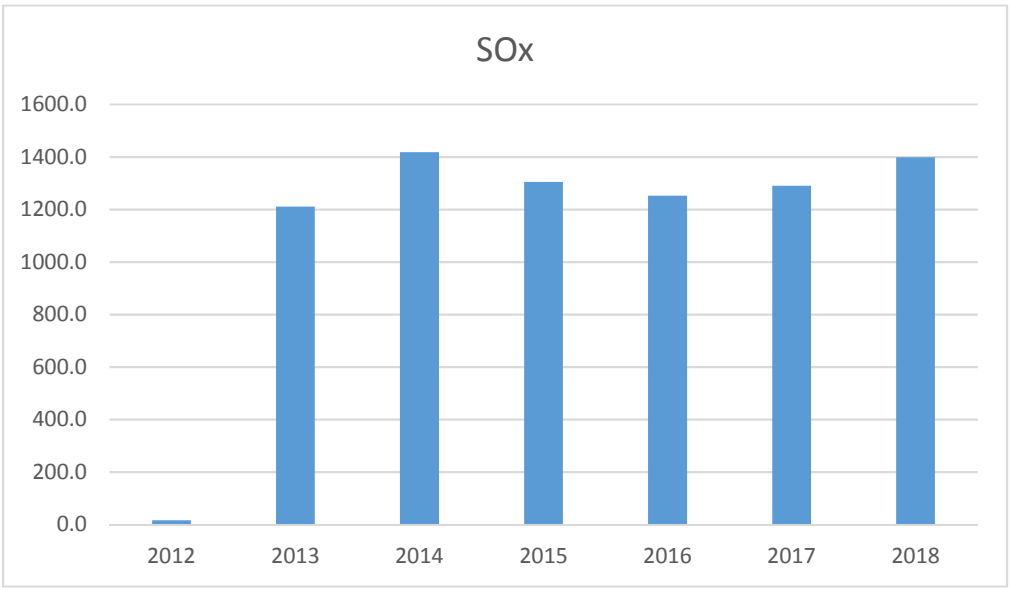
2500
2000
1500
1000
500
0
2012
2013
2014
2015
2016
2017
2018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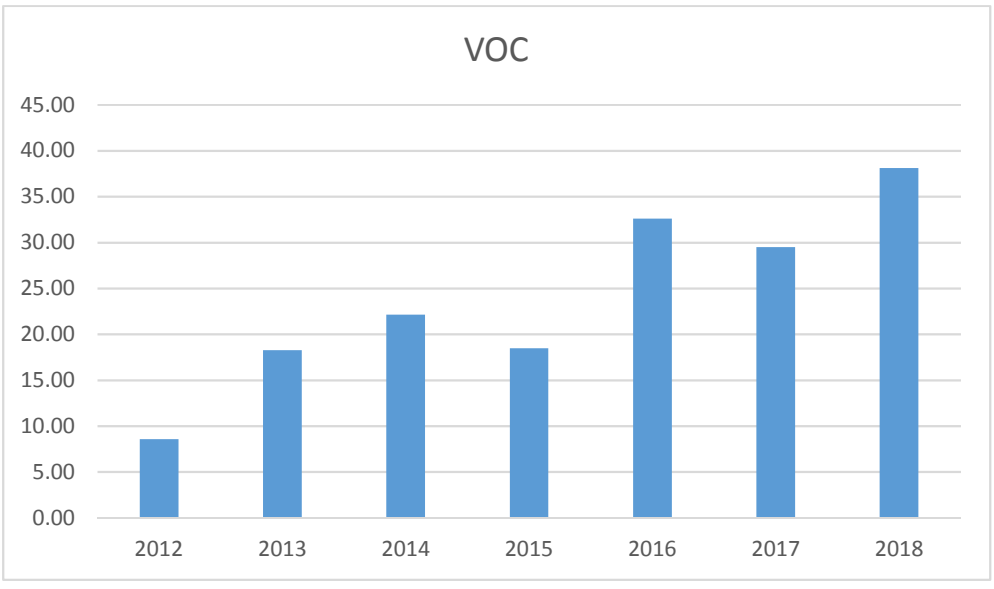
1200.0
1000.0
800.0
600.0
400.0
200.0
0.0
2012
2013
2014
2015
2016
2017
2018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35.00
30.00
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20.00
15.00
10.00
5.00
0.00
2012
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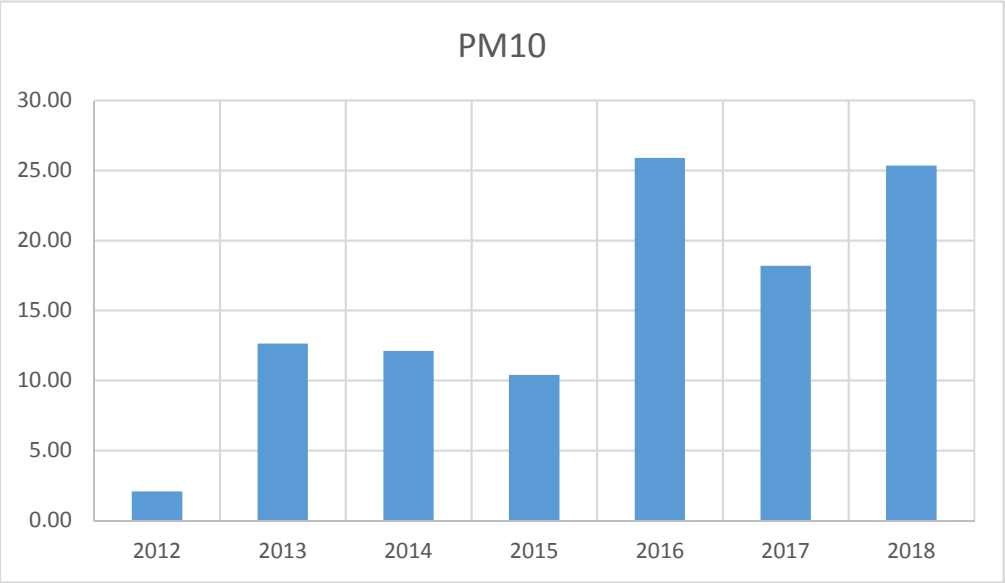
2015
2016
2017
2018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20.00
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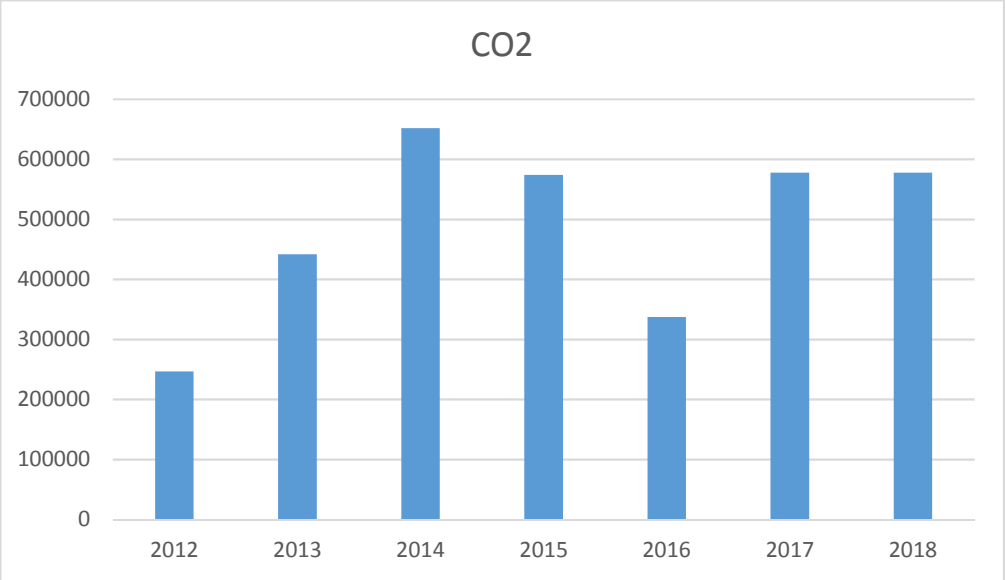
2012
2013
2014
2015
2016
2017
2018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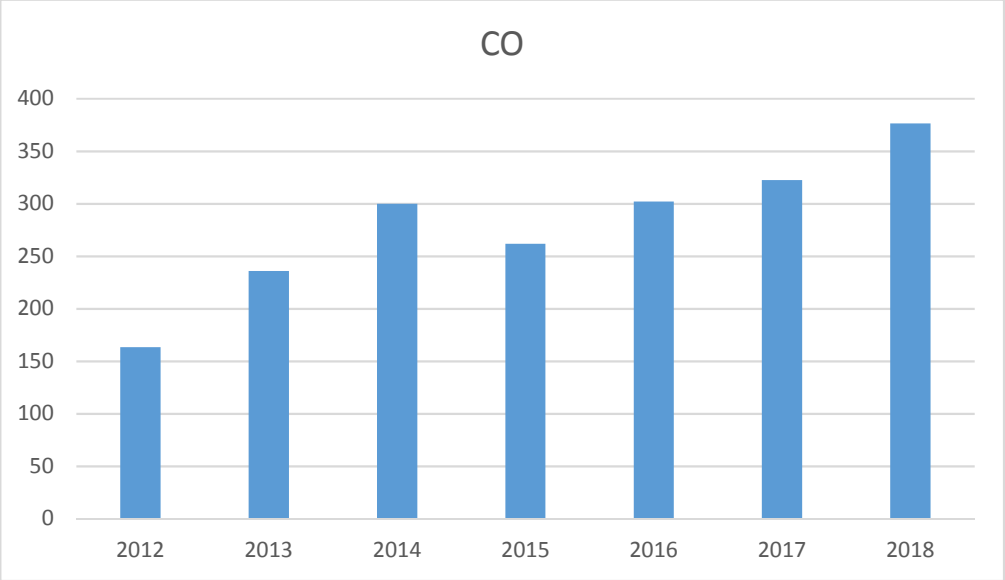
2012
2013
2014
2015
2016
2017
2018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200
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50
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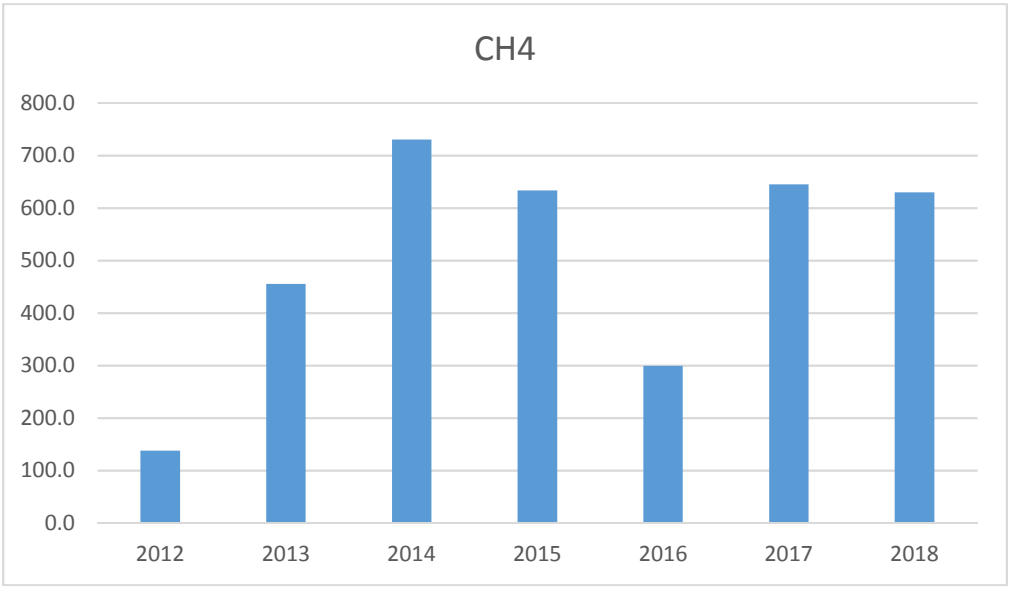
2012
2013
2014
2015
2016
2017
2018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700.0
600.0
500.0
400.0
300.0
200.0
100.0
0.0
2012
2013
2014
2015
2016
2017
2018

	2018		
	Diesel m^3	Gas MMscf	Flare MMscf
Totals	**9,290.40**	**2,912.55**	**4,702.42**

Equipment								
Diesel Engines								
Natural Gas Engines			Please Provide Estimate		Consumption			Source
Burners	**Fuel Used**	**More Details**	% of Annual FPSO Gas Consumption	% of Annual FPSO Diesel Consumption	**MMscf**	**m3**	**MMBtu**	
Recip. (Duel fuel)	Diesel		0	10	0	929	33631	https://www3.epa.gov/ttn/chief/ap42/ch03/final/c03s04.pdf
Recip. (Duel fuel)	Diesel		0	10	0	929	33631	
Recip. (Duel fuel)	Diesel		0	10	0	929	33631	
Recip. (emerg)	Diesel		0	5	0	464.5	16815	
Recip. (crane)	Diesel		0	10	0	929	33631	https://www3.epa.gov/ttn/chief/ap42/ch03/final/c03s03.pdf
Recip. (crane)	Diesel		0	10	0	929	33631	
Recip (shipbrd)	Diesel		0	5	0	464.5	16815	https://www3.epa.gov/ttn/chief/ap42/ch03/final/c03s04.pdf
Recip (shipbrd)	Diesel		0	5	0	464.5	16815	
Recip. (tanker)	Diesel		0	35	0	3252	117707	https://www3.epa.gov/ttn/chief/ap42/ch03/final/c03s04.pdf
Supply/contingency vessel	MGO	185 ft work boat	Please Confirm FPSO fuel use data provided on applies to FPSO only					
Hold back vessel	MGO							
Multi Service Vessel (MSV) with daughter vessel	MGO							
Turbine natural gas **(GTG A)**	Natural Gas	Electricity generation on FPSO	33	0	961	0	980364	https://www3.epa.gov/ttn/chief/ap42/ch03/final/c03s01.pdf
Turbine natiural gas **(GTG B)**	Natural Gas	Electricity generation on FPSO	34	0	990	0	1010072	
Turbine natural gas **(GTG C)**	Natural Gas	Electricity generation on FPSO	33	0	961	0	980364	
					MMscf	**Sm3**		
FLARE	Natural Gas	see Flare calc			4702	133158537		http://www.eea.europa.eu/publications/EMEPCORINAIR4/B926vs2.2.pdf

1% S

			Emission Factors							Calculated mass emission						
average heating value		average density	PM10	SOx	NOx	VOC	CO	CO2	CH4	PM10	SOx	NOx	VOC	CO	CO2	CH4
		lb/gallon	**lb/MMBtu**							**tonne/y**						
19300	Btu/lb	7.1	0.0573	1.01	3.2	0.09	0.85	165	0.09	0.874	15.407	48.815	1.373	12.966	2517	1.373
19300	Btu/lb	7.1	0.0573	1.01	3.2	0.09	0.85	165	0.09	0.874	15.407	48.815	1.373	12.966	2517	1.373
19300	Btu/lb	7.1	0.0573	1.01	3.2	0.09	0.85	165	0.09	0.874	15.407	48.815	1.373	12.966	2517	1.373
19300	Btu/lb	7.1	0.0573	1.01	3.2	0.09	0.85	165	0.09	0.437	7.704	24.407	0.686	6.483	1259	0.686
19300	Btu/lb	7.1	0.31	0.29	4.41	0.36	0.95	164	0.36	4.729	4.424	67.273	5.492	14.492	2502	5.492
19300	Btu/lb	7.1	0.31	0.29	4.41	0.36	0.95	164	0.36	4.729	4.424	67.273	5.492	14.492	2502	5.492
19300	Btu/lb	7.1	0.0573	1.01	3.2	0.09	0.85	165	0.09	0.437	7.704	24.407	0.686	6.483	1259	0.686
19300	Btu/lb	7.1	0.0573	1.01	3.2	0.09	0.85	165	0.09	0.437	7.704	24.407	0.686	6.483	1259	0.686
19300	Btu/lb	7.1	0.0573	1.01	3.2	0.09	0.85	165	0.09	3.059	53.925	170.851	4.805	45.382	8810	4.805
1020	Btu/scf		0.0066	0.940	0.32	0.0021	0.082	110	0.0086	~~3~~	~~418~~	142	0.934	36.464	48915	3.824
1020	Btu/scf		0.0066	0.940	0.32	0.0021	0.082	110	0.0086	~~3~~	~~431~~	147	0.962	37.569	50398	3.940
1020	Btu/scf		0.0066	0.940	0.32	0.0021	0.082	110	0.0086	~~3~~	~~418~~	142	0.934	36.464	48915	3.824
			g/Sm3							**tonne/y**						
					12	0.1	1					1598	13.32	133.2	404152	596
									TOTAL	**25.3**	**1399**	**2554**	**38.1**	**376**	**577520**	**630**

	2017		
	Diesel m^3	Gas MMscf	Flare MMscf
Totals	**5,457.70**	**2,788.50**	**4,899.93**

Operation	Equipment								
	Diesel Engines								
	Natural Gas Engines			Please Provide Estimate		Consumption			Source
	Burners	Fuel Used	More Details	% of Annual FPSO Gas Consumption	% of Annual FPSO Diesel Consumption	MMscf	m3	MMBtu	
FPSO	Recip. (Duel fuel)	Diesel		0	10	0	546	19756	https://www3.epa.gov/ttn/chief/ap42/ch03/final/c03s04.pdf
	Recip. (Duel fuel)	Diesel		0	10	0	546	19756	
	Recip. (Duel fuel)	Diesel		0	10	0	546	19756	
	Recip. (emerg)	Diesel		0	5	0	272.9	9878	
	Recip. (crane)	Diesel		0	10	0	546	19756	https://www3.epa.gov/ttn/chief/ap42/ch03/final/c03s03.pdf
	Recip. (crane)	Diesel		0	10	0	546	19756	
	Recip (shipbrd)	Diesel		0	5	0	272.9	9878	https://www3.epa.gov/ttn/chief/ap42/ch03/final/c03s04.pdf
	Recip (shipbrd)	Diesel		0	5	0	272.9	9878	
	Recip. (tanker)	Diesel		0	35	0	1910	69148	https://www3.epa.gov/ttn/chief/ap42/ch03/final/c03s04.pdf
	Supply/contingency vessel	MGO	185 ft work boat	Please Confirm FPSO fuel use data provided on applies to FPSO only					
	Hold back vessel	MGO							
	Multi Service Vessel (MSV) with daughter vessel	MGO							
	Turbine natural gas **(GTG A)**	Natural Gas	Electricity generation on FPSO	33	0	920	0	938609	https://www3.epa.gov/ttn/chief/ap42/ch03/final/c03s01.pdf
	Turbine natiural gas **(GTG B)**	Natural Gas	Electricity generation on FPSO	34	0	948	0	967052	
	Turbine natural gas **(GTG C)**	Natural Gas	Electricity generation on FPSO	33	0	920	0	938609	
						MMscf	**Sm3**		
	FLARE	Natural Gas	see Flare calc			4900	138751254		http://www.eea.europa.eu/publications/EMEPCORINAIR4/B926vs2.2.pdf

1% S

average heating value		average density	Emission Factors: PM10	SOx	NOx	VOC	CO	CO2	CH4	Calculated mass emission: PM10	SOx	NOx	VOC	CO	CO2	CH4
		lb/gallon	**lb/MMBtu**							**tonne/y**						
19300	Btu/lb	7.1	0.0573	1.01	3.2	0.09	0.85	165	0.09	0.513	9.051	28.676	0.807	7.617	1479	0.807
19300	Btu/lb	7.1	0.0573	1.01	3.2	0.09	0.85	165	0.09	0.513	9.051	28.676	0.807	7.617	1479	0.807
19300	Btu/lb	7.1	0.0573	1.01	3.2	0.09	0.85	165	0.09	0.513	9.051	28.676	0.807	7.617	1479	0.807
19300	Btu/lb	7.1	0.0573	1.01	3.2	0.09	0.85	165	0.09	0.257	4.525	14.338	0.403	3.809	739	0.403
19300	Btu/lb	7.1	0.31	0.29	4.41	0.36	0.95	164	0.36	2.778	2.599	39.520	3.226	8.513	1470	3.226
19300	Btu/lb	7.1	0.31	0.29	4.41	0.36	0.95	164	0.36	2.778	2.599	39.520	3.226	8.513	1470	3.226
19300	Btu/lb	7.1	0.0573	1.01	3.2	0.09	0.85	165	0.09	0.257	4.525	14.338	0.403	3.809	739	0.403
19300	Btu/lb	7.1	0.0573	1.01	3.2	0.09	0.85	165	0.09	0.257	4.525	14.338	0.403	3.809	739	0.403
19300	Btu/lb	7.1	0.0573	1.01	3.2	0.09	0.85	165	0.09	1.797	31.678	100.367	2.823	26.660	5175	2.823
1020	Btu/scf		0.0066	0.940	0.32	0.0021	0.082	110	0.0086	~~3~~	~~400~~	136	0.894	34.911	46832	3.661
1020	Btu/scf		0.0066	0.940	0.32	0.0021	0.082	110	0.0086	~~3~~	~~412~~	140	0.921	35.969	48251	3.772
1020	Btu/scf		0.0066	0.940	0.32	0.0021	0.082	110	0.0086	~~3~~	~~400~~	136	0.894	34.911	46832	3.661
			g/Sm3							**tonne/y**						
					12	0.1	1					1665	13.88	138.8	421126	621
									TOTAL	**18.2**	**1290**	**2386**	**29.5**	**323**	**577810**	**645**

	2016		
	Diesel m^3	Gas MMscf	Flare MMscf
Totals	**10,238.00**	**2,543.37**	**2,092.97**

Operation	Equipment								
	Diesel Engines								
	Natural Gas Engines			Please Provide Estimate		Consumption			Source
	Burners	Fuel Used	More Details	% of Annual FPSO Gas Consumption	% of Annual FPSO Diesel Consumption	MMscf	m3	MMBtu	
FPSO	Recip. (Duel fuel)	Diesel		0	10	0	1024	37061	https://www3.epa.gov/ttn/chief/ap42/ch03/final/c03s04.pdf
	Recip. (Duel fuel)	Diesel		0	10	0	1024	37061	
	Recip. (Duel fuel)	Diesel		0	10	0	1024	37061	
	Recip. (emerg)	Diesel		0	5	0	511.9	18530	
	Recip. (crane)	Diesel		0	10	0	1024	37061	https://www3.epa.gov/ttn/chief/ap42/ch03/final/c03s03.pdf
	Recip. (crane)	Diesel		0	10	0	1024	37061	
	Recip (shipbrd)	Diesel		0	5	0	511.9	18530	https://www3.epa.gov/ttn/chief/ap42/ch03/final/c03s04.pdf
	Recip (shipbrd)	Diesel		0	5	0	511.9	18530	
	Recip. (tanker)	Diesel		0	35	0	3583	129713	https://www3.epa.gov/ttn/chief/ap42/ch03/final/c03s04.pdf
	Supply/contingency vessel	MGO	185 ft work boat	Please Confirm FPSO fuel use data provided on applies to FPSO only					
	Hold back vessel	MGO							
	Multi Service Vessel (MSV) with daughter vessel	MGO							
	Turbine natural gas **(GTG A)**	Natural Gas	Electricity generation on FPSO	33	0	839	0	856099	https://www3.epa.gov/ttn/chief/ap42/ch03/final/c03s01.pdf
	Turbine natiural gas **(GTG B)**	Natural Gas	Electricity generation on FPSO	34	0	865	0	882041	
	Turbine natural gas **(GTG C)**	Natural Gas	Electricity generation on FPSO	33	0	839	0	856099	
						MMscf	**Sm3**		
	FLARE	Natural Gas	see Flare calc			2093	59266770		http://www.eea.europa.eu/publications/EMEPCORINAIR4/B926vs2.2.pd

1% S

average heating value		average density	Emission Factors PM10	SOx	NOx	VOC	CO	CO2	CH4	Calculated mass emission PM10	SOx	NOx	VOC	CO	CO2	CH4
		lb/gallon	**lb/MMBtu**							**tonne/y**						
19300	Btu/lb	7.1	0.0573	1.01	3.2	0.09	0.85	165	0.09	0.963	16.979	53.794	1.513	14.289	2774	1.513
19300	Btu/lb	7.1	0.0573	1.01	3.2	0.09	0.85	165	0.09	0.963	16.979	53.794	1.513	14.289	2774	1.513
19300	Btu/lb	7.1	0.0573	1.01	3.2	0.09	0.85	165	0.09	0.963	16.979	53.794	1.513	14.289	2774	1.513
19300	Btu/lb	7.1	0.0573	1.01	3.2	0.09	0.85	165	0.09	0.482	8.489	26.897	0.756	7.144	1387	0.756
19300	Btu/lb	7.1	0.31	0.29	4.41	0.36	0.95	164	0.36	5.211	4.875	74.134	6.052	15.970	2757	6.052
19300	Btu/lb	7.1	0.31	0.29	4.41	0.36	0.95	164	0.36	5.211	4.875	74.134	6.052	15.970	2757	6.052
19300	Btu/lb	7.1	0.0573	1.01	3.2	0.09	0.85	165	0.09	0.482	8.489	26.897	0.756	7.144	1387	0.756
19300	Btu/lb	7.1	0.0573	1.01	3.2	0.09	0.85	165	0.09	0.482	8.489	26.897	0.756	7.144	1387	0.756
19300	Btu/lb	7.1	0.0573	1.01	3.2	0.09	0.85	165	0.09	3.371	59.425	188.277	5.295	50.011	9708	5.295
1020	Btu/scf		0.0066	0.940	0.32	0.0021	0.082	110	0.0086	~~3~~	~~365~~	124	0.815	31.842	42715	3.340
1020	Btu/scf		0.0066	0.940	0.32	0.0021	0.082	110	0.0086	~~3~~	~~376~~	128	0.840	32.807	44010	3.441
1020	Btu/scf		0.0066	0.940	0.32	0.0021	0.082	110	0.0086	~~3~~	~~365~~	124	0.815	31.842	42715	3.340
			g/Sm3							**tonne/y**						
lf					12	0.1	1					711	5.93	59.3	179881	265
									TOTAL	**25.9**	**1252**	**1666**	**32.6**	**302**	**337025**	**300**

	2015		
	Diesel m^3	Gas MMscf	Flare MMscf
Totals	**733.00**	**2,975.78**	**4,889.95**

Operation	Equipment								
	Diesel Engines								
	Natural Gas Engines			Please Provide Estimate		Consumption			Source
	Burners	Fuel Used	More Details	% of Annual FPSO Gas Consumption	% of Annual FPSO Diesel Consumption	MMscf	m3	MMBtu	
FPSO	Recip. (Duel fuel)	Diesel		0	10	0	73	2653	https://www3.epa.gov/ttn/chief/ap42/ch03/final/c03s04.pdf
	Recip. (Duel fuel)	Diesel		0	10	0	73	2653	
	Recip. (Duel fuel)	Diesel		0	10	0	73	2653	
	Recip. (emerg)	Diesel		0	5	0	36.7	1327	
	Recip. (crane)	Diesel		0	10	0	73	2653	https://www3.epa.gov/ttn/chief/ap42/ch03/final/c03s03.pdf
	Recip. (crane)	Diesel		0	10	0	73	2653	
	Recip (shipbrd)	Diesel		0	5	0	36.7	1327	https://www3.epa.gov/ttn/chief/ap42/ch03/final/c03s04.pdf
	Recip (shipbrd)	Diesel		0	5	0	36.7	1327	
	Recip. (tanker)	Diesel		0	35	0	257	9287	https://www3.epa.gov/ttn/chief/ap42/ch03/final/c03s04.pdf
	Supply/contingency vessel	MGO	185 ft work boat	Please Confirm FPSO fuel use data provided on applies to FPSO only					
	Hold back vessel	MGO							
	Multi Service Vessel (MSV) with daughter vessel	MGO							
	Turbine natural gas **(GTG A)**	Natural Gas	Electricity generation on FPSO	33	0	982	0	1001648	https://www3.epa.gov/ttn/chief/ap42/ch03/final/c03s01.pdf
	Turbine natiural gas **(GTG B)**	Natural Gas	Electricity generation on FPSO	34	0	1012	0	1032001	
	Turbine natural gas **(GTG C)**	Natural Gas	Electricity generation on FPSO	33	0	982	0	1001648	
						MMscf	**Sm3**		
	FLARE	Natural Gas	see Flare calc			4890	138468581		http://www.eea.europa.eu/publications/EMEPCORINAIR4/B926vs2.2.pdf

				1% S												
						Emission Factors							Calculated mass emission			
average heating value		average density	PM10	SOx	NOx	VOC	CO	CO2	CH4	PM10	SOx	NOx	VOC	CO	CO2	CH4
		lb/gallon				**lb/MMBtu**							**tonne/y**			
19300	Btu/lb	7.1	0.0573	1.01	3.2	0.09	0.85	165	0.09	0.069	1.216	3.851	0.108	1.023	199	0.108
19300	Btu/lb	7.1	0.0573	1.01	3.2	0.09	0.85	165	0.09	0.069	1.216	3.851	0.108	1.023	199	0.108
19300	Btu/lb	7.1	0.0573	1.01	3.2	0.09	0.85	165	0.09	0.069	1.216	3.851	0.108	1.023	199	0.108
19300	Btu/lb	7.1	0.0573	1.01	3.2	0.09	0.85	165	0.09	0.034	0.608	1.926	0.054	0.512	99	0.054
19300	Btu/lb	7.1	0.31	0.29	4.41	0.36	0.95	164	0.36	0.373	0.349	5.308	0.433	1.143	197	0.433
19300	Btu/lb	7.1	0.31	0.29	4.41	0.36	0.95	164	0.36	0.373	0.349	5.308	0.433	1.143	197	0.433
19300	Btu/lb	7.1	0.0573	1.01	3.2	0.09	0.85	165	0.09	0.034	0.608	1.926	0.054	0.512	99	0.054
19300	Btu/lb	7.1	0.0573	1.01	3.2	0.09	0.85	165	0.09	0.034	0.608	1.926	0.054	0.512	99	0.054
19300	Btu/lb	7.1	0.0573	1.01	3.2	0.09	0.85	165	0.09	0.241	4.255	13.480	0.379	3.581	695	0.379
1020	Btu/scf		0.0066	0.940	0.32	0.0021	0.082	110	0.0086	~~3~~	~~427~~	145	0.954	37.256	49977	3.907
1020	Btu/scf		0.0066	0.940	0.32	0.0021	0.082	110	0.0086	~~3~~	~~440~~	150	0.983	38.385	51492	4.026
1020	Btu/scf		0.0066	0.940	0.32	0.0021	0.082	110	0.0086	~~3~~	~~427~~	145	0.954	37.256	49977	3.907
						g/Sm3							**tonne/y**			
					12	0.1	1					1662	13.85	138.5	420268	620
									TOTAL	**10.4**	**1305**	**2144**	**18.5**	**262**	**573698**	**633**

	2014		
	Diesel m^3	Gas MMscf	Flare MMscf
Totals	**1,286.00**	**3,217.90**	**5,635.70**

Operation	Equipment								
	Diesel Engines								
	Natural Gas Engines			Please Provide Estimate		Consumption			Source
	Burners	Fuel Used	More Details	% of Annual FPSO Gas Consumption	% of Annual FPSO Diesel Consumption	MMscf	m3	MMBtu	
FPSO	Recip. (Duel fuel)	Diesel		0	10	0	129	4655	https://www3.epa.gov/ttn/chief/ap42/ch03/final/c03s04.pdf
	Recip. (Duel fuel)	Diesel		0	10	0	129	4655	
	Recip. (Duel fuel)	Diesel		0	10	0	129	4655	
	Recip. (emerg)	Diesel		0	5	0	64.3	2328	
	Recip. (crane)	Diesel		0	10	0	129	4655	https://www3.epa.gov/ttn/chief/ap42/ch03/final/c03s03.pdf
	Recip. (crane)	Diesel		0	10	0	129	4655	
	Recip (shipbrd)	Diesel		0	5	0	64.3	2328	https://www3.epa.gov/ttn/chief/ap42/ch03/final/c03s04.pdf
	Recip (shipbrd)	Diesel		0	5	0	64.3	2328	
	Recip. (tanker)	Diesel		0	35	0	450	16293	https://www3.epa.gov/ttn/chief/ap42/ch03/final/c03s04.pdf
	Supply/contingency vessel	MGO	185 ft work boat	Please Confirm FPSO fuel use data provided on applies to FPSO only					
	Hold back vessel	MGO							
	Multi Service Vessel (MSV) with daughter vessel	MGO							
	Turbine natural gas **(GTG A)**	Natural Gas	Electricity generation on FPSO	33	0	1062	0	1083145	https://www3.epa.gov/ttn/chief/ap42/ch03/final/c03s01.pdf
	Turbine natiural gas **(GTG B)**	Natural Gas	Electricity generation on FPSO	34	0	1094	0	1115968	
	Turbine natural gas **(GTG C)**	Natural Gas	Electricity generation on FPSO	33	0	1062	0	1083145	
						MMscf	**Sm3**		
	FLARE	Natural Gas	see Flare calc			5636	159586186		http://www.eea.europa.eu/publications/EMEPCORINAIR4/B926vs2.2.pdf

1% S

average heating value		average density	Emission Factors							Calculated mass emission						
			PM10	SOx	NOx	VOC	CO	CO2	CH4	PM10	SOx	NOx	VOC	CO	CO2	CH4
		lb/gallon	**lb/MMBtu**							**tonne/y**						
19300	Btu/lb	7.1	0.0573	1.01	3.2	0.09	0.85	165	0.09	0.121	2.133	6.757	0.190	1.795	348	0.190
19300	Btu/lb	7.1	0.0573	1.01	3.2	0.09	0.85	165	0.09	0.121	2.133	6.757	0.190	1.795	348	0.190
19300	Btu/lb	7.1	0.0573	1.01	3.2	0.09	0.85	165	0.09	0.121	2.133	6.757	0.190	1.795	348	0.190
19300	Btu/lb	7.1	0.0573	1.01	3.2	0.09	0.85	165	0.09	0.060	1.066	3.379	0.095	0.897	174	0.095
19300	Btu/lb	7.1	0.31	0.29	4.41	0.36	0.95	164	0.36	0.655	0.612	9.312	0.760	2.006	346	0.760
19300	Btu/lb	7.1	0.31	0.29	4.41	0.36	0.95	164	0.36	0.655	0.612	9.312	0.760	2.006	346	0.760
19300	Btu/lb	7.1	0.0573	1.01	3.2	0.09	0.85	165	0.09	0.060	1.066	3.379	0.095	0.897	174	0.095
19300	Btu/lb	7.1	0.0573	1.01	3.2	0.09	0.85	165	0.09	0.060	1.066	3.379	0.095	0.897	174	0.095
19300	Btu/lb	7.1	0.0573	1.01	3.2	0.09	0.85	165	0.09	0.423	7.464	23.650	0.665	6.282	1219	0.665
1020	Btu/scf		0.0066	0.940	0.32	0.0021	0.082	110	0.0086	~~3~~	~~462~~	157	1.032	40.287	54044	4.225
1020	Btu/scf		0.0066	0.940	0.32	0.0021	0.082	110	0.0086	~~3~~	~~476~~	162	1.063	41.508	55681	4.353
1020	Btu/scf		0.0066	0.940	0.32	0.0021	0.082	110	0.0086	~~3~~	~~462~~	157	1.032	40.287	54044	4.225
			g/Sm3							**tonne/y**						
					12	0.1	1					1915	15.96	159.6	484363	714
									TOTAL	**12.10**	**1417.8**	**2464**	**22.13**	**300**	**651611**	**730**

	2013		
	Diesel m^3	Gas MMscf	Flare MMscf
Totals	**2,471.00**	**2,702.80**	**3,463.39**

Operation	Equipment					Consumption			Source
	Diesel Engines								
	Natural Gas Engines			Please Provide Estimate					
	Burners	Fuel Used	More Details	% of Annual FPSO Gas Consumption	% of Annual FPSO Diesel Consumption	MMscf	m3	MMBtu	
FPSO	Recip. (Duel fuel)	Diesel		0	10	0	247	8945	https://www3.epa.gov/ttn/chief/ap42/ch03/final/c03s04.pdf
	Recip. (Duel fuel)	Diesel		0	10	0	247	8945	
	Recip. (Duel fuel)	Diesel		0	10	0	247	8945	
	Recip. (emerg)	Diesel		0	5	0	123.6	4472	
	Recip. (crane)	Diesel		0	10	0	247	8945	https://www3.epa.gov/ttn/chief/ap42/ch03/final/c03s03.pdf
	Recip. (crane)	Diesel		0	10	0	247	8945	
	Recip (shipbrd)	Diesel		0	5	0	123.6	4472	https://www3.epa.gov/ttn/chief/ap42/ch03/final/c03s04.pdf
	Recip (shipbrd)	Diesel		0	5	0	123.6	4472	
	Recip. (tanker)	Diesel		0	35	0	865	31307	https://www3.epa.gov/ttn/chief/ap42/ch03/final/c03s04.pdf
	Supply/contingency vessel	MGO	185 ft work boat	Please Confirm FPSO fuel use data provided on applies to FPSO only					
	Hold back vessel	MGO							
	Multi Service Vessel (MSV) with daughter vessel	MGO							
	Turbine natural gas **(GTG A)**	Natural Gas	Electricity generation on FPSO	33	0	892	0	909762	https://www3.epa.gov/ttn/chief/ap42/ch03/final/c03s01.pdf
	Turbine natiural gas **(GTG B)**	Natural Gas	Electricity generation on FPSO	34	0	919	0	937331	
	Turbine natural gas **(GTG C)**	Natural Gas	Electricity generation on FPSO	33	0	892	0	909762	
						MMscf	**Sm3**		
	FLARE	Natural Gas	see Flare calc			3463	98072776		http://www.eea.europa.eu/publications/EMEPCORINAIR4/B926vs2.2.p

				1% S												
						Emission Factors							Calculated mass emission			
average heating value		average density	PM10	SOx	NOx	VOC	CO	CO2	CH4	PM10	SOx	NOx	VOC	CO	CO2	CH4
		lb/gallon				**lb/MMBtu**							**tonne/y**			
19300	Btu/lb	7.1	0.0573	1.01	3.2	0.09	0.85	165	0.09	0.232	4.098	12.983	0.365	3.449	669	0.365
19300	Btu/lb	7.1	0.0573	1.01	3.2	0.09	0.85	165	0.09	0.232	4.098	12.983	0.365	3.449	669	0.365
19300	Btu/lb	7.1	0.0573	1.01	3.2	0.09	0.85	165	0.09	0.232	4.098	12.983	0.365	3.449	669	0.365
19300	Btu/lb	7.1	0.0573	1.01	3.2	0.09	0.85	165	0.09	0.116	2.049	6.492	0.183	1.724	335	0.183
19300	Btu/lb	7.1	0.31	0.29	4.41	0.36	0.95	164	0.36	1.258	1.177	17.893	1.461	3.854	665	1.461
19300	Btu/lb	7.1	0.31	0.29	4.41	0.36	0.95	164	0.36	1.258	1.177	17.893	1.461	3.854	665	1.461
19300	Btu/lb	7.1	0.0573	1.01	3.2	0.09	0.85	165	0.09	0.116	2.049	6.492	0.183	1.724	335	0.183
19300	Btu/lb	7.1	0.0573	1.01	3.2	0.09	0.85	165	0.09	0.116	2.049	6.492	0.183	1.724	335	0.183
19300	Btu/lb	7.1	0.0573	1.01	3.2	0.09	0.85	165	0.09	0.814	14.343	45.442	1.278	12.070	2343	1.278
1020	Btu/scf		0.0066	0.940	0.32	0.0021	0.082	110	0.0086	~~3~~	~~388~~	132	0.867	33.838	45393	3.549
1020	Btu/scf		0.0066	0.940	0.32	0.0021	0.082	110	0.0086	~~3~~	~~400~~	136	0.893	34.864	46768	3.656
1020	Btu/scf		0.0066	0.940	0.32	0.0021	0.082	110	0.0086	~~3~~	~~388~~	132	0.867	33.838	45393	3.549
						g/Sm3							**tonne/y**			
df					12	0.1	1					1177	9.81	98.1	297662	439
									TOTAL	**12.63**	**1210.6**	**1717**	**18.28**	**236**	**441902**	**456**

