American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-12, Issue-3, pp-01-16
www.ajer.org
Research Paper Open Access

Modelling Risk Assessment of Oil Spillage in Southern IJAW Local Government Area of Bayelsa State, Nigeria Using Remote Sensing and GIS Technology

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ABSTRACT
Oil spillage in the Niger Delta is a major challenge, which threatens the environment. The oil spill contamination of the environment is as a result of exploration, equipment failure, sabotage and oil bunkering. This study presents a risk assessment of oil spill in Bayelsa state using Southern Ijaw as a sample area. The study was carried out with the aid of the Geographic Information System (GIS). Relevant oil spill data were collected and imported into the ArcGIS 10.4 platform for analysis. The land cover map was generated from masked satellite imagery. Hazard was modeled from sources of petroleum spill such as oil pipelines, and wellheads. Result on the oil spill occurrence showed that 2016 had the highest quantity spilled to the environment. The quantity of oil spilled recovered in the sample area was 1074.707 in the year 2016; 261.47 in the year 2017; 274.315 in the year 2018 and 49.18 in the year 2019. The final hazard map shows that very high hazard zone affect 0.57km^2 of built-up area, 0.50km^2 of the water bodies, and 2.29km^2 of mangrove vegetation. This study demonstrates the efficiency of the use of GIS in environmental vulnerability mapping of oil spill.
Keywords: *Oil spillage, GIS, Risk Assessment, Vulnerability*

Date of Submission: 18-02-2023 Date of acceptance: 02-03-2023

I. INTRODUCTION

Petroleum resources have contributed greatly to the global energy demand and economic development of oil producing countries, e.g. Nigeria, over the past fifty–five years. The petroleum industry has a lot of influence in the world today and petroleum hydrocarbons can be regarded as an essential commodity, which serve as the backbone of today's global economy (Asghar *et al.*, 2016). Since the discovery of petroleum resources in commercial quantities in Oloibiri in the year 1956, Nigeria has been placed among the group of oil producing countries, which today remains one of Africa's largest oil producing nations (Ite *et al.*, 2018). Since Nigeria is placed at one of Africa largest oil producing nations, it implies that Nigeria will have its fair share of oil spillage which is associated with oil production.

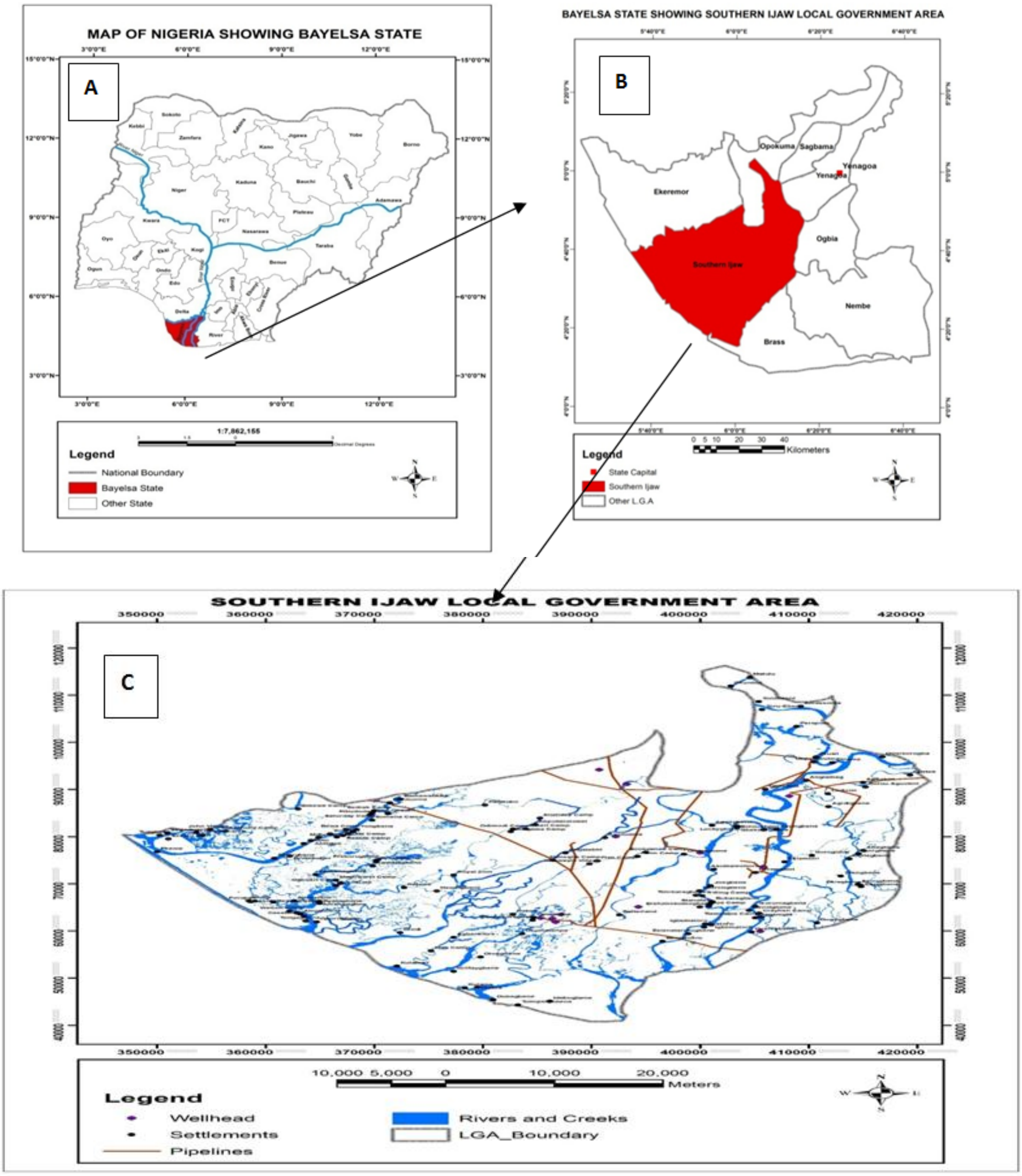
Oil spillage as a term is a release of a liquid petroleum hydrocarbon into the environment due to human activity, and is a form of pollution. Oil spills include releases of crude oil from tankers, offshore platforms, drilling rigs, pipelines and wells, as well as spills of refined petroleum products (such as gasoline, diesel) and their by-products, and heavier fuels used by large ships such as bunker fuel, or the spill of any oily white substance refuse or waste oil. Deliberate act such as sabotage, oil bunkering, lack of maintenance of engineering equipment, tanker accidents causes oil spill. The Niger Delta region of Nigeria in which majority of the petroleum hydrocarbon exploration is carried out in Nigeria, is faced with high oil spill cases and rated as one of the most crude oil spill vulnerable areas in the world (United Nations Environment Programme, 2011).

The exploration of petroleum hydrocarbon in the Niger Delta Region of Nigeria. has threatened the environment with pollution. Petroleum hydrocarbons contamination of the environment that is associated with exploration, development and production operations is now a common phenomenon in the Niger Delta Region of Nigeria where the incidence of facilities sabotage, operational failures, accidental discharges, pipeline vandalization and leakages, bunkering and illegal refining is a common occurrence. According to Ite *et al.*, 2018, the poor environmental management practices by the petroleum industries and the failure of Nigeria's environmental regulation bodies has contributed to environmental contamination with direct consequences on the surrounding populations' socio-economic wellbeing, human health and the environment.

Oil spillage is one of the greatest environmental problem Nigeria is currently battling with especially in the Niger Delta zone. Despite the known fact that not all oil spills in Nigeria are reported (Oyinloye and Olamiju, 2013), the Nigerian National Petroleum Corporation (NNPC) has reported more than 20,000 oil spill incidents in the transportation pipeline sector only between 2006 and 2013 (NNPC, 2013). In addition, an independent assessment estimated that more than 115,000 barrels of oil are spilled into the Niger Delta environment every year (Oyinloye and Olamiju, 2013). Researchers have reported 4,835 cases of oil spill incidents between 1976 and 1996, in Nigeria (Twumasi and Merem, 2006) that have caused severe damage to the coastal environment (Nwilo and Badejo, 2006a). These reports are at best not credible but mere speculations since best practices consistent with technological advances and widely adopted in the industry for gathering such information are not often used. It is a well known fact that the Niger Delta terrain is one of the most difficult to access in recent times during insurgency and restiveness. Also, previous efforts at gathering such information have largely depended on the reports of paid ecotoxicologists or environmental impact assessment (EIA) contractors who may not have the capacity to gather comprehensive information about these spills. However, very little is known about GIS technique for capturing, analyzing and providing answers related to oil spills in the Niger Delta. To date, there is also the absence of a comprehensive study that examines the historical and contextual issues related to oil spillage in Bayelsa State of the Niger Delta. There is little or no study that has been carried out to know the impact or vulnerability level of various land cover to that of oil spill in the study area. In addition, no study has utilized the oil spill data of different years to know the trend pattern of oil spill in the study area. Due to these lapses in the knowledge of this very crucial issue, this research was carried out to fill the gap in knowledge. This study is aimed at using GIS technology in identifying and assessing the impact of oil spills in the study area with a view of determining the trend pattern of the oil spillage and mitigating it.

