The Shell Petroleum Development Company of Nigeria Limited
Operator of the NNPC/Shell/Agip/TEPNG Joint Venture

ENVIRONMENTAL IMPACT ASSESSMENT (EIA) OF BONNY DEEP EXPLORATION AND APPRAISAL WELLS PROJECT.

FINAL REPORT

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List of Abbreviation and Acronyms

%	Percentage
BH	Borehole
BOD	Biochemical Oxygen Demand
BYSEPA	Bayelsa State Environmental Protection Agency
C	Carbon
Ca	Calcium
$CaCO_3$	Calcium Carbonate
cfu	Colony forming unit
Cl	Chloride
cm	Centimeter
CO	Carbon monoxide
COD	Chemical Oxygen Demand
CPF	Central Processing Facility
Cr	Chromium
Cu	Copper
dB	Decibel
DO	Dissolved Oxygen
DPR	Department of Petroleum Resources
EES	Environmental Evaluation Study
EGASPIN	Environmental Guidelines and Standards for the Petroleum Industries in Nigeria
EIA	Environmental Impact Assessment
EMP	Environmental management plan
FGD	Focus Group Discussion
FmoH	Federal Ministry of Health
GMoU	Global Memorandum of Understanding
GPS	Global positioning system
H	Hydrogen
H_2O	Water
H_2S	Hydrogen sulphide
HUB	Hydrocarbon Utilizing Bacteria
HUF	Hydrocarbon Utilizing Fungus
HIV/AIDS	Human Immuno-Deficiency Virus/ Acquired Immuno-Deficiency Disease Syndrome
HSE	Health Safety and Environment
HSE-MS	Health, safety and environment – management system
IOGP	Integrated Oil and Gas Project
ISO	International standard organisation
ITCZ	Inter-Tropical Convergence Zone
IUCN	International Union for the Conservation of Nature
K	Potassium
kg	Kilogramme
KII	Key Informant Interview
Km	Kilometer

LGA	Local Government Area
m	Metre
Mg	Magnesium
Mg	Milligramme
Mm	millimetre; million
Mn	Manganese
NAG	Non Associated Gas
NAOC	Nigeria Agip Oil Company
NOSDRA	National Oil Spill Detection and Response Agency
NO_x	Nitrogen oxides
NPC	National Population Commission
O_2	Oxygen
P	Phosphorus
Pb	Lead
PO_4	Phosphate
ppm	parts per million
QA/QC	Quality Assurance/ Quality Control
RH	Relative humidity
RoW	Right of Way
SCiN	Shell Companies in Nigeria
SO_4^{-2}	Sulphate ion
SPDC	Shell Petroleum Development Company
SPM	Suspended particulate Matter
STI	Sexually transmissible infections
TBA	Traditional Birth Attendant
TDS	Total Dissolved Solids
TDU	Thermal desorption unit
THB	Total heterotrophic bacteria
THC	Total hydrocarbon Content
TPH	Total Petroleum Hydrocarbon
VOC	Volatile Organic Compounds

EXECUTIVE SUMMARY

E.S. 1 Introduction

The Shell Petroleum Development Company of Nigeria Limited (SPDC), on behalf of its Joint Ventures partners (Nigerian National Petroleum Corporation, Total, and Nigeria Agip Oil Company) conducted an Environmental Impact Assessment studies for the Bonny Deep Exploration and Appraisal wells Project. The project is intended to assess hydrocarbon potential of the proposed XU1000 and XU 2000 sands underlying the Bonny field producing sands in the Greater Bonny deep Area. The proposed activities for the wells drilling campaign will have various interactions with the environment, hence the need to conduct an Environmental Impact Assessment (EIA) studies. In line with the provisions of Part VIII – Section A, 3.0 of the Environmental Guidelines and Standards for Petroleum Industries in Nigeria, 2002 (EGASPIN), an environmental screening of all concept options and a preliminary assessment of the selected option was conducted, and approval issued. Post approval of the environmental screening and preliminary impact assessment report, the Terms of Reference/Scope of Work (ToR/SoW) was submitted to the Department of Petroleum Resources (DPR) and Federal Ministry of Environment (FMEnv) for consideration and an approval obtained. This EIA study has identified the key potential impacts of the project activities on Biophysical, Social and Health components within the project area and proffered mitigation measures for Environmental Management. The findings are presented in this report.

E.S 2.0: Project Location

The Bonny field is in SPDC‟s OML-11, about 40 km southeast of Port Harcourt and approximately 6 km northeast of the Bonny Oil and Gas Terminal (BOGT) in Bonny Island, withinthe coastal swamp area of the eastern Niger Delta.

E.S 3.0: Objectives of the Environmental Impact Assessment

The objectives of the Environmental Impact Assessment of Bonny Deep Exploration and Appraisal wells Project include the following:

- establish the baseline conditions of the project area with respect to the biophysical, social and health environment.
- identify and evaluate the potential impacts of the project activities on the biophysical, social and health environments of the area.
- identify and assess the potential socio-economic effects of the project on the communities' livelihood patterns, including impacts on cultural properties, social infrastructures, natural resources and values.
- identify and evaluate health impacts that may be associated with different activities of the project.

ES 4.0: Project Scope

The project involves the following:

1. Drilling and completion of two exploration wells
2. Drilling and completion of two appraisal wells

The specific project activities include the following:

Pre-drilling

- Full Preparation Survey
- Land acquisition
- Pre-mobilisation
- Mobilisation of equipment and workforce to site
- Dredging and Location Preparation

Drilling

- Drilling, casing, logging, cementation and completion of two exploration wells
- Drilling, casing, logging, cementation and completion of two appraisal wells

Demobilisation

- Movement of equipment and workforce to site
- Restoration of site

Decommissioning and Abandonment

- Excavation
- Removal of suface facilities
- Restoration

E.S 5.0: Project Options and Alternatives

The Project Options include*:*

1. No Option: This option entails not implementing the project.
2. Delayed Project Option
3. Drill wells option

The preffered option is option 3, because of the benefits of carrying out the project. The project alternatives considered include:

- Drill wells from Existing Well platforms
- Drill wells from new well platforms

The preffered project alternative is to drill the wells from the existing well platform because it is more environmentally friendly, reduces landtake and project cost. Drill from the primary considerations in the selection of project sites and adopted technology include the following:

- Impact on and benefit to the local communities
- Impact on environmental sensitivities
- Capital cost impacts
- Operability of the facilities
- Distance to oil and gas reserves
- Location of current facilities and production operations
- Safety

Project Schedule:

Mobilization to site, site preparation and well drilling activities is expected to commence on in third quarter of 2020

ES 5.0: Description of Existing Environment

A multi-disciplinary approach was adopted for data acquisition and ecological characterization which included climate, air quality and noise, soil, land use/land cover, vegetation, wildlife and biodiversity, aquatic, geology, social and community health status. Data were also generated through literature review of existing environmental studies report in the area, consultations with the stakeholders, detailed field work/study, laboratory and statistical data analysis. Furthermore, a proper Participatory Rural Appraisal/Assessment technique and sampling could not be conducted due to heightened Security challenges especially around Abua/Odual Local Government Area in Rivers State. Also, inaccessibility to some sampling stations especially in the Dry season lead to the short fall in the number of samples approved in the Terms of Reference.

ES 5.1: Literature Review

Some information used for the description of the environment in this report was obtained from the following documents:

- ❖ Environmental Impact Assessment of Bonny and Bonny North Associated Gas (BNAG) Development Project, 2013;
- ❖ Environmental Compliance Monitoring Reports for Bonny Oil and Gas Terminal Facilities
- ❖ Environmental, Social and Health Management Plan for the Bonny Associated Gas Solution Project {part of the Bonny field development EIA}, 2010;
- ❖ Environmental Evaluation Based Environmental Impact Assessment (EIA) of Bonny Terminal Thermal Desorption Unit (TDU), 2009.
- ❖ Environmental Impact Assessment (EIA) report of Bonny field development project (2003).
- ❖ Environmental Evaluation of Oloma Field Facilities, 2017

ES 5.2: Description of Sampling location

A one season field data gathering was carried out from 3rd – 23rd May 2018. The sampling location covered a spatial boundary of 2km radius of the proposed well locations in the bonny field. The stratified sampling design protocol was adapted for the study. The summary of sampling points for various environmental spheres are as follows:

- Soil quality: 24 +2 controls
- Surface water: 20 +2 controls
- Sediment quality: 20 +2 controls
- Groundwater: 3 + 2 controls
- Vegetation/ Wildlife: transects and walk throughs study
- Air quality/Noise: 24+ 2
- Socio economic: study per community

ES 5.3: Quality Assurance/Quality Control

The following QA/QC was observed in sample collection and *in situ* analysis carried out in the field. Samples were collected in bottles that have been thoroughly washed with detergent (nutrient free) and rinsed thoroughly. Prior to sample collection, each container was rinsed with the water to be sampled before finally collecting the representative sample for laboratory analysis. All samples were analysed at Earthquest International Limited, Warri, Delta State.

- All sampling equipment were properly protected and maintained in accordance with manufacturers' manuals.

- Sampling bottles were adequately labeled with masking tapes and indelible markers to avoid mistaken identity.
- Only analytical reagents (Analar grade) and chemicals were used.
- Automated equipments were calibrated prior to field sampling
- The same stock solutions and standards of H_2SO_4, HNO_3, $Na_2S_2SO_3$ Winkler's (A and B), and Starch Indicator were used for all the batches of samples to ensure comparability and reliability of results.

ES 5.4 Results

A summary of the study results is presented below.

ES 5.4.1 Climate and meteorology

The study area is in the humid tropical Niger Delta region of Nigeria, characterized by distinct wet and dry seasons. The dry season occur between November and March while the wet season is from April to October. Mean rainfall ranges from 3000 – 4500mm. Mean tempratures ranges from 30.0 – 32.0°C and relative humidity range of 60.68-71.90%.

ES 5.4.2 Air Quality and Noise

The concentrations of sulphur dioxide (SO2), nitrogen dioxide (NO2), volatile organic compounds (VOCs) and hydrogen sulphide measured in all the sampling stations and the control station were below instruments detection limits of (<0.001). The concentration of carbon monoxide (CO) range from 0.25μg/m^3 to 2.0μg/m3 (Mean: 1.2μg/m^3). Suspended Particulate Matter (SPM), varied spatially over the selected stations, ranging between 0.9μg/m3 and 12.3μg/m^3(Mean: 5.3μg/m^3). The control station also recorded value (4.1 – 5.7μg/m^3) within the range observed for the project area. The mean concentration of SPM recorded in the current study was below Nigerian ambient air quality standards (NAAQS) of 250μg/m^3 (daily average of hourly values) and 600μg/m^3 (concentration not to be exceeded for more than once a year) FMEnv, 1991. This implies that there was no indication of SPM pollution in the project area.

Generally, the data gathered from the field showed that the existing air quality within and around the project area were within the relevant ambient air quality criteria stipulated by the FMEnv (FEPA, 1991) and DPR (EGASPIN, 2002) for the monitored pollutants.

ES 5.4.3 Surface water

The average value of the pH of the surface water within the proposed well locations is 7.7 with a maximum value of 7.9 and a minimum value of 7.2. These values though slightly alkaline are common with coastal waters such as lagoons and embayments and are still within permissible limit of most environmental agencies which are normally within the range of 6.5-8.0 (EPA, 2001).

The average values of 13994mg/L, 41705 µS/cm, and 20853mg/L with ranges of 12452-15751mg/L, 35800-46000 µS/cm, and 17900-23000 mg/L were recorded for the salinity, EC, and TDS respectively in the surface waters within the proposed well locations

The BOD of the surface water samples had average values of 2.82mg/L, with a range of 2-3.8mg/L. These values are within the permissible limit of most environmental protection agencies which is normally set at ≤ 5mg/L. Also, the average DO value of 5.74mg/L was recorded with a range of 4.9-6.8mg/L.

The average values of the nitrate and phosphate composition of the surface water were 0.02mg/L and 0.014mg/L respectively, with ranges of 0.0.014-0.028mg/L 0.002-0.078mg/l. These values fall within the EPA standard of < 0.7mg/L and < 50mg/L for nitrates and phosphates respectively. However, the average value of 1232mg/L with a range of 844-1505mg/L for the sulphate composition of the surface water was above the EPA permissible limit of < 250mg/L

The average values of the detectable heavy metals were 0.0153mg/L, 1.689mg/L, 0.003mg/L, 0.001mg/L, 0.046mg/L, and 0.439mg/L for Mn, Fe, Cd, Cr, Pb, and Zn respectively. These values fall within the EPA and WHO standards. Comparing the average values of these detectable trace elements and heavy metals in surface waters collected within the proposed well locations and the control samples, no significant difference was observed apart from Pb, which was considerably higher in the samples collected within the project area.

Organics were not detected in the surface water samples both within the project areas proposed well locations.

The result of microbial analysis revealed that the average count value for the total heterotrophic bacteria (THB) and total heterotrophic fungi (THF) is 1625 cfu/g and 72 cfu/g respectively within the proposed well locations. In the control surface water samples, the average count value of THB was higher (2550 cfu/g), while that of THF was lower (30 cfu/g) compared with those collected within the project area and the control stations.

ES 5.4.4 Sediment

The spatial distribution of heavy metals in the sediments generated by a kriging interpolation method shows that at some sampling points there is elevated concentrations potential pollutants. Analysis shows that within the vicinity of SD 3, SD 10, SD 11 and SD 19 the concentration of cadmium was high although still within the regulatory limits. Similarly, Chromium has elevated concentration near SD5, SD 6, SD 8, and SD 22. The concentration of Copper was relatively high within SD 13 only. The concentration of Nickel was elevated near SD 2, SD 10 and SD 14. Lead (Pb) was elevated near SD 3, SD 11, SD 12, SD 13, SD 14, SD 15 and SD 17. The concentration of Zinc was elevated near SD 8, SD 9, SD 15 and SD 20.

The sediments collected within the proposed well locations are majorly composed of sand size particles with an average value of about 63% and a range of 27-93%. The remainder of the sediments particles are composed of silt and clay with average percentage composition of about 7% and 30% respectively. These sediments are not entirely composed of silicate materials but contains appreciable amount of organism matter. Therefore, the sediments can be classified as sandy clay loams. There was no significant difference between the particle size distribution of soil samples collected within the proposed well locations and those collected at the control points.

Sediments pH collected is acidic with an average value of 4.7 and a range of 3.6-6.1. These values are slightly lower in the soil samples at the control points with average pH of 4.2 and a range of 3.8-4.5.

Sediment Electrical conductivity (EC) were generally high, averaging 17344 µS/cm with a range of 3380-35100 µS/cm. High values of EC is mostly attributed to the presence of ionisable salts in the sediments. This assertion is likely since the sediments are derived from swamps which are close to the shorelines. In general, the nutrient content of the sediment is low, hence may not support adequate plant growth required for self remedial of contaminated sediments.

The average concentration values of 5473, 3.42, 39.08, 7.52, 2.76, 5.66, and 0.16 were reported for Fe, Cu, Zn, Pb, Cd, Ni, and Cr respectively. Vanadium was not detected in the analyzed soil samples both within and beyond the proposed project area. Apart from Pb which is much higher in the sediment samples collected within the proposed well locations, the average concentration values of the heavy metals did not show much variation between the proposed project location and the control points.

An average concentration value of 1.76ppm of oil and grease was detected in the sediment samples within the proposed well locations, with a range of 0.9-2.9ppm. These values were lower in the sediment samples collected beyond this radius, with average concentration value of 0.85ppm and a range of 0.8-0.9ppm.

Similarly, the average concentration value of the total aliphatic hydrocarbon content (THC) was 0.79mg/kg in the sediment samples while an average concentration value of 0.4mg/kg was recorded in the samples collected at the control stations.

The sediment data revealed high microbial activities, with a mean count value of 5810 cfu/g and 29 cfu/g for the total heterotrophic bacteria (THB) and total heterotrophic fungi (THF) respectively within the proposed well locations. These values were higher in the control sediment with average count value of 10000 cfu/g and 50 cfu/g for THB and THF respectively.

ES 5.4.5 Soil

Soil physical properties
size distribution and Texture
Sand was highest in the top soil with decrease in the subsoil especially in the control station. Clay increased with depth and was highest in the subsoil of the control station while the least clay was recorded in the study area top soil. The soil texture was predominantly loamy sand and clay but with few pockets of sand, sandy loam and sandy clay in the top soil while in the subsoil, the soil texture was mainly clay and very few sandy loams, sand, loamy sand and sandy clay loam.
The soil bulk density for both the study area and the control were very low; mean bulk densities of 0.39 and 0.43 g/cm^3 as against 0.25 and 0.46 g/cm^3 were recorded in the top and subsoil of the study area and the control respectively. Mean porosity of 44.06 and 44.02% as against 33.75 and 33.93% were observed in the top soil and subsoil of the study area and the control. It was highest in the top and subsoil of the study area.

Soil Chemical Properties
pH and Electrical Conductivity
Soil pH of the study area top soil was strongly acidic (5.03) as against 0.49 (very strongly acidic) while in the control it was 5.05 and 4.85 indicating similar range of strongly acidic to very strongly acidic. The magnitude of pH of the study area and the control was similar and therefore not different significantly different. The Electrical conductivity EC was 11071.5 and 11107µS/cm in top and subsoil of the study area compared to higher values of 16350 and 16000 µS/cm in the control. The

high EC is associated with high salinity of the sea water. EC is directly associated with salt and ion concentrations found in soils.

Soil Organic Carbon, Total Nitrogen and Phosphorus

Total organic carbon was 0.38 and 0.35% in the study area and 0.13 and 0.06% in the control station. Though the TOC was slightly higher in the study area than the control, both soils were very deficient compared to the critical level of 1%. Total N content of the soil was similarly 0.07% (very low content) in both the study area and the control and therefore not variable. Total P content of the soils was very low when compared to the critical level of 15 mg/kg; mean contents of P recorded were 0.04 and 0.03 mg/kg in the top and subsoil of the study area, 0.03 and 0.02 mg/kg in the control station.

Exchangeable cations

Mean exchangeable K in the top and subsoil of the study area and control was 1.29 and 1.26 cmol/kg as against 1.78 and 2.31 cmol/kg. The concentrations of K in both soils were above the critical level of 0.24 and 0.12 cmol/kg and therefore sufficient. Mean Mg and Ca were generally deficient in both soils as the highest concentrations of 0.97 and 0.55 cmol/kg recorded in the study area subsoil were far below the critical level of 1.9cmol/kg Mg and 3.8 cmol/kg Ca and 1.0 cmol/kg Mg and 3.0 cmol/kg Ca. Sodium concentrations were highest in the top and subsoil of the control station (12.46 and 11.48 cmol/kg) and were above the critical level of 10 cmol/kg.

Heavy Metals

Mean vanadium (V), arsenic (As) and Hg among the heavy metals in the study area and the control station showed no variation in their concentrations. Vanadium and Hg occurred in low concentration of 0.05 mg/kg and As was 0.03 mg/kg in both top and subsoil of both soils. Barium showed uniform low distribution in soils of the control and the study area. Mean Cu contents increased with depth in both soils; the highest content of 1.73 and 1.93 mg/kg were recorded in the surface of the study area while the least content 1.08 mg/kg was recorded in the subsoil of the control. Copper was deficient in both soils as it was below the critical level of 3.0 mg/kg. Zinc content increased with depth that resulted in the highest mean of 45.87 and 38.95 mg/kg in the subsoil of the control and the study area respectively. The study area also had the highest mean of 34.75 mg/kg in the top soil. Low Pb, Ni, Cd and Cr were recorded generally in both soils. Ni showed similar trend of Pb but decreased with depth in the control. Generally, the above heavy metals were below soil threshold limits, therefore poses no threats to the soils. Fe concentration increased from 2435.63 to 2546.98 mg/kg in the study area as against decrease of 2171.79 to 1739.03 mg/kg in the control. Iron concentration was very high in the study area and the control and well above the threshold of 200 mg/kg.

Hydrocarbons

Oil and grease was generally very low; the study area had the highest mean value of 1.53 and 1.55 mg/kg in both depths and were not significant compared to 1.00 and 1.45 mg/kg recorded in the control.

THC was below the threshold of 2.81 mg/kg. Total petroleum hydrocarbon (TPH), total aliphatic hydrocarbon (TAH), polycyclic aromatic hydrocarbon (PAH) and BTEX contents of the soils occurred in traces or below detectable limits.

Microbiology

In the study area THB count was highest in the top and subsoil (1.25 and 0.98 x 10^4 cfu/g) as against 0.54 and 0.63 x10^4 cfu/g in the control. THF counts was also higher in the top and subsoil of the study area; mean THF 0.74 and 0.88 x 10^3 cfu/g were recorded in the study area as against 0.11 and 0.12 x 10^3 cfu/g in both depths. HUB was higher in soils of the control in the surface; mean HUB of 5.00 x 10^3 cfu/g was recorded as against 3.89 x 10^3 cfu/g in the study area. But in the subsoil, the content was slightly higher in the study area. HUF followed similar pattern of HUB.

Soil Microbiology

The evaluation of the soil microbiology shows that THF in both depths, THB and HUF in the top soil were rated *severe*. HUB in both depths was rated *low* and *negligible*; THB was *medium* in the subsoil. On the rating scale, the parameters were not significantly different. The THB was higher in the study area compared to the control.

ES 5.4.6 Groundwater

The average pH, EC, and TDS of the samples collected within the project area were 7.3, 31700µS/cm, and 15966mg/L with ranges of 7.1-7.4, 30400-32400µS/cm, and 15200-16500mg/L respectively. This shows that the groundwater was slightly alkaline, but still falls within EPA and DPR permissible limit of 6.5-8.0. The EC and TDS values exceeds the EPA and Nigerian standard for drinking water permissible limit of <500mg/L for TDS and < 1000 µS/cm for EC.

Among the heavy metals tested in the groundwater samples within the proposed well locations and at the control stations, only Cu, Fe, Pb and Zn were detected, with average concentration values of 0.035mg/L, 0.063mg/L, 0.008mg/L and 0.187mg/L respectively. Lead and Iron concentrations were relatively lower in the groundwater samples within the proposed well locations compared with the ones at the control stations, while the concentration level of Cu and Pb remained almost the same.

The spatial distribution of heavy metals with elevated concentrations is presented in the main report. It is shown that Cu is elevated in BH3, Fe in BH2, Pb in BH2, and Zn in BH2 and BH3. However, these values of Cu, Fe, Pb, and Zn are within the permissible limit of most environmental protection agencies.

Therefore, there is no hydrocarbon contamination of the groundwater within the catchment area of the proposed well locations. However, microbial activities were detected in some of the groundwater samples collected within the radius of the proposed well locations with average count value of 2967 cfu/g and 27 cfu/g for the total heterotrophic bacteria (THB) and total heterotrophic fungi (THF) respectively. This value was slightly higher for THB (3200 cfu/g) but was almost constant (20 cfu/g) for THF in the groundwater samples collected at the control stations.

ES 5.5 Surface Water

ES 5.5.1: pH, Salinity, EC, TDS, TSS and Turbidity

The average value of the pH of the surface water within the proposed well locations is 7.7 with a maximum value of 7.9 and a minimum value of 7.2 and shows no significant difference from values in the control points. The average values of 13994mg/L, 41705 µS/cm, and 20853mg/L with ranges of 12452-15751mg/L, 35800-46000 µS/cm, and 17900-23000 mg/L were recorded for the salinity, EC, and TDS respectively. salinity falls within the EPA permissible limit of ≤40000, the EC value is above the EPA permissible limit of 1000µS/cm, while there is no limit set for the TDS of surface waters by EPA. The average concentration values of the total suspended solids (TSS) and turbidity were 18 mg/L and 13.4 NTU in the surface water samples collected within the proposed well location. Unlike the values of EC, TDS, Salinity, and pH, there was a significant increase in the concentration level of TSS and turbidity in the surface water samples collected at the control points

ES 5.5.2: Dissolved Oxygen, Chemical Oxygen Demand, and Biochemical Oxygen Demand

The BOD of the surface water samples collected within the proposed well locations gave an average value of 2.82mg/L, with a range of 2-3.8mg/L. These values are within the permissible limit of most environmental protection agency which is normally set at ≤ 5mg/L. Also, the average DO value of 5.74mg/L was recorded for the samples collected within the radius with a range of 4.9-6.8mg/L. These values of the DO are slightly lower than the EPA standard of ≥ 7mg/L and may be as a result of relatively high temperature of the surface water (29.9^{o}C)

ES 5.5.3: Nutrients:

The average values of the nitrate and phosphate composition of the surface water collected within 500m radius from the proposed well locations are 0.02mg/L and 0.014mg/L respectively, with ranges of 0.0.014-0.028mg/L 0.002-0.078mg/l, while values for Sulphates were 1232mg/L with a range of 844-1505mg/L. Reduction in the amount of sulphate may lead to increased decomposition of organic matter, while increase in the amount of phosphates and nitrates usually leads to eutrophication.

ES 5.5.4: Heavy Metals:

Apart from Cd, Fe, Pb, Zn, Mn and Cr, all other elements were not at detectable concentration in the surface water samples collected within the proposed well location and at the control points. The average values of the detectable elements are 0.0153mg/L, 1.689mg/L, 0.003mg/L, 0.001mg/L, 0.046mg/L, and 0.439mg/L for Mn, Fe, Cd, Cr, Pb, and Zn respectively. These values fall within the EPA and WHO permissible limit for surface waters. Comparing the average values of these detectable trace elements and heavy metals in surface waters collected within the proposed well locations and the control, no significant difference was observed apart from lead which was considerably higher in the samples collected within the proposed well location radius

ES 5.5.5: Hydrocarbons

This include, TPH, oil and grease, Polycyclic, and Aliphatics. Problems associated with these substances include; interference with such vital processes as the mass transfer of oxygen from air to water (essential in river reaeration), blockage of pipes, odour and taste problems, cancers, etc. However, organoleptic and total aliphatic hydrocarbon (THC) was not detected in the surface water samples both within the proposed well locations and the control points.

ES 5.5.6 Hydrobiology

Phytoplankton

A total of 79 phytoplankton taxa were recorded during the study. These belong to seven divisions: Bacillariophyta (38), Chlorophyta (21), Cyanophyta (11), Dinophyta (05), Euglenophyta (02), Chrysophyta (01) and Xanthophyta (01). Bacillariohyta were the dominant phytoplankton community followed by the Chlorophyta, and Cyanophyta, while Xanthophyta and Chrysophyta were the least in terms of occurrence and abundance. Bacillariophyta contributed almost half (48%) of the total phytoplankton population. Chlorophyta and Cyanophyta contributed 27% and 14% respectively, while Dinophyta and Euglenophyta contributed only 6% and 3% of the total phytoplankton biomass of the water. Contributions by Chrysophyceae and Xanthophyceae were almost negligible as their percent contributions to the phytoplankton population were less than 1% for the two groups.

Zooplankton

Forty-seven species of zooplankton were recorded during the sampling period. This is made up of holoplankton (81%) and meroplanktonic (19%) zooplankton forms respectively. Among the holoplankton, the major occurring zooplankton group in the area was Cladoceran (42%) followed by Copepods (32%) and Rotifers (26%), while within the meroplankton shrimp zoea and larva were the dominant groups.

a) Benthic Invertebrate Fauna

The benthic invertebrates recorded during the study belong to the following Crustacea, Gastropod, Bivalves, Annelids and Insecta. Crustacean (43%) has the highest number of taxa and spread of species in the area while benthic Bivalves (4%) was the lowest with respect to taxonomic spread in the study area. *Balanus sp, Cardisoma armatum, Macrobrachium sp and Sesarma huzardi were the dominant Crustacean species, while* Tympanotonus fuscatus and Crassostrea gasar were the dominat Gastropods and Bivalves. *Insect larva and Annelids* species were sparsely distributed in the study area. Turbidity and TSS vary frequently due to variation in surface water movement, tides and sediment load.

ES 5.5.6 Fish and Fishery resources

The checklist of fish and shellfish species recorded during the field visit in the study area showed that the Family Aridae, Carangidae, Clupeidae, Crassosteidae, Gobidae, Haemulidae, Lutjanidae, Mugilidae, Muricidae, Penaeidae, Polynemidae, Sciaenidae and Squalidae appeared extensively in the catchment water. The Family Clupeidae included species such as *Illisha africana, Ethmalosa finbrinata, Sardinella eba and S. modenerrhi.* Virtually all the recorded species were well distributed in the area.

The size ranges of the various species varied in the different fishing grounds. Croaker *Pseudotolithus elongatus* varied between 15–60 cm in samples within the adjacent mouth of the ocean fishing ground, 10–54 cm in Bonny Estuary, 10– 42 cm in the creeks and creeklets.

In general, the size ranges in the ocean fishing grounds were higher than those along the creeks and creeklets. The most abundant sizes of commercially important species encountered comprised mostly of juveniles. The most abundant sizes for *Sardinella maderensis*, *Ethmalosa fimbriata*, *Ilisha africana*, *Cynoglossus senegalensis*, and *Pseudotolithus elongatus* were 10, 15, 18, 35 and 40 cm respectively. For *Pomadasys jubelini*, *Polydactylus quadrifilis*, *Pseudotolithus typus and Pseudotolithus senegalensis* were 10, 15, 20 and 25cm respectively.

There were more catches made from fishing grounds in the ocean compared with fishing grounds in the estuary; rivers and creeks based on the catch per unit effort from these fishing grounds. The highest catch per unit effort from the ocean was estimated at about 275 kg/trip/day while the catch per unit effort in the creeks and creeks fishing ground it was about 92 kg/trip/day.

ES 5.7 Vegetation and Wildlife (Biodiversity Studies)

Habitat Types

Habitat types observed were: mangrove swamp (natural habitats), freshwater (natural habitats) and secondary forest (disturbed habitat). Based on area sampled, mangrove swamp accounted for 71 % while freshwater and secondary forest accounted for the remaining 27 %. Undisturbed forest accounting for about 2% of the censored area called rain forest were observed only in the two control sites. Specifically, mangrove swamp was encountered at George Pepple, Alasakiri, Bomu- Bonny Trunk Line, Issille-Ogono and Bonny community, freshwater at Otuokolo and secondary forest at Abalamabie community.

Generally, it was observed that the vegetation characteristics of the study area were distinctly different from that of the control areas where only natural habitats (mangrove swamp and rain forest) were encountered. Plate 3.1 is an overview of the habitat types.

ES 5.7.1 Species Richness

A total of ninety-eight (98) flora species belonging to forty-two (42) taxonomic families were recorded in the study. This comprised of 67 species for Abalamabie community, 60 species for George Pepple, 47 for Issille-Ogono as against 23, 31, 32 and 36 species sampled for Bonny trunk line, Otuokolo, Bonny axis and Alasakiri communities respectively.

Similarly, species richness for the habitats was evaluated. Mangrove forest recorded the highest number of species (79) followed by secondary forest (67 species) as against fresh water swamp forest with 31 species. The control sites had 47 species. The indicative mangrove genera recorded in this study includes *Acrostichum*, *Avicinnia*, *Laguncularia* and *Rhizophora*. Expectedly, these notable genera were also documented by Ebigwai and Akomaye, 2014 and Abere and Ekeke, 2011 Niger delta mangrove environments. The species richness recorded in the mangrove and fresh water habitats could possibly be due to reduced anthropogenic activities and/or resistance to invasion while the numbers enumerated to the rain forest and secondary forests could be due to Thinning -out effects and fertile loci points for species colonization respectively.

Also, the predominance of seven cultivatable species (*Artocarpus altilis*, *Xanthosoma mafafa*, *Psidium guajava*, *Persia americana*, *Musa spp*, *Cocos nucifera* and *Annona muricata*) in the secondary and freshwater habitats, further buttress anthropogenic influences.

ES 5.7.2: Species Density

A species density of 36.8 m per species was recorded for the entire study area as against the 13.5 m to a species recorded in comparison to the study area. Furthermore, the highest SD of 7.5 m/species was recorded for Abalamabie community followed by George Pepple 8.3 m/species, Issille -ogono with 10.6 m/species, Alasiakiri with 13.9 m/species and Bonny axis with 15.6 m/species as against 21.7 and 16.1 m/ species recorded for Bonny trunk line and Otuokolo communities respectively.

Similarly, SD of 7.5, 16.1 and 31.7 m per species was recorded for secondary forest, fresh water and mangrove swamp habitats respectively while 7.5 m to a species was recorded for tropical rain forest in the control site. This result showed that species density was higher in the undisturbed forests and secondary forest than in freshwater swamp and mangrove swamp respectively.

Result obtained in this study conforms to the report of Agbagwa and Ndukwu (2014) and Agbagwa and Chemizie, 2011 which recorded high number of species per unit area in tropical rain forest than the freshwater forest and mangrove forest respectively. The low SD recorded in mangrove swamp habitat could be attributed to the sterno-haline properties of only a few species.

ES 5.7.3: Species Abundance

A total of 7,986 individuals were manually enumerated in the study area. The entire study environment was dominated by mangrove indicative species including *Avicinnia alba*, *Rhizophora spp* and *Acrostichum aureum*. In addition, *Militia thonningii, Triumphetta cordifolia, Phoenix reclinata,* and *Cocos nucifera* dominates in the freshwater habitat. Rain forest was expectedly dominated by tree and shrubby species, the secondary forests are dominated by shrubby and herbaceous species including *Ageratum conyzoides*, *Acanthospermum hispidum*, *Asystasia gangetica* and *Alchornea cordifolia.* Similar findings have been reported by Ebigwai and Akomaye (2014), who studied the regeneration potential of mangrove forests in the Niger Delta.

When species abundance was evaluated for the studies communities, Abalamabie with 1870 plant individuals recorded the highest followed by George Pepple with 1329 and Issille-Ogono with 1263 individuals as against Otuokolo with 579, Bonny trunk line with 871, Alasakiri with 1034 and Bonny axis with 1040 individuals respectively.

ES 5.7.4: Species Diversity Indices

In the present study, the Shannon's index (H) and equitability index (E) values for the sampled area was 3.734 and 0.820 respectively.

The Shannon's index values for rain, secondary, mangrove swamp and the fresh water swamp forest were 3.72, 3.69, 3.27 and 3.01 respectively while the equitability index values is 0.87 each for fresh water, rain forest and secondary forest against 0.75 recorded for mangrove swamp forest (Fig. 2.1 A). Similarly, the Shannon's index values for Abalamabie (Bal.), George Pepple (Gep.), Issille-Ogono (Iso.), Otuokolo (Oto.), Alasakiri (Ali.), Bonny axis (Bon.) and Bonny trunk line (Btl.) communities were 3.69, 3.48, 3.03, 3.01, 2.90, 2.52 and 2.43 respectively while the equitability index range from 0.87 for Bal. - 0.72 for Bonny community. **(**Fig 2.1 B).

ES 5.7.5: Species growth habitat

Species growth habit was equally evaluated for the identified habitats**.** Generally, the percentages of woody trees in all the habitats were higher compared to other growth forms. Statistically, freshwater habitat had more proportion of tree species (83.3 %), followed by the mangrove swamp forest (77.2 %) while the secondary forest recorded the least proportion of tree species (72.1%). Among the sampled communities, Alabakiri and Bonny trunk line recorded the highest proportion of woody species followed by Issille-ogono, Bonny axis and Otuokolo communities while Geoge Pepple followed by Balamabie recorded the least.

ES 5.7.6: Vegetation Structure of the study area

It was observed that sampled plant species in the studied area had average DBH of between 2 and 93 cm. Result of the study revealed that 81.0% of the species had DBH below 50 cm (Table 3.4). This is suggestive of a generally disturbed ecosystem. Harvesting of fuel woods for house hold energy, logging activities for house construction and oil exploration activities could be the main drivers for woody species loss. Furthermore, rain forest habitat mangrove swamp habitat recorded higher number of species with DBH above 50cm followed by secondary forest with freshwater swamp forest recording the least count. Similarly, George Pepple recorded the highest number of species with DBH ≥50cm followed by Abalamabie while Bonny trunk line and Alasakiri had the least number of species. This indicates that vegetation around George Pepple community is less disturbed as against those around Bonny trunk line that are more disturbed.

ES 5.7.*7:* IUCN Status of the censured flora species

The IUCN status of plants sampled was evaluated using the IUCN version 2018 -1 criterion. Results showed that four (4) species representing 5.1 % of the sampled species were classified as threatened by IUCN. These species include *Allanblackia gabonensis*, *Anopyxis Klaineana*, *Khaya grandifoliola* and *Lophira alata* which were categorized as Vulnerable (VU). One species (*Milicia excelsa*) was categorized as Near Threat (NT), while others were either Least concern, Not evaluated or Data deficient. The presence of threatened species is any habitat triggers the need for a Biodiversity Action Plan (BAP).

5.7.8: Fauna

A total of one ninety-four (94) fauna species were inventoried in the entire study area. This comprises of seventy-three (73) species censured via direct evidence and twenty-one (21) species obtained via indirect evidences. Avian group recorded the highest number of species followed by mammals while mollusks and arachnids (group of Arthropoda) recorded the least species abundance. Result showed that Alasakiri community had the highest number of species followed by Bomu-Bonny and Abalamabie as against Bonny axis followed by Issille-Ogono and Otuokolo communities with the least number of species. Reptilian species were recorded only in George Pepple, Abalamabie and Otuokolo communities. Avian, mammalian and insect groups recorded highest Shannon index and Equitability index values as against other fauna groups. High Shannon index indicates high species richness while high equitability index shows evenly distributed individuals among species. This high species diversity and abundance portents high ecosystem services for members of the study area. Similarly, Shannon index of 3.67, 3.42 and 3.39 and the correspondent Equitability index of 0.88, 0.91 and 0.92 were recorded for mangrove, secondary, and freshwater habitats respectively.

The mangrove swamp forest recorded the highest Shannon index for all the fauna groups with exception of insects which recorded highest in freshwater habitat. Similarly, secondary forest recorded the highest Equitability index for mammals, reptiles, and amphibians while aves recoded similar Equitability index across the sampled habitats. The diversity indices of 0.00 recorded for reptilian group in mangrove and freshwater habitat, molluska and arachnida groups in secondary and rain forests was expected due to the low species richness of these groups in the studied habitats.

ES 5.7.9: Fauna species abundance

A total of 2,384 individual across all fauna groups were enumerated. These were 1061 individuals for insects, 741 for aves, 235 for mammals, 124 for arachnids, 113 for Amphibians, 58 for mollusks and 38 for Reptiles.

Abalamabie community recorded a total of 511 individuals as the highest followed by Alasakiri community with 400 individuals while Bonny axis (252) and Bomu-Bonny (299) recorded the least individuals in terms of abundance.

ES 5.7.10: Fauna IUCN STATUS

Analysis for conservation status of the species censored in the study area was conducted using IUCN 2018 version 1 Red List of Threatened species. Results revealed the presence of eight (8) threatened species, representing 7.4 % of the sampled fauna species. In a similar report, Agbagwa and Ndukwu (2014) recorded a total of eight (8) threatened species some of which include *Cercopithecus erythrogaster* and *Osteolamus tetraspis* in Bonny.

ES 5.8: Social Impact

Quantitative and qualitative research designs were employed in the evaluation of social impact. With the use of validated research instruments administered on 355 residents, complemented by focus group discussion at each community, relevant data were collected and analyzed using frequencies, percentages and graphs. The communities studied belonged to the *Igbani* (*Ibani*) tribe except for *Otuokolomabie,* which is inhabited by the *Andonis*. The prominent livelihood of the area is fishing and farming. Other minor occupations are trading and lumbering. The average earnings associated with the economic activities of the area, which is about ₦7780/month, is relative low compared with the national minimum wage of ₦18000/month. This aptly captures the prevailing poverty nature of the project area. Most of the communities are small rural settlements of less than 5000 residents. Many were less than 500 in population size.

The status of infrastructure reveals that most of the communities had electric infrastructure although power supply was described as epileptic except for Agbalamabie. Many of the communities lacked educational facilities and school-aged children have to access such service in other communities. Most of the communities had water borehole facilities although there are complaints about the fitness of the water for human consumption. Telecommunication services were available in all the communities, although signal strength or reception was described sometimes epileptic. Physical access to the communities is possible only by boat, although Dema-Abbey community reported the possibility for the community to be linked to Bonny by land. Most of the communities had block-type housing, while few (e.g. Otuokolomabie and Alasiakiri) had housing made of thatched roofs. Almost all the communities have concrete/steel jetty, while few had public waste disposal facilities. Those without these facilities live in homes with such convenience.

While no major social challenge or conflict was reported in any of the communities, they appeared to be faced with serious environmental challenges such as shoreline erosion and pollution of the water ways. The communities have well established leadership or governance structure driven by local tradition. At the apex of the leadership structure is the 'Community Head' (sometimes referred to as '*Amaopusenibo'*), followed by 'Council of Elders'; then the 'Women' and 'Youth' groups, sometimes referred to as '*Asanwo'* and '*Eremenobo'* respectively, Social interaction at the community level is moderated by cultural norms or taboos that regulate communal behavior. Although respondents reported being Christians, they also acknowledged the existence of local deities that are revered. Communal shrines were reported in in some of the communities such as Otuokolomabie (*Ogbologbo* shrine) and Issile-Ojono (*Amakiri* shrine).

The proposed project is widely welcome by the communities, largely driven by the expected positive net impact on community life, specifically in the following areas: improved power supply, access to and support for education development, development of entrepreneurial competencies, livelihood support (inputs), access to safe drinking water, erosion control and employment.However, some reservations or concerns were also expressed over the potential negative impact of the project on the community, with possible impact points being increased pollution of the water ways andwater drinking sources, air pollution and its health implications, destruction of water habitats, loss and disruption of income and livelihoods and increased pressure on existing amenities. The need for the SPDC to have clearly documented GMoUs, jointly reached with each of the individual impact communities, was emphasized as a strategic mitigation measure. Other proposals include adequate compensation for land that may be acquired with due consultation with community leadership; provision of amenities such as functional and improved water boreholes, provision of farm chemicals (fertilizer) to improve soil fertility complemented with farmer training on improved farming practices and educational scholarships as well as sourcing locals (residents and/or indigenes) for work.

ES 5.8: Health impact

The Table below summarizes the findings of the Health Impact Assessment component of the Bonny Deep Exploration and Appraisal Wells Projects Environmental Impact Assessment study.

SN	Indicator	Finding in the host communities	Remark
1	Socio-economic characteristics of communities	Predominantly members of Ibani ethnic group, who are mainly fisher folks, traders and marine transporters	Consistent with the findings in the other communities in the Niger delta region
2	Access to safe drinking water	An average of 25% in the communities, but significantly better in Abalamabie that is supplied with a reticulated water supply from the Bonny Utility Company	This is less than the 69.6% average for south-south Nigeria, the 71.3% average for Rivers State, and the national average for rural communities of 49.2%
3	Quality of drinking water	Physico-chemical properties within regulatory limits	The same as most communities in the Niger delta region
4	Access to unshared sanitation facilities	Access to unshared sanitation facilities in the communities is 35% in the bigger communities of Oloma and Abalamabie, and significantly less at about 10% in the smaller communities of Alasiakiri and Nkpokiri.	Consistent with the 25.8% average for south-south Nigeria, the 28.0% average for Rivers State, and the national average for rural communities of 13.4%
5	Housing condition	The floors of the houses in the bigger communities were noted to have been constructed with cement (75%), mud (3%) and planks (12%); while those in the smaller communities were constructed with	The housing condition in the communities is therefore different from the national averages for rural communities of 0.4% for planks/wood, 40.1% for

		cement (9%), mud (11%) and planks (80%).	cement and 48.6% for earth/mud
6	Diseases vector activities	Presence of Anopheles, Culex and Aedesaegypti mosquitoes, tsetse fly, sand flies and housefly	Consistent with the findings in the other communities in the Niger delta region
7	Source of domestic fuel	More than 80% of respondents in the communities use firewood as their main source of domestic fuel.	Consistent with the national average of 83.3% for rural communities
8	Solid waste management	Indiscriminate dumping of refuse practised by all members of the communities	Consistent with the findings in the other communities in the Niger delta region
9	Use of alcohol beverages	More than 90% of members of the communities drink alcohol, and up to a third of them can be classified as engaged in harmful drinking	Consistent with the findings in the other communities in the Niger delta region
10	Prevalence of smoking	About a fifth of adult males in the communities are said to smoke cigarette, but an average of three sticks of cigarette a day. Women in the communities rarely smoke cigarette	Consistent with the findings in the other communities in the Niger delta region
11	Sexual behavior	Premarital sex and marital infidelity are common in the community	Consistent with the findings in the other communities in the Niger delta region
12	Knowledge of HIV/AIDS	Most members of the communities have heard of HIV/AIDS and STIs; several of them knew someone suspected to have the diseases, or to have died of HIV/AIDS; and more than 90% of the discussants knew the routes of transmission of HIV/AIDS.	Better than the average for the Niger delta region
13	Prevalence of HIV/AIDS	The prevalence rate for the whole of Bonny Kingdom was 28.92% in 2003, the highest in Rivers State, but decreased to 8.3% in 2010, thanks to the control effort of the	The prevalence for Rivers State was 6.6% in 2003 and 6.0% in 2010

		Ibani-Se HIV/AIDS Initiative	
14	Household food security	65% and worsening, due to the security situation in the communities and the incessant crude oil spill caused by oil bunkering	Worse than the average for Rivers State
15	Prevalence of Childhood undernutrition	7.79% in the bigger communities and 12.9% in the smaller communities	Better than the Rivers State average of 10%, but the situation in the communities is deteriorating on a daily basis
16	Incidence of malaria	Malaria is responsible for over half of the cases seen in health facilities in the communities.	Consistent with the findings in the other communities in the Niger delta region
17	Incidence of water-related diseases,	Water-related diseases such as typhoid fever, diarrheal diseases, food poisoning and skin diseases are responsible for 25% of all the cases seen in the health facilities.	Consistent with the findings in the other communities in the Niger delta region
18	Incidence of respiratory diseases	Responsible for about 10% of the patients seen in the health facilities that serve the communities	Consistent with the findings in the other communities in the Niger delta region
19	Incidence of traffic accidents	Traffic (road and water) accidents are responsible for about 1% of the cases seen in the health facilities that serve the communities.	Consistent with the findings in the other communities in the Niger delta region
20	Prevalence of non-communicable diseases (Hypertension)	Rising prevalence of hypertension, diabetes, arthritis and other non-communicable diseases	Consistent with the findings in the other communities in the Niger delta region
21	Prevalence of non-communicable diseases (cancer)	Rare	Consistent with the findings in the other communities in the Niger delta region

22	Under-five mortality rate	About 50 under-five deaths per 1,000 live births.	This is five times lower than the average for south-south Nigeria of 109 per 1,000 live births, and significantly better than the national average of 122 per 1000
23	Maternal mortality	Maternal mortality ratio estimated at 125 per 100, 000 live births.	This is more than four times lower than the national average of 576 maternal deaths per 100, 000 live births
24	Access to primary health care	The communities are served by health centers located at Oloma, Abalamabie and Dema-Abbey, and health posts located at Sangamaand Issile-Ogono	Better than the Rivers State average
25	Patronage of traditional medicine	Fairly high	Consistent with the findings in the other communities in the Niger delta region
26	Availability of emergency medical evacuation	Not available	Consistent with the findings in the other communities in the Niger delta region

ES 5.9: Impacts Assessment

The ISO 14001 method was applied in impact assessment for this project. Project phases and activities with the attendant sensitivities were identified. The determination of sensitivities that characterize the biophysical and social environment was carried out by the environmental consultant teams (biophysical, social and health) using their knowledge of the integrated baseline data. Interactions between project activities and sensitivities were determined by a group of experts using their background knowledge of the project and its biophysical, social and health environment. Each interaction was discussed followed by an assessment as to whether the effect of the interaction was expected to be positive or negative. The identified impacts were further listed according to the phases of the project in which they are likely to occur to identify those impacts which cut across different phases of the project activities. Identified impacts were qualified based on wether they are:

- Positive or negative
- Short term or long term
- Reversible or irreversible
- Direct or indirect

Impacts assessed based on their classification and their significance. Impact significance was determined based on the following criteria:

- Legal/regulatory requirements (L);
- Risk factor (R)
- Frequency of occurrence of impact

Impacts identified were ranked and mitigation measures were prescribed for high and medium negative impacts.

ES 5.10: Environmental Management Plan

An environmental management plan has been designed for the proposed project to assess the effectiveness of the mitigation measures in controlling identified moderate and high impacts. The plan shall provide for compliance monitoring of the various environmental components.

E.S 11.0: Conclusion

The Environmental Impact Assessment Studies of the Bonny Deep Exploration and Appraisal Wells Project was carried out in accordance with relevant local, national and international regulations. The methodology applied for the study involved field work, laboratory analyses, review of previous reports and current field data within the area. To achieve this objective, a multi-disciplinary approach was adopted in the assessment of the environmental status and sensitivities of the various biophysical components. The Project is an opportunity to explore and appraise reserves in a bid to sustain gas supply to NLNG and increase revenue earnings for the Federal Government. Other positive impacts of the proposed project include but not limited to the following: increase in business opportunities, provide Opportunity for direct and indirect Employment (Unskilled labour) and Opportunity for contracting.

The identified adverse impacts were generally short-term and can be prevented, reduced, ameliorated, or controlled if the recommended mitigation measures are implemented. An Environmental Management Plan and a Monitoring Plan have been developed to ensure that the identified potential impacts are reduced to “as low as reasonably practicable” (ALARP). The EMP should therefore form the basis for the actual project implementation and future monitoring of environmental components. The approval of this EIA report for the execution of the proposed project is hereby recommended

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2	Orire mayowa	Department of Petroleum Resources (DPR)

CHAPTER ONE
INTRODUCTION

1.1: Background and Project location

Shell Petroleum Development Company of Nigeria Limited is a major oil & gas exploration and production (E&P) Company in Nigeria. It operates a Joint Venture Partnership with Nigerian National Petroleum Corporation (NNPC), ELF Petroleum Nigeria Ltd (EPNL) and Nigerian Agip Oil Company (NAOC). The proposed project will involve exploration and appraising of Wells at Bonny. Bonny Deep exploration and appraisal wells project is located in SPDC OML-11, Bonny Island, Rivers State. MEDICHEM PROJECT LIMITED was commissioned to undertake the Environmental Impact Assessment.

1.2: Objectives of the Environmental Impact Assessment

The objectives of the Environmental Impact Assessment studies for the Bonny Deep Exploration Well Project include the following:

- Acquire baseline data of the environment as well as the socio-economic and health conditions of the host communities;
- Use the baseline data to describe and characterize the study area;
- Identify the environmental sensitivities of the project area;
- Determine and evaluate the potential impacts of the proposed project activities on the identified environmental sensitivities and the interactions between the sensitivities;
- Recommend appropriate mitigation measures; and
- Develop an Environmental Management Plan (EMP).

1.3 Project Location

The Bonny field is located in SPDC"s OML-11, about 40 km southeast of Port Harcourt and approximately 6 km northeast of the Bonny Oil and Gas Terminal (BOGT) in Bonny Island, within the coastal swamp area of the eastern Niger Delta (See Figures 1 and 2). The Bonny Field was discovered in 1959 by well Bonny-2. To date, a total of 31 wells have been drilled on the shallow field level and additional wells has been drilled in the greater Bonny structures including 4 Bonny North wells, two Chobiekiri wells and two Asaramatoru wells. These wells have penetrated more than 25 hydrocarbon-bearing sands between the depths 5,500 - 13,000ftss.

The STOIIP of the shallow Bonny field are estimated at 659 MMstb and 282 MMstb, respectively (ARPR 1/1/2003). The FGIIP and UR gas is estimated at 2489 and 1706 Bscf, respectively. The field was put on stream in 1973 and attained a peak production of 38,000 bpd in 1975. Production has gradually declined to 7500 - 8000 bpd due to increasing water production.

1.4: Legal and Administrative Framework

Chapter 1 There are legislations, guidelines and standards that govern the assessment of environmental impacts of development projects in the oil and gas industry in Nigeria. These regulations can be classified as follows:

1.4.1: International Laws and Regulations

Nigeria is signatory to several laws, treaties and regulations that govern the environment. Among these are:

(i) World Bank Guidelines on Environmental Assessment {EA} (1991)

(ii) International Union for Conservation of Nature and Natural Resources(IUCN) Guidelines

(iii) Convention on the Migratory Species of Wild Animals (Bonn Convention)

(iv) Convention of Biological Diversity

(v) Convention Concerning the Protection of the World Cultural and National Heritage Sites (World Heritage Convention)

(vi) Basel Convention on the Control of Trans-Boundary Movements of Hazardous Wastes and their Disposal and.

(vii) United Nations Framework Convention on Climate Change (1992)

World Bank Guidelines on Environmental Assessment {EA} (1991)

The World Bank requires the execution of an EIA on a proposed industrial activity by a borrower as a pre-requisite for granting any financial assistance in form of loans. Details of World Bank's EIA procedures and guidelines are published in the Bank's EA Source Book vols. I - III of 1991. Potential issues considered for EA in the upstream oil and gas industry include the following:

- Biological Diversity
- Coastal and Marine Resources Management
- Cultural Properties
- Hazardous and Toxic Materials and
- International waterways.

International Union for Conservation of Nature and Natural Resources (IUCN) Guidelines, 2001

The IUCN in conjunction with the Oil Industry International Exploration and production Forum presented a set of guidelines for oil and gas exploration and production in mangrove areas. These guidelines are aimed at conservation of mangroves and enhancing the protection of marine ecosystems during E & P activities. The document also discusses the policy and principles for environmental management in mangrove areas as well as EIA procedures, Environmental Audit and Monitoring.

Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention), 1979

The Bonn Convention concerns the promotion of measures for the conservation and management of migratory species.

Convention on Biological Diversity, 1992

The objectives of the Convention include the conservation of biological diversity, the sustainable use of its components, and the fair and equitable sharing of benefits arising out of the utilization of genetic resources.

Convention Concerning the Protection of the World Cultural and Natural Heritage Sites (or World Heritage Convention), 1972

The convention sets aside areas of cultural and natural heritage for protection. The latter is defined as areas with outstanding universal value from the aesthetic, scientific and conservation points of view.

Basel Convention on the Control of Trans-Boundary Movements of Hazardous Wastes and their Disposal, 1989

The convention focuses attention on the hazards of the generation and disposal of hazardous wastes. The convention defines the wastes to be regulated and control their trans-boundary movement to protect human and environmental health against their adverse effects.

United Nations Framework Convention on Climate Change (1992)

In order to achieve sustainable social and economic development, energy consumption for developing countries needs to grow taking into account the possibilities for achieving greater energy efficiency and for controlling greenhouse gas emissions in general. This also includes the application of new technologies on terms which make such an application economically and socially beneficial, determined to protect the climate system for present and future generations.

1.4.2: Legislations guiding Environmental management in Nigeria

The Mineral Oil (Safety) Act CAP 350 LFN 1990

Sections 37 and 40 of the Mineral Oil (Safety) Act CAP 350 LFN 1990 require provision of Personal Protective Equipment (PPE) and the safety measures for workers in drilling and production operation in accordance with international standards.

Federal Environmental Protection Agency (Now FMEnv) Act No. 58, 1988

This Act, which was issued in 1988 and amended by Act No. 59 of 1992, provides the setting up of the Federal Environmental Protection Agency, as the apex organization for the overall protection of the Environment and Conservation of Natural Resources. The act also makes environmental impact assessment (EIA) mandatory for all new major projects. In compliance with its mandate, FEPA issued the procedure, guidelines and standards for the execution of EIA with emphasis on the significance associated with current and potential impacts of such projects. The procedure also indicates the steps to be followed (in the EIA process) from project conception to commissioning to ensure that the project is executed with adequate consideration for the environment.

EIA Sectoral Guidelines for Oil and Gas Industry Projects, 1995

In compliance with its mandate, FEPA issued the EIA Sectoral Guidelines for Oil and Gas Industry Projects, 1995. Contained in the Procedural Guidelines (pg. 8) are Category I projects (mandatory study activities) and listed under item 15, sub-item (a) on page 10) (Petroleum) is Oil and Gas Fields Development, making an EIA mandatory for the proposed project. The Procedural Guidelines also indicate the steps to be followed (in the EIA process) from project conception to commissioning to ensure that the project is executed with adequate consideration for the environment. Annex C contains the EIA writing format as required by FMEnv. The guidelines are intended to assist in the proper and detailed execution of EIA studies of projects in consonance with the EIA Act.

S.I. 15 - National Environmental Protection Management of Solid and Hazardous Wastes Regulation (1991) (FMEnv)

This provides that the objective of solid and hazardous waste management shall be to:

- Identify solid, toxic and extremely hazardous wastes dangerous to public health and environment,
- Provide for surveillance and monitoring of dangerous and extremely hazardous wastes and substances until they are detoxified and safely disposed,
- Provide guidelines necessary to establish a system of proper record keeping, sampling and labelling of dangerous and extremely hazardous wastes,
- Establish suitable and provide necessary requirements to facilitate the disposal of hazardous wastes;
- Research into possible re-use and recycling of hazardous wastes.

Environmental Impact Assessment Act CAP E12 LFN 2004

The Act sets out general principles, procedures and methods to enable the prior consideration of Environmental Impact Assessment on certain public or private projects. The objectives of the Act is to promote the implementation of appropriate policies consistent with all the laws and decision making processes through which the goal and objectives maybe realized. The Act also encourages the development of procedures for information exchange, notification and consultation between the organs and persons when proposed projects or activities are likely to have significant environmental effects on boundary or trans-state or on the environment of bordering towns and villages.

FEPA (Now FMEnv) Nigeria's National Agenda 21 (1999)

Nigeria's National Agenda 21 was developed to:

Integrate environment into development planning at all levels of government and the private sector,

Intensify the transition to sustainable development,

Address sectoral priorities, plans, policies and strategies for the major sectors of the economy and,

Simultaneously foster regional and global partnerships.

FEPA (Now FMEnv) National Policy on the Environment (1989)

This gave the policy goals, conceptual framework and strategies for implementation.

Forestry Law CAP 51 LFN 1994

The Forestry Act 1958 which was amended as the Forestry Law CAP 51 LFN 1994 prohibits any act that may lead to the destruction of or cause injury to any forest produce, forest growth or forestry property in Nigeria. The law prescribes the administrative framework for the management, utilization and protection of forestry resources in Nigeria, which is applicable to the mangrove, and other forests of the Niger Delta.

Land Use Act CAP 202 LFN 1990
The land-use Act of 1978 states that "… it is also in the public interest that the rights of all Nigerians to use and enjoy land in Nigeria in sufficient quality to enable them to provide for the sustenance of themselves and their families should be assured, protected and preserved".

National Inland Waterways Authority Act No 13 of 1997
This Act established the National Inland Waterways Authority with a view to improving and developing inland waterways for navigation, providing an alternative mode of transportation for the evacuation of economic goods and persons, executing the objectives of the national transport policy as they concern inland waterways. The Act also prescribes regulations and sanctions on the use and exploitation of resources of inland waterways such as dredging, sand or gravel, mining and erection of permanent structures within the right-of-way or diversion of water from a declared waterway.

Endangered Species Act CAP E9 LFN 2004
This Act prohibits hunting, capture and trade of some *endangered species* like crocodile, alligator, turtles, Parrot, etc. The Endangered (Control of International Trade and Traffic) Decree (No. 11 of 1985) has been enacted by the Federal Republic of Nigeria specifically to implement CITES. It is broader than CITES in that it also covers domestic taking of listed species. Two schedules are included: Schedule I (Endangered Species – Animals in relation to which International Trade is absolutely Prohibited), and Schedule 2 (Animals in Relation to which International Trade may only be conducted under License). The decree prohibits taking of Schedule 1 species and requires that taking of Schedule 2 species be in accordance with a license issued under the decree.

Petroleum Act CAP 350 LFN 1990
An Act to provide for the exploration of petroleum from the territorial waters and the continental shelf of Nigeria and to vest the ownership of, and all on-shore and off-shore revenue from petroleum resources derivable therefrom in the Federal Government and for all other matters incidental thereto.

Territorial Waters Act CAP 428 LFN 1990
The territorial waters of Nigeria shall for all purpose include every part of the open sea within twelve nautical miles of the coast of Nigeria (measured from low water mark) or of the seaward limits of inland waters. Any act or omission which-

(a) is committed within the territorial waters in Nigeria, whether by a citizen of Nigeria or a foreigner; and
(b) would, if committed in any part of Nigeria, constitute an offence under the law in force in that part, shall be an offence under that law and the person who committed it may, subject to section 3 of this Act, be arrested, tried and punished for it as if he had committed it in that part of Nigeria

Water Resources Act CAP W2 LFN 2004

The Water Resources Act vests the right to the use and control of all surface and groundwater and of all water together with the bed and banks in any watercourse affecting more than one state in the Government of the Federation. However, the Act essentially preserves existing rights, including customary rights, provided they are for domestic use, watering of livestock and personal irrigation schemes. A proviso to section 1(1) states that the subsection shall not be deemed to infringe or to constitute a compulsory right over or interest in property. Apparently, the idea is to separate rights over water resources from other rights in property.

Nigerian Oil and Gas Industry Content Development Act 2010

The Act provides for the development of Nigerian Content in the Nigerian Oil and Gas Industry, Nigerian Content Plan, Supervision, Coordination, Monitoring and Implementation of Nigerian content and for related matters. All regulatory authorities, operators, contractors, subcontractors, alliance partners and other entities involved in any project, operation, activity or transaction in the Nigerian oil and gas industry shall consider Nigerian content as an important element of their overall project development and management philosophy for project execution.

Employee's Compensation Act No. 13, 2010

The objectives of the Act are to— (a) provide for an open and fair system of guaranteed and adequate compensation for all employees or their dependants for any death, injury, disease or disability arising out of or in the course of employment ; (b) provide rehabilitation to employees with work-related disabilities as provided in this Act ; (c) establish and maintain a solvent compensation fund managed in the interest of employees and employers ; (d) provide for fair and adequate assessments for employers ; (e) provide an appeal procedure that is simple, fair and accessible, with minimal delays ; and (f)combine efforts and resources of relevant stakeholders for the prevention of workplace disabilities, including the enforcement of occupational safety and health standards.

1.4.3: Legislations guiding Environmental management in Rivers State

- Rivers State Environmental Protection Agency Law No. 2 of 1994
- Rivers State Private Health and Allied Establishments Authority Law, 2001
- Rivers State Public Health Law, 1999
- Rivers State Noise Pollution Control Law of 1984

1.4.4: SPDC Policies and Principles

Shell Petroleum Development Company (SPDC) operates under the guidelines of Shell International and complies strictly with them. Where national standards and regulations are more stringent than Shell guidelines, SPDC's policy is to comply with the existing national legislation.

(a) Business Principles

Shell companies have a systematic approach to health, safety, security and environmental management in other to achieve continuous performance improvement. To this end, Shell companies manage these matters as critical business activities, set standards and targets for improvement, and measure, appraise and report performance externally.

(b) Governing Policies

The SPDC 1998 Corporate Policies emerged with five Business Governing policies. Of interest to this document is the section on HSE referred to as 'Health, Safety and Environment Policy'. This policy addresses the health, safety, and environmental risks to the business and the potential impacts on staff, personnel, and the host communities. The policy reflects good practice and is mandatory.

(c) HSE Policy

It is SPDC's Policy that all activities shall be planned and executed in a manner that,

- Preserves the health, safety and security of all Company and contractor personnel and members of the public;
- Preserves the integrity and security of Company assets;
- Minimizes the impact of operations on the environment; and
- Is sensitive to the needs and concerns of the Host Communities.

The implications of implementing this policy are that,

- All activities shall be analyzed to systematically identify related hazards, risks and sensitivities;
- Arrangements shall be put in place to control the hazards, risks and sensitivities and to deal with consequences should they arise;
- Any activity which is unhealthy, unsafe, environmentally unsound or may adversely impact relations with the community, shall be suspended until an acceptable solution is found;
- All personnel, including those of contractors, shall be trained and made fully aware of the hazards, risks, sensitivities and controls in place; and
- Plans and procedures shall be in place to respond to any emergency or loss of control.

Every employee and contractor employee must plan and perform his work in accordance with this policy. Each employee is required to report, and where necessary, suspend any activity considered to be in contravention of this policy.

(e) SCiN Biodiversity Policy

''In Shell, we recognize the importance of biodiversity. Therefore, we are committed to:

- Work with others to maintain Ecosystems
- Respect the basic concept of Protected Areas
- Partner with others to make positive contributions towards the conservation of biodiversity in our areas of operations
- Conduct Environmental Assessments with increased focus on impacts on biodiversity
- Engage and collaborate with other stakeholders to manage biodiversity responsibly especially in sensitive environments ''

(f) Waste Management Policy

It is the policy of SPDC to:

- Take all practical and reasonable measures to minimize the generation of solid and liquid wastes, as well as emissions from construction equipment and otherwise;
- Manage and dispose off wastes in an environmentally responsible manner;
- Track and maintain records of waste streams and provide an auditable trail as to their management and disposal.

(g) Emergency Response Policy

This states that the response to any emergency within SPDC will be directed towards

- Saving life
- Care for the injured
- Protection of the environment
- Limitation of damage to assets
- Defense of SPDC's good corporate image
- SPDC shall provide appropriate organization, facilities, procedures and training so that immediate coordinated action can be taken to manage the situation in line with the above
- Maintenance of emergency equipment shall receive high priority. Close liaison will be maintained with appropriate Government and industry organization and communities
- Regular exercises will be carried out to confirm effectiveness, and any necessary improvements made promptly so as to maintain our readiness at all times.

(h) Community Relations Policy

In order to pursue mutually beneficial relations with host communities, SPDC shall:

- Establish and maintain close relationships with all segments of the local population to better understand their concerns, needs and aspirations
- Continuously assess and abate social and economic impact of all business activities and take needed preventive or mitigating measures
- Respond to formal community request in an appropriate and timely manner
- Bring relevant issues affecting host communities to the attention of appropriate authorities and other bodies that can be of assistance
- Manage settlement of compensation for land acquired for company operations and for damages in a demonstrably fair, accountable and transparent manner and in accordance with statutory provisions and approved procedures.

1.5: Declaration

Shell Petroleum Development Company (SPDC) in its capacity as the operator of the Bonny field hereby declares her intention to abide by the existing international and national laws and regulations regarding environmental protection during the Project phases. Shell Petroleum Development Company (SPDC) is committed to the implementation of the Environmental Management Plan (EMP) covering the Bonny field. Shell Petroleum Development Company

(SPDC) avows that it has prepared this EIA report using the best available expertise in personnel, equipment and internationally acceptable methods.

1.6: Structure **of the EIA**

The structure of the Environmental Impact Assessment Report was prepared in line with the DPR and FMEnv approved format as shown below:

- **Chapter One** - Introduction presents the background information, EIA objectives, Legal and administrative framework.
- **Chapter Two -** Project Justification, discusses the project background, project objectives, rationale for the project, envisaged sustainability, and development options considered;
- **Chapter Three** - Project Description, describes the type of project, scope, location, material input/output and by-products, waste generation, technical layout and process, operation and maintenance, project schedule;
- **Chapter Four -** Description of Existing Environment - provides information on the baseline environmental conditions of the project area describing the physical, chemical, biological, social, and health aspects of the environment
- **Chapter Five** - Associated and Potential Environmental Impacts - highlights the Associated and Potential Environmental Impacts of the proposed project;
- **Chapter Six** – Mitigation Measures/Alternatives – describes the mitigation options of impacts;
- **Chapter Seven -** Environmental Management Plan - provides the proposed plans for environmental management;
- **Chapter Eight -** Conclusion and Recommendations – provides remediation plans after decommissioning/abandonment.

CHAPTER TWO
PROJECT JUSTIFICATION

2.1 Introduction

The Bonny field is part of the Swamp East hub and it is located in a tidal swamp within the Niger Delta, which is under the influence of the Bonny river and a network of creeks. The main vegetation is mangrove, but there are patches of fresh water swamp and bush fallow plants. The main soil is saline and contains mixtures of organic remains of mangrove and inorganic sediments deposit. This is responsible for the peaty 'chicoco' nature of the soil which is characteristic pf mangrove soil.

There are a number of creeks and creeklets, the major one being the Bonny river. These water channels serve as navigational routes and are also extensively used for fishing activities. Bonny town is a densely populated and congested metropolitan town with several oil and service companies. The occupation of the people is multi-facetted and include trading, fishing and contract work. There are functional facilities such as schools, hospitals, hotels and parks.

Legislation with respect to environmental aspects of oil and gas exploration and production exist both at the national and the state levels. Applicable requirements are laid down in the ministry of Environment (FEPA) Guidelines and Standards for Environmental Pollution in Nigeria (1999), FEPA's Environmental Impacts Assessment Procedural Guidelines (1995) and DPR's National Guidelines and Standards for the Petroleum Industry in Nigeria (1991).

2.2 Potential Environmental Impact of Bonny Deep-1X Exploration Well Activities

The environmental concerns for Bonny Deep-1X exploration well activities include site preparation (dredging, sand filling, and vegetation clearance), land take, construction works, drilling operations, waste discharge, gas flaring, potential community blockade and abandonment. Preliminary assessment and mitigation plans are summarized in table 1 below. The detailed assessment is captured in the EIA data gathering and analysis in chapters 4

Table 1: Preliminary Assessment of Activities Impacts and Mitigation

SN	Challenges	Class of Impact	Potential/Actual Environmental Impacts	Mitigation
1	Dredging	Major impact and long term	Loss of aquatic life; Increase in water salinity	Perform dredging during low tide
2	Landtake (7.4132 hectares)	Minor impact and short term	Loss of mangrove areas; Disturbance to habitat; Limited thoroughfare	Expansion of existing location; Use of existing RoWs; Dredge spoil management
3	Drilling Operations (1 Gas well)	Major impact and long term	Noise during drilling; Displacement of aquatic species; Waste generation; Increase in school drop out rate; Abandonement of traditional occupations	Drill new wells from existing locations; Drill cuttings to be slurred and re-injected into approved down-hole formation; Re-use drilling mud; Assist in improving traditional occupations
4	Waste Management	Major or minor impact; Long or short term (depending on content, volume and location)	Soil; water and air pollution; Increase in health problems of inhabitants	Proper drilling waste management; No burning of oily waste in flare; Septic tanks/sewage systems; Incinerate medical wastes
5	Aqueous Effluent	Major or minor impact; Long or short term (depending on content, volume and location)	Impact on flora and fauna; Impact on community water quality	Meet regulatory requirements on effluent discharge
6	Oil Spillage	Major impact and long term	Community unrest, soil pollution; water pollution; death of flora and fauna	Oil spill contingency plan; drip plans; regular monitoring of pipelines
7	Abandonement	Major impact and short term	Community unrest, wildlife disturbance; visual impact	Adhere to guidelines

2.2.1: Envisaged Sustainability

The proposed Bonny Deep-1X well consists essentially of gas exploration well. The project is an opportunity to sustain gas supply to the NLNG and maximize the utilization of the

NLNG trains 1-6 by developing gas from Bonny field. The Bonny Deep-1X project is envisaged to be sustainable (Environmental, Technical, Economic and Social).

2.2.2: Economic Sustainability

A long-term gas sale agreement (GSA) is in place that commits SPDC to supply a significant Daily Contractual Quantity to the six NLNG trains. It is an opportunity to sustain gas supply to NLNG and maximize utilization of the Bonny Oil and Gas Terminal (BOGT) The Bonny field has proven reserves of gas that can economically and commercially support the project thereby contributing to the revenue accruing to Nigeria and SPDC.

2.2.3: Technical Sustainability

Chapter 1 This project is technically sustainable because of SPDC's proven oil and gas technology and strict adherence to internationally and nationally acceptable engineering design and construction standards. Innovative technologies that are economically viable and having minimal environmental, social and health impacts shall be utilized in the execution of the proposed project. New gas well will be drilled and transported to the NLNG trains for export abroad.

2.2.4: Environmental Sustainability

National and international regulatory and engineering design standards, innovative technologies that have minimal environmental, social and health impacts shall be utilized in the execution of the proposed project. The incorporation of the findings and recommendations of this report at the various stages of the project development and strict adherence to the Environmental Management Plan (EMP) will ensure environmental sustainability.

2.2.5: Social Sustainability

The integration of appropriate social impact assessment and community interface management mechanisms in the Project are critical success factors to the realization of overall business objectives and SPDC corporate reputation in the area. A stakeholder engagement plan has been developed and all stakeholders, especially communities, partners, regulators and other government agencies will be engaged in a proactive and respectful manner to engender participation and secure enabling environment for the Project. The deployment of GMoU and allied processes for interface management and delivery of basic community development intervention projects and programs is critical to the success of this project. Its scope will ensure that we do not create legacy issues but enhance community participation in the business through active collaboration with SPDC Community Content Team. Skills will also be developed, and business supported to enable community participation in the project execution phase and beyond. Approximately, 2.5% of project cost (CAPEX) shall be provided for the implementation of Social Performance intervention programs and projects in the impacted communities. The fund assigned for community development through the GMoU shall be paid into a joint account maintained with the communities in tranches and spread over the duration of the agreement, which will also align with the duration of that project.

CHAPTER THREE
PROJECT AND PROCESS DESCRIPTION

3.1 Introduction

The details of the scope of work, proposed project activities and waste management in the Bonny Field are presented in this chapter.

The Bonny field is located in SPDC's OML 11. The latest license renewal for OML 11 is a 20 years lease obtained by the SPDC JV in 1999 and is expected to expire in 2019. The Bonny Deep prospect is located beneath the producing Bonny North field, approximately 40 km SE of Port Harcourt.

The field was discovered in 1959 by Bonny-2 well and to date 31 wells have been drilled. These wells have penetrated 25 hydrocarbon-bearing sands between the depths of 5500 and 11050 ftTVDss

The Bonny Deep prospect is in the Coastal Swamp depobelt, eastern Niger Delta (**Error! Reference source not found.**). The prospect is controlled by the south-hading (dipping) Bonny major growth fault. The Bonny Deep prospect is bounded to the south by the Bonny Fault and to the north by the Chobie-Asaramatoru Fault.

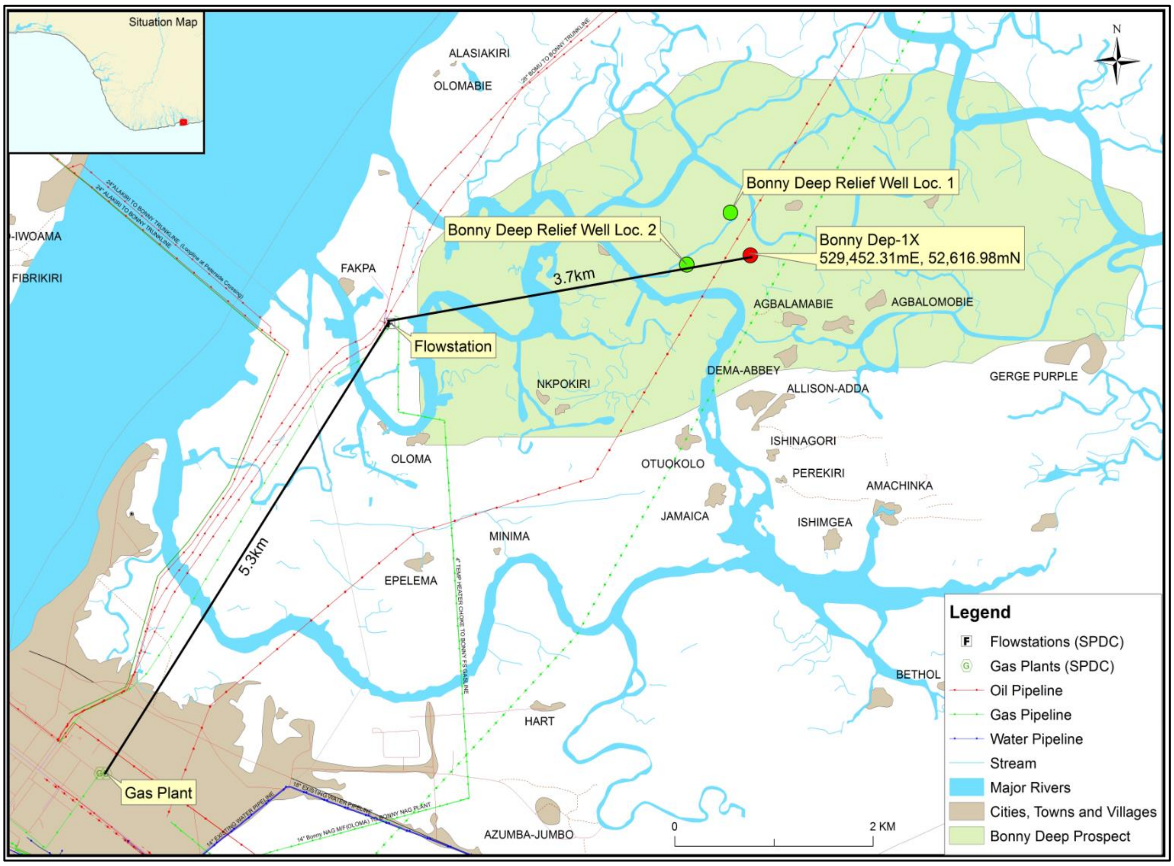


Figure 1: Location map of Bonny Deep and environs

The terrain is swamp. The prospect is located 9 Km northeast of the Bonny Gas Plant (GP) which has a capacity of 450 MMscf/day gas and 120,000 bpd liquid production. The gas from the Bonny GP is a major source of gas supply for the Nigeria Liquefied Natural Gas (NLNG).

The business driver is to prove new non-associated gas reserves to utilize ullage in the Bonny Gas Plant and meet NLNG supply obligation. Figure 2 shows the preliminary production profile of the Bonny Gas Plant indicating an OSD of 2021 for the Bonny Deep-1X well. The OSD may be brought forward to 2017 as a result of recent engagements for an Early Hookup option.

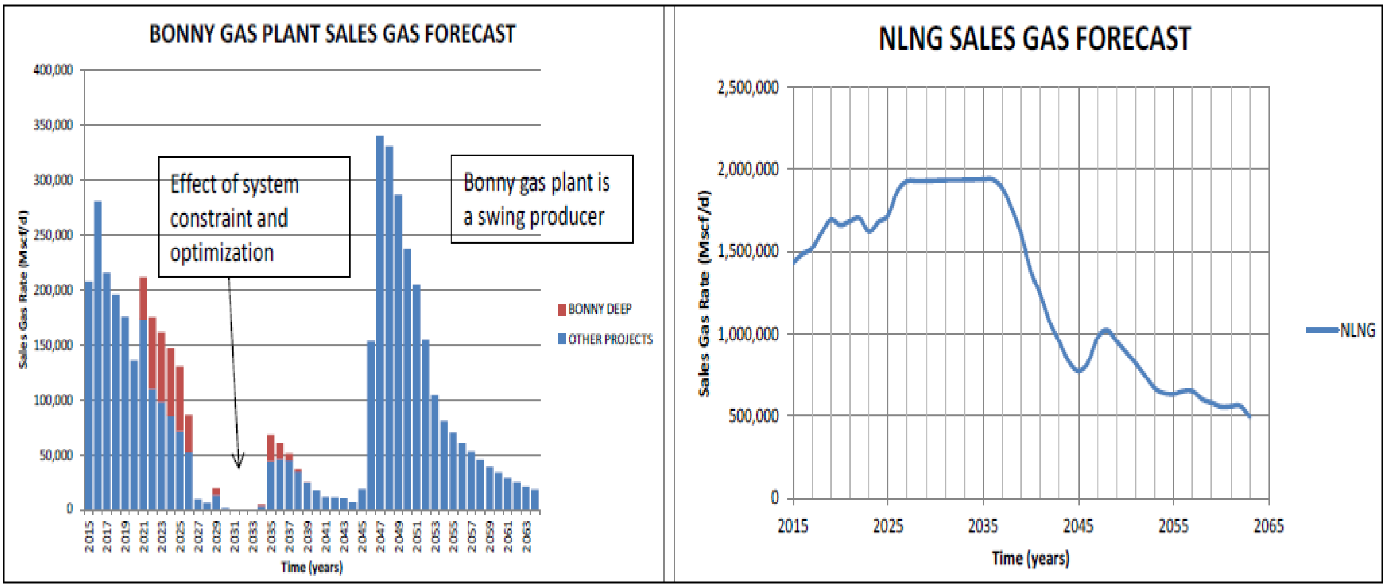


Figure 2: Production Profile Forecast

3.2 Project objectives

It is proposed to drill a deviated exploration well (maximum inclination of 15^0) to test a prospective stack of multiple fault-dependent closure with a closure area of ~7 km2 (at the shallowest target, O3000X). The Bonny Deep-1X well is planned to drill to a total depth of 15,471 ftss (15,847 ftah) and will test approximately 3,300 ft of untested stratigraphic interval containing three objective targets (O3000X, XU1000 & XU2000). The equivalence of the top O3000X has been penetrated in the Chobie block which is to the north of Bonny North field whilst the deeper targets are untested in and around the Bonny area of interest.

3.3 Proposed Project scope/Overview

The scope of drilling of Bonny Deep-1X exploration well are as follows:

i. to prove reservoir presence and quality of the O3000X – XU2000 prospective targets, establish hydrocarbon fill, fluid characteristics and basic mobility (composition, pressure, permeability etc) to a maximum TD of 15,243 ftss (15,714 ftah)
ii. There exists an opportunity to complete the O3000X – XU2000 using bottoms-up philosophy, in the case of success

If successful, the well would be safely suspended. This would be followed by completion and hook-up as specified in the notional development plan.

3.4 Well Casing and Completion Design

The approved well design following a Well Verification Board Review is shown in (Figure 3). The $9^{7/}{}_{8}$'' casing would be set in the shale below O3000X at 14,000 ftah within the predicted pressure ramp. The $8^{1/}{}_{2}$" hole section is not intended to penetrate the XU2000 because of the second pressure ramp expected across the XU2000. The $9^{7/}{}_{8}$'' casing shoe strength prognosis is not sufficient to allow drilling into the XU2000 with a possible maximum case pore pressure of 0.83 psi/ft at the base of the sand. The final well section would be a 6'' slim hole that would be drilled to a final total depth of 15,423 ftss (15,714 ftah) in open hole and plugged backed or cased off depending on the size of the hydrocarbon discovery. The shoe strength at the 7'' liner shoe can handle the equivalent circulating density and any influx taken while drilling across the XU2000 sand.

The well design is based on the following considerations:

i. Surface casing depth takes cognisance of the shallowest hydrocarbon (M1000 at 5,595 ftTVDss) which is expected to be encountered along the proposed well path, hence the surface casing is planned to be set at 5,000 ftah just before encountering the M1000 sand
ii. In addition to the high case pore pressure prediction, the mud weight is design to check borehole stability
iii. Incorporated learnings from offset Wells and recent HPHT drilling campaign at Gbaran-26, Gbaran-27 and Kolo Creek-41
iv. Case-off depleted sands (M9500 reservoir) before traversing HP reservoirs
v. Shallow hazard assessment and proposed mitigation measures

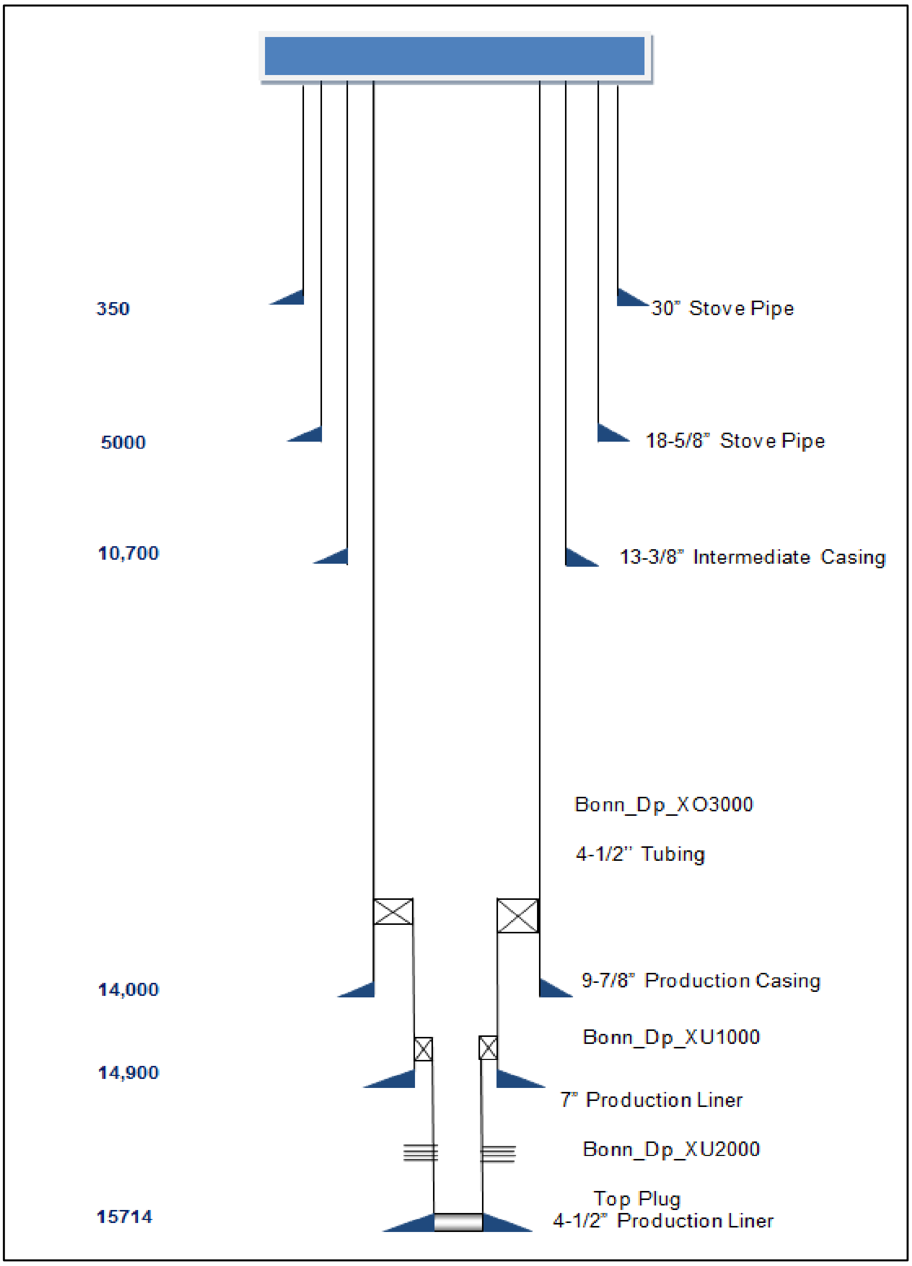


Figure 1: Well schematics for the proposed Bonny Deep-1X Well

The well is planned to be initially suspended for future completion based on the notional development plan. The plan for Bonny Deep-1X is to complete the reservoirs using a bottoms-up philosophy. The completion design is a case and perforate completion configuration with a tubing retrievable surface controlled subsurface safety valve and a permanent down-hole gauge (Figure 4). The perforations would be achieved under-balance with a tubing conveyed perforation system and the well completed with a 4½", 13Cr corrosion resistant alloy tubing and nickel-based alloy for the tubing accessories. The key features of the preferred completion scheme are as follows:

- Surface Safety Valve,
- Permanent Down-hole Gauge,

- Tubing Conveyed Perforation
- Surface Sand Detectors.

Although this completion scheme does not provide down-hole sand production protection, it is a simple and robust design similar to that planned for Gbaran-26 and has a high chance of being successfully deployed.

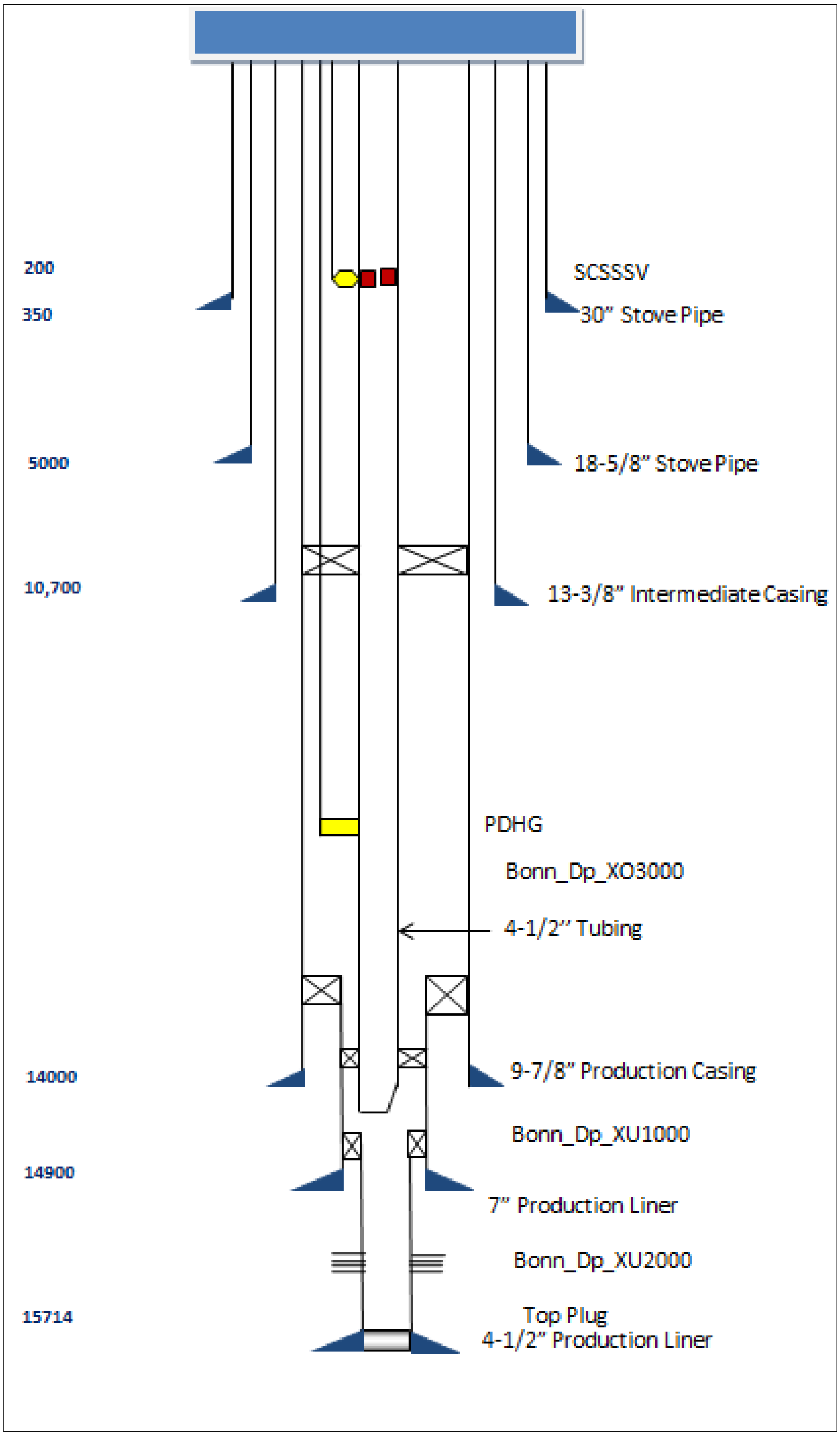


Figure 2: Bonny Deep-1X proposed completion design

3.5 Well Blow-out Analysis

The proposed completions have been designed to mitigate the basic risks of loss of control/blowout and ignition/wellhead fire. In the unlikely event of a blowout, a relief well will be drilled to intersect the blowing well at the top of the reservoir with a high kill fluid density of to kill the blowout well. The proposed relief well locations for Bonny Deep-1X are shown in Table 2 and Figures 5 below. Opportunity exists for further optimization where other locations become available before commencement of the drilling phase. After drilling the top hole with water-based mud (WBM) and the intermediate section with Pseudo-Oil Based (POBM) mud, the reservoir section will be drilled with WBM (Thixal system for gas and carbonate system for oil). This will provide the required overbalance and these sections will be cased off with a 9 5/8" casing or 7" liners or open hole completions. After cementing and testing the casing/liner, the wellbore cleanup will be done by displacement to standard 0.47 psi/ft Calcium Chloride or thixal brine to provide the right over balance. Oxygen scavenger and pH lower than 10 are required to ensure completion integrity. It should be noted that the low annular fluid weight also reduces the downhole completion equipment pressure rating requirements due to lower anticipated differential pressures.

Table 2: Well Status and Coordinates

Well	Location Status	Northings	Eastings
Bonny Deep-1X	New	52616.98	529452.31
Bonny Relief Location 1	New	53033.00	529251.00
Bonny-001 Potential Relief Well Location	Existing	528810.67	52527.31

3.6 Proposed Relief Well Locations

The Bonny Deep well is ranked as a Red (5D) in the Process Safety Risk Assessment Matrix in the event of a blowout. A Relief Well is a Process Safety requirement for the Bonny Deep well. As per the Shell Global Wells Relief Well Manual, the following guidelines was adopted to plan for the relief wells.

- Minimum of two suitable rig locations identified for two relief well locations
- Minimum surface location lateral distance of 1,500 ft (457 m) between wells
- Relief well inclination shall be less than 60°
- Incidence angle between relief well and target well shall be less than 8°

Two locations have been identified for the relief well location with the same considerations that was used for the Bonny Deep-1X location, namely:

- A minimum distance of 500 m from the wellhead to community will be maintained
- A minimum distance of 200 m from pipelines or pipeline ROW in order to leave a suitable buffer between SPDC acquired area and the existing pipeline.

The regulatory requirement to identify and select a potential relief well location for every planned HP drilling activity. This allows for minimal efforts at executing relief well drilling if/when the need arises. The preliminary simulations suggest that this is a Tier one well hence two possible relief well locations are required. These were identified and carried as possible options for drilling a relief well. These are Bonny-007/007ST1 and Bonny-001 well locations.

