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Oil Spill Trajectory Simulations Offshore Nigeria

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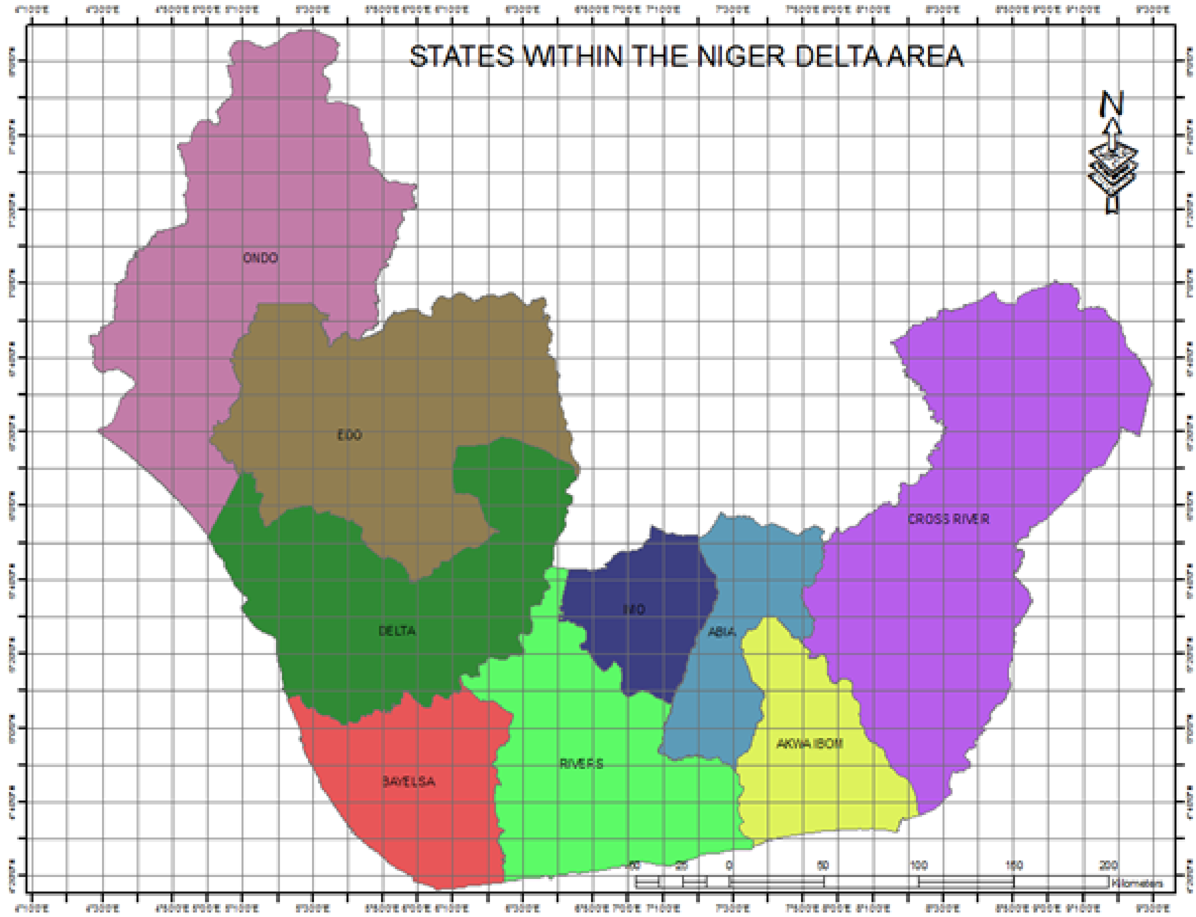
ABSTRACT:

The Niger Delta region has witnessed the continuous destruction of its environment due to oil and gas exploration, exploitation, corrosion of oil pipes and tanks, sabotage, port operations and inadequate care in oil production operations and engineering drills. The transport and fate of spilled oil in water bodies are governed by physical, chemical, and biological processes that depend on oil properties, hydrodynamics, meteorological and environmental conditions. These processes also include advection, surface spreading, evaporation, dissolution, emulsification, hydrolysis, photo-oxidation, biodegradation and particulation. As an oil spill management strategy, OIL SPILL MAPtrajectory model was used in this study to carry out simulations for six Floating Production Storage Offshore (FPSO) facilities offshore Nigeria for rainy and dry seasons. The results of the simulations for wet and dry seasons show that oil spill moves slower in deep sea and faster between the distances of 10km to 20km from the shoreline. The reason for this is that in the deep sea, there is minimal tidal effect while the tidal effect is more prevalent in the 10km to 20km region. Also, the net effect of the longshore current and tides increased the speed of the oil spill near the shoreline.This study reveals that in case of any major oil spill from any of the six FPSOs, the probability that the oil spill will get to the shore is very high. It therefore becomes highly imperative that more care should be taken in oil spill exploration and exploitation activities to prevent oil spill incidents.Existing laws and policies regulating oil exploration and exploitation activities should be strengthened and enforced to ensure strict compliance by the oil and gas companies in Nigeria so as to reduce oil spill incidents in the country.

KEY WORDS: *Niger Delta, Oil, Exploration, Exploitation, Floating Production Storage 0ffshore, Oil Spill Incidents, Trajectory Simulations.*

I. INTRODUCTION

The Niger Delta is located in the Atlantic coast of Southern Nigeria and is the world's second largest delta with a coastline of about 450km which ends at Imo river entrance (Awosika, 1995). The region is about 20,000sq/km as it is the largest wetland in Africa and the third largest in the world (Powell, et al., 1985; CLO, 2002; Anifowose, 2008; Chinweze and Abiola-Oloke, 2009). The Niger Delta mangrove swamp spans about 1900sq/km and it is the largest mangrove swamp in Africa (Awosika1995). The Niger Delta is classified as a tropical rainforest with ecosystems comprising of diverse species of flora and fauna both aquatic and terrestrial species. The region can be classified into four ecological zones; coastal inland zone, freshwater zone, lowland rainforest zone, mangrove swamp zone.The Niger Delta region is considered one of the ten most important wetlands and marine ecosystems in the world (FME, et al., 2006; ANEEJ, 2004). The Niger Delta consist of the following states Abia, AkwaIbom, Bayelsa, Cross River, Delta, Edo, Ondo, Imo and Rivers respectively. Figure 1 shows map of the nine oil producing states in the Niger Delta.



Oil Exploitation and Exploration in the Niger Delta : Historically, the Nigerian petroleum scene opened as far back as 1908, when a Germany company, the Nigeria Bitumen Corporation, was attached to what is now known as the south-western Nigerian Tar sand deposit. After World War 1, shell-D'Arcy, a consortium of shell and royal Dutch resumed oil exploration in 1937, this time in Owerri, on the northern frame of Niger Delta. In June 5, 1956, after drilling 28 wells and 25 core holes Royal Dutch Shell discovered crude oil at Oloibiri, a village in the Niger Delta, and commercial production began in 1958. Offshore exploration started in the 21st century in Nigeria, which made Shell Bonga the first, followed by Chevron Agbami, Total and others.Since the discovery of oil in Nigeria in the 1950s, the country has been suffering the negative environmental consequences of oil development, some of which are oil spill, gas flares, environmental degradation, destruction of the mangrove forests and many more. It has been estimated that between 9 million to 13 million barrels have been spilled into the environment since oil drilling started in 1958 (FME, et. al. 2006). The growth of the country's oil industry, combined with population explosion and lack of enforcement of environmental regulations led to substantial damage to Nigeria's environment, especially in the Niger Delta region.

Oil Trajectory and Fate Models : A model is a representation of a system that allows for investigation of the properties of the system and in some cases, prediction of future outcomes. A trajectory is a type of model that describes the path of a moving object following through space as a function of time. A trajectory can be described mathematically either by the geometry of the path or the position of the object over time. Trajectory modelling uses a mathematical model to predict the movement of spilled oil. It can be as simple as taking three percent of the wind speed as the velocity of the centre of the oil slick, or as complicated as a sophisticated computer model containing thousands of lines of code (HAZMAT, 1996).

The application of any model or mathematical procedure to describe the movement of spilled oil or other pollutants is subject to all sorts of errors and represents a simplification of the real world. Clearly, a model's usefulness depends on the value of its input data, its software design, and how its results are interpreted. Ultimately, the information available for estimating the movement and behaviour of the spilled oil, along with an understanding of the uncertainty inherent in the model predictions must be factored into spill response plans. Hundreds of model runs may be required to provide the necessary guidance gleaned from the variety of possible scenarios (HAZMAT, 1996).Oil spill simulation model is used in oil response and contingency planning and as a tool in oil fate and impact assessment (Rossouw, 1998). In the event of an oil spill taking place, predictions of the slick can be supplied, provided that the necessary meteorological information is available (Rossouw, 1998).
Two approaches for computing oil spills trajectories are commonly encountered in the literature; Lagrangian models and Eulerian models. The Lagrangian models consist basically in representing the oil slick by an ensemble of a large number of small parcels which are advected by a velocity which results from a combination of the action of winds and currents. Then, the slick is divided into pie shaped segments or strips, depending if the form of the slick is nearly circular or elongated. Fay (1969) spreading formulas are then applied to each segment. In the theEulerian approach, two models are usually encountered, those based on the mass and momentum equations applied to the oil slick (Hess and Kerr (1979), Benqué et. al.(1982)), and those based on a convection-diffusion equation (Venkatesh,1988), in which the diffusive part of the equation represents the spreading of oil by itself and the convective terms represents the advection of oil by currents and winds (PaladinoandMaliska, 2000).

II. TYPES OF MODELS

[1] Trajectory or deterministic models are used to predict the route of an oil slick over time and commonly estimate the weathering profile under the specified hydrodynamic and meteorological conditions. Modelling outputs include the predicted slick trajectory and estimates of slick area, changes to oil properties over time (e.g viscosity and flash point), potential beaching sites, the lengths of coastline impacted and estimates of the total amount of beached oil.