The study area is Bayelsa State, in South-South Nigeria. Bayelsa State is geographically located within latitude 4°15′ North and latitude 5°23′ North of the equator and longitudes 5°22′ and 6°45′ East of the Greenwich meridian (see figure 1.1). It is bounded to the north by Delta State, to east by Rivers State and to the west and south by the Atlantic Ocean. Bayelsa State is located within the lower delta plain believed to have been formed during the Holocene of the quaternary period by the accumulation of sedimentary deposits. The major geological characteristic of the state is sedimentary alluvium. The entire state is formed of abandoned beach ridges due to many tributaries of the River Niger. However, in this plain, considerable geological changes still abound. The major soil types in the state are young, shallow, poorly drained soils (inceptisolAquepts) and acid sulphate soils (Sulphaquepts).

Generally, Bayelsa State is a lowland state characterized by tidal flats and coastal beaches, beach ridge barriers and flood plains. The net features such as cliffs and lagoons are the dominant relief features of the state. The fact that the state lies between the upper and lower Delta plain of the Niger Delta suggests a low-lying relief. The broad plain is gentle-sloping. The height or elevation decreases downstream. There are numerous streams of varying volumes and velocities in the State. These include Rivers Nun, Ekoli, Brass, Koluama, etc. Rainfall in Bayelsa State varies in quantity from one area to another. The state experiences equatorial type of climate in the southern the most part and tropical rain towards the northern parts. Rain occurs generally every month of the year with heavy downpour. The state experiences high rainfall but this decrease from south to north. Akassa town in the state has the highest rainfall record in Nigeria. Bayelsa state has a tropical climate with high rainfall levels ranging between 2,000 – 4,000mm per annum. The climate is tropical i.e. wet and the dry season. The amount of rainfall is adequate for all-year-round crop production. The wet season is not less than 340 days.The mean monthly temperature is in the range are of 25°C to 31°C. Mean maximum monthly temperatures range from 26°C to 31°C. The mean annual temperature is uniform for the entire Bayelsa State. The hottest months are December to April. The difference between the wet season and dry season on temperatures is about 2°C at the most. Relative humidity is high in the state throughout the year and decreases slightly in the dry season. The vegetation of Bayelsa State is composed of four ecological logical zones. These include: coastal barrier island forests, mangrove forests, freshwater swamp e.g. forests and lowland rain forests. These different or vegetation types are associated with the various soil units in the area, and they constitute part of the complex Niger Delta ecosystems. There are coastal barrier highland forests and mangrove forests. Human activities are largely determined by natural conditions and other ecological opportunities. These hostile ecological conditions limit the occupation of the people to fishing. Bayelsa is a region which already has too much surface water with a high rainfall and long rainy days. This poses considerable problems for human settlement and land use. Almost every part of the state is under water at one time of the year or another. Associated with high rainfall, long rainy days, porous and very sandy soils, is prolonged and disastrous flood. These flooding incidents lead to continual changing of river courses in the state and renders rivers useless as good channels of transportation. Inter-settlement movements in the state have been restricted because of poor road and water transport development. The available roads are those within the towns and villages.



[A]Figure 1.1: Map of Nigeria Showing Bayelsa State, [B] Figure 1.2: Map of Bayelsa State Showing Southern Ijaw as the Study Area; [C] Figure 1.3: Map of Southern Ijaw Local Government Area

2.1 Materials and Methods

The research is designed to utilize Information on oil spill, land cover, wellhead and pipelines data. Information on the impact of oil spills, wellheads and pipelines location were acquired from the National Oil Spill Detection and Response Agency (NOSDRA). Land cover data was gotten from the satellite imagery derived from the Google Earth software. A simplified process of the GIS methodology adopted is shown in figure 2.1.

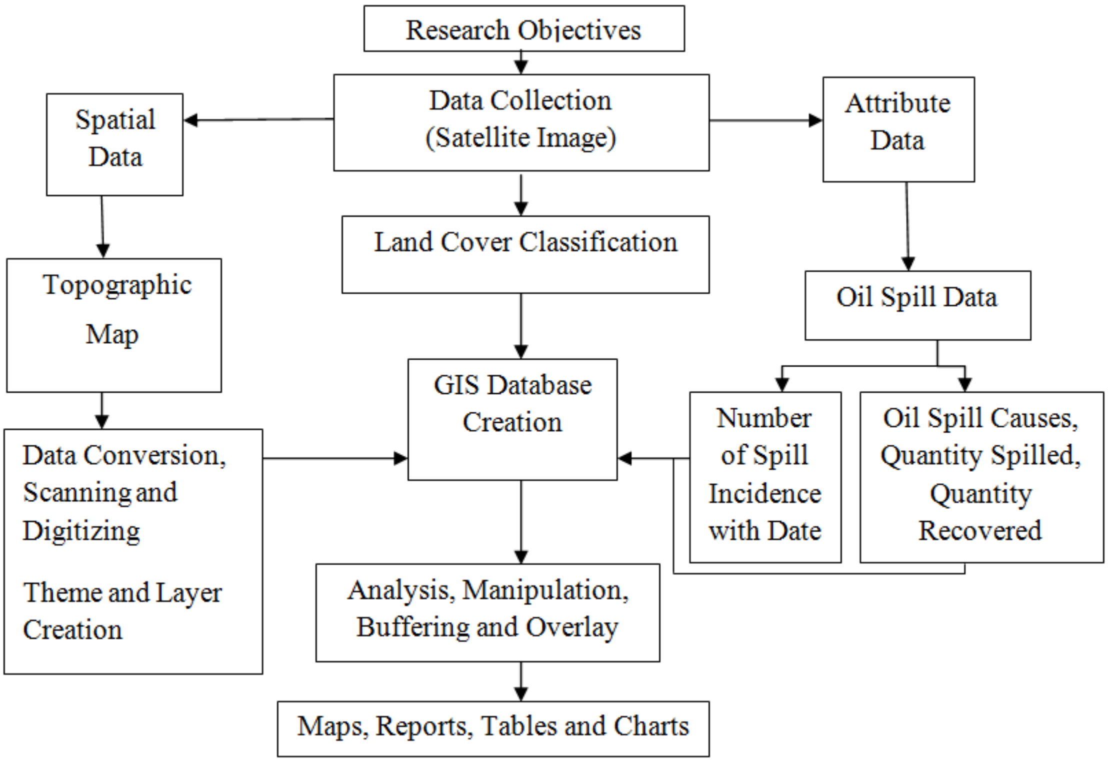


Figure 2.1: Schematic Diagram of Research Methodology
Source: Modified from Nwankwoala H. O. and C. Nwaogu (2009)

The topographic map of the study area was scanned and saved in TIFF (Tagged Image File Format) which is suitable for the raster data processing. The scanned map was then exported to ArcGIS 10.4 for georeferencing and digitizing so that spatial analysis would be performed. Oil spill incidences were obtained from NOSDRA (2020). The coordinates of all spill incidences within the period of study were extracted. These coordinates, x and y, were imported into the ArcGIS environment in a text file format, and geoprocessed. The actual locations of the oil spills and relevant features were identified in the ArcGIS environment. The attributes of the features extracted from the topographic map and the satellite image as well as oil spill data obtained from NOSDRA (2020) were integrated together and used to create a GIS database for further analysis in ArcGIS 10.4 environment. The quantity of oil spilled during each spill incident was added to the attributes of the oil spill. The inverse distance weighted (IDW) technique was used to interpolate the surface from the quantity of oil spill from the spill points.

The buffer zones are built to determine proximity of the area around the oil facilities to the impact of likely oil spill. To carry out this successfully, a command was given to the system to create buffer of 500m away from the pipelines and wellheads. Buffering was carried out at distances of 0.5km, 2km, 3.5km and above 3.5km away from the pipelines and wellheads. The four different region buffers were used to find the effects of oil spill with respect to the surrounding land surface.

The various features were overlaid over each other to have a better view of the highest oil spill risk area. Also, the settlements feature was overlaid with that of the oil spill risk area data of that of the pipeline and wellheads to know the level of impact or vulnerability level of these various land cover to the incidence of oil spill in the sampled area.

Trend analysis quantifies and explains trends and patterns of a data over time. A “trend” is an upwards or downwards shift in a data set over time. The purpose of this particular analysis is to measure and plot changes over time. A trend analysis of the spill occurrence over time was carried out. Also, a chat showing the causes of the oil spill in the study area was presented in a graph form.

3.1 RESULT AND DISCUSSION

Figure 3.0 shows the landuse/landcover types of the study area.