- To arrive at these locations the following factors were considered:
- Distance of each location from the HP drilling site
- General wind direction at the planned time of year for drilling the HP well
- Access to the proposed relief well location
- Land acquisition requirements
- Well path from potential location to HP well trajectory; and
- Proximity of relief well location to settlements

3.6.1 Bonny Relief Well Location 1

The Bonny-007 location (X = 529251.00 & Y = 53033.00, Nigeria Mid Belt, Minna Datum) is at a distance of 640 metres from the Bonny deep well location. This is higher than the minimum 457 metres that is required to ensure safety of personnel and equipment (Figure 4)

3.6.2 Bonny-001 Potential Relief Well Location

An alternative location considered was Bonny-001 location (X = 528810.67 & Y = 52527.31, Nigeria Mid Belt, Minna Datum is at a distance of 462 metres from the Bonny deep well location. This is slightly higher than the minimum 457 metres that is required to ensure safety of personnel and equipment (Figure 4).

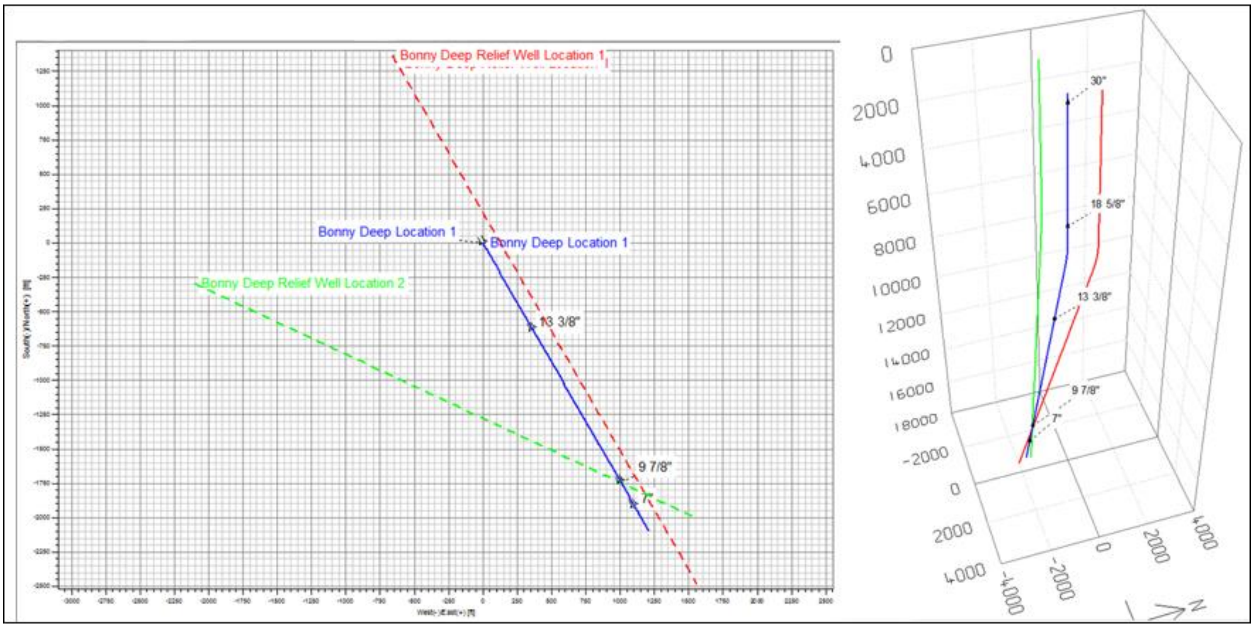


Figure 3: Section view showing trajectories for the relief well options for Bonny Deep-X

3.7 Well Testing Options

The well testing will be carried out through a dedicated flare pit and bund wall. This is recommended to be built as follows:

i. Construct the flare pit close to the wellhead and within the Bonny Gas Plant manifold
ii. This construction activities will be part of the early hook up activity schedule

Testing is to be done via the Bonny Gas Plant with consideration for the following:

i. Limitations of backpressure from the gas plant
ii. The test relies solely on shut down of the gas plant

3.8 Well Clean-Up

The wells will be cleaned up using coiled tubing assembly applying underbalanced clean-up technique to lift the well (~500 ft from the sandface) via dedicated test facilities, i.e., if the well can flow by itself. If the well could not sustain flow, coil tubing plus liquid nitrogen will be deployed to enhance lift. The underbalanced clean-up technique will help to remove the mud filter cake and other solids plugging the formation pores. The clean-up recipe will be designed such that a complete filter cake removal is achievable with minimum losses into the formation.

3.9 Project activities

3.9.1 Pre-mobilization

Pre-mobilization activities shall include community and other stakeholder engagements and land acquisition. This phase will also include designs and off-site fabrications of modules, pipes etc. During this phase, SPDC shall carry out pre-mobilization inspection of all items/personnel to be mobilized to site. All equipment and personnel mobilized to site shall be certified fit for purpose and approved by SPDC before deployment to site.

3.9.2 Mobilization Phase

This phase will involve:

1. moving construction equipment (dredger, bulldozers, excavators, graders, rollers, pay loaders, asphalt pavers, tippers, trailers, swamp bogey, generators, self loaders, cranes, crew bus, 4 wheel-drive truck, welding sets, flushing pumps, Hydro testing unit, generators, compressors, bending machine, grit blasting unit, oxy acetylene torch, line up clamps, cold cutter, x-ray units, thrust boring machine etc) from Contractor's base to site.
2. Movement of temporary offices and accommodation to site.
3. Set up site office and yard (telecommunication masts, temporary sewage system, messing facilities).
4. Movement of personnel from Contractor's base/ SPDC office to site by road.
5. Movement of rig to site (this is captured as part of mobilization for the purpose of impact assessment although this comes after well location preparation).

3.9.3 Well Locations Preparations

Well location preparations shall typically involve vegetation clearing, dredging, sand filling, pilling, concrete, etc. The well locations will be surfaced with asphalt to prevent groundwater and soil contamination. In addition, pits will be constructed to capture surface run-off. The pads will be graded so that rainfall on the active portions of the pad will be directed into the pit. Areas for storage of fuel, lubricants, chemicals, solid waste, produced oil, and waste oil will be designated within the well site area to protect the environment, and minimize possible fire and explosion hazards.

Well site construction in a seasonally flooded terrain is typically carried out over a period of 12 months. The number of personnel expected to be working at any point in time during the construction of the access and locations will normally be approximately 70 (seventy) persons. The activities that will be involved in the location preparation in the various fields are described below.

3.9.4 Drilling Workscope and Activities

Logging

This is the electrical/nuclear investigation of the drilled well to ascertain the lithology and fluid content. The interpretation of the log data gives an indication of the presence and the quantity of hydrocarbon (in this case gas) in the formation.

Completion

This is the process of hooking up a well for production. The process involves logging, well-bore clean-up, perforation, production testing, sand consolidation and installation of the Christmas tree. The completion of the drilling will be the hooking up to the field manifold.

Clearing and grading

The working width shall be cleared of trees and hedges. Ditches shall be flumed by installing pipes and ramped over with subsoil to give a continuous running track through the fields. Topsoil shall then be stripped across the working area and stored at one side. An area of the working width adjacent to the stored topsoil shall be designated as a running track for vehicular movements.

Reinstatement

At the end of site works, contractor shall ensure that the RoWs and work sites are properly cleaned up and reinstated. Although it is manifestly impossible to restore the route traversed by the pipelines to the exact condition in which it was before work started, the general aim should be to make it as nearly as possible. All the debris of construction shall be removed to Shell's approved site. Shell shall issue to the Contractor a Site Restoration Certificate on satisfactory completion of site re-instatement, which is a prerequisite for contract payment.

3.9.5 Risk of Accidents Resulting in Pollution or Hazards

Blow outs and tank leaks are potential causes of accidental spills during drilling activities. A blow out is an uncontrollable discharge of hydrocarbon from the formation. Though the chance of a blowout is very low, the potential impact on environment is very high. The primary safeguard against a blowout is the pressure exerted by the drilling mud. The mud shall be tested/checked regularly (every 15 minutes on site) to ensure the properties and weights are in order. The secondary control is the equipment referred to as Blow Out Preventer (BOP) with surface safety valves. This equipment shall be used to close in a well at the slightest detection of formation fluid ingress/flow into the well bore (mud system). This equipment shall be tested regularly to ensure proper functionality. Increased land and air logistics, which will result from movement of materials and workers to site, are another potential cause of accidents during drilling construction. Proper logistics management will be put in place as a safeguard.

Based on the nature of the project, activities that will be carried out during project execution, which may impact on the environment include: Location preparation, Vegetation clearing, Sand filling, Piling, Construction of camps, access road, locations and other civil works, Drilling of NAG wells, Laying of flow lines, construction of manifolds and other facilities, etc. These activities will involve human and equipment presence at sites and all waste handling during execution will be in line with all statutory and company guidelines.

3.9.6 Techniques for river crossing

The Bonny River and its creeks and creeklets are found in the project area. The Open cut method shall be considered at minor river crossing. For the major and medium river crossings, HDD, floatation method or push and pull method could be employed, however CONTRACTOR shall assess the areas at the time of construction and propose suitable construction methods for COMPANY's approval. River
and Creek Crossings

At creek/river crossing, the following RoW extent shall apply:

i. Medium size creeks/water crossings of between 50m and 200m, the ROW shall be 30m.
ii. Major water crossings wider than 200m, the RoW shall be 60m.
iii. On each bank of the crossing, the enlarge RoW width shall extend 30m inland from the bank.

3.9.7 Decommissioning, Abandonment and Restoration

The decommissioning of the project facilities shall involve these main activities:

i. Determining the regulatory requirements
ii. Evolving a community involvement strategy
iii. Establishing future land use objectives
iv. Determining objectives of the mothballing plan
v. Determining remediation requirements
vi. Determining reclamation objectives
vii. Developing a HSE plan

Facilities	Decommissioning
Wells	Leave potable water wells as agreed with local authorities; isolate production interval to prevent communication between aquifers of different nature or salinity; isolate from the surface; plug and abandon downhole according to applicable guidelines; place surface cement plug below the cellar to allow removal of surface components; backfill to surface.
Concrete and steel structures including concrete foundations, wellhead cellars, skid foundations and telecom masts, gratings, buildings (including workshops, offices, houses, etc.) and bridges.	Remove steel structures for reuse or recycling; remove wellhead cellar to 1 m below soil surface; remove concrete foundations and slabs down to soil level (unless abandoned in place for future use); break up concrete slabs at ground level into 1 m2 to allow vegetation to regrow through the fissures or remove completely according to proposed end land use; remove buildings or leave in place for reuse; provide access controls for physical structures remaining on-site, that are unsafe or hazardous to humans or animals.

Table 3: Decommissioning strategy

All wastes generated in the course of project execution will be handled in line with existing statutory and SPDC Waste Management guidelines.

3.9.8 Waste and/or By-Products Generated

This section describes the waste and by-products that could be generated during drilling activities.

Drilling Waste

The drilling waste management principles in this project will focus on waste minimisation and recycling. The wastes that will be generated during the drilling operations are:

i. Drill cuttings / excess
ii. Spent drilling mud and completion fluids
iii. Rig wash (Detergent) water
iv. Cementing waste
v. Discarded consumables
vi. Domestic waste (solid and sewage)
vii. Drilling effluents (waste water)

Table 4: Estimated Waste Volume Forecast

Activity	Waste	Amount
Drilling	WBM Cuttings	266.7 m3/well
	SBM Cuttings	114.3 m3/well
	Plastic drums	<1T
	Metal drums	<1T
	Sewage	11 m3/month
	Grey water	50 litres/person/day
	Spent Water Based Mud	101.6 m3/well
	Spent Synthetic Based Mud	154.41 m3/well
Others	Office waste	1.0 kg/day
	Medical waste	1.5 kg/day
	Kitchen waste (food waste)	10 kg/day

Waste water shall be treated and used for building new mud and also for the rig and equipment washing. Drill cuttings disposal will be carried out based on if they are generated by a water or an oil-based drilling fluid system. The wastewater and drilled cuttings from the drilling operations will be channeled into waste pits. A pay loader shall be used to scoop out the drilling waste from the waste pit into cutting skips. The cuttings will be washed and used for construction purposes while the waste fluid will be injected into DPR and FMEnv approved re-injection wells. While for oil based system cuttings will be washed and taken to a Thermal Desorption Unit (TDU) in compliance with FMEnv / DPR directives.

Non Drilling Waste

Discarded consumables include unused drilling chemicals, chemical/material bags, scrap metals used in constructions etc. All these will be trucked back to Kidney Island base in Port Harcourt for recycling. A strict inventory control of all chemicals in use shall be maintained. All chemicals, lubricating oils and fuels will be stored in containers and safely placed in a sheltered area on the rig. Appropriate Safe Handling of Chemicals (SHOC) cards will be provided for every chemical on board the rig for the safety of personnel and the environment.

Human Waste

All human wastes shall be treated on site using international standard in-built biological sewage treatment plants. This provides an excellent way of handling all human wastes on board the rig. Under normal circumstances, the total number of personnel on board the rig is not expected to exceed one hundred (100).

Waste Generation Forecast

The Project aims at a maximum of 1000 Personnel at the peak of the project. Allowing for occasional visitors, waste generation has been estimated with 1000 personnel working all – time – across all Project sites. Using a weighted average waste generation of 1kg/capital/day, the rate of waste generation is estimated as shown in Table 5.

Table 5: Estimated Rate of Waste to be Generated

WASTE	RATE OF WASTE GENERATED
Sewage	24lit./day/capita
Food wastes (vegetables/ putrescible)	300 kg/day
Glass wastes (burnt bulbs, broken bottles, glass plates and cups)	42 kg/day
Hazardous wastes (e.g. paints, thinners, aerosol cans)	10 kg/day
Plastics wastes (cans, polyethylene/ urethane packaging, plates, bags)	150 kg/day
Wood and Paper	260 kg/day
Metal Waste	190 kg/day
Batteries from cars, calculator, radios torches, cameras	0.2 kg/day
Textile (e.g. used Hand Gloves non-oil soaked rags)	40 kg/day
Saw Dust	2.2 kg/day

Table 6: Waste Identification, Handling and Disposal

WASTE TYPE / WASTE NAME	Handling			Minimization / Disposal Method /Facility
NON-HAZARDOUS WASTES				
Domestic	Color Code of Bin	Storage	Transportation	
Food/Kitchen Wastes	Green	Keep either in their bins or neatly packaged in a well labelled polythene	Either in their bins or neatly packaged in a well labelled polythene inside a covered truck	Land farming.
Garden Waste	Green	Move to designated storage site in the facility	Transport in covered vehicle with fully completed WCN (Waste Consignment Note)	Move to government approved dumpsite

WASTE TYPE / WASTE NAME	**Handling**			**Minimization / Disposal Method**
Garbage	Green	Can be sorted to recover recyclable items	In covered truck with fully completed WCN	Move to government approved dumpsite
Plastic	Brown	Collect & store temporary in recyclable Waste depot.	By land transport to RWD (Recyclable Waste Depot)	Sell to third party for recycling.
Wood	N/A	Store at designated scrap yard	Transport in trucks	Dump at approved dump sites or landfill/Sale to vendors
Office				
Toner cartridge	Navy Blue	Good Housekeeping procedure	Collected with the waste bag closed and transported with appropriate label for recycling	Reuse. Move to WRD – (Waste Recycling Depot), IA, P/H
Paper	Grey	Store under waste shed before moving to RWD	Transport to Recyclable Waste Depot	Recycle; sell to third party for recycling
Industrial				
Glass	Blue	Store in RWD	Transport in closed waste bag with appropriate label to RWD	Recovery & Recycling; Send to glass manufacturing company
Scrap metal	NA	Store in designated areas in the facility	Transport In vehicle/trucks fit for the type of metal to be moved	Re-use, recycle; Move to a WRD (Waste recycling Depot), IA
Cans and Tins	Black	NA	It shall be collected by waste contractor with the waste bag closed and transported with appropriate label to SPDC dumpsites	Dispose at SPDC approved dumpsite

WASTE TYPE / WASTE NAME	**Handling**			**Minimization / Disposal Method**
Computer Scraps & Consumables	N/A	Arrange neatly in a cool dry place	In covered truck with fully completed WCN	Move to the WRD, IA, PH
Oil/Fuel Filters	Blue	Drain oil, cut open to remove diaphragm and crush metal case	In trucks to the scrap metal yard	Send to designated scrap yard where the waste contractor collects them from
Oil Rags	Red Bin	Store in covered plastic bin	In covered truck to disposal site	Incinerate at TDU (Thermal Desorption Unit
WASTE TYPE / WASTE NAME	Handling			Minimization / Disposal Method /Facility
NON-HAZARDOUS WASTES				
Industrial Contd.	Color Code of Bin	Storage	Transportation	
Cables	NA	Neatly keep in the Waste depot	In covered truck to disposal site	Re-use; Can be sold to a vendor for re-cycle and reuse
Pigging Waste	Red	Store in Drums and transport to TDU at Bonny	Move to TDU	Burn off in Thermal Desorption Unit (TDU)
Absorbents	NA	Store in storage bins	In Covered Trucks	Burn off in TDU
Spent Oil		Store in dedicated pit	Transport in appropriate drums or tankers.	Collect in dedicated pits and sent to waste oil collector
Construction Debris	NA	Move neatly to a corner	Mostly done in open vehicles, depending on the size and location for reuse	Reuse in minor road mending
HAZARDOUS WASTES				

WASTE TYPE / WASTE NAME	**Handling**			**Minimization / Disposal Method**
Clinical Waste	Red	Neatly place in black polythene before putting in the red bin.	Transport in sealed bags to SPDC IA incinerator	Incinerated at high temperature in IA.
Fluorescent bulb	Red	Arrange neatly to avoid breaking	In covered truck with fully completed WCN	Recycle; Sell to vendor to recycle mercury.
Sewage	Red	Septic Tanks	The same hauler truck that pumps out the sewage can be used to transport and dispose the sewage	Stock pile in a cool dry place pending the final decision on appropriate disposal option
Chemical drums	Red	Segregate drums and store in compatible groups	In covered trucks	Crush metal drums and sell as scrap. Sell plastic containers to recycling companies.
Spent Batteries	Red	Arrange neatly without breakage in a cool dry place	In covered truck with dully completed WCN	Recycle/Recovery; Move to Recyclable Waste depot (RWD)
Spent Chemical	Red	Store in dedicated pit	Transport in appropriate drums or tankers.	Collect in dedicated pits and sent to waste oil collector

CHAPTER FOUR
DESCRIPTION OF THE EXISTING ENVIRONMENT

4.1: General

Environmental Impact Assessment procedure involves the use of adequately planned techniques and well-structured analyses to establish the environmental condition (status) of a proposed project area. This environmental status will provide the basis for identification of potential impacts of the project activities on the environmental receptors/ecological system and the resource use of the area. In addition, information on the existing environmental status of the proposed project area shall serve as a reference data for further studies and environmental monitoring. This chapter presents the environmental baseline description of the proposed Bonny Deep exploration and appraisal wells project located in SPDC OML-11, Bonny Island, Rivers State. Details of the methodologies adopted for data acquisition for each of the environmental components and the Impact indicators are described in succeeding sections.

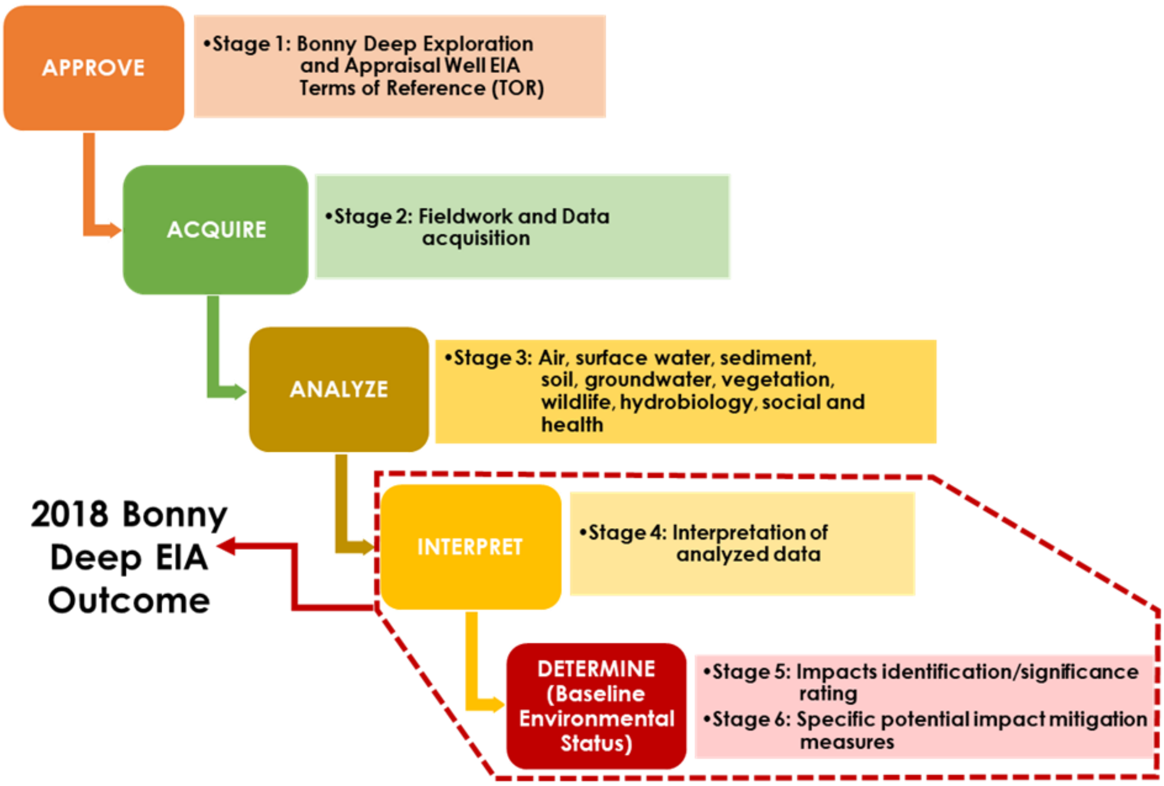


Figure 4.1.1 Systematic and structured procedures adopted for the Bonny Deep EIA

4.2: Data Acquisition

The ecological, social and health baseline information was obtained using a multi-disciplinary, one-season field data gathering exercise carried out between May 2nd and May 22nd, 2018. Following the TOR strictly, data was acquired on key environmental components that include wildlife, vegetation, soil, air, sediment, surface and groundwater, socio-economy and health (Table 4.2.1). Data acquisition and analysis were in accordance with the standards of international best practice. Figure 4.1.1 summarizes the major resources, processes, procedures and actions that led to the results discussed in this chapter. A baseline description of the environmental and social characteristics of the project area of influence is presented in order to establish, before the execution of the project, the status of the various environmental components that are likely to be affected by the project.

Table 4.2.1: TOR/Scope of work for the EIA of the Bonny Deep exploration and appraisal well project

S/N	Sample	Sample Type	Analysis	Parameters
1.	**Soil** **24 + 2 control** Soil samples shall cover the proposed Bonny Deep Wells locations, ecological features (wetlands) and communities/settlements within the project area	Surface (0-15cm) Subsurface (15-30cm)	Physico-chemical	pH, TPH, PAH, THC, BTEX, Phenols, Percent carbon, Available PO_4^{3-}, Total-N, NH_4^+, NO_3^-, NO_2, Na^+, K^+, Ca^+, and Mg^+, cation exchange capacity, (CEC), conductivity, oil & grease, heavy metals (Fe, Cd, Cr, Pb, Cu, Hg, Ar, Ni, V and Zn, Ba, As)
			Soil characterisation/classification	Texture, grain size analysis, porosity, permeability, bulk density, erosion potential
			Microbiology	Total heterotrophic bacteria and fungi, Total hydrocarbon utilizing bacteria and fungi
2.	**Sediment** **20 +2 controls** Sediment shall be sampled downstream and upstream direction on the Bonny River and its associated channels (creeks, and creeklets) within the defined study boundary	Composite Grab samples	Physico-chemical	pH, THC, Percent carbon, Available PO_4-P, Total-N, NH_4^+, NO_3^-, NO_2^-, Na^+, K^+, Ca^{2+}, and Mg^{2+}, Redox potential, oil & grease, heavy metals (Fe, Cd, Cr, Pb, Cu, Ni, V and Zn)
			Microbiology	Total heterotrophic bacteria and fungi, Total hydrocarbon utilizing bacteria and fungi
			Sediment characterisation	Colour and texture
			Benthos	Benthic macro-invertebrate studies – identification to the nearest taxonomic level as well as their species distribution, abundance,

				diversity and density
3.	**Surface water** **20 + 2 control** Surface water shall be sampled downstream and upstream direction on the Bonny River and its associated channels (creeks and creeklets) within the defined study boundary	Composite	Physico-chemical	Colour, alkalinity, TDS, TSS, Turbidity, EC, THC, pH, DO, Redox potential, BOD_5, COD, Oil and Grease, Anions/Cations, NH_4^+, NO_3^-, NO_2^-, PO_4^-, SO_4^{2-}, SiO_2, Na^+, K^+, Ca^{2+}, Mn^{2+}, Mg^{2+}. Heavy metals (Fe, Cd, Cr, Ni, V, Pb, Zn, Hg)
			Microbiology	Total heterotrophic bacteria and fungi, Total hydrocarbon utilizing bacteria and fungi
			Phytoplankton	Identification to the nearest taxonomic level, species diversity (composition, distribution and density) and productivity.
			Zooplankton	Identification to the nearest taxonomic level, species diversity (composition, distribution and density)
			Fisheries	Species types and distribution, catch assessment survey (CAS), breeding sites, migration routes, pathology, fisheries activities.
			Aquatic macrophyte	Identification and spatial distribution, biomass per unit area covered, including submerged vegetation, floating and emergent/bank types, *aufwuchs** density
			Hydrodynamics	River water depth and width, flow direction and flow rate. River bed current, and tidal information, bathymetric data etc.
4.	**Ground-water**	Composite	Physico-chemical	Temperature, pH, salinity, EC, DO, Turbidity, THC, Redox potential, oil and grease, anions and cations,

	3 + 2 control Boreholes shall be drilled within the 2km radius of the Bonny Deep field. Two control stations shall be drilled outside the spatial boundary (2km radius) of the field.			heavy metals (Fe, Cd, Cr, Pb, Cu, Ni, V and Zn)
			Hydrodynamics	Water table depth, flow direction and rate
			Microbiology	Total heterotrophic bacteria and fungi, Total hydrocarbon utilizing bacteria and fungi
			Hydrogeology	Stratigraphy of the initial underground layers
			Log analysis	Physico-chemical and heavy metal characterisation
5.	**Vegetation** Vegetation transects shall be located at the cardinal points that run parallel to the proposed well locations and to the slope of the wetland beginning at the upland edge	**Transect area	*In situ* study	Vegetation types, floral composition
			Herbarium studies	Sampled/field unidentifiable plant species
			Plants and crops pathological studies	Identification of health conditions, insect pests, fungi, bacterial and viral disease of crops around the field and associated villages, farmlands or plantations, plant tissue analysis
6.	**Wildlife**	Transect/ Visual observation	Mammals, reptiles, birds, amphibians and invertebrates	Diversity, distribution, density, conservation status, formal/traditional conservation practices, wildlife exploration methods

7.	**Air Quality** **24 + 2 control** Air quality/noise shall cover the proposed Bonny Deep Wells locations, Bonny River and its associated creeks and creeklets, ecological features (wetlands) and communities/settlements within the project area.		Physico-chemical	SO_x, NO_x, VOC/HC, Particulates, CO, CO_2, NH_3, soot
8.	**Socio-economic**	Demography, Social Structure and Organization, Livelihood, Social Infrastructure, Cultural Properties, Natural Resources and Land Use, Perception of the project, the role of women and children, Physically Challenged, Vehicular Traffic Analysis, Sex Trade		

4.3: Baseline Environmental Conditions

4.3.1: Climate and Meteorology

The study area is located in the humid tropical Niger Delta region of Nigeria, characterized by distinct wet and dry seasons. The dry season occur between November and March while the wet season is from April to October. The climatic information for the project area is based on the analysis of the climatic data of the study area collected from NIMET Oshodi, for Port Harcourt and Bonny. The climatic data spanned from 1983 to 2005. Meteorological data were also collected at twenty-four locations within the study area during the field data gathering process.

Temperature

Latitude is the main determinant of temperature. Other determinants like atmosphere, ocean currents, and altitude also influence temperature. The type and density of clouds influence the amount of solar radiation that reaches the Earth's surface. Some parts of Nigeria often experience overcast skies during the wet season. One of such areas is Port Harcourt in the southern part of the country. The amount of solar energy received, and the extent of energy losses drives a climatic system. Warm tropical ocean currents hardly affect Nigeria's temperature regime so also altitude does not alter the temperature regimes in Nigeria. Nigeria experiences consistent high temperatures all year round between 25-31ºC (Ologunorisa, 2011). The extreme coastal areas recorded temperatures in the range of 30.0 – 32.0°C according to Nigeria Climate review 2010 (NIMET, 2010). Furthermore, the southern region recorded minimum temperatures ranging from 20.0 to 24.1ºC.

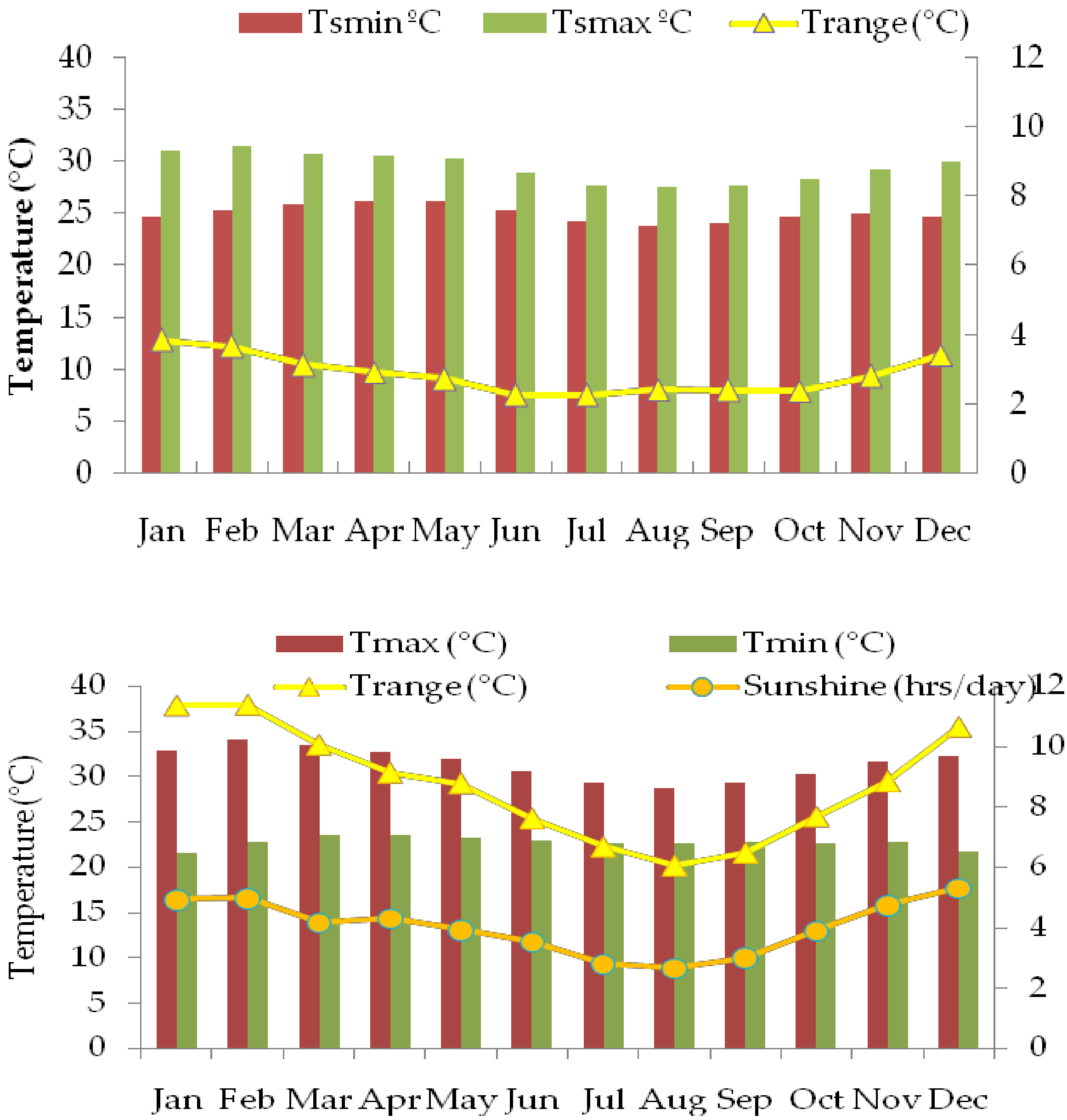


Figure 4.3.1.1: Monthly Average Minimum and Maximum Temperatures, Temperature Range and Sunshine Hours for Port Harcourt/Onne/Bonny Axis (a) 10m above the Earth (NASA) (b) Temperatures on the Earth's surface (NIMET)

Climate change is a change in the state of the climate that can be identified (eg. using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period typically decades or longer" IPCC (2007). Climate fluctuations or climatic variability occurs on shorter temporal scale. The most crucial things about the concept of climate change is not only the time periods involved but also the degree of variability that the change is subjected to as well as the duration and impact of such variability on man and the ecosystem. In the tropics, the lowest temperature during each day described as minimum temperature is experienced during the night while maximum temperatures are recorded during day time. In the Port Harcourt/Onne/Bonny axis and in Nigeria as a whole, the highest maximum temperatures are recorded in February, while the lowest maximum temperatures are recorded during the month of August. The 22 year average monthly temperatures for the period 1983 – 2005 from NASA is shown in Figure 4.3.1.1a while that of the period 1993 – 2001 including sunshine hours from NIMET is shown in Figure 4.3.1.1b . The annual temperature pattern in the two figures is essentially the same as described in the preceding paragraph for Port Harcourt/Onne/Bonny axis and in Nigeria as a whole. The only difference between them is the daily temperature range which is about 4°C for the dry season and drops to a low of 2.2°C in the wet season as compared with the respective 11°C and 6°C for the NIMET data.

Rainfall

Rainfall distribution both spatial and temporal is the single most important factor in differentiating seasons in the tropics. Rainfall occurrence and distribution in Nigeria are however dependent on the two air masses that prevail over the country. The Nigeria Climate Review 2010 noted that the southern part of the country experienced rainfall between 3000 – 4500mm. Some areas recorded higher than normal rainfall conditions and included some areas in the southwest and Ogoja, Calabar and Eket in the southeast. In 2010, the highest daily rainfalls of 199.5mm, 184.6mm and 183.8mm were recorded at Uyo (June), Benin (September) and Umuahia (June) respectively (NIMET, 2010).

Historical records show that the months of July, August and September have the highest precipitation while December, January and February record the lowest rainfall (Ologunorisa and Adejuwon, 2010). Table 4.3.1.1 shows the pattern of rainfall during the dry season (November - February) and wet season (March - October) which is typical of tropical rain forest covering Port Harcourt, Onne and Bonny areas. The Table indicates the mean annual rainfall for Port Harcourt to be 2370.5mm and that of Onne/Bonny to be 2438.4mm. Warri has the highest annual rainfall of 2907.8mm in the Niger Delta followed by Calabar (2903.8mm) and Onne

Table 4.3.1.1: Summary of Rainfall Statistics for Selected Stations in the Niger Delta

S/N	Station	MeanAnnual rainfall(mm)	Nov-Feb rainfall (mm) (% of Annual)	Mar - Oct rainfall (mm) (% of Annual)
1	Benin	2087.2	145.8 (7.05%)	1939.9 (92.95%)
2	Sapele	2391.5	167.5 (7.03%)	2223.4 (92.97%)
3	Warri	2907.8	228.7 (8.18%)	2578.0 (91.82%)
4	Port Harcourt	2370.5	237.9 (9.77%)	2138.9 (90.23%)
5	Onne	2438.4	222.4 (8.74%)	2225.3 (91.26%)
6	Opobo	3816.8	370.4 (9.44%)	3456.4 (90.56%)
7	Calabar	2903.8	304.1(10.75%)	2591.5 (89.25%)
8	Uyo	2142.2	142.1 (5.48%)	2007.7 (94.52%)

Source: Adapted from Ologunorisa and Adejuwon, 2010

The data shows that while there seems to be a general decrease of rain in Nigeria the coastal areas appear to have slight increase. Aside the general southward shift in rainfall pattern, the duration has also reduced from 80 - 360 (1941-1970) to 40-280 (1970-2002) rainy days per year (Odjugo 2005). Table 4.3.1.2 shows the rainfall and over 1993-2001 in Port Harcourt.

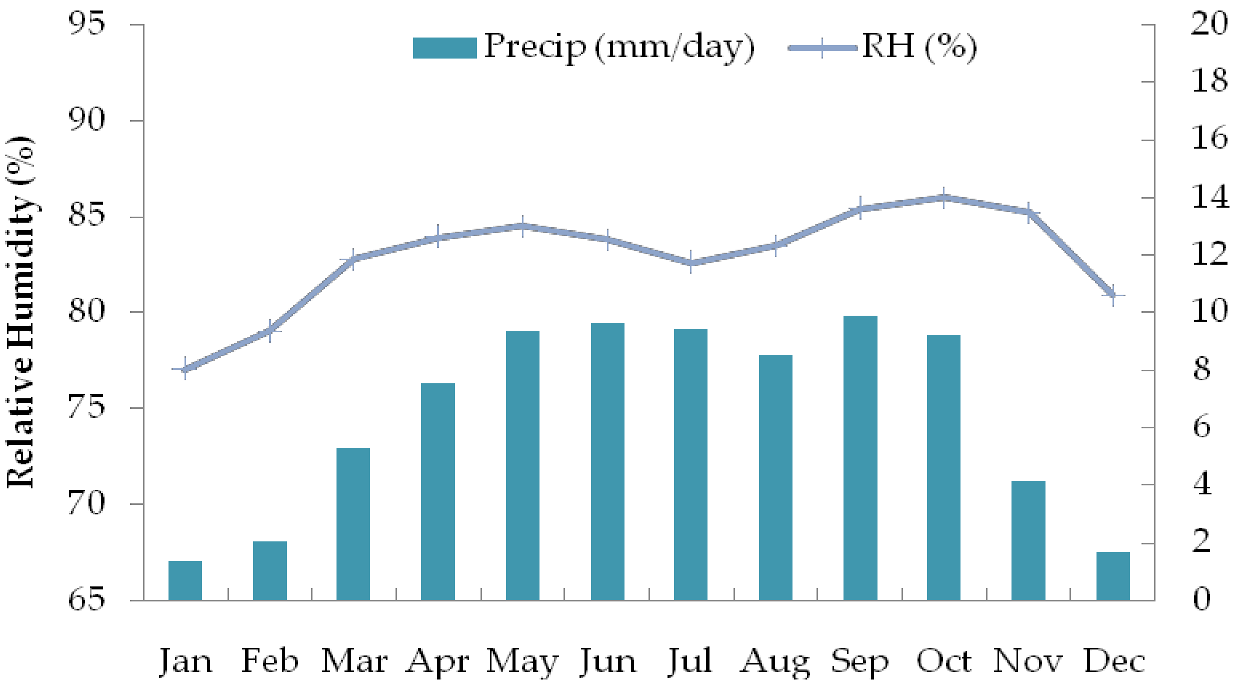
Table 4.3.1.2: Mean Monthly Rainfall and Number of Rainy Days in Port Harcourt (1993-2001).

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Rainfall (mm)	15.8	40.7	105.8	165.8	217.0	310.3	365.2	232.0	351.8	275.4	104.7	31.7	2216.2
Rainy days	2	4	8	10	14	19	22	19	21	19	8	3	149

Source: NIMET, Oshodi

Relative Humidity

The composite relative humidity curves in Figure 4.3.1.3 (a and b) show that mean monthly relative humidity is consistently high in the eighties with no month experiencing values greater than 88%. As expected, mean monthly relative humidity values are slightly high for the wet season months (approximately March to November) with the highest values occurring within the months of July to August. This is when the influence of the moisture-laden South-westerlies is greatest. In the dry season relative humidity drops to the high seventies.



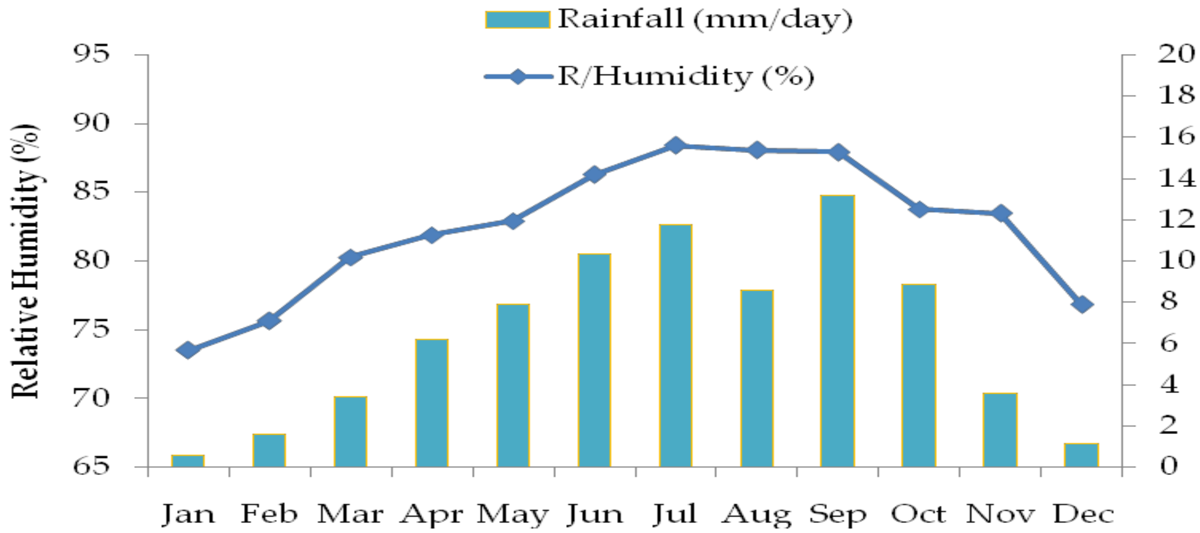


Figure 4.3.1.3: Daily Average Rainfall and Relative Humidity, for Port Harcourt/ Onne/Bonny Axis (a) 10m Above the Earth (NASA) (b) Earth's Surface (NIMET)

Wind Pattern

The wind pattern also follows the migratory Inter Tropical Discontinuity (ITD). Thus, it is mainly southwesterly during the rainy season and the northeasterly during the dry season. In general, a long low southwesterly swell is prevalent. During the wet season, this swell together with the characteristic rough sea becomes high, especially during heavy squalls. The wind speed varies between 1.5 and 3.9 m/sec. around the coast for most of the year with an average speed of 2.3m/sec. Incidences of severe windstorms are now more frequent with some rare occasions being as high as 8 - 10 m/sec. These are often associated with thunder and lightning especially during the changing season (Figure 4.3.1.4).

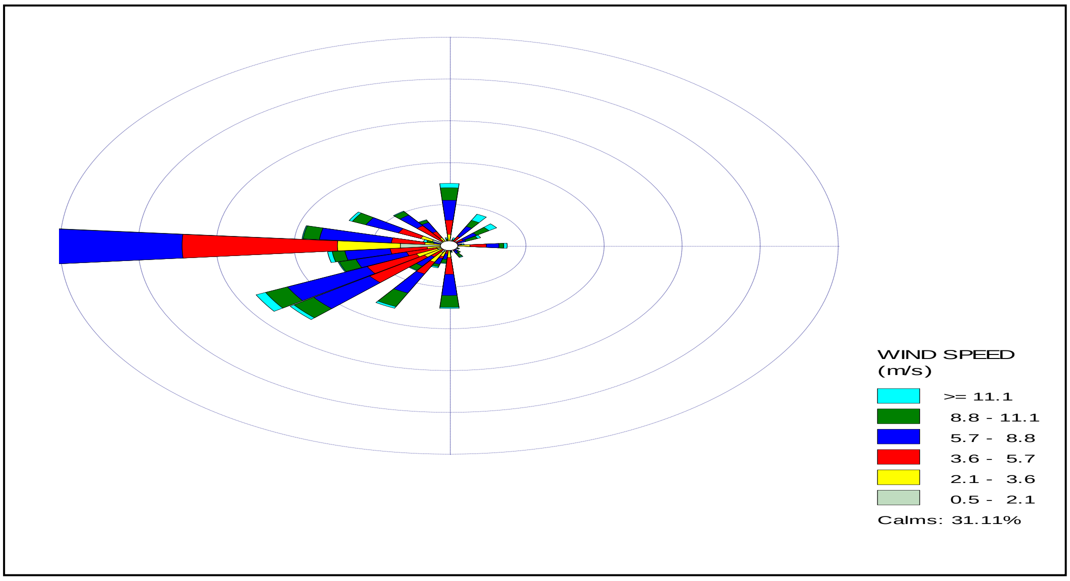


Figure 4.3.1.4: Wind Rose of Port Harcourt for the Period of 1993 – 2001 (Source: NIMET 2011)

a) **Site-Specific Micro Climate**

The measured daily averages of relative humidity, temperature and wind speed within the project site during the field data gathering of 3rd – 22nd May 2018 are presented in Table 4.3.1.3. Temperatures were moderate in the study area during the field data gathering in May 2018 and ranged from 22.4-32.5ºC with a mean value of 28.5 ºC while the corresponding values for the control stations were 27.6 - 29.0 ºC. The relatively higher temperatures recorded during the field study showed spatial variations at the monitoring points. However, these values were consistent with the historical data (Table 4.3.1.3) for the period study.

Table 4.3.1.3: Summary of Microclimatic Conditions of Bonny Deep Study Area

Parameter	**Bonny Deep**		**Control s**		**Historical Data**
	Range	**Mean**	**1**	**2**	**NIMET/NASA**
Temperature, oC	22.4-32.5	28.5	27.6	29.0	25-32ºC (May)
Relative Humidity, %	84.4-100	91.7	86.4	92.6	>85 in wet sesons (Mar. Nov.)
Wind Speed, m/s	0.5-4.1	1.6	1.4	1.7	1.5 - 3.9 m/sec. most andas high as 8 - 10 m/sec.
Wind Direction	SW	SW	SW	SW	SW, SSW, NE

Source: Bonny Deep EIA Field Work May 2018

The table indicates that the average relative humidity ranged from 84.4 - 100 % during the period of measurement and gives a reflection of the historical data obtained for the study area.

Wind velocities recorded during the study varied from 0.5-4.1m/s with a mean value of 1.60m/s. These values compared favourably with the average values obtained at the controls as strong south-westerly wind predominates during thisstudy, especially at the near shore while relatively weaker north-easterly wind was observed and gives a reflection of the historical data obtained for the study area.

4.3.2 Geology

The proposed Bonny deep exploration and appraisal wells are located in the Niger Delta sedimentary Basin within which three distinct lithostratigraphic units - Akata, Agbada, and Benin Formations in order of decreasing age (Short and Stauble, 1965) - have been identified. The overall thickness of these Tertiary sediments is about 10,000 metres. The oldest of the units is the Akata Formation which is Paleocene in age. It consists of plastic, low density, under compacted, high pressured, shallow marine to deep water clays, shales and limestones. Its approximate thickness is about 1000 metres. The Akata Formation is known to be the source rock of petroleum in the Niger Delta. The Agbada Formation overlies the Akata Formation. It is made up of alternation of marine shale and sandstones and has an overall thickness of 3000 metres. It is the reservoir rock for petroleum in the Niger Delta. The youngest unit in the Delta is the Benin Formation (Coastal Plain Sands) which consists primarily of coarse sands with occasional clay/clayey intercalations. It is the major aquifer in the Delta, and the bearing medium for most of the engineering structures. The Formation outcrops on the surface in the Niger Delta.

4.3.3 Air Quality

A summary of the air quality measurement in Bonny Deep fields is presented in Table 4.3.3.1a while the detailed results are in Appendix 2. The regulatory limits for these parameters are presented in Table 4.3.3.2a for FMEnv, and Table 4.3.3.2b for DPR.

The concentrations of sulphur dioxide (SO2), nitrogen dioxide (NO2), volatile organic compounds (VOCs) and hydrogen sulphide measured in all the sampling stations and the control station were found to be below instruments detection limits of (<0.001). The concentration of carbon monoxide (CO) range from 0.25µg/m^3 to 2.0µg/m3 (Mean: 1.2µg/m^3). Suspended Particulate Matter (SPM), however, varied spatially over the selected stations, ranging between 0.9µg/m^3 and 12.3µg/m^3(Mean: 5.3µg/m^3). The control station also recorded value (4.1 – 5.7µg/m^3) within the range observed for the project area (Figure 4.3.3.1). The observed low SPM values during this period (wet season) within the area may be due to washout of suspended particulates by rainwater. It has been observed that washout (wet deposition) is one the major mechanisms by which pollutants are removed from air (Harrison, 1996). The mean concentration of SPM recorded in the current study was below Nigerian ambient air quality standards (NAAQS) of 250µg/m^3 (daily average of hourly values) and 600µg/m^3 (concentration not to be exceeded for more than once a year) FMEnv, 1991. This implies that there was no indication of SPM pollution in the project area. Generally, the data gathered from the field showed that the existing air quality within and around the project area is within the relevant ambient air quality criteria stipulated by the FMEnv (FEPA, 1991) and DPR (EGASPIN, 2002) for the monitored pollutants (Tables 4.3.3.2a-c, Figure 4.3.3.1). This implies that the air within the study area and influence zone is at its present condition uncontaminated by air pollutants. The results of this study were quite similar to previous studies in the area (Table 4.3.3.1b).

Table 4.3.3.1a: Summary of Air Quality and Noise Values of Bonny Deep Study Area

Parameter	Bonny Deep		Control s		Regulatory Limits	
	Range	Mean	1	2	FMEnv	DPR
SOx (µg/m^3)	<0.01	<0.01	<0.01	<0.01	260	100-150
NOx (µg/m^3)	<0.01	<0.01	<0.01	<0.01	75-113	150
CO (µg/m^3))	0.25-2.0	1.2	<0.01	1.10	22.8	NS
VOC (µg/m^3)	<0.01	<0.01	<0.01	<0.01	160	NS
H2S (µg/m^3)	<0.01	<0.01	<0.01	<0.01	NA	NS
SP M (µg/m^3)	0.9-12.3	5.3	4.1	5.7	250	60-90
Noise level dB(A)	40.8-56.5	50.9	56.3	46.1	90	80-100

BDL = Below Instrument Detection Limit (<0.01)

Source: Bonny Deep EIA Field Work May 2018

Table 4.3.3.1b: Comparison of the Air Quality and Noise Values of Bonny Deep with previous studies

Parameters	Bonny Oloma (2018)	BNAG (2013)		Bonny Deep (2018)	
	Mean	**WET**	**Dry**	Range	Mean
SO_2, µg/m^3	<0.001	<0.01	<0.01	<0.01	<0.01
NO_2,µg/m^3	<0.001	<0.01	<0.01	<0.01	<0.01
CO, µg/m^3	2.15	1.00	2.00	0.25-2.0	1.2
Ammonia, µg/m^3	2	<0.01	2.00		
Ozone, µg/m^3	0	-	-	-	-
CO_2 , µg/m^3	-	<0.01	<0.01		
Suspended Particulate Matter, µg/m^3	21.3	21.7	33.24	0.9-12.3	5.3
Volatile Organic Carbon, µg/m^3	6.23	<0.01	<0.01	<0.01	<0.01
Atmospheric Pressure, mmHg	1008	960	960	-	-
Relative Humidity, %	69.8	81.3	58.3	84.4-100	91.7
Ambient temperature, ^{0}C	33.1	34.2	33.5	22.4-32.5	28.5
Wind Speed m/s	1.5	0.2	0.9	0.5-4.1	1.6
Wind Direction	SW	SW	NE	SW	SW
Noise Level dB(A)	82.4	64.1	47.2	40.8-56.5	50.9
Hydrogen Sulphide (H_2S) µg/m^3	<0.001	<0.01	<0.01	<0.01	<0.01
Lead µg/m^3	<0.001				
Zinc µg/m^3	<0.001				
Copper µg/m^3	<0.001				
Chromium µg/m^3	<0.001				

Table 4.3.3.2a: Nigerian Ambient Air Quality Standard

Pollutants	Time of Average	Limit
Particulates	Daily average of daily values 1 hour	250 µg/m3 600*µg/m3
Sulphur oxides (Sulphur dioxide)	Daily average of hourly values 1 hour	0.01ppm (26 µg/m3) 0.1ppm (260 µg/m3)
Non-methane Hydrocarbon	Daily average of 3-hourly values	160 µg/m3
Carbon monoxide	Daily average of hourly values 8-hourly average	10ppm (11.4 µg/m3) 20ppm (22.8 µg/m3)
Nitrogen oxides (Nitrogen dioxide)	Daily average of hourly values (range)	0.04ppm – 0.06ppm (75.0 µg/m3 - 113 µg/m3)
Photochemical oxidant	Hourly values	0.06ppm

*Note: Concentration not to be exceeded for more than once a year.

Source: FEPA (FMEnv) 1991

Table 4.3.3.2b: DPR National Air Quality Guidelines for Maximum Exposure

POLLUTANT	1-Hour Mean (µgm-3)	8-Hour Mean (µgm-3)	Daily Average/ Mean (µgm-3)	Annual (µgm-3)
Total SPM Carbon Monoxide* Sulphur Dioxide Nitrogen Dioxide* Lead	150-230 30 350 400	60-90 10 100-150 150		40-60 0.5 – 1.0

Source: EGASPIN, 2002; *Not to be exceeded

Table 4.3.3.2c: Noise Exposure Limits for Nigeria

Duration per Day, Hour	Permissible Exposure Limit dB(A)
8	90
6	92
4	95
3	97
2	100
1.5	102
1	105
0.5	110
0.25 or less	115

Source: FEPA (FMEnv) 1991

Noise

The baseline ambient noise levels measured during the field study exercise were generally low with minimum value of 40.8dBA and maximum value of 56.5dBA **(**Table 4.3.3.1**)**. The values recorded at the control stations were within the range observed for the project area (46.1-56.3dBA).

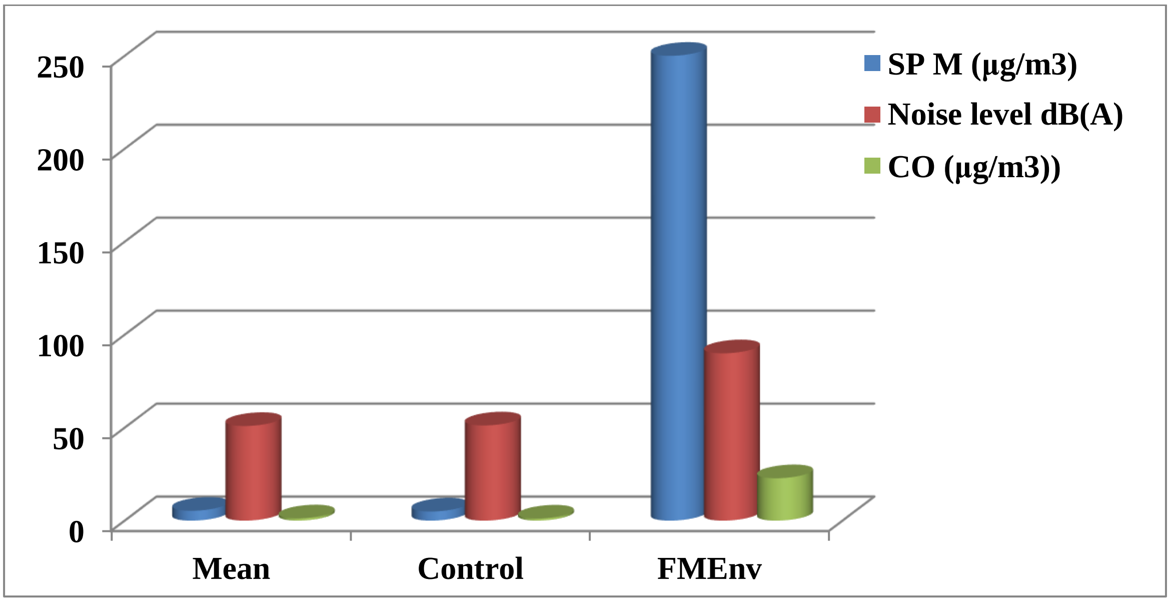


Fig. 4.3.3.1: SPM, CO concentrations and Noise levels of the study area compared to Control and FMEnv limits

Generally, noise levels recorded at the monitoring stations were lower than the 90 dBA FMEnv (Figure 4.3.3.1).

4.3.4 Surface water

The present condition of surface water quality within the catchment area of the proposed Bonny Deep exploration and appraisal wells project is presented. Water quality assessment is a means of determining the level of environmental pollution and possible environmental contaminants. Periodic environmental assessment will help in early detection of pollution and the source of the pollutant. Therefore, in order to evaluate the possible impact of a proposed project to the environment, the present conditions of the environment within the catchment area of the proposed project need to be ascertained. For this reason, 20 surface water samples were collected within 500m radius of the proposed project, while 2 samples were collected beyond this radius.

The samples were carefully bottled in triply filtered plastic bottles which were well labelled and were preserved at optimal conditions prior to laboratory analysis. The results of the analyzed parameters are presented in Appendix 3 and its summary was presented in Table 4.3.4.1a. The implications of these results to the environment are therefore summarized as follows:

pH, Salinity, EC, TDS, and TSS and Turbidity.

The average value of the pH of the surface water within the proposed well locations is 7.7 with a maximum value of 7.9 and a minimum value of 7.2. These values though slightly alkaline are common with coastal waters such as lagoons and embayments (Oviatt et al., 1986; Hinga 1992), and are still within permissible limit of most environmental agencies which are normally within the range of 6.5-8.0 (EPA, 2001).The average pH value of 7.7 from the surface waters shows no significant difference when compared with the average pH value of 7.5 from the control region (Fig. 4.3.4.1).

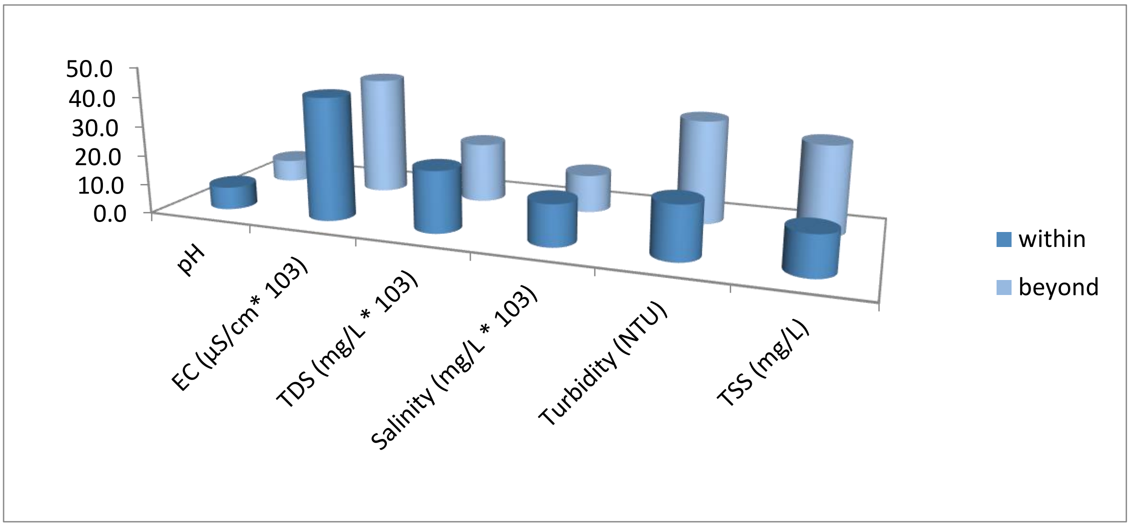


Figure 4.3.4.1: Average values of pH, EC, TDS, TSS, Turbidity and Salinity in the main and control surface water samples

The average values of 13994mg/L, 41705 µS/cm, and 20853mg/L with ranges of 12452-15751mg/L, 35800-46000 µS/cm, and 17900-23000 mg/L were recorded for the salinity, EC, and TDS respectively in the surface waters within the proposed well locations. The value of salinity falls within the EPA permissible limit of ≤40000, the EC value is above the EPA permissible limit of 1000µS/cm, while there is no limit set for the TDS of surface waters by EPA. However, the average TDS value of 20853mg/L is above the permissible limit of 1000ml/L set by world health organization (WHO) for drinking water; hence the water is not fit for direct consumption. These relatively high values in the salinity, EC, and TDS are common with waters within the mangrove forest region of the Niger delta and are attributed to the influx of sea water and effluents from anthropogenic activities (Efe and Mogborukor, 2012). There is no significant difference between the values of these parameters obtained within and beyond 500m from the proposed well locations (Fig.4.3.4.1).

The average concentration values of the total suspended solids (TSS) and turbidity were 18 mg/L and 13.4 NTU in the surface water samples collected within the proposed well location. Unlike the values of EC, TDS, Salinity, and pH, there was a significant increase in the concentration level of TSS and turbidity in the surface water samples collected at the control points (Fig.4.3.4.1). However, it is important to note that these parameters (TSS and turbidity) can frequently vary due to fluctuations in stream movement, ocean tides and sediment load.

Dissolved Oxygen, Chemical Oxygen Demand, and Biochemical Oxygen Demand:
Biochemical oxygen demand (BOD) is a measure of the amount of oxygen consumed in five days by biological processes breaking down organic waste and therefore is an indirect measure of the concentration of organic waste. Low dissolved oxygen (DO) can be detrimental to fish and other organisms living in the water. Higher BOD values indicate a greater degree of pollution from excess organic material. The BOD of the surface water samples collected within the proposed well locations gave an average value of 2.82mg/L, with a range of 2-3.8mg/L. These values are within the permissible limit of most environmental protection agency which is normally set at ≤ 5mg/L. Also, the average DO value of 5.74mg/L was recorded for the samples collected within the radius with a range of 4.9-6.8mg/L. These values of the DO are slightly lower than the EPA standard of ≥ 7mg/L and may be as a result of relatively high temperature of the surface water (29.9^{o}C); noting that the solubility of oxygen decreases with increase in temperature (Ibanez et al., 2008; Wetzel and Likens, 2000). However, Figure 4.3.4.2 revealed that there is no significant difference in the values of the DO, BOD and COD obtained from surface water samples collected within the proposed well locations. COD was 8.43 mg/l in the dry season and 20.23 in the wet season of 2013 but was 9.36 mg/l during this study.

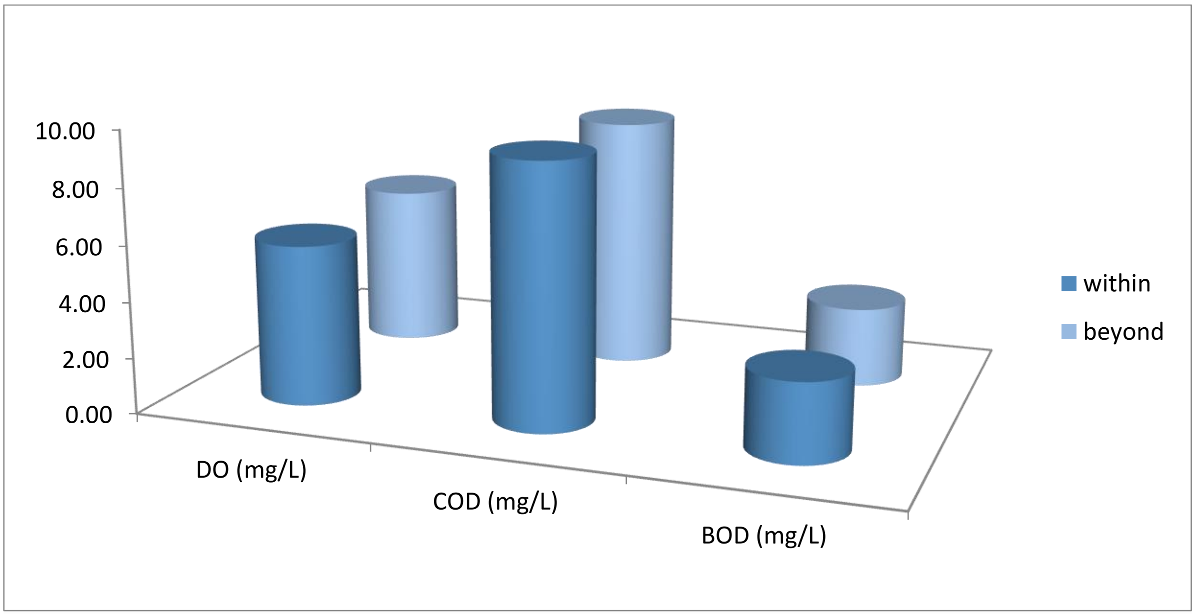


Figure 4.3.4.2: Average conc. values of BOD, COD, and DO in the main and control surface water sample

Nutrients:
The major compounds affecting the availability of nutrients in surface waters are nitrates, phosphates and sulphates. Reduction in the amount of sulphate may lead to increased decomposition of organic matter (Boomer and Bedford, 2008), while increase in the amount

of phosphates and nitrates usually leads to eutrophication (Jaynes and Carpenter, 1986). These processes typically promote excessive growth of algae. As the algae die and decompose, high levels of organic matter and the decomposing organisms deplete the water of available oxygen, causing the death of other organisms, such as fish. The average values of the nitrate and phosphate composition of the surface water collected within the proposed well locations are 0.02mg/L and 0.014mg/L respectively, with ranges of 0.0.014-0.028mg/L 0.002-0.078mg/l (Fig. 4.3.4.3). These values fall within the EPA standard of < 0.7mg/L and < 50mg/L for nitrates and phosphates respectively.

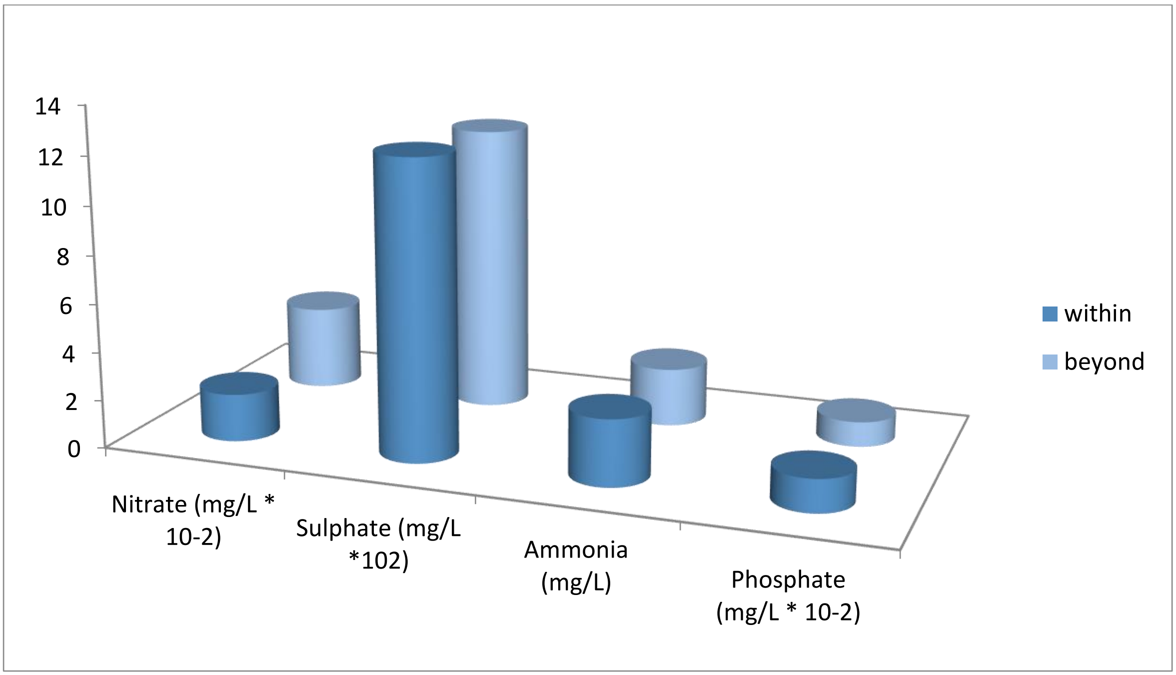


Figure 4.3.4.3: Average concentration values of sulphate, phosphate, nitrate and ammonia in the main and control surface water sample

However, the average value of 1232mg/L with a range of 844-1505mg/L for the sulphate composition of the surface water collected within 500m radius from the proposed well locations is above the EPA permissible limit of < 250mg/L for surface water. The relative high amount of sulphate in this surface water sample maybe attributed to the geology of the underlying sediments. Iron sulphides are present in sedimentary rocks from which they can be oxidised to sulphate in humid climates; the latter may then leach into watercourses so that surface waters are often excessively high in sulphates (EPA, 2001).

The average concentration level of ammonia in the surface water samples collected within the 500m radius from the proposed well locations was 2.76mg/L with a range of 2.16-3.41mg/L. these values of ammonia which is above 0.1mg/L indicates the presence of sewage or industrial contamination (EPA, 2001). Figure 4.3.4.3 shows the comparison between the average values of nitrates, phosphates and sulphates from surface water samples within and beyond 500m radius from the proposed well locations. The result implies that there is no significant difference between the values for phosphate, nitrate and sulphate.

Heavy metals and Trace elements:

These are element which at a very low concentration can be toxic to but human and animals, but their degree of toxicity vary greatly from metal to metal. They are easily accumulable in fish and other tissue and hence liable to enter food chain. They include; Antimony, Cobalt, Nickel, Tin, Arsenic, Copper, Selenium, Titanium, Beryllium, Lead, Silver, Uranium, Barium, Manganese, Cadmium, Mercury, Tellurium, Vanadium, Chromium, Molybdenum, Thallium, and Zinc. Apart from Cd, Fe, Pb, Zn, Mn and Cr, all other elements were not at detectable concentration in the surface water samples collected within the proposed well location and at the control points. The average values of the detectable elements are 0.0153mg/L, 1.689mg/L, 0.003mg/L, 0.001mg/L, 0.046mg/L, and 0.439mg/L for Mn, Fe, Cd, Cr, Pb, and Zn respectively. These values fall within the EPA and WHO permissible limit for surface waters.

Comparing the average values of these detectable trace elements and heavy metals in surface waters collected within the proposed well locations and the control, no significant difference was observed apart from lead which was considerably higher in the samples collected within the proposed well location radius (Fig. 4.3.4.4).

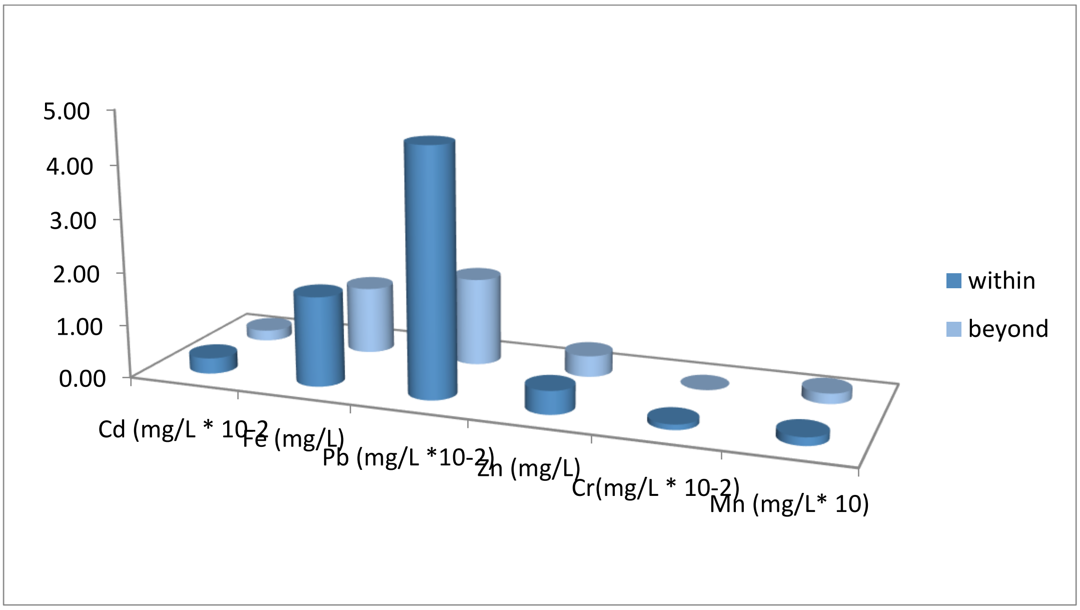


Figure 4.3.4.4: Average concentration values of Ba, Fe, Zn, and Mn in the main and control surface water samples

Hydrocarbons:

This includes, TPH, oil and grease, Polycyclic, and Aliphatics. Problems associated with these substances include; interference with such vital processes as the mass transfer of oxygen from air to water (essential in river reaeration), blockage of pipes, odour and taste problems, cancers, etc. However, organoleptic and total aliphatic hydrocarbon (THC) was not detected in the surface water samples both within and beyond 500m radius from the proposed well locations.

Microorganisms

Microbial activities in surface water can be a measure of the general quality of the environment. The total count of these organisms in surface water can be used to determine the nutrient load of the water body, the oxygen demands, and the level of contamination by toxic substances such as hydrocarbons. While increase in the number of heterotrophic bacteria and fungi may indicate influx of nutrients and good aeration of the surface water, excessive increase of these organisms may lead to eutrophication which may lead to death of fishes and other marine organisms. Therefore, it is important to periodically assess the microbial count of surface waters in order to detect any abnormal change in the immediate environment. For this reason, the microbial count in surface water samples within and beyond 500m radius from the proposed well locations was analyzed in order to determine the present condition of the surface waters within the catchment area.

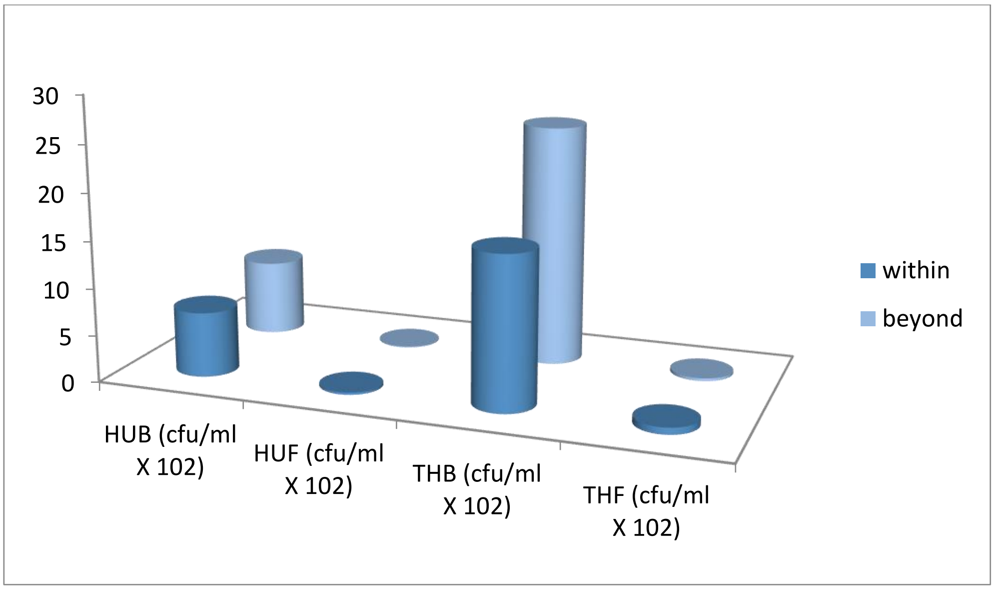


Figure 4.3.4.5: Average THB, THF, HUB, and HUF composition of sediments within and beyond 500m radius

The result (Fig.4.3.4.5) revealed that the average count value for the total heterotrophic bacteria (THB) and total heterotrophic fungi (THF) is 1625 cfu/g and 72 cfu/g respectively within 500m radius from the proposed well locations (Fig. 4.3.4.5). In the control surface water samples (samples collected beyond 500m radius), the average count value of THB was higher (2550 cfu/g), while that of THF was lower (30 cfu/g) compared with those collected within the 500m radius. However, the average count value of Hydrocarbon utilizing bacteria

(HUB) and hydrocarbon utilizing fungi (HUF) of 690 cfu/g and 24.5 cfu/g respectively for the surface water samples within 500m radius from the proposed well locations suggests that there has been previous hydrocarbon contamination (Atlas and Bartha, 1973). These values of hydrocarbon utilizing microorganisms compare favourably with the total heterotrophic microorganisms (Table 4.3.4.1a), which implies that a bioremediation process is in progress (Atlas, 1981; Bossert and Bartha, 1984).

Table 4.3.4.1a: Physicochemical composition of surface waters within the catchment area of the proposed Bonny deep exploration and appraisal wells.

PARAMETER	UNIT	WITHIN 2km			BEYOND 2km			
		Mean	Max	Min	Mean	Max	Min	EPA Limit
PHYSICOCHEMICAL PROPERTIES								
pH		7.7	7.9	7.2	7.6	7.7	7.6	6.5-8
Redox Potential	mV	-32.035	-31.1	-32.9	-32.6	-32.6	-32.6	
Electrical Conductivity	µS/cm	41705	46000	35800	40700	41400	40000	1000
Temperature	^{o}C	27.22	29.2	25.8	25.1	25.4	24.8	
Turbidity	NTU	18	36	2.6	34.65	43.7	25.6	
TSS	mg/L	13.38889	32	1	30	39	21	
TDS	mg/L	20852.5	23000	17900	20350	20700	20000	
THC	mg/L	ND	ND	ND	ND	ND	ND	< 1
COD	mg/L	9.3685	13.24	7.22	9.0355	9.85	8.221	
DO	mg/L	5.745	6.8	4.9	5.7	5.8	5.6	≥ 7
BOD_5	mg/L	2.82	3.8	2	2.85	2.9	2.8	≤ 5
Salinity as Cl	mg/L	13994	15751	12452	12802	12952	12652	≤ 40
Nitrite	mg/L	ND	ND	ND	ND	ND	ND	
Colour	mg/L	25.55	54	4	51.5	59	44	
Alkalinity	mg/L	94.85	104	82	90	96	84	
Oil & Grease	mg/L	ND	ND	ND	ND	ND	ND	
Nitrate	mg/L	0.020	0.028	0.014	0.035	0.035	0.035	< 0.7
Sulphate	mg/L	1232	1505	844	1192	1285	1099	< 250
Ammonia	mg/L	2.757	3.418	2.160	2.416	2.457	2.376	
Phosphate	mg/L	0.014	0.078	0.002	0.010	0.012	0.009	< 50
reactive silica	mg/L	2.305	3.840	1.360	1.825	2.580	1.070	
MICROORGANISM								
HUB	cfu/ml X 10^2	6.9	29	0	8	13	3	
HUF	cfu/ml X 10^2	0.245	0.8	0	0.1	0.2	ND	
THB	cfu/ml X 10^2	16.25	39	0	25.5	32	19	
THF	cfu/ml X 10^2	0.72	4.1	0	0.3	0.3	0.3	
EXCHANGABLE CATIONS								
Na	mg/L	7552	8348	6245	7594	7918	7270	
K	mg/L	1150	1903	933	1062	1138	987	

PARAMETER	UNIT	WITHIN 2km			BEYOND 2km			
		Mean	Max	Min	Mean	Max	Min	EPA Limit
Ca	mg/L	439	594	401	375	404	347	
Mg	mg/L	437	722	228	365	408	322	
HEAVY METALS								
Mn	mg/L	0.0153	0.025	0.007	0.0195	0.024	0.015	
Fe	mg/L	1.689	2.929	0.752	1.2635	1.523	1.004	
Cd	mg/L	0.003	0.009	0.000	0.002	0.004	0	
Cr	mg/L	0.001	0.008	0	ND	ND	ND	
Ni	mg/L	ND	ND	ND	ND	ND	ND	
V	mg/L	ND	ND	ND	ND	ND	ND	
Pb	mg/L	0.046	0.099	0.010	0.017	0.019	0.014	
Zn	mg/L	0.439	1.029	0.103	0.398	0.430	0.366	
Hg	mg/L	ND	ND	ND	ND	ND	ND	

Comparative analysis

T-test statistical analysis was employed to determine whether the observed variation between the concentration levels of the analyzed parameters in the surface water samples within 500m from the proposed well locations and those beyond 500m radius from the same reference point are as a result of chance alone. The null hypothesis of this test states that there is no significant variation between the mean of the samples collected within 500m radius from the well locations and those collected beyond this radius. This hypothesis can be rejected, and the results regarded as significant if the p-value is greater than or equals to 0.05 which was the predetermined confidence level; otherwise, the hypothesis will be accepted, and the results will be regarded as insignificant. Therefore, it can be concluded that there was a significant variation in the concentration levels of the redox potential, temperature, nitrate, salinity, ammonia, and Lead in the surface water samples which was collected within and beyond 500m radius from the proposed Bonny deep exploration and appraisal well locations (Table 4.3.4.1b). Thus, the observed variations in the concentration levels of these parameters were not as a result of chance. However, the observed variation in all other parameters which was analyzed for in the surface water samples that were collected within the catchment area (within and beyond 500m radius) of the proposed Bonny deep exploration and appraisal well locations is regarded as insignificant and were as a result of chance alone. Table 4.3.4.1c compared the data obtained during this study with that of previous studies and found close similarities.

Table 4.3.4.1b: Comparative analysis between the physicochemical properties of the surface water samples collected within the catchment area of the proposed Bonny Deep exploration and appraisal Well locations

PARAMETER	WITHIN 2km	BEYOND 2km	t-test

	MEAN	SD	MEAN	SD	α -level	p-Value	DECISION
pH	7.72	0.18	7.65	0.07	0.05	0.387	ACCEPT
Redox Potential (mV)	-32.04	0.63	-32.60	0.00	0.05	0.001	REJECT
Electrical Conductivity (uS/cm)	41705	2705	40700	990	0.05	0.357	ACCEPT
Temperature(oC)	27.220	1.012	25.100	0.424	0.05	0.030	REJECT
Turbidity(NTU)	18.000	9.781	34.650	12.799	0.05	0.299	ACCEPT
TSS(mg/L)	13.389	9.394	30.000	12.728	0.05	0.303	ACCEPT
TDS(mg/L)	20853	1353	20350	495	0.05	0.357	ACCEPT
THC(mg/L)	0.000	0.000	0.000	0.000			
COD(mg/L)	9.369	1.436	9.036	1.152	0.05	0.769	ACCEPT
DO(mg/L)	5.745	0.485	5.700	0.141	0.05	0.776	ACCEPT
BOD_5(mg/L)	2.820	0.621	2.850	0.071	0.05	0.841	ACCEPT
Salinity as Cl(mg/L)	13994	1003	12802	212	0.05	0.002	REJECT
Nitrite(mg/L)	0.000	0.000	0.000	0.000			
Colour(mg/L)	25.550	13.563	51.500	10.607	0.05	0.192	ACCEPT
Alkalinity(mg/L)	94.85	4.94	90.00	8.49	0.05	0.572	ACCEPT
Oil & Grease(mg/L)	0.000	0.000	0.000	0.000			
Nitrate(mg/L)	0.020	0.004	0.035	0.001	0.05	0.000	REJECT
Sulphate(mg/L)	1232	226	1192	131	0.05	0.743	ACCEPT
Ammonia(mg/L)	2.757	0.338	2.416	0.057	0.05	0.002	REJECT
Phosphate(mg/L)	0.014	0.017	0.010	0.002	0.05	0.433	ACCEPT
reactive silica(mg/L)	2.305	0.828	1.825	1.068	0.05	0.648	ACCEPT
HUB (cfu/ml X 10^2)	6.900	6.927	8.000	7.071	0.05	0.868	ACCEPT
HUF (cfu/ml X 10^2)	0.245	0.274	0.100	0.141	0.05	0.342	ACCEPT
THB (cfu/ml X 10^2)	16.250	9.840	25.500	9.192	0.05	0.406	ACCEPT

PARAMETER	WITHIN 2km		BEYOND 2km		t-test		
	MEAN	**SD**	**MEAN**	**SD**	**α -level**	**p-Value**	**DECISION**
THF (cfu/ml X 102)	0.720	1.096	0.300	0.000	0.05	0.103	ACCEPT
Na(mg/L)	7552	599	7594	458	0.05	0.923	ACCEPT
K(mg/L)	1150	212	1062	107	0.05	0.428	ACCEPT
Ca(mg/L)	439	45	375	40	0.05	0.278	ACCEPT
Mg(mg/L)	437	116	365	60	0.05	0.287	ACCEPT
Mn(mg/L)	0.015	0.005	0.020	0.006	0.05	0.532	ACCEPT
Fe(mg/L)	1.69	0.62	1.26	0.37	0.05	0.285	ACCEPT
Cd(mg/L)	0.003	0.003	0.002	0.003	0.05	0.732	ACCEPT
Cr(mg/L)	0.001	0.002	0.000	0.000	0.05	0.086	ACCEPT
Ni(mg/L)	ND	ND	ND	ND			
V(mg/L)	ND	ND	ND	ND			
Pb(mg/L)	0.046	0.028	0.017	0.004	0.05	0.000	REJECT
Zn(mg/L)	0.439	0.264	0.398	0.045	0.05	0.553	ACCEPT
Hg(mg/L)	0.000	0.000	0.000	0.000			

Table 4.3.4.1c Comparison of Bonny Deep studies with previous studies in the area

Parameters	Bonny Oloma (2018)		BNAG (2013)		Bonny Deep (2018)	
	Range	Mean	WET	Dry	Range	Mean
pH	7.50 - 7.80	7.63	7.55	6.92	7.7 – 7.9	7.7
electrical conductivity (µs/cm)	10956 -11520	11272	41,660	28,920	35800 - 46000	41705
TDS (mg/L)	6210 - 7420	6910	23.640	18.1	17900 - 23000	20852.5
SALINTY (%)	7.93 - 9.81	9.00			12452 - 15751	13994

TEMPERATURE (°C)	29.50 - 30.10	29.77	25.20	28.34	25.8 - 29.2	27.22
TSS (mg/L)	7.00 - 9.00	8.00	67.00	112.50	1 - 32	13.38
TURBIDITY (NTU)	8.80- 11.90	10.43	5.15	7.81	2.6 - 36	18
Cl^- (mg/L)	4387 - 5432	4981	12908	14,260	12452 - 15751	13994
SO_4^{2-} (mg/L)	455 - 768	565	7.71	6.35	844 - 1505	1232
Total Hardness (mg/l)			70.00	91.07		
Colour (Pt.Co)	16.00 - 24.00	20.67	3.96	9.0	4 - 54	25.55
Ammonia (mg/l)			<0.1	<0.1	2.160 - 3.418	2.757
Reactive silica(mg/l)					1.360 - 3.840	2.305
NO_3^-N (mg/L)	0.02 - 0.05	0.04	<0.1	<0.1	0.014 - 0.028	0.020
Nitrite (mg/l)			<0.1	<0.1	ND	ND
Odour (TONS)	BDL	BDL				
Phenol (mg/L)	0.00	0.00				
ALKALINITY (mg/L)	95.80 - 114.20	104.10	1.72	1.08	82 - 104	94.85
Redox Potential (mV)	-47.10- (-39.40)	-42.97			-32.9 – (-31.1)	-32.0.32
CO_3^- (mg/L)	0.00	0.00	<0.1	<0.1		
Bicarbonate (mg/l)			9.83	8.82		
O & G (mg/L)	0.00	0.00			ND	ND
THC (mg/L)	0.00	0.00				
COD (mg/L)	10.18 - 11.72	11.18	20.23	8.43	7.22 - 13.24	9.36
Total Phosphorous (mg/L)	0.003 - 0.011	0.007	0.33	0.39	0.002 - 0.078	0.014
DO (mg/L)	5.20 - 6.10	5.73	5.80	3.09	4.9 - 6.8	5.7
BOD5 (mg/L)	1.40 - 2.30	1.77	9.83	2.9	2 - 3.8	2.82

HEAVY METALS						
Ba (mg/L)	1.672 - 4.43	3.30				
Cr^{+6} (mg/L)	ND	ND	2.93	<0.01	0.008 - 0	0.001
Cd (mg/L)	ND	ND	0.11	<0.01	0.007 - 0.025	0.003
Co (mg/L)	ND	ND				
Cu (mg/L)	ND	ND	0.02	<0.01		
Pb (mg/L)	ND	ND	0.28	<0.001	0.010 - 0.099	0.046
Fe (mg/L)	0.894 - 1.724	1.310	0.64	0.249	0.752 - 2.929	1.689
Ni (mg/L)	ND	ND	0.84	0.02	ND	ND
V (mg/)	ND	ND	<0.01	<0.01	ND	ND
Zn (mg/L)	0.01- 0.01	0.01	0.09	0.1	0.103 - 1.029	0.439
As (mg/L)	ND	ND	<0.01	<0.01		
Hg (mg/L)	ND	ND	<0.01	<0.01	ND	ND
Mn (mg/L)	0.02 -0.03	0.04			0.007 - 0.025	0.0153
EXCHANGABLE CATIONS						
Ca (mg/L)	83.84 - 98.32	91.83			401 - 594	439
Mg (mg/L)	155.98 - 170.88	164.71			228 -722	437
Na (mg/L)	1841.01 - 1968.83	1909.08			6245 - 8348	7552
K (mg/L)	421.77 - 475.09	441.14			933 - 1903	1150
HYDROCARBON						
PAH (µg/L)	ND	ND				
TPH (µg/L)	0.003 - 0.012	0.008	<0.1	<0.1		
THC (mg/l)			<0.1	<0.1	ND	ND
BTEX (µg/L)	ND	ND	<0.1	<0.1		

Micro organism						
HUB cfu/ml		640 x 10^3			0-29 x 10^2	6.9 x 10^2
HUF cfu/ml		24 x 10^2			0 – 0.8 x 10^2	0.245 x 10^2
THB cfu/ml		3100 x10^4	Nil	nil	39 x 10^2	16.25 x 10^2
THF cfu/ml		110 x 10^2	Nil	nil	0 - 4.1 x 10^2	0.72 x 10^2
Total coliform (MPN/100ml)		9				

4.3.5 Sediments

The present condition of sediments quality within the proposed Bonny deep exploration and appraisal wells is presented here. The physicochemical composition of sediments within deltaic environment can have wide variation due to its relative potion to land and sea. The sources of chemical, physical and biological pollutants of these sediments can be very difficult to ascertain because they can be transported from very far distances to this environment both from land and sea. However, frequent assessment of the physicochemical properties of these sediments within a given area can help in determining any abnormal increment and the direction to which it comes from. For this reason, it is imperative to carry out sediment quality assessment within the catchment area of any proposed project prior to its commencement. This will help to understand the present condition of the environment and to ascertain the impact of the project on the environment after subsequent environmental evaluation reviews.