[2] Oil weathering model predict the changes in oil characteristics that may occur over time, under the influence of environmental conditions. Environmental parameters such as water temperature, wind speed, wave heights or sea state, salinity and sediment concentration can be entered by the user and the appropriate oil type is selected from the database. The model then estimates the percentages of the slick that evaporates emulsify and disperse into the water column. Oil weathering models are usually very easy to use and run quickly on modern computing platforms.

[3] Stochastic models which are also known as probability models shows the probability of where an oil spill may impact for defined time period. Historical wind records that contain the frequency of wind speed and direction are required. The model runs a series of trajectories under various wind conditions from records. It then combines the result to produce an overall illustration of the probability of where oil might travel in defined time periods. The results only indicate the chances of a particular area being oiled and do not show the quantity of oil present. These outputs allow the determination of which water bodies and shorelines that are most at risk during various seasons. In addition, stochastic modelling can show time contours, which illustrate the time taken for the oil to travel a particular distance or to reach a shoreline.

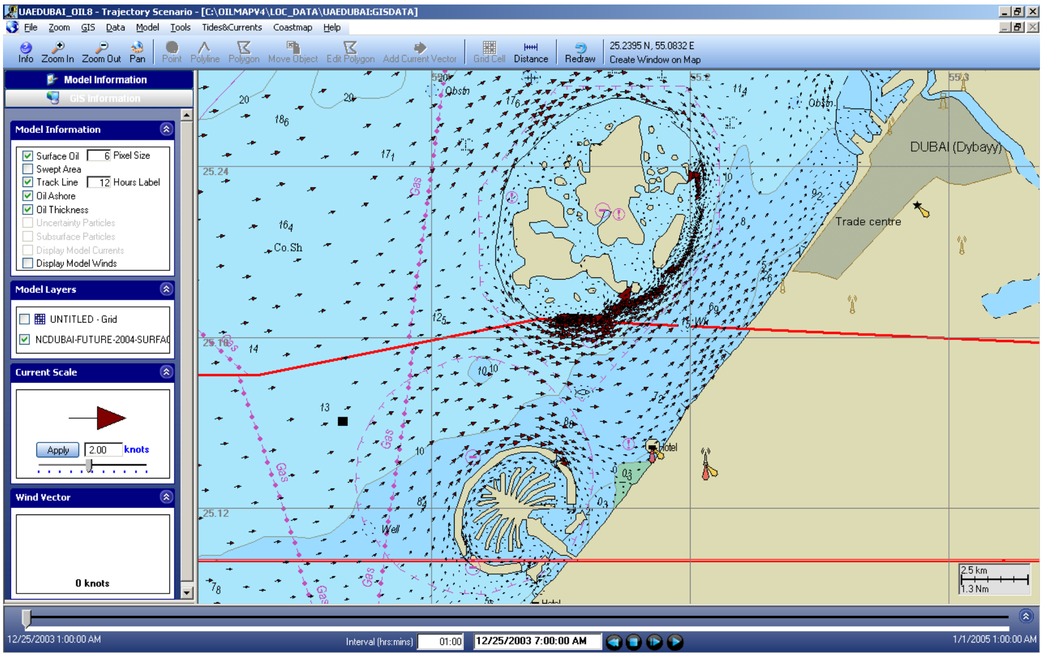
[4] Hind-cast models, sometimes known as backtrack models, reverse the trajectory modelling process. These can be used to estimate the spill origin in situations where the source or release point is unknown.

[5] Three-dimensional (3D) functions have also been developed. These models estimate trajectories and weathering profiles over time, make simulation of dispersion into the water column and estimate oil component concentration. In addition to standard inputs, a more sophisticated oil characterization is required. In these models, subsurface particles (representing entrained oil droplets and dissolved oil components) move within a 3D modeling system that specializes in simulating sub-sea release. Three-dimensionalmodeling programmers' require complex 3D current data and detailed oil characterization in order to provide reliable estimate of how oil will behave and migrate at various depths.

Existing Models : Some of the software developed and in use for oil spill management are those developed by Hang et al (1989), Kung et al (1997), OILMAP, GNOME, SIMAP, Coastal Zone Oil Spill model(COZOIL), Computer Model at S.L. Ross, Canada, Multiphase Oil Spill Model (MOSM), and Nigerian Oil Spill Model (NOSM).

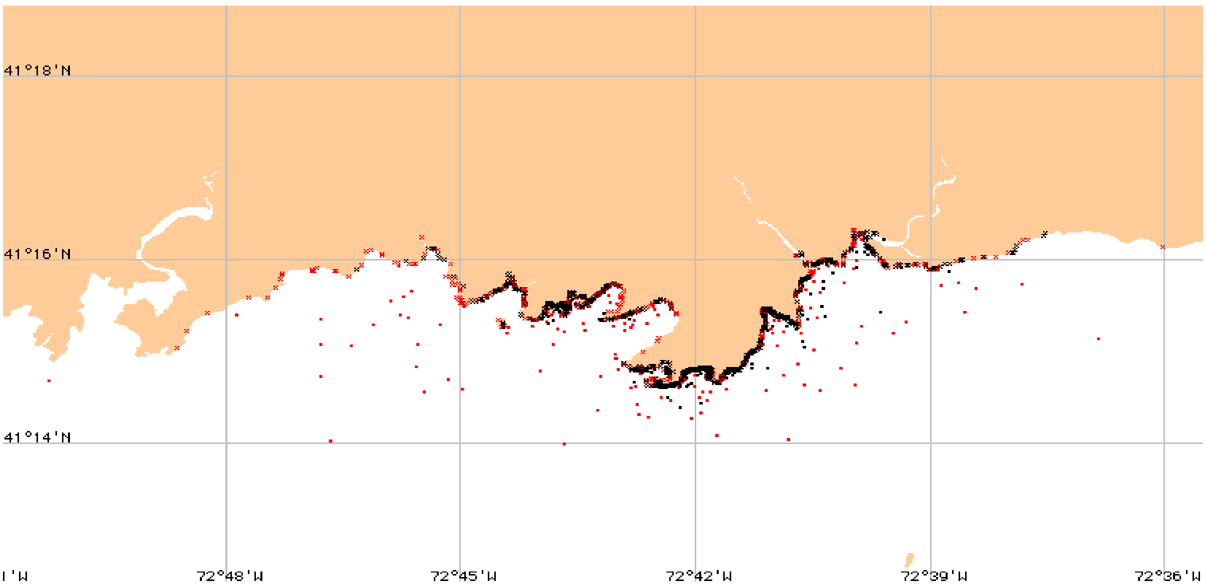
OIL MAP :

OILMAP is a user-friendly oil spill model system designed for oil spill response and contingency planning. It includes simple graphical procedures for entering spill information and connects to on-line weather forecast servers for accurate wind and current data. OILMAP uses a variety of electronic chart systems, including global nautical CMAP charts from Jeppesen Marine and is also compatible with ESRI GIS software. The power of OILMAP to rapidly provide oil spill trajectory predictions anywhere in the world makes oil spill modelling accessible to the oil and gas industry, shipping companies and government agencies. Many of the large oil companies including Chevron, Exxon, ConocoPhillips, Shell and Agip.rely only on OILMAP for oil spill predictions. Figure 2 shows the OILMAP environment.



GNOME : GNOME is an oil spill trajectory model that simulates oil movement due to winds, currents, tides, and spreading. GNOME was developed by the Hazardous Materials Response Division (HAZMAT) of the National Oceanic and Atmospheric Administration Office of Response and Restoration (NOAA OR&R). HAZMAT uses this model during spill response to calculate a "best guess" of a spill's trajectory and the associated uncertainty in that trajectory.

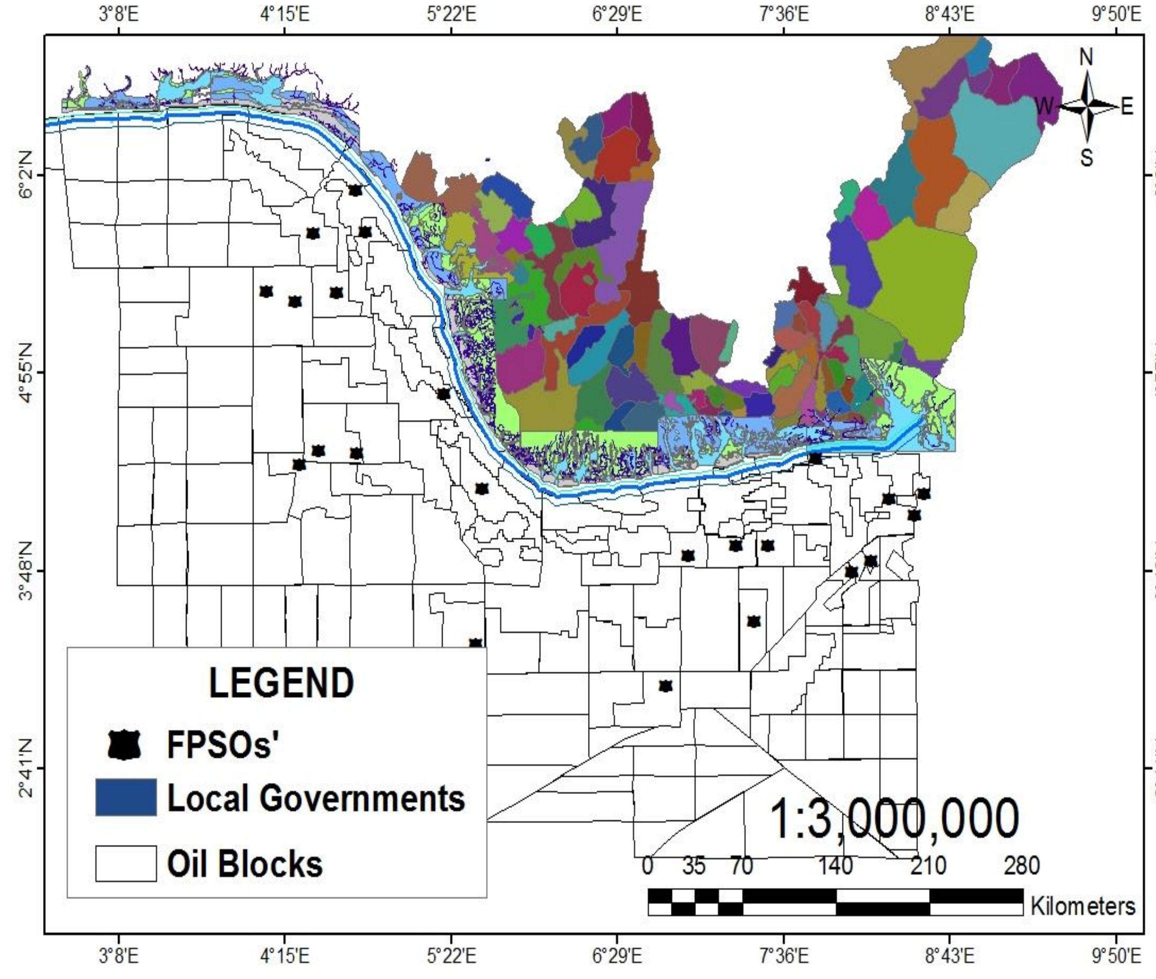
Figure 3 shows the GNOME environment.