	2012		
	Diesel m^3	Gas MMscf	Flare MMscf
Totals	**1,166.00**	**3,149.40**	**966.03**

Operation	Equipment					Consumption			Source
	Diesel Engines								
	Natural Gas Engines			Estimate					
	Burners	Fuel Used	More Details	% of Annual FPSO Gas Consumption	% of Annual FPSO Diesel Consumption	MMscf	m3	MMBtu	
FPSO	Recip. (Duel fuel)	Diesel		0	10	0	117	4221	https://www3.epa.gov/ttn/chief/ap42/ch03/final/c03s04.pdf
	Recip. (Duel fuel)	Diesel		0	10	0	117	4221	
	Recip. (Duel fuel)	Diesel		0	10	0	117	4221	
	Recip. (emerg)	Diesel		0	5	0	58.3	2110	
	Recip. (crane)	Diesel		0	10	0	117	4221	https://www3.epa.gov/ttn/chief/ap42/ch03/final/c03s03.pdf
	Recip. (crane)	Diesel		0	10	0	117	4221	
	Recip (shipbrd)	Diesel		0	5	0	58.3	2110	https://www3.epa.gov/ttn/chief/ap42/ch03/final/c03s04.pdf
	Recip (shipbrd)	Diesel		0	5	0	58.3	2110	
	Recip. (tanker)	Diesel		0	35	0	408	14773	https://www3.epa.gov/ttn/chief/ap42/ch03/final/c03s04.pdf
	Supply/contingency vessel	MGO	185 ft work boat	Please Confirm FPSO fuel use data provided on applies to FPSO only					
	Hold back vessel	MGO							
	Multi Service Vessel (MSV) with daughter vessel	MGO							
	Turbine natural gas **(GTG A)**	Natural Gas	Electricity generation on FPSO	33	0	1039	0	1060088	https://www3.epa.gov/ttn/chief/ap42/ch03/final/c03s01.pdf
	Turbine natiural gas **(GTG B)**	Natural Gas	Electricity generation on FPSO	34	0	1071	0	1092212	
	Turbine natural gas **(GTG C)**	Natural Gas	Electricity generation on FPSO	33	0	1039	0	1060088	
						MMscf	**Sm3**		
	FLARE	Natural Gas	see Flare calc			966	27355190		http://www.eea.europa.eu/publications/EMEPCORINAIR4/B926vs2.2.pdf

average heating value	average density	PM10	SOx	NOx	VOC	CO	CO2	CH4	PM10	SOx	NOx	VOC	CO	CO2	CH4
			1% S												
		Emission Factors							**Calculated mass emission**						
	lb/gallon	**lb/MMBtu**							**tonne/y**						
19300 Btu/lb	7.1	0.0573	1.01	3.2	0.09	0.85	165	0.09	0.110	1.934	6.127	0.172	1.627	316	0.172
19300 Btu/lb	7.1	0.0573	1.01	3.2	0.09	0.85	165	0.09	0.110	1.934	6.127	0.172	1.627	316	0.172
19300 Btu/lb	7.1	0.0573	1.01	3.2	0.09	0.85	165	0.09	0.110	1.934	6.127	0.172	1.627	316	0.172
19300 Btu/lb	7.1	0.0573	1.01	3.2	0.09	0.85	165	0.09	0.055	0.967	3.063	0.086	0.814	158	0.086
19300 Btu/lb	7.1	0.31	0.29	4.41	0.36	0.95	164	0.36	0.594	0.555	8.443	0.689	1.819	314	0.689
19300 Btu/lb	7.1	0.31	0.29	4.41	0.36	0.95	164	0.36	0.594	0.555	8.443	0.689	1.819	314	0.689
19300 Btu/lb	7.1	0.0573	1.01	3.2	0.09	0.85	165	0.09	0.055	0.967	3.063	0.086	0.814	158	0.086
19300 Btu/lb	7.1	0.0573	1.01	3.2	0.09	0.85	165	0.09	0.055	0.967	3.063	0.086	0.814	158	0.086
19300 Btu/lb	7.1	0.0573	1.01	3.2	0.09	0.85	165	0.09	0.384	6.768	21.443	0.603	5.696	1106	0.603
1020 Btu/scf		0.0066	0.940	0.32	0.0021	0.082	110	0.0086			154	1.010	39.430	52893	4.135
1020 Btu/scf		0.0066	0.940	0.32	0.0021	0.082	110	0.0086			159	1.040	40.624	54496	4.261
1020 Btu/scf		0.0066	0.940	0.32	0.0021	0.082	110	0.0086			154	1.010	39.430	52893	4.135
		g/Sm3							**tonne/y**						
				12	0.1	1					328	2.74	27.4	83026	122
								TOTAL	**2.06**	**16.6**	**860**	**8.55**	**163**	**246464**	**138**

2018

RMM flue gas	26.03	g	or	1 mole gas	0.0224	Nm3
Volume 1 mole gas	0.0224	Nm3			0.024451282	Sm3
Moles in 1 Nm3	44.64285714	mol/Nm3			0.863497026	SCF
Moles in 1 Sm3	40.89765101	mol/Sm3				
Mass in 1 Sm3 (Density)	1064.565856	g/Sm3		Flow rate of flue gas	4702423869	SCF/y
Mass in 1 SCF (Density)	30.14486353	g/SCF		Mole rate of flue gas	**5445790465.32**	**mole/y**
Mass flue gas rate	1.41754E+11	g/y				
Mole flue gas rate	**5445790465**	**mole/y**				

Flaring	1	year
Destruction Efficiency	0.99	Assuming 99% combustion efficiency

Component	Flashed Gas mole %	Flashed Gas mw%	Molecular mass of Mixture	RMM	Number of moles for components (mole/y)	Mass for components (g/y)	Moles of Carbon per component	Mass of carbon per component (g/y)	Mass of CO2 (g/y)
N2	0.72	0.77	0.20251	28.01	39209691.35	1098263455		0	
CO2	1.08	1.8	0.4734	44.01	58814537.03	2588427774	1	-	2587839629
H2S	0	0	0	34.08	0	0		0	
C1	68.23	41.52	10.91976	16.04	3715662834	59599231865	1	44587954014	
C2	8.76	9.99	2.62737	30.07	477051244.8	14344930930	2	11449229874	
C3	9.58	16.02	4.21326	44.1	521706726.6	23007266642	3	18781442157	
iC4	1.9	4.18	1.09934	58.12	103470018.8	6013677495	4	4966560904	
nC4	4.33	9.55	2.51165	58.12	235802727.1	13704854502	4	11318530903	
iC5	1.64	4.48	1.17824	72.15	89310963.63	6443786026	5	5358657818	
nC5	1.61	4.41	1.15983	72.15	87677226.49	6325911891	5	5260633589	
2MP	0.67	2.19	0.57597	86.18	36486796.12	3144432089	6	2627049320	
3MP	0.2	0.66	0.17358	86.18	10891580.93	938636444.6	6	784193827	
C6	0.51	1.66	0.43658	86.17	27773531.37	2393245198	6	1999694259	
MCP	0.23	0.75	0.19725	78.11	12525318.07	978352594.5	6	901822901.1	
BZ	0.04	0.11	0.02893	78.11	2178316.186	170148277.3	6	156838765.4	
2MH	0.06	0.22	0.05786	100.21	3267474.279	327433597.5	7	274467839.5	
3MH	0.07	0.25	0.06575	100.21	3812053.326	382005863.8	7	320212479.4	
C7	0.2	0.73	0.19199	97.04	10891580.93	1056919014	7	914892798.2	
MCH	0.07	0.25	0.06575	98.19	3812053.326	374305516.1	7	320212479.4	
TOL	0.06	0.21	0.05523	92.14	3267474.279	301065080.1	7	274467839.5	
C8	0.03	0.15	0.03945	114.22	1633737.14	186605456.1	8	156838765.4	
ETB	0	0	0	106.17	0	0	8	0	
PMXY	0	0	0	106.17	0	0	8	0	
OXY	0.01	0.03	0.00789	106.17	544579.0465	57817957.37	8	52279588.47	
C9	0.02	0.07	0.01841	128.248	1089158.093	139682347.1	9	117629074.1	
C10	0	0.01	0.00263	142.2738	0	0	10	0	
Totals	100	100			5446879623	1.43577E+11		1.10624E+11	2587839629
MW	26.3		26.30263						
Specific Gravity	0.91								
	26.4								
		0.200431		0.715825					

Summary

TOTAL AMOUNT OF PRODUCED CO2 (tonnes per y)	**404,152**
TOTAL AMOUNT OF PRODUCED CH4 (tonnes per y)	**596**

2017

RMM flue gas	26.03	g	or	1 mole gas	0.0224	Nm3
Volume 1 mole gas	0.0224	Nm3			0.024451282	Sm3
Moles in 1 Nm3	44.64285714	mol/Nm3			0.863497026	SCF
Moles in 1 Sm3	40.89765101	mol/Sm3				
Mass in 1 Sm3 (Density)	1064.565856	g/Sm3		Flow rate of flue gas	4899927732	SCF/y
Mass in 1 SCF (Density)	30.14486353	g/SCF		Mole rate of flue gas	**5674516051.38**	**mole/y**
Mass flue gas rate	1.47708E+11	g/y				
Mole flue gas rate	**5674516051**	**mole/y**				

Flaring	1	year
Destruction Efficiency	0.99	Assuming 99% combustion efficiency

Component	Flashed Gas mole %	Flashed Gas mw%	Molecular mass of Mixture	RMM	Number of moles for components (mole/y)	Mass for components (g/y)	Moles of Carbon per component	Mass of carbon per component (g/y)	Mass of CO2 (g/y)
N2	0.72	0.77	0.20251	28.01	40856515.57	1144391001		0	
CO2	1.08	1.8	0.4734	44.01	61284773.35	2697142875	1	-	2696530028
H2S	0	0	0	34.08	0	0		0	
C1	68.23	41.52	10.91976	16.04	3871722302	62102425722	1	46460667622	
C2	8.76	9.99	2.62737	30.07	497087606.1	14947424315	2	11930102546	
C3	9.58	16.02	4.21326	44.1	543618637.7	23973581924	3	19570270958	
iC4	1.9	4.18	1.09934	58.12	107815805	6266254585	4	5175158639	
nC4	4.33	9.55	2.51165	58.12	245706545	14280464397	4	11793914161	
iC5	1.64	4.48	1.17824	72.15	93062063.24	6714427863	5	5583723795	
nC5	1.61	4.41	1.15983	72.15	91359708.43	6591602963	5	5481582506	
2MP	0.67	2.19	0.57597	86.18	38019257.54	3276499615	6	2737386543	
3MP	0.2	0.66	0.17358	86.18	11349032.1	978059586.6	6	817130311.4	
C6	0.51	1.66	0.43658	86.17	28940031.86	2493762546	6	2083682294	
MCP	0.23	0.75	0.19725	78.11	13051386.92	1019443832	6	939699858.1	
BZ	0.04	0.11	0.02893	78.11	2269806.421	177294579.5	6	163426062.3	
2MH	0.06	0.22	0.05786	100.21	3404709.631	341185952.1	7	285995609	
3MH	0.07	0.25	0.06575	100.21	3972161.236	398050277.5	7	333661543.8	
C7	0.2	0.73	0.19199	97.04	11349032.1	1101310075	7	953318696.6	
MCH	0.07	0.25	0.06575	98.19	3972161.236	390026511.8	7	333661543.8	
TOL	0.06	0.21	0.05523	92.14	3404709.631	313709945.4	7	285995609	
C8	0.03	0.15	0.03945	114.22	1702354.815	194442967	8	163426062.3	
ETB	0	0	0	106.17	0	0	8	0	
PMXY	0	0	0	106.17	0	0	8	0	
OXY	0.01	0.03	0.00789	106.17	567451.6051	60246336.92	8	54475354.09	
C9	0.02	0.07	0.01841	128.248	1134903.21	145549066.9	9	122569546.7	
C10	0	0.01	0.00263	142.2738	0	0	10	0	
Totals	100	100			5675650955	1.49607E+11		1.1527E+11	2696530028
MW	26.3		26.30263						
Specific Gravity	0.91								
	26.4								
		0.200431		0.715825					

Summary

TOTAL AMOUNT OF PRODUCED CO2 (tonnes per y)	**421,126**
TOTAL AMOUNT OF PRODUCED CH4 (tonnes per y)	**621**

2016

RMM flue gas	26.03	g	or	1 mole gas	0.0224	Nm3
Volume 1 mole gas	0.0224	Nm3			0.024451282	Sm3
Moles in 1 Nm3	44.64285714	mol/Nm3			0.863497026	SCF
Moles in 1 Sm3	40.89765101	mol/Sm3				
Mass in 1 Sm3 (Density)	1064.565856	g/Sm3		Flow rate of flue gas	2092974885	SCF/y
Mass in 1 SCF (Density)	30.14486353	g/SCF		Mole rate of flue gas	**2423835661.79**	**mole/y**
Mass flue gas rate	63092442277	g/y				
Mole flue gas rate	**2423835662**	**mole/y**				

Flaring	1	year
Destruction Efficiency	0.99	Assuming 99% combustion efficiency

Component	Flashed Gas mole %	Flashed Gas mw%	Molecular mass of Mixture	RMM	Number of moles for components (mole/y)	Mass for components (g/y)	Moles of Carbon per component	Mass of carbon per component (g/y)	Mass of CO2 (g/y)
N2	0.72	0.77	0.20251	28.01	17451616.76	488819785.6		0	
CO2	1.08	1.8	0.4734	44.01	26177425.15	1152068481	1	-	1151806706
H2S	0	0	0	34.08	0	0		0	
C1	68.23	41.52	10.91976	16.04	1653783072	26526680476	1	19845396865	
C2	8.76	9.99	2.62737	30.07	212328004	6384703079	2	5095872095	
C3	9.58	16.02	4.21326	44.1	232203456.4	10240172427	3	8359324430	
iC4	1.9	4.18	1.09934	58.12	46052877.57	2676593245	4	2210538124	
nC4	4.33	9.55	2.51165	58.12	104952084.2	6099815131	4	5037700039	
iC5	1.64	4.48	1.17824	72.15	39750904.85	2868027785	5	2385054291	
nC5	1.61	4.41	1.15983	72.15	39023754.15	2815563862	5	2341425249	
2MP	0.67	2.19	0.57597	86.18	16239698.93	1399537254	6	1169258323	
3MP	0.2	0.66	0.17358	86.18	4847671.324	417772314.7	6	349032335.3	
C6	0.51	1.66	0.43658	86.17	12361561.88	1065195787	6	890032455	
MCP	0.23	0.75	0.19725	78.11	5574822.022	435449348.1	6	401387185.6	
BZ	0.04	0.11	0.02893	78.11	969534.2647	75730321.42	6	69806467.06	
2MH	0.06	0.22	0.05786	100.21	1454301.397	145735543	7	122161317.4	
3MH	0.07	0.25	0.06575	100.21	1696684.963	170024800.2	7	142521536.9	
C7	0.2	0.73	0.19199	97.04	4847671.324	470418025.2	7	407204391.2	
MCH	0.07	0.25	0.06575	98.19	1696684.963	166597496.5	7	142521536.9	
TOL	0.06	0.21	0.05523	92.14	1454301.397	133999330.7	7	122161317.4	
C8	0.03	0.15	0.03945	114.22	727150.6985	83055152.79	8	69806467.06	
ETB	0	0	0	106.17	0	0	8	0	
PMXY	0	0	0	106.17	0	0	8	0	
OXY	0.01	0.03	0.00789	106.17	242383.5662	25733863.22	8	23268822.35	
C9	0.02	0.07	0.01841	128.248	484767.1324	62170415.19	9	52354850.29	
C10	0	0.01	0.00263	142.2738	0	0	10	0	
Totals	100	100			2424320429	63903863924		49236828099	1151806706
MW	26.3		26.30263						
Specific Gravity	0.91								
	26.4								
		0.200431		0.715825					

Summary

TOTAL AMOUNT OF PRODUCED CO2 (tonnes per y)	**179,881**
TOTAL AMOUNT OF PRODUCED CH4 (tonnes per y)	**265**

2015

RMM flue gas	26.03	g	or	1 mole gas	0.0224	Nm3
Volume 1 mole gas	0.0224	Nm3			0.024451282	Sm3
Moles in 1 Nm3	44.64285714	mol/Nm3			0.863497026	SCF
Moles in 1 Sm3	40.89765101	mol/Sm3				
Mass in 1 Sm3 (Density)	1064.565856	g/Sm3		Flow rate of flue gas	4889945310	SCF/y
Mass in 1 SCF (Density)	30.14486353	g/SCF		Mole rate of flue gas	**5662955591.59**	**mole/y**
Mass flue gas rate	1.47407E+11	g/y				
Mole flue gas rate	**5662955592**	**mole/y**				

Flaring	1	year
Destruction Efficiency	0.99	Assuming 99% combustion efficiency

Component	Flashed Gas mole %	Flashed Gas mw%	Molecular mass of Mixture	RMM	Number of moles for components (mole/y)	Mass for components (g/y)	Moles of Carbon per component	Mass of carbon per component (g/y)	Mass of CO2 (g/y)
N2	0.72	0.77	0.20251	28.01	40773280.26	1142059580		0	
CO2	1.08	1.8	0.4734	44.01	61159920.39	2691648096	1	-	2691036497
H2S	0	0	0	34.08	0	0		0	
C1	68.23	41.52	10.91976	16.04	3863834600	61975906986	1	46366015202	
C2	8.76	9.99	2.62737	30.07	496074909.8	14916972538	2	11905797836	
C3	9.58	16.02	4.21326	44.1	542511145.7	23924741524	3	19530401244	
iC4	1.9	4.18	1.09934	58.12	107596156.2	6253488601	4	5164615500	
nC4	4.33	9.55	2.51165	58.12	245205977.1	14251371390	4	11769886902	
iC5	1.64	4.48	1.17824	72.15	92872471.7	6700748833	5	5572348302	
nC5	1.61	4.41	1.15983	72.15	91173585.02	6578174160	5	5470415101	
2MP	0.67	2.19	0.57597	86.18	37941802.46	3269824536	6	2731809777	
3MP	0.2	0.66	0.17358	86.18	11325911.18	976067025.8	6	815465605.2	
C6	0.51	1.66	0.43658	86.17	28881073.52	2488682105	6	2079437293	
MCP	0.23	0.75	0.19725	78.11	13024797.86	1017366961	6	937785446	
BZ	0.04	0.11	0.02893	78.11	2265182.237	176933384.5	6	163093121	
2MH	0.06	0.22	0.05786	100.21	3397773.355	340490867.9	7	285412961.8	
3MH	0.07	0.25	0.06575	100.21	3964068.914	397239345.9	7	332981788.8	
C7	0.2	0.73	0.19199	97.04	11325911.18	1099066421	7	951376539.4	
MCH	0.07	0.25	0.06575	98.19	3964068.914	389231926.7	7	332981788.8	
TOL	0.06	0.21	0.05523	92.14	3397773.355	313070836.9	7	285412961.8	
C8	0.03	0.15	0.03945	114.22	1698886.677	194046836.3	8	163093121	
ETB	0	0	0	106.17	0	0	8	0	
PMXY	0	0	0	106.17	0	0	8	0	
OXY	0.01	0.03	0.00789	106.17	566295.5592	60123599.52	8	54364373.68	
C9	0.02	0.07	0.01841	128.248	1132591.118	145252545.7	9	122319840.8	
C10	0	0.01	0.00263	142.2738	0	0	10	0	
Totals	100	100			5664088183	1.49303E+11		1.15035E+11	2691036497
MW	26.3		26.30263						
Specific Gravity	0.91								
	26.4								
		0.200431		0.715825					

Summary

TOTAL AMOUNT OF PRODUCED CO2 (tonnes per y)	**420,268**
TOTAL AMOUNT OF PRODUCED CH4 (tonnes per y)	**620**

2014

RMM flue gas	26.03	g	or	1 mole gas	0.0224	Nm3
Volume 1 mole gas	0.0224	Nm3			0.024451282	Sm3
Moles in 1 Nm3	44.64285714	mol/Nm3			0.863497026	SCF
Moles in 1 Sm3	40.89765101	mol/Sm3				
Mass in 1 Sm3 (Density)	1064.565856	g/Sm3		Flow rate of flue gas	5635702426	SCF/y
Mass in 1 SCF (Density)	30.14486353	g/SCF		Mole rate of flue gas	**6526603171.40**	**mole/y**
Mass flue gas rate	1.69887E+11	g/y				
Mole flue gas rate	**6526603171**	**mole/y**				

Flaring	1	year
Destruction Efficiency	0.99	Assuming 99% combustion efficiency

Component	Flashed Gas mole %	Flashed Gas mw%	Molecular mass of Mixture	RMM	Number of moles for components (mole/y)	Mass for components (g/y)	Moles of Carbon per component	Mass of carbon per component (g/y)	Mass of CO2 (g/y)
N2	0.72	0.77	0.20251	28.01	46991542.83	1316233115		0	
CO2	1.08	1.8	0.4734	44.01	70487314.25	3102146700	1	-	3101441827
H2S	0	0	0	34.08	0	0		0	
C1	68.23	41.52	10.91976	16.04	4453101344	71427745555	1	53437216126	
C2	8.76	9.99	2.62737	30.07	571730437.8	17191934265	2	13721530508	
C3	9.58	16.02	4.21326	44.1	625248583.8	27573462546	3	22508949018	
iC4	1.9	4.18	1.09934	58.12	124005460.3	7207197350	4	5952262092	
nC4	4.33	9.55	2.51165	58.12	282601917.3	16424823435	4	13564892031	
iC5	1.64	4.48	1.17824	72.15	107036292	7722668469	5	6422177521	
nC5	1.61	4.41	1.15983	72.15	105078311.1	7581400143	5	6304698664	
2MP	0.67	2.19	0.57597	86.18	43728241.25	3768499831	6	3148433370	
3MP	0.2	0.66	0.17358	86.18	13053206.34	1124925323	6	939830856.7	
C6	0.51	1.66	0.43658	86.17	33285676.17	2868226716	6	2396568685	
MCP	0.23	0.75	0.19725	78.11	15011187.29	1172523840	6	1080805485	
BZ	0.04	0.11	0.02893	78.11	2610641.269	203917189.5	6	187966171.3	
2MH	0.06	0.22	0.05786	100.21	3915961.903	392418542.3	7	328940799.8	
3MH	0.07	0.25	0.06575	100.21	4568622.22	457821632.7	7	383764266.5	
C7	0.2	0.73	0.19199	97.04	13053206.34	1266683144	7	1096469333	
MCH	0.07	0.25	0.06575	98.19	4568622.22	448593015.8	7	383764266.5	
TOL	0.06	0.21	0.05523	92.14	3915961.903	360816729.7	7	328940799.8	
C8	0.03	0.15	0.03945	114.22	1957980.951	223640584.3	8	187966171.3	
ETB	0	0	0	106.17	0	0	8	0	
PMXY	0	0	0	106.17	0	0	8	0	
OXY	0.01	0.03	0.00789	106.17	652660.3171	69292945.87	8	62655390.45	
C9	0.02	0.07	0.01841	128.248	1305320.634	167404760.7	9	140974628.5	
C10	0	0.01	0.00263	142.2738	0	0	10	0	
Totals	100	100			6527908492	1.72072E+11		1.32579E+11	3101441827
MW	26.3		26.30263						
Specific Gravity	0.91								
	26.4								
		0.200431		0.715825					

Summary

TOTAL AMOUNT OF PRODUCED CO2 (tonnes per y)	**484,363**
TOTAL AMOUNT OF PRODUCED CH4 (tonnes per y)	**714**

2013

RMM flue gas	26.03	g	or	1 mole gas	0.0224	Nm3
Volume 1 mole gas	0.0224	Nm3			0.024451282	Sm3
Moles in 1 Nm3	44.64285714	mol/Nm3			0.863497026	SCF
Moles in 1 Sm3	40.89765101	mol/Sm3				
Mass in 1 Sm3 (Density)	1064.565856	g/Sm3		Flow rate of flue gas	3463388644	SCF/y
Mass in 1 SCF (Density)	30.14486353	g/SCF		Mole rate of flue gas	**4010886593.55**	**mole/y**
Mass flue gas rate	1.04403E+11	g/y				
Mole flue gas rate	**4010886594**	**mole/y**				

Flaring	1	year
Destruction Efficiency	0.99	Assuming 99% combustion efficiency

Component	Flashed Gas mole %	Flashed Gas mw%	Molecular mass of Mixture	RMM	Number of moles for components (mole/y)	Mass for components (g/y)	Moles of Carbon per component	Mass of carbon per component (g/y)	Mass of CO2 (g/y)
N2	0.72	0.77	0.20251	28.01	28878383.47	808883521.1		0	
CO2	1.08	1.8	0.4734	44.01	43317575.21	1906406485	1	-	1905973309
H2S	0	0	0	34.08	0	0		0	
C1	68.23	41.52	10.91976	16.04	2736627923	43895511881	1	32839535073	
C2	8.76	9.99	2.62737	30.07	351353665.6	10565204724	2	8432487974	
C3	9.58	16.02	4.21326	44.1	384242935.7	16945113463	3	13832745684	
iC4	1.9	4.18	1.09934	58.12	76206845.28	4429141848	4	3657928573	
nC4	4.33	9.55	2.51165	58.12	173671389.5	10093781158	4	8336226696	
iC5	1.64	4.48	1.17824	72.15	65778540.13	4745921671	5	3946712408	
nC5	1.61	4.41	1.15983	72.15	64575274.16	4659106030	5	3874516449	
2MP	0.67	2.19	0.57597	86.18	26872940.18	2315909984	6	1934851693	
3MP	0.2	0.66	0.17358	86.18	8021773.187	691316413.3	6	577567669.5	
C6	0.51	1.66	0.43658	86.17	20455521.63	1762652299	6	1472797557	
MCP	0.23	0.75	0.19725	78.11	9225039.165	720567809.2	6	664202819.9	
BZ	0.04	0.11	0.02893	78.11	1604354.637	125316140.7	6	115513533.9	
2MH	0.06	0.22	0.05786	100.21	2406531.956	241158567.3	7	202148684.3	
3MH	0.07	0.25	0.06575	100.21	2807620.615	281351661.9	7	235840131.7	
C7	0.2	0.73	0.19199	97.04	8021773.187	778432870.1	7	673828947.7	
MCH	0.07	0.25	0.06575	98.19	2807620.615	275680268.2	7	235840131.7	
TOL	0.06	0.21	0.05523	92.14	2406531.956	221737854.4	7	202148684.3	
C8	0.03	0.15	0.03945	114.22	1203265.978	137437040	8	115513533.9	
ETB	0	0	0	106.17	0	0	8	0	
PMXY	0	0	0	106.17	0	0	8	0	
OXY	0.01	0.03	0.00789	106.17	401088.6594	42583582.96	8	38504511.3	
C9	0.02	0.07	0.01841	128.248	802177.3187	102877636.8	9	86635150.42	
C10	0	0.01	0.00263	142.2738	0	0	10	0	
Totals	100	100			4011688771	1.05746E+11		81475545907	1905973309
MW	26.3		26.30263						
Specific Gravity	0.91								
	26.4								
		0.200431		0.715825					

Summary

TOTAL AMOUNT OF PRODUCED CO2 (tonnes per y)	**297,662**
TOTAL AMOUNT OF PRODUCED CH4 (tonnes per y)	**439**

2012

RMM flue gas	26.03	g	or	1 mole gas	0.0224	Nm3
Volume 1 mole gas	0.0224	Nm3			0.024451282	Sm3
Moles in 1 Nm3	44.64285714	mol/Nm3			0.863497026	SCF
Moles in 1 Sm3	40.89765101	mol/Sm3				
Mass in 1 Sm3 (Density)	1064.565856	g/Sm3		Flow rate of flue gas	966034195.4	SCF/y
Mass in 1 SCF (Density)	30.14486353	g/SCF		Mole rate of flue gas	**1118746407.54**	**mole/y**
Mass flue gas rate	29120968988	g/y				
Mole flue gas rate	**1118746408**	**mole/y**				

Flaring	1	year
Destruction Efficiency	0.99	Assuming 99% combustion efficiency

Component	Flashed Gas mole %	Flashed Gas mw%	Molecular mass of Mixture	RMM	Number of moles for components (mole/y)	Mass for components (g/y)	Moles of Carbon per component	Mass of carbon per component (g/y)	Mass of CO2 (g/y)
N2	0.72	0.77	0.20251	28.01	8054974.134	225619825.5		0	
CO2	1.08	1.8	0.4734	44.01	12082461.2	531749117.5	1	-	531628292.9
H2S	0	0	0	34.08	0	0		0	
C1	68.23	41.52	10.91976	16.04	763320673.9	12243663609	1	9159848086	
C2	8.76	9.99	2.62737	30.07	98002185.3	2946925712	2	2352052447	
C3	9.58	16.02	4.21326	44.1	107175905.8	4726457448	3	3858332610	
iC4	1.9	4.18	1.09934	58.12	21256181.74	1235409283	4	1020296724	
nC4	4.33	9.55	2.51165	58.12	48441719.45	2815432734	4	2325202533	
iC5	1.64	4.48	1.17824	72.15	18347441.08	1323767874	5	1100846465	
nC5	1.61	4.41	1.15983	72.15	18011817.16	1299552608	5	1080709030	
2MP	0.67	2.19	0.57597	86.18	7495600.93	645970888.2	6	539683267	
3MP	0.2	0.66	0.17358	86.18	2237492.815	192827130.8	6	161099482.7	
C6	0.51	1.66	0.43658	86.17	5705606.678	491652127.5	6	410803680.8	
MCP	0.23	0.75	0.19725	78.11	2573116.737	200986148.4	6	185264405.1	
BZ	0.04	0.11	0.02893	78.11	447498.563	34954112.76	6	32219896.54	
2MH	0.06	0.22	0.05786	100.21	671247.8445	67265746.5	7	56384818.94	
3MH	0.07	0.25	0.06575	100.21	783122.4853	78476704.25	7	65782288.76	
C7	0.2	0.73	0.19199	97.04	2237492.815	217126302.8	7	187949396.5	
MCH	0.07	0.25	0.06575	98.19	783122.4853	76894796.83	7	65782288.76	
TOL	0.06	0.21	0.05523	92.14	671247.8445	61848776.39	7	56384818.94	
C8	0.03	0.15	0.03945	114.22	335623.9223	38334964.4	8	32219896.54	
ETB	0	0	0	106.17	0	0	8	0	
PMXY	0	0	0	106.17	0	0	8	0	
OXY	0.01	0.03	0.00789	106.17	111874.6408	11877730.61	8	10739965.51	
C9	0.02	0.07	0.01841	128.248	223749.2815	28695397.85	9	24164922.4	
C10	0	0.01	0.00263	142.2738	0	0	10	0	
Totals	100	100			1118970157	29495489038		22725767024	531628292.9
MW	26.3		26.30263						
Specific Gravity	0.91								
	26.4								
		0.200431		0.715825					

Summary

TOTAL AMOUNT OF PRODUCED CO2 (tonnes per y)	**83,026**
TOTAL AMOUNT OF PRODUCED CH4 (tonnes per y)	**122**

APPENDIX D WASTE MANAGEMENT PLAN

Tullow Ghana Limited

Waste Management Plan (WMP)

DOCUMENT NUMBER:	**TGL-EHS-PLN-04-0008**
Rev:	**5**
Date:	**30.12.18**
Review Frequency:	**Every 2 Years**

Revision History

Rev	Date	Reason for Issue	Prepared	Checked	Approved
0	30.06.10	Issued For Use	JW	GB	PW
1	05.10.10	Re-issued in accordance with EPA Comments	GB	EBA/JW	PW
2	04.01.13	Re-issued for use	FM	LD-FM	PW
3	01.10.13	Re-issued for use	EA	ETA/LD	PW
4	06.07.15	Re-issued for use	ERM (MC)	ERM (MI)	HA
5	30.12.18	Re-issued for use	MDG	EBA	ETA

Revision Control

Revision	Para /Sect	Change Description
1	General	A number of minor textual and administrative changes have been implemented where necessary to increase both the clarity and ease of interpretation of the document's contents
1	Sect. 1.2	Addition of a paragraph clarifying the WMP 'Review' period and process in line with the TGL Management of Change process (TGJ-PJM-PRC-07-0006-1), the integrated EHSS management system and also implementation of ISO 14001
1	Sect. 2.1	Expansion of this section to include TGL's (and Tullow Corporate) policy on compliance with all appropriate national legislation (and international conventions in the absence of applicable national legislation) as related to its activities, services and operations
1	Sect. 3.1	Clarification that documented waste type quantities are an estimation/indication based upon the envisaged steady state operational envelope and are documented on an annual basis
1	Sect. 4.1	Clarification of both hazardous/non-hazardous waste material storage strategies and hazardous waste storage facility
1	Sect. 4.3.1	Clarification of waste collection and operational PPE requirements
2	General	Document reviewed and re-issued for use due to introduction of new WMF
3	General	Global review of documents and errors identified in rev 2 corrected
4	General	Global review and update for inclusion of TEN Development and updated to include NORM.
5	General	Global review and update including minor textural changes and the inclusion of Zoil Services in the Waste Manifest Form.

This sheet must be completed in detail, at each revision once this document has been approved. Details must include revision number, description and indication of which pages and paragraphs have been revised, date of revision approval and approval indication.

Table of Contents

Table of Figures/Tables

1. Introduction

1.1. Purpose and Scope

Tullow Ghana Limited (TGL) operations; both onshore and offshore generate waste and hence there is the need to properly manage these waste streams in a responsible and safe manner. This Waste Management Plan (WMP) is therefore the framework to provide guidance on how the waste streams are to be managed at all locations.

This WMP details the methods adopted by TGL for the management of wastes, hazardous and non-hazardous, generated during the course of its exploration, development and operations activities within Ghana. This document covers collection, storage, treatment, transport and data management on the FPSOs, Drilling Rigs, Support Vessels, TGL Shore Base and offices.

The overall purpose of the WMP is to ensure that waste resulting from TGL activities are managed in a way that protects the natural environment, the health and safety of personnel, and the community in which we operate. This WMP will be followed at all TGL sites/facilities.

Wastes generated by contractors working directly for TGL (e.g. Operators, Support Vessels, drill rigs) and under its permits are required to follow the requirements of this WMP.

Service contractors working for TGL are required to likewise develop and implement a waste minimization policy and to responsibly handle their own waste streams. TGL reserves the right to audit all service contractors to verify that waste disposal is being achieved in a responsible and safe manner and that a system of improvement is in place.

Wastes[1] are defined as any scrap, unwanted, surplus, broken, worn out, contaminated or otherwise spoiled materials which have been produced as a result of TGL and or contractor operations.

The control of air emissions and discharges to water are covered in other project documents (e.g. Monitoring Plan, Environmental Management Plan) that comprise the project Environment Health and Safety (EHS) Management System.

1.2. Review and Update

As TGL operations progress and mature, this WMP will be updated and reissued in accordance with changes to legislation/environmental aspects/impacts/waste stream profile as per the TGL 'Management of Change' processes. This WMP will be reviewed every two years.

([1])*UN Definition of Waste*
"Wastes are materials that are not prime products (that is products produced for the market) for which the initial user has no further use in terms of his/her own purposes of production, transformation or consumption, and of which he/she wants to dispose. Wastes may be generated during the extraction of raw materials, the processing of raw materials into intermediate and final products, the consumption of final products, and other human activities. Residuals recycled or reused at the place of generation are excluded"
Glossary of Environment Statistics. 1997. UNSD. 1997. unstats.un.org

The WMP will also require mandatory revision in the event of:

- changes to Ghanaian Environmental Legislation and other legislation which the country subscribes to;
- changes to international conventions or practices that TGL is obliged to comply with (e.g. MARPOL updates and reviews);
- changes in TGL policies and reporting procedures;
- changes in TGL activities;
- identified deficiencies; and
- opportunities for improvement (e.g. Infrastructure development).

Audits and evaluations will be performed according to the TGL audit programme (see Section 6.1). Key outcomes from review and audit activities will be incorporated into the WMP to ensure that waste minimisation opportunities are identified, to help establish goals and objectives, and to improve TGL's waste management performance.

1.3. Roles and Responsibilities

Table 1-1 outlines the specific responsibilities for implementing this WMP. In the absence of the specified responsible party, the delegate will perform the same functions. Additional responsibilities may be assigned throughout the WMP.

Responsible Party	Responsibilities
EHSAP Manager	• Ensure that the WMP is developed in compliance with regulatory requirements and is implemented and updated accordingly. • Ensure that TGL and its contractors/subcontractors operate in accordance with the requirements of this WMP i.e. the applicable regulatory & company environment, health and safety requirements and plans. • Responsible for the execution of WMP and all legal/compliance issues therein. • Ensure that all personnel on site shall undergo environmental and waste management awareness as part of the induction/orientation. • Ensure that the management of all wastes generated at TGL operations sites are disposed safely and in a controlled and monitored manner. • Ensure effective communication of the appropriate aspects of the WMP with all internal/external (where applicable) stakeholders.
Environment Team Lead	• Develop the WMP to ensure it remains in compliance with Ghanaian and other relevant Legislative regulatory requirements. • Ensure the WMP is regularly reviewed and updated as required, including new waste streams as they arise. • Provide technical oversight and assist TGL operations departments with technical advice with implementing the WMP.

Responsible Party	Responsibilities
	• Perform technical performance assessment on waste contractors via audits and inspections to ensure contractors meet good practices in waste management. • Advise on Hazardous and Non-Hazardous Wastes and other waste stream management. • Ensure that appropriate staff are trained in waste management. • Ensure any issues arising from the undertaking of waste management activities are addressed in a timely manner and in accordance with EPA, International Finance Corporation (IFC) and TGL requirements. • Confirm the suitability of new waste disposal contractors, waste management/treatment/disposal facilities and waste receivers before use, and undertake periodic EHS audits for verification.
Environmental Advisor	• Implement the WMP at the operational level and on a daily basis. • Ensure the collection, compilation and analysis of performance statistics to ensure compliance. • Liaise with Floating Production Storage and Offloading (FPSO) & shore base operational management & personnel to ensure that duties and commitments in support of this WMP are expedited efficiently and in a timely manner. • Liaise with appointed persons responsible for coordinating waste at each facility. • Undertake periodic EHS audits of waste disposal contractors, waste management/treatment/disposal facilities and waste receivers. • Submit waste disposal records and status reports as appropriate to TGL Management, and Ghana authorities as required.
Logistics Base Manager	• Ensure that waste minimization is taken into consideration when reviewing procurement, shipping, storage and disposal method contracts, throughout the project life span. • Ensure waste is not disposed of to an unauthorised location or by an unauthorised contractor. • Provide the necessary resources (financial, manpower et al) to satisfactorily implement this WMP.
Department Managers including: Operations Managers; Project & Facilities Manager; and Well Engineering Manager, , TGL Area/Site Managers	• Each Departmental Manager shall have full knowledge and awareness of their environmental aspects and impacts of all their activities under their control or influence. • Communicate the procedure to all contractors used by TGL, including new contracts. • Ensure that any breaches of the WMP are investigated.

Responsible Party	Responsibilities
Contracts & Procurement (C&P) Manager	• Ensure waste management contract is properly set-up with an approved waste contractor.
TGL Offshore Operations EHS (FPSO) Drilling EHS Advisors (rigs) Marine Superintendent (Support Vessels)	• Reporting any non-compliance with the WMP. • Implementation of this plan within respective areas of responsibility. • Ensure that all wastes and excess materials are segregated at source, packaged, stored in suitable containers and labelled, detailing content and Company name prior to being shipped ashore for disposal. • Investigate any breach of the WMP and close-out of non-compliance issues. • Ensure waste manifested for shipment to waste contractor sites are accurate (QA/QC) and waste transfer records are properly kept • Maintain relevant Material Safety Data Sheets (MSDS's) for chemical wastes. • Ensure that a register of waste is maintained on each vessel. • Inspect Waste Management at their locations, including storage, segregation, labelling, containment, transport and disposal.
TGL Logistics Base Manager	• Ensure all wastes received by the Shore Base are managed as detailed in this document. • Ensure that appropriate staff are trained and competent in waste management, including in related activities such as the transportation of dangerous goods. • Allocates personnel and resources for Waste Management. • Ensure that all waste transporters meet acceptable standard before use, and undertake periodic audits for verification. • Ensure that a register of waste is maintained and a log of waste movements.
Marine Superintendent	• Ensure availability of offshore support vessels for the shipment, carting of waste from offshore installations to Port facilities. • Makes provision for waste skips for use by offshore installations. • Ensures waste shipments are in accordance with marine operations manual. • Ensure documentation in relation to waste shipments corresponds to actual waste shipped. • Ensure proper transfer of waste from offshore to TGL waste contractor at the port.
EHS Superintendent/ Advisor - Takoradi	• Reports any non-compliance contrary to the WMP. • Keeps on file a record of all Waste Manifest Forms for a minimum period of three years. • Maintains relevant Material Safety Data Sheets (MSDS's) for chemical wastes.

Responsible Party	Responsibilities
	• Providing status reports detailing waste movements and quantities to the EHS department on a monthly basis. • Ensuring that all waste transporters and disposal sites meet acceptable standard before use. • Ensuring waste is not disposed of to unauthorised location(s). • Investigates any breach of the WMP. • Inspects Waste Management at their locations and ensure that all TGL sites meet the requirements for storage, segregation, labelling, containment, transport and disposal.
Contractor Manager (e.g. MODU Offshore Installation Manager)	• Responsible for subcontractor technical performance and compliance with this WMP. • Ensure that all wastes and excess materials are segregated at source, packaged, stored in suitable containers and labelled detailing content and Company name prior to being shipped ashore for disposal. • Develop and maintain their own waste management systems that are compliant with this WMP. • Identify personnel for waste management. • Ensure that a register of waste is maintained and a log of waste movements is kept.
Contractor Project EHS Advisor/Manager	• Ensure that environment, health and safety regulatory requirements are met and that WMP requirements are properly implemented and in a timely manner. • Ensures appropriate waste containment units are available at all facilities. • Ensure that all wastes and excess materials are segregated at source, packaged, stored in suitable containers and labelled detailing content and Company name prior to being shipped ashore for disposal. • Ensure information on new waste streams are communicated to TGL. • Reports to the EHS department any non-compliance with the WMP. • Ensure the completion of Waste Manifest Forms and waste identification labels. • Investigating any breach of the WMP. • Maintain relevant Material Safety Data Sheets (MSDS's) for chemical wastes. • Ensuring waste is not disposed of to an unauthorised location.
All employees (TGL staff and contractors)	• Shall ensure that waste generated throughout TGL operations and activities are effectively and responsibly managed and disposed of in accordance with this WMP. • Are encouraged to suggest ways to minimise waste generation.

Table1-1: Roles and Responsibilities

1.4. Definitions

Table 1-2 provides definitions of terms used within this WMP.