For this reason, about 20 sediment samples were collected within 500m radius from the proposed Bonny Deep exploration and appraisal well locations, and 2 more samples further away from this radius. The samples were carefully sealed in a well labelled sampling bag prior to laboratory analyses. The results from the laboratory analysis were presented in Appendix 4 and its analysis in Table 4.3.5.1a. The interpretations from the data were thus as follows;

Textural properties

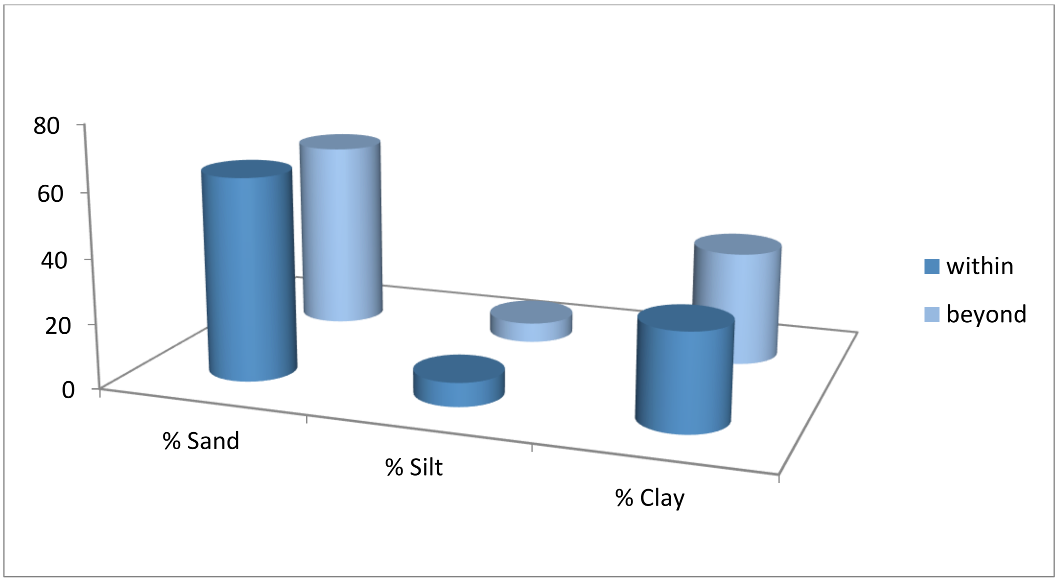


Figure 4.3.5.1: Average particle size distribution of sediments within and beyond 2km radius

The sediments collected within 500m from the proposed well locations are majorly composed of sand size particles with an average value of about 63% and a range of 27-93%. The remainder of the sediments particles are composed of silt and clay with average percentage composition of about 7% and 30% respectively. These sediments are not entirely composed of silicate materials but contains appreciable amount of organism matter. Therefore, the sediments can be classified as sandy clay loams. Figure 4.3.5.1 reveals that there was no significant difference between the particle size distribution of soil samples collected within 500m radius from the proposed well locations and those collected beyond this radius.

pH and EC

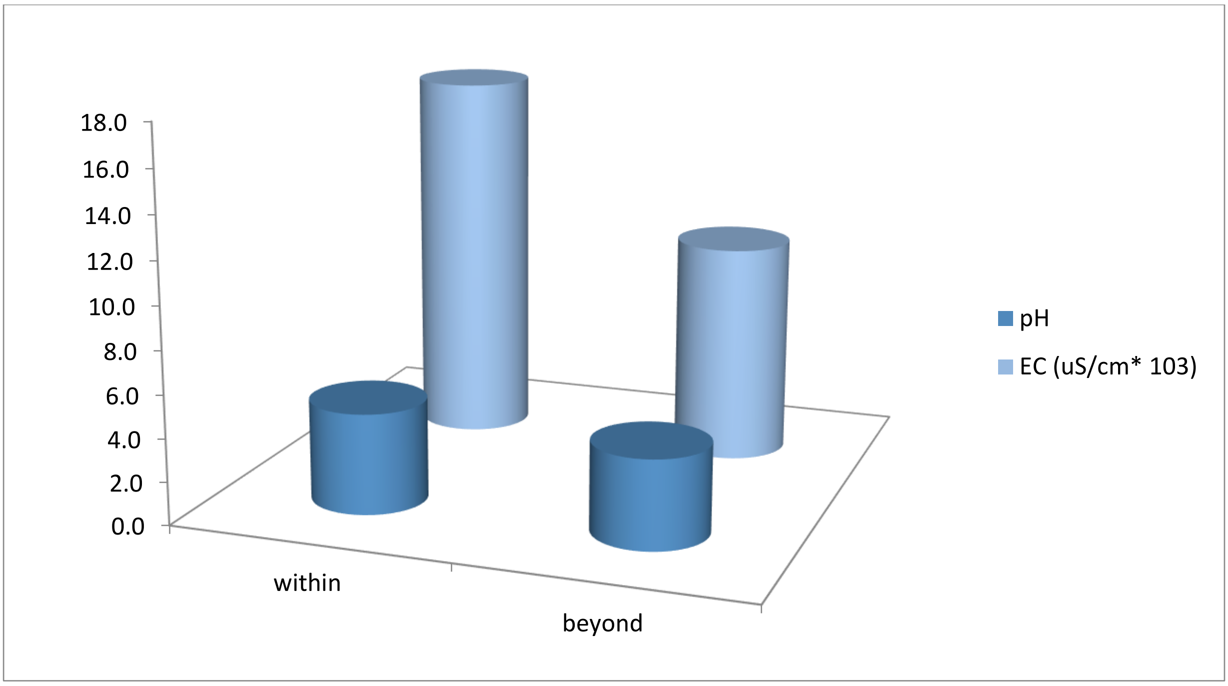


Figure 4.3.5.2: Average pH and EC of sediments within and beyond 2km radius

The pH of the sediments collected within 500m radius from the proposed well locations is acidic with an average value of 4.7 and a range of 3.6-6.1. These values are slightly lower in the soil samples collected beyond the radius of the reference point with average pH of 4.2 and a range of 3.8-4.5 (Fig. 4.3.5.2). Therefore, it implies that the sediments beyond 2km radius from the proposed well locations are more acidic than the ones within. These pH values of the sediments are similar with most other sediment quality reports generated within the region. Low values of pH of soils and sediments within this region have been attributed to acid rains which occurs as a result of hydrocarbon exploration activities (Emoyan et al., 2008; Efe and Mogborukor, 2012; and Amadi, 2014).

The electrical conductivity (EC) of the sediments collected within 500m radius from the proposed well locations are generally high with an average concentration value of 17344 µS/cm and a range of 3380-35100 µS/cm. High values of EC is mostly attributed to the presence of ionisable salts in the sediments. This assertion is likely since the sediments are derived from swamps which are close to the shorelines. The concentration levels of EC in the sediment samples collected beyond 500m radius from the proposed well locations are lower than those within the radius (Fig. 4.3.5.2). This observed difference could be because the control sediment samples were collected further inland and are relatively far from the sea tidal reach, (Egborge 1994).

Nutrients

One major nutrient that is very essential for plant growth is Phosphorus. The Phosphate content in the sediment within 500m radius from the proposed well locations ranged from 0.004 to 0.073% (mean 0.031%), and 0.003 to 0.035% (mean 0.019%) beyond 500m radius from same reference point. Other macro nutrient that is very significant and essential for plants growth is Nitrogen. The Total Nitrogen content of the sediment collected within 500m radius from the proposed well locations ranged from 0.007 to 0.07%, with a mean of 0.020%, and 0.015 to 0.0.022% (mean 0.019%) beyond 500m from the proposed well locations. Total nitrogen contents of the sediment of the facility are referred as low, as values of 0.15%, 0.15% - 0.20%, and >2.0% are respectively classified low, medium, and high (Enwezor et al, 1988). Major nutrients particularly nitrogen and phosphorus typically limiting and occurs at low concentrations in the soils and sediments of the Niger Delta.

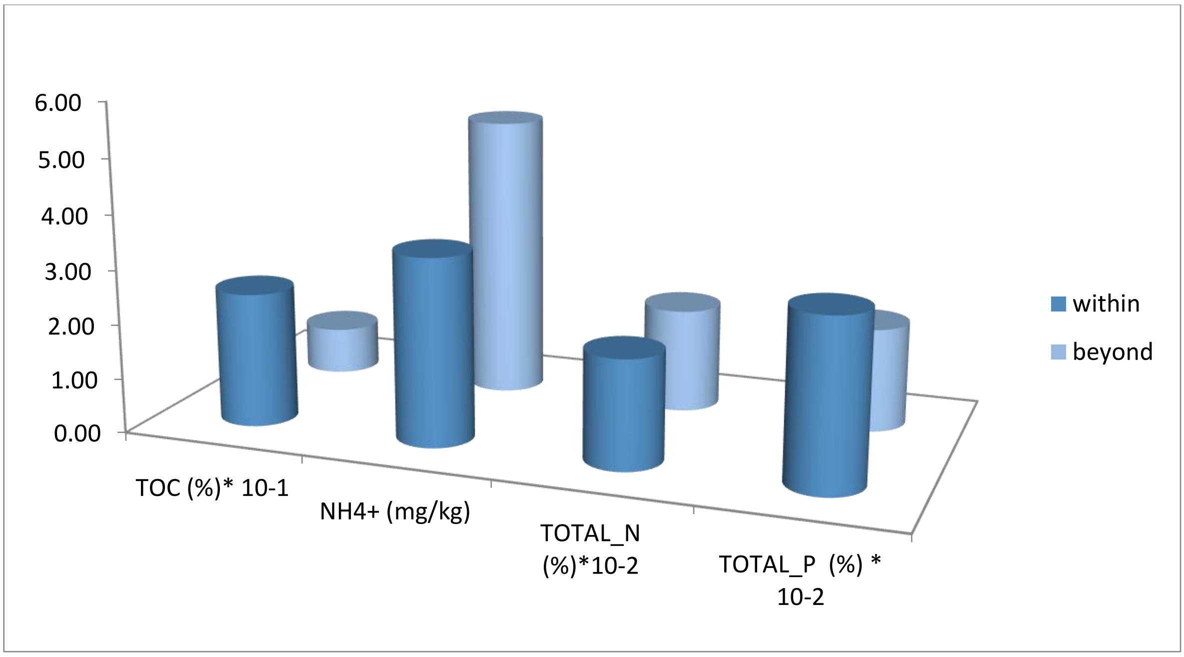


Figure 4.3.5.3: Average TOC, NH4, P, and N composition of sediments within and beyond 2km radius

The total organic carbon (TOC) within 500m radius from the proposed well locations are between 0.069 – 0.389 mg/kg (mean 0.246 mg/kg), and 0.072 – 0.10 mg/kg (mean 0.086 mg/kg) beyond 500m radius from the wells catchment area.

However, the concentration level of ammonium which ranged from 1.52 mg/kg to 5.86 mg/kg (mean, 3.44 mg/kg) in the sediment samples collected within 500m radius from the proposed well locations is much higher compared with other nutrients. These values of ammonia were slightly higher in the sediment samples collected beyond 500m radius from the reference point (Fig. 4.3.5.3).

In general, the nutrient content of the sediment is low, hence may not support adequate plant growth required for self-remediaiation of contaminated sediments.

Exchangeable cations

The average concentration values of sodium, potassium, calcium and magnesium in the sediments 500m radius from the proposed well locations is 2999, 660, 176, and 128 mg/kg respectively. Apart from the concentration level of sodium which was significantly high, the exchangeable cations are all moderate in quantity and within ranges that are adequate for arable crop production (FAO, 1979; Agboola and Corey, 1973). The concentration level of these cations was all lower in the sediment samples collected beyond the 500m radius (Fig. 4.3.5.4).

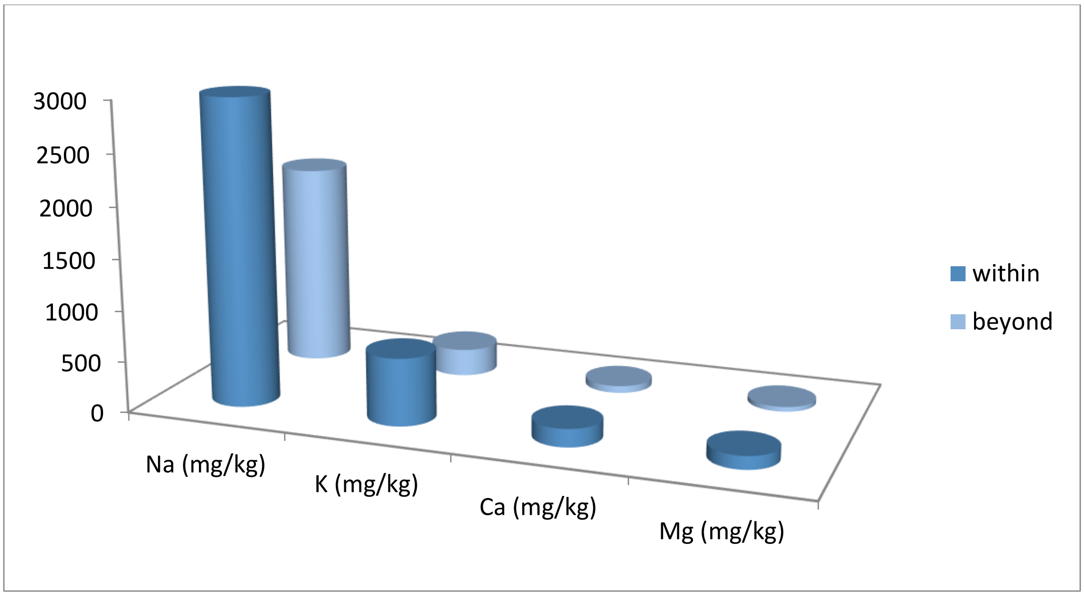


Figure 4.3.5.4: Average Na, K, Ca, and Mg composition of sediments within and beyond 500m radius

Heavy metals:

The sources of heavy metal composition of sediments may be difficult to ascertain due to their relative position to land and sea. However, higher amount in the concentration of some of these metals in sediments is an indication of anthropogenic pollution especially from hydrocarbon exploration and usage. It is very important to prevent heavy metal contamination of sediments because they usually enter the food chain through plant uptake; hence posing serious health challenge for humans. The average concentration values of 5473, 3.42, 39.08, 7.52, 2.76, 5.66, and 0.16 mg/kg were reported for Fe, Cu, Zn, Pb, Cd, Ni, and Cr respectively. Vanadium was not detected in the analyzed sediment samples both within and beyond the reference point. Apart from Pb which is much higher in the sediment samples collected within 500m radius from the proposed well locations, the average concentration values of the heavy metals did not show much variation between the sediment samples collected within and beyond 500m radius from the same reference point (Figs. 4.3.5.5). Sediments often acts as sinks for heavy metals especially in coastal estuarine locations. But the high concentration of iron in the study area is not due to anthropogenic sources, but iron occurs naturally in high concentrations in the soils and sediments of the Niger Delta.

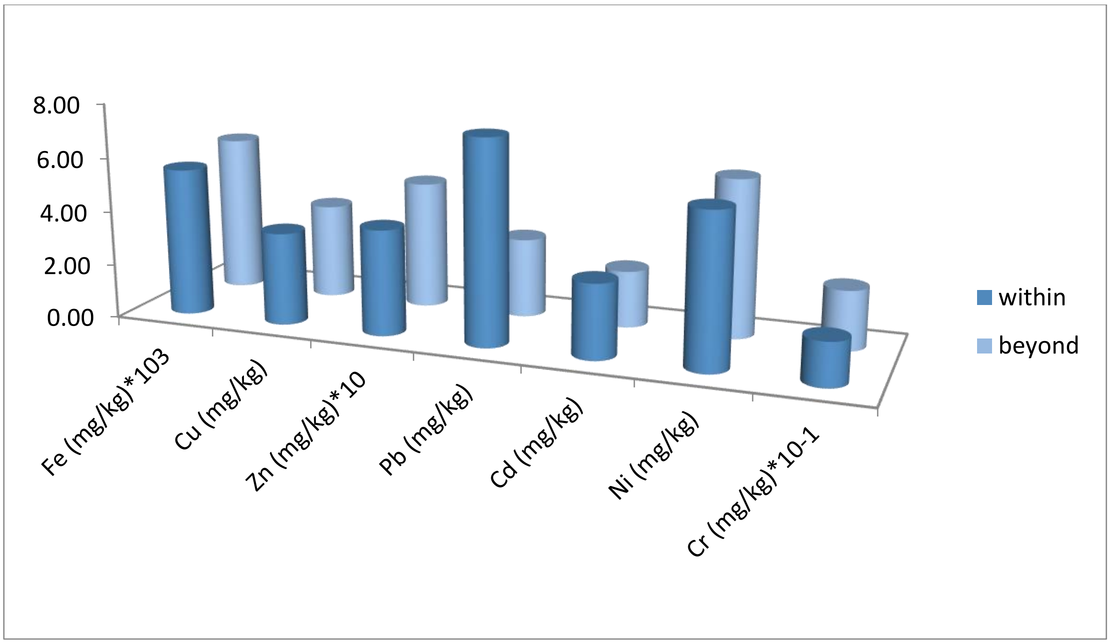


Figure 4.3.5.5: Average heavy metal composition of sediments within and beyond 500m radius

Spatial Distribution of Heavy Metals in the sediments

Spatial distribution models not only identify hotspots they also aid the determination of the extent of heavy metal contamination. Assessing the extent of metal contamination in deltaic sediments is hampered by the high heterogeneity of sediment characteristics, the spatial variability of trace element sources, sedimentary dynamics and geochemical processes in addition to the need of accurate reference values for deciphering natural to anthropogenic contribution. Some of these challenges were overcome by the high-resolution distribution models presented in the present Bonny Deep EIA report.

Some hot-spot areas were found in the area covered by the proposed project. These hot spots can be associated with locations where activities favorable for contamination are high. The concentration levels of the heavy metals, although still within the regulatory limits, may become a serious environmental concern in future. The spatial heavy metal distribution in the study area reflects the history of activities in the area. Spatial distribution trends relate to the natural and anthropogenic sources contributing to the metal concentrations.

Concentrations of zinc, copper, lead, nickel, chromium and cadmium were elevated more in upstream than downstream sediments. The spatial distribution of heavy metals in the sediments generated by a kriging interpolation method shows that at some sampling points there is elevated concentrations potential pollutants. Figure 4.3.5.6a shows that within the vicinity of SD 3, SD 10, SD 11 and SD 19 the concentration of cadmium was high although still within the regulatory limits. Figure 4.3.5.6b shows Chromium has elevated concentration near SD5, SD 6, SD 8, and SD 22. The concentration of Copper was relatively high within SD 13 only (Figure 4.3.5.6c). The concentration of Nickel was elevated near SD 2, SD 10 and SD 14 (Fig. 4.3.5.6d). Lead (Pb) was elevated near SD 3, SD 11, SD 12, SD 13, SD 14, SD 15 and SD 17 (Fig. 4.3.5.6e). The concentration of Zinc was elevated near SD 8, SD 9, SD 15 and SD 20 (Fig. 4.3.5.6f). The spatial heavy metal distribution in the study area is a reflection of the history of activities in the area. Spatial distribution trends relate to the natural and anthropogenic sources contributing to the metal concentrations. According to the concentrations measured and the distributions presented, the study area can be considered as non-contaminated. For most of the heavy metals, the concentrations tended to be higher upstream. Only a moderate enrichment in Cd, Ni, Pb and Zn, was detected in a few sites.

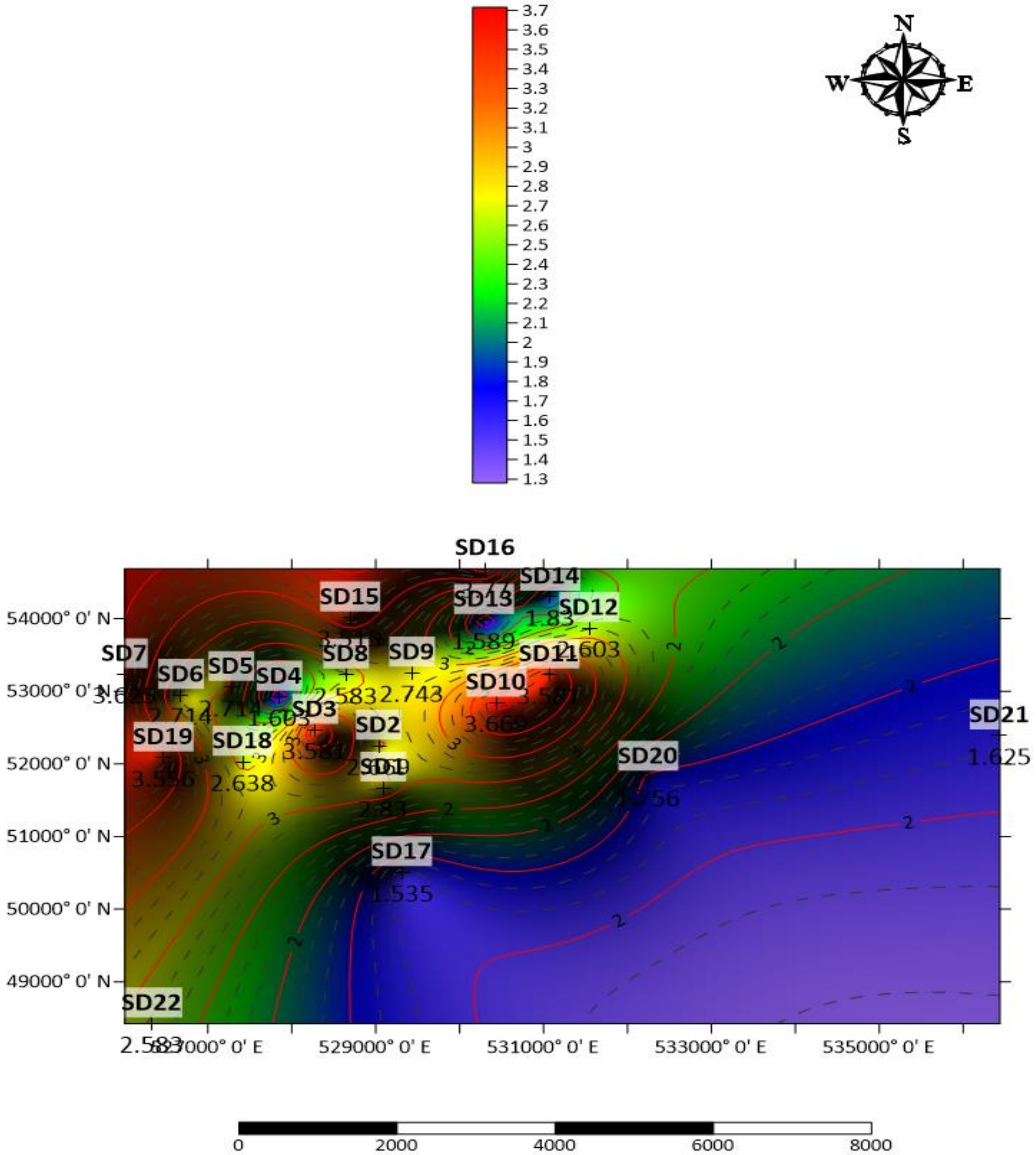


Figure 4.3.5.6a: Spatial distribution of Cadmium in the sediments within the area of study

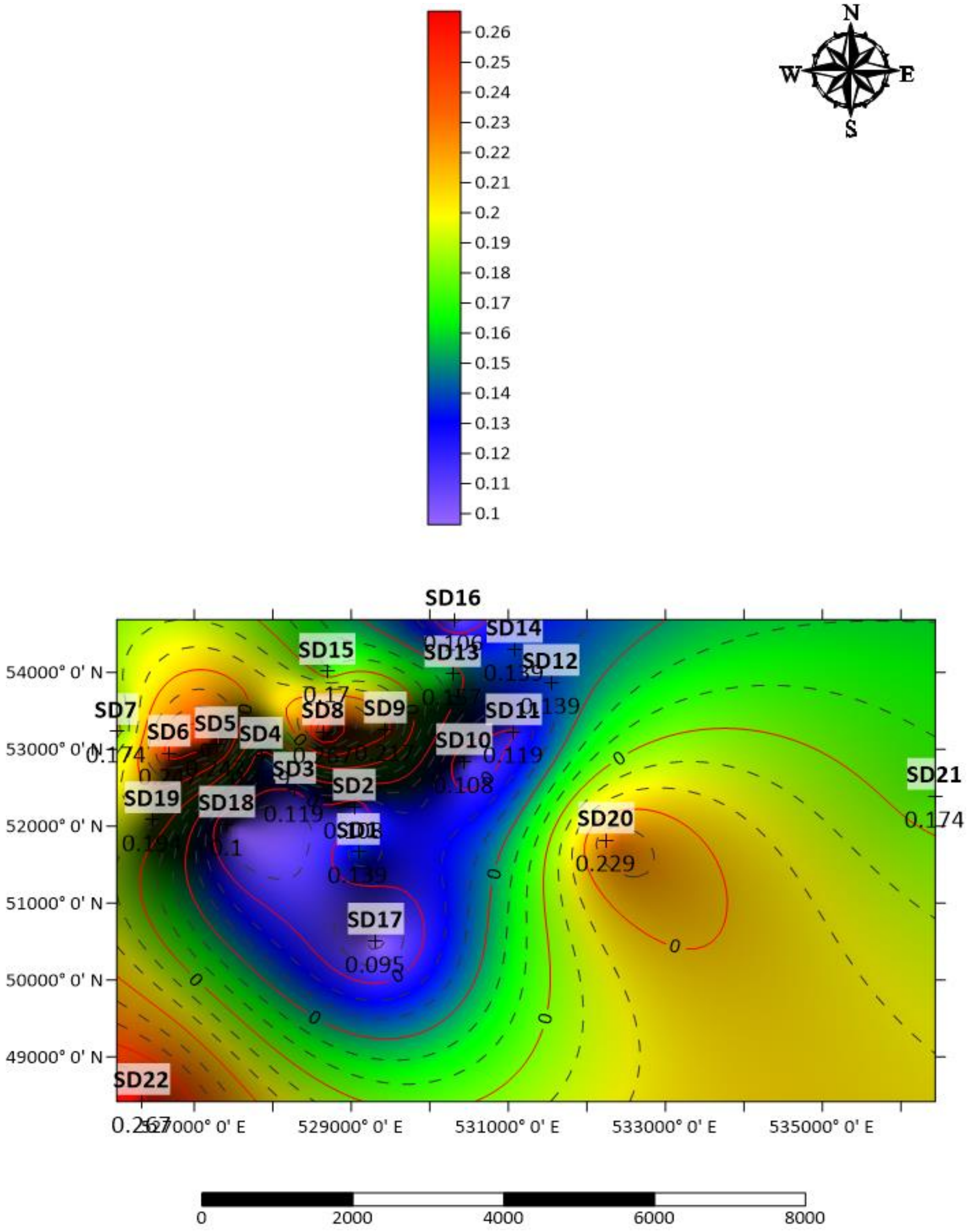


Figure 4.3.5.6b: Spatial distribution of Chromium in the sediments within the area of study

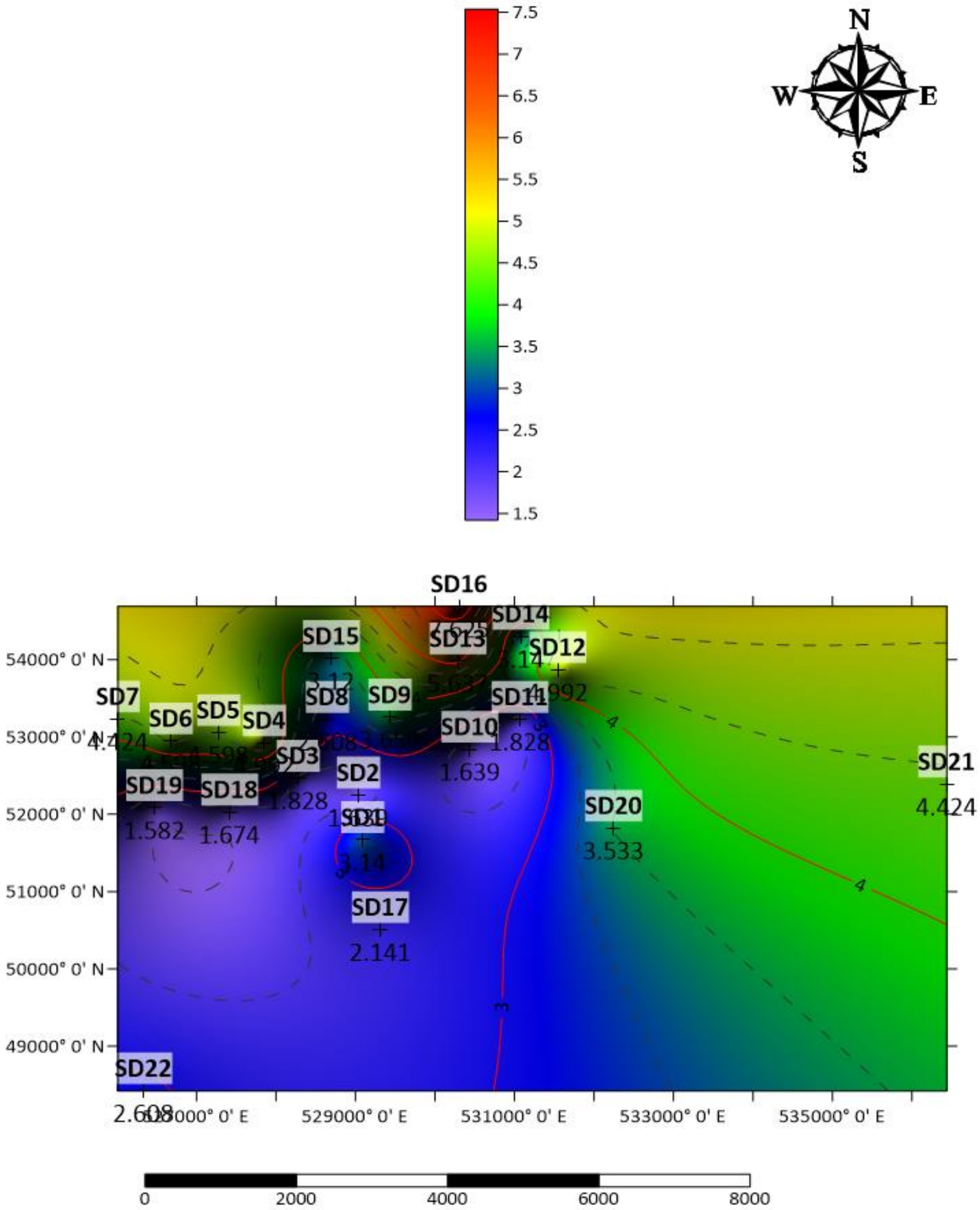


Figure 4.3.5.6c: Spatial distribution of Copper in the sediments within the area of study

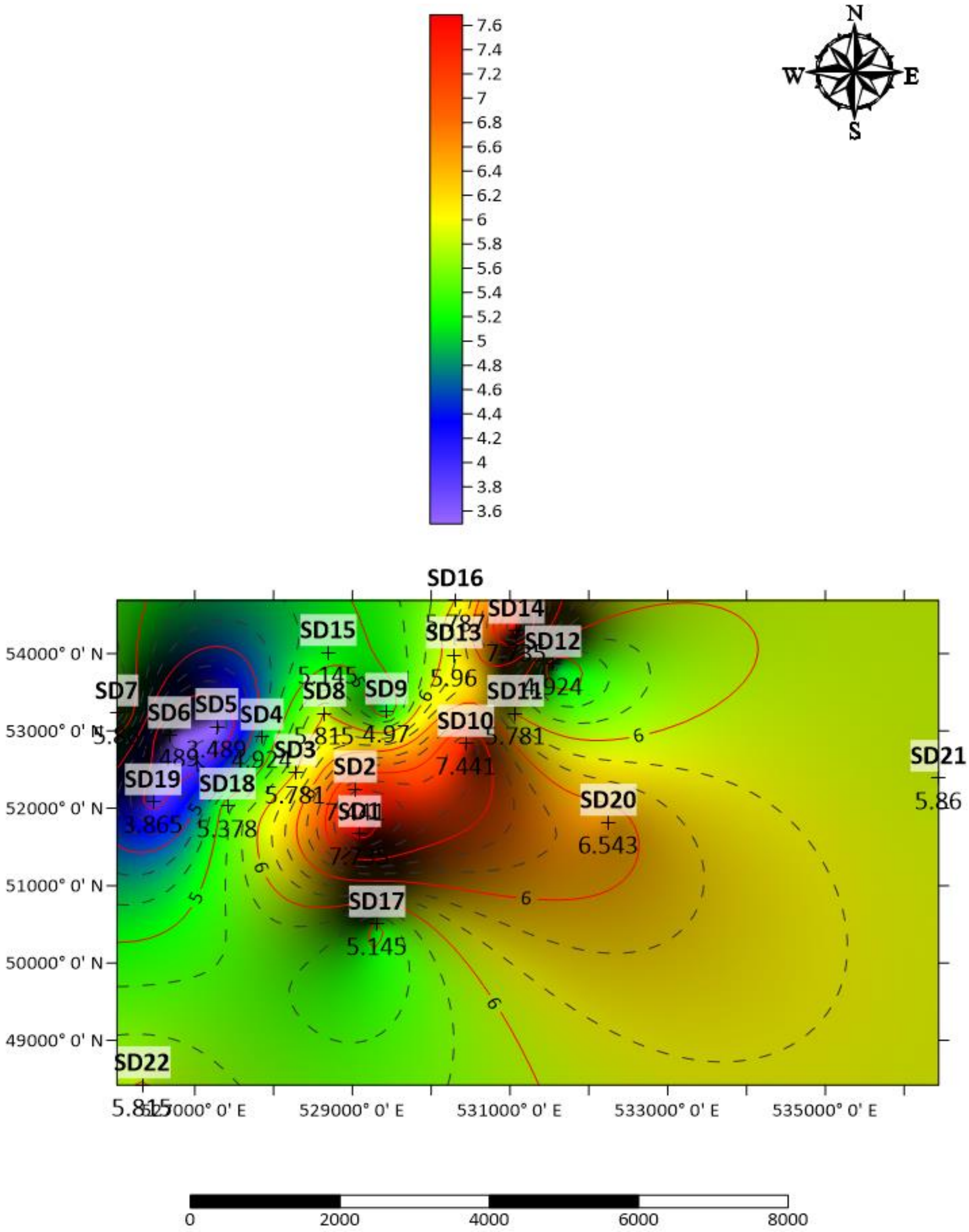


Figure 4.3.5.6d: Spatial distribution of Nickel in the sediments within the area of study

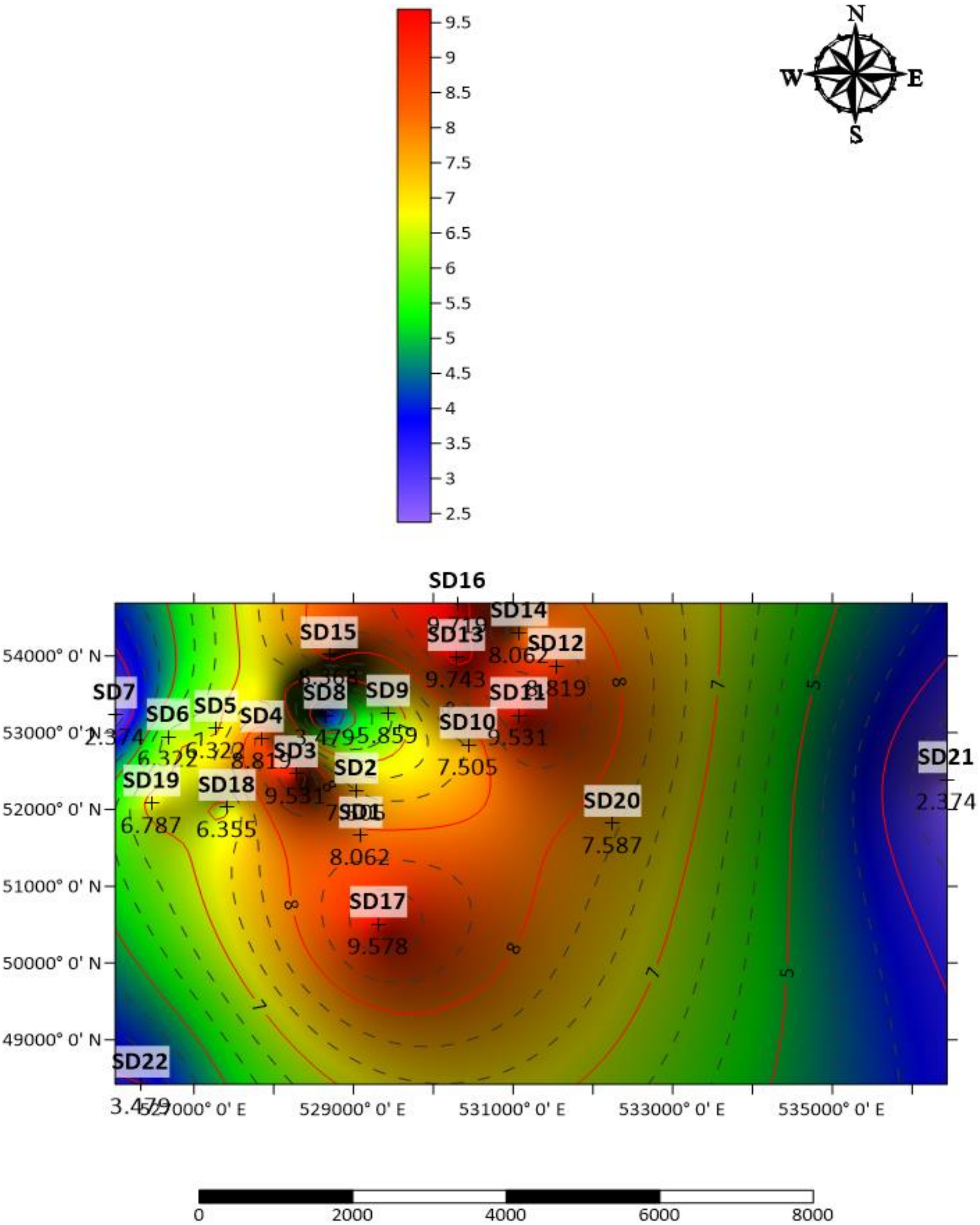


Figure 4.3.5.6e: Spatial distribution of Lead in the sediments within the area of study

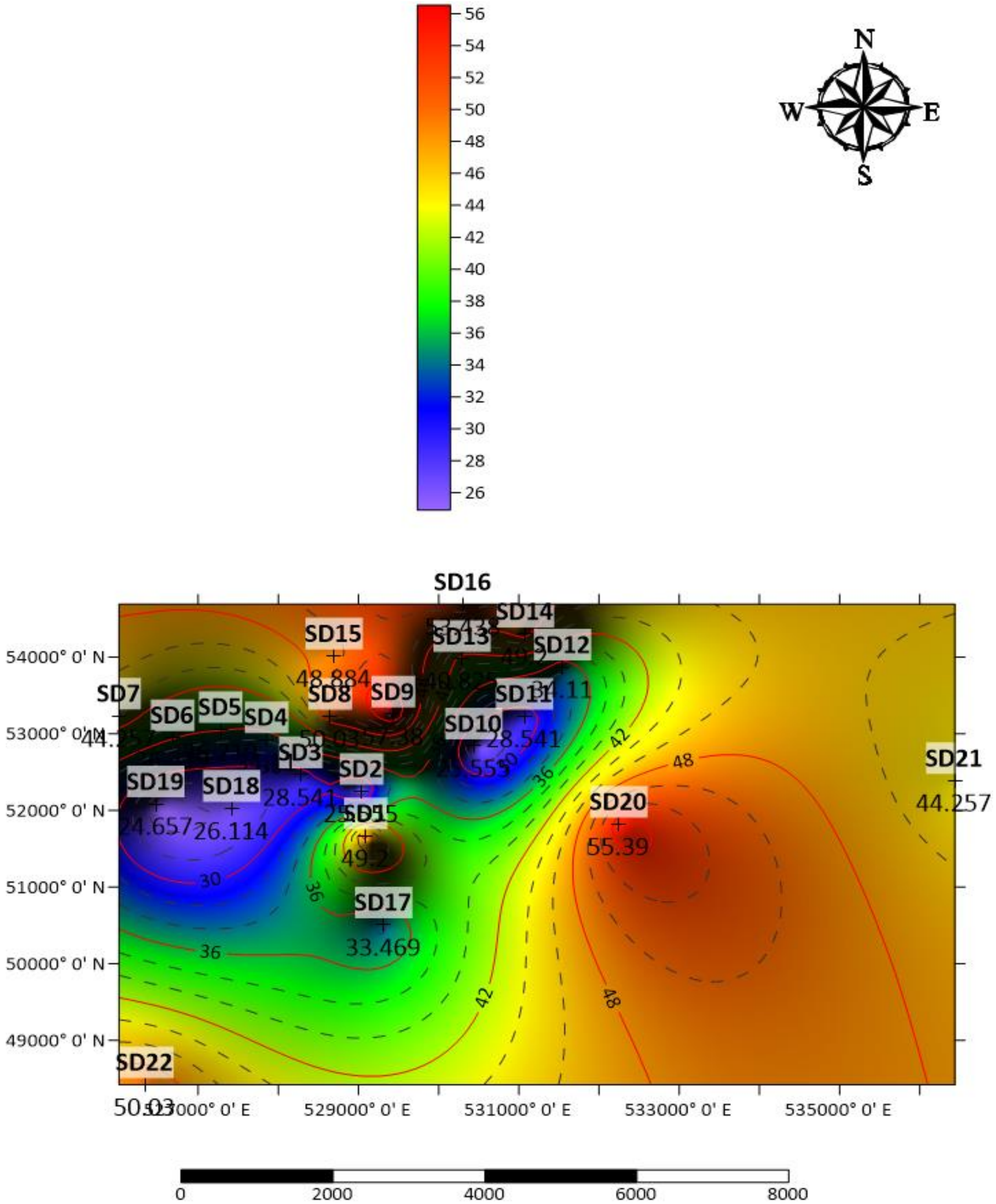


Figure 4.3.5.6f: Spatial distribution of Zinc in the sediments within the area of study

Hydrocarbon:

Organic substances like oil and grease (O &G) prevents oxygen penetration within the soil sediments. This in turn affects the microorganism activities within the soil, thus reducing the soil quality for agricultural purpose. Polycyclic and aliphatics are particularly dangerous to human health, especially when they contaminate the source of drinking water. An average concentration value of 1.76ppm of oil and grease was detected in the sediment samples within 500m radius from the proposed well locations, with a range of 0.9-2.9ppm. These values were lower in the sediment samples collected beyond this radius, with average concentration value of 0.85ppm and a range of 0.8-0.9 ppm (Fig. 4.3.5.7). Other hydrocarbon indicating parameters such as TOCand THC were similarly low. Previous studies also show low concentration of hydrocarbons in the study area.

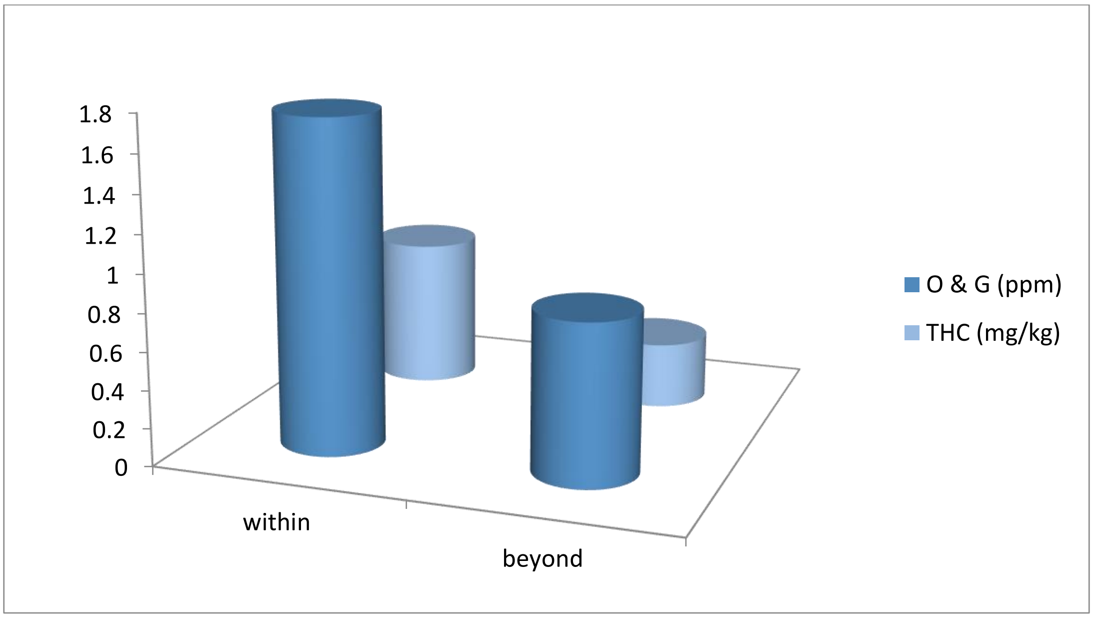


Figure 4.3.5.7: Average O&G and THC composition of sediments within project radius and control

Similarly, the average concentration value of the total aliphatic hydrocarbon content (THC) was 0.79mg/kg in the sediment samples collected within 500m radius from the proposed well locations, while an average concentration value of 0.4mg/kg was recorded in the samples collected beyond this radius. This trend in the concentration level of hydrocarbons within and beyond the 500m radius from the proposed well locations implies that the source of hydrocarbon pollutants is likely to be from the sea. This is because the control samples (samples beyond 500m radius from the proposed well locations) were collected landwards relative to the main samples (samples within 500m radius from the proposed well locations).

Microorganisms:

Sediments microbial activities are very important indicator of the sediments general quality. For sediment to be suitable for the growth of plant, high microbial activity is required for the breaking down of some of the sediment nutrients for plant uptake. For this reason, the microbial count in sediment samples within and beyond 500m radius from the proposed well locations was analyzed in order to determine the present condition of the sediments within the catchment area. The result revealed high microbial activities within the sediments, with a mean count value of 5810 cfu/g and 29 cfu/g for the total heterotrophic bacteria (THB) and total heterotrophic fungi (THF) respectively within 500m radius from the proposed well locations (Fig. 4.3.5.8). These values were higher in the control sediment with average count value of 10000 cfu/g and 50 cfu/g for THB and THF respectively; hence indicating that areas beyond 500m radius from the reference point are relatively less polluted with hydrocarbon.

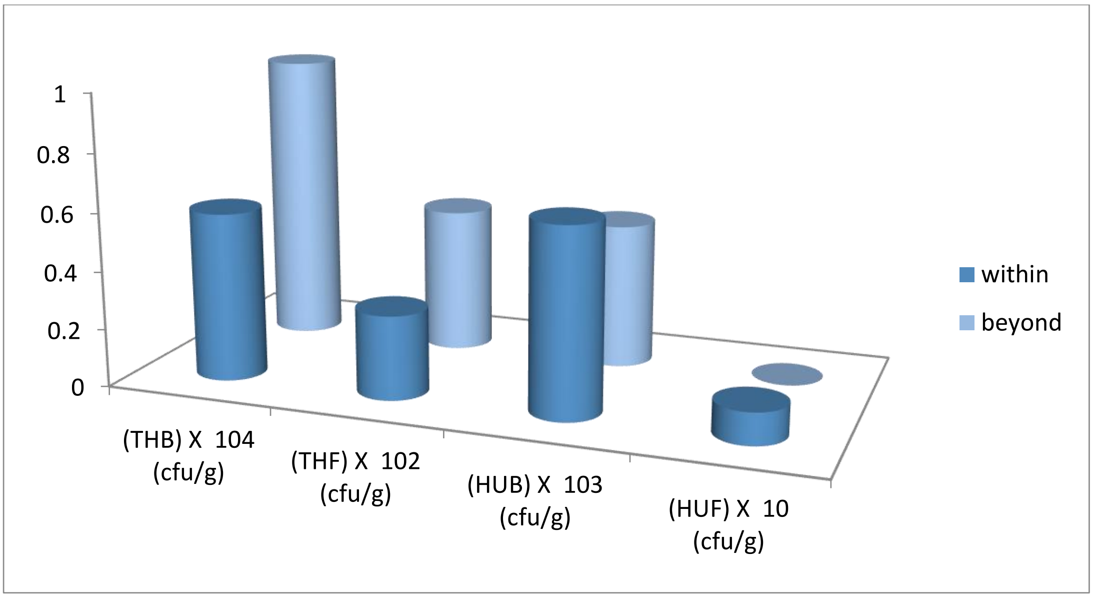


Figure 4.3.5.8: Average THB, THF, HUB, and HUF composition of sediments within project radius and control

However, the average count value of Hydrocarbon utilizing bacteria (HUB) and hydrocarbon utilizing fungi (HUF) of 684cfu/g and 1.1cfu/g respectively for the sediment samples within 500m radius from the proposed well locations suggests that there has been previous hydrocarbon contamination (Atlas and Bartha, 1973). These values of hydrocarbon utilizing microorganisms compare favorably with the total heterotrophic microorganisms (Table 4.3.5.1a), which implies that a bioremediation process is in progress (Atlas, 1981; Bossert and Bartha, 1984).

Table 4.3.5.1a: physicochemical composition of sediments within the catchment area of the proposed Bonny Deep exploration and appraisal wells.

PARAMETER (UNIT)	RANGE WITHIN 500m			RANGE BEYOND 500m		
	Mean	**Max**	**Min**	**Mean**	**Max**	**Min**
PHYSICOCHEMICAL PROPERTIES						
pH	4.695	6.1	3.6	4.15	4.5	3.8
Redox Potential (mV)	77.83	133.6	27.3	101.25	134.2	68.3
Electrical Conductivity (uS/cm)	17344	35100	3380	10237	16200	4274
TOC (%)	0.246	0.389	0.069	0.086	0.100	0.072
O & G (ppm)	1.755	2.9	0.9	0.85	0.9	0.8
NH4+ (mg/kg)	3.44	5.86	1.52	5.17	6.98	3.37
NO3- (mg/kg)	0.049	0.095	0.004	0.065	0.074	0.056
NO2- (mg/kg)	0.006	0.017	0.002	0.008	0.013	0.003
Total Phosphorous (%)	0.031	0.073	0.004	0.019	0.035	0.003
Total Nitrogen (%)	0.020	0.07	0.007	0.019	0.022	0.015
THC (mg/kg)	0.79	1.9	0.3	0.35	0.4	0.3
TEXTURE						
% Sand	62.75	93	26.9	58.75	62.2	55.3
% Silt	7.36	19.1	1.4	6.15	6.6	5.7
% Clay	29.89	71.2	5.3	35.1	39	31.2
EXCHANGABLE CATIONS						
Na (mg/kg)	2999	5739	555	1987	3239	734
K (mg/kg)	660	1914	130	266	414	117
Ca (mg/kg)	176	577	58	69	70	68
Mg (mg/kg)	128	358	42	47	50	44
HEAVY METALS						
Fe (mg/kg)	5473	6637	4719	5820	5945	5695
Cu (mg/kg)	3.42	7.62	1.58	3.52	4.42	2.61
Zn (mg/kg)	39.08	57.38	24.66	47.14	50.03	44.26
V (mg/kg)	ND	ND	ND	ND	ND	ND
Pb (mg/kg)	7.52	9.74	2.37	2.93	3.48	2.37
Cd (mg/kg)	2.76	3.77	1.54	2.10	2.58	1.62
Ni (mg/kg)	5.66	7.73	3.49	5.84	5.86	5.82
Cr (mg/kg)	0.16	0.27	0.10	0.22	0.27	0.17
MICROORGANISM						
(THB) X 104 (cfu/g)	0.581	1.5	0.03	1	1.1	0.9
(THF) X 103 (cfu/g)	0.029	0.09	ND	0.05	0.06	0.04
(HUB) X 103 (cfu/g)	0.648	1.75	ND	0.5	0.7	0.3
(HUF) X 102 (cfu/g)	0.011	0.06	ND	ND	ND	ND

Comparative Analysis

T-test statistical analysis was employed to determine whether the observed variation between the concentration levels of the analyzed parameters in the sediment samples within 500m from the proposed well locations and those beyond 500m radius from the same reference point are as a result of chance alone. The null hypothesis of this test states that there is no significant variation between the mean of the samples collected within 500m radius from the well locations and those collected beyond this radius. This hypothesis can be rejected, and the results regarded as significant if the p-value is greater than or equals to 0.05 which was the predetermined confidence level; otherwise, the hypothesis will be accepted, and the results will be regarded as insignificant. Therefore, it can be concluded that there was a significant variation in the concentration levels of TOC, Oil and grease, THC, Ca, Mg, Pb, THB, and HUF in the sediment samples which was collected within and beyond 500m radius from the proposed Bonny deep exploration and appraisal well locations (Table 4.3.5.1b). Thus, the observed variations in the concentration levels of these parameters were not as a result of chance. However, the observed variation in all other parameters which was analyzed for in the sediment samples that were collected within the catchment area (within and beyond 500m radius) of the proposed Bonny deep exploration and appraisal well locations is regarded as insignificant and were as a result of chance alone. Moreover, the data compared closely with that of previous studies in the area (Table 4.3.5.1c)

Table 4.3.5.1b: Comparative analysis between the physicochemical properties of the sediment samples collected within and beyond the proposed Bonny Deep exploration and appraisal Well locations

SEDIMENT							
PARAMETER	WITHIN 2km		BEYOND 2k m		t-test		
	MEAN	SD	MEAN	SD	α -level	p-Value	DECISION
pH	4.70	0.73	4.15	0.49	0.05	0.393	ACCEPT
Redox Potential (mV)	77.8	29.3	101.3	46.6	0.05	0.612	ACCEPT
ELECTRICAL CONDUCTIVITY (uS/cm)	17344	8484	10237	8433	0.05	0.460	ACCEPT
TOC (%)	0.246	0.113	0.086	0.020	0.05	0.000	REJECT
O & G (ppm)	1.755	0.560	0.850	0.071	0.05	0.000	REJECT
NH4+ (mg/kg)	3.442	1.326	5.174	2.551	0.05	0.517	ACCEPT
NO3- (mg/kg)	0.049	0.031	0.065	0.012	0.05	0.250	ACCEPT
NO2- (mg/kg)	0.006	0.005	0.008	0.007	0.05	0.851	ACCEPT

SEDIMENT							
PARAMETER	**WITHIN 2km**		**BEYOND 2k m**		**t-test**		
	MEAN	**SD**	**MEAN**	**SD**	**α -level**	**p-Value**	**DECISION**
TOTAL PHOSPHOROUS (%)	0.031	0.023	0.019	0.022	0.05	0.604	ACCEPT
TOTAL NITROGEN (%)	0.020	0.013	0.019	0.005	0.05	0.841	ACCEPT
THC (mg/kg)	0.790	0.380	0.350	0.071	0.05	0.001	REJECT
%Sand	62.75	19.02	58.75	4.88	0.05	0.493	ACCEPT
%Silt	7.360	4.886	6.150	0.636	0.05	0.320	ACCEPT
% Clay	29.9	18.5	35.1	5.5	0.05	0.411	ACCEPT
Na (mg/kg)	2999	1395	1987	1771	0.05	0.576	ACCEPT
K (mg/kg)	660	408	266	210	0.05	0.152	ACCEPT
Ca (mg/kg)	176.3	129.4	69.2	1.61	0.05	0.002	REJECT
Mg (mg/kg)	128.3	81.2	46.7	4.1	0.05	0.000	REJECT
Fe (mg/kg)	5473	525	5820	177	0.05	0.136	ACCEPT
Cu (mg/kg)	3.42	1.65	3.52	1.28	0.05	0.938	ACCEPT
Zn (mg/kg)	39.08	11.05	47.14	4.08	0.05	0.124	ACCEPT
V (mg/kg)	ND	ND	ND	ND			
Pb (mg/kg)	7.52	2.01	2.93	0.78	0.05	0.008	REJECT
Cd (mg/kg)	2.76	0.77	2.10	0.68	0.05	0.423	ACCEPT
Ni (mg/kg)	5.66	1.27	5.84	0.03	0.05	0.542	ACCEPT
Cr (mg/kg)	0.16	0.05	0.22	0.07	0.05	0.428	ACCEPT
(THB) X 104 (cfu/g)	0.58	0.47	1.00	0.14	0.05	0.045	REJECT
(THF) X 103 (cfu/g)	0.03	0.03	0.05	0.01	0.05	0.224	ACCEPT
(HUB) X 103 (cfu/g)	0.65	0.51	0.50	0.28	0.05	0.588	ACCEPT
(HUF) X 102 (cfu/g)	0.01	0.02	0.00	0.00	0.05	0.017	REJECT

Table 4.3.5.1b: Comparism of sediment physicochemical properties of Bonny deep with previous studies

Parameters	Bonny Oloma (2018)		Bonny NAG (2013)		Bonny Deep (2018)	
	Mean	Range	WET	Dry	Mean	Range
pH	5.13	5.00 - 5.30	6.74	6.37	4.695	3.6 - 6.1
electrical conductivity (µs/cm)	19320	19140 - 19550	5265 - 9715		77.83	3380 – 35100
Salanity (mg/kg)			16915	32886		
PO_4-P (%)	0.13	0.10 - 0.17	44.29	21.3 – 21.3	0.031	0.004 - 0.073
Total nitrogen (%)	0.53	0.40 - 0.71			0.020	0.007 - 0.07
CEC (Cmol/kg)			277 – 281	255		
CO_3^{-2} (mg/kg)	3.43	3.20 - 3.70				
Phenol (mg/kg)	0.00	0.00				
Oil & Grease (ppm)	9.17	7.70 - 11.20			1.755	0.9 - 2.9
Temperature (°C)	28.70	28.40 - 29.10				
Porosity (% pore space)	48	43 – 52				
Permeability (K-4 cm/hr)	1.10	1.00 - 1.20				
Bulk Density (g/cm)	0.21	0.19 - 0.24				
THC (mg/kg)	7.91	6.52 - 8.98	<0.001	253.8	0.79	0.3 - 1.9
TOC (%)	0.74	0.71 - 0.77			0.246	0.069 - 0.389
Cl^- (ppm)	3519	2865 – 4158				
SO_4^{2-}(ppm)	229	195 - 251	1158 – 1342	1149		
NO_3^- N (ppm)	0.03	0.02 -0.03	11 – 15	1.4 –	0.049	0.004 - 0.095

				1.4		
Nitite					0.006	0.002 - 0.017
Ammonium			3.2 – 4.1	2.1 – 2.1	3.44	1.52 - 5.86
Redox Potential (mV)	29.43	26.40 - 31.50			77.83	27.3 - 133.6
Texture						
%Total sand	40.07	11.90 - 55.70			62.75	26.9 - 93
%Total silt	25.50	12.80 - 49.60			7.36	1.4 - 19.1
%Total clay	34.43	30.20 - 38.50			29.89	5.3 - 71.2
Heavy Metals						
Ba (mg/kg)	1.13	0.90 - 1.54				
Cr(mg/kg)	0.76	0.63 - 0.93	10.5 – 192	34.22	0.16	0.10 - 0.27
Cd (mg/kg)	0.72	0.59 - 0.81	<0.01	0.29 – 0.34	2.76	1.54 - 3.77
Cu (mg/kg)	2.28	1.24 - 3.26			3.42	1.58 - 7.62
Pb (mg/kg)	10.30	8.89 - 12.91	28.55	2.38	7.52	2.37 - 9.74
Fe (mg/kg)	3209	3136 - 3279	551 – 607	1245 - 1388	5473	4719 – 6637
Ni (mg/kg)	20.76	15.83 - 23.73	33.35	0.14 – 0.21	5.66	3.49 - 7.73
V (mg/kg)	0.00	0.00	<0.001		ND	ND
Zn (mg/kg)	36.11	30.79 - 39.35	32.4 – 58.3	19.6 – 22.8	39.08	24.66 - 57.38
As (mg/kg)	0.00	0.00				
Hg (mg/kg)						
Mn (mg/kg)	27.14	25.06 - 28.96				

EXCHANGABLE CATIONS						
Ca (mg/kg)	564	510 - 614			176	58 – 577
Mg (mg/kg)	399	375 - 433			128	42 – 358
Na (mg/kg)	2788	2749 - 2848			2999	555 – 5739
K (mg/kg)	311	310 - 312			660	130 – 1914
MICROORGANISM						
(THB) X 10^2 (cfu/g)					0.581	0.03 - 1.5
(THF) X 10^2 (cfu/g)					0.029	ND – 0.09
(HUB) X 10^2 (cfu/g)					0.648	ND - 1.75
(HUF) X 10^2 (cfu/g)					0.011	ND -0.06

4.3.6 Soil

The status of the soil within the catchment area of the proposed Bonny Deep exploration and appraisal well is presented in this section.

- ❖ **Soil Physical properties**

Soil particle size distribution and Texture

The physico-chemical properties of soils of Bonny Deep Sea are presented in Table 4.3.6.1.1 and Appendix I. The particle size distribution of the study area and the control in both depths had high sand content (59.73% and 51.6%), moderate clay (27.76% and 31.2%) and moderate silt content (12.41 and 17.2%) in the top soil. In the subsoil, percent sand, silt and clay were 57.72%, 10.79% and 31.49% in the study area as against 39.65%, 16.50% and 43.49% in the control station. Sand was highest in the top soil with decrease in the subsoil especially in the control station. Clay increased with depth and was highest in the subsoil of the control station while the least clay was recorded in the study area top soil. Greater amount of clay sized particles results in an increase in OM decomposition by increasing water-holding capacity and nutrient exchange sites in these soils. Ohwoghere (2012) in agreement with Akamigbo and Asadu (1986) reported that these soils are similar to those derived from unconsolidated coastal plain sand or sandstone, deltaic plain, Sombreiro and meander belt of the Delta characterized by relatively low quantity of silt and clay contents. The low content of silt and clay reflects subjection of the soils to some degree of leaching, water erosion and the source of the parent materials. The soil separates in the study area and the control were not different significantly ($p>0.05$). The soil texture was predominantly loamy sand and clay but with few pockets of sand, sandy loam and sandy clay in the top soil while in the subsoil, the soil texture was mainly clay and very few sandy loams, sand, loamy sand and sandy clay loam. The predominant clay texture in the subsoil is due to the increased clay in the profile.

Soil Bulk Density and Porosity

The soil bulk density for both the study area and the control were very low; mean bulk densities of 0.39 and 0.43 g/cm^3 as against 0.25 and 0.46 g/cm^3 were recorded in the top and subsoil of the study area and the control respectively. For a normal mineral soil, the value is about 1.25g/cm^3 (Brady, 1990). Such low value is a reflection of soil without much degradation in the study area. The mean values were not significantly different but increased with depth. Generally, the soils are loose, not compacted and poorly aggregated.

Porosity is directly proportional to the bulk density; mean porosity of 44.06 and 44.02% as against 33.75 and 33.93% were observed in the top soil and subsoil of the study area and the control. It was highest in the top and subsoil of the study area. The mean values indicate moderate pore space in the study area while that of the control was waterlogged. However, porosity of both soils showed no significant difference. Abu-Hamdeh and Al-Jalil (1999) reported that reduction of soil bulk density increases porosity.

- **Soil Chemical Properties**

Soil pH and Electrical Conductivity

The chemical properties of the soils are presented in Table 4.3.6.2.1 Soil pH of the study area top soil was strongly acidic (5.03) as against 0.49 (very strongly acidic) while in the control it was 5.05 and 4.85 indicating similar range of strongly acidic to very strongly acidic. The magnitude of pH of the study area and the control was similar and therefore not different significantly different. The strong to very strongly acidity could be attributed to leaching loss of exchangeable bases due to high soil moisture. Aroh (2003) reported pH range of 3.8 - 4.0 (1 mol/L KCl) for most soils of Niger Delta which Foth (1984) observed was not good for crop production as most essential nutrients become available at pH 5.5 -7.3. Severe acidification can cause nonreversible clay mineral dissolution and a reduction in cation exchange capacity, accompanied by structural deterioration (Goulding, 2016).

Electrical conductivity EC was 11071.5 and 11107µS/cm in top and subsoil of the study area compared to higher values of 16350 and 16000 µS/cm in the control. The high EC is associated with high salinity of the sea water. EC is directly associated with salt and ion concentrations found in soils. The EC are inversely correlated to solution pH; it decreases as the pH increases and vice versa, indicating that the solubilization and precipitation of ions in the solution also rely on the H^+ concentrations (Sousa *et al.*, 2007). Smith and Doran (1996) found that EC above 1000 uS/cm is detrimental for crop growth. Soil microorganism activity declines as EC increases. This impacts important soil processes such as respiration, residue decomposition, nitrification, and denitrification.

Table 4.3.6.1.1a Physico-chemical properties of soils around Bonny Deep Area

Parameters	Top soil (0 – 15 cm)			Subsoil (15 – 30 cm)		
	Stydy Area (mean±SD)	Control (mean±SD)	P- value	Stydy Area (mean±SD)	Control (mean±SD)	P- value
Ph	5.03±1.13	5.05±0.92	0.984	4.9±1.26	4.85±0.92	0.957
EC (uS/cm)	11071.5±8530.51	16350±4454.77	0.402	11107.83±8398.78	16000±4384.06	0.429
TOC (%)	0.38±0.22	0.13±0.01	0.129	0.35±0.22	0.06±0.001	0.085
O & G (mg/kg)	1.53±0.64	1±0.28	0.265	1.55±0.78	1.45±0.21	0.860
NH4+ (mg/kg)	0.09±0.11	0.06±0.04	0.728	0.14±0.3	0.07±0.05	0.738
NO3- (mg/kg)	4.09±2.8	3.93±2.61	0.939	3.62±2.51	5.44±1.26	0.328
NO2- (mg/kg)	0.01±0.01	0.01±0.001	0.769	0.01±0	0.01±0.001	0.373
TOTAL P (%)	0.04±0.03	0.02±0.03	0.638	0.03±0.02	0.03±0.02	0.972
TOTAL N (%)	0.07±0.02	0.07±0.01	0.924	0.07±0.02	0.07±0.01	0.968
Bulk density (g/cm)	0.39±0.31	0.25±0.12	0.515	0.43±0.38	0.46±0.29	0.915
Porosity (%)	44.06±8.67	33.75±12.94	0.128	44.02±7.21	33.93±12.62	0.080
CEC (cmol/kg)	1.86±0.59	1.52±0.08	0.426	1.95±0.73	1.44±0.001	0.347
% Sand	59.73±29.01	51.6±25.17	0.705	57.72±27.35	39.65±16.48	0.372
% Silt	12.41±11.63	17.2±7.64	0.577	10.79±7.52	16.5±17.82	0.354
% Clay	27.76±22.97	31.2±17.54	0.839	31.49±23.73	43.85±1.34	0.477
Na (mg/kg)	7.99±6.03	12.46±2.94	0.317	7.88±5.97	11.48±3.13	0.413
K (mg/kg)	1.29±1.18	1.78±0.22	0.578	1.26±1.15	2.31±0.19	0.216
Ca (mg/kg)	0.53±0.48	0.45±0.03	0.820	0.55±0.48	0.48±0.06	0.842
Mg (mg/kg)	0.88±0.84	0.43±0.15	0.471	0.97±0.93	0.53±0.05	0.519
Fe (mg/kg)	2435.63±640.6	2171.79±93.87	0.573	2546.98±751.67	1739.03±294.26	0.150
Cu (mg/kg)	1.7±1.04	1.08±0.64	0.416	1.93±1.1	1.54±0.49	0.621
Zn (mg/kg)	34.75±18.56	21.28±6.34	0.325	38.95±13.68	45.87±21.91	0.512
Pb (mg/kg)	2.39±2.11	1.96±1.36	0.778	2.79±1.98	1.7±1.09	0.458

Parameters	Top soil (0 – 15 cm)			Subsoil (15 – 30 cm)		
	Stydy Area (mean±SD)	**Control (mean±SD)**	**P- value**	**Stydy Area (mean±SD)**	**Control (mean±SD)**	**P- value**
Cd (mg/kg)	1.54±0.65	1.1±0.01	0.364	1.87±0.85	1.11±0.01	0.227
Ni (mg/kg)	4.49±2.55	2.98±2.07	0.426	4.59±2.75	2.59±1.67	0.326
Cr (mg/kg)	0.33±0.21	0.14±0.03	0.226	0.35±0.25	0.26±0.1	0.593
V (mg/kg)	0.05±0.001	0.05±0.001	0.070	0.05±0.001	0.05±0.001	0.070
As (mg/kg)	0.03±0.001	0.03±0.001	0.062	0.03±0.001	0.03±0.001	0.052
Hg (mg/kg)	0.05±0.001	0.05±0.001	0.070	0.05±0.001	0.05±0.001	0.070
Ba (mg/kg)	1.57±0.19	1.54±0.001	0.811	1.6±0.21	1.41±0.18	0.229
(THB) X 10^4 (cfu/g)	1.25±0.9	0.54±0.3	0.281	0.98±0.64	0.63±0.3	0.445
(THF) X 10^3 (cfu/g)	0.74±0.95	0.11±0.11	0.366	0.88±1.75	0.12±0.04	0.555
(HUB) X 10^3 (cfu/g)	3.89±2.76	5±3.18	0.591	3.84±3	3.47±1.92	0.868
(HUF) X 10^2 (cfu/g)	0.83±1.37	NA	0.408	0.53±0.71	0.05±0.06	0.351
THC (mg/kg)	0.80±0.36	0.25±0.21	0.045	0.79±0.48	0.65±0.07	0.684
Phenol (mg/kg)	0.05±0.001	0.05±0.001	0.070	0.05±0.001	0.05±0.001	0.070
TAH (mg/kg)	0.01±0.02	NIL		<0.001	<0.001	NA
PAH (mg/kg)	<0.001	<0.001	N/A	<0.001	<0.001	NA
Total TPH (mg/kg)	0.01±0.02	<0.001	NA	<0.001	<0.001	NA
Total BTEX (mg/kg)	<0.001	<0.001	NA	<0.001	<0.0001	NA

Soil Organic Carbon, Total Nitrogen and Phosphorus

Total organic carbon was 0.38 and 0.35% in the study area and 0.13 and 0.06% in the control station. Though the TOC was slightly higher in the study area than the control, both soils were very deficient compared to the critical level of 1% in Nigeria (Agboola and Ayodele, 1987). Low organic carbon is an indicator of low organic matter and its contribution to plant nutrient availability (Brady and Weil, 1999). High EC of the soil will lead to the destruction of useful soil microbes.

Total N content of the soil was similarly 0.07% (very low content) in both the study area and the control and therefore not variable. Total P content of the soils was very low when compared to the critical level of 15 mg/kg; mean contents of P recorded were 0.04 and 0.03 mg/kg in the top and subsoil of the study area, 0.03 and 0.02 mg/kg in the control station. The low total N and P is in relation to low soil organic carbon that could be mineralized to enrich the soil N and P. The soil ammonium, nitrite and nitrate in line with the soil organic carbon were very low in the study area and the control and showed no significant variability. This indicates low organic materials and low mineralization by microbes in the soil. Ogunjinmi et al. (2017) reported declining levels of N in Nigeria soils. The very low N and P of the soils could also be attributed to leaching loss, low litter mineralization due to high EC and nature of clay mineral. Odigi (1994) gave the clay minerals that constitute Niger Delta soils to include smectite, kaolinite, mixed-layer illite/smectite and illite as the principal clay minerals, with subordinate quantities of chlorite. The kaolinite clay mineral constitutes the mineral with the lowest nutrient reserve and usually more common.

Exchangeable cations

Mean exchangeable K in the top and subsoil of the study area and control was 1.29 and 1.26 cmol/kg as against 1.78 and 2.31 cmol/kg. The concentrations of K in both soils were above the critical level of 0.24 (Agboola and Ayodele, 1987) and 0.12 cmol/kg (SOIL TEST LABORATORY 2014) and therefore sufficient. Mean Mg and Ca were generally deficient in both soils as the highest concentrations of 0.97 and 0.55 cmol/kg recorded in the study area subsoil were far below the critical level of 1.9cmol/kg Mg and 3.8 cmol/kg Ca (Agboola and Ayodele, 1987) and 1.0 cmol/kg Mg and 3.0 cmol/kg Ca (SOIL TEST LABORATORY 2014). The concentrations of the exchangeable cations in both soils showed no significant differences. In line with Shehu et al. (2015) the low concentrations of exchangeable cations (Ca and Mg) could be due to the inherent low contents of the clay minerals and the soils have significantly lost these cations through leaching and other weathering processes.

K concentrations increased with depth in the control station but decreased in the study area. Calcium and Mg increased slightly with depth in both soils. However, the differences were not statistically significant. Sodium concentrations were highest in the top and subsoil of the control station (12.46 and 11.48 cmol/kg) and were above the critical level of 10 cmol/kg. This is detrimental to soil aggregation and stability, as high Na causes deflocculation of clay and therefore high dispersion of soil particles. The high Na of the soil could be due to leaching of Ca and Mg accumulation of Na. In relation to the low exchangeable cations especially Ca and Mg in both soils, the CEC was very low and was below the critical level of

4cmol/kg for most tropical soils. The highest CEC of 1.95cmol/kg was recorded in the subsoil of the study area.

Heavy Metals

Mean vanadium (V), arsenic (As) and Hg among the heavy metals in the study area and the control station showed no variation in their concentrations. Vanadium and Hg occurred in low concentration of 0.05 mg/kg and As was 0.03 mg/kg in both top and subsoil of both soils. Barium showed uniform low distribution in soils of the control and the study area; the highest Ba content of the soil 1.60 mg/kg was recorded in subsoil of the study area. Mean Cu contents increased with depth in both soils; the highest content of 1.73 and 1.93 mg/kg were recorded in the surface of the study area while the least content 1.08 mg/kg was recorded in the subsoil of the control. Copper was deficient in both soils as it was below the critical level of 3.0 mg/kg given by Deb and (Sakal, 2002). Zinc content increased with depth that resulted in the highest mean of 45.87 and 38.95 mg/kg in the subsoil of the control and the study area respectively. The study area also had the highest mean of 34.75 mg/kg in the top soil. The high Zn contents of soils of both stations may be attributed to lack of adsorption on the surfaces of clay-sized particles (Alloway, 2008). The concentrations of Zn in both soils were above the threshold of 3.0 mg/kg (Pam, 1990) suitable for plants.

Low Pb, Ni, Cd and Cr were recorded generally in both soils; Pb increased with depth in the study area alone, Cd and Cr showed slight increase with depth in both soils, Ni showed similar trend of Pb but decreased with depth in the control. Generally, the above heavy metals were below soil threshold limits, therefore poses no threats to the soils. Fe concentration increased from 2435.63 to 2546.98 mg/kg in the study area as against decrease of 2171.79 to 1739.03 mg/kg in the control. Iron concentration was very high in the study area and the control and well above the threshold of 200 mg/kg. The high concentration was further justified by non-significant difference between the study area and the control. Adefemi et al. (2007) had earlier reported the occurrence of Fe in high concentrations in Niger delta soils of Nigeria. The high Fe is also associated with the type of clay mineral.

Oil and Gas

Oil and grease was generally very low; the study area had the highest mean value of 1.53 and 1.55 mg/kg in both depths and were not significant compared to 1.00 and 1.45 mg/kg recorded in the control. The observation revealed that the soils do not contain contaminants from spent oils and other used petroleum products.

Hydrocarbons

Total hydrocarbon content (THC) of the study area and the control was very low; generally, the concentrations were 0.80 and 0.79 mg/kg in the study area, 0.25 and 0.65 mg/kg in the control in both depths. Soil THC was below the threshold of 2.81 mg/kg. Total petroleum hydrocarbon (TPH), total aliphatic hydrocarbon (TAH), total polycyclic aromatic hydrocarbon (PAH) and total BTEX contents of the soils occurred in traces or below detectable limits and therefore possesses no threats in soils of the study area and the control.

Soil Microbiology

In the study area THB count was highest in the top and subsoil (1.25 and 0.98 x 10^4 cfu/g) as against 0.54 and 0.63 x10^4 cfu/g in the control. THF counts was also higher in the top and subsoil of the study area; mean THF 0.74 and 0.88 x 10^3 cfu/g were recorded in the study area as against 0.11 and 0.12 x 10^3 cfu/g in both depths. In reverse to the higher THB in the study area, HUB was higher in soils of the control in the surface; mean HUB of 5.00 x 10^3 cfu/g was recorded as against 3.89 x 10^3 cfu/g in the study area. But in the subsoil, the content was slightly higher in the study area. HUF followed similar pattern of HUB. The observations shows that HUB and THB decreased with depth since microbes are more in the surface soils due to litter abundance and favourable thriving conditions. However, microbe contents were not significantly different in both soils. Rashid et al. (2016) asserted that the proliferation of soil bacteria and fungi contributes to bioavailability and aggregate formation in degraded soils especially with very low nutrient reserve.

Table 4.3.6.1.1b: Comparison of Bonny Deep soil properties with that of previous studies

Parameters	Bonny Oloma (2018)		Bonny NAG (2013)		Bonny Deep (2018)	
	Top	Bottom	WET	Dry	Top	Bottom
pH	5.86	5.90	6.1 – 7.0	6.0-6.2	5.03±1.13	4.9±1.26
electrical conductivity (µs/cm)	125.30	121.94	4258 - 11349	15243 - 16723	11071.5± 8530.51	11107.83± 8398.78
Salanity (mg/kg)			11107			
PO_4-P (%)	0.04	0.03	43 - 52	17.9 – 26.7	0.04±0.03	0.03±0.02
Total nitrogen (%)	0.13	0.11			0.07 ± 0.02	0.07 ± 0.02
CEC (Cmol/kg)	1.60	1.58	151 – 278	234 – 273		
CO_3^{-2} (mg/kg)	5.88	6.50				
Phenol (mg/kg)	ND	ND			0.05 ± 0.001	0.05 ± 0.001
Oil & Grease (ppm)	1.46	1.22			1.53 ± 0.64	1.55 ± 0.78
Temperature (°C)	29.14	28.64				
Porosity (% pore space)	63.60	66.00			44.06 ± 8.67	44.02 ±7.21
Permeability (K-4 cm/hr)	1.66	1.52				
Bulk Density (g/cm)	0.14	0.17			0.39 ± 0.31	0.43 ± 0.38

THC (mg/kg)	0.77	0.77	<0.001 – 81250	1.83 – 207	0.80 ± 0.36	0.79 ± 0.48
TOC (%)	0.71	0.64			1.38 ± 0.22	0.35 ± 0.22
Cl^- (ppm)	34.97	31.00				
SO_4^{2-}(ppm)	3.37	3.95	558.4	410.46		
NO_3^- N (ppm)	0.05	0.05	11 – 15	0.5 -28	4.09±2.8	3.62 ± 2.51
Nitite			<0.001	<0.001	0.01±0.01	0.01±0
Ammonium			7.5	7.03	0.09 ± 0.11	0.14 ± 0.3
Redox Potential (mV)	14.68	17.80				
%Total sand	94.48	94.66			59.73 ± 29.01	10.79 ± 7.52
%Total silt	2.50	2.22			12.41 ± 11.63	10.79 ± 7.52
%Total clay	3.02	3.12			27.76 ± 22.97	31.49 ± 23.73
Heavy Metals						
Ba (mg/kg)	0.34	0.40			1.57 ± 0.19	1.6 ± 0.21
Cr(mg/kg)	0.29	0.27	<0.01 – 99.1	1.88 – 6.34	0.33 ± 0.21	0.35 ± 0.25
Cd (mg/kg)	0.57	0.42	<0.01 – 2.2	0.02 – 0.17	1.54 ± 0.65	1.87 ± 0.85
Cu (mg/kg)	0.28	0.27			1.7 ±1.04	1.93 ±1.1
Pb (mg/kg)	3.77	4.00	9.7 – 63.6	0.12 – 1.45	2.39 ± 2.11	1.7 ± 1.09
Fe (mg/kg)	1187.51	1055.40	450 -598	603 - 933	2435.63 ± 640.6	2546.98 ±751.67
Ni (mg/kg)	5.00	4.68	27.0 – 57.9	0.01 – 0.04	4.49±2.55	4.59 ± 2.75
V (mg/kg)	0.06	ND	<0.01	<0.01	0.05 ± 0.001	0.05 ± 0.001

Zn (mg/kg)	16.97	17.84	28.4 – 247	13.4 -31.1	34.75 ± 18.56	38.95 ± 13.68
As (mg/kg)	ND	ND			0.03 ± 0.001	0.03 ± 0.001
Hg (mg/kg)					0.05 ± 0.001	0.05 ± 0.001
Mn (mg/kg)	14.17	13.46				
EXCHANCEABLE CATIONS						
Ca (mg/kg)	1.60	1.94	162.75	65.9	0.53 ± 0.48	0.55 ± 0.49
Mg (mg/kg)	0.83	1.57			0.88 ± 0.84	0.97 ± 0.93
Na (mg/kg)	14.17	12.36	2876.23	534	7.99 ± 6.03	7.88 ± 5.97
K (mg/kg)	1.85	3.26			1.29 ±1.18	1.26 ± 1.15
TEXTURE						
Sand	94.48	94.66				
Silt	2.5	2.22				
Clay	3.02	3.12				
Texture	SAND	SAND				
HYDROCARBON						
PAH (µg/L)	ND	ND			<0.001	<0.001
TAH					0.01 0.02	<0.001
BTEX (µg/L)	ND	ND			<0.001	<0.001
Micro-Biology						
THB cfu/g	30000 $x10^4$	30000 $x10^4$	1.26 $x10^5$– 8.6 $x10^6$	3.5 -6.7 $x10^5$	1.25 ± 0.9 $x10^4$	0.98 ± 0.64 $x10^4$
THF cfu/g	3500	4040	1.0 -3.4	1.1 – 3.8 $x10^2$	0.74	0.88 ± 1.75

	x10^3	x10^3	x10^2		±0.95 x10^3	x10^3
HUB cfu/g	10200 x10^4		1.45 x10^2 - 7.2 x10^3		3.89 ± 2.76 x10^3	3.84 ± 3 x10^3
HUF cfu/g	640 x10^3		1.25 x10 – 5.5 x10		0.83 ±1.37 x10^2	0.53 ± 0.71 x10^2
SRB cfu/g	1040 x10^3	1230 x10^3				

4.3.7 Groundwater

The current groundwater quality within the catchment area of the proposed Bonny deep exploration and appraisal wells is presented. Groundwater serves as source of drinking water and for other domestic use to most people in the Niger delta region of Nigeria. Therefore the quality of this source of water needs to be ascertained in other to ensure that it meets the standard required by most environmental protection agencies. It should be noted that groundwater quality can be affected by geogenic or anthropogenic factors. However, the aim of this study is not to determine the quality of the groundwater for consumption or domestic purposes, but to evaluate the present condition of the pre-existing quality of the groundwater. This will help in determining the impact of the proposed project on the environment following subsequent environmental evaluation reviews.

To achieve this, three ground water samples were collected from wells at the depth of 4m within 500m radius from the proposed well locations, and two samples from wells beyond 500m radius from the same reference points. The groundwater samples were bottled in triply filtered plastic bottles which were also well labelled, and were preserved in optimal conditions prior to laboratory analysis. The samples were analysed for its physicochemical properties, heavy metal, hydrocarbon, and biological content. The raw result from the laboratory was presented in Appendix 6 which was summarized in Table 4.3.7.1a. The interpretations are summarized of the results were as follows:

pH, EC, TDS, TSS, Salinity, and Turbidity:

The average pH, EC, and TDS of the samples collected within 500m radius from the proposed well locations were 7.3, 31700µS/cm, and 15966mg/L with ranges of 7.1-7.4, 30400-32400µS/cm, and 15200-16500mg/L respectively. This shows that the groundwater within 500m radius is slightly alkaline, but still falls within EPA and DPR permissible limit of 6.5-8.0. The EC and TDS values exceeds the EPA and Nigerian standard for drinking water permissible limit of <500mg/L for TDS and < 1000 µS/cm for EC. These results are consistent with other similar report such as Efe and Mogborukor (2012), and Amadi and Akobundu, (2014) within the Niger delta region.

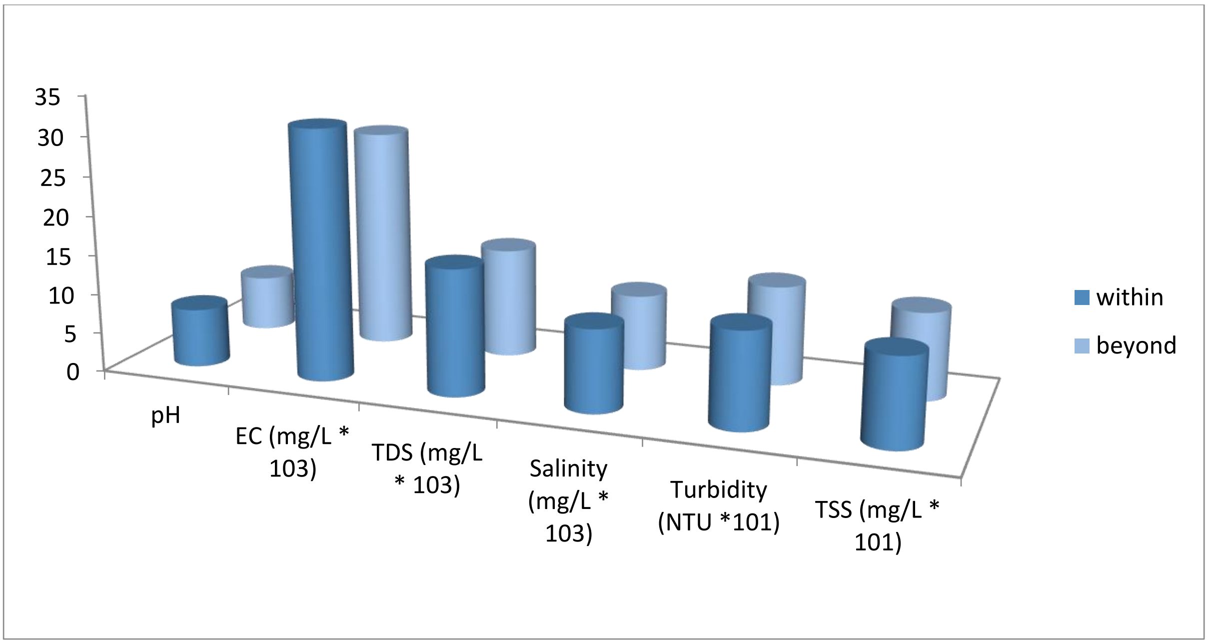


Figure 4.3.7.1: Average values of pH, EC, TDS, Salinity, Turbidity and TSS in the main and control groundwater samples

Figure 4.3.7.1 revealed that there was no significant difference between the concentration levels of these parameters in groundwater samples within and beyond 500m radius from the proposed well locations. Similar observation was made in concentration levels of turbidity, salinity and total suspended solids (TSS) which has average concentration values of 121 NTU, 10424 mg/L, and 110 mg/L respectively. The high salinity value implies that the ground water is probably composed of sea water rather than fresh water.

Oxygen Demands:

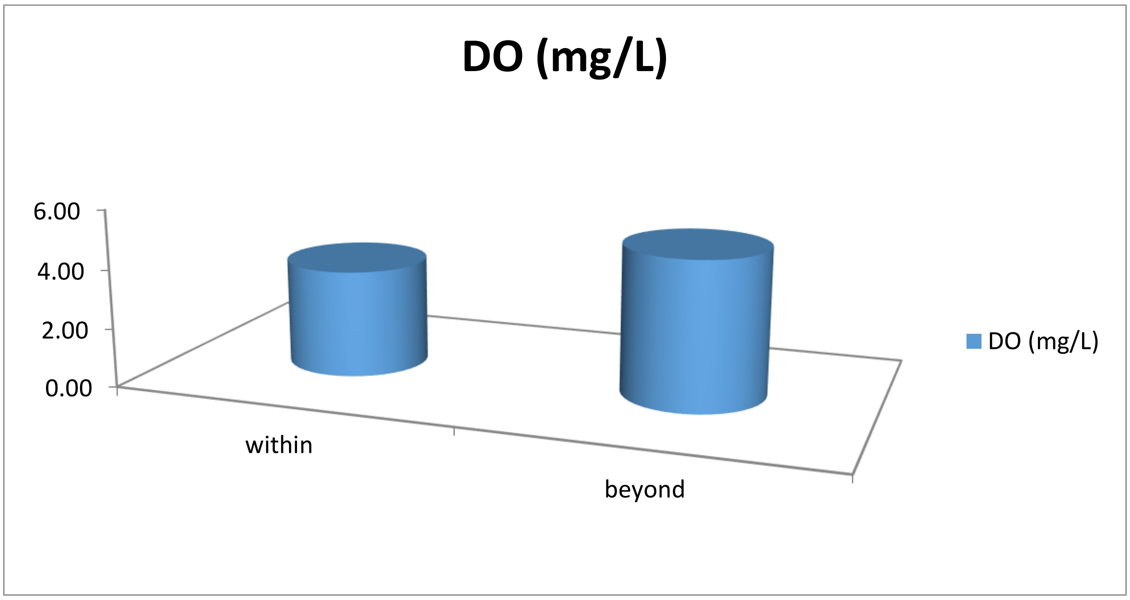


Figure 4.3.7.2: Average concentration values DO in the main and control groundwater samples

The average values of the dissolved oxygen (DO) from groundwater samples in wells within 500m radius from the proposed well locations is 3.63mg/L, with a range of 3.1-4.5mg/L. These values compares favourably with the values obtained in wells beyond 500m radius from the reference point (Fig. 4.3.7.2); hence it can be inferred that the groundwater quality within and beyond the catchment area are apparently of the same quality. However, the values of the DO are low and signify high organic activities. Depletion of dissolved oxygen in water supplies can encourage the microbial reduction of nitrate to nitrite and sulphate to sulphide. It can also cause an increase in the concentration of ferrous iron in solution, with subsequent discoloration at the tap when the water is aerated (WHO, 2008). Therefore this should be taken into consideration in further environmental development studies within the area.

Heavy metals and trace elements:

These parameters include; Antimony, Cobalt, Nickel, Tin, Arsenic, Copper, Selenium, Titanium, Beryllium, Lead, Silver, Uranium, Barium, Manganese, Cadmium, Mercury, Tellurium, Vanadium, Chromium, Molybdenum, Thallium, and Zinc. Most of these elements are toxic to humans and animals even at lower concentration. Most importantly, they can enter the food chain through uptakes by plants and consumptions by livestock; hence posing a problem to human health. Among the heavy metals tested in the groundwater samples within and beyond 500m radius from the proposed well locations, only Cu, Fe, Pb and Zn were detected, with average concentration values of 0.035mg/L, 0.063mg/L, 0.008mg/L and 0.187mg/L respectively. Lead and Iron concentrations were relatively lower in the groundwater samples beyond 500m radius from the proposed well locations compared with the ones within 500m radius, while the concentration level of Cu and Pb remained almost the same (Fig. 4.3.7.3).

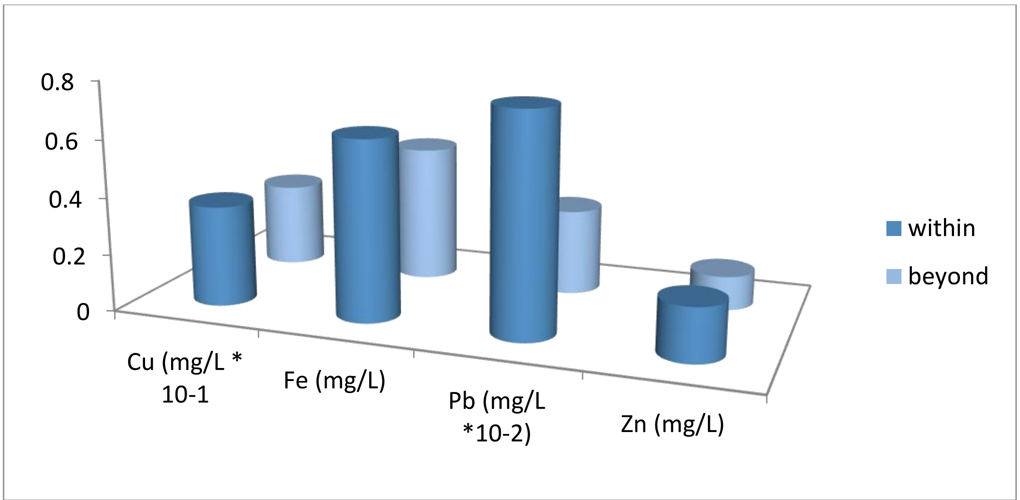


Figure 4.3.7.3: Average concentration values of Cu, Fe, Pb, and Zn in the main and control groundwater samples

The spatial distribution of heavy metals with elevated concentrations in the groundwater is presented Figures 4.3.7.4 a-d. It is shown that Cu is elevated in BH3, Fe in BH2, Pb in BH2, and Zn in BH2 and BH3. However, these values of Cu, Fe, Pb, and Zn are within the permissible limit of most environmental protection agencies.