OIL SPILL MAP : OIL SPILL MAP trajectory model was developed by using appropriate wave driven current equations coupled with that of wind drift current, ocean current, tidal current and longshore current to generate advection of oil spill on coastal waters (Badejo and Nwilo, 2011). Existing oil fate models for calculating the rate of spreading and evaporation of oil were also included in the work to enable efficient tracking of oil spill on water. In the model, oil spill is assumed to spread radially under steady gravity and viscous forces, thus Fay's radial spreading formula for gravity and inertial forces was used. The formula developed by Mackay (1980) was used to calculate the evaporate rate of oil in the model. OIL SPILL MAP trajectory model was developed within ArcGIS Environment using Arc GIS VBA. The model was linked with Environmental Sensitivity Maps within the same Arc GIS environment.

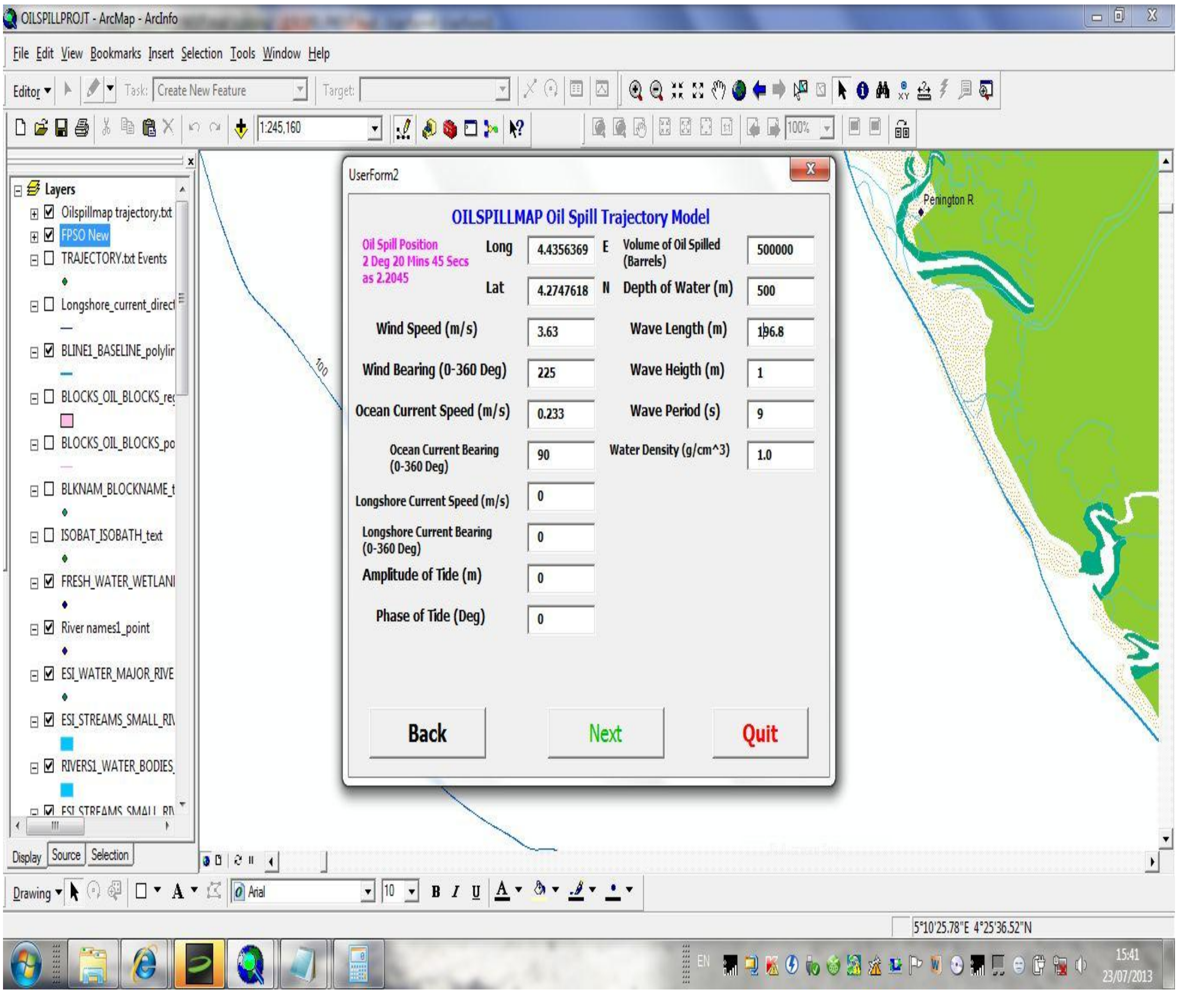
III METHODOLOGY

OIL SPILL MAP trajectory model was used for trajectory simulation in this work. A new map layer in OIL SPIL MAP was created for this study using Nigerian Energy Map produced by NNPC in 2011. Some of the requirement for studies of this nature are multi-sourced dataset that are well documented with good data quality. The wind, current, tidal and oil properties used in Badejo and Nwilo (2011) were used for this study.Features Extracted from the Nigerian Energy Map are oil producing states and their local government areas, oil wells, oil fields and Oil blocks and locations of FPSOs. The extractions where done by first Geo-referencing the map; giving every location on the map its geographic co- ordinates after which it was digitized. Figure 4 shows the extractions from the Nigerian Energy Map in Arc GIS environment.



The assumption made by OIL SPILL MAP is that oil will not mix with water, and that the density of oil spill is less than that of water, thus the oil spill will move on water and not sink. The full description of OIL SPILL

MAP mathematical models are given in Badejo and Nwilo (2011). To run the model, the following basic data are needed,coordinates of spill point, volume of spill, wind speed, wind direction, current speed, current direction, longshore current speed, longshore current direction, amplitude and phase of tide, wavelength, wave height, wave period, water depth, density of oil, density of sea, temperature of oil, kinetic viscosity of oil, API of oil and Molar volume of oil. Other data needed are acceleration due to gravity, numbers of hours after oil spillage, time, height of high water 1, time of high water 1, height of low water 1, time of low water 1, height of high water 2 , time of high water 2, height of low water 2, time of low water 2. Oil trajectory simulations were then made with OIL SPILL MAP from the positions of six FPSO's for wet and dry seasons. Figure 5 shows the OIL SPILL MAP environment.