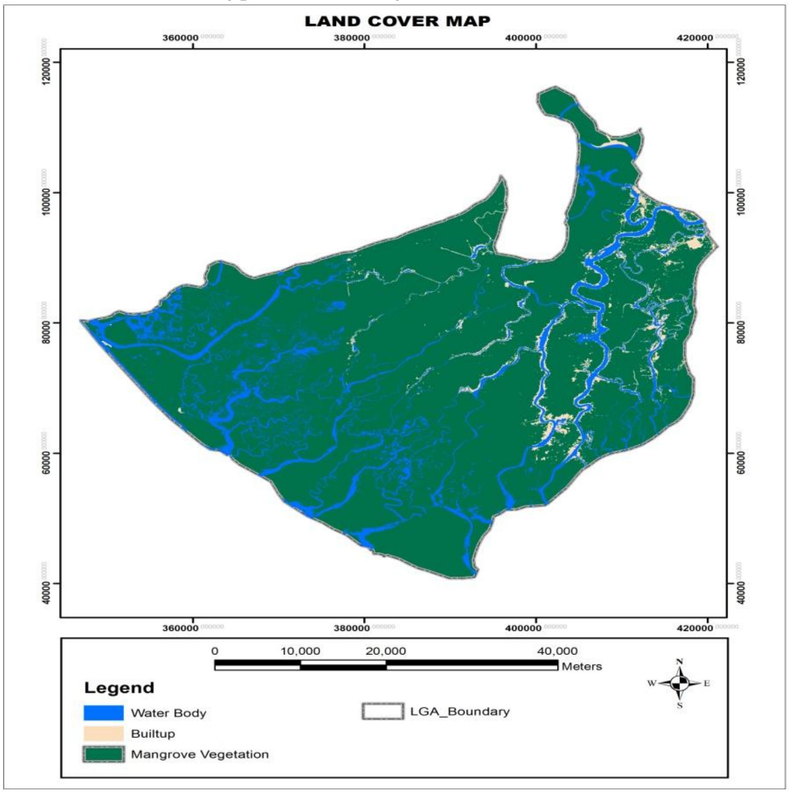


Figure 3.1 shows the location of the oil pipeline, wellheads and settlements were they are located. A total length of 202.197km of pipeline and about 12 functional wellheads were identified. These oil facilities (wellheads and pipelines) are susceptible to oil spill and pose as potential threat to the surrounding environment around them. This is because of the high level of bunkering that is associated to the Niger Delta Region where the study area is located.

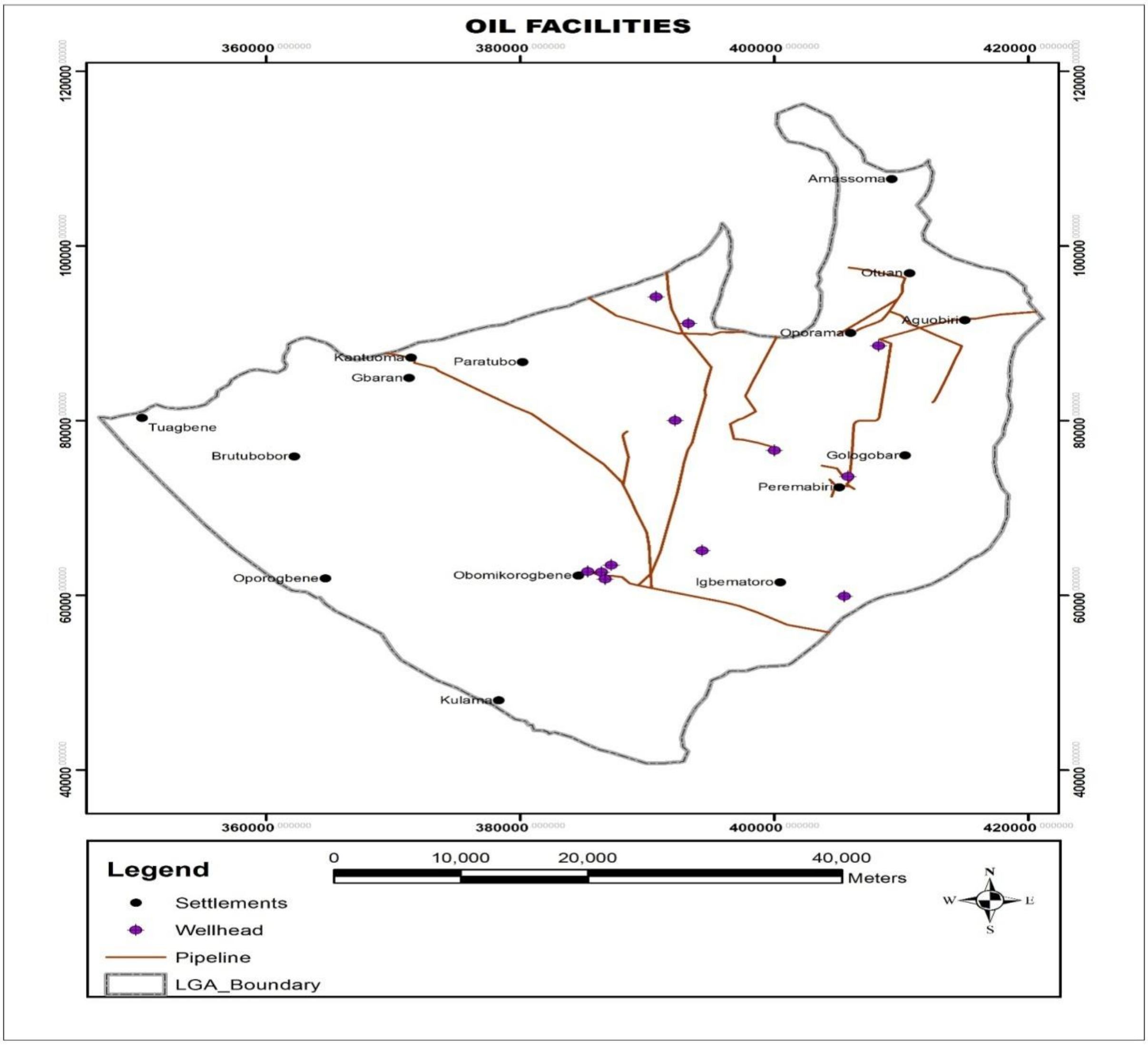


Figure 3.1: Map of Oil Facilities Distribution

Figure 3.2 shows the graphical representation of the various causes of oil spill in the study area. It can be seen that the number of oil spill caused by third party interference (such as drilling and breaking) in the year 2016 is about 55, 6 of the oil spill were caused by equipment failure, 5 of the oil spill in the study area were caused by blasting of the pipelines, while 3 of the oil spill in the study area were caused by corrosion. In the year 2017, the major cause of oil spill in the study area was by third party interference (hack saw cutting, bombing, connecting the valves and hose) for the purpose of oil theft. Third part interference led to 15 of the oil spill that occurred in the year 2017 in the study area, equipment failure caused 8 of the oil spill in the year 2017, while corrosion led to a single case of oil spill. The occurrence of oil spill in the year 2018 was mainly caused by third party interference, which led to 20 cases, while only 2 oil spill were caused by blast. In the year 2019, due to increase in the water level, 2 oil spill were caused by facility submergence, third party interference led to 27 cases of oil spill in the study area.