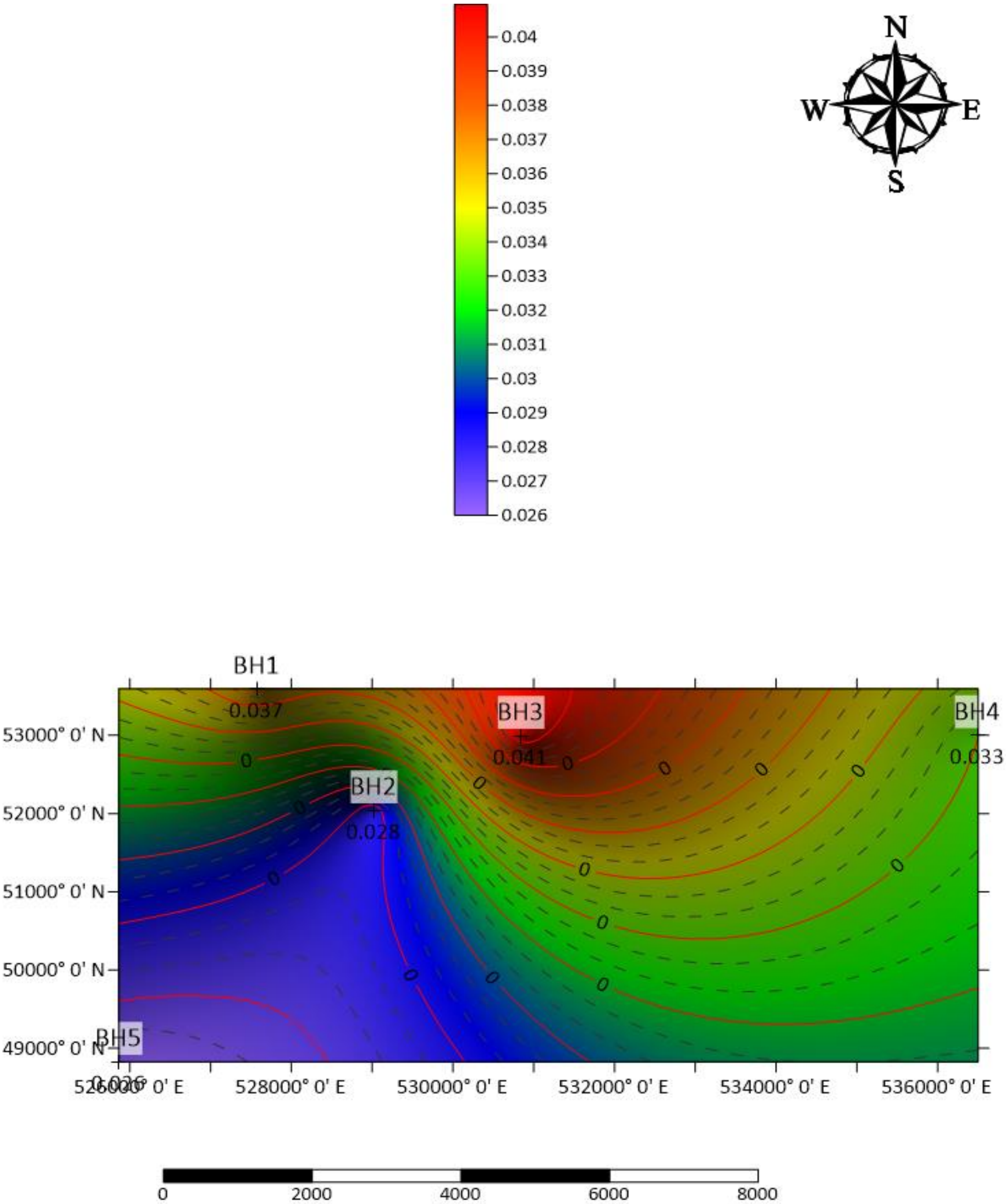


Figure 4.3.7.4a Spatial distribution of Copper in groundwater in the study location

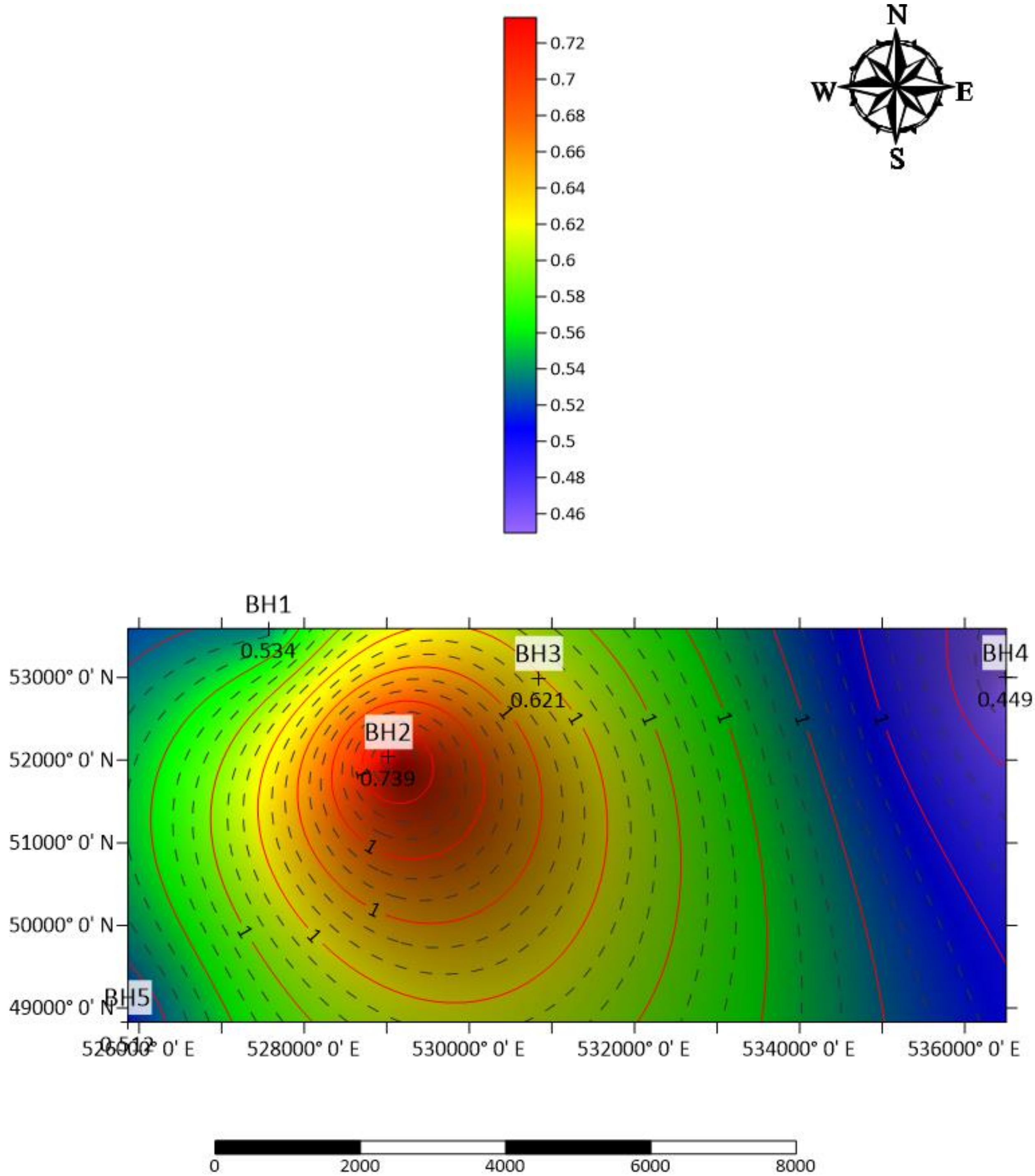


Figure 4.3.7.4b Spatial distribution of Iron in groundwater in the study location

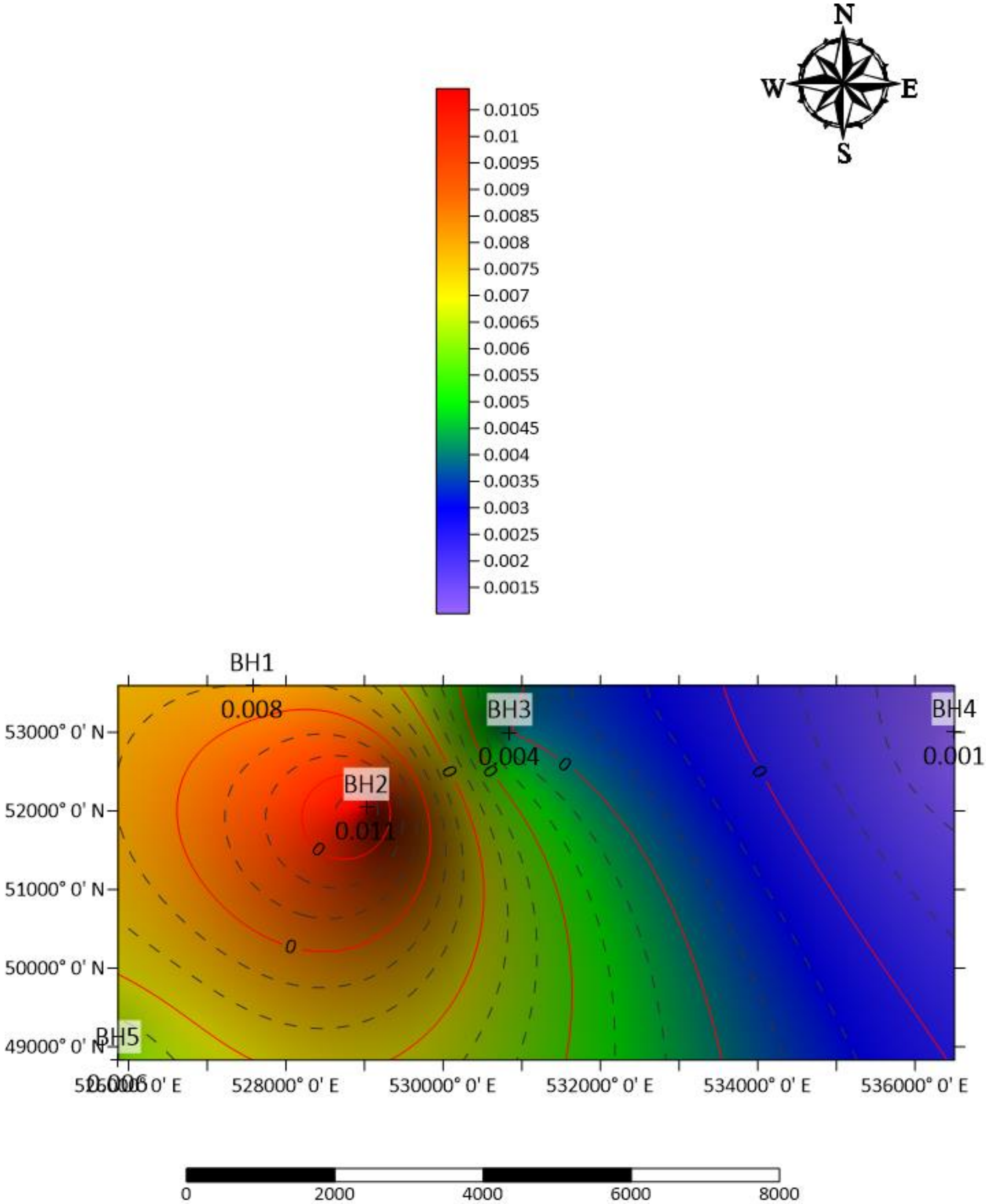
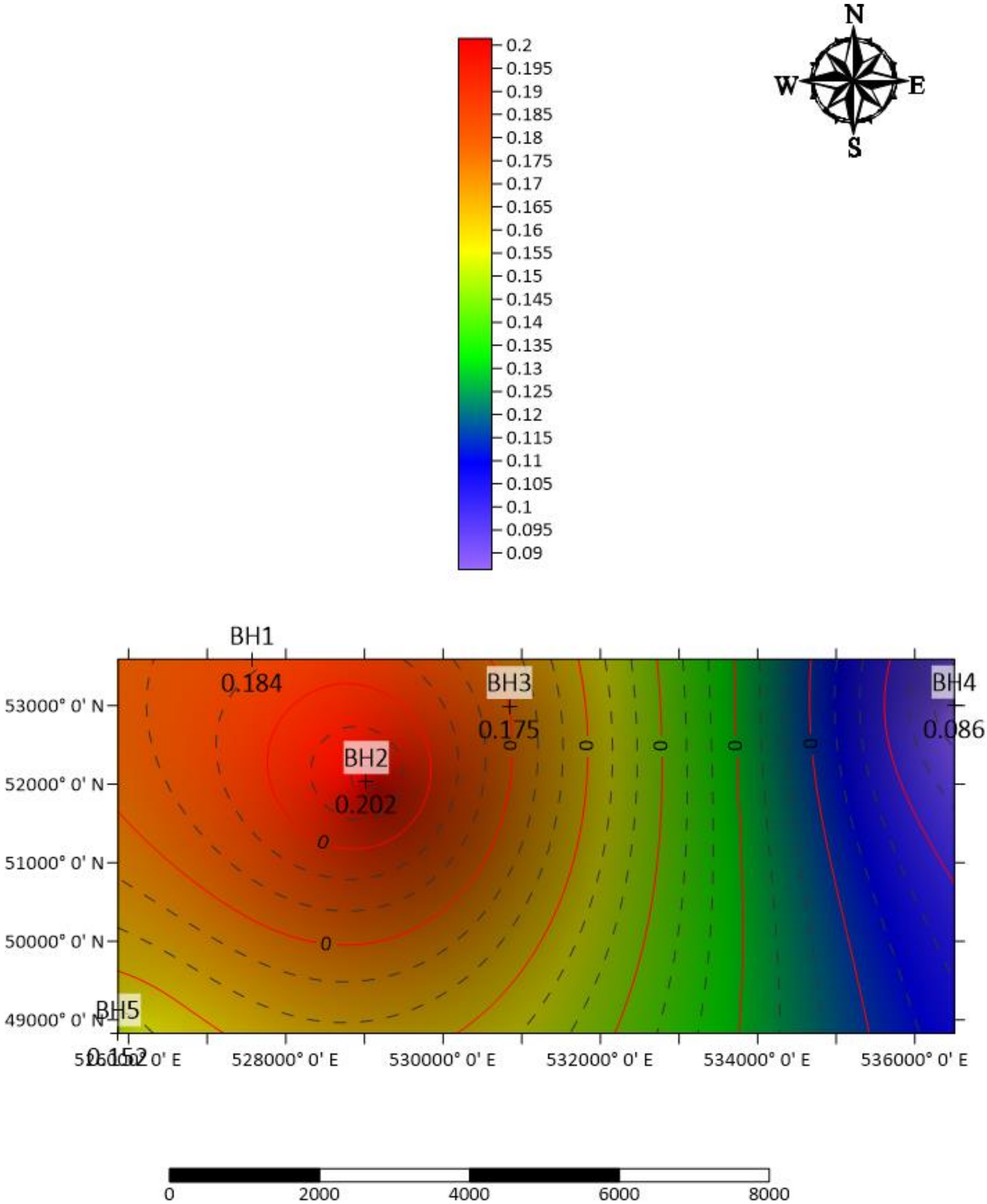


Figure 4.3.7.4c spatial distribution of Lead in groundwater in the study location



0.2
0.195
0.19
0.185
0.18
0.175
0.17
0.165
0.16
0.155
0.15
0.145
0.14
0.135
0.13
0.125
0.12
0.115
0.11
0.105
0.1
0.095
0.09
N
W
E
S
BH1
0.184
BH2
0.202
BH3
0.175
BH4
0.086
BH5
0.152
53000° 0' N
52000° 0' N
51000° 0' N
50000° 0' N
49000° 0' N
528000° 0' E
530000° 0' E
532000° 0' E
534000° 0' E
536000° 0' E
0
2000
4000
6000
8000

Figure 4.3.7.4d spatial distribution of zinc in groundwater in the study area

Hydrocarbon:

This includes Organoleptic (petroleum, oil, grease and related materials), Polycyclic, and Aliphatics. Problems associated with these substances include; interference with such vital processes as the mass transfer of oxygen from air to water (essential in river reaeration), blockage of pipes, odour and taste problems, cancers, etc. However, none of these compounds were detected in the wells tested. Therefore there is no hydrocarbon contamination of the groundwater within the catchment area of the proposed well locations.

Microorganisms:

Microbial activities were detected in some of the groundwater samples collected within 500m radius from the proposed well locations with average count value of 2967 cfu/g and 27 cfu/g for the total heterotrophic bacteria (THB) and total heterotrophic fungi (THF) respectively. This value was slightly higher for THB (3200 cfu/g), but was almost constant (20 cfu/g) for THF in the groundwater samples collected beyond the same radius (Fig. 4.3.7.5).

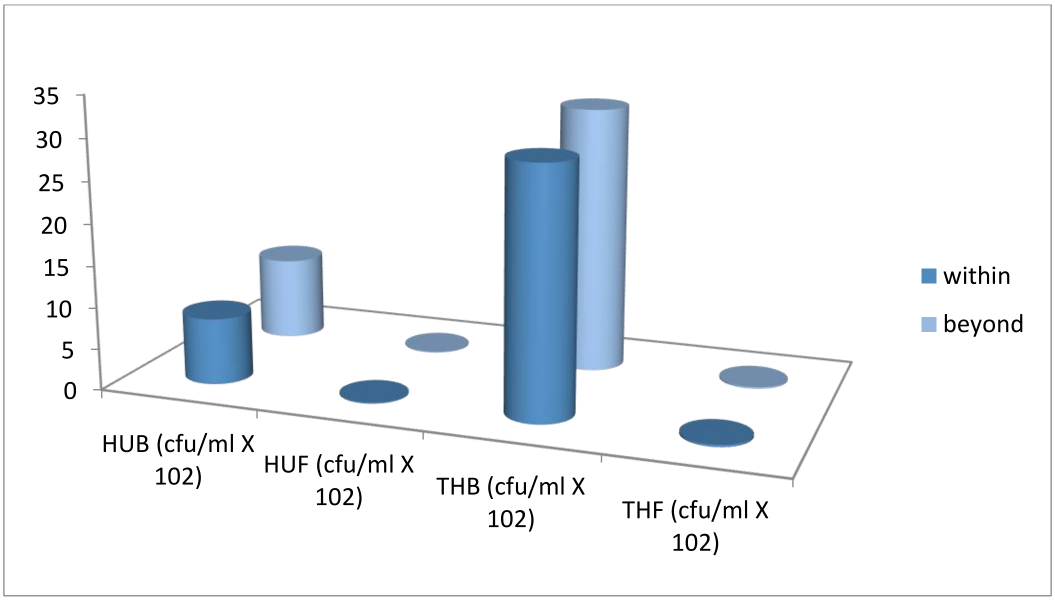


Figure 4.3.7.5: Average count values of HUF, HUB, THB, and THF in the main and control groundwater samples

However, the presence of Hydrocarbon utilizing bacteria (HUB) and hydrocarbon utilizing fungi (HUF) with average count value of 800 cfu/g and 13 cfu/g respectively in the groundwater samples collected within 500m radius from the proposed well locations suggests that there have been previous hydrocarbon contamination (Atlas and Bartha, 1973). These values of hydrocarbon utilizing microorganisms compare favourably with the total heterotrophic microorganisms (Table 4.3.7.1a), which implies that a bioremediation process is in progress (Atlas, 1981; Bossert and Bartha, 1984).

Table 4.3.7.1a: Physicochemical properties of groundwater within the catchment area of the proposed Bonny deep exploration and appraisal well locations

PARAMETER	**UNIT**	**WITHIN**			**BEYOND**			**DPR limit**
		mean	**max**	**min**	**mean**	**max**	**min**	
PHYSICOCHEMICAL PROPERTIES								
pH		7.3	7.4	7.1	7	7	7	6.5-8.5
Redox Potential	mV	-31.0667	-30.7	-31.3	-30.55	-30.3	-30.8	
Electrical Conductivity	µS/cm	31700	32400	30400	27800	40200	15400	
Temperature	^{o}C	27.5	28	27	27.55	28.2	26.9	
Turbidity	NTU	121	165	46	125	136	114	
TSS	mg/L	110	149	40	113	121	105	
TDS	mg/L	15966	16500	15200	13900	20100	7700	
THC	mg/L	ND	ND	ND	ND	ND	ND	0.6
DO	mg/L	3.63	4.5	3.1	4.05	4.1	4	
Salinity as Cl	mg/L	10424	12300	7896	9609	14992	4226	600
Oil & Grease	mg/L	ND	ND	ND	ND	ND	ND	
HEAVY METALS								
Cu	mg/L	0.035	0.041	0.028	0.0295	0.033	0.026	
Fe	mg/L	0.631	0.739	0.534	0.4805	0.512	0.449	1
Cd	mg/L	ND	ND	ND	ND	ND	ND	
Cr	mg/L	ND	ND	ND	ND	ND	ND	
Ni	mg/L	ND	ND	ND	ND	ND	ND	
V	mg/L	ND	ND	ND	ND	ND	ND	
Pb	mg/L	0.0077	0.011	0.004	0.003	0.006	ND	
Zn	mg/L	0.187	0.202	0.175	0.119	0.152	0.086	1.5
MICROORGANISM								
HUB	cfu/ml X 10^2	8	18	ND	10	11	9	
HUF	cfu/ml X 10^2	0.13	0.4	ND	0.1	0.2	ND	
THB	cfu/ml X 10^2	29.677	34	27	32	35	29	
THF	cfu/ml X 10^2	0.27	0.5	ND	0.2	0.4	ND	

Comparative analysis

T-test statistical analysis was employed to determine whether the observed variation between the concentration levels of the analysed parameters in the groundwater samples within 500m from the proposed well locations and those beyond 500m radius from the same reference point are as a result of chance alone. The null hypothesis of this test states that there is no significant variation between the mean of the samples collected within 500m radius from the well locations and those collected beyond this radius. This hypothesis can be rejected, and the results regarded as significant if the p-value is greater than or equals to 0.05 which was the predetermined confidence level; otherwise, the hypothesis will be accepted, and the results will be regarded as insignificant. Therefore, it can be concluded that there is no significant variation in the concentration levels of all the parameters that was analysed for in the groundwater samples which was collected within and beyond 500m radius from the proposed Bonny deep exploration and appraisal well locations (Table 4.3.7.1b). Thus, any observed variation in the concentration levels of the parameters was as a result of chance alone.

Table 4.3.7.1b: Comparative analysis between the physicochemical properties of the groundwater samples collected within the catchment area of the proposed Bonny Deep exploration and appraisal Well locations

GROUNDWATER							
PARAMETER	**WITHIN 2km**		**BEYOND 2km**		**t-test**		
	MEAN	**SD**	**MEAN**	**SD**	**α -level**	**p-Value**	**DECISION**
pH	7.30	0.17	7.00	0.00	0.05	0.10	ACCEPT
Redox Potential(mV)	-31.07	0.32	-30.55	0.35	0.05	0.24	ACCEPT
Electrical Conductivity(µS/cm)	31700	1127	27800	17536	0.05	0.81	ACCEPT
Temperature (Oc)	27.50	0.50	27.55	0.92	0.05	0.96	ACCEPT
Turbidity(NTU)	121.17	65.26	124.95	15.63	0.05	0.93	ACCEPT
TSS (mg/L)	110.67	61.27	113.00	11.31	0.05	0.95	ACCEPT
TDS(mg/L)	15967	681	13900	8768	0.05	0.80	ACCEPT
THC(mg/L)	0.00	0.00	0.00	0.00			
DO(mg/L)	3.63	0.76	4.05	0.07	0.05	0.44	ACCEPT
Salinity as Cl(mg/L)	10424	2273	9609	7612	0.05	0.91	ACCEPT
Oil & Grease(mg/L)	ND	ND	ND	ND			
Cu(mg/L)	0.04	0.01	0.03	0.005	0.05	0.34	ACCEPT

GROUNDWATER							
PARAMETER	**WITHIN 2km**		**BEYOND 2km**		**t-test**		
	MEAN	**SD**	**MEAN**	**SD**	**α -level**	**p-Value**	**DECISION**
Fe(mg/L)	0.63	0.10	0.48	0.04	0.05	0.11	ACCEPT
Cd(mg/L)	ND	ND	ND	ND			
Cr(mg/L)	ND	ND	ND	ND			
Ni(mg/L)	ND	ND	ND	ND			
V(mg/L)	ND	ND	ND	ND			
Pb(mg/L)	0.01	0.00	ND	ND	0.05	0.33	ACCEPT
Zn(mg/L)	0.19	0.01	0.12	0.05	0.05	0.29	ACCEPT
HUB (cfu/ml X 10^2)	8.00	9.17	10.00	1.41	0.05	0.75	ACCEPT
HUF (cfu/ml X 10^2)	0.13	0.23	0.10	0.14	0.05	0.85	ACCEPT
THB (cfu/ml X 10^2)	29.67	3.79	32.00	4.24	0.05	0.59	ACCEPT
THF (cfu/ml X 10^2)	0.27	0.25	0.20	0.28	0.05	0.81	ACCEPT

Table 4.3.7.1c: Comparism of Bonny Deep groundwater physicochemical parmeers with previous studies

Parameters	Bonny Oloma (2018)		Bonny NAG (2013)		Bonny Deep (2018)	
	Range	Mean	WET	Dry	Range	Mean
pH	6.80 - 7.10	6.93	6.2	6.2	7.1 - 7.4	7.3
electrical conductivity (µs/cm)	520.00 - 780.00	673.33	299.0	294.0	30400 - 32400	31700
TDS (mg/L)	382.00 - 484.00	423.67	143.9	138.4	15200 – 16500	15966
SALINTY (%)	0.79 - 0.97	0.87	0.1	0.1		
TEMPERATURE (°C)	28.90 - 30.00	29.37	24.7	25.1	27 - 28	27.5

TSS (mg/L)	6.00 - 50.00	24.67	20.00	11.00	40 – 149	110
TURBIDITY (NTU)	8.00 - 58.00	28.50	8.43	8.11	46 – 165	121
Cl^- (mg/L)	96.00 - 118.00	106.16			7896 – 12300	10424
SO_4^{2-} (mg/L)	17.20 - 31.91	27.01	2.40	1.85		
Hydrogen sulphide mg/l			<0.001	<0.01		
Total Hardness (mg/l)			40.00	32.00		
Colour (Pt.Co)	13.00 - 45.00	33.33				
Ammonia (mg/l)			<0.01	<0.01		
Reactive silica(mg/l)						
NO_3^-N (mg/L)	0.00 - 0.05	0.03	0.120	0.100		
Nitrite (mg/l)			0.020	0.015		
Odour (TONS)	BDL	BDL				
Phenol (mg/L)	0.00	0.00				
ALKALINITY (mg/L)	116.00 – 87.00	98.00	31.99	6.43		
Redox Potential (mV)	-42.50 - 13.50	-5.37			-31.3 – (-30.7)	-31.06
CO_3^- (mg/L)	0.00	0.00	<0.01	<0.01		
Bicarbonate (mg/l)						
O & G (mg/L)	0.00	0.00			ND	ND
THC (mg/L)	0.00	0.00	<0.01	<0.01	ND	ND
TOC (Mg/l)			0.15	0.10		
TPH (Mg/l)	ND	ND	<0.001	<0.001		
COD (mg/L)	6.62 - 7.82	7.16	0.16	0.13		
Total Phosphorous (mg/L)	0.00	0.00	0.113	0.100		

DO (mg/L)	4.50 - 5.00	4.77	6.26	6.29	3.1 - 4.5	3.63
BOD5 (mg/L)	1.90 - 2.40	2.10	<0.01	<0.01		
Heavy Metals						
Ba (mg/L)	0.01 - 0.05	0.03				
Cr^{+6} (mg/L)	ND	ND	0.002	0.001	ND	ND
Cd (mg/L)	ND	ND	<0.005	<0.005	ND	ND
Co (mg/L)	ND	ND				
Cu (mg/L)	ND	ND	0.833	0.322	0.028 - 0.041	0.035
Pb (mg/L)	ND	ND	<0.002	<0.002	0.004 - 0.011	0.0077
Fe (mg/L)	0.43 - 0.69	0.55	28.37	18.41	0.534 - 0.739	0.631
Ni (mg/L)	ND	ND	0.009	0.003	ND	ND
V (mg/)	ND	ND	<0.001	<0.001	ND	ND
Zn (mg/L)	0.03 - 0.28	0.13	0.927	0.613	0.175 - 0.202	0.187
As (mg/L)	ND	ND	<0.001	<0.001		
Hg (mg/L)	ND	ND	<0.001	<0.001		
Mn (mg/L)	ND	ND	<0.001	<0.001		
Se^{2+}	ND	ND	<0.001	<0.001		
Ag+	ND	ND	<0.002	<0.002		
EXCHANGEABLE CATION						
Ca (mg/L)	10.25 - 17.01	13.86				
Mg (mg/L)	1.35 - 5.82	2.92				

Na (mg/L)	88.27 - 94.12	91.14				
K (mg/L)	10.58 - 12.28	11.58				
PAH (µg/L)	ND	ND				
TPH (µg/L)	0.012 - 0.003	0.008	<0.1	<0.1		
THC (mg/l)	0.00	0.00	<0.1	<0.1	ND	ND
BTEX (µg/L)	ND	ND	<0.1	<0.1		
Micro organism						
HUB (cfu/ml)		3300 $x10^3$			0-18 $x10^2$	8 $x10^2$
HUF (cfu/ml)		153 $x10^3$			0 – 0.4 $x10^2$	0.13 $x10^2$
THB (cfu/ml)		37300 $x10^3$	Nil	Nil	27 – 34 $x10^2$	29.677 $x10^2$
THF (cfu/ml)		$187x10^3$	Nil	Nil	0 - 0.5 $x10^2$	0.27 $x10^2$
Total Coliform MPN/100ml		22.67				
Fecal coliform MPN/100ml		6.67				

4.3.8 Hydrobiology

Hydrobiology studies are concerned with species composition, community structure and diversity of the biota (phytoplankton, zooplankton, benthic invertebrates and fisheries) of the aquatic environment, their interactions amongst themselves and their relationships with the physico-chemical components of the environment. The results of field and laboratory investigations of the ecological studies of Study area are presented below. Twenty sampling stations SW1-SW20 and two control points (SWC1-SWC2) were studied.

- **Phytoplankton**

Phytoplanktons are the autotrophic microscopic plant organisms in water bodies, which fix solar energy by the process of photosynthesis. Phytoplanktons are of great ecological significance because they constitute the major portion of primary producers in the aquatic ecosystems and are at the base of the aquatic food pyramid. Majority of phytoplankton species are used for biological monitoring of the environment since they cannot survive in adverse environmental conditions like high turbidity, anoxic state, extreme salinity and low nutrient level (Fonge et. al. 2012; Peerapornpisal et. al. 2004). Major important members of the phytoplankton group include the divisions Chlorophyta (green algae), Cyanophyta or Cyanobacteria (blue-green algae) and Bacillariophyta (diatoms).

A total of 79 phytoplankton taxa were recorded during the study as shown in Table 4.3.8.1a. These belong to seven divisions: Bacillariophyta (38), Chlorophyta (21), Cyanophyta (11), Dinophyta (05), Euglenophyta (02), Chrysophyta (01) and Xanthophyta (01).

Table 4.3.8.1a.: Phytoplankton species identified in the Study Area

S/N	DIVISION	Species	SW1	SW2	SW3	SW4
	Bacillariophyta		36	20	12	0
1		*Asterionella glacialis*	7	19	0	8
2		*Asterionella formosa*	8	67	73	0
3		*Aulocoseria granulataa*	0	0	0	29
4		*Bidulphia aurita*	0	50	0	0
5		*Bidulphia loniscruris*	0	0	46	20
6		*Bidulphia paradosa*	0	0	93	0
7		*Coscinodiscus centralis*	5	0	0	0
8		*Coscinodiscus radiatus*	57	0	0	0
9		*Coscinodiscus coincinus*	15	0	15	43
10		*Coscinodiscus lacustris*	11	0	0	20
11		*Cyclotella omta*	34	27	19	15
12		*Cyclotella*	0	0	29	0

S/N	DIVISION	Species	SW1	SW2	SW3	SW4
		operculata				
13		*Cymbella lata*	26	37	0	29
14		*Ditylum brightwelli*	0	0	0	0
15		*Fragilaria javanica*	0	0	0	0
16		*Fragilaria intermedia*	0	37	69	2
17		*Frustulia rhomboides*	11	0	3	45
18		*Gyrosigma acuminatum*	29	27	0	34
19		*Lauderia borealis*	0	15	0	0
20		*Melosira distance*	34	27	37	15
21		*Melosira granulate*	4	0	0	53
22		*Melosira pusilla*	25	20	15	0
23		*Melosira varians*	0	43	0	0
24		*Navicula vividula*	36	21	0	13
25		*Nitzschia sigma*	41	18	75	0
26		*Odontella regia*	0	28	0	18
27		*Ondotella laevis*	37	5	5	31
28		*Ondotella sinensis*	28	29	15	20
29		*Pinnularia horealis*	93	0	47	0
30		*Surirrella robusta*	16	47	65	39
31		*Tepsinoe americana*	49	0	15	0
32		*Tepsinoe musica*	0	11	0	7
33		*Synedra acus*	28	23	93	6
34		*Synedra affinis*	24	83	37	0

S/N	DIVISION	Species	SW1	SW2	SW3	SW4
35		*Synedra ulna*	35	24	8	13
36		*Stephanodiscus asroea*	0	0	31	0
37		*Tabellaria fenestrate*	10	56	17	45
38		*Triceratium favus*	0	0	0	0
39	Chlorophyta	*Closterium intermedium*	0	18	0	10
40		*Closterium pervulum*	31	27	53	17
41		*Closterium gracile*	5	0	0	0
42		*Coelastrum reticulate*	25	37	21	0
43		*Crusigenia puadrata*	49	44	2	68
44		*Crusigenia truncate*	0	0	21	3
45		*Desmidium* sp	41	15	0	10
46		*Eudorina elegans*	54	0	0	0
47		*Gonatozygon aculeatum*	0	0	11	61
48		*Netrium digitatus*	0	0	0	0
49		*Netrium intermedium*	0	32	0	17
50		*Pediastrum duplex*	7	0	29	0
51		*Pediastrum simplex*	21	45	0	37
52		*Scenedesmus quadricauda*	0	34	15	0
53		*Spirogyra* sp	54	0	19	0
54		*Spirotaenia*	0	0	18	0

S/N	DIVISION	Species	SW1	SW2	SW3	SW4
		condensata				
55		*Ulothrix variabilis*	0	0	9	0
56		*Ulothrix zonanta*	16	47	0	0
57		*Volvos africana*	0	0	0	61
58		*Volvox aureus*	0	29	20	0
59		*Volvox globator*	66	0	35	0
60	Cyanophyta	*Anabaena affinis*	27	0	53	18
61		*Anabaena arnoldii*	21	43	0	0
62		*Anabaena cylindrical*	0	0	45	0
63		*Chrococus sp*	0	0	10	0
64		*Lynbya limnetica*	29	28	0	17
65		*Phormidium amniguun*	15	0	12	79
66		*Oscillatoria amphibia*	29	28	0	17
67		*Oscillatoria limosa*	66	0	35	0
68		*Raphidiopsis mediteranea*	29	28	45	19
69		*Rivularia sp*	42	11	15	8
70		*Spirulina major*	36	20	12	0
71	Dinophyta	*Ceratium furca*	7	19	0	8
72		*Ceratium fusus*	8	67	73	0
73		*Dinophysis caudata*	0	0	0	29
74		*Gymnodium* sp	0	50	0	0
75		*Peridinium* sp	0	0	46	20
76	Euglenophyta	*Euglena acus*	0	0	93	0

S/N	DIVISION	Species	SW1	SW2	SW3	SW4
77		*Phacus longicauda*	5	0	0	0
78	Chrysophyceae	*Dinobryon sertularia*	57	0	0	0
79	Xanthophyceae	*Tribonema sp*	15	0	15	43
Total species diversity (S)			80	80	80	80
Total phytoplankton abundance (N)			1454	1356	1526	1047

Bacillariohyta were the dominant phytoplankton community followed by the Chlorophyta, and Cyanophyta, while Xanthophyta and Chrysophyta were the least in terms of occurrence and abundance. Bacillariophyta contributed almost half (48%) of the total phytoplankton population. Chlorophyta and Cyanophyta contributed 27% and 14% respectively, while Dinophyta and Euglenophyta contributed only 6% and 3% of the total phytoplankton biomass of the water. Contributions by Chrysophyceae and Xanthophyceae were almost negligible as their percent contributions to the phytoplankton population were less than 1% for the two groups (Figure 4.3.8.1.).

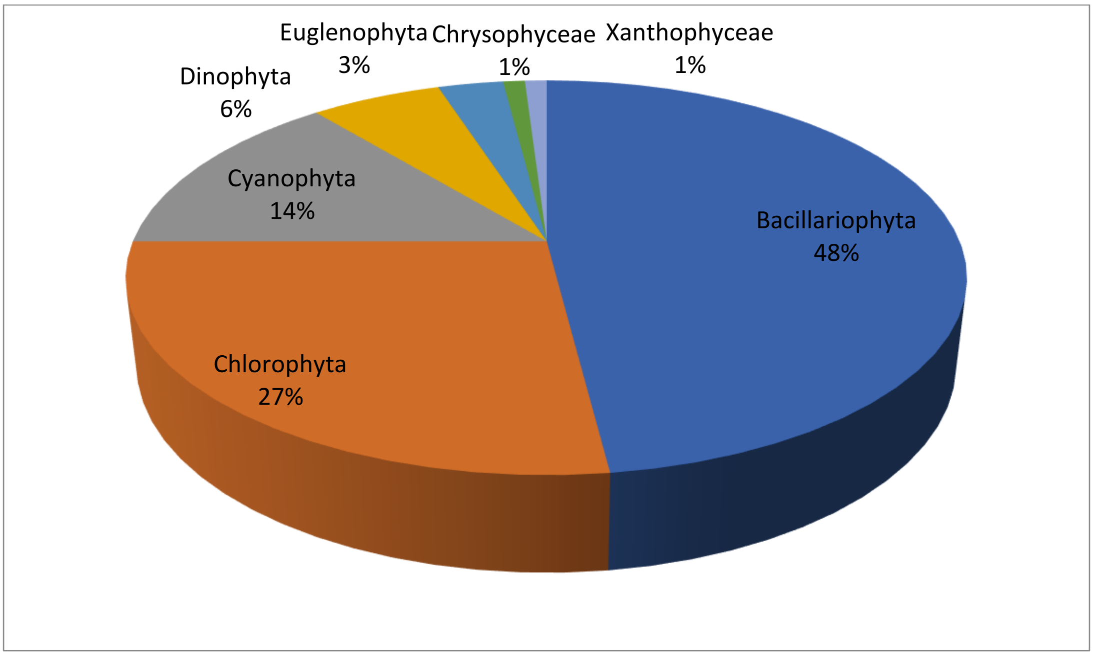


Figure 4.3.8.1.: Percentage composition of phytoplankton division in the Study Area

The species richness was evaluated using Margalef's (d) and Menhinick's (D) indices. Margalef's index ranged between 10.85 (SW 1) and 11.36 (SW4) while Menhinick's index range between 2.05 (SW3) and 2.47 (SW4). Evaluating the species diversity in the study area, Shannon-Weiner index (Hs) ranged between 1.50 (SW4) and 1.61 (SW1), Equitability index (j) ranged between 0.79 (SW4) and 0.84 (SW1) while Simpson's Dominance index (C) ranged between 0.03 (SW1, SW2, SW3) and 0.04 (SW4) (Table **4.3.8.1b**).

Table 4.3.8.1b: Phytoplankton Community Biological Indices

BIOLOGICAL INDICES	SW1	SW2	SW3	SW4
Log of Species diversity (Log S)	1.90	1.90	1.90	1.90
Log of phytoplankton abundance (Log N)	3.16	3.13	3.18	3.02
Shannon-Wiener Index (Hs)	1.61	1.57	1.54	1.50
Menhinick Index (D)	2.10	2.17	2.05	2.47
Margalef Index (d)	10.85	10.95	10.78	11.36
Equitability Index (j)	0.84	0.83	0.81	0.79
Simpson's Dominance Index (C)	0.03	0.03	0.03	0.04

Zooplankton

Zooplanktons are microscopic animals found mainly in the pelagic zone of water bodies where they depend on water currents and waves for motion. They consist of the Rotifera, Cladocera, Copepoda and Planktonic Ostracoda, and constitute important components of inland and coastal waters. Zooplankton community may be holoplanktonic (those organisms that spend their entire life cycle as zooplankton e.g. rotifers, cladocerans and copepods) or meroplanktonic (organisms that spend only part of their life cycle as plankton e.g. larvae of fish, crabs, molluscs and polychaete worms). The meroplanktonic forms are more sensitive to pollution than the holoplanktonic community because the former is composed largely of larval forms, that are, by their nature more sensitive to environmental perturbation (RPI, 1985). Besides the interruption of delicate food webs, the decimation of larval stocks can have serious impacts on the recruitment levels of economically important fish species. The zooplankton occupy a central position in the food webs of aquatic ecosystems and many of them feed largely on phytoplankton, algae and bacterial, and in turn, fall prey to numerous invertebrate and fish predators. They are good biological indicators of water quality as their sensitivity to environmental factors (natural and man-made), makes them of considerable significance in pollution and environmental impact assessment studies (Asibor 2001).

Occurrence and distribution of zooplankton in the Study area are presented in Table 4.3.8.2a. Forty-seven species of zooplankton were recorded during the sampling period. This is made up of holoplankton (81%) and meroplanktonic (19%) zooplankton forms respectively. Among the holoplankton, the major occurring zooplankton group in the area was Cladoceran (42%) followed by Copepods (32%) and Rotifers (26%), while within the meroplankton shrimp zoea and larva were the dominant groups.

Table 4.3.8..2a: Zooplankton distribution and abundance in the study area

S/N	DIVISION	Species	SW1	SW2	SW3	SW4
HOLOPLANKTONIC						
	CLADOCERA					
1	Bosminidae	*Bosmina longirostris*	0	0	10	1
2		*Bosminopsis deitersi*	13	4	5	34
3	Chydoridae	*Alona affinis*	0	0	0	0
4		*Alona diaphana*	10	0	8	11
5		*Alonella excisa*	6	4	2	2
6		*Chydorus eurynotus*	0	7	0	3
7		*Chydorus sphaericus*	7	1	3	3
8		*Chydorus parvus*	36	67	5	11
9		*Euryalona orientalis*	16	21	6	22
10		*Kurzia longirostris*	8	10	9	8
11	Daphnidae	*Ceriodaphnia cornuta*	8	10	12	0
12		*Daphnia sp*	43	17	15	20
13	Moinidae	*Moina micrura*	10	16	19	4

S/N	DIVISION	Species	SW1	SW2	SW3	SW4
14		*Moinodaphnia mecleayi*	11	21	10	0
15	Sididae	*diaphanosoma excisum*	3	0	5	0
16		*Penilia* sp	0	35	7	15
	COPEPODA					
17		*Cryptocyclops bicolor*	75	89	66	39
18		*Eucyclops serrulatus*	21	0	10	0
19		*Halicyclops korodiensis*	11	7	2	9
20		*Mesocyclops sp*	9	21	0	2
21		*Microcyclops varicans*	3	6	53	4
22		*Thermocyclops crassus*	23	34	55	15
23		*Thermocyclops decipiens*	3	0	4	4
24		*Thrermocyclops neglectus*	18	28	0	0
25		*Paracalanus parvus*	42	7	1	4
26		*Eucalanus elongatus*	4	0	0	6
27		*Pseudocalanus elongates*	2	12	19	12
28		Copepod nauplius	15	18	22	17
	ROTIFERA					
29	Asplanchnidae	*Asplanchna*	12	25	15	11

S/N	DIVISION	Species	SW1	SW2	SW3	SW4
		priodonta				
30	Brachionidae	*Asplanchnopus multiceps*	3	0	8	12
31		*Brachionus caudatus*	14	35	4	10
32		*Brachionus falcatus*	7	11	0	7
33		*Keratella* sp	9	0	1	6
34	Trichocercidae	*Trichocerca cylindrica*	43	25	5	10
35		*Trichocerca longiseta*	7	27	0	10
36	Hexarthridae	*Filina opoliensis*	2	7	11	0
37	Lecanidae	*Lecane curvicornis*	17	10	0	0
38		*Lecane (Monostyla) quadridentata*	88	0	7	28
MEROPLANKTONIC						
39		Shrimp zoea	14	6	8	7
40		Shrimp larva	2	0	6	4
41		Gastropod veligar larva	0	0	10	1
42		Doloidid larva	13	4	5	34
43		Zoae (crab)	0	0	0	0
44		Brachiopod larva	10	0	8	11
45		Polycheate larva	6	4	2	2
46		Fish eggs	0	7	0	3

S/N	DIVISION	Species	SW1	SW2	SW3	SW4
47		Fish larva	7	1	3	3
			44	44	44	44
Total species diversity (S)			619	587	415	401
Total phytoplankton abundance (N)						

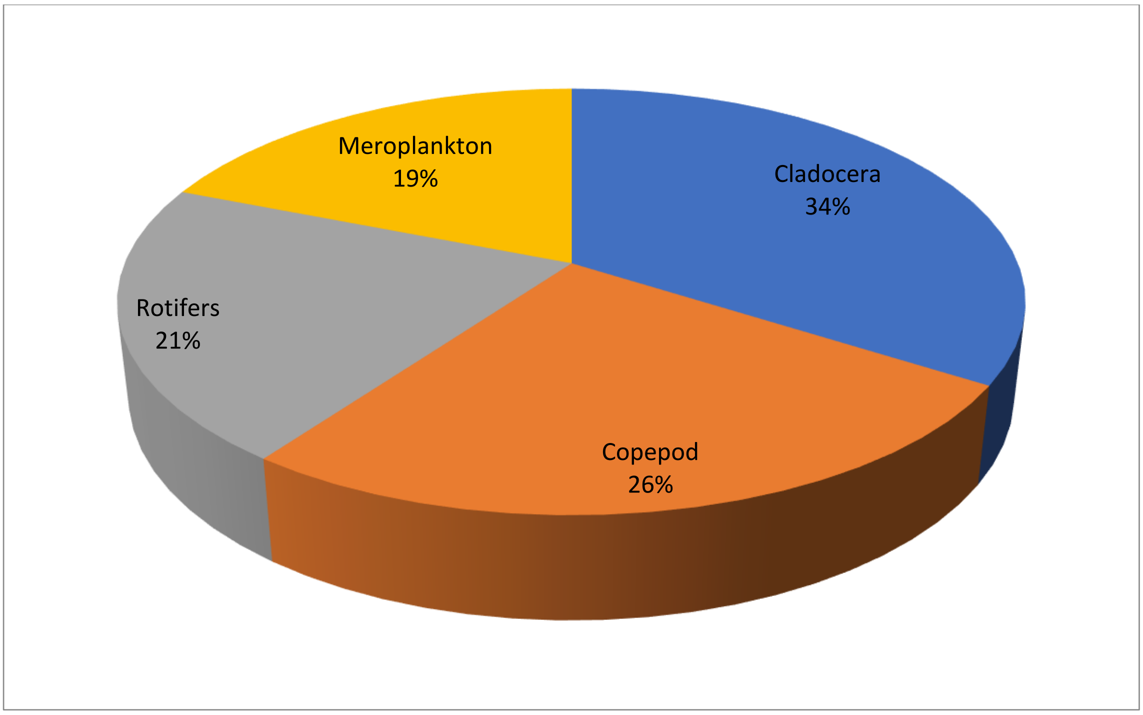


Figure 4.3.8.3: Percentage composition of Zooplankton division in the Study Area

The species richness was evaluated using Margalef's (d) and Menhinick's (D) indices. Margalef's index ranged between 6.69 (SW 1) and 7.17 (SW4) while Menhinick's index range between 1.77 (SW1) and 2.20 (SW4). Evaluating the species diversity in the study area, Shannon-Weiner index (Hs) ranged between 1.30 (SW3) and 1.42 (SW4), Equitability index (j) ranged between 0.79 (SW3) and 0.86 (SW4) while Simpson's Dominance index (C) ranged between 0.05 (SW4) and 0.08 (SW3) (Table 4.3.8.2b).

Table 4.3.8.2b: Zooplankton Community Biological Indices

Biological indices	SW1	SW2	SW3	SW4
Log of Species diversity (Log S)	1.64	1.64	1.64	1.64
Log of phytoplankton abundance (Log N)	2.79	2.77	2.62	2.60
Shannon-Wiener Index (Hs)	1.37	1.33	1.30	1.42
Menhinick Index (D)	1.77	1.82	2.16	2.20
Margalef Index (d)	6.69	6.75	7.13	7.17
Equitability Index (j)	0.83	0.81	0.79	0.86
Simpson's Dominance Index (C)	0.06	0.06	0.08	0.05

Benthic Invertebrate Fauna

The benthic invertebrate fauna are organisms which are over 1.0mm in size, living on or in the substrate of a water body. They may be wholly or partially buried in soft or hard substrates. They constitute the consumer trophic level and contain the top-level predators in the aquatic ecosystem. These organisms are economically and ecologically important. They have been used as bio-indicators in pollution/impact assessment studies (Asibor and Adeniyi 2017; Asibor 2015; Okoroafor 2014.; Ayoade and Olusegun 2012; Arimoro *et. al*. 2007).

The composition, abundance and diversity of macrobenthic invertebrate fauna in the study area are presented in Table 4.3.8.3a. The benthic invertebrates recorded during the study belong to the following Crustacea, Gastropod, Bivalves, Annelids and Insecta. Crustacean (43%) has the highest number of taxa and spread of species in the area while benthic Bivalves (4%) was the lowest with respect to taxonomic spread in the study area. *Balanus sp, Cardisoma armatum, Macrobrachium sp and Sesarma huzardi were the dominant Crustacean species, while* Tympanotonus fuscatus and *Crassostrea gasar* were the dominat Gastropods and Bivalves. *Insect larva and Annelids* species were sparsely distributed in the study area.

Table 4.3.8.3a: Macro-invertebrate distribution and abundance in the study area

GROUP	Scientific Name	Common Name	SW1	SW2	SW3	SW4
Crustacea	*Alpheus pontederiae*	Snapping shrimp	1	3	4	1
	Balanus sp		0	3	0	1
	Callinectes amnicola	Swimming crab	1	0	0	0
	Cardisoma armatum	Rainbow crab	0	2	0	3
	Clibanarius sp	Hermit crab	0	0	0	0
	Cthamalus dentatus		2	1	4	1
	Macrobrachium macrobrachium		0	1	1	3
	Mysis sp		2	0	1	2
	Palaemon maculates		0	0	0	0
	Sesarma elegans	Mangrove crabs	0	1	0	1
	Sesarma huzardi	Mangrove crabs	4	8	0	0
	Sesarma alberti	Mangrove crabs	1	0	2	0
	Uca tangeri	Fiddler crab	0	0	1	4
Gastropoda	*Littorina* sp		0	6	0	2
	Nerita glabrata		3	0	4	4
	Pachymelania aurita		8	10	15	10
	Thais sp		3	0	5	7
	Tympanotonus	Mud-flat	7	10	0	5

GROUP	Scientific Name	Common Name	SW1	SW2	SW3	SW4
	fuscatus	periwinkle				
Bivalve	*Crassostrea gasar*	Oysters				
			7	6	10	2
Annelida	*Capitella* sp		2	1	5	5
	Nereis pelagica		9	7	15	7
	Notomastus aberans		2	0	3	0
	Eiseniella tetrahedral		25	11	28	28
	Tubifex sp		2	7	0	10
Insecta	*Baetis* sp	Mayfly larva	21	6	22	0
	Coenagrion sp	Dragonfly larva	15	35	15	28
	Chironomus sp		31	0	21	11
	Libellula sp		4	0	0	5
Total species diversity (S)			26	26	26	26
Total phytoplankton abundance (N)			148	112	153	138

The species richness was evaluated using Margalef's (d) and Menhinick's (D) indices. Margalef's index ranged between 4.97 (SW 3) and 5.30 (SW2) while Menhinick's index range between 2.10 (SW3) and 2.46 (SW2). Evaluating the species diversity in the study area, Shannon-Weiner index (Hs) ranged between 1.00 (SW2) and 1.10 (SW4), Equitability index (j) ranged between 0.71 (SW2) and 0.78 (SW4) while Simpson's Dominance index (C) ranged between 0.11 (SW3 &SW4) and 0.14(SW2) (Table 4.3.8.3b).

Table 4.3.8.3b: Macro-invertebrate Community Biological Indices

Biological indices	SW1	SW2	SW3	SW4

Log of Species diversity (Log S)	1.41	1.41	1.41	1.41
Log of phytoplankton abundance (Log N)	2.17	2.05	2.18	2.14
Shannon-Wiener Index (Hs)	1.06	1.00	1.04	1.10
Menhinick Index (D)	2.14	2.46	2.10	2.21
Margalef Index (d)	5.00	5.30	4.97	5.07
Equitability Index (j)	0.75	0.71	0.73	0.78
Simpson's Dominance Index (C)	0.12	0.14	0.11	0.11

4.3.9 Fish and Fishery Resources

Introduction

Fish is an importance source of animal protein in Nigeria. Fish constitutes 40% of animal protein intake in Nigeria). Fish consumption in Nigeria accounts for 35-50% of animal protein consumption (Olatunde, 1989; Arawomo, 1987), contribute 4.0 % of agriculture gross domestic production in Nigeria national economy (Sikoki, 2013) and domestic production (less than 30%) cannot keep pace with the huge demand, this has led to over 60% of fish consumption being imported (Adebayo *et al.* 2014).Apart from its requirement for human consumption fish is also important for livestock feeds and export. Though the contribution of fisheries to the economy appear to be small when compared to those of petroleum and crops, its impact on the health of the nation and development is quite significant. Fish can be arbitrarily separated into food fishes and ornamental fishes (Ibim *et al.* 2016). The Food fishes are mainly used for consumption either by man or animals and the ornamental fishes popularly known as ‘’Aquarium Fishes’’ are usually kept in glass aquarium and generally used in decorations of homes, parks offices or institutions. However, there is no clear-cut line between the two groups as their uses can be interchanged. Both fish types are commercially important, as they are marketed nationally and internationally and serve as major source of income for many countries.

The fishery sub sector is important because of the employment opportunities it provides for the people of the country. Its contribution to employment opportunities can be seen from both the direct and indirect angles. Direct employment is provided for those who are directly engaged in fish harvesting, processing and marketing, while indirect employment is also offered to people who are engaged in the production of fish inputs. Similarly, users of fish products such as fish canners, food establishments like restaurants as well as manufacturers of livestock feeds are indirectly employed. In Nigeria, fishery generates more than 3% of the country’s foreign exchange earnings and provides paid and self-employment to 8% of the population. Central Bank of Nigeria Annual Report (2012) reported that the fisheries sector contributes 6% to the total GDP at a growth rate of 6% (Namso and Umoh, 2016). Fisheries involved the exploitation of harvestable aquatic organisms in the aquatic environment. Information on the biology of the fish species is required for the sustained exploitation of the fishery at optimum level.

Communities in the Bonny and its adjoining areas depended to a large extent on the aquatic resources of the environment as they are surrounded by water and fishing being a dominant source of their livelihood. This is particularly true, even prior to oil exploration and production activities in the area. Several creeks, creeklets, river and flood channels are linked to the continental shelf and the open ocean (Atlantic) within the study area. This formed a maze of water throughout the years, but more pronounced during the rainy season. Fisheries activities in the communities range from actual fishing, crafts and gear maintenance, fish processing and marketing. The fishery resources in this area are exploited by different artisanal group within and outside the communities.

Study Methodology

Delineation of the important species and harvest methodology were arrived at, through:

i. Inspection of catches by local fishermen both in the field and in fishing camps,
ii. Interviews of fishermen in camps regarding catch composition and methodology,
iii. Survey of the fishes on sale within the project environment, and interview with the fisheries middlemen about the source of their fishes.

Fisheries involve the utilization of harvestable aquatic organisms in fresh, brackish and marine waters; it represents complex interaction between the population of organisms being harvested, the population of fishermen and environmental conditions.

In the laboratory the fishes that were purchased as well as those obtained by oral interview in local language were identified and authenticated using relevant keys and guides by FAO (1981), Schneider (1990), Daget *et al*. (1991), Teugels *et al*. (1992), Wheeler (1994), Olaosebikan and Raji (1998), Idodo-Umeh (2003), Adesulu and Sydenham (2007), Ibim and Francis (2012) and Froese and Pauly (2013).

Fishing Gears and Fishing Season

The types of fishing gears used and the way they are operated in Nigeria are influenced by various factors such as tribe's pattern, financial status of the fishers, seasons of the year, depth of the water to be fished, types of fish and the shoreline pattern (Adesulu and Sydenham 2007). Information on types of fishing gear, catching principles and constructions are very important for decision making in fisheries management and conservation of other aquatic resources.

Fishing gears in the Niger Delta are many and varied (Otobo, 1995) but similar to those recorded for other parts of Nigeria (Udolisa *et al*., 1994). Based on the observations made during the field survey and the analysis of the interview carried out with the fishermen, the fishing gears used in the study area include: gillnets (*Teemen*), tow nets, cast nets (*Gbon*), beach seines (*Ngolo*), lift nets, traps, hooks and lines, fences and stakes as well as wounding implements (Figures 4.3.9.1a -d). The types of fishing gear and target fish species in use in the study area are summarized in Table 1. Bailing of ponds to collect stranded fish is also one of the traditional fishing methods used in the area. These methods are commonly used along the creek and creeklet channels, river and the open coastal waters. The catch of lift net is non-selective of fish type and size as the mesh sizes are small. Traps are used together with fish fences where creek channels are blocked and the traps strategically placed to collect crayfish and fishes. This is usually in the swamps during low ebb (Figure 4.3.9.1.).

Although some components of the fisheries operate all year round, fisher folks generally take advantage of seasonal distribution patterns which are influenced by moon phases, currents, fish movement and behaviour (Sikoki and Otobotekere, 1999). Moon phases are particularly important for pelagic species. “Good” fishing is recorded at the spring tide (often during full moon). The period between July and mid-September usually experience low fishing activity due to rough water (usually pronounced at this period of the year). Fisher folks usually alternate the type of fishing during these periods.

The main commercial fish catch within the study area are bonga, croakers, sardines, and red snappers, while the main shellfish of commercial importance in the area are lobsters, prawns, shrimps, oysters and periwinkles. Good season for bonga fishing is from June to August, while for January to April and May to September is good catch periods for croakers and crayfish. Bad season for bongas, croakers and crayfish is from December - April, May - September and October - January respectively. During these seasons other fish types are harvested.

During the fishing off-season, fisher folks engage in gear mending and construction in preparation for the next fishing season. Fishing is generally done from canoes operating from fishing camps.

Table 4.3.9.1.: Fishing gear in use in the study area and their target fish species

S/N	FISHING GEAR	FISH SPECIES OFTEN CAUGHT
1	CAST NET	TILAPIA, MULLET, CROAKER, SNAPPERS
2	DRIFT NET	CROAKERS, SARDINELLA, BONGA, CATFISH
3	SET NET	CROAKER, SNAPPERS, CATFISH, GRUNTERS
4	HOOKS	CATFISH, THREADFINS (SHINYNOSE), SNAPPER, GRUNTERS
5	HAND NET	SHRIMPS, VARIETY OF SMALL FISHES
6	FISH TRAPS	SHRIMP, TILAPIA, MUDFISH
7	FISH FENCE	TILAPIA, CRAYFISH, VARIETY OF FISHES
8	BAG NET	CRAYFISH, VARIETY OF SMALL FISHES

Plate 4.3.9.1a: Fishing conical trap nets on the Bonny River estuary

plate 4.3.9.1b: Different types of fishing nets used in the study area

Plate 4.3.9.1c: Different types of fishing nets awaiting deployment

Plate 4.3.9.1d: Fishing nets used to trap crayfish and fish

Investigated Taxa

Studies on fish assemblage in the Niger Delta Basin have been carried out by several researchers in the Niger Delta areas and its connecting creeks. (Scott, 1966; Chinda and Osuamkpe (1994) reported 57 species from 25 Families (Bonny River); Alison *et.al*. (1997) 22 Families (Upper Bonny River); Sikoki *et al.* (1998) 15 families (Nun River); Alfred-Ockiya (1998) 11 species (Kolo Creek River); Sikoki *et al. (*1999) 11 families (Brass River) and Ezekiel *et al., (*2002) reported 25 species in the New Calabar River. Some of the reported harvested families include Albulidae, Anabantidae, Aridae, Bagridae, Carangidae, Channidae, Cichlidae, Characidae, Cichlidae, Citharinidae, Clariidae, Clupeidae, Cynoglossidae, Cyprinidae, Cyprinodontidae, Dactyloprediae, Daysyatidae, Gobiidae, Gymnarchidae, Haemulidae, Hepsetidae, Lutjanidae, Malapteruridae, Mochokidae, Mormyridae, Mugilidae, Nandidae, Notopteridae, Osteoglossidae, Pantodonitdae, Phractolaemidae, Polypteridae, Rajidae and Sciaenidae

The checklist of fish and shellfish species recorded during the field visit in the study area showed that the Family Aridae, Carangidae, Clupeidae, Crassosteidae, Gobidae, Haemulidae, Lutjanidae, Mugilidae, Muricidae, Penaeidae, Polynemidae, Sciaenidae and Squalidae appeared extensively in the catchment water as indicated in Table 4.3.9.2 The Family Clupeidae included species such as *Illisha africana, Ethmalosa finbrinata, Sardinella eba and S. modenerrhi.* Virtually all the recorded species were well distributed in the area. Some of the caught fish species are shown in Plate 4.3.9.1.5a-e

Table 4.3.9.2.: Checklist of sighted and reported Fish species from the Area

S/N	Family	Scientific Name	Common Name	Economically Important
1	Acanthuridae	*Adioryx hestatus*		
2	Albulidae	*Albula vulpes*	Lady fish	X
3	Ariidae	*Arius heudeloti*	Marine catfish	X
4	Bagridae	*Chrysichthys nigrodigitatus*	Grey catfish	X
5	Callionymydae	*Canary drum*		
6	Carangidae	*Caranx carangus*	Horse eye mackerel	
7	Carangidae	*Caran hippos*		
8	Carangidae	*Carangoides chrysophrys*	Threadfin jackfish	
9	Carangidae	*Galeodies decadactylus*	Threadfin	
10	Carangidae	*Vomer septinis*		

S/N	Family	Scientific Name	Common Name	Economically Important
11	Carangidae	Selarcru menopthalmus	Jackfish	
12	Carangidae	*Vomer setapinnis*	Moon fish	
13	Cichlidae	*Oreochromis rukwa*		
14	Cichlidae	*Pagellus ehrenberyi*		
15	Cichlidae	*Sarotherodon galilaeus*		
16	Cichlidae	*Sarotherodon malanotheron*		
17	Cichlidae	*Tilapia heudeloti*		
18	Cichlidae	*Tilapia guineensis*		
19	Cichlidae	*Tilapia zillii*		X
20	Citharinidae	*Citharinus citharus*		
21	Claroteidae	*Chrysichthys nigrodigitatus*		
22	Clupeidae	*Ethmalosa fimbricata*	Bonga	X
23	Clupeidae	*Ethmalosa dorsalis*		X
24	Clupeidae	*Ilisha africana*	Shad	X
25	Clupeidae	Sardinella eba	Flat sardine	X
26	Clupeidae	*Sardinella modenerhi*	Flat sardine	X
27	Congridae	*Corvica nigrita*		
28	Cynoglossidae	*Cynoglossus senegalensis*	Tongue sole	
29	Dactylopteridae	*Cephalocuthus volitan*	Flying gurnard	
30	Daysyatidae	*Dayatis margarita*	Sting ray	
31	Ephippidae	*Chaetodipterus goreensis*	Spade fish	
32	Ephippidae	*Drepane africanus*	Spade fish	
33	Gerreidae	*Eucinostomus malanopterus*		
34	Gobiidae	*Periopthalmus papilio*	Mudskipper	
35	Haemulidae	*Pomadasys jubeleni*	Grunter	
36	Haemulidae	*Pomadasys peroteti*		
37	Haemulidae	*Pomadasys rogerii*	Pigsnout Grunt	
38	Haemulidae	*Pomadasys commersonnii*		
39	Lutjanidae	*Lutjanus goreensis*	Red Snapper	X
40	Lutjanidae	*Lutjanus campenchanus*		X
41	Lutjanidae	*Lutjanus dentatus*		X
42	Lutjanidae	*Lutjanus agennes*		X
43	Monodactylidae	*Monodactylus sebae*		
44	Mugilidae	*Mugil babanensis*	Banana mullet	X
45	Mugilidae	*Mugil cephalus*		X
46	Mugilidae	*Mugil falcippinnis*		X
47	Polynemidae	*Galeoides decadactylus*	Shine nose	X
48	Polynemidae	*Polydactylus quadrifilis*	Royal threadfish	
49	Polynemidae	*Pentanemus quinquarius*		
50	Pomadasyidae	*Pomadasys jubelini*	Common grunter	X
51	Pomadasyidae	*Diagramma macrolepsis*	Big lip grunt	X
52	Rajidae	*Raja miraletus*	Ray	
53	Scaridae	*Sciana umbra*		
54	Sciaenidae	*Pseudotolithus* elongatus	Longnose Croaker	X
55	Sciaenidae	*Pseudotolithus senegalensis*		X
56	Sciaenidae	*Pseudotolithus typus*	Nigerian croaker	X
57	Sciaenidae	*Pseudotolithus epipercus*	Golden fish croakers	X
58	Sciaenidae	*Umbirina canariensis*	Shortnose croaker	X
59	Scombidae	*Scomberomorus japanicus*	Mackerel	X
60	Serranidae	*Serranus aranus*		X
61	Sphyraenidae	*Sphyreana sphyreana*	Barracuda	X

S/N	Family	Scientific Name	Common Name	Economically Important
62	Sphyraenidae	*Sphyraena guachancho*	Barracuda	X
63	Squalidae	*Squalus fernandinus*	Shark (dogfish)	X
64	Stromateidae	*Stromateus fiatola*		
65	Trichiuridae	*Trichiurus lepturus*	Silverfish/Cutlass fish	X
66	Trypterygilidae	*Umbrina cunariensis*		
SHELL FISH				
1	Crapsidae	*Sesarma huzardi*	Hairy Mangrove crab	
2	Crassostreidae	*Crassos trenagascar*	Mangrove oyster	
3	Gecarcinidae	*Cardisoma armatum*	Rainbow crab	
4	Muricidae	*Thais callifera*	Whelk	
5	Ocypodidae	*Ocypodia Africana*	Ghost crab	
6	Ocypodidae	*Uca tangeri*	Fiddler crab	
7	Palaemonidae	*Macrobrachium vollenhovenii*		
8	Palaemonidae	*Nematopalaemon hastatus*	White shrimp	
9	Palaemonidae	*Nematopalaemon maculates*		
10	Penaeidae	*Parapenaeopsis sp*	Shrimp	
11	Penaeidae	*Penaeus kerathurus*	Shrimp	
12	Penaeidae	*Penaeus notialis*	Shrimp	
13	Potamidae	*Tympanotonus fuscatus*	Periwinkle	
14	Potamidae	*Tympanotonus auratus*	Periwinkle	
15	Portunidae	*Callinectes amnicola*		
16	Portunidae	*Callinectus anoniaala*	Swimming crab	
17	Portunidae	*Callinectus marginatus*		
18	Thiaridae	*Pachymelania aurita*		
19		*Balanus sp*		
19		*Clibanarius africana*	Hermit crab	

The size ranges of the various species varied in the different fishing grounds. Croaker *Pseudotolithus elongatus* varied between 15–60 cm in samples within the adjacent mouth of the ocean fishing ground, 10–54 cm in Bonny Estuary, 10– 42 cm in the creeks and creeklets.

In general, the size ranges in the ocean fishing grounds were higher than those along the creeks and creeklets. The most abundant sizes of commercially important species encountered comprised mostly of juveniles. The most abundant sizes for *Sardinella maderensis, Ethmalosa fimbriata, Ilisha africana, Cynoglossus senegalensis*, and *Pseudotolithus elongatus* were 10, 15, 18, 35 and 40 cm respectively. For *Pomadasys jubelini, Polydactylus quadrifilis, Pseudotolithus typus and Pseudotolithus senegalensis* were 10, 15, 20 and 25cm respectively.

There were more catches made from fishing grounds in the ocean compared with fishing grounds in the estuary; rivers and creeks based on the catch per unit effort from these fishing grounds. The highest catch per unit effort from the ocean was estimated at about 275 kg/trip/day while the catch per unit effort in the creeks and creeks fishing ground it was about 92 kg/trip/day.

Plate4.3.9.1.a: Species of Cynoglossus senegalensis, Trichiuru sleptorus and Pseudotolithus elongates and Arius hendeloti

Plate4.3.9.1.b: Fish species of, Ethmalosa finbrinata, Pseudotolithus elongates Galeoides decadactylus and Ilisha africana

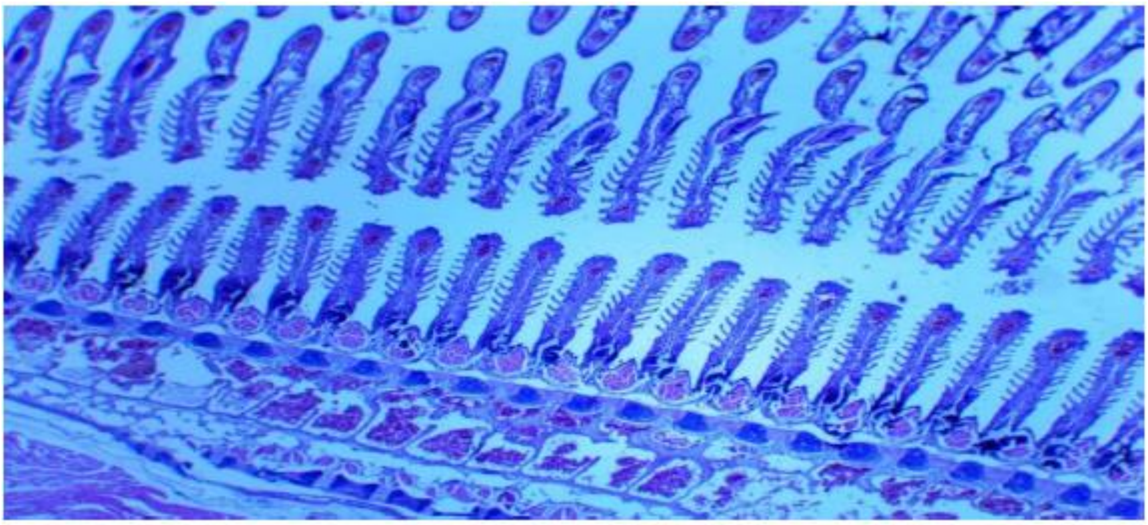
Plate4.3.9.1.c: Local method for processing crayfish and prawn

Plate4.3.9.1.d: Processed and smoked crayfish and fish displayed in the local market

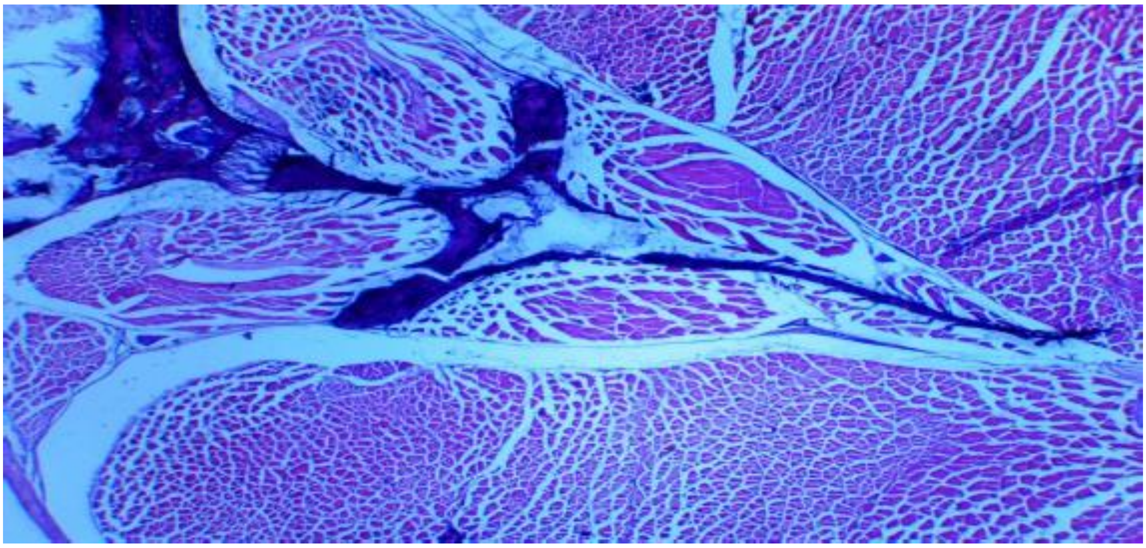
Plate 4.3.9.1.e: *Balanus* sp attached to mangrove plant and harvested periwinkle in a sack

Tissue Studies

The results of the histopathological assessment of the tissue of *Tilapia guineensis* (fish) is presented in Plate 4.3.9.2.



Gill



Muscle and cartilage

Plate 4.3.9.2. Photomicrographs of Tilapia fish

Fisheries economics

i. Fishermen population: - The fishermen population could not be estimated during the survey, however, from the interview conducted, the fishermen are made up of mainly of Ogonis, Ijaws, Efiks, Ibibios, Yorubas/Ilajes and Ibos. Most of them are full-time fishermen.
ii. Fish Marketing and Processing: The fishes caught by the fishermen are sold fresh or processed (Figure by smoking and to fishmongers or transported to Ette and Ibeno Market within the State or to Oil Mill Market (Port-Harcourt) in Rivers State.
iii. The shellfish component plays a key role in the diet and economy of the people of the area.
iv. About two-third of the fish species recorded in the area could be classified as commercial. Among the big commercial ones are the croakers (*Pseudotolithus senegalensis* and *P. elongates),* bongas (*Ethmalosa timbricate* and *E. finbricata*), , mullet (*Mugil babanensis),* the sea catfish (*Arius sp)* and the Cutlass fish (T*richiurus lepturus),* crayfish and periwinkle.
v. In general catch both by number and by weight is much lower in the rainy season than in the dry season according to the fishermen interviewed.

Potential fish yield and catch statistics

Agriculture occupies a prominent position in the national economy, contributing about 39% of GDP and employing more than 65% of the population. It is the main source of food and raw materials supply to the country's teeming population and industries. Ninety percent of Nigeria's agriculture comes from peasant farmers who reside in the rural areas (Inoni and Oyaide, 2007).

Nigeria's fish production data has reflected that 5,788,474 tonnes of fish had been produced between 2010 and 2015 (NBS 2017). Year 2014 recorded the highest tonnes of fish produced with 1,123,011 tonnes; the second highest tonnes of fish produced were recorded in 2015 while the least were recorded in 2010 (Table 4.3.8.1.6). Coastal and brackish water fisheries contribute between 42.07% and 75.96 %, while the balance was from industrial fisheries and aquaculture.

Nigeria, like many other countries in sub-Saharan Africa, is endowed with substantial marine and inland fisheries resources, upon which the fisheries sector is based. However, production trend in the sector has been very unstable particularly, in the coastal/brackish water artisanal sector which provides the bulk of the domestic production. It is a common knowledge that fish catch in the Niger Delta has been on the decline. This was first noticed in the early 1970s when it was attributed to the civil wars (NEDECO, 1980). But this declining trend has continued up to date. The local people have often implicated environmental pollution resulting from oil and gas exploitation in the area. It should be noted that over fishing, population increase and use of small size nets and chemicals has played a leading role in fish decline.

Table 4.3.9.3: Nigeria's Fish Production: 2010 -2015 (metric tonnes)

S/N	SECTOR	SUB-SECTOR	YEAR				
			2011	**2012**	**2013**	**2014**	**2015**
1	Artisanal	Coastal & Brackish Water	346381	370918	418537	435384	382964
		Inland: Rivers & Lakes	292105	297836	326393	324444	311903
		SUB-TOTAL	638486	668754	744930	759828	694487
2	Aquaculture (Fish Farm)	SUB-TOTAL	221128	253898	278706	313231	316727
3	Industrial (Commercial Trawlers)	Fish (Inshore)	19736	27977	37652	29237	10727
		Shrimp (Inshore)	13749	17654	22219	20715	4737
		EEZ	-	-	-	-	-
		SUB-TOTAL	33485	45631	59871	49952	15464
GRAND TOTAL			893099	968283	1083507	1123011	1027058

Source: NBS (2017)

Fish Handling

Fish handling involves transportation, processing, preservation and marketing. The study area constitutes both part-time and full-time activity. The fishermen and members of their family are engaged in fish handling. Fishes for processing and preservation may be gutted or merely washed in water for drying (Figures 4.3.8.1.5c). Large size fishes are gutted, washed and are either preserved whole or cut into two or more pieces. Small fishes and most juveniles are washed and preserved without gutting. Smoke-drying over fire is the most common form of fish preservation. Fishes to be dried are spread out on raised platforms or altars and energy for drying is obtain from wood (Figures 4.3.8.1.5d).

There is ready market for fresh and processed fish in Bonny Island main jetty and Market. Fish mongers are at hand to buy fresh fish or arrange for smoke-drying and subsequently sell to consumers in and around the fishing settlement and to markets outside the area. Fresh, smoke-dried and live fish kept in baskets, tins and plastic containers are transported to markets in either Bonny Main Market or Port-Harcout City. Smoke-dried fish are packaged in bags, baskets or carried in basins for marketing.

4.4 Terrestrial Biodiversity Studies

4.4.1 Biodiversity Studies Introduction

Oil-rich regions are facing great and increasing impacts, including those resulting from, habitat destruction and changes in biodiversity. The increasing impact of human activities on coastal ecosystems requires great effort for the assessment of their ecological quality. Performance Standard 6 recognizes that protecting and conserving biodiversity, maintaining ecosystem services, and sustainably managing living natural resources are fundamental to sustainable development. To investigate impact of habitat modifications on biodiversity and to support the present study, a review of literatures on flora and fauna resources of the region were carried out. The reviewed literatures on flora resources of the region include: Keay (1989), Adegbehin & Nwaigbo (1992), Okafor et al (1994), FORMECU (1999), Carroll & Turpin (2002), Osuji & Ezebuiro (2006), Ndukwu & Edwin-wosu (2007), Olusola and Oluwatoyin (2009), Ebigwai *et al* (2014), Ebigwai & Akomaye (2014) while the available literatures on fauna resources include Moses (1985), FORMECU (1999), Ezealor (2002) SPDC (2004), Abere and Ekeke (2011), Udoidiong & Ekwu (2011). The findings from the reviewed literature for flora and fauna are as presented in Table 4.4.1.1 and Table 4.4.1.2 respectively.

Table 4.4.1.1: Floristic Resources Reviewed for the Coastal Niger Delta

S/N	Freshwater Swamp Forest	Mangrove Forest	Lowland Rain Forest	Modified habitat
1	*Alstonia congensis*	*Rhizophora racemose*	*Khaya ivorensis*	*Chromolaena odorata*
2	*Symphonia globulifera*	*Avicinnia nitida*	*Lovoa kleineana*	*Puereria phaseoloides*
3	*Cleistopholis patens*	*Ecastophyllum brownie*	*Lophira procera*	*Phyllantus spp*
4	*Anthonotha macrophylla*	*Hibiscus tiliaceus*	*Lovoa trichiloides*	*Aspilia africana*
5	*Carapa procera*	*Rhizophora harrisonii*	*Pterygota macrocarpa*	*Nephrolepsis biserrata*
6	*Pterocarpus mildraedii*	*Papsalum vaginatum*	*Sterculia*	*Alstonia boonei*

			tragacantha	
7	*Pistia stratioites*	*Avicinnia germinans*	*Triplochiton scleroxylon*	*Costus afer*
8	*Ficus spp*	*Ipomoea pescarprae*	*Alstonia boonei*	*Newbouldia laevis*
9	*Berlinia auriculataa*	*Nymphaea lotus*	*Cocos nucifera*	*Sidaacuta*
10	*Vosssia cuspidate*	*Acrostichum aureus*	*Elaeis guineensis*	*Mangifera indica*
11	*Raphia hookeri*	*Laguncularia racemose*	*Irvingia gabonensis*	*Panicum maximum*
12	*Cocos nucifera*	*Rhizophora mangle*	*Terminalia cattappa*	*Cynodon dactylus*
13	*Spondianthus preussii*	*Symphonia globulifera*	*Tectona grandis*	*Cyperus digitatus,*
14	*Lemna sp*	*Nypa fruticans*	*Gmelina arborea*	*Selaginella spp*
15	*Pandamus candelabrum*	*Rhizophora mangle*	*Sterculia tragacantha*	
16	*Cyrtosperma senegalensis*	*Ouratea spp*	*Cola gigantean*	
17	*Grewia coriacea*	*Paulinia pinnata*	*Mansonia altissima*	
18	*Xylopia rubescens*	*Chrysobalanus orbicularis*	*Milicia excels*	
19	*Lophira procera*	*Vosssia cuspidate*	*Klainedoxa gabonensis*	
20	*Sarcocephalus nervosus*		*Ceiba pentandra*	
21	*Nymphaea lotus*		*Cynometra megalophylla*	
22	*Mitragyna ciliate*		*Ricinodendron heudelotii*	
23	*Elaeis guineensis*			
24	*Albizia adianthifolia*			
25	*Hallea ledermannii*			
26	*Oncocalamus spp*			

1 Sources: Keay 1989, Formecu (1999), Okafor *et al* (1994), NFAP (1995; Ezealor (2002) MCarthy *et al* (2010). Abere & Ekeke (2011) and Ebigwai *et al* 2014

Table 4.4.1.2: List of Fauna Resources found in Niger Delta Coastal Areas

S/N	Mangrove Forest	Fresh water Swamp forest	Lowland rainforest	Modified habitat
MAMMALS				
1	*Protexerus stranger*	*Manis tetradachyta* (black bellied pangolin)	*Syncerus caffer* (African buffalo)	*Xerus erythropus*
2	*Trichecus senegalensis*	*Manis longicondata (long tailed pangolin)*	*Pan troglodytes*	*Protexerus strangeri*

S/N	Mangrove Forest	Fresh water Swamp forest	Lowland rainforest	Modified habitat
3	*HYemoschus aquaticus*	Cercopithecus spp	*Cricetomys gambianus*	*Anthemrus africanus*
4	*Galago spp*	*Anomalurus peli*	*Genetta spp (genets)*	*Erinaceus albiventris*
5	*Cercopithecus spp*	*Protexerus stranger*	*Eidolon helvum (fruit bat)*	*Lemniscomys striatus*
6		*Loxodonta cyclotis*	*Cercopithecus nictitans (white nosed monkey)*	*Crocidure Occidontalis nigeriae*
7			*Cephalophus niger (black duiker)*	
8			*Hybomys trivirgatus (three-striped mouse)*	
9			*Neotragus pygmarreus (Royal antelope)*	
10			*Syricapra grimmia (Bushrel)*	
11			*Loxodonta cyclotis*	
		BIRDS		
	Halycon malimbicicus	*Halycon senegalensis*	*Stigmatopelia Senegalensis*	*Stigmatopelia Senegalensis*
	Nettapus auritus	*Nettapus auristus*	*Francohanus Bicedcaratus*	*Francohanus Bicedcaratus*
	Butroides striatus	*Anser spp*	*Gallus gallus*	*Tehitrea spp*
	Bubicus ibis	*Bubicus ibis*	*Dendpicus fuscescens*	*Bycanisters fistulator*
	Milvus migrans	*Halietus vocifer*	*Muscicapa strata*	*Necrosyrtes monochus*
	Circus aeruginosus	*Circus aeruginosus* (marsh harrier)	*Corvus albus*	
			Pycononotus barbatus	
			Malinibus rubricollis	
			Hyphanturgus Prachypterus	
			Bulbicus ibis	

S/N	Mangrove Forest	Fresh water Swamp forest	Lowland rainforest	Modified habitat
			Corytheala cristata	
	Reptiles			
			Agama agama	*Agama agama*
			Dendroapsis viridis	*Dendroapsis viridis*
			Naja nivae	*Disphodus typus*
			Naja nigricollis	*Hemidactylus gasciatus*
			Hemidactylus gasciatus	
			Mabura blandingii	
	Amphibians			
	Dicroglossus Occipentalis	*Hyperlolius* spp	*Bufo regularis*	*Rama spp.*
	Xenopus tropicalis	*Chiromantus* spp	*Hyperlolius* spp	
	Gigantorrim goliath	*Xenopus tropicalis*	*Rama spp.*	
		Gigantorrim goliath		

Sources: Moses (1985), SPDC (2004), Udoidiong & Ekwu (2011)

Characterization Method

To characterize the biodiversity resources, present at the study area, a combination of field surveys, laboratory examination and desktop assessments was used. Detailed biodiversity survey was conducted between 2nd and 22nd May, 2018 (Plate 4.4.1.1).

Plate 4.4.1.1: Biodiversity Sampling Activities

4.4.2 Biodiversity Sampling Site

During the survey, seven (7) sampling transects and two (2) control points (transects) were delineated using community settlement and habitat types as criteria. Table 4.4.2.1 shows the sampling sites and their coordinates, while Figure 4.4.4.1 shows habitat map.

Table 4.4.2.1: Sampling Habitats and Coordinates

Sampling ID	Coordinate		Habitat type	Community
	Latitude (N)	Longitude (E)		
SP1	4.4462848 - 4.4463596	7.2440513 - 7.2458967		George Pepple
SP2	4.4665157 - 4.466521	7.2677976 - 7.2696752	Mangrove	Alasakiri
SP3	4.4619406 - 4.4620476	7.1846383 7.1864622		Bomu to Bonny Trunk Line
SP4	4.4244731 - 4.4244731	7.2174722 - 7.2192747	Secondary forest	Abalamabie
SP5	4.4816716- 4.4818428	7.2210075 - 7.2228528		Issille-Ogono
SP6	4.4904851- 4.4905707	7.2322942- 7.2341396	Mangrove swamp	Bonny Axis
SP7	4.4360802 - 4.4361444	7.2458645 - 7.2477313		Otuokolo
SP8	4.4492466 4.4492466	7.2088033 7.2107774		Eferewari
SP9	4.4937902 - 4.4944747	7.2649815 - 7.2669127	Fresh water and Rain forest	Burukiri

SP = Sampling Plot

Source: Medichem (2018)

4.4.3 Sampling Size

A 500 m line transect was adopted as sampling size. This resulted in a total sampled area of 3,500 m sampling area. The enumeration was done by counting the Plants whose leaf touches the belt created by the transect.

4.4.4 Sampling parameters and methods

Specific and standard methodology was adopted for specific flora/faunal parameter and taxon for which baseline information is required as contained in the Biodiversity component of the

Terms of Reference (ToR). Detailed flora and fauna sampling methods are presented in Appendix 7.

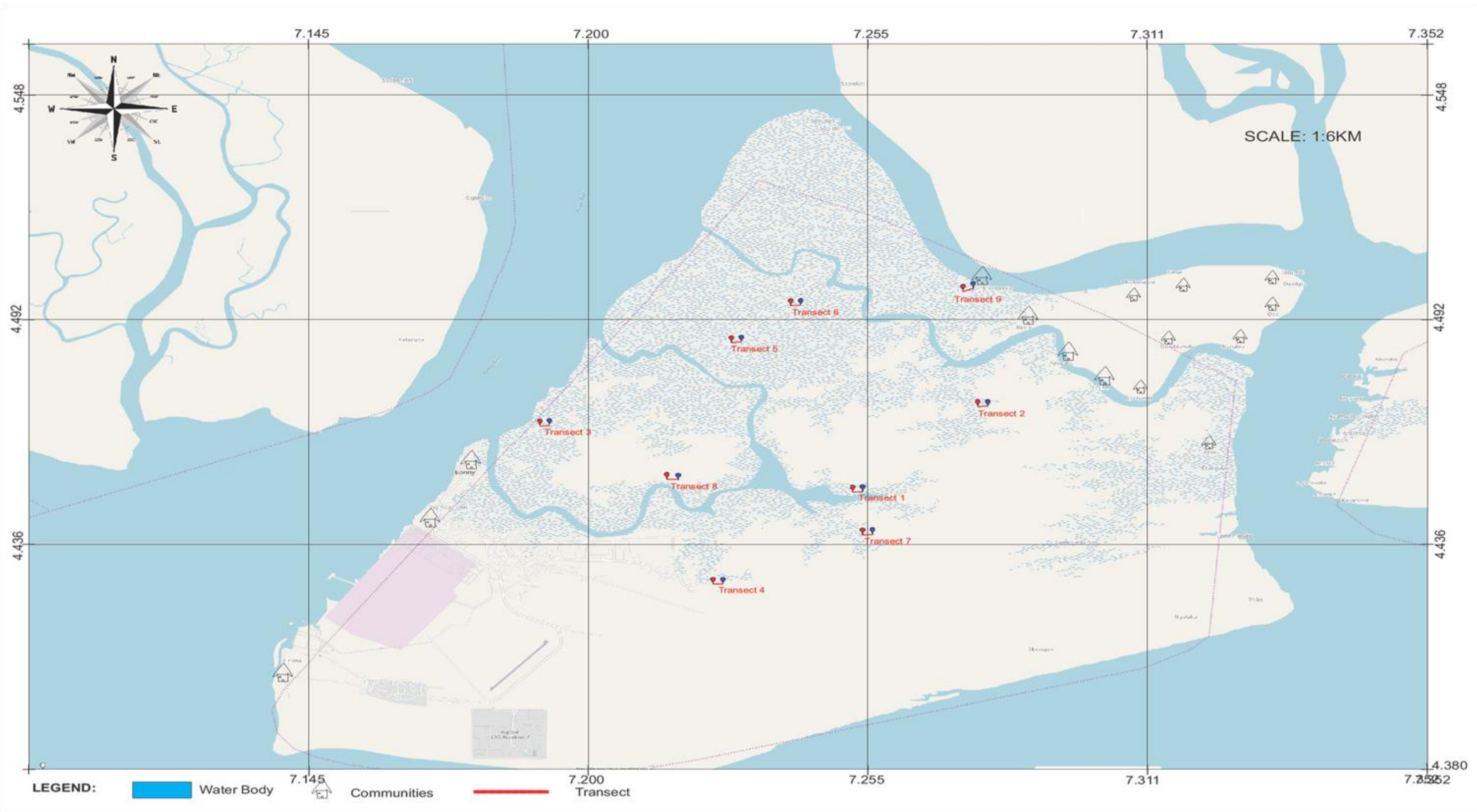


Figure 4.4.4.1: Habitat and sampling map

4.4.5 Habitat Types / Floral Status

Four (4) habitat types were observed. They are; mangrove swamp (natural habitats), freshwater (natural habitats) and secondary forest (disturbed habitat). Based on area sampled, mangrove swamp accounted for 71 % while freshwater and secondary forest accounted for the remaining 27 %. Undisturbed forest accounting for about 2% of the censored area called rain forest were observed only in the two control sites. Specifically, mangrove swamp was encountered at George Pepple, Alasakiri, Bomu- Bonny Trunk Line, Issille-Ogono and Bonny community, freshwater at Otuokolo and secondary forest at Abalamabie community.

Generally, it was observed that the vegetation characteristics of the study area were distinctly different from that of the control areas where only natural habitats (mangrove swamp and rain forest) were encountered. Plate 4.4.5.1 is an overview of the habitat types.

Secondary forest

Mangrove forest

Freshwater forest

Rain forest

Plate 4.4.5.1: Habitat overview

Previous studies (NDBS 2010 and Bonny NLNG and PCIA 2014) in the area had confirmed occurrence of such habitats. The occurrence of rain forest in these reports and in the control areas of this study (Eferewari and Burukiri communities) perhaps has given way to secondary forests. This is a testament of habitat modification and transformation perhaps due to localized factors. This assertion however, was not different from the report of Ebigwai *et al.,* 2014, who documented over exploitation, habitat fragmentation/ invasion and anthropogenic activities as possible drivers of habitat change.

Species Richness

This is the total number of species censored in a defined area. It is often used as a criterion for disturbance or ecosystem stability.

A total of ninety-eight (98) flora species belonging to forty-two (42) taxonomic families were recorded in the study. This comprised of 67 species for Abalamabie community, 60 species for George Pepple, 47 for Issille-Ogono as against 23, 31, 32 and 36 species sampled for Bonny trunk line, Otuokolo, Bonny axis and Alasakiri communities respectively. A comprehensive list of the censored flora species is presented in Appendix 8.

Similarly, species richness for the habitats was evaluated. Mangrove forest recorded the highest number of species (79) followed by secondary forest (67 species) as against fresh water swamp forest with 31 species. The control sites had 47 species. The indicative mangrove genera recorded in this study includes *Acrostichum, Avicinnia*, *Laguncularia* and *Rhizophora*. Expectedly, these notable genera were also documented by Ebigwai and Akomaye, 2014 and Abere and Ekeke, 2011 Niger delta mangrove environments. The species richness recorded in the mangrove and fresh water habitats could possibly be due to reduced anthropogenic activities and/or resistance to invasion while the numbers enumerated to the rain forest and secondary forests could be due to Thinning -out effects and fertile loci points for species colonization respectively.

Also, the predominance of seven cultivatable species (*Artocarpus altilis*, *Xanthosoma mafafa*, *Psidium guajava*, *Persia americana*, *Musa spp*, *Cocos nucifera* and *Annona muricata*) in the secondary and freshwater habitats, further buttress anthropogenic influences.

Species Density (SD)

Density refers to the number of species per given area. Estimates of density are useful for monitoring plant responses to defoliation or environmental perturbations.

A species density of 36.8 m per species was recorded for the entire study area as against the 13.5 m to a species recorded in comparison to the study area. Furthermore, the highest SD of 7.5 m/species was recorded for Abalamabie community followed by George Pepple 8.3 m/species, Issille -ogono with 10.6 m/species, Alasiakiri with 13.9 m/species and Bonny axis with 15.6 m/species as against 21.7 and 16.1 m/ species recorded for Bonny trunk line and Otuokolo communities respectively.

Similarly, SD of 7.5, 16.1 and 31.7 m per species was recorded for secondary forest, fresh water and mangrove swamp habitats respectively while 7.5 m to a species was recorded for tropical rain forest in the control site. This result showed that species density was higher in the undisturbed forests and secondary forest than in freshwater swamp and mangrove swamp respectively. Result obtained in this study conforms to the report of Agbagwa and Ndukwu (2014) and Agbagwa and Chemizie, 2011 which recorded high number of species per unit area in tropical rain forest than the freshwater forest and mangrove forest respectively. The low SD recorded in mangrove swamp habitat could be attributed to the sterno-haline properties of only a few species.

Species Abundance

Species abundance is a record depicting the number of individuals of a particular species. It is an important concept in ecological study since it can be used to assess degree of impacts. A total of 7,986 individuals were manually enumerated in the study area. Table 4.4.5.1 shows plant species with the most and least abundant individuals in the entire study area.

Table 4.4.5.1: Checklist of the Five most abundant and Five least abundant plant species of the habitats of the study area

Most Abundant Species	Abundance	Least Abundant species	Abundance
Avicinnia africana	783	*Morinda lucida*	4
Rhizophora mangle	716	*Alstonia macrophylla*	6
Nypa fruticans	631	*Calamus deeratus*	7
Rhizophora harrissonii	512	*Crescentia cujete*	7
Acrostichum aureum	453	*Ficus congesta*	7

Source: Medichem (2018)

The entire study environment was dominated by mangrove indicative species including *Avicinnia alba*, *Rhizophora spp* and *Acrostichum aureum*. In addition, *Militia thonningii, Triumphetta cordifolia, Phoenix reclinata,* and *Cocos nucifera* dominates in the freshwater habitat. Rain forest was expectedly dominated by tree and shrubby species, the secondary forests are dominated by shrubby and herbaceous species including *Ageratum conyzoides, Acanthospermum hispidum*, *Asystasia gangetica* and *Alchornea cordifolia.* Similar findings have been reported by Ebigwai and Akomaye (2014), who studied the regeneration potential of mangrove forests in the Niger Delta.

