Final Environmental and Social Impact Assessment Report for the Proposed 100MW Solar Independent Power Plant and 18 KM Transmission Line Project, Ganjuwa Local Government Area, Bauchi State by Nigerian Solar Capital Partners/Globeleq/ARM-Harith

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Acronyms/Abbreviations

AC	Alternating Current
ASTM	American Society for Testing of Materials
ALARP	As Low As Reasonably Possible
BAT	Best Available Technology
BOD	Biological Oxygen Demand
BASEPA	Bauchi State Environmental Protection Agency
BP	Bank Procedure (World Bank)
BSMEnv	Bauchi State Ministry of Environment and Forestry
CDM	Clean Development Mechanism
CDP	Community Development Plan
CdTe	Cadmium Telluride
CFCS	Chlorofluorocarbons
CH_4	Methane
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COD	Chemical Oxygen Demand
CRO	Community Relations Officer
CSP	Concentrated Solar Power
DC	Direct Current
DNI	Direct Normal Irradiation
dB	Decibels
DO	Dissolved Oxygen
EBS	Environmental Baseline Survey
ECN	Energy Commission of Nigeria
EMS	Environmental Management System
EPA	Environmental Protection Agency
EPSR	Electric Power Sector Reform
ES	Executive Summary
ESIA	Environmental and Social Impact Assessment
ESMP	Environmental & Social Management Plan
FEPA	Federal Environmental Protection Agency
FGN	Federal Government of Nigeria
FMEnv	Federal Ministry of Environment
GDP	Gross Domestic Product
GHG	Green House Gases
GPS	Global Positioning System
ha	Hectare
HDB	Hydrocarbon-Degrading Bacteria
HDF	Hydrocarbon-Degrading Fungi
HSE	Health, Safety and Environment
HV	High Voltage
ITCZ	Inter-Tropical Convergence Zone
IPP	Independent Power Project
KV	Kilovolt
KW	Kilowatt
KWh	Kilowatt Hour
LGA	Local Government Area
LV	Low Voltage
MDGs	Millennium Development Goals
MJ/m^2	Megajoules per square meter
MVA	Megavolt Ampere
MW	Megawatt
MWh	Megawatt Hour
N	Nitrogen
NAAQS	National Ambient Air Quality Standards
NIMET	Nigerian Meterological Agency
NBET	Nigerian Bulk Electricity Trading
NSCP	Nigeria Sola Capital Partners
NESREA	National Environmental Standards and Regulations Enforcement Agency

NO_X	Oxides of Nitrogen
NSCP	Nigerian Solar Capital Partners
NO	Nitrogen Oxide
NO_2	Nitrogen Dioxide
O&M	Operation and Maintenance
OP	Operational Policy (World Bank)
P	Total Phosphorus
PCDP	Public Consultation and Disclosure Plan
PM	Particulate Matter
PM_1	Particulate Matter with Particle Size Less Than 1.0 Micrometer in Diameter
PM_{10}	Particulate Matter with Particle Size Less Than 10 Micrometer in Diameter
$PM_{2.5}$	Particulate Matter with Particle Size Less Than 2.5 Micrometer in Diameter
PPE	Personal Protective Equipment
PTW	Permit to Work
PPP	Public Private Partnership
PV	Photovoltaic
RAP	Resettlement Action Plan
REA	Rural Electrification Agency
RH	Relative Humidity
RoW	Right of Way
SOP	Standard Operating Procedure
SO_2	Sulphur dioxide
SO_X	Oxides of Sulphur
SPM	Suspended Particulate Matter
SRB	Sulphate Reducing Bacteria
S.I	Standard Instrument
STC	Standard Test Conditions
TDS	Total Dissolved Solids
THB	Total Heterotrophic Bacteria
THC	Total Hydrocarbon Content
THF	Total Heterotrophic Fungi
TOC	Total Organic Carbon
ToR	Terms of Reference
TPH	Total Petroleum Hydrocarbon
TSP	Total Suspended Particles
TSS	Total Suspended Solids
TL	Transmission Line
UF	Ultra-Filtration
UV	Ultra Violet
VES	Vertical Electrical Sounding
WHO	World Health Organization
QA/QC	Quality Assurance /Quality Control
USD	United States Dollar
VOC	Volatile Organic Compounds
%	Percent
^oC	Degree Celsius
%	percentage
µS/cm	microSiemens per centimetre
atm	atmosphere
cfu/ml	colony forming unit per millilitre
cfu/g	colony forming unit per gramme
cm	centimetre
ft	feet
g	grammes
g/l	grammes per litre
g/kg	grams per kilogramme
meq/100g	milliequivalent per 100 gramme
in	inches
kg	kilogram
km	kilometre
m	metre
m/s	metre per second
m^2	metre square

m^3	metre cube
mg/kg	milligramme per kilogramme
mg/l	milligramme per litre
mV	millivolt
mg/m^3	milligramme per metre cubic
ml	millilitre
mm	millimetre
mm/hr	millimetre per hour
mS/cm	milliSiemens per centimetre
mw	megawatts
NTU	nephelometric Turbidity Units
^oC	degrees Celsius
ppm	parts per million
ppt	part per thousand
s	second
t	tonne

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Executive Summary

Background

Whilst Nigeria relies heavily on fuels to meet its energy needs, the country is well endowed with renewable energy resources that offer sustainable alternatives to fossil fuels. Renewable energy harnesses naturally occurring non-depletable sources of energy, such as solar, wind, biomass, hydro, tidal and ocean current, to produce electricity, gaseous and liquid fuels, heat, or a combination of these energy types. The successful use of renewable energy technology in Nigeria still requires extensive investigation, however, solar power technologies have been identified as being potentially viable and capable of being employed on a large scale.

Project Overview

Nigerian Solar Capital Partners (NSCP), together with Globeleq and ARM-Harith, is proposing the establishment of an independent solar power plant in Ganjuwa, Bauchi State. The proposed facility will be located in Zongoro Community in Ganjuwa Local Government Area (LGA), because of the abundance of solar radiation which is critical for optimum generation of solar energy.

The facility is expected to have a footprint of 200 ha within which the following infrastructure will be set-up:

Office and control buildings;
Transmission line; Guard house; Lay down area, campsite and assembly area;
Residential quarters; Internal access road; and
An on-site substation

The power plant, which will utilize solar technology processes for power production, will generate 100 MW of electricity. This would boost power supply in the nation while providing jobs in the host community and the state.

The total project cost is estimated at about US$100,000,000 (One Hundred Million United States' Dollars). The following fundamental factors will contribute to the sustainability of the proposed project as follows:

Environmental sustainability through implementation of the Environmental Management Plan contained in this report to ensure mitigation of adverse impacts on the environment;

Social sustainability through ongoing consultation with community stakeholders throughout the project life-cycle to ensure social support and acceptability;

Economic sustainability in consideration of institutional support and policy implementation for development of the electricity market, economic development through job creation, capacity building, and infrastructural development;

Technical sustainability through adequate technical training on plant operations and maintenance; and international collaboration, partnerships, and knowledge sharing on the operation of large scale solar power plants.

Need for the Project

Increasing economic growth and social development within Nigeria is placing a growing demand on its energy supply. Consequently, the need to enhance power generation is a critical problem in the nation. Coupled with the rapid advancement in economic and social development is the growing awareness of environmental impact, climate change, and the need for sustainable development.

The primary objective of the project is to generate electricity and contribute some to the power grid to improve the epileptic power supply situation in the country. This will contribute to local job creation and achievement of the longer-term goals of economic growth. It will also help reduce the dependency on fossil fuels and reverse the environmental degradation caused by gas flaring in Nigeria. Other environmental benefits include reductions in air, water, and soil pollution.

Analysis of Alternatives

No Action Option: Resorting to the no action option (i.e. not carrying out the project) would result in the continued low power generation and epileptic supply situation in Bauchi State and in the country at large.

Alternative Technology: The existing solar technology alternatives are Photovoltaic (PV) systems and Concentrated Solar Power (CSP) technology. CSP technology employs the use of various techniques to track the Sun and focus sunlight. They systems are however high maintenance and complex systems and require a very large land area (about 5 to 10 acres per MW of capacity). PV, on the other hand, involves a simple design with few technical components, is lower in cost, and is quite reliable due to the absence of moving parts.

Alternative Location: The site in Bauchi was chosen as the preferred site due to: its proximity to the existing transmission line, optimal solar radiation of the area, and availability of required land, though facilitation of Bauchi State Government.

Project Description

In an effort to enhance power generation, Nigeria Solar Capital Partners (NSCP), together with Globeleq and ARM-Harith, intends to develop a 100 MW photovoltaic (PV) Independent Power Project (IPP) in Zongoro Village, Ganjuwa L.G.A, Bauchi State. The project will be situated on 200 ha of land near the town of Kafin Madaki approximately 20 km from Bauchi, the capital of Bauchi State.

The plant will convert solar radiation to electricity using solar panels. The ancillary components of the project include: an on-site substation, 18km 330 kV overhead transmission line to interconnect the solar energy plant to the National Grid, internal access roads, guard house, office and control centre and lay down area, campsite and assembly area. Operation and maintenance of the system would be expected to occur on a limited basis at certain points during the system's estimated 25-year life cycle.

Specific components of the project are as follows:

Solar Farm

The plant would use a renewable method of generating electrical power by converting solar radiation into direct current electricity using silicon panels that exhibit the photovoltaic effect. Photovoltaic (PV) power generation employs solar panels composed of a number of solar cells containing silicon. Power produced by the plant would be approximately 100 MW DC, converted to AC through inverters. Transformers would be installed to step up voltage so that it is compatible with the national grid. The stepped-up power would then be connected to the national grid.

The following infrastructures would be established within the project site:

A solar PV plant constructed using poly crystalline PV modules, installed in regular arrays
A system of inverters and step up transformers

Aboveground and underground electrical conduits and cabling which connect the arrays to the inverters and transformers
Marshalling switchgear to collect the power from the PV arrays
Internal access tracks to allow for maintenance of the site
Supervisory control centre
Site office and maintenance building
Lay down, campsite and assembly area

Transmission Line

The power generated from the solar power plant will be transmitted through a 330kV transmission line to the national grid. It will be stepped up to 33kV, through suitably rated transformers, and then up to the required 132kV level. It will consist of about 30 steel towers, extending to the connection point on the Bauchi-Gombe Road. The steel towers shall pass close to the settlements of - Yuli, Waya, Runde, Dungulhi and Zongoro in Ganjuwa and Bauchi LGAs."

Regulatory Requirements

The project has been classified as a Category I project according to the Nigerian Environmental Impact Assessment (ESIA) Act No. 86 of 1992, similar to the World Banks category A, and hence requires a full and detailed Environmental and Social Impact Assessment (ESIA).

Applicable national regulations include:

FEPA Sectoral Guidelines for Drainage and Irrigation, Power Generation, Industry (Manufacturing, Agriculture/Agro-Allied), and Infrastructure Projects (1992)
Pollution Abatement in Industries Generating Wastes Regulations (1991)
National Effluent Limitations Regulations (S.I.8) 1991
National Pollution Abatement in Industries and Facilities Generating Wastes (S.I.9) 2004
National Management of Solid and Hazardous Wastes Regulations (S.I.15) 1991
Guidelines and Standards for Environmental Pollution Control in Nigeria 1991
Bauchi State Environmental Edict, BASEPA (1994)
National Policy on the Environment, 1989
Environmental Impact Assessment Procedural Guidelines 1995
Environmental Impact Assessment (ESIA) Act No. 86 of 1992
National Guidelines and Standards for Water Quality 1999
Electric Power Sector Reform Act (EPSR Act 2005)
Electricity (Private Licences) Regulations, 1965
Electricity (Annual Returns) Regulations, 1974
Electricity Installation Regulations, 1996
Electricity Supply Regulations, 1996
NEPA Act, Cap 256 LFN 1990
Energy Commission of Nigeria Act, Cap 109 LFN 1990
Utilities Charges Commission Act No. 104 of 1992
Electricity [Amendment] Act No. 28 of 1998
NEPA [Amendment] Act No. 29 of 1998
Ganjuwa and Bauchi LGA Bye-Law
National Electric Power Policy, 2001
NERC (Acquisition of Land and Access Rights for Electricity Projects) Regulations, 2012
NERC (Embedded Generation) Regulations, 2012
NERC (Independent Electricity Distribution Networks) Regulations, 2012
NERC Application for Licence Regulation 2010

NERC Regulation for the Procurement of Generation Capacity, 2014 Land Use Act of Nigeria 1978
Forestry (Amendment Law) 2002
Abandonment Guidelines (FMEnv Sectoral Guidelines, 1995)

Applicable World Bank/IFC policies and guidelines include:

Guidelines for ESIA of Energy and Industry Projects, 1991.
OP/BP 4.01 Environmental Assessments
General Environmental Guideline 1998

Environmental Baseline

A two-season sampling activity was carried out in August 12-18, 2013 (Wet Season) and November 10 -15, 2013 (Dry Season). The team used the grid sampling method to develop a sampling plan to collect samples along air, soil, vegetation and noise transects. Samples were transported to Light House Laboratory, Warri, Delta State for analysis.

Geographical Location

The proposed site is situated at Zongoro Village in Ganjuwa Local Government Area (LGA), Bauchi State, approximately 20 km from Bauchi Township, the state capital. It lies within Latitudes 9°58'51.492"N - 9°59'54.024"N and Longitudes 10°25'45.444"E - 10°26'57.012"E.

Climate and Meteorology

Twenty-Six years (1987 – 2012) meteorological data used in this study were from the Nigeria Meteorological Agency (NIMET, 2013), Abuja. The study area is located in the semi-arid climatic zone characterized by distinct dry and rainy season periods. The area witnesses little or no rainfall in January, February, November and December but its significant rainfall comes in May with maximum in June/August. Its mean relative humidity is 20.5%–78.1% with air temperatures of 14.4 ºC–37.3ºC. The monthly sunshine period is 4.8 to7.6 hours per day with cloud cover of 6.1–6.9 Oktas. Its monthly visibility is 1.9–12.3 km with the minimum in September and maximum in January while its mean surface wind is 0.5–8.8m /s with about 5% calmness and of the south-westerly/north-easterly prevailing wind directions.

Ambient Air Quality

At the power generating site in the wet season, CO was 0.1 ppm, NO_2 was 0.01 – 0.13 and NH_3 was 0.13 ppm, but in the dry season, they were respectively 0.1 ppm, 0.5 ppm and 1.0 – 6.0 ppm. In the wet season, the daily CO and NH_3 were within their limits but NO_2 breached its limit in a location. In the dry season, CO was within its limit but NO_2 and NH_3 breached their limits where detected. There was no significant variation between the wet and dry seasons' concentrations. Particulates at the solar generating site were 6.4 – 19.5 $\mu g/m^3$, 26.1 – 47.8 $\mu g/m^3$, and 29.9 – 54.7 $\mu g/m^3$ for $PM_{2.5}$, PM_{10} and TSP respectively in the wet season. In the dry season, they were 18.2 – 47.2 $\mu g/m^3$, 64.0 – 162.7 $\mu g/m^3$, and 82.3 – 302.3 $\mu g/m^3$ for $PM_{2.5}$, PM_{10} and TSP respectively. These were within limits in the two seasons except $PM_{2.5}$ that breached its limit in two locations in the dry season. The wet and dry seasons' concentrations were significantly different with higher concentrations in the dry season.

The wet season background noise was 40.4 – 48.0 dB(A) in the day but 36.2 – 38.2 dB(A) in the night which were all were within the limits except the night-time noise that breached its limit in a location. In the dry season, the background noise was 29.9 – 35.9 dB(A) in the daytime but 32.5 – 34.1 dB(A) at night. All these were within their limits. Significant difference was noticed between the wet and dry seasons' noise levels with higher levels in the wet season during the day and night.

In the transmission line, NO_2 and NH_3 were detected in the wet season but in the dry season, CO and NH_3 were detected. The wet season NO_2 was 0.05 – 0.06 ppm while NH_3 was 0.13 – 0.75 ppm. The dry season CO was 1.0 ppm with NH_3 level of 2.0 – 3.0 ppm. Though wet season NO_2 were within its limit, NH_3 breached its limit in four locations. In the dry season, CO was within its limit but NH_3 breached its limit in all locations where detected. Though NH_3 was in the two seasons, its concentrations in the wet season were not significantly different from that of the dry season. The transmission line wet season $PM_{2.5}$ were 5.4 – 25.1 $\mu g/m^3$, PM_{10} were 23.4 – 53.6 $\mu g/m^3$, and TSP were 33.6 – 64.6 $\mu g/m^3$ but in the dry season, these were 21.8 – 182.8 $\mu g/m^3$, 65.4 – 287.6 $\mu g/m^3$, and 95.3 – 314.9 $\mu g/m^3$ respectively. The wet and dry seasons particulates were within the set limits in all locations but in the dry season, $PM_{2.5}$ breached its limit in three locations. While wet and dry seasons PM_{10} and TSP were significantly different, there was no seasonal variation in their PM_{10}. The transmission line corridor has day-time background noise of 40.1 – 43.8 dB(A) but 32.5 – 37.5 dB(A) at night in the wet season which were all within the limits. In the dry season, the transmission line corridor day-time background noise was 27.9 – 45.3 dB(A) but 30.8 – 31.2 dB(A) at night. All these were within the set limits except the night-time background noise that breached its limit in one location.

Within the communities, measured CO was 0.1 – 0.3 ppm with NO_2 and NH_3 levels of 0.05 ppm and 0.13 – 0.50 ppm respectively in the wet season. In the dry season, CO was 1.0 ppm and NH_3 was 1.0 -9.0 ppm. While CO was within its limit in the two seasons, NO_2 was within its limit in the wet season but NH_3 breached its limit in two locations. Though NH_3 was detected in the two seasons, there was no significant seasonal variation.

The wet season $PM_{2.5}$ in the communities were 5.8 – 9.2 $\mu g/m^3$, its PM_{10} were 21.4 – 63.5 $\mu g/m^3$ with TSP levels of 15.1 – 68.8 $\mu g/m^3$. In the dry season, $PM_{2.5}$ were 24.8 – 113.3 $\mu g/m^3$, PM_{10} were 53.5 – 163.7 $\mu g/m^3$ and TSP were 83.8 – 176.7 $\mu g/m^3$. Particulates in the two seasons were within their limits except $PM_{2.5}$ that breached its set limit in all but one sampling locations. The wet and dry seasons PM_{10} and TSP show significant variation with higher concentrations in the dry season.

In the communities, the wet season daytime background noise was 46.4 – 57.8 dB(A) with night-time levels of 33.1 – 41.7 dB(A). All these were within all the noise limits but breached the day-time ambient limit in one of the communities. The night-time background noise breached the night-time limit in all the sampling locations in the season. In the dry season, the daytime background noise was 34.7 – 49.8 dB(A) with night-time background levels of 31.3 – 43.1 dB(A). These were within all the ambient noise limits in all the sampling locations. The seasonal variation of noise within the communities between the wet and dry season is insignificant.

The heavy metals tested for were Cd, Pb, Cr, Si, Ti, V, Mn, Fe, Ni, Zn, Cu, Se, As, Sn and Sb. In the proposed farm site, Cr and Fe were not detected and in the neighbouring communities, Cr, Fe, and Zn were not detected. However, all the metals were detected in the proposed transmission line. The detected metals in all the sampling locations were very low ranging between 0.01 and 7.97 $\mu g/m^3$ with Ni, Cu, and As being the minimum and Sn being the maximum detected in the neighbouring community. All were within their 24-hour limit of the Federal Ministry of Environment.

From the air quality parameters' concentrations obtained, there is a high carrying capacity airshed for industrial activities in the study area. Overall, the airshed in the project location can be classified as Class II. With respect to particulates and gaseous pollutants, the airshed can further be classified as having an un-degraded air quality using the World Bank/IFC Guidelines.

Geology and Hydrogeology

The project area is located within Gongola basin of Gombe sub-basin of the Upper Benue river basin. The surrounding of the study area is marked by an up-warped basement ridge spotted by a number of volcanic intrusions. Its hydrogeology is described by aquiferous formations making up the geological sequence in the Gongola basin. Permeability in the area is high, and water table is variable but generally low from near-surface to 200 m in places.

Ground &Surface Water Quality

At the proposed solar farm area, the pH of the groundwater is slightly acidic to slightly alkaline with mean values of 6.81 and 7.35 in the wet and dry seasons respectively while the pH of the groundwater is slightly alkaline with mean values of 7.05 and 7.32 in the wet and dry seasons respectively along the transmission line. Turbidity was marginal during both seasons while BOD and COD varied significantly with seasons. Heavy metal concentrations were generally low, below detection limit of 0.01ml/l for most metals during both seasons except for Fe and K. Six (6) samples each were analysed along the transmission line and the solar farm site.

At the solar farm area, the pH of the water body is slightly alkaline, with a mean value of 8.10 and 7.26 respectively during the wet and dry seasons while along the transmission line, pH of the water body is also slightly alkaline, with mean concentration value of 8.06 in the wet season and 7.95 in the dry season. Salinity was low for both seasons although turbidity was high for both seasons. Nutrients (anions and cations) were high for both seasons indicative of potential for weed and algae growth. A total of twelve (12) and nine (9) samples were analysed respectively in wet season and dry season each along the transmission line and solar farm site.

Sediments

At the solar farm site, pH of the sediment samples is slightly acidic with a range of 5.56–6.6.6 in the river within the proposed site while a mean range of 5.5.62–6.27 was recorded along the transmission line for both seasons. The sediments were slightly acidic and predominantly sandy for both seasons with high Fe content. Microbial diversity and population density did not vary significantly with seasons. A total of twelve (12) and nine (9) samples were analysed respectively in wet season and dry season each along the transmission line and solar farm site.

Land Use

The predominant land use in the study area is agriculture, mostly crop farming and livestock rearing. The primary climax vegetation is savanna grassland ecosystem and has been substantially converted into a subsistence agricultural ecosystem, although patches of grassland still exist in some parts of the project area, thus providing a mosaic of farmland and grassland. Cropping is mostly mixed, and typically cultivated crops include tomatoes, maize, rice, onion, sorghum, millet, and guinea corn. Bush burning is usually employed for site clearing as it allows for the regeneration of green grass, and the regenerates are subsequently fed upon by the livestock (cattle, goats, sheep). Farming in the area of study is mostly rainfall dependent and as such farming season is dictated by the amount of rainy days. Virtually all the cultivated arable crops had been harvested as of the time of dry season field study.

Soil

The soils are moderately to very deep, well drained, sandy loam on surface with subsoil slightly clayey layer. They are slightly acidic to near neutral, with low to moderate fertility, and low in sulphate and chloride. Heavy metal contents of the soils were generally within the normal range reported for soils in different countries of the world, and the concentrations of

the heavy metals were all below the critical levels specified for polluted soils. Total hydrocarbon contents (THC) of the soil are very low and are considerably below the critical level for terrestrial habitat in Nigeria. The microbial diversity, population and distribution in the soil do not reflect a polluted environment. It was concluded that the soil's morphology, physical, chemical and microbial properties do not show any evidence of a stressed or polluted environment. No significant seasonal variations were observed in all of the physical, chemical and biological properties of the soils.

Wildlife

The study area contains diverse species and varying population of avians (birds) and reptiles. Common birds in the study area include the Red Eyed Doves (*Stretopelia semitorquata*), Guinea Fowl (*Numida meliagaris*), Cattle Egret (*Bubulcus igris*), Brown Quail (*Coturnix ypsilophora*), Village Weavers (*Ploceus cucullatus*), Canary (*Serinus canari domestica*), Curckoo (*Guira guira*), Crow (*Corvus*), African Hooded Vulture (*Necrosyrtes monachus*), and Stork (*Cicconidae*). Mammals encountered and or reported present in the project area include Hare (*Lepus capensis*), Squirrel (Alpine marmot), Bush Rat (*Rattus fuscipes*), Red Eye Monkey (*Presbitis rubicund*), and Cow (*Bos primigenius*). Reptiles reportedly found in the area include Python snake (*Python mulurus*), Cobra snakes (*Boulengerina annulata*), Viper snake (*Crotalus basiliscus*), Agama Lizards (*Agama mwanzae*), and Monitor Lizards (*Varanus Albigularis*) amongst others.

Vegetation

The proposed project is located within the Northern Guinea vegetation zone. The area is characterized by woodland savanna trees such as *Parkia clappertoniana*, *Vitellaria paradoxaa*, *Monotes* sp. *Azadicrachta indica*, Neem, *Mangifera indica* (Mango), *Isoberlina doka (Abogo)* and *Adansonia digitata* (Baobab). There is evidence of grazing by cattle within the secondary savanna woodland. The major impact expected on the vegetation is that of land take to install facilities for the solar panels. The effect of this is adverse and long-term as some arable and grazing land will be converted. However, the effect is not expected to be significant as the expected land take will account for less than 1% of the total available land, only very few stands of economic trees (generally less than 20 stands) would be affected and the human population therein is very highly sparse. Main noticeable seasonal variation is that most of the grasses had dried up leaving only the few trees and shrubs as at time of dry season field investigation.

Hydrobiology

A total of 13 taxa of benthic macrofauna dominated by the insects during the dry and wet seasons were identified in the samples collected from the study area. Annelids, nematodes molluscs and crustaceans made up the remaining component of the benthic community. Spatial distribution of the different species shows that all the species were generally sparsely distributed as no species was numerous enough to dominate a site and there was no significant difference ($P>0.05$) in population and species diversity among the stations.

A total of 24 taxa of phytoplankton belonging to four divisions namely Chlorophyta (green algae), Bacillariophyta (diatoms), Euglenophyta (euglenids) and Cyanophyta (blue-green algae) were recorded in the samples during the dry season as against the 22 taxa during the previous wet season survey. The green algae dominated the phytoplankton community constituting 66% and 58% of the total phytoplankton population during the dry and wet seasons respectively. The blue-green algae, euglenids and diatoms following in that order of abundance constituted the rest of the phytoplankton.

Zooplankton was represented by seventeen species during the dry season as against the eighteen reported for the wet season. The most frequently encountered and more diverse were the Crustaceans consisting of copepods and cladocerans. Other zooplankton encountered

included 3 species of rotifera, 2 protozoans and 1 ostracod. Generally, the zooplankton were sparse in terms of numbers of individuals and taxa richness across the stations.

There was generally, similarity in taxa composition and population density of both flora and fauna in the water and sediment during both seasons across the stations in all the sites and along the transmission line sampled, such that there was no significant difference ($p > 0.05$) amongst them. The low diversity levels reported for the biotic community investigated may not be unconnected with the oligotrophic status of the water bodies.

Socio-economic Baseline

In January 2017, ERM completed the project RAP study detailing the number of affected households, the key project impacts, and compensation recommendations. 297 household will be impacted within the Project Footprint; 172 located within the Project site and 125 located in the Transmission Line RoW. The Project requires a permanent land take of 200 ha, currently used by the communities of Angwa Fulani, Angwa Waiziri, and Gawa. There are 46 houses situated within the Project Footprint that will require physical relocation. Physical losses include agricultural land excluding houses (269.5 ha), trees (5,342), and grazing land (96.6 ha).
For loss of housing and land, PAPs will receive compensation packages tailored to their specific assets and entitlements. Compensation packages will include an agreed combination of fit-for-purpose replacement housing/agricultural land, physical assistance with the relocation process or a cash amount to cover the cost, and livelihood restoration and improvement programmes. Livelihood restoration programmes will consist of packages of options tailored to the level of impact experienced. Livelihood restoration will be carried out together with implementing partner including NGOs, government services, training institutes, etc.

Altogether, 250 individual respondents were interviewed for the study, in addition to 3 Focus Group Discussion sessions (2 for males and 1 for females) in the study communities.

Population and Demography

There are ten settlements in the Project Footprint comprising a total population of 2,312 people that will be physically and/or economically displaced by the project. Within and around the project area are five (5) communities namely; Zongoro in Ganjuwa LGA and Dungulbi, Runda, Waya and Yuli in Bauchi LGA. The population of the two (2) LGAs are 493,730 and 278,471 respectively by the 2006 national population census. The predominant tribes inhabiting the study area are Hausa, Fulani and Gerawa, with mostly Islamic religion (93%), while Christianity accounted for 7%. Household sizes are generally large with only 10% reporting households of three or fewer people in their family. Almost a third (27%) of respondents reported living in a household of between 4 to 6 people, with 24% living with 7 to 10 people, 24% had 11 to 15 people, and 14% had 16 or more people.

Educational Level

About 70% of residents reported that they cannot read or write, and 30% reported that they were literate.

Occupation

The main livelihood activity practiced in the Project Footprint is agriculture, with between 17 and 50% households reporting crop farming as their primary occupation Other occupations include trading/business (14.4%), civil service (3.1%) and industrial worker (0.4%).

Income and Expenditure

Due to the subsistence nature of the local economy, income levels are very low varying from as little as 5,000 Naira (USD16) a month to over 60,000 Naira (USD189).

Land and Home Ownership

Majority of the inhabitants (87%) are land owners.

Water Supply

Drinking water sources include hand-dug yard wells (72%), stream/river (16.4%), piped water /boreholes (10.7%) and rainfall (1%). There is presently a rural water scheme in Zongoro but it's dysfunctional. Water is consumed even without treatment. The most common type of toilet facility in the study communities is the non-ventilated pit latrine.

Waste Management

Solid waste is collected and piled up behind the compound, while polythene bags and other non-organic materials are removed and incinerated, while the organic waste is taken to the farm at the onset of the rainy season and used as manure.

Community Infrastructure

The proposed project site is accessible by tarred road from Bauchi the state capital. Within the project site, as with most rural communities, infrastructural development in the area is poor. The road network in the study communities was observed to be poor and untarred, while the houses within the communities are linked together by footpaths. Zongoro, the nearest community, is connected to the national grid but electricity supply is very highly epileptic.

Schools

The existing primary and junior secondary schools in the area are in dilapidated state and without necessary furniture and qualified teachers.

Public Health

There are no health facilities at the site. Among the five communities along the transmission line corridor, only Gawa has a primary health care facility. Common illnesses in the communities are malaria, cough, yellow fever, dysentery/diarrhea, and skin diseases/rashes.

Communities Concerns

The communities expect the project to improve existing infrastructure and provide employment for the youth of the area. The major fears from the project are land acquisition, destruction of farmlands, pollution of fishing waters, noise from construction equipment and cultural interference.

Potential Impacts and Mitigation Measures

NSCP, along with Globeleq and ARM-Harith, would implement measures and practices detailed in this ESIA report to mitigate potential adverse environmental impacts during the construction, operation and decommissioning phases of the project. Table ES.1 summarizes the anticipated impacts and the associated mitigation measures.

Table ES.1: Summary of Potential Impacts and Mitigation Measures

Environmental Media	Potential Impacts	Mitigation Measures
Pre-Construction Phase		
Air Quality	– Dust from land clearing	NSCP shall – Ensure sprinkling of stock-piles and areas of activity – Ensure proper management of the movement/removal of material to minimise dust emissions
Noise emissions	– Elevated ambient noise levels from machinery and vehicular traffic	NSCP shall – Ensure contractor's equipment is in good working condition, not damaged, and fitted with noise-reducing devices where necessary – Restrict activities to day-time working hours
Surface Water Quality	– Increased turbidity of surface water due to run-off from stock-piles of excavated material	NSCP shall – Ensure that excavated materials are stacked properly to reduce turbidity effect on surface runoffs – Ensure that cleared materials are stacked properly to reduce turbidity effect on surface runoffs
Vegetation and Wildlife	– Loss of vegetation and grazing area	NSCP shall – Ensure minimal vegetation losses and re-plant the economic vegetation species around the site perimeters – Ensure that land clearing and site grading are well planned to avoid excessive land take beyond what is required.
Soil and Land Use	– Erosion of top soil that will be exposed during site clearing – Soil compaction – Alteration of land-use pattern in the project area	NSCP shall – Ensure proper storage of excavated material to reduce run-off. – Ensure that site clearing is limited to acquired boundaries; excessive land-take shall be avoided. Ensure backfilling and compaction trenches to minimize the mobilization of highly erodible silt and clay particles.
Socioeconomic Resources	– Loss of farmland and source of income/employment as a result of land acquisition and site clearing – Displacement of existing inhabitants on the proposed site as a result of land acquisition and site clearing – Incidental destruction or alteration of significant cultural, historical, or archaeological sites.	NSCP shall – Ensure adequate compensation for all lands and facilities on acquired lands through implementation of a Resettlement Action Plan (RAP). – Ensure adequate recruitment of labour from surrounding communities, as appropriate. – Ensure protection of known or potential cultural archaeological sites by implementing appropriate operational controls /procedures.