Term	Definition
Biodegradable waste	Waste typically originating from plant or animal sources, which may be broken down by other living organisms. E.g. green waste, food waste, paper waste, biodegradable plastics, human waste, manure, sewage.
Biohazard waste	A biological hazard or biohazard is an organism, or substance derived from an organism, that poses a threat to (primarily) human health. This includes medical waste, samples of a microorganism, virus or toxin (from a biological source) that can impact human health. It can also include substances harmful to animals. The term and its associated symbol is generally used as a warning, so that those potentially exposed to the substances will know how to take precautions
Consignment	A controlled movement of waste from TGL or one of its contractors to a waste management contractor.
Construction and demolition / decommissioning waste	Waste arising from construction, repair, maintenance and demolition of buildings and structures. They can sometimes contain hazardous waste as asbestos, oil, grease, chemical compounds.
Duty of care	The responsibility of managing waste from its point of generation to disposal. Under the Duty of Care, organisations should: • Classify their waste • Obtain all relevant permits for waste storage, transport and disposal • Store waste safely and securely • Check that businesses used to deal with their waste have relevant licences in place • Fill in and keep waste manifest forms
Hazardous waste	Hazardous wastes are materials that can potentially be harmful to human health and/or could potentially damage the natural environment if not managed and disposed of appropriately. They exhibit one or more of the following characteristics; ignitability, corrosivity, reactivity, toxicity, mutagenic, teratogenic, infectious, irritant, carcinogenic, bioaccumulate/biomagnify, flammable, explosive. In addition to hazardous waste special categories of hazardous waste include the following. • Biohazards such as medical waste, (sharps such as syringes or scalpels; and softs such as soiled medical dressings). • Radioactive waste such as Naturally Occurring Radioactive Material (NORM). • Expired chemicals
Non-hazardous waste	Wastes that do not exhibit any hazardous properties are classified as non-hazardous. These may be inert or potentially biodegradable and include a range of materials that may be recycled or can safely be

Term	Definition
	disposed in a landfill. Categories of non-hazardous waste or inert waste are further classified according to their source
IAEA	International Atomic Energy Agency
IATA	International Air Transport Association
IMDG	International Maritime Dangerous Goods
Incineration	The controlled thermal destruction of waste in an incinerator in order to reduce its volume and/or toxicity.
Inert waste	Waste which, when deposited into a waste disposal site, does not undergo any significant physical, chemical or biological transformation. E.g. concrete, glass wood, clean plastic, aluminium.
Industrial waste	Any waste arising from an industrial premise.
Landfill	Area of land, typically a void from previous mining or quarrying, or specifically engineered, in which waste is deposited. In areas where there is no available void, the process is referred to as land rising and waste is deposited on the land surface.
Material Safety Data Sheet (MSDS)	A document, written in English, containing information to enable the recipient of a substance or product to take the necessary measures relating to the protection of health and safety at work and relating to the protection of the environment.
Medical / clinical waste	Refers to waste products that cannot be considered as a general waste, produced from healthcare premises, such as hospitals. These waste are classified as infectious or biohazardous. Examples include: wastes made in whole or part of human tissue, animal tissue, blood or other body liquids, secretions, drugs or other pharmaceutical products (included sell-by date medicine), bandages, syringes, needles or other medical sharp objects, or any other wastes whether contagious chemical or radioactive produced by medical activities, nursing, treatment, medical care, dental etc. These types of waste require proper handling & disposal, and are often incinerated.
NORM	Naturally Occurring Radioactive Materials (NORM). Naturally occurring radionuclides can be concentrated and enhanced by processes associated with the recovery of oil and gas; this is often known as TENORM (Technologically-Enhanced Naturally Occurring Radioactive Materials). NORM can accumulate in downhole installations and at the surface in scale, sludge and scrapings. The NORM nuclides of primary concern in oil production are Radium-226 and Radium-228.
Radioactive waste	Any waste containing radionuclide (i.e. a nuclide that is radioactive). Frequently categorised according to activity content and other criteria as low level, intermediate level and high level waste. Disposal of radioactive waste is subject to national and international legislation. Radioactive waste may include source materials found in equipment used in logging and detection of pipeline welds, smoke detectors and laboratory equipment. Radioactive waste also includes NORM.
Recycling	The reprocessing of waste into the same or a different product. Typical recyclable wastes include glass, paper, plastics, scrap of metal, etc.
Reduction	Process of reducing the quantity of waste produced through the review of operational practices and optimal use of raw materials.
Re-use	The reuse of a material without reprocessing.

Term	Definition
Waste inventory	Document identifying all sources of waste generated by a facility and the amounts for each of the waste sources.
Waste producer / originator	TGL waste producers / originator are TGL FPSOs, temporary sites (e.g. drilling rig), the Takoradi logistic base and TGL offices in Takoradi and Accra. With regards to contractors, waste producers are all parties undertaking activities on behalf of TGL (e.g. drilling contractors, catering, etc.).
Waste receiver	Authorised persons, sections, departments or companies outside TGL (contractors) whose business concerns the collection, treatment and disposal of waste on behalf of the waste producer (e.g. for TGL offshore operations ZEAL is the key the waste receiver).
Waste treatment	Physical, chemical or biological processing of waste in order to make it harmless, reduce its volume or for recycling.
WMF	Waste Manifest Form; The WMF is a mandatory document used to track the transfer of waste between TGL facilities and / or all waste handlers. The WMF has six duplicate (carbon copy) pages in different colours.
Waste type	A specific waste with the same origin and characteristics, such as paper, oil or plastic.
Waste stream	A mix of compatible waste types that will be managed in a similar way will form a waste stream.

Table 1-2: Definitions

1.5. Linked Documents

This EHS Management System document should be read in conjunction with the following linked documents:

- Tullow Ghana Ltd Environmental Management Plan (TGL-EHS-PLN-04-00040).
- Tullow Ghana Ltd Environmental Monitoring Plan (TGL-EHS-PLN-04-0006).
- Tullow Ghana Ltd Chemicals Management Guidelines (TGL-EHS-GUD-EN-0001).
- Tullow Ghana Ltd Ionising Radiation Management Procedure (TGL-EHS-PRC-04-0059)
- Tullow Ghana Ltd Takoradi Supply Base Operating Guidelines Manual (TGL-EHS-MAN-04).
- Tullow Ghana Ltd Marine Operations Manual (TGL-OPS-MAN-10-0001).
- Modec Waste Management Plan - FPSO Kwame Nkrumah MV21.
- Modec Waste Management Plan - FPSO Prof. John Evans Atta Mills.
- Modec Hazardous Material Procedure - FPSO Kwame Nkrumah MV21.
- Modec Hazardous Material Procedure - FPSO Prof. John Evans Atta Mills.
- Individual contractor waste management plans and related bridging documentation.

2. Legal Framework and Policy

2.1. National Regulatory Environment

General waste management in Ghana is the responsibility of the Ministry of Local Government and Rural Development, which supervises the decentralised Metropolitan, Municipal and District Assemblies (MMDAs). However, regulatory authority is vested in the Environmental Protection Agency (EPA) under the auspices of the Ministry of Environment, Science and Technology.

The EPA is responsible for the environmental and operational permitting of waste management facilities; this includes treatment and final disposal facilities. All waste carriers and treatment facilities should hold the appropriate licences or permits from the EPA or be on approved supplier lists. The MMDAs are responsible for the collection and final disposal of solid waste through their Waste Management Departments and their Environmental Health and Sanitation Departments.

The legislation guiding the management of hazardous, solid and radioactive waste is spread amongst a range of Acts and policies, including the Local Government Act 462 (1994), the Environmental Protection Agency Act 490 (1994), the Pesticides Control and Management Act 528 (1996), the Environmental Assessment Regulations LI 1652 (1999) the Environmental Sanitation Policy of Ghana (1999), the Guidelines for the Development and Management of Landfills in Ghana, and the Guidelines for Bio-medical Waste (2000). The Nuclear Regulatory Authority licenses importers and users of radioactive material. Management of any radioactive material would need to be approved by the Nuclear Regulatory Authority.

The Ghana Ports and Harbour Authority is responsible for planning, managing, building and operating Ghana's seaports. The GPHA owns Ghana's two main seaports (Takoradi and Tema) and has the responsibility to regulate the use of ports and of the port facilities, including receiving waste from ships.

It is the policy of TGL (and the Tullow Corporate body) to fully comply with all applicable national legislation and appropriate international conventions governing its activities, services and operations.

2.2. Waste Related International Conventions

2.2.1. MARPOL Convention

Ghana is a signatory to the MARPOL Convention (Marine Pollution Convention) aimed at preventing and minimising pollution from ships. MARPOL currently has six annexes, all of which Ghana has ratified. The annexes which are pertinent to managing waste include:

- Annex I Regulations for the Prevention of Pollution by Oil;
- Annex IV Prevention of Pollution by Sewage from Ships; and
- Annex V Prevention of Pollution by Garbage from Ships.

A draft Marine Pollution Bill has been prepared to adopt the requirements of the MARPOL annexes into Ghanaian legislation. It is the intent of Tullow to comply with the MARPOL annexes.

2.2.2. Basel Convention

The Convention on the Control of Trans-boundary Movements of Hazardous Wastes and their Disposal (Basel Convention) aims to protect human health and the environment against the adverse effects resulting from the generation, management, movement and disposal of hazardous waste.

Ghana gained accession to the Basel Convention on 30 May 2003 (accession has the same legal effect as ratification) which means that it must comply with all the requirements of the Convention. Therefore, certain wastes generated in Ghana, or within its territorial waters, that are exported to another country, will be subject to the provisions of the Basel Convention.

The Convention obliges producers of hazardous waste to therefore dispose of their waste in an environmentally responsible manner close to where it is generated. Strong controls on the movement, storage, transport, treatment, reuse, recycling, recovery and final disposal of hazardous waste are imposed. The Convention regulates the trans-boundary movement of hazardous waste using the Prior Informed Consent Procedure such that shipments without prior consent are illegal.

Trans-boundary movements are generally approved, if:

(a) the state of export does not have the capability of managing or disposing of the waste in an environmentally sound manner, or

(b) the receiving state has appropriate, environmentally sound facilities, and agrees to accept the waste.

2.2.3. Bamako Convention

Ghana is a signatory to the 1991 Convention on the Ban of the Import into Africa and the Control of Trans-boundary Movement of Hazardous Wastes within Africa (Bamako Convention). This convention is supplementary to the Basel Convention and covers movement of hazardous waste into or between signatory African countries. The Convention has many provisions virtually identical, or analogous, to the Basel Convention provisions.

2.2.4. Other Conventions

The Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972 (known as the London Protocol) prohibits all dumping, except for possibly acceptable wastes (which still require permits) on the so-called 'reverse list', contained in an annex to the Protocol. Ghana is a contracting state to the Protocol.

The Vienna Convention for Protection of the Ozone Layer & Montreal Protocol (1987) with Copenhagen Amendments (1992) on Substances that Deplete the Ozone Layer apply in Ghana.

United Nations Convention on the Law Of the Sea UNCLOS (1989); Protection And Preservation Of The Marine Environment Part XII.

2.3. TGL Waste Management Guidelines

2.3.1. Waste Hierarchy

Wastes resulting from TGL activities will be managed to ensure protection of the natural environment and the health and safety of personnel and the community. Waste management activities will be performed in accordance with the waste hierarchy principles illustrated in Figure 2-1 and presented below.

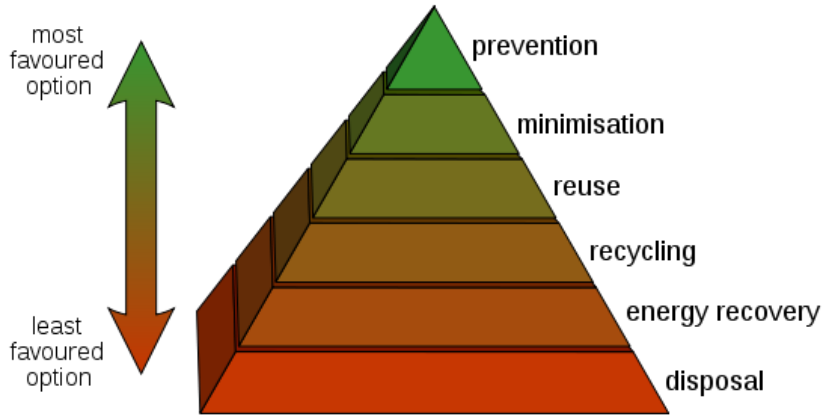


Figure 2-1: Waste Hierarchy Principles

1. Waste prevention. As much as possible responsible parties should prevent the generation of waste. This is the first option in with TGL's waste hierarchy.
2. Reduce the quantity of waste generated. This will be achieved by optimising purchasing, process and design requirements, thereby minimising the amount of waste generated in the first place.
3. Re-use materials/containers where possible or return to suppliers where surplus to requirements.
4. Recycle waste materials where practicable (e.g. oils, metal, wood, paper, plastics) to reduce the quantity of wastes landfilled. This requires segregation of wastes at source as far as practicable.
5. Recover as much as possible, such as oils from contaminated cuttings or energy within materials.
6. Responsible disposal of waste to landfills or alternative following appropriate treatments to reduce hazards and long-term impacts on the environment.

Waste minimisation and the application of these principles shall be addressed by the TGL Contracts and Procurement Department and taken into consideration when reviewing shipping, storage and disposal method throughout the project life span.

Disposal of all waste must be justified by demonstrating that recovery, reuse or recycle is not reasonably practicable. Long-term containment must be assured for any oily and hazardous waste which cannot be rendered non-hazardous (**Error! Reference source not found.**).

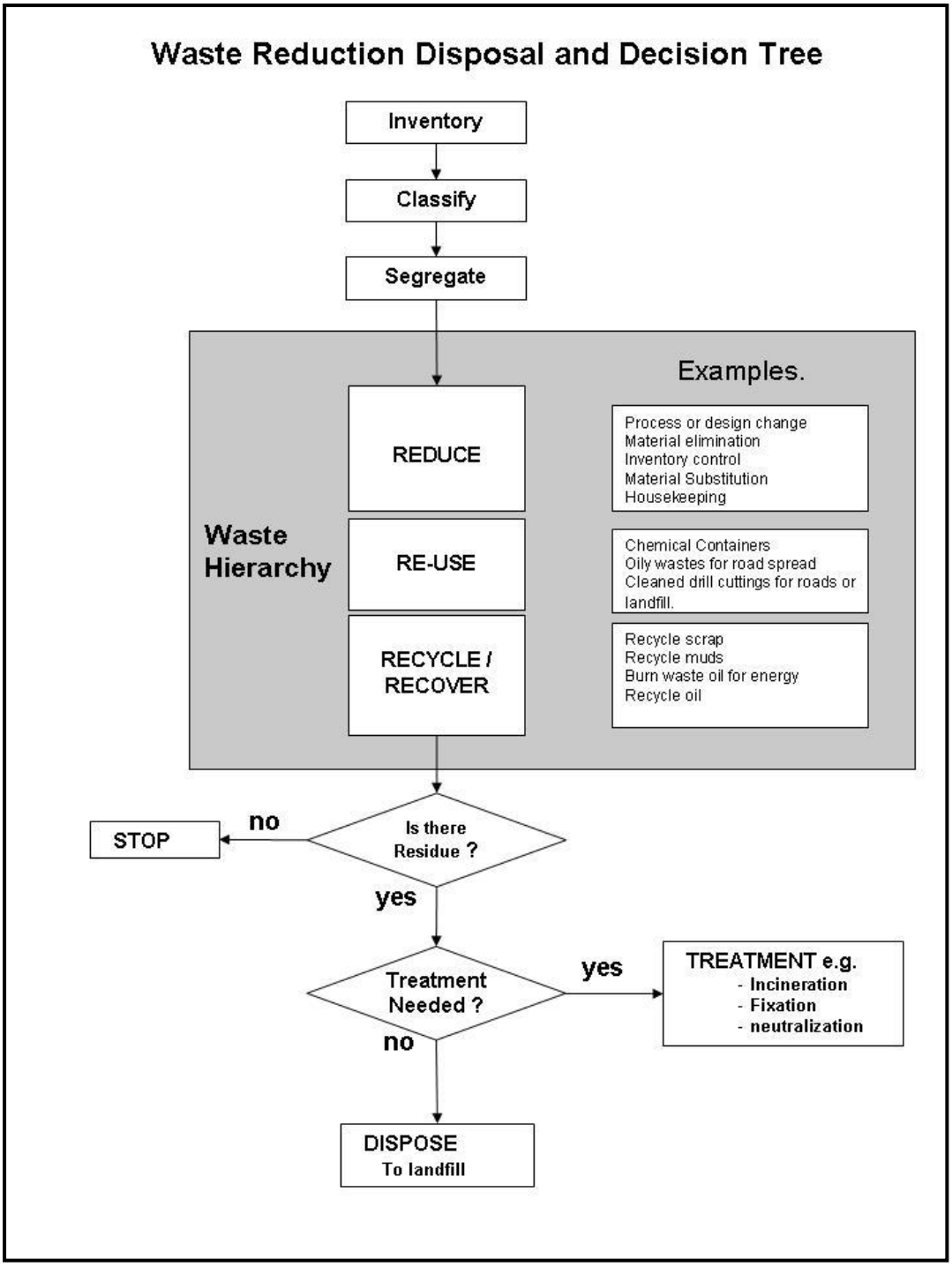


Figure 2-2: Waste Reduction and Disposal Decision Tree

2.3.2. TGL Waste Strategy

TGL's Waste Strategy requires the following.

- TGL will develop and implement a forward-looking WMP, ensuring that maximum effort is given to waste prevention, reduction, re-use and recycling.
- Work to achieve the following waste minimisation targets on an annual basis.
- More than 95% of recoverable waste oil produced by TGL activities will be recycled.
- More than 95% of all scrap metal produced will be recycled.
- Zero percent loss of containment during storage, transport and handling of waste by TGL.
- Continually work to reduce waste volumes going to landfills. Reduction targets will be set on an annual basis and recorded within the facility score cards.
- Audit waste management contractors annually.
- Maximise waste recycling opportunities as far as practical.
- The performance of each asset will be assessed on a regular basis.
- TGL will maintain an inventory of waste streams by type, quantity and their fate, to ensure cradle-to-grave tracking. Such data will be in a consistent format across the facilities and offices, and include data on quantities of waste streams recycled/reused.
- No waste is to be discharged overboard offshore, unless under permitted authorisation from the EPA (e.g. produced sand <1% oil).
- Priority should be given to the management of wastes at source or as close to source as practicable. Waste management solutions should be identified on an international level only when appropriate technologies cannot be identified in-country.
- TGL will purchase products in a manner that minimises waste generation.
- Sites will carry out internal audits, monitoring and spot checks on procedures, working practices and facilities, to ensure compliance with permits, legislation and the WMP.

3. Waste Types, Sources and Streams

3.1. Waste Types and Quantities

The waste types that TGL expect to produce from its operations are listed below. All wastes are classified as either non-hazardous (Table 3-1) or hazardous (Table 3-2) to facilitate their safe collection, storage, transport and management by TGL sites and waste contractors.

The composition of the various waste streams generated will vary between sites (i.e. FPSO, Support Vessels, and MODU) and over time as a direct result of changes in operations.

Type	State	Source/Description	Estimated Quantity (t/yr)
Glass	Solid	Drink bottles and food jars.	4.0 - 8.0
Cooking grease	Sludge	Used cooking oil and galley grease from oil separators in kitchens	6.0 - 12.0
Metals (non-contaminated)	Solid	All ferrous and non-ferrous metals from offshore and onshore operations. Mixed metals to be delivered may include copper cable, steel plate, aluminium drink cans, food cans.	70.0 - 150.0
Paper and cardboard (not contaminated with oil, grease, chemicals)	Solid	Magazines, office paper, newspaper, cardboard packing.	40.0 - 200.0
General plastic	Solid	Bottles and mixed plastics such as end caps and packing materials. All plastic types (i.e. 1 to 7) are included.	15.0 - 30.0
Residual mixed waste	Solid	General domestic waste that may contain food scraps, plastics, cans, bottles, textiles, paper and office bin waste.	1500.0 - 3000.0
Wood	Solid	Pallets, crates, furniture.	120.0 - 250.0
Food waste	Solid	Scraps from kitchens	100.0 - 120.0
Desiccant	Solid	Produced from gas dehydration system	2.0 – 40.0

Table 3-1: Non-Hazardous Wastes

Type	State	Source/Description	Estimated Quantity (t/yr)
Batteries	Solid	All types of battery from alkali, lead acid to lithium ion.	0.2 - 0.6
Chemicals, various	Liquid	Small amounts of various solvents, paints, cleaners left over in containers or no longer required.	15 - 30.0
Chemical drums	Solid	Plastic and metal drums that may contain residual wastes such as oil, solvent, cleaners or paint.	Included in metals
	Liquid	Effluent from drum washing plus residual contents.	Included in Chemicals
Aerosol cans	Solid	Aerosol cans that may contain pesticide, paint, thinner, etc plus propellant.	0.2 - 0.4 Included in metals
Medical/clinical	Solid	Swabs, dressings, old medicine.	0.2 - 0.4
Oil contaminated materials	Solid	Oily rags, used PPE contaminated with oil, used spill absorbent, hydraulic hoses, minor quantities of grease	45.0 - 90.0
Hydrocarbons, used	Liquid	Engine oil, lubricants, parts cleaning agent.	24.0 - 70.0
Bulbs and fluorescent tubes	Solid	Fluorescent tubes & bulbs	0.2 - 0.4
Water, slops	Liquid	Oil contaminated water from bilges, etc.	900 - 1800
E-waste (Electrical goods and instrumentation)	Solid	Old computers, screens, televisions, fridges, air conditioners, instrumentation and other electrical goods.	2.0 – 2.4
Oil contaminated sediments	Solid	Packing gravel, produced sand, drill cuttings	Produced sand from FPSO cargo tanks cleaning operations. Drill cuttings ~1,100t per well currently discharged under EPA permit.
NORM (Naturally Occurring Radioactive Material)	Solid	Scale build up in FPSO/MODU	Estimate to be obtained following an FPSO shutdown
Tank slops/tank bottom sludge	Solid	Barite and other solids resulting from tank cleaning on rigs and ships.	10.0 – 20.0
	Solid	Un-pumpable hydrocarbon sludge	230.0 – 460.0
	Liquid	Wash water used for tank cleaning – may have high salt content (i.e. CaCl2).	20.0 – 40.0
Filters	Solid	Glycol filters, brine filters, water filters, oil filters.	Included in oil contaminated materials

Table 3.2: Hazardous Wastes

3.2. Waste Sources and Streams

Waste will be generated by four different areas of TGL's operations.

1. FPSO - Field production operations.
2. Support Vessels – Logistical support to offshore operations.
3. Mobile Offshore Drilling Units (MODU) – Drilling Operations i.e. exploration/development.
4. Shore Base (Logistics Warehouse, Chemical Storage) including offices.

Each area produces its own particular mix of waste and waste streams, reflecting both the activities that are undertaken as well as site specific constraints and opportunities for management. There are 19 different waste streams that are produced by TGL Operations. These waste streams are categorised (for classification/reporting purposes) as shown in Table 3-3.

#	Waste Stream	Classification	#	Waste Stream	Classification
1	General Waste	GEN/WST	11	Hazardous Waste – Oil	HAZ/OIL
2	Kitchen Grease/Oil	GEN/KIT/GRS	12	Hazardous Waste – Oily Solids	HAZ/OIL/SOL
3	Metals	GEN/MET	13	Hazardous Waste – Oily Sediments	HAZ/OIL/SED
4	Wood	GEN/WOD	14	Hazardous Waste – Tank Slops	HAZ/OIL/TNK
5	General Plastic	GEN/PLS	15	Hazardous Waste – Chemicals	HAZ/CEM
6	Paper	GEN/PAP	16	Hazardous Waste – Containers	HAZ/CON
7	Food	GEN/FOD	17	Hazardous Waste – Fluorescent Lights	HAZ/FLU
8	Hazardous Waste – Batteries	HAZ/BAT	18	Medical Waste	HAZ/MED
9	Hazardous Waste – Electronic	HAZ/ELE	19	Radioactive Waste (NORM)	HAZ/RAD
10	Hazardous Waste – Flammable Liquids	HAZ/FLM	-		

Table 3-3: TGL Waste Streams

Table 3-4 provides a list of waste materials, where they are expected to be generated, waste stream classification and comments for immediate handling, storage and disposal options at the point of generation (ie on the FPSOs, MODUs, Supply Vessels or Shore Base).

The ultimate waste treatment / disposal options (for waste returned or generated onshore) are discussed in Section 5 of this WMP.

Waste Type	State	Source/Description	Waste Stream (Classification)	Key Requirements	Generated			
					FPSO	MODU	Supply Vessel	Shore Base
Glass	Solid	General bottles and jars from kitchen.	General Waste (GEN/WST)	No specific requirements.	✓	✓	✓	✓
		Laboratory glassware and reagent bottles.	General Waste (GEN/WST)	All bottle containing chemicals shall be drained of all contents, triple rinsed and rendered unusable prior to placing in general waste stream.	✓	✓	✓	✓
Cooking Grease	Sludge	Galley grease.	Kitchen Grease/Oil (GEN/KIT/GRS)		✓	✓	✓	
	Liquid	Used cooking oil from separators and deep fryers.	Kitchen Grease/Oil (GEN/KIT/GRS)	Send back to shore in 20L drums	✓	✓	✓	✓
Metals (non-contaminated)	Solid	Ferrous and non-ferrous metals (steel & aluminium) including food cans.	Metals (GEN/MET)	Food cans to be rinsed prior to being placed in metals bin. Engine and other parts to be generally free of oil and lubricants.	✓	✓	✓	✓
		Drink cans (aluminium).	Metals (GEN/MET)	Stored separately and pressed into bails using compactor on FPSOs.	✓	✓	✓	✓
Paper and cardboard	Solid	Papers, magazines, office paper, cardboard boxes, etc.	Paper (GEN/PAP)	Paper and cardboard is comingled and disposed of with general waste.	✓	✓	✓	✓
General plastic (does not include plastic drums or containers)	Solid	Mixed plastics such as packaging material for dry goods from type 1 to 7. Includes plastic bottles used for food storage.	General Plastic (GEN/PLS)	All general plastic is comingled and disposed of with general waste.	✓	✓	✓	✓
		Plastics (e.g. wrapping) associated with kitchen waste.	General Waste (GEN/WST)	Plastics contaminated with food scraps (not suitable for recycling)	✓	✓	✓	✓

Waste Type	State	Source/Description	Waste Stream (Classification)	Key Requirements	Generated			
					FPSO	MODU	Supply Vessel	Shore Base
Residual mixed waste	Solid	Domestic types, packaging, bin waste, etc.	General Waste (GEN/WST)	Waste recycling bins used to segregate at source.	✓	✓	✓	✓
Wood	Solid	Pallets, crates, furniture.	Wood (GEN/WOD)		✓	✓	✓	✓
Food Waste	Solid	Food scraps.	Food (GEN/FOD)	Macerate and discharge food scraps in compliance with MARPOL 73/78 Annex V from FPSO, MODU and supply vessels.	✓	✓	✓	✓
Desiccant	Solid	Compressed Air System.	General Waste (GEN/WST)		✓			
Batteries	Solid	Lead acid.	Hazardous Waste – Batteries (HAZ/BAT)	Unsealed lead acid batteries to be stored and transported separately.	✓	✓	✓	✓
		Lithium ion, NiCad, etc.	Hazardous Waste – Batteries (HAZ/BAT)		✓	✓	✓	✓
Instruments	Solid	Some instruments may contain mercury or circuit boards.	Hazardous Waste – Electronic (HAZ/ELE)	Only those electrical items that contain computerised systems would be considered hazardous. Suitable e-waste recycling company needs to be identified to manage this stream upon collection.	✓	✓	✓	✓
Electrical goods	Solid	Computers, monitor and some instrumentation.	Hazardous Waste – Electronic (HAZ/ELE)		✓	✓	✓	✓
		General electrical goods such as washing machines, etc.	Metals (GEN/MET); OR General Waste (GEN/WST)		✓	✓	✓	✓

Waste Type	State	Source/Description	Waste Stream (Classification)	Key Requirements	Generated			
					FPSO	MODU	Supply Vessel	Shore Base
Chemicals	Liquid	Solvents, thinners, paints.	Hazardous Waste – Flammable Liquids (HAZ/FLM)		✓	✓	✓	✓
	Liquid	Laboratory waste – solvents and other hydrocarbon residue from sample analysis.	Hazardous Waste – Waste Oil (HAZ/OIL)	Returned to export oil stream.	✓	✓		✓
	Solid	Laboratory waste – residues, used filters.	Hazardous Waste – Oily Solids (HAZ/OIL/SOL)	Sent to TGL waste contractor for incineration.	✓	✓		✓
	Solid	Paint residue/dried paint/used brushes or rollers.	Hazardous Waste – Oily Solids (HAZ/OIL/SOL)		✓	✓	✓	✓
Medical/clinical	Solid	Swabs, dressings, old medicine.	Medical Waste (HAZ/MED)	Medical waste to be handled by WARA. Contain in yellow 'Sharps' bins.	✓	✓	✓	✓
Oil contaminated materials	Solid	oily rags, absorbents, gloves.	Hazardous Waste – Oily Solids (HAZ/OIL/SOL)	Sent to TGL waste contractor for incineration.	✓	✓	✓	✓
Oil contaminated sediments	Solid	Produced sand.	Hazardous Waste – Oily Sediments (HAZ/OIL/SED)	If >1% oil (dry weight) contamination, ship to shore for treatment. If <1% oil (dry weight) contamination discharge to sea is permissible.	✓	✓		
Hydrocarbons, used	Liquid	Engine oil, lubricating oils, hydraulic oils,	Hazardous Waste – Waste Oil (HAZ/OIL)	Waste oil to be sent to export oil on FPSOs. Waste oil to be sent to shore from MODU's and support vessels.	✓	✓	✓	✓

Waste Type	State	Source/Description	Waste Stream (Classification)	Key Requirements	Generated			
					FPSO	MODU	Supply Vessel	Shore Base
		Parts washing fluid (diesel/kerosene).	Hazardous Waste – Flammable Liquids (HAZ/FLM)	Sent to export oil on FPSOs. Transfer to shore from MODU's and support vessels for disposal.	✓	✓	✓	✓
Tank bottom sludge	Sludge	Tank clean out and unpumpable sludges/solids. Hydrocarbons in unpumpable tank residues.	Hazardous Waste – Oily Solids (HAZ/OIL/SOL) Hazardous Waste – Waste Oil (HAZ/OIL)	Residue that is not suited to export oil. Only material suited to waste oil to be sent to export oil stream on FPSOs.	✓	✓	✓	
Tank Slops / Drilling Fluids	Liquid	Drilling fluids from pit cleaning on rigs.	Hazardous Wastes – Tank Slops (HAZ/OIL/TNK)	Oily fluids/slops (e.g. NADF) produced from cleaning of tanks to be returned to shore, to supplier for incorporation into mud system. Non-oily liquids (i.e. <15ppm) to be discharged overboard if they comply with MARPOL 73/78. Use low waste generating tank cleaning system.		✓	✓	
Steel drums	Solid	Drums that may contain hydrocarbons and other chemicals.	Hazardous Waste – Containers (HAZ/CON)	Drums to be fully drained on board. Maximise use of tote tanks, IBCs and other reusable forms of containers where possible to minimise this waste stream.	✓	✓	✓	✓
Plastic drums	Solid	Drums that may contain hydrocarbons and other chemicals.	Hazardous Waste – Containers (HAZ/CON)	Drums to be fully drained on board.	✓	✓	✓	✓

Waste Type	State	Source/Description	Waste Stream (Classification)	Key Requirements	Generated			
					FPSO	MODU	Supply Vessel	Shore Base
Aerosol / pressurised spray cans	Solid	A number of pressurised cans may be used that contain residual paint, lubricants or oil.	Hazardous Waste – Containers (HAZ/CON)	Cans should be fully used prior to being sent to waste.	✓	✓	✓	✓
Bulbs and fluorescent tubes	Solid	General lighting on FPSO – industrial and domestic style lights.	Hazardous Waste – Fluorescent lights (HAZ/FLU)	Requires separate sealed container in which bulbs are to be stored until ready to be sent ashore.	✓	✓	✓	✓
Water, slops	Liquid	Oil contaminated water, bilge water, etc.	Hazardous Waste – Waste Oil (HAZ/OIL)	Treatment on board via oily water separator to MARPOL requirements. Oil to waste oil stream and treated water discharged overboard.	✓	✓	✓	
Filters	Solid	Filters (oil, glycol, fuel oil, potable water).	Hazardous Waste – Oily Solids (HAZ/OIL/SOL)	Used filters to be drained prior to placing in bin. Potable water filters included to avoid uncertainty. Recovered liquids to appropriate waste streams.	✓	✓	✓	✓
NORM	Solid	Scale build up in system.	Radioactive Waste (HAZ/RAD)	See Section 4.2.3 of this WMP for further details on the handling and disposal of NORM.	✓			✓

Table 3-4: Waste Types, Classifications and Key Requirements

3.2.1. Unidentified or New Wastes

Any unidentified waste or new waste stream should be quarantined at site in a designated area. The Environmental Team Lead should then be consulted to ensure that all relevant risks are assessed and appropriate storage and disposal options are provided. Any unidentified wastes will be treated as hazardous and quarantined until full investigation of risks is carried out and final disposal option is identified.

Classification of an unknown waste may require sampling and testing to confirm presence or otherwise of hazardous components. Personnel are to adhere to Personal Protective Equipment (PPE) requirements.

Details of newly identified wastes should be added to this WMP through revision.

4. Waste Handling – Transport and Storage

4.1. Purpose

The purpose of this section is to identify the specific requirements for the storage and transport of wastes.

The storage and transport of all wastes shall also comply with TGL's Chemicals Management Guidelines (TGL-EHS-GUD-EN-0001), which outlines controls required to reduce risk to ALARP (As Low As Reasonably Practicable) for any hazards associated with the transport, handling, use and storage of chemical substances to and from the FPSOs, support vessels, MODUs and shore base.

With respect to the packaging and labelling of dangerous goods for transport, the relevant IMDG, IATA and IAEA codes must be followed. These requirements are not covered in this procedure as they are provided in detail as follows:

- IMDG Code - www.imo.org/Publications/IMDGCode
- IATA Regulations - www.iata.org/publications/dgr
- IAEA Regulations - www-pub.iaea.org/MTCD/publications/PDF/Pub1570_web.pdf

These codes are based on the requirements of the UN's 'Recommendations on the Transport of Dangerous Goods' known as the UN 'Orange Book'.

- UN Orange Book - http://www.unece.org/trans/danger/what.html

Additional guidelines on complying with these requirements are provided within TGL's Takoradi Supply Base Operating Guidelines Manual (TGL-EHS-MAN).

4.2. Storage

Both hazardous and non-hazardous wastes will be labelled and stored in designated and appropriately segregated storage areas i.e. both at the point of origin and the Takoradi shore base chemical storage area. Waste materials shall be stored in a manner to prevent:

- accidental spillage or leakage;
- contamination of soils and groundwater;
- corrosion or wear of containers;
- loss of integrity from accidental collisions or weathering;
- theft by people; and
- scavenging by animals.

4.2.1. Non-hazardous wastes

The non-hazardous wastes presented in Table 3-1 shall be taken directly from the point of origin (or the Takoradi Port off-loading area if originating on the FPSOs, MODUs or other related vessels/facilities) to EPA approved waste contractor facilities for recycling (e.g. metals), re-use, disposal etc.

4.2.2. Hazardous Waste

The hazardous wastes presented in Table 3-2 will be temporarily stored in appropriate containers within the Takoradi shore base chemical storage area. This facility has an impermeable floor (hard standing) with fully contained drainage to prevent surface and groundwater contamination. The area is bunded to ensure 110% containment of the single largest container. Drainage water is routed for treatment through an oily water separator. A detailed inventory will be kept of all stored waste materials.

Hazardous waste materials will be stored at the facility until there is an enough to be sent for treatment or disposal; the frequency of these transfers (or 'consignments') will depend on factors such as the amount waste material generated, logistical considerations (i.e. size of vehicle loads), and waste contractor requirements (such as minimum load sizes). Long-term stock-piling of hazardous waste shall be avoided.

Those hazardous waste types that cannot currently be handled/treated in Ghana using EPA approved waste management contractors shall be stored until appropriate treatment protocols are developed and approved by the EPA or, will be exported in accordance with relevant Ghanaian regulations and international conventions.

Such wastes will be stored at the Takoradi Shore Base (as described/detailed above and below in Figure 4-1) or at an appropriate site designated/approved by the Sekondi Takoradi Metropolitan Assembly (STMA). TGL shall liaise with the STMA regarding any waste materials that are required to be stored / manipulated outside of the Takoradi shore base secure facility.

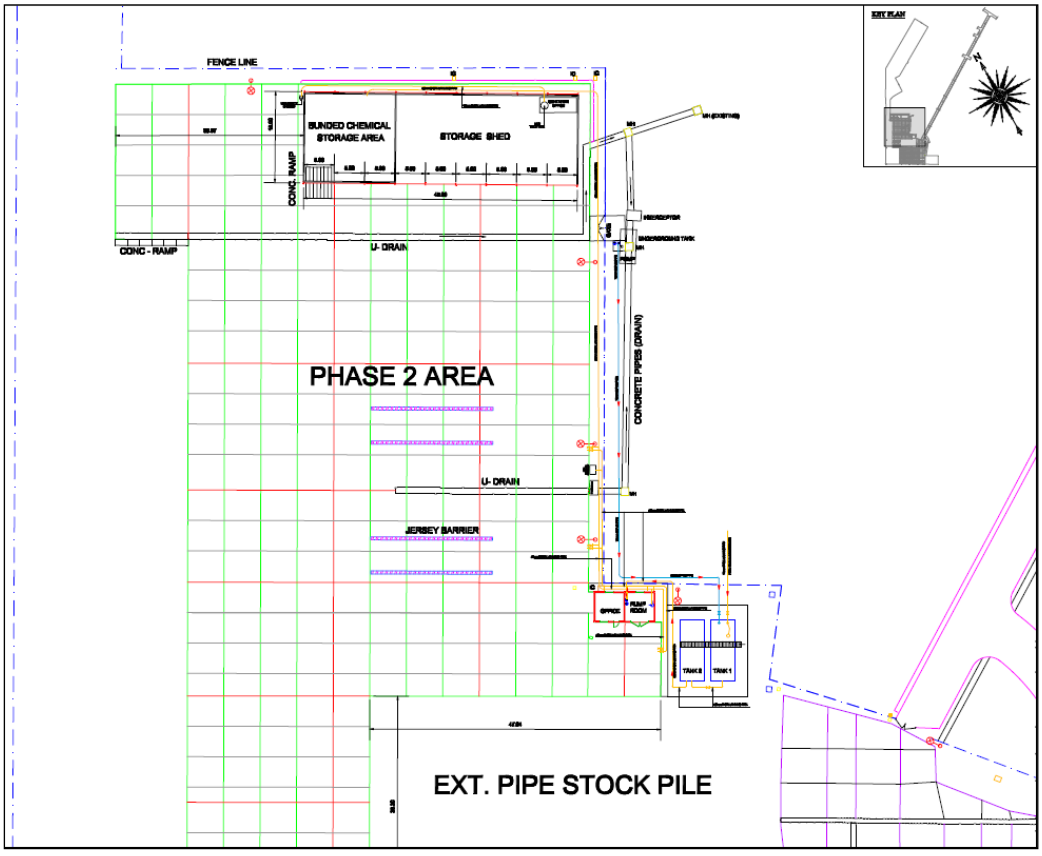


Figure 4-1: Location of Chemical Storage Area within TGL Takoradi Shore Base

4.2.3. NORM Contaminated Waste

Short-term or interim storage may be necessary before the final disposal of NORM waste can occur. Where this is required, NORM waste should be kept in suitable container which should comply with the following requirements.

- Be in good condition with no visible indications of internal or external corrosion, and be made of a durable material such that it provides adequate containment of the NORM waste during the storage period.
- Be made of or lined with materials that will not react with or be incompatible with the NORM waste so that the ability of the container is not impaired or compromised.
- Be resistant to degradation by ultra violet radiation.
- Be closed and sealed during storage, and practical to open and re-seal when it is necessary to add or remove waste.
- Not be opened, handled, or stored in a manner that may rupture the container or cause it to leak.
- Bear the radiation symbol and a label clearly indicating that it contains NORM contaminated waste.
- Pay due regard to any other materials which may be present in the NORM waste matrix (ie oils, grease or chemicals etc).
- Be resistant to normally expected range of temperature in storage environment.
- Be resistant to water ingress.
- Be stored in a dry environment to prevent corrosion.
- Be physically robust to prevent damage during transport.

As with other hazardous wastes, NORM should be stored in an impermeable, bunded area to prevent contamination of ground or surface waters and the creation of contaminated land from any potential leaks or spills from incidents during storage.

The NORM contaminated waste identification, handling and disposal procedure provides additional detailed requirements.

4.3. Container Suitability and Labelling

Waste storage containers will be appropriate in terms of volume, composition, and shape and access for the material that is being stored. Only containers in good condition will be utilised. Bungs and lids will be securely fastened or other forms of covering shall be provided. Containers used shall be inert in relation to their content, clearly labelled, indicating the characteristics of the content, date of containerising or packing, and data on toxicity and/or potential contaminant.

Prior to allowing a consignment of waste to leave an operational site, the facility specific designated personnel shall ensure that the waste containers are:

- clearly labelled - to describe the contents using the appropriate waste labels which should be completed in full (old labels should be removed to avoid confusion);
- in good condition and are not leaking;
- appropriate to the waste they contain;

- appropriately sealed (e.g. with a lid or bung); and
- not emitting any harmful gases or generating heat.

Liquid wastes will either be:

- transported in sealed drums (fit for purpose) – transported as is;
- transported in sealed vacuum skips - to be emptied; or
- transferred directly from the ship to a Contractor facility at the Takoradi port.

If any of these have not been done or have been done to a poor standard, the waste consignment should not be allowed to leave the facility. The EHS Advisor should be contacted and will assist identifying all necessary corrective action(s) to rectify the situation before allowing the waste to leave the facility.

Note the following shall be applied:

- for safety reasons, hazardous wastes should not be mixed; only one waste stream may be placed in any one container;
- solid and liquid wastes shall not be mixed;
- no containers will be used that are susceptible to reaction with the wastes, which may lead to the release of harmful substances; and
- any unidentified waste should be contained separately.

A colour coded system (container labels) will be used to identify waste segregation receptacles as outlined in Table 4-1.