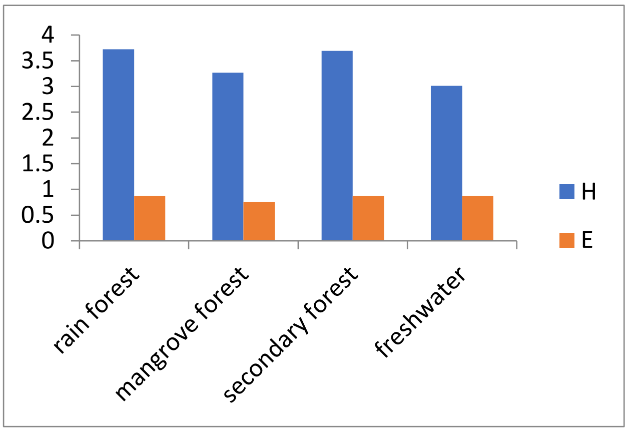
When species abundance was evaluated for the studies communities, Abalamabie with 1870 plant individuals recorded the highest followed by George Pepple with 1329 and Issille-Ogono with 1263 individuals as against Otuokolo with 579, Bonny trunk line with 871, Alasakiri with 1034 and Bonny axis with 1040 individuals respectively.

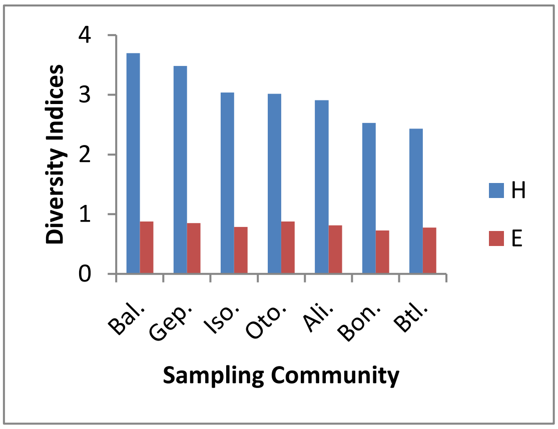
Generally, forest with high species abundance is indicative of one either under disturbance and/or one with efficient dispersal mechanisms (Ebigwai *et al* 2014). This assertion supports the species abundance studies in the study.

Species Diversity Indices

Species diversity index is a quantitative measure that reflects the extent of diversity in a habitat. Volvenko, 2011 stated that species diversity is a criterion for selecting nature conservation areas. In the present study, the Shannon's index (H) and equitability index (E) values for the sampled area was 3.734 and 0.820 respectively. The Shannon's index values for rain, secondary, mangrove swamp and the fresh water swamp forest were 3.72, 3.69, 3.27 and 3.01 respectively while the equitability index values are 0.87 each for fresh water, rain forest and secondary forest against 0.75 recorded for mangrove swamp forest (Fig. 4.4.5.4.1 A).

Similarly, the Shannon's index values for Abalamabie (Bal.), George Pepple (Gep.), Issille-Ogono (Iso.), Otuokolo (Oto.), Alasakiri (Ali.), Bonny axis (Bon.) and Bonny trunk line (Btl.) communities were 3.69, 3.48, 3.03, 3.01, 2.90, 2.52 and 2.43 respectively while the equitability index range from 0.87 for Bal. - 0.72 for Bonny community. **(**Fig 4.4.5.1 B).





A: Sampling habitats B: Sampling communities

Fig 4.4.5.1: Diversity Indices for habitat and communities in the Study area

The high Shannon index recoded for rain and secondary forest, Abalamabie and George Pepple was expected given the high number of species recorded in these areas. The result obtained from this study, portends areas with high ecosystem services as report by Volvenko, 2011 who documented that area with rich flora diversity is capable of offering more ecosystem services.

Species Growth Habit in the study area

Species growth habit is the characteristic form in which a given species of plant grows. Species growth determines the vegetation structure and succession in an ecosystem. The censured plant species were classified according to growth form (Trees, Shrubs, Herbs, Climbers/creepers, Fern and Aquatic floaters). According to Cristina *et al.*, 2014, differences in growth form and between different locations could be linked to differences in ecosystem function, which could help in understanding biodiversity dynamics. In this study, woody species (trees and shrubs) accounted for 75.5 % of plant growth habit in the study area (Table 4.4.5.2).

Table 4.4.5.2: Distribution of plant habit across the Study Area

Plant habit	**No of plant species**	**Percentage (%)**	**Some representative genera**
Trees (T)	74	75.5	*Militia thonningii, Albizia adianthifolia, Alstonia congensis, Carapa procera*
Shrubs (S)	12	12.2	*Combretum paniculatum, Baphia nitida, Grewia auriculata, Machaerium lancetum*
Herbs (H)	8	8.2	*Acanthus montanus, Ageratum conyzoides, Asystasia gangetica*
Climbers/	4	4.1	*Calamus deeratus, Gongronema latifolium,*

Creepers (C)			*Gongronema latifolium, Smilax anceps*
Ferns (F)	2	2.0	*Acrostichum aureum, Nephrolepis biserrata*
Total	98	100	

Source: Medichem (2018)

The obtained result did not differ much from the report of Agbagwa & Chimezie, 2011 in the Niger Delta.

Species growth habit was equally evaluated for the identified habitats**.** Generally, the percentages of woody trees in all the habitats were higher compared to other growth forms. Statistically, freshwater habitat had more proportion of tree species (83.3 %), followed by the mangrove swamp forest (77.2 %) while the secondary forest recorded the least proportion of tree species (72.1%).

Table 4.4.5..2: Distribution of plant habit across the habitats

Habitats	**Habits abundance in %**				
	T	**S**	**C**	**H**	**F**
Rain Forest	91.2	8.4	-	0.4	-
Freshwater swamp forest	83.3	10.0	3.3	0.0	3.3
Secondary forest	72.1	14.7	1.5	10.3	1.5
Mangrove swamp forest	77.2	11.4	33.8	5.1	2.5

T =tree, H =herb, S =shrub and C =climber/creeper, F = Ferns

Source: Medichem (2018)

Among the sampled communities, Alabakiri and Bonny trunk line recorded the highest proportion of woody species followed by Issille-ogono, Bonny axis and Otuokolo communities while Geoge Pepple followed by Balamabie recorded the least.

Vegetation Structure of the study area

Spatial orientation of species in space is termed vegetation structure**.** It is one of the components for measuring ecosystem restoration processes. An ecosystem with an excellent vegetation structure is a measure of a healthy ecosystem and high productivity. Vegetation structure also called community structure was measured in this study using Diameter at Breast Height (Dbh).

It was observed that sampled plant species in the studied area had average Dbh of between 2 and 93 cm. Result of the study revealed that 81.0% of the species had Dbh below 50 cm (Table 4.4.5.3). This is suggestive of a generally disturbed ecosystem. Harvesting of fuel woods for house hold energy, logging activities for house construction and oil exploration activities could be the main drivers for woody species loss.

Table 4.4.5.3 Vegetation Structure for the Study

Diameter size class (cm)	**No of species**	**%**	**Representative species**
0-9	17	16.8	*Chromolaena odorata, Piper guineensis*
10-19	3	4.2	*Bambusa vulgaris, Baphia nitida, Dialium guineense*
20-29	14	14.7	*Spondias mombin, Conocarpus erectus*
30-39	28	29.5	*Harungana madagascariensis, Antidesma laciniatum*

40-49	15	15.8	*Rhizophora harrissonii, Alchornea cordifolia*
50-59	8	8.4	*Pycnanthus angolensis, Carapa procera*
60-69	7	7.4	*Anthocleista procera, Cocos nucifera*
70-79	2	2.1	*Uapaca heudelotii, Avicinnia africana*
≥80	1	1.1	*Nypa fruticans*

Source: Medichem (2018)

Furthermore, rain forest habitat mangrove swamp habitat recorded higher number of species with DBH above 50cm followed by secondary forest with freshwater swamp forest recording the least count.

Similarly, George Pepple recorded the highest number of species with Dbh ≥50cm followed by Abalamabie while Bonny trunk line and Alasakiri had the least number of species. This indicates that vegetation around George Pepple community is less disturbed as against those around Bonny trunk line that are more disturbed.

The present result shows little or no difference form that documented in 2017 Soku EES where 12.8% of the censored species had DBH of ≥50cm. The result however, corresponded with reports of Ebigwai *et al*., 2014 from the same region in terms of community structure.

Ecosystem services

Ecosystem services are the benefits people including businesses derive from the ecosystems (IFC 2012). They are organized into four groups namely:

- Provisioning services (food, medicine and raw materials);
- Regulating services (carbon sequestration and storage, local climate regulation (air quality), waste water treatment and detoxification, regulation of water flow, biological control, erosion prevention and maintenance of soil fertility and moderation of extreme events such as storm and shorelines);
- Supporting services (soil formation, nutrient cycling, primary productivity and habitat mediation & space) and
- Cultural services (spiritual and religious values, knowledge systems and educational values, inspiration, aesthetic values, social relations, cultural diversity, cultural heritage values and recreation and ecotourism).

Impacts on biodiversity often adversely affect the delivery of ecosystem services. The functional ecosystem services played by the censored plant species in the study area was evaluated via desk top review.

Result showed that a total of seventy-six (76) flora species sampled in the study area provide at least one or two ecosystem services. Appendix 2 showed that seventy (70) species serves provisional services, eight (8) species serves regulating services, ten (10) species serve supporting services and fourteen (14) species serves cultural services function. Figure 4.4.5.7.1 illustrates this information graphically.

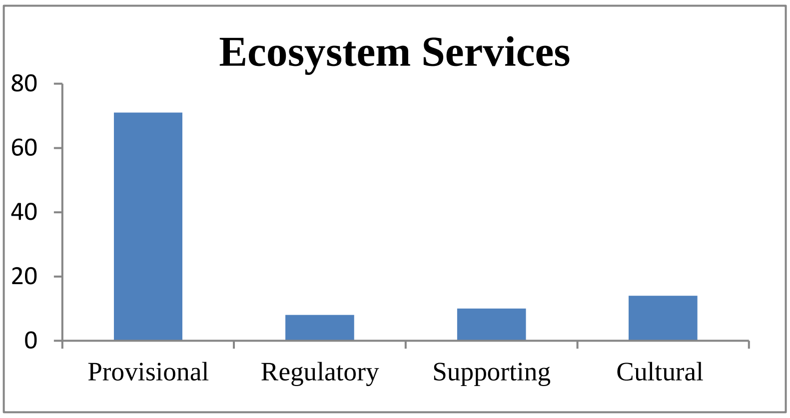


Figure 4.4.5.2: Species in various Ecosystem services

Also, it was observed that three (3) species (*Ceiba pentandra*, *Costus afer* and *Elaeis guineensis*) offers three (3) ecosystem services each as against fifty-three (53) species that serves one (1) function each. Species with diverse ecosystem services portrays multi-functionalities and indispensability to the locals.

IUCN Status of the censured flora species

The IUCN Red List is set to evaluate the extinction risk of species. The aim is to convey the urgency of conservation issues to the public and policy makers, as well as help the international community to reduce species extinction (IUCN, 2007).

The IUCN status of plants sampled was evaluated using the IUCN version 2018 -1 criterion. Results showed that four (4) species representing 5.1 % of the sampled species were classified as threatened by IUCN. These species include *Allanblackia gabonensis*, *Anopyxis Klaineana*, *Khaya grandifoliola* and *Lophira alata* which were categorized as Vulnerable (VU). One species (*Milicia excelsa*) was categorized as Near Threat (NT), while others were either Least concern, Not evaluated or Data deficient.

Evaluation of censored species conservation status in other studies from contiguous areas was equally analyzed. Agbagwa and Ndukwu (2014) recorded 2.7% threatened species in Bonny while Eze and Okoro 2009 recorded 4.8% in the upper Orashi forest of the Niger Delta.

The presence of threatened species is any habitat triggers the need for a Biodiversity Action Plan (BAP). Plate 4.4.5.8.1 shows pictures of the threatened species (with local names where available are given in parenthesis) while Table 4.4.5.8.1 spells out a proposed conservation action.

Anopyxis klaineana

Khaya grandifoliola

*Lophira alata (*Kuru*)*

Allanblackia gabonensis

Plate 4.4.5.1: Threatened plant species of the study

Table 4.4.5.4: Threatened Flora species of the Study Area

Plant species	Common name	Conservation status	Habitat/location in study area	Reproduction season	Dispersal agents	Major threats	Conservation action
Allanblackia gabonensis	Vegetable Tallow tree	Vulnerable A2c ver3.1	Mangrove swamp	Flowering January to September	Wind and Animals	Forest clearance for agriculture and wood	Enforcement of the forest reserve boundaries for its survival. Detailed survey should be carried out on the area to know the where else it could be found
Khaya grandifoliola	African mahogany	Vulnerable A1cd ver.2.3	Mangrove swamp, secondary forest	Flowering December to February	Wind	High intensity of logging and illegal exploitation	Enforcement of forest laws, establishment of reserve boundaries for it survival and log export bans
Lophira alata	Iron wood tree	Vulnerable A1cd ver.2.3	Mangrove swamp, Freshwater swamp	Flowering November to January	Wind	Slow growth rate and poor regeneration potential	Seed banking is advised, enforcement of encroachment laws
Anopyxis Klaineana	White Oak	Vulnerable A1cd ver.2.3	Mangrove swamp, secondary forest	Flowering August to October	Wind	logging and illegal exploitation	Enforcement of the forest reserve boundaries for its survival

Source: Medichem (2018)

Alien species and Invasive species

Alien species are plant resources that are accidentally introduced into an area while invasive species may or may not be alien except that they may out-compete other species and establish dominance. About twenty-four (24) plant species have been documented by IUCN as alien and twenty-nine (29) as invasive to Nigeria. Three of the censored species (*Chromolaena odorata* classified as alien and *Rhizophora mangle* and *Psidium guajava* classified as invasive) were censored in this study (See Plate 4.4.5.9.1).

The presence of these species in an environment could possibly lead to loss of native habitat; loss of native species, with attendant loss in ecosystem services (Crowl, 2008).

Chromolaena odorata *Psidium guajava* *Rhizophora mangle*

Plate 4.4.5.2: Pictures of Invasive Alien species sampled in the study Area

Lichen Study

Some species of lichens and mosses accumulates carbon, sulphur or other pollutants in their thalli and as such are reliable bio-indicators of atmospheric pollution. In the present study, the occurrence of macro lichen and moss species along the sampled transects was documented.

A total of nine (9) lichen and three (3) moss species were identified (Table 4.4.5.10.1).

Table 4.4.5.5: Checklist of macro lichen and Moss species found in the project area

Botanical Names	**Sampling Plots**						
Lichens	1	2	3	4	5	6	7
Amandinea punctata			x		x	X	
Aspidothelium fugiens			x		x		X
Buellia dispersa		X				X	
Cladonia furcate				X			X
Diploicia canescens	x	X	x			X	
Lecanora expallens	x						X
Lobaria pulmonaria			x				X
Usnea rubicunda		X					
Xanthoria parietina	x				x		X
Moss							
Bartramia pomiformis	x	X	x		x	x	
Calymperes erosum			x	X	x		
Racopilum africanum	x						X

Source: Medichem (2018)

No lichen or moss species were found across all the sampled plots. *Diploicia canescens* (57 %) was the lichen with the highest occurrence as against *Lecanora expallens* (14 %). Similarly, *Bartramia pomiformis* (71 %) was the moss species with the highest frequency of occurrences as against *Racopilum africanum* (14 %) with the least frequency. *Amandinea punctata*, *Buellia dispersa*, *Diploicia canescens*, *Usnea rubicunda* and *Bartramia pomiformis* were sampled only in mangrove swamp habitat while *Cladonia furcate* was limited to only freshwater habitat and secondary forest. The distribution of macro lichens and mosses is influenced by availability of substrate, precipitation, gaseous pollutants and forest structure and/or age.

Pathological Assessment

Plant diseases are impairment of the normal state of a plant that interrupts or modifies its vital functions. Losses from plant diseases can have a significant economic impact, causing a reduction in income for crop producers. The pathological condition of the sample plant species was examined, first by visual assessment of plant organs in the field. During this exercise, diseases symptoms were observed on twelve (12) of the sampled plant species. Samples were obtained from the 12-infected species for laboratory assay for severity and causal organism. Table 4.4.5.11.1 shows the severity scale adopted to calculate the severity index.

Table 4.4.5.6: Severity scale for plant pathological conditions

Index	Severity of infection
0	No disease on leaf and pods
1	1: Small brown spot covering <1% leaf area (pin point spots on pod)
2	3: Brown sunken spots 1-10% leaf area (< 1% pod area)
3	5: Brown spots 11-25% leaf area (1-10% pod areas)
4	7: Circular brown sunken spots 26-50% leaf area (11-25% pod area)
5	9: Circular to irregular >51% leaf area (>26% pod and stem area)

Source: Medichem (2018)

Damping off, root-knot, brown rot, wilt, leaf blight, root galls, gall on crown, ringspot, root scale, vine clearing, Leaf spot, leaf curl and canker on branches were the prevalent pathological conditions while *Fusarium spp, Rhizoctonia spp, Verticillium dahlia, Monilinia fructicola, Colletotrichum spp, Taphrina deformans, Cylindrocarpon didymium* (fungi), *Agrobacterium* spp, *Pseudomonas* spp. and *Xanthomonas* spp. (bacteria), *Meloidogyne* spp (nematode) and *Plum pox virus* (virus) are the prevalent pathological agents observed. Species with the highest incidence of diseases was *Costus afer with* 38 % followed by *Musanga cecropoides* (29 %) while *Treculia africana* (10 %) and *Annona muricata* (12 %) recorded the least incidence of diseases. The severity index ranged between 2 for *Annona muricata* and *Venonia amygdalina* to 6 for *Musanga cecropoides* and *Costus afer*.

Incidence of plant disease occurrence was high in the secondary habitats of Abalamabie followed by Bonny axis as against Otuokolo community with the least. Humidity, temperature, wind speed, sunshine and precipitation have been observed as important weather parameters affecting development of plant diseases (Turkington *et al.* 2006).

Table 4.4.5.7: Plant Diseases, Causal Organisms and Severity Index of Infection of plant species censored in the project area

S/N	Plant Species	Type of Disease	Causal Organism	Plant Part Affected	Disease Incidence %	Severity Scale	Sampling site	Habitat of Collection
1	*Acrostichum aureum*	Damping off, root-knot	Fungi *(Fusarium, Rhizoctonia),* Nematode *(Meloidogyne* spp), Bacteria (*Agrobacterium* spp.)	Roots, leaves	16	3	George Pepple, Bomu-Bonny trunk line, Issile-Ogono	Mangrove
2	*Treculia africana*	Wilt, Brown rot	Fungi (*Verticillium dahlia, Monilinia fructicola*)	Leaves, fruit	10	3	Abalamabie	Secondary forest
3	*Avicinnia alba*	Wilt, leaf blight, Root galls	Fungi (*Verticillium dahlia),* Bacteria (*Pseudomonas* spp. and *Xanthomonas* spp.), Nematode *(Meloidogyne* spp.)	Leaves, roots	15	4	George Pepple, Alasakiri, Bomu-Bonny trunk line, Bonny axis, Issile-Ogono	Mangrove
4	*Sarcocephalus latifolius*	leaf blight, Crown gall	Bacteria *(Xanthomonas campestris, Agrobacterium tumefaciens)*	Leave, branches	18	5	George Pepple, Abalamabie and Eferewari	Secondary and rain Forest
5	*Pesea Americana*	leaf blight, Brown rot, Ringspot	Bacteria *(Xanthomonas* campestris), Fungi (Rhizoctonia *solani, Monilinia fructicola*), Virus (*Plum pox virus*)	Leaves, fruit, stem	20	3	Abalamabie	Secondary Forest
6	*Costus afer*	Root scale, Root galls, Leaf blight, vine clearing	Fungus *(Colletotrichum spp),* Nematode *(Meloidogyne* spp.), Bacteria (*Xanthomonas axonopodis, X. campestris*)	Roots, leaves	38	6	Abalamabie and Burukiri	Freshwater, Secondary Forest
7	*Rhizophora*	Leaf spot,	Bacteria *(Xanthomonas*	Leaves,	14	3	Alasakiri, Bomu-Bonny trunk	Mangrove

S/N	Plant Species	Type of Disease	Causal Organism	Plant Part Affected	Disease Incidence %	Severity Scale	Sampling site	Habitat of Collection
	racemosa	Crown gall	*campestris, Agrobacterium tumefaciens)*	stems and branches			line, Bonny axis, Issile-Ogono	
8	*Rhizophora mangle*	Leaf spot, leaf blight, Crown gall	Bacteria *(Xanthomonas spp, Agrobacterium tumefaciens)*	Leaves, stems and branches	18	4	George Pepple, Alasakiri, Bomu-Bonny trunk line, Bonny axis, Issile-Ogono	Mangrove
9	*Venonia amygdalina*	leaf curl, Canker on branches, Leaf blight	Fungi (*Taphrina deformans*, *Nectria galligena*), Bacteria (*Xanthomonas axonopodis*, *X. campestris*)	Leaves, branches	17	2	Abalamabie and Eferewari	Rain and Secondary Forest
10	*Musanga cecropoides*	Leaf spot, leaf blight	Bacteria *(Xanthomonas spp)*	Leaves	29	6	Abalamabie,	Secondary forest
11	*Annona muricata*	Canker on branches	Fungus *(Cylindrocarpon didymium)*	Stem and branches	12	2	Abalamabie,	Secondary
12	*Rhizophora harisonii*	Leaf spot, leaf blight, Crown gall	Bacteria *(Xanthomonas spp, Agrobacterium tumefaciens),*	branches, roots	14	4	Alasakiri, Bomu-Bonny trunk line, Bonny axis, Issile-Ogono	Mangrove
13	*Pycnanthus angolensis*	Leaf spot, Canker on branches	Bacteria *(Xanthomonas campestris, Nectria galligena*)	Leave, stem, branches	28	3	Burukiri and Abalamabie	Rain and secondary forest

Source: Medichem (2018)

Heavy Metal Analysis

Heavy metal accumulation studies on stem and leaf of the most abundant woody species was conducted to evaluate their candidacy for phyto-remediation. The species include *Rhizophora mangle, Rhizophora harrisonii, Conocarpus erectus, Avicinnia africana,* and *Triumphetta cordifolia* (Table 4.4.5.12.1).

Table 4.4.5.8: Heavy Metal Analysis

Plant species	**Heavy Metals Concentration (mg/kg)**								
	Plant part	**Pb**	**Cu**	**Cd**	**Ni**	**Zn**	**Cr**	**Fe**	**Mn**
R. mangle	Stem	3.92±0.02	0.13±0.00	0.20±0.4	5.51±0.4	14.30±1.4	0.11±0.00	84.54±3.5	133.10±6.4
	Leaves	3.10±0.02	0.11±0.00	0.17±0.02	4.62±0.4	14.25±1.7	0.07±0.01	85.60±0.02	97.60±6.4
A. africana	Stem	2.53±0.1	0.20±0.00	0.47±0.00	4.13±0.02	20.03±1.4	0.35±9.23	114.21±0.02	120.72±7.3
	Leaves	2.22 ±0.3	0.16±0.00	0.36±0.00	3.99±0.02	16.57±0.02	0.18±0.00	123.24±0.02	99.80±4.7
R. harrissonii	Stem	2.44±0.4	0.15 ±0.03	0.22±0.00	3.97±1.6	20.00±2.2	0.35±0.11	114.22±5.2	120.77±6.4
	Leaves	2.05 ± 1.12	0.11±0.00	0.16±0.02	2.99±0.4	18.08±0.4	0.18±0.00	120.40±4.5	116.98±6.4
C. erectus	Stem	1.55 ± 0.2	0.08±0.02	0.10±0.00	3.15 ±1.2	15.37 ±1.4	0.04±0.00	73.00±1.4	104.22±6.4
	Leaves	0.88±0.02	0.06±0.00	0.11±0.00	3.00±0.4	13.90±1.4	0.05±0.00	72.90±4.1	114.05±6.4
T. cordifolia	Stem	0.15±0.00	0.03±0.02	0.08±0.00	2.63±0.4	5.93±0.4	0.01±0.02	68.30±1.4	71.16±6.4
	Leaves	0.10±0.02	0.03±0.02	0.05±0.02	2.12±0.4	5.40±0.4	0.01±0.00	58.40±0.02	66.10±3.8

Source: Medichem (2018)

Generally, there was higher concentration of heavy metals in the stem of all the species analyzed except for iron (Fe) where the concentration was observed to be much higher in the leaves compared to the stem. There was a significantly high concentration of heavy metals in *R. mangle, A. africana* and *R. harrissonii* compared with *C. erectus* and *T. cordifolia*. The concentration of Mn, Fe and Zn were significantly high in all the samples evaluated. The high concentration of heavy metals evaluated in *R. mangle, A. africana* and *R. harrissonii* is in consonance with the reports of Aprill and Sims (1990); and FYIP (2014).

Possible sources of heavy metal accumulation are expectedly crude oil activities, sewage deposition and transport of underlying rocks for cadmium sources (Hart, 2005).

4.4.6 Faunal Studies

Fauna refers to all of the animal life of any particular region or time. They are agents of plant pollination and seeds dispersal and therefore play vital role in terrestrial ecosystem stability. The fauna resources were studied using the already established transects for flora study. The parameters studied are species richness, species diversity, Species abundance, conservation status and ecosystem services of the sampled fauna species. Migratory species and raptors were also evaluated for avifauna group. The data obtained will be used as baseline for monitoring impact on fauna and in proposing mitigation measures.

Species richness

Species richness is the number of population represented in an ecological community at a particular time. It is often used as a criterion when assessing the relative conservation values of habitats or landscapes.

A total of one ninety-four (94) fauna species were inventoried in the entire study area. This comprises of seventy-three (73) species censured via direct evidence and twenty-one (21) species obtained via indirect evidences. Table 4.4.6.1.shows summary of the result, while detailed result is presented in the Appendix.

Table 4.4.6.1: Summary of Fauna Species of the Study Area

Fauna Group	**Study area**	
	Direct Evidence	Indirect Evidence
Mammals	17	8
Aves	28	0
Reptiles	3	13
Amphibians	5	0
Insects	14	0
Mollusks	2	0
Arachnids	4	0
Total	73	21

Source: Medichem (2018)

Avian group recorded the highest number of species followed by mammals while mollusks and arachnids (group of Arthropoda) recorded the least species abundance.

For species that were sighted directly, 87.7 % were sampled in the mangrove habitat, 58.9 % in the secondary and rain forest and 53.4 % in the fresh water swamp (Table 4.4.6.2). This showed that mangrove habitat is home to most of the censured species. Agbagwa and Ndukwu (2014) reported similar result for Bonny. According to Agbagwa and Ndukwu (2014), homogeneous and serine habitat are suitable breeding sites for wildlife and could be the major attractants of fauna species to mangrove habitat as observed in the study area.

Table 4.4.6.2: Summary of Sighted Fauna Resources of the Habitats in the Study Area

Fauna group	Secondary/Rain Forest	Mangrove Swamp	Freshwater Swamp
Mammals	8	15	8
Aves	15	23	12
Reptiles	2	1	1
Amphibians	4	5	3
Insects	12	15	12
Mollusks	1	2	1
Arachnids	1	3	2
Total	43	64	39

Source: Medichem (2018)

Species richness was equally evaluated for each sampled community. The result showed that Alasakiri community had the highest number of species followed by Bomu-Bonny and Abalamabie as against Bonny axis followed by Issille-Ogono and Otuokolo communities with the least number of species (see Table 4.4.6.3).

Table 4.4.6.3: Summary of Sighted Fauna Resources in the project affected communities

Sampled Community	Fauna group							
	Mammals	**Aves**	**Reptiles**	**Amphibians**	**Insects**	**Mollusks**	**Arachnids**	**Total**
George Pepple	11	8	1	3	12	2	2	39
Alasakiri	8	18	0	3	11	2	2	44
Bomu-Bonny	7	19	0	3	10	1	2	42
Abalamabie	8	15	2	4	10	2	1	42
Issille-Ogono	6	17	0	2	10	2	1	38
Bonny axis	1	15	0	4	8	2	1	31
Otuokolo	8	11	1	3	12	1	2	38

Source: Medichem (2018)

As could be seen in Table 4.4.6.3, 60 % of the sighted species were sampled in Alasari community. Also, reptilian species were recorded only in George Pepple, Abalamabie and Otuokolo communities.

Species Diversity Indices

Species diversity index is a quantitative measure that reflects how many different species are in a community, and how evenly the individuals are distributed among the species. Shannon Weiner Index (H) and Equitability Index (E) were used to evaluate species diversity for the study area. Species diversity was evaluated across faunal groups for entire study area, habitat and sampled communities respectively.

The result revealed a Shannon index value of 3.81 and Equitability index value of 0.89 for fauna species for the entire study area. Table 4.4.6.4show the result of species diversity indices for the entire study area.

Table 4.4.6.4: Diversity indices for the entire study area

Indices	**Mammals**	**Aves**	**Reptiles**	**Amphibians**	**Insects**	**Mollusks**	**Arachnids**
H	2.51	2.92	0.60	1.40	2.42	0.55	1.16
E	0.88	0.89	0.87	0.87	0.89	0.80	0.84

Source: Medichem (2018)

As could be seen Table 4.4.6.1.2.1, avian, mammalian and insect groups recorded highest Shannon index and Equitability index values as against other fauna groups. High Shannon index indicates high species richness while high equitability index shows evenly distributed individuals among species. This high species diversity and abundance portents high ecosystem services for members of the study area. Similarly, Shannon index of 3.67, 3.42 and 3.39 and the correspondent Equitability index of 0.88, 0.91 and 0.92 were recoded for mangrove, secondary, and freshwater habitats respectively (Table 4.4.6.5).

Table 4.4.6.5: Diversity indices for each habitat

Fauna group	**Secondary /Rain Forest**		**Mangrove**		**Freshwater**	
	H	E	H	E	H	E
Mammals	1.84	0.89	2.35	0.87	1.77	0.85
Aves	2.46	0.91	2.86	0.91	2.26	0.91
Reptiles	0.43	0.63	0.00	0.00	0.00	0.00
Amphibians	1.30	0.94	01.38	0.86	1.00	0.91
Insects	2.19	0.88	2.29	0.85	2.30	0.93
Mollusks	0.00	0.00	0.51	0.73	0.00	0.00
Arachnids	0.00	0.00	0.98	0.89	0.68	0.98

H=Shannon index, E=Equitability index
Source: Medichem (2018)

The mangrove swamp forest recorded the highest Shannon index for all the fauna groups with exception of insects which recorded highest in freshwater habitat. Similarly, secondary forest recorded the highest Equitability index for mammals, reptiles, and amphibians while aves recoded similar Equitability index across the sampled habitats. The diversity indices of 0.00 recorded for reptilian group in mangrove and freshwater habitat, molluska and arachnida groups in secondary and rain forests was expected due to the low species richness of these groups in the studied habitats. Diversity indices was evaluated for the communities. George Pepple with 3.47 and Alasakiri with 3.43 recorded the highest Shannon index as against Issille-Ogono with 2.89 and Bomu-Bonny and Issille-Ogono with 3.34 each. However, a high Equitability index of 0.92 each, was evaluated for Bomu-Bonny, Issille-Ogono and Otuokolo communities while the least value of 0.86 was recorded for Bonny axis. Result of the study as was in agreement with the report of Bock *et al. (*2007) who attributed low Shannon index and Equitability indices as indicative of an unstable ecosystem.

Species Abundance

Species abundance is a record depicting the number of individuals of a particular species. It is an important concept in ecological study since it can be used to assess degree of impacts. This was conducted for the entire study area, habitat, and communities for each faunal group. A total of 2,384 individual across all fauna groups were enumerated. These were 1061 individuals for insects, 741 for aves, 235 for mammals, 124 for arachnids, 113 for Amphibians, 58 for mollusks and 38 for Reptiles (Table 4.4.6.6).

Table 4.4.6.6: Checklist of the most abundant and least abundant fauna per fauna group

Fauna group	**Most abundant**	**Abundance**	**Least Abundant**	Abundance
Mammals	*Rattus norvegicus*	52	*Heiosciurus rufobrachium*	2
	Hypsignathus monstrosus	34	*Procolobus preussi*	3
Aves	*Streptopelia semitorquata*	115	*Tyto alba*	2
	Turtur brehmeri	86	*Accipeter erythropus*	4
Reptiles	*Agama agama*	27	*Mabuya sp*	11
Amphibians	*Amietophrymus maculates*	43	*Amietophrymus regularis*	8
	Hylarana albolabris	38	*Ptychadena mascareniensis*	11
Insects	*Lasioglossum imitatum*	217	*Zonocerus variegatus*	4
	Lucilia sericata	156	*Scudderia mexicana*	14
Mollusk	*Scutalus mariopenai*	44	*Achatina fulica*	14
Arachnids	*Loxosceles reclusa*	61	*Eratigena agrestis*	11

Source: Medichem (2018)

Species abundance was equally evaluated for the habitats studied; the result revealed 68.4 % of the total number of individuals was sampled in mangrove swamp habitat, 21.4 % in secondary and rain forest and 11.1 % in fresh water swamp forest. Table 4.4.6.1.3.2 show summary of the result

Table 4.4.6.6: Abundance of fauna per habitat

Fauna Group	Secondary/rain Forest	Mangrove	Freshwater
Mammals	52	156	27
Aves	164	488	89
Reptiles	32	2	4
Amphibians	18	88	7
Insects	221	726	114
Mollusk	6	48	4
Arachnids	18	101	19
Total	511	1609	264

Source: Medichem (2018)

The preference of mangrove swamp by animals is the serene environment these habitats provide. They are non-assessable to humans and receive less pressure from poachers, hunters and farmers, making it relative stable in the absence of industrial pollutants.
Similarly, Abalamabie community recorded a total of 511 individuals as the highest followed by Alasakiri community with 400 individuals while Bonny axis (252) and Bomu-Bonny (299) recorded the least individuals in terms of abundance (Table 4.4.6.7).

Table 4.4.6.7: Abundance per community

Sampling community	Mammals	Aves	Reptiles	Amphibians	Insects	Mollusks	Arachnids	Total
George Pepple	65	105	2	7	167	10	22	378
Alasakiri	38	121	0	14	170	13	44	400
Bomu-Bonny	34	92	0	9	137	0	27	299
Abalamabie	52	164	32	18	221	6	18	511
Issille-Ogono	17	108	0	30	102	17	10	284
Bonny axis	2	62	0	28	150	0	10	252
Otuokolo	27	89	4	7	114	0	19	260

Source: Medichem (2018)

As reported by Ollerton *et al*., 2011 and *Damgaard (2009)* availability of breeding sites, less predation, and habitat homogeneity and tranquility are the major attractants of animals, hence the reason for the high number of individuals recorded in most these areas.

IUCN STATUS

Analysis for conservation status of the species censored in the study area was conducted using IUCN 2018 version 1 Red List of Threatened species. Results revealed the presence of eight (8) threatened species, representing 7.4 % of the sampled fauna species. In a similar report, Agbagwa and Ndukwu (2014) recorded a total of eight (8) threatened species some of which include *Cercopithecus erythrogaster* and *Osteolamus tetraspis* in Bonny. Table 4.4.6.8 and Plate 4.4.6.1.4.1 presents some of the threatened species sampled in the study.

Table 4.4.6.8: Threatened fauna species of the study area

Fauna group	Scientific Name	Common name	Local name	IUCN Status
MAMMALS	*Pan troglodytes*	Chimpanzee	Gbaranama	EN
	Cercopithecus erythrogaster	White throated monkey	Bukor	VU
	Phataginus tricuspis	Pangolin	Epie	VU
AVES	*Necrosyrtes monachus*	Hooded vulture	Edele	CR
	Psittacus erithacus	African grey parrot	Okoko	EN
REPTILES	*Alligator sinensis*	Alligator	Siki	CR
	Osteolaemus tetraspis	West African dwarf crocodile	Siki	VU
	Chelonia sp	turtle	-	EN

Source: **Medichem (2018)**

*C. erythrogaster (*Bukor*)*

*N. monachus (*Edele*)*

*A. sinensis(*siki*)*

*O. tetraspis (*siki*)*

P. erithacus **(**Okoko**)**

Plate 4.4.6.1..: Pictures of Threatened species

Ecosystem services

Analysis on the ecosystem services provided by the fauna species across the fauna group was conducted. The ecosystem services reviewed are provisional services (food and energy, medicine, raw material), regulatory services (biological control, pollination), supportive services and cultural services. According to Claude *et al.*, 2015 species are an integral component of ecosystems, and the value they provide in terms of services should be a

standard part of ecosystem assessments Details of the ecosystem services are presented in the Appendix , while Table 4.4.6.9 presents the summary. In the study, a total of 56 fauna species were reviewed as offering one or two ecosystem services. A breakdown of the number of species with respect to fauna group revealed that the mammals, aves and insects with 20, 15 and 13 species respectively were the groups with the highest number of species offering ecosystem services while arachnids and mollusk with a single species each had the least number of species with ecosystem services. However, there was no species with ecosystem service recorded for amphibian group. A checklist of these species and their ecosystem services are provided in Appendix 2.
Similarly, regulatory service was the ecosystem service with the highest number of species followed by provisional service against supportive service with the least number of species. Table 4.10 showed this result.

Table 4.4.6.9: Ecosystem services of faunal groups

Ecosystem services	Mammals	Aves	Reptiles	Amphibians	Insects	Mollusks	Arachnids
Provisional services (PS)	6	6	4	0	2	1	0
Regulatory services (RS)	13	11	1	0	13	0	1
Supportive Services (SS)	5	5	1	0	0	1	0
Cultural services	9	7	6	0	1	0	0

Source: Medichem (2018)

The presence of species with regulatory services entails the availability of pollinators as discussed in the proceeding section (Claude *et al.*, 2015).

Pollination Services

Efficient pollination is critical in supporting and maintaining biodiversity and ecosystem productivity. An estimated 78-94% of flowering plant species rely on animals for pollination (Ollerton *et al*., 2011). Paucity of pollinators is the main causal factor for reproductive failure in plants and the consequence threat to biodiversity, global food webs, food security and human health.
In the present study, animal pollinators were sampled via field observation for foraging on flowering plants as well as desktop evaluation of the sampled fauna species for possible pollination services offered.

Result showed that a total of 1586 individual of 36 species of the sampled fauna resource offer pollination services. Table 4.4.6.10 is a summary of the sampled fauna species with pollination service.

Table 4.4.6.10: Summary of biotic pollinators sampled

Pollinator group	No of species	Abundance	Some pollinator species
Mammals	12	152	*Cercopithecus mona, Nycteris arge, Paraxerus poensis, Hypsignathus monstrosus, Paraxerus species*
Birds	10	418	*Turtur brehmeri, Treron calvus, Columba iriditorques, Psittacus erithacus, Pycnonotus barbatus*
Insects	13	964	*Lasioglossum imitatum, Vanessa cardui, Apis spp, Dolomedes triton, Aglais urticae*
Arachnids	1	52	*Dolomedes triton*
Total	36	1586	

Source: Medichem (2018)

Approximately, 1:4 and 1:5 pollinators to plants ratio was obtained in terms of species richness and individual abundance respectively. These results indicated low pollinators density in the study area. It is therefore indicative of an existing threat on pollinator in the study area. Pollinators are vulnerable to poaching, habitat fragmentation, climate change, environmental pollution, pesticides use, pathogenic attacks, predation and high-pitched sounds. An effective policy and management responses to safeguard pollinators and sustainable pollination services in the studied area is hence advocated. Below shows five recommended policy areas for pollinator conservation and protection in the study area.

Enact Pollinator-Friendly Pesticide Policies:

- ✓ Heavily restrict or ban pesticides known to be toxic to pollinators
- ✓ Require pesticide labels to include information about impact to pollinators
- ✓ Incorporate pollinator impact into pesticide permitting or licensing processes
- ✓ Ensure users have access to training for pesticide application

Conserve & Enhance Pollinator Habitats:

- ✓ Promote pollinator habitat conservation through financial or other incentives for beneficial on-farm activities, penalties for harmful activities, and/or mandatory habitat set-asides
- ✓ Ensure pollinators conservation is included in agricultural extension program
- ✓ Utilize protected species laws to protect pollinators as appropriate
- ✓ Utilize pollinator-friendly plants in public areas, coordinating with the appropriate local entities

Develop Incentives & Payments for Ecosystem Services (PES) from Pollinators: ✓ Provide outreach and education to farmers and landowners emphasizing how habitat management for pollinators can improve crop yields ✓ Incentivize conservation and sustainable agricultural practices by payments for ecosystem services or by cost share arrangements ✓ periodically modifying PES practices to benefit to pollinators
Ensure Participation & Empowerment of Diverse Stakeholders, Including Rural and Indigenous People Public outreach, raising awareness and tapping local knowledge are key elements to reversing the pollinator crisis. ✓ Ensure that networks and organizations working on pollinator protection include representatives from rural and indigenous groups ✓ Identify individuals and groups with a stake in pollination; include indigenous groups, women, and urban citizens in policy advocacy efforts ✓ Utilize technology to empower local citizens to contribute to pollination management
Support Collaborative Research and Training Much basic information is missing about how to maintain pollinator populations, despite increased research in the past decades. ✓ Invest in research and create a clearinghouse of information on pollinators ✓ Train scientists and citizen scientists on identification and pollinator protection ✓ Provide research funding for wild pollinators and the assessing the economic value of pollination services

Avian migration

Avian migration is either a regular or irregular; seasonal movement of birds species between north and south geographic regions usually in response to changes in weather conditions and in-search of food, breeding and wintering grounds (veen *et al.,* 2014).

In Nigeria as in other countries in the Northern hemisphere, migratory birds commence this movement between February, March and April to warmer areas and return between August, September and October to winter grounds (veen *et al.,* 2014). Migratory movement often results in high mortality and predation. In this study, a total of seven (7) migratory species were inventoried (Table 4.4.6.11).

Table 4.4.6.11: Details of migratory birds censored in the project area

SPECIES	IUCN Status	HABITAT	NESTING GROUNDS	BREEDING SEASON	MAJOR THREATS	CONSERVATION ACTIONS
Ardea alba	LC	Terrestrial and freshwater	Reed beds, bamboo, bushes.	April to July	Wetland degradation and loss	Colony protection, control of vegetation management.
Ardea cinera	LC	Freshwater	Low trees and bushes	February to June	Renewed hunting and timber harvesting	Colony protection, control of vegetation management
Psittacus erithacus	EN	Freshwater and Mangrove Swamp	Tree cracks	November to February	Renewed hunting and timber harvesting	Nesting sites should be protected and vegetation
Bubulcus ibis	LC	Terrestrial, freshwater	Trees and bushes	March to August	Wetland degradation and loss	Nesting sites should be protected
Egretta alba	LC	Freshwater and Mangrove Swamp	Trees and bushes	March to September	Wetland degradation and loss	Nesting sites should be protected
Egreta garzetta	LC	Mangrove and freshwater	On grounds of protected sites, mangroves.	March to July	Wetland degradation and loss through drainage for agriculture.	Nesting sites should be protected
Milvus migrans	LC	Terrestrial and freshwater	Branches of trees	July to October	Poisoning, shooting and pollution of water	Establish non-intrusion zone around colonies.

Source: Medichem (2018)

In the report of Aizen *et al.*, 2008 migration of these birds species could be due to scarcity of food, search for nesting ground and day length, photo-periodism, light, etc. The result showed that the habitats of the censored species cut across the three identified forest habitats as evaluated in the study. The nesting grounds for these species ranges from rooftops, branches, tree cracks, bushes, protected sites, emergent vegetation to bushes over water. All the species were observed to be full migrants and majority of them have their breeding seasons from March to October. The IUCN status of all the species is Least Concern except for *Psittacus erithacus* with the conservation status of Endangered.

Migratory birds play a critical role in the ecosystem, pollinating plants, dispersing seeds, and consuming insects and small mammals, thus cleaning and balancing the earth's ecosystem (Aizen *et al.*, 2008). Plate 4.4.6.2 shows some of these species.


P. erithacus (Okoko)


Egretta garzetta (Ituru)

Plate 4.4.6.2: Some Migratory Species of the Study Area

Raptors

A diurnal predatory bird that hunts and feed on rodents, insects and small animals exerts strong biodiversity influences on the ecosystem. In such environments, they act as keystone species by regulating their prey population. Some are known as 'Earth Cleaners; for their role in eating up dead carcasses. Raptors are members of Accipitridae, Pandionidae, Sagittaridae, Falconidae and Cathartidae belonging to Acciptriformes, Apodidae and Falconiformes orders (Fowler *et al.*, 2009). In this study, a total of seven (7) raptors were sighted; representing 7.37 % of the avian species recorded in the study. The most abundant raptors for the study were *Milvus migrans*, *Ardea alba* and *Ardea cinera.* Table 4.4.6.1.8.1 shows details of raptors sampled in the study area.

Table 4.4.6.12: Raptors of the Study Area

S/N	Species	Common Name	Prey
1	*Milvus migrans*	Black kite	Small live prey e.g. lizards, bats, rodents, fish, household refuse and carrion.
2	*Polybroides typus*	African harrier hawk	Rodents, bats, birds, amphibians, lizards and insects
3	*Tyto alba*	Owl	Small live prey e.g. bats, rodents, insects and carrion.
4	*Accipiter nisus*	Eurasian sparrow hawk	Small birds, and other live preys.
5	*Ardea cinera*	Grey heron	Fish, lizards and amphibians.
6	*Ardea alba*	Great white egret	Amphibians, fish, insects lizards etc
7	*Cypsiurus pavus*	African palm swift	Insects e.g. spiders, termites, beetles etc

Source: Medichem (2018)

The presence of raptors as reported by Helander *et al.*, 2008 indicates a healthy environment, with a wide and balanced diversity of animal and plant species, adequate ground cover and no poisons. Since these groups of organisms (Large birds of prey) are especially vulnerable to environmental influences, changes in their population size gives early warning regarding the status of the environment.

4.5 Social Impact Assessment

4.5.1 Study area and population structure

The impacted communities of the proposed project were visited for SIA purposes (see Table 4.5.1.1). The communities located in Bonny LGA of Rivers State with a land mass of 645.601km^2 and a population of 214983. Based on the 2006 census population figures for the affected communities the projected figures for 2018 and 2030, using an estimated population growth rate of 3.2%, are 313733 and 457843 respectively. Occupants of the communities are largely of the *Igbani* (*Ibani*) tribe except for Otuokolomabie which is inhabited by the *Andonis*. Other minor tribes reported to reside in the communities or settlements are include the Ogonis, Andonis, Ibibios, Ilajes and Calabars.

Table 4.5.1.1: Distribution of host communities by LGA, tribe and population

SN	Communities	2006	Population (2018)**	Population projection (2030)
1.	Dema-Abbey		300	438
2.	Otokolomabie		250	365
3.	John Jumbo		300	438
4.	Nkpokiri		250	365
5.	Oloma		2150	3,138
6.	Agbalamabie		4200	6,135
7.	Alasiakiri		100	146
8.	Issile-Ojono Jumbo		300	438
9.	Allison-Adda		450	657
10.	Agbalomobie		350	511
11.	Alotin		300	438
12.	Gbegbekiri		200	292
13.	Okeiolnuch		180	263
14.	Okupko		200	292
15.	Orubi		850	1,240
16.	Perekiri		150	219
17.	Wasakiri		250	365
	Bonny LGA	**214983***	**313,733**	**457,843**

**Source: NPC, 2006 Census figure; **community estimate*

Source: Field survey, 2018

4.5.2 Historical review of communities/ History and Ethnography

The history of the Bonny Kingdom dates back to about 1000AD when Alagbariye (known in Bonny tradition as "Amakoromabo", meaning "founder",) and his brothers, Opuamakuba and Asimini founded the present-day Bonny Island Kingdom. The founding group of the Island Kingdom were said to have migrated from the Ebeni-toru area, precisely from Isedani

Lineage of Kolokuma in the present-day Kolokuma in Opokuma LGA of Bayelsa State (an ancestral Ijaw land in the Central Niger Delta). According to oral traditions, these founders migrated from Kolokuma because of civil conflict which was said to have occurred between the 12th and 15th century CE (AD).

The leaders of the migration team were Opuamakuba, his brother Kala-Beni (Alagbariye) and Asikunuma alias OkparaAsimini. They first settled in the now Ndoki territory before moving on to the now Ogoni area and encamped at a site where Opuoko town now stands. Kala-Beni was said to have discovered the site of Bonny Town and eventually lead the group to the site which they named Okoloama. The first crowned ruler was King Asimini followed by a succession of rulers called Amanayabo (Amanayabo in the western delta). From these leaders the entire founding generation of the Kingdom evolved through the lineage/house system of governance whereby the exalted position of "*Amanyanabo*" or Monarch/King (meaning "*owner of the land*") and the position of "*Amadapu*" (meaning component/subordinate traditional rulers of the Kingdom) came into existence. The Bonny Island Kingdom has Five Duawaris (ruling Houses of the Ancestors, Founding Royal Houses) representing the founding generation of the Kingdom. These are the (i) Bristol-Alagbarigha Royal House (Founder of Grand Bonny), (ii) King Halliday-Awusa Royal House, (iii) Dublin Green House (Lala, Ebie, Prince Asimini-Oruakpa Lineage, (iv) Prince OruasawoTolofari Royal House (Kumaluya-NdendeOmuigbem Lineage, and (v) Buoye-Omuso (Brown) Major House.Bonny Historical Society (Wikipedia, 2018).

However, with respect to community-specific history respondents provided some historical genesis on Agbalamabie_and Adda-Alisson communities which were reported to have originated from the Bonny kingdom in the 18th century. Agbalamabie community was said to have been founded by a man named Imoh. According to ancient history, Iganipuma Allison and Imoh fought the Abala people the original owners of the land. After winning the war, Iganipuma took over Adda-Alisson while Imoh took over the present Agbalamabie. The present day Dema-Abbey community was founded by Chief Abbey Onigbe, who was said to have migrated from Tombia at Kalagbari in present day Bayelsa State while Otokolamabie was originally founded by the Bonnis though the present occupants who are Adonis by tribe migrated from '*Adoni'* land in Adoni LGA of Rivers State. Many of the other communities traced their origin to the Bonny Island from where their forefathers migrated from to their present location chiefly for fishing purposes. These initial fishing settlements are what have now grown to become established communities.

4.5.3 Socio-economic Characteristics of Respondents

This section examines the age, sex, marital status, household size and educational status of the respondents.

Age, Sex and Educational status of respondents

The age distribution of the respondents (Figure 4.5.3.1.1) reveals a predominantly middle-aged group of 31-40 years (29.9%) and 41-50 years (23.1%). The mean age of the respondents, which was 37 years, is suggestive of active and energetic residents. The sex distribution indicates the dominance of male among the respondents (63.9%) while the female constitute 36.1% (Figure 4.5.3.1.2). This closely aligns with the LGA population census figures for the study area i.e. Bonny LGA which indicate a slightly higher male presence: male (116340 representing 54%) and female (98643; 46%) in the study area (NPC, 2010).

Figure 4.5.3.3 reveals the educational status of the respondents and it shows that most respondents had secondary education (62.8%) as their highest level of schooling while 31% had post-secondary education. An insignificant 6.2% and over 11% of the respondents had primary school and post graduate education respectively. In terms of gender distribution males were found to be slightly more educated than the females in the settlements but further skewed in favor of the males in the fishing settlements. This clearly shows that the residents of the communities are educated and enlightened citizenry. These results also compares favorably with the findings from the national educational survey on River State which showed about 26.3% of women and 30.1% of male have completed secondary education in the state (NPC and ICF International, 2014).

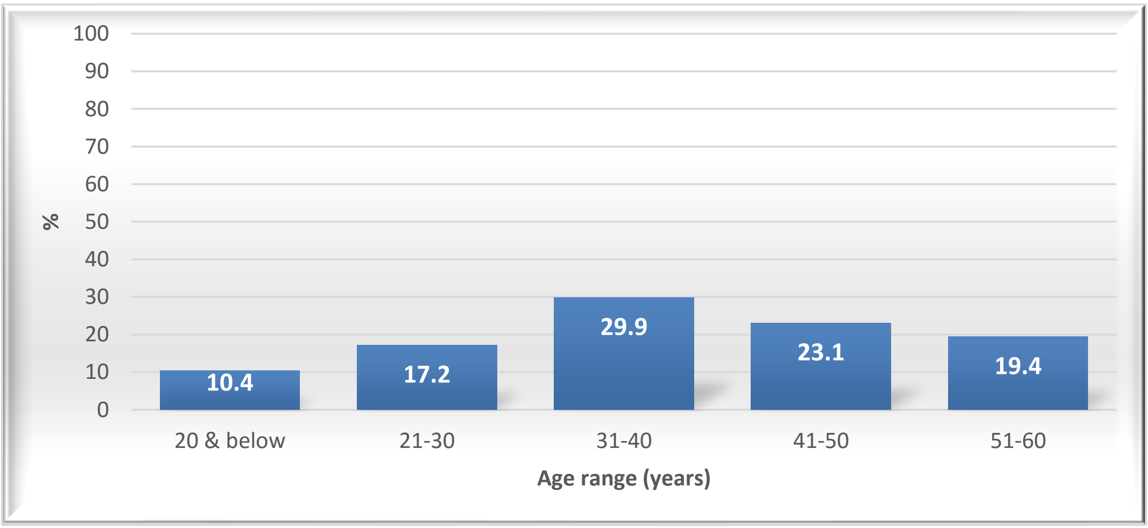


Figure 4.5.3.1: Age distribution of respondents
Source: Field survey, 2018

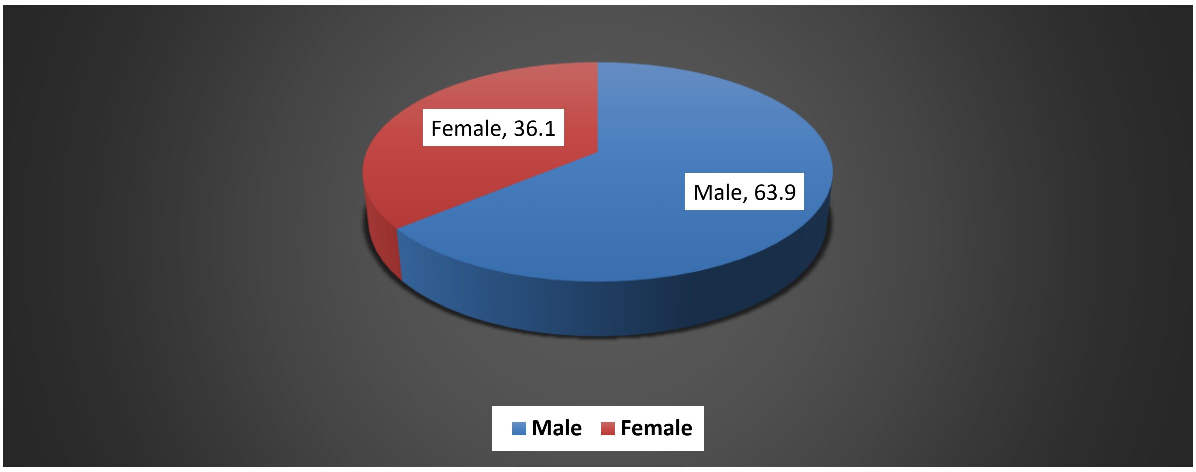


Figure 4.5.3.2: Sex of respondents
Source: Field survey, 2018

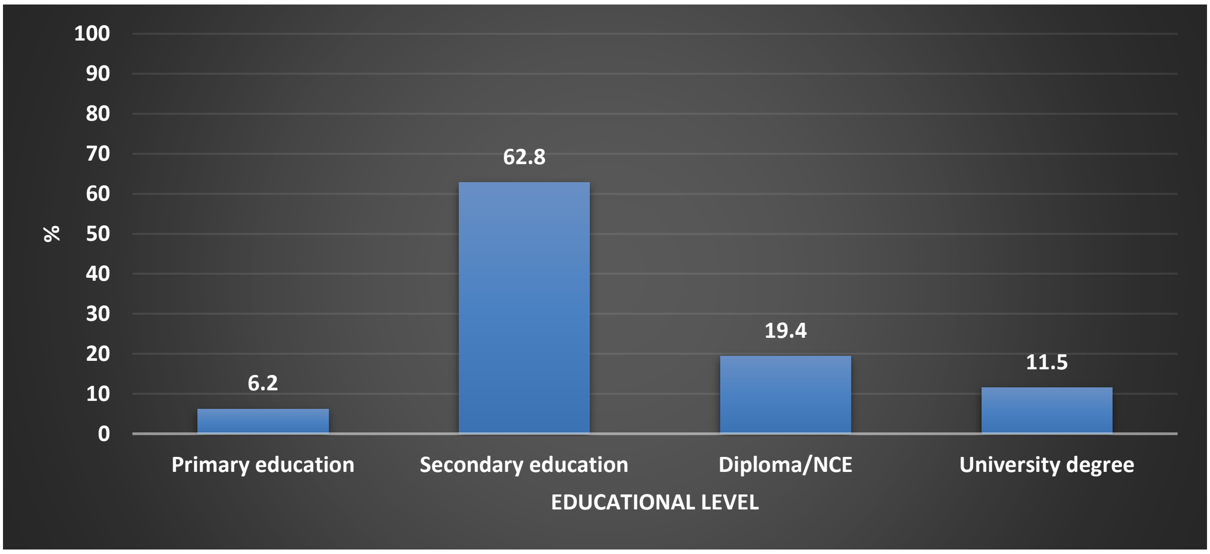


Figure 4.5.3.3: Educational level of respondents
Source: Field survey, 2018

Marital status and household size

Married persons dominate among the studied respondents as 75.8% of the respondents were married while the remaining 24.2% comprise widows, widowers and singles (Figure 4.5.3.1.4). This aligns with the existing situation at the state level where about 69.4% of the women and 49.1% of men were reported as married (NPC and ICF International 2014). The modal household size for the study area was over 12 members (35.8%) and is far higher than the national average of five reported for the demographic and health survey conducted in 2013 (NPC and ICF International, 2014). This is an indication that the study area is dominated by large families and further suggests a high dependency ratio more so when the economically active members are few as these results indicate (Figure 4.5.3.1.5).

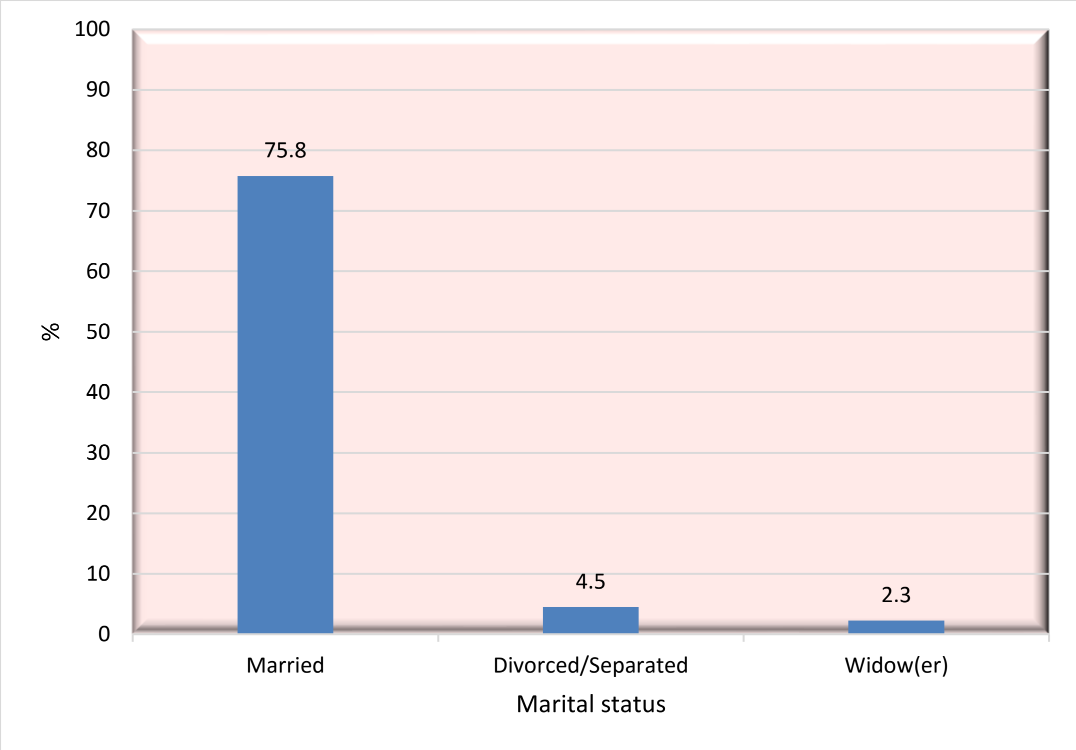


Figure 4.5.3.4: Marital status of respondents

Source: Field survey 2018

Religious affiliations and cultural attributes of communities

All the respondents interviewed claimed to be Christians and members of various Orthodox and pentecostal denominations as evidenced in Plate: 4.5.3.1.1. The introduction of Christianity in the study area or Bonny is traced to King William Dappa Pepple according to the Bonny Historical Society (2016), the King while in England elected to become a Christian King so that God will grant him power and wisdom to rule his people. However, some respondents did observe that many people in the area still reverence the African traditional religion. Some of the communities claimed to have no shrine that is centrally worshipped though it is not out of place for individual members to worship traditional deities at a personal or family level. Community shrines were reported to exist in some of the communities such as Otuokolomabie (*Ogbologbo* shrine) and Issile-Ojono (*Amakiri* shrine).

Church Buildings at Dema-Abbey (left) and Nkpokiri (right)

Traditional site (left) and Church Building (right) at Agbalamabie

Plate 4.5.3.1 Religious centres in some communities
Source: Field survey, 2018

Festivals are part of the African culture and the communities visited are not exempted. Several festivals were reported in some of the communities: Dema-Abbey celebrates two principal festivals namely *Oke-Ikpe* (January 5th) and *Owuogbo* festivals in August (women are forbidden to enter into the *Owuogbo* shrine); Otuokolomabie celebrates *Ekuku-Asha* festival on December 25thand *Ogbologbo* festival once in every seven years, the last being done in 2014. Issile-Ojono Jumbo celebrates *Nwatan* festival (masquerade dance) every 25th of December. Other communities noted that the major 'festival' celebrated was the annual Christmas festival on every December 25th. These festivals were described as occasion where sons and daughters of the communities come together to celebrate and thus serves as a strong platform for social integration.

Objects of cultural values were reported in few communities and include the local Ram at Otuokolomabie and the python snake at Issile-Ojono Jumbo community that are used for sacrifice during traditional festivals. In addition, it was also noted that in major Ijaw communities the traditional canoe is deployed during the coronation of a King or Chief. At Agbalamabie in particular cultural artefacts such as guns, canoes (used for coronation of kings, burials or wars) and pot used by former kings to cook for Europeans can still be found (Plate 4.5.3.2)


Cultural boat at Dema-Abbey (left) and Agbalamabie (right)


Cultural artefacts at Agbalamabie

Plate: 4.5.3.2 : Cultural objects in study area
Source: Field survey, 2018

In all the communities visited women were reported to have right to inheritance or to own properties (e.g. housing). The key leadership positions are however male dominated reflecting the patriarchal nature of the communities. Nevertheless, women form an integral part of the leadership structure, taking part in community decisions processes. .Social interaction in the area is moderated by cultural norms or taboos as defined in each community. While some communities reported having no specific traditional taboos, others with norms/ taboos noted the following:

- Members of the community shall not engage in fights using physical weapons; some communities such as Issile-Ojono Jumbo have a timeline incorporated into this norm, which is that no community member must engage in any fight from 8pm;
- No member of the community shall engage in naked bath by the water front or river shore;

- Cooking pots should not be washed at the river shore;
- Uncontrolled libations on graves is discouraged (Otuokolomabie);
- At John Jumbo and Nkpokiri communities there is this norm that forbids members from engaging in fishing activities at the creek when such is suspended for a time period; this suspension is usually enacted to promote growth of marine life;
- Pounding of pepper and beans from 8pm is forbidden (Issile-Ojono Jumbo)

Economic Profile of respondents/ Economic Livelihood Activities of the People

Livelihood Activities

Results from individual interviews reveal fishing as the modal livelihood activity (58%) among the sampled respondents. This is followed by farming (36.9%) and trading/business (5.1%) in that order (Figure 4.5.3.5). Thus, agriculture particularly fishing constitutes the dominant livelihood activity of residents in the study area with the men predominantly engaged in fishing in the open waters while the women get involved in fish processing (including fish drying) and marketing. The NPC and ICF International (2014) report on Rivers State revealed that about 25% of women and 14% of men of Rivers state residence were engaged in agriculture. The fact that the study area recorded a higher participation in these primary activities is an indication of the agrarian nature of the area as well as the low level of industrial/entrepreneure development.

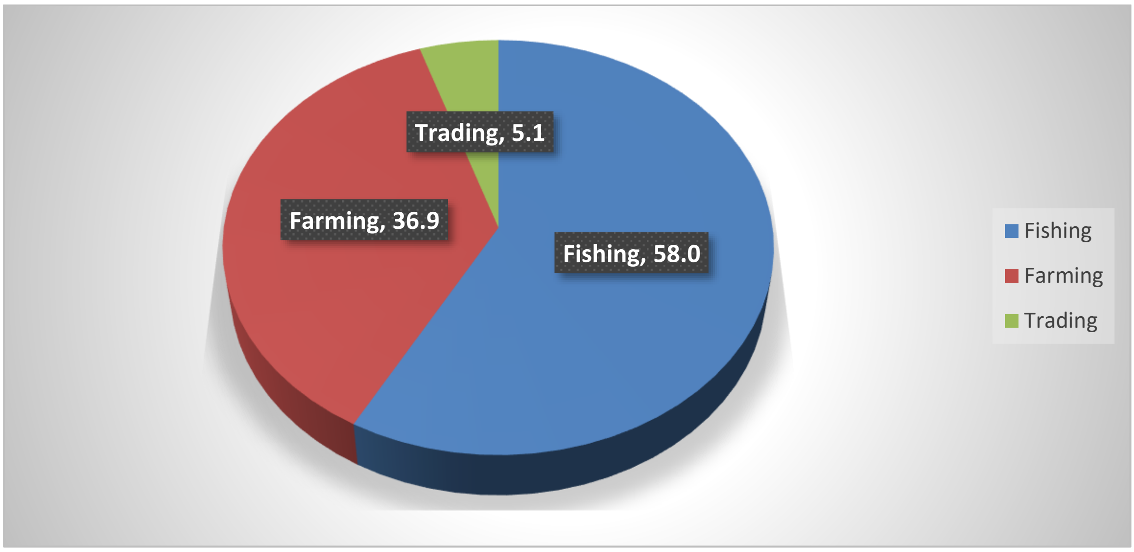


Figure 4.5.3.5: Major livelihood sources in study area (%)
Source: Field survey, 2018

Crop farming is practiced in several of the communities visited and common crops cultivated include cassava, oil palm, mango, plantain, banana, yam and sugar cane. Livestock was less common but where ever it existed the local poultry and goat were involved, and these are bred for domestic consumption mainly. These livelihoods are not without their challenges or constraints; for crop farming poor yield arising from soil infertility and destruction by rodents (grass-utter). On the other hand fishing is constrained by river pollution, poor fishing catch in shallow waters, lack of modern fishing equipment and technology as well as inadequate financial investment and or inputs (Plate 4.5.3.6).


Cassava farm (Dema-Abbey) Lumbering at Agbalamabie


‘*Bush meat’* and trading shop at Agbalamabie


Fishing gears and lumbering at Otuokolomabie

Plate :4.5.3.3: Livelihood activities in study area

Source: Field survey, 2018

4.5.3.4.2 Income Distribution

Income realized from livelihood activities varied among gender and occupational structure. In the main settlements where fishing is carried out as secondary occupation (by civil servants, informal sector operators, traders and oil sector workers) income received monthly ranged from N8000- N10000(76. 3% of the respondents) while those that earn between ₦10, 001-20,000/monthly constitute 23.7%. (Figure 4.5.3.6). However, for those that engage in fishing activities as primary occupation as is common in the fishing camps monthly revenue varied between N15001- N25000 and N10000-N15000 among the males and females respectively. The mean monthly income for the study was about ₦7780 a month, a value that is lower than Nigerian National minimum wage of ₦18, 000.00 per month. The focus group discussants revealed that income from fishing activities also depend on seasons; income usually realized at the peak of the rainy season can be as high as N70,000 monthly which can drop to as low as ₦10,000 at the height of the dry season.

Generally, the low earnings of the inhabitants given the mean income of about ₦7780 per month placed them very high on the poverty scale. However, this was not surprising because many focus group discussants rated the poverty level in the community above 75-80%. The result of the individual interviews indicated that 82% of the respondents rated themselves as poor (Figure 4.5.3.7). This was quite high compared to the national average of about 63% (NBS, undated). Self-rating approach provides an important feedback on how people perceived themselves and this can go a long way to shape their behavioral orientation (Arrow, 2016). This high perceived poverty level they described make savings difficult; about 92% of the respondents claimed they had no savings while only 10% reported that they were only able to save about 8.5%- 10.0% of their monthly income (Figure 4.5.3.8). This highly skewed savings reflective of a poor saving culture further shows their high vulnerability state and inability to absorb or deal with economic or social shocks.

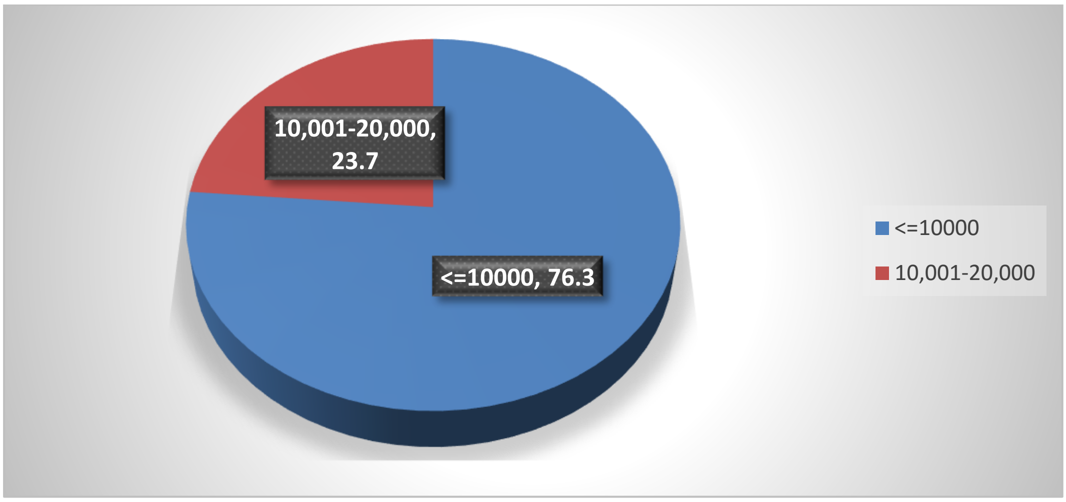


Figure 4.5.3.6 Income distribution of respondents (%)

Source: Field survey, 2018

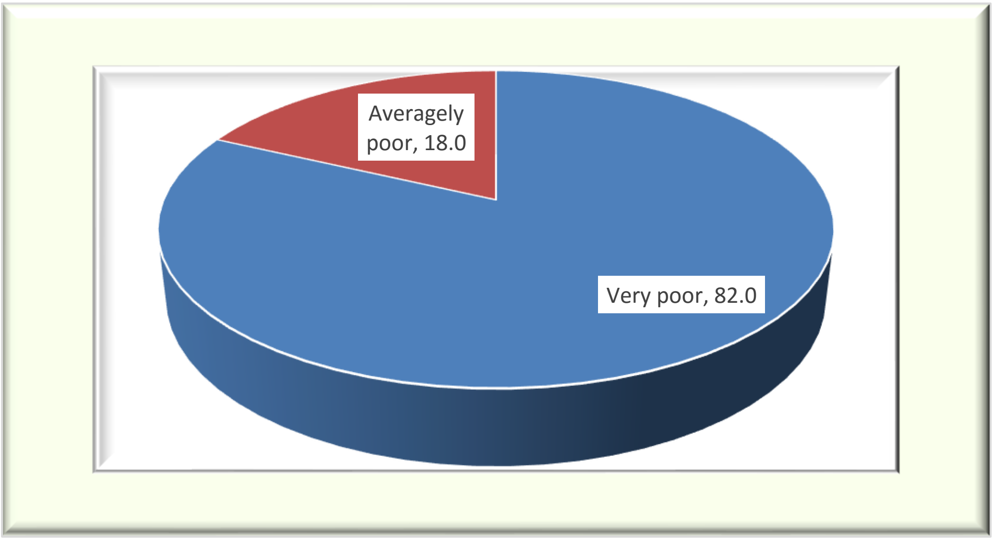


Figure 4.5.3.7: Self-Poverty Rating among Respondents (%)
Source: Field survey, 2018

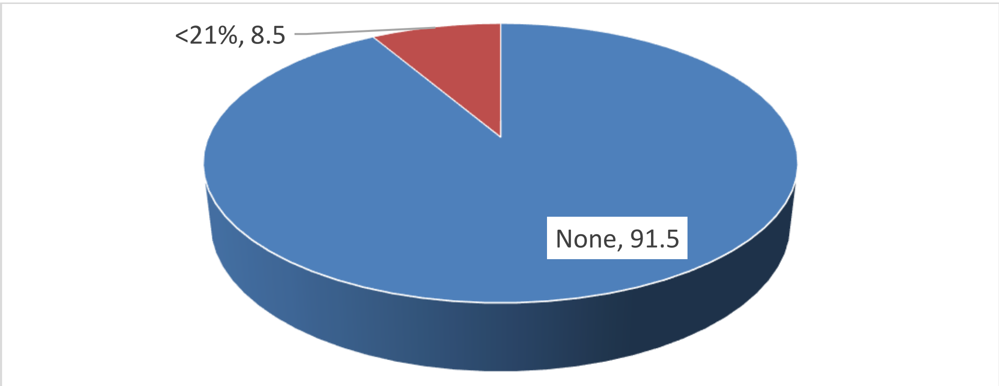


Figure 4.5.3.8: Proportion of income saved by respondents (%)
Source: Field survey, 2018

Work experience of respondents

Figure 4.5.3.4.9 shows the length of time respondents have been engaged in their respective economic endeavors. Specifically, 17.2% of the respondents had spent over 30 years, 13%% (21-30 years) 34.9% (11-20 years), while the remaining 34.9% have spent less than 10 years in their respective occupations The mean working experience of 17 years suggests some level of experience among the people in their various livelihood activities.

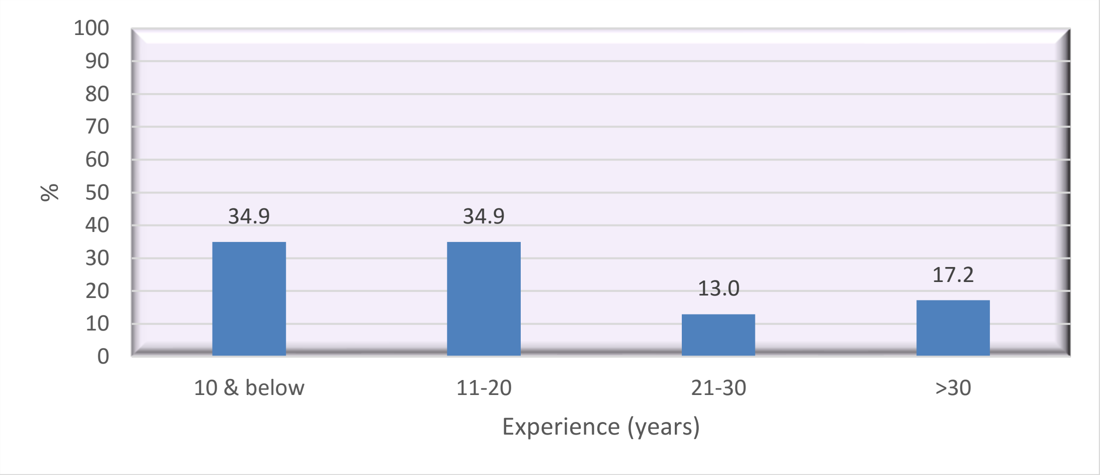


Figure 4.5.3.9: Work experience of respondents
Source: Field survey, 2018

Leadership Structure

The general leadership structure of the communities reflects a hierarchical model characteristic of Bonny or *Igbani* communities with the 'Chief' and 'Community Head' (sometimes referred to as '*Amaopusenibo*') at the apex of the community leadership structure. This is followed by the 'Council of Elders' and the 'Women' and 'Youth' groups sometimes referred to as '*Asanwo*' and '*Eremenobo*' respectively (Figure 4.5.3.10). At the head of the Elders' Council is the *Amanadabo*, who is usually the oldest man in the community and could be from any of the founding *Burusus* (group of houses). This structure manages the decision-making processes at the community level. The community head oversees the day-to-day operations at the community level; decisions are taken in conjunction with representatives of the other leadership strung i.e. Council of Elders, youths and women. Any dissatisfaction with any decisions taken can be reported to the Chief who calls for a meeting of the leadership to resolve such matters.

The Chiefs are subordinate to the paramount ruler or King of the Bonny kingdom, known as the *Amanyanabo*. Closely align to the *Amayanobo* is the Bonny Chiefs Council (BCC) and the Bonny Kingdom Development Committee (BKDC), which assist in the administration of the Bonny Kingdom.

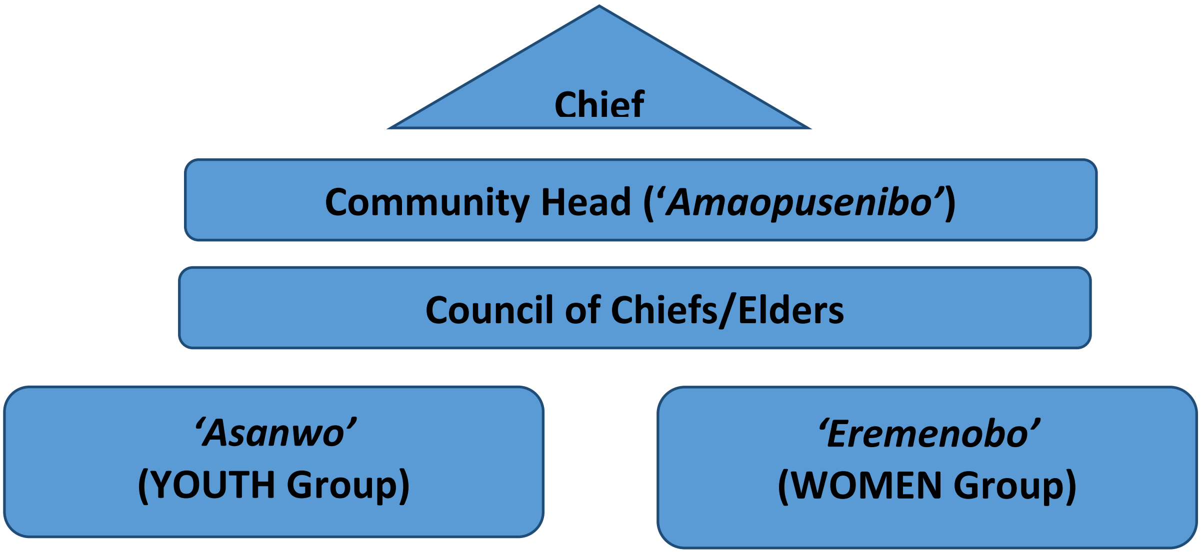


Figure 4.5.3.10: Community LeadershipStructure
Source: Field survey, 2018

4.5.3.4.5 Land Use, Settlement Patterns and Housing

The settlement pattern of the communities is largely linear except in Agbalamabie which exhibited some clustering in addition to the linear format/pattern. These communities are rural in nature and apart from Agbalamabie which hosts few tarred roads, modern health and educational centers, markets and drainage infrastructure all the other communities lack the urban amenities like tarred roads for vehicular transportation. Furthermore, the communities are highly homogeneous in terms of housing pattern and livelihood pursuits. Land ownership is largely vested in the community head, even though in some cases, families or individuals may own land. However, land allocation is largely at the prerogative of the community leadership; the process of land acquisition starts with a member making request to the community head who then makes appropriate allocation. Land use in the community is largely for residential purposes and farming only.

The dominant housing structure in the study area comprises sand-crete block wall, cemented floors and corrugated zinc roofing sheets. An exception to this was at Otuokolomabie and Alasiakiri where the houses were mainly constructed of bamboo/thatched walls floors and roofs (Plate 4.5.3.4.5.1) Compared with national characterization of houses in the rural areas of the country constructed with planks/ disused wood (0.4%), cement (40.1%) and earth/mud (48.6%) (NPC and ICF International, 2014), the study area generally reflected a mixed picture of houses built with sandcrete block and thatch houses. The large household size earlier noted among respondents suggests the possibility of overcrowding.

Dema –Abbey

Agbalamabie

Otuokolomabie

Alasiakiri

Plate 4.5.3.4.: Housing structures in some communities in study area
Source: Field survey, 2018

Social and Environmental Challenges
No particular conflict was reported by any of the community respondents however, the major social challenge noted was unemployment. Issues of leadership conflict and land disputes were said to be not so serious in the area. This could possibly be traced to the fact the communities have established leadership system based on tradition and which is highly revered. From discussion sessions with stakeholders at the various communities the possibility of the project impacting adversely on leadership conflict or land disputes is the area is very low i.e. insignificant. The foremost environmental challenges identified by respondents across the communities studied were oil pollution and shoreline erosion (Plate4.5.3.4). This is consistent with environmental challenges associated with the Niger Delta (Lekwot, Balasom, Dyaji and Ali, 2016). These were blamed on oil spills in the water ways and vessel/boat traffic. In some of the communities such as Otuokolomabie, John Jumbo, Dema-Abbey and Nkpkiri flooding was said to be serious while homes in the fishing camps are ussually threatened by shoreline erosion.

Shoreline erosion at Dema-Abbey; flooding at Otuokolomabie

Plate4.5.3.5 : Shoreline erosion in some communities
Source: Field survey, 2018

Amenities
Educational institutions:
Many of the communities lacked educational facilities (primary and secondary schools). The exception was Agbalamabie that was found to host both primary and secondary schools during the period of the field data gathering exercise. Against this background, school-age children in these community access educational institutions from the nearest community with such facility. For example, children at John Jumbo or Nkpokiri attend school at Burukiri that is about 25-30 minutes and 45-50 minutes by canoe transport depending on whether they are attending primary or secondary school respectively. Children at Otuokolomabie equally attend school at Burukiri or Dema-Abbey. Due to the difficulties usually experienced by pupils in attending educational institutions in the affected areas some communities had to device a roaster for individuals to transport the children to and from Bonny island daily using engine boat. The limited educational facilities in the area suggest that available schools are probably overburdened and any increase in population will worsen this condition resulting to overcrowding and overstretching of existing school facilities. However, the nature of the population influx may determine the likely impact of the proposed project on school enrolment.

Electricity:
Apart from Dema-Abbey, Oloma and Agbalamabie, other communities lacked electricity power infrastructure. Even among these three only Agbalamabie enjoy consistent power supply from the Bonny Utility Company (BUC). At Dema-Abbey the community has a generator plant provided by the local government council but maintained by the community; this facility is only occasionally used and there is a strong reliance on community members who visit during festive periods to fund the supply of fuel for powering the generator (Plate 4.5.3.6).

Dema-Abbey

Generator house

Agbalamabie

Nkpokiri

Plate 4.5.3.6: Electricity infrastructure in some communities

Source: Field survey, 2018

Water sources:

There is strong reliance on hand-dug wells for meeting the domestic water needs in the project zone of influence. These wells are either provided through communal efforts or are personally owned. However, in communities such as Agbalamabie, residents have access to pipe-borne water provided by the BUC. Bore-holes are found in the community as well as in Oloma, Dema-Abbey and John Jumbo communities although that of Dema-Abbey was described as non-functional (Plate 4.5.3.7). Some residents did complain that the quality of water from the bore-hole is poor, as it has s colour, taste and odour. Thus access to safe drinking water is quite low (less than 15%) among residents and this compares poorly with the national and state average figures of 39.2% and 71.3% respectively (NPC and Macro, 2014). A significant proportion (45%) of the respondents noted that they rely on the faecal and crude oil contaminated river water for washing and bathing. This observation aligns with similar studies in the Niger Delta area (Ordinioha and Brisibe, 2013).

Dema-Abbey Nkpokiri

'Water 'Kiosk' at Agbalamabie(left); Well at Issile-Ogono

Plate 4.5.3.7: Water sources in study area
Source: Field survey, 2018

Road networks:
All the communities are accessible through the network of creeks and rivers criss crossing the study area (i.e, the water ways) these being island communities. Apart from Agbalamabie and Oloma that have concrete/tarred road networks the intra-road network systems in the other communities are characterized by ungraded earthen road or walk ways/ footpaths (Plate 4.5.3.8). For those communities with motorable ways (Agbalamabie and Oloma) means of transport include buses, tricycles and motorbikes.

Concrete road at Agbalamabie (left); Canoe anchored at Otuokolomabie

Plate 4.5.3.8: Road network and transport facilities in study area
Source: Field survey, 2018

GSM Communications:
GSM communication is possible in all the communities with at least one of the network (GLO, MTN and Airtel) service available. However, the signal strength was described as epileptic in some communities

Jetties:
Jetties are an important infrastructure in riverine communities, as it facilitates safe on- and off-boarding of boats as well as convenient community entry particularly where such is waterlogged. Dema-Abbey, John Jumbo, Agbalamabie and Issile-Ojono Jumbo had concrete jetties (Plate 4.5.3.4.7.4). That of John Jumbo and Dema-Abbey was provided by SPDC.

Dema-Abbey   Iron Jetty at Nkpokiri

Plate 4.5.3.9: Road network and transport facilities in study area
Source: Field survey, 2018

Public waste convenience (sanitation facility):
Most of the communities had public sewage disposal facilities (toilets) except for Issile-Ojono Jumbo and Alakasiri where sewage is directly disposed off into surface water bodies/ river. Communities like Oloma, Agbalamabie and Dema-Abbey equally have personal buildings/structures fitted with modern septic tank/soakaway toilet facilities. Many of the public sanitation facilities are constructed of wooden structures and are usually provided by the communities themselves although the concrete sewage facility in John Jumbo was provided by the local government. These facilities are generally of the jetty-type overhanging the river which indicates that human waste is disposed directly into the river (Plate 4.5.3.10).This result corroborated the widespread use of over-hung (jetty-type) toilet in the Niger Delta riverine communities (SPDC, 2015).

Nkpokiri

Agbalamabie

Otuokolomabie

Issile-Ogono

Plate **Plate 4.5.3.10 :**Public toilet facilities in communities

Source: Field survey, 2018

Town halls:

Town halls or central meeting points are important infrastructure for community interaction and discussion of important issues relating to the development of communities. Only few of the communities had standard townhall buildings and these include those at Dema-Abbey, Otuokolomabie and Issile-Ojono Jumbo. The SPDC was responsible for the construction and ongoing furnishing of the townhall building at Dema-Abbey settlement (recently constructed in 2017).

Health centres:

Very few communities such as Dema-Abbey, Agbalamabie and Oloma can boast of a health centre building (Plate 4.5.3.11). However, some of them they complain of lack of adequate medical personnel. The potential impact of the planned project on provision of health centers / buildings is likely to be very low. However, many respondents the commended the efforts of SPDC in supporting available health centers in the areas personnel, drugs and provision of services

Plate 4.5.3.11: Health centres at Dema-Abbey (left) and Agbalamabie (right)
Source: Field survey, 2018

Community perception of existing positive impacts of the project
Focus group discussants expressed in strong terms their expectations that the project would add value to their communities. These expectations are highlighted below:

- **Electricity infrastructure and light:** Some of the communities such as Dema-Abbey and Otuokolomabie, had expected SPDC in developing and running these projects would facilitate the provision of electricity infrastructure for them. The value of this is best captured in a statement expressed by a resident when he said, "*if there is light we can do other things*", meaning that other latent livelihood opportunities can be explored by residents if there was regular power supply. It was equally anticipated that power supply could be more regular in the future considering the poor functionality of existing community generators operated in the study area.

- **Education**: Only few public educational centres were seen in the project communities during the field data gathering exercise; these were found in Oloma, Agbalamabie and Dema-Abbey. The respondents acknowledged or rationalised the absence of public educational institutions on the small size of the community in terms of the requisite population threshold to support such a facility. This was found to be the case in the fishing camps or temporary settlements. Educational scholarship was reported as one of the major intervention area that can be used to complement provision of instructional materials to promote access to and improve the quality of education as observed by respondents. They reported that having improved access to education will make indigenes to be more competitive at the workplace.

- **Development of entrepreneurial competencies:** In addition to educational scholarships, respondents hoped a positive fallout from project would be the development of entrepreneurial competencies of indigenes. This competences the respondents noted, should align with the present and future needs of the oil and gas industry to make them relevant to the sector, thus leveraging on the main industries within their domain.Others felt the training scope should go beyond the oil and gas industry to make the youths less dependent on oil companies for jobs, and empowering them to take advantage of alternative livelihoods. Majority of respondents in the fishing camps expect SPDC assist them to acquire new fishing equipment and gears.

- **Empowerment**: Closely align with the entrepreneurial trainings, discussants emphasized the need for graduates of the programme to be empowered with necessary inputs and capital. Furthermore, respondents noted that agricultural inputs such as fishing nets and improved seeds are areas that the project can impact on community livelihood, especially since most residents derive their livelihoods mainly from fishing and crop cultivation.

- **Improved water sources:** Many of the communities lacked water bore-hole, and respondents anticipate that this infrastructure will be provided. For those with bore-holes, the water was described by respondents as impure and unfit for human consumption, thus compromising access to safe water. In these communities, which were earlier mentioned, rehabilitation of existing water facilities to provide water purer quality is an unmet expectation that is long overdue.

- **Jetty construction:** Communities such as Otuokolomabie lacked jetty be it wooden or concrete. The community leaders hoped provision of concrete jetty is an area of urgent expectation. . High expectation was also reported by leaders at Dema-Abbey in the area of inter community road construction; SPDC should facilitate the completion of the road network l the community with Bonny Island. This road which was started by the government had been abandoned. The completion of the access road it is believed will enhance trading and overall economic development of the community.

- **Shoreline protection:** Several of the communities suffer from flooding and shoreline erosion. Discussants noted that an area of development intervention from SPDC would be the construction of shoreline protection structures to secure the affected communities like Otuokolomabie, Oloma, Dema- Abbey as well as the provision of concrete roads/walkways to facilitate intra-community movement.

- **Employment**: Lack of employment was a recurring expectations in all the communities visited during the field data gathering exercise. In particular respondents and stakeholders in the fishing camps expressed strong expectations that SPDC could engage selected community residents for the surveillance of existing well and pipeline assets in their respective communities, They opined that giving the task to the communities to render would be more cost-effective for the Company compared to contracting it non indigenous personnel. . If this is done the cumulative project impact on employment generation in the communities is likely going to be higher in the future.

- **Health centres/services:** Of particular interest to the respondents was the provision of health centres and/or the rendering of health services to distant communities to foster good health among residents. An additional and related expectation was the supply of drugs in existing health centres.
  The provision of public toilet facilities: particularly among communities that lacked concrete facilities such as Otuokolomabie is an area of high expectation

The result of assessment of the views of respondents are summarized in Figure 4.5.3.4.7.1 From the results the following issues were rated high; employment (100%), educational scholarships (100%), shoreline protection (100%), business credit (97.5%), fishing inputs (96.6%) and entrepreneurial capacity development schemes (87.6%) while construction of market stalls and town halls were rated very low.. These expectations align with those indicated in the proposed master plan for the Bonny kingdom (NLÉ, 2018).