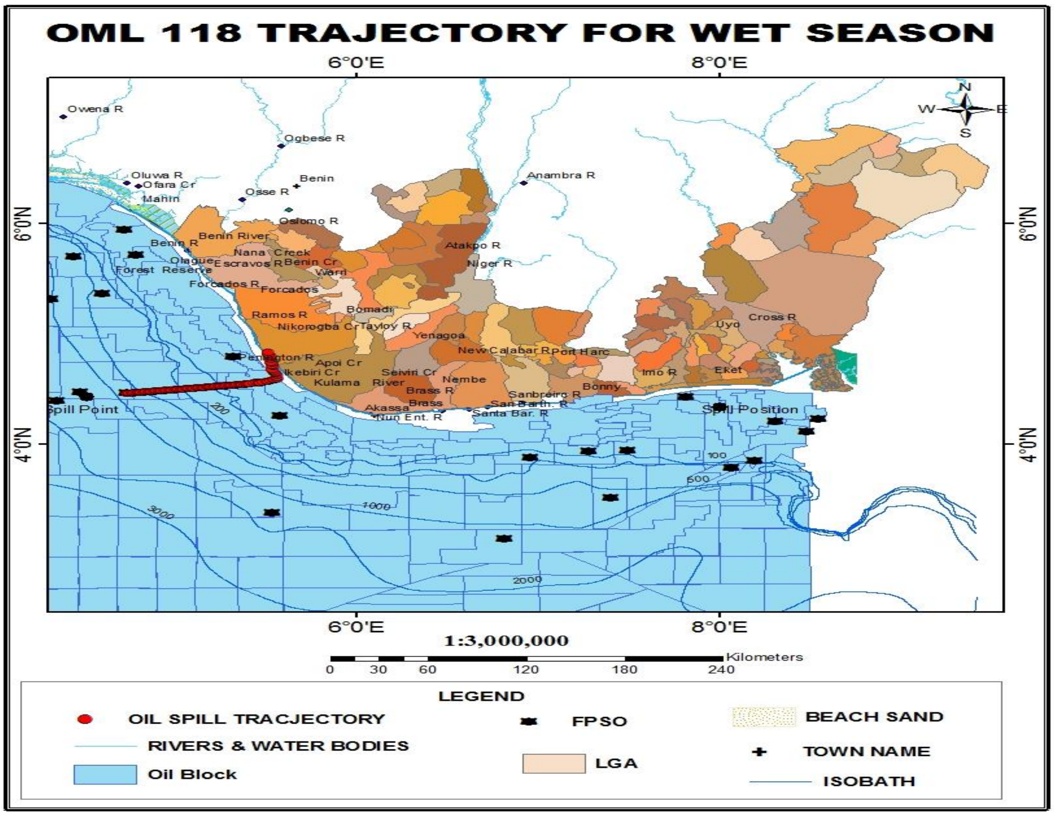


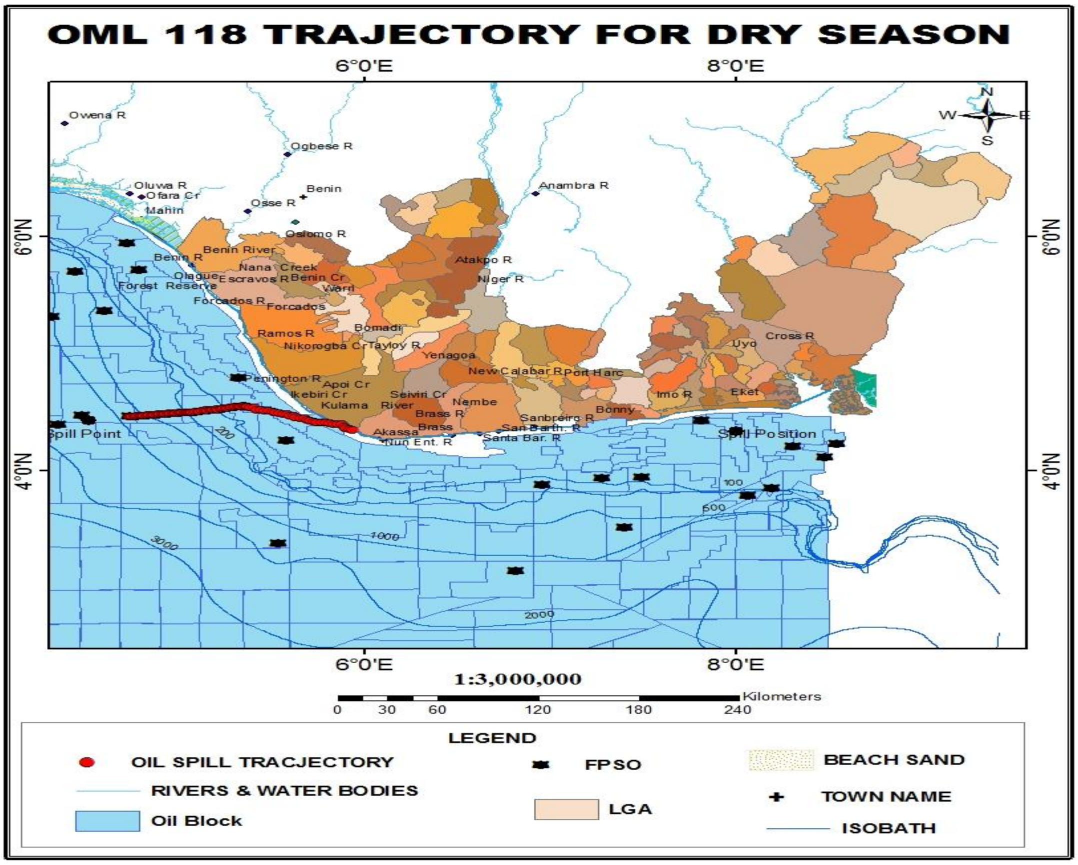
The simulations for the wet and dry seasons were done in four phases for each season, for phase one, simulations were made from the spill point up to a point around 500m isobath. In phase two, simulations were made from the point around the 500m isobath to a point about 15m to the coastline. Simulations for phase three were made from the point about 15m to the coastline up to another point about 5m to the coastline. Simulations for the last phase were made from the point about 5m to the coastline up to the coastline. The reason for making the simulations in four phases is that the effect of tides is negligible for the deep sea, while the tidal effect increases as one move closer to the coastline. We have to vary the amplitudes and phases of tides along the coastal waters, the major difference in the seasons data include wind speed and direction, current speed and direction, amplitude and phase of tides.

IV RESULTS AND ANALYSIS OF RESULTS

Results

The various results obtained during the course of this research work are presented in this section.


OML 118 TRAJECTORY FOR WET SEASON
6°0'E
8°0'E
6°0'N
4°0'N
Spill Point
Spill Position
1:3,000,000
0 30 60 120 180 240 Kilometers
LEGEND
OIL SPILL TRACJECTORY
RIVERS & WATER BODIES
Oil Block
FPSO
LGA
BEACH SAND
TOWN NAME
ISOBATH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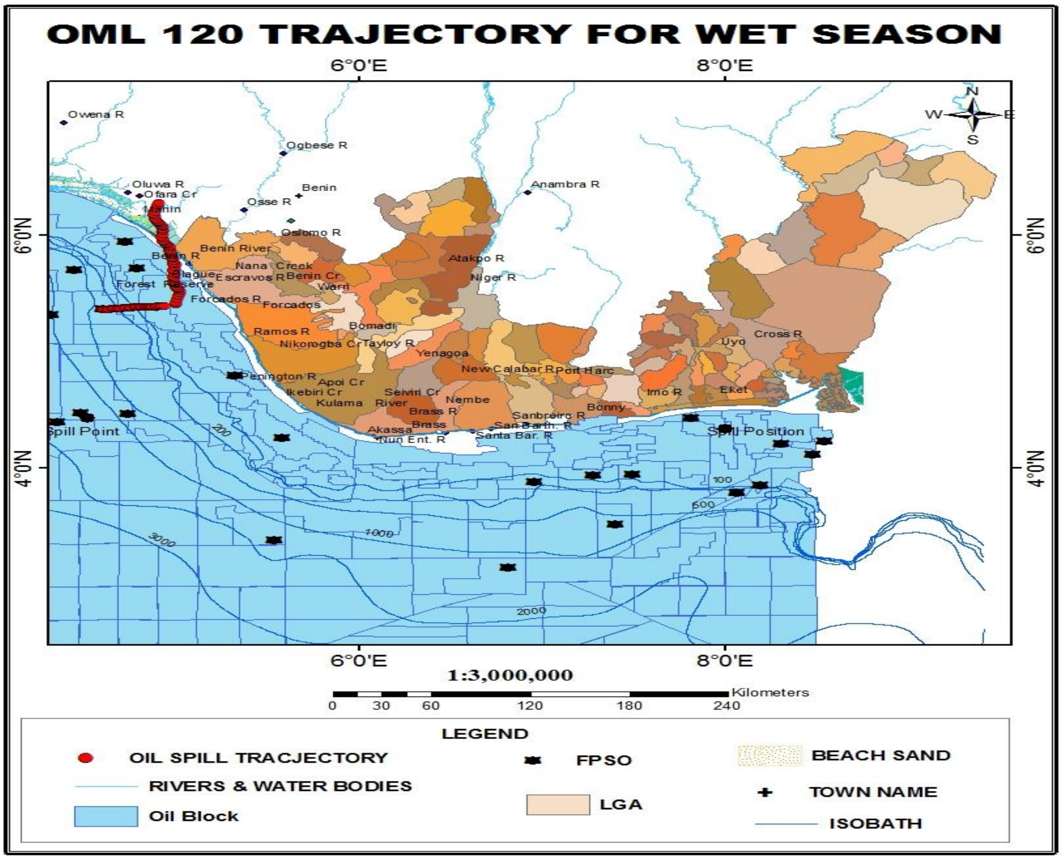
4°0'N
Spill Point
Spill Position
1:3,000,000
0 30 60 120 180 240 Kilometers
LEGEND
OIL SPILL TRACJECTORY
RIVERS & WATER BODIES
Oil Block
FPSO
LGA
BEACH SAND
TOWN NAME
ISOBATH


OML 120 TRAJECTORY FOR WET SEASON
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4°0'N
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LEGEND
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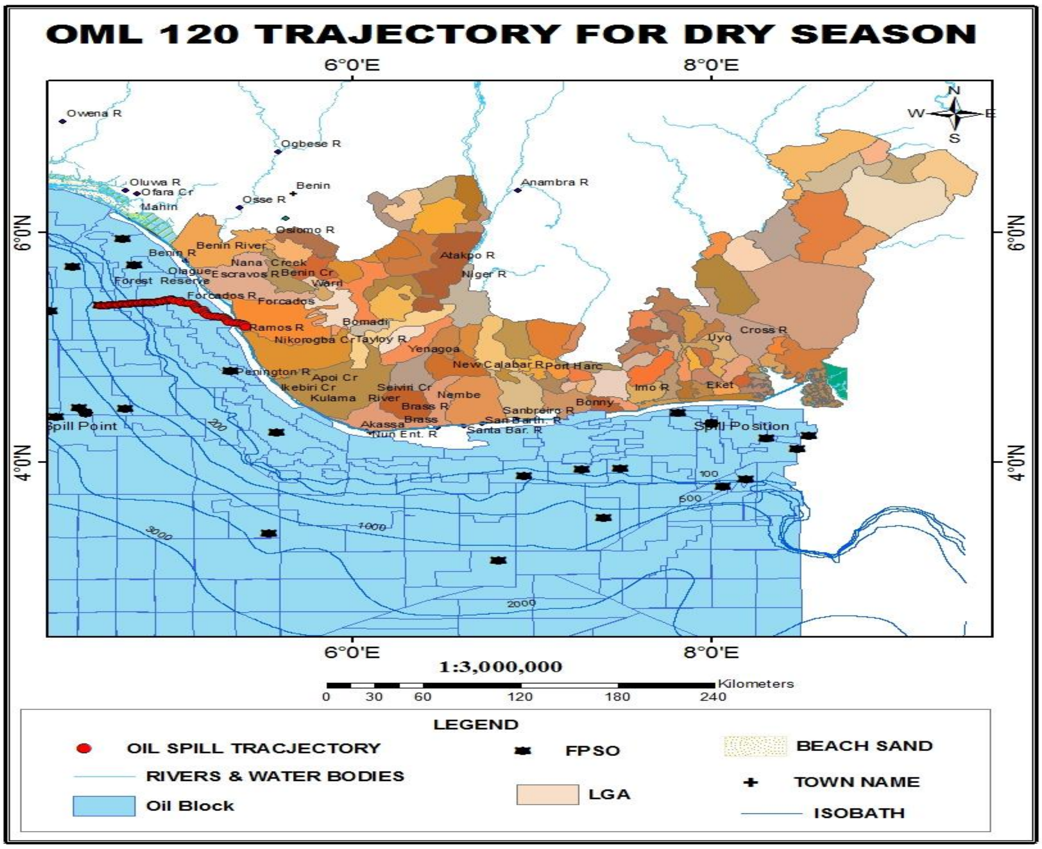
RIVERS & WATER BODIES
Oil Block
FPSO
LGA
BEACH SAND
TOWN NAME
ISOBATH
Spill Point
Spill Position