Environmental Media	Potential Impacts	Mitigation Measures
		– Ensure training of workers on health, safety and environmental protection measures.
Visual Amenity	– Alteration of natural landscape and physical environment	NSCP shall – Ensure site is adequately fenced off – Ensure waste generated is transported offsite by an approved contractor
Construction Phase		
Air Quality	– Air emissions from construction equipment – Dust and gaseous emissions from vehicle movement (VOCs, CO, NO_x, SO_2, H_2S, O_3, NH_3, particulates, and greenhouse gases	NSCP shall – Ensure periodic watering of dusty sites to reduce the dust emission – Ensure contractor personnel are trained in adequate environmental management. Implement appropriate operational control/procedures such as (air emission management, compliance and permitting).
Noise emissions	– Increased noise levels from generators, heavy machinery and equipment, and vehicular traffic – Nuisance to the nearby settlements due to increased noise level – Night time activity and generators will increase noise level within the nearby settlements – Hearing impairment of project workers and neighbours	NSCP shall – Ensure contractor manages construction activities in such a way as to minimize the impacts to the local community, – Ensure regular servicing and routine maintenance of all construction equipment – Ensure provision of ear protective devices to workers at the project site during land preparation/construction stage, and installation of mufflers on large equipment. – Ensure construction activities are restricted to day-time periods only
Surface Water Quality	– Water pollution from surface run-off, disposal of sewage and probable accidental spillage of lubricants and oils – Increased turbidity of water body from run-off of waste piles	NSCP shall – Ensure containment of surface runoffs and storm water through appropriate drainage systems at the project site; – Provide spill containment facilities on site
Groundwater	– Accidental discharge of hazardous materials (oils, wastewater) to soil – Leaching activity from solid waste disposal	NSCP shall – Ensure that contractor handles, stores and disposes off materials and wastes in accordance with the waste management plan and the environmental management plan developed for this project. – Ensure that contractor personnel to handle hazardous wastes are trained on safe practices
Soil	– Accidental spill of oil and lubricant during equipment fueling operations	NSCP shall – Ensure that contractor handles hazardous materials in

Environmental Media	Potential Impacts	Mitigation Measures
	– Soil pollution arising from emitted particulates, soot and gasses being brought back as pollutants by rainfall/precipitation into the soils	accordance with the site waste management plan and the project environmental plan – Provide spill containment facilities on site
Socioeconomic Resources	– Strain on infrastructure, social and cultural conditions, access to goods and services and means of livelihood due to influx of construction workers. – Disruption of community activities – Disruption of fishing activities	NSCP shall – Ensure adequate recruitment of labour from surrounding communities as appropriate – Ensure presence of workers during working hours only at site and for limited construction period. – Ensure maintenance of closed construction camps and restriction of access to camps and work locations to authorized personnel only – Strive on the improvements of local infrastructure, such as transportation upgrades, in order to improve workers' access. – Minimize disruption to road traffic, farming, and other community activities by the project workers and project activities. Implement appropriate operational controls/procedures (e.g. external communications)
	– Loss of livelihood for displaced farmers	NSCP shall – Ensure payment of compensation to all the project affected people including displaced farmers – Ensure careful implementation of the Resettlement Action Plan prepared for this project Ensure that qualified labour from within the project's host communities are given preference in employment opportunities by the project Monitor the implementation of the CDP
Health and Safety	– The spread of sexually transmitted diseases (STDs) including HIV/AIDS among construction workers and community people/ hawkers.	NSCP shall – Ensure implementation of HIV/AIDS awareness programs for the project workers and the community.
	– Effects on local life style and cultural settings, tensions as the local community is not accustomed to a multicultural environment and their perceptions about people of different culture	NSCP shall – Develop appropriate Community Development Plan (CDP) to properly address the local community concerns, systems for smooth interactions of the expatriate employees with local community, awareness for employees about local life style and culture

Environmental Media	Potential Impacts	Mitigation Measures
Traffic	– Increased level of traffic due to heavy equipment and machinery transport; – Increased road accidents due to unsafe driving habits. – Occupational accidents around the construction areas	NSCP shall – Implement standard international HSE management practices. – Train the project workers in use of protective equipment and chemical handling – Prepare and ensure the display of warning and caution signs within and around the project worksite as appropriate and for hazard recognition – Ensure the development of site emergency response plan. – Prepare and implement Traffic Management Plan including transport procedures, vehicle fitness requirements, emergency response plan, defensive driving procedures, etc
Operations Phase		
Air Quality	– No air emissions during operation	
Soil	– Soil contamination from accidental spills of transformer oil and lubricant during plant maintenance	NSCP shall – Ensure that transformers are installed on concrete paved floors – Ensure that bunds are provided to contain possible oil/lubricant spills – Subject project workers through adequate training in proper environmental hygiene. The training will also include proper handling and disposal of liquid wastes to avoid accidental spills. – Prepare and ensure display of appropriate warning and caution signs to reduce hazards from oil, lubricants and related hazardous chemicals and materials
Surface Water	– Discharge from cleaning of the PV modules – Accidental leakage of transformer oils into nearby surface-water bodies	NSCP shall – Ensure adequate treatment of waste water before discharge. – Ensure that treated waste waters meet the FMEnv standards before discharge
Socioeconomic Resources	– Stress on infrastructure around the project area – Loss of livelihood for displaced farmers	NSCP shall – Improve existing infrastructure in affected communities as part of its social responsibility – Ensure payment of compensation to all the project affected people including displaced farmers – Ensure careful implementation of the Resettlement Action Plan prepared for this project – Ensure that qualified labour from within the project's host communities are given preference in employment opportunities

Environmental Media	Potential Impacts	Mitigation Measures
		by the project – Monitor the implementation of the CDP
Traffic	– Increased traffic during substation and transmission line maintenance	NSCP shall – Implement transport management procedures developed for this project – Ensure that project drivers are well trained in defensive driving procedures
Health and Safety	– Public and occupational health and safety risks	NSCP shall – Train staff in HSE and Security management – Maintain a First Aid Clinic within the project site – Subscribe to the services of a Retainer Clinic in Bauchi to handle health issues that are beyond first aid attention – Maintain an ambulance at the project site for emergency health challenges for quick evacuation of the affected project staff to the project's retainer clinic in Bauchi town. – Ensure the provision of relevant fire extinguishers at site – Maintain a dedicated telephone lines to the State Fire Station to enable quick contact should the situation arise – Create a mustering point and ensure that it is clearly identified at site – Provide a gate to the project site and will be manned by trained personnel to check unauthorized entries
Decommissioning/Abandonment Phase		
Air Quality	– Temporary elevated noise levels from equipment and vehicular traffic – Localised gaseous emissions from machinery and vehicles – Fugitive dust emissions in adjacent areas	NSCP shall – Ensure work is restricted to day-time hours
Soil and Land Use	– Reversal of land use from construction and operation – Erosion of soil due to surface disturbance and exposure from removal of structures	NSCP shall – Ensure minimal surface area disturbance during decommissioning. Grading activities should be limited to areas previously disturbed – Ensure site is re-graded to leave it smooth, regular and maintain natural drainage patterns – Ensure open gaps from the removal of structures in the ground are backfilled with topsoil and subsoil and graded to ensure adequate drainage

Environmental Media	Potential Impacts	Mitigation Measures
		– Ensure appropriate erosion control measures are adopted according to best practices including soil de-compaction and re-contouring to blend with the surrounding areas.
Vegetation	–	NSCP shall – Ensure prevention of the spread of weeds during the decommissioning process – Ensure re-vegetation of the area using native species
Surface Water	– Increased turbidity and contamination from soil nutrients due to decommissioning activities	NSCP shall – Ensure disturbed areas are levelled, restored, and re-vegetated in order to minimise soil erosion – Ensure electrical components are properly isolated and demolished – Ensure adequate spill protection is employed during decommissioning
Socioeconomic Resources	– Creation of temporary jobs for locals and the associated economic activities	NSCP shall – Ensure adequate fencing of the site to keep construction workers away from sensitive cultural areas – Create opportunities for local off-takers of scrap metals, unwanted electrical components, and other recyclable material
Traffic	– Temporary increase in road traffic due to transport of personnel and machinery	NSCP shall – Implement traffic management procedures – Ensure that project drivers and contractor personnel are well-trained in defensive and safe driving procedures – Ensure coordinated movement of vehicles and personnel to and from the site – Regularly inspect and remediate access roads and highways for possible damage caused by the movement of heavy vehicles
Health and Safety	– Potential health and safety impacts resulting from operation of machinery, and transport of large materials	NSCP shall – Ensure a health and safety plan and procedures are developed and followed – Ensure personnel are trained accordingly and are aware of the project's environmental management procedures and emergency response plan Ensure adequate PPE are provided for workers
Visual Amenity	– Increased activity over de-commissioning period – Removal of solar plant infrastructure and facilities	– Ensure site is adequately fenced off during decommissioning – Ensure site is restored to its near pre-construction state and to match the surrounding environment after de-commissioning

Environmental Media	Potential Impacts	Mitigation Measures
Waste Disposal	–	NSCP shall – Ensure recycling of solar modules at the end of their useful life through an approved facility or contractor – Ensure reusable materials are transferred to an approved contractor or offtaker – Ensure complete removal of waste materials and adequate disposal through an approved contractor

Environmental and Social Management Plan (ESMP)

Environmental and Social Management Plan (ESMP) is a tool which ensures continuous assessment of the impact of a project operation as well as proactive response to the impacts to reduce their overall effect on the identified environmental parameters. It makes an organization to do the right thing at the right time rather than responding to situations borne out of statutory or legal compulsion. This essential tool is contained in the International Standards Organization (ISO) Environmental Protection Blue print, code-named ISO 14000.

Safeguarding the Environment, Health, Safety and Security of Workers

ESMP prepared for this project is geared towards safeguarding the environment and the health and safety of project workers. All NSCP/Globeleq/ARM-Harith contractors, staff and third party shall be well informed and trained on all HSE issues at site. All facilities shall be designed to enhance safety planning. All activities shall be executed within the confines of the relevant Nigerian legislation (including FMEnv guidelines) as well as stakeholders' interests.

All project activities shall be properly managed through careful planning and the application of relevant safety policies such as:

Use of Permit to Work (PTW);
Job Hazard Analysis and toolbox meetings before embarking on a job;
Use of appropriate personal protective equipment (PPE);
Prohibition of alcohol in the project area;
Proper journey management;
Regular emergency drills;
Use of appropriate caution signs.

Waste Management

The proposed solar power generation project is not expected to generate significant quantity of waste such as the PV cells at the end of their shelf life, nevertheless, adequate waste management guideline and disposal facilities have been integrated into the implementation of the proposed project. The principle of waste reduction, recycling, recovery and re-using shall be practiced. All wastes, which cannot be reused, will be managed and disposed in accordance with regulatory standards prescribed by the FMEnv or ISO.

ESMP Implementation

The total cost of ESMP implementation is estimated at US$1.554 million.

NSCP/Globeleq/ARM-Harith's responsibilities include staff training on their specific functions as well as on environmental and safety procedures, development of an emergency response plan (ERP), facility surveillance to detect malfunctions and initiate repair. NSCP/Globeleq/ARM-Harith will also be responsible for impact and mitigation monitoring including:

Site management: the development and implementation of an effective environmental and social management system (ESMS) for the construction period; continuous monitoring of site management practices during site clearing, Monitor the implementation of waste management plans including quantities of waste generated, recycled and disposed, and incident reporting

Emissions monitoring: monthly monitoring of air emissions and water quality parameters, quarterly monitoring of noise levels

Vegetation and wildlife conservation: annual inspection of vegetation and wildlife habitats

Stakeholder Consultations: Continuous stakeholder engagement through the services of a socio-economic and RAP consultant; public complaints register, continuous monitoring of the results of the RAP on livelihood and employment, Communicate necessary information to the communities with regards to the impact of project site activities such as noise, vehicular traffic, and presence of construction workers.

BASEPA will:

Supervise the implementation of monitoring activities by NSCP/Globeleq/ARM-Harith during the operational phase

FMEnv will:

Ensure implementation of air and water quality monitoring activities during pre-construction, construction, and decommissioning

EPC Contractor will:

Implement mitigation measures during pre-construction, construction and decommissioning (except for continuous stakeholder engagement and RAP implementation)

Ensure implementation of migration measures as required by all sub-contractors

Socio-economic/RAP consultants will:

Ensure continuous stakeholder engagement during pre-construction

Stakeholder Consultation

Stakeholder engagement ensures the continued sharing of project information and relationship building with stakeholders. It also allows for understanding stakeholder concerns and is a key element for effective project delivery. The stakeholder engagement approach includes stakeholder identification, consultations at the scoping phase and ESIA phase.

Stakeholders in the project were identified as Key Administrative Stakeholders (Federal Government Agencies, Bauchi State Government, Ganjuwa Local Government Authority and Traditional Leaders), Project Affected Persons (PAPs), vulnerable groups, the host community and service providers. During the ESIA, consultation was held with Yuili, Zongoo, Dungulbi and Waya communities which are in close proximity to the proposed project site. Interviews and smaller focus group discussions were held with key stakeholders in each community including youth groups, women's groups and other community representatives. The objective was to present the preliminary findings of the ESIA, suggested mitigation measures and collect feedback from the community.

Stakeholder consultation will be required as an ongoing activity during ESIA disclosure and throughout the life of the project. A stakeholder engagement plan also includes the development and implementation of a grievance system to obtain complaints or suggestions on project implementation. The project will appoint a community liaison officer (CLO) to oversee the implementation of the stakeholder engagement plan.

Conclusion

The proposed project is a solar power plant with adequate pollution control measures to minimise impacts on the host environment. The potential impacts of the proposed

development are minimal and will be managed by appropriate mitigation measures to reduce the residual impacts to *As Low as Reasonably Practicable* (ALARP) levels and prevent further deterioration of the receiving environment. NSCP/Globeleq/ARM-Harith, contractors, and third party involved will ensure strict implementation and compliance with the ESMP to achieve its target of an environmentally and socially responsible project.
The project will enhance existing power generation and supply for domestic and industrial consumption especially in Bauchi State.

Chapter One: Introduction

1.1 Background

Nigeria has an installed power generation capacity of 8,644 MW of which 6,905 MW is government owned. With rapid developing industrial sectors and a growing population transitioning from agrarian to urban communities, Nigeria has a growing demand for electricity. Over the past two decades, population has increased to 170 million, and over the last 5 years, average GDP growth rate is 6.66%. However, within this period, power generation capacity has stagnated due to inadequate maintenance of existing power generation stations. These factors have given rise to severe electricity shortages which has impacted significantly on industrial productions. It is estimated that 26,561 MW will be required in the next 9 years to meet demand as envisioned in the Vision 2020 target.

Government investment in power generation and distribution has been unable to keep up with these demands, which has necessitated the Federal Government of Nigeria (FGN) to embark on a power sector reform programme through which private sector participation is encouraged. As part of the *Roadmap for Power Sector Reform,* which elaborates the plan to meet the power requirement in the country by the year 2020, the government is committed to promoting private sector participation investment in renewable energy projects. This is in line with the National Energy Policy objective of developing renewable energy resources and incorporating these options into the national energy mix.

On the earth's surface, there is more than sufficient solar radiation to satisfy a vastly increased demand for solar power systems. On average, each square meter of land is exposed to enough sunlight to produce 1,700 kW of power every year. Nigeria lies within a high sunshine belt and within the country solar radiation is fairly well distributed. The annual average of total solar radiation varies from about 12.6 MJ/m^2-day in the south to about 25.2 MJ/m^2-day in the North (Nigerian Renewable Energy Policy). Solar energy is renewable and its utilization is environmentally friendly.

The total thermal energy resource of Nigeria is the totality of the solar radiation falling on its 923,768 km^2 land area. This total solar radiation includes the direct radiation as felt on sunny days; diffuse radiation scattered by clouds and atmospheric gases and vapors and felt on cloudy days even when the sun is not visible.

Studies relevant to the availability of the solar energy resource in Nigeria have fully indicated its viability for practical use. Although solar radiation intensity appears rather dilute when compared with the volumetric concentration of energy in fossil fuels, it has been confirmed that Nigeria receives 5.08 × 1012 kWh of energy per day from the sun and if solar energy appliances with just 5% efficiency are used to cover only 1% of the country's surface area then 2.54×10^6 MWh of electrical energy can be obtained from solar energy. This amount of electrical energy is equivalent to 4.66 million barrels of oil per day.

A major limitation to the development of solar technologies is the high capital layout involved. The key recommendations for further development of solar energy in Nigeria are:

Provision of fiscal incentives such as import duty exemptions, tax holiday, investment grants to encourage investments in solar powered generating plants and local manufacturing of solar photovoltaic applications.

Continuous active support of research and development activities to cater for site specificity of designs for all parts of the country.

Execution of demonstration and pilot projects to ensure that the general public is aware of the potentials of solar energy technologies which will as well assist in creation of markets for solar energy systems.

1.2 Overview

In an effort to enhance power generation, Nigeria Solar Capital Partners (NSCP), Globeleq, and ARM-Harith intends to develop a 100 MW photovoltaic (PV) Independent Power Project (IPP) in Ganjuwa, Bauchi State. The project will be situated on 200 ha of land at Zongoro village approximately 20 km from Bauchi, the capital of Bauchi State.

The plant will convert solar energy into usable power, generating electricity from sunlight. The ancillary components of the project include power inverters, transformers, weather stations, substation, an 18km 132 kV overhead power line to interconnect the solar energy plant to the national grid, internal access roads, guard house, office and control centre and lay down, campsite and assembly area.

This Environmental and Social Impact Assessment (ESIA) study will ensure that potential adverse environmental and social impacts from the project are identified, and mitigation measures are recommended and implemented to prevent or ameliorate the impacts as much as it is practically possible. This ESIA is carried out in compliance with the Nigerian statutory requirements EIA Act (1992) and in conformance with World Bank environmental assessment requirements.

1.3 Project Scope

The plant would generate electrical power by converting solar radiation into direct current (DC) electricity using silicon panels that exhibit the photovoltaic effect, and converting the DC power to AC by inverters that plug into a medium voltage (MV) transformer which is connected to high voltage (HV) transformer and then evacuates the produced energy to a high voltage distribution network.

The plant would consist of solar panel arrays, each array would comprise sufficient silicon panels installed to generate 100 MW DC that would be transformed to 80 - 90 MW AC. The system would include a combination of fixed arrays facing to the south. The arrays would be embedded into the ground with concrete footings.

Power produced by the plant would be approximately 100MW DC, converted to AC through inverters. Transformers would be installed to step up voltage so that it is compatible with the national grid. The stepped-up power would then be connected to the national grid.

The following infrastructures would be established within the project site:

A solar PV plant constructed using poly crystalline PV modules

A system of inverters and step up transformers

Aboveground and underground electrical cabling which connect the arrays to inverters and transformers

Marshalling switchgear to collect the power from the PV arrays

Associated facilities include:

An 18-km transmission line to connect the solar plant to national grid Internal access tracks to allow for maintenance of the site

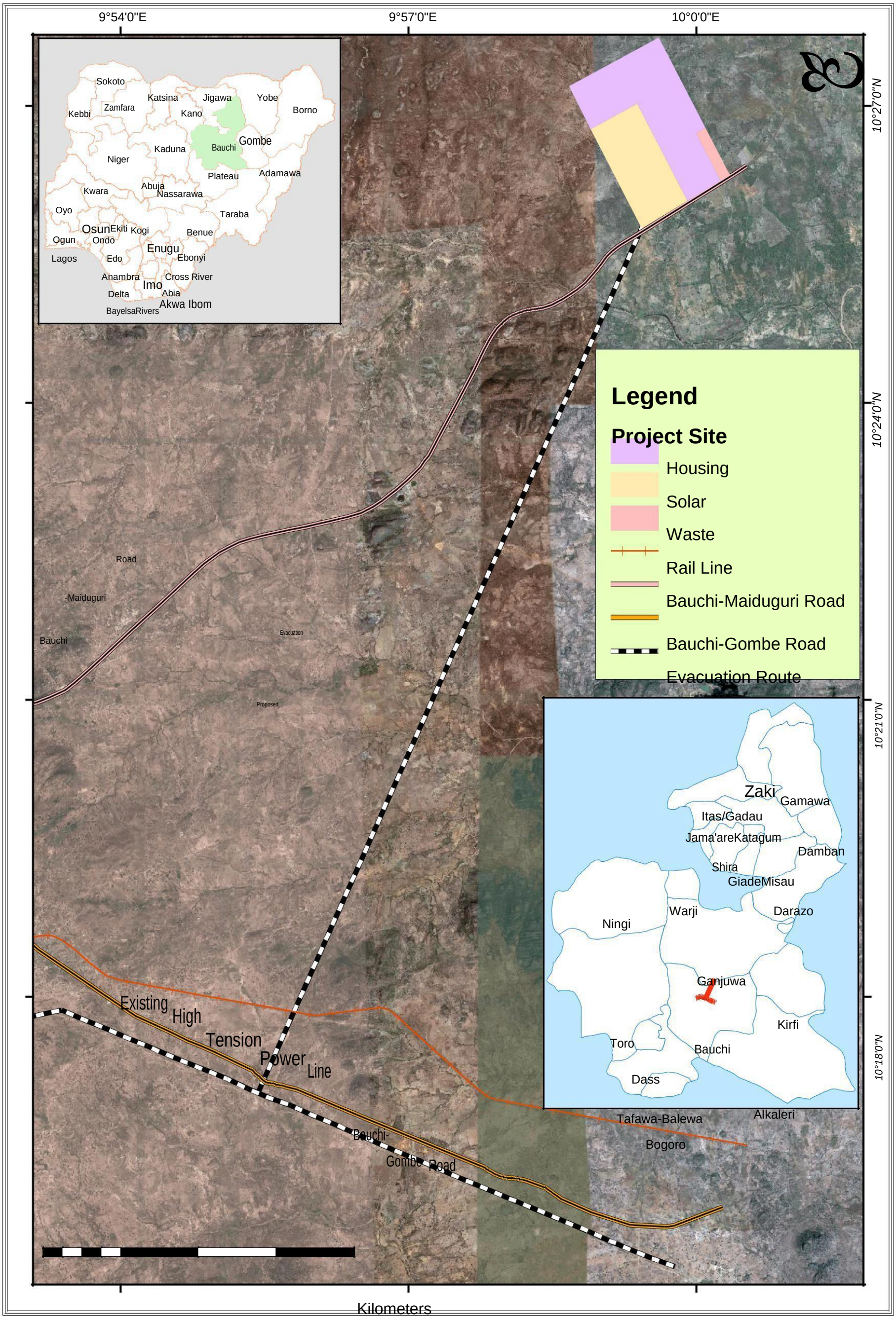
Supervisory control centre. Site office and maintenance building

Lay down, campsite and assembly area

1.4 Project Location

The proposed site is a 200-ha land situated in Zongoro village in Ganjuwa local government area (LGA), Bauchi State (Figure 1.1). The site is about 20 km from Bauchi Township. It lies within Latitudes 9°58'51.492"N - 9°59'54.024"N and Longitudes 10°25'45.444"E - 10°26'57.012"E, and runs parallel to the Zongoro River.

The project location was chosen due to its climatic, topographic, and general physical setting including solar radiation conditions which are ideal for the solar energy generation. In addition, there is an existing 132 kV national utility power grid for easy interconnection adjacent to the proposed site. The site is also accessible by Bauchi – Maiduguri road.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Kaduna
Niger
Plateau
Adamawa
Abuja
Kwara
Nassarawa
Oyo
Taraba
Osun
Ekiti
Kogi
Benue
Ogun
Ondo
Enugu
Lagos
Edo
Ebonyi
Anambra
Cross River
Imo
Delta
Abia
Akwa Ibom
BayelsaRivers
Legend
Project Site
Housing
Solar
Waste
Rail Line
Bauchi-Maiduguri Road
Bauchi-Gombe Road
Evacuation Route
Road
-Maiduguri
Bauchi
Evacuation
Proposed
Existing
High
Tension
Power
Line
Bauchi-
Gombe Road
Zaki
Gamawa
Itas/Gadau
Jama'areKatagum
Damban
Shira
GiadeMisau
Warji
Darazo
Ningi
Ganjuwa
Kirfi
Toro
Bauchi
Dass
Tafawa-Balewa
Alkaleri
Bogoro
Kilometers
0 0.75 1.5 3 4.5 6

Figure 1.1: Location Map of the Proposed Solar Power Project

1.5 Study Objective and Terms of Reference

The overall objective of the study is to carry out an ESIA which includes:

Establishment of a baseline inventory representing the present condition and ecological status of the proposed project site prior to the construction and operation of the facility;
Assessment of potential environmental, socio-economic and health impact of the proposed project;
Recommendation of appropriate mitigation measures; and
Development of an environmental management plan.

As contained in the terms of reference (ToR) the scope of work includes:

Drafting of project proposal and registration with Federal Ministry of Environment (FMEnv);
Project screening and scoping;
Consultation with stakeholders (government agencies, parastatals, host communities, other stakeholders);
Preparation and submission of the ESIA report;
Presentation of draft ESIA report and project defense at all panel or public reviews; and
Documentation and submission of final ESIA report.

1.6 Report Structure

The report is structured in line with the Nigerian EIA Procedural Guideline. The sections of the report include the followings:

Chapter 1 – Introduction: provides an overview of the proposed development and project background. It presents the objectives of the study, and the scope of work entailed in conducting the ESIA study.

Chapter 2 – Policy, Legal and Administrative Framework: presents local, national and international regulations that govern the project, and identifies the relevant institutions with a stake in the project.

Chapter 3 – Project Description: describes the design basis of the proposed project, process description and site location, preparation and construction, and project plant operations.

Chapter 4 – Actual Specific Environmental Baseline: provides a summary of physical environment (air, surface water, ground water, and soil), biological (aquatic and terrestrial including flora and fauna), and socioeconomic conditions in the project area.

Chapter 5 – Potential Environmental and Social Impacts: discusses and analyzes the potential impacts resulting from project activities during construction and operational phases.

Chapter 6 – Project Justification and Alternatives: describes the need for the project, potential value, benefits and envisaged sustainability. The project and process related alternatives considered during project concept and design stages are also discussed.

Chapter 7 – Environmental and Social Management Plan (ESMP): provides management measures, monitoring plan, implementation schedule and capacity building program.

Chapter 8 – Decommissioning and Abandonment Plan: summarizes decommissioning plan.

Chapter 9 – Summary and Conclusions: summarizes conclusions drawn during the analysis and provides recommendations for future work.

References – a full list of the published sources used in the report.

Appendices – presents detailed laboratory data etc.

Chapter Two: Policy, Legal and Administrative Framework

A number of national and international regulations are applicable to this project. This section highlights relevant provisions of these regulations and identifies relevant institutions with a stake in the project.

2.1 Applicable National Policies

Nigerian National Energy Policy (2004)

This policy the National Energy Policy establishes guidelines for the protection of the environment in the exploitation of Nigeria's fossil fuels. It also emphasizes the exploration of renewable and alternative energy sources, primarily solar, wind and biomass.

The overall thrust of the energy policy is the optimal utilization of the nation's energy resources for sustainable development. It addresses diverse issues such as research and development, energy pricing and financing, legislation, energy efficiency, environment etc.

The policy objectives and implementation strategies have been carefully defined with the fundamental guiding premises that energy is crucial to national development goals and that government has a prime role in meeting the energy challenges facing the nation. The overall energy policy objectives are:

- Ensure the development of the nation's energy resources, with diversified energy resources option, for the achievement of national energy security and an efficient energy delivery system with an optimal energy resource mix;
- Guarantee increased contribution of energy productive activities to national income;
- Guarantee adequate, reliable and sustainable supply of energy at appropriate costs and in an environmentally friendly manner, to the various sectors of the economy, for national development;
- Guarantee an efficient and cost-effective consumption pattern of energy resources;
- Accelerate the process of acquisition and diffusion of technology and managerial expertise in the energy sector and indigenous participation in energy sector industries, for stability and self- reliance;
- Promote increased investments and development of the energy sector industries with substantial private sector participation;
- Ensure comprehensive, integrated and well-informed energy sector plans and programmes for effective development;
- Foster international co-operation in energy trade and projects development in both the African region and the world at large; and
- Successfully use the nation's abundant energy resources to promote international co-operation.

Renewable Electricity Policy (2006)

This policy aims to expand the role of renewable electricity in sustainable development through effective promotional and regulatory measures. It is derived on the premise that increased power generation from conventional sources and electricity grid extensions alone are insufficient to achieve electricity targets rapidly and cost-effectively. Renewable energy is a key aspect of the Government's strategy to increase access to electricity in the country. The specific objectives of the Renewable Electricity Policy are to:

Expand electricity generating capacity to meet national economic and social development goals;

Encourage the diversification of sources of electricity supply through renewable energy, and as such improve the energy security of the country;

Increase access to electricity services nationwide, especially in rural areas;

Stimulate growth in employment generation through and expanded renewable electricity industry;

Enhance technological development through increased domestic manufacturing of renewable electricity components;

Stimulate competition in the delivery of renewable electricity;

Promote rapid expansion of renewable-based electricity market through cost-reducing supply side and demand side incentives;

Develop regulator procedures that are sensitive to the peculiarities of renewable energy based power supply;

Create a stable and predictable investment climate in renewable electricity markets;

Provide effective protection to consumers through regulation; and

Reduce air pollution and greenhouse gas emissions, thus contributing to improved health and overall social development.

National Policy on the Environment (1988)

This policy aims to achieve sustainable development in Nigeria, and in particular to:

Secure a quality of environment adequate for good health and wellbeing;

conserve and use the environment and natural resources for the benefit of present and future generations;

Restore, maintain and enhance the ecosystems and ecological processes essential for the functioning of the biosphere to preserve biological diversity and the principle of optimum sustainable yield in the use of living natural resources and ecosystems; and

Raise public awareness and promote understanding of the essential linkages between the environment, resources and development, and encourage individuals' and communities' participation in environmental improvement efforts.

National Electric Power Policy (2001)

The Policy set the following as critical objectives for Nigeria's electric power sector:

Ensure that the power sector attracts private investment both from Nigeria and from overseas

Develop a transparent and effective regulatory framework for the power sector.

Develop and enhance indigenous capacity in electric power sector technology.

Ensure that the Government divests its interest in State-owned entities and entrenches the key principles of restructuring and divestiture in the electric power sector.

Promote competition to meet growing demand through the full liberalization of the electricity market.

- Review and update electricity laws in conformity with the need to introduce private sector operation and competition.

2.2 Applicable National Regulations

A number of national legislation regulating industrial activities and their impacts on the environment are applicable to this project. Relevant legislations are listed below.

National Legislation

Environmental Protection Agency Decree (1988)

This created the Federal Environmental Protection Agency (FEPA) charged with the responsibility for environmental protection. This agency was later upgraded to the Federal Ministry of Environment (FMEnv) in 2005, and its scope expanded to include natural resources conservation and sustainable development.

Environmental Impact Assessment (ESIA) Act CAP E12 LFN 2004

This decree makes an ESIA mandatory for major development projects and prescribes the procedure for conducting and reporting an ESIA. It involves submission of a project proposal by the proponent to the FMEnv. An initial evaluation of the proposal is conducted by the ministry to categorize the project after which it undergoes screening and scoping, production of a draft report, public hearing, review, preparation of the final report before approval by a technical committee.

S.I.15 National Environmental Protection (Management of Solid and Hazardous Wastes) Regulations, 1991

This regulation establishes the objectives of solid waste management to include:

The identification of toxic and hazardous wastes;

Surveillance and monitoring of dangerous and extremely hazardous wastes and substances until they are detoxified and safely disposed;

Establish guidelines necessary to establish a system of proper record keeping, sampling and labeling of dangerous and extremely hazardous wastes;

Establish suitable and provide necessary requirements to facilitate the disposal of hazardous wastes; and

Research into possible reuse and recycling of hazardous waste.

The decree provides the minimum requirements for the management of medical and industrial waste from points of generation, handling, transportation and eventual disposal.

S.I.8 National Environmental Protection (Effluent Limitation) Regulations, 1991

This guideline sets limits for industrial effluents and makes it mandatory for industrial facilities to install anti-pollution and effluent treatment equipment/facility. It prescribes a maximum allowable limit for effluent parameters. It also provides that all industries in Nigeria should be operated on the basis of Best Available Technology (BAT).

S.I.9 National Environmental Protection (Pollution Abatement in Industries Generating Wastes) Regulations, 1991

This regulation imposes restrictions on the release of toxic substances and stipulates requirements for monitoring of pollution. It also makes it mandatory that industries and facilities conduct periodic environmental audits.

S.I.15 National Environmental Protection (Management of Solid and Hazardous Wastes) Regulations, 1999

This regulates the collection, treatment and disposal of solid and hazardous wastes from municipal and industrial sources. It stipulates standards for industrial effluent, gaseous emissions and hazardous wastes with which managers and operators must comply to improve the environment by limiting pollution and other environmental hazards.

Harmful Waste Decree (Special Criminal Provisions) Act CAP 165 LFN 1990

This establishes the legal framework for effective control of the disposal of toxic and hazardous waste into any environment within Nigeria.

Land Use Act CAP 202 LFN 2004

This act sets the legal basis for land acquisition and resettlement in Nigeria. It vests land in the Governor of each State, and provides that it shall be held in trust for the use and common benefit of all people. The administration of land is divided into urban land which will be directly under the control and management of the Governor of each State; and non-urban land, which will be under the control and management of the Local Governments.

Factories Act CAP 126 LFN 1990

The Act makes provision for health and safety of persons employed in places statutorily defined as factories and for which a certificate of registration is required by law. It requires that workers should be adequately protected from occupational health and safety hazards.

Electricity Act (1990)

The Electricity Act, Cap 106 of 1990 contains regulations pertaining to permit for electrical installations, placement of overhead lines, construction of substations and switching stations, penalties for breaches of licenses and regulations etc. The specific part and sub parts relevant to the project is Part VI: Regulations appertaining to overhead lines and restrictions to placing electric lines above ground. This section includes the following stipulations:

- Except under and in accordance with the terms of a written authority granted by the Minister, no electric lines (other than service lines) shall be placed above the ground.
- Every support carrying electric lines shall be made of wood, steel or reinforced concrete or any other approved materials and shall be protected against decay, corrosion or other deterioration
- Every support shall be so constructed and placed as to withstand the transverse, horizontal and vertical loads calculated in accordance with Regulation 48 without exceeding the materials strength limits as set out in Regulations 53.

Every electric line shall be made of copper, aluminum or steel, or any alloy or combination of any of such materials, subject to the approval of the Minister.

All overhead electric lines shall be attached to suitable insulators carried on cross-arms or brackets of suitable materials and cross-section

All lines at angles shall be attached to the insulator so that the insulator and not the binding wire takes the strain.

The foundations shall be so constructed and placed, taking into account the reaction of the soil at times of the year in which they are embedded to the load that they are to carry

Every electric line shall have a copper equivalent cross-section area of not less than 16 square millimeters and an ultimate tensile strength of not less than 4 kilo-Newtons.

Overhead electric line supports, in conjunction with stays and struts, if provided, shall withstand the longitudinal, transverse and vertical loads due to fittings, conductors and wind loadings under the most adverse temperature conditions.

Electric Power Sector Reform Act (EPSR), 2005

An Act to provide for the formation of companies to take over the functions, assets, liabilities and staff of the National Electric Power Authority, to develop competitive electricity markets, to establish the Nigeria Electricity Regulatory Commission; to provide for the licensing and regulation of the generation, transmission, distribution and supply of electricity; to enforce such matters as performance standards, consumer rights and obligations; to provide for the determination of tariffs; and to provide for matters connected with or incidental to the foregoing:

Formation of Initial and Successor Companies and the transfer of assets and liabilities of the National Electric Power Authority

Development of a Competitive Electricity Market

Establishment, functions and powers of the Nigerian Electricity Regulatory Commission

Licenses and Tariffs

Acquisition of Land and Access Rights

Consumer Protection and Licensee Performance Standards

Competition and Market Power

The Power Consumer Assistance Fund

Rural Electrification Fund

Offences

Consequential and Transitional Provisions

Wild Animals Preservation Act CAP132 LFN 1990

The act was designed to protect the rare and more valuable kinds of game by giving complete protection to certain species. The use of traps and weapons was limited and the slaughter of female game prohibited. The act sets out in the attached schedule those animals, which are protected, the hunting, killing or capturing of which require special permission from the Administrative Officer or magistrate.