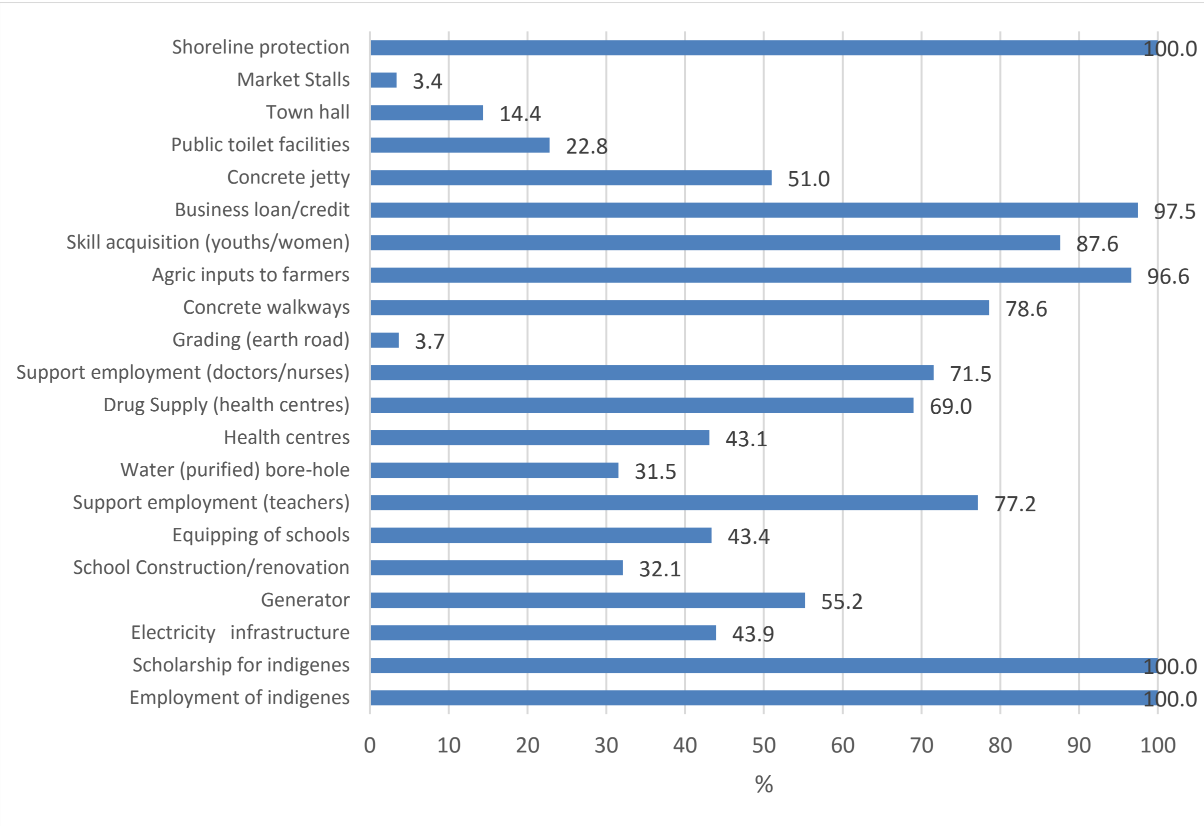


Figure 4.5.3.11: Perceived positive impact of project on community development
Source: Field survey, 2018

Community concerns about project impact

Concern over project impact on community physical environment

Focus group discussants expressed some concerns over the potential negative impact of the project on the community physical environment. The major areas border on the following:

- **River/air pollution** arising from gas flaring and oil spill respectively. Respondents traced this concern to precedence recorded in the area from oil company activities which has negatively impacted on their environment, water sources and livelihood. For example, residents in Agbalamabie recalled the 1993 oil spill which caused a lot of harm including the decline of fishing in theie shallow waters, Residents at Otuokolomabie also recalled the 2012 spill which caused the death of four persons in the community.
- **Water contamination** has impacted adversely on existing domestic water sources. Most of the communities visited depend on and/or use water from the wells for drinking and are concerned about possible worsening of the trend in the future.
- **Shoreline erosion:** A major factor blamed for the increased shoreline erosion by respondents was increased vessel/boat traffic in the area. It is believed that the location of similar projects in the future would likely increase vessel/boat traffic further worsening the shoreline erosion.
- **Loss of farmland/forest resources:** Respondents equally feared that surrounding farmlands/forests were destroyed to make way for the projects. This, they asserted have affected biodiversity adversely including access to bush meat which is one of the important sources of protein, and vital nutrition item in the area.
- **Dearth of fish**: Another major concern among respondents about the project is its adverse impact on fisheries and fishing activities in the study area. They averred that the serious oil pollution of mangroves and water ways in the area has caused both mortality and migration of resilient fishes and has led to scarcity of fisheries in the rivers and creeks., The impact of oil pollution on the livelihoods and welfare of residents in the project area cannot be over-emphasized.

Figure 4.5.3.12 presents the summary of the assessment of stakeholders and respondents concerns about the project. Figure reveals some of their major concerns borders on air pollution from gas flaring (100%) with its potential impact on roof corrosion (100%) and increased heat level (76.26%) Pollution of water ways (100%), noise pollution that may arise from constant boat/vessel movements (100%) and increased shoreline erosion (78%).These concerns are consistent with the pattern of concerns identified by similar studies inthe study area (Akintoye, Eyong,Agada, Digha and Okibe, 2016).

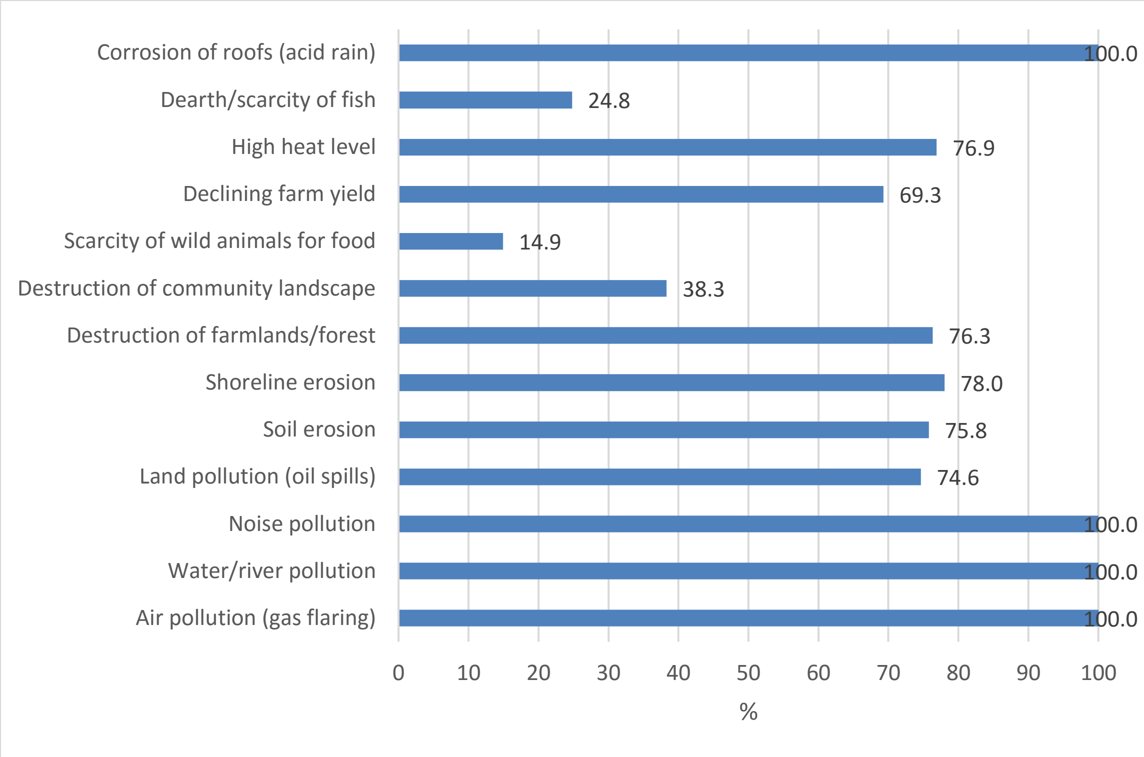


Figure 4.5.3.12.: Potentialnegative impact of project on physical environment

Source: Field survey, 2018

Perceived community concerns over project impact on socio-economic environment
On the social environment, the fears of the respondents (FGD discussants) over the proposed project bordered on the following:

- There are concerns that the company is not giving adequate attention to the developmental needs of the communities that are primarily or directly impacted by the project. . This concern is aptly expressed by a respondent at Otuokolomabie thus, '*we hear SPDC gives money, but we don't see this money. years ago, when there was oil spill close to the community, people die; we tell SPDC, but it did not answer us'*. The possibility of this occurrence is very low, given the standard operating procedures of SPDC.
- **Youth restiveness:** The failure of SPDCto honour its memorandum of understanding with the communities was cited as a source of serious concern because of its potential effect on youth restiveness and or militant activities in the area. Furthermore, the operation, they fear may further instigate militant activities in the area. A respondent captures it thus, '*if SPDC fails to do what it says it would do, people will not be happy. If SPDC destroy our river where we eat and fail to care for us, people will be angry and can do anything'*. Thus, the impact of the project on youth restiveness is likely t high.

- **Disruption of livelihoods:** A major economic outcome of river pollution, according to the respondents, was the potential disruption of community livelihoods, which is largely agrarian (i.e. fishing and farming)and consequent loss of income. Like a discussant noted, "*anything that happens to the river affect our life since we are fishermen and women. That is where we get money to eat, buy clothes, take care of our houses and send our children to school. Government does not remember us*".Also, possible destruction/pollution of creeks and water ways may lead to destruction of habitats for periwinkles and oysters making it more difficult to catch these organisms, a major livelihood for women in the community.
- **Food insecurity:** Another concern expressed by the respondents was the adverse impact of the project on the food and nutritional status of residents in these communities. Stakeholders expressed grave concern over the destruction of hitherto healthy t natural capital resources by oil operational activites in the area (that is farm land, forest and fisheries resources), which are the major sources of food (carbohydrates, proteins and micronutrients) for the communities without a sustained alternative livelihood restoration program is to say the least not good enough for the area
- **Increased demand on amenities:** Also reported was the issue of increased influx of persons into the community. On its own this is positive impact as it promotes the visibility of the communities however, respondents noted that available or existing infrastructure/amenities are not being improved upon at the rate of population influx into landed communities like Abalamabie thereby placing huge burden on few socio-economic facilities in the area.
- **Increased cost of goods/services:** With increase in population, an additional concern expressed by respondents over the potential increase in population was the likely increase in cost of goods/services. If this is not matched by increased income, the general welfare of residents may worsen. Thus, the cumulative net impact of the project on cost of goods and services is likely going to be high.

The views expressed above were equally rated by the study as indicated in Figure 4.5.3.5.2. The results indicate that disruption of community livelihoods particularly fishing is rated very high (100%) so also was the increased influx of persons into the community (76.3%), increased burden on existing amenities e.g. health and educational services (100%), failure of company to honour agreement or GMoUs with communities (76.9%), spread of sexual related diseases (81.1%) (Figure 4.5.3.5,2)

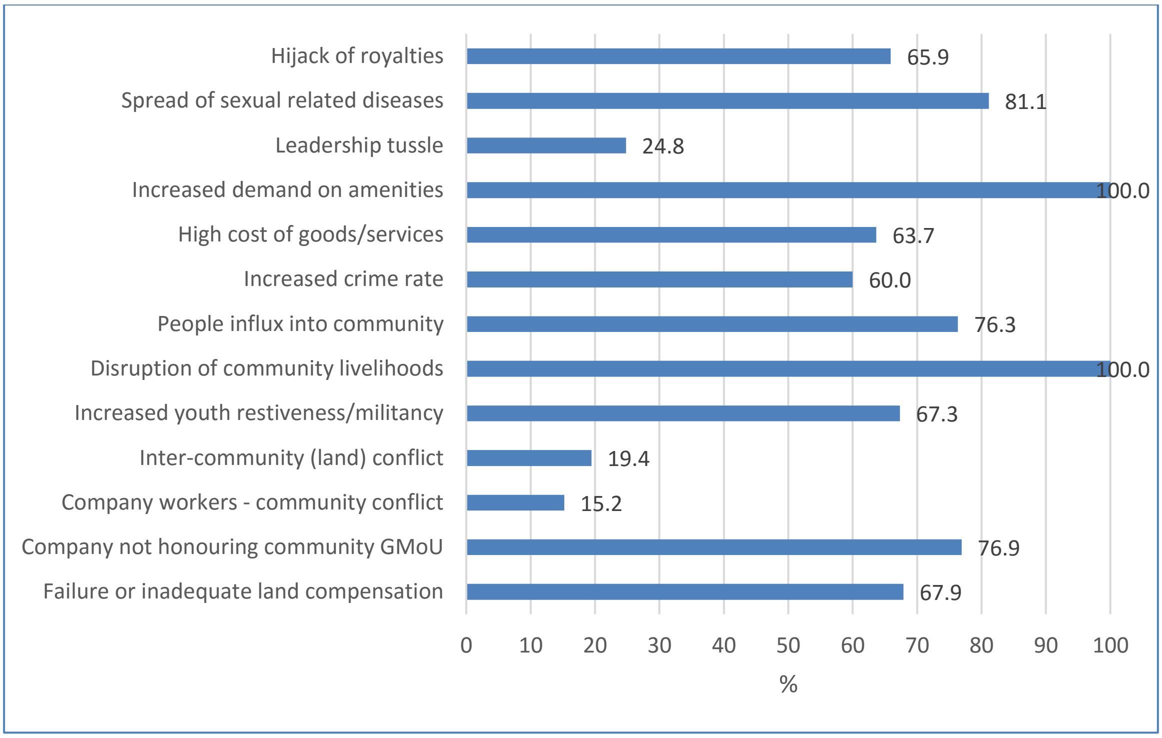


Figure 4.5.3.13 : Perceived potential negative impact of project on social environment

Source: Field survey, 2018

4.6 Health Impact Assessment

4.6.1 General

The Nigerian policy on the environment and Decree 88 of 1992 require the filing of an Environmental Impact Assessment (EIA) report, before any major project with significant impact on the environment can be undertaken; and Health Impact Assessment is now recognized as an important part of a comprehensive Environmental Impact Assessment study. This Health Impact Assessment study conducted for the Bonny Deep Exploration and Appraisal Wells Projects is to satisfy the requirements of the Nigerian EIA legislation. The specific objectives of the study are:

- To determine the baseline health status of members of the host communities of the projects
- To ascertain the presence and prevalence of risk factors to health in the host communities
- To assess the quality of health services in the communities, and test the robustness of the health system;
- To evaluate the possible effects of the Exploration and Appraisal Wells Projectson the health, wellbeing and the environment of the communities; and
- To develop cost-effective mitigation measures and appropriate Environmental Management Plan (EMP) based on the identified hazards.

For this study, health is defined according to the World Health Organization's 1948 definition as a state of complete physical, mental and social wellbeing, and not merely the absence of disease or infirmity. This definition is also consistent with the relevant environmental and health laws in Nigeria.

4.6.2 Data collection methods

The followingten (10) communities in the Bonny Local Government Area of Rivers State are officially recognized as host communities of the Bonny Deep Exploration and Appraisal Wells Projects: Abalamabie, Dema Abbey, Otokolomabie, Oloma, Sangama, Nkpokiri, Issile-Ogono Jumbo, Addah Allison, Alasiakiri and Okulo-Lodge.

The data for the health impact assessment of the project were collected from the communities, using a variety of methods, including:

- The analysis of the report of Disease Surveillance and Notification (DSN) activities in the communities
- The analysis of the data generated by the Health Management Information System (HMIS)
- Population demography of the area, as obtained from the National Population Commission (NPC); and
- A review of relevant literatures and other impact assessment studies previously carried out in the communities.

Gaps in these data were filled through community survey, conducted between Thursday 3rd May and Tuesday 22nd May 2018, and supervised by the relevant government agencies, including the Directorate of Petroleum Resources of the Nigerian National Petroleum Corporation, and officials of the State and Federal Ministries of Environment. Data collection during the field studies were carried out, using both quantitative and qualitative methods. Emphasis was however given to participatory rapid appraisal methods, because they are encouraged by the relevant Nigerian EIA legislations, to ensure the inputs of members of the host communities.

The following rapid appraisal methods were used during the community survey:

- Focal Group Discussion, with Chiefs, youths and women of the communities
- Key informant interviews, especially with health workers in the communities and community leaders; and
- On-the-spot observations

These rapid appraisal methods were complemented by the use of a self-administered, semi-structured questionnaire. The Focus Group Discussions were conducted using the standard methods, in the town halls of communities, and other convenient places.

Plate 4.6.2.1: Focus Group Discussion at Otokolomabie, Sagama, Issile-Ogono-Jumbo

Key informant interviews were held with key opinion leaders of the communities, and the health workers who practice in the communities, using the standard method, and in an environment, that guarantee valid responses. The interviews of the opinion leaders in the communities were to get a detail view of the living conditions in the communities; the presence of risk factors in the communities; health seeking behavior of members of the communities; and to explore the interviewee's view on the possible health impact of the exploration and appraisal wellprojects on members of the communities. The interviews of health workers in the communities were to assess the quality of health services, and the health seeking behaviour of members of the communities.

Fig. 4.6.2.2: Key Informant Interview at Abalamabie community

Direct observations were used to assess the quality of health services, and health care delivery in orthodox and traditional health care facilities that serve the communities. Direct observations were also used to assess the environmental health conditions in the communities, especially the layout of the buildings, the sources of drinking water, methods of refuse disposal, and the type of sanitation facilities used in the communities. The EIA team, assisted by a local guide moved round the communities, taking note of these and taking photographs where possible.

The rapid appraisal methods were complemented with a self-administered, semi-structured questionnaire, administered to households in the communities; and the collection and analyses of samples of surface and ground water, and air quality measurements carried out by the bio-physical team during the field study, using standard methods, certified by the regulators.

Questionnaires were distributed to all heads of household present at the meeting between the communities and the HIA/SIA team. To prevent bias, efforts were also made to administer the questionnaire to other heads of household in the communities that were not present during the meeting. The questionnaire was self-administered, but clarifications and interpretations were provided when requested. A total of 300 questionnaires that were administered, but only 157 questionnaires were retrieved, giving a response rate of 52.33%. The health condition of the host communities of the Bonny Deep Exploration and Appraisal Wells Projects is similar to those of the other communities in the Bonny Kingdom. The communities thrived during the trans-Atlantic trade, in the pre and early colonial times, but have since fallen into hard socio-economic condition, especially with the growing attraction of the economic opportunities in Bonny main town, and in recent years due to the incessant crude oil spills in the communities, caused by oil bunkering that destroyed the environment and made fishing and farming, the main sources of livelihood of the peoplenot lucrative.

4.6.3 Socio-economic characteristics:

The socio-demographic characteristics of the host communities of the Bonny Deep Exploration and Appraisal Well projects are consistent with those of comparable communities in the coastal sandy barrier island ecological zone of the Niger delta region (*UNDP, 2006*). The communities in the ecological zone are mainly small, rural and populated mainly by fisher folks, traders and marine transporters. These occupational activities have significantly deteriorated in the host communities in recent years due to insecurity and the incessant oil spills caused by oil bunkering, as can be deciphered from the following comments made by discussants during the Focus Group Discussions held in the communities.*"Before we used to fish, have enough to feast on, and then sell the surplus in Bonny. Now we go to Bonny to buy ice-fish, because the fish are no longer there in the water."* The respondents of the questionnaire administered during the field study were young, with an average age of 25.61 +/- 11.3years; most 147 (93.63%) had at least secondary school education and were mostly unemployed.

4.6.4 Access to safe drinking water

Source of drinking water of members of communities

Access to potable water is one of the Sustainable Development Goals and was assessed during the field study. Most members of the host communities are able to meet the daily per capita water requirement of 20 – 40 liters, albeit from several non-improved sources. The main sources of drinking water in the communities are the hand-dug well, sachet/bottled water, water borehole and rain. The hand-dug well is the most important source of drinking water in the community, like most of the other communities in the coastal barrier island ecological zone of the Niger delta. Several of these hand-dug wells are as old as the community and are most likely fed with water from above the first impervious layer. Water seep into the wells, and accumulate in significant quantity in the morning, but is easily exhausted by the evening, especially during the dry season.

Fig.4.6.4.1: Water facilities in Oloma community - A non-functional public water facility (Left) Private water facility (Right)

Fig.4.6.4.2: Water kiosk at Abalamabie community

Several water borehole facilities were sighted in the communities during the field study, many of which were owned by private individuals, especially in the bigger communities of Oloma and Abalamabie. The water boreholes were however said to yield poor quality water such that they are mostly used for sanitation and cooking, but not so much for drinking. Access to safe drinking water is best in Abalamabie community, because the community is served by reticulated water provided by the Bonny Utility Company (BUC), and sponsored by the Joint Ventures Companies (SPDC, NLNG and Mobil).

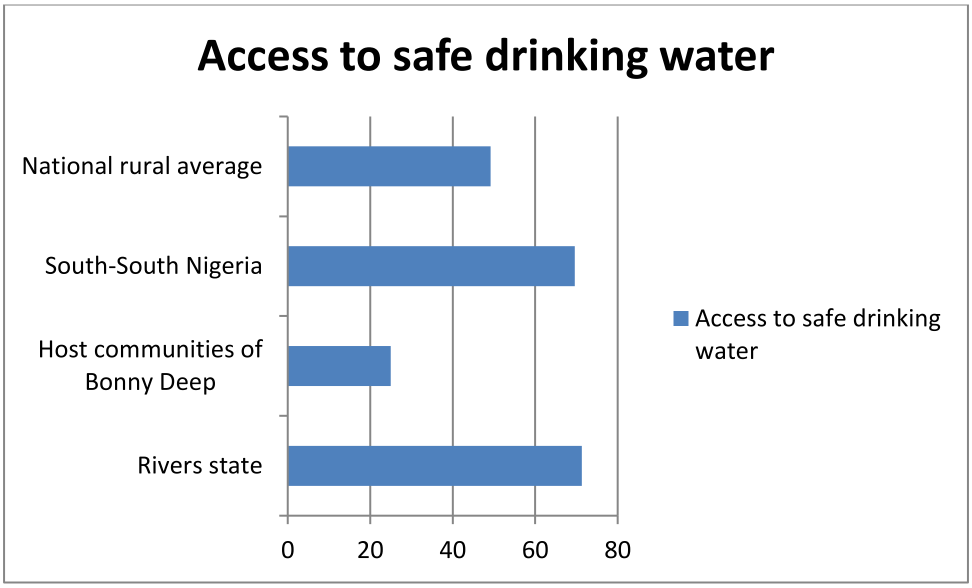


Fig.4.6.4.1: Access to safe drinking water in the host communities of Bonny Deep compared to national and regional averages

Access to safe drinking water was noted to be about 25% in the communities during the field study, which is comparable to the figure recorded in the communities in previous EIA studies (*SPDC, 2013)*,but less than the 69.6% average for south-south Nigeria, the 71.3% average for Rivers State, and the national average for rural communities of 49.2% (*NPC and Macro, 2013*).

Access to safe drinking water can however be improved in the communities not by the construction of new water facilities, but by rehabilitating existing water facilities, adding a desalination technology to the facilities, and generally adopting the Village Level Operation management of Maintenance (VLOM) technology advocated at the start of the International Drinking Water and Sanitation decade, for the maintenance of water facilities (*WEEL 1998*).

4.6.5 The quality of drinking water in the communities

The WHO recognizes the possible health effects of the various constituents of drinking water, and therefore set guideline values for each of them. Surface and ground water samples were taken by the relevant bio-physical experts, during the field studies. The results of these samples are presented in Table 4.6.5.1. The data presented in Table 4.6.5.1 showed the presence of coliforms, much higher the WHO guideline value of less than 10/dl. This is however consistent with the findings in comparable communities and have been attributed to the widespread use of the over-hung (jetty-type) toilet in the communities (*Ordinioha 2011*). The use of water contaminated with coliforms is capable of causing diarrhea but can be made potable by the addition of chlorine tablets, especially those that also contain coagulants and flocculants, like the "water guard" marketed by the Society for Family Health. (*Clasen et al 2005*).

The presence of trace metals such as iron and zinc in the samples of ground water is not necessarily a health hazard but can be a valuable source of these essential micro-nutrients to members of the communities *(Ordinioha and Sawyer, 2012).* Although the quality of ground water in the communities is good, it however does not guarantee that the water at the point of use would also be as good. This is because most households in the communities do not have piped water supply and have to collect and store water at home. Good quality water collected from the vending tap and other water collection points can easily become grossly contaminated, in course of their transportation and storage at home *(Clasen et al 2005*). Chemical contamination of water in the communities is very likely, because discarded drums of drilling chemicals were noted during the field study, to be common water storage containers. The health implications of this must be recognized and tackled, as the health effects, especially from chronic exposures can easily be wrongly attributed to the proponent.

4.6.6 Access to sanitation facility

Access to sanitation facility is one of the Sustainable Development Goals and was assessed during the field study. Sanitation facility was defined during the field study as a private excreta disposal facility that is either a toilet or a latrine, but not an overhung toilet, or a flush toilet without septic tanks that channels it effluents directly into the river; while household access to sanitation was defined as when a household has a private sanitation facility, or shares a facility with not more than five other households in the building or compound (*Billig et al, 1999).*

Nearly all the members of the host communities have a toilet facility within the recommended 50m distance from their houses, but most of the facilities are the jetty-type (over-hung) toilets that grossly contaminate surface water and are not technically considered a toilet facility. Access to unshared sanitation facilities in the communities was thus noted to be about 35% in Oloma, Abalamabie and the other big communities, and significantly less at about 10% in the smaller communities of Alasiakiri andNkpokiri. Access to sanitation facilities in the communities is therefore consistent with the 25.8% average for south-south Nigeria, the 28.0% average for Rivers State, and the national average for rural communities of 13.4% (*NPC and Macro, 2013*).

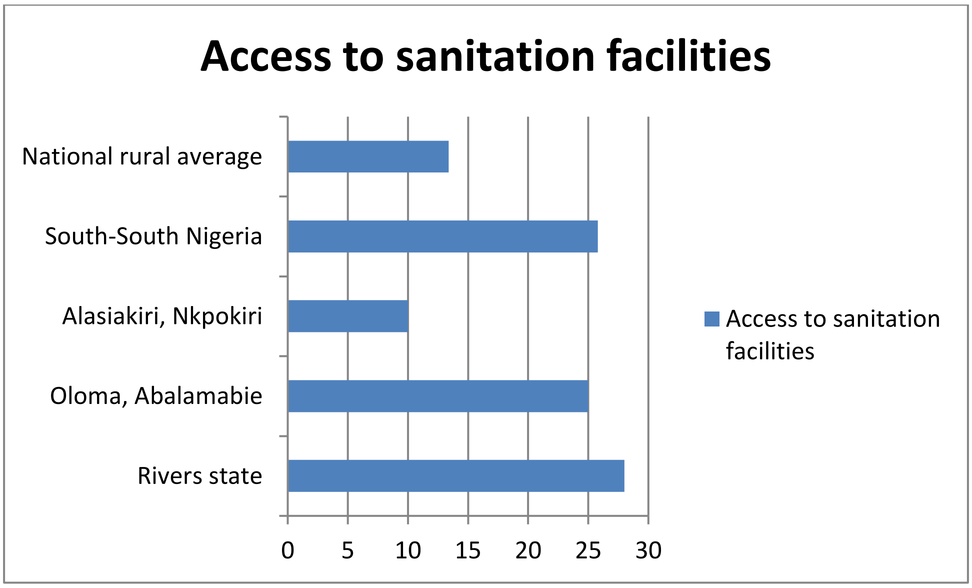


Fig.4.6.6.1: Access to unshared sanitation facilities

Access to sanitation facility can be improved in the communities through the use of sewerage system with sewage treatment facility, because of the high groundwater level in the communities that makes pit latrine almost impossible to construct and use in the communities (*Ordinioha, 2010*)

4.6.7 Housing condition

The characteristics of the houses in the host communities were noted during the field study.The houses in the more established communities such as Oloma, Abalamabie, Dema Abbey are both old and modern, indicating the past and present affluence of members of the communities. Most of the houses were however unoccupied, as was noted in the 2013 EIA study (*SPDC, 2013*). On the other hand, the houses in the smaller communities like Alasiakiri, Nkpokiri were mostly built with corrugated roofing sheets and planks, because the communities are basically fishing settlements.

Plate 4.6.7.1: Houses in Otokolomabie (Left), Alasiakiri (Right)

The floors of the houses in the bigger communities were noted to have been constructed with cement (75%), mud (3%) and planks (12%); while those in the smaller communities were constructed with cement (9%), mud (11%) and planks (80%). The housing condition in the communities is therefore different from the national averages for rural communities of 0.4% for planks/wood, 40.1% for cement and 48.6% for earth/mud (*NPC and Macro, 2013*).

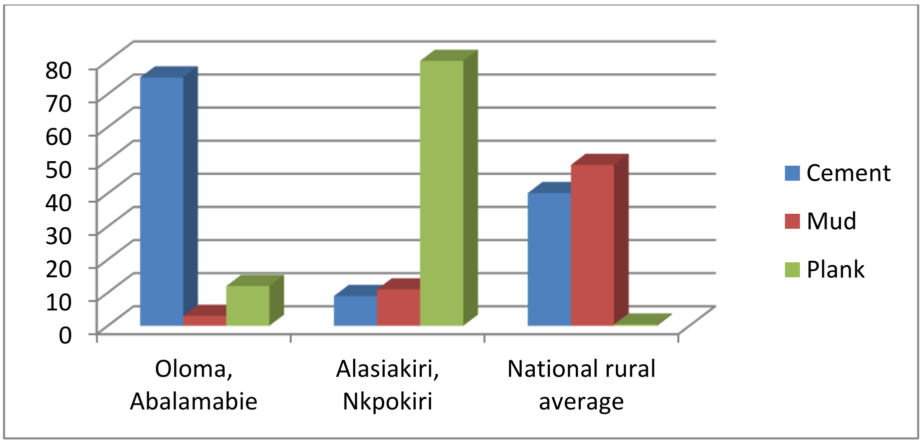


Fig.4.6.7.2: Flooring materials used in houses of the communities compared to national averages

4.6.8 Vector/pest control:

The following vectors were identified in the communities during the field study:

- Anopheles mosquito – the vector for malaria
- Culex mosquito – the vector for filariasis
- Aedes mosquitoes– the vector for yellow fever
- Tsetse fly (Glossina sp.) – the vector for sleeping sickness
- Chrsops – the vector of loaloa (eye swelling)
- Sand flies (Phlebotomus spp.) – the vector for Leishmaniasis
- Housefly – carrier of enteric infections such dysentery, typhoid and diarrhea; and eye infections such as trachoma and epidemic conjunctivitis

The vectors identified in the communities are comparable to those found in similar communities in the coastal barrier island ecological zone of the Niger delta region (*Ordinioha, 2014*). Of all the vectors, the nuisance and diseases caused by mosquitoes are most seriously felt in the communities, as reflected in the focus group discussions held with members of the communities. The severe mosquito infestation of the communities is most likely due to the several water bodies in the communities, and the fact that the communities are surrounded by forest. Mosquito trees such as plantain and banana trees were also noticed closed to residential houses in the communities.

The prevalence of the various vector-borne diseases, except for malaria and filariasishave remained low in the communities. This is as indicated by health facility data and key informant interviews conducted as part of this EIA. No case of trypanosomiasis (sleeping sickness), leishmaniasis, dengue fever or yellow fever was reported to the Bonny Local Government health office in the period between 1999 and date. A total of 31 cases of filariasis were however recorded in the health office between 1999 and 2006. These patients were initially treated in Bonny General Hospital, before being transferred to the tertiary hospitals in Port Harcourt. Filariasis is transmitted by culex and aedes mosquitoes which breed in dirty stagnant water and artificial containers respectively. The disease can therefore be controlled with better effort at solid waste disposal (*Ordinioha, 2010*).

The records of the LGA health office show a fluctuation in the cases of malaria reported in Bonny Island. Malaria cases dropped from 5,000 cases in 1999, to 2,000 cases in 2003, before increasing to about 6,000 cases in 2004. There are indications that the incidence of malaria in the island has significantly decreased with the malaria control efforts of the Rivers State government, and some private initiatives, some of which were sponsored by the NLNG and SPDC. In recent years, malaria diagnosis and treatment are being offered without charge to patients, and thousands of ITNs were distributed to householders in Bonny Island, as part of the Rivers State government's target of giving out two ITNs to each household.

4.6.9 Indoor and outdoor Air quality:

Firewood is the main fuel used in cooking, and in fish drying, a common fish preservation method in the communities. More than 80% of respondents in the communities use firewood as their main source of domestic fuel. This is consistent with the national average of 83.3% for rural communities (*NPC and Macro, 2013*), and similar to the findings in other Niger delta communities where an average of 73% of the households in the communities were noted to use firewood as their primary energy source (*UNDP*, *2006*).

The use of firewood and other bio-mass fuel as domestic fuel is a major cause of indoor air pollution, with wide-ranging health implications (*WHO*, *2003*), one of which is acute respiratory infection in under-five children. According to the 2013 NDHS, 1.7% of under-five children in the Niger delta region (south-south Nigeria) had symptoms of Acute Respiratory Infections compared to 0.8% in the south-west zone and 2.1% in the south-east zone. The national average was 2.0% (*NPC and Macro, 2013*).

The results show that the levels of particulate matter recorded in the communities are below the Federal Ministry of Environment acceptable limit. This is even with the extensive use of firewood in the communities. The air quality in the communities are therefore good, considering that PM10 (Particulate Matter with diameter less than 10 microgram) do not just cause nose and throat irritation, but are also capable of lodging deeper into the respiratory tract, to trigger off asthmatic attack, and worsen pre-existing cardio-respiratory ailments. The WHO estimates a 0.74% increase in the daily total number of deaths, and 0.8% increase in the daily total number of hospital respiratory admissions for every 10ug/m3 increase in SPM (WHO, 2000).

4.6.10 Ambient noise levels

The noise levels are within the regulatory limit of the Nigerian Ministry of Environment, and importantly not up to the 55-dB level known to cause annoyance, the harbinger for most of the noise-induced health problems that include aggression, sexual impotence and sleep disorder (*Berglund et al, 1999).* The likelihood of the projects becoming a noise hazard is low, considering that they are basically gas/oil wells and pipelines that are not known to be noisy. This is good especially as conservative estimate of the amount of disability caused by environmental noise in European countries alone, measured as Disability Adjusted Life Years (DALYs) was put at 61 000 years for ischaemic heart disease, 45 000 years for cognitive impairment of children, 903 000 years for sleep disturbance, 22 000 years for tinnitus and 587 000 years for annoyance (*WHO, European Commission, 2011*).

4.6.11 Waste management

The wastes generated in the communities are mainly garbage and other domestic wastes. These wastes are often dumped close to residential accommodation, or at the bank of the river, where they sometimes served for land reclamation and/or shoreline protection. Almost all the respondents (94.90%) were noted to have managed their solid waste in this manner. This problem is compounded by the near total absence of municipal solid wastes disposal services in communities, including Abalamabie community that is close to Bonny Main Town.

Although the wastes generated in the communities are mainly garbage, leaches from them can be a major source of contamination of the water bodies in the communities, especially with the increasing use and open dumping of energy saving bulbs that have been shown to contain significant quantity of mercury (*Ordinioha, 2012*). Leachates from energy saving bulbs and similar waste with high content of heavy metals have been shown to cause the bio-accumulation of the heavy metals in aquatic animals, including fish, and therefore capable of causing human diseases when consumed (*Ordinioha, 2012*).

4.6.12 Presence of risk factors (Use of alcohol and cigarette):
Alcohol is commonly used in the communities, like most other riverine communities in the Niger delta region. A study carried out in a similar community in Bayelsa State showed that more than 90% of the respondents in the community regularly took alcohol, most of them preferring the locally produced drinks; more than a third of respondents were classified as engaged in harmful drinking, while 12.73% had alcohol dependence problem(*Brisibe and Ordinioha, 2011*).

Alcoholic beverages, including imported gin and the locally distilled gin called *kai*-kai or *ogogoro*, are freely available and at all times in the communities. Alcoholic beverages are used during social functions and even in ancestral worship in the communities, just like most other communities in the Niger delta region (*Brisibe and Ordinioha, 2011*). They are freely given and received during marriage ceremonies, and are mandatory component of the gifts given by a groom to family of the bride. Alcohol is also a ubiquitous solvent for several traditional medicines, ranging from pain relief to aphrodisiac.

Cases of alcoholism were said to be low, in spite of the large number of persons that take alcohol in the communities; binge drinking was however said to be high in the communities, especially during festive periods and burial ceremonies, when indigenes converge in the communities, from all works of life.

Smoking is common in the communities, especially amongst young men. About a fifth of adult males in the communities are said to smoke cigarette, but an average smoker takes at most three sticks of cigarette a day. Women in the communities rarely smoke cigarette

4.6.13 Sexual behaviour:
Respondents acknowledged that the sexual behaviour of members of the host are comparable to those of the other indigenous communities of the Bonny Kingdom. The sexual behvaiourcan however encourage the transmission of sexually transmitted infections, including HIV/AIDS. Most adult males and single girls in the communities have multiple sexual partners, and infidelity among the men of the community is very high, even as it remained an abomination for married women of the communities.

The sexual behaviour in the communitieswas said to have deteriorated in the 1990s during the construction phase of the NLNG, as was also noted in the other traditional communities of

Bonny Kingdom. The 2006 HIV/AIDS and Reproductive Health Survey carried out by the Society for Family Health (SFH) on behalf of the Ibani-se HIV/AIDS Initiative (*Ibani-Se, 2006*) showed that:

- 69% of respondents aged 15 – 24 years have had sex, with 79.5% of them having sex in the 12 months preceding the survey.

- Of the total number of respondents that had sex in the 12 months preceding the survey, 62% had sex with their spouse, 43% had sex with their boy/girl friend, while between 5 – 9% had sex with a Commercial Sex Worker or causal friend.

- A total of 11% of sexually active respondents had exchanged sex for financial or other gratifications, including 13.3% of the respondents aged 15 – 24 years.

- 21% of the respondents had sex with multiple partners in the 12 months before the study, including the 5.2% of female respondents, 34.6% of male respondents and 22.2% of the respondents aged 15 – 24 years. This is significantly higher than the national average of 2.7%, the 1.1% in the North West zone and 2.0% in the South west zone.

This statistic however improved with the interventions carried out by the Ibani-se HIV/AIDS Initiative, as reflected in a post-intervention survey carried out in 2011 (*Ibani-se, 2012).* The sexual behavior in the communities of the Bonny Kingdom is currently believed to be similar to that of the other communities of the south-south region of Nigeria. The south-south region however remains the region with one of the worst sexual behaviours, according to the Nigerian National HIV/AIDS and Reproductive Health Surveys *(FMOH, 2004)* (*FMOH, 2013*) as shown below:

- The age at first sexual intercourse in the Niger delta region has increased from 16.7 years in 2003 to 17 years in 2013, but still the lowest in the southern Nigeria.

- The proportion of women in the region who had sex with a non-marital partner in the 12 months before the survey increased from 20.9% in 2003 to 41.4% in 2013, even as the national averages for the periods were 9% and 25.0% respectively.
- In the 2012 survey, 25% of men in the south-south region had sex with a non-marital partner in the 12 months before the study, compared to the national average of 12.2%,
- The proportion of womenaged 15 – 19 years in the region who had sex in exchange for gift or favourdecreased from 15.3% in 2003 to 12.8% in 2012, but the proportion remained significantly worse than the 1.4% in the North-west zone, the 8.4% in the South-east zone, and the national average of 5.3%.
- The proportion of women in the south-south region who had sex with multiple partner in the 12 months before the survey increased from 5.9% in 2003 to 6.4% in 2012, which is significantly higher than the 1.6% recorded in the North-West zone and 7.1% in the South west zone. The national average was 5.7%

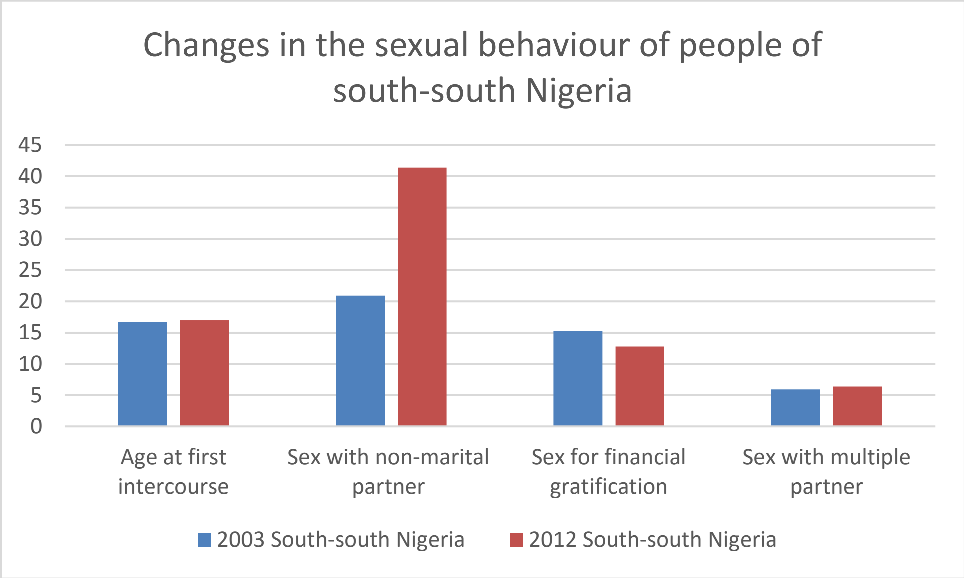


Fig.4.6.13.1: Changes in the sexual behavior of people of the south-south region of Nigeria

4.6.14 Knowledge of HIV/AIDS and Sexually Transmitted Infections

Oil/gas projects in the Niger delta have been found to increase HIV transmission rate, especially with the presence of Commercial Sex Workers close to the project site (*Nwauche and Akani2006*). The Bonny Deep Exploration and Appraisal Well project presents a genuine risk of increase in the prevalence of Sexually Transmitted Infections (STI) and HIV/AIDS in the host communities. Most discussants in the focus group discussions conducted in the communities have heard of HIV/AIDS and STIs; several of them knew someone suspected to have the diseases, or to have died of HIV/AIDS; and more than 90% of the discussants knew the routes of transmission of HIV/AIDS. These are consistent with the findings of the 2006 and 2011 surveys conducted by the Ibani-Se HIV/AIDS Initiative. The 2006 survey showed that:

- 8.5% of the respondents drawn from the general population had heard of STI, including 82.4% of respondents aged 15 – 24 years
- 9% of the respondents had experienced the symptoms of STI in the 12 months preceding the survey, including 9.4% of the female respondents. This is similar to the 8.4% of the respondents drawn from the Commercial Sex Worker population that experienced symptoms of STI in the two months preceding the survey.
- However, only about half (48.8%) of the female respondents who experienced symptoms of STI sought medical treatment, while 28% engaged in self-medication. According to a respondent quoted in the report of the survey: *"Hospital na chalks, chalk them go give you. The native way will cure quickly your body go free"*
- 23% of respondents knew somebody with HIV, or someone that died of the disease; 32% of these respondents knew a friend or close relative that had the disease.
- 8% of respondents could mention the three main methods of preventing HIV, with 48% being able to mention the use of condom. This is much lower than the 35% of

Commercial Sex Workers in the survey who were able to mention correctly the three methods, including the 81% that mentioned the use of condom.

The statistics have however improved with the interventions carried out by the Ibani-Se HIV/AIDS Initiative, as reflected in a post-intervention survey carried out in 2011 (*Ibani-Se, 2012).*

4.6.15 Household Food Security and the nutritional status of under-five children
Household food security in the communities was put at about 65% during the field study, and was said by respondents to be worsening, due to the security situation in the communities and the incessant crude oil spill caused by oil bunkering. The nutritional status of under-five children of the communities was assessed during the field survey, through the anthropometric measurement of under-five children in the communities. The result of the anthropometric measurements is presented in Table 4.6.15.1 and Fig. 4.6.15.1 below.

Table 4.6.15.1: The Anthropometric measurement of under-five children in the communities

Community	No. of children measured	Weight for age (< -2 SD)
South-South Nigeria	**2, 619**	**12.8%**
Oloma, Abalamabie	39	3 (7.79%)
Rivers State average	**217**	**10.0%**
Alasiakiri, Nkpokiri	**31**	**4 (12.90)**
National average	**26, 190**	**28.7%**
Rural areas	**16, 465**	**32.2%**

* The values for South-South Nigeria and the urban areas are according to National Demographic and Health Survey, 2013.

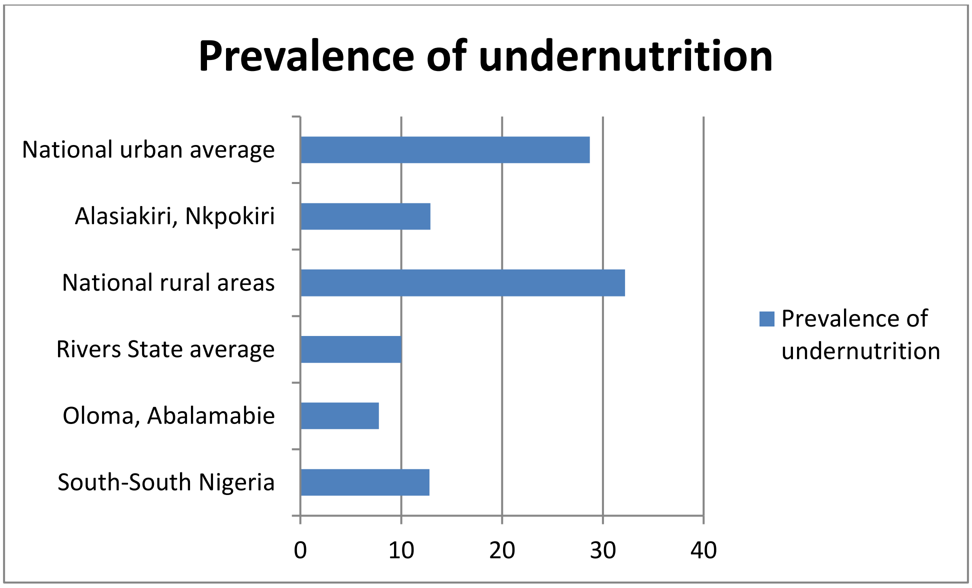


Fig. 4.6.15.1: A comparison of the prevalence of childhood malnutrition

The prevalence of childhood under-nutrition in the bigger host communities of the Bonny Deep Exploration and Appraisal Wells Projects is lower than the prevalence in the whole of Rivers State, whereas the prevalence in the smaller communities are higher than the Rivers State average, but significantly lower than the national averages. The prevalence of malnutrition is however not only a reflection of the diet and socio-economic status of the people, but also points to the environmental conditions in the communities *(Ruel and Menon 2003).*

4.6.16: Morbidity pattern

The morbidity rates in the host communities of the Bonny Deep Exploration and Appraisal Wells Projects, according to respondents from the communities are not different from those of comparable oil bearing communities of the Niger delta region. The reported health problems are similar to those noted in the records of the health facilities that serve the communities; and consistent with the diseases reported in similar Nigerian communities (*NDHS, 2013*). By combining these different sources of data, the top five causes of ill health in the host communities of the Bonny Deep Exploration and Appraisal Wells Projects are as follows:

- Malaria,
- Water-related diseases,
- Respiratory diseases
- Traffic accidents;
- Non-communicable diseases

Malaria

Like most other communities in south-south Nigeria, malaria is holoendemic in the host communities and the other communities in Bonny Island, with transmission occurring throughout the year, with seasonal peaks corresponding to the wet season. Most of the malaria transmissions are carried out by *Anopheles gambiae*and *Anopheles funestus*that are most active between 10pm – 1am, and therefore very susceptible to the use of ITN *(Adjuik et al, 1998).*

The records of the health facilities in Bonny LGA show that malaria is easily the most common cause of morbidity seen in the health facilities, accounting for over half of the cases seen. However, the actual number of malaria cases reported to the health offices of the Bonny Local Government council of the host communities has shown a consistent decrease thanks to increased malaria control efforts of the government and oil/gas companies.

Water-related diseases

The following water-related diseases (*Ordinioha, 2010*) were noted to be common in the host communities: typhoid fever, diarrhoeal diseases and food poisoning; and skin diseases. While typhoid, diarrhoeal diseases and food poisoning are often due to the drinking of water contaminated with faeces, skin diseases can be due to water shortage or irritations that can be caused by chemical irritants (*Ordinioha, 2010*). They are the second most common cause of ill health in the host communities, behind malaria, constituting more than 25% of all the cases seen in the health facilities.

The cases of the water-related diseases recorded in the communities can be attributed to the continuing use of the over-hung (jetty-type) toilet in the communities, and poor access to clean water, caused by the breakdown of the water facilities that serve the communities, which forces members of the communities to drink or bath in faecal and crude oil contaminated river.

Upper respiratory tract infections and asthma

Upper respiratory tract infections and asthma are related to air pollution (*Ordinioha, 2010*). These diseases constituted about 10% of the patients seen in the health facilities that serve the communities, and not different from those in the other communities of the Niger delta region. Respiratory ailments in most Niger delta communities have been linked to indoor air pollution, from the use of firewood, and outdoor air pollution principally caused by gas flaring.

The cases of respiratory ailments recorded in the host communities are more likely to be due to the use of firewood for cooking and in fish drying, which is significant and widespread in the communities.This is especially as theair quality assessment carried out as part of past EIA studies and the present EIA showed that the pollutants emitted by the flares from the nearby flow station are all within the Federal Ministry of Environment acceptable limit.

Traffic accidents

The host communities are part of the island of the Bonny Kingdom. They are therefore accessed mainly through the waterways. Almost all the traffic accidents witnessed in the communities are mainly water traffic accidents, except for Abalamabie community where motorcycle accidents are said to be fairly frequent. These traffic accidents were said to be responsible for less than 1% of the cases seen in the health facilities that serve the communities. The cases seen in the health facilities as a result of water-traffic accidents are mainly cases of near-drowning, and bruises that resulted from the collision of water vehicles.

Water-traffic accidents were said to have increased during the construction phases of the other oil and gas facilities in the communities, and therefore likely to increase with the present study, if adequate preventive measures are not taken. The accidents in the water-ways of the communities mostly occur following the problem created for dug-out canoes, by the turbulence generated by engine-powered vessels.

4.6.17 Prevalence of non-communicable diseases:

The more prevalent non-communicable diseases in the host communities, according to members of the communities are hypertension, diabetes and arthritis. This is consistent with the records of the health facilities that serve the communities, and similar to the findings in comparable communities in the Niger delta region.

The discussions held with members of the communities point to a rising prevalence of the non-communicable diseases, a trend noted in other communities of the Niger delta region in recent years. For instance, the prevalence of hypertension has increased from 27.9% in 2010 in a rural Ogoni community *(Wokoma and Alasia, 2011)*, to 68.9% amongst the traditional chiefs of an oil bearing community in Rivers State (*Ordinioha and Brisibe, 2013*). The rising prevalence of hypertension and other non-communicable diseases has been blamed on several factors including the increasing adoption of western lifestyle (*Omran, 1971*).
However, the incidence of cancer was said to have remained low in the communities, as none of the discussants at the Focus Group Discussions held in the communities knew any member of the communitythat had or died of cancer. This is even as they believed that oil exploration and exploitation activities could cause cancer.

4.6.18 Mortality pattern

The mortality rates of the host communities were said to be comparable to those of the other communities ofBonny Kingdom. Discussants at the Focus Group Discussions held with members of the communities acknowledged that women still die in pregnancy, and duringlabour in their communities, but not as many as in the past. An average of one woman was said to die in the communities for every 800 deliveries, which gives a maternal mortality ratio of 125 per 100, 000 live births. This is more than four times lower than the national average of 576 maternal deaths per 100, 000 live births (*NDHS, 2013*). This decrease in maternal mortality was attributed to the decreasing fertility rate of women of the community, and the speed with which emergencies are recognized and taken to Bonny and Port Harcourt, for appropriate treatment. The causes of the maternal deaths recorded in the community in the last five years, according to verbal autopsy were due to post-partum haemorrhage and eclampsia.

Under-five mortality was said to be high in the past but was acknowledged during the field study to have reduced considerably in recent years, from immunization and better medical care. An average of 5 under-five deaths were said to occur in the communities in a year, giving an under-five mortality rate of about 50 under-five deaths per 1,000 live births. This is five times lower than the average for south-south Nigeria of 109 per 1,000 live births, and significantly better than the national average of 122 per 1000 ((*FMOH, 2013*). The common causes of under-five mortality include: malaria and its complications, especially anaemia and febrile convulsion, gastro-enteritis (diarrhoea and vomiting), acute lower respiratory tract infection; and vaccine preventable diseases, especially measles. These causes are also common in most other communities in south-south Nigeria, but they point to poor environmental conditions, poor health seeking behaviour, and poor standard of health care delivery in the communities (*NDHS, 2013*).

Adult members of the host communities, according to the health workers in the health facilities that serve the community die mostly from the following communicable diseases: malaria; water-related diseases such as typhoid and diarrheal diseases; and respiratory diseases such as pneumonia and bronchitis. Non-communicable diseases such as diabetes and hypertension were also said to be growing causes of death, especially amongst the elderly and middle-aged persons of the community.

4.7 The health system:

4.7.1 Primary Health Centers:

The communities are served by health centers located at Oloma, Abalamabie and Dema-Abbey, and health posts located at Sangama and Issile-Ogono. The other communities are part of the catchment communities of the health centers and health post. The health facilities are spatially located to ensure that members of the host communities are able to access primary health care within the prescribed 30-minutes travel time.

Plate 4.7.1.1: Health centers serving the communitiesAbalamabie (Left), Dema-Abbey (Middle), Oloma (Right)

Nearly all the health facilities that serve the communities were found to be dilapidated and barely functionalduring the field study. None offered round the clock service, as most of the health workers were not resident in the communities, citing security concerns and very low *de facto* population of the communities. This compels members of the communities to travel to Bonny mainland for the treatment of even minor medical ailments.

4.7.2 Traditional Medicine

The use of traditional medicine is common in the host communities of the Bonny Deep Exploration and Appraisal Wells Projects, like most communities inrural Niger delta. The use of herbal drugs is very common, and sometimes preferred to western medicine.

Herbal drugs are used in the communities for various ailments, ranging from fever, aches and pains to aphrodisiac. They are prepared from different herbs, leaves, barks and roots sourced from the forests of the communities, or brought in from other communities, sometimes from sources outside the Niger delta region. The herbal preparations used in the communities are often concoctions of alcohol, prepared and packaged by the herbalist in various containers, and sold in neigbourhood shops, throughout the communities. The herbal preparations are commonly prepared from the following (*Nwauzoma and Dappa, 2013*):

Table 4.7.2.1: Common Medicinal Plants and their Uses in the communities

Common/local names	Botanical Names	Medicinal Uses

Common/local names	Botanical Names	Medicinal Uses
Pawpaw leaves	*Carica papaya*	Treatment of malaria
Alligator pepper plant	*Afromomummelegueta*	Galactogogue, purgative, sore throat, malaria
Lemon orange	*Citrus aurantium*	Abdominal upset, and as a base for other herbs in treatment of malaria
Cashew fruit, leaf and bark	*Anarcadiumoccidentale*	Treatment of diarrhoea and menstrual problems
Mango leaves and bark	*Mangiferaindica*	Treatment of malaria
Banana plant	*Musa spp*	Treatment of fever
Guava tree leaves and bark	*Psidiumguajava*	Treatment of malaria, diarrhoea and menstrual disorders
Siam weed (awolowo)	*Chromolaenaodorata*	Dysentery, malaria, skin disease
Coconut	*Cocosnucifera*	The water is used as poison antidote
African walnut	*Tetracarpidiumconophorum*	Aphrodisiac
Black mangrove	*Avicenniaafricana*	Abortifacient, detergent

4.7.3 Secondary health care facilities

General Hospital Bonny provides secondary health care services to the communities. The hospital is located within a 60 minutes travel time from any of the communities and has most of the relevant manpower and facilities expected of a secondary health care facility. The hospital has the capacity to attend to accident and emergency cases, provides in-patient services, and also runs general out-patient clinics. It also provides surgical care and other medical services, far beyond what is expected in a secondary health care facility. This is because it has at least two specialist doctors, capable of rendering these services.

4.7.4 Tertiary health care

Members of the communities access tertiary health care services in Port Harcourt, especially at Braithwaite Memorial Specialty Hospital, Port Harcourt and the University of Port Harcourt Teaching Hospital. These tertiary health care facilities havemore than two thousand in-patient beds, and provide services in almost all specialties of medicine, including emergency care, orthopedics, medical and surgical care, and at a cost that is affordable to a large proportion of the citizenry.

4.7.5 Medical Emergency Evacuation System:

There is no formal medical emergency evacuation system in the host communities. The Rivers State Emergency Medical Service is not extended to the communities, and the ambulance of the public health facilities in Bonny are not readily available for the conveyance of the sick and injured, for appropriate care. Consequently, members of the communities make their own private arrangement in convening their sick, for appropriate treatment.

Table 4.7.5.1: Table of summary of findings

SN	Indicator	Finding in the host communities	Remark
1	Socio-economic characteristics of communities	Predominantly members of Ibani ethnic group, who are mainly fisher folks, traders and marine transporters	Consistent with the findings in the other communities in the Niger delta region
2	Access to safe drinking water	An average of 25% in the communities, but significantly better in Abalamabie that is supplied with a reticulated water supply from the Bonny Utility Company	This is less than the 69.6% average for south-south Nigeria, the 71.3% average for Rivers State, and the national average for rural communities of 49.2%
3	Quality of drinking water	Physico-chemical properties within regulatory limits	The same as most communities in the Niger delta region
4	Access to unshared sanitation facilities	Access to unshared sanitation facilities in the communities is 35% in the bigger communities of Oloma and Abalamabie, and significantly less at about 10% in the smaller communities of Alasiakiri and Nkpokiri.	Consistent with the 25.8% average for south-south Nigeria, the 28.0% average for Rivers State, and the national average for rural communities of 13.4%
5	Housing condition	The floors of the houses in the bigger communities were noted to have been constructed with cement (75%), mud (3%) and planks (12%); while those in the smaller communities were constructed with cement (9%), mud (11%) and planks (80%).	The housing condition in the communities is therefore different from the national averages for rural communities of 0.4% for planks/wood, 40.1% for cement and 48.6% for earth/mud
6	Diseases vector activities	Presence of Anopheles, Culex and Aedesaegypti mosquitoes, tsetse fly, sand flies and housefly	Consistent with the findings in the other communities in the Niger delta region
7	Source of domestic fuel	More than 80% of respondents in the communities use firewood as their main source of domestic fuel.	Consistent with the national average of 83.3% for rural communities

SN	Indicator	Finding in the host communities	Remark
8	Solid waste management	Indiscriminate dumping of refuse practised by all members of the communities	Consistent with the findings in the other communities in the Niger delta region
9	Use of alcohol beverages	More than 90% of members of the communitiesdrink alcohol, and up to a third of them can be classified as engaged in harmful drinking	Consistent with the findings in the other communities in the Niger delta region
10	Prevalence of smoking	About a fifth of adult males in the communities are said to smoke cigarette, but an average of three sticks of cigarette a day. Women in the communities rarely smoke cigarette	Consistent with the findings in the other communities in the Niger delta region
11	Sexual behaviour	Premarital sex and marital infidelity are common in the community	Consistent with the findings in the other communities in the Niger delta region
12	Knowledge of HIV/AIDS	Most members of the communities have heard of HIV/AIDS and STIs; several of them knew someone suspected to have the diseases, or to have died of HIV/AIDS; and more than 90% of the discussants knew the routes of transmission of HIV/AIDS.	Better than the average for the Niger delta region
13	Prevalence of HIV/AIDS	The prevalence rate for the whole of Bonny Kingdom was 28.92% in 2003, the highest in Rivers State, but decreased to 8.3% in 2010, thanks to the control effort of the Ibani-Se HIV/AIDS Initiative	The prevalence for Rivers State was 6.6% in 2003 and 6.0% in 2010
14	Household food security	65% and worsening, due to the security situation in the communities and the incessant crude oil spill caused by oil bunkering	Worse than the average for Rivers State
15	Prevalence of Childhood undernutrition	7.79% in the bigger communities and 12.9% in the smaller communities	Better than the Rivers State average of 10%, but the situation in the communities is deteriorating on a daily basis
16	Incidence of malaria	Malaria is responsible for over half of the cases seen in health facilities in the communities.	Consistent with the findings in the other communities in the Niger delta region

SN	Indicator	Finding in the host communities	Remark
17	Incidence of water-related diseases,	Water-related diseases such as typhoid fever, diarrhoeal diseases, food poisoning and skin diseases are responsible for 25% of all the cases seen in the health facilities.	Consistent with the findings in the other communities in the Niger delta region
18	Incidence of respiratory diseases	Responsible for about 10% of the patients seen in the health facilities that serve the communities	Consistent with the findings in the other communities in the Niger delta region
19	Incidence of traffic accidents	Traffic (road and water) accidents are responsible for about 1% of the cases seen in the health facilities that serve the communities.	Consistent with the findings in the other communities in the Niger delta region
20	Prevalence of non-communicable diseases (Hypertension)	Rising prevalence of hypertension, diabetes, arthritis and other non-communicable diseases	Consistent with the findings in the other communities in the Niger delta region
21	Prevalence of non-communicable diseases (cancer)	Rare	Consistent with the findings in the other communities in the Niger delta region
22	Under-five mortality rate	About 50 under-five deaths per 1,000 live births.	This is five times lower than the average for south-south Nigeria of 109 per 1,000 live births, and significantly better than the national average of 122 per 1000
23	Maternal mortality	Maternal mortality ratio estimated at 125 per 100, 000 live births.	This is more than four times lower than the national average of 576 maternal deaths per 100, 000 live births
24	Access to primary health care	The communities are served by health centers located at Oloma, Abalamabie and Dema-Abbey, and health posts located at Sangama and Issile-Ogono	Better than the Rivers State average
25	Patronage of traditional medicine	Fairly high	Consistent with the findings in the other communities in the Niger delta region
26	Availability of emergency medical evacuation	Not available	Consistent with the findings in the other communities in the Niger delta region

CHAPTER FIVE
POTENTIAL AND ASSOCIATED ENVIRONMENTAL IMPACTS

5.1: Introduction

A number of methods exist for evaluating potential impacts of any project on the environment. These include the Overlays techniques (McHarg, 1968), Leopold matrix (Leopold *et al*., 1971), Battelle Environmental Evaluation System (Dee *et al*., 1973), and Peterson Matrix (Peterson *et al*., 1974) and ISO 14001. The method employed in this EIA study is the ISO 14001 method. The ISO 14001 method is simple to apply and provides a high level of detail, and also relies on limited data. The following considerations were adopted in this impact assessment:

- Comprehensiveness - ability to handle all possible range of elements and combinations thereof;
- Selectivity - capability to identify early in the procedure those aspects that are important;
- Mutual exclusiveness - should be able to examine every component of an impact from different perspectives;
- Confidence limits - is the method able to ascertain and isolate uncertainties?
- Objectivity - should allow no bias either from the assessor or project initiator;
- Interactions - should be able to examine both sides of a coin and provide feedback.

5.2: Uncertainties

In our efforts to produce a credible EIA report, we are constantly assailed by the problem of uncertainties. Any Impact Assessment contains five kinds of uncertainties mainly due to:

- The natural variability of the environment, particularly the occurrence of rare events such as floods, unpredictable climate change and natural disasters;
- Inadequate understanding of the behaviour of the environment;
- Inadequate time-tested data for the area being assessed;
- Socio-economic uncertainties (inadequate data for prediction of human response to economic crises). There is always uncertainty in predicting the way a community will respond to the activities of oil companies in their domain.
- Health uncertainties such as the problem of determining the direct causes and effects of diseases, and that of ascertaining the disease vectors that are brought into the project environment by itinerant applicants.

In this study, we have endeavored to use available cost-effective techniques and review of published data to mitigate these uncertainties where possible.

5.3: Impact screening

Comprehensive checklists of developmental activities and possible environmental/health/social impacts were produced and based on experience and reviews of literature and Impact Assessment reports on similar projects; these lists were tailored to specific project components and associated historical effects.

Basis for Screening

The rationale for assessing the likely impacts of the proposed project derives from the following considerations:

- Knowledge of the project activities, equipment types, material inputs/outputs and operational procedures;
- An initial assessment of the likely key environmental considerations;
- Findings of other EIA studies on similar projects and other literature findings on the primary project activities;
- Comparison with Environmental Guidelines and Standards for Petroleum Industries in Nigeria, 2002 and FMEnv Procedural guidelines;
- Series of expert group discussions.

The criteria applied to the screening of various activities are:

- Magnitude - probable level of severity.
- Prevalence - likely extent of the impact.
- Duration and frequency - likely duration - long-term, short-term or intermittent.
- Risks - probability of serious impacts.
- Importance - value attached to the undisturbed project environment.

In assessing potential impacts, cognizance was taken of the inherent judgmental subjectivity involved; consequently, the analytical results of field studies, relevant literature reviews and observations of existing facilities and practices were used to assess the level of potential impacts of the proposed project.

5.4: Determination of project activities

This involves the determination of individual project activities to be undertaken in the respective phases as described in Chapter 3. A list of activities which interact with the biophysical, social and health environments either due to their nature or due to timing is summarized in Table 5.1.

Table 5.1: Phases of project development activities used in Interaction Matrix

S/N	Project phase	Project activities
1	Pre-mobilization	Consultation, Land acquisition and Compensation
2	Mobilization	Movement of equipment and personnel, Rig movement
3	Construction	Route & location clearing (site preparation), Dredging & Sand filling, Pilling, Concrete and asphalt works, Excavation, Backfilling, Pipeline coating, Stringing & welding; NDT and cathodic protection, Base camp activities, Drilling and well hook-up, Well & pipeline testing, Cathodic Protection, Commissioning & Handover

S/N	Project phase	Project activities
4	Demobilization	
5	Operation	Well work-over, Gas production, Pipeline maintenance & replacement
6	Decommissioning and abandonment	Flushing of pipelines, Vacuum drying of pipeline, Capping of pipeline, Removal of surface installations, Plugging of wells, Site restoration, Return of land to owner(s)

5.5: Determination of sensitivities

The determination of sensitivities that characterize the biophysical and social environment was carried out by the environmental consultant teams (biophysical, social and health) using their knowledge of the integrated baseline data. Table 5.2 presents the list of environmental sensitivities.

Table 5.2: Sensitivities describing Biophysical, Social and Health Environments of Bonny field

S/N	Environmental components	Environmental sensitivities
1	Biophysical Environment`	Air quality, Level of noise and vibrations, Surface water quality, Groundwater quality, Soil and sediment quality, Access to farming and hunting grounds, biodiversity (vegetation and wildlife)
2	Socio-economic Environment	Access to ancestral and culturally significant sites, Safeguarding traditional occupations, Cost of living/Inflation, Opportunities for economic enhancement, Skill Acquisition, Boom and bust economy, Access to sanitation and waste management, Balance in gender, Lifestyle (use of alcohol, drugs, physical activities etc.), Morals and family values, Current levels of youth restiveness, Current level of workers safety, Current level of road traffic accidents
3	Health Environment	Access to and quality of clean drinking water, Exposure to nuisance (dust, noise etc.), Level of disease & disease vectors (including STDs), Access to primary health care, Access to traditional medicine

Interaction Matrix

Interactions between project activities and sensitivities were determined by a group of experts using their background knowledge of the project and its biophysical, social and health environment. Each interaction was discussed followed by an assessment as to whether the effect of the interaction was expected to be positive or negative. The identified impacts were further listed according to the phases of the project in which they are likely to occur in order to identify those impacts which cut across different phases of the project activities. The interaction matrix is presented in Table 5.3. In the interaction matrix, the following codes are used:

(+) = likely positive effect of the project;
(-) = likely negative effect/interaction of the project,

(+/-) = when the interaction can both be positive and/or negative.

Table 5.3: Interaction Matrix

Project Phase	Project Activity	Description of Impact	Nature of Impact
Pre-mobilization	Consultation, Land acquisition and Compensation	Increase in project awareness	(-)
		Anticipated Loss of land associated resources	(-)
		Financial enhancement	(+/-)
		Third party agitation	(-)
Mobilization	Movement of equipment and personnel, Rig movement	Loss of livelihood	(-)
		Increase in road traffic, potential for accidents and injuries	(-)
		Damage to road infrastructure	(-)
		Influx of people causing Pressure on health and other Infrastructure	(-)
		Increase in sexually transmitted disease and other communicable diseases	(-)
		Reduction in air quality	(-)
		Loss of vegetation and wildlife	(-)
		Habitat fragmentation	(-)
		Loss of aquatic species (Fisheries, Planktons and benthic fauna)	(-)
		Distortion of aquatic environment (physical components)	(-)
		Increase in noise and vibration	(-)
		Increase in refined hydrocarbon contents of soil and vegetation	(-)
		Increase in crime rate	(-)
		Loss of cultural/heritage sites	(-)
		Contamination of groundwater	(-)
		Soil compaction	(-)
		Increase in waste	(-)
Construction	**Wells/locations/pipelines** Route & location clearing, Pipeline crossing, Excavation Backfilling Pipeline coating	Increase in respiratory tract infection	(-)
		Land take	(-)
		Increase in population due to influx of persons	(-)
		Increase in social vices (Alcohol and drug abuse, CSWs)	(-)
		Crime and insecurity (Kidnapping, Hostage-taking, armed robbery, Militancy)	(-)

Project Phase	Project Activity	Description of Impact	Nature of Impact
	Stringing & welding; NDT and cathodic protection Base camp activities	Injury/fatality of workforce and/or third party	(-)
		Road traffic disruption	(-)
		Increase in volume of wastes	(-)
		Increase in employment/business opportunities	(-)
		Shift from traditional occupations	(-)
		Inflation	(-)
		Gender imbalance	(-)
		Potential for skills acquisition	(+)
		Pressure on existing infrastructure and services (Water, Electricity, Recreational facilities, Health facilities, Roads and others)	(-)
		Increase in communicable diseases, STIs HIV/AIDS	(-)
		Change in topography	(-)
		Change in hydrology (groundwater)	(-)
		Surface water pollution/distortion	(-)
		Soil pollution	(-)
		Loss of biodiversity and Distortion of food chain	(-)
		Impairment/Loss of aquatic life	(-)
		Increase in disease vectors	(-)
		Blockage of natural water courses	(-)
		Increase in road traffic/ potential for accidents and injuries	(-)
		Decrease in nutritional status	(-)
		Erosion	(-)
		Loss of indigenous languages	(-)
		Loss of fish breeding sites and migratory routes	(-)
		Noise and vibration	(-)
		Reduction in air quality	(-)
		Opportunity for direct and indirect Employment	(+)
		Opportunity for wealth creation	(+)
		Opportunity for Corporate Social Responsibility	(+)

Project Phase	Project Activity	Description of Impact	Nature of Impact
		Exposure to radioactive materials	(-)
		Third party agitation	(-)
		Potential attack from wild/predatory animals (Snakes, Scorpions)	(-)
		Increase in exposure to trans border diseases (Zika virus, Ebola, Birdflu, SARS), Antimicrobial resistant bacteria	(-)
		Crime and insecurity (Kidnapping, Hostage-taking, armed robbery, Militancy)	(-)
		Access to hunting grounds	(-)
		Potential reduction in household water quality and contamination of potable water	(-)
	Drilling and well hook-up	Increase in noise & vibration nuisance	(-)
		Increase in light nuisance	(-)
		Generation of drilling waste	(-)
		Contamination of environment (soils/surface and groundwater)	(-)
		Work related injury/fatality of workforce	(-)
		Non work related injury/fatality of workforce	(-)
		Increase in explosion potential (Well blowout)	(-)
		Increase in diseases STIs, HIV/AIDS	(-)
		Increase in endemic diseases	(-)
		Emergent Infectious diseases resulting from displacement of disease vectors (rodents and monkeys)	(-)
		Loss of biodiversity	(-)
		Potential for development of infrastructures and economic enhancement	(+)
		Increase in road traffic volume & accident potential/injuries	(-)
		Tank leaks	(-)
		Influx of insect pests	(-)
		Opportunity for direct and indirect Employment (Unskilled labour)	(+)
		Opportunity for wealth creation	(+)

Project Phase	Project Activity	Description of Impact	Nature of Impact
		Opportunity for Corporate Social Responsibility	(+)
		Gender imbalance	(-)
		Potential for skills acquisition	(+)
		Pressure on existing infrastructure and services (Water, Electricity, Recreational facilities, Health facilities, Roads and others)	(-)
		Third party agitation	(-)
		Attack from wild/predatory animals (Snakes, Scorpions)	(-)
		Exposure to radioactive materials	(-)
		Crime and insecurity (Kidnapping, Hostage-taking, armed robbery, Militancy)	(-)
		Generation of waste (Pigging waste, domestic waste, metal scraps, plastics)	(-)
		Contamination of environment (soils/surface and groundwater)	(-)
		Work related injury/fatality of workforce	(-)
Demobilization		Increase in road traffic, potential for accidents and injuries	(-)
		Damage to road infrastructure	(-)
		Reduction in air quality	(-)
		Increase in noise and vibration	(-)
		Increase in refined hydrocarbon contents of soil and vegetation	(-)
		Increase in crime rate	(-)
		Contamination of groundwater	(-)
		Soil compaction	(-)
		Waste generation (Scrap metals, Woods, Food waste)	(-)
		Opportunity for contracting	(+)
		Opportunity for direct and indirect Employment (Unskilled labour)	(+)
		Loss of Employment (local labour)	(-)
		Third party agitation	(-)

Project Phase	Project Activity	Description of Impact	Nature of Impact
		Crime and insecurity (Kidnapping, Hostage-taking, armed robbery, Militancy)	(-)
		Increase in RTIs due to dust particles	(-)
		Social dislocation	(-)
		Increased exposure to carcinogenic substances	(-)
		Alcohol and drug abuse	(-)
Decommissioning and abandonment	Removal of surface installations Plugging of wells Site restoration Return of land to owner(s)	Increase in potential for soil and water contamination	(-)
		Increase in litigation potential	(-)
		Loss of revenue for Govt. & SPDC	(-)
		Loss of job by community surveillance team	(-)
		Increase in usable land resource to the community	(-)
		Opportunity for contracting	(+)
		Opportunity for direct and indirect Employment (Unskilled labour)	(+)
		Third party agitation	(-)
		Crime and insecurity (Kidnapping, Hostage-taking, armed robbery, Militancy) and other social vices	(-)
		Waste generation (Scrap metals, Woods, Food waste)	(-)
		Increased exposure to carcinogenic substances	(-)
		Alcohol and drug abuse	(-)
		Prevalence of STIs HIV/AIDS	(-)

5.6: Impact Qualification

The identified impacts of the project were qualified based on the following four criteria:

- Positive or negative
- Short-term or long-term
- Reversible or irreversible
- Direct or indirect

Negative impacts are those that adversely affect the biophysical, health and social environments while positive impacts are those, which enhance the quality of the environment. For this study, short term means a period of time less than three months while any period greater than three months is considered long term. By reversible/irreversible, is meant whether the environment can either revert to previous conditions or remain permanent when the activity causing the impact is terminated.

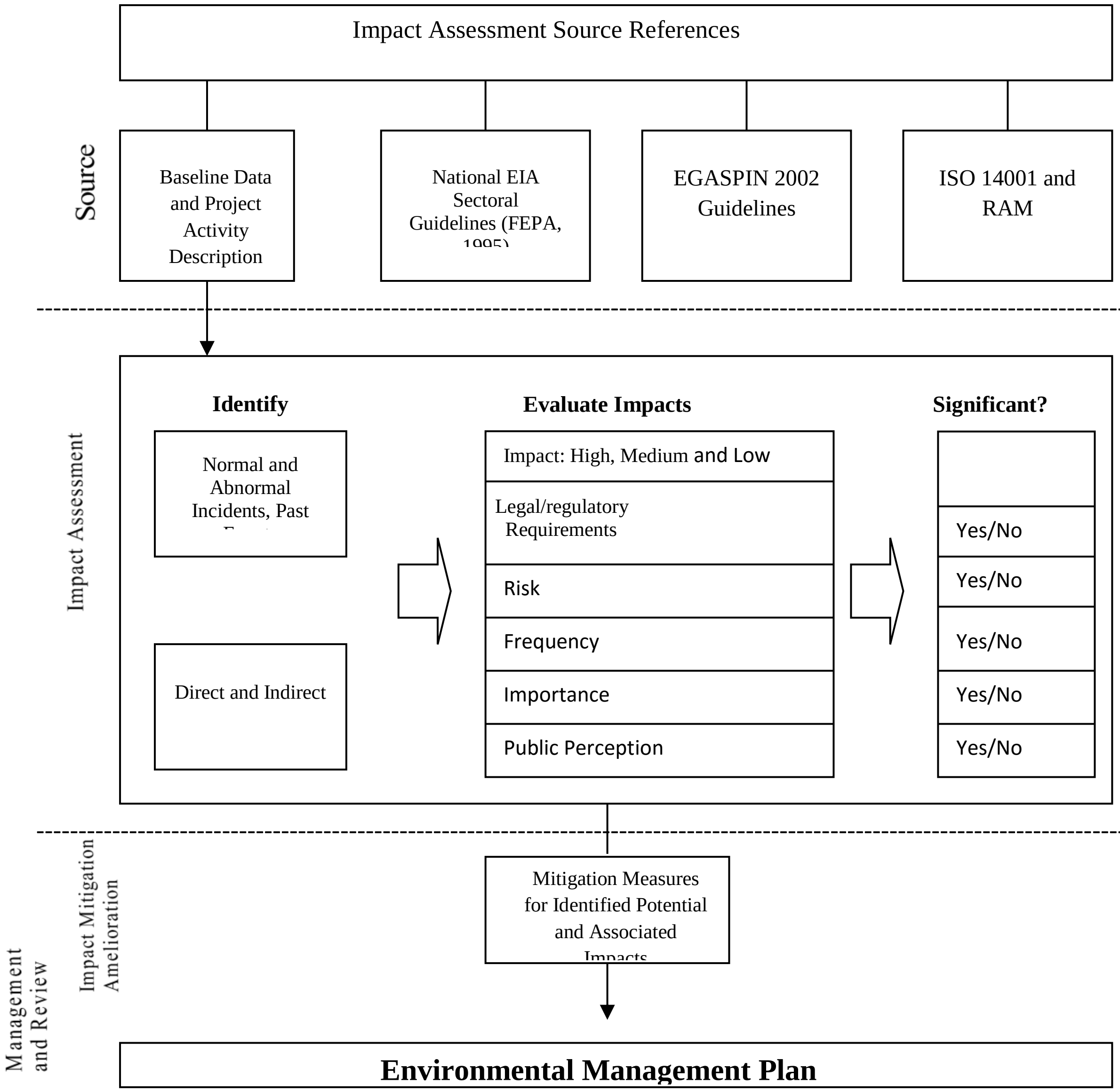


Fig. 5.1: Approach to Impact Assessment

5.7: Risk Assessment for Environmental Consequences

Risk (R) – What is risk/hazard rating based on Risk Assessment Matrix (RAM) (Table 5.3 and Table 5.4). The risks/hazards associated with the project were rated as follows:

1= Low risk

3 = Medium/intermediate risk

5 = High risk

The severity of risks/hazards was further defined as in Table 5.3 and Table 5.4.

Table 5.4: Risk Assessment Matrix

CONSEQUENCES					INCREASING LIKELIHOOD				
					A	B	C	D	E
Severity	People	Assets	Environment	Reputation	Never heard of in the industry	Heard of in the industry	Has happened in the Organization or more than once per year in the industry	Has happened at the location or more than once per year in the organization	Has happened more than once per year at the Location
0	No injury or health effect	No damage	No effect	No impact					
1	Slight injury or health	Slight damage	Slight effect	Slight impact		Low			
2	Minor Injury or health	Minor damage	Minor effect	Minor impact		Risk			
3	Major Injury or health	Moderate damage	Moderate effect	Moderate impact			Medium		
4	PTD or up to 3 fatalities	Major damage	Major effect	Major impact			Risk	High	
5	More than 3 fatalities	Massive damage	Massive effect	Massive impact				Risk	

Table 5.5: Further definition of consequence – severity rating for risk matrix

Severity	Potential Impact	Definition
0	Zero effect	No environmental damage. No change in the environment. No financial consequences.
1	Slight effect	Local environmental damage within the fence and within systems. Negligible financial consequences.
2	Minor effect	Contamination, damage sufficiently large to affect the environment. Single exceedance of statutory or prescribed criteria, single complaint. No permanent effect on the environment
3	Localized effect	Limited loss of discharges of known toxicity. Repeated exceedance of statutory or prescribed limit. Affecting neighborhood
4	Major effect	Severe environmental damage. The company is required to take extensive measures to restore the contaminated environment to its original state. Extended exceedance of statutory or prescribed limits
5	Massive effect	Persistent severe environmental damage or severe nuisance extending over a large area. In terms of commercial or recreational use or nature conservancy, a major economic loss for the company. Constant high exceedance of statutory or prescribed limits.

Source: SIEP (1996)

5.8: Impact Assessment Methodology

Stage one: Classification

The first stage involved in the assessment of impact is impact classification. Impacts are classified as follows:

- Adverse (-) or Beneficial (+) in nature,
- Short term < 3 months (S) or Long term > 3 months (L), and
- Reversible (R) or Irreversible (I).

Adverse impacts are those, which impact negatively on the environmental components while beneficial impacts are those that enhance the quality of the environment. For this study, short term means a period of time less than three months while any period greater than three months is considered long term. By reversible/irreversible, is meant whether the environment can either revert to previous conditions or remain permanent once the activity causing the impact is terminated.

Stage two: Significance

The second stage involves evaluation to determine whether or not the impact is significant. The criteria and weighting scale employed in evaluation are as follows:

- Legal/regulatory requirements (L);
- Risk factor (R);
- Frequency of occurrence of impact (F);
- Importance of impact on an affected environmental component (I); and
- Public perception/interest (P).

The quantification scale of 0, 1, 3 and 5 was used. This is a modification of the arbitrary scale proposed by Vesilind, *et al*. (1994). The ratings are as described below and are adapted from The International Organization for Standardization (ISO, 14001) – Environmental Management System Approach.

- **Legal/Regulatory Requirements (L) – Is there a legal/regulatory requirement or a permit required?**
  - 0 = There is no legal/regulatory requirement
  - 3 = There is legal/regulatory requirement
  - 5 = There is a legal/regulatory requirement and permit required
- **Risk Factor (R) – What is the risk/hazard rating based on the Risk Assessment Matrix?**
  - 1 = Low risk
  - 3 = Intermediate risk
  - 5 = High risk

- **Frequency of Impact (F) – What is the frequency rating of impact based on the Risk Assessment Matrix?**
  - 1 = Low frequency (rare)
  - 3 = Intermediate frequency (likely)
  - 5 = High frequency (very likely)

- **Public interest/perception (P) – What is the rating of public perception and interest in proposed project and impacts based on consultation with stakeholders?**
  - 1 = Low interest/perception
  - 3 = Intermediate interest/perception
  - 5 = High interest/perception

- **Importance of affected environmental components and impacts (I) – What is the rating of importance based on consensus of opinions?**
  - 1 = Low
  - 3 = Medium
  - 5 = High

This approach combines the following factors in assessing the overall impact rating of the project on the environment:

- The sensitivity/vulnerability of the ecosystem components;
- The productivity evaluation/rating of the ecosystem components;
- Knowledge of the possible interactions between the proposed project and the environment;
- Envisaged sustainability of the project environment;
- The economic value of the proposed project activities; and
- Projected duration of the impact of each project activity on various environmental components.

The frequency of occurrence of each impact was determined from historical records while the importance of affected environmental component was determined through consultation and consensus of opinions. The perception of the communities and the general public on each potential impact and its effects as reported in the various reports reviewed were determined through consultation with the communities and consensus of opinions of environmental professionals. The overall impact rating is determined as shown in Table 5.6. The potential and associated impacts of the project are presented in Table 5.7.

Table 5.6: Impact Value and Rating

Impact value	Cut off values	Impact Rating
L+R+F+I+P	<8	Low
L+R+F+I+P	≥8 but <15	Medium
L+R+F+I+P	≥15	High
F + I	≥6	
P	= 5	
Positive		Positive

Table 5.7: Potential Impacts Identification, Qualification, Quantification and Rating

Project phase	Project activity	Description of impact	IMPACT QUALIFICATION									IMPACT QUANTIFICATION							
			ADVERSE	BENEFICIAL	DIRECT	INDIRECT	SHORT TERM (<3 months)	LONG TERM (>3 Months)	REVERSIBLE	IRREVERSIBLE	LOCAL OR WIDESPREAD	LEGAL	RISK FACTOR	FREQUENCY	IMPORTANCE	PUBLIC INTEREST	TOTAL	F + I	IMPACT RATING
Pre-mobilization	• Consultation, • Land acquisition and • Compensation, Resolution of legacy issues	Increase in project awareness	X	X	X	X	X		X		L	3	1	5	5	5	19	10	HIGH
		Anticipated Loss of land associated resources	X		X			X	X		L	3	3	3	5	5	19	8	HIGH
		Financial enhancement		X	X	X	X		X		L	-	-	-	-	-	-	-	P
		Third party agitation	X		X		X	X	X		L/W	0	5	5	5	5	20	10	HIGH
Mobilization	• Movement of equipment and personnel, • Rig movement	Loss of livelihood	X		X		X	X	X		L	0	3	3	5	3	14	8	HIGH
		Increase in marine traffic, potential for accidents and	X		X		X		X	X	L/W	3	3	3	3	5	17	6	HIGH

		injuries																	
		Influx of people causing Pressure on health and other Infrastructure	X		X		X	X	X		L	0	3	3	3	5	14	6	HIGH
		Increase in sexually transmitted disease and other communicable diseases	X		X		X	X	X	X	L	0	3	3	3	3	12	6	HIGH
		Reduction in air quality	X		X		X	X	X		L/ W	3	5	5	5	5	23	10	HIGH
		Loss of vegetation and wildlife	X		X		X	X	X		L	0	1	3	3	3	10	6	HIGH
		Habitat fragmentation	X		X		X	X	X	X	L	0	1	3	3	3	10	6	HIGH
		Loss of aquatic species (Fisheries, Planktons and benthic fauna)	X		X		X		X		L	3	3	3	3	3	15	6	HIGH
		Increase in noise and vibration	X		X			X	X		L	3	3	3	3	3	15	6	HIGH
		Increase in refined hydrocarbon contents of soil	X		X			X	X		L/ W	3	3	3	3	1	13	6	HIGH

		and vegetation																	
		Increase in crime rate	X		X		X	X		X	L	0	3	1	3	3	10	4	MEDIUM
		Loss of cultural/heritage sites	X		X			X	X	X	L	3	3	1	3	3	13	4	MEDIUM
		Contamination of surface water	X		X		X		X		L	3	3	1	5	3	15	6	HIGH
		Soil compaction	X		X			X		X	L	0	1	1	3	1	6	4	LOW
		Increase in waste	X		X			X	X		L	3	3	3	3	3	15	6	HIGH
Construction	**Wells/locations** Route & location clearing • Dredging, • Pilling, • Concrete and asphalt works, • Base camp activities	Increase in respiratory tract infection	X		X		X		X		L	3	3	5	5	5	21	10	HIGH
		Land take	X		X		X		X		L	3	1	1	3	3	11	4	MEDIUM
		Increase in population due to influx of persons	X	X	X	X	X	X	X		L	0	3	5	3	3	14	8	HIGH
		Increase in social vices (Alcohol and drug abuse, CSWs)	X		X		X		X		L	0	5	3	5	3	16	8	HIGH
		Crime and insecurity (Kidnapping, Hostage-taking, armed robbery,	X		X		X		X		L	0	5	5	5	5	20	10	HIGH

		Militancy)																	
		Injury/fatality of workforce and/or third party	X		X		X	X	X	X	L	3	5	3	3	3	17	6	HIGH
		Marine traffic disruption	X		X		X	X	X		L	0	3	5	5	5	18	10	HIGH
		Increase in volume of wastes	X		X		X	X	X		L	3	3	5	5	5	21	10	HIGH
		Increase in employment/business opportunities		X	X	X	X	X	X		L/W	-	-	-	-	-	-	-	P
		Shift from traditional occupations	X		X		X		X		L	0	3	5	3	3	14	8	HIGH
		Inflation	X		X		X	X	X		L	0	3	5	3	3	14	8	HIGH
		Gender imbalance	X		X		X	X	X		L	0	1	5	3	3	12	8	HIGH
		Potential for skills acquisition		X	X	X	X	X		X	L/W	-	-	-	-	-	-	-	P
		Pressure on existing infrastructure and services (Water, Electricity, Recreational facilities, Health facilities, Roads	X		X		X		X		L	0	3	5	5	3	16	10	HIGH

		and others)																	
		Increase in communicable diseases, STIs HIV/AIDS	X		X			X	X	X	L/ W	0	5	5	5	5	20	10	HIGH
		Change in hydrology (groundwater)	X		X		X	X	X	X	L	3	3	1	3	3	13	4	MEDIU M
		Surface water pollution/distortion (increase in turbidity and Total Suspended Solids)	X		X		X		X		L	3	5	5	5	5	23	10	HIGH
		Soil pollution	X		X		X	X	X		L	3	3	3	3	3	15	6	HIGH
		Loss of biodiversity and Distortion of food chain (Economic trees)	X		X		X	X	X	X	L	3	3	3	3	3	15	6	HIGH
		Impairment/Loss of aquatic life (Loss of juvenile fishes due to gill damage from silt particles)	X		X		X	X	X		L	3	3	3	5	5	19	8	HIGH
		Increase in disease vectors	X		X			X	X		L	0	5	3	3	3	14	6	HIGH

		Food insecurity	x		x		x	x	x	X	L	0	3	5	5	3	16	10	HIGH
		Erosion	X		X	X	X	X	X		L	0	5	5	5	5	20	10	HIGH
		Loss of indigenous languages	X		X	X		X		X	L/ W	0	1	1	3	1	6	4	LOW
		Loss of fish breeding sites and migratory routes	X		X		X		X		L	0	3	3	3	3	12	6	HIGH
		Noise and vibration	X		X			X	X		L	3	3	5	3	3	17	8	HIGH
		Reduction in air quality	X		X		X		X		L	3	3	3	3	5	17	6	HIGH
		Opportunity for direct and indirect Employment		X	X	X	X	X	X		L/ W	-	-	-	-	-	-	-	P
		Opportunity for wealth creation		X	X	X	X	X	X		L/ W	-	-	-	-	-	-	-	P
		Opportunity for Corporate Social Responsibility		X	X	X	X	X	X	X	L/ W	-	-	-	-	-	-	-	P
		Exposure to radioactive materials	X		X	X	X		X		L	3	5	3	3	3	17	6	HIGH
		Third party agitation	X		X		X	X	X		L/ W	0	5	5	5	3	18	10	HIGH

		Potential attack from wild/predatory animals (Snakes, Scorpions)	X		X		X		X	X	L	0	3	1	5	3	12	6	HIGH
		Increase in exposure to transborder diseases (Zika virus, Ebola, Birdflu, SARS), Antimicrobial resistant bacteria	X		X	X	X	X	X	X	L/ W	0	3	3	5	5	16	8	HIGH
		Crime and insecurity (Kidnapping, Hostage-taking, armed robbery, Militancy)	X		X		X		X	X	L	0	5	3	5	5	18	8	HIGH
		Access to hunting grounds	X		X	X	X	X	X	X	L	0	3	1	3	1	8	4	MEDIU M
		Potential reduction in household water quality and contamination of potable water	X		X		X	X	X		L	3	5	3	5	3	19	8	HIGH
		Temporary disruption of local fishing/harvestin	X		X	X	X	X	X	X	L	0	3	1	3	1	8	4	MEDIU M

		g activities.																	
		Acidification of the soil and surface water because of deposition of dredge spoils on the banks of the river	X		X	X	X	X	X	X	L	3	3	1	3	1	11	4	MEDIU M
		Spoil disposal will smother epifauna and impair surface drainage especially in wetland areas	X		X	X	X	X	X	X	L	0	3	1	3	1	8	4	MEDIU M
		Disaggregation of benthic habitats and loss of benthic organisms.	X		X	X	X	X	X	X	L	0	3	1	3	1	8	4	MEDIU M
		Disturbance of riverbed topography and re-suspension of fine sediments and bottom materials	X		X	X	X	X	X	X	L	0	3	1	3	1	8	4	MEDIU M
		Disturbance of riverbed topography	X		X	X	X	X	X	X	L	0	3	1	3	1	8	4	MEDIU M

	Wells Drilling and completion	Increase in noise & vibration nuisance	X		X		X	X	X	X	L	3	3	3	5	5	19	8	HIGH
		Increase in light nuisance	X		X	X	X		X		L	0	3	3	3	1	10	6	HIGH
		Generation of drilling waste	X		X		X		X		L	5	5	5	5	5	25	10	HIGH
		Contamination of environment (soils/surface and groundwater)	X		X	X	X		X		L	3	3	3	3	3	15	6	HIGH
		Work related injury/fatality of workforce	X		X		X	X	X	X	L	3	3	3	5	5	19	8	HIGH
		Non work related injury/fatality of workforce	X		X		X	X	X	X	L	0	3	3	3	5	14	6	HIGH
		Increase in explosion potential (Well blowout)	X		X	X	X		X	X	W	0	5	1	5	5	16	6	HIGH
		Increase in diseases STIs, HIV/AIDS	X		X		X	X	X	X	L	0	5	5	5	5	20	10	HIGH
		Increase in endemic diseases	X		X		X	X	X	X	L/ W	0	5	3	5	5	18	8	HIGH

		Emergent Infectious diseases resulting from displacement of disease vectors (rodents and monkeys)	X		X	X	X	X	X	X	L/ W	0	3	3	5	5	16	8	HIGH
		Loss of biodiversity	X		X		X	X	X	X	L	0	3	3	3	3	12	6	HIGH
		Potential for development of infrastructures and economic enhancement		X	X		X	X		X	L	-	-	-	-	-	-	-	P
		Increase marine traffic volume & accident potential/injuries	X		X		X	X	X	X	L	0	5	3	3	3	14	6	HIGH
		Influx of insect pests	X		X	X	X	X	X	X	L	0	5	5	5	5	20	10	HIGH
		Opportunity for direct and indirect Employment (Unskilled labour)		X	X		X		X		L	-	-	-	-	-	-	-	P
		Opportunity for wealth creation		X	X	X	X	X	X		L	-	-	-	-	-	-	-	P
		Opportunity for Corporate Social		X	X	X	X	X	X	X	L	-	-	-	-	-	-	-	P

		Responsibility																	
		Gender imbalance	X		X		X	X	X		L	0	1	5	3	3	12	8	HIGH
		Potential for skills acquisition		X	X	X	X	X	X		L	-	-	-	-	-	-	-	P
		Pressure on existing infrastructure and services (Water, Electricity, Recreational facilities, Health facilities, Roads and others)	X		X		X		X		L	0	3	5	5	3	16	10	HIGH
		Third party agitation	X		X		X	X	X		L/ W	0	5	5	5	3	18	10	HIGH
		Attack from wild/predatory animals (Snakes, Scorpions)	X		X		X	X	X		L	0	1	3	3	3	10	6	HIGH
		Exposure to radioactive materials	X		X	X	X		X		L	3	5	3	3	3	17	6	HIGH
		Crime and insecurity (Kidnapping, Hostage-taking, armed robbery, Militancy)	X		X		X		X		L	0	5	5	5	5	20	10	HIGH

		Discharge of untreated test water into the receiving environment	X		X	X	X	X	X	X	L	0	3	1	3	1	8	4	MEDIUM
	Commissioning & Handover	Increase in Business opportunities		X	X	X	X	X	X		L/W	-	-	-	-	-	-	-	P
		Gas flaring from well tests	X		X		X		X		L	3	5	5	5	5	23	10	HIGH
		Increase in noise & vibration nuisance	X		X		X	X	X	X	L	3	3	3	5	5	19	8	HIGH
		Generation of waste (Pigging waste, domestic waste, metal scraps, plastics)	X		X			X	X		L	3	3	3	3	3	15	6	HIGH
		Contamination of environment (soils/surface and groundwater)	X		X	X	X		X		L	3	3	3	3	3	15	6	HIGH
		Work related injury/fatality of workforce	X		X		X	X	X	X	L	3	3	3	5	5	19	8	HIGH
		Non work related injury/fatality of workforce	X		X		X	X	X	X	L	0	3	3	3	5	14	6	HIGH

		Increase in explosion potential	X		X		X	X	X	X	L	0	5	5	5	3	18	10	HIGH
		Increase in diseases STIs, HIV/AIDS	X		X		X	X	X	X	L	0	3	3	3	3	12	6	HIGH
		Increase in endemic diseases (Malaria, Typhoid, RTI)	X		X		X	X	X	X	L	0	3	3	3	3	12	6	HIGH
		Development of infrastructures and economic enhancement (GMoU)		X	X	X	X	X	X		L/ W	-	-	-	-	-	-	-	P
		Increase in road traffic volume & accident potential/injuries	X		X		X	X	X	X	L	0	5	3	3	3	14	6	HIGH
		Tank leaks	X		X		X		X		L	3	5	3	5	3	19	8	HIGH
		Opportunity for direct and indirect Employment (Unskilled labour)		X	X		X		X		L	-	-	-	-	-	-	-	P
		Opportunity for wealth creation		X	X	X	X	X	X		L	-	-	-	-	-	-	-	P
		Loss of Employment	X		X	X	x		x		L	3	5	5	3	5	21	8	HIGH

		(local labour) (Boom burst cycle)																	
		Third party agitation	X		X		X	X	X		L/ W	0	5	5	5	3	18	10	HIGH
		Attack from wild animals (Snakes, Scorpions)	X		X		X	X	X		L	0	1	3	3	3	10	6	HIGH
		Crime and insecurity (Kidnapping, Hostage-taking, armed robbery, Militancy)	X		X		X		X		L	0	5	5	5	5	20	10	HIGH
		Increased exposure to carcinogenic substances	X		X		X		X		L	3	5	3	5	3	19	8	HIGH
		Alcohol and drug abuse	X		X			X	X	X	L/ W	0	5	5	5	5	20	10	HIGH
Demobilizat ion		Increase in marine traffic, potential for accidents and injuries	X		X		X	X	X	X	L	0	5	3	3	3	14	6	HIGH
		Impairment in air quality	X		X		X		X		L	3	3	3	3	5	17	6	HIGH
		Increase in noise	X		X		X	X	X	X	L	3	3	3	5	5	19	8	HIGH

		and vibration																	
		Increase in refined hydrocarbon contents of soil and vegetation	X		X			X	X		L/ W	3	3	3	3	1	13	6	HIGH
		Increase in crime rate	X		X		X		X		L	0	5	5	5	5	20	10	HIGH
		Contamination of groundwater, surface w	X		X			X	X		L	3	3	3	3	3	15	6	HIGH
		Soil compaction	X		X			X		X	L	0	1	1	3	1	6	4	LOW
		Waste generation (Scrap metals, Woods, Food waste)	X		X			X	X		L	3	3	3	3	3	15	6	HIGH
		Opportunity for contracting		X	X	X	X	X	X		L	-	-	-	-	-	-	-	P
		Opportunity for direct and indirect Employment (Unskilled labour)		X	X	X	X	X	X		L	-	-	-	-	-	-	-	P
		Loss of Employment (local labour)	X		X	X	x		x		L	3	5	5	3	5	21	8	HIGH
		Third party	X		X		X	X	X		L/	0	5	5	5	3	18	10	HIGH

		agitation									W								
		Crime and insecurity (Kidnapping, Hostage-taking, armed robbery, Militancy)	X		X		X		X		L	0	5	5	5	5	20	10	HIGH
		Increase in RTIs due to dust particles	X		X		X	X	X	X	L	0	3	3	3	3	12	6	HIGH
		Social dislocation	x		x		x		x		L	0	5	5	5	5	20	10	HIGH
		Increased exposure to carcinogenic substances	X		X		X		X		L	0	5	3	5	3	16	8	HIGH
		Alcohol and drug abuse	X		X		X		X		L	0	3	3	3	3	12	6	HIGH
	Removal of surface installations Plugging of wells Site restoration Return of land to owner(s)	Increase in potential for soil and water contamination	X		X	X	X		X		L	3	3	3	3	3	15	6	HIGH
		Increase in litigation potential	X		X	X	X	X	X		L/ W	3	3	3	3	3	15	6	HIGH
		Loss of job by community surveillance	X		X	X	X		X		L	3	5	5	3	5	21	8	HIGH

		team																	
		Increase in usable land resource to the community		X	X		X		X		L	-	-	-	-	-	-	-	P
		Opportunity for contracting		X	X		X		X		L	-	-	-	-	-	-	-	P
		Opportunity for direct and indirect Employment (Unskilled labour)		X	X		X		X		L	-	-	-	-	-	-	-	P
		Third party agitation	X		X		X	X	X		L/ W	0	3	3	3	3	12	6	HIGH
		Crime and insecurity (Kidnapping, Hostage-taking, armed robbery, Militancy) and other social vices	X		X		X		X		L	0	5	5	5	5	20	10	HIGH
		Waste generation (Scrap metals, Woods, Food waste)	X		X			X	X		L	3	3	3	3	3	15	6	HIGH
		Increased exposure to carcinogenic substances	X		X		X		X		L	0	5	3	5	3	16	8	HIGH

		Alcohol and drug abuse	X		X		X		X		L	0	3	3	3	3	12	6	HIGH
		Prevalence of STIs HIV/AIDS	X		X		X	X	X	X	L	0	3	3	3	3	12	6	HIGH

CHAPTER SIX
MITIGATION MEASURES

6.1: Introduction

The actions and measures that SPDC intend to take to reduce (or eliminate) negative impacts and thus promote the positive impacts of the Bonny Deep Exploration Wells Project are presented in this chapter. The mitigation measures are aimed at reducing the impacts to As Low As Reasonably Practicable (ALARP). None significant impacts are expected to be mitigated through effective implementation of Health, Safety and Environment (HSE) plans that are in operational and the new ones that will be introduced. The mitigation measures proposed are in consonance with the following:

- Department of Petroleum Resources guidelines and standards,
- Environmental laws at national, regional and international levels,
- Best Available Technology for Sustainable Development;
- Social wellbeing and
- Concerns of stakeholders.