Colour	Description	Waste Streams	Classification
Blue	General waste	General Waste	GEN/WST
		Food	GEN/WST
Green	Non-hazardous & segregated wastes for recycling	Wood	GEN/WOD
		Paper	GEN/PAP
		Kitchen Grease/Oil	GEN/KIT/GRS
Brown	Non-hazardous - Rubber and plastics	Water bottles, empty plastics containers for which contents were non-hazardous	GEN/PLS
Black	Scrap Metal	Metals	GEN/MET
Red	Hazardous Wastes	Hazardous Waste – Batteries	HAZ/BAT
		Hazardous Waste – Electronic	HAZ/ELE
		Hazardous Waste – Flammable Liquids	HAZ/FLM
		Hazardous Waste – Oil	HAZ/OIL
		Hazardous Waste – Oily Solids	HAZ/OIL/SOL
		Hazardous Waste – Oily Sediments	HAZ/OIL/SED
		Hazardous Waste – Tank Slops	HAZ/OIL/TNK
		Hazardous Waste – Chemicals	HAZ/CEM
		Hazardous Waste – Containers	HAZ/CON
		Hazardous Waste – Fluorescent Lights	HAZ/FLU
Yellow	Special Hazardous Wastes	Medical Waste (first-aid sources)	HAZ/MED
		Radioactive Waste (NORM)	HAZ/RAD

Table 4-1: TGL Waste Management Colour Coding – Labels

4.4. Transport

Waste from offshore locations (MODU and FPSO) will be transported to shore (Takoradi Commercial Port) by supply vessels for onward transfer to treatment and/or disposal sites by TGL waste contractor. Land transport of waste from the port to designated treatment or disposal sites shall be done in accordance with bye-laws of the STMA.

Only approved contractors, which meet the appropriate standards, shall be used for transportation and disposal of wastes. Waste transportation to offsite disposal or recycling facilities will be via well maintained, legally compliant vehicles. Contractors will be required to ensure relevant training for their drivers and where relevant vehicles shall carry spill containment equipment.

Waste will be transported so that no waste will escape from the bin/container/skip as it is being transported. This includes:

- the use of nets over solid waste skips;
- ensuring all liquids are transported in sealed tanks/drums. All lids are to be sealed tightly and checked by the contractor prior to transport;
- having spill kits available on all vehicles transporting liquid waste; and
- having a spill response plan for transport of wastes.

NORM waste (including scale or NORM-contaminated components) should be transported in exclusive-use vehicles. Supply vessels used to transport NORM contaminated material or equipment, should utilise standard transport containers appropriately segregated and marked to house the contaminated items. NORM-contaminated items that cannot be stored in standard transport containers should be protected in such a manner as to ensure no leak of NORM material during transport.

4.4.1. Collection Vehicles

The Contractor will collect TGL wastes using waste collection vehicles that, as a minimum, comply with TGL's vehicle policy. All vehicles in the Contractor's fleet shall:

- be fit for purpose;
- have regular maintenance checks and servicing, fully documented and logged;
- not leak fuel or oil;
- load skips automatically or minimise manual handling of waste;
- have road legal tyres exceeding minimum tread requirements; and
- comply with all Ghanaian vehicle laws and TGL minimum vehicle standards including registration and insurance.

The vehicle carrying NORM material or NORM-contaminated equipment should bear appropriate transports placard and signage as required by the IAEA.

The Contractor will ensure that vehicle drivers/operators are adequately trained in vehicle operation and the handling of TGL wastes. Training records shall be maintained to demonstrate that all drivers are suitably qualified and trained. In the case of waste collected by barge from vessels by the Contractor, the barge must meet with TGL approval with regard to design and condition.

All staff operating the vehicles will wear appropriate PPE as a minimum:

- when loading materials, including coveralls, high visibility vests, steel toe-capped boots, protective gloves and hard hats;
- when loading / transferring liquid wastes goggles or face visor should be worn; and
- when loading / transferring hazardous liquids a chemical splash suit should be worn.

4.4.2. Waste Transfer

All collected wastes will be delivered to the respective Waste Contractor's treatment facility (or pre-approved sub-contractor) without undue delay and in no case later than the end of the working day on which the waste was collected.

No vehicles containing waste originating from TGL activities may be parked and left unattended other than at one of the Contractor's own facilities within an appropriately constructed and designated area capable of ensuring the security of the load and capable of preventing any leakage or spillage being released into the environment.
Vehicles may be parked temporarily only for the purposes of making additional collections of waste with the vehicle but only long enough to facilitate any such collections.

No TGL waste will be transported in the same vehicle as incompatible wastes or materials unless the wastes and/or materials are packaged in such a way as to prevent the wastes / materials coming into contact with each other.

4.4.3. Waste Manifest Forms/Documentation

Waste manifest forms (WMF) are fundamental to ensuring that wastes are transferred from the generator, through the transportation chain to the disposer and provide a record of due diligence and duty of care. The WMF tracks the waste stream from the point of origin to the deposit location. WMF will accompany all waste consignments (along with cargo manifest) originating from relevant operational sites, and will be duly completed with the details required within the WMF and the appropriate signatories. Appendix A provides an example of the TGL WMF; Appendix B provides a flow diagram detailing responsibilities for the completion of the WMF.

On arrival at the waste treatment / disposal facility all wastes will be weighed or quantified by other means. The Contractor will provide TGL with copies of the WMF to confirm the receipt of the consignments.

The Contractor shall create a WMF for every movement of TGL waste, whether for the original pick-up from TGL sites or for subsequent transport to sub-contractors for final treatment/disposal. Each WMF shall have the following.

- A unique identifying number for tracking purposes.
- Generating Source/Operational Site details.
- Brief description of the waste bulk.
- Total quantity of each waste received – weight (metric t or kg) or volume (L or m^3) or units (for drums). All wastes received by the Contractor from TGL shall be quantified by Contractor.

- Container description, e.g. 4m^3 open skip, 200L drum, 4m^3 sealed skip, and 1m^3 pod.
- Transporter.
- Designated treatment/disposal facility.
- Relevant dates and times from pick-up, transport modes whiles in transit.
- Name and signature of Contractor representative collecting the waste from the port/TGL site.
- In the case of wastes passed on to a third party/sub-contractor for treatment and/or disposal, a WMF shall be raised documenting this transfer.

The Waste Contractor shall provide TGL with copies of each WMF at the end of each month. WMF are to be retained by TGL for a minimum period of three years.

5. Waste Treatment

5.1. Treatment Options

Table 5-1 provides a summary of the waste treatment methods approved by TGL for each waste type.

Wastes from TGL shall be processed as soon as practicable, allowing for the accumulation of the minimum batch quantity necessary for treatment. Materials for recycling may be stored by the Contractor pending accumulation of a practicable and economic quantity for shipment to the end user / recycling company.

Category	Waste Stream and Classification	Waste Types	Source	Current Management	Long-term Management / Alternative Options
1	General Waste	(GEN/WST)		• Takoradi Landfill	• Recycling options for Paper, Plastics, glass to be evaluated and if identified, segregate at source from the general waste and recycle. • Incineration option to be evaluated, especially if recycling maximised.
2	Kitchen Grease/Oil	(GEN/KIT/GRS)		• Incineration	• Residue from grease traps will be incinerated. • Evaluate recycling options for oil
3	Metals (non-contaminated)	(GEN/MET)		• Recycled by Western Steel and Forgings in Tema	NA
4	Wood	(GEN/WOD)		• Wood should be sorted, recycled as appropriate either for fuel wood in local communities or as building materials. Protruding nails are to be removed and materials otherwise made safe. • If wood is contaminated with oil or chemicals, it should be incinerated.	NA
5	General Plastic	(GEN/PLS)		• Landfill • Segregated bulk plastics (eg IBCs / chemical plastic drums) recycled	• Incineration
6	Paper	(GEN/PAP)		• Landfill	• Recycling options for Paper to be evaluated. If identified,

Category	Waste Stream and Classification	Waste Types	Source	Current Management	Long-term Management / Alternative Options
					paper will be segregated at source from the general waste and sent to the recycling facility. • Incineration
7	Food	(GEN/FOD)		• Food scraps generated offshore will be macerated to <25mm in size and discharged more than 12 nautical miles from land • Food scraps generated onshore will be sent to landfill by catering company • TGL will direct contracted catering company to evaluate recycling options for food scraps including supplying as fodder for farm animals.	NA
8	Hazardous Waste – Batteries	(HAZ/BAT)		• Batteries shall be stored in hazardous waste facility (either contractor or TGL) until sufficient quantity has been accumulated for export to a registered waste recycling facility in the EU or other acceptable location. • Acid from lead-acid batteries to be drained and neutralised. • WARNING: No battery is to be broken up by Waste Contractor to recover the metal. Only whole batteries are to be exported.	NA

Category	Waste Stream and Classification	Waste Types	Source	Current Management	Long-term Management / Alternative Options
9	Hazardous Waste – Electronic	(HAZ/ELE)		• Electrical waste shall be stored in hazardous waste facility (either contractor or TGL) until sufficient quantity has been accumulated for export to a registered waste recycling facility in the EU or other acceptable location. • Consideration will be given to providing refurbished computer equipment to NGO.	NA
10	Hazardous Waste – Flammable Liquids	(HAZ/FLM)		• Incinerated at Zeal Environmental Technologies, Takoradi. • Storage in hazardous waste facility (either contractor or TGL).	• The potential for recycling flammable wastes in a waste to energy facility to be evaluated..
11	Hazardous Waste – Oil	(HAZ/OIL)		• Waste oil produced on FPSOs is recycled via oil export system • Waste Oil from the Rigs and Support Vessels shall be shipped to shore and treated at the Zeal waste treatment facility.	• Recycled - Used as road sealing and waste to energy.
12	Hazardous Waste – Oily Solids	(HAZ/OIL/SOL)		• Oily Solids shall be incinerated at Zeal Environmental Technologies, Takoradi. • Metal recovered to be recycled.	• Evaluate potential for waste to energy
13	Hazardous Waste – Oily Sediments	(HAZ/OIL/SED)		• Drill cuttings with dry weight OOC < 3% are discharged in situ • Drill cuttings with dry weight OOC >3% are sent to shore for storage	• Recycled – Coarser materials (produced sand and packing gravel to be used as road sealing or road base materials

Category	Waste Stream and Classification	Waste Types	Source	Current Management	Long-term Management / Alternative Options
				in hazardous waste facility (either contractor or TGL). • Produced sand with dry weight oil content >1% is sent to shore and used in brick making	
14	Hazardous Waste – Tank Slops	(HAZ/OIL/TNK)	Tank clean outs from drilling and completions	• Mud slops/spent mud solids are stabilised with like and used to produce sandcrete blocks. • See oil contaminated particulates for solids treatment. • Oily fluids/slops (e.g. NADF) produced from cleaning of tanks to be returned to supplier for incorporation into mud system. • Non-oily liquids to be used in brine solution. Any discharge water to meet EPA 10ppm TOG/TPH oil/grease discharge standard for freshwater. • Use low waste producing cleaning systems for pit cleaning only. • Cement and barite from tank cleaning returned to supplier for incorporating into mud system.	NA
			Cement and barite from tank clean outs		NA
15	Hazardous Waste – Chemicals	(HAZ/CEM)		• Non-aqueous laboratory wastes sent to the Waste Oil stream. • Solid residues from the laboratory on the FPSO and MODU/rig sent to the Oily Solids waste stream.	NA

Category	Waste Stream and Classification	Waste Types	Source	Current Management	Long-term Management / Alternative Options
				• Unused chemicals shall be returned to supplier and use of tote tanks and other re-usable containers results in minimal residual chemicals being produced. • Empty drums will be drained on board and residual used for original purpose.	
16	Hazardous Waste – Containers	(HAZ/CON)	Steel drums that may contain hydrocarbons and other chemicals.	• Drums to be drained, crushed and recycled. • Drained liquid to be stored in treated as Hazardous Waste – Chemicals or Hazardous Waste -– Flammable liquids.	NA
			Plastic drums that may contain hydrocarbons and other chemicals	• Drums to be drained, crushed and recycled. • Drained liquid to be treated as Hazardous Waste – Chemicals or Hazardous Waste – Flammable liquids.	NA
			Old paint cans that may contain residual paint	• Residual paint to be dried in cans and cans stored in hazardous waste facility (either contractor or TGL).	• Incinerate. Recovered metal to be recycled post incineration.
			Empty or near empty aerosol cans	• Storage in hazardous waste facility (either contractor or TGL).	• Recycling. Empty can, puncture to depressurise and send to metal recycler. Recover liquids and store in hazardous waste facility.

Category	Waste Stream and Classification	Waste Types	Source	Current Management	Long-term Management / Alternative Options
					• Recovered hydrocarbons to be recycled. • Incinerate. Recovered paints and solvents to be incinerated.
17	Hazardous Waste – Fluorescent Lights	(HAZ/FLU)		• All bulbs and fluorescent tubes to be stored in hazardous waste facility (at waste contractor site) until sufficient quantity has been accumulated for export to a registered waste recycling facility in the EU or other acceptable location.	• Waste contractor to invest in a suitable fluorescent tube crusher that extracts mercury preventing atmospheric discharge.
18	Medical Waste	(HAZ/MED)		• Incinerated in medical waste incinerator used by WARA in Takoradi.	NA
19	Radioactive Waste	(HAZ/RAD)			If NORM is identified during monitoring, TGL will undertake a separate study to identify the most appropriate management options and agree with the Radiation Protection Board and EPA on the most appropriate course of action. NORM disposal options will need to be identified based upon an assessment of the material (such as determination of specific activity and any other hazardous properties), quantity of material

Category	Waste Stream and Classification	Waste Types	Source	Current Management	Long-term Management / Alternative Options
					and availability of disposal methods. The disposal selection criteria should include a consideration of risk, technical feasibility, cost and regulatory and public acceptance. Disposal methods for NORM (low specific activity scale) generated by oil and gas operations in other regions include the following. • Hazardous waste landfill. • Low/intermediate level radioactive waste disposal facility. • Discharge as a slurry into marine waters. • Disposal in abandoned wells between concrete plugs. • Radiation Protection Institute Facility

Table 5-1: Summary of the Approved Waste Treatment Methods

5.2. Waste Management Contractors

5.2.1. Current Status

Waste management facilities and contractors currently available to TGL in Ghana are presently under-developed.

Zeal Environmental technologies have the following waste treatment capabilities.

1. Incinerator for thermal destruction of hazardous waste.
2. Oily wastewater treatment facility.
3. Plastics shredding.
4. Container crushing.
5. Tank cleaning services.
6. Drilling mud waste stabilisation via bioremediation

Zoil Services have the following waste treatment capabilities.

1. Incinerator for thermal destruction of hazardous waste.
2. Anaerobic Thermal Desorption Unit for the treatment of sludge and oily sediments/sands
3. Cuttings dryer
4. Plastics shredding.
5. Container crushing.

Other waste management facilities in Ghana that work in collaboration with Zeal include Western Forgings (recycle scrap metal) and Cyclus Recycling Company (recycle plastics)

5.2.2. Contractor Requirements

Only those waste management contractors, subcontractors or third parties that meet the appropriate standards and are approved by the TGL EHS Department shall be used to manage TGL waste or recovered products. Waste management contractors shall undertake the following.

- Obtain and maintain all required permits for their facilities and operations. As a minimum this shall include an EPA permit to manage the wastes for which they have been awarded a contract and a permit from the Ghana Ports and Harbour Authority to receive wastes off ships in the Takoradi Commercial Harbour.
- Provide a copy of their current EPA permit (or application thereof) plus schedule and approved EIS/PER to the TGL EHS Department.
- Provide details of all waste treatment methods, including safety protocols.
- Accompany TGL EHS personnel in inspecting the sites of any subcontractors or third party. TGL shall advise the contractor in writing as to whether the subcontractor or third party is approved for use.
- Ensure that waste shall only be treated by, or disposed via, TGL approved methods.

- Ensure that waste shall not be dumped at any location and shall not be forwarded to non-approved sub-contractors.
- Submit a Monthly Waste Report (see Section 6).
- Provide quarterly reports on waste management options applied for each waste stream showing metrics on recycling rates, recovery/re-use, treatment etc
- Provide documentation confirming receipt of waste and quantities involved using the TGL WTF system.
- Report to TGL any infringements of disposal standards or any EHS issues of concern.
- Monitor discharges to the environment and report to TGL monthly.

The waste contractor facility should be designed to prevent any uncontrolled surface water drainage from waste processing and/or waste storage areas. All liquids being discharged from site must comply with any discharge consent permit issued or with a specification agreed with the EPA. All emissions to air will comply with EPA emissions standards. In the absence of any discharge standards, the contractor shall comply with acceptable international practices and standards.

5.2.3. Waste Export Requirements

TGL will export certain waste types where the available management technology is not available in Ghana or is not practicable.

The approval process for the shipment of wastes to other countries is governed by the Basel Convention (and Bamako Convention in Africa) which requires approval to be sought from the exporting and importing countries and those countries through which the waste must transit. The general policy of most governments is that wastes should not be imported for disposal unless the exporting country does not have, and cannot reasonably acquire, the technical capacity and necessary facilities to dispose of the waste in question in an environmentally sound manner.

The basic approval process required by the Basel Convention is described below.

The generator or exporter of the wastes must notify the competent authorities of the States of import and transit of the proposed trans-boundary movement of hazardous or other wastes. The notification must contain specific information which is detailed within the Basel Convention, although this can also be found on transit documents prepared by each country. The notification package is the completed notification form accompanied with the following information.

- The source, composition and quantity of the waste for disposal, the producer's identity and, in the case of waste from various sources a detailed inventory of the waste and, if known, the identity of the original producers.
- The arrangements for routing and for insurance against damage to third parties.
- The measures to be taken to ensure safe transport and compliance by the carrier with the conditions laid down for transport by the Member States concerned.
- The identity of the consignee of the waste, the location of the disposal centre and the type and duration of the authorisation under which the centre operates. The centre must have adequate technical capacity for the disposal of the waste in question under conditions presenting no danger to human health or to the environment.

- The operations involving disposal.
- Guarantees that specify that the disposal and recovery operation is carried out in an authorised centre and complies with the requirements for environmentally sound management.

In addition to the Basel Convention notification, WMFs must be completed and must accompany any transfer of waste between different holders. These documents must contain enough information about the waste to enable anyone coming into contact with it to handle it safely and either dispose of it or allow it to be recovered within the law. Once the State of import receives the official notification, it must respond to the notifier in writing, consenting to the movement with or without conditions, denying permission for the movement, or requesting additional information. The notifying organisation will either be TGL or a designated waste contractor exporting the waste on behalf of TGL. A copy of the final response of the State of import is to be sent to the competent authorities of the other States concerned.

The Ghana EPA will not allow waste to be exported until it has received written confirmation that:

a) the notifier has received the written consent of the State of import; and

b) the notifier has received from the State of import, confirmation of the existence of a contract between the exporter and disposer specifying environmentally sound management of wastes in question.

Each State of transit must also acknowledge the notifier that they have received the notification.

The disposer must inform both the exporter and the competent authority of the State of export when it receives the wastes and also when disposal has been completed. The Competent Authority is the body that has responsibility for administering the requirements of the Basel Convention.

These wastes will be exported in a timely manner following all international export procedures.

6. Reporting

6.1. Waste Management Audit Programme

The TGL EHS audit programme is supported by an audit process, which states how EHS audit standards in the area of waste management (i.e. 'cradle to grave') shall be maintained by TGL and which, shall also be in compliance with the requirements of ISO 14001: 2015.

The purpose of EHS Audit Programme/Process is also to define the methodology for the execution and follow up of project EHS management system audits. Therefore, the audit programme/process shall be utilised to perform audits that:

- verify compliance with the applicable laws and regulations of Ghana;
- verify that there is compliance with the TGL and the related operational and project EHS management system process and related project EHS management plans;
- determine whether the elements of the integrated management system (EHSMS related) and/or the related environmental management plan (EMP) are in alignment with the requirements of ISO 14001: 2015;
- identify opportunities to improve the waste management (EHS) management system process & its implementation; and
- ensure compliance by TGL contractors with the requirements and stipulations of the TGL EHS management system process and any other contractual EHS stipulations.

The following waste management audits shall be conducted for TGL facilities and waste contractors at least once per year to ensure compliance and good practice is in place at all sites. These are as follows.

1. TGL Offshore Installations (MODUs and FPSOs).
2. TGL Onshore Installations (Shore Base, Port Operations, FPSO Chemical Support Facility).
3. Waste Management Contractor(s).
4. Waste recycling/disposal sites.

6.2. Environmental Key Performance Indicators

The assessment and measurement of TGL's waste related performance uses environmental key performance indicators (KPIs). KPIs are generated for emissions to all environmental media (air, land and water) for which produced waste is an important performance aspect. Performance data gathered and processed by TGL can be found in the TGL Environmental Monitoring Plan. Environmental KPIs are recorded on the facility (Jubilee and TEN) score cards.

Appendix A WASTE MANIFEST FORM (WMF)

TULLOW GHANA LTD - - WASTE MANIFEST FORM

PART A – To be Completed by GENERATOR ☐ No attachments OR ___ page(s) attached

Responsible facility: ☐ Airport base ☐ Port facilities ☐ TGL Baker building ☐ RIG ☐ IT Department ☐ Accra Office ☐ FPSO ☐ EHS Vessel ☐ Supply vessel ☐ Other (specify)

	Waste description (use attachments as necessary) **Provide MSDS as often as possible for hazardous waste.**	Waste Type ID #	Hazard or Non H	Container No.	Container Type	Quantity Shipped	Units	Handling / Disposition	Receiver Use Also (Part C) No. Containers Received	Container Type	Quantity Received	Units	Handling/ Disposition
1													
2													
3													
4													
5													
6													
7													
8													
9													
10													

Final Intended Receiver: ☐ ZEAL Facility ☐ Other TGL approved facility

If "other" selected, include facility (company) name, full address, telephone number, and name of contact individual:

Certification:	**I declare that the information I have provided in Part A is correct and complete.**	
Name (print):	**Signature:**	**Date** (DD/MM/YY)**:**
Telephone:	**Fax:**	**24-hr Emergency: : (+233) (0) 244 339 945 / 204 339 945**

PART B – To be Completed by 1st TRANSPORTER ☐ **No attachments OR ___ page(s) attached**

Final Intended Transporter:
☐ Supply vessel approved transporter ☐ Helicopter ☐ Other TGL
☐ ZEAL Transport ☐ ZOIL Transport

Name of Transporter: *(Include company name, full address, telephone number, name of contact individual and id applicable the name of the vessel)*

Certification:	**I declare that I have received the wastes as described in Part A for delivery to the Intended Receiver and that the information in Part B is correct and complete.**	
Name (Print):	**Signature:**	**Date** (DD/MM/YY)**:**
Unit No.:	**Telephone:**	**24-hr Emergency:**

No: ####

PART C – To be Completed by 1st RECEIVER

☐ **No attachments OR** ___ **page(s) attached** *(if applicable)*

Date received (DD/MM/YY):	**Intended Receiver?** (see Part A) ☐ Yes

Receiving location: ☐ TGL Port facilities … ☐ ZEAL Port:facility ……..☐ ZOIL Port ☐ Other TGL approved facility

If Other selected, include facility (company) name, full address, telephone number, and name of contact individual:

Irregularities or discrepancies noted between waste received and data appearing in Part A? ☐ Yes ☐ No

*If **"Yes"** selected, describe (use attachment(s) as necessary):*

Certification:	**Except for the irregularities and discrepancies noted above, I declare that I have received the wastes as described in Part A and that the information in Part C is correct and complete.**

Name (print):	**Signature:**	**Date** (DD/MM/YY):
Telephone:	**Fax:**	**24-hr Emergency:**

PART D – To be Completed by 2nd TRANSPORTER

☐ **No attachments OR** ___ **page(s) attached** *(if applicable)*

Final Intended transporter: ☐ ZEAL Transport ☐ ZOIL Transport ☐ Other TGL approved transporter

*If o**ther** selected, include transporter (company) name, full address, telephone number, name of the driver and registration number of the vehicle:*

Certification:	**I declare that I have received the wastes as described in Part C for delivery to the Intended Receiver and that the information in Part D is correct and complete.**

Name (Print):	**Signature:**	**Date** (DD/MM/YY):
Unit No.:	**Telephone:**	**24-hr Emergency:**

PART E – To be Completed by the FINAL RECEIVER

☐ **No attachments OR** ___ **page(s) attached**

Date received (DD/MM/YY):	**Intended Receiver?** (see Part A) ☐ Yes ☐

Receiving location: ☐ ZEAL Facility ☐ ZOIL Facility ☐ Other approved facility

*If **Other** selected, include facility (company) name, full address, telephone number, and name of contact individual:*

Irregularities or discrepancies noted between waste received and data appearing in Part C? ☐ Yes ☐ No

*If **"Yes"** selected, describe (use attachment(s) as necessary):*

Certification:	**Except for the irregularities and discrepancies noted above, I declare that I have received the wastes as described in Part C and that the information in Part E is correct and complete.**	
Name (print):	**Signature:**	**Date** (DD/MM/YY):
Telephone:	**Fax:**	**24-hr Emergency:**

PART F – To be Completed by HSE/E

☐ **No attachments**

OR ___ page(s) attached

Irregularities or discrepancies existed in waste shipment? ☐ Yes ☐ No

If Yes selected, describe the irregularities or discrepancies and the corrective actions that were undertaken (use attachments as necessary):

If No selected, describe why the irregularities or discrepancies noted above in Part C are not genuine (use attachments as necessary):

Name of authorised person (RSES):	**Signature:**	**Date** (DD/MM/YY): **Telephone:**

Waste Type	Code	Hazard
Acid and caustic solutions	06 01 06	H
Activated carbon / molecular sieves	06 13 02	H
Asbestos	17 06 05	H
Barrels, drums, containers, bottle of glass and gas cylinders, aerosol can (empty or full)	15 01 06	H or NH *
Batteries (Cadmium/ Lead / Mercury)	20 01 33	H
Biohazard waste	18 01 04	H
Catalyst	16 08 07	H
CFCs (R22)	20 01 23	H
Cement-contaminated/drilling mud (water based)	01 05 06	NH
Chemical waste	20 03 01	H
Completion and workover fluids	01 01 02	H or NH *
Contaminated waste (PPE, rags, absorbents, paper, cardboard…)	15 02 02	H
Construction debris	17 09 04	NH
Domestic waste (included paper/cardboard)	20 03 01	NH
Fluorescent tubes/bulbs and other mercury containing waste	20 01 21	H
Glass (non contaminated)	20 01 02	NH
Grist blast & swarf	12 01 02	H or NH *
Hydrotest fluid	05 01 99	H or NH *
Injection water filter cartridges	15 02 02	H or NH *
Insulation / lagging (non-asbestos)	17 06 04	NH
Laboratory chemicals	16 05 06	H
Bulbs containing mercury	20 01 21	H
Lube oil or motor oil (used)	13 02 08	H
Organic liquids (Non halogenated solvents)	07 03 04	H
Oil filters and oil filter sludge	16 01 07	H or NH *
Other chemical sludge (emulsified)	14 06 05	H
Paint (and other coating) waste/residues	20 01 27	H
Petroleum hydrocarbon sludge	06 05 02	H
Plastic and rubber (Non contaminated)	20 01 39	H or NH *
Pyrophoric waste	05 01 99	H
Radioactive waste	20 01 35	H
Radioactive waste (smoke detectors)	20 01 35	H
Scrap metal	17 04 07	H or NH *
Separator or vessel sludge and pigging waste	05 01 03	H
Solvents	20 01 13	H
Unused, spent, expired, waste chemicals and additives	20 03 01	H or NH *
Waste water (non hazardous) and sewage	20 03 04	NH
Wastewater (oily)	13 05 08	H
Toners and Cartridges	08 03 17	H
Other miscellaneous wastes	01 05 99	H or NH *

Hazard	Code
Hazardous	H
Non-hazardous	NH

Container type	Code
BigBags (master…)	BB
Container for used batteries	Cb
Container for fluorescent light	Cfl
Drum (plastic or HDPE)	Dp
Drum (metallic)	Dm
Skip	S
Tank	T
Tote tank	TT
Other	AU

Units	Code
Kilogram	K
Tonne	T
Liter	L
Cubic meter	M

Handling/Disposition	Code
Recycle	1
Community reuse	2
Landfill, non-hazardous	3
Landfill, hazardous	4
Incineration	5
Discharged in crude-oil	12
Produced water injection well	13
Other	99

*: a type of waste can be hazardous or non hazardous according to its use and potential contamination. E.g.: office used paper is usually Non Hazardous, but a cardboard contaminated by oil is Hazardous.

Instructions:

STEP 1 **Generator** completes Part A in full.

STEP 2 1st T**ransporter** completes Part B in full at Generator's facility. **Transporter** gives to the **Generator** the (top)**WHITE** sheet which shall be forward to TGL EHS/E Dept within 7 days.

STEP 3 Upon arrival of Transporter's vessel or truck at Receiver's facility, 1st **Receiver** inspects the waste shipment and completes Part C in full. **Receiver** keeps the CANARY sheet, gives to the **Transporter** the PINK sheet, and forwards the remaining GREEN, BLUE and "WATERMARKED" sheets:

1. To the TGL EHS/E Dept within 7 calendar days of receipt of the waste shipment stockpiled at TGL Port facility.
2. To the **2nd Transporter** if applicable.

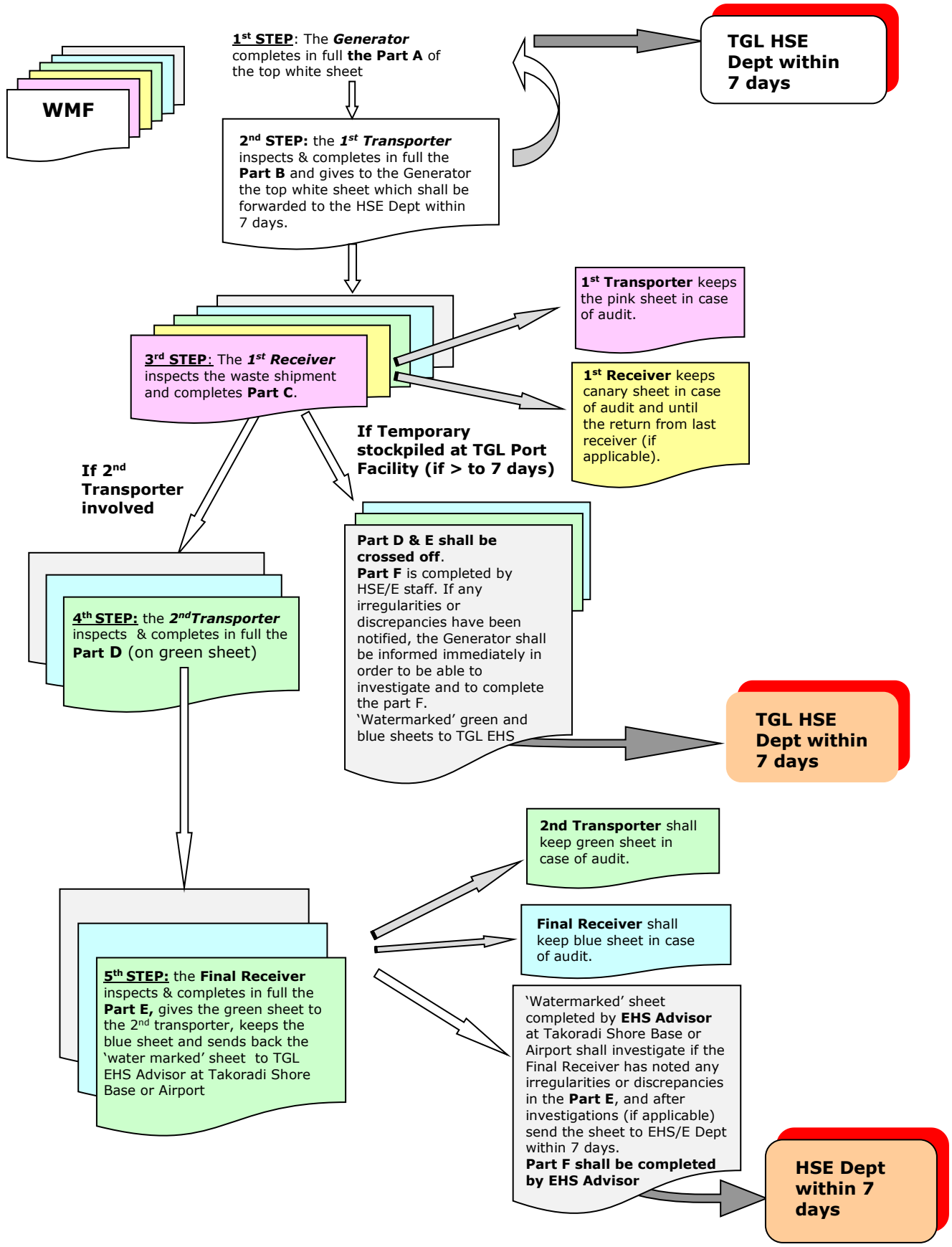
STEP 4 The 2nd transporter inspects and completes in full the GREEN sheet

STEP 5 Upon arrival at the Disposal Facility or other approved final destination, the **Final Receiver** inspects the waste shipment, completes Part E in full, gives to the Transporter the GREEN sheet, keeps the BLUE sheet and forwards the remaining "WATERMARKED" sheet to TGL EHS Advisor at Airport or Port Base who will forward to the EHS/E Dept.

NB1 If irregularities or discrepancies were recorded by the Receiver in **Part C**, TGL Takoradi Airport Base or Port facility shall investigate and take actions to reconcile the irregularities or discrepancies. If Irregularities and discrepancies have been recorded by the final receiver in **Part E**, the **EHS Advisor** of TGL Airport base investigates and takes actions in order to reconcile the irregularities or discrepancies. The EHS Advisor documents investigative results and corrective actions in Part F. Once discrepancies have been reconciled, the EHS Advisor of Airport base forwards the "WATERMARKED" sheet to EHS /E Dept. staff for data entry.

Notes: Generator, Transporters, Receivers, and TGL EHS Organization shall retain their appropriate manifest sheet(s) and supporting data for a minimum of 5 years. If all or a portion of a waste shipment is lost during transportation (for example due to a truck accident), Transporters must notify Generator within 24 hours.

Appendix B WMF FLOWCHART



APPENDIX E ENVIRONMENTAL MANAGEMENT PLAN

Tullow Ghana Limited

Environmental Management Plan (EMP)

Jubilee and TEN Developments

DOCUMENT NUMBER:	**TGL-EHS-PLN-04-0004**
Rev:	**6**
Date:	**16.06.18**
Review Frequency:	**Every 2 years**

Revision History

Rev	Date	Reason for Issue	Prepared	Checked	Approved
0	30.06.10	Issued for Use	GBe	JW/EBA	PW
1	01.10.10	Re-issued in response to EPA comments on Rev. 0	GBe	JW/EBA	PW
2	30.04.12	Revised for Jubilee Operations Permit Renewal	EBA	ETA	PW
3	08.01.13	Re-issued for use	FM	FM	PW
4	15.10.13	Re-issued for use	EBA	ETA	PW
5	06.10.15	Re-issued for use	EBA	HA	SR
6	16.06.18	Re-issued for use	Emmanuel Benjamin Arthur	Esi Tunde-Anjous	Sean Reilly

Revision Control

Revision	Para /Sect	Change Description
1	Sect. 1	Addition of a 'clarification' paragraph explaining the purpose of the plan as it relates to the specific technical environmental issues identified and associated with the Jubilee operational phase only i.e. 'social and community' related mitigation and management issues are dealt with in the PCDP and other Stakeholder Framework documentation/agreements
1	Sect. 1	Addition of a paragraph clarifying the EMP 'Review' period and process in line with the TGL Management of Change process (TGJ-PJM-PRC-07-0006-1), the integrated EHSS management system and also implementation of ISO 14001
1	Sect. 2	Narrative updated to accurately reflect minor changes to current operational description
1	Sect. 2	Clarification of the Jubilee operational area exclusion/advisory zones
1	Sect. 6.1	Addition of an indicative environmental budget (Table 6.1.1) for the 2011 operational/fiscal year
1	Sect. 6.7/ Table 6.7.1	Upgrading of the 'Legal Compliance' section to include other key Ghanaian environmental regulations and acts
3	Sect. 2.1	New TGL EHS policy
3	Sect 5.1/ Table 5.1.1	The table has been cancelled and an indicative budget mentioned
3	Sect. 5.11/ Table 5.11.1 - # 2.03	Definition of the "produced water" term and modification of the max. oil contented in water discharged

3	Sect. 5.11 – Table 5.11.1 - # 2.09	New topic about the WWTP in Accra and Takoradi
3	Sect 6	Section erased
3	Sect.7	one reference added concerning the new EPA Environmental certificate
4	Global Changes to document	Update of EMP for Jubilee Operation permit renewal to reflect current management practices and the inclusion of the environmental action plan for the next 3 years
5	Global Changes to document	Global review and update for inclusion of the TEN Development.
6	Global Changes to document	Update of EMP for TEN and Jubilee Operations permit renewal to reflect current management practices and the inclusion of the environmental action plan for the next 3 years
	Sect. 2.1 and related sections	Change of EHS Policy to Safe and Sustainable Operations Policy and at all sections where policy is named or referenced
	Sect. 1.5	Update of Linked Documents with the inclusion of Tullow Safety Rules and Tullow Oil Non- Technical Risk Standard
	Sect. 3.5	Operational areas - redefinition of offshore Ghana/Cote D'Ivoire Maritime boundary with an updated map supplied with coordinates
	Sect. 4	EMP Roles and Responsibility - updated to reflect current organisation and structure for the management of environmental aspects
	Global changes	Production chemicals supplier changed from Baker Hughes to Nalco Champion in the entire document
	Sect. 6	Environmental Action Plan: Updated to reflect strategic environmental management actions for the next 3 years

This sheet must be completed in detail, at each revision once this document has been approved. Details must include revision number, description and indication of which pages and paragraphs have been revised, date of revision approval and approval indication.

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Abbreviations and Definitions

Abbreviation or Phrase	Definition
bar	Measurement of Pressure (1 bar = Atmospheric Pressure)
bbls	Barrels
BoD	Basis of Design
BOD	Bio-chemical oxygen demand
Bq	Becquerel (measure of surface radiation level)
COD	Chemical oxygen demand
CSR	Corporate Social Responsibility (Manager)
EEZ	Exclusive Economic Zone
EHS	Environmental, Health, and Safety
EHS MS	Environmental Health and Safety Management System
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
FPSO	Floating, Production, Storage and Offloading Vessel
GNPC	Ghana National Petroleum Corporation
IMS	Integrated Management System
ISO 14001: 2004	International Environmental Management Standard
KPI	EHS – Key Performance Indicator
MMscf	Million Standard Cubic Foot (Gas Volume Measurement Unit)
NORM	Naturally Occurring Radioactive Material
OSRL	Oil Spill Response Limited
PCDP	Public Consultation and Disclosure Plan
pH	Standard measure of acidity/alkalinity (hydrogen ion concentration)
ROV	Remotely Operated Vehicle
SOP	Standard Operating Procedure
Supt	Superintendent
TGL	Tullow Ghana Ltd
TSS	Total suspended solids

1. Introduction

1.1. The Company

Tullow Oil plc is one of the largest independent oil and gas exploration and production companies in Europe. The company is in the next phase of transformational growth with a major focus on Africa, where it has become a dominant player. Tullow has a large portfolio of exploration and production assets including interests in over 90 licences in 22 countries. The company continue to be focused on its high-impact exploration program in West Africa. In 2007, the company made its largest discovery to date − the Jubilee Field. Since then, further major discoveries have been made including Tweneboa Enyenra and Ntomme offshore the west coast of Ghana.

Tullow Ghana Limited (TGL), a wholly owned subsidiary of Tullow Oil plc based in the United Kingdom was registered as an oil and gas exploration and production company initially with the Ghana National Petroleum Corporation (GNPC) prior to the establishment of the Petroleum Commission by Act 821, 2011 as the upstream petroleum industry regulator. TGL has been registered with the Petroleum Commission since its establishment. TGL is the designated operator of the Jubilee and TEN development fields. TGL operates the Jubilee and TEN Fields on behalf of the joint venture partners; Tullow Oil, Kosmos Energy, Anardarko, Petro SA and Ghana National Petroleum Corporation.

The Tullow Oil plc Corporate Vision is to be the leading global independent exploration and production company and believes this will be achieved through a continuing focus on Africa and related geological plays in South America.

1.2. Background

The Jubilee and TEN Field Developments involve the production of hydrocarbons from subsea reservoirs located in deepwater 60 − 80 km offshore the West Coast of Ghana. The Jubilee development is currently in production phase covered by Environmental certificate number CE0018280707 and TEN Development is also production phase covered by Environmental Certificate number CE0018280622. The Environmental Management Plan was reviewed and updated in order to secure the Environmental certificates for the Jubilee and TEN Field Development and Operations. The Jubilee Operations Environmental certificate has a validity period of 3 years and will be due to expire May 25, 2021. The TEN Operations Environmental Certificate also has a validity period of 3 years and will be due to expire December 31, 2020. and ay 2and TEN environmental certificates each has to Per the Environmental Assessment Regulations LI 1652 and EPA requirements, the submission of an updated Environmental Management Plan (EMP) for an undertaking is the regulatory requirement for obtaining certificate renewal every 3 years. The Jubilee and TEN development EMP has therefore been revised to satisfy the requirement for Environmental permit/certificate renewal for the TEN and and Jubilee operations. The supporting documents to the TGL EMP is as outlined below:

1. Environmental Monitoring Plan
2. Waste Management Plan
3. Jubilee Oil Spill Contingency Plan
4. TEN Oil Spill Contingency Plan

Jubilee and TEN development broadly being the same type of undertaking with same environmental aspects, the two developments are being managed under the same Environmental Management System. As such, subsidiary Environmental Management Plans to this EMP is applicable to both Jubilee and TEN Operations. Basis for EMP Development

This environmental management plan (EMP) is the mechanism by which Tullow Ghana Limited (TGL) shall manage the significant environmental impacts associated with the Jubilee oil and gas operational activities.