National Resource Conservation Action Plan, 1992

The plan was established to set out objectives for living resources conservation through:

maintaining genetic diversity in order to ensure permanence in the supply of materials to satisfy basic human needs and thus improve the well-being of society;

promoting the scientific value of natural ecosystems, the study of which is required to enhance conservation itself, to improve the management of man-made systems, and to provide clues to technical innovations in agriculture, medicine and industry;

regulating environmental balance in such factors as carbon dioxide and radiation levels and the bio-geo chemical cycles;

maintaining ecological services through the protection of catchment's areas in order to enhance water resources and check soil erosion and flooding, protection of grazing lands against desert encroachment and the stabilization of coastal zones and;

enhancing the amenities values of natural resources, including aesthetic, heritage, religious, sentimental, ethical and recreational values on which tourism may be built.

Other national regulations that are applicable to this project include:

Interim Guidelines and Standards for Environmental Pollution Control in Nigeria 1988

National Guideline and Standard for Environmental Pollution Control 1991

Workmen Compensation Act 1987

Electricity (Private Licences) Regulations, 1965;

Electricity (Annual Returns) Regulations, 1974;

Electricity Installation Regulations, 1996; and

Electricity Supply Regulations, 1996;

NEPA Act, Cap 256 LFN 1990;

Energy Commission of Nigeria Act, Cap 109 LFN 1990;

Utilities Charges Commission Act No. 104 of 1992;

Electricity [Amendment] Act No. 28 of 1998;

NEPA [Amendment] Act No. 29 of 1998;

National Wood Fuel Substitution Proramme

Natural Resources Conservation Act CAP 286 LFN 1990

Public Health Law Act CAP 103 LFN 47 1995

Abandonment Guideline (FMEnv Sectoral Guidelines, 1995)

State Legislation

The Nigerian Constitution allows States to make legislations, laws and edicts on the Environment. The FEPA Amended Act No. 58 of 1988 also recommends the setting up of State Environmental Protection Agencies (SMENV), to participate in regulating the consequences of project development on the

environment in their area of jurisdiction. SMENVs thus have the responsibility for environmental protection at the state level within their states. The functions of the SMENVs include:

Routine liaison and ensuring effective harmonization with the FME in order to achieve the objectives of the National Policy on the Environment;

Co-operate with FMEnv and other relevant National Directorates/Agencies in the promotion of environmental education;

Be responsible for monitoring compliance with waste management standards;

Monitor the implementation of the ESIA and the Environmental Audit Report (EAR) guidelines and procedures on all developments policies and projects within the State.

In accordance with the provisions of Section 24 of FEPA Act 58 of 1988 (Cap 131 LFN 1990), State Environmental Protection Agency was formed in Bauchi State. The State Environmental protection Agency and Ministry of Environment are important stakeholders in the proposed project.

Bauchi State Environmental Protection Agency (BASEPA) Edict (1994)

BASEPA was established by an edict No 10 of 1994 as amended by Edict No. 3 of 1997. Its objectives include:

- Implementation of environmental policies towards protection, sustenance and development of the environment.
- Identifying detecting and evolving environmental problems such as pollution, desertification, soil degradation, bush burning, indiscriminate felling of trees, protection of water and air among others.

2.3 Institutional Framework

Federal Institutions

Federal Ministry of Power

The Federal Ministry of Power is the policy making arm of the Federal Government with the responsibility for the provision of power in the country. The Ministry in discharging this mandate is guided by the provisions of the National Electric Power Policy (NEPP) of 2001, the Electric Power Sector Reform (EPSR) Act of 2005, and the Roadmap for Power Sector Reform of August 2010.

The following parastatals are under the ministry:

Energy Commission of Nigeria (ECN)

Nigerian Electricity Regulatory Commission (NERC)

Power Holding Company of Nigeria (PHCN)

Rural Electrification Agency (REA)

The responsibilities of the Federal Ministry of Power are as follows:

Initiating and formulating broad policies and programmes on the development of the power sector

Initiating concessions in the power sector

Licensing of electrical contractors and electric generating sets of 1MW capacity and below

Conducting investigation on electrical accidents and to ensure safety in the electricity industry in Nigeria

Conducting statutory tests and certification of electric poles (concrete, wooden, steel etc.) and other major electrical materials before they are used on the grid and networks in Nigeria

Implementing renewable energy progammes/initiatives (solar, wind, biomass, small hydro etc.)

Coordinating activities of the power sector

Handling policy matters relating to research and development in the power sector

Promoting the development of hydro power plants through public private partnership (PPP)

Participating in bilateral and multilateral relations affecting the power sector

Facilitating the overall coordination of the activities of the parastatals under its supervision

Energy Commission of Nigeria (ECN)

ECN was established by Act No. 62 (1979), as amended by Act No.32 (1988) and Act No. 19 (1989), with the statutory mandate for the strategic planning and co-ordination of national policies in the field of energy in all its ramifications. By this mandate, the ECN is empowered to:

Carry out overall energy sector planning & policy implementation

Promote the diversification of energy resources through the development and optimal utilization of all, including the introduction of new and alternative energy resources like solar, wind, biomass and nuclear energy

Serve as a centre for solving any inter-related technical problems that may arise in the implementation of any policy relating to the field of energy

Advise the Federal or State Government on questions relating to energy

Prepare after consultation with such agencies of government whose functions relate to the field of Energy development or supply as the Commission considered appropriate, periodic master plans for the balanced and coordinated development of energy in Nigeria

Lay down guidelines on the utilization of energy types for specific purposes

Advise the Government on adequate funding of the energy sector including research and development, production and distribution

Collate, analyze and publish information relating to the field of energy

Carry out such other activities as are conclusive to the discharge of its functions under this Decree

Monitor the performance of the energy sector in the execution of government policies on energy

Promote training and manpower development in the Energy sector

Liaise with all international organizations on Energy

National Electricity Regulatory Commission

NERC was established under the Electric Power Sector Reform Act (2005). Its primary functions include the following:

Ensure orderly development of a competitive power market

Ensure efficient, safe and adequate production of electricity

Promote competition & private sector participation

Protect consumers and the public interest

Evolve standards & codes that measure with international best practice

Evolve stable & equitable rates - cost reflective + reasonable profit

License and regulate persons engaged in electricity business

Settle disputes amongst industry participants

Ensure expansion of access to rural and urban dwellers

Establish and administer the Power Consumer Assistance Fund for subsidizing underprivileged consumers

Nigerian Bulk Electricity Trading (NBET) Company

NBET was incorporated on July 29, 2010 in line with the "Roadmap to Power Sector Reform" and, in fulfillment of the requirements of Electric Power Sector Reform Act (EPSRA), 2005 for a "trading licensee holding a bulk purchase and resale license" to "engage in the purchase and resale of electrical power and ancillary services from independent power producers and from the successor generation companies".

The objectives of the NBET are to:

Put in place an effective transaction environment which minimizes risk and allocates it fairly to the parties best able to manage it;

Implement a procurement process that is transparent and will result in the economic procurement of needed power;

Have all existing and new power capacity under contract by 2016, although the commercial operation date when this capacity comes on line may be later;

Ensure efficient settlement in the short term until this function is subsumed under the market operator;

Become sustaining as soon as practical, thereby minimizing the cost to the Federal Government;

Be ready to novate contracts and wind up as soon as the suppliers are ready to take on their own procurement; and

Enter into contracts that are well structured and managed in a manner that precludes recourse to any credit guarantee instrument.

Federal Ministry of Environment (FMEnv)

The Federal Ministry of Environment (FMEnv) was created in 1999 to ensure effective coordination of all environmental matters. The ministry has a mandate to:

Prepare a comprehensive national policy for the protection of the environment and conservation of natural resources, including the procedure for ESIAs of all developing projects;

Prepare in accordance with the national policy on the environment, periodic master plans for redevelopment of environmental science and technology and advise the federal government on the financial requirements for the implementation of such plans;

Advise the federal government on national environmental policies and priorities, the conservation of natural resources and sustainable development, and scientific and technological activities affecting the environment and natural resources;

Promote cooperation in environmental science and conservation technology with similar bodies in other countries and with international bodies;

Cooperate with federal and state ministries, local governments, statutory bodies, and research agencies on matters and facilities relating to the protection of the environment and the conservation of natural resources;

Prescribe standards for and make regulations on water quality, effluent limitations, air quality, atmospheric protection, ozone protection, noise control as well as the removal and control of hazardous substances; and

Monitor and enforce environmental protection measures.

National Environmental Standards and Regulations Enforcement Agency (NESREA)

NESREA was established as a parastatal of the Federal Ministry of Environment by the NESREA Act of 2007. Some functions of the Agency, amongst others are to:

Enforce compliance with laws, guidelines, policies and standards on environmental matters including water quality, environmental health and sanitation, and pollution abatement;

Coordinate and liaise with stakeholders, within and outside Nigeria, on matters of environmental standards, regulations and enforcement;

Enforce compliance with the provisions of international agreements, protocols, conventions and treaties on the environment;

Enforce compliance with guidelines, and legislation on sustainable management of the ecosystem, biodiversity conservation and the development of Nigeria's natural resources;

Enforce compliance with any legislation on sound chemical management, safe use of pesticides and disposal of spent packages thereof;

Enforce compliance with regulations on the importation, exportation, production, distribution, storage, sale, use, handling and disposal of hazardous chemicals and waste, other than in the oil and gas sector;

Enforce through compliance monitoring, the environmental regulations and standards on noise, air, land, seas, oceans and other water bodies, other than in the oil and gas sector;

Ensure that environmental projects funded by donor organizations and external support agencies adhere to regulations in environmental safety and protection;

Enforce environmental control measures through registration, licensing and permitting systems, other than in the oil and gas sector;

Conduct environmental audits and establish data bank on regulatory and enforcement mechanisms of environmental standards, other than in the oil and gas sector; and

Create public awareness and provide environmental education on sustainable environmental management, promote private sector compliance with environmental regulations other than in the oil and gas sector and publish general scientific or other data resulting from the performance of its functions.

State Institutions

Bauchi State Ministry of Power

This Ministry was created for the purpose of complementing the effort of the Federal Government Development policies on power generation, transmission and distribution. Its focus is on electrical power generation, transmission/distribution to towns and cities, and procurement of assorted distribution transformers.

Bauchi State Ministry of Environment and Forestry

This Ministry was set up to protect and develop the general environment of the State. Other duties as outlined include:

Monitor the Implementation of ESIA guidelines and procedures on all developmental projects in the State;

Monitor and regulate disposal of solid, gaseous, and liquid wastes from facilities;

Monitor air, water, land and soil in the State to determine pollution levels; and

Establish penalties for persons obstructing personnel of the ministry in the performance of their duties.

Bauchi State Ministry of Lands and Housing

The ministry ensures efficient and effective land resource management which promotes equitable access, enabling environment for land delivery, land information and ability to contribute to sustainable socio-economic development of the state.

Bauchi State Ministry of Special Duties

This is a ministry set up for ancillary duties which may be specified or assigned from time to time. The mandate of this ministry is wide and covers extensive governmental functions.

Bauchi State Ministry of Justice

The ministry is a service provider in the area of administration of Justice. The ministry of Justice is an office of government responsible for legal administration of laws of the land.

Bauchi State Ministry of Local Governments Affair

This has responsibility for policy formulations and coordination for the third-tier of Government and by extension, the Emirate Councils. The ministry provides qualitative service delivery that is reform driven at the third-tier of government for a sustainable grassroots development.

Bauchi State Environmental Protection Agency (EPA)

The EPA is mandated to set environmental quality standards and ensure compliance with pollution control. It is responsible for the implementation of environmental policies towards protection, sustenance and development of the environment.

Bauchi and Ganjuwa Local Government Areas (LGAs)

Decree No 12, 1989 of the Federal Republic of Nigeria, vested the statutory function refuse management in the local council under its primary health care department. The LGAs being the third tier of government also ensures economic planning and development of the communities under their area of influence. The common interest of these communities, traditional association and administrative convenience of the communities is equally administered by the local government councils.

2.4 Applicable International Agreements and Policies

Nigeria is a signatory to several international agreements. The treaties/agreements applicable to the proposed project are listed below.

Rio Declaration on Environment and Development (1992)

Basel Convention on the Control of Transboundary Movement of Hazardous Waste and their Disposal (1992)

Stockholm Convention on persistent Organic Pollutant (2001)

The Montreal Protocol on Substance that Deplete the Ozone Layer (1987)

Bamako Convention on the Ban of the Import into Africa and the Control of Transboundary Movement and Management of Hazardous Waste within Africa, (1991)

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

World Bank Policies

The World Bank has 10 Environmental and Social Safeguard Policies to reduce or eliminate the adverse social and environmental effects of development projects, and improve decision making. Based on the general applicability of these policies to development projects, the proposed project will trigger four of these policies - Environmental Assessment, Natural Habitat, Involuntary Resettlement, and Forests.

OP 4.01: Environmental Assessment [IFC Policies-P.S.1]

This policy is triggered by any project that is likely to have potential adverse environmental impacts in its area of influence. Projects that trigger this policy are classified as Category A, B, or C according to the nature and magnitude of potential environmental impacts.

A Category A project is likely to have significant adverse environmental impacts that are sensitive, diverse, or unprecedented. These impacts may affect and area broader than the project site.

A Category B project is likely to have potential adverse environmental impacts on human populations or environmentally important areas – including wetlands, forests, grasslands, and other natural habitats. The impacts are site specific and in most cases, mitigation measures can be designed readily. The assessment for this category examines the project's negative and positive environmental impacts and recommends measures to prevent, minimize, mitigate or compensate for adverse impacts and recommend environmental enhancement measures.

A Category C proposed project is likely to have minimal or no adverse impacts on the environment and thus requires no Environmental Assessment.

The 100MW Solar Power Plant Project can be classified as a Category B project and thus triggers this policy.

OP/BP 4.04: Natural Habitat [IFC Policies-P.S.6]

This policy supports the protection, conservation, maintenance and rehabilitation of natural habitats and their functions. The policy aims to prevent significant conversion or degradation of critical natural habitats, and requires implementation of conservation and mitigation measures to minimize habitat loss.

The 100MW Solar Power Plant project triggers this policy as the operational area will include areas of natural habitats. The ESMP proposes mitigation measures to avoid degradation of the natural habitat within and around the solar farm site and along the transmission line.

OP 4.09: Pest Management [IFC Policies-P.S.6]

This policy necessitates an environmental assessment for projects that raise potential pest management issues. Such projects include the manufacture, use, or disposal of pest control products.

The 100MW Solar Power Plant project does not involve pesticide use or other pest management practices and as such does not trigger this policy.

OP 4.12: Involuntary Resettlement [IFC Policies-P.S.5]

This policy addresses the direct socio-economic impacts arising from projects which could result in disruption of livelihoods, involuntary land take and restriction of access to land. Proponents of such projects are required to prepare a resettlement plan or policy framework addressing the following issues:

- Measures to ensure that displaced persons are duly informed of their rights, resettlement alternatives, and replacement costs for loss of assets;
- Provision of assistance to aid displaced persons in relocating; and
- Ensure that displaced persons are supported after displacement.

The 100MW Solar Power Plant project involves the displacement of people due to unavailability of alternative sites, and as such triggers this policy. In compliance, it aims to assist displaced persons in restoring their livelihoods and standards of living through implementation of a resettlement action plan.

OP/BP 4.10: Indigenous Peoples [IFC Policies-P.S.7]

This policy is aimed at poverty reduction and sustainable development by ensuring that developmental projects fully respect the dignity, human rights, economies and cultures of Indigenous Peoples. Indigenous Peoples are defined as people of a distinct, vulnerable, social and cultural group possessing self-identification, attachment to a geographically distinct habitat, customary institutions different from dominant society and culture, and an indigenous language different from the official language of the region.

The 100MW Solar Power Plant project does not trigger this policy as the Project Affected Persons within the project area cannot be regarded as Indigenous Peoples based on the criteria specified.

OP 4.11: Physical Cultural Resources [IFC Policies-P.S.8]

This policy seeks to avoid or mitigate adverse impacts of development projects on physical cultural resources which are objects, sites, structures and natural features and landscapes that have archeological, paleontological, historic, architectural, religious, aesthetic or other cultural significance.

Although, no known cultural resources have been identified, the 100MW Solar Power Plant Project may trigger this policy if there are discoveries of cultural resources during pre-construction (chance finds). The ESMP in this assessment proposes measures to mitigate adverse impacts on physical cultural resources.

OP 4.36: Forests

This policy addresses the management, conservation and sustainable development of forest ecosystems and their associated resources. It applies to projects that have the potential to impact on the health and quality of forests, the rights and welfare of people and their level of interaction with forests. A forest is defined as an area of land of not less than 1 hectare with tree crown cover of more than 10 percent that have trees with the potential to reach a minimum of 2 meters at maturity in situ. This definition does not include areas dominated by agriculture, grazing or settlements.

The 100MW Solar Power Plant triggers this policy as it will affect a natural forest area where the solar farm and transmission line are to be located.

BP/OP 4.37: Safety of Dams

This policy applies to projects that include a new dam or rely on the performance of an existing dam or a dam under construction.

The 100MW Solar Power Plant project does not trigger this policy as it does not affect the performance or functioning of a new or existing dam.

BP/OP 7.50: Projects on International Waterways

This policy applies to projects that involve the use or potential pollution of international waterways. International waterways include any body of surface water that flows through or forms a boundary between two or more states. The policy aims to ensure the efficient use and protection of international waterways by ensuring cooperation and good will between the Bank and its borrowers and between states.

The 100MW Solar Power Plant project does not trigger this policy as it does involve the use or potential pollution of international waterways.

BP/OP 7.60: Projects in Disputed Areas

This policy applies to projects sited in a location where there is a dispute over the area. Through this policy, the Bank aims to mitigate potential problems that may affect relations between the Bank and its member countries and between neighboring countries where such project is located.

The 100MW Solar Power Plant project does not trigger this policy as it is not located in a disputed area.

Permit Requirements

The different legislations on the environment provide instances when environmental permits are required. Such permits are usually granted by the FMEnv and State Ministries of Environment where applicable.

The National Environmental Protection (Pollution Abatement in Industries and Facilities Generating Wastes) Regulations, provides that a permit will be required for:

Storage, treatment and transportation of harmful toxic waste within Nigeria; and

An industry or facility with a new point source of pollution or a new process line with a new point source.

Permits when granted are project specific and are usually not transferable. The FMEnv stipulates an environmental audit every 2-3 years after commencement of operations. There are permissible limits for various emissions such as specific pollutants from stationary sources, work place noise limits, and effluents.

Chapter Three: Project Description

3.1 Project Overview

The Nigeria Solar Capital Partners (NSCP), Globeleq, and ARM-Harith propose to develop and operate a 100 MW solar independent power project (IPP) on 200 hectares of land in Zongoro Village, Ganjuwa LGA, Bauchi State. The plant would provide Bauchi State and its environs with a cost-efficient renewable energy source to augment the existing energy provided by other sources including wood, kerosene, petrol and charcoal.

The plant would use a renewable method of generating electrical power by converting solar radiation into direct current electricity using silicon panels that exhibit the photovoltaic effect. Photovoltaic (PV) power generation employs solar panels composed of a number of solar cells containing silicone.

The plant would consist of solar panel arrays sufficient to generate 100 MW DC that would be transformed to 80 - 90 MW AC. The system would include a combination of fixed arrays facing to the south. The arrays would be embedded into the ground with concrete footings.

Power produced by the plant would be approximately 100 MW DC, converted to AC through inverters. Transformers would be installed to step up voltage so that it is compatible with the national grid. The stepped-up power would then be connected to the grid.

The following infrastructure would be established for the project:

- A solar PV plant constructed using poly crystalline PV modules, installed in regular arrays
- An overhead power line to connect the solar plant to national grid
- A system of inverters and step up transformers
- Aboveground and underground electrical conduits and cabling which connect the arrays to the inverters and transformers
- Marshalling switchgear to collect the power from the PV arrays
- Internal access tracks to allow for maintenance of the site
- Supervisory control centre
- Site office and maintenance building
- Lay down, campsite and assembly area

3.2 Project Requirements

Land: the total land requirement for the solar farm is 200 ha while the transmission line would be 50 m corridor across the 18.1 km full length. There are 173 affected households on the solar site and 117 affected households along the transmission line. A resettlement action plan has been developed to address the impact of the land uptake for the project on affected persons.

Water: Water usage would be minimal and would be mainly for the monthly cleaning of PV panels and domestic use. This is estimated at about 600,000 litres every six (6) weeks using the assumptions in Table 3.1 below:

Table 3.1: Project Water Requirement Basis

Solar Modules/panels (qty)	335,000
Area of Individual modules	2 m^2
Water required to clean each module	1 L
Annual Cleaning Cycle	12
Total water Requirement	600 m^3

Water requirement would be met by building rain/runoff water harvesting pond and also from groundwater extraction. Over abstraction can lead to rivers drying up thereby leading to mortality of fish and invertebrates or the level of groundwater aquifers reducing unacceptably. Groundwater study will be required to assist NSCP/Globeleq/ARM-Harith in taking informed decision on controlled abstraction limit on the amount of water that can be extracted per time.

Reasonable efforts would be taken to conserve water through recycling and reuse during the operation phase. It should be noted that water runoff/discharge from the panel cleaning would be either evaporated or absorbed into the soil below the panels which keeps the used water within the water cycle. No drainage canal is required due to the low volume.

3. 3 Project Components

The project comprises four components:

A solar PV farm complete with inverters and transformers,
Substation,
Transmission line, and
Buildings (control room, site office and residential areas).

The power plant will use solar panels fitted on fixed structures (mounts), and it will consist of 344,830 panels.

The advantages of solar energy include its non-polluting nature; it is non-depletable, reliable, and free fuel. The disadvantages of solar energy are that the solar energy concentration is very dilute, so collectors with large surface area are needed. In addition, solar radiation is neither constant nor continuous for terrestrial applications (i.e. low capacity factor). The solar energy received depends on latitude, season, time-of-day, and atmospheric conditions.

Table 3.2 gives a summary of the main characteristics of the processes while the schematics for the solar PV system are provided in Figure 3.1. A detailed description of each component and associated processes is given below.

Table 3.2: Key Project Characteristics

Characteristic	**Description**
Solar Farm	Outputs:100MW electricity
Plant area	Approx 200 hectares
Substation	132 kVa
Energy Efficiency	Typical efficiencies for solar cells currently run from 10 to 30% have been achieved
Evacuation	Evacuation via an 18km transmission line connected to the existing 132Kva line
Gaseous Emissions:	None
Discharges:	Uncontaminated storm water to be diverted around plant, to be made to pass through sedimentation chamber before being finally discharged to natural watercourses at appropriate.

Noise	< 15 dB(A) at nearest noise sensitive premises ≤ 15 dB(A) at plant boundary
Roads	A single Road offering access to the field will be constructed from Bauchi Rd into the plants perimeter. All other means of transportation will be held within the boundaries of the field.

Component 1: Solar PV Farm

Solar PV Modules

A PV cell is a semiconductor device that converts sunlight into electricity using photovoltaic effect. Multiple cells can be combined to form a PV module. The efficiency of a PV module is measured by its ability to absorb light particles called photons. The more photons that are absorbed, the more efficient the panel is at converting light into electricity.

When light strikes a PV cell, some of the light energy is absorbed within the semiconductor material. The energy knocks electrons loose, allowing them to flow freely. The electrons will flow in one direction within the module and exit through connecting wires as solar electricity, ultimately providing power for residential and commercial users.

The modules are connected together in strings. These strings are then connected together to form arrays. This is required to provide a certain amount of voltage and current to the input of the inverters (Figure 3.1).

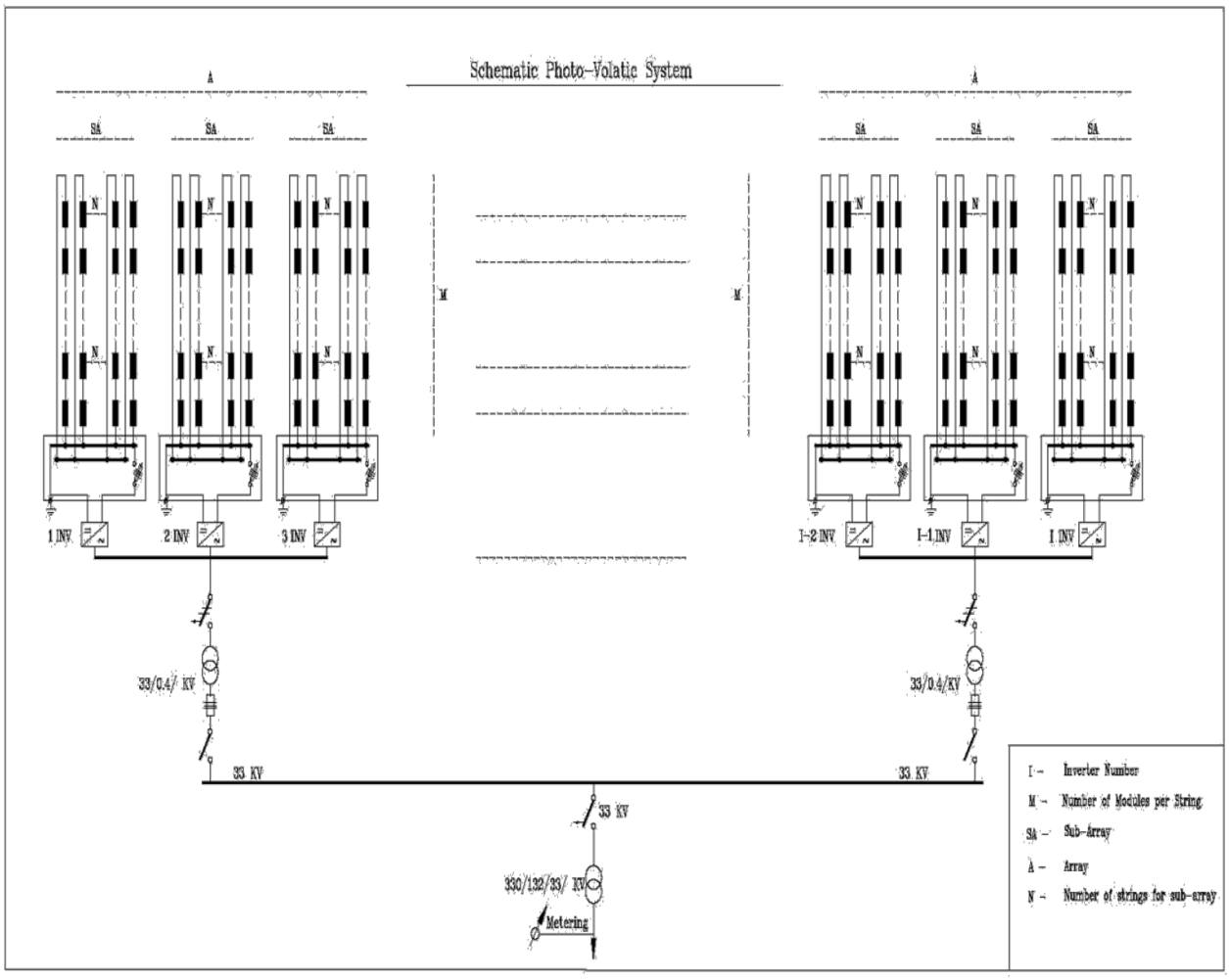


Figure 3.1: Schematic of the Photovoltaic System

Solar PV Mounting System

The proposed solar farm would consist of arrays of over 335,000 modules, mounted on fixed structures to obtain a total project capability of about 100 MW of direct current (DC). The feedstock (solar radiation) is readily available as a byproduct from sunlight, and the long-term supply is guaranteed. Each module would have dimensions of approximately 1 x 2 x 0.5m, weigh 27 kg, and have a standard rating of 300 W. The panels are generally considered to have a lifetime of upwards of 30 years (Alsema, E.A., de Wild-Scholton, M.J., & Fthenakis, V.M. (2006).

Electrical Components

Strings of modules would be wired together in series. Fused combiner boxes with disconnect switches would connect strings of modules and lead to 32 concrete equipment pads of about 100 ft^2 (9.3 m^2) each, placed around the array.

The DC (direct current) power from the solar arrays is fed to an inverter for conversion into AC (alternating current), which is the requirement for feeding into the grid (Figure 3.2). The inverter is designed to export all the available solar power to a utility grid supply.

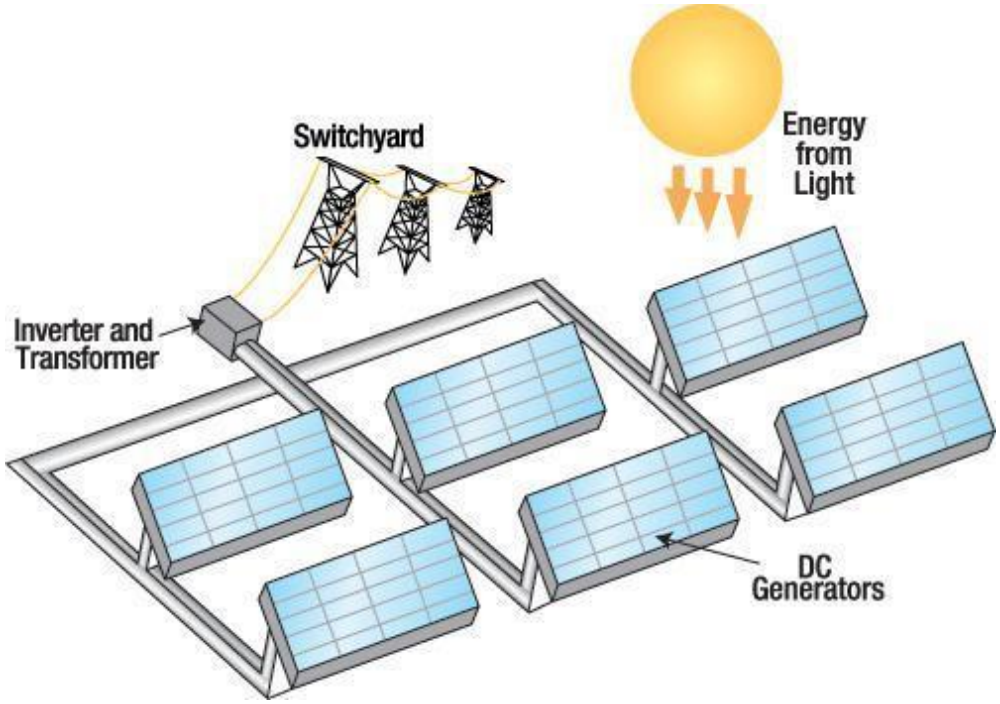


Figure 3.2: Schematic of Solar PV Electricity Generation

Each equipment pad would contain two inverters and one MVA. It is anticipated that the wiring between the modules and equipment pads would be trenched. Conductors would combine at a 22-kV outdoor, metal-clad, switchgear on a 250 square-foot concrete pad. A 22/132 kV transformer, with associated circuit breakers, disconnect switches, and a small (12' × 24') control enclosure mounted on pads totaling 2,000 ft^2, would then step up the power and supply it via transmission line to the national electricity grid.

The facility is to produce direct current electricity (DC) by using photovoltaic technology and converting the DC power to AC by inverters that plug into a medium voltage transformer which is connected to high voltage transformer and then evacuates the produced energy to a high voltage distribution network.

There are numerous photovoltaic panels installed inside the facility that can absorb solar radiation and produce energy using "photovoltaic effect".

The facility includes:

- Photovoltaic panels.
- Power inverters.
- Transformers from LV to MV.
- Cables and support equipment.
- Constructions and structures.
- Electric panels and boards.

Transformer stations and substations.

Measurement and control systems.

Substation

The panels are mounted on steel frames that are fixed to the ground, and directed to the south at a fixed angle, that ensures the optimal absorption of solar radiation.

The panels absorb the solar radiation and convert it into electric energy in the form of direct current. DC power flows through the cables to power inverters that convert the DC current into AC current and synchronizes with the national grid.

Produced energy flows from the inverters to the power transformers, then to switching equipment which includes the energy counter and finally to the national grid.

The voltage of the national grid is 132 kV. Measurement equipment will be installed near the field and near the connection with the grid. When there is no electricity in the grid the facility will be disconnected.

Panels

Energy source (generator) of the facility is the solar panel. Panel consists of photo – voltaic cells which are made of semiconductor crystal silicone. The panels connect to each other by serial connection (String). The number of panels that should be connected in serial connection is determined by the panel type and inverter specifications. All strings are connected in parallel. Quantity of parallel strings is determined by the type of the inverter. The number of panels connected into the string determines the working DC voltage of the facility.

The power rating of the panel is determined by the power that the panel can produce under the Standard Test Conditions (STC). Selected panel supplier Suntech 300 Wp by standard testing conditions. Lamination of the panels includes:

Water and dust proof anti-reflex glass layer.
Ethylene Vinyl Acetate sealing material.
The cells themselves.
Light opaque layer.

All these layers are packed in aluminum frame that gives the final shape and dimensions to the panel.

There would be 20 panels connected in series to reach the nominal voltage of the inverter. The 20 panels would be arranged in 17200 parallel connections. Panels are installed on the fixed aluminum or stainless-steel construction to the ground. One construction unit is called "table" (Figure 3.3).

Poly silicone has been selected for the project. It should perform satisfactorily in relative humidity up to 100% with temperatures between -10°C and +85°C and withstand gust up to 200 km/h from back side of the panel.

Tables are arranged in rows across the field. The active area of the panels is facing southward (northward) with a tilted angle of 10 degrees, in relation to horizontal plane.

The field of 6880 tables is arranged in rows and columns. The strings are connected in parallel to match an amount of current flow to nominal value of the inverter.

There are 335,000 panels in the field each one of 300 W rating so the total installed power is 100 MW of power.

Strings connection to the inverter:

17200 strings are attached to the 100 inverters of 1000 kVA each.

100 inverters accept all strings.

The string connection is made by cables. All cables are connected to the array boxes and to the group boxes.