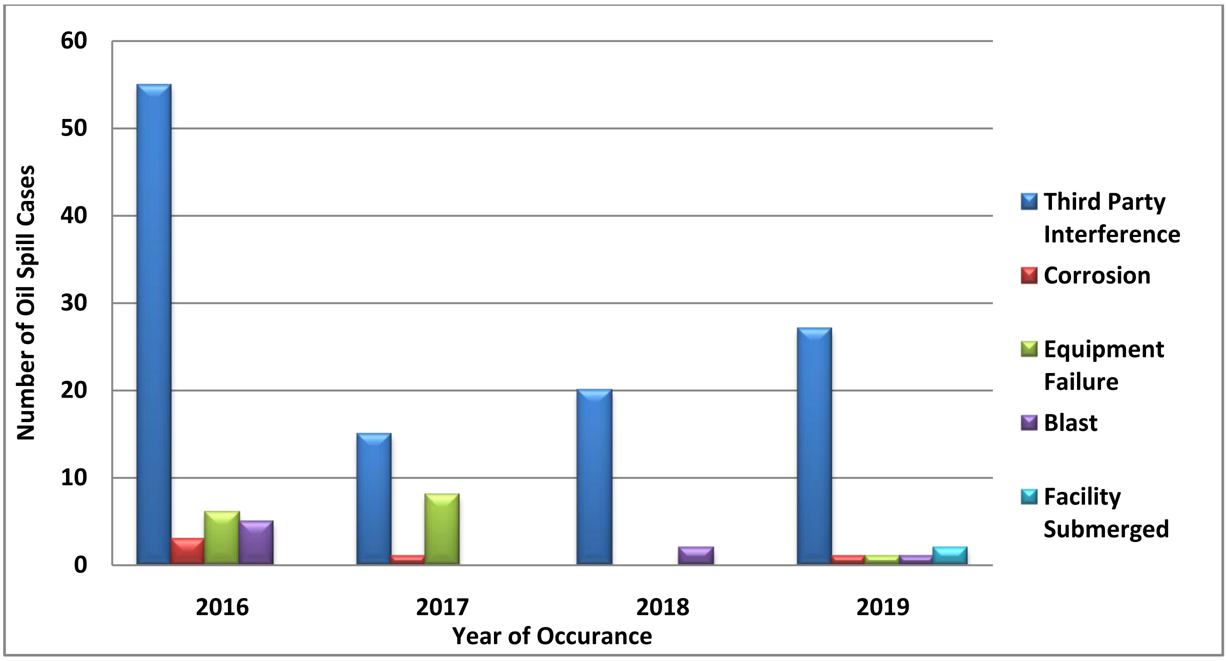


Figure 3.2: Causes of Oil Spill in the Study Area

Table 1.1 shows a sample the attributes table of the database created for the year 2016. The table revealed that third party interference as the major cause of oil spillage in the area.

Table 1.1: 2016 oil spill Attribute table

FID	Shape *	Id	Cause	Quantity	Recovered	x	y
0	Point	0	Third Party Interference	5	1	394926.231497	59527.518106
1	Point	0	Oil Theft	3	1	377542.629859	82936.410082
2	Point	0	Oil Theft	4	0.377	373288.175664	85989.021926
3	Point	0	Corrosion	7.45	2	388286.02891	77020.969374
4	Point	0	Equipment Failure	15	5	388415.271675	61727.986356
5	Point	0	Third Party Interference	6	0	394454.552124	82147.917912
6	Point	0	Equipment Failure	180.26	0	393646.771532	78177.570757
7	Point	0	Equipment Failure	55	36	371664.801356	86883.086355
8	Point	0	Third Party Interference	7	2	394720.32147	84590.870659
9	Point	0	Third Party Interference	6	0.44	399988.004555	57297.090229
10	Point	0	Third Party Interference	10	2	387065.243513	74376.723753
11	Point	0	Blast	70	1	392517.923182	72618.559875
12	Point	0	Third Party Interference	11	0	387301.788939	74078.763472
13	Point	0	Blast	2	1.5	368506.923131	85341.409261
14	Point	0	Third Party Interference	10	0	392489.684181	72523.975918
15	Point	0	Third Party Interference	7	0	392006.157255	60367.785736
16	Point	0	Third Party Interference	2.03	0	401703.828542	56428.919907
17	Point	0	Third Party Interference	2	0	384466.635761	77148.592761
18	Point	0	Third Party Interference	2	0	394939.102867	86194.703152
19	Point	0	Third Party Interference	15	0	388432.268244	78745.19986
20	Point	0	Equipment Failure	4	0	394006.544239	91472.808842
21	Point	0	Third Party Interference	5	0	403236.315559	56074.812792
22	Point	0	Blast	15	0	374783.460388	86698.814106
23	Point	0	Third Party Interference	250	0	395892.477916	59261.201297
24	Point	0	Blast	4	0	401704.153015	56437.764752
25	Point	0	Third Party Interference	8	0	394104.216005	80402.66804
26	Point	0	Third Party Interference	30	0	387070.78531	74379.995545
27	Point	0	Third Party Interference	31	0	393735.057488	77148.909515
28	Point	0	Third Party Interference	5	0	400725.978213	56838.107554
29	Point	0	Third Party Interference	100	0	401389.589546	56513.878287
30	Point	0	Third Party Interference	10	0	387426.134275	73935.346935
31	Point	0	Third Party Interference	2	0	396824.718664	58924.854453
32	Point	0	Third Party Interference	7	0	399120.741956	57836.152698
33	Point	0	Equipment Failure	3	0	393579.48891	77833.610334
34	Point	0	Third Party Interference	10	0	387104.806624	74321.682148
35	Point	0	Third Party Interference	10	0	394076.529488	80378.014714
36	Point	0	Third Party Interference	6	0.6	394902.783274	59544.461311
37	Point	0	Third Party Interference	5	0.8	403906.87907	55809.625187
38	Point	0	Third Party Interference	25	1.5	400432.748638	57018.660874

The analysis of the occurrence of oil spill in the study area shows that there is a sharp decline in the spill occurrence from the year 2016 to the year 2019. From the analysis shown in figure 3.3, 2016 has the highest oil spill occurrence of about 69 spill cases. In the year 2017 as seen in the trend analysis in figure 3.3, there was a decline in the oil spill occurrence to 23 cases and a further decline to 22 cases in the year 2018. Although with this decline in the oil spill occurrence in the sample area, there was still an increase to 32 oil spill cases in the year 2019.

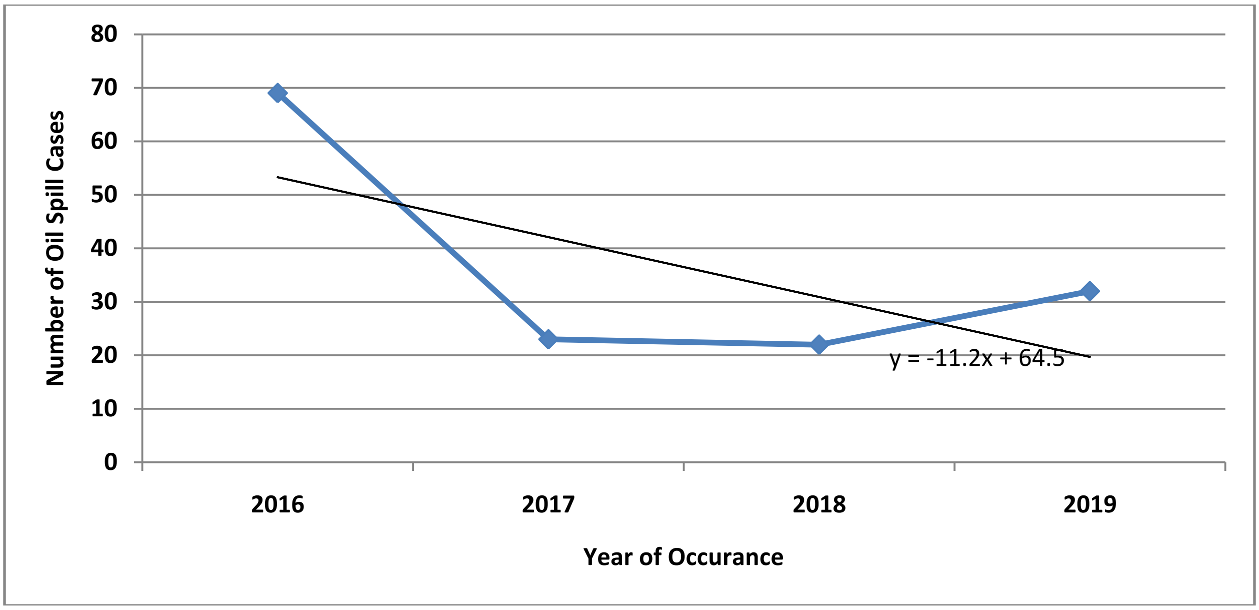


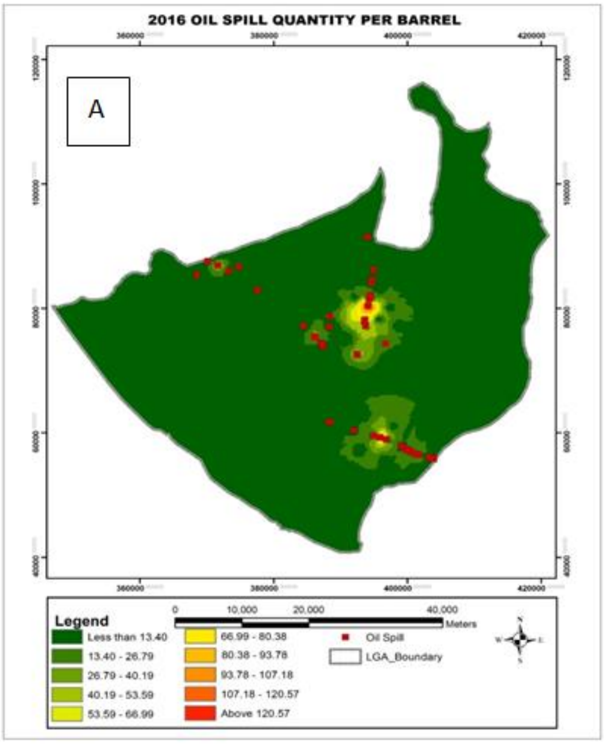
Figure 3.3: Oil Spill Trend Analysis (2016-2019)

Figure 3.4a-3.4d shows the quantity of oil spilled in the study area from oil spill points from the year 2016 to 2019. Figure 3.4a reveals that in the year 2016, 47 oil spill points spilled less than 13.4 barrels of oil. 10 spill points spilled oil quantity that ranges from 13.40-26.79 barrels of oil. Just only 1 spill point fell within 66.99-80.38 and 93.78-107.18 oil spill range. Furthermore, 2-spill point have oil spill of about 26.79-40.19 barrels. In addition, about 3 oil spill point cases in the year 2016 had above 120 barrels of oil spilled with one of the point spilling about 1450 barrels of oil to the surrounding environment.