From a Ghanaian regulatory perspective, the requirements for an EMP are contained in the Environmental Assessment Regulations of 1999. Under Part II, Section 24, an Environmental Management Plan is required within 18 months from commencement of operations and thereafter every 3 years. In Section 24 of the LI, the regulations further require that:

24. (1) "The person responsible for an undertaking in respect of which a preliminary environmental report or an environmental impact statement has been approved shall submit to the Agency an environmental management plan in respect of his operations within 18 months of commencement of operations and thereafter every 3 years".

And

(4) "The environmental management plan shall set out steps that are intended to be taken to manage any significant environmental impact that may result from the operation or the undertaking".

The goal of this environmental management plan is, therefore, to provide a framework/platform for achieving the avoidance or minimisation of the identified and documented adverse and significant environmental impacts arising from the Jubilee oil and gas operational activities, both within the operational footprint and also the wider i.e. operationally associated environs e.g. shore line communities and shore logistics bases.

The TGL EMP for TEN and Jubilee operations has been prepared in line with the requirements of the Tullow Oil Safe and Sustainable Operations Policy and Ghana Environmental Management System. The Tullow Ghana Limited Safe and Sustainable Operations 'Policy' statement provides the overarching framework/platform for controlling and managing its operational environmental impacts and aspects. The Safe and Sustainable Operations Policy is as presented as follows (refer to Figure 2-1):

This EMP relates specifically to the technical environmental aspects/impacts associated with the Jubilee and TEN Field operational phase activities.

Thus, it is intended that this EMP will serve as the framework document to effectively manage all environmental aspects and impacts of the Jubilee and TEN Field Operations. This EMP is written and submitted for approval to the Ghana EPA in compliance with section 24 of the Environmental Assessment Regulations (LI 1652).

1.3. Review and Update

This EMP will be reviewed every two years and updated and reissued in accordance with the TGL 'Management of Change' processes. Additionally, the EMP will be updated following legislative, process, procedural or organisational changes on an as required basis.

1.4. Linked Documents

The following documents are referenced below as they are relevant to the scope of this plan.

- Tullow Integrated Management System (IMS) (TOP-IMS-PRO-08-01).
- Tullow Safe and Sustainable Operations Policy (T-HSS-POL-0001).
- Tullow Safety Rules (T-EHS-STD-002)
- Tullow Oil Non-Technical Risk Standard (T-SEA-STD-0001).
- Tullow Ghana Ltd EHS Management Framework (TGL-EHS-PRC-04-0052).
- Tullow Ghana Ltd EHS Management Review Process (TGL-EHS-PRC-04-0053).
- Tullow Ghana Ltd Incident Management Plan (TGL-EHS-PLN-04-0003).
- Tullow Ghana Ltd Environmental Monitoring Plan (TGL-EHS-PLN-04-0006).
- Tullow Ghana Ltd Waste Management Plan (TGL-EHS-PLN-04-0008).
- Tullow Ghana Ltd Ballast Water Management Plan (TGL-EHS-PLN-04-0009).
- Tullow Ghana Ltd Oil Spill Contingency Plan – Jubilee (TGL-EHS-PLN-04-0010).
- Tullow Ghana Ltd Oil Spill Contingency Plan – TEN (00002-TLW-ES-PLN-0014).
- TGL Chemicals Management Guidelines (TGL-EHS-GUD-EN-0001).
- TGL Marine Mammal and Turtle Avoidance Guidelines (TGL-EHS-GUD-04-0002).
- TGL Guidelines for minimising impacts to birds and wetlands from flight operations (TGL-EHS-GUD-04-0001).
- Marine Operations Manual (TGL-OPS-MAN-10-0001).
- TGL Legal Compliance & Evaluation – SOP (TGL-EHS-PRC-04-0045).
- TGL Jubilee Field Phase 1 Development Final Environmental Impact Statement. November 27, 2009.
- TGL Jubilee Phase 1A Development Technical Note, November 4, 2011.
- TGL Jubilee Phase 1A Infill Development EIA Addendum, October 20, 2014
- TGL Temporary Spread Mooring Environmental Assessment, October 25, 2016
- TGL Permanent Spread Mooring Environmental Assessment, September 19, 2018
- TGL TEN Field Development Final Environmental Impact Statement, September 5, 2014.
- EPA Jubilee Field Phase 1 Productions Operations Environmental Certificate – CE0018280474. May 2, 2015.
- EPA Environmental Permit for TEN Field Operations, CE0018280518, June 30, 2016
- IFC Environmental and Social Action Plan (TGL–IFC–Project Number 27918 and 31483). April 9, 2014.

Key Contractor documentation includes:

- MODEC Environmental Management Plan (0005-ACC60-15SM-1201).
- MODEC HSEQ Standards Framework (2507-MI60-15SM-0001).
- MODEC Offtake Operational Procedure (0245-MI20-OPSM-0794).

- MODEC Special Operations Procedures - Helicopter Operations Procedures (10-01-MOD-J87-00763).

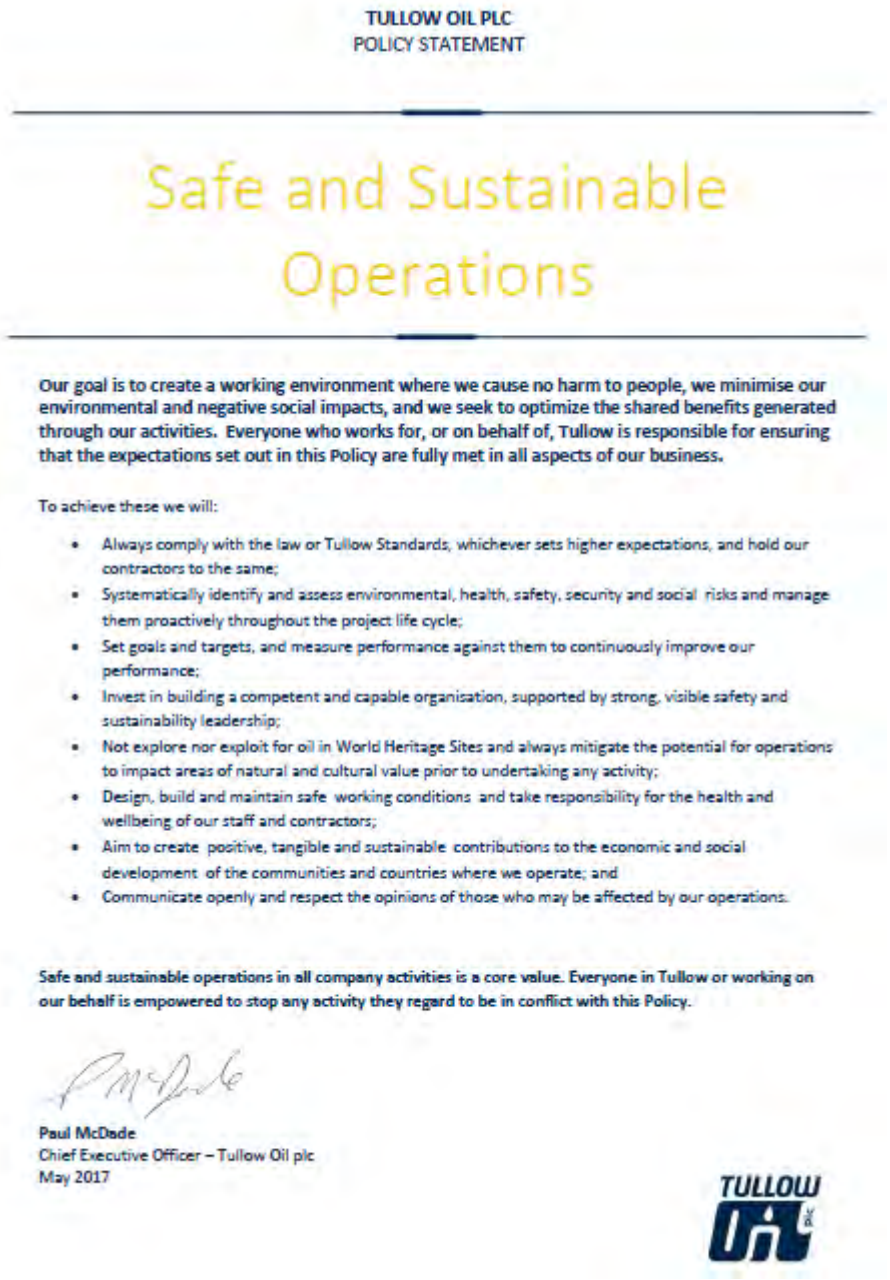
In addition, the following guidelines and standards are relevant to the plan.

- BS EN ISO 14001: 2015 Environmental Management Standard.
- EPA Guidelines for Environmental Assessment and Management in the Offshore Oil and Gas Development.
- IFC (International Finance Corporation). EHS Guidelines for Offshore Oil and Gas Development. June 05, 2015.
- IFC (International Finance Corporation). EHS Guidelines for Thermal Power Plants. March 11th, 2008.
- EPA – Guidelines for Environmental Assessment and Management in the Offshore Oil and Gas Development – 2011.

2. EHS Management Structure

2.1 Environment Health and Safety Policy

TGL complies with the Tullow Oil plc Safe and Sustainable Operations Policy Statement.



TULLOW OIL PLC
POLICY STATEMENT

Safe and Sustainable Operations

Our goal is to create a working environment where we cause no harm to people, we minimise our environmental and negative social impacts, and we seek to optimize the shared benefits generated through our activities. Everyone who works for, or on behalf of, Tullow is responsible for ensuring that the expectations set out in this Policy are fully met in all aspects of our business.

To achieve these we will:

- Always comply with the law or Tullow Standards, whichever sets higher expectations, and hold our contractors to the same;
- Systematically identify and assess environmental, health, safety, security and social risks and manage them proactively throughout the project life cycle;
- Set goals and targets, and measure performance against them to continuously improve our performance;
- Invest in building a competent and capable organisation, supported by strong, visible safety and sustainability leadership;
- Not explore nor exploit for oil in World Heritage Sites and always mitigate the potential for operations to impact areas of natural and cultural value prior to undertaking any activity;
- Design, build and maintain safe working conditions and take responsibility for the health and wellbeing of our staff and contractors;
- Aim to create positive, tangible and sustainable contributions to the economic and social development of the communities and countries where we operate; and
- Communicate openly and respect the opinions of those who may be affected by our operations.

Safe and sustainable operations in all company activities is a core value. Everyone in Tullow or working on our behalf is empowered to stop any activity they regard to be in conflict with this Policy.

Paul McDade
Chief Executive Officer – Tullow Oil plc
May 2017

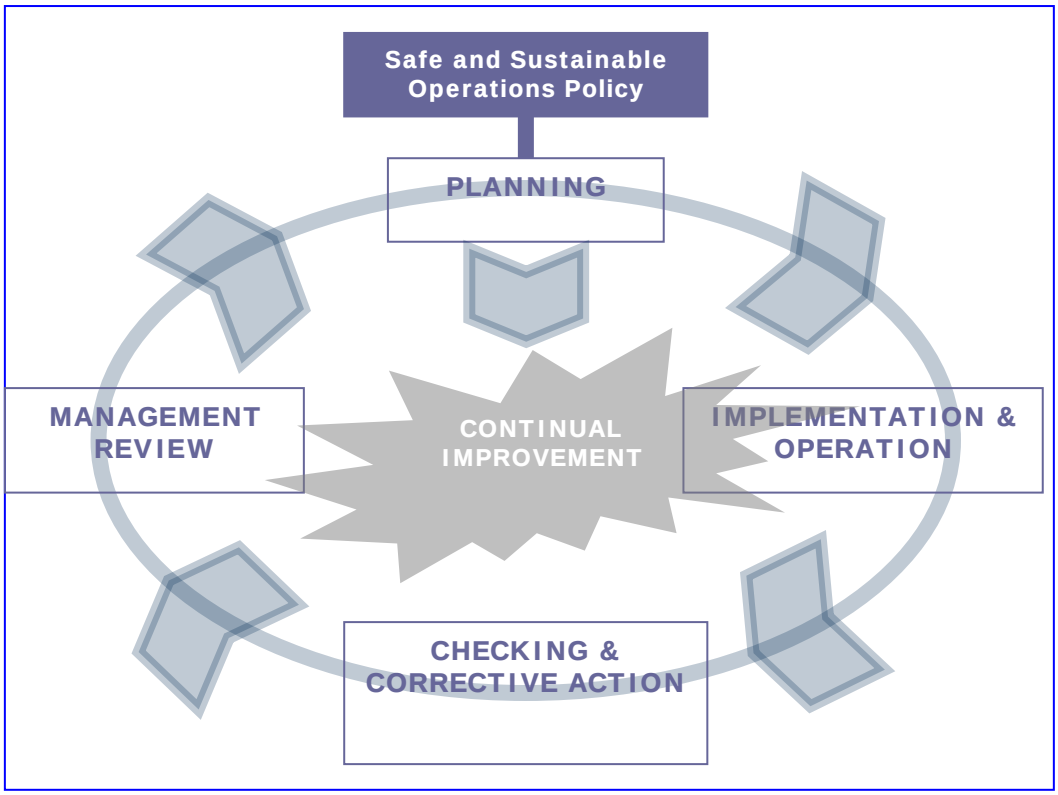
Figure 2-1: TGL Safe and Sustainable Operations Policy

2.2 Jubilee / TEN Operational EHS Management

TGL employs a number of management tools to manage environmental impacts and risks associated with the Jubilee and TEN Development Operations. These include developing

appropriate procedures and work instructions, auditing, regularly inspecting sites for compliance, communicating responsibilities and monitoring.

The Jubilee/TEN Oil/Gas Operations environmental management plan (EMP) also forms part of the 'planning' phase of the (EHS) business management cycle; the overall purpose of which is to ensure a continual improvement of TGL's operational environmental performance. The key phases of the EHS business cycle (see Figure 2-2) are further explained as follows: the Safe and Sustainable Operations **POLICY** (Figure 2-1) provides the framework and platform from which the business is conducted; the **PLANNING** phase involves the compilation and agreement of the necessary plans required for the successful expediting of the business; the **IMPLEMENTATION AND OPERATION** phase of the cycle involves the development and implementation of the required processes, guidelines, procedures, instructions et al relating to operational control, training and awareness, asset integrity etc. i.e. to translate the requirements of the plans/policy into frontline working documents; the **CHECKING and CORRECTIVE ACTION** phase of the cycle involves the application of the EHS audit and inspection programmes and supporting processes to all key operational/EHS management processes to ensure compliance with the policy and applicable legislation and also identify areas of non-conformity; the **MANAGEMENT REVIEW** phase of the cycle involves an organised and structured performance review of all aspects of the EHS business cycle with the ultimate goal of identifying areas for further environmental performance improvement and the setting of appropriate, achievable and measurable objectives and targets to achieve the identified performance improvements:
Figure 2-2: The EHS Business Management Cycle



Thus, this EHSS Planning and Management 'cycle', which is line with the international environmental management standard **ISO 14001: 2015**, will be applied to achieve the mitigation and control of the operational environmental impacts (and aspects). These environmental 'impacts' and the proposed impact mitigation and management controls to be applied are summarised as follows:

1 **Project Footprint –** Relates to the environmental impacts associated with the 'physical presence' of the FPSOs and its subsea structures and its relationship with the local environs;

2 **Operational Discharges** – Mitigation and management of the environmental impacts associated with marine liquid phase discharges from the FPSOs, its subsea systems, and marine (and other transportation) vessels et al;

3 **Air Emissions** – Details and describes air emissions originating/arising from all FPSOs (fixed point source) and marine/aviation transportation (mobile point source) combustion, routine and non-routine flaring operations and non-combustion (e.g. venting) sources and their associated environmental impacts;

4 **Waste Management** – Relates to solid/liquid waste materials derived from both the FPSOs (and subsea systems) and supporting infrastructure (marine vessels, shore bases et al) and the measures applied to mitigate and manage the associated environmental impacts;

5 **Loss of Containment** – Specifically relates to all 'spills/accidental releases' (offshore and onshore) scenarios and the contingencies and plans to be implemented should a loss of containment occur;

6 **Process Chemical Management** – Identifies and relates the environmental impacts of and the management controls/mitigation measures associated with the volumes and types of process and non-process related chemicals that will be stored and utilised during FPSO operations/production, subsea equipment operation and MODU drilling and completion operations;

7 **Audits and Inspections** – In line with the requirements of the TGL EHS MS and also as part of the overall environmental impact mitigation strategy, annual EHS audit programme is implemented yearly. The FPSOs/MODU and support infrastructure and oilfield services are audited annually on a regular basis.

8 **Biodiversity Management** – This section exclusively deals with the possible environmental impacts on offshore (marine) flora and fauna arising from the presence of the FPSOs, MODU and its associated operational activities. Also detailed, are the intended environmental mitigation measures and the management control strategy designed to protect the various identified marine species; and

9 **Project Decommissioning** – Details the envisaged 'field' termination and abandonment activities and environmental impacts associated with the decommissioning of the FPSOs and related subsea systems at the conclusion of the planned operational lifetime of the Jubilee and TEN Fields.

Therefore, to achieve the above, the EMP is structured as follows (key sections are described):

Sect. 1: **INTRODUCTION** – A brief profile about the company and its operations in Ghana, background to the development of the Environmental Management Plan and Basis for its development.

Sect. 2: **EHS MANAGEMENT STRUCTURE -** TGL EHS Policy and EHS Management Structure and the concept/philosophy behind its development as a system that is continually being reviewed and enhanced to ensure continual improvement in the delivery of operational EHS performance. A description of the 'structure' and 'layout' of the EMP is also contained within this section.

Sect. 3: **OPERATIONS OVERVIEW AND SCOPE** – This section describes a high level 'operational envelope' i.e. a mass balance of inputs and outputs, key

geographically referenced features of the marine spread, and the overall battery limits of the Jubilee and TEN oil/gas operations/production phase.

Sect. 4: **EMP – ROLES AND RESPONSIBILITIES** – This section defines the roles and responsibilities of key TGL and Contractor involved in the Jubilee and TEN oil/gas operations and productions phase.

Sect. 5: **EMP – ORGANISATION** – Key areas and the structure of the EMP are detailed in this section. Specifically, an overview of these subsections is detailed as follows:

5.1 Environmental Impact Mitigation Hierarchy: Informs the reader of the environmental impact 'mitigation' strategy to be adopted by TGL i.e. in order of preference: 1. Avoid or reduce (impacts) at source; 2. Abatement of impact at the point of origin; 3. Abatement of impact at the impact receptor; 4. Repair or remedy (the affected environment; and 5. Compensate in kind i.e. when all mitigation measures outlined in 1,2, 3, and 4 are not successful.

5.2 EHS and Operational Management Structure: Explains the management structure (onshore Accra/Takoradi and FPSO related) that TGL will implement to ensure the effective and safe management of the Jubilee and TEN oil/gas operations/production phase including relevant information regarding (key) contractor management.

5.3 Contractor EHS Interfacing and Bridging: Details of the levels and mechanisms for bridging the contractor key EHS documentation/systems with this EMP and also other TGL management (EHS and non-EHS) systems and plans are contained within this section. General contractor interfacing mechanisms are also described in this section.

5.4 Environmental Management and Monitoring Table(s) Construction: The construction of both the environmental management tables and the (summary) environmental monitoring table i.e. table 'fields' is detailed within this section.

5.5 Environmental Reporting Requirements: of the Jubilee and TEN oil/gas operations/production phase are described in this section.

5.6 Related EHSS Management Plans: Documents the key environmental management and monitoring plans that are referenced within, and which have also been developed in parallel with this EMP inter alia, the oil spill contingency plan (OSCP), the waste management plan (WMP), environmental monitoring plan (E.Mon.P).

5.7 Compliance Hierarchy and Framework: An overview of the Ghanaian key environmental legislation and conventions to which Ghana is a signatory and which, therefore constitutes the legal framework in which TGL operates in, is contained within this section.

5.8 TGL Environmental Legal Compliance Register: A description of the comprehensive environmental regulatory compliance requirements currently utilised by TGL to contain and track the various environmental commitments arising from a number of sources.

5.9 EHS Training and Awareness: An overview of the level and nature of the training and awareness programme that is being developed to ensure that all operational and EHS personnel are kept abreast of the latest developments within their professional fields and to demonstrate a level of operational control.

5.10 Document Organisation: Details the construction of the EMP and environmental monitoring summary tables.

5.11 EMP and Environmental Monitoring Activity Tables: Lists the key issues relating to the Jubilee and TEN oil/gas operations/production phase major environmental impacts, and details the management measures and strategies to be implemented to mitigate the identified environ impacts. A summary of the

environmental monitoring mechanisms to be applied during this operational phase is also included in this section.

Sect. 6: **ENVIRONMENTAL ACTION PLAN –** Specific environmental action programmes that address existing environmental problems that need to be addressed to ensure operational environmental performance is achieving regulatory compliance and good practice standards.

Section 6 contains the environmental impact and mitigation/management tables. In Table 2.1 below, therefore, is a distillation of the key performance indicators derived from the detailed tables which, will forms the Jubilee and TEN oil/gas operations/production phase environmental 'objectives and targets'. These environmental objectives and targets are a key feature of, and are aligned with, the contents of this environmental management plan (EMP)

Impact Category/Key Activity	Environmental Impact Source	TGL Objectives/Targets
FPSOs footprint related	Disposal of solid (kitchen/sewage) waste materials to the sea	- Achieve compliance with MARPOL regulations for the discharge of food waste to the sea - Ensure that all food/kitchen waste discharged to the sea is < 25 mm maximum particle size - Ensure no inorganic waste are discharged to and no floating solids are observed on the surface of the sea
MODUs Infill drilling	Drill cuttings discharge	- Achieve < 3% (weighted average) oil on cuttings with no observable 'free oil' - If NADF (non aqueous drilling fluids) are required to be utilised (i.e. on a well engineering basis) use LOW TOXICITY formulations Utilise barite with the following limitations: < 1 mg/kg Hg & < 3 mg/kg Cd.
FPSOs operational/production discharges	Marine sanitation device (MSD)/Sewage system discharge of black and grey water	Ensure: - No floating solids on the sea surface - No discolouration of surrounding waters - Free chlorine < 1 mg/l (i.e. prior to discharge)
MODUs/FPSOs Physical Presence in Position	Bilge machinery water discharge Vessel ballast water discharge	- Ensure a maximum level of 15 ppm oil/grease content is not exceeded

Impact Category/Key Activity	Environmental Impact Source	TGL Objectives/Targets
FPSOs Production operations MODUs Well flow and testing operations	Process Discharges - Produced water discharge - Desulphation water discharge - Desalination water discharge - Cooling water discharge - Slops	- Ensure that the oil in water content does not exceed 29 mg/l at any time - Achieve 'no visible sheen' on the sea surface
MODUs/FPSOs operational/production discharges	Well completion and work over fluids discharge Produced water and slops discharge	- Ensure that the oil in water content does not exceed 29 mg/l over a 30-day period and 42 mg/l at any time - Achieve 'no visible sheen' on the sea surface - Measured (i.e. prior to discharge) pH of the discharge fluid should be in the range 6 → 9
Logistics Base Operations/FPSO Chemical Storage Facility	Shore base/port run off water	Ensure that any discharges meet the following requirements: - pH range 6 → 9 - COD maximum 125 mg/l - Oil/grease maximum 10 mg/l - TSS maximum 50 mg/l
Marine vessels operational discharges	Sewage discharge Bilgewater discharge Food waste discharge	Ensure: - No floating solids on the sea surface - No discolouration of surrounding waters - Free/Residual chlorine < 1 mg/l (i.e. prior to discharge) - Ensure a maximum level of 15 ppm oil/grease content is not exceeded - Achieve compliance with MARPOL regulations for the discharge of food waste to the sea - Ensure that all food/kitchen waste discharged to the sea is < 25 mm maximum particle size - Ensure no inorganic waste are discharged to and no floating solids are observed on the surface of the sea
FPSOs Production Operations	Produced sand	Ensure that any produced sand contains < 1% residual oil prior to discharge

Impact Category/Key Activity	Environmental Impact Source	TGL Objectives/Targets
FPSOs Production Operations	Naturally occurring radioactive material (NORM) discharge	Ensure that any materials discharged does not exceed 4 Bq cm^{-2} (Gamma/Beta radiation) and 0.4 Bq cm^{-2}. Comply with Nuclear Regulatory Authority (NRA) requirements and approval for NORM scale discharge offshore
FPSOs operational/production air emissions	Greenhouse gas emissions (GHG) – various combustion (mobile and static point) sources	Based upon type of fuel (diesel and fuel gas) utilised and its consumption, for static and mobile point combustion sources, the following emission limits should not be breached: **Engines –** *Gas fired* (> 3MW): NOx – 200 mg/Nm^3 (Spark Ignition); 400 mg/Nm^3 (Dual Fuel); 1,600 mg/Nm^3 (Compression Ignition) *Liquid fuel* (> 3 MW): Particulate Matter – 50 mg/Nm^3; SO_2 - 1.5% sulphur; NOx - 1,460 - 1,850 mg/Nm^3 (depending on bore size diameter) **Turbine** Natural Gas (15 MWth to < 50 MWth): NOx – 51 mg/Nm^3 Fuels other than Natural Gas (15 MWth to < 50 MWth): 0.5% sulphur; NOx – 74 ppm **Boiler** *Gas*: NOx – 320 mg/Nm^3 *Liquid*: Particulate Matter - 50 or up to 150 mg/Nm^3 if justified by environmental assessment; SO_2 – 2000 mg/Nm^3; NOx – 460 mg/Nm^3 *Solid*: Particulate Matter - 50 or up to 150 mg/Nm^3 if justified by

Impact Category/Key Activity	Environmental Impact Source	TGL Objectives/Targets
		env. assessment; SO_2 – 2000 mg/Nm^3 NOx – 650 mg/Nm^3
FPSOs Production Operations	Flaring	Generally, routine flaring levels not expected to exceed 3% of monthly gas produced for TEN FPSO. On Jubilee, a new purge rate of 3 – 4 mmscf/d has been instituted as a protective measure for the replaced flare tip. This purge rate ensures flare flame is lifted off the flare tip. Aside these, consent applications will be made for non-routine flaring operations i.e. start-ups, shutdowns and maintenance periods. Regulatory notifications will be made for unplanned events such as process upsets or flaring for safety imposed by emergency situations. Technical justification will be provided for all non-routine flaring operations which exceeds the 3% regulatory limit beyond the purge rate of each facility.
FPSOs operational/production waste management	Storage, segregation and transportation of waste materials	- Achieve zero loss of containments of hazardous wastes - Maximise 're-cycling' opportunities • Metals – 95% • Plastics – 95% • Waste oil – 95% - Maximise "re-use" opportunities • Woodwaste – 70% - Minimise the generation of 'hazardous' wastes - Continuous drive to reduce waste quantities going to a landfill via recycling and re-use opportunities (recycling

Impact Category/Key Activity	Environmental Impact Source	TGL Objectives/Targets
		of plastics, scrap metal, wood waste, glass etc)
MODUs/FPSOs operations	Loss of Containment of crude and other liquid phase materials	- Ensure production trees are function tested as per operational routines - Ensure well (drilling) BOPs (blow out preventers) are function / pressure tested every 14 to 21 days (maximum) - Ensure that a minimum of on-site x3 (three) Tier 1 loss of containment scenario drills/exercises are accomplished per year - Perform update training of personnel in equipment use by OSRL specialist as and when required
FPSOs operations/production	Process chemicals usage and discharge	Give priority to OSPAR Green and Yellow class of chemicals for production chemical requirements Identify and replace (where technically feasible) those chemicals which are bio-accumulating and/or toxic to marine life - Develop a chemicals database (including material safety data sheets – MSDS – and eco-toxicity data) and ensure all identified chemicals are 'permitted' for use by the EPA.
FPSOs operations/production	Audit and inspection	- Develop and implement an annual audit/inspection programme - Perform a minimum of x4 EHS audits related to the 'FPSO' and 'Key Contractor' operations - Identify and record any 'opportunities for improvement' and 'issues of non-compliance' - Ensure that a minimum of 95% of all audit/inspection actions are closed out within the given time frame

Impact Category/Key Activity	Environmental Impact Source	TGL Objectives/Targets
FPSOs operations/production	Wildlife management	- Achieve and maintain a minimum of 8 trained personnel to ensure continuity of the mammal observation programme - Perform annual analysis of MMO data sets

Table 2-1: Key Jubilee and TEN Oil/Gas Operations/Production Phase Environmental Objectives and Targets

3. Operations Overview and EMP Scope

3.1. Introduction

TGL has two interests in the Deepwater Tano (DWT) and West Cape Three Points (WCTP) blocks namely the Jubilee Development and the Tweneboa, Enyenra and Ntomme (TEN) Development as shown in Figure 3-1. Offshore operations are supported out of Takoradi TGL Logistics Supply Base.

Figure 3-1: Tullow Ghana Operations

3.2. Jubilee Development

Jubilee Field Location. The Jubilee Field was first discovered in 2007 and is located ca. 60 km offshore western Ghana. The field underlies areas of both the 'West Cape Three Points' and the 'Deepwater Tano' oil production blocks. See Figure 3-2.

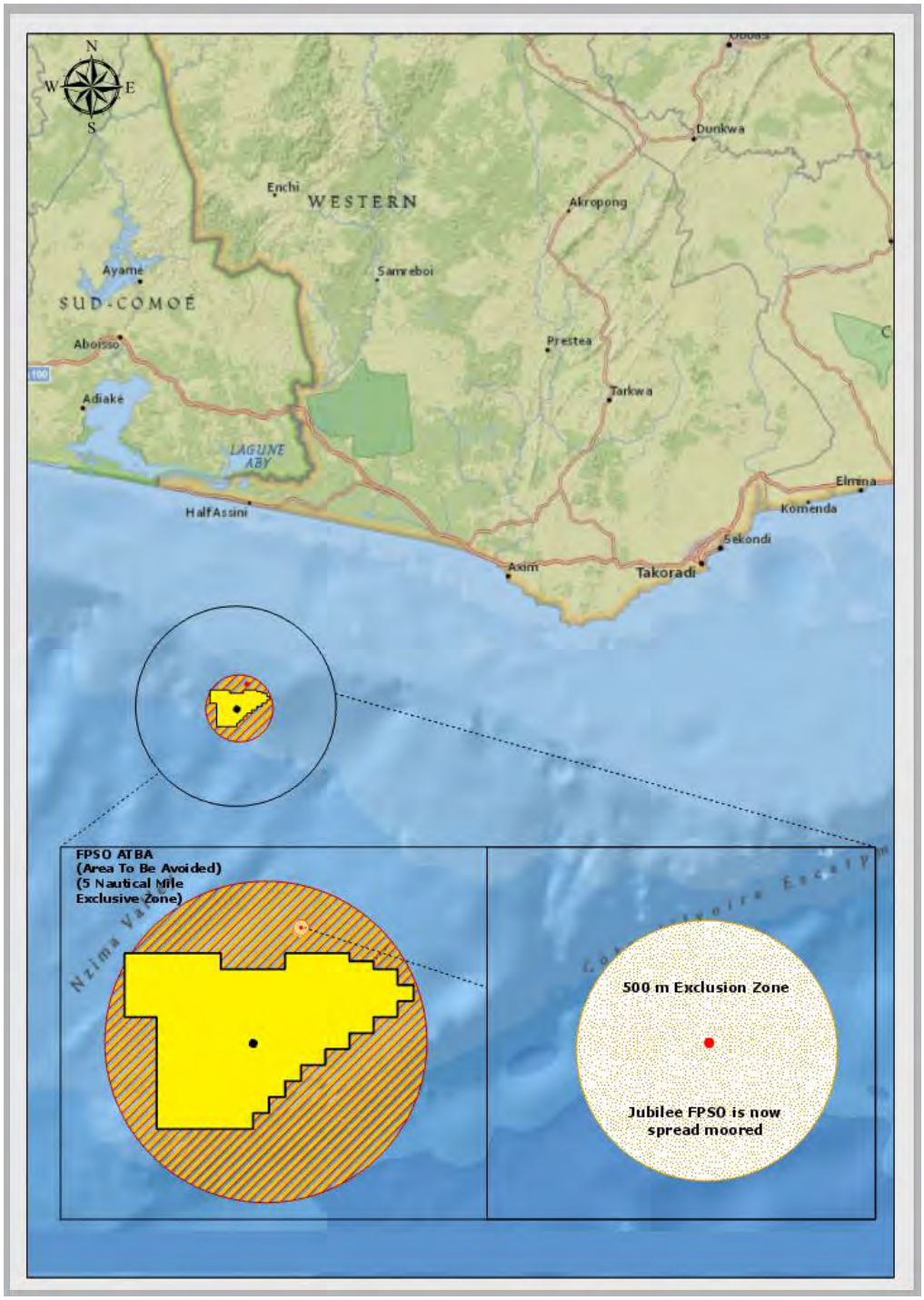


Figure 3-2: Jubilee Location and Key Maritime Features of the oil/gas production field

The assets and infrastructure comprising the Jubilee Field Development comprise the following:

i. **Floating, Production, Storage and Offloading** (**FPSO Kwame Nkrumah**) vessel (see Figure 3-3)

ii. **Subsea Production System** ((SPS) i.e. wellheads, manifolds and wellhead/manifold connection systems);

iii. **Onshore Support Infrastructure** (i.e. Chemical support facility, logistics supply base – equipment and spares warehousing, pipe yard, chemicals storage, laydown areas, port facilities; oil spill response equipment and packages);

iv. **MODU – Well drilling, completion, workovers and other interventions**

v. **MPV for field servicing** i.e. subsea infrastructure inspection, maintenance and well treatments;

vi. **Field support vessels** (supply vessels for cargo operations, field patrol vessels);

vii. **Air transportation for personnel transfers** (fixed wing and rotary wing flights for personnel and crew changes).

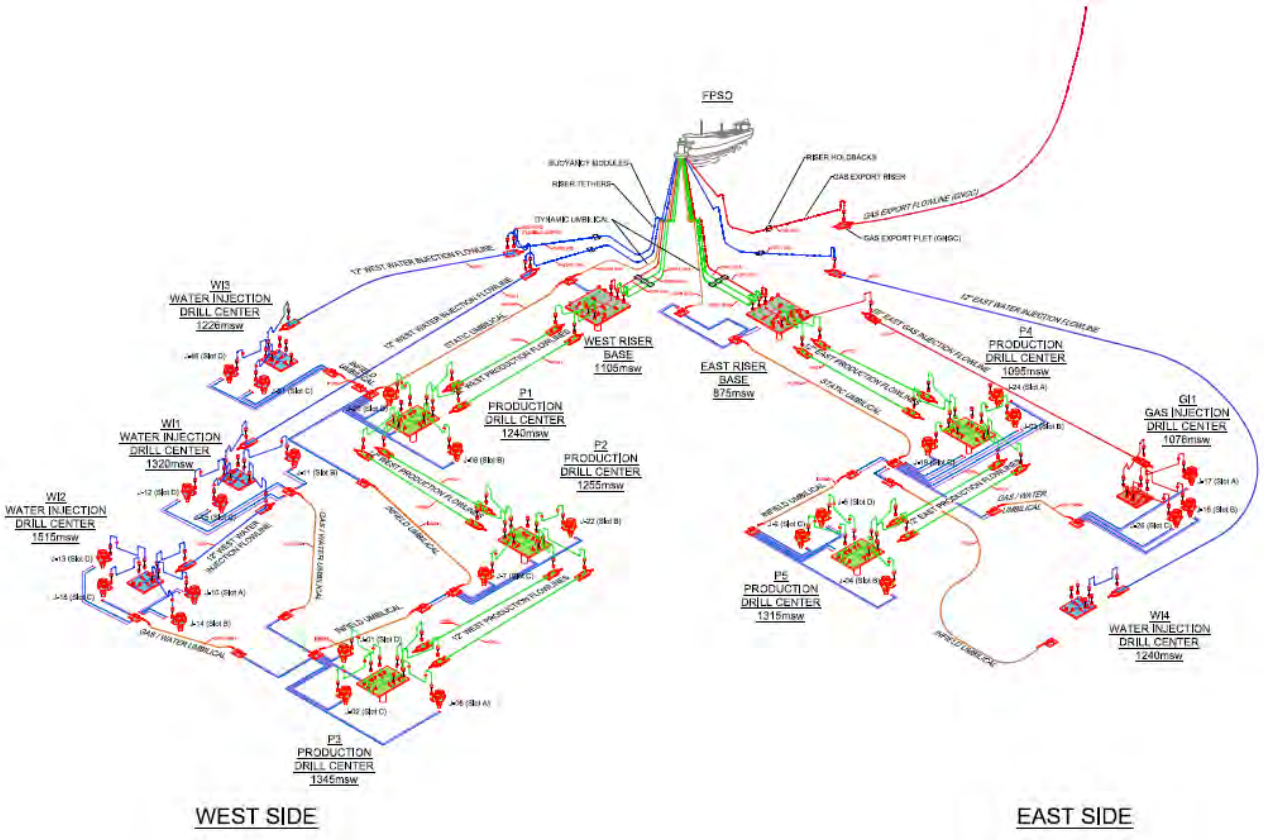


Figure 3-3: Jubilee Subsea Systems – Wells and Manifolds

An overview of the subsea (production and injection) manifolds is as follows.

1. Production manifolds (x5) and associated production wells:

   P1 (J08-P, J20-P well), P2 (J07 ST1-P, J22-P) P3 (J01-P, J02-P and J06 ST1-P wells), P4 (J03-P, J-19, J24-P, J37-P) and P5 (J04 ST1-P, J05-P and J09-P wells);

2. Water injection manifolds (x4) and associated wells:

   W1 (J11-WI, J12-WI and J15-WI wells) and W2 (J10-WI, J13-WI, J-14-WI and J-18-WI wells); W3 (J21-WI and J46-WI) and W4 (J36-WI4 3 slots open)

3. Gas injection manifold and associated wells:

   G1 (J16-GI, J17 ST1-GI and J-26).

There are some wells within the Jubilee Field that have been drilled but currently not part of the subsea production system. J23 tophole was drilled in January 2013. Lower GOR was needed to increase production. In 2H 2013, J23-P and J-25-WI swapped with J50 and J49 WI. J50 did not encounter sufficient hydrocarbons to be completed as a producer and was suspended pending further studies. J49-WI was put on hold and replaced with J46-WI. J36WI and J-37P wells were required to assure and increase production. J37-P has been drilled and completed in 2015. J-36-WI was drilled in November 2015. The well will be completed once a rig becomes available.

Field maintenance and optimisation programme involving well workovers, reservoir acid stimulation and other well intervention programmes may be required from time to time to give field production sustenance and longevity. In order to maintain the required reservoir output at desired production levels for the envisaged duration of the operational phase (i.e. full production to 2020 with a subsequent steady decline in output to ca. 2030), an on-going field development programme involving seismic (2D & 3D) surveys, further drilling and completions, and possible future tie-backs to the FPSO may also be required. This future field expansion termed Greater Jubilee Full Field Development (GJFFD) Plan of Development (POD) has obtained Government of Ghana approval. The GJFFD has been subjected to the appropriate environmental impact assessment supplementary to the original Jubilee EIA and subsequent updates.

A basic operational mass balance of the FPSO is contained in Figure 3-4. Essentially, the treated (i.e. stabilised by separation) crude is transferred to export tankers which are directly connected to the FPSO i.e. the FPSO has the capability of 'direct loading'. Storage capacity on the FPSO is ca. 1.6 million bbls of crude oil (vessel dimensions are 330 m length by 60 m width. The vessel can accommodate 120 personnel (maximum). A schematic of the FPSO operational flow systems is presented in Figure 3-4.

From the schematic in Figure 3-4 the Operational Envelope i.e. the production, treatment and injection capacity, of the FPSO is as follows.

- A production capacity of 120,000 barrels of crude oil/day at steady state;
- A processing capacity of up to 80,000 barrels of produced water/day this includes 50% redundancy processing capacity.
- 160 MMscf/day of gas for various usage e.g. injection (for reservoir maintenance), power generation, etc.
- 232,000 barrels/day of injection water for reservoir maintenance;

- Varying barrels of treated seawater (uplift)/day to produce treated injection make up water; and
- 20 years of operational activity.