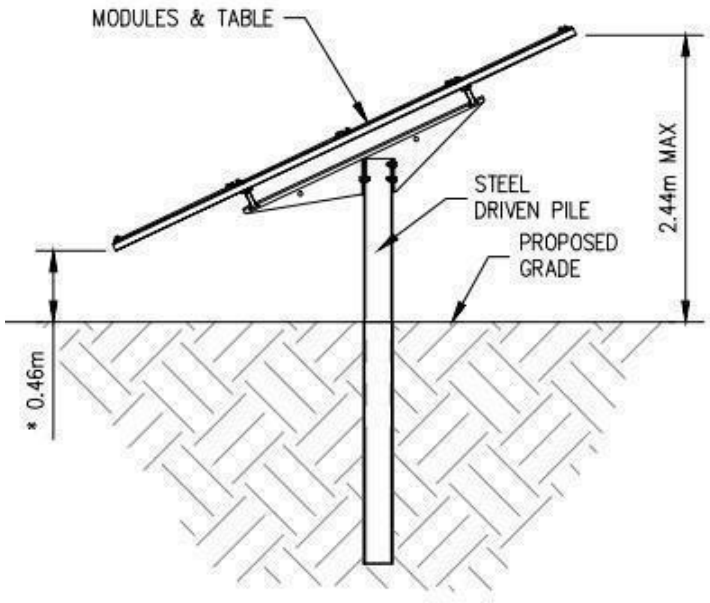


Figure 3.3: Cross-section of Typical PV Module/Table

Inverters

100 inverters are installed in the containers or outside on proper mounting solution. Inverter receives DC electrical energy that flows from photovoltaic panels and transforms it into AC electrical energy that is passed to the national grid. The inverter adapts itself to the photovoltaic string to get the maximum electrical energy available and pass it to the grid. This method is called Maximum Power Point Tracking (MPTT).

Transformers

All inverters are connected to a transformer. The role of the transformers is to step- up the voltage from an inverter nominal voltage to a medium voltage of the national grid. Transformers consist of three coils. One coil is connected to the high voltage; two coils are connected to each of the inverter units master / slave. There are 50 transformers in total in the above system, 2.0MVAeach and one transformer of 0.63MVA. They are installed along with the inverters.

The system in Bauchi is expected to produce 185784 MWh/year during the first year of operation. The expected deterioration is about 0.5% each year. The system is expected to consume about 0.5- 1.5% of the produced energy for internal use.

The proposed project layout (Figure 3.4) comprising the solar power plant site and transmission line have taken into account the solar radiation, wind direction and evacuation corridor.

Two inverters and two transformers per array would be installed on a pad-mounted kiosk. The transformers would feed into 22 kV reticulation cables that would be connected to combining switchgear installed in the project switchyard.

Component 2: Sub-station

An on-site substation is planned for the proposed plant with a capacity of MV/HV 22/132kV. The sub-station will be located in close proximity to the existing power lines. It will include an inverter which will contain transformer oils. Transformer oil is usually a highly refined mineral oil that is stable at high temperatures and has excellent electrical insulating properties, this typically has the following constituents - pentaerythritol tetra fatty acid natural, synthetic esters or mineral oil. Bund walls will be constructed to ensure that any oil spills will be adequately attenuated and not released into the environment. The substation will be securely fenced to prevent unauthorized access.

Component 3: Access Roads

Access roads within the facility will be constructed. The roads will link all project components and be laid out in an efficient manner to ensure easy access for operation and maintenance as well as access from outside the facility.

Component 4: Buildings

Ancillary facilities include residential quarters for the security, maintenance, and control room staff who will be required full-time, a guard house and an office/control centre.

Control Building

The control building would take up an area of approximately 30 m × 15 m. The main construction compound would temporarily require an area of approximately 60 m × 40 m, however; this area would be fully reinstated after construction.

Lay down and Staging Area

A staging area where solar panels would be assembled would be constructed within the project area. The entire area would be enclosed by a chain link fence with a gate. Regular cleaning of the solar panels would be accomplished by either rinsing with water, blowing with compressed air, or a combination of both. Expected waste from this area would include wooden crates, plastics wrappings and Styrofoam.

Component 5: Transmission Line

The power generated from the proposed solar power plant would be evacuated through a 330-kV transmission line to the grid. The power generated from the plant would be stepped up to the required level through suitably rated transformers and then to 132 kV level.

The single overhead transmission line shall have total length of approximately 18.1 km consisting about 30 steel towers to the connection point to the existing national grid at Bauchi-Gombe Road. These towers shall pass by some villages namely - Yuli, Waya, Runde, Dungulhi and Zongoro in Ganjuwa and Bauchi LGA (Table 3.3). The RoW of the transmission line is currently cultivated with staple crops (sorghum and

millets). The clearing of the RoW across the whole length would affect the livelihood of the existing inhabitants close to the proposed transmission line.

Table 3.3: Right of Way Details across the Different Villages

Communities	Yuli	Waya	Runde	Dungulbi	Zongoro
Total Land (ha)	4.8	11.66	8.54	6.77	13.58
Government Land (ha)	0	0	0	0	0
Private Land (ha)	4.8	11.66	8.54	6.77	13.58

The route alignment shall be optimized by NSCP/Globeleq/ARM-Harith to minimize displacement, construction and maintenance costs. Where there are important road crossings, the towers shall be fitted with double suspension and tension insulator etc.

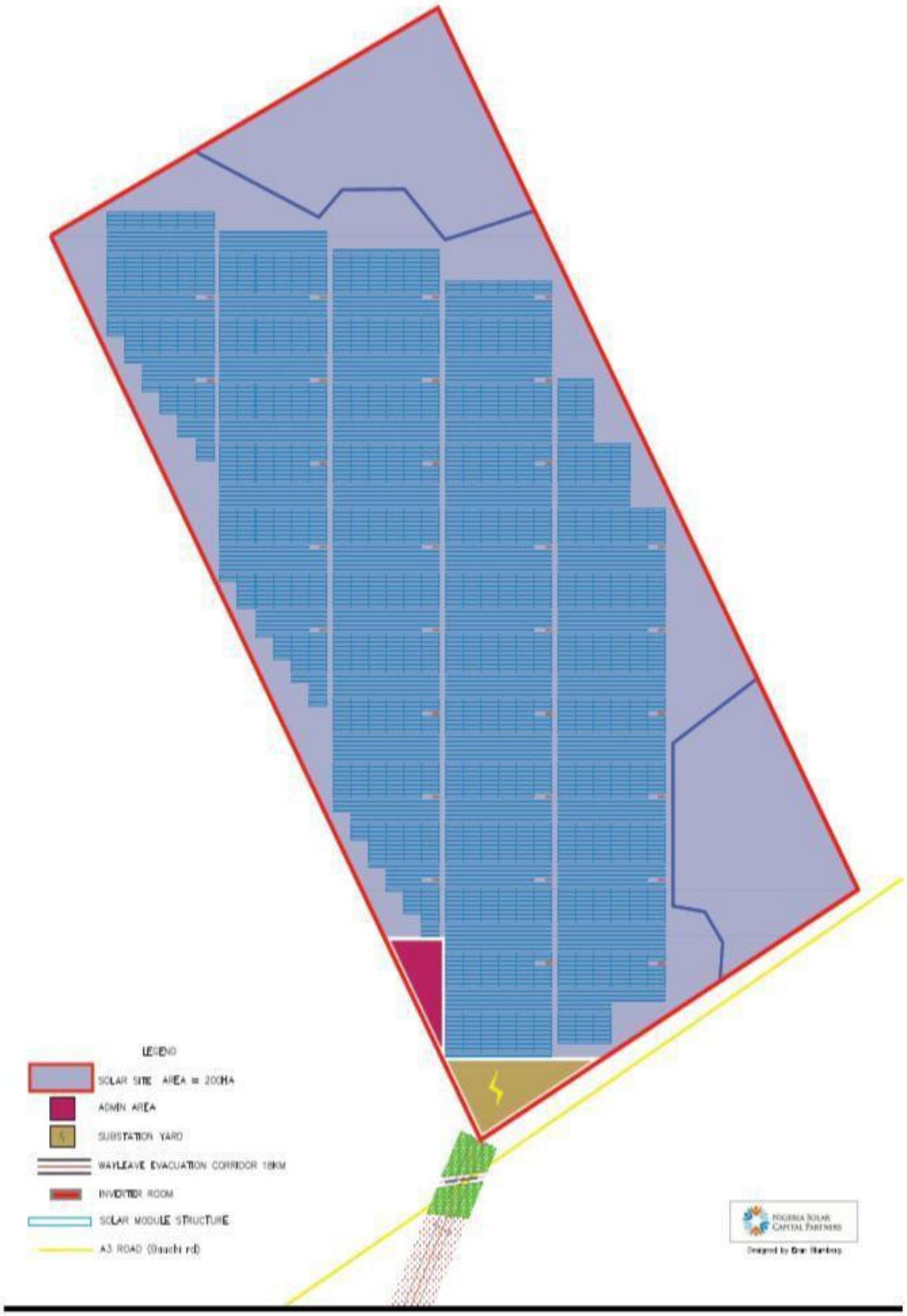

LEGEND
SOLAR SITE AREA = 200HA
ADMIN AREA
SUBSTATION YARD
WAYLEAVE EVACUATION CORRIDOR 18KM
INVERTER ROOM
SOLAR MODULE STRUCTURE
A3 ROAD (Bauchi rd)
NIGERIA SOLAR CAPITAL PARTNERS

Figure 3.4: Project Site Layout

3.4 Operation and Maintenance

Operation and maintenance of the system would be expected to occur on a limited basis at certain points during the system's estimated 25-year life cycle. To enhance the performance and reliability of the plant, the following types of maintenance will be carried out:

Preventive Maintenance, which involves routine inspection and servicing of plant equipment to prevent breakdowns. This includes panel cleaning, vegetation management, wildlife prevention, water drainage, monitoring of electrical components. It also involves retro-commissioning to improve the efficiency of the PV plant by detecting and solving problems in the system.

Corrective Maintenance, which involves repair of broken down equipment. This includes on-site monitoring and mitigation, and critical and non-critical repairs of plant components.

Condition-based maintenance, which involves monitoring equipment and plant operations real-time and addressing potential problems early on in order to prevent plant downtime. This includes continuous monitoring via remote and on-site methods, warranty enforcement, and planned and unplanned equipment replacement.

Maintenance activities will be carried out by skilled manpower with backgrounds in electrical/electronic engineering and unskilled local labour where applicable. Specific maintenance activities include the following:

PV Modules

PV modules need to be cleaned weekly in the dry season and monthly in the wet season to prevent accumulation of dust. Also, the cabling around the modules need to be checked regularly for damages.

Panels need to be checked regularly for cracks and breaks.

Panel testing needs to be conducted annually to ensure they live up to the manufacturer's warranty.

– *Electrical System*

- Inverter components need to be checked to prevent breakdown which can occur during very hot weather conditions.
- Electrical wiring and earthing protection need to be checked for wear and tear. Also, the underground cabling needs to be monitored regularly for damages from pests. Infra-red technology may be employed to identify spots where there are electricity leaks.

– *Civil Structures*

- Mounting structures need to be checked regularly for bending damage which can affect the PV modules
- Access roads, drainage works, plant foundation and array structures need to be checked by visual inspection for water damage during the rainy season

– *Vegetation*

Growth of shrubs and other vegetation needs to be curtailed to prevent shadowing effect on the solar panels leading to a decrease in the output from the plant. Weeds also need to be eliminated as they present a fire hazard.

Vegetation around the transmission line RoW needs to be cleared quarterly to maintain a vegetation height at less than 2 ft (0.61 m).

A stock-pile of spare parts will be kept on-site to facilitate replacement of broken-down or out- dated solar panels and inverters. On-site security and inventory management will be implemented to prevent theft of spare parts and installed plant components.

Monitoring of the PV system components needs to be conducted to ensure increased system output and to reduce down-time. Traditional monitoring methods that compare actual energy generation against predicted energy generation will help to track the system's relative health.

3.5 Project Activities

3.5.1 Construction

Construction activities would last about 12-18 months. The major facilities to be constructed will include:

Land clearing;
Civil works;
Towers;
Transformers;
Control building;
Weather station;
Transmission lines; and
Residential quarters.

The proposed construction programme would be as follows:

Construct the site access roads with gates and temporary fencing;
Excavate the foundations;
Construct the panel foundations;
Construct the transformer and install the grid connection;
Lay power and instrumentation cables;
Construct the control station;
Erect and connect the panels;
Erect weather station;
Commission the panels/transmission lines; and
Carry out land reinstatement, remove temporary compounds and clear the site.

The construction will normally be completed during daytime hours; however, there will be requirements for extended hours during major concrete pours or other installations that cannot be interrupted.

3.6 Implementation Schedule

The project activities will be carried out on a Phase by Phase basis as follows;

Site Survey
Site Leveling
Leveling & Grading
Marking for Mounting Structures
Inverter Room Construction
Auguring
Pier Foundations
Structure Erection
Structure & Model Alignment
DC Cable Laying & Conduit Dressing
Cable Termination

In Parallel Erection of substation yard and 18KM of HV line

The proposed schedule for the plant engineering, procurement and construction is provided in Table 3.4 below:

Table 3.4: Proposed Project Timeline

#	Activities	Q4 2012	Q1 2013	Q2 2013	Q4 2015	Q1 2016	Q2 2016	Q3 2016	Q4 2016	Q1 2017	Q2 2017	Q3 2017
1	Initial Conception											
2	Site Survey & Mapping											
3	Grid & Load Flow Survey											
4	Permitting											
5	Feasibility Studies											
6	Environmental Assessment											
7	Financial Closure											
8	Engineering & Construction											
9	Interconnection & Commissioning											
10	Start Operation											

Schedule of Works

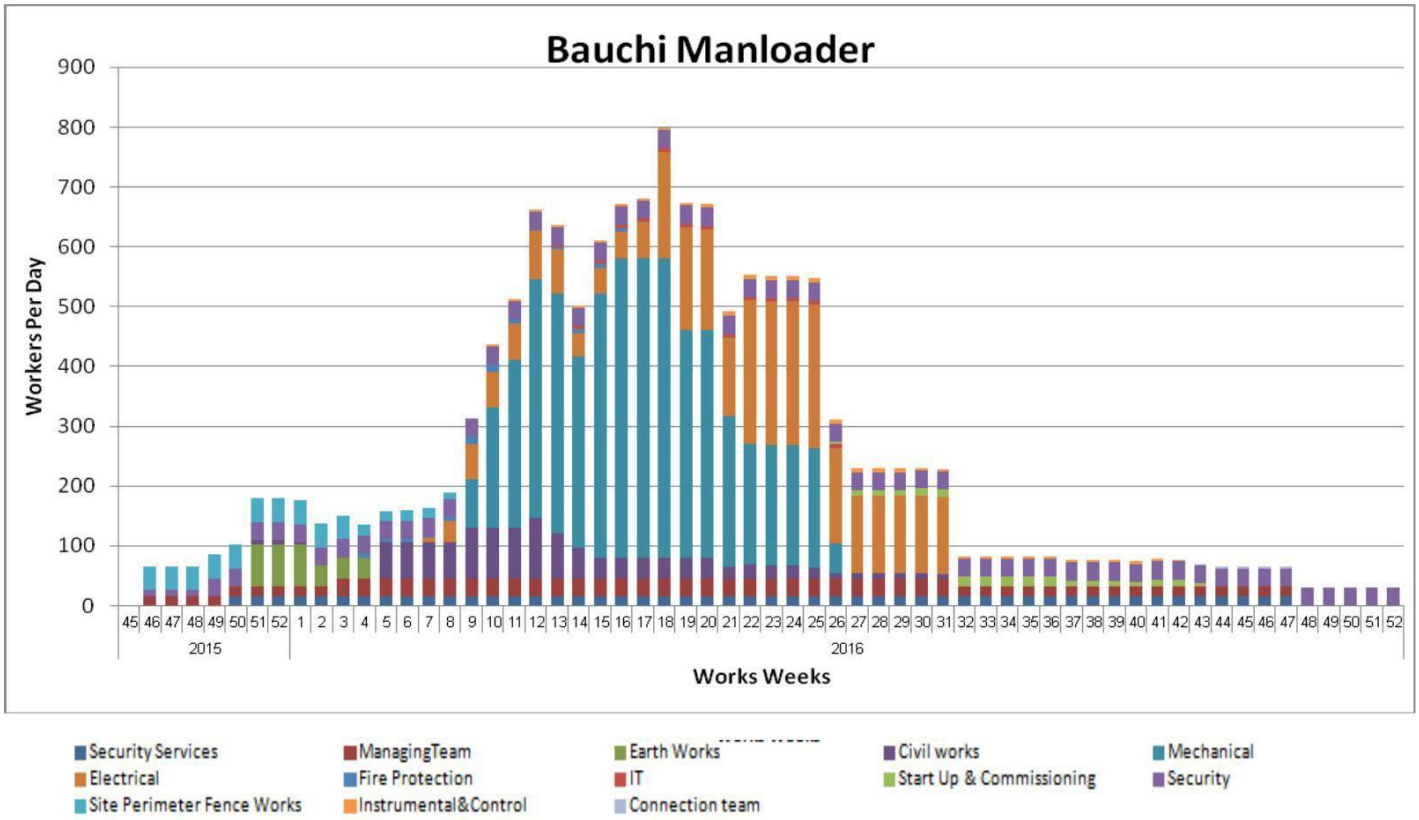
The proposed timeframe for the completion of works, from Notice to Proceed to Commercial Operation Date, is 16 months. A breakdown of this schedule if provided in Table 3.5 whilst Table 3.6 provides a description of staff requirements for each phase of the project.

Table 3.5: Proposed Work Schedule

#	Activities	Duration
Phase 1: Project Initiation	Evaluation of local conditions, preliminary design and finalize commercial and technical discussions with the customer, due diligence on all necessary permits and ensure fulfilment of all EPC contract requirements.	3 months
Phase 2: Engineering and Procurement	Undertake detailed design and engineering of the plant and systems, finalise supply contracts and commence order of materials.	4 months
Phase 3: Construction	Mobilize and execute the construction, including site preparation, training of staff and delivery of materials.	12-13 months
Phase 4: Commission and pre-operation	Commission and grid connect the PV plant.	2 months

Table 3.6: Staff requirements

PERSONNEL	NO.
CONSTRUCTION STAGE	
Manual Workers	700
Skilled Labor/ Professionals/ Managers	60
Security	50
OPERATIONS STAGE	
Cleaners	40
Security	30
Heavy maintenance	7
Light electrical maintenance	10
Infrastructure maintenance	10
Parts and Inventory management	3
DECOMMISSION STAGE	
Manual Workers	350
Skilled Labor/ Professionals/ Managers	30
Security	25



Chapter Four: Description of the Project Environment

4.1 General

This chapter provides a description of the environmental and social setting for the proposed project and includes those components of the environment potentially affected by the proposed project. This has been prepared from available published information, discussions with communities' representatives, relevant mapping, and information collected during two seasons of field investigations, and sampling along with laboratory analyses of the various environmental media collected from the field study.

4.2 Study Area and Location

The overall study area comprises two zones around the solar site complex. These are

The solar power generation site, and

The transmission line (TL) corridor.

These locations and the proposed project's area of influence constitute the study area. Spread over a total land area of about 200 hectares, the proposed project site and its area of influence is located about 20 km north-east of the city of Bauchi. It lies within Latitudes 9°58'51.492"N– 9°59'54.024"N and Longitudes 10°25'45.444"E–10°26'57.012"E. The River Zongoro is few metres away on the southern boundary of the proposed solar farm.

4.2.1 Reconnaissance Field Visit

A reconnaissance field visit was carried out on February 26, 2013 by a team comprising representatives of EnvironQuest (EQ); the Soil, Air Quality & Noise, and Land Use/GIS Consultants; and the representatives of the Proponent, Bauchi State Ministry of Environment and Forestry (BSMEnv & For) and Federal Ministry of Environment (FMEnv).

The team first visited the various communities within and around the area of influence of the project to explain the need for the proposed ESIA and requested their cooperation. During such visits to the various communities, arrangements for local hands (field guides and assistants) for each of the thematic group were made, inclusive of all the communities within the area of influence of the project. An area of influence of 3 km radius was established around the site while 50m corridor was established on each side of the of the transmission line.

Meetings were held with several stakeholders (the Waziri of Zongoro, Sarkins–in-council, women leaders and youth representatives) wherein details of the proposed ESIA were carefully explained before the actual field investigations and sampling started.

4.2.2 Baseline Data Acquisition

This chapter has drawn on a number of information sources including literature and publically available data, as well as primary field studies, and laboratory analyses, as follows:

Literature review and gathering publically available data: The literature review encompassed background information on the climatic condition of the area including recent environmental studies. Literature was sourced from the project proponent, Nigerian Meteorological Agency, Federal and State Ministries of Environment, and State Ministry of Lands and Agriculture. Additional data sources include published articles in journals, gazettes, and technical reports, maps, internet, amongst others.

Primary Data Gathering: Field sampling efforts covered the proposed project site and transmission line route corridor and its area of influence (Figure 4.1a and Figure 4.1b). A two-season field survey was conducted for ground/surface water, air quality, noise levels, water and sediment, soil, vegetation, land use and wildlife in August 12-18, 2013 (Wet Season) and November 10 -15, 2013 (Dry Season). Samples taken were transported to Light House Laboratory, Warri, Delta State for analysis. In addition, public consultations and socio-economic surveys were held in the communities around the site.

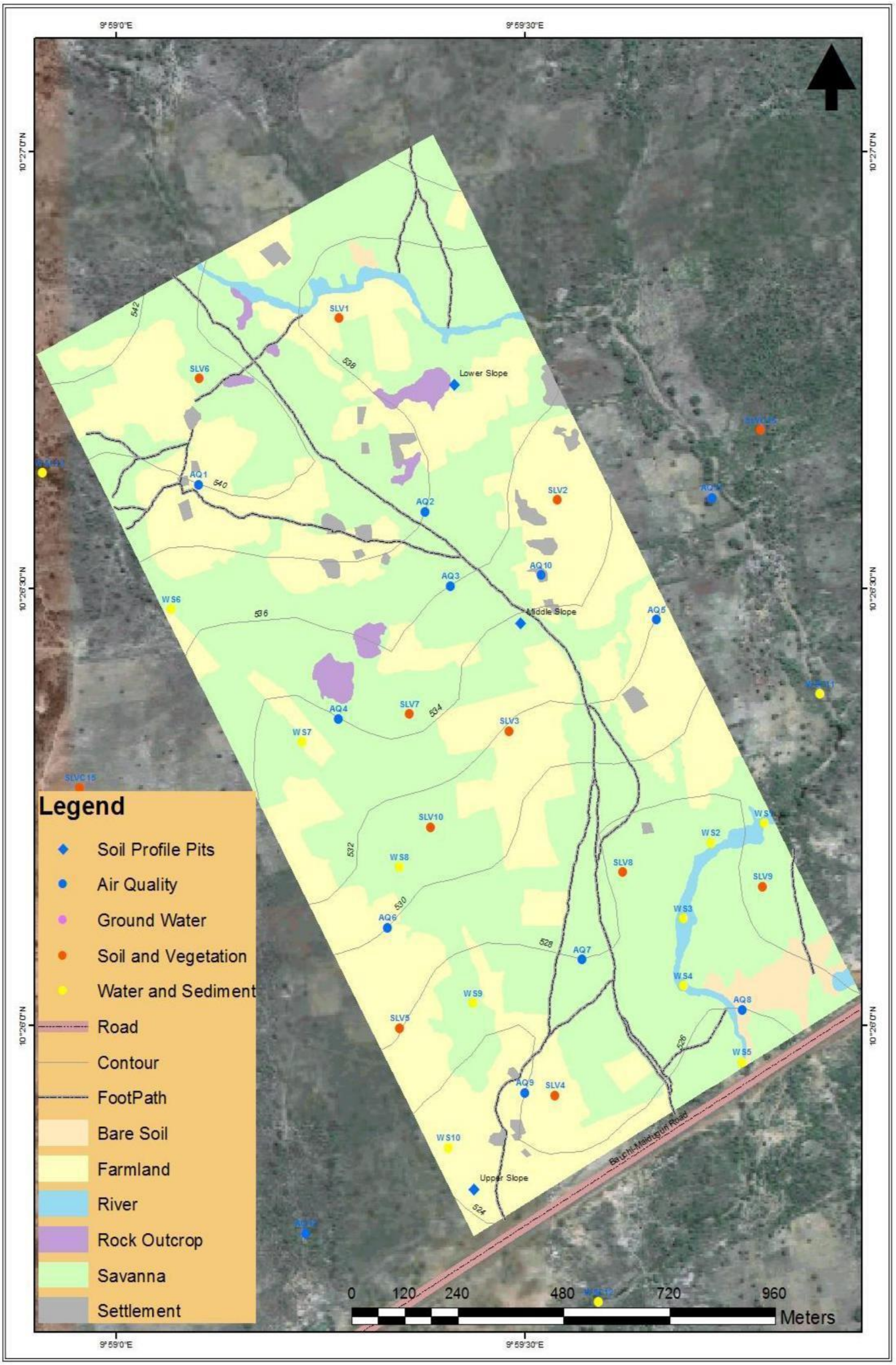


Figure 4.1a: Map of Study Area (Solar Farm) Showing Sampling Stations

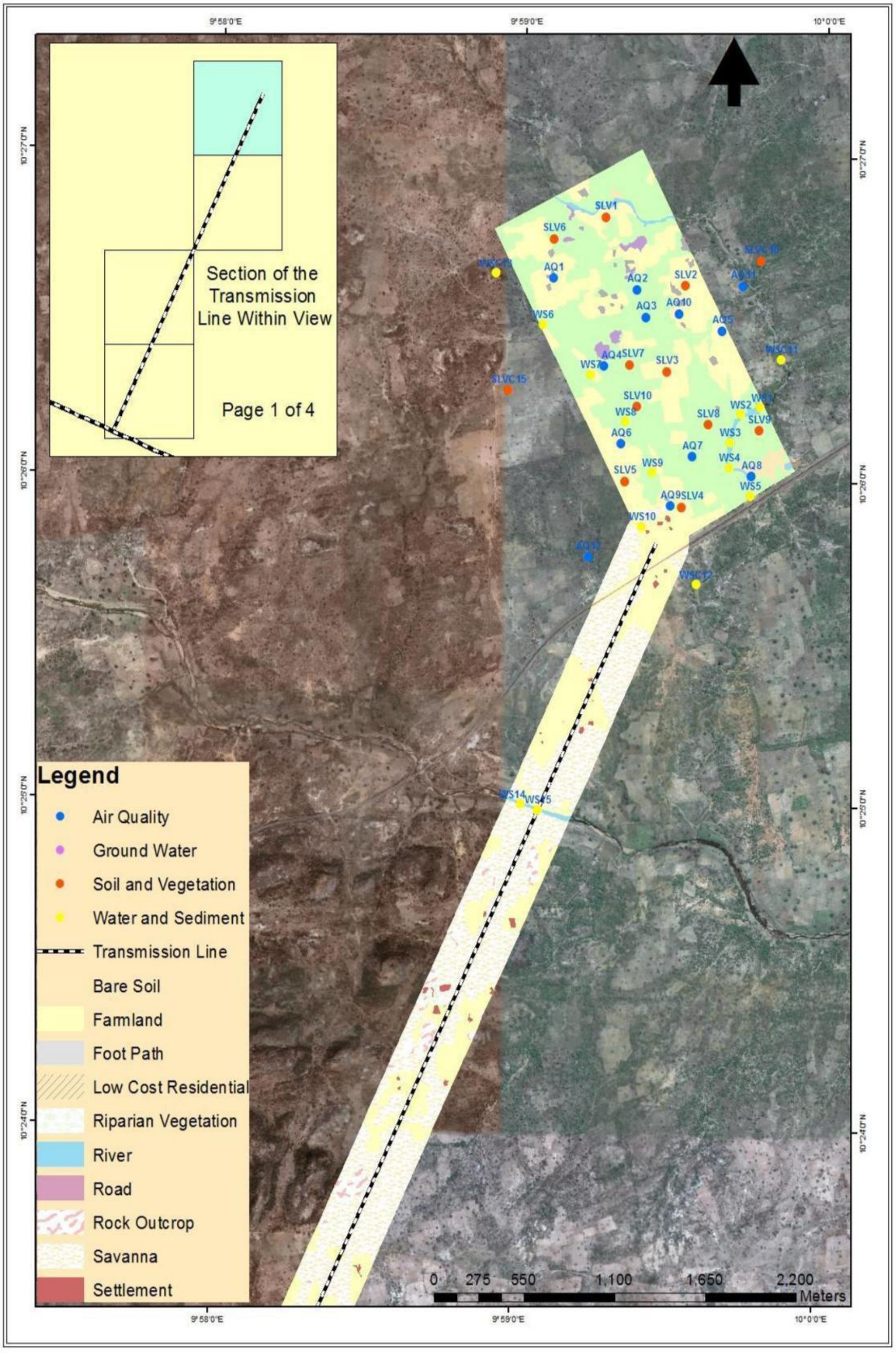


Figure 4.1b: Map of Study Area(Transmission Line) Showing Sampling Station (1 of 4)

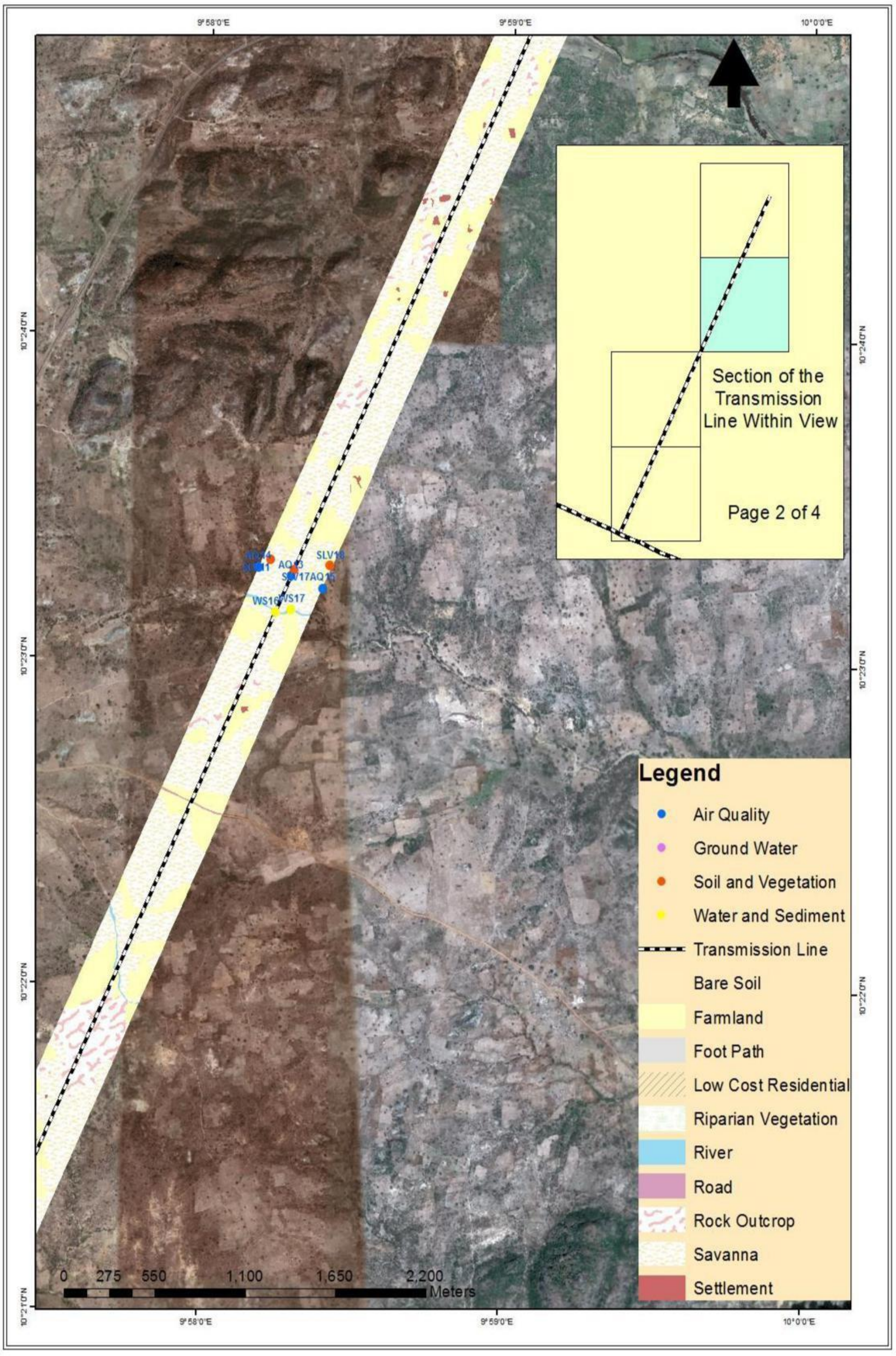


Figure 4.1b: Map of Study Area (Transmission Line) Showing Sampling Station (2 of 4)

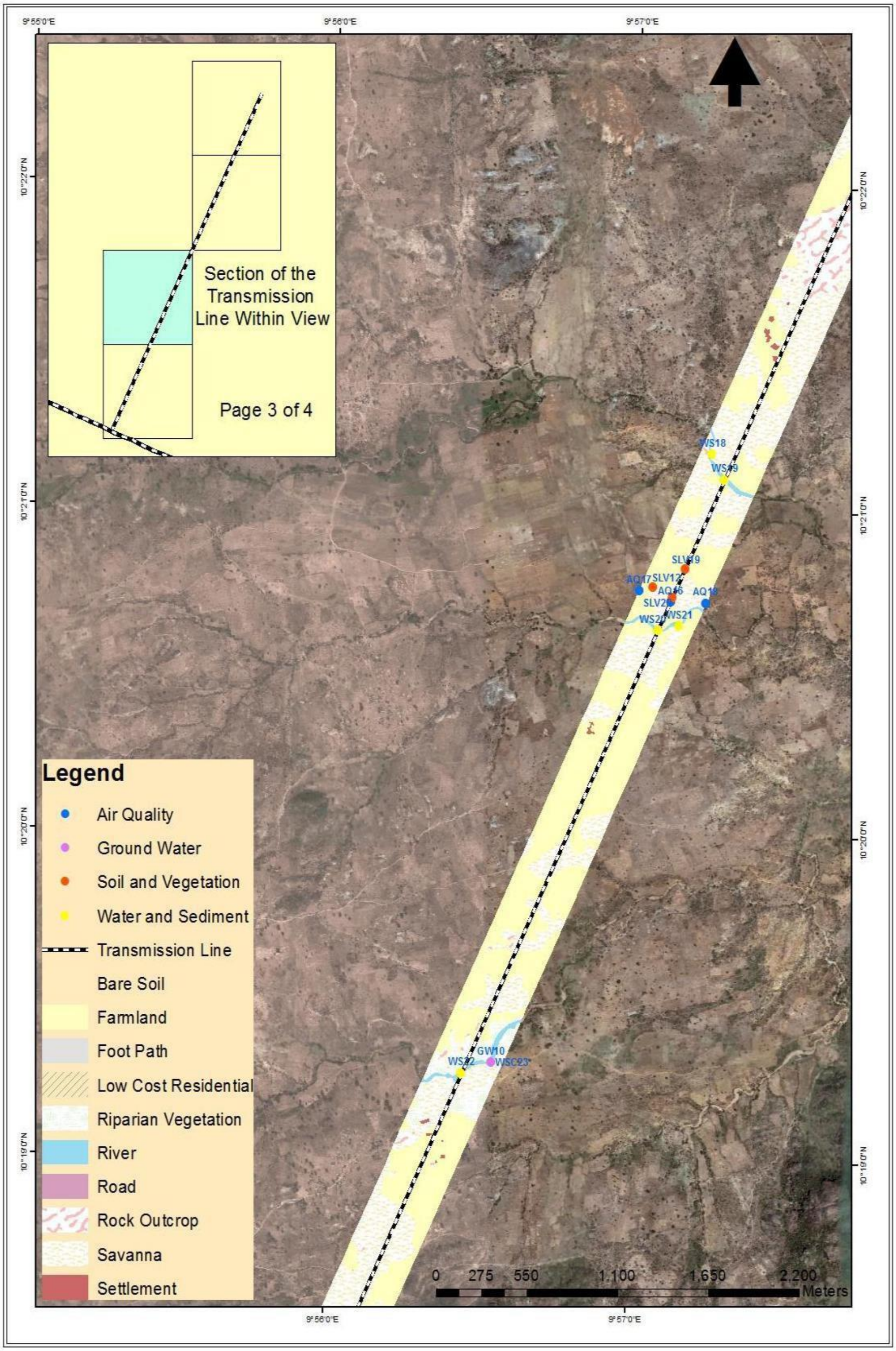


Figure 4.1b: Map of Study Area (Transmission Line) Showing Sampling Station (3 of 4)