Figure 3.4b shows that 14 oil spill points spilled less than 17.94 barrels of oil in the year 2017. 2 oil spill points spilled oil quantity that ranges from 17.94-35.88 barrels of oil. Also, 2 spill cases led to spillage of oil that ranges from 53.82 to 71.76 barrels. While there were other oil spill incidences that spilled about 131 barrels, 143 barrels and a peak of 180 barrels.

There were about 903.20 barrels of oil spilled from the 22 spill points in the year 2018 as seen in figure 3.4c. 3 of these spill points spilled between 61.94 to 92.91 barrel of oil. 16 of the spill incidence spilled less than 30 barrels of oil. 2 of the spill incidence in the sample area spilled between 92.91to123.88 barrels of oil. Furthermore, 1 spill occurrence in the year 2018 spilled about 278.73 barrels of oil.

Spillage of oil from the activities of oil exploration and transporting has been in existence over time and the sample area is not an exception due to the oil activities going on in the areais located. These spills have been a threat to the environment and the well-being of the people. There were about 748.98 barrels of oil spilled from the 32 spill points in the year 2019. 9 of these oil spill points spilled between 1 to5.99 barrels of oil (see figure 3.4d). 4 of the spill incidence in the sample area spilled 6-10.99 barrels of oil. 3 of the spill incidence in the sample area spilled between 11 to 15.99 barrels of oil. Another 3 of the spill incidence in the sample area spilled between 16 to 20.99 barrels of oil. 8 spill occurrences spilled above 42.99 barrels of oil with a peak spill of 104 barrels.



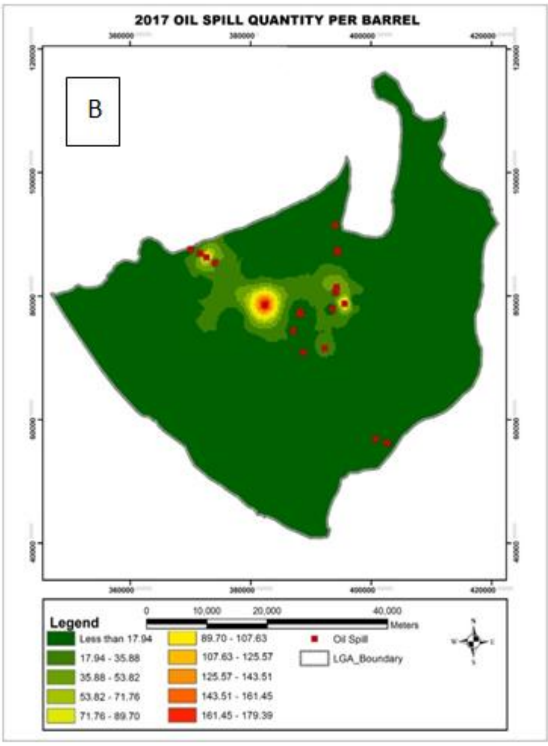
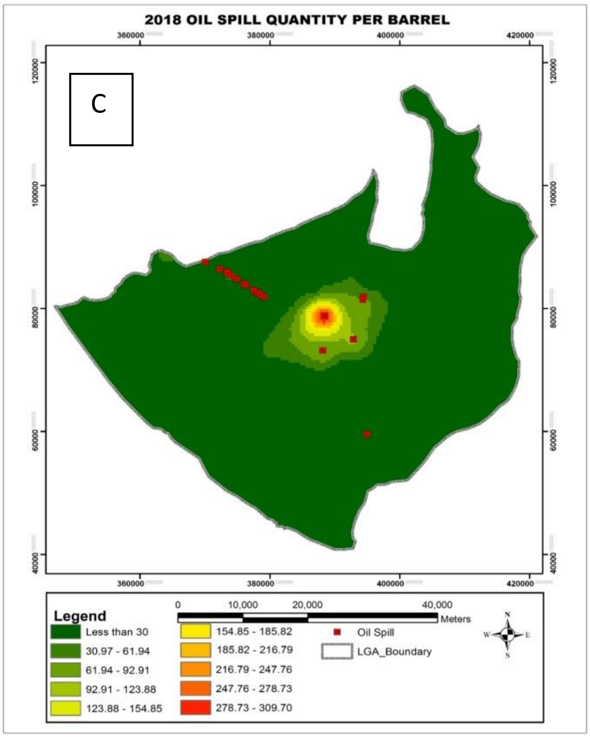


Figure 3.4a:Oil Spill Quantity Per Barrel(2016) Figure 3.4b: Oil Spill Quantity Per Barrel (2017)



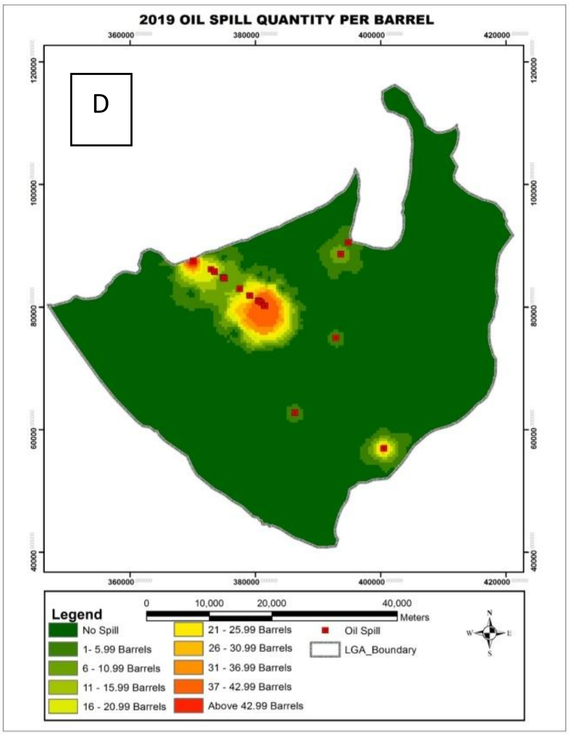


Figure 3.4c:Oil Spill Quantity Per Barrel(2018) Figure 3.4d:Oil Spill Quantity Per Barrel(2019)

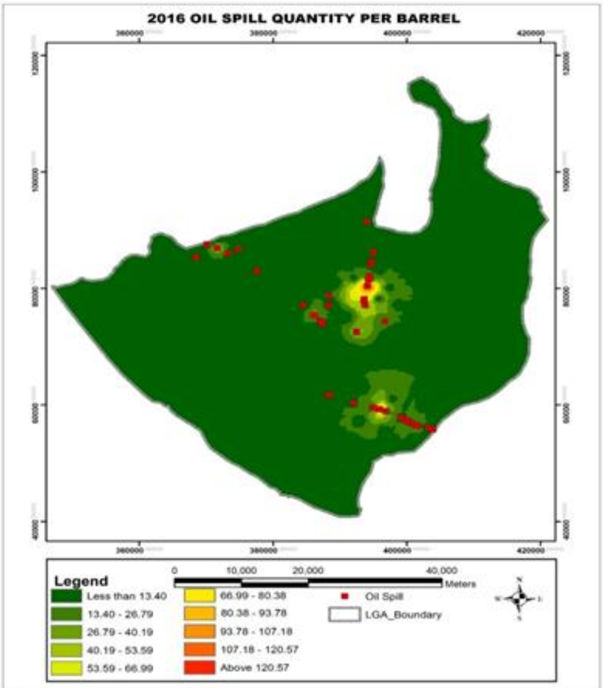
In the occurrence of oil spill, a recovery process is immediately started to combat or reduce the impact the oil spill has on the surrounding environment. From the study carried out on oil spill recovering in the year 2016(see figure 3.5a), it shows that out of 2737.01 barrels of spilled oil, 1074.707 barrels which represent 39.27% of the spilled oil was recovered. This was mainly as a result of the inability of recovering spilled oil in about 37 spill sites. Although in 25 areas where oil spill occurred, recovering was carried out but about less than

2.31 but above 0 barrels was successfully recovered in each location. While there was a peak recovery of 1000 barrels in one of the spill point.