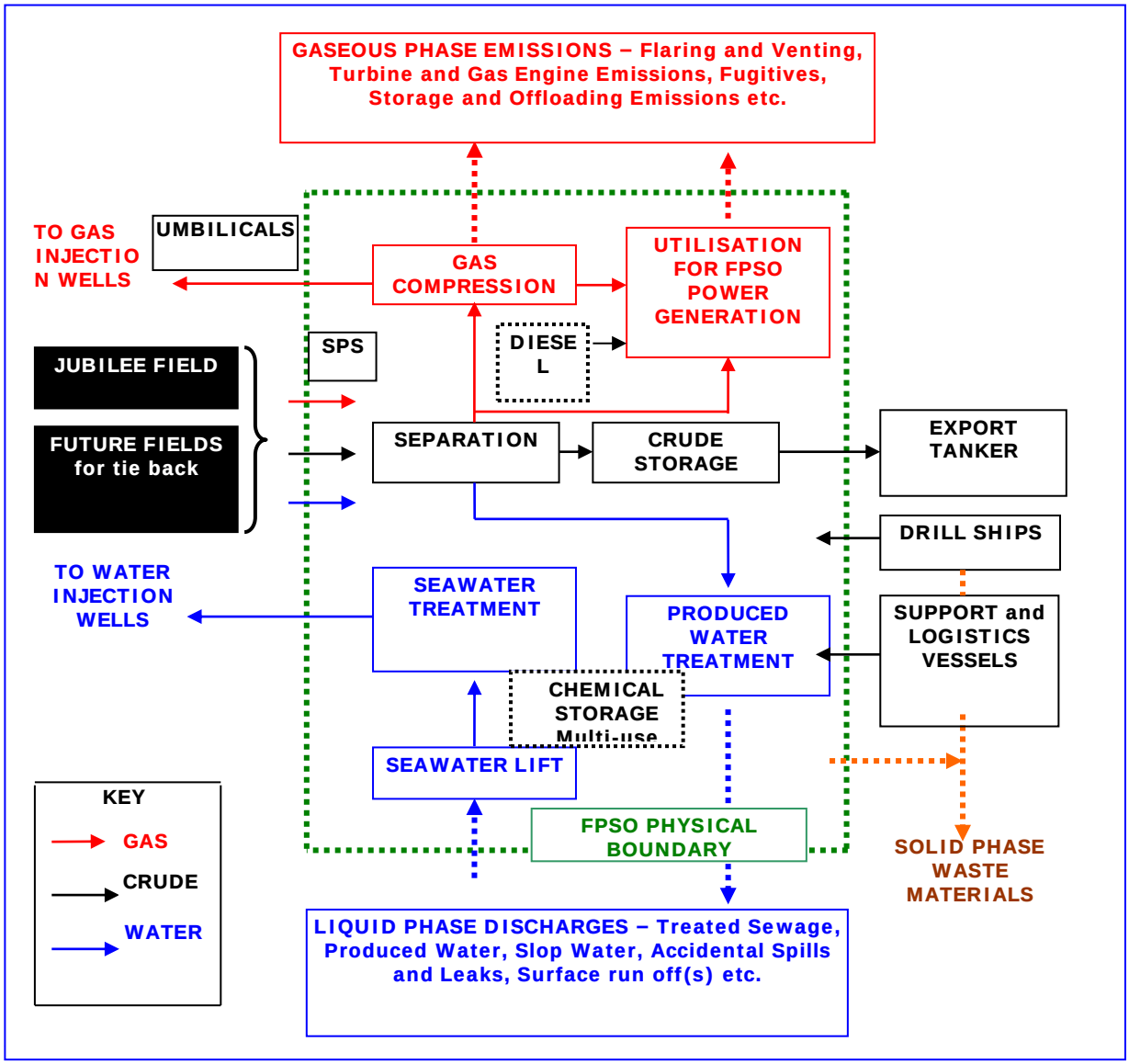


Figure 3-4: FPSO Operational Mass Balance

3.2.1. Jubilee Alternate Crude Oil Offloading Operations

Due to the failure of the FPSO KNK turret bearing recorded in February 2016, an impairment which makes the facility unable to weathervane as per its original design, the facility had to be spread moored. The spread mooring installation was completed in February 2017. The original tandem offloading operation have had to be substituted with an alternate arrangement. The alternative lifting operations include offloading crude oil in 250,000 barrel (bbl) parcels from the FPSO to a shuttle tanker every 3-4 days which

then transfer the product to a storage tanker via ship to ship (STS) transfer operations in a designated Lightering Area (see figure 3-5). When the 2,055,000 bbl storage tanker is full it discharges the crude to an export tanker approximately every 10-11 days in the Lightering Area. The offloading operation is graphically illustrated in figure 3–6. Table 3-1 provide a summary of marine assets employed in the lifting arrangement.

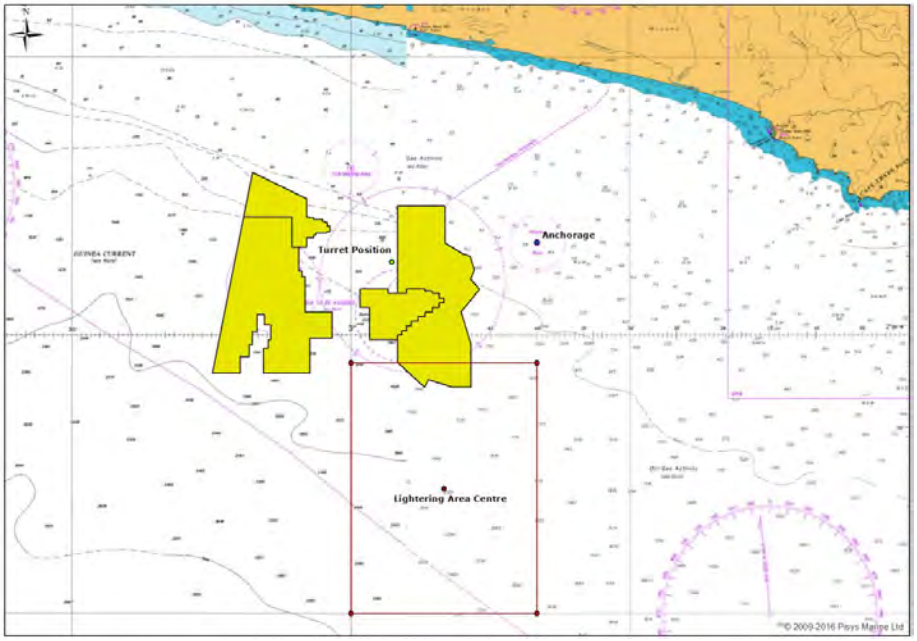


Figure 3 – 5: Designated lightering area south of the Jubilee Field

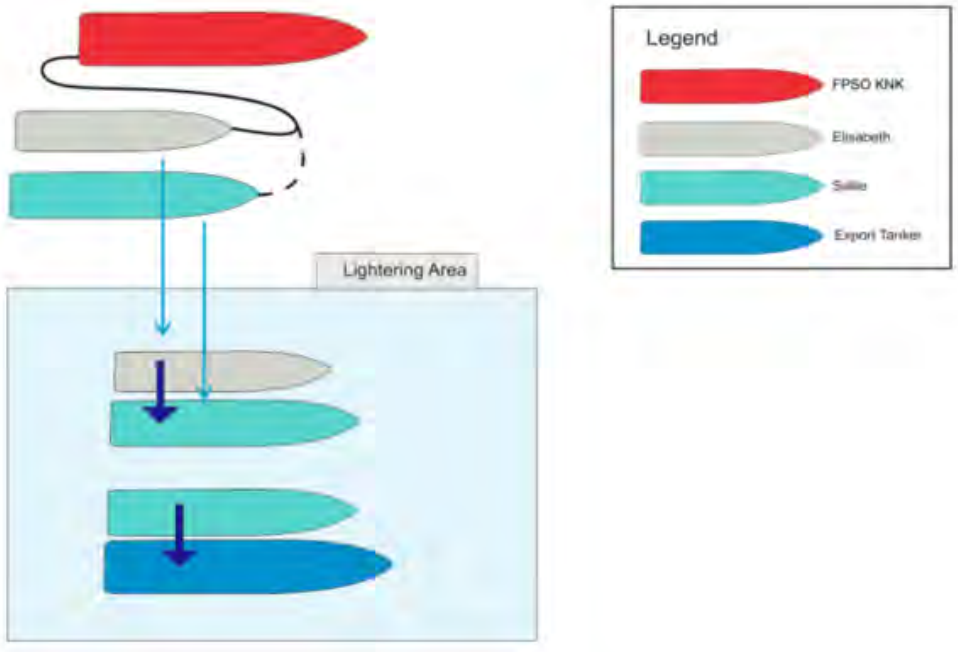


Figure 3 – 6: Jubilee Lifting Plan using shuttle and storage tankers

Vessel Type	Name	Function
FPSO	Kwame Nkrumah	Currently temporarily spread moored due to the impairment of the original turret mooring system. Facility remains as the oil and gas production facility for the Jubilee field. The FPSO has a crude oil storage capacity of 1.7 million bbls.
Shuttle/ Storage Tankers	Sallie and Elisabeth Knutsen	The Sallie and Elisabeth Knutsen are double hulled tankers with a combined storage capacity of 1.8 million bbls. The Elisabeth Knutsen serves as a shuttle between the FPSO and Sallie. The Sallie acts as both a shuttle tanker from the FPSO and also as storage tanker. Transfers are undertaken every 2 to 3 days utilising both vessels. Once the Sallie is full she transfers oil to the Export Tanker. The vessels have a dynamic positioning system for maintaining position.
Export tanker	Various	Export tankers visit to purchase crude parcels for the international market. Export tankers will berth to the Kokkari in the designated Lightering Area for ship-to-ship transfer operations.

Table 3-1: Description of vessels employed in the Jubilee alternate lifting arrangement

3.3. TEN Development

3.3.1. Development Location

The TEN Development area covers approximately 450 km^2 and is located within the DWT block. The TEN facilities, including the FPSO vessel, lie approximately 60 km south of the nearest coastline in Ghana, 140 km southwest of the port at Takoradi, 10 km east of the Ghana and Cote d'Ivoire maritime border and 20 km west of the Jubilee field. Water depths at the fields range from about 1,000 to 2,000 m.

The FPSO is located near to the central part of the Enyenra reservoir (E 484470 m, N 507230 m), at similar latitude to the Jubilee FPSO (E 511990 m, N 508074 m). The position of the FPSO was selected taking into consideration known geohazards, bathymetry, mooring requirements, oil offloading requirements and metocean data. The water depth at this location is approximately 1,450 m.

3.3.2. TEN Operations Overview

The TEN Development and Production Area falls within the DWT block in water depths between 1,000 and 2,000 m, and covers an area of approximately 450 km^2. The approved mid-case development comprises a total of 24 wells including 11 production wells, 10 water injection wells, 2 gas injection wells and 1 gas production well. Production is gathered through subsea manifolds and conveyed by subsea flowlines to a FPSO, *Professor John Evans Atta Mills*, moored in the area of the TEN fields (E 484470 m, N 507230 m).

Processed crude is stored and exported to global markets. Produced gas is compressed, dehydrated, and used as a fuel gas, exported, or injected. All excess associated gas and non-associated gas is either re-injected into Ntomme reservoir gas cap to assist in the development of Ntomme Oil or exported to a Ghana National Gas Company operated subsea gas export pipeline under a gas sales agreement.

The Technical specification for the TEN development is provided in Table 3-2 and the layout shown in Figure 3-7. The simplified process flow diagram is shown in Figure 3-7 and the subsea layout is shown in Figure 3-8.

Feature	Capacity / Number	Units / Notes
Oil processing	80,000	bpd (nominal)
Liquids (oil and water) processing	100,000	bpd (nominal)
Gas processing	180	MMscfd (nominal)
Produced water treatment	65,000	bpd (nominal)
Gas injection	135	MMscfd (nominal)
Water injection	132,000	bpd (nominal)
Fuel gas	10	MMscfd (nominal)
Power generation capacity	54	MWe (nominal)
Storage capacity	1,700,000	bbl (nominal)
Offloading rate	1,000,000	In 20 hours
Minimum availability	95%	
Topsides dry weight (excluding turret)	19,939	Metric Tonne
Turret capacity	24	-
Turret allocation slots (used/future)	15/9	-
Mooring pattern	3x3	-
Mooring composition	-	Polyester chain
Mooring piles	9	Estimated
Crane capacity	15	Te (at 40 m radius)
	25	Te (at 30 m radius)
Accommodation	120	Personnel on Board

MMscfd = million standard cubic feet per day; bbl = barrels; bpd = barrels per day; MWe = megawatt electrical; te = tonnes.

Table 3-2: TEN FPSO Technical Specifications

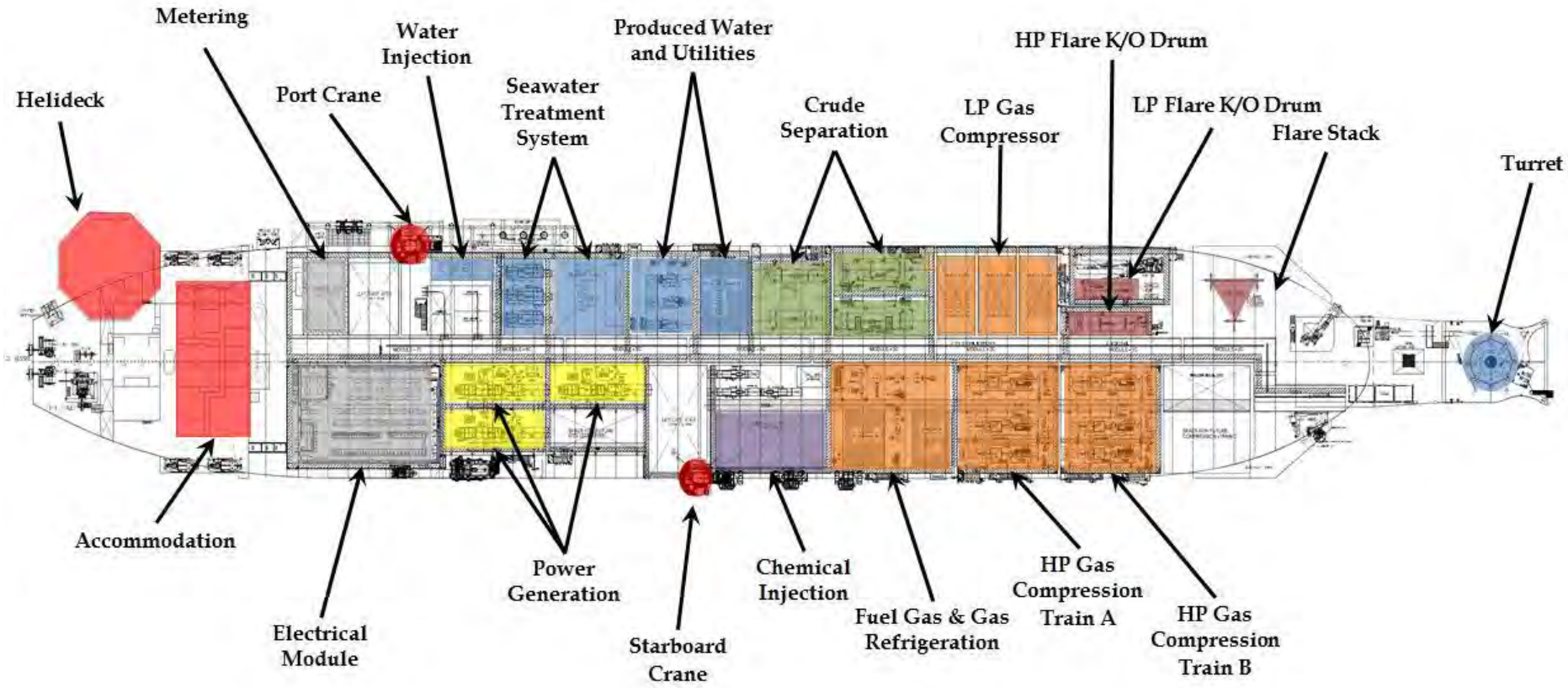


Figure 3-7: Indicative Layout of an FPSO

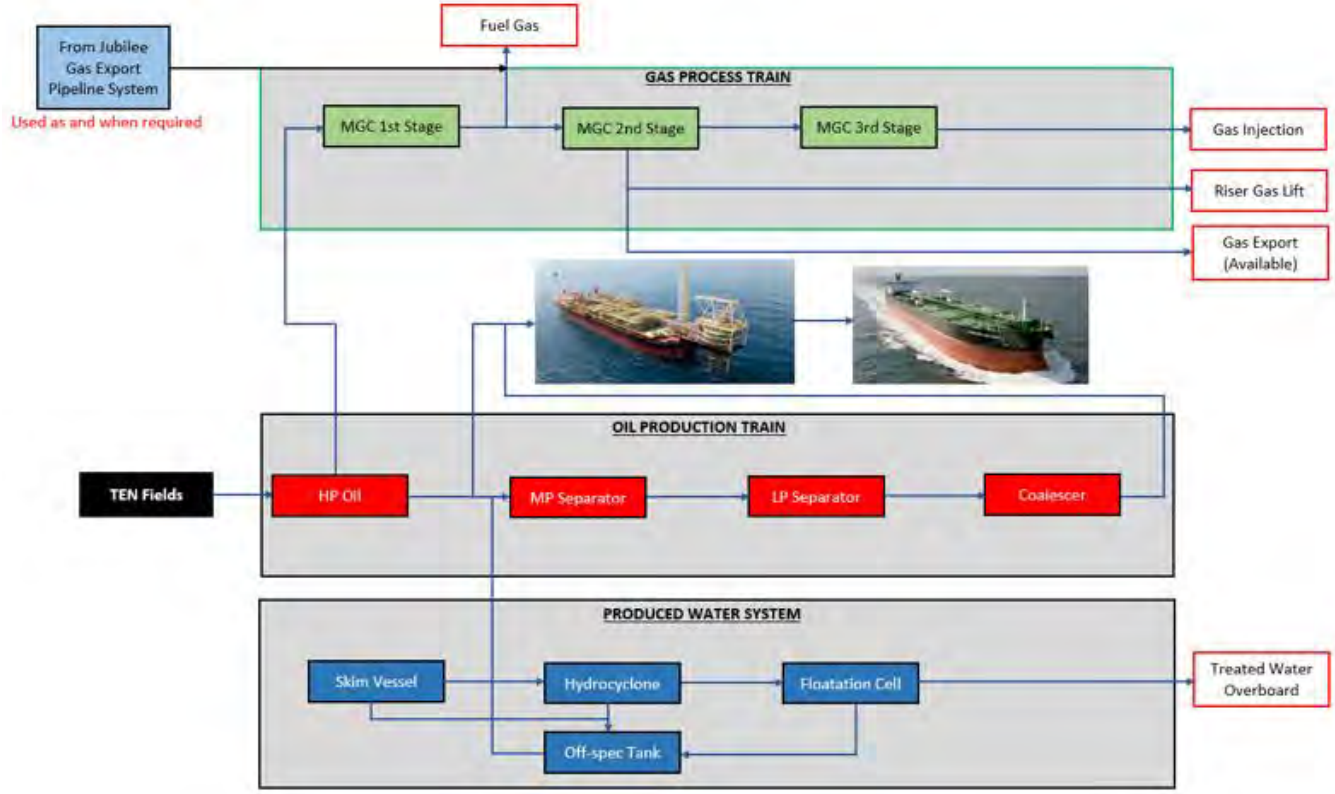


Figure 3-8: Simplified Process Flow Diagram

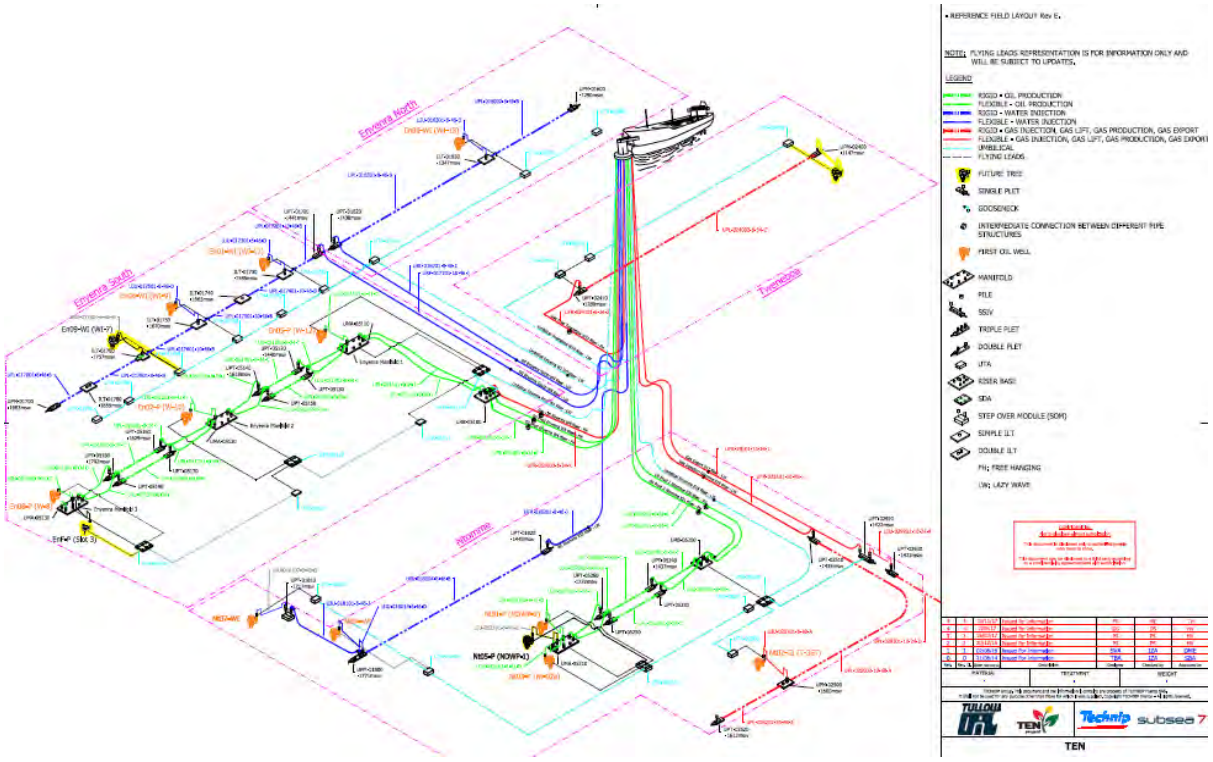


Figure 3-9: Subsea layout for TEN

3.3.3. TEN Commissioning

- TEN production operations environmental permit was issued on June 30, 2016 with a validity period of 18 months expiring 31 December 2017. Within that permit, the commissioning period specified was up to 31 December 2016 (i.e. 6 months).
- Following the issuance of the operations environmental permit, First Oil was achieved Aug 17, 2017 and commissioning flaring occurred until Mid -December when gas injection was established. Thereafter commissioning issues were incurred with the Main Electrical Generation Facilities which precluded the Operation and full commissioning of the Gas process/compression facilities. A flare commissioning period extension application was made for an additional 3 months period which was granted in an EPA letter with reference CE: 1828/05/56 issued January 23, 2017. This extended commissioning flaring period up to March 31, 2017.
- Prior to reaching March 31, 2017 and anticipating the commissioning flaring expiry was not going to be met by the due date due to the continued impact of the commissioning issues on the Main Electrical Generation Facilities, EPA was approached again for a 2nd extension by a period of 3 months. EPA in responding to this request granted 6 months extension instead of 3 months, with a new end date of 30 September 2017 in a letter with ref: CE:1828/05/59) issued April 7, 2017. The commissioning period for flaring was officially closed on Saturday 30th

September 2017, therefore the 48 mmscf/d commissioning allowance is no longer applicable. For the entire commissioning period, out of the flare allowance of 19, 632 mmscf (i.e. based on 48 mmscf/d), actual cumulative gas volume flared was 14,516 mmscf.

- With the commissioning period ended, the routine flaring limit which is set at 3% of total gas produced in the original operations environmental permit in place for TEN is now the applicable limit on flaring operations.

3.3.4. Jubilee and TEN Production Profiles

TEN: Average oil production in 2016 was 14.6 kstb/d, and rising to an estimated rate of above 54.3 kstb/d in 2017. A total oil and condensate recovery of 239 million barrels (Mbbl) is expected by the end of the contract term in 2036. The 20-year profile is presented in Figure 3-8.

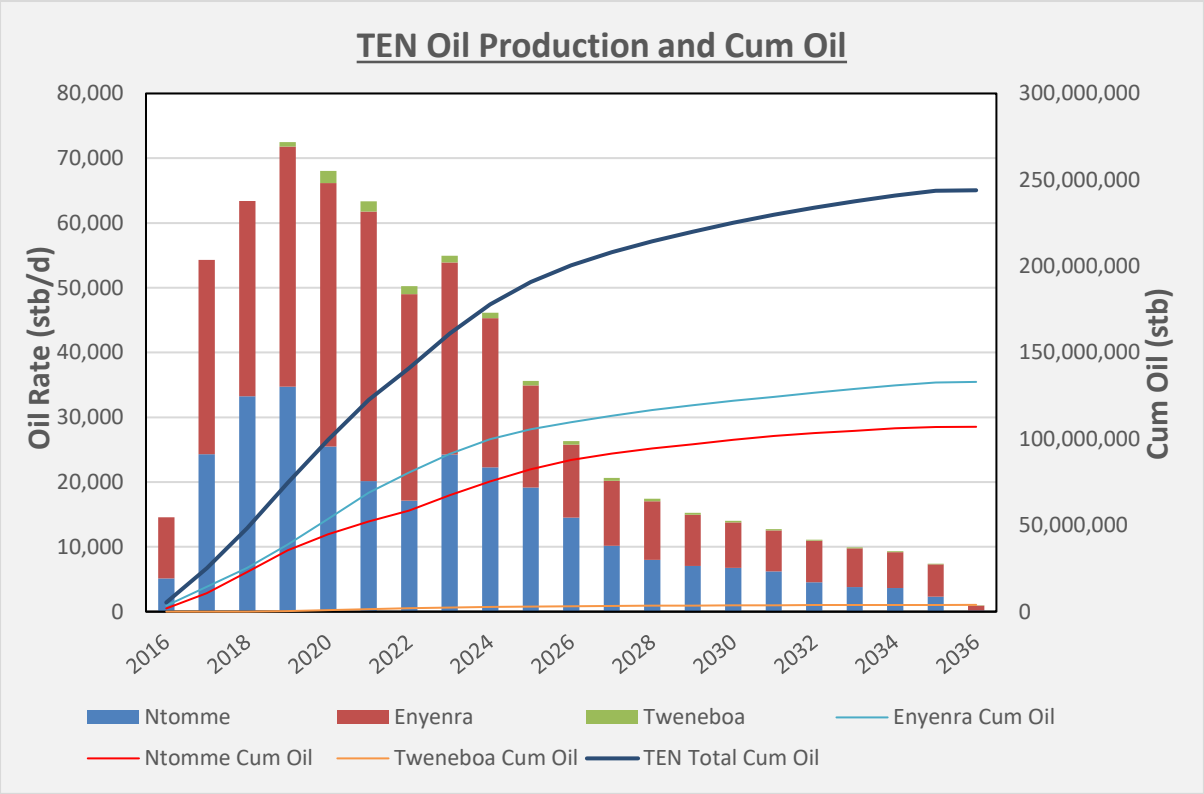


Figure 3-10: Estimated Oil Production and Cumulative Oil Recoveries for TEN Development

Greater Jubilee Full Field Development: The Jubilee Phase 1 and Phase 1A development activities focused on the two major reservoirs, the MH1 and the MH4, with the first set of wells (one oil producer, one water injector and one gas injector) drilled into the MH5 reservoir in 2013. Infill drilling was then undertaken in the MH4 and MH5 reservoirs during Phase 1A. In Phase 1A2 drilling was focused on the largely untested and undeveloped north-eastern area of the MH1 reservoir.

The GJFFDP Plan of Development (POD) which was approved on October 20, 2017 seeks to delineate the Mahogany and Teak Development and Production Areas, and develop Mahogany reservoirs (MH4 (UM3), MH2 (LM1), LM3 and MDeep) and Teak reservoirs (Campanian (Teak Main) and Turonian (Teak 2)).

Without further development wells, the Jubilee field (Phase 1, Phase 1A and Phase 1A2 wells), has an Estimated Ultimate Recovery (EUR) of 500 MMstb(1) of oil. This is referred to as the 'no further activity' (NFA) scenario. The GJFFDP Development Case forecast oil EUR is 642 MMstb, of which 95% will be produced from the Jubilee Field and the remainder from Mahogany Field. The GJFFDP is therefore expected to provide an incremental 142 MMstb of oil (see figure 3−11).

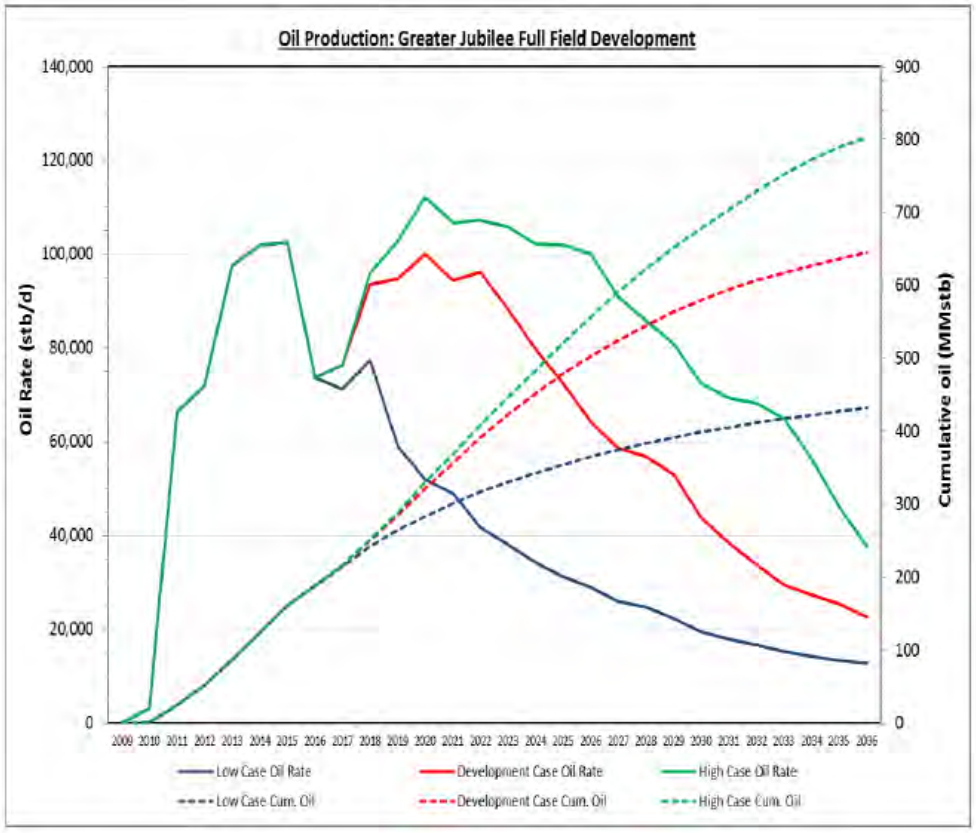


Figure 3-11: Estimated Oil Production and Cumulative Oil Recoveries for Greater Jubilee Full Field Development

3.4. Offshore Operations Support – Logistics and Transport

The Jubilee and TEN 'offshore' oil/gas operational activities is supported/serviced by an onshore infrastructure consisting of: logistics supply base (Takoradi); an administrative/office centre (Baycourt - Takoradi); Tullow headquarters (Accra); Takoradi commercial/Sekondi naval port facilities; FPSO chemical support facility and domestic air support (embarkation/disembarkation) facilities in Accra and Takoradi i.e. for personnel air transportation purposes. Takoradi logistics base is utilised as a 'secured' materials

(1) Million standard barrels of oil

(*inter alia:* piping, equipment, machinery, valves etc.) storage and laydown area and, bulk storage of chemicals/fuel for offshore process and operational support.

The Jubilee/TEN 'offshore' oil/gas operational activities require marine supply vessel support. This offshore support infrastructure involves the deployment of the following number and types of vessels.

1. Anchor Handling Tugs and Supply Vessels (AHTS x 2). These vessels are multi-functional with duties involving the general supply of goods/equipment to the FPSOs, and export tanker positioning.

2. Multi-Purpose Vessel (with daughter vessel) (MPV x 1). This vessel is principally utilised as the remotely operated vehicle (ROV) support and launch base, but is also utilised for export tanker and terminal operations (hose and line handling, security, and general field support etc.).

3. Fisheries Patrol Vessels (FPV x 3). These vessels are primarily utilised in an 'on scene' patrol capacity to both ensure the security and integrity of the Jubilee and TEN oil/gas operations' assets, and also to aid in the protection and ongoing safety of any mariners who may inadvertently/accidentally stray into the exclusion/safety zones.

Air/marine operational transportation routes and corridors from Takoradi logistics base(s) to the FPSOs and offshore support infrastructure (i.e. for personnel transportation and delivery of supplies) have also been determined and implemented (see Figure 3-12 and 3-13). These routes and corridors are designed to avoid or minimise the perceived environmental (and safety) impacts on shoreline communities, offshore fishing activities and the Amansuri Wetlands (plus other Gazetted areas and areas of conservation interest).

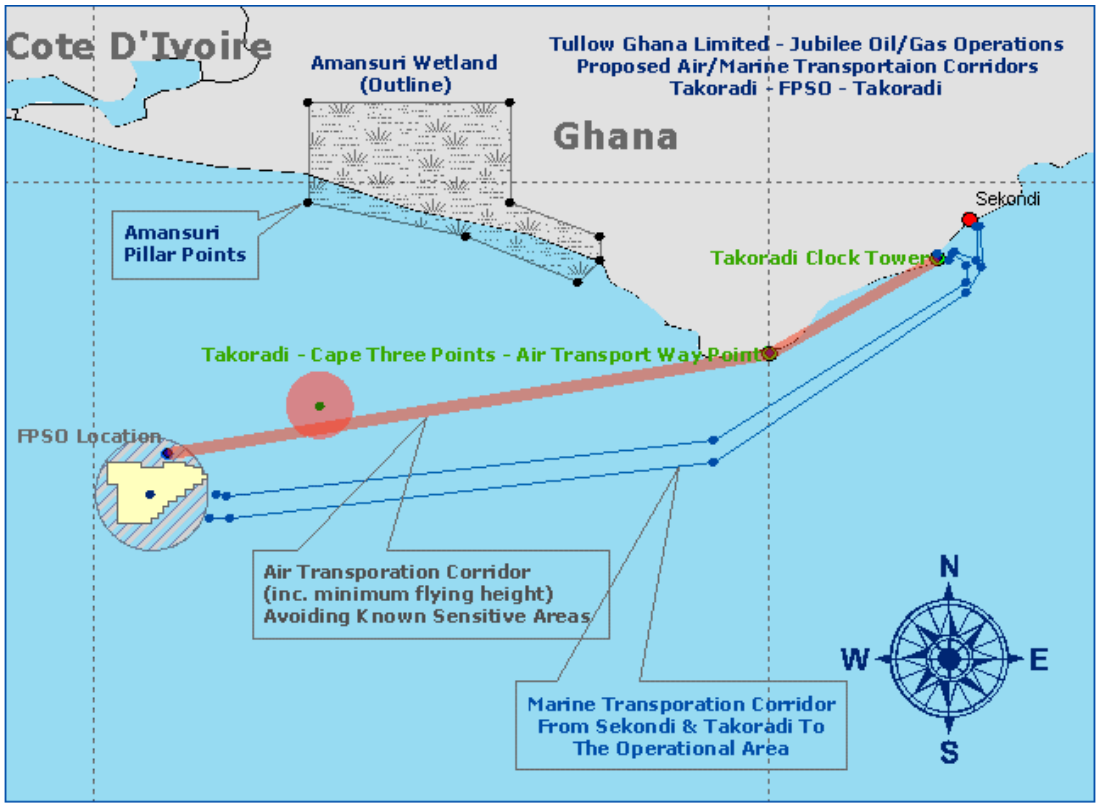


Figure 3-12: Designated Transport Routes For Jubilee Operations

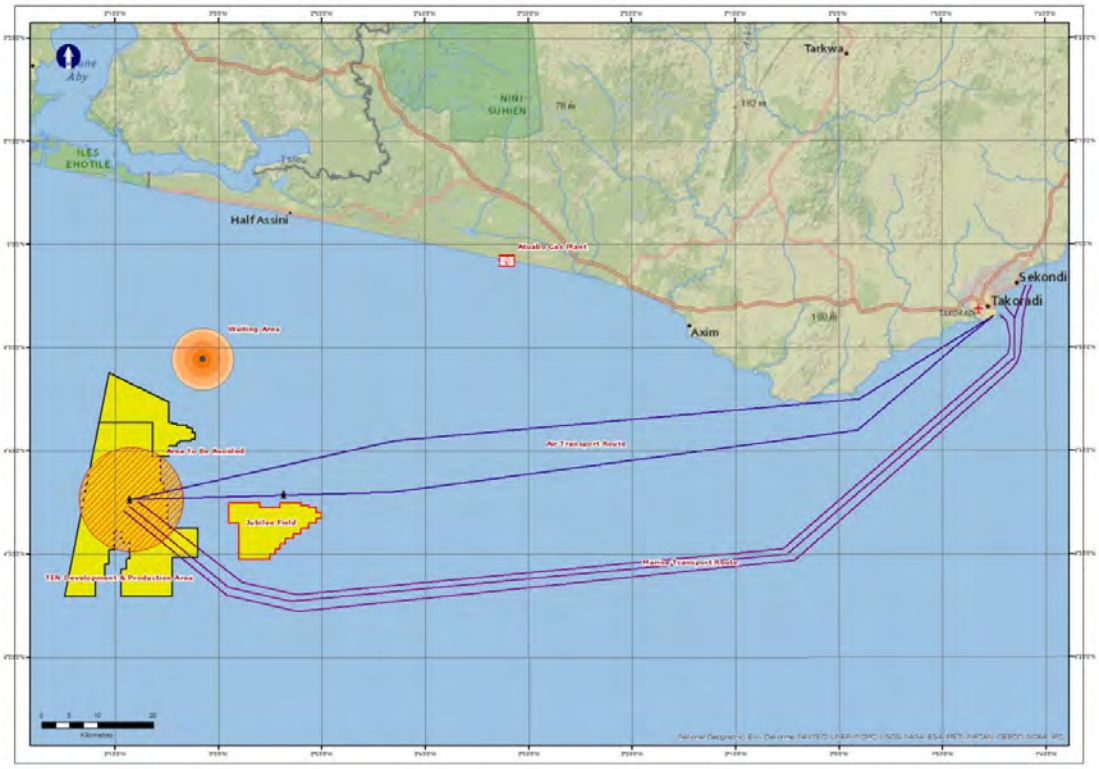


Figure 3-13: Designated Transport Routes For TEN Operations

3.4.1. Takoradi Areas (Harbour, Airport and Bay Court)

The onshore logistics support base located at Takoradi Harbour is approximately 140 km and 160 km from the Jubilee and TEN field, respectively. Takoradi harbour supports the TGL's offshore operations through:

- the importation of materials with some dock space to serve as a loading/offloading point for equipment and machinery;
- quayside facilities for dispatching fuel, chemicals and equipment;
- temporary storage of materials, equipment spares, production chemicals, fuel and other supplies; and
- pre-deployment checks (e.g. hydrotesting) and assembly of equipment (e.g. production trees).

Dedicated berths have been leased by TGL to service offshore activities. Support vessels for offshore operations are serviced at berths 5 and 6. On occasion if the Takoradi Harbour is full, the Naval Port at Sekondi may be used.

During exploration activities, on average one support vessel calls at the Takoradi Harbour daily, with a maximum of four support vessel calls per day. During operations, a supply boat visits each of the FPSOs a number of times per week, depending on the requirements for supplies. Additional calls will be required during the installation and commissioning activities.

Specific activities at the harbour that occur include bunkering, transfer of waste to waste contractor, loading supplies, and during installation and commissioning phases the loading/unloading of seabed infrastructure.

The Air Force Base is used as a helicopter support base and lay down yard for pipes and other machinery. TGL does not own or operate a bulk fuel facility; this is owned by the Ghana Air Force and operated by GOIL. There are bunded hazardous waste storage facilities as well as ability to store chemicals at the airbase.

TGL has an administration office in Baycourt – Takoradi, and is headquartered in Accra.

3.4.2. Sekondi Naval Base

The Sekondi Naval Base (SNB) is part of the Western Command of the Ghana Navy, an arm of the Ghana Armed Forces[2]. The site includes the Headquarters of the Western Naval Command, Ghana Navy Fleet, the Naval Dockyard Complex, Ghana Navy Stores Depot and the Naval Trade Training School. The Naval Base also serves as a base for oil and gas industry support to relieve some of the pressure on the Takoradi Port.

A formal lease agreement was signed on March 03, 2014 between Tullow and the Ghana Navy for five years, with a 5 year option to renew, to use part of the site for onshore fabrication for the TEN project. As the lessee Tullow will have ownership and supervise overall project site activities with a number of contractors and subcontractors working for and on behalf of Tullow. The major contractors will include MODEC, ORSAM, GROUP FIVE, Technip, and FMC. The environmental management of the contractors' activities will be controlled by their own management systems. The site was used for fabrication works by Technip[3] as part of the Jubilee project and continues to support operations in the Jubilee and TEN fields.

The Naval Yard is located approximately 12 km to the east of the Takoradi Port and the total area of the site is approximately 13,162 m^2. Activities at the naval yard include welding, sand blasting, fabrication and painting work, mechanical work and electrical work. The site used by Tullow is adjacent to the outfitting quay and in close proximity to the SNB maintenance workshop, fuel station and dry dock (see Figure 3-14).

The only residential facility at the Naval Base is dormitories for personnel under training and for management.

[2] The Ghana Armed Forces is made up of the Ghana Army, Ghana Navy and Air Force: all operate under a Joint Service General Headquarters. The Ghana Navy was established in 1959 by an act of parliament (Ghana Armed Forces (GAF), 2011).
[3] Technip is a French engineering and construction company that carries out project management, engineering and construction for the energy industry. In 2009, Technip's role in the Jubilee Phase 1 was to design, supply and install flexible risers, jumpers and suction piles for Tullow and its joint partners (Anadarko, GNPC and Kosmos)

Figure 3-14: View of Fabrication Yard Site

3.5. Operational Areas

A major environmental (and safety) management feature of the offshore Jubilee and TEN operational areas is the introduction and establishment of a number of marine advisory/exclusion zones by the Government of Ghana. This safety related zones (refer to Figure 3-15) has been legally designated by the Ghana Maritime Authority (GMA) and the International Maritime Organisation (IMO), around the key Jubilee and TEN operational areas, and is designed to maximise the protection of local fishermen and other ocean going vessels from TGL activities/operations. These 500 m Safety zones and 5 Nm / 3 Nm advisory zones (FPSO and Export Tanker respectively) can be described as follows.

1. An Area To Be Avoided (ATBA). A 5 Nm (five nautical mile) radius advisory zone.

2. An Export Tanker Anchorage/Pilotage Waiting and Boarding Area. These 3 Nm (three nautical mile) radius advisory area has been assigned in proximity to the ATBA and is designed to act as a safe waiting area for the export tankers prior to coupling with the FPSOs for crude oil offloading purposes.