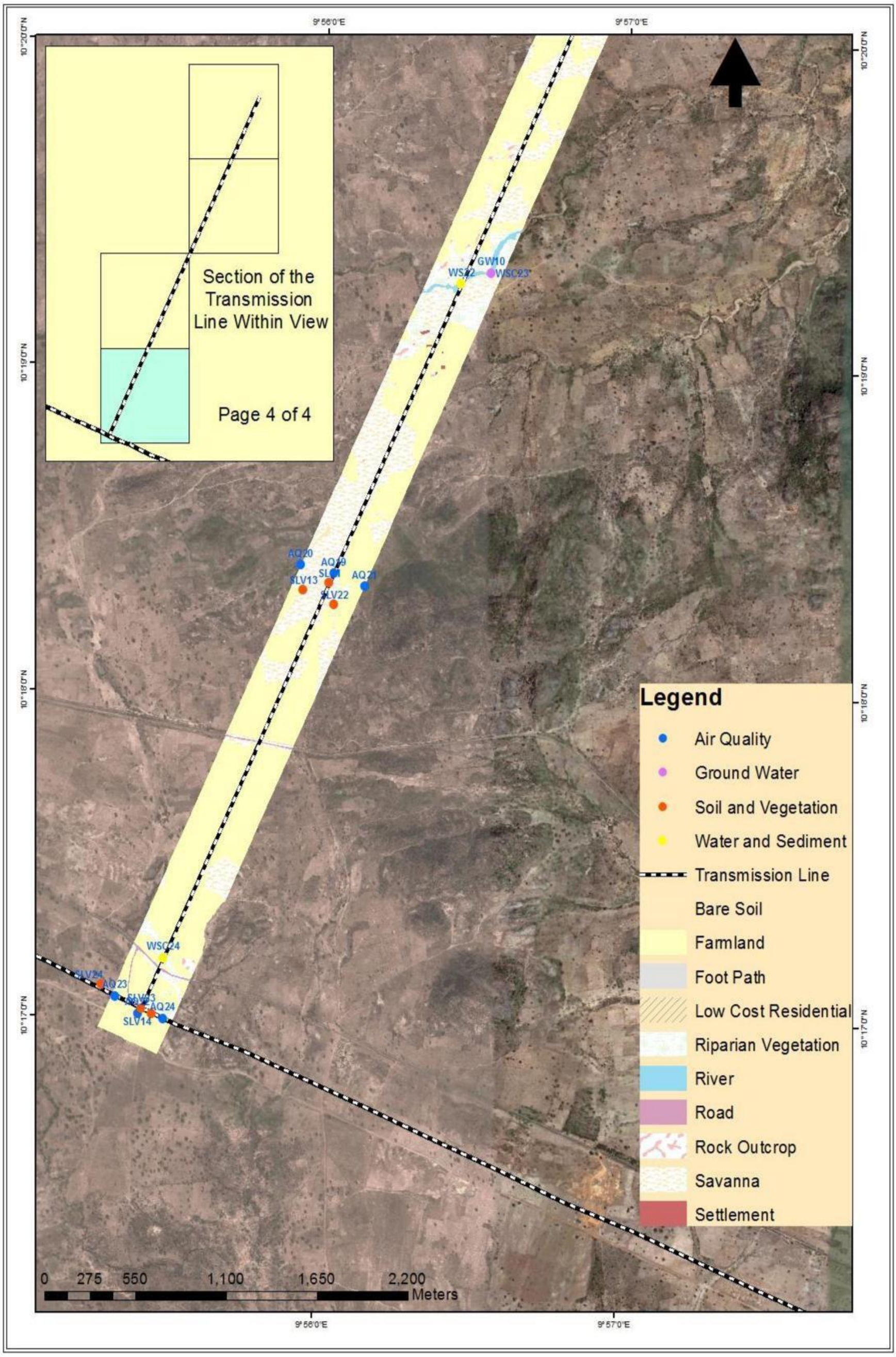


Figure 4.1b: Map of Study Area (Transmission Line) Showing Sampling Station (4 of 4)

4.2.3 Sampling Design

The field observation and sampling design varied for each of the environmental attributes. A brief summary of the sampling methods is presented here while detailed sampling methods are contained in Appendix 2. All the field sampling methods employed are in line with the recommended methods by the Federal Ministry of Environment (FEPA, 1991) and ASTM E1903-97 Standard Guide for Environmental Site Assessments: Phase II Environmental Site Assessment Process (ASTM 2005).

Sampling stations were designed and adequately well distributed to adequately cover both the study area comprising the solar power generation site, the transmission line corridor and the neighboring communities. The locations of sampling stations and codes for each of these environmental attributes are presented in Figures 4.1a and 4.1b. Coordinates of these points are provided in Appendix 9.

4.2.4 Field Sampling Methods

Meteorological Parameters

Meteorological data at the regional level were obtained from the Nigerian Meteorological Agency (NIMET), and a weather tracker (Kestrel 4500) was used to determine temperature, humidity, and wind speed in the study area.

Air Quality and Noise

The gaseous air pollutants—nitric oxide (NO), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), hydrogen sulphide (H_2S), ammonia NH_3, volatile organic compounds (VOCs), and carbon monoxide (CO_2)—were monitored *in-situ* using various gas monitors.

Heavy metal content of the ambient air samples was measured using 2.5 cm diameter Whatmann cellulose filter and a Negretti Air sampler. Particulate matter (PM) was measured by the gravimetric sampling method using the GT-331 particle mass monitor. Five mass ranges of particulates were measured: less than 1µm in diameter (PM_1), 2.5µm ($PM_{2.5}$), 7 µm (PM_7), 10 µm (PM_{10}) and Total Suspended Particles (TSP).

Noise measurements were also taken at the air quality sampling points with a digital, battery-powered, sound pressure level meter (EXTEC Instruments, US Model 407730) for both day time and night time noise level. For all the pollutants (gases and particulates) and ambient noise levels, a sampling period of 8 hrs was adopted.

Soil and Vegetation

At each soil sampling location, representative soil samples were collected at two depths (0–15 cm and 15–30 cm), representing the topsoil and subsoil, respectively. To ensure the collection of representative soil samples, 10 core soil samples were taken within a 5–10 m radius of the sampling location which were composited/bulked in a plastic bucket, and thoroughly homogenized before sub- sampling for laboratory analysis. Soil profiling was also carried out with a profile each at the upper, mid and lower slope physiographic units of the power generating land area. Along the transmission line proposed right of way (RoW), three soil profile pits were also established. Thereafter, soil samples were collected at 0–50 cm and 50–100 cm soil depth for geotechnical determination of triaxial test (to measure the mechanical properties), Atterberg limit, particle size distribution, and soil strength.

At each vegetation sampling point, the floral diversity and population density of key economic species composition were obtained using 50 m transects and 10 m quadrats. Where counting of individual species was not possible, such as where creeping plants were present, cover was measured using the Braun- Blanquet scale (Sutherland, 2006). Rare, exotic, invasive and endangered species were listed.

Samples of plants that could not be identified in the field were collected, pressed and carried to the herbarium for further identification. The health status of the vegetation was visually determined.

Where a disease symptom was noticed, samples of the plant organ(s) were taken to the laboratory for identification of causative organism(s).

Surface Water and Sediment

Surface water samples were collected upstream and downstream of the Zongoro River using the direct dip method. The water and sediment samples were preserved appropriately, and transported to the laboratory for analyses.

Sediment samples of a minimum of 5 litres were collected from the same sampling stations with the aid of a scoop into a bucket, carefully spread and sieved through a 1mm mesh sieve and the organisms washed free of sediment in water and stored in labeled bottles containing 10 percent buffered formalin solution. Roots of macrophytes were also collected at all the sampling stations, vigorously shaken in a bucket containing 10 percent formalin, and the content filtered through the same sieve.

Zooplankton and phytoplankton samples were collected from the selected stations by using astandard Hydrobios plankton net of 55 μm mesh size (Goswami, 2004). Quantitative samples were collected by filtering 50 litres of water through 55 μm mesh plankton net and reduced to 50 ml concentration. The concentrated samples collected were preserved in buffered 4 percent formalin in 200 ml plastic containers. In the laboratory, sorting and identification of specimens from the samples were done using a stereo zoom dissecting microscope and an Olympus Universal Vanox Research Microscope.

Groundwater

Field (i.e. *in-situ*) determinations were carried out on groundwater for parameters with a short holding time while heavy metals and other physiochemical analyses were carried out in the laboratory.

Wildlife Studies

Wildlife observations were conducted during the day and at night to cover for diurnal and nocturnal animals. Binoculars were used to enable the study of birds and other far distant animals. Specimens of animals and other samples obtained in the field were later studied in detail in the laboratory for proper identification of the animals.

Socio-economic Studies

The field work was conducted using the following techniques of data collection:

Census of Zongoro Village

The census of the entire village was conducted using an informal "small group discussion" (SGD) technique based on the five geographic clusters that constitute Zongoro.

Focus Group Discussions (FGD)

During the field survey, the team conducted three FGDs using the designed FGD guide—one for male community leaders and elders; the second for male community youth; while the third was for female members of the community.

Questionnaire Interview

Questionnaires were used to obtain socio-economic and demographic data such as age, sex, occupation, marital status, income, household size, and religion; awareness of the proposed projects; fears; aspirations and expectations. The questionnaire interview targeted all household heads in the communities, as well as one female out of every four households. The fieldwork was conducted on a sample of respondents from among the study population who were selected using a convenience sampling technique. Socio-economics survey tools are presented in **Appendix 4**.

4.2.5 Laboratory Methods

A summary of the methods used to analyse the soil/sediment, water and air quality samples collected during the field studies is provided in **Table A12. 1,** while further details of these analytical methods are provided in **Appendix 2**.

Laboratory analyses were conducted in line with applicable local and international standards and protocols. Appropriate Quality Assurance/ Quality Control (QA/QC) measures were taken in accordance with standard operating procedure (SOP) and analytical procedures.

Other QA/QC measures adopted were:

- the use of trained personnel at all phases of the study;
- written analytical standard operating procedures were followed during analyses; and
- routine auditing and checking of analyses results, including control solutions and midpoint standard, were introduced into every batch of ten samples as applicable, and analyses for which deviation of these quality control / mid-point standards are outside 90 percent to 110 percent of expected value were repeated.

4.3 Biophysical Environmental Baseline Condition of the Proposed Project Location

4.3.1 Climate and Meteorology

The following sub-sections draw, where relevant, on data for Bauchi obtained from the Nigeria Meteorological Agency (NIMET, 2013), which covers 26 years (1987 – 2012). Data collected from the weather station as part of the field survey is also then presented where relevant, and compared to the data from NIMET.

Regional Overview

The study area is located in the semi-arid climatic zone of Nigeria and characterized by two distinct seasons which are the hot dry season and a cool rainy season.

Generally, Nigeria's climate is characterized by the dry and wet conditions associated with the movement of the Inter-Tropical Convergence Zone (ITCZ) north and south of the equator. The Inter-Tropical Convergence Zone (ITCZ) appears as a band of clouds, usually thunderstorms that circle the globe near the equator and Nigeria is located just north of the equator. When the ITCZ is to the south of the equator, the north-east winds prevail producing the dry-season and whenever it moves into the Northern Hemisphere, the south westerly wind prevails to bring rainfall and the rainy (wet) season.

Air Temperature

Due to the latitudinal location of the region within the tropics, the temperature in the study area is generally high with mean monthly minimum and maximum ranges of 14.4ºC–23.6ºC and 29.5ºC–37.3ºC respectively (Figure 4.2). Usually, the highest maximum temperature occurs in February and March, the peak of the dry season, while the lowest temperature occurs in August, the peak of the wet season.

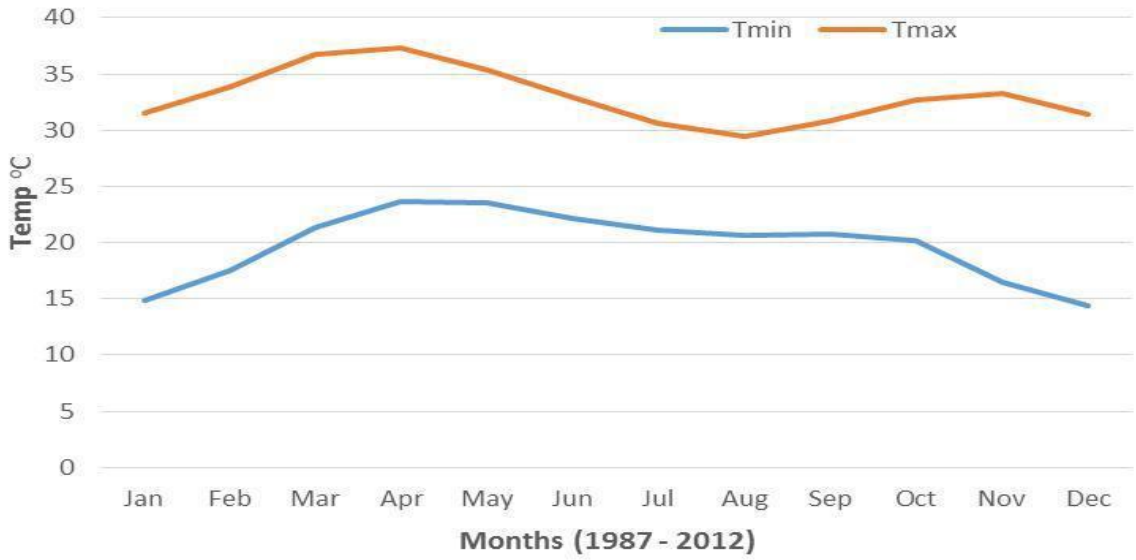


Figure 4.2: Mean Monthly Air Temperature for Bauchi (NIMET, 2013)

This was found to be consistent with the measured temperature of 23.5ºC–36. 0ºC obtained during the fieldwork (Table 4.1). Recorded ambient air temperature for both the dry and the wet season are presented in this table. The values are within the mean minimum and maximum obtained from NIMET for the last 25 years. Detailed in-situ measurements from each sampling station are presented in **Appendix 3.1**.

Table 4.1: Measured Ambient Air Temperature at the Project Site

Level	Air Temperature (°C)	
	Wet Season	Dry Season
Minimum	23.5	30.4
Maximum	36	38.6

Mean	32.5	35.4

Relative Humidity (RH)

Mean monthly relative humidity values obtained from NIMET from 1987–2012 are presented in Figure 4.3. The minimum RH as shown in Figure 4.3 occurs in March, which is the peak of the dry season and the maximum occurs in August, which is the peak of the wet season.

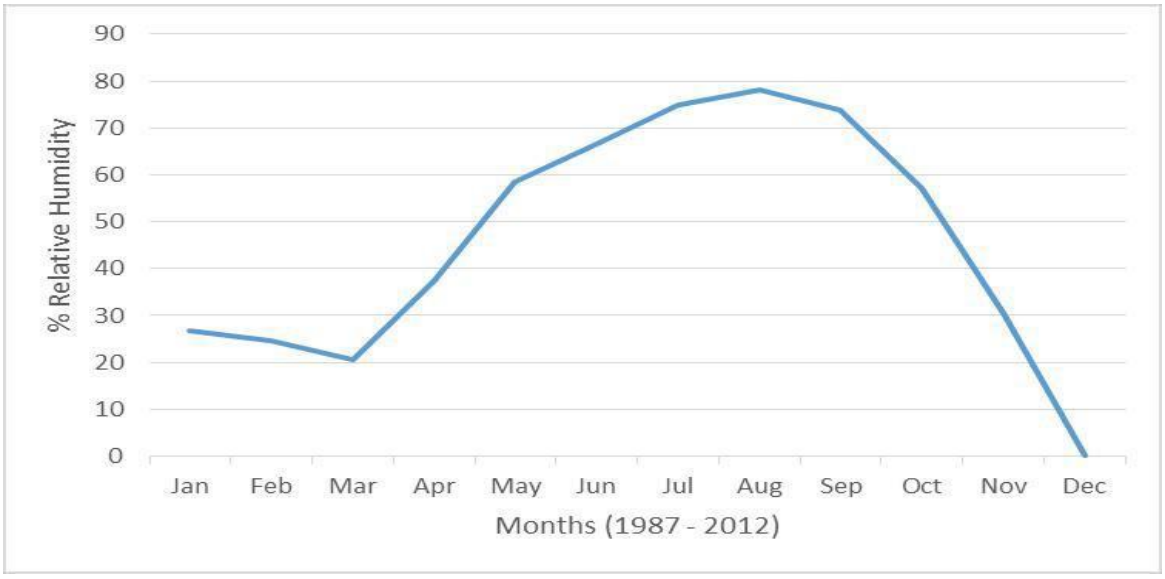


Figure 4.3: Mean Monthly Relative Humidity Data for Bauchi (NIMET, 2013)

These data are consistent with the 45.6%–82.7% RH range recorded during wet season sampling and 13.0% – 24.9% recorded during the dry season at the project site (Table 4.2).

Table 4.2: Measured Relative Humidity at the Project Site

Level	Relative Humidity (%)	
	Wet Season	Dry Season
Minimum	45.6	13.0
Maximum	82.7	24.9
Mean	56.1	16.5

Rainfall

The study area receives little or no rainfall from November to February, but significant rainfall from May onwards. The mean monthly rainfall (mm) for the period 1987 to 2012 (Figure 4.4), shows that August has the highest mean rainfall (624.7 mm), while from September, the average rainfall reduces.

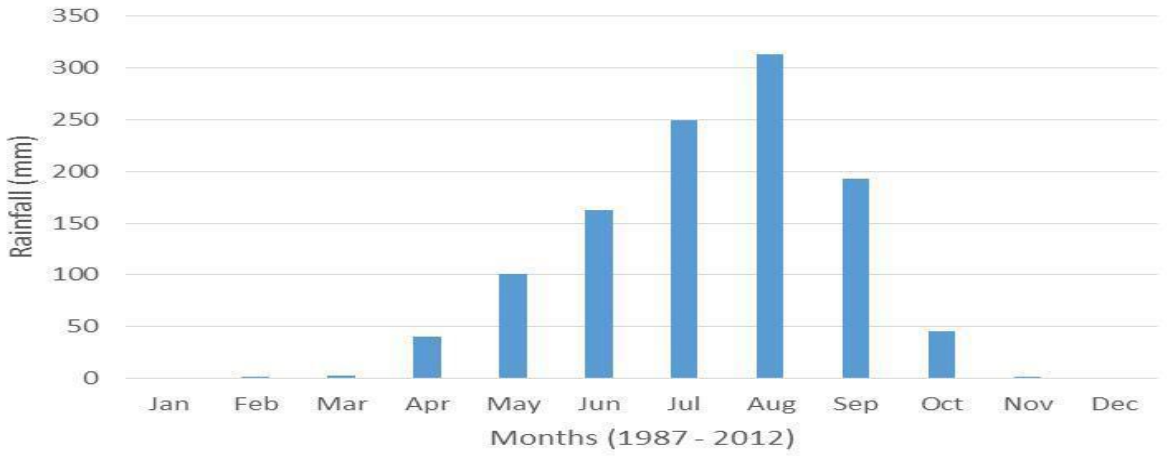


Figure 4.4: Mean Monthly Rainfall for Bauchi (NIMET, 2013)

Wind Speed and Direction

This section has considered wind data from two sources; surface wind data from Bauchi was obtained from NIMET (2013), and upper wind data which is required in air dispersion modelling, was obtained from Lakes Environment (2013), Canada.

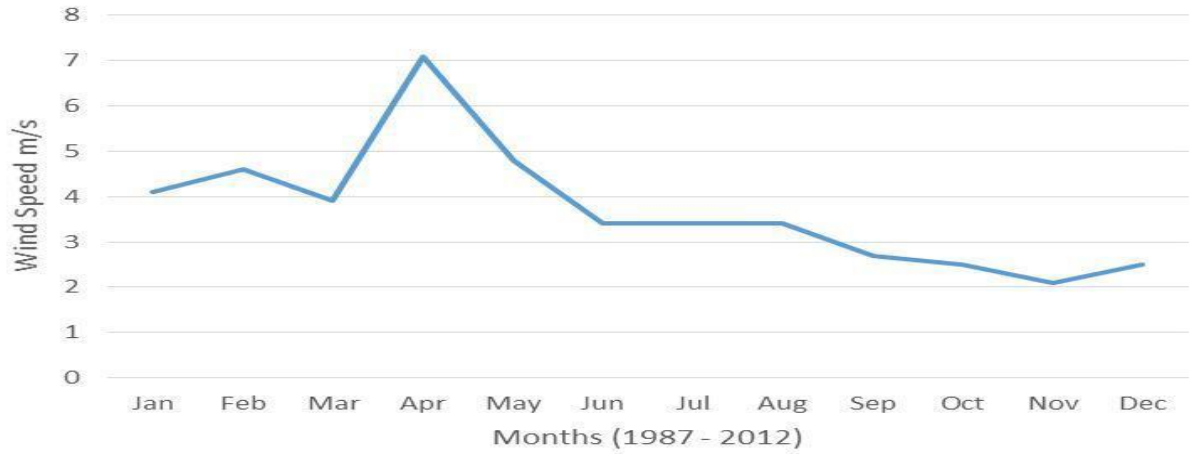


Figure 4.5: Mean Monthly Wind Speed Variation in the Study Area (NIMET 2012)

Figure 4.5 shows that the mean surface wind in Bauchi is 2.1–7.1 m/s with the minimum and maximum in November and April respectively.

Hourly data acquired from the 2012 Lakes Environment for windrose generation at the Project site to determine the prevailing wind direction of the area shows that the wind speed is 0.5–8.8 m/s with about 5% calmness while the prevailing wind directions are the south-westerly and north-easterly (Figure 4.6).

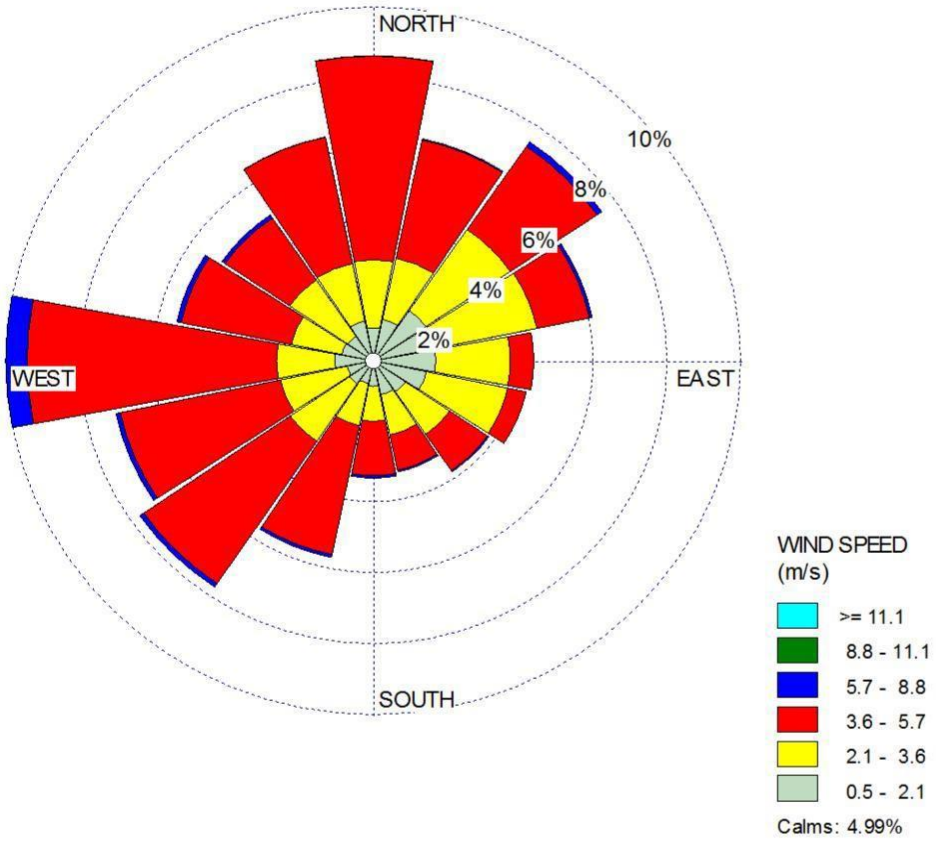


Figure 4.6: Windrose of the Proposed Project Area (Lakes Environment, 2012)

These data are generally consistent with the wind speeds measured during the field survey (**Appendix 3, Table A3.4**). This showed a wet season measured wind speed of 0.5–4.0 m/s in the northeast and 0.5–5.3 m/s in the southwest.

Sunshine

Data obtained from NIMET for Bauchi shows that the mean monthly sunshine period is between 4.8 hours to 7.6 hours per day (Figure 4.7). This is suitable for harnessing solar energy during day-time hours to generate electricity. Between July and October, the lowest sunshine period is recorded, while the maximum period is in November. The shortest period is in July, when there is a greater amount of cloudiness and rainfall. In November, the sunshine periods are higher due to the prevalent clear skies when the ITCZ has started its northward migration. The duration reflects the double maxima feature of the rainfall pattern.

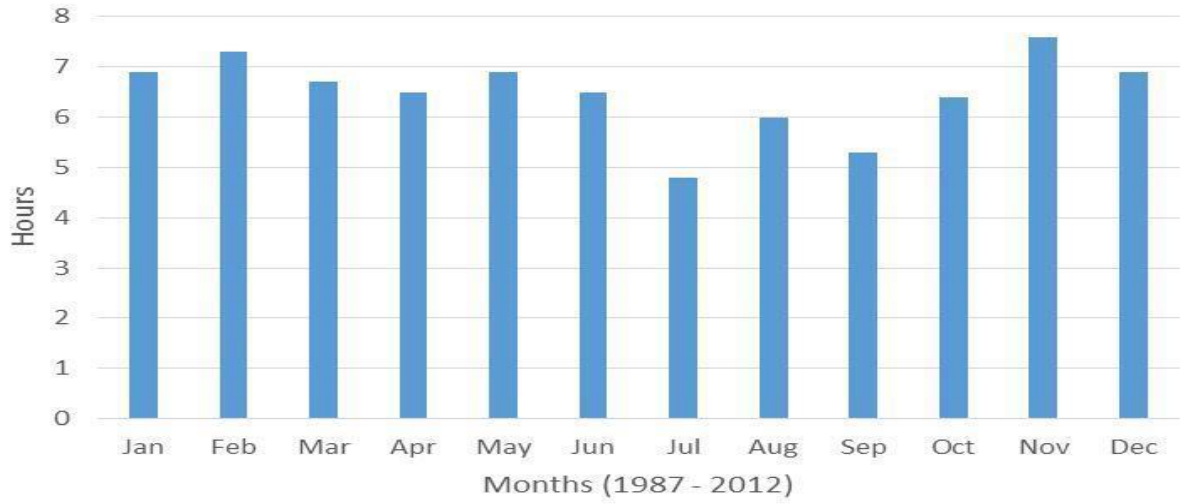


Figure 4.7: Mean Sunshine hours in Bauchi (NIMET,2012)

Cloud cover

Cloud cover in the Bauchi area is generally high throughout the year and has very little variation. The mean monthly range is between 6.1 Oktas and 6.9 Oktas (Figure 4.8), indicating an overcast sky with some blue sky. The minimum cover occurs in December, and the maximum in July.

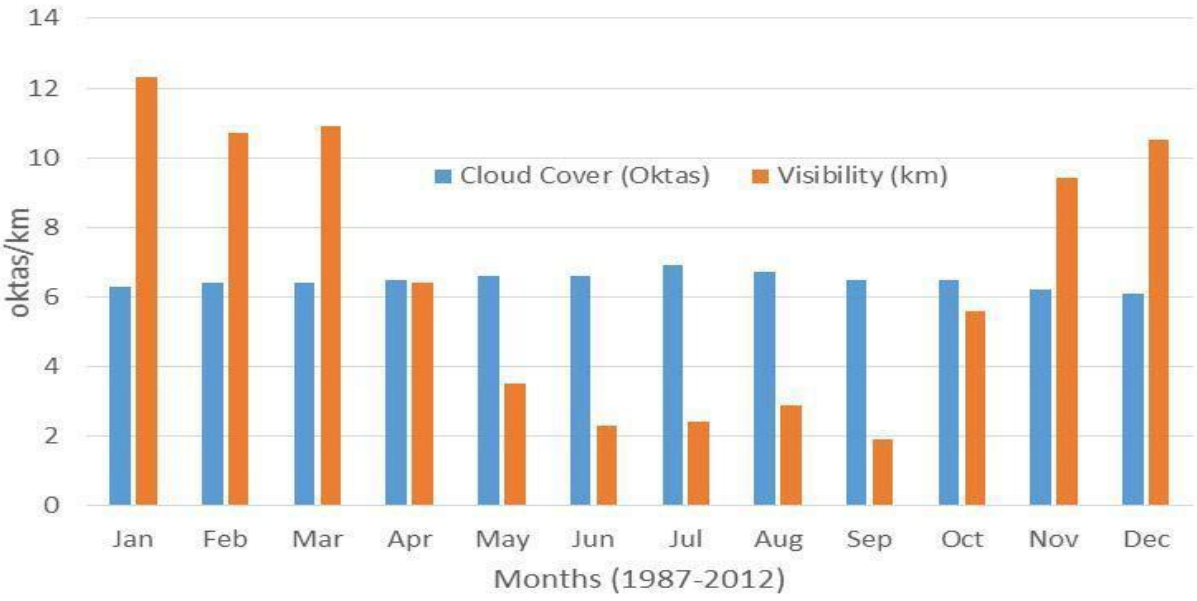


Figure 4.8: Cloud Cover and Visibility Data for Bauchi (NIMET, 2013)

Visibility

As reported in Figure 4.8, the mean monthly visibility of the proposed project area ranges from 1.9–12.3 km. While the minimum is in September, the maximum is in January.

4.3.2 Ambient Air Quality

This section presents the results of the air quality monitoring field survey. The results of both gaseous pollutants (CO, NO, NO_2, SO_2, VOCs, H_2S and NH_3) and suspended particulates monitored during the study are presented.

4.3.2.1 Gaseous Pollutants

Table 4.3 and Table 4.4 summarize the mean measured gaseous pollutants in the proposed solar power plant site, its transmission line and the neighbouring communities over 8hrs and 24hrs respectively. The actual measured values are presented in **Appendix A3.5**.

Proposed Solar Power Generating Site

On this site, only CO, NO_2, and NH_3 were detected in the two seasons. In the wet season, over an 8hr period, CO was 0.0 - 0.1 ppm, (mean, 0.04 ppm), NO_2 was 0.01 – 0.13 ppm (mean, 0.02 ppm) and NH_3 was 0.13 ppm (mean, 0.09 ppm). In the dry season, they were respectively 0.0 - 0.1 ppm (mean, 0.43 ppm), 0.0 - 0.5 ppm (mean, 0.07 ppm) and 1.0 – 6.0 ppm (mean, 1.43 ppm). Out of seven sampling locations in the wet season, CO was detected in three, NO_2 in two, and NH_3 in five. However, in the dry season, CO and NH_3 were detected in three locations, and NO_2 in one (Table 4.3).

On extrapolation to a 24-hour averaging period, the measured CO, NO_2 and NH_3 all became 0.10 ppm, with mean 0.04 ppm, 0.01 ppm, and 0.09 ppm respectively in the wet season. In the dry season, the extrapolated values became 0.5 ppm (mean,0.21 ppm), 0.26 ppm (mean,0.04 ppm) and 0.51 – 3.08 ppm (mean,0.73 ppm) respectively (Table 4.4).

In the wet season, the daily CO was within its 10 ppm FMEnv limit and NH_3 was within its 0.28 ppm limit. However, the daily NO_2 breached its 0.04 – 0.06 ppm FMEnv limit in one location. In the dry season, the daily CO was also within its set limit while NO_2 and NH_3 breached their set limits in all the locations where detected.

Statistically, the wet season and dry season concentrations of the three detected gaseous pollutants (CO, NO_2 and NH_3) were not significantly different using *p-value* computed to be greater than 0.05 (i.e. *p-value > 0.05*) for all. However, slightly higher concentrations of the three gaseous pollutants in the dry season than the wet season could be attributed to "washout" effect of rain that constantly removes atmospheric pollutants during the wet season thus reducing their concentrations.

With the non-detection of NO, SO_2, VOCs and H_2S in any of the sampling locations on the proposed generating site in the two seasons, they could be taken to be within their FMEnv limits and that of the World Bank. Since both CO and NO_2 are combustion products, their detection could be attributed to vehicular emissions. However, the NH_3 detection could be attributed to inorganic fertilizers involved in farming and from cattle grazing activities in the area.