The results of the analysis revealed that out of 782.58 barrels of spilled oil in the year 2017, 261.47barrels, which represent 33.41% of the spilled oil, was recovered (see figure 3.5b). This was mainly as a result of the inability of recovering spilled oil in about 7 spill sites. Although in 11 areas where oil spill occurred, recovering was carried out but less than 1.91 and above 0 barrels was successfully recovered in each location. While the recovery of spilled oil in 2 spill sites were above 100 barrels.

In the year 2018, the result shows that out of 903.2 barrels of spilled oil, 274.315barrels, which represent 30.37% of the spilled oil, was recovered (see figure 3.5c). This was mainly as a result of the inability of recovering spilled oil in about 8 spill sites. Although in 13 areas where oil spill occurred, recovering was carried out but less than 3.04 and above 0 barrels was successfully recovered in each location. There was a peak spill recovery of 259.64 barrels of oil.

The result of year 2019 oil spill recovery shows that out of 748.98 barrels of spilled oil, 49.18 barrels, which represent 6.57% of the spilled oil, was recovered (see figure 3.5d). This was mainly due to the low level of recovery that cuts across all the oil spill sites in the sample area. Although there was a peak recovery of 20 barrels of spilled oil.



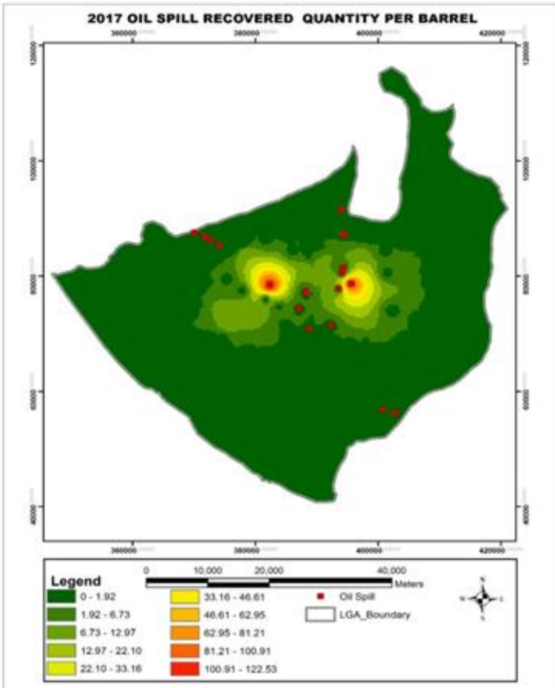
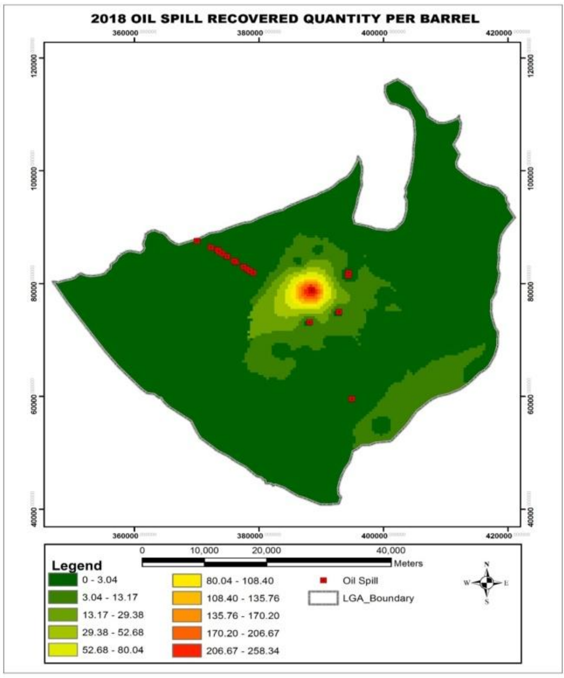


Figure 3.5a: Oil Spill Recovered Per Barrel (2016) Figure 3.5b: Oil Spill Recovered Per Barrel (2017**)**



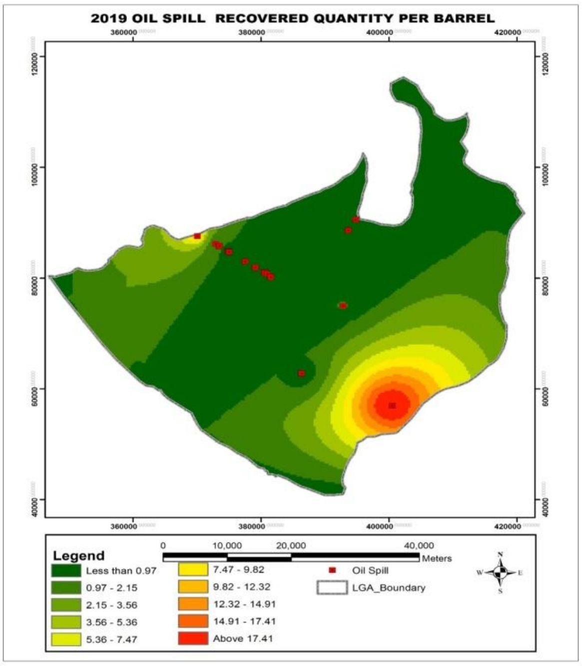


Figure 3.5c: Oil Spill Recovered Per Barrel (2018) Figure 3.5d: Oil Spill Recovered Per Barrel (2019)

Further analysis was carried out to model the likely impact of oil spill from the oil pipeline in the study area. From the result of the analysis as seen in figure 3.6, 14.82km^2 of built-up are at the risk of been impacted highly by oil spill from the pipeline, this represent 6.58% of the total built-up area in the study area. Also, 20.79km^2 of the built-up areas are at the risk of been moderately impacted by potential oil spill from the pipeline in the study area. Furthermore, 15.30km^2 which represent 6.80% of the built-up area in the study area are at the risk of been impacted lowly by potential oil spill from the pipeline. While 174.17km^2 which represent 77.38% of the built-up area are at risk of very low oil spill impact.

The potential risk of oil spill from the oil pipelines on water bodies in the study area show that 13.80km^2 of water bodies are at the risk of been impacted highly by oil spill from the pipeline, this represent 4.38% of the total water bodies. Also, 42.51km^2 which represent 13.49% of the water bodies are at the risk of been moderately affected by potential oil spill from the pipeline. Furthermore, 27.34km^2 which represent 8.68% of the water bodies in the study are at the risk of been impacted lowly by potential oil spill from the pipeline.

For the oil spill impact risk of spill from pipeline on the mangrove swamp vegetation in the study area, it show that 166.42km^2 of mangrove vegetation are at the risk of been highly impacted by oil spill from the pipeline, this represent 7.97% of the total mangrove vegetation. Also, 445.12km^2 of mangrove vegetation are at the risk of been moderately impacted by potential oil spill from the pipeline. Furthermore, 322.41km^2 which represent 15.44% of the mangrove vegetation are at the risk of been lowly impacted by potential oil spill from the pipeline.