3. An FPSO Safety Zone. This 500 m (five hundred metre) radius safety exclusion zone, has been additionally assigned to the FPSOs i.e. in addition to the ATBA, and is designed to further maximise the safety of local fishermen and other ocean going vessels and also minimise damage to the FPSOs and associated operational assets.

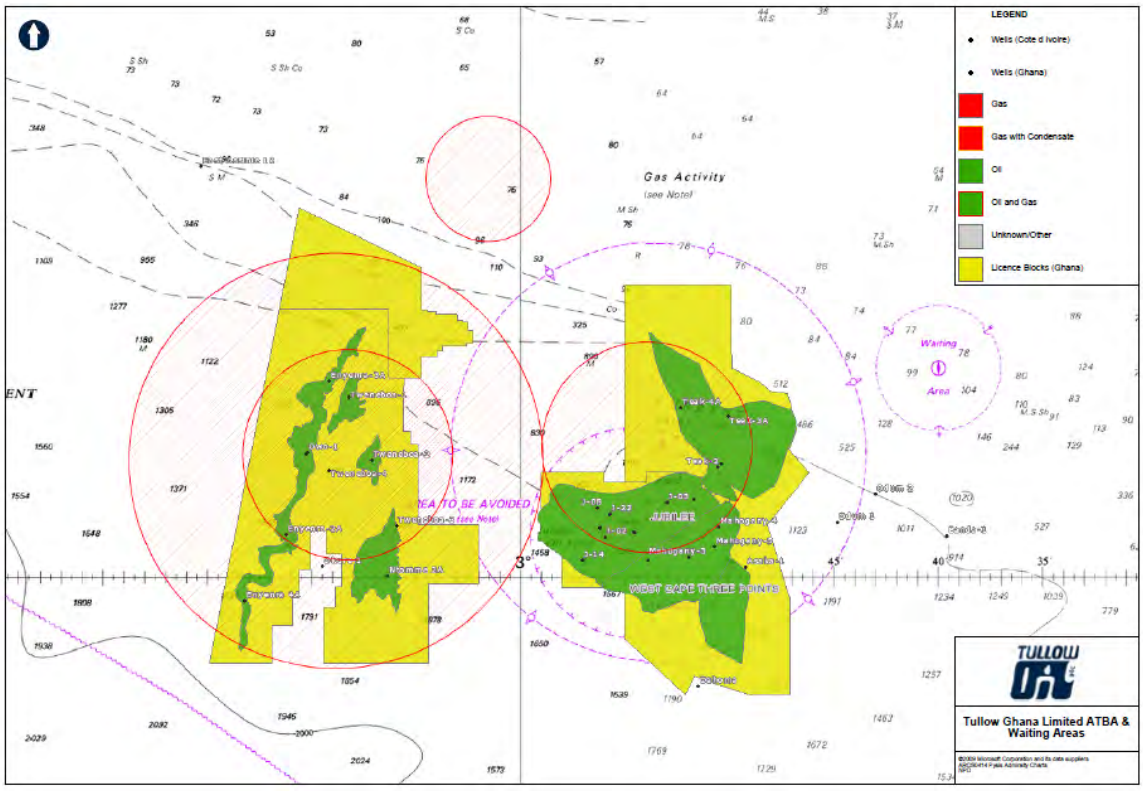


Figure 3-15: Jubilee and TEN Location and Key Maritime Features

ITLOS Maritime Boundary

The International Tribunal for the Law of the Sea (ITLOS) judgment of 23rd September 2017 provides settlement of the maritime boundary dispute between Ghana and Côte d'Ivoire. The settlement decides that the single maritime boundary for the territorial sea, the EEZ and the continental shelf within and beyond 200 nm starts at BP 55+ with the coordinates 05° 05′ 23.2″ N, 03° 06′ 21.2′′ W (WGS 84 as a geodetic datum) and is defined by turning points A, B, C, D, E, F with the following coordinates and connected by geodetic lines:

- A: 05° 01′ 03.7″ N 03° 07′ 18.3″ W
- B: 04° 57′ 58.9″ N 03° 08′ 01.4″ W
- C: 04° 26′ 41.6″ N 03° 14′ 56.9″ W
- D: 03° 12′ 13.4″ N 03° 29′ 54.3″ W
- E: 02° 59′ 04.8″ N 03° 32′ 40.2″ W
- F: 02° 40′ 36.4″ N 03° 36′ 36.4″ W

From turning point F, the single maritime boundary continues as a geodetic line starting at an azimuth of 191° 38′ 06.7′′ until it reaches the outer limits of the continental shelf.

Following the ITLOS ruling on the Ghana/Cote D'Ivoire maritime boundary dispute and the delineation of the new boundary line per the above coordinates, it has been geographically established that both Jubilee and TEN fields are within the Ghanaian EEZ and therefore not subject to further litigation.

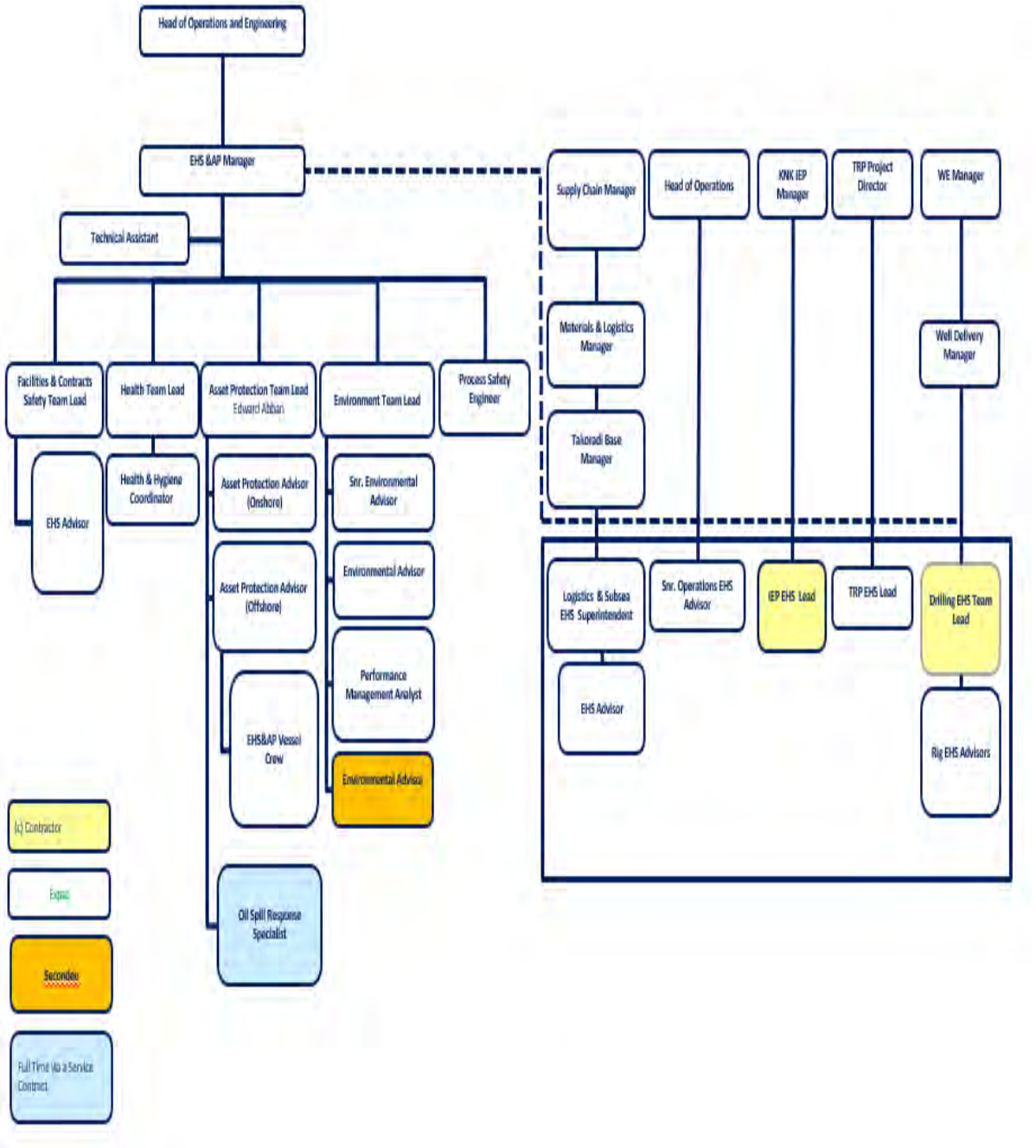
4. EMP – Roles and Responsibilities

TGL Management provides leadership and direction to ensure the company operates in an environmentally responsible manner. Safe and Sustainable Operations Policy awareness is communicated effectively to the entire workforce and top management commitment to achieving the objectives of the statement drives the implementation process.

Environmental control and management measures/responsibilities identified in this EMP will be, where appropriate, integrated into the TGL EHS Management system(s) (EHSMS) for steady state production phase of Jubilee and TEN operations and any other incremental development activities.

Figure 4-1 below illustrates the organisation of the EHS department within TGL and the roles and responsibilities are presented in Table 4-1. The Environment Team Lead reports to the EHSAP Manager, who in turn reports to the Director for Exploration and Development, who also report to the Managing Director of the Business Unit. A number of EHS resources are deployed throughout the organisation, both offshore and onshore, to help with the deployment EHS management communicating performance expectations of the company across all operational functions and sites.

Figure 4-1: Organisation Chart of the TGL EHS Department



Responsible Party	Responsibilities
Managing Director	• Provide overall leadership for organisational EHS performance expectations signing off the EHS Policy activating its execution across all Tullow sites
Head of Operations and Engineering	• Ensure the delivery of EHS Policy commitments within the Operations and Engineering functions. • Set EHS performance objectives and targets for the Operations and Engineering functions.
Head of Exploration, Development and Subsurface	• Ensure the delivery of EHS Policy commitments within the Exploration and field Development functions. • Set EHS performance objectives and targets for the Exploration and field Development functions.
EHS&AP Manager	• Oversee and coordinate all activities pertaining to the EHS&AP aspects of TGL Operations. Ensure delivery by the asset of its EHS and operational targets; • Ensure that the project and its contractors/subcontractors operate in accordance with applicable regulatory and company environment, health and safety requirements and plans; • Ensure effective communication with all internal/external (where applicable) stakeholders; and • Provide the necessary resources (financial, manpower et al) to satisfactorily implement and successfully complete the proposed EHSS management controls and initiatives etc.
Technical Managers including: Operations Manager; Topsides Engineering Manager, Subsea Engineering Manager; Well Engineering Manager, Well Delivery Manager, Supply Chain Manager et al	• Oversee the technical aspects of TGL development and operations including contractor and subcontractor supervision. • Responsible for contractor and subcontractor technical performance and EHS compliance.
Environmental Team Lead	• Responsible for formulation and advice on Environmental policy, standards, site procedures and / or guidelines necessary for the management of all operational environmental risks and or impacts. • Oversee and manages the TGL Environmental Management and Monitoring Programme ensuring compliance with environmental regulatory requirements • Provide ongoing oversight of the implementation of TGL environmental and social protection and management measures, and assist with technical input into TGL EHS management controls and initiatives including Operations related oil spill response requirements.
Environmental/EHSS Advisor	• Support the EMP at the operational level; • Perform monitoring and data collection/manipulation duties where directed; and • Liaise with FPSOs, MODUs and TGL operational sites and personnel to ensure that duties and commitments in support of this EMP are expedited efficiently and in a timely manner.
Social Performance Manager	• Liaise with CSOs, NGOs and other and other stakeholders including the public on Jubilee's behalf; • Responsible for the development and implementation of the PCDP; and • Employment/deployment of Community Liaison Officers. • In charge CSR related activities

Table 4-1: Roles and Responsibilities for Functional EHS Management

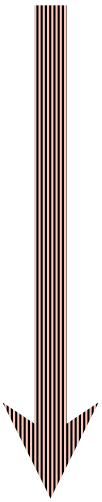
5. Environmental Management Plan – Organisation

5.1. Environmental Impact Mitigation Hierarchy/Philosophy

The underpinning principles of developing and Environmental Management Plan is to have a blueprint that details management strategies for identified environmental impacts and problems associated with an organisation's operations. Management measures, controls and processes for mitigating adverse environmental impacts have to be structured and documented to ensure effective implementation with the operation. Again, the formulation and deployment of this environmental management plan (EMP) is in compliance with the Environmental Assessment Regulations LI 1652 and EPA Oil and Gas Environmental Guidelines.

The impact mitigation hierarchy (and hence the principle by which this EMP is built upon) describes practical, commensurate and cost effective mitigation/management measures that avoid, reduce, control, remedy or compensate for negative impacts and enhance positive benefits. These environmental mitigation measures can, where appropriate, be implemented at any project phase i.e. from 'concept selection/definition through to operations and onto to 'decommissioning/abandonment'.

The approach taken to defining mitigation measures is based on a hierarchy of decisions and measures as follows:



1. AVOID or REDUCE AT SOURCE: Avoidance or reduction at source is designing and engineering the project so that a feature causing a potential negative impact is designed out (e.g. a waste stream is eliminated) or altered (e.g. reduced waste volume)
2. ABATE at SITE: This mitigation level involves the addition of a design or engineering measure resulting in the abatement of the potential impact e.g. pollution 'controls'
3. ABATE at the IMPACT RECEPTOR: If an impact cannot be avoided, reduced or abated on-site, then measures can be implemented off-site (e.g. noise or visual screening at properties)
4. REPAIR or REMEDY: Some impacts involve unavoidable damage to a resource, e.g. land disturbance. 'Repair or Remedy' essentially involves restoration and reinstatement type measures
5. COMPENSATE in KIND: Where other mitigation approaches are not possible or not fully effective, then compensation in some measure for loss or damage may be deemed appropriate

The greater majority of environmental mitigation measures implemented for TGL Developments and Operations, and hence within this EMP, fall into levels 1 and 2 in the above hierarchy. TGL Jubilee and TEN Development environmental mitigation strategy (as described in this document) and the implementation of the ISO 14001 environmental management programme require significant resourcing i.e. manpower, training, hardware (monitoring), software, and waste management budgets.

5.2. EHS and Operational Management Structure

The key to the success of any oil and gas field development (at all stages/phases) is the provision of suitably qualified and experienced personnel. Therefore, Tullow Ghana Limited (TGL) has recruited highly skilled human resources essential to the delivery of operational EHS performance through the implementation of plans.

Tullow Ghana Limited (TGL) is the appointed Jubilee and TEN Unit Operator and is ultimately responsible for the management and supervision of all Jubilee and TEN Field development activities. Internally, TGL has both EHS and Social Performance/CSR departments with highly experienced and dedicated staff, who are highly competent on the basis of appropriate education, training, and experience.

Of strategic importance to the effective management of the development of the Jubilee and TEN fields is the supervision and oversight of contractor/subcontractor activities. These supervisory duties are conducted by the Tullow 'Operations' team. This is accomplished through management controls over strategic operational aspects and multi-level interaction with contractor/subcontractor staff where project activities take place.

The Tullow EHS and Social Performance/CSR departments are headquartered in Accra, where staffs overseeing the onshore and offshore operations are located. Some personnel are located in Takoradi to facilitate EHS oversight of site activities as well as to allow direct interface and access for stakeholders in the western region. These key management functions manage the successful implementation of this EMP and the continuation of the stakeholder consultation process. TGL EHS and operations' are deployed for all aspect of offshore operations from commissioning of production installations to actual routine operations of the offshore producing assets (i.e. Jubilee and TEN FPSOs). The key personnel (Tullow management and contractor) and their respective project/operational responsibilities are highlighted in section 4 above. A schematic visualising the relationships between TGL (key functions), MODEC (TGL's principal FPSO operational management contractor) and other entities is presented in Figure 5-1.

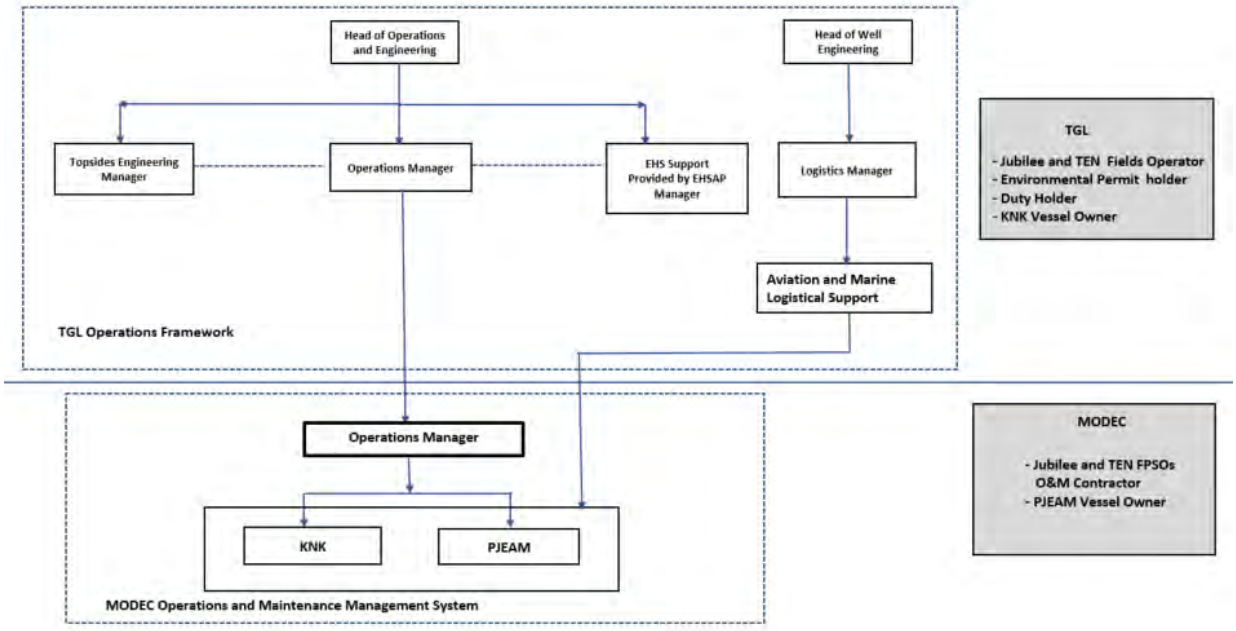


Figure 5-1: TGL Operations Organogram and Relationship with MODEC

MODEC is responsible for defining and executing O&M on the FPSOs as per agreed workplan and budget. Tullow takes an assurance/oversight role, MODEC ways of working conform as a minimum to Tullow's Operational Standards. MODEC uses its own management systems and tools which meets and is bridged into Tullow's standards and reporting requirements as the Duty Holder for the two offshore operations.

5.3. Contractor EHSS Interfacing and Bridging

An important and strategic aspect of the TGL operational environmental management performance and the overall Jubilee and TEN oil/gas production operations is the interface with contractors and subcontractors. TGL is the Operator and Environmental Permit Holder of the Jubilee and TEN Fields and therefore holds ultimate responsibility for all environmental incidents recorded within its offshore operations as per the EPA permit conditions.

The Jubilee and TEN oil/gas operations team engage contractors and subcontractors to undertake specific activities according to their respective specialities. Therefore, all contractors engaged by TGL are responsible for performing agreed production related activities:

- in compliance with relevant national and international EHS legislation and regulations and with other requirements to which the project subscribes;
- in full conformance with the TGL EMP (this document) and the overall EHS management system; and
- in accordance with contractual technical and quality specifications.

As the operator and environmental permit holder, TGL exercise oversight, control and supervision of all activities within our controlled sites to ensure EHS expectations and standards are met by contractors and subcontractors working for or on behalf of TGL. Consequently, as TGL's environmental management plan (EMP) and related EHS MS are the overarching contractual documents, all contractor (including those of MODEC – the main contractor engaged by TGL as the FPSOs operations and maintenance management team) EHS management plans/documents is bridged with and aligned to the TGL EMP and other key plans (e.g. waste management (WMP), oil spill contingency plan (OSCP), and environmental monitoring plan (E.Mon.P)).

For Jubilee and TEN Operations and any incremental field development, the EMP is implemented and controlled using the management systems of Tullow Ghana Limited (FPSOs owner) and MODEC (facilities operations and maintenance contractor) with the former being the controlling instrument. The relative company/contractor management systems (plus any related 'bridging' documentation).

1. provide the framework that regulates the EHS activities both on location and at the shore/beach support bases;
2. define responsibilities and reporting relationships for expediting, mitigation and monitoring actions as specified/scheduled in the EMP; and
3. specify the mechanisms for inspecting and auditing to ensure/be certain that the agreed actions are implemented.

Management system responsibilities are defined in the applicable management plans and the procedures and specifications that support them.
TGL EHS and Production Operations teams provide specifications for environmental compliance and performance (this EMP and associated plans) and, as a contractual requirement, the contractor (MODEC) implement their management and demonstrate to TGL how they comply with the TGL stipulated requirements which, are the overarching requirements.
Contractors also provide documentation detailing their plans for:

- implementing the measures required in this EMP;
- detailing how compliance with the EPA environmental permit conditions will be ensured;

- logistical arrangements; and
- managing and expediting community relations.

In essence, contractor operations plans conform to the requirements of the Tullow Ghana Ltd overarching plans. Therefore, as a minimum, contractor plans is reviewed and approved by Tullow and incorporated into, and form part of, the Jubilee and TEN Operations overall EMP and its supporting EHS Management Plans.

5.4. Environmental Management and Monitoring Tables Construction

The EMP which, as described above, presents the mitigation/management actions that address project impacts, and associated monitoring actions (i.e. the monitoring plan) to evaluate whether the proposed mitigation/management measures are having the desired effect, is presented in Table 5-1.

Column #	Description
1	Major project activities
2	Corresponding sources of impact
3	Potential consequences (impacts)
4	Specific mitigation measures or management actions
5	EIA Reference
6	Applicable mitigation/management timing (project phase)
7	Implementation responsible party
8	Key Performance Indicators (KPIs) and Related Targets
9	Reference to projects plan(s), procedures, specifications, standards et al

Table 5-1: Environmental Management Plan Table Construction

The environmental monitoring table (Table 5-2) is similarly organised, with monitoring measures tied to specific impacts that may result from major project activities. The monitoring table (Table 5-2) (the construction of which is detailed below) presents specific parameters to be monitored with references provided to plans, procedures and specifications that inform the measurements to be made, monitoring methodologies, frequency and responsible parties.

Column #	Description
1	Major Operational Activities
2	Monitoring Processes
3	Responsible Party
4	Analysis Methodology Reference
5	Analysis Frequency
6	Applicable Legal/Compliance Limit and Reference

Table 5-2: Environmental Monitoring Table Construction

5.5. Environmental Reporting Commitments

Periodic environmental monitoring/management status reports will be submitted in accordance with the Ghana EPA requirements.

5.6. Related EHS Management Plans

This EMP has been developed in conjunction with other key project management plans (see Table 5-3). Where applicable, an indication where the plans below interact and/or support this EMP are included in the EMP tables (refer to section 5.11).

Plan Name	Includes	Plan Owner
Jubilee and TEN Fields EMP	Overarching plan linking all the other plans to TGL Environmental Management System.	EHS&AP Manager
Environmental Monitoring Plan	Air emissions and ambient air quality, noise, chemical usage and discharge, Seabed and water column monitoring, routine effluent and discharge monitoring and Marine Mammal Observation Programme, other environmental quality studies.	EHS&AP Manager
Waste Management Plan	TGL operational waste handling procedures for hazardous and non-hazardous wastes including drilled cuttings and fluid disposal methods and procedures.	EHS&AP Manager
Ghana Incident Management Plan/Emergency Response Plan	Accident and Incident Investigation and Reporting Procedure. Investigation process to determine accident root cause and feedback for process improvement or prevention	EHS&AP Manager
Oil Spill Contingency Plan	Spill preventative measures and spill response procedure	EHS&AP Manager
Chemicals Management Guidelines	Offshore chemicals (production, drilling, completion chemicals managed by TGL chemical suppliers – Baker Hughes, Mi Swaco, Schlumberger) at TGL controlled sites onshore and offshore.	EHS&AP Manager
Helicopter Operations Plan, Marine Logistics Plan and Transport Management Plan	Transport risk assessment, water transport routes, overland routes, air routes, transport rules	Logistics and Materials Manager
FPSOs Facility Management Plan/Preventative Maintenance Plan	FSPO Facility management system provides procedures and description of the FPSO maintenance management system (AMOS)	Operations Manager (Tullow/MODEC)
Marine Operations Plans	Tanker Vetting Procedure, Cargo Transfer Procedure and Fuel Oil Transfer Procedure. Ballast Water Management Procedure	Operations Manager/Marine Team Lead

Table 5-3: Developments EMP and other Related Key Project Management Plans

5.7. Compliance Hierarchy and Framework

The compliance (legal and internal) requirements associated with the activities and operations of the Jubilee and TEN oil and gas operational/production activities are defined in a descending hierarchy of order below with further details in Table 5-4.

1. Compliance requirements imposed by the Ghanaian 'Regulatory Framework' including those documented in the 'Schedule' to the project Environmental Permit;
2. MARPOL;
3. Internal compliance requirements imposed by the IFC (International Finance Corporation) and documented in the EHS Guidelines – Oil and Gas Development (Offshore) – April 30th 2007; and
4. Tullow Corporate requirements (Non-Technical Risk Standard) including those recommended by those organisations to which Tullow Oil is a member.

In general, Ghanaian legislation related to environment, health and safety compliance issues within the oil and gas industry is at this stage still under development.

As detailed above, in cases where there is no specific Ghanaian legislation coverage, the above hierarchy of compliance standards will be applied.

Particular Ghanaian legislation and international conventions applicable to the Jubilee and TEN oil/gas operations are (inter alia) listed as follows:

- Ghana EPA – Guidelines for Environmental assessment & Management in the Offshore Oil & Gas Development (2011);
- Ghana EPA Act 490 1994 (incorporating The Pesticides Control and Management Act, 528, 1996);
- Ghana EPA – Hazardous and Electronic Waste Management Control Act 917, 2016
- Ghana EPA – Environmental Assessment Regulations LI 1652, 1999;
- Ghana EPA – National Oil Spill Contingency Plan
- Ghana EPA – Approved Fees and Charges LI 2228, 2015
- Other regulatory requirements contained within the stipulated Jubilee and TEN Fields Environmental Certificate and Permit Conditions;
- The Oil in Navigable Waters Act, 1964 (Act 235);
- International Convention on Oil Pollution, Preparedness and Response Cooperation, 1995;
- International Convention for the Prevention of Marine Pollution from Ships (MARPOL 73/78);
- International Tribunal for the Law of the Sea (ITLOS) 23 September 2017 Ruling on the Ghana/Cote D'Ivoire Maritime Boundary Dispute
- OSPAR Convention (Commission of the Convention for the Protection of the Marine Environment of the North – East Atlantic);
- Basel Convention;
- IFC – Offshore Oil/Gas Development – General EHS Guidelines (2007) and Thermal Power Plant EHS Guidelines (2008).

Reference	General (Key) Summary
Ghana EPA Act 490 1994	The Environmental Protection Act (Act 490 of 1994) establishes the authority, responsibility, structure and funding of the EPA. Part I of the Act mandates the EPA with the formulation of environmental policy, issuing of environmental permits and pollution abatement notices and prescribing standards and guidelines. The Act defines the requirements and responsibilities of the Environmental Protection Inspectors and empowers the EPA to request that an EIA process be undertaken.
Ghana EPA Act 490 1994 (incorporating The Pesticides Control and Management Act, Act 528, 1996)	Ghana Environmental Protection Agency Act to amend and consolidate the law relating to environmental protection, pesticides control and regulation and for related purposes
Ghana EPA – Offshore Environmental Impact Assessment and Management General Guidelines, November 1999	Ghana EPA guidelines on the compilation, construction of a project related environmental impact assessment and subsequent environmental management plans
Environmental Assessment Regulations (LI 1652), 1999	The EIA process is legislated through the Environmental Assessment Regulations (LI 652, 1999) as amended (2002), the principal enactment within the Environmental Protection Act (Act 490 of 1994). The EIA Regulations require that all activities likely to have an adverse effect on the environment must be subject to environmental assessment and issuance of a permit before commencement of the activity. The Regulations set out the requirements for the following: • Preliminary Environmental Reports (PERs); • Environmental Impact Assessment (EIA); • Environmental Impact Statements (EISs); • Environmental Management Plans (EMPs). • Environmental Certificates; and • Environmental Permitting.
Hazardous and Electronic Waste Management Control Act 917, 2016	An Act to provide for the control, management and disposal of hazardous waste, electrical and electronic waste and for related purposes.
Approved Fees and Charges	Schedule of environmental permit fees for list of undertakings for which an environmental permit is required.
Oil in Navigable Waters Act (Act 235), 1964	The Oil in Navigable Waters Act (Act No. 235 of 1964) is the law which is mostly concerned with the control of water pollution. It was enacted in 1964 to give effect to the International Convention for the Prevention of Pollution of the Sea by Oil (1954) and also addresses oil pollution in inland waters
Ghana National Oil Spill Contingency Plan	The aim of this plan is to outline the national arrangements for responding to oil spills into the marine environment, with the aim of protecting it from oil pollution or, where this is not possible, to minimise its effects. The plan delineate responsibilities for the preparation and operational response to incidents, which could or result in spillage of oil into the marine as well as the coastal environment of the Republic of Ghana.
Guidelines for Environmental assessment & Management in the Offshore Oil & Gas Development (2011)	Provide guidance on integrating environment, health, safety and community requirements into the offshore oil and gas operations. The guidelines include effluent limitations for discharges from offshore oil and gas operations.
International Convention for the Prevention of Marine Pollution from Ships (MARPOL 73/78)	Prevention of Marine Pollution from waste generated by the FPSO and associated marine vessels.
International Convention on Oil Pollution, Preparedness, Response, and Cooperation, 1995	Oil Spill Preparedness and Response

Reference	General (Key) Summary
International Convention for the Prevention of Pollution from Ships (MARPOL)	MARPOL is the main international convention covering prevention of pollution of the marine environment by ships from operational or accidental causes The Convention includes regulations aimed at preventing and minimizing pollution from ships - both accidental pollution and that from routine operations - and currently includes six technical Annexes: - I Regulations for the Prevention of Pollution by Oil (1983) - II Regulations for the Control of Pollution by Noxious Liquid Substances in Bulk (1983) - III Prevention of Pollution by Harmful Substances Carried by Sea in Packaged Form (1992) - IV Prevention of Pollution by Sewage from Ships (2003) - V Prevention of Pollution by Garbage from Ships (1988) VI Prevention of Air Pollution from Ships (2005)
International Tribunal for the Law of the Sea (ITLOS) 23 September 2017 Ruling on the Ghana/Cote D'Ivoire Maritime Boundary Dispute	The settlement decides that the single maritime boundary for the territorial sea, the EEZ and the continental shelf within and beyond 200 nm starts at BP 55+ with the coordinates 05° 05′ 23.2″ N, 03° 06′ 21.2′′ W (WGS 84 as a geodetic datum) and is defined by turning points A, B, C, D, E, F with the following coordinates and connected by geodetic lines: • A: 05° 01′ 03.7″ N 03° 07′ 18.3″ W • B: 04° 57′ 58.9″ N 03° 08′ 01.4″ W • C: 04° 26′ 41.6″ N 03° 14′ 56.9″ W • D: 03° 12′ 13.4″ N 03° 29′ 54.3″ W • E: 02° 59′ 04.8″ N 03° 32′ 40.2″ W • F: 02° 40′ 36.4″ N 03° 36′ 36.4″ W
BASEL Convention	Ghana acceded to the Basel Convention in 2003. The convention establishes a framework for: • reduction of hazardous waste generation and promotion of environmentally sound management of hazardous wastes • restriction of transboundary movements of hazardous wastes except where it is perceived to be in accordance with environmentally sound management; and • a regulatory system applying to cases where transboundary movements are permissible
IFC Offshore EHS Guidelines and Performance Standards	The EHS Guidelines are technical reference documents that address IFC's expectations regarding the industrial pollution management performance of projects. They are designed to provide relevant industry background and technical information. This information supports actions aimed at avoiding, minimising, and controlling EHS impacts during the construction, operation, and decommissioning phase of a project or facility

Table 5-4: A further description of the compliance framework listed

Changes to and variations in Ghanaian environmental legislation and applicable international environmental conventions etc. will be tracked, implemented and communicated via procedures and processes contained in the TGL Environmental Management System (EMS).

5.8. TGL Environmental Legal Compliance Register

TGL have legal commitments to expedite actions designed to manage and/or improve environmental performance. These commitments take a number of forms with the specific actions intended to address a particular environmental (and wider EHS) issues. The commitments are detailed in the 'TGL Environmental Legal Register' which is used both to manage and track the progress of actions arising from individual commitments to completion.

5.9. EHS Training and Awareness

Training and awareness raising form a key element of both EHS/operational control and the expediting of this environmental management plan. Key staff have been appropriately trained in key areas of EHS management and operational control with core skills and competencies being validated on an ongoing basis. Training and awareness requirements and expediting of the identified training/awareness events will be the responsibility of the TGL Human Resources (HR) department with input from relevant operational departments. Similarly, the key FPSO operations and maintenance contractor (MODEC) will also constitute a similar training and awareness programme strategy for FPSO operational and management personnel.

A training and awareness gap analysis is performed for each key member of staff and a training and awareness matrix is maintained as a method of managing and expediting the identified training requirements. These requirements are reviewed for efficacy on an ongoing basis.

Specific environmental impact and EHS related training is offered to improve the environmental performance of the company and affiliates. Examples of training events already undertaken are inter alia:

- EHS&AP induction programme for all incoming personnel including visitors;
- OSCP (oil spill contingency plan) training courses;
- Offshore marine mammal observation courses
- OSPAR Environmental Requirements
- Environmental management plan training
- ISO 14001 EMS Development training
- Hazardous waste management

5.10. Document Organisation

For clarity and ease of use, the EMP is issued in tabular form comprising 9 sections. Each section is designed as 'stand alone' and also as an integrated table, and also corresponds to the main areas that are assessed in the Jubilee and TEN EIAs (see Table 5-5).

Section #	Title
1	Operational Footprint
2	Operational Discharges
3	Air Emissions
4	Waste Management
5	Loss of Containment
6	Process Chemical Management
7	Audits and Inspections
8	Wildlife Management
9	Jubilee and TEN Operations Decommissioning

Table 5-5: EMP – Main Areas

5.11. EMP and Environmental Monitoring Activity Tables

The EMP activities are presented in Table 5-6 and the monitoring summary table is presented in Table 5-7.

Project Activity Ref	Impact Source / Environmental Aspect	Impact / Aspect Consequence	Impact / Aspect Mitigation or Management Action	Project Phase	Resp. Party	KPIs and Related Targets	Applicable Document References
1. Physical Presence							
1.01 Jubilee and TEN Field/FPSOs operational activities)	Physical Presence – FPSOs, wells cluster plus subsea infrastructure (wells, christmas trees, manifolds, umbilicals, risers) and associated sea bed/sea surface activities	Disturbance of the seabed (e.g. from sediment suspension) with secondary impacts on the benthic and demersal community e.g. smothering. Permanent habitat and associated species loss or damage from coverage of areas of seabed by subsea structures. Permanent changes to the habitat arising from the physical presence of subsea infrastructure (e.g. sediment disturbance and reef effects from marine organisms growing on subsea infrastructure).	Pre installation side sonar scan and ROV surveys conducted to determine if there are significant seabed features that should be avoided where possible. The layout of the subsea infrastructure is been designed to avoid seabed features considered to be geo-hazards. This protects areas with potentially more diverse habitats and species. Subsea flow lines have been laid on the seabed. No trenching or jetting for pipeline burial was done.	Development Drilling, design, planning. engineering Production phase	TGL Field Development Project Team including Subsea Engineering Manager TGL Operations Manager	EIA (recorded baseline conditions)	Jubilee and TEN Projects BoD Project Geophysical and Geotechnical Report(s) Original PODs and subsequent PODs for incremental developments
1.02 Drilling process and associated activities	Drill cuttings discharge	Temporary physico-chemical disturbance to water column and benthic (sea bed) flora/fauna from presence of non-indigenous materials.	Use of solids control systems including dryers to minimise oil on cuttings as far as is achievable with current technology. Programme of continuous improvement by enhanced cuttings treatment and to investigate, and where practicable implement, alternative options for drill cuttings treatment and disposal. Seabed impacts from drill cuttings disposal at sea have been monitored and assessed through a seabed drill cuttings impact survey.	Infill development drilling phase	Well Engineering Manager	< 3% (weighted average) oil on cuttings. Only low toxicity (group III) NADF or WBDF used in the drilling process 100% Barite used has < 1mg/kg Hg & < 3mg/kg Cd.	Environmental Monitoring Plan 2011 Drill Cuttings Impact Study Report 2012 BPEO study for the management of drilling discharges for the TEN Development

Project Activity Ref	Impact Source / Environmental Aspect	Impact / Aspect Consequence	Impact / Aspect Mitigation or Management Action	Project Phase	Resp. Party	KPIs and Related Targets	Applicable Document References
			3 year cycle periodic monitoring of marine environment within the producing fields. Use of low toxicity (group III) NADF with no free oil. Utilise Barite with < 1mg/kg Hg and < 3mg/kg Cd.				2015 Jubilee Offshore Marine Environmental Monitoring Survey Report
2. Operational Discharges							
2.01 Jubilee and TEN Field/FPSOs operational activities	Black water (sewage) and food (galley) waste discharge Disposal of solid waste materials to the sea.	Temporary disturbance of feeding, migratory and behavioural patterns of marine fauna and water quality. Impacts on marine fauna as a result of marine debris settling through the water column. Settling of marine discharges/waste allowed by MARPOL on the seabed. Entanglement of macro fauna in inorganic waste.	Black water: compliance with MARPOL 73/78 Annex V – requirements for discharging biodegradable wastes. The FPSOs are fitted with an IMO certified marine sanitation device (MSD) for sewage treatment. MODU and marine support vessels equipped with IMO certified marine sanitation devices. Organic food waste: Compliance with MARPOL. FPSO Waste Management Plan implemented in compliance with MARPOL 73/78 Annex V – requirements for discharging waste to the ocean. Macerate organic waste to achieve particle size < 25 mm No inorganic waste to be discharged.	All project phases	OIM for MODUs and FPSOs MODEC/ Vessel Marine Department	Black water: - No floating solids; - No discolouration of surrounding waters; No inorganic waste to be discharged and no floating solids Galley/food waste: < 25 mm maximum particle size	Project BoD Environmental Monitoring Plan Waste Management Plan (WMP)
2.02 MODUs and FPSOs operational activities	Deck drainage and bilge water discharge.	Temporary physico-chemical disturbance to sea surface and water column (limited depth)	The FPSOs, MODUs and marine vessels treat oily water (e.g. from open and closed drain systems, bilges and slop tank water) in accordance with the MARPOL Annex I requirements and discharge to sea.	All project phases	OIM for MODUs and FPSOs/ MODEC/	15 ppm oil/grease maximum limit	Project BoD Environmental Monitoring Plan

Project Activity Ref	Impact Source / Environmental Aspect	Impact / Aspect Consequence	Impact / Aspect Mitigation or Management Action	Project Phase	Resp. Party	KPIs and Related Targets	Applicable Document References
		and associated marine fauna.	Oil discharge analysers are used to monitor oil in water content targets. Records are maintained for all discharges and oil content to verify if controls in place are working effectively.		Vessel Marine Department		
2.03 FPSOs' operational activities (production)	Process Discharges - Produced water discharge - Desulphation water discharge - Desalination water discharge - Cooling water discharge Deck drainage discharge - Closed & opened drains NB: All the above is collectively termed process wastewater	Temporary physical disturbance to sea surface and water column (limited depth) and associated marine fauna	The FPSO's produced water treatment system include a three stage process of a water skim vessel, followed by hydrocyclones and ending with a flotation cell prior to discharge to sea. A closed drain system collects hazardous fluids from process equipment in hydrocarbon service. If the deck becomes contaminated, oily deck drainage will be contained by absorbents or collected by a hazardous drain for recycling and/or disposal. The FPSO, MODUs and marine vessels treat oily water from various sources, except from bilge machinery in accordance with MARPOL Annex I requirements on discharge to sea. Continuous monitoring of oil-in-water levels and alarm/re-routing system to an off-spec tank with 24 hour storage capacity for re-treatment if required. Produced water/slops is treated through the produced water treatment system and discharged overboard when discharge limits are met.	Operations	MODEC Jubilee and TEN Operations Managers Jubilee/TEN OIMs and MODEC Offshore Facility Managers	Oil in water content: 29 mg/l (maximum 30 day average) 42 mg/l (maximum) No visible surface sheen	Project BoD Environmental Monitoring Plan Produced water and bilgewater management treatment systems
2.04 Jubilee and TEN Field operations -	Well completion and work over fluids discharge, well interventions	Temporary physical disturbance to sea surface and water column (limited depth)	Completions fluids circulation is kept in a closed system.	Well Interventions, completion and work over's	Jubilee and TEN FPSO OIMs	Oil in water content: 29 mg/l (maximum 30 day average)	Well completions/work over process/plan