OML 120 TRAJECTORY FOR DRY SEASON
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4°0'N
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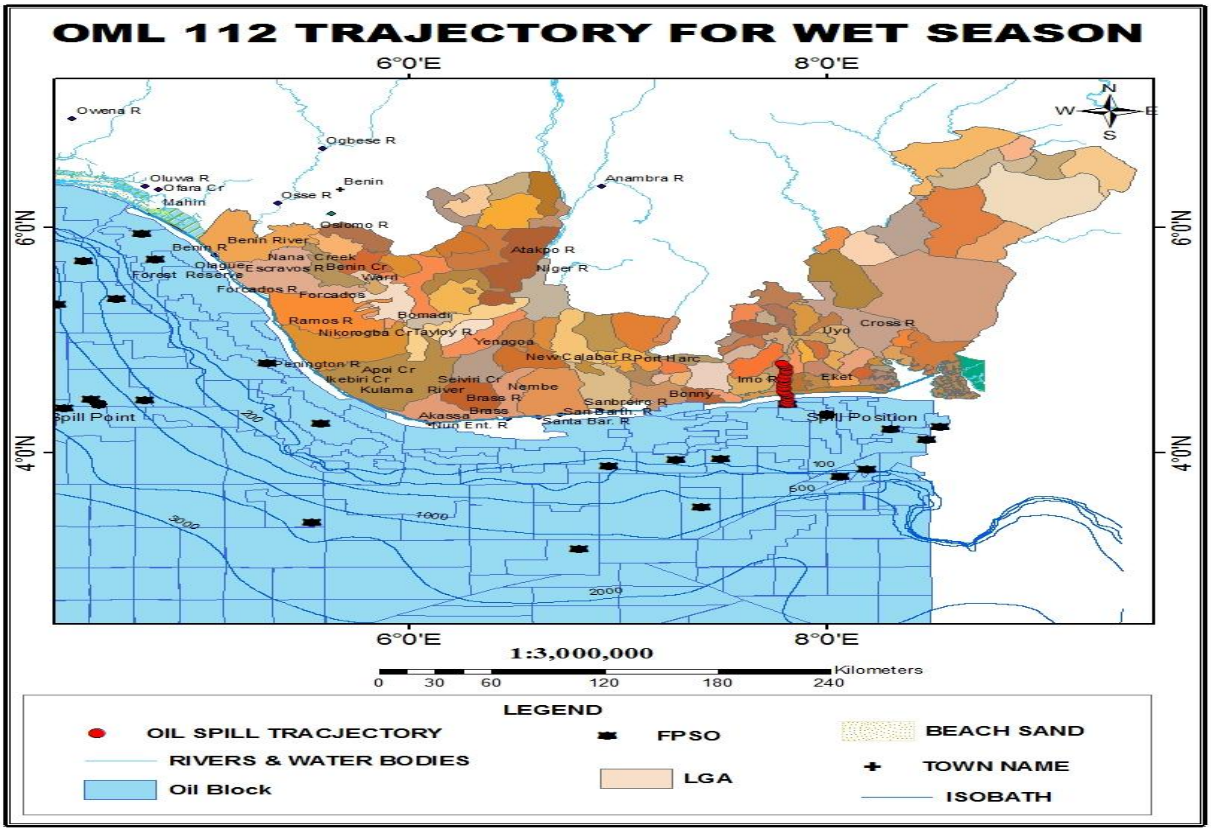
0 30 60 120 180 240 Kilometers
LEGEND
OIL SPILL TRACJECTORY
RIVERS & WATER BODIES
Oil Block
FPSO
LGA
BEACH SAND
TOWN NAME
ISOBATH
Spill Point
Spill Position