Proposed Transmission Line Corridor

At the sampling locations along the proposed transmission line corridor, only NO_2 and NH_3 were detected in the wet season; but in the dry season, only CO and NH_3 were detected. In the wet season, NO_2 was 0.05 – 0.06 ppm (mean, 0.01 ppm) and detected in two of the ten sampling locations, while NH_3 was 0.13 – 0.75 ppm (mean, 0.30 ppm) and detected in seven locations (Table 4.3). In the dry

season, CO was 1.0 ppm (mean, 0.20 ppm) and detected in two of the sampling locations, while NH_3 was 2.0 – 3.0 ppm (mean, 1.10 ppm) and detected in four locations (Table 4.3).

The wet season measured NO_2 became 0.04 – 0.05 ppm (mean,0.01 ppm) as daily averaging period concentrations while its NH_3 became 0.10 – 0.60 ppm (mean, 0.24 ppm) (Table 4.4). The dry season CO became 0.5 ppm (mean, 0.10 ppm) on conversion to daily averaging period while its NH_3 became 1.03 – 1.54 ppm (mean, 0.57 ppm) daily level (Table 4.4).

Table 4.3: Mean Measured Gaseous Pollutants Levels (ppm) around the Project Site with Seasons

Study Location	Season	CO	NO	NO_2	SO_2	VOCs	H_2S	NH_3
SGS (n=7)	WS	0.04	0.00	0.02	0.00	0.00	0.00	0.09
	DS	0.43	0.00	0.07	0.00	0.00	0.00	1.43
TL (n=10)	WS	0.00	0.00	0.01	0.00	0.00	0.00	0.30
	DS	0.20	0.00	0.00	0.00	0.00	0.00	1.10
Communities (n=4)	WS	0.10	0.00	0.01	0.00	0.00	0.00	0.32
	DS	0.50	0.00	0.00	0.00	0.00	0.00	2.50

Note: mean= taken over 8hr period, WS = west season, DS = dry season, n=number of samples

Table 4.4: Extrapolated 24-Hour Gaseous Pollutants Levels (ppm) around the Project Site with Seasons

Study Location	Season	CO	NO	NO_2	SO_2	VOCs	H_2S	NH_3
SGS (n=7)	WS	0.04	0.00	0.01	0.00	0.00	0.00	0.07
	DS	0.21	0.00	0.04	0.00	0.00	0.00	0.73
TL (n=10)	WS	0.00	0.00	0.01	0.00	0.00	0.00	0.24
	DS	0.10	0.00	0.00	0.00	0.00	0.00	0.57
Communities (n=4)	WS	0.08	0.00	0.01	0.00	0.00	0.00	0.25
	DS	0.25	0.00	0.00	0.00	0.00	0.00	1.28

Note: mean= taken over 8hr period, WS = west season, DS = dry season, n=number of samples

Though the wet season daily NO_2 were within its 0.04 – 0.06 ppm FMEnv limit, NH_3 breached the 0.28 ppm FMEnv limit in four locations. In the dry season, the daily CO was within its set limit but NH_3 was in breach of the daily limit in all the locations where detected. The CO, NO, SO_2, VOCs and H_2S were taken to be within their set limits since they were not detected in any of the sampling locations on the transmission corridor in the wet season. Also in the dry season, NO, NO_2, SO_2, VOCs and H_2S were below the monitored instruments detection limits thus taken to be within the limits.

Though NH_3 was detected in the two seasons, its concentrations in the wet season were not significantly different from that of the dry season concentrations using their *p-value* which was computed to be greater than 0.05 (i.e. *p-value > 0.05*). Its elevated level in the dry season than the wet season could be attributed to the "washout" effect of wet season rainfall as earlier explained.

The detected NO_2 in the wet season and CO in the dry season could be attributed to vehicular emissions while NH_3 detection in the two seasons could be attributed to the farmers' use of organic fertilizers in farming and cattle grazing activities in the area.

Neighbouring Communities

During the wet season, the measured CO in the communities was 0.1 – 0.3 ppm (mean, 0.10 ppm) with NO_2 and NH_3 levels of 0.05 ppm (mean,0.01 ppm) and 0.13 – 0.50 ppm (mean, 0.32 ppm) respectively (Table 4.3). But in the dry season, CO was 1.0 ppm in the two locations where detected and NH_3 was 1.0 -9.0 ppm (**Appendix 3.5**). Though NO_2 was detected in one of the four sampling locations in the wet season, CO was in two and NH_3 was detected in all the locations. These measured wet season CO became 0.1 – 0.2 ppm daily concentration with the measured NO_2 and NH_3 becoming 0.04 ppm and 0.10 – 0.40 ppm respectively while the measured CO and NH_3 became 0.5 ppm (mean, 0.25 ppm) and 0.51 – 4.62 ppm (mean, 1.28 ppm) daily averaging period concentrations in the dry season (Table 4.4).

While the daily CO was within its 10 ppm FMEnv limit in the two seasons, NO_2 was within its 0.04 – 0.06 ppm FMEnv daily limit in the wet season. The 0.28 ppm FMEnv limit of NH_3 was breached in two of the sampling locations in the two seasons. All the gaseous pollutants not detected in the communities in the two seasons were taken to be within their set limits. Ammonia, though detected in the two seasons, shows no significant seasonal variation using the *p-value* computed to be greater than 0.05 (i.e. *p-value > 0.05*). In these communities, CO and NO_2 could be from vehicular emissions and domestic cooking, while NH_3 could be from domestic animals and cattle grazing activities.

4.3.2.2 Suspended Particulates

As summarized in Table 4.5, particulates were detected in all the sampling locations of the proposed generating site, its transmission corridor and the communities in the two seasons.

Table 4.5: Mean Measured Particulate Concentrations (ppm) in the Study Area with Seasons

Study Area	Season	PM_1	$PM_{2.5}$	PM_7	PM_{10}	TSP
SGS (n=7)	WS	1.51	15.36	25.87	32.40	37.33
	DS	2.16	29.57	64.56	90.83	124.90
TL (n=10)	WS	1.74	15.28	29.80	39.85	47.66
	DS	2.05	46.02	82.76	103.58	135.35
Communities (n=4)	WS	1.8	7.475	23.75	32.85	42.4
	DS	2.4	53.475	92.325	104.875	139.875

WS = Wet season sampling result, DS = Dry season sampling result, n = number of samples

Proposed Solar Power Generating Site

The measured particulate concentrations on the proposed power generating site were 1.2 – 1.8 $\mu g/m^3$ (PM_1), 6.4 – 19.5 $\mu g/m^3$ ($PM_{2.5}$), 13.9 – 31.2 $\mu g/m^3$ (PM_7), 26.1 – 47.8 $\mu g/m^3$ (PM_{10}), and 29.9 – 54.7 $\mu g/m^3$ (TSP) in the wet season (**Appendix A3.7**). In the dry season, they were 1.5 – 3.3 $\mu g/m^3$ (PM_1), 18.2 – 47.2 $\mu g/m^3$ ($PM_{2.5}$), 51.5 – 101.6 $\mu g/m^3$ (PM_7), 64.0 – 162.7 $\mu g/m^3$ (PM_{10}), and 82.3 – 302.3 $\mu g/m^3$ (TSP) as represented in **Appendix A3.7**.

When converted to 24-hour averaging period levels, the measured particulates in the wet season became PM_1:1.0 – 1.4 $\mu g/m^3$ (mean, 1.20 $\mu g/m^3$), $PM_{2.5}$: 5.1 – 15.5 $\mu g/m^3$ (mean,12.20 $\mu g/m^3$), PM_7: 11.0 – 24.8 $\mu g/m^3$ (mean, 20.54 $\mu g/m^3$), PM_{10}: 20.7 – 38.0 $\mu g/m^3$ (mean, 25.71 $\mu g/m^3$) and TSP: 23.7 – 43.4 $\mu g/m^3$ (mean, 29.64 $\mu g/m^3$). In the dry season, the 24-hour averaging period levels became PM_1: 1.2 – 2.6 $\mu g/m^3$ (mean, 1.70 $\mu g/m^3$), $PM_{2.5}$: 14.5 – 37.5 $\mu g/m^3$ (mean, 23.49 $\mu g/m^3$), PM_7: 40.9 - 80.7 $\mu g/m^3$ (mean, 51.29 $\mu g/m^3$), PM_{10}: 50.8 – 129.2 $\mu g/m^3$ (mean, 72.11 $\mu g/m^3$), and TSP: 65.3 – 240.0 $\mu g/m^3$(mean, 99.17 $\mu g/m^3$) (Table 4.6).

Table 4.6: Daily Extrapolated Particulate Concentrations (ppm) in the Study Area with Seasons

Study Area	Season	PM_1	$PM_{2.5}$	PM_7	PM_{10}	TSP
SGS (n=7)	WS	1.20	12.20	20.54	25.71	29.64
	DS	1.70	23.49	51.29	72.11	99.17
TL (n=10)	WS	1.70	12.15	23.65	31.64	37.85
	DS	1.62	36.53	65.70	82.24	107.46
Communities (n=4)	WS	1.43	5.93	18.85	26..08	33.65
	DS	1.90	42.48	73.33	83.28	111.05

WS = Wet season sampling result; DS = Dry season sampling result, n = number of samples

On comparison, the 24-hour wet season $PM_{2.5}$ was 20.3 – 61.9% of the 25 $\mu g/m^3$ WHO limit, PM_{10} was 25.9 – 47.4% of the 80 $\mu g/m^3$World Bank limit, and TSP were 9.5 – 17.4% of the 250 $\mu g/m^3$ FMEnv limit. In the dry season, the daily $PM_{2.5}$ was 57.8 – 88.0% of the limit (except in two locations where it was 1.1 – 1.5 folds of the limit), the daily PM_{10} was 20.3 – 51.7% of its limit and the daily TSP was 26.1 – 96.0% of the limit.

Statistically, both season's concentrations of particulates were significantly different using *p-value* computed to be less than 0.05 (i.e. *p-value* < *0.05*) for all particulate fractions. This may suggest difference in sources of particulates in the two seasons. While the additional particulates' concentrations in the dry season could include bush burning, there could have been heavy dust re- suspension in the dry season due to the exposed soil surface that always characterizes the dry season. Dust re-suspension and vehicular emissions were the major possible sources of particulates in the two seasons.

The Proposed Transmission Line Corridor

The wet season measured values were 1.3 – 2.2 $\mu g/m^3$ (PM_1), 5.4 – 25.1 $\mu g/m^3$ ($PM_{2.5}$), 14.4 – 46.0 $\mu g/m^3$(PM_7), 23.4 – 53.6 $\mu g/m^3$ (PM_{10}), and 33.6 – 64.6 $\mu g/m^3$ (TSP); while the dry season values were 1.5 – 3.9 $\mu g/m^3$ (PM_1), 21.8 – 182.8 $\mu g/m^3$ ($PM_{2.5}$), 56.9 – 198.8 $\mu g/m^3$ (PM_7), 65.4 – 287.6

$\mu g/m^3$ (PM_{10}), and 95.3 – 314.9 $\mu g/m^3$ (TSP) as presented in **Appendix A3.7**.

When converted to 24-hour averaging period concentrations, wet season measured particulates became PM_1: 1.0 – 1.7 $\mu g/m^3$ (mean,1.7 $\mu g/m^3$), $PM_{2.5}$: 4.3 – 19.9 $\mu g/m^3$ (mean, 12.15 $\mu g/m^3$), PM_7: 11.4 – 36.5 $\mu g/m^3$ (mean, 23.65 $\mu g/m^3$), PM_{10}: 18.6 – 42.6 $\mu g/m^3$ (mean. 31.64 $\mu g/m^{3)}$, and TSP: 26.7 – 51.3 $\mu g/m^3$ (mean, 37.85 $\mu g/m^3$) but in the dry season, they became PM_1: 1.2 – 3.1 $\mu g/m^3$ (mean,1.62 $\mu g/m^3$), $PM_{2.5}$: 17.3 – 145.1 $\mu g/m^3$ (mean, 36.53 $\mu g/m^3$), PM_7: 45.2 – 157.8 $\mu g/m^3$ (mean, 65.70 $\mu g/m^3$), PM_{10}: 51.9 – 228.3 $\mu g/m^3$ (mean, 82.24 $\mu g/m^3$) and TSP: 75.7 – 250.0 $\mu g/m^3$ (mean, 107.46$\mu g/m^3$) as presented in Table 4.9.

The wet season daily $PM_{2.5}$ were 17.1 – 79.7% of the 25 $\mu g/m^3$ WHO limit for $PM_{2.5}$ while its daily PM_{10} were 23.2 – 53.2% of its 80 $\mu g/m^3$ World Bank limit with the daily TSP being 10.7 – 20.5% of its 250 $\mu g/m^3$ FMEnv limit. In the dry season, the daily $PM_{2.5}$ was 69.2 – 93.4% of its set limit in seven of the sampling locations but 1.2 – 5.8 folds of the limit in the remaining three locations. However, $PM_{2.5}$ was 20.8 – 91.3% of the limit while its TSP was 30.3 – 100.0% of its set limit.

While the wet and dry seasons PM_7, PM_{10} and TSP concentrations were significantly different using their *p-value* computed to be < 0.05, the seasonal variations in their PM_1 and PM_{10} concentrations were not (*p-value* > 0.05). As earlier noted in the proposed power generating site, the dry season higher particulates concentrations in the proposed transmission corridor could be due to reasons earlier mentioned above.

The Neighbouring Communities

In the wet season, measured values were 1.4 – 2.7 $\mu g/m^3$ (PM_1), 5.8 – 9.2 $\mu g/m^3$ ($PM_{2.5}$), 14.9 – 41.8 $\mu g/m^3$ (PM_7), 21.4 – 63.5 $\mu g/m^3$ (PM_{10}) and 15.1 – 68.8 $\mu g/m^3$ (TSP) as presented in **Appendix A3.7**. The dry season measured values were 1.7 – 3.6 $\mu g/m^3$ (PM_1), 24.8 – 113.3 $\mu g/m^3$ ($PM_{2.5}$), 50.2 – 154.1 $\mu g/m^3$ (PM_7), 53.5 – 163.7 $\mu g/m^3$ (PM_{10}) and 83.8 – 176.7 $\mu g/m^3$ (TSP).

On conversion to daily concentrations, the wet season measured values became PM_1: 1.1 – 2.1 $\mu g/m^3$ (mean, 1.43 $\mu g/m^3$), $PM_{2.5}$: 4.6 – 7.3 $\mu g/m^3$ (mean, 5.93 $\mu g/m^3$), PM_7: 11.8 – 33.2 $\mu g/m^3$ (mean, 18.85 $\mu g/m^3$), PM_{10}: 17.0 – 50.4 $\mu g/m^3$ (mean, 26.08 $\mu g/m^3$), and TSP: 12.0 – 54.6 $\mu g/m^3$ (mean, 33.65 $\mu g/m^3$). While the dry season measured values became PM_1: 1.3 – 2.9 $\mu g/m^3$ (mean, 1.90 $\mu g/m^3$), $PM_{2.5}$: 19.7 – 90.0 $\mu g/m^3$ (mean, 42.48 $\mu g/m^3$), PM_7: 39.9 – 122.4 $\mu g/m^3$ (mean, 73.33 $\mu g/m^3$), PM_{10}: 42.5 – 130.0 $\mu g/m^3$ (mean, 83.28 $\mu g/m^3$), and TSP: 66.5 – 140.3 $\mu g/m^3$ (mean, 111.05 $\mu g/m^3$) as presented in Table 4.6.

On comparison, the wet season daily $PM_{2.5}$ was 18.4 – 29.2% of the WHO limit for PM_2. Its daily PM_{10} and TSP were 21.2 – 63.0% and 4.8 – 21.9% of their respective limits indicating that all of these particulates were within the set limits during the season (Table 4.6). In the dry season, $PM_{2.5}$ was 78.8% of the limit in the only location where this was not breached but in others, it was 1.0 – 3.6 folds of the limit. $PM_{2.5}$ was 17.0 – 52.0% of the limit while TSP was 26.6 – 56.1% of the limit.

Over both seasons, PM_1 showed no seasonal variation (*p-value* > 0.05) though, PM_7, PM_{10} and TSP concentrations varied significantly using their *p-value* computed to be < 0.05. Exposed earth surface was the major additional source of particulates in the dry season to the dust re-suspension, vehicular emissions and domestic cooking which were the major possible sources of particulates identified in the neighbouring communities in the two seasons.

Heavy Metals in the Atmosphere

As presented in **Appendix A3.10** and summarized in Table 4.7, though several elements were investigated in the PIXE analysis of the exposed filters, emphasis were more on Cd, Pb, Cr (because they are dangerous to human health) as well as Si, Ti, V, Mn, Fe, Ni, Zn, Cu, Se, As, Sn, and Sb which are elements of higher concern in an environmental study.

The Proposed Solar Power Generating Site

In the wet season, Cr and Fe were not detected in any of the sampling locations at the proposed generating site. The concentration of detected metal range as follows, Cd: 0.32 – 2.20 µg/m^3 (mean, 0.71 µg/m^3), Pb: 0.00 - 0.94 µg/m^3 (mean, 0.13), Si: 0.23 – 1.69 µg/m^3 (mean, 0.56 µg/m3), and Ti: 0.10 – 0.26 µg/m^3 (mean, 0.09 µg/m^3). Other metals detected were: V (0.00 - 0.02 µg/m^3), Mn (0.00 - 0.03 µg/m^3), Ni (0.00 - 0.01 µg/m^3), Zn (0.01 – 0.04 µg/m^3), Cu (0.02 – 0.03 µg/m^3), Se (0.03 – 0.07 µg/m^3), As (0.00 - 0.04 µg/m^3), Sn (0.62 – 3.58 µg/m^3) and Sb (0.00- 4.63 µg/m^3) (Appendix A3.10). The measured Cd (3.00 µg/m^3), Pb (5.00 µg/m^3) and Mn (10.00 µg/m^3) were within their respective FMEnv daily limit.

During the dry season, atmospheric metals in the proposed solar power generating site did not contain Cd, Cr, V, As, and Sn. **Appendix 3.10** presents the detected metals concentration, the range is as follows; Pb:0.00 - 0.48 µg/m^3(mean, 0.24 µg/m^3), Si: 1.21 – 1.30 µg/m^3(mean, 1.26 µg/m^3), Ti: 0.06 – 0.07 µg/m^3(mean 0.07 µg/m^3), Mn: 0.00 - 0.04 µg/m^3 (mean, 0.07 µg/m^3), Fe: 0.35 – 0.70 µg/m^3 (mean, 0.53 µg/m^3), Ni: 0.00 - 0.02 µg/m^3 (mean, 0.02 µg/m^3), Zn: 0.00 - 0.04 µg/m^3 (mean, 0.02 µg/m^3), Cu: 0.00 - 0.02 µg/m^3 (mean, 0.01 µg/m^3), Se: 0.00 - 0.12 µg/m^3 (mean, 0.06 µg/m^3), and Sb: 0.00 - 5.60 µg/m^3 (mean, 2.80 µg/m^3). Table 3.12 presents the average concentration levels of the metals. Six of the investigated metals (Mn, Se, Fe, Ni, Zn, and Sb) were higher in the dry season than in the wet season, eight others (Sn, As, Cu, V, Ti, Si, Pb and Cd) were higher in the wet season than in the dry season. However, both Pb and Mn concentrations were within their respective FMEnv limits over both seasons.

The Proposed Transmission Line Corridor

The values of detected metals in the samples located in the proposed transmission line corridor were Cd: 0.70 – 3.66 µg/m^3 (mean, 0.78 µg/m^3), Pb: 0.18 – 0.19 µg/m^3 (mean 0.06 µg/m^3), Cr: 0.05 – 0.7 µg/m^3 (mean 0.01 µg/m^3), Si: 0.02 – 2.73 µg/m^3 (mean 0.58 µg/m^3), Ti: 0.04 – 0.18 µg/m^3 (mean 0.04 µg/m^3), V: 0.03 – 0.08 µg/m^3 (mean 0.02 µg/m^3), Mn: 0.02 – 0.07 µg/m^3(mean 0.02 µg/m^3), and Fe: 0.08 – 0.52 µg/m^3 (mean 0.06 µg/m^3) as presented in **Appendix A3.10**. Other detected metals were Ni, Zn, Cu, Se, As, Sn, and Sb detected to be 0.01 – 0.08 µg/m^3(mean, 0.02 µg/m^3), 0.02 – 0.65 µg/m^3 (mean, 0.10 µg/m^3), 0.01 – 0.12 µg/m^3 (mean, 0.02 µg/m^3), 0.02 – 0.12 µg/m^3 (mean, 0.05 µg/m^3), 0.01 – 0.02 µg/m^3(mean, 0.003 µg/m^3), 1.75 – 7.97 µg/m^3 (mean, 1.95 µg/m^3), and 2.68 µg/m^3 (mean, 0.27 µg/m^3) respectively (Appendix A3.10). The following detected metals Cd (3.00 µg/m^3), Cr (1.00 µg/m^3), Pb (5.00 µg/m^3) and Mn (10.00 µg/m^3) were within their respective FMEnv daily limit.

Cd, Ti, V, Se, and As were not detected in the dry season along the proposed transmission line corridor. Other metals were measured to be Pb: 0.00 - 0.13 µg/m^3 (mean, 0.07 µg/m^3), Cr: 0.00 - 0.05 µg/m^3 (mean, 0.03 µg/m^3), Si: 1.81-2.05 µg/m^3 (mean 1.93 µg/m^3), Mn: 0.00 - 0.03 µg/m^3 (mean 0.03 µg/m^3), Fe: 0.41 - 0.59 µg/m^3 (mean 0.50 µg/m^3), Ni: 0.00 - 0.02 µg/m^3 (mean 0.02 µg/m^3), Zn: 0.02 - 0.03 µg/m^3(mean, 0.03 µg/m^3), Cu: 0.00 - 0.03 µg/m^3 (mean 0.02 µg/m^3), Sn: 0.00 -7.78 µg/m^3

(mean, 3.89 µg/m^3), and Sb: 0.00 - 6.61 µg/m^3 (mean, 3.31 µg/m^3) as presented in **Appendix 3.10**. Average concentration level is presented in Table 4.12. In about 73% of the sampling locations, concentrations of measured metals were higher in the wet season than in the dry season. The following detected metals Cd, Pb, Mn and Cr were within their respective FMEnv limits.

Neighbouring Communities

In the wet season, the concentration of detected metals ranges as follows Cd: 0 - 2.36 µg/m^3 (mean, 0.59 µg/m^3), Pb:0- 0.09 µg/m^3 (mean 0.02 µg/m^3), Si:0 - 1.15 µg/m^3 (mean 0.29 µg/m^3), Ti:0.04 – 0.09 µg/m^3 (mean 0.05 µg/m^3) , V:0 - 0.02 µg/m^3 (mean 0.01 µg/m^3), Mn:0 - 0.04 µg/m^3 (mean, 0.01 µg/m^3), Ni:0.00 - 0.01 µg/m^3 (mean, 0.003 µg/m^3) , Cu:0.01 – 0.02 µg/m^3 (mean, 0.01 µg/m^3), Se:0.08 – 0.16 µg/m^3 (mean,0.06 µg/m^3), As:0.02 – 0.08 µg/m^3(mean 0.03 µg/m^3) , Sn:0.00 - 5.60 µg/m^3 (mean 1.40 µg/m^3) , and Sb:0.00 - 6.33 µg/m^3 (mean, 1.58 µg/m^3) as presented in Appendix A3.10.

The dry season atmospheric metal concentration levels in the communities were Pb (0.14 µg/m^3), Cr (0.03 µg/m^3), Si (1.69 µg/m^3), Ti (0.23 µg/m^3), V (0.07 µg/m^3), Mn (0.06 µg/m^3), Fe (1.31 µg/m^3), Se (0.15 µg/m^3), and Sb (4.67 µg/m^3) as presented in **Appendix 3.10**, average concentration level is presented in Table 4.7. 40% of the metals detected in the wet season were found to be higher than their respective dry season concentrations, only 33% of the metals assessed in the dry were higher than their respective wet season concentrations. Over both seasons, the following detected metals were found to be within their corresponding daily limits Cd (3.00 µg/m^3), Pb (5.00 µg/m^3) and Mn (10.00 µg/m^3) as indicated.

With these measured air quality parameters concentrations, there is a high carrying capacity airshed for industrial activities in the study area. Overall, the airshed in the project location can be classified as Class II. With respect to particulates and gaseous pollutants, the airshed can further be classified as having an un-degraded air quality using the World Bank Guidelines.

Table 4.7: Average Heavy Metal Analysis Concentrations (ppm) in the Study Area with Seasons

Study Areas	Season	Cd	Pb	Cr	Si	Ti	V	Mn	Fe	Ni	Zn	Cu	Se	As	Sn
SGS (n=7)	WS	0.71	0.13	0	0.56	0.09	0	0	0	0	0.02	0.01	0.01	0.01	1.7
	DS	0	0.2	0	1.3	0.1	0	0.02	0.53	0.02	0.02	0.01	0.06	0	0
TL (n=10)	WS	0.79	0.06	0.01	0.58	0.04	0.02	0.02	0.06	0.02	0.1	0.02	0.05	0	1.95
	DS	0	0.1	0.03	1.9	0	0	0.03	0.5	0.02	0.03	0.02	0	0	3.89
Communities (n=4)	WS	0.59	0.02	0	0.29	0.05	0.01	0.01	0	0	0	0.01	0.06	0.03	1.4
	DS	0	0.1	0.03	1.7	0.23	0.10	0.06	1.31	0	0	0	0.15	0	0

4.3.2.3 Ambient Noise Levels

This section reports the results of the noise sampling conducted. The mean measured ambient noise and the calculated L_{90} (background noise) are summarized in Table 4.10 while **Appendix A3.9** presents the actual measured noise levels.

The Proposed Solar Power Generating Site

In the wet season, the minimum daytime noise was 31.8 – 39.4 dB(A) (mean. 36.71 dB(A) with a maximum of 45.0 – 66.9 dB(A) (mean,56.67 dB(A)) (Table 4.8 and **Appendix A3.9**). Its minimum night-time noise was 29.6 – 36.6 dB(A) (mean, 29.90 dB(A) with maximum levels of 50.0 – 54.8 dB(A) (mean, 38.60 dB(A)) as shown in Table 4.9. Its background noise was 40.4 – 48.0 dB(A) in the daytime but 36.2 – 38.2 dB(A) in the night-time. These values were all within the 70 dB(A) industrial area ambient noise limit of the World Bank (Figure 4.9). The day-time background noise was within the 55 dB(A) World Bank day-time ambient noise level limit, while the night-time background noise was within the 45 dB(A) World Bank night-time limit except in one location (Figure 4.10).

In the dry season, the minimum daytime noise was 29.1 – 35.2 dB(A) (mean, 31.09 dB(A)) with a maximum of 40.7 – 44.0 dB(A) (mean, 42.20 dB(A)), as shown in **Appendix A3.9** and Table 4.8. The minimum night-time noise was 27.4 – 32.4 dB(A) (mean, 33.10 dB(A)) with maximum levels of 35.3 – 41.9 dB(A) (mean, 38.60 dB(A)) as shown in Table 4.9. The background noise was 29.9 – 35.9 dB(A) in the daytime and 32.5 – 34.1 dB(A) at night. These values were within the 70 dB(A) industrial area ambient noise limit of the World Bank (Figure 4.3). The daytime background noise was within the 55 dB(A) World Bank daytime ambient noise level limit (Figure 4.9), while the night-time background noise was within the World Bank 45 dB(A) limit (Figure 4.10).

A significant difference was noticed between the wet and dry seasons' noise levels (*p-value <0.*05) with the wet season levels higher than that of the dry season level both during the day and night. Higher noise level during the wet season than in the dry season could be attributed to more cattle grazing activities in the study area during the wet season than in the dry season. Distant vehicles and cattle activities as well as natural sources including wind and river were the observed major sources of noise.

Table 4.8: Average Daytime Measured Ambient Noise in the Area during the Study with Seasons

Sampling Station	Season	Noise Level, dB(A)		
		L_{miin}	L_{max}	L_{90}
SGS (n=7)	DS	36.71	55.67	31.83
	WS	31.09	42.20	42.64
TL (n=10)	DS	33.42	45.92	34.07
	WS	34.18	45.41	41.08
Communities (n=4)	DS	39.675	59.825	40.05
	WS	40.375	60.475	50.125

***Many of the sampling locations could not be accessed at night due to unfavourable security situation.**

Table 4.9: Average Night-time Measured Ambient Noise in the Area during the Study with Seasons

Sampling Station	Season	Noise Level, dB(A)		
		L_{miin}	L_{max}	L_{90}

SGS (n=7)	DS	33.10	52.40	37.20
	WS	29.90	38.60	33.30
TL (n=10)	DS	34.75	41.70	35.00
	WS	29.50	36.70	31.00
Communities (n=4)	DS	33.075	46	36.625
	WS	32.325	43.7	35.825

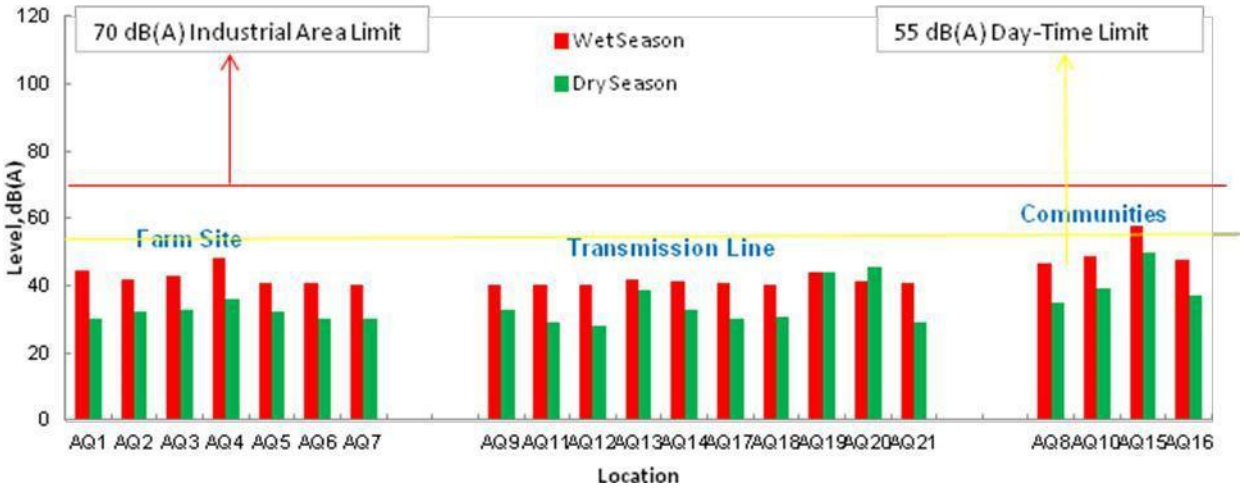


Figure 4.9: Day-Time Background Noise (L_{90}) Compared to the Standards

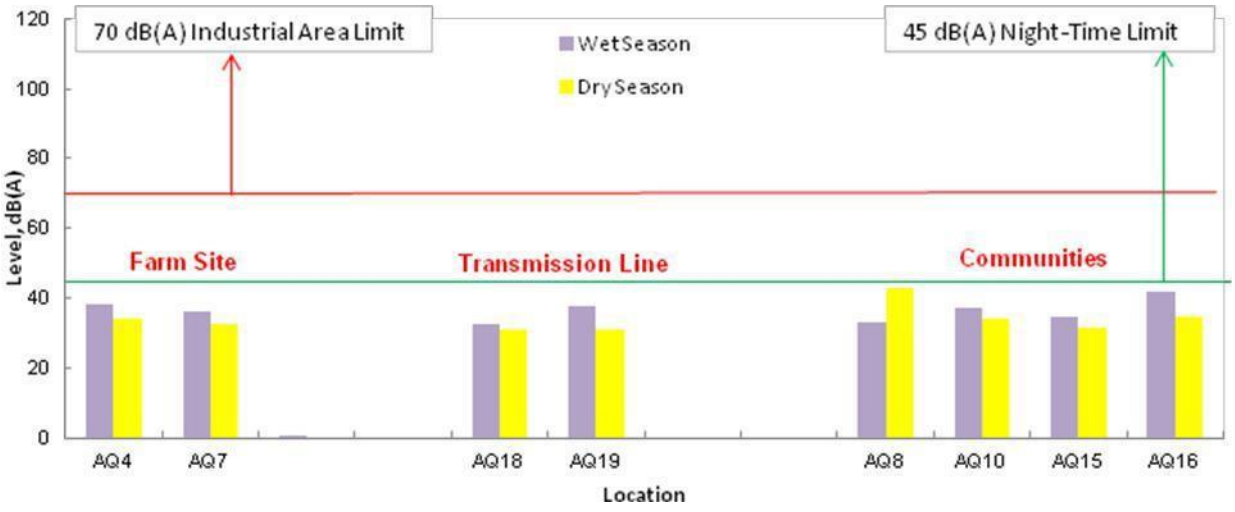


Figure 4.10: Nighttime Background Noise Levels (L_{90}) Compared to the Standards

The Proposed Transmission Line Corridor

As summarized in **Appendix A3.9** and Table 4.8, the transmission line corridor has a daytime minimum noise of 30.5 – 43.6 dB(A) (mean, 34.18 dB(A)) with maximum levels of 41.1 – 51.5 dB(A) (mean, 45.41 dB(A) in the wet season. Its night-time minimum noise was 32.1 – 37.4 dB(A) (mean, 34.75 dB(A)) while the maximum noise was 40.2 – 43.2 dB(A) (mean, 41.70 dB(A)) as reported in Appendix A3.9 and Table 4.8. in the wet season, the day-time background noise was 40.1 – 43.8 dB(A) but 32.5 – 37.5 dB(A) at night which were within the 70 dB(A) industrial area ambient noise limit of the World Bank (Figure 4.10). The day-time wet season background noise was also within the 55 dB(A) day-time ambient noise level limit (Figure 4.10) while its night-time background noise were within the World Bank 45 dB(A) night-time limit (Figure 4.11).