6.2: Mitigation Measures for the Cumulative impacts/effects

The proposed mitigation measures for the cumulative impacts/effects are presented in Table 6.1.

Table 6.1: Mitigation measures for the identified impacts of the Bonny Deep Exploration Well project.

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact
Pre-mobilization	• Consultation, • Land acquisition and • Compensation, Resolution of legacy issues	Increase in project awareness	HIGH	• SPDC shall ensure adequate consultation with all stakeholders especially communities. • SPDC shall carry out sound community sensing to evaluate existing relationship between SPDC & fence line communities, collate legacy projects & agree with community on ways of addressing them to change the perception to positive.	LOW
		Anticipated Loss of land associated resources	HIGH	• Land take shall be limited to the minimum required. • SPDC shall ensure consultation is done with the right responsible persons.	LOW
		Financial enhancement	POSITIVE	• SPDC shall discuss and agree on sustainable community development project and implement agreed projects, these will serve the whole fence line communities without bias. • SPDC shall sign and implement GMoU with communities; • Stakeholder's engagement shall be sustained through the project lifecycle.	LOW

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact
				• SPDC shall encourage Infrastructural development via GMoU implementation	
		Third party agitation	HIGH	• Relevant stakeholders/legacy issues shall be identified. • Regular consultation with stakeholders (Govt., Community, NGOs, CBOs etc.) shall be carried out to understand community perceptions, issues and concerns • Effective liaison/communication channels (CICs) from the communities to the project execution team shall be established. • Project Advisory Committee (PAC) to guide MoU implementation shall be set up	LOW
Mobilization	• Movement of equipment and personnel, • Rig movement	Loss of livelihood	HIGH	• Alternative income generating activities through skills acquisition that will empower communities shall be supported. • SPDC shall encourage skills acquisition and training programmes	LOW
		Increase in marine traffic, potential for accidents and injuries	HIGH	▪ SPDC shall ensure all marine vessels observe the speed limits and have warning sounds/ lights to alert other water users	LOW

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact
				▪ SPDC shall ensure all project marine vessels are pre-mobbed and certified. ▪ The 12 Life Saving Rules (LSR) shall be enforced on all project marine users. ▪ Effective journey Management system shall be implemented, including no night sailing policy. ▪ Proper Risk Assessment (using JHA and Toolbox meeting) before work begins	
		Influx of people causing Pressure on health and other Infrastructure	HIGH	▪ Workers camps shall be provided for the workforce by the Contractor to reduce the pressure on housing. ▪ SPDC shall ensure access control is implemented at work site ▪ Patronage of commercial sex workers by workforce shall be discouraged through health awareness campaigns to be conducted by SPDC. ▪ SPDC shall ensure unskilled and where feasible semi-skilled workers are sourced from immediate communities. ▪ SPDC shall honour all GMoU	LOW

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact
				agreements ▪ SPDC and contractor shall provide for health care needs of workforce outside of those in the community. ▪ SPDC shall avoid the use of the communities' welfare facilities such as water, and Health facilities.	
		Increase in sexually transmitted disease and other communicable diseases	HIGH	▪ Workers shall be encouraged to undergo voluntary counselling and testing in order to know their HIV status and in turn guide behaviour ▪ SPDC shall enforce access control to base camps. ▪ SPDC shall enforce Alcohol and drug policy in the camps /worksite as part of culture of health.	LOW
		Reduction in air quality	HIGH	• SPDC shall ensurethat movement is carried out in such a manner that will ensure minimal dust generation • Health advise to the communities' members (particularly the under aged) to stay away from construction site • Access control to the project area shall be enforced to minimize contact will dust • Appropriate PPEs shall be worn by	LOW

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact
				workers to minize dust inhalation	
		Loss of vegetation and wildlife	HIGH	• SPDC shall restrict project activities to within agreed scope and establish bond walls / fencing to avoid encroachment into unplanned zones. • Any vegetation cleared in the lay-down area shall be re-planted with native species.	LOW
		Habitat fragmentation	HIGH	• Clearing should be limited to areas of operation. • Wildlife reserves and sacred forests shall be identified and avoided. • Re-vegetation shall be undertaken after the project work where desirable.	LOW
		Loss of aquatic species (Fisheries, Planktons and benthic fauna)	HIGH	• SPDC shall establish skill acquisition / training scheme. • SPDC shall implement Biodiversity Action Plan of the Gbaran Ubie IOGP. • Research and development shall be encouraged to prevent habitat alteration to the barest minimum.	LOW
		Distortion of aquatic environment (physical components)	HIGH	• SPDC shall establish skill acquisition / training scheme. • SPDC shall implement Biodiversity Action Plan of the Gbaran Ubie	LOW

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact
				IOGP. • Research and development shall be encouraged to prevent habitat alteration to the barest minimum.	
		Increase in noise and vibration	HIGH	▪ Mufflers shall be installed on machineries and low noise generators shall be used. ▪ Noise level shall be monitored to ensure safe levels are not exceeded. ▪ There shall be no night work	LOW
		Increase in refined hydrocarbon contents of soil and vegetation	HIGH	• SPDC shall ensure fuel bunkering is done within stipulated bonded area that is leak proof to avoid contamination. • SPDC shall encourage regular servicing of vehicles to reduce emissions from exhaust. • Vehicles should fuel and refuel at designated stations.	LOW
		Increase in crime rate	HIGH	• SPDC shall advise the contractor to site recruitment office away from the work site to reduce job seekers at the site. • SPDC shall ensure access control is implemented at work site • SPDC shall implement proper journey management system.	MEDIUM

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact
				• SPDC shall work with the Government, communities and other relevant agencies to improve security in the project area • SPDC shall ensure that security orientation and awareness is conducted for workforce. • SPDC shall ensure that security orientation and awareness is conducted for workforce.	
		Loss of cultural/heritage sites	MEDIUM	• Historical sites/sacred places, fishing sites/grounds and other areas of interest to the communities shall be avoided during land acquisition, and where unavoidable, agreements shall be reached with the respective communities & duly compensated for. • Designate authentic shrines as protected cultural properties	LOW
		Soil compaction	LOW	• SPDC shall ensure that there is restriction to permanent wheel tracks. • SPDC shall ensure trucks avoid waterlogged routes.	LOW
		Increase in waste	HIGH	▪ SPDC and contractors shall ensure that all wastes are segregated and	LOW

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact
				managed according to EGASPIN/FMEnv. ▪ Ensure proper documentation of the quantity of waste from generated site to disposal point	
Construction	**Wells/locations/pipelines** • Route & location clearing • Dredging, • Base camp activities • Concrete and asphalt works, • Excavation	Air pollution	HIGH	• SPDC shall ensure the use of only pre-mobbed and standard equipmens in all phases of the project to minimize emission to air. • Access control to the project area and use of appropriate PPEs shall be enforced to minimize exposure to emission	LOW
		Land take	MEDIUM	• Land take shall be limited to the minimum required. • SPDC shall ensure consultation is done with the right responsible persons	LOW
		Increase in population due to influx of persons	HIGH	• SPDC shall advise the contractor to site recruitment office away from the work site to reduce job seekers at the site. • SPDC shall ensure access control is implemented at work site • SPDC shall ensure health awareness campaigns are conducted for workforce on the risks of STIs from	LOW

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact
				the services of CSWs to discourage patronage • SPDC shall ensure unskilled and where feasible semi-skilled workers are sourced from immediate communities • SPDC shall support existing health facilities upgrade and staff training. • SPDC will house workers in camps to reduce pressure and local housing stock. • SPDC shall comply with local content policy.	
		Increase in social vices (Alcohol and drug abuse, CSWs)	HIGH	▪ Ensure the implementation of the company's alcohol and drug policies ▪ Pre-activity health/sex education campaign shall be conducted for both workforce and communities.	LOW
		Crime and insecurity (Kidnapping, Hostage-taking, armed robbery, Militancy)	HIGH	• SPDC shall advise the contractor to site recruitment office away from the work site to reduce job seekers at the site. • SPDC shall ensure access control is implemented at work site • SPDC shall implement proper	MEDIUM

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact
				journey management system. • SPDC shall work with the Government, communities and other relevant agencies to improve security in the project area • SPDC shall ensure that security orientation and awareness is conducted for workforce. • SPDC shall ensure that security orientation and awareness is conducted for workforce.	
		Injury/fatality of workforce and/or third party	HIGH	• SPDC shall enforce the use of appropriate PPEs (life jackets, work vests/ goggles etc). • SPDC shall ensure first aid box on site and emergency response and med-rescue/medevac are in place. • Toolbox meetings shall be held before the start of daily tasks • Awareness shall be created among site workers on the likelihood of exposure to poisonous wildlife & plants. • Trained First Aiders shall form part of the workforce • SPDC policy on road traffic journey management shall be adhered to (all	LOW

Project phase	**Project activity**	**Description of impact**	**Cumulative Impact**	**Mitigation measures**	**Residual Impact**
				journey must be approved, no night journeys, speed limits on land)	
		Increase in volume of wastes	HIGH	▪ SPDC and contractors shall ensure that all wastes are segregated and managed according to EGASPIN/FMEnv guidelines. ▪ Ensure proper documentation of the quantity of waste from generated site to disposal point	LOW
		Increase in employment/business opportunities	POSITIVE	NA	POSITIVE
		Shift from traditional occupations	HIGH	• SPDC shall discuss and agree on sustainable community development project and implement agreed projects.	LOW
		Inflation	HIGH	• Alternative income generating activities through skills acquisition that will empower communities shall be introduced and supported by SPDC and Contactors. • SPDC and Contractors shall provide accommodation for operational staff at the base camps and provide catering services.	LOW
		Gender imbalance	HIGH	• SPDC shall enforce existing laws	LOW

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact
				against gender-based employment discrimination and against sexual harassment. • SPDC shall Increase mentorship and other efforts to boost the number of women in traditionally male occupations.	
		Potential for skills acquisition	P	NA	POSITIVE
		Pressure on existing infrastructure and services (Water, Electricity, Recreational facilities, Health facilities, Roads and others)	HIGH	▪ SPDC shall advise the contractor to locate recruitment office away from the work site to reduce job seekers at the site ▪ Workers camps shall be provided for the workforce by the Contractor to reduce the pressure on housing. ▪ SPDC shall ensure access control is implemented at work site ▪ Patronage of commercial sex workers by workforce shall be discouraged through health awareness campaigns to be conducted by SPDC. ▪ SPDC shall ensure unskilled and where feasible semi-skilled workers are sourced from immediate communities.	LOW

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact
				▪ SPDC shall honour all GMOU agreements ▪ SPDC and contractor shall provide for health care needs of workforce outside of those in the community. ▪ Construction should be done in phases so as to reduce the number of workers at site in any particular time ▪ Health education on communicable disease transmissions.	
		Increase in communicable diseases, STIs HIV/AIDS	HIGH	▪ Workers shall be encouraged to undergo voluntary counselling and testing in order to know their HIV status and in turn guide behaviour ▪ SPDC shall enforce access control to base camps ▪ SPDC shall enforce Alcohol and drug policy in the camps /worksite as part of culture of health.	LOW
		Surface water pollution/distortion (increase in turbidity and Total Suspended Solids)	HIGH	SPDC shall deploy the most appropriate technology (silt curtain), to minimize loss of benthic organisms.	LOW
		Soil pollution	HIGH	• Wastes shall be segregated at source into color-coded or labelled bins and	LOW

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact
				disposed of in line with a project specific waste management plan. • Safe Handling of Chemicals (SHOC) cards shall be visibly displayed at all sites where chemicals are handled • Fuel, lube oils and chemicals shall be safely stored in containers in bunded areas	
		Loss of biodiversity and Distortion of food chain (Economic trees)	HIGH	• Any vegetation cleared in the lay-down area shall be re-planted with native species. • SPDC shall ensure awareness campaigns are conducted for the workforce on the need to preserve the environment. • Route clearing shall be done in stages to allow mobile fauna escape from the project area.	LOW
		Impairment/Loss of aquatic life (Loss of juvenile fishes due to gill damage from silt particles)	HIGH	SPDC shall deploy the most appropriate technology (silt curtain), to minimize loss of benthic organisms and fishery resources.	LOW
		Increase in disease vectors	HIGH	▪ Health education on the Health Implication of Rodents/other	LOW

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact
				disease vectors in their homes. ▪ SPDC shall ensure that waste generated from the project during the period of construction are managed from cradle to grave using DPR and FMEnv approved waste management contractors. ▪ Health education on the consumption of rodents shall be provided by appropriate health authorities	
		Blockage of natural water courses	HIGH	SPDC shall ensure that no natural water course is unduly obstructed /blocked during the implementation of the project, equalization culverts shall be installed where necessary.	LOW
		Increase in marine traffic/ potential for accidents and injuries	HIGH	▪ SPDC shall ensure all marine vessels observe the speed limits and have warning sounds/ lights to alert other water users ▪ SPDC shall ensure all project marine vessels are pre-mobbed and certified. ▪ The 12 Life Saving Rules (LSR) shall be enforced on all project marine users. ▪ Effective journey Management	LOW

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact
				system shall be implemented, including no night sailing policy. • Proper Risk Assessment (using JHA and Toolbox meeting) before work begins	
		Food insecurity	HIGH	▪ Livewire Program shall be introduced for the youths in the communities	LOW
		Erosion	HIGH	SPDC shall ensure that no natural water course is unduly obstructed/blocked during the implementation of the project, equalization culverts shall be installed.	LOW
		Loss of fish breeding sites and migratory routes	HIGH	• SPDC shall reduce vegetation clearing to the minimum. • SPDC shall implement the Biodiversity Action Plan • SPDC shall optimize the existing pipelines RoW and roads.	LOW
		Noise and vibration	HIGH	▪ Mufflers shall be installed on machineries and low noise generators shall be used. ▪ Noise level shall be monitored to ensure safe levels are not exceeded. ▪ There shall be no night work	LOW
		Reduction in air quality	HIGH	• SPDC shall wet the site before	LOW

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact
				excavation and construction to minimize dust. • Health advise to the communities' members (particularly the under aged) to stay away from construction site • Access control to the project area shall be enforced.	
		Opportunity for direct and indirect Employment	POSITIVE	NA	POSITIVE
		Opportunity for wealth creation	POSITIVE	NA	POSITIVE
		Opportunity for Corporate Social Responsibility	POSITIVE	NA	POSITIVE
		Exposure to radioactive materials	HIGH	• SPDC shall ensure that only certified personnel handle radioactive materials. • SPDC shall ensure that radioactive materials are stored safely. • SPDC shall ensure toolbox talks are conducted before the commencement of the job. • SPDC shall ensure appropriate	LOW

Project phase	**Project activity**	**Description of impact**	**Cumulative Impact**	**Mitigation measures**	**Residual Impact**
				PPEs are used by the workers	
		Third party agitation	HIGH	• SPDC shall enlighten its contractors and project personnel prior to deployment on proper conduct within stakeholder communities • SPDC shall maintain effective liaison/communication with communities and ensure the community cultural profile is not infringed.	LOW
		Potential attack from wild/predatory animals (Snakes, Scorpions)	HIGH	SPDC shall ▪ SPDC shall ensure that waste generated from the project during the period of construction are managed from cradle to grave. ▪ The site clinic shall stock anti-snake bite venom ▪ Awareness shall be created among workers on the possibility of exposure to poisonous wildlife ▪ Ensure adequate Medivac system and on site referral system.	LOW
		Increase in exposure to transborder diseases (Zika virus, Ebola, Birdflu, SARS), Antimicrobial resistant	HIGH	▪ SPDC shall ensure that Expatriate staff pass through proper immigration Health checks before arriving at the worksite. ▪ SPDC shall ensure Health	LOW

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact
		bacteria		education is part of orientation for all foreign staff. ▪ Fitness–to-Work protocol must be adhered strictly to and Implemented by site supervisors and OHNs.	
		Crime and insecurity (Kidnapping, Hostage-taking, armed robbery, Militancy)	HIGH	SPDC shall • advise the contractors to site recruitment office away from the work site to reduce job seekers at the site • SPDC shall ensure access control is implemented at work site. • SPDC shall implement proper journey management system. • Work with the Government, communities and other relevant agencies to improve security in the project area. • ensure that security orientation and awareness is conducted for workforce. • Work with the Government, communities and other relevant agencies to improve security in the project area	LOW

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact
				• ensure that security orientation and awareness is conducted for workforce.	
		Temporary disruption of local fishing/harvesting activities.	MEDIUM	SPDC shall ensure strict compliance with good marine journey management practice, including sensitization of quarter masters / boat masters on how to pass fishing and commercial boat	LOW
		Acidification of the soil and surface water as a result of deposition of dredge spoils on the banks of the river	MEDIUM	SPDC shall ensure dredge spoil is deposited at least 10 metres into the buffer zone or Cap spoil with clean sand.	LOW
		Spoil disposal will smother epifauna and impair surface drainage especially in wetland areas	MEDIUM	SPDC shall dispose dredge spoils in an environmentally-friendly manner in line with approved procedures	LOW
		Disturbance of riverbed topography	MEDIUM	SPDC shall ensure minimal disturbance to the river bed during pipeline crossing.	LOW
	Well Drilling and Completion	Increase in noise & vibration nuisance	HIGH	• SPDC shall provide PPEs (ear muffs, eye goggles) for drilling staff. • Where possible SPDC shall provide acoustic enclosure for noisy	LOW

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact
				equipment. • First Aid boxes shall be provided at the drilling site and trained First Aiders remain part of the workforce.	
		Increase in light nuisance	HIGH	• Construction activities requiring continuous light at night shall be reduced to the barest minimum. • Construction activities shall be completed on schedule	LOW
		Generation of drilling waste	HIGH	• SPDC shall ensure that high G-shakers are used to reduce the amount of mud in drill cuttings. • Recovered drilling mud shall be stored in containers for re-use. • Where feasible cuttings re-injection shall be utilized • Drill cutting s that will not be re-used shall be managed in approved third party thermal desorption units.	LOW
		Contamination of environment (soils/surface and groundwater)	HIGH	• All generated wastes shall be managed in accordance with the provisions of the SPDC Waste Management Guidelines. • Where contamination occurs SPDC shall clean up and remediate as appropriate.	LOW

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact
		Work related injury/fatality of workforce	HIGH	• Workers shall use appropriate PPEs (life jackets, work vests/ goggles etc) • SPDC shall ensure first aid box on site and emergency response and med-rescue/medevac are in place. • Toolbox meetings shall be held before the start of daily tasks • Awareness shall be created among site workers on the likelihood of exposure to poisonous wildlife & plants. • Trained First Aiders shall form part of the workforce. • SPDC policy on road and water borne traffic journey management shall be adhered to (all journey must be approved, no night journeys, speed limits on land and water.	LOW
		Non work related injury/fatality of workforce	HIGH	• SPDC shall ensure all the workers at site have a medical fitness to work and are in good physical and mental health. • SPDC policy on road and water borne traffic journey management shall be adhered to (all journey must be approved, no night journeys,	LOW

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact
				speed limits on land and water.	
		Potential for Well blowout	HIGH	• Firefighting extinguishers shall be provided at worksites. • Emergency response procedures shall be put in place. • SPDC shall use the optiwell (bore hole management) process, blow out preventers & other industry best practice to drill wells.	LOW
		Increase in diseases STIs, HIV/AIDS	HIGH	▪ Workers shall be encouraged to undergo voluntary counselling and testing in order to know their HIV status and in turn guide behaviour ▪ SPDC shall ensure condoms are provided for workers at the site clinic and distributed to the communities ▪ SPDC shall enforce access control to base camps ▪ SPDC shall enforce Alcohol and drug policy in the camps /worksite as part of culture of health.	LOW
		Increase in endemic diseases	HIGH	• SPDC shall support existing health facilities upgrade and staff training. • SPDC shall maintain workers in camp and provide access control measure to reduce intermingling	LOW

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact
				with host communities.	
		Emergent Infectious diseases resulting from displacement of disease vectors (rodents and monkeys)	HIGH	▪ SPDC shall ensure that waste generated from the project during the period of construction are managed from cradle to grave. ▪ Health education on the consumption of rodents shall be provided by appropriate health authorities.	LOW
		Loss of biodiversity	HIGH	▪ Any vegetation cleared in the lay-down area shall be re-planted with native species. ▪ SPDC shall ensure that her workforce do not engage in hunting or fishing. ▪ SPDC shall ensure awareness campaigns are conducted for the workforce on the need to preserve the environment. ▪ Route clearing shall be done in stages to allow mobile fauna escape from the project area. ▪ SPDC shall implement the BAP policy.	LOW
		Potential for development of infrastructures and	P	NA	POSITIVE

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact
		economic enhancement			
		Increase in road traffic volume & accident potential/injuries	HIGH	• SPDC policy on road and water borne traffic journey management shall be adhered to (all journey must be approved, no night journeys, speed limits on land and water • SPDC shall upgrade existing roads to suite the anticipated project activities and additional access road provided, where necessary	LOW
		Tank leaks	HIGH	• All Liquid containers shall be placed in leak-proof bonded concreate housing with proper ventilation. • SPDC shall ensure only certified personnel are allowed to carry-out fuel bunkering / transfer. • The storage shall be properly marked and condoned off from the general worksite public.	LOW
		Influx of insect pests	HIGH	▪ SPDC shall carryout health education programmes on the Rollback Malaria interventions. ▪ Ensure adequate referral system	LOW
		Opportunity for direct and indirect Employment (Unskilled	P	NA	POSITIVE

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact
		labour)			
		Opportunity for wealth creation	P	NA	POSITIVE
		Opportunity for Corporate Social Responsibility	P	NA	POSITIVE
		Gender imbalance	HIGH	• SPDC shall enforce existing laws against gender-based employment discrimination and against sexual harassment. • SPDC shall Increase mentorship and other efforts to boost the number of women in traditionally male occupations.	LOW
		Potential for skills acquisition	P	NA	P
		Pressure on existing infrastructure and services (Water, Electricity, Recreational facilities, Health facilities, Roads and others)	HIGH	▪ SPDC shall advise the contractor to locate recruitment office away from the work site to reduce job seekers at the site ▪ Workers camps shall be provided for the workforce by the Contractor to reduce the pressure on housing. ▪ SPDC shall ensure access control is implemented at work site	LOW

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact
				▪ Patronage of commercial sex workers by workforce shall be discouraged through health awareness campaigns to be conducted by SPDC. ▪ SPDC shall ensure unskilled and where feasible semi-skilled workers are sourced from immediate communities. ▪ SPDC and contractor shall provide for health care needs of workforce outside of those in the community. ▪ Construction should be done in phases so as to reduce the number of workers at site in any particular time.	
		Third party agitation	HIGH	▪ SPDC shall implement the PGMOU in line with agreed template. ▪ SPDC shall enlighten its contractors and project personnel prior to deployment on proper conduct within stakeholder communities and maintain effective liaison/communication with communities and ensure the community's economic and cultural profiles are not infringed.	LOW

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact
		Attack from wild/predatory animals (Snakes, Scorpions)	HIGH	▪ SPDC shall ensure that waste generated from the project during the period of construction are managed from cradle to grave. ▪ The site clinic shall stock anti-snake bite venom ▪ Awareness shall be created among workers on the possibility of exposure to poisonous wildlife ▪ Ensure adequate Medivac system and on site referral system.	LOW
		Exposure to radioactive materials	HIGH	▪ SPDC shall ensure that only certified personnel handle radioactive materials. ▪ SPDC shall ensure that radioactive materials are stored safely. ▪ SPDC shall ensure toolbox talks are conducted before the commencement of the job ▪ SPDC shall ensure appropriate PPEs are used by the workers	LOW
		Crime and insecurity (Kidnapping, Hostage-taking, armed robbery, Militancy)	HIGH	• SPDC shall advise the contractor to site recruitment office away from the work site to reduce job seekers at the site. • SPDC shall ensure access control is implemented at work site	MEDIUM

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact
				• SPDC shall implement proper journey management system. • SPDC shall work with the Government, communities and other relevant agencies to improve security in the project area • SPDC shall ensure that security orientation and awareness is conducted for workforce. • SPDC shall ensure that security orientation and awareness is conducted for workforce.	
	Commissioning & Handover	Increase in Business opportunities	P	NA	POSITIVE
		Gas flaring from well tests	HIGH	SPDC shall ensure • Safety signage shall be deployed at strategic locations. • Emergency response plan shall be in place • Use of appropriate PPEs • provision of adequate firefighting equipment	LOW
		Increase in noise & vibration nuisance	HIGH	▪ Mufflers shall be installed on machineries and low noise generators shall be used. ▪ Noise level shall be monitored to	LOW

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact
				ensure safe levels are not exceeded. ▪ There shall be no night work ▪ Noise in the communities shall be measured every three months	
		Generation of waste (Pigging waste, domestic waste, metal scraps, plastics)	HIGH	▪ SPDC and contractors shall ensure that all wastes are segregated and managed according to EGASPIN and FMEnv guidelines. ▪ Enforce access control to ensure that wastes are not indiscriminately transferred from one place to the other by members of the communities in the act of picking properties. ▪ Ensure proper documentation of the quantity of waste from generated site to disposal point	LOW
		Contamination of environment (soils/surface and groundwater)	HIGH	• Waste management plans (in line with regulatory guidelines and SPDC procedures) shall be strictly adhered to during all phases of the project. • Wastes shall be segregated at source into color-coded or labelled bins and disposed of in line with a project specific waste management plan.	LOW

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact
				• SPDC shall ensure that sewage wastes in base camps are properly managed. • Safe Handling of Chemicals (SHOC) cards shall be visibly displayed at all sites where chemicals are handled • Fuel, lube oils and chemicals shall be safely stored in containers in bonded areas	
		Work related injury/fatality of workforce	HIGH	▪ Workers shall use appropriate PPEs (life jackets, work vests/ goggles etc) ▪ SPDC shall ensure first aid box on site and emergency response and medevac are in place ▪ Toolbox meetings shall be held before the start of daily tasks ▪ Awareness shall be created among site workers on the likelihood of exposure to poisonous wildlife & plants ▪ Trained First Aiders shall form part of the workforce in the ratio of 1:25 ▪ Ensure adequate MEDEVAC and referral system	LOW
		Non work-related	HIGH	• SPDC shall ensure every worker	LOW

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact
		injury/fatality of workforce		have a medical certificate of fitness to work. • SPDC shall ensure that workers suffering from terminal diseases are not accommodate in camp. • SPDC shall ensure that a trained medic is assigned to the site camp.	
		Increase in explosion potential	HIGH	• Firefighting extinguishers shall be provided at worksites • Emergency response procedures shall be put in place. • SPDC shall use the optiwell (bore hole management) process & other industry best practice to drill her wells	LOW
		Increase in diseases STIs, HIV/AIDS	HIGH	▪ Workers shall be encouraged to undergo voluntary counselling and testing in order to know their HIV status and in turn guide behaviour ▪ SPDC shall enforce access control to base camps ▪ SPDC shall enforce Alcohol and drug policy in the camps /worksite as part of culture of health.	LOW
		Increase in endemic diseases (Malaria,	HIGH	▪ Carryout health education on the Rollback Malaria interventions. ▪ Ensure adequate referral system	LOW

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact
		Typhoid, RTI)			
		Development of infrastructures and economic enhancement (GMoU)	P	NA	POSITIVE
		Increase in road traffic volume & accident potential/injuries	HIGH	• SPDC shall ensure all vehicles are pre-mobbed and certified. • Visible warning signs shall be placed on roads and vehicle. • SPDC shall ensure all drivers undergo the defensive driving course and are certified. • Vehicle monitoring, and communication devices shall be installed in project vehicles. • SPDC shall ensure journey management and 'no night driving policy' shall be adhered to. • SPDC shall ensure compulsory medical fitness test for all drivers	LOW
		Tank leaks	HIGH	• All Liquid containers shall be placed in leak-proof bonded concreate housing with proper ventilation. • SPDC shall ensure only certified personnel are allowed to carry-out fuel bunkering / transfer.	LOW

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact
				• The storage shall be properly marked and condoned off from the general worksite public.	
		Opportunity for direct and indirect Employment (Unskilled labour)	P	NA	POSITIVE
		Opportunity for wealth creation	P	NA	POSITIVE
		Loss of Employment (local labour) (Boom burst cycle)	HIGH	SPDC shall as long as reasonably possible ensure the engagement of community members when actual production begins	LOW
		Third party agitation	HIGH	• SPDC shall implement the GMoU in line with agreed template. • SPDC shall enlighten its contractors and project personnel prior to deployment on proper conduct within stakeholder communities and maintain effective liaison/communication with communities and ensure the community's economic and cultural profiles are not infringed.	LOW
		Attack from wild	HIGH	• SPDC shall ensure that waste	LOW

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact
		animals (Snakes, Scorpions)		generated from the project during the period of construction are managed from cradle to grave. • Health education on the consumption of rodents shall be provided by appropriate health authorities • The site clinic shall stock anti-snake bite venom • Awareness shall be created among workers on the possibility of exposure to poisonous wildlife • Ensure adequate Medivac system and on site referral system.	
		Crime and insecurity (Kidnapping, Hostage-taking, armed robbery, Militancy)	HIGH	• SPDC shall advise the contractor to site recruitment office away from the work site to reduce job seekers at the site. • SPDC shall ensure access control is implemented at work site • SPDC shall implement proper journey management system. • SPDC shall work with the Government, communities and other relevant agencies to improve security in the project area • SPDC shall ensure that security	MEDIUM

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact
				orientation and awareness is conducted for workforce. • SPDC shall ensure that security orientation and awareness is conducted for workforce.	
		Increased exposure to carcinogenic substances	HIGH	▪ SPDC shall carryout awareness campaign in educating the communities members to keep the required distance when rays are being used for welding joints and other radioactive services. ▪ SPDC shall ensure that the emergency contingencies are in place to address any spill to minimise contamination of food and water sources.	LOW
		Alcohol and drug abuse	HIGH	▪ Ensure the implementation of the company's alcohol and drug policies ▪ Pre-activity health/sex education campaign shall be conducted for both workforce and communities.	LOW
Demobilization		Increase in marine traffic, potential for accidents and injuries	HIGH	• SPDC shall ensure all boats observe the speed limits and take cognizanc eof other water users. • SPDC shall ensure all project	LOW

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact
				vessels are pre-mobbed and certified	
		Impairment in air quality	HIGH	• SPDC shall wet the site before excavation and construction to minimize dust. • Access control to the project area should enforced • Health education shall be delivered to the communities' members on the need to dependence on the use of firewood due to negative health effect.	LOW
		Increase in noise and vibration	HIGH	▪ Mufflers shall be installed on machineries and low noise generators shall be used. ▪ Noise level shall be monitored to ensure safe levels are not exceeded. ▪ There shall be no night work	LOW
		Increase in crime rate	HIGH	• SPDC shall advise the contractor to site recruitment office away from the work site to reduce job seekers at the site. • SPDC shall ensure access control is implemented at work site • SPDC shall implement proper journey management system. • SPDC shall work with the	MEDIUM

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact
				Government, communities and other relevant agencies to improve security in the project area • SPDC shall ensure that security orientation and awareness is conducted for workforce. • SPDC shall ensure that security orientation and awareness is conducted for workforce.	
		Waste generation (Scrap metals, Woods, Food waste)	HIGH	• Waste management plans (in line with regulatory guidelines and SPDC procedures) shall be strictly adhered to during all phases of the project. • Wastes shall be segregated at source into color-coded or labelled bins and disposed of in line with a project specific waste management plan	LOW
		Opportunity for contracting	P	NA	POSITIVE
		Opportunity for direct and indirect Employment (Unskilled labour)	P	NA	POSITIVE
		Loss of Employment	HIGH	SPDC shall	LOW

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact
		(local labour)		• support entrepreneurial skill development and opportunities for community members to cushion the effect of reduction in economic/income generating activities.	
		Third party agitation	HIGH	• SPDC shall discuss and agree on sustainable community development project and implement agreed projects, these will serve the whole fence line communities without bias. • SPDC shall sign and implement GMoU with communities; • SPDC shall sustain stakeholders engagement throughout the project lifecycle. • SPDC shall ensure Infrastructural development via GMoU implementation	LOW
		Crime and insecurity (Kidnapping, Hostage-taking, armed robbery, Militancy)	HIGH	• SPDC shall advise the contractor to site recruitment office away from the work site to reduce job seekers at the site. • SPDC shall ensure access control is implemented at work site • SPDC shall implement proper journey management system.	MEDIUM

Project phase	**Project activity**	**Description of impact**	**Cumulative Impact**	**Mitigation measures**	**Residual Impact**
				• SPDC shall work with the Government, communities and other relevant agencies to improve security in the project area • SPDC shall ensure that security orientation and awareness is conducted for workforce. • SPDC shall ensure that security orientation and awareness is conducted for workforce.	
		Social dislocation	HIGH	• SPDC shall advise the contractor to site recruitment office away from the project site to reduce job seekers at the site. • SPDC shall ensure access control is implemented at work site. • SPDC shall ensure health awareness campaigns are conducted for workforce on the risks of STIs from the services of CSWs to discourage patronage	LOW
		Increased exposure to carcinogenic substances	HIGH	• SPDC shall ensure that only certified personnel handle radioactive materials. • SPDC shall ensure that radioactive materials are stored safely. • SPDC shall ensure toolbox talks are	LOW

Project phase	**Project activity**	**Description of impact**	**Cumulative Impact**	**Mitigation measures**	**Residual Impact**
				conducted before the commencement of the job • SPDC shall ensure appropriate PPEs are used by the workers	
		Alcohol and drug abuse	HIGH	▪ Ensure the implementation of the company's alcohol and drug policies. ▪ Carryout awareness campaign on alcohol and drug abuse in schools, churches and town halls to reduce alcohol intake in the communities. ▪ Pre-activity health/sex education campaign shall be conducted for both workforce and communities.	LOW
		Opportunity for direct and indirect Employment (Unskilled labour)	POSITIVE	NA	POSITIVE
		Third party agitation	HIGH	• SPDC shall discuss and agree on sustainable community development project and implement agreed projects, these will serve the whole fence line communities without bias. • SPDC shall sign and implement GMoU with communities;	LOW

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact
				• SPDC shall sustain stakeholders engagement throughout the project lifecycle. • SPDC shall ensure Infrastructural development via PGMoU implementation	
		Crime and insecurity (Kidnapping, Hostage-taking, armed robbery, Militancy) and other social vices	HIGH	• SPDC shall advise the contractor to site recruitment office away from the work site to reduce job seekers at the site. • SPDC shall ensure access control is implemented at work site • SPDC shall implement proper journey management system. • SPDC shall work with the Government, communities and other relevant agencies to improve security in the project area • SPDC shall ensure that security orientation and awareness is conducted for workforce. • SPDC shall ensure that security orientation and awareness is conducted for workforce.	LOW
		Waste generation (Scrap metals, Woods,	HIGH	• Waste management plans (in line with regulatory guidelines and SPDC procedures) shall be strictly	LOW

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact
		Food waste)		adhered to during all phases of the project. • Wastes shall be segregated at source into color-coded or labelled bins and disposed of in line with a project specific waste management plan.	
		Alcohol and drug abuse	HIGH	▪ Ensure the implementation of the company's alcohol and drug policies. ▪ Carryout awareness campaign on alcohol and drug abuse in schools, churches and town halls to reduce alcohol intake in the communities. ▪ Pre-activity health/sex education campaign shall be conducted for both workforce and communities.	LOW
		Contamination of surface water/Sediment	HIGH	• Waste management plans (in line with regulatory guidelines and SPDC procedures) shall be strictly adhered to during all phases of the project. • Wastes shall be segregated at source into color-coded or labelled bins and disposed of in line with a project specific waste management plan. • SPDC shall ensure that sewage wastes in base camps are properly	LOW

Project phase	**Project activity**	**Description of impact**	**Cumulative Impact**	**Mitigation measures**	**Residual Impact**
				managed (i.e. using a sewage treatment plant). • Safe Handling of Chemicals (SHOC) cards shall be visibly displayed at all sites where chemicals are handle • Fuel, lube oils and chemicals shall be safely stored in containers in bonded areas.	
Decommissioning and abandonment	• Removal of surface installations • Plugging of wells • Site restoration • Return of land to owner(s)	Increase in potential for soil and water contamination	HIGH	SPDC shall ensure: • all wastes are properly segregated and contained before disposal • all wastes are properly disposed of and monitored from cradle to grave • All effluents are treated to regulatory limits before discharge	LOW
		Increase in litigation potential	HIGH	• The relevant stakeholders/legacy issues shall be identified • Regular consultation with stakeholders (Govt., Community, NGOs, CBOs etc.) shall be undertaken. • Project Advisory Committee (PAC) shall be set up to guide MOU implementation and address issues/concerns	LOW

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact
		Loss of job by community surveillance team	HIGH	SPDC shall • support entrepreneurial skill development and opportunities for community members to cushion the effect of reduction in economic/income generating activities.	LOW
		Increase in usable land resource to the community	POSITIVE	NA	POSITIVE
		Opportunity for contracting	POSITIVE	NA	POSITIVE
		Opportunity for direct and indirect Employment (Unskilled labour)	POSITIVE	NA	POSITIVE
		Third party agitation	HIGH	• SPDC shall discuss and agree on sustainable community development project and implement agreed projects, these will serve the whole fence line communities without bias. • SPDC shall sign and implement GMoU with communities; • SPDC shall sustain stakeholders' engagement throughout the project	LOW

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact
				lifecycle. • SPDC shall ensure Infrastructural development via GMoU implementation	
		Crime and insecurity (Kidnapping, Hostage-taking, armed robbery, Militancy) and other social vices	HIGH	• SPDC shall advise the contractor to site recruitment office away from the work site to reduce job seekers at the site. • SPDC shall ensure access control is implemented at work site • SPDC shall implement proper journey management system. • SPDC shall work with the Government, communities and other relevant agencies to improve security in the project area • SPDC shall ensure that security orientation and awareness is conducted for workforce. • SPDC shall ensure that security orientation and awareness is conducted for workforce.	LOW
		Waste generation (Scrap metals, Woods, Food, plastic wastes etc)	HIGH	▪ SPDC and contractors shall ensure that all wastes are segregated and managed according to EGASPIN and FMEnv guidelines ▪ Enforce access control to ensure	LOW

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact
				that wastes are not indiscriminately transferred from one place to the other by members of the communities in the act of picking properties. ▪ Ensure proper documentation of the quantity of waste from generated site to disposal point	
		Alcohol and drug abuse	HIGH	▪ Ensure the implementation of the company's alcohol and drug policies	LOW
		Prevalence of STIs HIV/AIDS	HIGH	▪ SPDC shall enforce access control to base camps ▪ SPDC shall enforce Alcohol and drug policy in the camps /worksite as part of culture of health	LOW

CHAPTER SEVEN
ENVIRONMENTAL MANAGEMENT PLAN

7.1: Introduction

Environmental management is concerned with a planned and integrated programme aimed at ensuring that adverse impacts of a proposed project are contained and brought to acceptable minimum levels, while the positive impacts are enhanced to optimize the benefits. Environmental management provides confidence on the part of project planners that a reliable scheme has been put in place to deal with any contingency that may arise during all phases of the project development, from mobilization to abandonment. In keeping with SPDC's policy on the environment, considerations of environmental implications of this project began from feasibility study, conceptual design and will continue throughout the project life cycle.

Environmental management will be carried out in accordance with the provisions of ISO 14001, sections 4.3.2 to 4.3.4, which are reflected in SPDC HSSE & SP Control Framework (HSSE & SP CF). The HSE-MS addresses the overall approach adopted for management of HSE risks through the project development phases by the project management team. HSE-MS document provides central guidance and co-ordination for project-wide documents - work procedures, standards, work practices, etc., and demonstrates how the Hazards and Effects Management Process (HEMP) will be applied on the project such that HSE risks are kept As Low As Reasonably Practicable (ALARP). Good environmental management, which is part of SPDC's HSE-MS goals, has the following long-term objectives:

- Ensure compliance with Legislations and Company policy;
- Achieve, enhance and demonstrate sound environmental performance built around the principle of continuous improvement;
- Provide strategy for overall planning, operation, audit and review;
- Enable project planners establish environmental priorities.

To provide assurance that the risk management and control procedures identified are implemented, a comprehensive EMP was developed (Table 7.2) for utilization throughout the project life cycle.

7.2: SPDC's Corporate HSE Programme

It is the policy of Shell companies to conduct their activities in such a way as to take foremost account of the health and safety of all their employees and other persons, and to give proper regards to the conservation of the environment. In implementing this policy, Shell companies not only comply with the requirements of the relevant legislations but promote, in an appropriate manner, measures for the protection of health, safety, environment and the security of all who may be involved directly or indirectly with their activities. The Environmental Management activities initiated by SPDC are intended to implement the above policy and the policy will be applied to all stages of the project life cycle. The projects' HSE-MS is fully aligned to SPDC's corporate HSE programs.

7.3: Monitoring Objectives

The following monitoring objectives are established:

- to create local data bank on the impacts of project activities on the environment, for future development of predictive models;
- to monitor emissions and discharges at all stages of project development to ensure they meet national standards;
- to determine whether environmental changes are results of development or a result of natural variations;
- to determine the effectiveness of the mitigation measures;
- to determine long term impacts.
- to determine the duration of return to normalcy of the environmental components of the project area.

7.4: Resourcing

Shell Petroleum Development Company (SPDC) considers environmental management as an important aspect of project procedures. Consequently, in any project for which project management team is set up, an environmental specialist always forms an integral part of the team. In this project, an environmental focal point has been appointed to liaise between the project managers and the environmental specialist, consultants as well as advises on all environmental issues in conformity with SPDC's HSE policy. Shell Petroleum Development Company (SPDC) recognizes the need to use external environmental consultants to supplement in-house environmental specialists. To this end, the environmental consultants will continue to provide expert advice to the SPDC environmental managers throughout the Life cycle of this project.

7.5: Environmental Audits

Shell Petroleum Development Company (SPDC) has an audit scheme, as part of its programme on environmental management. The scheme is aimed at verifying the effectiveness of environmental control and highlighting areas of weakness in environmental management requiring further improvements. The audits are focused on areas of project perceived as having the highest environmental impacts. It is recognized that to be truly effective, these audits need to be conducted within the overall structured management systems. The structured approach is aimed at disseminating information, providing advice and assistance in its application, and at corporate assurance of performance in meeting the environmental requirement/targets. External audits are also carried out for SPDC assets and projects and SPDC subscribes to ISO 14001 standards.

7.6: Responsibilities and Training

Within SPDC, environmental protection, like safety, is a line responsibility for which staff, at all levels, have accountabilities. An environmental specialist assists the line management with advice on environmental matters, from an expert point of view. However, responsibility and accountability is clearly defined, from senior management who allocate resources and monitor environmental performance to individual contractors who have responsibility for environmentally sound practices in their workplace. All staff will be made aware of their responsibilities through induction and training opportunities as outlined in the projects' HSE-MS document. In addition, procedures, guidelines and notices will advise staff on how to respond in the event of an environmental emergency. The Shell Corporate Environment Department is responsible for internal and facilitating external monitoring and auditing the environmental activities of this project.

7.7: Waste Management

The Waste Management Plan includes procedures for safe handling, control and disposal of generated waste in accordance with the SPDC procedure. Wastes emanating from all phases of the Bonny Deep Exploration Wells project (premobilization, mobilization, construction, demobilization, and decommissioning) activities are mainly food wastes, garbage, shrubs/vegetation, scrap metals, woods, waste papers etc. These wastes are handled in compliance with the Petroleum (Drilling & Productions) Regulations, 1969, Sections 25, 36 49 and (b), (c) and (d), which stipulate *inter alia* that:

The licensee or lessee shall adopt all practical precautions, including the provision of up-to-date equipment to prevent the pollution of inland waters, rivers, creeks, water courses, the territorial waters of Nigeria or the high seas by oil, mud or other fluids or substances which might contaminate the water or marine life, and where any such pollution occurs or has occurred, shall take prompt steps to control and, if possible, end it."

The waste management strategy to be adopted in the proposed project has been highlighted in Section 3.5 of chapter three.

7.8: Emergency Response Programme

In compliance with all regulatory standards, as well as Health, Safety, Environment and Security (HSES) procedures shall form the basis for the execution of the project. However, emergency situations could still occur as a result of equipment failure, negligence and/or sabotage. Consequently, a site-specific contingency plan shall be developed as back up to site specific emergency response systems which shall be put in place to handle any incident emergency. As a minimum, the contingency plans that shall apply shall address the following emergency situations:

- Fires and explosions;
- Serious injury or illness;
- Road and water mishaps.

In order to accomplish the above targets, the EMP has considered each environmental, social and health impacts and parameters for their monitoring. It also specifies the responsible party/parties for each action, responsible party as well as parameters for monitoring.

7.9: Contractor Management

The contractor staff shall be well informed and trained on the HSE policies and guidelines and be made aware of SPDC's HSE performance targets including the 12 Life Saving Rules. All activities shall be executed within the confines of relevant legislation and stakeholders' interests. Contractors shall provide adequate health services as well as site first aid services for its workforce. The first aid services shall be extended to visiting personnel. All project activities shall be properly managed through careful planning and the application of relevant HSE policies including the following:

- Enforcement of 12 Life Saving Rules.
- Job Hazard Analysis and toolbox meetings;
- Regular emergency drills;

Table 7.1: Environmental Monitoring Plan

Environmental component	**ASSOCIATED LIMITATIONS**		**MONITORING PROGRAMME**			
	Regulation/ Standard	**Requirements/ Limits**	**Parameters to be monitored**	**Sampling Location**	**Frequency** during Project Life cycle.	**Data collection method**
Air Quality	DPR EGASPIN III E 4.4.5 Table III-3 National Ambient Air Quality Standards	Daily average mean (μg/m^3) Total SPM: 60-90 Carbon monoxide: 10 SO_2: 100-150 NO_2: 150 Lead: 0.08ppm	SPM, NO_2, SO_2, CO, H_2S, NH_3, CH_4 Noise levels VOC, heavy and trace metals in ambient air	Wells location and camp	Monthly	Sample collection and analysis by a DPR/FMEnv approved Environmental Contractor
Soil	Baseline data	-	pH, Heavy metals and Organics	Wells location, camp and Chemical/Gasoline storage area	Monthly	Sample collection and analysis by a DPR/FMEnv approved Environmental Contractor

Environmental component	**ASSOCIATED LIMITATIONS**		**MONITORING PROGRAMME**			
	Regulation/ Standard	**Requirements/ Limits**	**Parameters to be monitored**	**Sampling Location**	**Frequency** during Project Life cycle.	**Data collection method**
Surface water (Recipient water)	Baseline data	-	p H, TSS, Turbidity, DO, COD, BOD, Heavy metals and Organics (TPH, Oil and grease, BTEX, PAH)	Upstream and downstream of wells and camp areas	Monthly	Sample collection and analysis by a DPR/FMEnv approved Environmental Contractor
Ground water	WHO, DPR and FMEnv Standards for Drinking Water		p H, TSS, Turbidity, DO, COD, BOD, Heavy metals and Organics (TPH, Oil and grease, BTEX, PAH), Heavy metals, Coliform	Wells and camp areas	Monthly	Sample collection and analysis by a DPR/FMEnv approved Environmental Contractor

Table 7.2: Environmental Management Plan for the impacts of the Bonny Deep Exploration Wells Project.

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
Pre-mobilization	• Consultation, • Land acquisition and • Compensation, Resolution of legacy issues	Increase in project awareness	HIGH	• SPDC shall ensure adequate consultation with all stakeholders especially communities. • SPDC shall carry out sound community sensing to evaluate existing relationship between SPDC & fence line communities, collate legacy projects & agree with community on ways of addressing them to change the perception to positive.	LOW	Stakeholders' engagement reports/agreement	Quarterly	Central Hub Asset Manager
		Anticipated Loss of land associated resources	HIGH	• Land take shall be limited to the minimum required. • SPDC shall	LOW	Site inspection report	Biannually	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				ensure consultation is done with the right responsible persons.		Vegetation studies report		
		Financial enhancement	POSITIVE	• SPDC shall discuss and agree on sustainable community development project and implement agreed projects, these will serve the whole fence line communities without bias. • SPDC shall sign and implement GMoU with communities; • Stakeholder's engagement shall be sustained through the	LOW	GMoU Community Engagement reports	Annually	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				project lifecycle. • SPDC shall encourage Infrastructural development via GMoU implementation				
		Third party agitation	HIGH	• Relevant stakeholders/legacy issues shall be identified. • Regular consultation with stakeholders (Govt., Community, NGOs, CBOs etc.) shall be carried out to understand community perceptions, issues and concerns • Effective liaison/communication channels	LOW	Employment records Community Engagement reports	Quarterly	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				(CICs) from the communities to the project execution team shall be established. • Project Advisory Committee (PAC) to guide MoU implementation shall be set up				
Mobilization	• Movement of equipment and personnel, • Rig movement	Loss of livelihood	HIGH	• Alternative income generating activities through skills acquisition that will empower communities shall be supported. • SPDC shall encourage skills acquisition and training programmes	LOW	Inspection records Employment records Community Engagement reports	Annually	Central Hub Asset Manager

Project phase	**Project activity**	**Description of impact**	**Cumulative Impact**	**Mitigation measures**	**Residual Impact**	**Parameter for Monitoring**	**Frequency of Monitoring / Formal Reporting**	**Responsible/ Action Party**
		Increase in road traffic, potential for accidents and injuries	HIGH	▪ Visible warning signs shall be placed at strategic positions along the roads ▪ SPDC shall ensure there is traffic control at strategic points along the road ▪ SPDC shall ensure all vehicles observe the speed limits and large vehicles have warning lights to alert other road users ▪ SPDC shall ensure all project vehicles are pre-mobbed and certified. ▪ Reverse alarm shall be installed	LOW	Site inspection/ stakeholder engagement reports IVMS checks/Reports Inventory of approved journey management forms	Quarterly	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				in all Operational vehicles ▪ Speed control facilities such as IVMS and Strata shall be installed in all vehicle ▪ The 12 Life Saving Rules (LSR) shall be enforced on all road users. ▪ Effective journey Management system ▪ Proper Risk Assessment (using JHA and Toolbox meeting) before work begins				
		Damage to road infrastructure	HIGH	▪ SPDC shall construct roads to its location where they do not exist and	LOW	Site inspection Inventory of	Quarterly	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				maintain existing roads to its location without refusing the general public from using same.		approved Journey Management forms		
		Influx of people causing Pressure on health and other Infrastructure	HIGH	▪ SPDC shall advise the contractor to locate recruitment office away from the work site to reduce job seekers at the site. ▪ Workers camps shall be provided for the workforce by the Contractor to reduce the pressure on housing. ▪ SPDC shall ensure access control is	LOW	Site inspection report	Biannually	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				implemented at work site ▪ Patronage of commercial sex workers by workforce shall be discouraged through health awareness campaigns to be conducted by SPDC. ▪ SPDC shall ensure unskilled and where feasible semi-skilled workers are sourced from immediate communities. ▪ SPDC shall honour all GMoU agreements ▪ SPDC and contractor shall provide for				

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				health care needs of workforce outside of those in the community. ▪ SPDC shall avoid the use of the communities' welfare facilities such as water, and Health facilities.				
		Increase in sexually transmitted disease and other communicable diseases	HIGH	▪ Workers shall be encouraged to undergo voluntary counselling and testing in order to know their HIV status and in turn guide behaviour ▪ SPDC shall enforce access control to base	LOW	Reports on community engagement sessions Health Report Site inspection	Quarterly	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				camps. ▪ SPDC shall enforce Alcohol and drug policy in the camps /worksite as part of culture of health.		report/tool box meetings		
		Reduction in air quality	HIGH	• SPDC shall ensure the use of sprinklers with high pressure water guns to minimize dust. • Health advise to the communities members (particularly the under aged) to stay away from construction site • Access control to the project area should enforced.	LOW	• Pre-mob certificates • Vehicle Maintenance records	Weekly	Central Hub Asset Manager
		Loss of vegetation	HIGH	• SPDC shall restrict project activities to	LOW	Inspection records	Biannually	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
		and wildlife		within agreed scope and establish bond walls / fencing to avoid encroachment into unplanned zones. • Any vegetation cleared in the lay-down area shall be re-planted with native species.		Site incident report		
		Habitat fragmentation	HIGH	• Clearing should be limited to areas of operation. • Wildlife reserves and sacred forests shall be identified and avoided. • Re-vegetation shall be undertaken after the project work where desirable.	LOW	Fragmentation index, Biodiversity reports, wildlife migration pattern	Annually	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
		Loss of aquatic species (Fisheries, Planktons and benthic fauna)	HIGH	• SPDC shall establish skill acquisition / training scheme. • SPDC shall implement Biodiversity Action Plan of the Gbaran Ubie IOGP. • Research and development shall be encouraged to prevent habitat alteration to the barest minimum.	LOW	Site inspection reports Environmental Complaince Monitoring report	Biannually	Central Hub Asset Manager
		Distortion of aquatic environment (physical components)	HIGH	• SPDC shall establish skill acquisition / training scheme. • SPDC shall implement Biodiversity Action Plan of the Gbaran Ubie IOGP.	LOW	Site inspection reports Environmental Complaince	Biannually	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				• Research and development shall be encouraged to prevent habitat alteration to the barest minimum.		Monitoring report		
		Increase in noise and vibration	HIGH	▪ Mufflers shall be installed on machineries and low noise generators shall be used. ▪ Noise level shall be monitored to ensure safe levels are not exceeded. ▪ There shall be no night work	LOW	• Pre-mob certificates • Maintenance records • Evidence of issuance of PPEs • Site inspection reports	Quarterly	Central Hub Asset Manager
		Increase in refined hydrocarbon contents of soil and vegetation	HIGH	• SPDC shall ensure fuel bunkering is done within stipulated bonded area that is leak proof to avoid	LOW	• Pre-mob certificates • Maintenance records • Evidence of issuance of PPEs	Quarterly	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				contamination. • SPDC shall encourage regular servicing of vehicles to reduce emissions from exhaust. • Vehicles should fuel and refuel at designated stations.		• Site inspection reports		
		Increase in crime rate	HIGH	• SPDC shall advise the contractor to site recruitment office away from the work site to reduce job seekers at the site. • SPDC shall ensure access control is implemented at work site • SPDC shall implement proper journey	MEDIUM	• Evidence of stakeholders engagements • Records of security incidences • Project security plan • Record of security orientation and	Quarterly	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				management system. • SPDC shall work with the Government, communities and other relevant agencies to improve security in the project area • SPDC shall ensure that security orientation and awareness is conducted for workforce. • SPDC shall ensure that security orientation and awareness is conducted for workforce.		awareness		
		Loss of cultural/herita	MEDIUM	• Historical sites/sacred places, fishing	LOW	Community engagement	Annually	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
		ge sites		sites/grounds and other areas of interest to the communities shall be avoided during land acquisition, and where unavoidable, agreements shall be reached with the respective communities & duly compensated for. • Designate authentic shrines as protected cultural properties		sessions Site inspection report		
		Soil compaction	LOW	• SPDC shall ensure that there is restriction to permanent wheel tracks. • SPDC shall ensure trucks	LOW	• Site inspection reports Environmental Complaince	Monthly	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				avoid waterlogged routes.		Monitoring report		
		Increase in waste	HIGH	▪ SPDC and contractors shall ensure that all wastes are segregated and managed according to EGASPIN/FME nv. ▪ Ensure proper documentation of the quantity of waste from generated site to disposal point	LOW	Waste consignment note Monitoring of recipient environment in line with EGASPIN 2002	Monthly	Central Hub Asset Manager
Construction	**Wells location** • Route & location clearing • Dredging, • Base camp activities • Pilling,	Increase in respiratory tract infection	HIGH	• SPDC shall wet the site before excavation and construction to minimize dust. • Health advise to the communities members (particularly the	LOW	Medical records Awareness records	Annually	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
	• Concrete and asphalt works,			under aged) to stay away from construction site • Access control to the project area should enforced				
		Land take	MEDIUM	• Land take shall be limited to the minimum required. • SPDC shall ensure consultation is done with the right responsible persons	LOW	• Site inspection reports • Evidence of support for farmer groups and cooperativ es	Annually	Central Hub Asset Manager
		Increase in population due to influx of persons	HIGH	• SPDC shall advise the contractor to site recruitment office away from the work site to reduce job seekers at the site. • SPDC shall ensure access control is	LOW	Community engagement report Site inspection reports	Quarterly	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				implemented at work site • SPDC shall ensure health awareness campaigns are conducted for workforce on the risks of STIs from the services of CSWs to discourage patronage • SPDC shall ensure unskilled and where feasible semi-skilled workers are sourced from immediate communities • SPDC shall support existing health facilities upgrade and staff training. • SPDC will house				

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				workers in camps to reduce pressure and local housing stock. • SPDC shall comply with local content policy.				
		Increase in social vices (Alcohol and drug abuse, CSWs)	HIGH	▪ Ensure the implementation of the company's alcohol and drug policies ▪ Pre-activity health/sex education campaign shall be conducted for both workforce and communities.	LOW	Reports on community engagement sessions Site inspection report/tool box meetings	Quarterly	Central Hub Asset Manager
		Crime and insecurity (Kidnapping, Hostage-taking, armed robbery, Militancy)	HIGH	• SPDC shall advise the contractor to site recruitment office away from the work site to reduce job	MEDIUM	• Evidence of stakeholders engagements • Records of	Quarterly	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				seekers at the site. • SPDC shall ensure access control is implemented at work site • SPDC shall implement proper journey management system. • SPDC shall work with the Government, communities and other relevant agencies to improve security in the project area • SPDC shall ensure that security orientation and awareness is conducted for workforce. • SPDC shall		security incidences • Project security plan • Record of security orientation and awareness		

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				ensure that security orientation and awareness is conducted for workforce.				
		Injury/fatality of workforce and/or third party	HIGH	• SPDC shall enforce the use of appropriate PPEs (life jackets, work vests/ goggles etc). • SPDC shall ensure first aid box on site and emergency response and med-rescue/medevac are in place. • Toolbox meetings shall be held before the start of daily tasks • Awareness shall be created among site workers on	LOW	Competence certification of workforce Emergency response plan HAZID register Pep-talk records	Quarterly	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				the likelihood of exposure to poisonous wildlife & plants. • Trained First Aiders shall form part of the workforce • SPDC policy on road traffic journey management shall be adhered to (all journey must be approved, no night journeys, speed limits on land)				
		Marine traffic disruption	HIGH	SPDC shall adhere to approved marine journey management Plan SPDC shall ensure that boats are premobbed and in	LOW	• Journey management records • Pre-mob certificates • Pep-talk records	Weekly	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				good conditions SPDC shall plan marine movement at off peak hours to avoid disruption of movement for other water users. SPDC Shall ensure that marine movements are carried out in such a manner that local boat users are not nagetively affected		• Monitoring Analysis		
		Increase in volume of wastes	HIGH	▪ SPDC and contractors shall ensure that all wastes are segregated and managed according to EGASPIN/FME	LOW	Waste consignment note Environmental compliance	Monthly	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				nv guidelines. ▪ Health Education for members of the communities on the management of waste. ▪ Ensure proper documentation of the quantity of waste from generated site to disposal point		monitoring report		
		Increase in employment/ business opportunities	POSITIVE	NA	POSITIVE	-	-	-
		Shift from traditional occupations	HIGH	• SPDC shall discuss and agree on sustainable community development project and implement agreed projects.	LOW	Status report on traditional occupation Implement	Annually	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
						GMoU		
		Inflation	HIGH	• Alternative income generating activities through skills acquisition that will empower communities shall be introduced and supported by SPDC and Contactors. • SPDC and Contractors shall provide accommodation for operational staff at the base camps and provide catering services.	LOW	Implement GMoU	Annually	Central Hub Asset Manager
		Potential for skills acquisition	P	NA	POSITIVE	-	-	-

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
		Pressure on existing infrastructure and services (Water, Electricity, Recreational facilities, Health facilities, Roads and others)	HIGH	▪ SPDC shall advise the contractor to locate recruitment office away from the work site to reduce job seekers at the site ▪ Workers camps shall be provided for the workforce by the Contractor to reduce the pressure on housing. ▪ SPDC shall ensure access control is implemented at work site ▪ Patronage of commercial sex workers by workforce shall	LOW	Site inspection report	Annually	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				be discouraged through health awareness campaigns to be conducted by SPDC. ▪ SPDC shall ensure unskilled and where feasible semi-skilled workers are sourced from immediate communities. ▪ SPDC shall honour all GMOU agreements ▪ SPDC and contractor shall provide for health care needs of workforce outside of those in the community.				

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				▪ Construction should be done in phases so as to reduce the number of workers at site in any particular time ▪ Health education on communicable disease transmissions.				
		Increase in communicable diseases, STIs HIV/AIDS	HIGH	▪ Workers shall be encouraged to undergo voluntary counselling and testing in order to know their HIV status and in turn guide behaviour ▪ SPDC shall enforce access control to base camps	LOW	Medical records Access Control/ID card Awareness records	Annually	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				▪ SPDC shall enforce Alcohol and drug policy in the camps /worksite as part of culture of health.				
		Change in topography	HIGH	• Trenching shall be limited to the minimum size required and excavated sand managed properly. • Fill material for sand filling shall be sourced from BYSMENV approved sites	LOW	Site inspection report	Quarterly	Central Hub Asset Manager
		Surface water pollution/distortion (increase in turbidity and Total Suspended	HIGH	SPDC shall deploy the most appropriate technology (silt curtain), to minimize loss of benthic organisms.	LOW	Environmental Compliance monitoring report Site	Quarterly	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
		Solids)				inspection report		
		Soil pollution	HIGH	• Wastes shall be segregated at source into color-coded or labelled bins and disposed of in line with a project specific waste management plan. • Safe Handling of Chemicals (SHOC) cards shall be visibly displayed at all sites where chemicals are handled • Fuel, lube oils and chemicals shall be safely stored in containers in bunded areas	LOW	Site inspection report ECM report	Quarterly	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
		Loss of biodiversity and Distortion of food chain (Economic trees)	HIGH	• Any vegetation cleared in the lay-down area shall be re-planted with native species. • SPDC shall ensure awareness campaigns are conducted for the workforce on the need to preserve the environment. • Route clearing shall be done in stages to allow mobile fauna escape from the project area.	LOW	Inspection records Site incident report Environmental Compliance monitoring report	Annually	Central Hub Asset Manager
		Impairment/Loss of aquatic life (Loss of juvenile fishes due to gill damage from silt particles)	HIGH	SPDC shall deploy the most appropriate technology (silt curtain), to minimize loss of benthic organisms and fishery resources.	LOW	Inspection records Environmental compliance monitoring	Quarterly	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
						report Site incident report		
		Increase in disease vectors	HIGH	▪ SPDC shall assist the communities in pest control measures ▪ Health education on the Health Implication of Rodents/other disease vectors in their homes. ▪ SPDC shall ensure that waste generated from the project during the period of construction are managed from cradle to grave. ▪ Health	LOW	Pep Talks/tool box meetings Health Records for all the workforce	Monthly Annually	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				education on the consumption of rodents shall be provided by appropriate health authorities				
		Blockage of natural water courses	HIGH	SPDC shall ensure that no natural water course is unduly obstructed /blocked during the implementation of the project, equalization culverts shall be installed where necessary.	LOW	Inspection records Site incident report	Quarterly	Central Hub Asset Manager
		Increase in road traffic/ potential for accidents and injuries	HIGH	• Road safety awareness campaigns for both workers and the community. • Medical facilities shall be provided on-site with critical cases	LOW	• Journey managem ent records • Pre-mob certificat es • Pep-talk records	Weekly	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				transferred to retainer clinics in Yenagoa or Port Harcourt. • SPDC shall ensure Med-rescue/medevac services are adequate and in place. • Visible warning signs shall be placed at strategic positions along the roads. • SPDC shall ensure there is traffic control at strategic points along the road. • SPDC shall ensure all vehicles observe the speed limits and large vehicles have warning lights to alert		• Certificate of defensive driving • Vehicle Monitoring Analysis		

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				other road users. • SPDC shall ensure all project vehicles are pre-mobbed and certified				
		Food insecurity	HIGH	▪ Livewire Program shall be introduced for the youths in the communities	LOW	Shell briefing note	Annually	Central Hub Asset Manager
		Erosion	HIGH	SPDC shall ensure that no natural water course is unduly obstructed/blocked during the implementation of the project, equalization culverts shall be installed.	LOW	Inspection records Site incident report	Annually	Central Hub Asset Manager
		Loss of fish breeding sites and migratory routes	HIGH	• SPDC shall reduce vegetation clearing to the minimum. • SPDC shall implement the	LOW	Site incident report	Bi-annually	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				Biodiversity Action Plan • SPDC shall optimize the existing pipelines RoW and roads.				
		Noise and vibration	HIGH	▪ Mufflers shall be installed on machineries and low noise generators shall be used. ▪ Noise level shall be monitored to ensure safe levels are not exceeded. ▪ There shall be no night work	LOW	• Pre-mob certificates • Maintenance records • Evidence of issuance of PPEs • Environmental compliance monitoring report	Weekly	Central Hub Asset Manager
		Reduction in air quality	HIGH	• SPDC shall wet the site before excavation and construction to minimize dust. • Health advise to the communities members	LOW	• Pre-mob certificates • Vehicle Maintenance records • Environmental compliance	Weekly	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				(particularly the under aged) to stay away from construction site • Access control to the project area shall be enforced.		monitoring report		
		Opportunity for direct and indirect Employment	POSITIVE	NA	POSITIVE	-	-	-
		Opportunity for wealth creation	POSITIVE	NA	POSITIVE	-	-	-
		Opportunity for Corporate Social Responsibility	POSITIVE	NA	POSITIVE	-	-	-
		Exposure to radioactive materials	HIGH	• SPDC shall ensure that only certified personnel handle radioactive materials.	LOW	Certification of workforce Emergency response plan	Monthly During activities involving	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				• SPDC shall ensure that radioactive materials are stored safely. • SPDC shall ensure toolbox talks are conducted before the commencement of the job. • SPDC shall ensure appropriate PPEs are used by the workers		HAZID register Pep-talk records	radioactive materials – welding, NDT	
		Third party agitation	HIGH	• SPDC shall enlighten its contractors and project personnel prior to deployment on proper conduct within stakeholder communities	LOW	Minutes of consultation sessions Evidence of GMoU agreement and implementat	Monthly	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				• SPDC shall maintain effective liaison/communication with communities and ensure the community cultural profile is not infringed.		ion Site reports on how disputes were settled		
		Potential attack from wild/predatory animals (Snakes, Scorpions)	HIGH	SPDC shall ▪ SPDC shall ensure that waste generated from the project during the period of construction are managed from cradle to grave. ▪ The site clinic shall stock anti-snake bite venom ▪ Awareness shall be created among workers on the	LOW	Inspection records Site incident report	Monthly	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				possibility of exposure to poisonous wildlife ▪ Ensure adequate Medivac system and on site referral system.				
		Increase in exposure to transborder diseases (Zika virus, Ebola, Birdflu, SARS), Antimicrobial resistant bacteria	HIGH	▪ SPDC shall ensure that Expatriate staff pass through proper immigration Health checks before arriving at the worksite. ▪ SPDC shall ensure Health education is part of orientation for all foreign staff. ▪ Fitness–to-Work protocol must be adhered strictly to and	LOW	Inspection records Site incident report	Monthly	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				Implemented by site supervisors and OHNs.				
		Crime and insecurity (Kidnapping, Hostage-taking, armed robbery, Militancy)	HIGH	SPDC shall • advise the contractors to site recruitment office away from the work site to reduce job seekers at the site • SPDC shall ensure access control is implemented at work site. • SPDC shall implement proper journey management system. • Work with the Government, communities and other relevant agencies to	LOW	• Evidence of stakeholders engagements • Records of security incidences • Project security plan • Record of security orientation and awareness	Monthly	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				improve security in the project area. • ensure that security orientation and awareness is conducted for workforce. • Work with the Government, communities and other relevant agencies to improve security in the project area • ensure that security orientation and awareness is conducted for workforce.				
		Potential reduction in household water quality and	HIGH	• SPDC shall provide water for their staff in the camps during construction and	LOW	Site Inspection records	Annually	Central Hub Asset Manager

Project phase	**Project activity**	**Description of impact**	**Cumulative Impact**	**Mitigation measures**	**Residual Impact**	**Parameter for Monitoring**	**Frequency of Monitoring / Formal Reporting**	**Responsible/ Action Party**
		contamination of potable water		operations. • Large proportion of the semi-skilled and un-skilled labours shall be sourced from the communities to reduce migrant workers. • Staff recruitment shall be done outside the communities for skilled labours not excluding the members of the communities.				
		Temporary disruption of local fishing/harvesting activities.	MEDIUM	SPDC shall ensure strict compliance with good marine journey management practice, including sensitization of quarter masters / boat masters on how to	LOW	• Pre-mob certificates • Maintenance records • Evidence of issuance of PPEs	Quarterly	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				pass fishing and commercial boat				
		Acidification of the soil and surface water as a result of deposition of dredge spoils on the banks of the river	MEDIUM	SPDC shall ensure dredge spoil is deposited at least 10 metres into the buffer zone or Cap spoil with clean sand.	LOW	Site Inspection records Environmental Compliance monitoring	Quarterly	Central Hub Asset Manager
		Spoil disposal will smother epifauna and impair surface drainage especially in wetland areas	MEDIUM	SPDC shall dispose dredge spoils in an environmentally-friendly manner	LOW	Site Inspection records Environmental Compliance	Quarterly	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
						monitoring		
		Disaggregation of benthic habitats and loss of benthic organisms.	MEDIUM	SPDC shall adopt due diligence to minimize adverse impacts on benthic organisms	LOW	Site Inspection records Environmental Compliance monitoring	Quarterly	Central Hub Asset Manager
		Disturbance of riverbed topography and re-suspension of	MEDIUM	SPDC shall ensure minimal disturbance to the river bed during pipeline crossing.	LOW	Site Inspection records	Quarterly	Central Hub Asset Manager

Project phase	**Project activity**	**Description of impact**	**Cumulative Impact**	**Mitigation measures**	**Residual Impact**	**Parameter for Monitoring**	**Frequency of Monitoring / Formal Reporting**	**Responsible/ Action Party**
		fine sediments and bottom materials						
		Disturbance of riverbed topography	MEDIUM	SPDC shall ensure minimal disturbance to the river bed during pipeline crossing.	LOW	Site Inspection records	Quarterly	Central Hub Asset Manager
	Well Drilling and completion	Increase in noise & vibration nuisance	HIGH	• SPDC shall provide PPEs (ear muffs, eye goggles) for drilling staff. • Where possible SPDC shall provide acoustic enclosure for noisy equipment. • First Aid boxes shall be provided at the drilling site and trained First	LOW	Site Inspection records	Weekly	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				Aiders remain part of the workforce.				
		Increase in light nuisance	HIGH	• Construction activities requiring continuous light at night shall be reduced to the barest minimum. • Construction activities shall be completed on schedule	LOW	• Pre-mob certificates • Maintenance records • Evidence of issuance of PPEs	Monthly	Central Hub Asset Manager
		Generation of drilling waste	HIGH	• SPDC shall ensure that high G-shakers are used to reduce the amount of mud in drill cuttings. • Recovered drilling mud shall be stored in containers for re-use. • Where feasible cuttings re-	LOW	Site Inspection records	Monthly	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				injection shall be utilized				
		Contamination of environment (soils/surface and groundwater)	HIGH	• All generated wastes shall be managed in accordance with the provisions of the SPDC Waste Management Guidelines. • Where contamination occurs SPDC shall clean up and remediate as appropriate.	LOW	Waste consignment note Environmental Compliance monitoring report	Quarterly	Central Hub Asset Manager
		Work related injury/fatality of workforce	HIGH	• Workers shall use appropriate PPEs (life jackets, work vests/ goggles etc) • SPDC shall ensure first aid box on site and emergency response and med-	LOW	Certification of workforce Emergency response plan HAZID register Pep-talk	Monthly	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				rescue/medevac are in place. • Toolbox meetings shall be held before the start of daily tasks • Awareness shall be created among site workers on the likelihood of exposure to poisonous wildlife & plants. • Trained First Aiders shall form part of the workforce. • SPDC policy on road and water borne traffic journey management shall be adhered to (all journey must be approved, no night journeys, speed limits on		records		

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				land and water.				
		Non work related injury/fatality of workforce	HIGH	• SPDC shall ensure all the workers at site have a medical fitness to work and are in good physical and mental health. • SPDC policy on road and water borne traffic journey management shall be adhered to (all journey must be approved, no night journeys, speed limits on land and water.	LOW	Certification of workforce Emergency response plan HAZID register Pep-talk records	Monthly	Central Hub Asset Manager
		Increase in explosion potential (Well blowout)	HIGH	• Firefighting extinguishers shall be provided at worksites. • Emergency response procedures shall	LOW	Inspection records Site incident	Quarterly	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				be put in place. • SPDC shall use the optiwell (bore hole management) process & other industry best practice to drill wells.		report		
		Increase in diseases STIs, HIV/AIDS	HIGH	▪ Workers shall be encouraged to undergo voluntary counselling and testing in order to know their HIV status and in turn guide behaviour ▪ SPDC shall ensure condoms are provided for workers at the site clinic and distributed to the communities ▪ SPDC shall	LOW	Medical records Awareness records	Biannually	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				enforce access control to base camps ▪ SPDC shall enforce Alcohol and drug policy in the camps /worksite as part of culture of health.				
		Increase in endemic diseases	HIGH	• SPDC shall support existing health facilities upgrade and staff training. • SPDC shall maintain workers in camp and provide access control measure to reduce intermingling with host communities.	LOW	Medical records Awareness records	Biannually	Central Hub Asset Manager
		Emergent Infectious diseases	HIGH	▪ SPDC shall ensure that waste generated	LOW	Medical records	Biannually	Central Hub Asset Manager

Project phase	**Project activity**	**Description of impact**	**Cumulative Impact**	**Mitigation measures**	**Residual Impact**	**Parameter for Monitoring**	**Frequency of Monitoring / Formal Reporting**	**Responsible/ Action Party**
		resulting from displacement of disease vectors (rodents and monkeys)		from the project during the period of construction are managed from cradle to grave. ▪ Health education on the consumption of rodents shall be provided by appropriate health authorities.		Awareness records		
		Potential for development of infrastructures and economic enhancement	P	NA	POSITIVE	-	-	-
		Increase in road traffic volume & accident potential/injur	HIGH	• SPDC policy on road and water borne traffic journey management shall be adhered to (all	LOW	• Journey management records • Pre-mob	Weekly	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
		ies		journey must be approved, no night journeys, speed limits on land and water • SPDC shall upgrade existing roads to suite the anticipated project activities and additional access road provided, where necessary		certificates • Pep-talk records • Certificate of defensive driving • Vehicle Monitoring Analysis		
		Opportunity for direct and indirect Employment (Unskilled labour)	P	NA	POSITIVE	-	-	-
		Opportunity for wealth creation	P	NA	POSITIVE	-	-	-
		Opportunity for Corporate Social	P	NA	POSITIVE	-	-	-

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
		Responsibility						
		Gender imbalance	HIGH	• SPDC shall enforce existing laws against gender-based employment discrimination and against sexual harassment. • SPDC shall Increase mentorship and other efforts to boost the number of women in traditionally male occupations.	LOW	Community engagement sessions	Annually	Central Hub Asset Manager
		Potential for skills acquisition	P	NA	P	-	-	-
		Pressure on existing infrastructure and services	HIGH	▪ SPDC shall advise the contractor to locate recruitment	LOW	Site inspection report	Biannually	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
		(Water, Electricity, Recreational facilities, Health facilities, Roads and others)		office away from the work site to reduce job seekers at the site ▪ Workers camps shall be provided for the workforce by the Contractor to reduce the pressure on housing. ▪ SPDC shall ensure access control is implemented at work site ▪ Patronage of commercial sex workers by workforce shall be discouraged through health awareness campaigns to be conducted by SPDC.				

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				▪ SPDC shall ensure unskilled and where feasible semi-skilled workers are sourced from immediate communities. ▪ SPDC and contractor shall provide for health care needs of workforce outside of those in the community. ▪ Construction should be done in phases so as to reduce the number of workers at site in any particular time.				
		Third party agitation	HIGH	▪ SPDC shall implement the	LOW	Employment records	Biannually	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				PGMOU in line with agreed template. ▪ SPDC shall enlighten its contractors and project personnel prior to deployment on proper conduct within stakeholder communities and maintain effective liaison/communication with communities and ensure the community's economic and cultural profiles are not infringed.		Community Engagement reports		
		Exposure to radioactive materials	HIGH	▪ SPDC shall ensure that only certified personnel handle radioactive	LOW	Certification of workforce Emergency response	Quarterly	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				materials. ▪ SPDC shall ensure that radioactive materials are stored safely. ▪ SPDC shall ensure toolbox talks are conducted before the commencement of the job ▪ SPDC shall ensure appropriate PPEs are used by the workers		plan HAZID register Pep-talk records		
		Crime and insecurity (Kidnapping, Hostage-taking, armed robbery, Militancy)	HIGH	• SPDC shall advise the contractor to site recruitment office away from the work site to reduce job seekers at the site. • SPDC shall	MEDIUM	• Evidence of stakeholders engagements • Records of security incidences	Monthly	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				ensure access control is implemented at work site • SPDC shall implement proper journey management system. • SPDC shall work with the Government, communities and other relevant agencies to improve security in the project area • SPDC shall ensure that security orientation and awareness is conducted for workforce. • SPDC shall ensure that security		• Project security plan • Record of security orientation and awareness		

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				orientation and awareness is conducted for workforce.				
		Discharge of untreated test water into the receiving environment	MEDIUM	SPDC waste management specifications and guidelines (especially with regards to the discharges into the environment) shall be complied with.	LOW	Inspection records Site incident report	Quarterly	Central Hub Asset Manager
	Commissioning & Handover	Increase in Business opportunities	P	NA	POSITIVE	-	-	-
		Gas flaring from well tests	HIGH	SPDC shall ensure • Safety signage shall be deployed at strategic locations. • Emergency response plan shall be in place • Use of appropriate PPEs	LOW	Certification of workforce Emergency response plan HAZID register Pep-talk	Quarterly	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				• provision of adequate firefighting equipment		records		
		Increase in noise & vibration nuisance	HIGH	▪ Mufflers shall be installed on machineries and low noise generators shall be used. ▪ Noise level shall be monitored to ensure safe levels are not exceeded. ▪ There shall be no night work ▪ Noise in the communities shall be measured every three months	LOW	• Pre-mob certificates • Maintenance records • Evidence of issuance of PPEs • Site inspection reports Environmental compliance monitoring report	Weekly	Central Hub Asset Manager
		Generation of waste (Pigging waste,	HIGH	▪ SPDC and contractors shall ensure that all wastes are	LOW	Waste consignment note	Monthly	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
		domestic waste, metal scraps, plastics)		segregated and managed according to EGASPIN and FMEnv guidelines. ▪ Enforce access control to ensure that wastes are not indiscriminately transferred from one place to the other by members of the communities in the act of picking properties. ▪ Ensure proper documentation of the quantity of waste from generated site to disposal point		Monitoring of recipient environment in line with EGASPIN 2002		
		Contamination of environment	HIGH	• Waste management plans (in line with	LOW	Waste consignment note	Quartely	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
		(soils/surface and groundwater, Air quality)		regulatory guidelines and SPDC procedures) shall be strictly adhered to during all phases of the project. • Wastes shall be segregated at source into color-coded or labelled bins and disposed of in line with a project specific waste management plan. • SPDC shall ensure that sewage wastes in base camps are properly managed. • Safe Handling of Chemicals (SHOC) cards		Monitoring of recipient environment in line with EGASPIN 2002		

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				shall be visibly displayed at all sites where chemicals are handled • Fuel, lube oils and chemicals shall be safely stored in containers in bonded areas				
		Work related injury/fatality of workforce	HIGH	▪ Workers shall use appropriate PPEs (life jackets, work vests/ goggles etc) ▪ SPDC shall ensure first aid box on site and emergency response and medevac are in place ▪ Toolbox meetings shall be held before the	LOW	Certification of workforce Emergency response plan HAZID register Pep-talk records	Monthly	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				start of daily tasks ▪ Awareness shall be created among site workers on the likelihood of exposure to poisonous wildlife & plants ▪ Trained First Aiders shall form part of the workforce in the ratio of 1:25 ▪ Ensure adequate MEDEVAC and referral system				
		Non work related injury/fatality of workforce	HIGH	• SPDC shall ensure every worker have a medical certificate of fitness to work. • SPDC shall ensure that workers suffering	LOW	Certification of workforce Emergency response plan HAZID register	Monthly	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				from terminal diseases are not accommodate in camp. • SPDC shall ensure that a trained medic is assigned to the site camp.		Pep-talk records		
		Increase in explosion potential	HIGH	• Firefighting extinguishers shall be provided at worksites • Emergency response procedures shall be put in place. • SPDC shall use the optiwell (bore hole management) process & other industry best practice to drill her wells	LOW	Certification of workforce Emergency response plan HAZID register Pep-talk records	Quarterly	Central Hub Asset Manager
		Increase in diseases STIs,	HIGH	▪ Workers shall be encouraged to	LOW	Medical records	Monthly	Central Hub

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
		HIV/AIDS		undergo voluntary counselling and testing in order to know their HIV status and in turn guide behaviour ▪ SPDC shall enforce access control to base camps ▪ SPDC shall enforce Alcohol and drug policy in the camps /worksite as part of culture of health.		Awareness records		Asset Manager
		Increase in endemic diseases (Malaria, Typhoid, RTI)	HIGH	▪ Carryout health education on the Rollback Malaria interventions. ▪ Ensure adequate referral system	LOW	Medical records Awareness records	Monthly	Central Hub Asset Manager
		Development of	P	NA	POSITIVE	-	-	-

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
		infrastructures and economic enhancement (GMoU)						
		Increase in road traffic volume & accident potential/injuries	HIGH	• SPDC shall ensure all vehicles are pre-mobbed and certified. • Visible warning signs shall be placed on roads and vehicle. • SPDC shall ensure all drivers undergo the defensive driving course and are certified. • Vehicle monitoring and communication devices shall be installed in project vehicles.	LOW	Site inspection/ stakeholder engagement reports IVMS checks/Reports Inventory of approved journey management forms	Quarterly	Central Hub Asset Manager

Project phase	**Project activity**	**Description of impact**	**Cumulative Impact**	**Mitigation measures**	**Residual Impact**	**Parameter for Monitoring**	**Frequency of Monitoring / Formal Reporting**	**Responsible/ Action Party**
				• SPDC shall ensure journey management and 'no night driving policy' shall be adhered to. • SPDC shall ensure compulsory medical fitness test for all drivers				
		Opportunity for direct and indirect Employment (Unskilled labour)	P	NA	POSITIVE	-	-	-
		Opportunity for wealth creation	P	NA	POSITIVE	-	-	-
		Loss of Employment (local labour) (Boom burst cycle)	HIGH	SPDC shall as long as reasonably possible ensure the engagement of community members when actual	LOW	Community Engagement reports	Biannually	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				production begins				
		Third party agitation	HIGH	• SPDC shall implement the GMoU in line with agreed template. • SPDC shall enlighten its contractors and project personnel prior to deployment on proper conduct within stakeholder communities and maintain effective liaison/communication with communities and ensure the community's economic and cultural profiles are not infringed.	LOW	Employment records Community Engagement reports	Biannually	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
		Crime and insecurity (Kidnapping, Hostage-taking, armed robbery, Militancy)	HIGH	• SPDC shall advise the contractor to site recruitment office away from the work site to reduce job seekers at the site. • SPDC shall ensure access control is implemented at work site • SPDC shall implement proper journey management system. • SPDC shall work with the Government, communities and other relevant agencies to improve security in the project area • SPDC shall	MEDIUM	• Evidence of stakeholders engagements • Records of security incidences • Project security plan • Record of security orientation and awareness	Monthly	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				ensure that security orientation and awareness is conducted for workforce. • SPDC shall ensure that security orientation and awareness is conducted for workforce.				
		Alcohol and drug abuse	HIGH	▪ Ensure the implementation of the company's alcohol and drug policies ▪ Pre-activity health/sex education campaign shall be conducted for both workforce and communities.	LOW	Reports on community engagement sessions Site inspection report/tool box meetings	Quarterly	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
Demobilization		Increase in road traffic, potential for accidents and injuries	HIGH	• Visible warning signs shall be placed at strategic positions along the roads. • SPDC shall ensure there is traffic control at strategic points along the road. • SPDC shall ensure all vehicles observe the speed limits and large vehicles have warning lights to alert other road users. • SPDC shall ensure all project vehicles are pre-mobbed and certified	LOW	Site inspection/ stakeholder engagement reports IVMS checks/Reports Inventory of approved journey management forms	Quarterly	Central Hub Asset Manager
		Damage to road infrastructure	HIGH	SPDC shall built roads to its location where they do not exist and maintain	LOW	Site inspection	Quarterly	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				existing roads to its location without refusing the general public from using same.		Inventory of approved Journey Management forms		
		Impairment in air quality	HIGH	• SPDC shall wet the site before excavation and construction to minimize dust. • Health advise to the communities members (particularly the under aged) to stay away from construction site • Access control to the project area should enforced • Health education shall be delivered to the communities members on the need to	LOW	• Pre-mob certificates • Vehicle Maintenance records	Weekly	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				dependence on the use of firewood due to negative health effect.				
		Increase in noise and vibration	HIGH	▪ Mufflers shall be installed on machineries and low noise generators shall be used. ▪ Noise level shall be monitored to ensure safe levels are not exceeded. ▪ There shall be no night work ▪ Noise in the communities shall be measured every three months	LOW	• Pre-mob certificates • Maintenance records • Evidence of issuance of PPEs • Site inspection reports	Weekly	Central Hub Asset Manager
		Increase in crime rate	HIGH	• SPDC shall advise the contractor to site recruitment office	MEDIUM	• Evidence of stakeholders	Monthly	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				away from the work site to reduce job seekers at the site. • SPDC shall ensure access control is implemented at work site • SPDC shall implement proper journey management system. • SPDC shall work with the Government, communities and other relevant agencies to improve security in the project area • SPDC shall ensure that security orientation and awareness is		engagements • Records of security incidences • Project security plan • Record of security orientation and awareness		

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				conducted for workforce. • SPDC shall ensure that security orientation and awareness is conducted for workforce.				
		Soil compaction	LOW	• SPDC shall ensure that there is restriction to permanent wheel tracks. • SPDC shall ensure trucks avoid waterlogged routes.	LOW	• Site inspection reports	Quartely	Central Hub Asset Manager
		Waste generation (Scrap metals, Woods, Food , Plastic wastes, etc.)	HIGH	• Waste management plans (in line with regulatory guidelines and SPDC procedures) shall be strictly	LOW	Waste consignment note Monitoring of recipient environment	Monthly	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				adhered to during all phases of the project. • Wastes shall be segregated at source into color-coded or labelled bins and disposed of in line with a project specific waste management plan		in line with EGASPIN 2002		
		Opportunity for contracting	P	NA	POSITIVE	-	-	-
		Opportunity for direct and indirect Employment (Unskilled labour)	P	NA	POSITIVE	-	-	-
		Loss of Employment (local labour)	HIGH	SPDC shall • support entrepreneurial skill development and	LOW	Contractor engagement report, employment	Quarterly	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				opportunities for community members to cushion the effect of reduction in economic/income generating activities.		records		
		Third party agitation	HIGH	• SPDC shall discuss and agree on sustainable community development project and implement agreed projects, these will serve the whole fence line communities without bias. • SPDC shall sign and implement GMoU with communities; • SPDC shall sustain stakeholders	LOW	Employment records Community Engagement reports	Quarterly	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				engagement throughout the project lifecycle. • SPDC shall ensure Infrastructural development via GMoU implementation				
		Crime and insecurity (Kidnapping, Hostage-taking, armed robbery, Militancy)	HIGH	• SPDC shall advise the contractor to site recruitment office away from the work site to reduce job seekers at the site. • SPDC shall ensure access control is implemented at work site • SPDC shall implement proper journey management system.	MEDIUM	• Evidence of stakeholders engagements • Records of security incidences • Project security plan • Record of security orientation and awareness	Monthly	Central Hub Asset Manager

Project phase	**Project activity**	**Description of impact**	**Cumulative Impact**	**Mitigation measures**	**Residual Impact**	**Parameter for Monitoring**	**Frequency of Monitoring / Formal Reporting**	**Responsible/ Action Party**
				• SPDC shall work with the Government, communities and other relevant agencies to improve security in the project area • SPDC shall ensure that security orientation and awareness is conducted for workforce. • SPDC shall ensure that security orientation and awareness is conducted for workforce.				
		Increase in RTIs due to dust particles	HIGH	• SPDC shall wet the site before excavation and construction to minimize dust.	LOW	Medical records	Biannually	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				• Health advise to the communities members (particularly the under aged) to stay away from construction site • Access control to the project area should enforced		Awareness records		
		Increased exposure to carcinogenic substances	HIGH	• SPDC shall ensure that only certified personnel handle radioactive materials. • SPDC shall ensure that radioactive materials are stored safely. • SPDC shall ensure toolbox talks are conducted before the commencement	LOW	Medical records Awareness records Site incident report HAZID register Pep-talk records	Biannually	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				of the job • SPDC shall ensure appropriate PPEs are used by the workers				
		Alcohol and drug abuse	HIGH	▪ Ensure the implementation of the company's alcohol and drug policies. ▪ Carryout awareness campaign on alcohol and drug abuse in schools, churches and town halls to reduce alcohol intake in the communities. ▪ Pre-activity health/sex education campaign shall be conducted for both workforce	LOW	Reports on community engagement sessions Site inspection report/tool box meetings	Biannually	Central Hub Asset Manager

Project phase	**Project activity**	**Description of impact**	**Cumulative Impact**	**Mitigation measures**	**Residual Impact**	**Parameter for Monitoring**	**Frequency of Monitoring / Formal Reporting**	**Responsible/ Action Party**
				and communities.				
Decommissioning and abandonment	• • Removal of surface installations • Plugging of wells • Site restoration • Return of land to owner(s)	Increase in potential for soil and water contamination	HIGH	SPDC shall ensure: • all wastes are properly segregated and contained before disposal • all wastes are properly disposed of and monitored from cradle to grave • All effluents are treated to regulatory limits before discharge	LOW	• Waste consignment note • Monitoring of recipient environment in line with EGASPIN 2002	Quartely	Central Hub Asset Manager
		Increase in litigation potential	HIGH	• The relevant stakeholders/legacy issues shall be identified • Regular consultation with stakeholders (Govt., Community, NGOs, CBOs etc.) shall be undertaken. • Project Advisory	LOW	Stakeholders engagement session	Biannually	Central Hub Asset Manager

Project phase	**Project activity**	**Description of impact**	**Cumulative Impact**	**Mitigation measures**	**Residual Impact**	**Parameter for Monitoring**	**Frequency of Monitoring / Formal Reporting**	**Responsible/ Action Party**
				Committee (PAC) shall be set up to guide MOU implementation and address issues/concerns				
		Loss of job by community surveillance team	HIGH	SPDC shall • support entrepreneurial skill development and opportunities for community members to cushion the effect of reduction in economic/income generating activities.	LOW	Contractor engagement report, employment records	Quarterly	Central Hub Asset Manager
		Increase in usable land resource to the community	POSITIVE	NA	POSITIVE	-	-	-
		Opportunity for	POSITIVE	NA	POSITIVE	-	-	-

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
		contracting						
		Opportunity for direct and indirect Employment (Unskilled labour)	POSITIVE	NA	POSITIVE	-	-	-
		Third party agitation	HIGH	• SPDC shall discuss and agree on sustainable community development project and implement agreed projects, these will serve the whole fence line communities without bias. • SPDC shall sign and implement GMoU with communities; • SPDC shall sustain stakeholders	LOW	Minutes of consultation sessions Evidence of GMoU agreement and implementation Site reports on how disputes were settled	Quarterly	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				engagement throughout the project lifecycle. • SPDC shall ensure Infrastructural development via GMoU implementation				
		Crime and insecurity (Kidnapping, Hostage-taking, armed robbery, Militancy) and other social vices	HIGH	• SPDC shall advise the contractor to site recruitment office away from the work site to reduce job seekers at the site. • SPDC shall ensure access control is implemented at work site • SPDC shall implement proper journey management system.	LOW	• Evidence of stakeholders engagements • Records of security incidences • Project security plan • Record of security orientation and awareness	Quarterly	Central Hub Asset Manager

Project phase	**Project activity**	**Description of impact**	**Cumulative Impact**	**Mitigation measures**	**Residual Impact**	**Parameter for Monitoring**	**Frequency of Monitoring / Formal Reporting**	**Responsible/ Action Party**
				• SPDC shall work with the Government, communities and other relevant agencies to improve security in the project area • SPDC shall ensure that security orientation and awareness is conducted for workforce. • SPDC shall ensure that security orientation and awareness is conducted for workforce.				
		Waste generation (Scrap metals, Woods, Food	HIGH	▪ SPDC and contractors shall ensure that all wastes are segregated and	LOW	Waste consignment note	Monthly	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
		waste)		managed according to EGASPIN and FMEnv guidelines ▪ Enforce access control to ensure that wastes are not indiscriminately transferred from one place to the other by members of the communities in the act of picking properties. ▪ Ensure proper documentation of the quantity of waste from generated site to disposal point		Monitoring of recipient environment in line with EGASPIN 2002		
		Alcohol and drug abuse	HIGH	▪ Ensure the implementation of the company's	LOW	Reports on community engagement	Quarterly	Central Hub Asset Manager

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring / Formal Reporting	Responsible/ Action Party
				alcohol and drug policies		sessions Site inspection report/tool box meetings		
		Prevalence of STIs HIV/AIDS	HIGH	▪ SPDC shall enforce access control to base camps ▪ SPDC shall enforce Alcohol and drug policy in the camps /worksite as part of culture of health.	LOW	Medical records Awareness records	Quarterly	Central Hub Asset Manager

CHAPTER EIGHT
CONCLUSION

The Environmental Impact Assessment Studies of the Bonny Deep Exploration Well Project was carried out in accordance with relevant local, national and international regulations. The methodology applied for the study involved field work, laboratory analyses, review of previous reports and current field data within the area. To achieve this objective, a multi-disciplinary approach was adopted in the assessment of the environmental status and sensitivities of the various biophysical components. The Bonny Deep Exploration Project is an opportunity to further explore for gas and thus sustain gas supply to NLNG. Other positive impacts of the proposed project include but not limited to the following: increase in business opportunities, provide Opportunity for direct and indirect Employment (Unskilled labour) and Opportunity for contracting.