OML 112 TRAJECTORY FOR WET SEASON
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6°0'N
4°0'N
Spill Point
Spill Position
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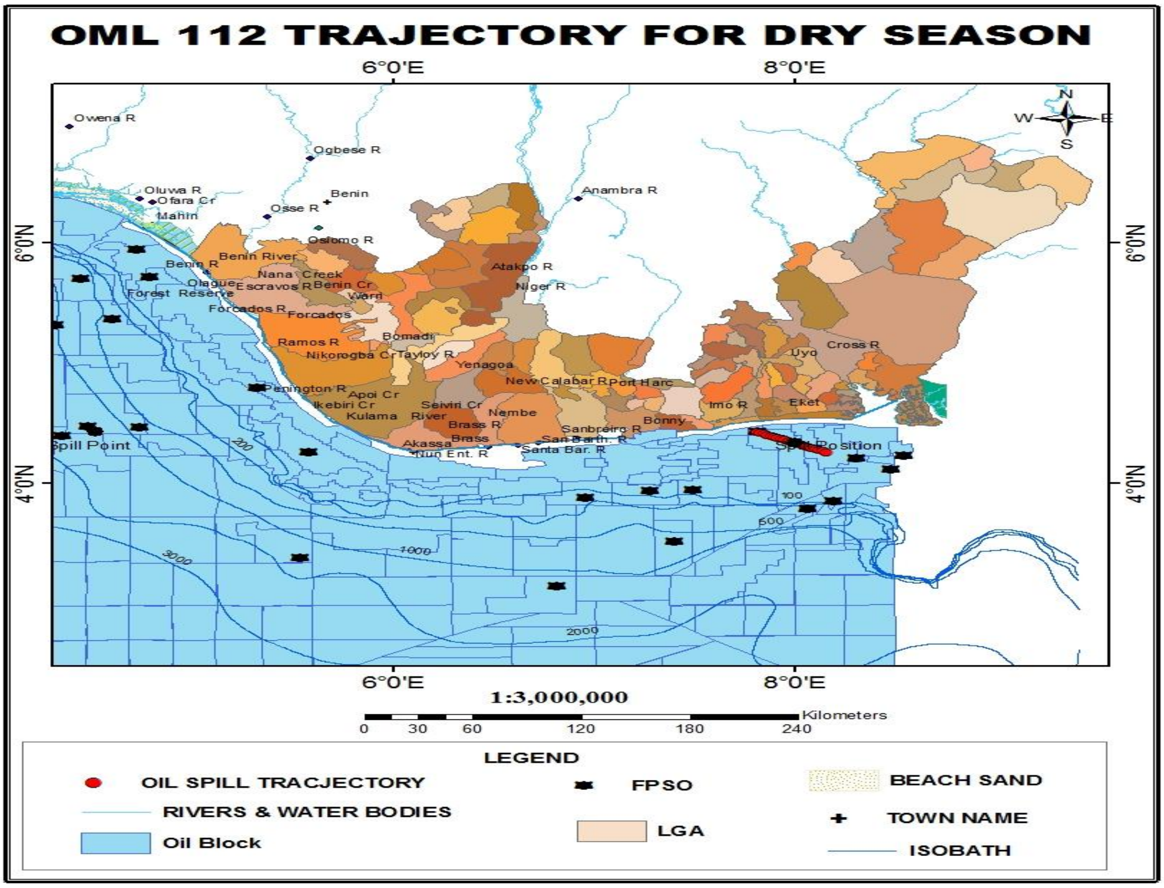
Kilometers
LEGEND
OIL SPILL TRACJECTORY
RIVERS & WATER BODIES
Oil Block
FPSO
LGA
BEACH SAND
TOWN NAME
ISOBATH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4°0'N
Spill Point
Spill Position
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0 30 60 120 180 240
Kilometers
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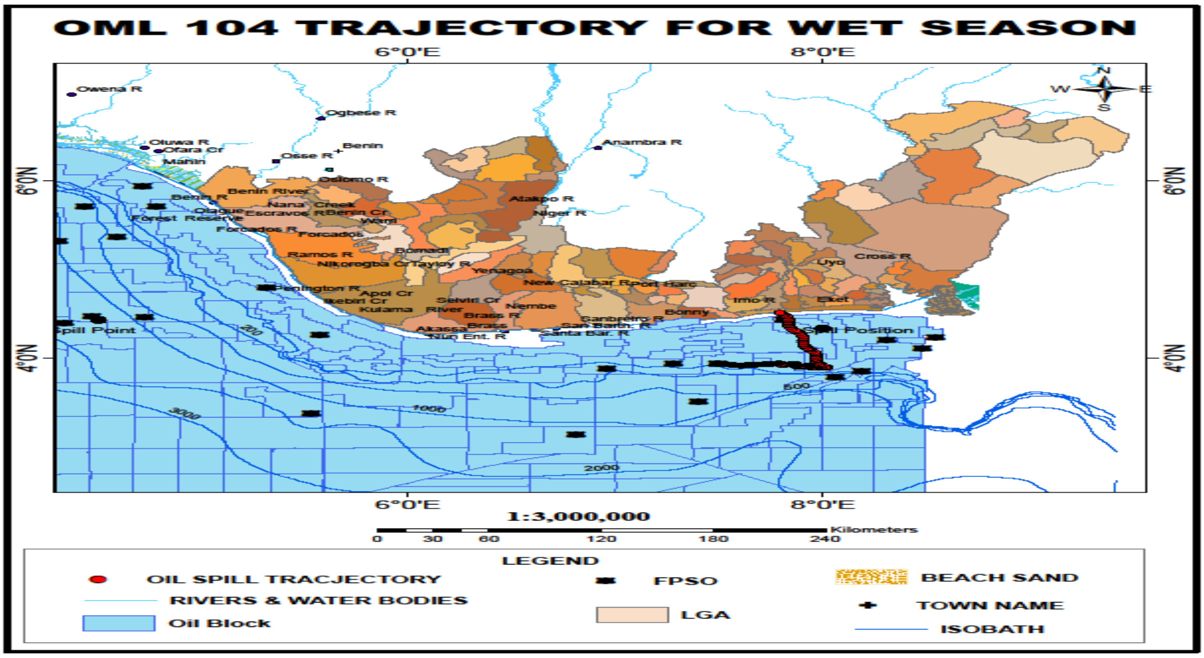
RIVERS & WATER BODIES
Oil Block
FPSO
LGA
BEACH SAND
TOWN NAME
ISOBATH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4°0'N
1:3,000,000
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Kilometers
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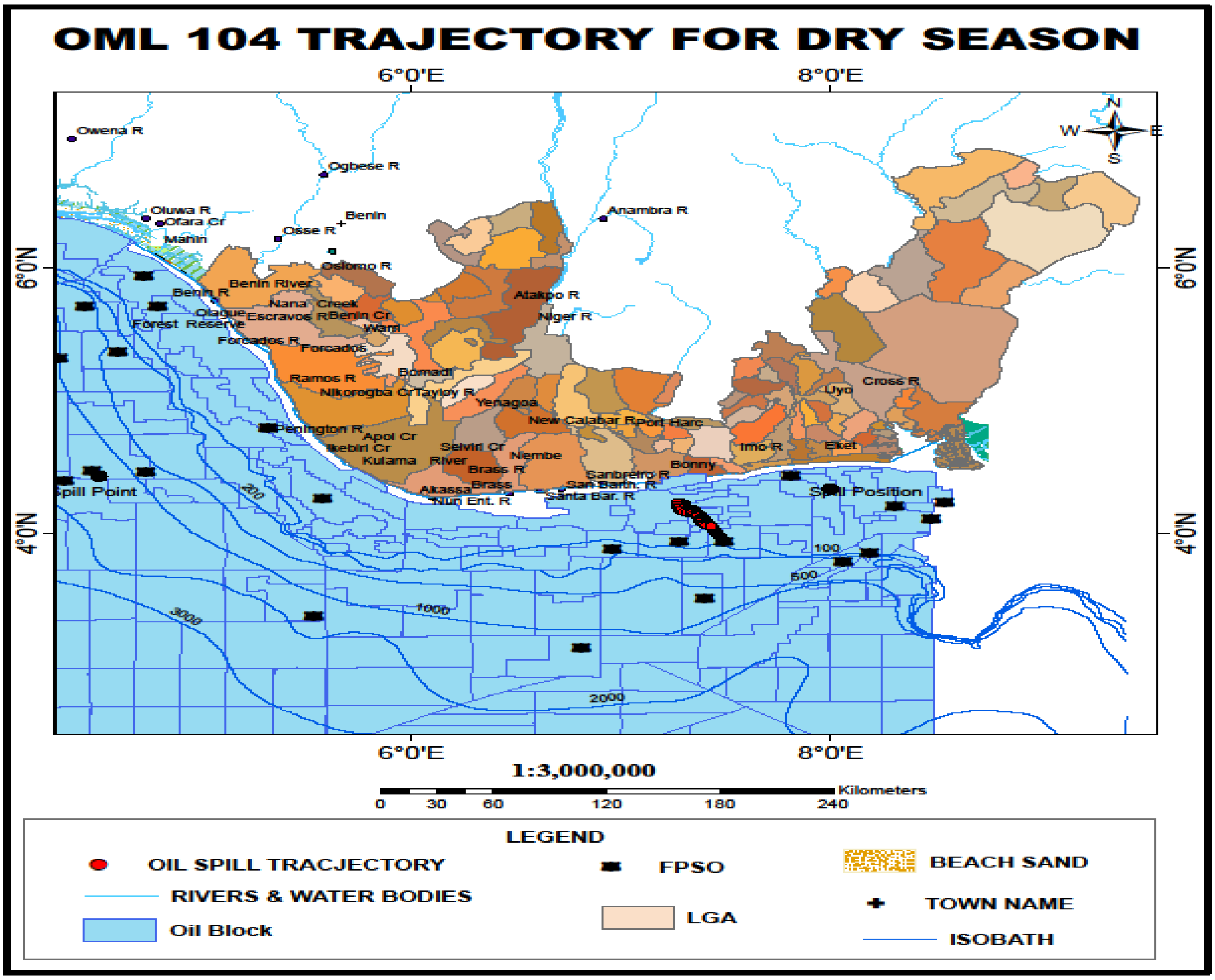
OIL SPILL TRACJECTORY
RIVERS & WATER BODIES
Oil Block
FPSO
LGA
BEACH SAND
TOWN NAME
ISOBATH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6°0'N
4°0'N
1:3,000,000
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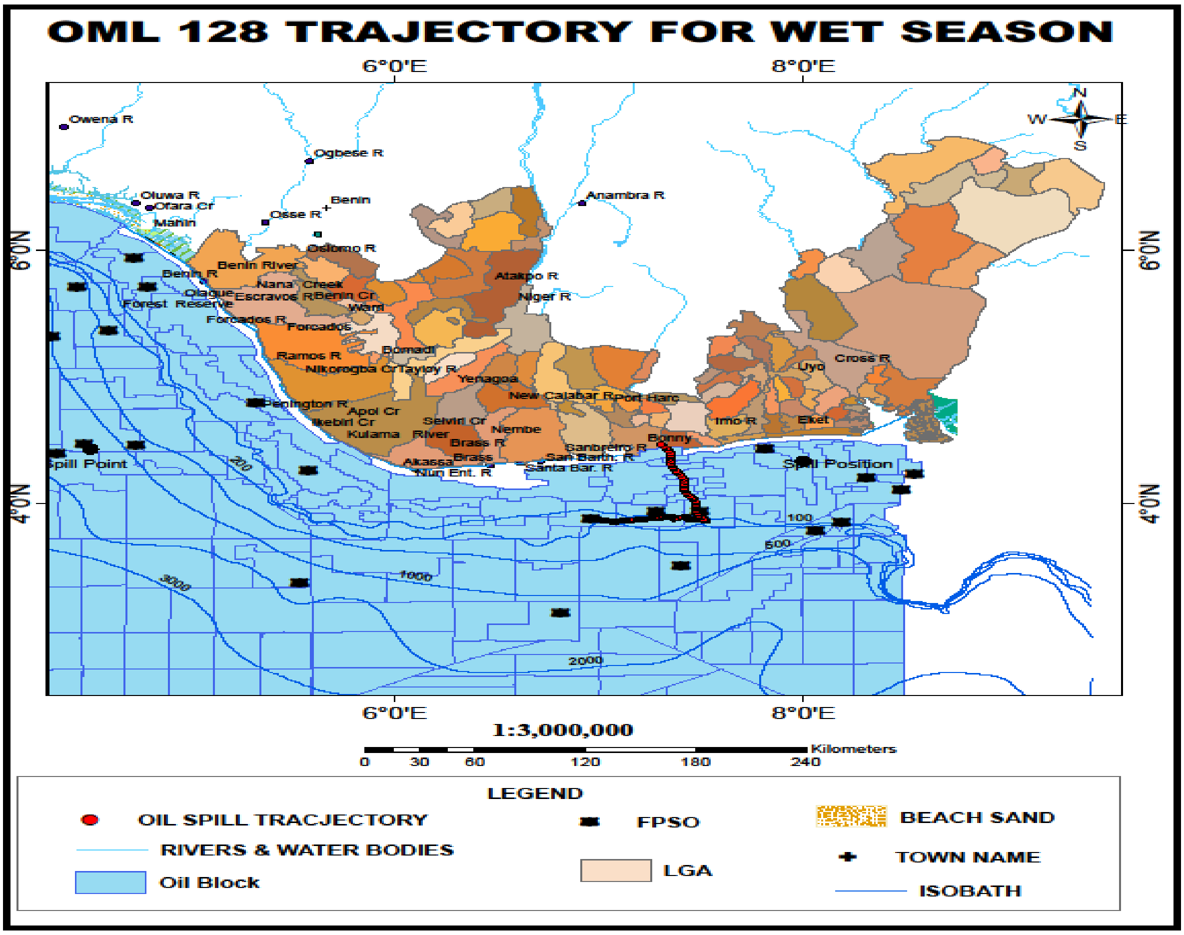
Kilometers
LEGEND
OIL SPILL TRACJECTORY
RIVERS & WATER BODIES
Oil Block
FPSO
LGA
BEACH SAND
TOWN NAME
ISOBATH


OML 128 TRAJECTORY FOR WET SEASON
6°0'E
8°0'E
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4°0'N
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W
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Owena R
Ogbese R
Oluwa R
Ofara Cr
Mahin
Benin
Osse R
Anambra R
Osiomo R
Benin River
Benin R
Atakpo R
Nana Creek
Olague
Escravos R
Benin Cr
Niger R
Forest Reserve
Warri
Forcados R
Forcados
Bomadi
Ramos R
Nikorogba Cr
Taylor R
Uyo
Cross R
Yenagoa
New Calabar R
Port Harc
Penington R
Apol Cr
Ikebiri Cr
Selvin Cr
Nembe
Imo R
Eket
Kulama
River
Brass R
Bonny
Sanbreiro R
Spill Point
Akassa
Brass
San Barth. R
Spill Position
Nun Ent. R
Santa Bar. R
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100
500
1000
3000
2000
1:3,000,000
Kilometers
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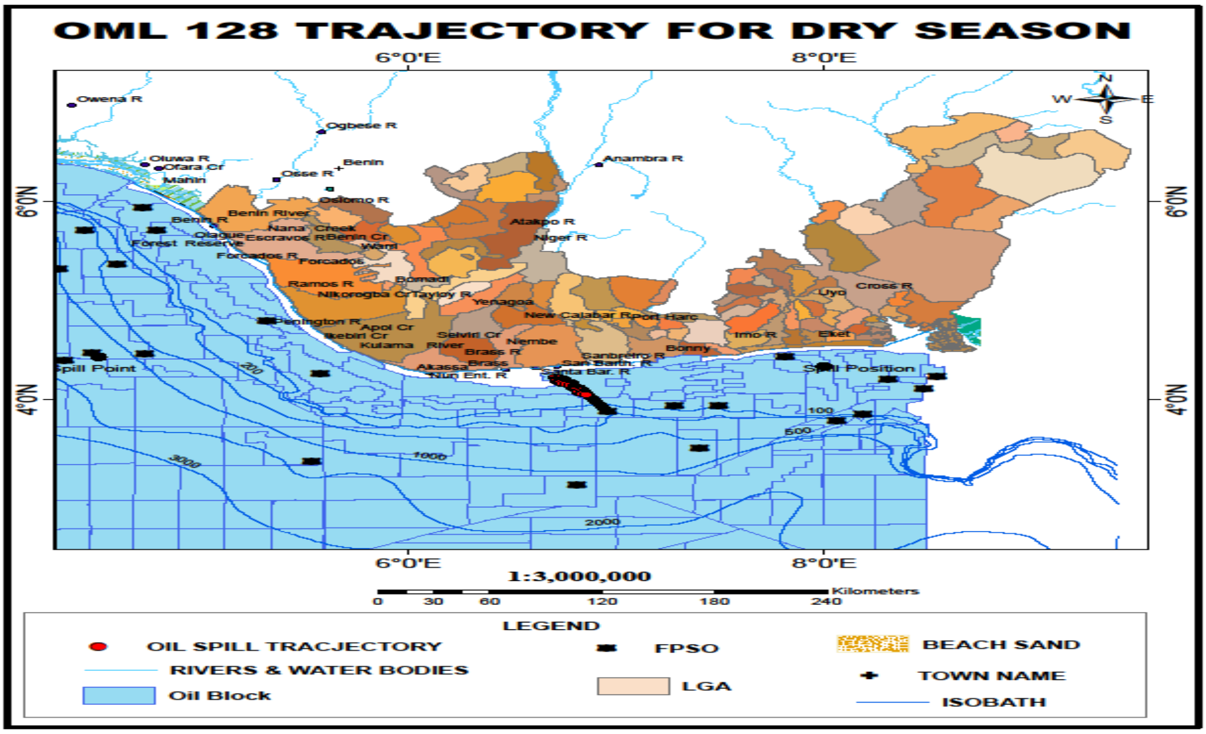
120
180
240
LEGEND
OIL SPILL TRACJECTORY
FPSO
BEACH SAND
RIVERS & WATER BODIES
TOWN NAME
LGA
Oil Block
ISOBATH