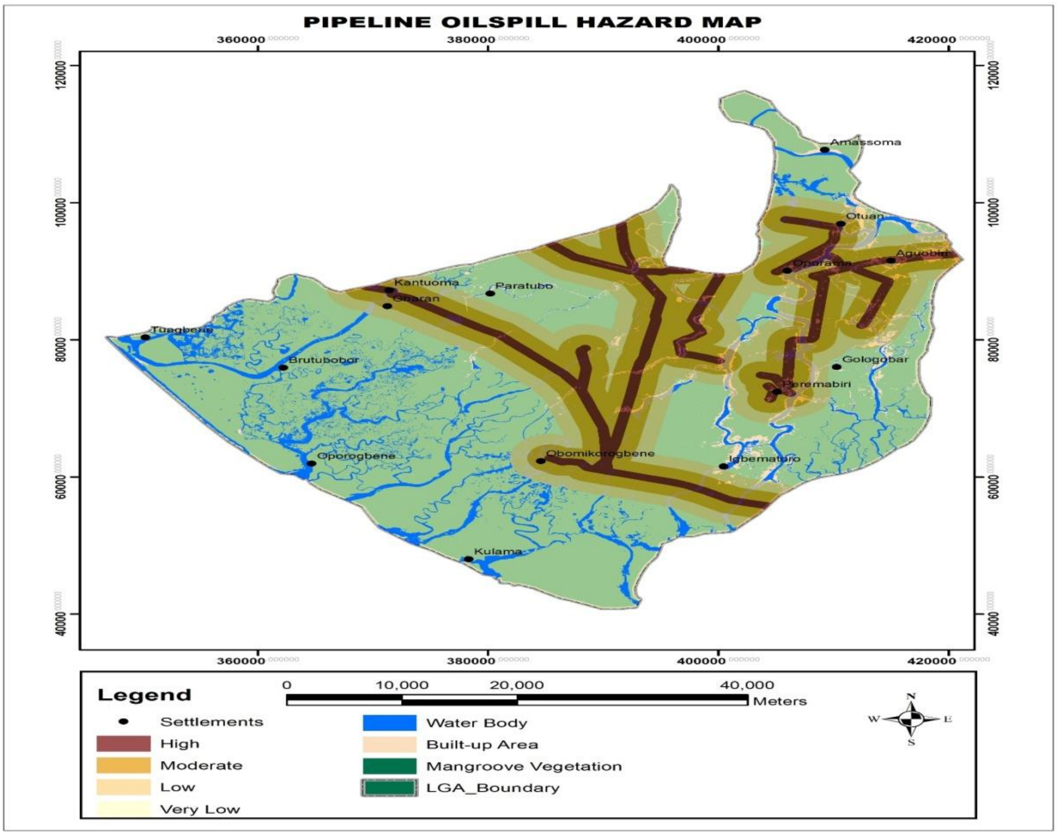


Figure 3.6: Pipeline Oil Spill Hazard Map

In the study area, the environment is at risk of been impacted by oil spill from the wellheads. The wellheads have regions of potential risk impact of oil spill, which ranges from high, medium, low and very low. These likely impacts have its potential effect on the different land cover (Built-up, Water bodies and Mangrove Vegetation) of the study area. As seen in figure 3.7, for the built-up, the potential risk of high impact of oil spill is 0.87km^2 which represent 0.39% and 8.21km^2, which represent 3.65%, are likely to be impacted moderately. 0.83km^2 of the water bodies which represent 0.26% of water bodies are at risk of been highly impacted and 13.71km^2 which is 4.35% of the water bodies in the study area are at risk of been moderately impacted by potential oil spill from the wellheads. In the study area, 7.66km^{2}which represent 0.37% of mangrove vegetation falls along the pathway of been highly impacted by potential oil spill from the wellhead and 93.06km^2 which represent 4.46% of the study area mangrove vegetation are at the risk of been moderately impacted by the potential oil spill from the well heads.

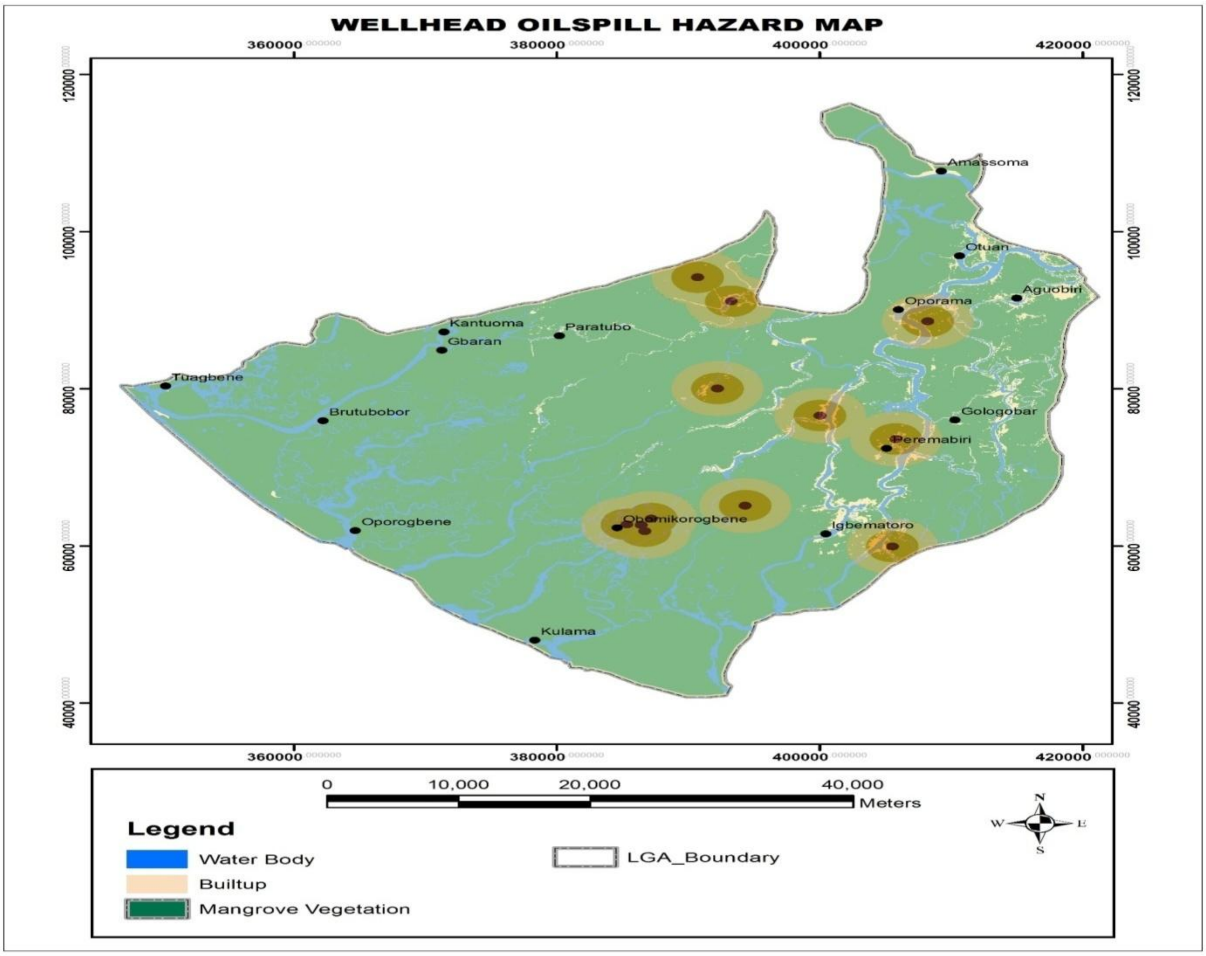


Figure 3.7: Wellheads Oil Spill Hazard Map

After the integration of the different layers of oil spill hazard, a final hazard on the risk of oil spill on the environment was created as seen in figure 3.8. From the analysis, 0.57km^2 which represent 0.25% of built-up area falls along the very high potential impact area and in any occurrence of oil spill from the oil facilities, these area of built-up would be worst hit. 14.56km^2, which represent 6.47% of the built-up area, are along the pathway of high risk and 21.79km^2, which represent 9.68% of the built-up area, falls in areas that are moderately impacted by potential oil spill.

Furthermore, 0.50km^2 ,which represent 0.16% of the water bodies are at risk of been very highly impacted and 13.46km^2 which is 4.27% of the water bodies in the study are at risk of been highly impacted by potential oil spill. In the study, 2.29km^2 which represent 0.11% of mangrove vegetation falls along the pathway of very highly impacted area by potential oil spill and 164.65km^2 which represent 7.89% of the study area mangrove vegetation are at the risk of been highly impacted by the potential oil spill.