Project Activity Ref	Impact Source / Environmental Aspect	Impact / Aspect Consequence	Impact / Aspect Mitigation or Management Action	Project Phase	Resp. Party	KPIs and Related Targets	Applicable Document References
well completion and work over activities over the entire field life Engineering interventions for field production optimisation by MODUs. Well maintenance services	including plugging and abandonment of wells with lost or exhausted useful life	and associated marine fauna	Spent completions fluids are neutralized, treated and discharged if they meet effluent discharge limits. Spent completion fluids that cannot be treated offshore are shipped to shore for treatment by EPA approved waste management facilities/contractors. Only discharge used wellbore cleanup fluids (i.e. brine, diatomaceous earth filter and surfactant) to sea after measurement of oil content. Any acidic completion and work over fluids used that require discharge at sea shall be neutralised by mixing in soda ash or similar product. Current operations give preference to low toxicity, readily biodegradable and non-bio accumulative chemical systems, where commercially available, according to EPA Guidelines for Environmental Assessment and Management in the Offshore Oil and Gas Development, Article 9b. Chemical selection is justified via product ecotoxicity assessment criteria.		Rig Supt/MODU OIM Well Completions Team	42 mg/l (maximum) No visible surface sheen pH range 6 → 9 (prior to discharge)	Environmental Monitoring Plan Waste management plan – WMP
2.05 Additional subsea infrastructure hook up and commissioning activities	Commissioning pressure testing (hydrotest) fluid discharge	Temporary physico-chemical disturbance to sea surface and water column (limited depth) and associated marine fauna	Minimise hydrotest volume by testing equipment prior to importation to Ghana where practicable. The volume of pre-commissioning water required will be reduced by testing equipment onshore where possible. Preferential use of low toxicity and readily biodegradable chemicals.	Commissioning	Jubilee/TEN Operations Managers/FPSO OIMs TGL Well Completions Team	Keep discharge volumes as low as reasonably practicable. Use chemical products with good ecotoxicity properties	Jubilee and TEN Project BoD EMP Jubilee and TEN Project specific pre-commissioning disposal/Hydro test plans

Project Activity Ref	Impact Source / Environmental Aspect	Impact / Aspect Consequence	Impact / Aspect Mitigation or Management Action	Project Phase	Resp. Party	KPIs and Related Targets	Applicable Document References
			Ensure correct chemical dilution with seawater in the testing fluids. Pre-commissioning fluid disposal plans prepared to assess acceptability of selected chemicals and dose rates (including site specific risk assessment).				
2.06 Installation, operation and decommissioning of subsea production systems	Subsea equipment hydraulic discharges	Temporary physico-chemical disturbance to sea bed and water column and associated benthic marine flora/fauna	Selection and use of chemicals shall be in compliance with the EPA's Chemicals Guidelines for Environmental Assessment and Management in the Offshore Oil and Gas Development. Preference is given to chemical products with good OSPAR rating and also achieves effectiveness in its stated application i.e. low toxicity, readily biodegradable and non-bio accumulative chemical systems. Chemicals in the red and black category shall only be chosen if they are necessary for technical and safety reasons.	All project phases	Subsea Engineering Team FPSOs OIM Production Chemicals Supplier Operations Manager		Jubilee and TEN Project BoD Project specific pre-commissioning disposal/Hydro test plans
2.07 FPSO operations	Ballast water discharge	Temporary physico-chemical disturbance to sea surface and water column (limited depth) and associated marine fauna.	FPSOs equipped with segregated ballast tanks. Compliance with the *International Convention for the Control and Management of Ships Ballast Water and Sediments* to minimise the transfer of organisms. Compliance with MARPOL (Annex I) for marine vessels. Visiting export tankers and other vessels discharging ballast water are required to undertake ballast water management measures in accordance with the requirements of the *International*	All project phases	Operations Superintendent FPSOs OIM MODEC Marine Superintendent	< 15 ppm oil or grease in water (prior to discharge) for TGL vessels No ballast water discharge within 200nm off the coast of Ghana by export tankers	Jubilee and TEN Project BoD Export tanker vetting procedure TGL Ballast Water Management Plan

Project Activity Ref	Impact Source / Environmental Aspect	Impact / Aspect Consequence	Impact / Aspect Mitigation or Management Action	Project Phase	Resp. Party	KPIs and Related Targets	Applicable Document References
			Convention for the Control and Management of Ships Ballast Water and Sediments.				
2.08 Activities in the vicinity of the onshore bases (e.g. Takoradi Port (Chemical Support Facility), Takoradi Air Force Base)	Surface water run-off	Physico-chemical disturbance of base/port surrounding environs.	Effective spill prevention and control measures and secondary containment procedures to avoid accidental or intentional releases of contaminated containment fluids. Logistics base in Takoradi /Port Operators have waste water collection sump within pipe yard. Contaminated wastewater is collected and transferred off-site for treatment and disposal by waste contractor. Port operations do not allow contaminated discharges to sea unless discharge limits for various parameters are met.	Jubilee and TEN Fields Lifetime	Logistics Base Manager Marine Superintendent Chemicals Supplier Base Manager FPSOs Chemical Support Facility, Commercial Port	pH range 6 - 9 COD max. 125 mg / l Oil/grease max. 10 mg/l TSS max. 50 mg/dm^3	Jubilee and TEN Project BoD Oil spill contingency plan – OSCP Logistics Base Operations Manual Cargo tanker transfer and fuel oil transfer procedure Marine Operations Manual TGL Chemicals Management Guidelines
2.09 Activities in the vicinity of the onshore bases (e.g. Takoradi Port)/FPSO Chemical Support Facility	Chemical storage	Physical disturbance of base/port surrounding environs.	Storage Mitigation: Appropriate primary and secondary containment in place, and procedures for managing the secondary containment of the chemical storage areas. Impervious concrete surfaces with bunding in place at all areas of potential chemical leaks and spills, including below gauges, pumps, sumps and loading and unloading areas. Storage tanks and components will meet international standards, such as those of the American Petroleum Institute (API) for structural design and integrity.	Production phase	Logistics Base Manager Marine Superintendent Baker Hughes Base Manager, FPSO Chemical Support Facility Logistics Base EHS Superintendent		Jubilee and TEN Project BoD TGL Chemicals Management Guidelines Assets lease agreements Oil spill contingency plan – OSCP

Project Activity Ref	Impact Source / Environmental Aspect	Impact / Aspect Consequence	Impact / Aspect Mitigation or Management Action	Project Phase	Resp. Party	KPIs and Related Targets	Applicable Document References
			Storage tanks and components will undergo periodic inspections for corrosion and integrity and be subject to regular maintenance. Chemical loading and unloading activities is conducted by appropriately trained personnel according to established standard operating procedures. Spill control and emergency response plan developed in consultation with the GPHA Takoradi Commercial Port				Cargo tanker transfer and fuel oil transfer procedure
2.10 FPSO operations	Produced sand discharge	Temporary physico-chemical disturbance to sea surface and water column (limited depth) and associated marine fauna	Sand control screens installed in all wells during well completions to prevent or minimise produced sand. Any produced sand with residual oil >1% dry weight will be shipped to shore for proper treatment and disposal	Production Phase	Well Completions Team/ Engineering Design TGL Operations Manager	< 1% residual oil (prior to discharge) 1% = 10g/kg of dry sand	Jubilee and TEN Project BoD Waste management plan – WMP
2.11 FPSO operations	Naturally Occurring Radioactive Material (NORM) storage and discharge	Physico-chemical disturbance to sea surface and water column (limited depth) and associated marine fauna	Water injection sulphate removal plant installed on the FPSO for removal of the sulphates from injection water to prevent scale formation. Injection of scale inhibitor into the wells and process facilities. Assessment of scale build-up as part of routine preventative maintenance programme.	Production Phase	MODEC Maintenance/ Marine Superintendent OIM/OFM Operations Manager Environmental Advisor MODEC Safety Specialist	NORM levels on materials discharged <1.1 Bq/g NORMs scale discharge per NRA approvals	Waste management plan – WMP Environmental monitoring plan NORM Management Plan
3. Air Emissions							

Project Activity Ref	Impact Source / Environmental Aspect	Impact / Aspect Consequence	Impact / Aspect Mitigation or Management Action	Project Phase	Resp. Party	KPIs and Related Targets	Applicable Document References
3.01 FPSO operations	Emission of atmospheric pollutants and greenhouse gases (GHG)	Short/long term degradation of local air quality	Routine Operations: The FPSOs are designed to minimise process electricity demand through optimal sizing, configuration and selection of equipment, in particular, compressors and pumps. To ensure efficient energy use, the FPSO is designed with centralised electrical power generation, provided by high efficiency gas turbines, sized and configured to life-of-field power demand. Relief valves on process vessels and pipe work are subject to inspection and maintenance and replacement to reduce leakage. Compliance with MARPOL limits on SO_x and NO_x, no deliberate emissions of ozone-depleting substances and no incineration of certain products on board (e.g. plastics). Use of low-sulphur diesel fuel (S < 0.5%). Programme of leak detection and repairs to reduce fugitive emissions are constantly running. Reduce VOC emissions from hydrocarbon and chemical storage and transfer activities through equipment selection and fuelling activities. Cargo tanks to be pressurised and the vapour space filled with an inert gas. A Vapour Recovery Unit (VRU) is installed (TEN FPSO) to collect the vapours from the gas treatment system's TEG dehydration reboiler unit to mitigate the venting of aromatic hydrocarbon compounds that can be released by these units.	All project phases	MODEC Operations and Maintenance Superintendent	Based upon fuel (diesel and fuel gas) consumption for static and mobile point combustion sources: **Engines –** Gas fired (> 3MW): NOx – 200 mg/Nm^3 (Spark Ignition); 400 mg/Nm^3 (Dual Fuel); 1,600 mg/Nm^3 (Compression Ignition) Liquid fuel (> 3 MW): Particulate Matter – 50 mg/Nm^3; SO_2 - 1.5% sulphur; [note 1—50 below] NOx - 1,460 - 1,850 mg/Nm^3 (depending on bore size diameter) **Turbine** *Natural Gas (15 MWth to < 50 MWth):* NOx - 25 ppm. *Fuels other than Natural Gas (3*	Jubilee and TEN Project BoD Offshore Maintenance Operating Systems Cargo tanker transfer and fuel oil transfer procedure Environmental monitoring plan

Project Activity Ref	Impact Source / Environmental Aspect	Impact / Aspect Consequence	Impact / Aspect Mitigation or Management Action	Project Phase	Resp. Party	KPIs and Related Targets	Applicable Document References
			The original "As built" Jubilee FPSO did not come with a VRU. Long-term solution to minimise Jubilee FPSO venting is currently under consideration. The vessel fleet used are fairly new or have had a recent refit. Routine preventative maintenance is undertaken to maintain engine efficiency. Vessels visiting the port depart at partial power. Tullow Monitor and report GHG emissions. Ambient air quality monitoring on the FPSOs and Takoradi conducted at least once annually. Flaring: Tullow operates a "no flaring" policy except in situations of operational upsets, shutdowns and start-ups to maintain safe operating conditions. Thus routine flaring beyond the EPA limit of 3% is avoided (i.e. gas compression occurring at full capacity) to the extent possible and allowed only operational safety grounds during trips and upsets or during maintenance periods. Tullow will monitor gas flared and quantify annually total GHG emission from production routine and non-routing flaring activities as an aggregate in accordance with internationally recognised methodologies and reporting procedures.			*MWth to < 15 MWth):* 0.5% sulphur; NOx - 96 ppm (electric generation) and 150 ppm (mechanical drive). *Fuels other than Natural Gas (15 MWth to < 50 MWth):* 0.5% sulphur; NOx – 74 ppm **Boiler** *Gas*: NOx – 320 mg/Nm^3 *Liquid*: Particulate Matter 10 - 50 or up to 150 mg/Nm^3 if justified by env. assessment; SO_2 – 2000 mg/Nm^3; NOx – 460 mg/Nm^3 *Solid*: Particulate Matter 10 -50 or up to 150 mg/Nm^3 if justified by env. assessment; SO_2 – 2000 mg/Nm^3 NOx – 650 mg/Nm^3 **Flaring**	

Project Activity Ref	Impact Source / Environmental Aspect	Impact / Aspect Consequence	Impact / Aspect Mitigation or Management Action	Project Phase	Resp. Party	KPIs and Related Targets	Applicable Document References
						Zero flaring policy in normal condition. Monitoring and quantification of GHG emissions	

4. Waste Management							
4.01 FPSO and shore base support/field development operations	Inappropriate storage, containment and transportation of waste materials	Impacts on marine environment, terrestrial environment, local communities and waste facilities	<u>Storage, segregation and transportation of waste</u>: TGL Waste Management Plan (WMP) has been implemented to ensure waste management meets standard regulatory requirements. Treatment options for certain waste streams are non-existent in-country and such streams are currently stored. Waste minimisation, reuse and recycling strategies are continuously being sourced for economic and environmental benefits. Waste segregation, classification and storage is maintained onboard the FPSOs and all support vessels. Appropriate, and clearly labelled waste transfer skips used for offshore waste transfer to port. All wastes are properly manifested and handling procedures rigorously followed to ensure transfer/transport is conducted in a safe and environmentally friendly manner. Registered and licensed waste carrier trucks are employed by TGL waste contractors (Zeal and Zoil) to transfer waste from port and shore base to the waste facility in Nyankrom, Takoradi. Waste transfer chain of custody is maintained for all waste in transit from point of generation to point of treatment and/or disposal. Generated waste is transported by Tullow appointed waste contractor(s) licensed by EPA. Tullow waste contractor has constructed a waste reception and temporary storage	All project phases	Logistics Base Manager Logistics Base EHS Superintendent Environment Team Lead Marine Superintendent	Zero loss of containments during storage and transporting of hazardous waste materials. Zero LTI (lost time incidents) related to waste storage, manhandling and transporting of hazardous waste materials Reduction targets will be set on an annual basis and recorded within the facility score cards	Audit programme and processes Waste management plan (WMP) Land Transport Safety management Procedure Material Safety Data Sheets (MSDS)

			facility at the Takoradi Port for receiving offshore waste for onward transfer to treatment and/or disposal sites.				
4.02 Management and disposal of waste materials onshore	Inappropriate storage, containment and transportation of waste materials.	Disturbance of terrestrial environment, local communities and waste facilities.	Appropriate treatment, recycling/reuse and disposal routes for different waste streams have been defined in the TGL WMP. TGL waste contractor follows treatment prescriptions in the WMP for various waste categories. Recyclable waste streams like scrap metals and plastics are transferred to recycling facilities in Takoradi. Waste oils are cleaned up and recovered for reuse in other industrial applications. Tullow continues to audit waste contractors and ensure that all facilities receiving waste from their operations demonstrate high EHS performance in the running of their operations. Tullow will work with responsible and dedicated waste contractors to help in meeting the operational requirements	All project phases	Logistics Base Manager Logistics Base EHS Superintendent Marine Superintendent Environment Team Lead		Audit programme and processes Waste management plan (WMP)
5. Spills							
5.01 Offshore Installations (FPSOs/MODUs) and shore base support/field development operations	Loss of containment of crude oil and other hydrocarbons (e.g. diesel)	Disturbance to vulnerable components of the ecosystem in both offshore and coastal environments (e.g. seabirds, marine mammals, turtles, coastal habitats) and fishing activities and other livelihoods dependent on the coast	<u>Loss of containment prevention measures</u>: To minimise the risk of potential spills, TGL designed the Jubilee and TEN FPSOs and Subsea infrastructure facilities with a range of inherent measures designed to reduce the risk of a loss of containment. Loss of containment prevention measures implemented as part of operations include the following: Blow-Out Preventers (BOPs) permanently installed on the subsea wells during well completions, and the use of a double mechanical barrier system during production and injection operations using the subsea Christmas trees and other barriers.	All project phases	FPSOs OIMs TGL Asset Integrity and Maintenance Lead Technical Safety Lead MODU OIM/Rig Superintendent FPSO Mooring Master Jubilee and TEN Operations Managers	Ensure well (drilling) BOPs (blow out preventers) are function and pressure tested every 14 to 21 days (maximum) Ensure that a minimum of on-site x3 (three) Tier 1 loss of containment scenario training exercises are accomplished per year	Jubilee and TEN Project BoD Ghana Incident Management Plan Offshore Installations site specific Emergency Response Plans (ERP) TGL Jubilee and TEN Oil Spill Contingency Plans (OSCP)

			A system of wells, subsea flow lines, risers and FPSO topsides designed to international process codes and with alarm and shutdown systems to maintain the system within its design criteria at all times. This system is function tested, inspected and maintained to ensure performance standards are met. The FPSO deck and drainage system is designed to contain spills (as well as leaks and contaminated wash-down water) to minimise the potential for overboard release. Specific procedures have been developed for offloading crude from the FPSO onto the shuttle tankers. These include vetting of tankers involved in offloading, management of offloading activities by trained and experienced personnel, the use of a quality marine fleet to undertake the operation of hose handling and tanker movements (including contingencies for any engine failures), and the continuous monitoring and actions to be taken in the event of any non-routine events or equipment failures.		EHSAP Manager Operations Manager Environment Team Lead Asset Protection Team Lead OSRL Spill Response Specialist	Perform update training of personnel in equipment use by an external specialist as and when required.	Offshore Maintenance Operating Systems Formal safety assessment (Safety Case) Export tanker vetting and loading procedures
5.02 FPSO and shore base support/field development operations	Loss of containment of crude oil and other hydrocarbons (e.g. diesel)	Disturbance to vulnerable components of the ecosystem in both offshore and coastal environments (e.g. seabirds, marine mammals, turtles, coastal habitats) and fishing activities and other livelihoods dependent on the coast	<u>Loss of containment response measures</u>: *The Oil Spill Contingency Plan (OSCP) is maintained on all vessels for quick reference in the event of a spill. The OSCP will be linked to the Ghana National Oil Spill in particular scenarios where governmental intervention would be required for resource mobilization in responding to large spills. OSCP describes*: • the response strategies for minor, medium and major spill scenarios; • spill alert and notification procedures for emergency response authorities and potentially affected groups;	All project phases	Jubilee and TEN Operations Managers EHSAP Manager FPSOs OIMs Logistics Base Manager Logistics Base EHS Superintendent Environment Team Lead		Ghana Incident Management Plan Oil Spill Contingency Plan (OSCP) Waste Management Plan National Oil Spill Contingency Plan

			• available spill response equipment supplies and services; • the response organisation and key job functions of the participants in spill response; • types and frequency of spill response training and practice exercises; • the waste management plan (WMP) for removal of waste resulting from the spill cleanup; • site specific response scenarios for coastal sensitive habitats potentially affected by oil spills; • oil spill equipment contained onboard the standby vessel or other suitable vessel and available for use at short notice and access to external spill response equipment supplies and services (OSRL) for large spills. Site specific response scenarios have been developed and regularly kept up to date within the OSCP as site conditions changes. Tullow currently holds adequate capacity (logistics, resources and manpower) for up to Tier 2 oil spill response and trained personnel so as to facilitate an immediate response. In the event of a Tier 3 spill situation, initiation of both mutual aid resources which will be leveraged from industry partners within Ghana and the OSRL call-out guarantee from the Oil Spill Response Base in Southampton, UK.				

6. Chemicals Management							
6.01 FPSOs operational activities	Loss of containment of process and associated chemicals and additives	Disturbance of the terrestrial and marine environs and associated vulnerable components of the related ecosystems (flora and fauna)	Chemicals selection: Selection of chemicals shall be in compliance with the EPA's Chemicals Guidelines for Environmental Assessment and Management in the Offshore Oil and Gas Development: - Article 9a (Ecotoxicological testing of chemicals); - Article 9b (Categorization of chemicals); - Article 9c (Environmental assessments) - Article 9d (Choice of chemicals) Chemicals management: Use of chemicals shall be in accordance with the EPA's Chemicals Guidelines for Environmental Assessment and Management in the Offshore Oil and Gas Development Article 10 (Use and discharge of chemicals). A chemicals inventory that includes identification, classification, quantification and delivery methods has been developed. This chemical inventory includes chemical properties such as hazard potential, toxicity and health and safety recommendations as described in Material Safety Data Sheets (MSDS). Appropriate storage and handling procedures have been documented. Appropriate emergency procedures have been developed for chemical storage sites.	Operations and decommissioning phases	FPSO OIMs Production Chemicals Supplier Chemical Custodian Jubilee and TEN Operations Managers Production Chemist Chemical Suppliers Operations Manager Environment Team Lead	Identify and replace (where technically feasible) those chemicals which are bio-accumulating and/or toxic to marine life. Develop a chemicals database (including material safety data sheets – MSDS – and eco-toxicity data – HOCNF – is compiled) and ensure all identified chemicals are 'permitted' for use by the EPA	Chemical Management Guidelines Environmental Monitoring Plan Emergency Response Plan (ERP) Waste Management Plan (WMP) FPSO Chemical Support Facility Operational Procedures TGL Annual EHS Assurance Programme TGL EHS Audit Process

7. Audits and Inspections							
7.01 FPSO marine support, operational activities and field development programmes -MODU Operations - Logistics Base Operations	EHS/EMS checking mechanism aimed at correcting management system deficiencies and achieving continual improvement	Potential environmental harm due to systemic deficiencies, asset damage, operational downtime and reputational damage	EHS management and planning activities are undertaken to support TGL's activities to achieve excellent EHS operational performance Methodology for the execution of EHS/Environmental management system audits developed Contractor audits part of the Integrated Audit Plan put together annually. Opportunities for improvement in EHS management system is continually being identified and implemented in relation to the Jubilee and TEN field development and support activities. Compliance is ensured by TGL's associated contractors with the requirements of TGL EHS management system. Compliance is also verified with applicable laws and regulations. All identified EHS non-compliances are communicated and tracked to successful close out	All project phases	OIM and TGL Operations Managers and EHS management functions	Minimum of 12 EHS audits per annum (TGL and contractor). Audit programme focussed on perceived risk i.e. the higher risk interfaces and processes to be priority audited e.g. waste storage and disposal, chemicals mgt., FPSO Operations, MODU Operations. Ensure that a minimum of 95% of all audit and inspection actions are closed out within the given time frame	TGL Annual EHS Audit Programme TGL EHS Audit Process
8. Wildlife Management							
8.01 Offshore Installations Operational Environs (FPSO, MODUs) Aviation and marine traffic transport	FPSO and MODUs physical presence Vessel and helicopter movements and underwater sounds Seismic operations releasing sound	Temporary disturbance of feeding, migratory and behavioural patterns of marine mammals, birds and other fauna (e.g. turtles)	Trained Observers are used on EHSS Support vessels to monitor and record marine mammal and turtle sightings. Disturbance to marine and coastal ecology from vessels and helicopters have been reduced by maintaining specific routes, speeds and flight heights, including helicopter pilots being required to fly at a minimum altitude of 2,300 feet (710 m) when flying over the Amansuri Wetland IBA to minimise disturbance to wildlife.	All project phases	FPSO OIM Rig OIM Offshore EHS Coordinators Environmental Advisor(s) Aviation Superintendent Marine Superintendent	Achieve a minimum of 8 trained personnel to ensure continuity of the programme Annual analysis of MMO data	Environmental Monitoring Plan Marine Transportation and Logistics Procedures Guidelines for minimising impacts to birds and wetlands from flight operations

Seismic Surveys using seismic vessel fleet and equipment	waves into the water column		Bird aggregations and any deaths at the FPSO will be recorded and reported. Noise generated by FPSO and export tanker on marine environment has been monitored by a survey and documented Have a dedicated MMO on-board seismic survey vessel during offshore seismic activities. Requirement to have passive acoustic monitoring devices on-board seismic survey vessels.				TGL Marine Mammal and Turtle Avoidance Guidelines Marine mammal observation training procedure and associated protocols and training programme
9. Decommissioning							
9.01 Field and FPSO decommissioning	Loss of containment of hydrocarbons, process and associated chemicals and additives and abandonment of subsea systems and elements and components	Disturbance of the terrestrial and marine environs (seabed and water column) and associated and vulnerable components of the related ecosystems (flora and fauna)	Decommissioning plan: *A preliminary decommissioning plan has been prepared which will be updated as the field life and when changes in Jubilee or TEN operations infrastructure occur.* Terminal decommissioning planning and preparation should commence at a time pre-agreed with the GNPC, EPA, PC and other stakeholders when Jubilee or TEN field approach low yield or productivity. Local, regional and international laws, regulations and conventions would be assessed to ensure that the possible decommissioning arrangements are thoroughly evaluated. When production from the fields begins to show significant decline, stakeholder dialogue would immediately commence to create a common perception of the issues surrounding the decommissioning process. The necessary 'approvals' (internal, partnership and regulatory) processes would be commenced as early as possible to ensure that the approvals are received in a timely manner and preparations for the	De - commissioning	Jubilee and TEN Asset Teams Topsides Engineering Manager Subsea Engineering Manager Operations Manager EHSAP Manager Environment Team Lead		FPSOs and field decommissioning plans (TEN & Jubilee)

			works and activities are performed seamlessly. TGL will, as a minimum, utilise the principles of 'Best Practicable Environmental Option (BPEO) following a thorough assessment of options governing decommissioning activities				
9.02 Field decommissioning	Loss of containment of hydrocarbons, process and associated chemicals and additives and abandonment of subsea systems and elements and components	Disturbance of the terrestrial and marine environs (seabed and water column) and associated and vulnerable components of the related ecosystems (flora and fauna)	<u>Decommissioning studies and reviews</u>: *To support decommissioning planning and decision making processes, the following studies and reviews will be performed*: Formal assessment of the possibility of reusing all or parts of the facilities, either at their current location or at another site; Formal assessment of the possibility of recycling all or parts of the facilities. Risk and management assessments. Programme and approval(s) planning. Public consultation and dialogue with stakeholders. Decommissioning of production and utility systems and associated equipment assessments. Well plugging and abandonment assessments. Post decommissioning monitoring plans and surveys. Cancellation of rights and obligations, hand over rights and obligations documentation in the event of asset transfers and any remaining activities.	De-commissioning	Jubilee and TEN Asset Teams Subsea Engineering Manager Topsides Engineering Manager EHSAP Manager Environment Team Lead		TEN and Jubilee Field de-commissioning plan

			Equipment dismantling, recycling and disposal assessments including material/waste management assessments				
9.03 Field decommissioning	Loss of containment of hydrocarbons, process and associated chemicals and additives and abandonment of subsea systems and elements and components	Disturbance of the terrestrial and marine environs (seabed and water column) and associated and vulnerable components of the related ecosystems (flora and fauna)	<u>Decommissioning processes</u>: *The subsea equipment utilised is designed to ensure that after use, the complete system (with exceptions) can be withdrawn from the seabed thereby avoiding equipment becoming waste or permanent seabed scrap. Therefore, the decommissioning strategy will include the following:* Removal of the subsea trees; Flushing of the manifolds/well jumpers to the FPSO for efficient fluid collection and treatment. The manifolds/well jumpers could be abandoned in-situ; Cementing the wells to isolate the hydrocarbon bearing zones; Isolation of the production casing annulus; Removal of the well completion with the well head to be left in place in-situ. *For flow lines, risers and umbilicals, the decommissioning operations will be the reverse of the installation operations and will be performed with an equivalent marine spread i.e.*: Flushing the flow lines, umbilicals, riser systems and flexibles to the FPSO for efficient fluid collection and treatment; Disconnection and retrieval of the flexible jumpers and umbilicals; Disconnection and retrieval of the spool pieces;	Operational De-commissioning	Jubilee and TEN Asset Teams Topsides Engineering Manager Subsea Engineering Manager Operations Manager EHSAP Manager		FPSO decommissioning plans Field decommissioning plans

			Disconnection of the riser systems from the spool pieces and the flexible joint; Towing of the risers to the shore for decommissioning; The onshore scrapping of the recovered equipment at a suitable steel smelting facility. *At the end of the field lifetime, the riser systems and associated flexibles to the FPSO will be retrieved and towed to shore. All subsea flow lines and umbilicals will be purged of hydrocarbons, and flushed with water. The following will be left in-situ:* Flow line bundles; Water/gas injection flow lines.				

Table 5-6: Environmental Management Plan – Activities Table

(*) Note: Detailed and concise monitoring protocols are contained in the related Environmental Monitoring Plan – TGL-EHSS-PLN-04-0006)

Ref Number	Relevant Project Component	Monitoring Parameter / Measurement Requirements	Compliance Limits/Target	Compliance source	Frequency / Timing	Responsibility
Air Emissions						
AE1	FPSO, MODU	**Fuel Consumption Offshore – Point Source Emissions** Monitoring of point source emissions from production-related activities. Covers requirements for measuring emissions from combustion devices onboard the FPSO and MODUs.	Combustion equipment: various limits, equipment dependent. See Plan AE1.	EPA, IFC, TGL	Daily, Monthly Compilation	FPSO – MODEC Operations and Maintenance Superintendent MODU – Chief Operations Engineer Support Vessel – Marine Superintendent
AE2	FPSO, MODU	**Production Operations Venting** Formula to calculate an estimated quantity of gas vented to be used until a flow meter is installed. Twice per year analysis of vented gas composition. Vent gas composition.	N/A	EPA,IFC,TGL	Daily, Monthly Compilation	FPSO Marine Superintendent
AE3	FPSO	**Atmospheric Emissions – Offshore Activities** Monitoring of SO_2, CO_2, NOx, VOCs and CH_4 from all sources (complemented by AE1 and AE4).	N/A	EPA	Daily, Monthly Compilation	FPSO – OIM (MODEC) Support vessels – Marine Superintendent
AE4	All	**Emissions to Air from Flaring** Monitoring of the volume of gas sent to the flares.	≤3.0% of monthly total gas production	EPA	Daily, Monthly Compilation	FPSO OIM (MODEC) MODU Company Man
AE5	FPSO	**Ambient Air Monitoring – FPSO** Monitoring of ambient air quality on board the FPSO, for the parameters NOx, NO_2, SO_2 and Ozone using passive captors.	Various time-weighted limits for NOx.	EPA IFC	Once Annually and/or during periods of protracted non-routine elevated flaring exceeding 60 days.	FPSO Operations and Maintenance Department
AE6	Shore bases	**Ambient Air Monitoring – Shore bases** Monitoring of ambient air quality at shore bases, for the parameters NOx, NO_2, SO_2 and Ozone using passive captors.	Various time-weighted limits for NOx.	EPA Ambient Air Quality Guidelines IFC	Annually	Environmental Advisor (s)
AE7	Shore bases	**Fuel Consumption Onshore – Point Source Emissions** Monitoring of point source emissions from support-related activities. Covers requirements for measuring emissions from	N/A	Internal (TGL)	Monthly Compilation	Environmental Advisor in consultation with relevant departments

Ref Number	Relevant Project Component	Monitoring Parameter / Measurement Requirements	Compliance Limits/Target	Compliance source	Frequency / Timing	Responsibility
		mobile support sources such as vehicles and aircraft.				
Chemicals						
CM1	FPSO	**Chemical Management** Injection chemical monitoring (type, volume, discharge details) using flow meters on injection system.	N/A	EPA, IFC, TGL	Daily, Monthly compilation	FPSO Production Chemicals Custodian (Nalco Chemicals)
CM2	MODU	**Barite Quality of Drilling Materials** Monitoring mercury (Hg) and cadmium (Cd) levels in stock barite.	Hg: max 1g/kg dry weight in stock barite; Cd 3mg/kg dry weight in stock barite	EPA, IFC, TGL	Batch	Drilling Fluids Project Engineer (MI Swaco)
CM3	Offshore Chemicals	**Ecological testing, categorization and environmental assessment of operational chemicals** Perform ecotoxicological control via data available: MSDS, Ecotox, OCNS database, bioaccumulation & biodegradability values. Ecotox reports of products supplied by vendor will suffice.	N/A	EPA standard permit requirement	Annually	Environmental Advisor
Ecology						
EC1	FPSO	**Marine Avifauna** Bird monitoring in the vicinity of the FPSO to determine any effects on bird life.	N/A	EPA	Opportunistic recording of bird sightings. Special birds study required when unusual bird behavioural activity is observed	FPSO crew Ornithologist/Trained FPSO Personnel
EC2	MODU, FPSO, Support Vessels	**Offshore Installations Environs** Seabed and water column monitoring associated with activities in the offshore environment.	N/A	EPA	Every 3 years	Third party marine scientists/Environmental Advisor. Joint industry effort with EPA coordinating
EC3	MODU, FPSO, Support Vessels	**Marine Megafauna**	N/A	EPA	Marine Mammals and turtles – Continuous	Crew on-board offshore installations/Marine Mammal Observers in

Ref Number	Relevant Project Component	Monitoring Parameter / Measurement Requirements	Compliance Limits/Target	Compliance source	Frequency / Timing	Responsibility
		Faunal monitoring in the water column to identify any impacts from offshore activities. Includes mammals, turtles and fish.			Fish – one off	specialised studies required
EC4	MODU, FPSO, Support Vessels	**Near shore Environs** Monitoring the receiving near shore environment for presence of impact from operations.	N/A	EPA	Initially 2012, then every 3 years or as and when required	Third party marine scientists/Environmental Advisor/Operator Technician
EC5	Offshore Field Surveillance (Aerial Photography)	**Visual Intrusion Observations - Record of Unusual Sea Surface Environmentally Important Observations**	N/A		Opportunistic	Aviation crew
Energy						
EU1	FPSO, MODU, Support Vessels, Shore bases	**Energy Consumption** Monitoring of energy usage, covering power generation, grid electricity and renewable energy and recorded in GJ.	N/A	TGL	Monthly	Environmental Advisor in consultation with relevant departments
Liquid Discharges						
LD1	FPSO	**FPSO Produced Water Discharges** Produced water monitoring for volumes and oil in water content using In-line analysers and manual sampling. Analysis of produced water to assess its chemical composition and quantities of discharged offshore chemicals.	42 mg/L maximum daily oil in water 29 mg/L 30-day average oil in water 20 mg/l(Tullow)	EPA sector specific effluent quality guidelines – oil and gas, IFC, TGL	Daily, Monthly Compilation	TGL Production Operations Dept/Nalco Champion Lab Technician
LD2	FPSO, MODU, Support Vessels	**Black/Grey Water Discharges** Black water (treated sewage) monitoring for residual chlorine content using hand held equipment. Sewage discharge quality analysis	No floating solids or discoloration Residual chlorine < 1 mg/L	EPA sector specific effluent quality guidelines – oil and gas, IFC, TGL	Daily discharge volumes – Monthly Compilation sewage discharge quality analysis – six monthly	MODEC Operations and Maintenance Department
LD3	FPSO, MODU, Support Vessels	**Deck Drainage and Bilge Water Discharges** Monitoring of oily water discharges, including deck drainage, bilge water and ballast water for oil in water content using in-line analysers.	Oil in water < 15 mg/L	EPA sector specific effluent quality guidelines – oil and gas, IFC, TGL	Continuous	FPSOs - Maintenance/Production Superintendent MODUs – Chief Engineer

Ref Number	Relevant Project Component	Monitoring Parameter / Measurement Requirements	Compliance Limits/Target	Compliance source	Frequency / Timing	Responsibility
LD4	FPSO	**FPSO Ballast Water Management and Discharges** Monitoring oil content in ballast water. Monitoring temperature differential of cooling water at the inlet and outlet locations.	Oil in water < 15 mg/L Temperature	EPA	Continuous	FPSOs Marine Superintendent (MODEC)
LD5	FPSO, MODU,	**Desalination Brine Discharge and Water Use** Monitoring volume and salinity of desalination brine discharges from the FPSO, MODU and Support Vessels.	N/A	TGL	Daily, Monthly Compilation	MODU (Chief Engineer), FPSOs (Marine Superintendent - MODEC)
LD6	FPSO	**Desulphation Water** Monitoring of desulphation water volumes at the SRU.	N/A	TGL	Daily, Monthly Compilation	FPSO Production Operations Department
LD7	MODU	**Well Completion and Workover** Monitoring oil content in wellbore clean-up fluids	Oil and grease < 42 mg/L (daily), < 29 mg/L (monthly), pH 6-9	EPA, IFC, TGL	Continuous, Daily	Completions Supervisor/Rig Superintendent/Offshore EHS Advisor
LD8	FPSO, MODUs, Support Vessels	**Liquid Discharges – Spills** Monitoring characteristics of materials spilt.	Zero discharge to the external environment	EPA, TGL	Continuous	Offshore EHS Advisor/Rig Superintendents
LD9	Shore bases	**Shore Base Liquid Discharges** Monitoring of industrial wastewater discharges on a batch basis.	pH (6-9), oil and grease (max permitted 10 mg/L) and Total suspended solids (max permitted 50 mg/L).	EPA, IFC	Prior to discharge	Facilities Maintenance Officer/Third party lab (Intertek Lab)
Noise						
N1	FPSO, Shore bases	**Environmental Noise Monitoring** Monitoring of ambient environmental noise levels at prescribed locations.	Offshore - N/A Shore bases - EPA Ambient Noise levels [Industrial – 70 dB(A)]	EPA, TGL,	Annually and in response to potential noise complaints that may be lodged by surrounding community	Environmental Advisor
Production						

Ref Number	Relevant Project Component	Monitoring Parameter / Measurement Requirements	Compliance Limits/Target	Compliance source	Frequency / Timing	Responsibility
P1	FPSO, MODU	**Production Monitoring** Monitoring of hydrocarbon production data for wells, flaring and onsite combustion.	N/A	EPA, TGL	Monthly	TGL/MODEC Production Superintendents/OIM DST Operations Supervisor
Transport						
VT1	Shore bases	**Transport – Marine Vessels and Air Transport Movements** Monitoring of helicopter and vessel movements within defined corridors/routes ensuring minimal environmental impacts.	Flying height > 710 m over wetlands/bird collision Recoding of vessel collision with marine mammal during sail	EPA	Continuous, per trip	Marine and Aviation Superintendents
Waste Management						
WM1	FPSO, MODU, Support Vessels, Shore bases	**Waste Management Plan Monitoring** This is to measure the quantity of hazardous and non-hazardous wastes produced and specify the method of treatment or disposal.	N/A	EPA	Monthly Compilation, Annually	Environmental Advisor /Marine Superintendent/Logistics Base EHS Superintendent
WM2	MODU, FPSO, Support Vessels	**Offshore Food Waste Discharges** Monitoring the volume of organic food discharged off-shore.	<25mm mesh to be used; Discharge distance > 12 nm offshore	EPA/MARPOL	Daily, Monthly Compilation	Chief Engineer/Marine Superintendents for FPSO/MODU
WM3	FPSO	**Produced Sand Discharges** Monitoring the produced sand oil volume and concentration.	Oil <10g/kg dry matter, or 1%	EPA, IFC	Batch	MODEC Operations and Maintenance Department
WM4	FPSO	**Naturally Occurring Radioactive Materials (NORM)** Monitoring sludges and scale accumulations in pipe work, valves etc.	4 $Bq.cm^{-2}$ Gamma 0.4 $Bq.cm^{-2}$ Alpha/Beta	IFC	Annual survey/As part of maintenance routines	MODEC Operations and Maintenance Department/Company RPA
WM5	MODU	**Drill Cuttings Discharge** Drill cuttings treatment and ROC (retention on cuttings) measurement prior to discharge	20 g/kg of dry matter (2% ROC)	EPA	OPF Drilling - Continuous	MODU Mud Engineer

Table 5-7: Environmental Management Plan – Monitoring Summary Table

6. Environmental Action Plan

Environmental Programme	Objective(s)/Target(s)	Actions	Timeline	Indicative Budgeted Cost per annum (US$)
TGL ISO 14001 Environmental Management System	To maintain the recently certified TGL EMS to the ISO 14001 standard. To drive overall TGL environmental management strategy within the ISO 14001 EMS Framework.	Frequently carry out internal audits of TGL EMS against the ISO 14001 standard. Conduct annual management review of the TGL EMS to ensure its continuing suitability, adequacy and effectiveness.	Annually	50,000
FPSO Flaring Minimisation	To reduce non-routine flaring to less than 5% of total gas production.	Prepare a flare management plan to provide guidance on TGL flaring strategy, compliance requirements and regulatory notification protocols to be followed for non-routine flaring. Maintain rigorous and preventative maintenance programme for all process units/modules within the hydrocarbon fluids separation line on-board the FPSO. Developing and implement engineering reliability processes, procedures, performance standards and Key Performance Indicators to improve Maintenance and Integrity performance.	Continuous	3,000,000
Waste Management Improvement	To continually improve in-country waste management capability of industrial waste facilities. Build and consolidate waste management solutions for waste streams from the oil and gas industry. Minimise non-hazardous waste volumes going to landfills for disposal. Facilitate and support the establishment of industrial waste facilities for oil and gas industries in Ghana.	Facilitate capacity building of in-country waste treatment facilities as part of the company's local content development initiatives. Actively promote waste management technology transfer to local waste contractors. Establish a procedure for the management of Naturally Occurring Radioactive Materials (NORMS) with the assistance of the Radiation Protection Institute and the Nuclear Regulatory Authority Implement a waste management contracting strategy that encourage competitive pricing and improved service delivery within Ghana's industrial waste	Continuous	50,000

Environmental Programme	Objective(s)/Target(s)	Actions	Timeline	Indicative Budgeted Cost per annum (US$)
		management sector – implement a primary and a secondary contractor arrangement.		
Operational Area environmental quality monitoring	Ensure overall jubilee project area of influence environmental quality is not adversely affected. Maintain environmental quality of air, water column, fisheries resources and marine ecological conditions. To check the effectiveness of environmental protection controls for emissions and discharges.	Establish monitoring programme for the external environment that assess environmental quality parameters within project area of influence are within acceptable limits for sustenance of life.	Annually	100,000
Stack Emissions Monitoring	To determine pollutant gas (mainly NOx and SOx) emissions from engines, boilers and turbines do not create ambient air quality problems within the vicinity of the FPSO and on-board personnel. To check if installed air pollution control devices are effective in reducing the release of pollutant gases and particulates.	Draw up detailed scope of work and develop work programme for annual stack emissions monitoring on the FPSOs.	Annually	60,000
Marine Mammal Observation Programme	To monitor mammals behaviour/activity in the vicinity of the FPSO as a means to assess FPSO presence influence on marine mammal behavioural patterns.	Record opportunistic sighting of marine mammals activities within the Jubilee and TEN Fields. Strange behavioural patterns to be noted for analysis by marine mammal experts.	Continuous	60,000
Spill Prevention	To achieve zero discharge of hydrocarbons annually. To continuously identify potential sources of leaks or spills.	Routine inspection and maintenance of subsea infrastructure (hydrocarbon fluid flow lines and risers) FPSO topsides storage facilities. Containment integrity audit for all storage facilities. Conduct environmental risk assessment.	Continuous	100,000
Water Column and sediment sampling and analysis		3 year cycle water column and sediment quality sampling programme within the vicinity of the FPSOs and field boundaries to check water quality and sediment parameters are within normal limits.	Every 3 years	2,500,000

APPENDIX F SOCIAL PERFORMANCE PLAN

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