OML 128 TRAJECTORY FOR DRY SEASON
6°0'E
8°0'E
6°0'N
4°0'N
N
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W
E
Owena R
Ogbese R
Oluwa R
Ofara Cr
Mahin
Benin
Osse R
Anambra R
Osiomo R
Benin River
Benin R
Atakpo R
Nana Creek
Olague
Escravos R
Benin Cr
Niger R
Forest Reserve
Warri
Forcados R
Forcados
Bomadi
Ramos R
Nikorogba Cr
Taylor R
Uyo
Cross R
Yenagoa
New Calabar R
Port Harc
Penington R
Apol Cr
Ikebiri Cr
Selvin Cr
Nembe
Imo R
Eket
Kulama
River
Brass R
Bonny
Sanbreiro R
Spill Point
Akassa
Brass
San Barth. R
Spill Position
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Santa Bar. R
200
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Kilometers
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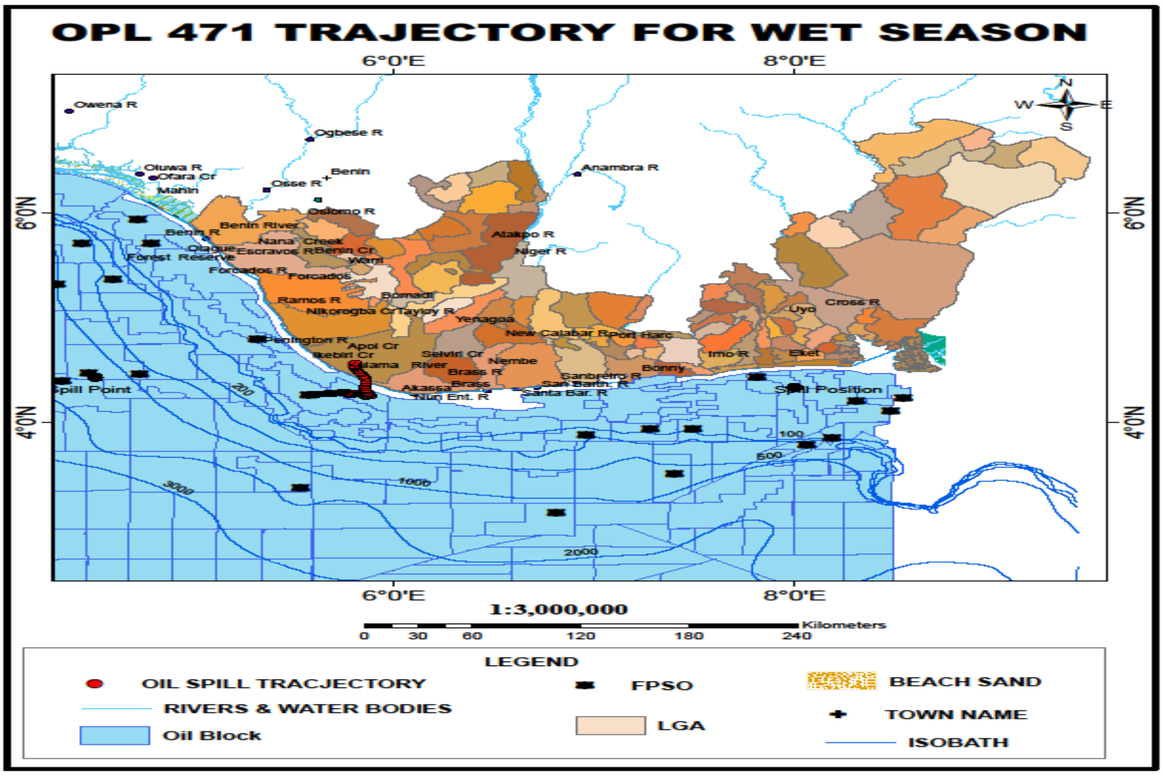
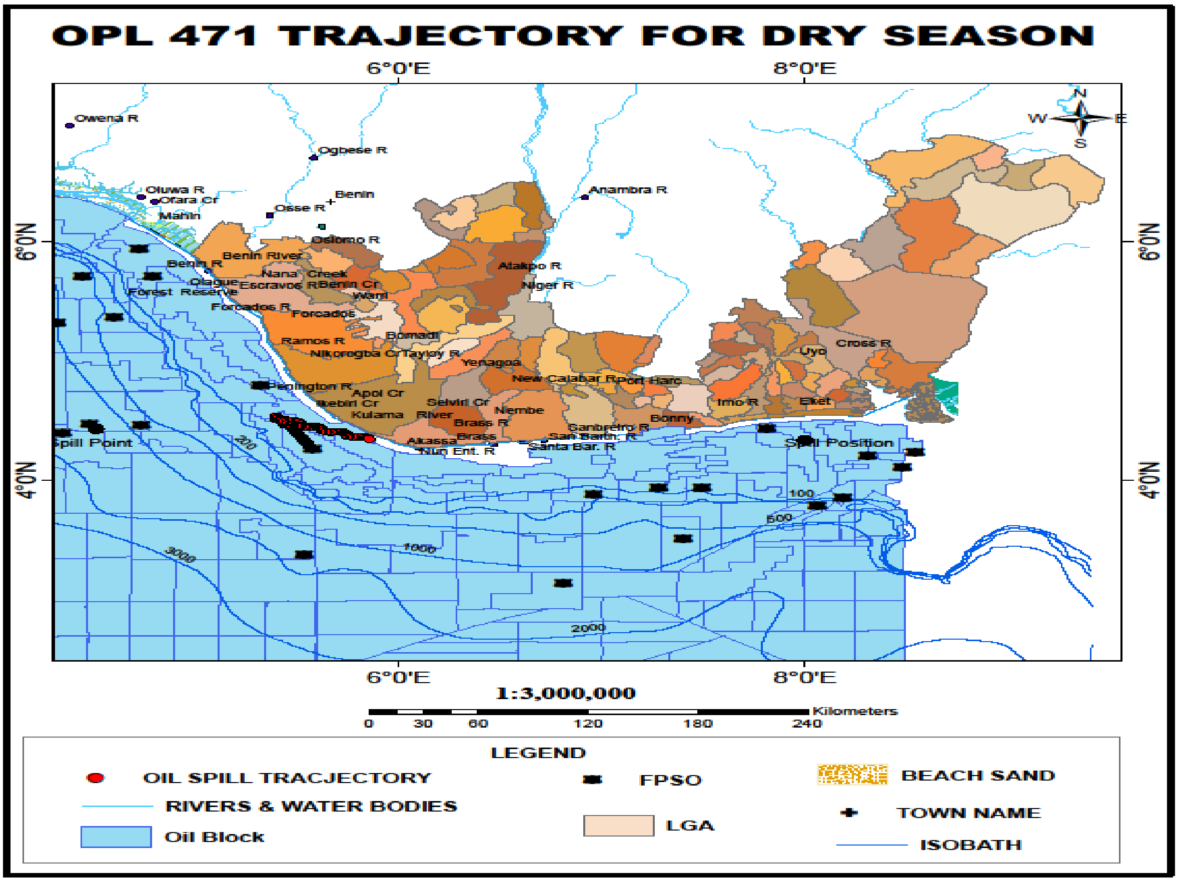
LEGEND
OIL SPILL TRACJECTORY
FPSO
BEACH SAND
RIVERS & WATER BODIES
TOWN NAME
LGA
Oil Block
ISOBATH


OPL 471 TRAJECTORY FOR WET SEASON
6°0'E
8°0'E
6°0'N
4°0'N
1:3,000,000
0 30 60 120 180 240
Kilometers
Spill Point
Spill Position
LEGEND
OIL SPILL TRACJECTORY
RIVERS & WATER BODIES
Oil Block
FPSO
LGA
BEACH SAND
TOWN NAME
ISOBATH


OPL 471 TRAJECTORY FOR DRY SEASON
6°0'E
8°0'E
6°0'N
4°0'N
1:3,000,000
0 30 60 120 180 240
Kilometers
Spill Point
Spill Position
LEGEND
OIL SPILL TRACJECTORY
RIVERS & WATER BODIES
Oil Block
FPSO
LGA
BEACH SAND
TOWN NAME
ISOBATH