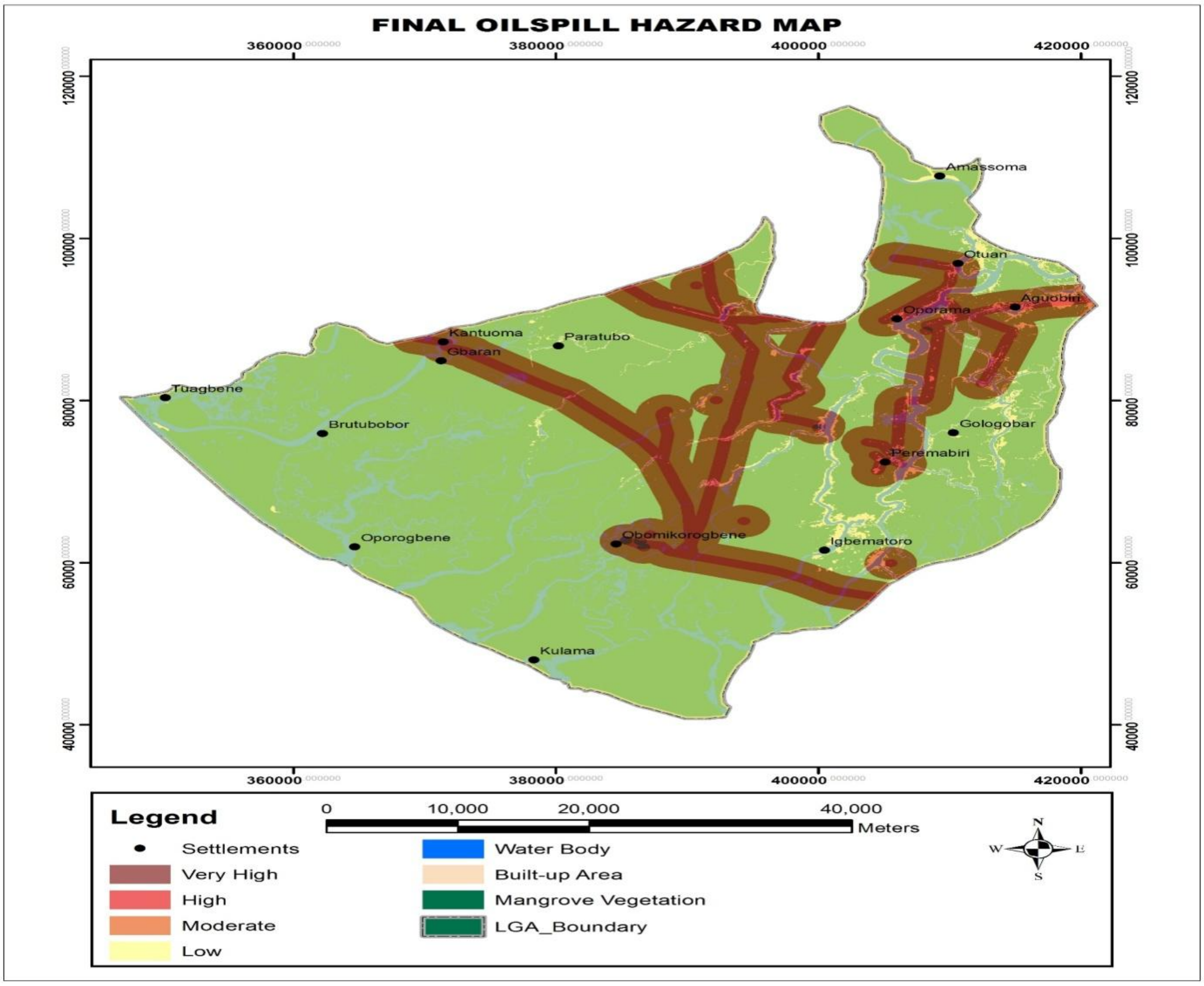


Figure 3.8: Final Oil Spill Hazard Map

In the sample area, there are regions of very high, high, low and very low concentration of the occurrence of oil spill. The major cause of oil spill in the sample area is caused by third party interference, which is mainly due to oil bunkering that is a criminal act. Due to the nature of the major cause of oil spill in the sample area, it is the responsibility of the police to curtail it. In the analysis in figure 3.9, there are 8 police stations within the sample area. Theses police stations has an area of influence to attend to oil spill situations. The closer the police station to the oil facility, the lesser the risk of oil spillage, which can be seen in figure 3.9, where few oil spill incidence occurs within the sphere of influence of the police stations. This shows that the location of the police stations has an effect on the occurrence of oil spill within the sample area. This brings the reason for the creation of more police stations in the sample area, which can cover the oils spill hotspots. This will help in reducing the occurrence of oil spill in the sample area, this because the closer the police stations to the oil facilities, there is the possibility of quicker response to situation of spill and checkmating the activities of oil bunkers that plague the Niger Delta region.

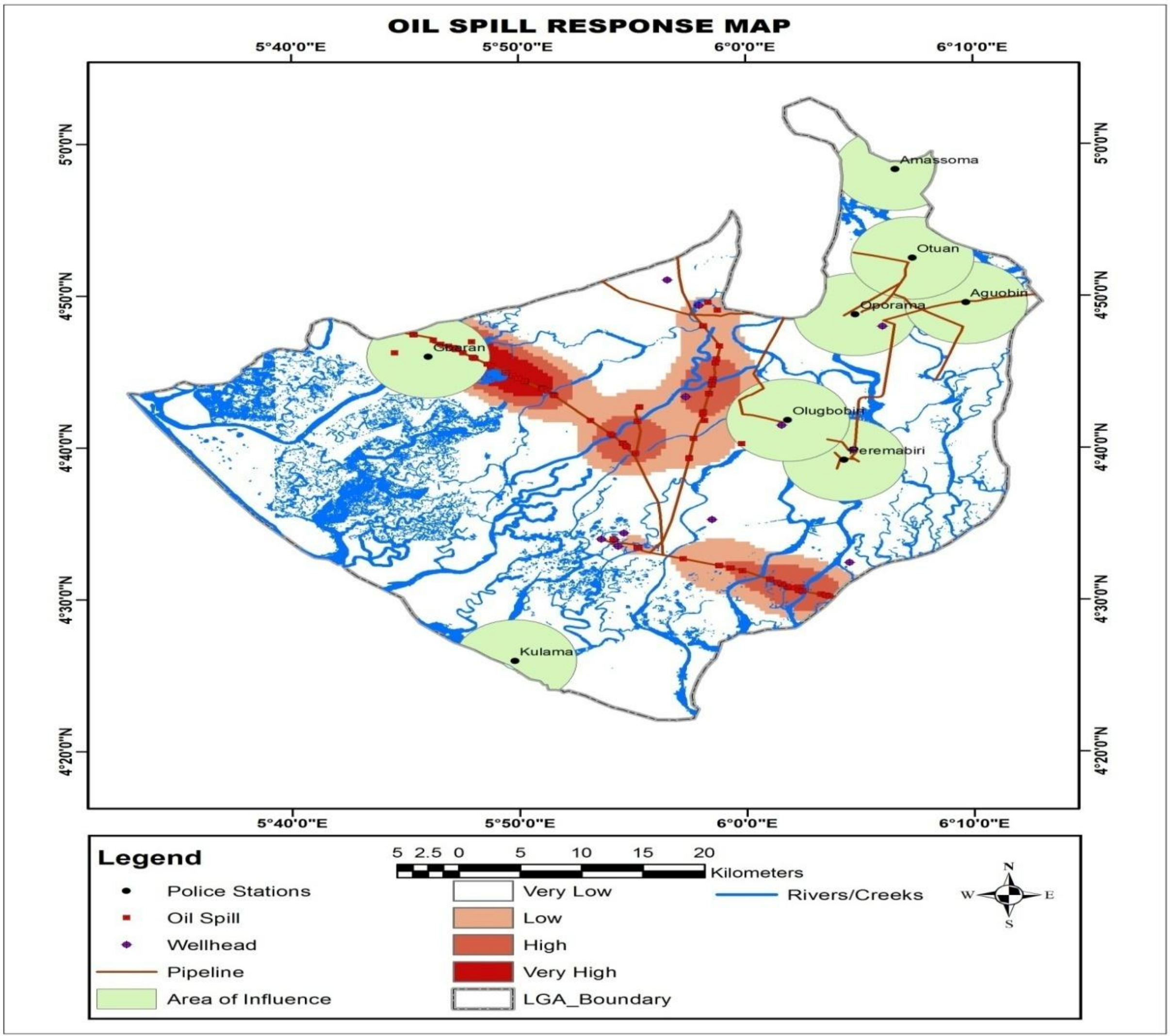


Figure 3.9: Oil Spill Hotspot and Response Map

IV. CONCLUSION AND RECOMMENDATIONS

4.1.1 CONCLUSION

Geographic Information System (GIS) has becomes very popular in the field of oil spill studies. This study has provided with the use of GIS useful input in tackling the major elements of a contingency plan, which are hazard/risk identification and vulnerability assessment. The study was carried out develop a GIS based oil spill risk assessment model for Bayelsa State of the Nigeria. Oil spill data of four consecutive years was used to get the intensity of oil spilled in the study area. Also, analysis of the number of cases and trend of the spill was carried out.

The potential oil spill facility (pipelines and wellheads) were analyzed to assess their level of risk on the land cover types of the study area. From the result, 0.57km^2 representing 0.25% of the total built-up area fell within the very high impact area, 6.47% of the built-up area fell within the high hazard zone, while 9.68% and 83.60% of the built-up area fell into moderately and low hazard zone respectively. However, 0.16% of the water bodies are within the very high hazard zone, 4.27% of the water bodies are within the high hazard zone and 13.88% of the water bodies are moderately hazard zone. 0.11% of the mangrove vegetation are within the very high hazard zone, 7.89% fell into the high hazard zone and 22.63% of the mangrove vegetation are within moderate oil spill hazard zone. Although, the study shows that year 2016 had the highest occurrence of oil spill cases, the result shows that the year 2017 had the highest oil spill quantity.

This study had further demonstrated the severity of oil spills in Bayelsa State of the Niger Delta Region, and how much the Nigerian environment is in danger.

4.1.2 RECOMMENDATIONS

From the results of this study, it is hereby recommended that;

1. Presence of Police and other law enforcement agencies should be increased in areas that have been identifies as very high and high risk zones such as ….
2. Waterbodies that have been impacted negatively by oil spillage should be cleaned and the villagers advised to desist from drinking water from such source.
3. The major cause of oil spillage in the area is third party interference. There should be a massive awareness for the citizens on the dangers of destroying oil facilities and its attendant consequences.
4. Furthermore, the creation of regional spill response centers in the Niger Delta Region would help in managing oil spill problems. The centers will make use of oil spill models for combating oil spill problems.
5. To minimize the harmful effect of oil spill, there is need for a comprehensive contingency GIS based plan for oil spill management in the study area.

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