The identified adverse impacts were generally short-term and can be prevented, reduced, or controlled if the recommended mitigation measures are implemented. An Environmental Management Plan and a Monitoring Plan have been developed to ensure that the identified potential impacts are reduced to "as low as reasonably practicable" (ALARP). The EMP should therefore form the basis for the actual project implementation and future monitoring of environmental components. The approval of this EIA report for the execution of the proposed project is hereby recommended

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APPENDICES
APPENDIX 1a

DPR Approval of the Bonny Deep Exploration Wells EIA Terms of Reference

MINISTRY OF PETROLEUM RESOURCES

DEPARTMENT OF PETROLEUM RESOURCES

7 KOFO ABAYOMI STREET, VICTORIA ISLAND, LAGOS.

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Website: www.dprnigeria.com

Ref. No:........DPR/HSE.02/001.101/2015/051

Date:........................12[th] November, 2015...

The Managing Director
Shell Petroleum Development Company
Freeman House
21/22 Marina
Lagos

Dear Sir,

TERMS OF REFERENCE/SCOPE OF WORK FOR THE ENVIRONMENTAL IMPACT ASSESSMENT (EIA) OF THE BONNY DEEP EXPLORATION AND APPRAISAL WELLS PROJECT

We write to acknowledge receipt of your letter referenced UIO/G/NG/SPDC-HSSE-10-2015-013L of 21[st] October 2015 and the joint scoping workshop held from 11[th] – 14[th] August, 2015 on the above subject matter.

2. We have reviewed the submitted Terms of Reference/Scope of Work for the Environmental Impact Assessment (EIA) of the Bonny Deep Exploration and Appraisal Wells Project and are pleased to convey to you our **acceptance** and **approval** as follows:

(i) A randomized and targeted sampling rationale shall be adopted to cover existing wells, flowstation, gas plant and compressor stations, pipelines, existing point sources and other facilities.

(ii) Sampling stations shall be established at distances of 200m, 400m and 800m in the four cardinal directions of the proposed Bonny Deep Wells location. The boreholes should be positioned in triangular form to aid determination of direction of flow of the ground water. Similarly, random and targeted sampling shall be employed for air quality/noise and soil and shall cover the proposed Bonny Deep Wells locations, Bonny River and its associated creeks and creeklets, ecological features (wetlands) and communities/settlements within the project area

(iii) The field data gathering for the study shall be for **one season** and the collected samples would be analysed for the following parameters:

S/N	Sample	Sample Type	Analysis	Parameters
1	**Soil** **24 + 2 control**	Surface (0 –15cm) Subsurface	Physico-chemical	pH, TPH, PAH, THC, BTEX, Phenols, Percent carbon, Available PO_4^{3-}, Total-N, NH_4^+, NO^-_3, NO_2, Na, K, Ca and Mg, cation exchange capacity, (CEC), conductivity, oil & grease, heavy metals (Fe, Cd, Cr, Pb, Cu, Hg, Ar, Ni, V and Zn, Ba, As)

S/N	Sample	Sample Type	Analysis	Parameters
	Soil samples shall cover the proposed Bonny Deep Wells locations, ecological features (wetlands) and communities/settlements within the project area	(15-30cm)	Soil characterisation/ classification,	Texture, grain size analysis, porosity, permeability, bulk density, erosion potential
			Microbiology	Total heterotrophic bacteria and fungi, Total hydrocarbon utilising bacteria and fungi
2.	**Sediment 20 + 2 control** Sediment shall be sampled downstream and upstream direction on the Bonny River and its associated channels (creeks and creeklets) within the defined study boundary	Composite Grab samples	Physico-chemical	pH, THC, Percent carbon, Available PO_4-P, Total-N, NH_4+, NO_3^-, NO_2^-, Na^+, K^+, Ca^{2+} and Mg^{2+}, Redox potential, oil & grease, heavy metals (Fe, Cd, Cr, Pb, Cu, Ni, V and Zn).
			Microbiology	Total heterotrophic bacteria and fungi, Total hydrocarbon utilising bacteria and fungi
			Sediment characterisation	Colour and texture
			Benthos	Benthic macro-invertebrate studies – identification to the nearest taxonomic level as well as their species distribution, abundance, diversity and density
3.	**Surface water 20 + 2 control** Surface water shall be sampled downstream and upstream direction on the Bonny River and its associated channels (creeks and creeklets) within the defined study boundary	Composite	Physico-chemical	Colour, alkalinity, TDS, TSS, Turbidity, EC, THC, pH, DO, Redox potential, BOD_5, COD, Oil & Grease, Anions/Cations, NH_4^+, NO_3^-, NO_2^-, PO_4^-, SO_4^{2-}, SiO_2, Na^+, K^+, Ca^{2+}, Mn^{2+}, Mg^{2+}. Heavy metals (Fe, Cd, Cr, Ni, V, Pb, Zn, Hg).
			Microbiology	Total heterotrophic bacteria and fungi, Total hydrocarbon utilising bacteria and fungi
			Phytoplankton	Identification to the nearest taxonomic level, Species diversity (composition, distribution and density) and productivity.
			Zooplankton	Identification to the nearest taxonomic level, species diversity (composition, distribution and density)
			Fisheries	Species types and distribution, catch assessment survey (CAS), breeding sites, migration routes, pathology, fisheries activities.
			Aquatic macrophyte	Identification and spatial distribution, biomass per unit area covered, including submerged vegetation, floating and emergent/bank types, *aufwuchs** density
			Hydrodynamics	River water depth and width, flow direction and flow rate. River bed current, and tidal information, bathymetric data etc.
4.	**Ground-water 3 + 2 control** Boreholes shall be drilled within the 2km radius of the Bonny Deep field. Two control stations shall be drilled outside the spatial boundary (2km radius) of the field.	Composite	Physico-chemical	Temperature, pH, salinity, EC, DO, Turbidity, THC, Redox potential, oil & grease, anions and cations, heavy metals (Fe, Cd, Cr, Pb, Cu, Ni, V and Zn)
			Hydrodynamics	Water table depth, flow direction and rate.
			Microbiology	Total heterotrophic bacteria and fungi, Total hydrocarbon utilising bacteria and fungi
			Hydrogeology	Stratigraphy of the initial underground layers.
			Log analysis	Physico-chemical and heavy metal characterisation.

S/N	Sample	Sample Type	Analysis	Parameters
5.	**Vegetation** Vegetation transects shall be located at the cardinal points that run parallel to the proposed well locations and to the slope of the wetland beginning at the upland edge	**Transect area	*In situ* study	Vegetation types, floral composition
			Herbarium studies	Sampled /field unidentifiable plant species
			Plants and crops pathological studies	Identification of health conditions, insect pests, fungi, bacteria and viral disease of crops around the field and associated villages, farmlands or plantations, plant tissue analysis
6.	Wildlife	Transect/ Visual observation	Mammals, reptiles, birds, amphibians and invertebrates	Diversity, distribution, density, conservation status, formal/traditional conservation practices, wildlife exploitation methods.
7.	**Air Quality** 24 + 2 control Air quality/noise shall cover the proposed Bonny Deep Wells locations, Bonny River and its associated creeks and creeklets, ecological features (wetlands) and communities/settl ements within the project area. 2		Physico-chemical	SO_x, NO_x, VOC/HC, Particulates, CO, CO_2, NH_3, soot
8.	**Socio-economic**	Demography, Social Structure & Organisation, Livelihood, Social Infrastructure, Cultural Properties, Natural Resources and Land Use, Perception of the project, the role of women and children, Physically Challenged, Vehicular Traffic Analysis, Sex Trade		

3. Furthermore, we request that the draft Environmental Impact Assessment (EIA) study report be forwarded to the DPR in both hard and electronic copies. The electronic copy of the study report should be submitted on a compact disc (CD).

4. Finally, you are required to liaise with our Port Harcourt Zonal office to ensure adequate representation of the DPR during the field data gathering exercise and laboratory analysis.

Yours faithfully,

Dr. Musa M. Zagi ***SPE, mei***
for: Director of Petroleum Resources.

Appendix 2
Methodology

Field and Laboratory Procedures

Climate and Air Quality

During the field sampling campaign, climate and meteorological parameters collected were wind speed and direction, ambient air temperature, atmospheric pressure and relative humidity. The gaseous air pollutants measured included ammonia (NH_3), Carbon monoxide (CO), Nitrogen dioxide (NO_2), Sulphur dioxide (SO_2), and Volatile Organic Compounds (VOCs). In addition, the ambient air was analysed for suspended particulate matter (SPM). Online monitors were used to obtain real-time measurements for the air quality and microclimatic parameters.

Meteorological Measurements

Weather Tracker Kestrel 4500 was used for the measurements of meteorological parameters. This Weather Tracker is a sophisticated, multi-function environmental monitoring instrument used to measure major environmental conditions including Barometric Pressure, Temperature, Humidity, Wind Speed and Wind direction.

Air Quality Measurements

Particulates

Particulate matter (PM) was measured with GT-331 Particle Mass Monitor, an equipment from Met One Instruments. It is handheld, battery operated and completely portable unit measuring five mass ranges of TSP: PM_1, $PM_{2.5}$, PM_7, PM_{10}, and TSP with a concentration range of 0 – 10 mg/m^3 (and resolution of 0.1 µg/m^3), a sampling time of 2 minutes and a flow rate of 2.83 l/min. To measure, it is placed at 1 m above the ground level, switched on in the environment of interest and the measured concentration read directly on the screen after particle capturing.

Gaseous Pollutants

Ammonia (NH_3), Carbon monoxide (CO), Nitrogen dioxide (NO_2), Sulphur dioxide (SO_2), Hydrogen sulphide (H_2S) and Volatile Organic Compounds (VOCs) gaseous air pollutants were monitored during the study in the ambient environment of the project site using various methods of sampling as described below:

Ammonia (NH_3): NH_3 measurements were taken using an in situ non-integrated single gas ammonia monitor (ToxiRAE Model PGM-1150). The monitor is a measuring instrument with an instantaneous direct readout displays through which current ammonia concentrations can be continuously monitored in ppm (parts per million). It has detection range of 0 – 20 ppm with 0.1 ppm resolution.

Carbon Monoxide (CO): CO measurements were taken using an *in situ* non-integrated single gas carbon monoxide monitor (ToxiRAE Model PGM-1150). The monitor is a 9.3 cm x 4.9 cm x 2.2 cm measuring instrument weighing about 0.1 kg with an instantaneous direct readout displays through which current carbon monoxide concentrations can be continuously monitored in ppm (parts per million). It has detection range of 0 – 500 ppm with 1 ppm resolution.

Oxides of Nitrogen (NO_X): NO_X concentrations were measured as NO_2 using in situ single gas NO_2 monitor (ToxiRAE Model PGM-1120). The monitor is a measuring instrument with an instantaneous direct readout displays through which current NO_2 concentrations can be continuously monitored in ppm (parts per million) with a detection range of 0 – 20 ppm and 0.1 ppm resolution.

Sulphur Dioxide (SO_2): To measure the SO_2 concentrations during the field study, an *in situ* single gas SO_2 monitor (ToxiRAE Model PGM-1130) was used. The monitor is a 9.3 cm x 4.9 cm x 2.2 cm measuring instrument weighing about 0.1 kg with an instantaneous direct readout displays through which current SO_2 concentrations can be continuously monitored in ppm (parts per million) with a detection range of 0 – 20 ppm and 0.1 ppm resolution.

Hydrogen Sulphide (H_2S) and Volatile Organic Compounds (VOCs): These compounds were measured using an *in situ* MultiRAE gas monitor (Model PGM50-5P). It is measuring instrument with an instantaneous direct readout displays through which current VOCs and H_2S concentrations can be continuously monitored in ppm (parts per million). It has detection range of 0 – 20 ppm with 0.1 ppm resolution.

Noise Survey

Noise measurements were taken with a digital, battery-powered, sound pressure level meter (pre-calibrated BK precision 732 sound level meters). To measure the noise levels at any of the sampling locations, the sound level meter was placed at a distance of at least 3 m from any barrier or other sound reflecting sources and at about 1.2 – 1.5 m above ground level. Measurements were taken by setting the sound level meter to the “A” weighting network.

Soil studies

The soil sampling stations were positioned in a stratified grid pattern (IITA 1979). In the grids were cells of approximately 100 m^2 each from which soil samples were collected. This sampling location pattern was with a view to also ensuring that adequate representative soil samples were collected. A hand-held Dutch type Soil Auger was used to collect representative soil sample at each soil sampling location. At each sampling station and soil depth (0-15 cm, and 15-30cm) for top soil and sub soil levels respectively composite soil samples were collected bulked and thoroughly mixed for homogenization in a plastic bag. The surface and the subsurface level are depths at which most chemical and nutrient elements are most readily available for plants absorption.

Soil samples for physical and nutrient elements analyses were sub sampled into polyethylene bags that had been appropriately labeled with masking tape and indelible ink to indicate sample location and soil depth level. Soil samples for microbial characteristics were sub sampled into sterilized bottles, while samples for hydrocarbon contents were collected into aluminum foils, wrapped up and labeled appropriately also with masking tape and indelible ink. Field and in-situ physical attributes of the sampled soils such as colour, texture, and structure were noted using the Munsell Soil Colour Chart with reference to the combination in the Munsell system of time, values, hue and by rolling the soil samples in between fingers. All in-situ observations were recorded in a field notebook.

Vegetation

The method adopted with modifications was that of Peet, *et al.* (1988) and has been adopted by the North Carolina vegetation survey as its standard vegetation sampling method (Peet, *et al*., 1997). Basically, the method employs a set of 10 modules (sub plots) in a 20 meters X 50 meters layout. The grids are located such that the long axis of the plot is oriented to minimize environmental heterogeneity within the plot. However, in adopting the method for this work, the modules were neglected, and the dimension of the plot area was reduced to 10 meters X 40 meters.

A panoramic view of each site and the dominant vegetation type present was used to characterize the overall vegetation type. Systematic randomized sampling was used to observe plants communities and different vegetation types within the spatial boundaries of the facilities with Control points taken outside the defined spatial boundary. Phytosociological and floristic analyses were done by visual inspection. The Vegetation consultant moved randomly on each designated sampling site observing and collecting plants. Photographs were taken to document the general views of each site. For documentation and for detailed determination of species, plant specimens were collected, described, pressed and taken to the herbarium at University of Benin for drying and identification. Plants were categorized according to their taxonomy, growth form, native origin, and primary and secondary uses.

Within the layout, the plant species were enumerated and identified to species and genera as far as possible. Standard quantitative floristic information such as density, relative cover and abundance were recorded (Lewis and Taylor, 1972). Random samples were taken along the survey route in the vegetation communities.

Wildlife studies

Interviews

The wildlife assessment involved a survey of amphibians, reptiles, birds, and mammals in the study areas following methodology described by Agbagwa and Ndukwu (2014). Due to special security contraints prevailing in the Niger Delta areas, night surveillance which would have been ideal for most noctunal fauna was impossible. To augment this, recents available reports on the fauna pertaining to the Niger Delta were used instead (Powell, 1994; Baker and Olubode (2007); Luiselli *et al*., (2015) and Wikipedia (2015). Other members of the fauna observed were photographed *in-situ*, identified and presented. In addition field based interviews were conducted to collect wildlife biodiversity data by discussing with local hunters and farmers. The people had earlier been briefed of the purpose of the survey and the benefits to the community. They provided names of birds, reptiles, amphibians and mammals in their local vernacular.

Transect surveys (Observations)

In each transect of about 50 meters apart, the survey team walked through the transect recording animals sighted. The presence of animals was also inferred from indices like dung, burrows, footprints, claw marks, nests and feathers where available.

Aquatic Studies

Surface Water

The surface water samples were collected and preserved according to standard methods in relation to the parameters to be determined. The water for Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD) were collected using a 250 ml reagent glass bottles. The samples were filled and stoppered under the water. After the collections, the DO samples were fixed immediately with Winklers A and B solutions while that of BOD were wrapped with Aluminium foil and tied up in a black polythene bags and put in a cooler.

- Samples for oil and grease were collected with a wide mouth Oil and Grease Sample bottles
- Heavy metals were collected with 250ml plastic bottles and fixed with a few drops of Concentrate Nitric Acid.
- Samples for microbiology were collected in a sterilized McCartney bottle directly from the water bodies.
- Water samples for other physico-chemical analysis were also collected in labeled plastic containers and preserved in ice-cooler.

Water temperature and dissolved oxygen were measured using SHOTT temperature meter (Model 896) with sensitivity of 0.1°C temperature. Conductivity was measured using WTW LF 90 conductivity meter with sensitivity of 0.01 (µS/cm) of conductivity. Salinity was measured using ATAGO refractometer with a sensitivity of 0.5 ppt of salinity.

Sediment Studies

Samples for physicochemical parameters were raped up in polythene bags and aluminium foils for microbial studies respectively after the sediment for benthic studies have been removed.

Hydrobiological Studies

Plankton Studies

The samples were collected by filtering 60 litres of surface water through 55µ plankton net and the filtrate was poured into a 250ml plastic container and preserved with 4% Formalin.

Benthic Studies

The upper part of the bottom sediments collected for sediment studies were removed, and washed in a sieve. The retained materials in the sieve were placed in wide mouth plastic containers and preserved with 4% Formalin.

Fisheries Studies

Fisheries studies were carried out at the points of surface water collection. The approach used in this study was interviewing the members of the community to get information on the fisheries resources, fishing and preservation methods of the area. This will be complemented by literature survey from research works in those areas.

Hydrogeology

Nine boreholes were drilled within the study area using percussion drilling method (Plates 3.8). Lithologs of the boreholes were recorded. These boreholes were cased using 4" PVC pipes, gravel packed and cemented core samples were collected at every 5ft and analysed for lithological profile. Groundwater samples were collected from these boreholes 24 hours after drilling, with the aid of a Teflon hose while depth to water level was measured using a measuring tape. *In situ* readings for some parameters were taken at the location of the boreholes before the samples were taken to the lab for laboratory analysis.

Social Profile Methodology

Information for this study was obtained from both secondary and primary sources. Reports of earlier impact assessment and related studies in and around the study area, as well as publications of the National Population Commission (NPC); the National Bureau of Statistics (NBS); and other authors were the main secondary sources of information for the study. Primary information was to be obtained from focus group discussion (FGD); Key Informant Interviews (KII); Town Hall Meetings/Participatory Rural Appraisal (PRA), and structured interviews. However, because of security reasons, the Town Hall Meetings and PRA, as well as the structured interviews could not be conducted. In the alternative, representatives of the leadership of each of the stakeholder communities were invited to Yenagoa and consultations held using KII techniques to extract as much information as possible from them. Subsequently, a visit was made the communities for ground trotting and photo shots. The data collected were analyzed and presented in tables, pie charts, histograms, etc.

Appendix 3: Biophysical Samples Raw Results

Groundwater Results							
S/N	**PARAMETER**	**UNIT**	**BH 1**	**BH 2**	**BH 3**	**BH CTRL 1**	**BH CTRL 2**
1	pH		7.40	7.10	7.40	7.00	7.00
2	Redox Potential	mV	-31.20	-30.70	-31.30	-30.80	-30.30
3	Electrical Conductivity	µS/cm	32300.0	30400.0	32400.0	40200.0	15400.0
4	Temperature	°C	28.00	27.00	27.50	28.20	26.90
5	Turbidity	NTU	46.2	152.0	165.3	113.9	136.0
6	TSS	mg/L	40.0	143.0	149.0	105.0	121.0
7	TDS	mg/L	16500.0	15200.0	16200.0	20100.0	7700.0
8	THC	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
9	DO	mg/L	3.30	3.10	4.50	4.00	4.10
10	Salinity as Cl	mg/L	12300.27	7896.14	11076.90	14991.69	4226.03
11	Oil & Grease	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Heavy Metals							
1	Cu	mg/L	0.037	0.028	0.041	0.033	0.026
2	Fe	mg/L	0.534	0.739	0.621	0.449	0.512
3	Cd	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
4	Cr	mg/L	<0.005	<0.005	0.006	<0.005	<0.005
5	Ni	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005
6	V	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005
7	Pb	mg/L	0.008	0.011	0.004	<0.001	0.006
8	Zn	mg/L	0.184	0.202	0.175	0.086	0.152
Microbiology							
1	HUB	cfu/ml X 103	1.80	NIL	0.60	0.90	1.10
2	HUF	cfu/ml X 102	NIL	0.40	NIL	NIL	0.20
3	THB	cfu/ml X 103	2.80	3.40	2.70	3.50	2.90

4	THF	cfu/ml X 102	0.30	0.50	NIL	NIL	0.40

Sediment Results

FIELD CODE	SD 1	SD/2	SD/3	SD/4	SD/5	SD/6	SD/7	SD/8	SD/9	SD/10	SD/11	SD/12	SD/13	SD/14	SD/15	SD/16	SD/17	SD/18	SD/19	SD/20	SD/CTRL 1	SD/CTRL 2
pH	3.6	3.6	5.1	5.7	6.1	4.7	4.8	5	4.6	4.2	3.6	4.9	5.1	4.4	5	4.5	4.8	4.7	5.9	3.6	4.5	3.8
Redox Potential (mV)	133.6	131.1	72.5	55.4	27.3	68.3	69.2	62.2	68.2	69.4	128.2	64.9	72.2	69.4	72.1	68.4	68.3	68.1	54.6	133.2	68.3	134.2
ELECTRICAL CONDUCTIVITY (uS/cm)	7290	8040	10100	17200	7180	22000	20800	35100	21800	22700	15100	12100	15200	20200	34400	17900	11890	19300	25200	3380	4274	16200
TOC (%)	0.17	0.34	0.39	0.39	0.33	0.39	0.31	0.07	0.24	0.27	0.09	0.23	0.35	0.07	0.1	0.24	0.27	0.09	0.23	0.35	0.07	0.1
O & G (ppm)	1.3	1.8	2	1.8	1.2	2.3	1.3	0.9	2.2	2.9	2	1.3	2	2	1.6	2.4	1.3	1.2	2.6	1	0.9	0.8
NH_4^+ (mg/	5.13	3.776	4.544	1.611	2.579	2.96	2.344	3.628	2.813	2.674	4.309	1.64	3.107	5.247	5.863	2.432	1.523	3.107	4.045	5.511	3.37	6.978

Sediment Results																						
kg)																						
NO_3^- (mg/kg)	0.095	0.078	0.048	0.039	0.004	0.052	0.087	0.039	0.065	0.082	0.004	0.048	0.004	0.03	0.087	0.065	0.013	0.039	0.013	0.087	0.056	0.074
NO_2^- (mg/kg)	0.003	0.002	0.006	0.003	0.004	0.002	0.004	0.003	0.007	0.01	0.017	0.006	0.004	0.013	0.003	0.007	0.01	0.017	0.006	0.004	0.013	0.003
TOTAL PHOSPHOROUS (%)	0.004	0.033	0.011	0.029	0.069	0.058	0.066	0.032	0.029	0.073	0.012	0.021	0.005	0.012	0.016	0.019	0.036	0.068	0.008	0.015	0.003	0.035
TOTAL NITROGEN (%)	0.007	0.01	0.017	0.015	0.07	0.024	0.017	0.014	0.013	0.021	0.018	0.022	0.017	0.02	0.015	0.018	0.022	0.021	0.02	0.017	0.015	0.022
THC (mg/kg)	0.8	0.7	0.5	1.2	0.4	0.8	0.5	0.4	1.2	1.9	0.3	0.6	0.9	0.5	0.9	1.2	0.8	0.5	1	0.7	0.3	0.4
% Sand	93	93	51.4	44.2	41.4	58.5	54.3	35.4	82.3	65.5	64.7	57.5	47	75.2	26.9	80.3	59.3	82.7	83.6	58.8	55.3	62.2
% Silt	1.7	1.4	4.5	19.1	7.8	5.5	7.5	10.3	7.8	5.6	5.2	5.5	16.8	14.7	1.9	11.6	3.9	6.2	6.1	4.1	5.7	6.6
% Clay	5.3	5.6	44.1	36.7	50.8	36	38.2	54.3	9.9	28.9	30.1	37	36.2	10.1	71.2	8.1	36.8	11.1	10.3	37.1	39	31.2
Texture	SAND	SAND	CLAY	CLAY LOAM	CLAY	CLAY LOAM	CLAY LOAM	CLAY	SANDY LOAM	SANDY CLAY LOAM	SANDY CLAY LOAM	SANDY CLAY	CLAY LOAM	LOAMY SAND	CLAY	LOAMY SAND	SANDY CLAY	SANDY LOAM	SANDY LOAM	SANDY CLAY	SANDY CLAY	SANDY CLAY LOAM
Na (mg/kg)	1215.591	1338.708	1756.264	2747.986	1138.792	3800.269	3441.694	5294.42	4064.342	3569.153	2643.439	2142.53	3054.623	3734.459	5738.798	3192.342	2269.153	3743.439	4542.53	554.623	734.459	3238.798

Sediment Results

K (mg/kg)	343.945	328.133	330.931	816	319.397	955.946	721.818	1224.513	726.43	836.812	522.657	621.303	373.358	817.06	1914.212	526.43	236.812	522.657	921.303	130.358	117.06	414.212
Ca (mg/kg)	83.739	77.753	82.358	277.258	82.478	281.192	373.34	576.951	154.01	184.526	174.819	73.736	80.98	170.342	268.063	194.01	84.526	74.819	173.736	57.98	70.342	68.063
Mg (mg/kg)	65.333	62.907	64.704	201.105	64.503	158.417	260.362	357.968	159.777	169.586	152.745	55.932	60.724	102.75	149.613	159.777	69.586	52.745	155.932	41.724	43.75	49.613
Fe (mg/kg)	5085.51	5950.59	5540.32	5458.03	5011.48	5011.48	5945.41	5695.47	6636.83	5950.59	5540.32	5458.03	4718.75	5085.51	6429.93	5349.31	5180.35	5696.66	4734.14	4979.66	5945.41	5695.47
Cu (mg/kg)	3.14	1.639	1.828	4.992	4.598	4.598	4.424	2.608	3.659	1.639	1.828	4.992	5.637	3.14	3.12	7.625	2.141	1.674	1.582	3.533	4.424	2.608
Zn (mg/kg)	49.2	25.555	28.541	34.11	36.219	36.219	44.257	50.03	57.38	25.555	28.541	34.11	40.825	49.2	48.884	53.438	33.469	26.114	24.657	55.39	44.257	50.03
V (mg/kg)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Pb (mg/kg)	8.062	7.505	9.531	8.819	6.322	6.322	2.374	3.479	5.859	7.505	9.531	8.819	9.743	8.062	8.368	9.719	9.578	6.355	6.787	7.587	2.374	3.479
Cd (mg/kg)	2.83	2.669	3.581	1.603	2.714	2.714	3.625	2.583	2.743	3.669	3.581	2.603	1.589	1.83	3.515	3.77	1.535	2.638	3.556	1.756	1.625	2.583
Ni (mg/kg)	7.735	7.441	5.781	4.924	3.489	3.489	5.86	5.815	4.97	7.441	5.781	4.924	5.96	7.735	5.145	5.787	5.145	5.378	3.865	6.543	5.86	5.815
Cr (mg/kg)	0.139	0.108	0.119	0.139	0.247	0.247	0.174	0.267	0.217	0.108	0.119	0.139	0.157	0.139	0.17	0.106	0.095	0.1	0.194	0.229	0.174	0.267

Sediment Results

(THB) X 10^4 (cfu/g)	0.75	0.05	0.88	0.08	0.09	0.05	1.03	0.98	1.25	0.03	0.03	0.2	0.4	0.5	0.4	0.8	1.5	0.8	0.5	1.3	0.9	1.1
(THF) X 10^3 (cfu/g)	0.05	0.08	0.03	NIL	0.09	0.03	0.05	0.08	NIL	NIL	NIL	NIL	0.05	0.03	0.03	NIL	NIL	NIL	0.04	0.02	0.06	0.04
(HUB) X 10^3 (cfu/g)	0.19	0.25	1.25	0.5	0.32	0.25	0.11	0.13	1	NIL	NIL	1.5	0.9	1.1	0.75	0.55	1.75	0.9	1	0.5	0.7	0.3
(HUF) X 10^2 (cfu/g)	0.02	NIL	NIL	NIL	0.03	NIL	0.03	NIL	NIL	NIL	NIL	NIL	0.05	NIL	NIL	NIL	NIL	0.06	0.03	NIL	NIL	NIL

Surface water Results

PARAMETER	**UNIT**	**SPDC/SW 1**	**SPDC/SW 2**	**SPDC/SW 3**	**SPDC/SW 4**	**SPDC/SW 5**	**SPDC/SW 6**	**SPDC/SW 7**	**SPDC/SW 8**	**SPDC/SW 9**	**SPDC/SW 10**	**SPDC/SW 11**	**SPDC/SW 12**	**SPDC/SW 13**	**SPDC/SW 14**	**SPDC/SW 15**	**SPDC/SW 16**	**SPDC/SW 17**	**SPDC/SW 18**	**SPDC/SW 19**	**SPDC/SW 20**	**SPDC/SW/CTRL 1**	**SPDC/SW/CTRL 2**
pH		7.90	7.60	7.60	7.90	7.80	7.60	7.60	7.70	7.90	7.80	7.80	7.70	7.80	7.70	7.20	7.40	7.70	7.90	7.80	7.90	7.70	7.60
Redox Potential	mV	-31.60	-31.20	-31.30	-32.50	-32.10	-31.20	-32.50	-31.90	-32.90	-31.80	-32.10	-31.90	-32.60	-32.90	-31.30	-31.10	-31.70	-32.90	-32.30	-32.90	-32.60	-32.60

Surface water Results

PARAMETER	UNIT	SPDC/SW 1	SPDC/SW 2	SPDC/SW 3	SPDC/SW 4	SPDC/SW 5	SPDC/SW 6	SPDC/SW 7	SPDC/SW 8	SPDC/SW 9	SPDC/SW 10	SPDC/SW 11	SPDC/SW 12	SPDC/SW 13	SPDC/SW 14	SPDC/SW 15	SPDC/SW 16	SPDC/SW 17	SPDC/SW 18	SPDC/SW 19	SPDC/SW 20	SPDC/SW/CTRL 1	SPDC/SW/CTRL 2
Electrical Conductivity	µS/cm	43500.0	43700.0	41900.0	43100.0	44300.0	44100.0	36800.0	39000.0	40200.0	40900.0	42000.0	41800.0	40700.0	42100.0	43400.0	42700.0	37600.0	44500.0	46000.0	35800.0	40000.0	41400.0
Temperature	ºC	26.60	27.00	25.90	26.20	26.00	25.80	26.40	27.20	27.00	28.10	27.90	27.10	27.20	28.00	29.10	26.30	27.90	28.40	29.20	27.10	25.40	24.80
Turbidity	NTU	<0.1	2.6	6.8	6.8	<0.1	8.9	20.0	18.4	27.9	31.5	19.0	20.9	11.6	36.0	13.8	19.7	15.2	7.2	31.7	26.0	43.7	25.6
TSS	mg/L	<0.1	1.0	2.0	2.0	<0.1	4.0	16.0	14.0	22.0	26.0	14.0	15.0	7.0	32.0	9.0	15.0	11.0	3.0	26.0	22.0	39.0	21.0
TDS	mg/L	21750.0	21850.0	20950.0	21550.0	22150.0	22050.0	18400.0	19500.0	20100.0	20450.0	21000.0	20900.0	20350.0	21050.0	21700.0	21350.0	18800.0	22250.0	23000.0	17900.0	20000.0	20700.0
THC	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
COD	mg/L	8.67	9.15	8.35	7.22	10.56	9.22	13.24	10.51	7.38	8.90	9.11	9.48	8.75	9.52	9.06	8.52	12.41	9.54	8.76	9.02	8.22	9.85
DO	mg/L	5.70	5.70	5.00	6.10	5.40	4.90	5.60	6.00	5.40	6.20	5.90	5.30	5.80	5.10	6.20	6.10	6.10	6.80	6.20	5.40	5.60	5.80
BOD_5	mg/L	2.10	3.70	3.60	2.40	3.50	3.00	2.90	2.10	2.10	2.20	3.10	3.40	2.30	3.80	2.60	3.40	2.10	2.00	3.00	3.10	2.80	2.90
Salinity as Cl	mg/L	12814.76	12927.23	14651.69	15251.51	13552.03	13652.00	13951.91	13851.94	13252.13	13252.13	15251.51	15351.47	14651.69	15551.41	13452.06	13652.00	13252.13	13352.09	15751.35	12452.37	12952.22	12652.31
Nitrite	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Colour	mg/L	9	14	5	23	4	21	31	33	30	25	28	24	21	48	19	26	29	17	54	50	59	44
Alkali	mg/L	104	100	95.	95.	99.	94.	86.	82.	99.	95.	95.	93.	93.	91.	98.	94.	92.	99.	99.	94.	84.00	96.00

Surface water Results

PARAMETER	UNIT	SPDC/SW 1	SPDC/SW 2	SPDC/SW 3	SPDC/SW 4	SPDC/SW 5	SPDC/SW 6	SPDC/SW 7	SPDC/SW 8	SPDC/SW 9	SPDC/SW 10	SPDC/SW 11	SPDC/SW 12	SPDC/SW 13	SPDC/SW 14	SPDC/SW 15	SPDC/SW 16	SPDC/SW 17	SPDC/SW 18	SPDC/SW 19	SPDC/SW 20	SPDC/SW/CTRL 1	SPDC/SW/CTRL 2
nity		.00	.00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00		
Oil & Grease	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate	mg/L	0.014	0.022	0.014	0.021	0.021	0.018	0.014	0.028	0.021	0.024	0.014	0.017	0.025	0.016	0.023	0.022	0.017	0.020	0.020	0.025	0.035	0.035
Sulphate	mg/L	843.82	1465.55	1476.75	1504.75	1387.15	1409.55	1034.35	911.15	886.38	1244.78	1430.70	1314.22	1233.58	1258.22	1117.10	1303.02	1034.22	1464.30	1423.98	893.10	1099.18	1285.10
Ammonia	mg/L	3.252	2.160	3.140	2.955	2.897	3.311	2.830	2.614	3.418	2.920	2.758	2.600	2.533	2.758	2.457	2.609	2.713	2.385	2.475	2.358	2.376	2.457
Phosphate	mg/L	0.017	0.006	0.009	0.007	0.078	0.007	0.002	0.003	0.018	0.010	0.009	0.003	0.038	0.015	0.012	0.009	0.003	0.005	0.010	0.008	0.009	0.012
reactive silica	mg/L	3.72	1.57	1.36	2.93	1.67	1.59	1.90	2.18	2.64	3.84	1.38	1.42	2.78	3.39	2.98	1.48	3.19	2.28	1.48	2.32	2.58	1.07
HUB	cfu/ml X 10^3	NIL	0.6	0.4	0.4	1.1	0.8	0.2	0.6	2.9	1.1	1.6	NIL	0.8	NIL	0.30	0.2	1.3	0.1	0.9	0.5	0.30	1.20
HUF	cfu/ml X 10^2	NIL	0.4	0.2	NIL	0.8	0.5	NIL	0.3	NIL	0.8	NIL	0.3	0.4	NIL	0.2	NIL	0.6	NIL	0.4	NIL	0.2	NIL
THB	cfu/ml X 10^3	2.1	1.40	0.9	1.90	1.1	0.3	3.9	3.2	2.5	1.70	1.9	1.1	NIL	2.2	1.10	1.60	0.3	1.4	1.1	2.8	3.20	1.90
THF	cfu/ml X 10^2	NIL	0.5	NIL	4.1	0.7	1.1	0.9	3.4	NIL	0.4	0.1	0.2	0.4	NIL	0.5	0.3	0.3	NIL	0.5	1.0	0.3	0.3
Na	mg/L	7517.180	7746.300	7739.800	7924.500	7947.000	8215.000	6368.000	6848.000	6986.300	7297.000	8004.740	7814.090	7661.570	7962.300	8347.910	7886.040	6786.040	7775.960	7964.090	6244.700	7270.400	7918.400

Surface water Results

PARAMETER	UNIT	SPDC/SW 1	SPDC/SW 2	SPDC/SW 3	SPDC/SW 4	SPDC/SW 5	SPDC/SW 6	SPDC/SW 7	SPDC/SW 8	SPDC/SW 9	SPDC/SW 10	SPDC/SW 11	SPDC/SW 12	SPDC/SW 13	SPDC/SW 14	SPDC/SW 15	SPDC/SW 16	SPDC/SW 17	SPDC/SW 18	SPDC/SW 19	SPDC/SW 20	SPDC/SW/CTRL 1	SPDC/SW/CTRL 2
K	mg/L	1009.696	1083.147	1082.361	1104.710	1107.432	1264.060	1058.373	1147.483	1333.967	1109.782	933.350	1017.745	1005.741	1051.356	1094.571	1081.826	1062.619	1436.545	1903.340	1119.254	1138.163	986.535
Ca	mg/L	448.640	401.419	401.309	404.449	404.831	412.787	411.988	410.458	438.559	410.781	437.748	455.740	435.760	443.732	475.720	487.708	467.728	593.756	439.756	406.492	403.529	347.336
Mg	mg/L	722.190	577.297	375.711	420.778	526.268	360.460	518.992	507.032	509.777	511.668	314.415	355.540	311.090	306.640	227.765	384.965	359.990	483.315	511.090	450.107	407.578	322.215
Mn	mg/L	0.015	0.009	0.012	0.025	0.021	0.017	0.008	0.012	0.017	0.011	0.013	0.018	0.020	0.023	0.016	0.017	0.012	0.021	0.007	0.012	0.015	0.024
Fe	mg/L	1.676	1.665	2.192	1.329	2.929	1.324	1.712	0.960	2.160	0.752	1.103	2.781	1.704	2.518	1.031	1.680	1.519	1.390	2.360	0.995	1.004	1.523
Cd	mg/L	0.003	<0.001	0.005	0.004	<0.001	0.006	<0.001	0.009	0.005	0.008	<0.001	0.003	<0.001	0.003	<0.001	0.005	<0.001	<0.001	0.008	<0.001	0.004	<0.001
Cr	mg/L	<0.005	<0.005	0.006	<0.005	<0.005	<0.005	0.006	<0.005	<0.005	<0.005	<0.005	<0.005	0.008	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Ni	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
V	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Pb	mg/L	0.021	0.067	0.032	0.032	0.016	0.010	0.027	0.025	0.051	0.036	0.095	0.028	0.042	0.066	0.035	0.099	0.047	0.081	0.018	0.093	0.019	0.014
Zn	mg/L	0.865	0.184	0.475	0.342	0.405	0.236	0.134	0.181	0.418	0.479	0.656	1.029	0.824	0.253	0.367	0.747	0.490	0.103	0.170	0.413	0.430	0.366
Hg	mg/L	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02

SOIL Results

COMPONENT	Total THC (mg/kg)	PAH	TPH	BTEX	Fe (mg/kg)	Cu (mg/kg)	Zn (mg/kg)	Pb (mg/kg)	Cd (mg/kg)	Ni (mg/kg)	Cr (mg/kg)	V (mg/kg)	As (mg/kg)	Hg (mg/kg)	Ba (mg/kg)	pH	ELECTRICAL CONDUCTIVITY (uS/cm)	TOC (%)	O&G (ppm)	NH_4^+ (mg/kg)	NO_3^- (mg/kg)	NO_2^- (mg/kg)	TOTAL PHOSPHOROUS (%)	TOTAL NITROGEN (%)	BULK DENSITY (g/cm)	THC (mg/kg)	Phenol (mg/kg)	Porosity (% pore space)	CEC (Cmol/kg)	% Sand	% Silt	% Clay	Texture	Na (mg/kg)	K (mg/kg)	Ca (mg/kg)	Mg (mg/kg)	(THB) X 10^4 (cfu/g)	(THF) X 10^3 (cfu/g)	(HUB) X 10^3 (cfu/g)	(HUF) X 10^2 (cfu/g)
SPD C/SS 1 top	**0.014**	**<0.001**	**0.014**	**<0.001**	2109.473	1.885	26.306	5.042	1.107	7.679	0.163	<0.05	<0.03	<0.05	1.408	5.60	19100.00	0.10	2.1	0.065	6.303	0.011	0.045	0.063	0.25	1.2	<0.05	51.70	2.18	82.6	10.3	7.1	SAND	2983.79	657.34	240.64	288.83	0.15	0.25	1.00	NIL
SPD C/SS 1 bottom	**<0.001**	**<0.001**	**<0.001**	**<0.001**	2075.993	1.970	38.880	5.667	3.102	8.630	0.222	<0.05	<0.03	<0.05	1.535	6.00	21300.00	0.45	2.3	0.074	6.684	0.009	0.051	0.067	0.27	1.7	<0.05	50.20	1.17	46.3	13.2	40.5	ClAY	3509.58	615.79	269.18	288.78	1.68	0.92	1.34	NIL
SPD C/SS 2 top	**<0.001**	**<0.001**	**<0.001**	**<0.001**	2723.474	1.612	39.324	1.743	1.122	2.656	0.224	<0.05	<0.03	<0.05	1.793	5.60	8091.00	0.64	1.8	0.039	6.098	0.007	0.043	0.070	0.30	0.9	<0.05	48.20	1.78	71.5	7.9	20.6	LOAM SAND	1259.31	395.63	42.57	55.48	2.00	0.41	3.42	0.40
SPD C/SS 2 bottom	**<0.001**	**<0.001**	**<0.001**	**<0.001**	3152.081	2.400	40.936	1.430	1.133	2.179	0.533	<0.05	<0.03	<0.05	1.408	5.80	9236.00	0.21	1.0	0.069	5.071	0.009	0.030	0.077	0.25	0.4	<0.05	46.80	2.48	91.3	4.5	4.2	SAND	1359.31	626.25	85.49	66.58	1.85	0.38	9.75	0.50
SPD C/SS 3 top	**<0.001**	**<0.001**	**<0.001**	**<0.001**	3135.341	0.989	31.984	0.671	2.100	4.593	0.189	<0.05	<0.03	<0.05	1.666	6.60	12106.00	0.65	2.0	0.087	9.910	0.007	0.035	0.062	0.22	0.9	<0.05	52.60	1.43	85.2	6.6	8.2	SAND	2039.11	716.06	103.95	66.63	1.78	0.34	4.86	NIL
SPD C/SS 3 bottom	**<0.001**	**<0.001**	**<0.001**	**<0.001**	4237.422	1.875	18.193	0.683	1.121	3.420	0.124	<0.05	<0.03	<0.05	1.535	6.70	12250.00	0.21	0.8	0.100	2.784	0.008	0.057	0.069	0.33	0.3	<0.05	48.90	1.56	62.6	14.2	23.2	SANDY LOAM	1699.21	516.77	44.03	311.08	0.20	0.05	1.50	NIL
SPD C/SS 4 top	**0.018**	**<0.001**	**0.018**	**<0.001**	3184.298	2.123	7.145	0.224	1.126	5.102	0.072	<0.05	<0.03	<0.05	1.408	5.90	11221.00	0.26	0.7	0.035	5.071	0.006	0.053	0.084	0.33	0.4	<0.05	41.40	2.42	71.6	4.0	24.4	LOAM SAND	1819.11	644.50	90.26	84.62	0.80	0.88	7.50	0.25
SPD C/SS 4 bottom	**<0.001**	**<0.001**	**<0.001**	**<0.001**	2786.623	0.989	18.348	0.689	3.100	3.430	0.125	<0.05	<0.03	<0.05	1.793	6.00	10453.00	0.36	1.0	0.048	4.133	0.010	0.035	0.090	0.20	0.4	<0.05	41.80	2.32	73.4	6.2	20.4	LOAM SAND	1599.01	534.31	133.73	125.37	1.24	1.80	2.64	0.70
SPD C/SS 5 top	**<0.001**	**<0.001**	**<0.001**	**<0.001**	3060.175	0.783	20.627	5.890	1.096	8.970	0.136	<0.05	<0.03	<0.05	1.535	4.00	1574.00	0.58	2.9	0.078	2.310	0.012	0.029	0.087	0.33	0.9	<0.05	40.00	1.90	86.9	5.7	7.4	LOAM SAND	241.51	94.50	31.82	13.90	0.98	0.33	5.15	1.10

SOIL Results

COMPONENT	Total THC (mg/kg)	PAH	TPH	BTEX	Fe (mg/kg)	Cu (mg/kg)	Zn (mg/kg)	Pb (mg/kg)	Cd (mg/kg)	Ni (mg/kg)	Cr (mg/kg)	V (mg/kg)	As (mg/kg)	Hg (mg/kg)	Ba (mg/kg)	pH	ELECTRICAL CONDUCTIVITY (uS/cm)	TOC (%)	O&G (ppm)	NH_4^+ (mg/kg)	NO_3^- (mg/kg)	NO_2^- (mg/kg)	TOTAL PHOSPHOROUS (%)	TOTAL NITROGEN (%)	BULK DENSITY (g/cm)	THC (mg/kg)	Phenol (mg/kg)	Porosity (% pore space)	CEC (Cmol/kg)	% Sand	% Silt	% Clay	Texture	Na (mg/kg)	K (mg/kg)	Ca (mg/kg)	Mg (mg/kg)	(THB) X 10^4 (cfu/g)	(THF) X 10^3 (cfu/g)	(HUB) X 10^3 (cfu/g)	(HUF) X 10^2 (cfu/g)
SPD C/SS 5 bottom	**<0.001**	**<0.001**	**<0.001**	**<0.001**	1875.111	2.691	25.533	6.494	1.139	9.891	0.908	<0.05	<0.03	<0.05	1.408	4.20	798.00	0.66	2.4	0.087	2.791	0.014	0.001	0.093	0.25	1.1	<0.05	42.85	2.88	98.5	0.9	0.6	SAND	128.64	37.06	5.10	3.03	1.15	0.18	8.50	1.25
SPD C/SS 6 top	**<0.001**	**<0.001**	**<0.001**	**<0.001**	1942.071	2.583	25.475	5.373	1.137	8.183	0.765	<0.05	<0.03	<0.05	1.280	4.10	568.00	0.35	1.2	0.056	2.193	0.006	0.015	0.093	0.21	0.8	<0.05	41.80	1.73	8.0	24.0	68.0	CLAY	103.63	29.14	4.09	2.15	0.20	0.08	1.50	NIL
SPD C/SS 6 bottom	**<0.001**	**<0.001**	**<0.001**	**<0.001**	3275.901	0.824	32.004	5.787	3.097	8.813	0.252	<0.05	<0.03	<0.05	1.920	4.00	728.00	0.54	3.1	0.048	2.005	0.006	0.020	0.096	0.35	1.3	<0.05	42.80	2.83	74.6	6.0	19.4	LOAM SAND	119.51	23.62	9.75	9.14	1.99	0.89	0.45	NIL
SPD C/SS 7 top	**0.041**	**<0.001**	**0.041**	**0.005**	3192.200	2.102	47.185	1.411	1.121	2.150	0.526	<0.05	<0.03	<0.05	1.408	5.70	18900.00	0.42	1.9	0.030	2.931	0.020	0.053	0.096	0.25	0.7	<0.05	42.50	1.19	71.9	8.2	19.9	LOAM SAND	2969.45	753.27	218.71	258.54	4.09	0.78	0.12	1.10
SPD C/SS 7 bottom	**<0.001**	**<0.001**	**<0.001**	**<0.001**	1874.847	1.262	49.233	1.203	2.123	1.834	0.163	<0.05	<0.03	<0.05	1.793	5.80	20200.00	0.27	2.0	0.082	2.608	0.006	0.059	0.077	0.31	0.9	<0.05	41.60	1.18	43.6	12.5	43.9	CLAY	3359.61	726.25	225.55	265.21	0.65	0.28	6.00	2.00
SPD C/SS 8 top	**<0.001**	**<0.001**	**<0.001**	**<0.001**	1774.406	1.055	40.599	1.369	1.115	2.086	0.592	<0.05	<0.03	<0.05	1.535	4.80	776.00	0.35	2.4	0.061	3.401	0.010	0.035	0.080	0.20	1.5	<0.05	51.20	3.29	92.9	2.3	2.6	SAND	149.81	26.12	2.74	2.57	1.65	0.63	NIL	5.50
SPD C/SS 8 bottom	**<0.001**	**<0.001**	**<0.001**	**<0.001**	2036.665	3.233	59.605	4.467	1.152	6.804	0.254	<0.05	<0.03	<0.05	1.666	4.80	1084.00	0.11	1.2	0.082	2.216	0.011	0.029	0.083	0.33	0.9	<0.05	50.00	2.88	95.1	2.5	2.4	SAND	189.11	35.68	13.57	4.92	1.45	0.29	7.15	0.30
SPD C/SS 9 top	**<0.001**	**<0.001**	**<0.001**	**<0.001**	2028.104	1.528	25.572	2.214	2.113	3.372	0.698	<0.05	<0.03	<0.05	1.920	4.60	695.00	0.14	1.8	0.143	1.759	0.005	0.015	0.086	0.33	0.6	<0.05	54.40	2.74	96.8	1.2	2.0	SAND	109.33	21.71	12.49	3.38	1.40	0.45	8.25	4.00
SPD C/SS 9 bottom	**<0.001**	**<0.001**	**<0.001**	**<0.001**	2271.370	2.100	46.934	3.695	3.126	5.628	0.318	<0.05	<0.03	<0.05	1.408	4.30	493.00	0.12	1.1	0.052	1.970	0.006	0.048	0.096	0.20	0.6	<0.05	53.90	2.84	96.8	1.3	1.9	SAND	86.29	13.46	1.18	2.73	1.14	1.19	6.35	0.17

SOIL Results

COMPONENT	Total THC (mg/kg)	PAH	TPH	BTEX	Fe (mg/kg)	Cu (mg/kg)	Zn (mg/kg)	Pb (mg/kg)	Cd (mg/kg)	Ni (mg/kg)	Cr (mg/kg)	V (mg/kg)	As (mg/kg)	Hg (mg/kg)	Ba (mg/kg)	pH	ELECTRICAL CONDUCTIVITY (uS/cm)	TOC (%)	O&G (ppm)	NH_4^+ (mg/kg)	NO_3^- (mg/kg)	NO_2^- (mg/kg)	TOTAL PHOSPHOROUS (%)	TOTAL NITROGEN (%)	BULK DENSITY (g/cm)	THC (mg/kg)	Phenol (mg/kg)	Porosity (% pore space)	CEC (Cmol/kg)	% Sand	% Silt	% Clay	Texture	Na (mg/kg)	K (mg/kg)	Ca (mg/kg)	Mg (mg/kg)	(THB) X 10^4 (cfu/g)	(THF) X 10^3 (cfu/g)	(HUB) X 10^3 (cfu/g)	(HUF) X 10^2 (cfu/g)
SPD C/SS 10 top	**<0.001**	**<0.001**	**<0.001**	**<0.001**	2301.005	0.972	52.922	5.011	3.100	7.632	0.166	<0.05	<0.03	<0.05	1.535	4.80	423.00	0.19	0.9	0.082	1.677	0.009	0.035	0.079	0.22	0.3	<0.05	47.30	1.57	72.7	11.1	16.2	LOAM SAND	69.22	18.34	3.18	3.63	1.25	0.80	5.24	0.30
SPD C/SS 10 bottom	**<0.001**	**<0.001**	**<0.001**	**<0.001**	2917.402	1.948	25.572	1.356	1.098	2.067	0.224	<0.05	<0.03	<0.05	1.793	4.30	336.00	0.11	0.6	0.052	2.240	0.009	0.021	0.084	0.19	<0.1	<0.05	48.900	3.57	71.8	10.4	17.8	LOAM SAND	49.11	15.84	2.95	2.71	0.73	1.30	6.50	2.00
SPD C/SS 11 top	**0.056**	**<0.001**	**0.056**	**<0.001**	2855.499	1.694	38.667	0.503	1.094	5.526	0.198	<0.05	<0.03	<0.05	1.666	5.70	1910.00	0.28	1.7	0.043	2.491	0.015	0.014	0.076	0.20	1.2	<0.05	41.10	1.56	11.1	48.6	40.3	CLAY	269.86	81.25	6.87	5.48	0.08	0.03	0.50	NIL
SPD C/SS 11 bottom	**<0.001**	**<0.001**	**<0.001**	**<0.001**	3125.897	1.824	45.717	6.387	1.120	9.727	0.254	<0.05	<0.03	<0.05	1.920	5.60	1820.00	0.28	1.1	0.052	0.966	0.007	0.117	0.081	0.16	0.7	<0.05	44.80	2.55	18.7	32.2	49.1	ClAY	199.30	60.61	6.57	3.08	0.06	1.15	0.70	0.30
SPD C/SS 12 top	**<0.001**	**<0.001**	**<0.001**	**<0.001**	4251.877	2.504	62.096	0.747	2.135	3.518	0.332	<0.05	<0.03	<0.05	1.408	5.20	1224.00	0.10	0.8	0.078	3.195	0.006	0.036	0.093	0.25	0.3	<0.05	47.50	2.23	77.1	3.5	19.4	LOAM SAND	215.97	54.86	5.18	3.23	2.52	3.88	7.36	NIL
SPD C/SS 12 bottom	**<0.001**	**<0.001**	**<0.001**	**<0.001**	4252.272	2.177	54.216	1.050	2.128	1.601	0.295	<0.05	<0.03	<0.05	1.666	4.90	1254.00	0.10	0.6	0.061	3.576	0.007	0.022	0.090	0.26	0.3	<0.05	41.60	1.57	29.5	23.3	47.2	CLAY	145.10	43.79	5.41	2.98	1.05	8.75	9.75	NIL
SPD C/SS 13 top	**<0.001**	**<0.001**	**<0.001**	**0.003**	1698.700	1.044	26.904	0.662	1.102	5.768	0.165	<0.05	<0.03	<0.05	1.793	5.40	19000.00	0.55	1.3	0.108	6.948	0.006	0.035	0.084	0.23	0.7	<0.05	42.10	1.20	22.0	34.4	43.6	ClAY	3129.80	825.90	210.06	203.19	1.72	3.32	6.74	0.21
SPD C/SS 13 bottom	**<0.001**	**<0.001**	**<0.001**	**<0.001**	1735.710	0.987	32.602	0.313	1.100	4.048	0.192	<0.05	<0.03	<0.05	1.280	5.60	16680.00	0.32	2.4	0.074	1.699	0.007	0.029	0.087	0.31	1.5	<0.05	41.70	1.21	18.9	7.0	74.1	ClAY	2561.93	818.83	199.06	192.87	0.23	0.05	0.50	0.25
SPD C/SS 14 top	**<0.001**	**<0.001**	**<0.001**	**<0.001**	1936.421	0.985	15.702	1.051	1.100	1.602	0.112	<0.05	<0.03	<0.05	1.535	3.70	18420.00	0.62	2.0	0.026	4.098	0.009	0.028	0.079	0.25	1.2	<0.05	50.00	2.21	70.9	11.3	17.8	LOAM SAND	2919.30	988.34	167.26	209.98	1.28	0.18	6.50	1.50

SOIL Results

COMPONENT	Total THC (mg/kg)	PAH	TPH	BTEX	Fe (mg/kg)	Cu (mg/kg)	Zn (mg/kg)	Pb (mg/kg)	Cd (mg/kg)	Ni (mg/kg)	Cr (mg/kg)	V (mg/kg)	As (mg/kg)	Hg (mg/kg)	Ba (mg/kg)	pH	ELECTRICAL CONDUCTIVITY (uS/cm)	TOC (%)	O&G (ppm)	NH_4^+ (mg/kg)	NO_3^- (mg/kg)	NO_2^- (mg/kg)	TOTAL PHOSPHOROUS (%)	TOTAL NITROGEN (%)	BULK DENSITY (g/cm)	THC (mg/kg)	Phenol (mg/kg)	Porosity (% pore space)	CEC (Cmol/kg)	% Sand	% Silt	% Clay	Texture	Na (mg/kg)	K (mg/kg)	Ca (mg/kg)	Mg (mg/kg)	(THB) X 10^4 (cfu/g)	(THF) X 10^3 (cfu/g)	(HUB) X 10^3 (cfu/g)	(HUF) X 10^2 (cfu/g)
SPDC/SS 14 bottom	<0.001	<0.001	<0.001	<0.001	2059.253	1.255	48.903	4.608	1.126	7.019	0.872	<0.05	<0.03	<0.05	1.280	3.50	18100.00	0.62	1.5	0.004	5.271	0.016	0.024	0.076	0.33	0.9	<0.05	48.80	1.21	71.8	8.1	20.1	LOAM SAND	2918.60	905.11	173.73	225.37	1.15	0.18	1.56	0.48
SPDC/SS 15 top	0.063	<0.001	0.063	<0.001	1684.739	1.201	73.512	2.977	3.105	4.535	0.386	<0.05	<0.03	<0.05	1.666	6.60	18300.00	0.65	1.8	0.053	1.259	0.013	0.161	0.049	0.40	1.0	<0.05	16.70	1.26	50.0	7.1	42.9	SANDY CLAY	3229.43	869.73	153.06	143.50	1.29	0.21	2.13	NIL
SPDC/SS 15 bottom	<0.001	<0.001	<0.001	<0.001	1328.071	1.340	66.983	2.706	2.109	4.122	0.355	<0.05	<0.03	<0.05	1.535	6.50	19100.00	0.64	2.8	1.505	1.911	0.007	0.019	0.060	0.42	0.8	<0.05	44.50	1.20	46.1	13.9	40.0	CLAY	3219.10	954.77	201.74	182.10	1.28	0.13	3.00	NIL
SPDC/SS 16 top	<0.001	<0.001	<0.001	<0.001	1774.669	1.409	38.126	1.509	2.110	2.300	0.219	<0.05	<0.03	<0.05	1.666	2.10	18500.00	0.37	2.4	0.559	11.817	0.011	0.025	0.076	0.25	1.3	<0.05	50.00	2.21	4.3	2.7	93.0	ClAY	3108.11	847.89	193.23	186.66	0.93	0.13	0.25	NIL
SPDC/SS 16 bottom	<0.001	<0.001	<0.001	<0.001	2736.961	2.348	47.243	4.294	1.117	6.541	0.866	<0.05	<0.03	<0.05	1.535	2.50	17900.00	0.24	1.8	0.247	8.532	0.006	0.019	0.084	0.90	0.6	<0.05	46.20	2.22	7.0	23.0	70.0	CLAY	3047.38	949.68	184.76	155.11	1.11	0.17	0.24	NIL
SPDC/SS 17 top	0.012	<0.001	0.012	<0.001	2589.842	1.519	30.690	0.840	2.132	1.281	0.244	<0.05	<0.03	<0.05	1.920	3.80	22800.00	0.28	1.0	0.026	8.321	0.008	0.022	0.024	1.30	0.4	<0.05	42.10	2.18	70.8	10.6	18.6	LOAM SAND	3679.90	1160.48	224.02	220.00	0.53	0.08	5.00	0.50
SPDC/SS 17 bottom	<0.001	<0.001	<0.001	<0.001	2761.986	2.292	34.051	1.553	2.107	2.367	0.106	<0.05	<0.03	<0.05	1.408	3.60	23100.00	0.53	2.2	0.013	6.913	0.015	0.032	0.028	1.20	1.5	<0.05	19.40	1.16	55.7	4.8	39.5	SANDY CLAY	3538.34	1443.67	235.51	245.25	0.41	0.05	2.98	0.80
SPDC/SS 18 top	<0.001	<0.001	<0.001	<0.001	2377.053	1.563	35.712	1.669	1.130	2.543	0.247	<0.05	<0.03	<0.05	1.280	3.70	22700.00	0.32	1.5	0.039	3.781	0.005	0.061	0.077	0.16	0.9	<0.05	22.30	1.17	71.4	15.5	13.1	SANDY LOAM	3525.32	1361.68	224.02	230.81	2.23	0.23	8.75	1.50
SPDC/SS 18 bottom	<0.001	<0.001	<0.001	<0.001	2125.950	0.973	29.319	2.111	1.114	3.216	0.336	<0.05	<0.03	<0.05	1.666	4.10	21900.00	0.44	2.3	0.100	3.664	0.020	0.060	0.081	0.66	1.2	<0.05	29.50	1.19	71.7	12.9	15.4	SANDY LOAM	3576.16	1052.08	196.25	219.70	2.56	0.40	6.44	NIL

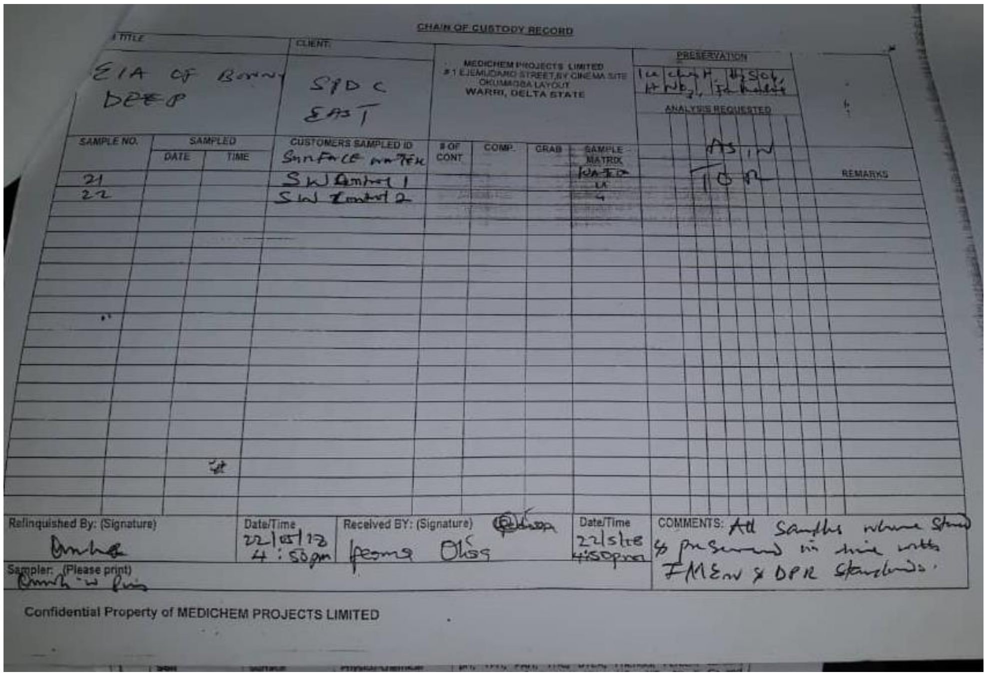
SOIL Results

COMPONENT	Total THC (mg/kg)	PAH	TPH	BTEX	Fe (mg/kg)	Cu (mg/kg)	Zn (mg/kg)	Pb (mg/kg)	Cd (mg/kg)	Ni (mg/kg)	Cr (mg/kg)	V (mg/kg)	As (mg/kg)	Hg (mg/kg)	Ba (mg/kg)	pH	ELECTRICAL CONDUCTIVITY (uS/cm)	TOC (%)	O&G (ppm)	NH_4^+ (mg/kg)	NO_3^- (mg/kg)	NO_2^- (mg/kg)	TOTAL PHOSPHOROUS (%)	TOTAL NITROGEN (%)	BULK DENSITY (g/cm)	THC (mg/kg)	Phenol (mg/kg)	Porosity (% pore space)	CEC (Cmol/kg)	% Sand	% Silt	% Clay	Texture	Na (mg/kg)	K (mg/kg)	Ca (mg/kg)	Mg (mg/kg)	(THB) X 10^4 (cfu/g)	(THF) X 10^3 (cfu/g)	(HUB) X 10^3 (cfu/g)	(HUF) X 10^2 (cfu/g)
SPD C/SS 19 top	0.012	<0.001	0.012	<0.001	1925.068	2.108	15.238	4.768	1.214	7.262	0.676	<0.05	<0.03	<0.05	1.535	5.00	22100.00	0.16	1.1	0.108	2.872	0.032	-0.008	0.072	0.60	0.9	<0.05	43.40	1.17	51.3	3.0	45.7	CLAY	3563.45	1247.28	254.76	214.14	0.49	1.20	1.24	0.09
SPD C/SS 19 bottom	<0.001	<0.001	<0.001	<0.001	2979.701	0.869	31.907	0.861	3.215	1.313	0.192	<0.05	<0.03	<0.05	1.666	2.20	20200.00	0.10	0.4	0.043	11.107	0.015	0.010	0.084	0.25	<0.1	<0.05	41.90	2.19	43.8	6.8	49.4	ClAY	3170.17	995.29	212.20	219.70	0.35	1.20	1.75	NIL
SPD C/SS 20 top	<0.001	<0.001	<0.001	<0.001	2829.039	0.723	19.642	0.515	1.113	3.165	0.313	<0.05	<0.03	<0.05	1.280	3.80	19000.00	0.54	0.5	0.043	1.875	0.017	0.024	0.046	1.00	<0.5	<0.05	50.00	1.19	48.8	9.5	41.7	CLAY	3122.69	1024.10	214.44	196.36	0.28	1.10	1.43	0.07
SPD C/SS 20 bottom	<0.001	<0.001	<0.001	<0.001	2879.259	1.117	36.639	3.588	1.103	5.466	0.217	<0.05	<0.03	<0.05	1.793	3.60	18600.00	0.63	1.2	0.039	1.552	0.006	0.018	0.052	0.39	0.7	<0.05	53.30	1.20	65.2	13.9	20.9	SANDY LOAM	3082.15	1025.67	202.53	181.14	0.18	0.13	1.50	0.50
SPD C/SS 21 top	<0.001	<0.001	<0.001	<0.001	2879.259	1.491	30.613	1.010	1.112	1.540	0.230	<0.05	<0.03	<0.05	1.535	5.60	2320.00	0.71	0.5	0.048	3.260	0.009	0.001	0.013	0.20	<0.1	<0.05	44.40	2.13	80.9	9.7	9.4	LOAMY SAND	466.81	22.07	1.79	1.14	1.42	0.26	3.64	1.96
SPD C/SS 21 bottom	<0.001	<0.001	<0.001	<0.001	2075.730	2.270	27.677	2.077	2.100	3.164	0.380	<0.05	<0.03	<0.05	1.408	5.70	3900.00	0.68	1.5	0.104	2.803	0.006	0.019	0.029	0.20	0.9	<0.05	44.40	1.42	77.9	9.7	12.4	SANDY LOAM	672.75	92.23	8.26	7.31	1.05	0.28	4.00	2.25
SPD C/SS 22 top	0.069	<0.001	0.069	<0.001	2125.950	1.575	10.583	2.708	1.126	4.125	0.316	<0.05	<0.03	<0.05	1.793	6.50	12900.00	0.07	1.1	0.091	3.190	0.006	0.065	0.062	1.00	0.6	<0.05	45.20	1.13	65.5	16.3	18.2	SANDY LOAM	2588.93	110.53	38.72	36.36	1.26	0.49	3.65	NIL
SPD C/SS 22 bottom	<0.001	<0.001	<0.001	<0.001	2429.684	2.632	65.187	1.381	1.138	2.105	0.346	<0.05	<0.03	<0.05	1.666	6.30	12500.00	0.09	0.8	0.204	3.319	0.007	0.067	0.060	1.80	0.3	<0.05	42.90	2.04	55.9	9.5	34.6	SANDY CLAY LOAM	2473.93	57.25	30.56	14.14	1.13	0.03	2.00	NIL
SPD C/SS 23 top	0.034	<0.001	0.034	<0.001	2200.116	5.974	82.077	1.679	1.130	2.558	0.727	<0.05	<0.03	<0.05	1.408	6.40	10218.00	0.09	1.3	0.087	1.864	0.005	0.023	0.093	0.20	0.7	<0.05	42.90	2.50	2.0	33.0	65.0	CLAY	2115.93	153.74	120.26	97.47	0.58	1.25	5.50	1.50

SOIL Results

COMPONENT	Total THC (mg/kg)	PAH	TPH	BTEX	Fe (mg/kg)	Cu (mg/kg)	Zn (mg/kg)	Pb (mg/kg)	Cd (mg/kg)	Ni (mg/kg)	Cr (mg/kg)	V (mg/kg)	As (mg/kg)	Hg (mg/kg)	Ba (mg/kg)	pH	ELECTRICAL CONDUCTIVITY (uS/cm)	TOC (%)	O&G (ppm)	NH_4^+ (mg/kg)	NO_3^- (mg/kg)	NO_2^- (mg/kg)	TOTAL PHOSPHOROUS (%)	TOTAL NITROGEN (%)	BULK DENSITY (g/cm)	THC (mg/kg)	Phenol (mg/kg)	Porosity (% pore space)	CEC (Cmol/kg)	% Sand	% Silt	% Clay	Texture	Na (mg/kg)	K (mg/kg)	Ca (mg/kg)	Mg (mg/kg)	(THB) X 10^4 (cfu/g)	(THF) X 10^3 (cfu/g)	(HUB) X 10^3 (cfu/g)	(HUF) X 10^2 (cfu/g)
SPD C/SS 23 bottom	**<0.001**	**<0.001**	**<0.001**	**<0.001**	1473.082	5.988	31.487	0.892	3.114	1.360	0.729	<0.05	<0.03	<0.05	1.280	6.20	11362.00	0.05	0.8	0.134	1.243	0.005	0.028	0.083	0.40	0.3	<0.05	43.50	1.58	5.0	5.0	90.0	CLAY	2139.93	180.75	169.18	41.92	0.45	1.03	2.96	1.23
SPD C/SS 24 top	**<0.001**	**<0.001**	**<0.001**	**<0.001**	1876.375	1.475	37.296	7.873	2.112	9.611	0.215	<0.05	<0.03	<0.05	1.666	5.60	2870.00	0.66	1.9	0.061	1.477	0.015	0.004	0.079	0.70	1.1	<0.05	48.60	2.34	67.4	11.4	21.2	SANDY LOAM	442.09	32.64	6.49	5.25	1.18	0.4	3.51	NIL
SPD C/SS 24 bottom	**<0.001**	**<0.001**	**<0.001**	**<0.001**	2660.491	1.073	27.600	3.556	2.102	5.416	0.169	<0.05	<0.03	<0.05	1.920	5.40	3294.00	0.64	2.3	0.069	1.911	0.007	0.008	0.070	0.25	1.5	<0.05	46.20	2.30	64.1	17.2	18.7	SANDY LOAM	637.72	112.48	20.19	11.97	0.50	0.20	4.50	NIL
SPD C/SS C1 top	**0.004**	**<0.001**	**0.004**	**<0.001**	2105.417	0.625	16.803	2.919	1.092	4.446	0.118	<0.05	<0.03	<0.05	1.535	5.70	19500.00	0.14	1.2	0.030	2.080	0.010	0.001	0.074	0.16	0.4	<0.05	24.60	1.46	33.8	22.6	43.6	CLAY	3344.28	754.98	86.39	64.92	0.75	0.18	7.25	NIL
SPD C/SS C1 bottom	**<0.001**	**<0.001**	**<0.001**	**<0.001**	1947.103	1.188	30.381	0.926	1.105	1.412	0.182	<0.05	<0.03	<0.05	1.280	5.50	19100.00	0.06	1.6	0.100	4.544	0.006	0.018	0.080	0.66	0.6	<0.05	25.00	1.44	28.0	29.1	42.9	ClAY	3150.83	957.48	87.59	67.88	0.84	0.15	4.83	0.09
SPD C/SS C2 top	**<0.001**	**<0.001**	**<0.001**	**<0.001**	2238.171	1.532	25.765	0.997	1.113	1.519	0.160	<0.05	<0.03	<0.05	1.535	4.40	13200.00	0.13	0.8	0.087	5.775	0.013	0.047	0.066	0.33	<0.1	<0.05	42.90	1.57	69.4	11.8	18.8	SANDY LOAM	2387.44	633.32	96.00	39.35	0.33	0.03	2.75	NIL
SPD C/SS C2 bottom	**<0.001**	**<0.001**	**<0.001**	**<0.001**	1530.955	1.888	61.362	2.473	1.121	3.767	0.328	<0.05	<0.03	<0.05	1.535	4.20	12900.00	0.07	1.3	0.035	6.332	0.007	0.052	0.069	0.25	0.7	<0.05	42.85	1.44	51.3	3.9	44.8	ClAY	2131.16	849.99	103.99	59.02	0.41	0.09	2.11	NIL

Sample Chain of Custody



CHAIN OF CUSTODY RECORD

JOB TITLE: EIA OF BONNY DEEP

CLIENT: SPDC EAST

MEDICHEM PROJECTS LIMITED
#1 EJEMUDARO STREET,BY CINEMA SITE
OKUMAGBA LAYOUT
WARRI, DELTA STATE

PRESERVATION: Ice chest, H_2SO_4, HNO_3, [illegible]

ANALYSIS REQUESTED: As in TOR

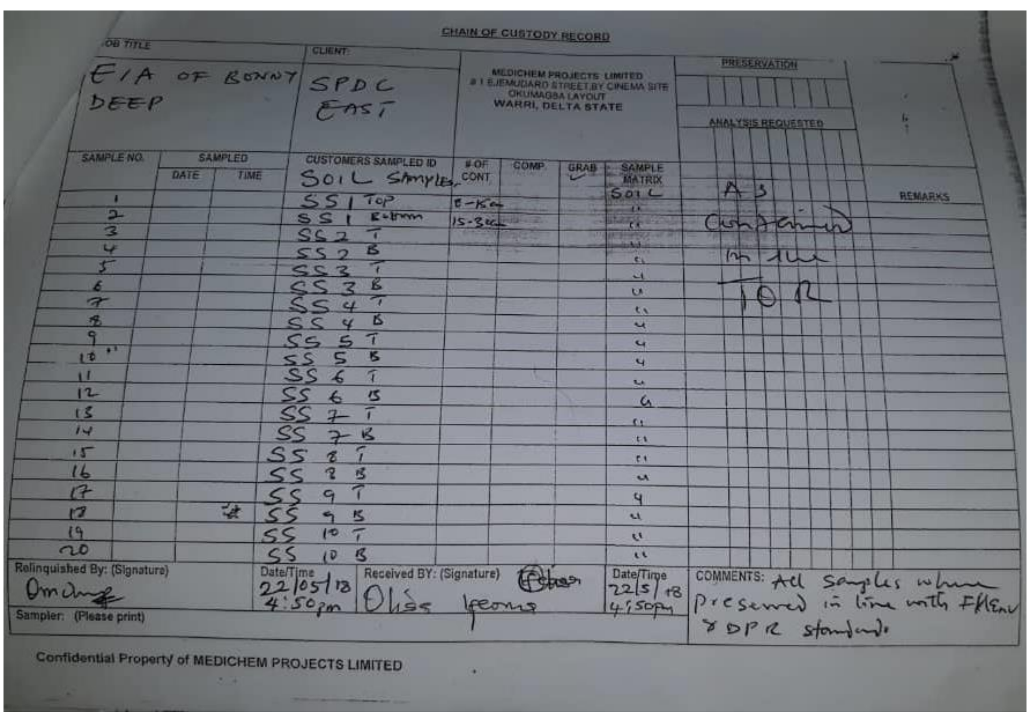
SAMPLE NO.	SAMPLED DATE	SAMPLED TIME	CUSTOMERS SAMPLED ID	# OF CONT	COMP.	GRAB	SAMPLE MATRIX	REMARKS
			Surface water					
21			SW Control 1				Water	
22			SW Control 2				"	

Relinquished By: (Signature) [signature] Date/Time 22/05/18 4:50pm Received BY: (Signature) Ifeoma Olise [signature] Date/Time 22/5/18 4:50pm

Sampler: (Please print) [signature]

COMMENTS: All samples where stored & preserved in line with FMEnv & DPR standards.

Confidential Property of MEDICHEM PROJECTS LIMITED



CHAIN OF CUSTODY RECORD

JOB TITLE: EIA OF BONNY DEEP

CLIENT: SPDC EAST

MEDICHEM PROJECTS LIMITED
#1 EJEMUDARO STREET,BY CINEMA SITE
OKUMAGBA LAYOUT
WARRI, DELTA STATE

PRESERVATION

ANALYSIS REQUESTED: As contained in the TOR

SAMPLE NO.	SAMPLED DATE	SAMPLED TIME	CUSTOMERS SAMPLED ID	# OF CONT	COMP.	GRAB	SAMPLE MATRIX	REMARKS
			SOIL Samples			✓		
1			SS 1 Top	0-15cm			SOIL	
2			SS 1 Bottom	15-30cm			"	
3			SS 2 T				"	
4			SS 2 B				"	
5			SS 3 T				"	
6			SS 3 B				"	
7			SS 4 T				"	
8			SS 4 B				"	
9			SS 5 T				"	
10			SS 5 B				"	
11			SS 6 T				"	
12			SS 6 B				"	
13			SS 7 T				"	
14			SS 7 B				"	
15			SS 8 T				"	
16			SS 8 B				"	
17			SS 9 T				"	
18			SS 9 B				"	
19			SS 10 T				"	
20			SS 10 B				"	

Relinquished By: (Signature) [signature] Date/Time 22/05/18 4:50pm Received BY: (Signature) Olise Ifeoma [signature] Date/Time 22/5/18 4:50pm

Sampler: (Please print)

COMMENTS: All samples where preserved in line with FMEnv & DPR standards.

Confidential Property of MEDICHEM PROJECTS LIMITED

CHAIN OF CUSTODY RECORD

JOB TITLE:

CLIENT:

MEDICHEM PROJECTS LIMITED
1 EJEMUDARO STREET,BY CINEMA SITE
OKUMAGBA LAYOUT
WARRI, DELTA STATE

PRESERVATION

ANALYSIS REQUESTED

SAMPLE NO.	SAMPLED DATE	SAMPLED TIME	CUSTOMERS SAMPLED ID	# OF CONT	COMP.	GRAB	SAMPLE MATRIX	ANALYSIS REQUESTED	REMARKS
			SOIL SAMPLE TOPS & Bottom						
41			SS21 Top	0-15cm			Soil	AS	
42			SS 21 Bottom	15-30cm			"	IN	
43			SS 22				"		
44			SS 22				"	TOR	
45			SS 23				"		
46			SS 23				"		
47			SS 24				"		
48			SS 24				"		
49			SS 1 Control Top	0-15cm			"		
50			SS 1 Control Bottom	15-30cm			"		
51			SS 2 Control Top	"			"		
52			SS 2 Control Bottom	"			"		

Relinquished By: (Signature) Omoluwa
Date/Time 22/05/18 4:50pm
Received BY: (Signature) Oliga Ifeoma
Date/Time 22/5/18 4:50pm
COMMENTS: All samples where preserved & stored in line with FMEnv & DPR Standards.
Sampler: (Please print) Omoluwa-W. Pius

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	Soil 24 + 2 control	Surface (0 -15cm)	Physico-chemical	pH, ..., Available PO_4^{3-}, Total-N, NH_4^+, NO_3^-, NO_2^-, Na, K, Ca and Mg, cation exchange capacity, (CEC), conductivity, oil & ... heavy metals (Fe, Cd, Cr, Pb, Cu, Hg, Ar, Ni, V and ...

CHAIN OF CUSTODY RECORD

JOB TITLE: EIA OF BONNY DEEP

CLIENT: SPDC EAST

MEDICHEM PROJECTS LIMITED
1 EJEMUDARO STREET,BY CINEMA SITE
OKUMAGBA LAYOUT
WARRI, DELTA STATE

PRESERVATION: Ice chest, H_2SO_4, HNO_3, Formalin

ANALYSIS REQUESTED

SAMPLE NO.	SAMPLED DATE	SAMPLED TIME	CUSTOMERS SAMPLED ID	# OF CONT	COMP.	GRAB	SAMPLE MATRIX	ANALYSIS REQUESTED	REMARKS
			SURFACE WATER				WATER		
1			SW 1				"	AS	
2			SW 2				"		
3			SW 3				"	CONTAINED	
4			SW 4				"		
5			SW 5				"	IN THE	
6			SW 6				"		
7			SW 7				"	TOR	
8			SW 8				"		
9			SW 9				"		
10			SW 10				"		
11			SW 11				"		
12			SW 12				"		
13			SW 13				"		
14			SW 14				"		
15			SW 15				"		
16			SW 16				"		
17			SW 17				"		
18			SW 18				"		
19			SW 19				"		
20			SW 20				"		

Relinquished By: (Signature) Omoluwa
Date/Time 22/05/18 4:50pm
Received BY: (Signature) Oliga Ifeoma
Date/Time 22/05/18 4:50pm
COMMENTS: All samples where stored & preserved in line with FMEnv & DPR Standards
Sampler: (Please print) Omoluwa-W. Pius

Confidential Property of MEDICHEM PROJECTS LIMITED

CHAIN OF CUSTODY RECORD

JOB TITLE: EIA OF BONNY DEEP

CLIENT: SPDC EAST

MEDICHEM PROJECTS LIMITED
1 EJEMUDARO STREET,BY CINEMA SITE
OKUMAGBA LAYOUT
WARRI, DELTA STATE

PRESERVATION

ANALYSIS REQUESTED

SAMPLE NO.	SAMPLED DATE	SAMPLED TIME	CUSTOMERS SAMPLED ID	# OF CONT	COMP	GRAB	SAMPLE MATRIX	ANALYSIS REQUESTED	REMARKS
			SOIL SAMPLE TOP & BOTTOM				Soil	AS IN TOR	
21			SS 11 TOP	0-15cm			"		
22			SS 11 Bottom	15-30cm			"		
23			SS 12 T				"		
24			SS 12 B				"		
25			SS 13 T				"		
26			SS 13 B				"		
27			SS 14 T				"		
28			SS 14 B				"		
29			SS 15 T				"		
30			SS 15 B				"		
31			SS 16 T				"		
32			SS 16 B				"		
33			SS 17 T				"		
34			SS 17 B				"		
35			SS 18 T				"		
36			SS 18 B				"		
37			SS 19 T				"		
38			SS 19 B				"		
39			SS 20 T				"		
40			SS 20 B				"		

Relinquished By: (Signature)

Date/Time

Received BY: (Signature) Olise Ifeoma

Date/Time 22/5/18 4:50pm

COMMENTS:

Sampler: (Please print)

Confidential Property of MEDICHEM PROJECTS LIMITED

CHAIN OF CUSTODY RECORD

TITLE: EIA OF BONNY DEEP

CLIENT: SPDC EAST

MEDICHEM PROJECTS LIMITED
1 EJEMUDARO STREET,BY CINEMA SITE
OKUMAGBA LAYOUT
WARRI, DELTA STATE

PRESERVATION: Ice chest

ANALYSIS REQUESTED

SAMPLE NO.	SAMPLED DATE	SAMPLED TIME	CUSTOMERS SAMPLED ID	# OF CONT	COMP.	GRAB	SAMPLE MATRIX	ANALYSIS REQUESTED	REMARKS
			SEDIMENT SAMPLES				SEDIMENT	AS CONTAINED IN THE TOR	
21			SED 21 Control	SED C1			"		
22			SED 22 Control	SED C2			"		

Relinquished By: (Signature) Omoh

Date/Time 22/05/18 4:56pm

Received BY: (Signature) Olise Ifeoma

Date/Time 22/5/18 4:50pm

COMMENTS: All samples where stored & preserved in line with FMEnv & DPR Standards

Sampler: (Please print) Omoh-W. Prince

Confidential Property of MEDICHEM PROJECTS LIMITED

CHAIN OF CUSTODY RECORD

JOB TITLE: EIA OF BONNY DEEP

CLIENT: SPDC EAST

MEDICHEM PROJECTS LIMITED
1 EJEMUDARO STREET,BY CINEMA SITE
OKUMAGBA LAYOUT
WARRI, DELTA STATE

PRESERVATION

ANALYSIS REQUESTED: AS IN TOR

SAMPLE NO.	SAMPLED DATE	SAMPLED TIME	CUSTOMERS SAMPLED ID (SOIL SAMPLE Top & Bottom)	# OF CONT	COMP.	GRAB	SAMPLE MATRIX	REMARKS
21			SS 11 Top	0-15cm			Soil	
22			SS 11 Bottom	15-30cm			"	
23			SS 12 T				"	
24			SS 12 B				"	
25			SS 13 T				"	
26			SS 13 B				"	
27			SS 14 T				"	
28			SS 14 B				"	
29			SS 15 T				"	
30	"		SS 15 B				"	
31			SS 16 T				"	
32			SS 16 B				"	
33			SS 17 T				"	
34			SS 17 B				"	
35			SS 18 T				"	
36			SS 18 B				"	
37			SS 19 T				"	
38		[illegible]	SS 19 B				"	
39			SS 20 T				"	
40			SS 20 B				"	

Relinquished By: (Signature) | Date/Time | Received BY: (Signature) Oliss Ifeoma [signature] | Date/Time 22/5/18 4:50pm | COMMENTS:

Sampler: (Please print)

Confidential Property of MEDICHEM PROJECTS LIMITED

CHAIN OF CUSTODY RECORD

JOB TITLE: EIA OF BONNY DEEP

CLIENT: SPDC EAST

MEDICHEM PROJECTS LIMITED
1 EJEMUDARO STREET,BY CINEMA SITE
OKUMAGBA LAYOUT
WARRI, DELTA STATE

PRESERVATION: ICE CHEST

ANALYSIS REQUESTED: AS CONTAINED IN THE TOR

SAMPLE NO.	SAMPLED DATE	SAMPLED TIME	CUSTOMERS SAMPLED ID (SEDIMENT SAMPLES)	# OF CONT	COMP.	GRAB	SAMPLE MATRIX	REMARKS
1			SED 1	500 1			SEDIMENT	
2			SED 2				"	
3			SED 3				"	
4			SED 4				"	
5			SED 5				"	
6			SED 6				"	
7			SED 7				"	
8			SED 8				"	
9			SED 9				"	
10	"		SED 10				"	
11			SED 11				"	
12			SED 12				"	
13			SED 13				"	
14			SED 14				"	
15			SED 15				"	
16			SED 16				"	
17			SED 17				"	
18		[illegible]	SED 18				"	
19			SED 19				"	
20			SED 20				"	

Relinquished By: (Signature) Omoh [signature] | Date/Time | Received BY: (Signature) Oliss Ifeoma [signature] | Date/Time 22/5/18 4:50pm | COMMENTS: All samples where stored & preserved in line with FMEnv & DPR standards.

Sampler: (Please print) Omoh. W. Pius

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