Analysis of Results

The result of the simulations for wet and dry seasons show that the oil spill moves slower in deep sea and faster between the distances of 10km to 20km from the shoreline. The reason for this is that in the deep sea, the tidal effect is minimal, while the tidal effect is more prevalent in the 10km to 20km region. Also, the net effect of the longshore current and tides increased the speed of the oil spill near the shoreline.The simulated oil spill for OML 118 for wet season reached the shores after 104 hours (about 4.3days). The oil spill will continue to move along the shorelines. When the tide is high, the oil spill will move into the coastal lands and negatively impact the ecosystem. By the end of the 104 hours a total of 5,533.134 barrels of oil would have evaporated. This amount represents 11.06% of 50,000 barrels of oil spilled. The simulated oil spill for OML 118 for dry season reached the shores after 98 hours (about 4 days). The oil spill will continue to move along the shorelines. When the tide is high, the oil spill will move into the coastal lands and negatively impact the ecosystem. By the end of the 98 hours, a total of 11680.29 barrels of oil would have evaporated. This amount represents 23.36% of 50,000 barrels of oil spilled.The simulated oil spill for OML 120 for wet season reached the shores after 88 hours (about 3.7days). The oil spill will continue to move into the coastal land. When the tide is high, the oil spill will move into the coastal lands and negatively impact the ecosystem. By the end of the 88 hours a total of 20,556 barrels of oil would have evaporated. This amount represents 41.112% of 50,000 barrels of oil spilled.The simulated oil spill for OML 120 for dry season reached the shores after 68 hours (about 2.8days). The oil spill will continue to move into the coastal land. When the tide is high, the oil spill will move into the coastal lands and negatively impact the ecosystem. By the end of the 89 hours a total of 13034.74 barrels of oil would have evaporated. This amount represents 20.07% of 50,000 barrels of oil spilled.The simulated oil spill for OML 112 for wet season reached the shores after 21hours. The oil spill will continue to move into the coastal land. When the tide is high, the oil spill will move into the coastal lands and negatively impact the ecosystem. By the end of the 21 hours a total of 11082.81 barrels of oil would have evaporated. This amount represents 21.16% of 50,000 barrels of oil spilled.

The result of the simulation OML 112 for dry season shows that the oil spill moves slower in deep sea and faster between the distances of 10km to 20km from the shore line during the dry season. The reason for this is that in the deep sea, there tidal effect is minimal, while the tidal effect is more prevailent in the 10km to 20km boundary.Also, the net effect of the longshore current and tides increased the speed of the oil spill near the shoreline. Tides and ocean currents are also the major factors responsible for oil spill movement along our coastline during the wet and dry seasons. Oil spill moves slower during the dry season. The reason for this is that the magnitude of the ocean current is lesser during the dry season. Wind drift current and waves are secondary factors for moving oil spill during the dry season. The wind drift current is about 2% of the wind speed during the dry season. The wave velocity increases as one move towards the shoreline. The magnitude of the wave velocity is lower than that of the wind drift in the first three phases, but higher than that of the wind drift current in the fourth phase. The effect of waves is negligible in deep sea (1000m+) but cannot be dispensed with in shallow sea or near the coastline. The simulated oil spill for OML 112 for dry season after 21 hours didn't get to the shores rather it moved slowly into the sea, at the end of the 21 hours a total of 11082.81barrels of oil would have evaporated. This amount represents 22.16% of 50,000 barrels of oil spilled.The OML 104 wet season trajectory was run for a total of 120 hours- 20, 20, 40 and 40 hours for Phase 1, 2, 3 and 4 respectively. In Phase 4, the spillage reached the shoreline after 100 hours and ended at a position in Imo state.For the dry season in OML 104, the trajectory moved toward the shoreline at Phase 1 and Phase 2 after 30 hours and 20 hours respectively. In Phase 3, after 30 hours, it turns back towards the sea. The spill did not reach the shore after 100 hours.The wet season trajectory in OML 128 had a total number of 120 hours of spill flow between Phase 1 and Phase 4. It flowed eastward during Phases 1 and 2, and thereafter Northward. In Phase 4, the spillage ended at Bonny.For OML 128 dry season, the trajectory moved very close to the shoreline at Phase 1 and Phase 2 after 30 hours in each of the two phases. In Phase 3, after 30 hours, it turns back towards the ocean. The wet and dry season trajectory in OPL 471 was donefor Phase 2 to Phase 4 because its position is at the 50m depth. The total number of hours of spill flow in the wet season between Phase 2 and Phase 4 is 60 hours. The oil spill flowed into BayelsaState.In the dry season in OPL 471, the spill ends at the shoreline, after flowing for a total of 120 hours – 50, 20 and 50 hours for Phase 2, 3 and 4 respectively.

V CONCLUSION AND RECOMMENDATION

Conclusion

The cost of carrying out the project was quite expensive since data acquisition was very difficult. The developed OIL SPILL MAP model within Arc GIS aided in simulating the different oil trajectory scenarios for the six FPSOs in wet and dry seasons. This study reveals that in the case of any major oil spill from the six FPSOs, the probability that the oil spill will get to the shore is very high. It therefore becomes highly imperative that more care should be taken in oil spill exploration and exploitation activities to prevent oil spill incidents. In the event of any oil spill incident, rapid oil spill cleaning and remediation efforts should be taken to contain it before it will cause a wide range of pollution in the Nigerian coastal areas.

Recommendations

Based on our findings in his work, we make the following recommendations:

[1] Further study on trajectory simulations with real time wind and current data should be carried out offshore Nigeria. Efforts should therefore be made by all the stakeholders in the oil and gas industry to collect and provide real time wind and current data.

[2] In the event of an oil spill, Lidarimages should be taken to determine the location of the oil spill. This location can be fed into this oil spill model to predict or simulate the trajectory of the oil spill. Furthermore, the Lidar images would assist in oil spill rescue and cleaning operations

[3] Existing laws and policies regulating oil exploration and exploitation activities should be strengthened and enforced to ensure strict compliance by the oil and gas companies in Nigeria. This we believe will reduce oil spill incidents in the country.

[4] Adequate funds should be provided by all stakeholders to fund more studies within the Nigerian Coastal Areas. To this end there should be collaborations by all the stakeholders in the oil and gas sectors in Nigeria to facilitate the studies.

[5] Training and retraining of personnel to prevent and manage oil spill incidents should be carried out from time to time.

REFERENCES

[1] ANEEJ . Oil of Poverty in the Niger Delta. A publication of the African Network for Environment and Economic Justice, 2004.

[2] B. Anifowose. Assessing the Impact of Oil & Gas Transport on Nigeria’s Environment. U21 Postgraduate Research Conference Proceedings 1, University of Birmingham UK, 2008.

[3] Applied Science Associates (ASA) Inc. Deep water oil spill model and analysis system. http://www.asascience.com/software/oilmap/oilmapdeep.shtml, 2011.

[4] L.F. Awosika. Impacts of global climate change and sea level rise on Coastal resources and energy development in Nigeria. In: Umolu, J.C., (Ed). Global Climate Change: Impact on Energy Development. DAMTECH Nigeria Limited, Nigeria, 1995.

[5] O.T. Badejoand P.C. Nwilo.Oil Spill Model for Oil Pollution Control. Peer Reviewed FIG Paper. FIG Working Week, Marrakech, Morocco, pp 1-31, 2011.

[6] J.P. Benque, HauguelA. and Viollet,P.L. Engineering Application of Computational Hydraulics II. Pitman Advanced Publishing Program, London, pp. 57-63, 1982.

[7] C. Chinweze, and G. Abiol-Oloke, G. Women Issues, Poverty and Social Challenges of Climate Changes in the Nigerian Niger Delta Context. 7th International Conference on the Human Dimension of Global Environmental Changes, UN Campus, Bonne, Germany, 2009.

[8] Civil Liberties Organization (CLO). Blood Trail: Repression and Resistance in the Niger Delta, Ikeja, 2002.

[9] Country Analysis Brief http:/www.eia.doe.gov/cab/index.html.pds

[10] J.A. Fay. The spread of oil slicks on a calm sea. In oil on the sea. David P. Hoult ed., Plenum Press, New York, 53-63, 1969

[11] Federal Ministry of Environment Abuja, Nigerian Conservation Foundation Lagos, WWF UK and CEESP-IUCN Commission on Environmental, Economic, and Social Policy. Niger Delta Resource Damage Assessment and Restoration Project, 2006.

[12] O. Hang, P.Evensen, and E.A.Martinsen. Oil models for the South China Sea. Technical Report No. 70. DetNorslseMeteorologiskeInstitutt, 1989.

[13] HAZMAT. Hazardous materials response and assessment division report 96-6, spill Trajectory Analysis, 1996.

[14] R.W. Hess and C.L. Kerr. A Model to Forecast the Motion of Oil on the Sea. Proceedings of the Oil Spill Conference, pp 653-663, 1979.

[15] D. Mackay, S. Paterson and S. Nadeau. A mathematical model of oil spill behaviour, Technical Report, Environmental Protection Service, Fisheries and Environment Canada, Ottawa, Ontario, Canada, 1980.

[16] C. Kung, K. Su, Y. Chen and Y. Teng. Y.Simulation of oil spills in a harbour. 1997. Available at: http://sol.oc.ntu.edu.tw/omisar/wksp.mtg/wom1.97c/rep/rep1-4-3.htm

[17] E.E. Paladino and C.R. Maliska. Mathematical Modeling and Numerical Simulation of Oil Spill Trajectories on the Sea. Federal University of Santa Catarina Brazil, 2000.

[18] C.B. Powell, S.A. White, D.O.Ibiebele, M. Bara, B. DutKwicz, M.Isoun. andF.U. Oteogbu.Oshika Oil Spill Environmental Impact; effect on Aquatic biology. Paper presented at NNPC/FMHE International Seminar on petroleum industry and the Nigerian Environment 11 – 13 Nov. 1985, Kaduna, Nigeria, 1985:168 – 178, 1985.

[19] M. Rossouw. Oil spill simulation: Reducing the impart. CSIR Division of Earth, Marine and Atmospheric Science Technology (EMATEK), 1998.

[20] S. VenkatesH. The Oil Spill Behaviour Model of the Canadian AtmosphericEnvironment Service, Part I, Atmosphere-Ocean, Vol. 26, pp 93-108, 1988.