In the dry season, the transmission line corridor daytime minimum noise of was 26.8 – 45.1 dB(A) (mean, 34.18 dB(A)) with maximum levels of 36.9 – 58.0 dB(A) (mean, 45.41 dB(A)) as shown in Appendix A3.9 and Table 4.8. Its night-time minimum noise was 29.4 – 29.6 dB(A) (mean, 29.50 dB(A)) while its maximum noise was 36.4 – 37.0 dB(A) (mean, 36.70 dB(A)) as reported in Appendix A3.9 and Table 4.9. The day-time background noise was 27.9 – 45.3 dB(A) but 30.8 – 31.2 dB(A) at night which were within the 70 dB(A) industrial area ambient noise limit of the World Bank (Figure 4.9). The day-time wet season background noise was also within the 55 dB(A) day- time ambient noise level limit (Figure 4.10) while its night-time background noise was within the World Bank 45 dB(A) night-time limit except in one location (Figure 4.10). Distant vehicles, wind and river were its major noise sources. Intensive cattle grazing was observed present in the wet season than the dry season.

The Neighbouring Communities

In the communities, the daytime minimum noise levels were 33.4 – 47.7 dB(A) (mean, 39.68 dB(A)) in the wet season with a maximum level of 55.7 – 71.3 dB(A) (mean, 59.83 dB(A)) as shown in Appendix A3.9 and Table 4.10 but at night (Appendix A3.9 and Table 4.9), the minimum noise were 31.2 – 34.7 dB(A) (mean, 33.08 dB(A)) with a maximum level of 36.9 – 50.8 dB(A) (mean, 46.00 dB(A)). The wet season daytime background noise levels in these communities were 46.4 – 57.8 dB(A) with night-time background levels of 33.1 – 41.7 dB(A). All these were within the 70 dB(A) industrial area ambient noise limit of the World Bank (Figure 4.10). Similarly, the daytime background noise was within the 55 dB(A) daytime ambient noise level limit except in one of the communities where it was breached (Figure 4.10). However, the night-time background noise was within the World Bank 45 dB(A) night-time limit in all the sampling locations (Figure 4.11).

In the dry season, the communities' daytime minimum noise was 34.4 – 49.7 dB(A) (mean, 40.38 dB(A)) with maximum levels of 54.2 – 73.7 dB(A) (mean, 60.48 dB(A)) as shown in Appendix A3.9 and Table 4.8 but at night (Appendix A3.9 and Table 4.9), the minimum noise levels were 29.3 - 30.8 dB(A) (mean, 32.33 dB(A)) with a maximum level of 38.2 – 55.9 dB(A) (mean, 43.70 dB(A)). The season daytime background noise levels in these communities were 34.7 – 49.8 dB(A) with night-time background levels of 31.3 – 43.1 dB(A). While the minimum noise was within the 70 dB(A) industrial area ambient noise limit of the World Bank in the season (Figure 4.10), the maximum noise breached it in one location. However, the daytime background noise was within the 55 dB(A) daytime ambient noise level limit in all the sampling locations in the season (Figure 4.10). Similarly, the night- time background noise was within the World Bank 45 dB(A) night-time limit in all the locations in the season (Figure 4.11).

The seasonal variation of noise within the communities between the wet and dry season is insignificant with computed *p-value > 0.05*. Distant vehicles and domestic activities were the major sources of noise observed in the area in addition to the natural sources including wind and river in the two seasons.

4.3.3 Geology and Hydrogeology

Regional Geology

The project area is regionally concealed within Gongola basin of the upper Benue trough of Nigeria (Figure 4.11). The Benue Trough is a rift basin in central West Africa that extends NNE-SSW for about 800 km in length and 150 km in width. The trough contains up to 6000 m of Cretaceous– Tertiary sediments of which those pre-dating the mid-Santonian have been compressionally deformed, faulted, and uplifted in several places. Compressional folding during the mid-Santonian tectonic episode affected the whole of the Benue Trough and was quite intense, producing over 100 anticlines and synclines (Benkhelil, 1989). Following mid-Santonian tectonism and magmatism, depositional axis in the Benue Trough was displaced westward resulting in subsidence of the Anambra Basin.

Local Geology and Hydrogeology

Zongoro is located within Gongola basin of Gombe sub-basin of the Upper Benue river basin. Gombe sub-basin is located north of the Upper Benue river basin and separated from Lau sub-basin to the south by Lamurde anticline and from the Chad basin by Zambuk ridge. The anticline is marked by an up-warped basement ridge spotted by a number of volcanic intrusions. Its hydrogeology is described by aquiferous formations making up the geological sequence in the Gongola basin.

The lithostratigraphic logs obtained and sequence encountered from the observation boreholes (5 Nos) drilled at the power plant and transmission sites between August 5, 2013 and August 10, 2013 are provided in **Table A10.1**. Hydrogeologically, the formation comprises coarse grained to pebbly sandstone, clayey sand and clays. Groundwater occurs mostly under water table condition and builds up on the underlying impermeable boundaries or on some of the inter-bedded clays. However, lenses of confining clays could give rise to perched aquifers at higher levels. Whilst the heterogeneity of the aquifer caused by the occurrence of inter-bedded, intra-bedded and interstitial clays could be responsible for some low yields; the fractured basement in places could enhance high yield.

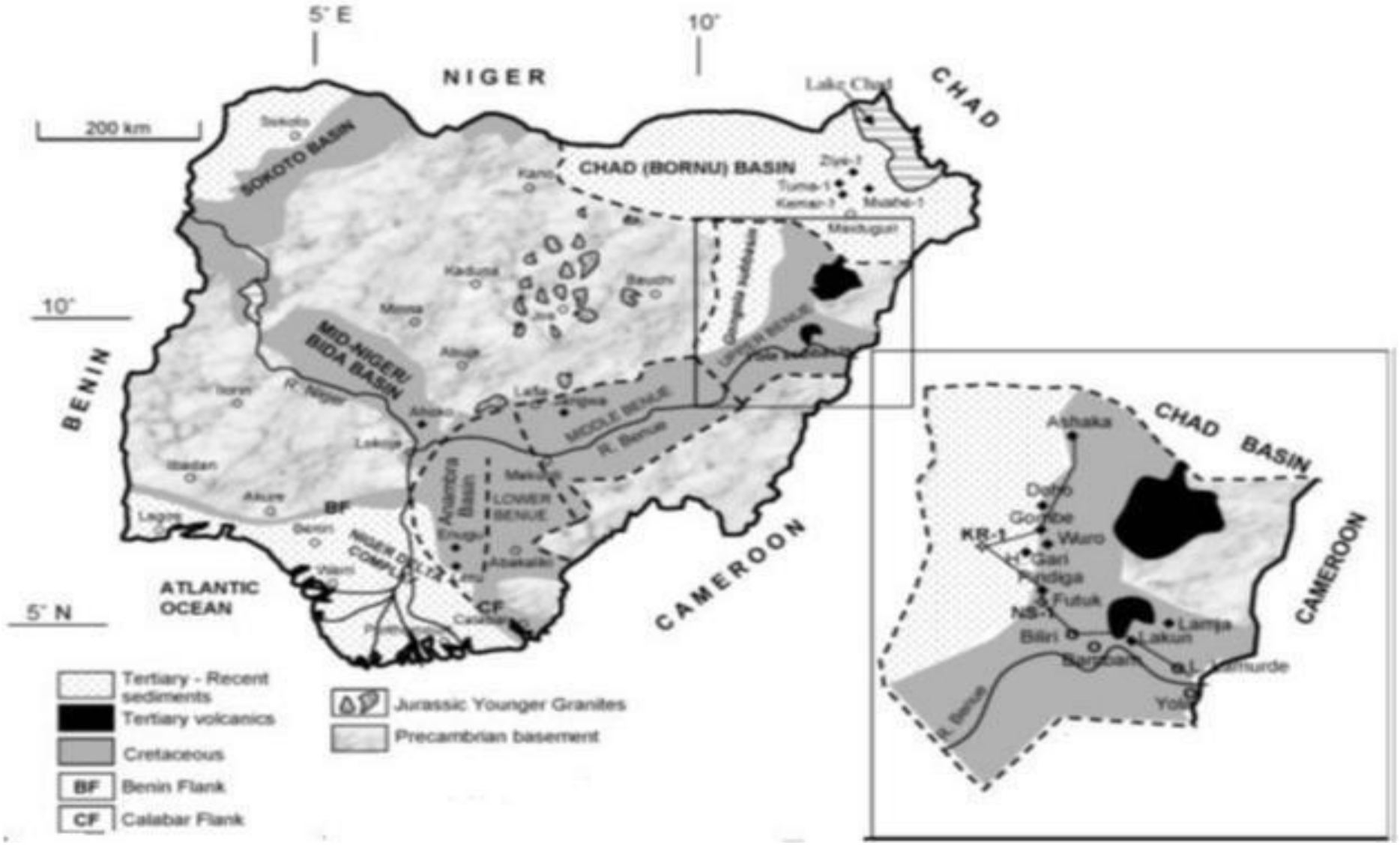


Figure 4.11: Geological map showing Upper Benue Region

Geology of the Study Area

The aquifer within the project site and along the transmission line lies within highly decomposed to partially weathered basement rocks and fractured basement rocks. These are found at depth in excess of 2 m. The weathered and fractured basement with a relatively thin overburden underlies the entire study area. VES interpreted results with inferred lithologies across the site and transmission line are presented in full in **Appendix 10**. Four stations were located within the site with two control stations located outside the site. Six stations were located along the transmission line.

The sub-surface geology is generally characterized by four layers at the investigated VES stations; it reveals a lateritic cover, reddish brown in colour with clayey portions. The second layer is inferred to consist of decomposed crystalline rock. While third layer extends from the base of the second layer and consists of weathered crystalline rock, the fourth layer is inferred to consist of weathered to fresh crystalline rock. Significant variations occurred only in relation to the thicknesses of the layers.

4.3.4 Groundwater Quality

This section draws on the results of the field survey conducted to inform this ESIA.

Six (6) borehole samples each were taken and analysed along the transmission line and the solar farm site.

Physico-chemical properties

The Proposed Solar Power Generating Site

At the proposed solar farm area, the pH of the groundwater is slightly acidic to slightly alkaline with mean values of 6.81 and 7.35 in the wet and dry seasons respectively (Table 4.10).

Electrical conductivity was relatively high, with mean value of 565.33 µS/cm (dry season) in comparison to 179.70 µS/cm recorded during the wet season. Turbidity was marginal, with mean concentration of 1 NTU and 1.08 NTU over the wet and dry season respectively.

Along the proposed transmission line, pH of the groundwater is slightly alkaline with mean values of 7.05 and 7.32 in the wet and dry seasons respectively (Table 4.10). Electrical conductivity was relatively high, with mean value of 327.23 µS/cm (dry season) in comparison to 179.70 µS/cm recorded during the wet season. Turbidity was also marginal, giving a mean concentration of 1.10 NTU and 1.72 NTU over the wet and dry seasons respectively (Table 4.10).

Oxygen Parameters and Nutrients (N, P)

The Proposed Solar Power Generating Site

At the solar farm site, BOD was detected with mean value of 0.63 mg/l and 3.55mg/l, while COD had mean values of 5.23mg/l and 7.52mg/l respectively during the wet and dry seasons (Table 4.10) indicating non-contamination of groundwater by extraneous sources of organic carbon. This is further corroborated by the low level of total hydrocarbon (THC) recorded which is below detection limit (BDL) of 0.01mg/l.

Transmission Line Corridor

Along the transmission line, BOD was detected with mean values of 0.48 mg/l and 0.10mg/l, while COD has mean values of 5.12mg/l and 5.17mg/l respectively (Table 4.10) during the wet and dry seasons, indicative of non-contaminated groundwater. The low level of total hydrocarbon (THC) recorded which is below detection limit (BDL) seems to further corroborate the claim of non-contaminated ground water along the proposed transmission line.

Table 4.10: Mean Chemical Properties of Groundwater Samples for Wet and Dry Seasons in the study area

Study Location	Season	pH	E. Cond	Sal.	Temp.	TDS	TSS	Turb.	NO_3
			(uS/cm)	(o/oo)	(^oC)	(mg/l)			
SPGS (n=6)	WS	6.81	179.70	0.18	25.38	95.18	0.80	1.00	1.88
	DS	7.35	565.33	0.58	27.57	283.35	8.40	1.08	4.78
TL(n=6)	WS	7.05	115.87	0.07	24.20	64.91	1.00	1.10	1.15
	DS	7.32	327.23	0.05	26.42	164.15	5.33	1.72	3.05
WHO Limit		6.5-8.5	-	-	-	500	10	1	10

Study Location	Season	PO_4	Acidity	Hardness	BOD	SO_4	Cl	THC	COD
		(mg/l)							
SPGS (n=6)	WS	BDL	13.92	20.42	0.63	7.43	22.78	BDL	5.23
	DS	BDL	20.42	39.63	3.55	16.43	74.20	BDL	7.52
TL(n=6)	WS	BDL	13.70	18.73	0.48	11.99	12.75	BDL	5.12
	DS	BDL	15.33	21.53	0.10	9.27	40.63	BDL	5.97
WHO Limit		5	-	-	-	50	250	-	-

SPGS = Solar Power Generating Site, TL = Transmission Line, WS = Wet Season, Dry Season, BDL= Below Detection Limit

Basic and Heavy Metals

The Proposed Solar Power Generating Site

Concentration of iron in the groundwater at the solar farm site is also low, generally below the detection limit (BDL) of 0.01mg/l in the wet season while a mean concentration value of 0.15mg/l was recorded in the dry season. Potassium was also detected with a mean value of 2.66mg/l and 7.76mg/l during wet and dry season monitoring respectively (Table 4.11). The concentrations of other heavy metals were low, indicating that the area is non-stressed. Generally, heavy metals concentrations varied during the wet and dry seasons.

Transmission Line Corridor

Along the transmission line, concentration of iron in the groundwater is also very low, generally below the detection limit (BDL) in the wet season, but a mean concentration value of 0.10mg/l was recorded in the dry season. Potassium was also detected with mean values of 1.956mg/l and 5.68mg/l

during wet and dry season monitoring respectively (Table 4.11). The concentrations of other heavy metals were low, indicating that the area is non-stressed. However, the heavy metals' concentrations varied during the wet and dry season monitoring periods.

Table 4.11: Mean Basic and Heavy Metal Concentrations (mg/l) of Groundwater Samples

Study Location	Season	Cu	Pb	Fe	K	Ba	Cr	Cd
		(mg/l)						
SPGS (n=6)	WS	0.02	BDL	BDL	2.66	BDL	0.01	BDL
	DS	0.06	BDL	0.15	7.76	BDL	BDL	0.01
TL(n=6)	WS	0.02	BDL	BDL	1.95	BDL	0.01	0.01
	DS	0.02	BDL	0.10	5.68	BDL	0.01	0.01
WHO Limit		-	0.05	1	-	-	-	-

SPGS = Solar Power Generating Site, TL = Transmission Line, WS = Wet Season, Dry Season, BDL= Below Detection Limit (i.e. < 0.01mg/ml)

4.3.5 Surface Water

This section draws on the results of the field survey conducted to inform this ESIA.

A total of twelve (12) and nine (9) samples were taken downstream, midstream, and upstream of river Zongoro and River Maji and analysed respectively in wet season and dry season each along the transmission line and solar farm site.

Physico-chemical properties

Surface water physico-chemical data are presented in Table 4.16

At the SPG site, the pH of the water body is slightly alkaline, with a mean value of 8.10 and 7.26 respectively during the wet and dry seasons. The chloride concentration, which reflects the salinity of the water, was very low, with a mean concentration of 15.00mg/l and 24.67mg/l as recorded respectively during wet and dry seasons monitoring, thus indicative of a fresh water environment. Mean concentrations of bicarbonate were 55.92mg/l (wet season) and 67.09 mg/l (dry season), while recorded turbidity mean concentration is 35.18 NTU (wet season) reflecting turbulence due to exposed bedrock at the river bed which results in sediment re-suspension, and 27.00NTU a slight drop as expected in the dry season. The mean value of total suspended solids (TSS) was 73.42mg/l (wet season) and 47.89mg/l (dry season). Mean electrical conductivity was 92.92µs/cm (wet season) and 124.27µs/cm (dry season). Total dissolved solids (TDS) have mean concentration of 55.00mg/l in the wet season while higher value of 61.90mg/l was obtained in the dry season.

Along the transmission line, pH of the water body is also slightly alkaline, with mean concentration value of 8.06 in the wet season and 7.95 in the dry season. Mean electrical conductivity (EC) recorded was 95.00µs/cm (wet season) and 227.73 µs/cm (dry season). The chloride mean concentration was low with an average value of 15.36mg/l (wet season) and 33.75mg/l (dry season), a trend that was indicative of a fresh water environment across the study area. Turbidity level of 35.45NTU (wet season) and 32.20NTU (dry season) was recorded. The high values observed may be due to turbulence occasioned by the presence of exposed basement complex rocks at the river bed. The

average concentration of TSS was 66.67 mg/l (wet season) and 51.40mg/l (dry season). TDS mean value of 54.92mg/l (wet season) and 113.78mg/l (dry season) were also recorded.

Oxygen Parameters and Nutrients (N, P)

At the SPG site, mean dissolved oxygen (DO) concentration of 7.47mg/l (wet season) and 6.03mg/l (dry season) was recorded (Table 4.12). Magnitude of the DO indicates low organic matter content and the ability of the water body to sustain aquatic life. This is further strengthened by the low mean value of biological oxygen demand (BOD) of 1.68mg/l (wet season) and 2.34mg/l (dry season) with mean chemical oxygen demand (COD) value of 6.80 (wet season) and 5.17mg/l in the dry season (Table 4.12). High levels of nitrate and phosphate (PO_4) in surface water bodies indicate the potential for excessive weed and algal growth, which could lead to eutrophication and reduction in oxygen in the water. In the study area, the concentrations of nitrate and PO_4 ranged between 0.55 and 2.23 mg/l for nitrate, and 0.79 and 0.91 mg/l for total phosphorus over both seasons (Table 4.12).

Along the transmission line, the mean DO concentration also ranged from 6.57 to 7.47mg/l over both seasons while COD values ranged on the average from 6.62 to 8.98 mg/l over both seasons (Table 4.12). The mean nitrate and total phosphorus mean concentrations were 0.69mg/l (wet season) and 1.13mg/l (dry season) (Table 4.12).

Major Ions

Sulphate is a major ion occurring in natural waters. In fresh unpolluted water, sulphate concentrations lie between 5 mg/l and 100 mg/l (Hynes, 1971). The mean concentration of sulphate in the water body was 5.70mg/l (wet season) and 14.44mg/l (dry season) at the SPG site, and 5.70mg/l (wet season) and 18.73mg/l (dry season) along the transmission line (Table 4.12). Mean concentration of magnesium (Mg) was 1.71mg/l (wet season) and 2.86mg/l (dry season) at the site, and 2.54mg/l (wet season) and 3.82mg/l (dry season) along the transmission line (Table 4.12). Mg concentrations were in the range of 0.19–4.04 mg/l at the site and 1.22–4.10 mg/l (Table 4.12) along the transmission line RoW.

Total Hydrocarbon Content (THC)

THC was not detected in any of the surface water sampling stations in the study area.

Table 4.12: Mean Chemical Properties of Surface Water Samples in the Study area for Wet and Dry Seasons

Study Location	Season	pH	Cond.	Temp.	TDS	DO	Salinity	Turb.	TSS	Color	COD
			(µS/cm)	(0C)	(mg/l)					(Pt -Co)	(mg/l)
SPGS	WS (n=12)	8.10	92.92	29.22	55.00	7.60	0.00	35.18	73.42	32.67	6.80
	DS (n=9	7.26	124.27	28.17	61.90	6.03	0.00	27.00	47.89	22.22	5.17
TL	WS (n=12)	8.06	95.00	29.39	54.92	7.47	0.00	35.45	66.67	30.08	6.62
	DS (n=10)	7.95	227.73	29.87	113.78	6.57	0.01	32.20	51.40	24.60	8.98
Study	Season	BOD	T.Hard	NH_4	SO_4	Cl	Nitrate	Avail. P.	T. PO_4	Alkalinity	HCO_3

Location		(mg/l)									
SPGS	WS (n=12)	1.68	13.58	0.63	5.70	15.00	0.55	0.79	2.48	45.83	55.92
	DS (n=9	2.34	26.79	0.57	14.44	24.67	2.23	0.91	2.42	54.99	67.09
TL	WS (n=12)	1.37	24.17	0.56	5.70	15.36	0.69	0.54	1.73	44.00	53.68
	DS (n=10)	1.20	27.96	3.92	18.73	33.75	1.13	0.74	2.29	53.70	65.51

SPGS = Solar Power Generating Site, TL = Transmission Line, WS = Wet Season, Dry Season

Basic and Heavy Metals

Heavy metals in surface water bodies are required in trace amount by aquatic plants although high concentrations of the metals may easily be accumulated in aquatic organisms. The concentrations of most of the investigated heavy metals in the water samples were below the detection limit (BDL) of 0.01mg/l except for iron with mean concentrations of 1.05mg/l (wet season) and 1.33mg/l (dry season) at the SPG site, and 1.23mg/l (wet season) and 1.78mg/l (dry season) along the transmission line. Magnesium was also detected with mean values of 1.71mg/l (wet season) and 2.86mg/l (dry season) at the SPG site and, 2.54mg/l(wet season) and 3.82mg/l (dry season) along the transmission line (Table 4.13). Concentrations of Fe and Mg recorded are within the FMEnv limits.

Table 4.13: Mean Concentrations (mg/l) of Heavy Metals in Surface Water Samples for Wet and Dry Seasons in the study area.

Study Location	Season	Cu	Cr	Cd	Pb	Fe	Ni	V	Zn	As	Ag
SPGS	WS (n=12)	BDL	BDL	BDL	BDL	1.05	BDL	BDL	BDL	BDL	BDL
	DS (n=9	BDL	0.02	BDL	BDL	1.33	BDL	BDL	0.65	BDL	BDL
TL	WS (n=12)	BDL	BDL	BDL	BDL	1.23	BDL	BDL	BDL	BDL	BDL
	DS (n=10)	BDL	BDL	BDL	BDL	1.78	BDL	BDL	BDL	BDL	BDL

SPGS = Solar Power Generating Site, TL = Transmission Line, WS = Wet Season, Dry Season, BDL= Below Detection Limit (i.e. < 0.01mg/l).

Microbiology

At the SPG site, the mean total heterotrophic bacteria (THB) count in the surface water samples was 1.24×10^2 cfu/ml and 1.33×10^2 cfu/ml in the dry and wet season respectively, while 1.29×10^2 cfu/ml (wet season and 1.35×10^2 cfu/ml (dry season) along the transmission line were obtained. Fungi species were also recorded in the water samples (Table 4.14). The presence of coliform bacteria in the surface water bodies is indicative of pollution by feces.

Table 4.14: Average Microbiology Diversity and Population density in the Surface Water Samples from the study area for Wet and Dry Seasons

Study Location	Season	Coliform (MPN/100ml)	THB ($X10^2$ cfu/ml)	THF ($X10^2$ cfu/ml)
SPGS	WS (n=12)	16.50	1.24	0.73
	DS (n=9	30.00	1.33	0.78

TL	WS (n=12)	13.00	1.29	0.76
	DS (n=10)	54.80	1.35	0.91

4.3.6 Sediment

This section draws on the results of the field survey conducted to inform this ESIA.

Particle Size Distribution

The result of the grain size analysis of sediment samples, indicated predominance of sand, 57%, followed by silt, 27% and clay, 16% on the average during the wet season. Seasonal variations observed were not significant.

Physico-chemical characteristics

At the SPG site, pH of the sediment samples is slightly acidic with a range of 5.56–6.6.6 in the river within the proposed site while a mean range of 5.5.62–6.27 was recorded along the transmission line for both seasons. Electrical conductivity values of 49.94µS/cm and 86.12µS/cm were recorded at the SPG site; 44.98µS/cm and 70.31µS/cm along the transmission line respectively in the wet and dry seasons. Mean concentrations of total Phosphates recorded were 0.06 mg/kg (wet season) and 0.05mg/kg (dry season) at the SPG site, while 0.18mg/kg (wet season) and 0.15mg/kg (dry season) concentrations were obtained along the transmission line (Table 4.15).

Table 4.15: Mean concentrations of the Chemical Properties of Sediment Samples from the study area for Wet and Dry Seasons

Study Location	Season	pH	E.Cond	SO_4^{2-}	Cl^-	TOC	T. Nit	T. Phos	Exch Acid
			(uS/cm)	(mg/kg)		(%)			(Cmol/kg)
SPGS (n=12)	WS	5.56	49.94	2.25	16.23	1.56	0.08	0.06	0.87
	DS	6.16	86.12	6.12	34.68	1.63	0.16	0.05	1.16
TL (n=12)	WS	5.62	44.98	2.40	16.66	1.56	0.08	0.18	0.67
	DS	6.27	70.31	6.76	48.84	1.49	0.12	0.15	1.14

Organics

The mean concentrations of organic content were 1.56mg/kg (wet season) and 1.53 mg/kg (dry season) around the site, while 1.56mg/kg (wet season) and 1.49 mg/l (dry season) were recorded along the transmission line.

Basic and Heavy Metals

At the SPG site, the mean concentrations of Iron (Fe), Chromium (Cr), Lead (Pb) recorded respectively for wet and dry seasons were: (349.68 mg/kg, 1020.59mg/kg), (4.75mg/kg, 1.30mg/kg) and (5.01mg/kg, 2.13mg/kg). Along the transmission line, their mean concentrations respectively over the wet and dry seasons were: 335.66mg/kg, 1618.48mg/kg (Fe), 0.36mg/kg, 0.56mg/kg (Cr), and 5.13mg/kg, 2.27mg/kg (Pb) (Table 4.16).

Table 4.16: Mean Concentrations (mg/kg) of Basic and Heavy Metals in Sediment Samples from the study area for Wet and Dry Seasons

Study Location	Season	Basic Metals					Heavy Metals	
		Ca	Mg	Na	K		Mn	Ba
		mg/kg						
SPGS (n=12)	WS	1.17	0.19	6.17	2.13		0.14	0.05
	DS	2.07	0.97	9.47	2.22		1.75	BDL
TL (n=12)	WS	1.30	0.32	5.93	2.19		0.14	0.16
	DS	1.63	0.99	7.67	2.52		0.42	BDL

		Heavy Metals						
Study Location	Season	Cd	Ni	Cu	Zn	Cr	Fe	Pb
	Unit	mg/kg						
SPGS (n=12)	WS	3.92	0.05	6.24	4.71	4.75	349.68	5.01
	DS	2.53	0.05	2.29	3.57	1.30	1020.59	2.13
TL (n=12)	WS	4.01	0.05	6.42	5.14	0.36	335.66	5.13
	DS	1.33	0.30	2.64	6.24	0.52	1618.48	2.27

Microbiology

At the site (Table 4.17), the mean Sulphate Reducing Bacteria (SRB) count recorded was 2×10^3 cfu/g (wet season) and 6.1×10^2 cfu/g (dry season) while the total heterotrophic fungi (THF) count in the sediment is 0.39×10^2 cfu/g (wet season) and 0.53×10^2 cfu/g (dry season). Along the transmission line, SRB conut is 1.98×10^3 cfu/g (wet season) and 2.45×10^2 cfu/g (dry season) while the total heterotrophic fungi (THF) in the sediment recorded is 0.30×10^2 cfu/g (wet season) and 0.45×10^2 cfu/g (dry season).

Table 4.17: Mean Microbial Diversity and Population Density in Sediment Samples from the study area for Wet and Dry Seasons

Study Location	Parameter	THF ($x10^2$, cfu/g)	HDB ($x10^4$, cfu/g)	HDF ($x10^3$, cfu/g)	SRB ($x10^3$, cfu/g)
SPGS(n=12)	WS	0.39	0.71	0.81	2
	DS	0.53	0.2	0.34	6.1
TL(n=12)	WS	0.3	0.59	0.76	1.98
	DS	0.45	0.62	0.95	2.45

HDB = Hydrocarbon Degrading Bacteria; SRB = Sulphate Reducing Bacteria; HDF = Hydrocarbon Degrading Fungi

4.3.7 Soils

This section describes the soils in the study area. This is based on the findings of the field survey conducted for the ESIA.

Physical Properties

Morphology

Soils within the study area are developed in different types of Pre-Cambrian Basement Complex rocks, comprising mostly the granite gneisses, phyllites and metasediments. The soils are predominantly ferruginous, moderately to deeply weathered, brownish to reddish tropical soils, with colours varying from 10YR 4/6 to 5R 2/4 within and around the proposed project location. The soil colours were not significantly affected with seasons.

Lithosols, (very shallow soils with plinthic ironstone pans or bedrocks at depths <100 cm of the surface) are found around the commonly occurring rock outcrops and the inselbergs at the study area. These shallow soils could readily be lost during site preparation involving bush clearing, stumping and land grading prior to the construction phase of the proposed project. However, the predominant soils in the study area are moderately to deeply weathered, moderately ferruginous tropical soils.

The soils are moderately sandy loam (52%–76% sand) on top and a little more clayey in the subsoil. Sandy loam to loamy sand soils are reported to be very porous, highly permeable and well aerated (Brady, 2002). The soils have common to frequent rock outcrops, with surface boulders, stones, and ironstone capping. However, in view of their sandy loam texture, they have low to very low water holding capacity and high hydraulic conductivity. This implies that aqueous contaminant, such as spent paints, diesel oil and related aqueous contaminants may readily infiltrate into the soils and percolate deeper with little hindrance to possibly pollute groundwater in the unconfined shallow aquifers, if any, within the area of study.

Grain Size Distribution

The spatial and vertical distribution of the grain sizes for the topsoil (0–15 cm) and subsoil (15– 30 cm) are presented in **Appendix 3**.

The soils are mostly sandy loam in texture in the surface 0–15cm depth. The sand particles ranged from 52%–76% with a mean of 69±6%. The silt content varied from 13%–28% (mean, 19±4%), while the clay particles accounted for 8%–20% (mean, 12±3%) within the surface 0–15 cm of the soils (Figure 4.12).

Solar Power Generating Site

For all the various soil separates, the standard deviation (std) was generally low (3–6) for the surface 0–15 cm soil depth (subsoil), which implies that the soil separates, and hence the soil texture, do not vary so much within the proposed SPG location in Bauchi State.

Transmission Line (TL)

The soils are more highly varied with much larger standard deviations ranging from 9–18 (**Appendix 3**) probably due to the longer distance (18 km). Soils with appreciable clay content at depth may be subjected to subsidence if it is made to carry heavy loads without appropriate foundation. This therefore calls for proper geotechnical soil test so as to come up with appropriate foundation for the proposed transmission line.

Soils at the various sampling locations including the control areas are seen to be slightly less sandy at the subsoil 15–30 cm depths when compared to those of the surface 0–15 cm soil depth. Previous studies (Esu *et al.*, 2008) have reported that soils in Bauchi State are sandy on top and slightly clayey in the subsoils (Figure 4.12). The sand particles at the subsoil ranged from 46%–72% with a mean of 66 ± 7%. The relatively large value of the standard deviation (07) indicates that soils at the various sampling locations within the SPG area are not sufficiently homogenous at the subsoil, hence may not be similar with regards to particle size distribution, aeration, porosity and hence in hydraulic conductivity.

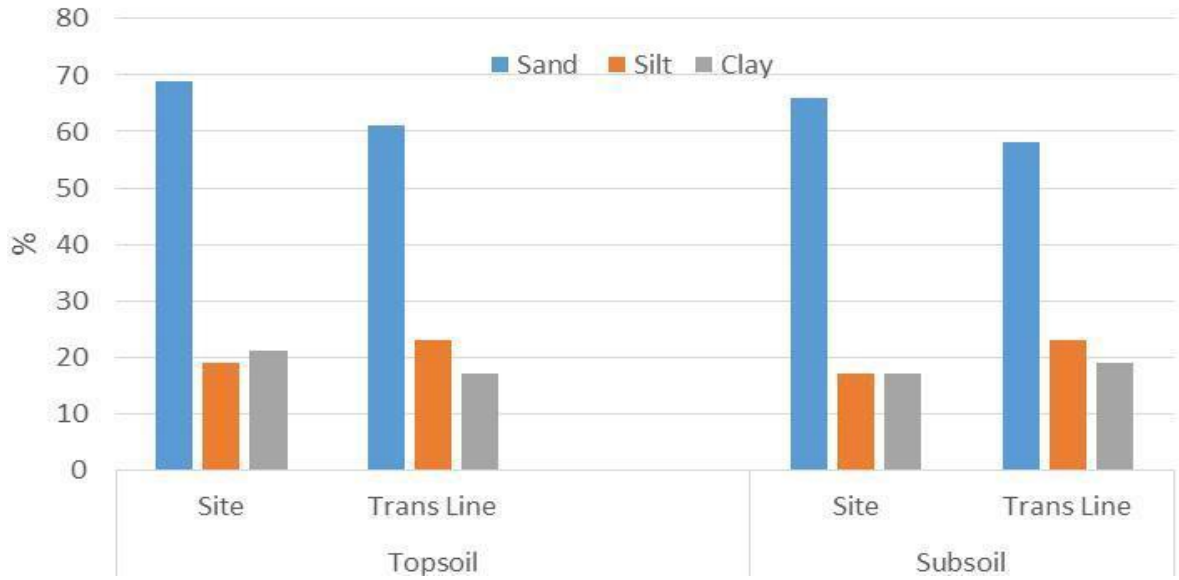


Figure 4.12: Mean Particle Size Distribution

Generally, the silt and clay content of the soils are low especially at the surface 0–15 cm and moderately high at the subsoil 15–30 cm. The low silt and clay content of the soils at the surface makes the soil aggregates to be weak, thus predisposing the soils to possible accelerated water erosion and encrustation. The higher clay and silt content at the subsoil implies that infiltration into the soils and transmission within the immediate surface 0–15cm of the soils of aqueous materials will be rapid and unhindered, and that possible aqueous contaminants may be retained for much longer period at the subsoil. Therefore, aqueous materials such as oil, paints and related materials would have to be carefully handled and hygienically disposed during the construction and operational/maintenance phases of the proposed project. It was observed that the soil data obtained in respect of soil particle size distribution (i.e. grain size) for both the wet and dry season periods were not significantly different. Grain size data for the topsoil for both seasons were considerably similar with no noticeable differences. Same comments are applicable to the subsoil particle size data as well. These results were in conformity with results from previous studies that indicated none significant seasonal variation in most of the soils physical parameters (Brady, 2008; Esu et al., 2008).

In general, issues concerning environmental hygiene would have to be carefully planned and executed in the project area. Furthermore, site preparation that will involve bush clearing, stumping, land grading and related site preparation activities, where necessary, would have to be carefully planned and executed in a manner such as to avoid accelerated water erosion of the soils and subsequent siltation in the river courses and downstream areas of the project location. This is especially important because of the gently to strongly undulating relief in parts of the study area.

Chemical Properties of the Soils

The chemical characteristics of samples of soils within and around the proposed project location including the planned transmission line are presented in Table 4.218.

pH

The pH of the soils is in the range of slightly acidic to near neutral with a minimum of 5.8 and a maximum of 6.8, mean 6.5 ± 0.42 for the wet season. Esu *et al.* (2002) noted that most soils in central Nigeria savanna ecosystem in Northern Nigeria are slightly acidic to near neutral in pH. The slightly acidic nature of the soils is ascribed to the acidic parent rocks that weathered to give rise to the soils (the granite gneisses, phyllites and metasediments which predominate in Bauchi State including the study area), plus the short duration but usually heavy annual rainfall thereby enhancing leaching of the basic cations (Na, K, Ca, & Mg). Other factors partly responsible for the soil acidity in soils of northern Nigeria savanna ecosystem is the uncontrolled practice of annual bush burning that destroys the herbaceous grasses and other weeds by turning them into ashes.

The storm and strong winds that accompany the first early rains effectively remove the ash produced as a result of annual bush burning and transport them several metres away, thereby impoverishing the soils of the basic cations. However, it was noted that there is no significant variation in the pH of the subsoil 15–30 cm soil depth when compared with those of the topsoil, 0–15 cm, although in general, pH values for the subsoils are slightly lower than those of the topsoil. Nevertheless, the differences are not significant. pH values recorded for the soils during the dry season period were generally very slightly higher compared to those of the wet/rainy season period. Probable reason is that more soluble salts tend to accumulate in soils close to the soil surface following intense evaporation in semi-arid regions (Brady, 2002). However, the differences in the pH values of the soils for both the topsoils and subsoils between the two climatic seasons were not statistically significant.

Electrical Conductivity

The electrical conductivity (EC) of the surface soils varies from 117–279 µS/cm for the wet season with a mean of 181.33±59.29 µS/cm. Values recorded during the dry season were also slightly higher than those of the wet season due to the presence of more soluble salts in soils surface and the rhizosheres during the dry season period but again, the differences were not statistically significant. The EC of soils is a measure of the soluble salt (basic cations and other soluble salts) content of the soil, and values below 4,000 µS/cm are considered not to be injurious to normal arable crops (Spark *et al*., 1996) and buried metals (Brady, 2002).

The EC values obtained in soils of the study area for both seasons are several orders of magnitude lower than the 4,000 µS/cm considered as the threshold for optimal arable crops' growth and development, and beyond which buried metals could experience accelerated external corrosion.

Therefore, on the basis of the soluble salt content of the soils as measured by the EC for both seasons, soils in the proposed project location are not envisaged to be chemically aggressive.

Anions

Other soil chemical properties that are often considered to evaluate the chemical aggressivity of any given soil are the sulphate (SO_4^{2-}) and chloride (Cl^-) content. These parameters vary from 26.23– 79.41 ppm (mean, 53.82±15.35 ppm) SO_4^{2-} and 28.16–70.4 ppm (mean, 45.1 ± 11.19 ppm) Cl^- (Table 4.18), for the wet season as against the threshold values of 5,000 ppm SO_4^{2-} and 1,000 ppm Cl^-. Sulphate and chloride concentrations of the soils for the dry season period were also not significantly different from those of the wet season, although, in most parts, slightly higher values were recorded during the dry season period. The values of sulphate and chloride recorded for the topsoil and subsoils in the proposed project location are several orders of magnitude lower than the threshold values established for these parameters.

The very low sulphate and chloride content of the soils could be due to the location of the study area which is several kilometres away from the nearest shoreline. Therefore, soils within the study area could not be envisaged to be chemically aggressive as to enhance rapid external corrosion of buried metals. In general, the chemical characteristics of these soils are to a large extent the same both at the surface and subsurface layers. This is because the variations observed in the chemical parameters for both the top and subsoil layers are not statistically significant. Same comments hold for seasonal variation in these soils in regard their chemical properties.

Exchangeable Cations

From the soil fertility view point, soils in the study area have low to moderate fertility judging from the high levels of exchangeable Ca, but low levels of Mg and K. Concentrations of these cations vary from 5.01–7.79 (mean, 5.44 ± 0.80) cmol/kg Ca; 1.31–1.78 (mean 1.51 ± 0.13) cmol/kg Mg; and 0.11–0.27 (mean 0.20 ± 0.06) cmol/kg K. When these values are considered against the critical limits of 4.0, 2.0, and 0.40 cmol/kg soil of exchangeable Ca, Mg and K respectively, it is observed that soils in the study area contain sufficient levels of Ca, but are deficient in Mg and K. The essentiality of Na for crops growth and development has not yet been established. However, the levels of these cations in soils of the study area for both seasons do not show any evidence of bioaccumulation. This is because their concentrations are within the range commonly observed in normal unpolluted mineral soils for both seasons.

Total Organic Carbon

The TOC content of the soils for both seasons appeared to be sub-optimal, for normal fertile unpolluted mineral soils to enable them support crop growth and development. Values obtained varied from 0.35%–1.40% with an average of 0.75±0.29% for the wet season with similar values during the dry season. These values are against the background of 2.5% TOC regarded as the critical level for good arable crop growth and performance in Nigeria (Adepetu *et al*., 1979).

Macro Nutrients (Phosphates and Nitrates)

Similarly, sub-optimal is the Total-N values which vary from 0.21%–0.84% with an average of 0.34±0.19% Total-N during the wet season period. Probable reason for the low Total-N is attributable to the low TOC since organic matter is generally regarded as the store house for biological P and N.

These (N, P, S) are often released through mineralization following the decomposition of the organic matter. Based on the chemical characteristics of soils within and around the study area, there are no evidences of bioaccumulation of any of the basic metals and other soil chemical parameters. It can therefore be concluded that as at the time of soil sampling, no evidence of soil pollution was reflected in any of the soils' chemical properties that were investigated.

Considering the spatial distribution of the soils within and around the study area, the chemical properties of the soils as observed from the data obtained for soils sampled from different parts of the study area, it was noted that there were insignificant variations between the values recorded for both the top (0–15 cm) and sub (15–30 cm) soils. This is further interpreted to mean that soils at the various sampling locations are sufficiently homogeneous in regard to their chemical characteristics. Soils in the entire study area are not also envisaged to be chemically aggressive in view of their good internal drainage, good aeration and moderate ferruginization coupled with low chloride and sulphate contents which are considerably lower than the critical level of 5000 mg/kg for SO_4^{2-} and 1000 mg/kg for Cl^- (Brady, 2002).

Total Hydrocarbon Content

The total hydrocarbon content (THC) of soil samples collected from various soil sampling locations within the study area is indicated in Table 4.18 for the topsoil and subsoil for both seasons. Values obtained ranged from below detection limit (BDL) of 0.001 mg/kg soil for some samples to specific low concentrations in other samples. The detection limit of the method employed is 0.001 mg THC/kg soil. Concentration of THC recorded for some other samples varied from 4.13–5.12 mg THC/kg soil with a mean of 4.53±1.51 mg THC /kg soil in the topsoil samples for the wet season with similarly lower values in the dry season. Concentrations of THC in the subsoil samples were not significantly different from those of the topsoils for both seasons. When values obtained were considered against the Nigerian intervention level of 5,000 mg TPH/kg soil, it was observed that the THC concentrations recorded were of several orders of magnitude lower than the intervention concentration. It is therefore concluded that there was no evidence of hydrocarbon pollution in soils of the study area as at the time of field investigation and soil sampling at the proposed project location for the two seasons.

Table 4.18: Mean Chemical Properties of Topsoil (0–15 cm) and Subsoil (15–30 cm) Samples for Wet and Dry Seasons

Study Location	Soil Depth	pH	TOC	Avail P	Na	K	Mg	Ca	EC	T-N	SO_4	Cl	THC
			(%)	(ppm)	(Cmol/kg soil)				(µS/cm)	(%)	(ppm)		
SPG (n=22)	Topsoil WS	6.5	0.75	17.49	0.22	0.2	1.51	5.44	181.33	0.34	53.82	45.1	4.53
	Topsoil DS	6.6	0.68	16.89	0.23	0.22	1.52	5.03	178.56	0.33	58.66	47.12	2.11
	Subsoil WS	6.19	0.56	16.15	0.18	0.19	1.39	5.33	225.5	0.3	57.16	39.56	2.59
	Subsoil DS	6.20	0.49	14.22	0.20	0.20	1.36	5.00	240.1	0.28	57.45	42.12	1.23
TL Corridor (n=20)	Topsoil WS	6.77	0.84	16.10	0.28	0.34	3.52	6.45	212	0.40	33.04	34.19	5.68
	Topsoil DS	6.80	0.57	13.6	0.30	0.33	3.48	6.12	230	0.34	36.13	35.14	2.34
	Subsoil WS	6.5	0.60	23.61	0.26	0.26	2.69	6.64	208.71	0.42	36.16	45.21	3.65

	Subsoil DS	6.6	0.45	18.12	0.24	0.25	2.44	5.87	230.43	0.32	38.22	48.14	1.97

SPG= solar power generating site; TL= transmission line; WS = wet season; DS = dry season

Heavy Metals

Due to the vertical and spatial (i.e. widespread) physical and chemical homogeneity in soils of the study area, the concentrations of the various heavy metals (Mn, Fe, Zn, Cu, Pb, Cr, Cd, Co, Ni and V) investigated in the topsoils do not differ significantly from those of the subsoil samples (see **Appendix 3**) for the two seasons.

Furthermore, for both the top and subsoil samples, no unusual concentrations of any of the investigated heavy metal were recorded. Therefore, there was no evidence of bioaccumulation of any of the investigated heavy metals in soils of the entire study area for the two-season period of field investigations. In general, the concentrations of the heavy metals are very low when compared to corresponding concentrations in naturally occurring unpolluted soils (Table 4.19) as reported by Alloway (1991) and Allen *et al.* (1974).

As earlier indicated, from the heavy metal concentration data reported for soils in the study area, there was no evidence of heavy metal accumulation/bioaccumulation in the soils as at the time of field investigations. Brady (2002) indicated that Fe and Mn concentrations that are considerably higher than 10,000 mg/kg in soils are not unusual. Thus, the concentrations of Fe and Mn reported for the soils are not unusual.

Table 4.19: Mean Heavy Metal Content (mg/kg) of the Topsoil and Subsoil Samples for the Wet and Dry seasons

Study Area	Soil Depth	Fe	Cu	Mn	Zn	Pb	Ni	Co	Cd	V	Cr
Solar Farm (n=22)	Topsoil WS	37.09	1.79	39.89	21.67	0.29	0.12	0.05	0.05	0.04	0.04
	Topsoil DS	34.11	1.56	38.87	22.00	0.31	0.11	0.05	0.04	0.04	0.03
	Subsoil WS	34.83	1.80	40.76	19.49	0.26	0.11	0.05	0.05	0.04	0.05
	Subsoil DR	32.65	1.12	42.10	16.23	0.22	0.10	0.03	0.03	0.04	0.04
		Fe	**Cu**	**Mn**	**Zn**	**Pb**	**Ni**	**Co**	**Cd**	**V**	**Cr**
Trans Line (n=20)	Topsoil WS	35.38	1.16	34.45	15.96	0.06	0.04	0.09	0.09	0.06	0.10
	Topsoil DS	36.00	1.12	32.76	16.00	0.06	0.04	0.07	0.07	0.04	0.20
	Subsoil WS	37.89	1.07	35.77	12.98	0.05	0.04	0.16	0.08	0.04	0.06
	Subsoil DS	33.46	1.04	33.42	10.98	0.05	0.04	0.14	0.06	0.03	0.03

Soil Microbiology

Microbial Types and Distribution in Soils of the Study Area

The microbiological properties of the soils are summarized in Table 4.20 for the surface (0–15 cm) and subsurface (15–30 cm) soil samples respectively for the two seasons of field and laboratory studies. Detailed data are presented in **Appendix 3**.

Bacteria

Total heterotrophic bacteria (THB) are 0.7–2.6 × 10^7 cfu/g, with a mean of 1.54 × 10^7 ± 0.6 × 10^7 cfu/g for the surface 0–15cm soil samples, and 0.3–1.1 × 10^7 with a mean of 0.78 × 10^7 ± 0.26 × 10^7 cfu/g in the subsoil 15–30 cm soil depth. This shows a significant decrease in THB in the subsurface compared with the surface soil samples. This could be due to the presence of more substrate from phytocycling (i.e. litter fall and decomposition) and hence higher proliferation of the microbes in the topsoils than in the subsoils. At all the sampling locations, THB exhibits a higher population in the topsoil compared to the subsoil.

Total heterotrophic fungi (THF) vary between 0.11 and 4.0 × 10^4 cfu/g, mean 1.84 × 10^3 ± 1.5 × 10^4 cfu/g in the topsoils, and 0.2–2.0 × 10^4 cfu/g with a mean of 1.04 × 10^4 ± 0.68 × 10^4 cfu/g in the subsoil (Table 4.20). The occurrence of THF is also significantly higher in the surface than in the subsurface soils for all the sampling locations.

The observed levels of hydrocarbon utilizing bacteria (HUB) in the soil samples ranged from 1.0–5.6 × 10^6 cfu/g with a mean of 2.4 – 10^6 ± 1.3×10^6 cfu/g in topsoils, and 0.4 × 2.1 x 10^6 cfu/g and a mean of 0.83 × 10^6 ± 0.48 × 10^6 cfu/g in the subsoil samples. Similar to THB and THF, HUB is also significantly higher in the topsoils than in the subsurface soils. Similarly, hydrocarbon utilizing fungi (HUF) ranged from 0.5–11 × 10^2 cfu/g mean 1.9 ×10^2 ± 3.0 × 10^2 cfu/g in the surface soils, and 0.2–2.1 × 10^2 cfu/g mean 0.58 × 10^2 ± 0.54 × 10^2 cfu/g in the subsoil samples. It was noted that the percentage of HUB to THB, and HUF to THF is each significantly less than 1.00% thus suggesting that there was no evidence of hydrocarbon contamination of soils in the study area prior to field investigation and sampling.

The sulphur reducing bacteria (SRB) also varied spatially in the surface and subsoil samples. The observed values of SRB ranged from 0.9–4.0 × 10^2 cfu/g mean 1.88 × 10^2 ± 1.0 x 10^2 cfu/g in the topsoils samples with 0.3–1.1× 10^2 cfu/g, and mean 0.67 x 10^2 ± 0.25 × 10^2 cfu/g in the subsoil samples. Generally, the population of the microbiota is optimal in the soils of the study area probably due to adequate presence of organic matter which serves as substrate for the microbes and the rainy season period of field investigation when moisture required for microbial proliferation is not limiting.

In general, microbial diversity recorded during the dry season was essentially the same as for the wet season field investigation. However, in terms of population/abundance, values recorded during the dry season field and laboratory studies were significantly ($p > 0.05$) lower than those of the wet season. Probable reason is that more nutrients are readily more available in soils during the wet than dry season period. Further reason is that most of the top soils were dry during the dry season thereby inhibiting normal microbial growth and multiplication. For both seasons however, the observed microbial diversity and population density are not indicative of hydrocarbon pollution of soils in the project area as at the time of field investigations and samplings.

Microbial Isolates

The list of micro-organisms identified in the study area is as follows:

Solar Power Generating Site

Micro-organisms identified here included *Rhizopus japonicus, Rhizopus japonicas,* and *Rhizopus stolonifer*. The bacteria species identified include *Pseudomonas aeruginosa, Acinectobacter*

parapertussis, Klebisella edwadisii, Actinomycetes bovis, Desulfovibrio desulfuricans, Aariectobacter mallei, Klebisella ozoenae, Actinomycetes bovis, Stretomyces sp, Klebisella edwadisii, Actnomyces parapertussis and *Desulfovibrio desulfuricans*

Transmission line

Micro-organisms identified here included *Mucor mucedo, Rhizopus japonicas, Cephalosporium* sp, *Aspergillus glaucus, Aspergillus restrictus, Trichophyton schoenleinii, Rhizopus japonicus* while the Bacteria species identified are *Klebsiella edwadsii,* and *Pseudomonas aeruginosa, Acinectobacter mallei, Pseudomonas aeruginosa, Klesbiella pneumonae,* and *Klesbiella ozoenae*

Table 4.20: Microbial Type and Population Density in Topsoil and Subsoil for the Wet and Dry Seasons

Study Area	Soil Depth	THB at 35^{o}C	THF at 30^{o}C	HUB at 30^{o}C	HUF at 30^{o}C	SRB at 30^{o}C
		(x 10^7 cfu/g)	(x 10^4 cfu/g)	(x 10^5 cfu/g)	(x 10^2 cfu/g)	(x 10^2 cfu/g)
SPGS (n=22)	Topsoil WS	1.54	1.84	2.4	1.91	1.88
	Topsoil DS	1.45	1.78	2.3	1.86	1.68
	Subsoil WS	0.78	1.04	0.83	0.58	0.67
	Subsoil DS	0.70	1.02	0.80	0.52	0.65
Study Area	**Soil Depth**	**THB at 35^{o}C**	**THF at 30^{o}C**	**HUB at 30^{o}C**	**HUF at 30^{o}C**	**SRB at 30^{o}C**
		(x 10^7 cfu/g)	(x 10^4 cfu/g)	(x 10^5 cfu/g)	(x 10^2 cfu/g)	(x 10^2 cfu/g)
TL Corridor (n=20)	Topsoil WS	1.69	2.01	2.33	1.07	2.14
	Topsoil; DS	1.70	2.00	2.01	1.04	1.00
	Subsoil WS	0.61	0.39	0.60	0.29	0.61
	Subsoil DS	0.54	0.31	0.40	0.23	0.54

4.3.8 Vegetation

Overview

The vegetation of the study area is typical of Northern Guinea savanna zone of Nigeria comprising mostly *Anogeisus leocarpus, Commiphora kerstingii, Guirea senegalensis* vegetation complex in association with *Parkia biglobosa, Moringa oleifera, Vitex doniana*. The grass cover is dominated by *Tridax procumbens, Striga hermontheca, Eleusine indica,* and *Andropogon gayanus*. Noticeable shrubs include *Accacia compylacatha, Isoberlina doka, Ziziphus absyssnica* among others. Dominant species are presented in Table A11.1. The following sections are based on results of field surveys at the project site.

Trees

The most abundant and characteristic trees in the study area are *Isoberlina doka, Monotes kerstingi*i and *Uapaca togoensis*. Others include *Parinari curatellifolia, Combretum binderianum, Piliostigma*

thonningii (Caesalpiniaceae), *Parkia clappertoniana* (Mimosaceae), *Lophira lanceolata* (Ochnaceae), and *Vitex* sp (Verbanaceae) which form associations.

The well-developed woodland is from 10 to 15 meters high, with trees crowns more or less touching. The trees are mostly broad-leaved. Herbaceous species are dominant beneath scattered preserved and planted trees, which form the upper, very discontinuous, canopy. The Caesalpiniaceae and Sapotaceae are present, together with: *Adansonia digitata Mangifera indica.* Grasses, herbs (including weeds) and sucker shoots of woody species combine to form scrub, with rather little undergrowth.

Grasses

Wherever the canopy is open, grasses such as *Andropogon gayanus, Brachiaria* sp., *Imperata cylindrica, Hyparrhenia involucrata, H. rufa, Sporobolus pyramidalis, Pennisetum polystachion, Loudetia hordeiformis, Cynodon dactylon. Dactyloctenium aegyptiacum Schizachyrium exile* and *Eragrostis spp* are dominant. Erect shrubs (e.g., *Gardenia* spp, and *Protea elliotii*) are frequent but woody climbers (e.g., *Opilia celtidifolia* and *Uvaria chamae*) are present. *Monotes kerstingii* forms pure open stands of rather scrubby trees on sandy and eroded slopes where the grass cover is often very sparse. *Uapaca togoensis* is locally dominant especially on low hill or slopes of ironstone boulders. *Terminalia* spp. and *Bauhinia thonningii* are common on abandoned farmlands.

Farming and grass fire tend to make the vegetation more open and modify the floristic composition. In farms, valuable fruits such as *Parkia clappertoniana, Mangifera indica, Ceiba pentandra* and *Vitex doniana* are preserved, and mature trees of species such as *Daniellia oliveri, Afzelia africana*, which are used for making articles such as mortars.

On rocky hills, there are abundant climbers (e.g., *Acacia ataxacantha* and *Canthium venosum* as well as trees such as *Bombax costatum, Ficus* spp, *Steganotaenia araliacea*. In flatter, poorly drained areas, the palm, *Raphia sudanica* are frequently dominant. Others include *Borassus aethiopum* and *Terminalia glaucescens.*

Most of the grasses are perennial and grow in tufts with bare grounds between them during the dry season but close-up during the wet season. The outer portions of these turfts appear to protect the inner parts from fire; thus enabling these grasses, most of which have their surviving buds at the ground level (Hemicryptophytes), to survive the burning during the dry season. Growing on the bare ground between the perennial grass turfts during the dry season were occasional Geophytes mainly *Anchomanes welwitschii* (Araceae) and Therophytes. Most of the herbs, both grasses and forbs, possess fibrous root system. Herbaceous plants include *Aspilia africana, Cleome viscosa, Calopogonium sp, Centrosema pubescens, Phyllanthus amarus, Tridax procumbens, Euphorbia heterophylla, E. hirta, Hyptis suavolens, Spigellia anthelmia, Anchomanes welwitschii.*

Economic Plants

The common economic plants within the study area are presented in Table 4.21. The density of the economic plants in the study area is variable. The population density of economic plants is variable, and their economic uses are also detailed in Table 4.21

Table 4.21: Species List, Local Name and Use/Economic Importance of Main Plants in the Study Area

Species	Common	Local Name	Economic Uses

	Name		
Maqnifera indica	Mango	Mangoro	**Medicinal**: fruit as source of vitamins, leaves treat typhoid fever, bark treats toothache **Other uses:** timber, wood, bee - forage, shade, wind breaks.
Commiphora africana		Dashi	**Medicinal:** bark cures pile and toothache, leaves cure dysentery and eye and intestinal infections. **Other uses:** fuel wood, conservation of soil, wind breaks.
Diospyros misphiliformis	West African Ebony	Kanya	**Medicinal**: fruit (unripe) treats mouth lesions, ripe fruits are edible. Other uses: fuel wood, charcoal, timber, bee forage, conservation of soil.
Parkia biglobosa	Locust tree	Dorowa	**Medicinal:** leaves/bark/fruit, treats fever. Stomach pain and body rashes. Other uses: seeds are use as food seasoning, fruit is edible fuel wood and shade.
Adansonia digitata	Baobab	Kuka	**Medicinal:** leaves/bark treats cough and throat infections. Other uses: fruit is edible and use in beverage making. Bee forage and conservation of soil.
Borassus aethiopium	Fan/Deleb palm	Giginya	**Medicinal:** fruit is edible and source of vitamins. Other uses: leaves are used in making shelter.
Pterocarpus erinaceus	African rose wood	Madobiya	**Medicinal:** bark treats cough in children and tooth ache. Other users: wood, fuel wood and charcoal production.
Balanites aegyptica	Desert date	Aduwa	**Medicinal:** fruits are edible and source of vitamins. Other uses: carving, wood, bee - forage and soil conservation.
Vitex doniana		Dinya	**Medicinal:** leaves (fresh) edible and a source of vitamins. Fruits: are edible and source of vitamin Barks: treats fever, stomach pains. **Other uses:** timber/wood, conservation, shade.
Prosopis africana		Kirya	**Medicinal:** treats pile and the bark cures rashes. **Other user:** carvings, timber, wood, conservation of soil.
Butryospermum paradoxum	Shea butter	Kadanya	**Medicinal:** oil extract cures rashes and skin diseases, fruits are eaten and are a source of vitamins. Leaves: eaten by cows to boost milk production.
Guinea senegalensis		Sabara	**Medicinal:** leaf, bark, roots treats dysentery and purging in children. **Other uses:** conservation of soil, fuel wood.
Ziziphyus abyssinica	Catch thorn	Magaryar	**Medicinal:** roots are used in curing stomach pains. **Other uses:** fruits are edible, soil conservation.
Commiphora		Dali	**Medicinal:** bark and roots are used as anti-biotic, because it

kerstingii			treats a lot of diseases.

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			Other uses: timber/wood.
Azadiracta indica	Neem	Maina/Dogon yaro	**Medicinal:** leaves, bark and roots are used in the cure of fever, stomach pain, and pile. **Other uses:** conservation, shading, bee forage wood.
Bombax costatum	Red-flowered silk cotton	Gurjiya	**Medicinal:** bark treat rashes on the bodies of infants **Other uses:** bee forage, fire wood, shading, conservation.
Acacia Albida		Gawo	**Medicinal:** fruits treat stomach upset. **Other uses:** fruits are eaten by animals, conservation.
Moringa oliefera	Moringa	Zogale	**Medicinal:** leaves, stems, seeds, cure high blood pressure, diabetics, HIV-AIDs and serves as antibiotics. **Other uses:** conservation, fodder for animals, bee-forage.
Erythiriya senegalensis		Minjirya	**Medicinal:** bark treats yellow fever Other uses: conservation, bee-forage, fuel wood.
Psidium guajava	Guava	Gwaba	**Medicinal:** fruit is edible as a source of vitamins, leaves treat typhoid fever, malaria, dysentery, chewing stick. **Other uses:** conservation, fuel wood, ornamental, bee-forage.
Ancardium occidentalis	Cashew	Kashu	**Medicine:** fruits are edible as source of vitamin also treats stomach upset, nuts are edible too Other uses: conservation in fuel wood, ornamental bee-forage, shade.
Danielli Olivieri	Coipa balsam	Maje	**Medicinal:** bark used for treatment of fever. Other uses: fodder for animals, timber wood fuel wood, conservation.
Ficus spp			**Medicinal:** exudation from the tree cure cough. Other uses: conservation, fodder for animals, shade.
Sterculia stigera	Karaya gum tree	Kukuki	**Medicinal:** bark is used as blood tonic. Other uses: fuel wood, bee-forage.
Detarium macrocarpum		Taura	**Medicinal:** fruits cure pile, and is edible. Other uses: conservation, bee-forage.
Khaya senegalensis	Mahogany	Madaci	**Medicinal:** leaves, bark treat stomach pain, fever, pile. Other uses: timber, wood, conservation, wind breaks, shade, bee-forage.
Annogeisus leocarpus	Chewstick tree	Marke	**Medicinal:** bark treats cough in children and tooth ache. Other uses: wood, fuel wood and charcoal.

Tamarindus indica	Tamarind	Tsamiya	**Medicinal:** leaves/bark treat fever, heal open wound and body Rashes, fruits are edible and source of vitamin c. Other uses: timber, wood, fuel wood, shade, conservation, bee-forage.

4.3.9 Hydrobiology

This section draws on the results of the field survey. ***Benthic Macro fauna***

The benthic macrofauna community in the study area includes a diverse assemblage of animals across several animal phyla. A total of 12 taxa of benthic macrofauna were recorded in the area sampled during the wet season, 13 taxa including eleven of the previous 12 taxa and additional 2 taxa (*Gerris lacustris and Pelocoris femoratus*) were collected during the dry season survey. The original data are listed in **Appendix 3,** while photographs of some of the benthic fauna observed at the sampling sites are presented in Figure 4.18.

The benthic macro-invertebrates' community was dominated by the insects in terms of abundance and species richness, constituting 67% and 38.3% of the total population during the dry and wet seasons respectively. Annelids, nematodes molluscs and crustaceans made up the remaining component of the benthic fauna (Figure 4.14). Most of the species encountered are those that are either highly tolerant or moderately tolerant to pollution. No species was however, numerous enough to dominate a site as they were all occasionally encountered in samples from the different sampling points. Overall there was a generally poor population of benthic macro-invertebrates in the water bodies.

Spatial distribution of the different species shows that the average number of species per sampling point was 3.2 and 3.4 respectively for the wet and dry seasons. There was no discerned significant difference ($P>0.05$) in species composition among the sampling points along the transmission line and the selected sites.

The number of individuals encountered was generally low across the sampling points, with population density in the range of between 2 and 5 individuals / sampling point. There was no significant difference ($p > 0.05$) with respect to the population density of the benthic macrofauna among all the sampling points. The diversity computed (Table 4.22) show that there was generally low species diversity across the stations.

Table 4.22: A Comparative analysis of the Diversity indices of benthic macroinvertebrates in the Study area during the Wet and Dry seasons.

	Wet Season	Dry Season
Number of sampling points	24	24
Total number of individuals enumerated	47	68
Total number of species (S)	12	13
Mean Number of species/sampling point	3.2	3.4
Range of Species Richness - Margalef's Index (D)	1.116 - 1.864	0.9102 - 2.164
Mean Margalef's Index (D)	1.65	1.712
Range of Shannon- Wiener diversity Index (H')	0.6931 - 1.332	0.6365 - 1.386

Mean Shannon- Wiener diversity Index (H')	1.11	1.15
Range of Simpson's dominance (1-D)	0.5 - 0.72	0.4444 - 0.75
Mean of Simpson's dominance (1-D)	0.66	0.66
Range of Evenness Index (E)	0.9428 - 1	0.9428 - 1.0000
Mean of Evenness Index (E)	0.97	0.96

Plankton

Phytoplankton

A total of 24 taxa of phytoplankton belonging to four divisions namely Chlorophyta (green algae), Bacillariophyta (diatoms), Euglenophyta (euglenids) and Cyanophyta (blue-green algae) were recorded in the samples during the dry season as against the 22 taxa that was recorded during the wet season survey. The original data are listed in **Appendix 3**. The green algae dominated the phytoplankton community with 15 species and 13 species during the dry and wet seasons respectively.

It also constituted 66% and 58% of the total phytoplankton population during the dry and wet seasons respectively. The blue-green algae, euglenids and diatoms following in that order constituted the rest of the phytoplankton during both seasons. The distribution of algae population was relatively even across the stations and there was no significant difference (P = 0.8572) amongst them. There was also no significant spatial variation in the number of taxa which range between 5 and 14 at the different stations.

Taxa richness, diversity and abundance across the sampling stations were relatively low (Table 4.23), as the stations had an average of 10.8 and 11.6 taxa with abundance average of 44.4 and 50.2 cells/l/sampling point· during the dry and wet seasons, respectively. The low to moderate diversity levels reported for the phytoplankton flora may be attributable to unfavourable environmental conditions such as low light intensity due to very high turbidity and nutrient status of the water body.

Table 4.23: A summary of the Diversity indices and the distribution of individuals and taxa within the main taxonomic groups of phytoplankton in the Study area.

	Wet Season	**Dry Season**
Number of sampling points	24	24
Total number of individuals enumerated	602	754
Total number of species (S)	22	24
Mean Number of individuals/sampling point	50.2	44.4
Mean Number of species/sampling point	11.6	10.8
Range of Species Richness - Margalef's Index (D)	2.154 - 3.726	1.358 - 3.323
Mean Margalef's Index (D)	2.7	2.58
Range of Shannon- Wiener diversity Index (H')	2.072 - 2.712	1.476 - 2.529

Mean Shannon- Wiener diversity Index (H')	2.36	2.26
Range of Simpson's dominance (1-D)	0.8614 - 0.9305	0.7368- 0.9144
Mean of Simpson's dominance (1-D)	0.9	0.88
Range of Evenness Index (E)	0.8622 - 0.9605	0.8371- 0.9717
Mean of Evenness Index (E)	0.93	0.9

Figure 4.13: Benthic Organism in the study area

Zooplankton

Seventeen species of zooplankton were encountered in the plankton samples during the dry season as against the eighteen reported for the wet season. The difference in number was due to the absence of the only calanoid copepod (*Thermodiaptomus sp*) earlier reported during the wet season. Outside this all other species were also observed during this dry season survey. The relative abundance and spatial distribution of the species over the stations and the scientific names are given in **Appendix 3**.

The most frequently encountered and more diverse were the Crustaceans. The crustaceans consisting of 6 species each of copepods and cladocerans dominated the plankton in number of species and population during both the dry and wet seasons. Other zooplankton encountered included 3 species of rotifera, 2 protozoans and 1 ostracod. The population was generally more during the dry season than the wet season

The crustaceans composed of both the cladocerans and copepods made up 65.9% and 73.1% of the total population during the dry and wet seasons respectively. In natural environments, high abundance of cladocera and copepods relative to other freshwater zooplankton is generally related to oligotrophic conditions (Sendacz et al. 1985; Imoobe & Adeyinka, 2009). Generally, the zooplankton are sparse in terms of numbers of individuals and taxa richness across the stations.

All the Stations showed low population and there was no significant difference (P = 0.9612) amongst the Sampling Stations. There was generally low species diversity in the study area (Table 4.24) an indication that the water bodies were poor in nutrients status (phosphate, nitrate and sulphate).

Table 4.24: A summary of the Diversity indices in the Study Area during the Wet and Dry Season

	Wet Season	**Dry Season**
Number of sampling points	24	24
Total number of individuals enumerated	93	135
Total number of species (S)	18	17
Mean Number of individuals/sampling point	7.75	7.94
Mean Number of species/sampling point	5.9	5.23
Range of Species Richness - Margalef's Index (D)	1.674 - 2.885	1.443 - 2.919
Mean of Margalef's Index (D)	2.41	2.04
Range of Shannon- Wiener diversity Index (H')	1.33 - 1.906	1.04 - 2.02
Mean of Shannon- Wiener diversity Index (H')	1.71	1.56
Range of Simpson's dominance (1-D)	0.72 - 0.8438	0.625 - 0.8595
Mean of Simpson's dominance (1-D)	0.81	0.77
Range of Evenness Index (E)	0.9051-1	0.8571- 0.9661
Mean of Evenness Index (E)	0.95	0.94

4.3.10 Wildlife

National Overview

Nigeria has a wide variety of plant and animal species. These include about 7,895 plant species, 20,000 insects, 1000 birds, 1000 fishes, 247 mammals, and 123 reptiles. An estimated 0.36% of these are threatened or endangered (**Appendix 11, Table A11.2).**

The following sections are based on observations at the project site, supported by published records for the local area where available.

Mammals

Mammals encountered in the project area are listed in **Appendix 3**. The most common carnivores include the medium and small-sized mammals such as Hare (*Lepus capensis*), these predators are important in maintaining the balance in the ecosystem.

The common herbivores include Red Eye Monkey (*Presbitis rubicund*), Cows (*Bos primigenius*), and Goats. Rodents include Squirrel (*Alpine marmot),* Bush Rat (*Rattus fuscipes*), grass cutter, squirrels and mice while primates were mainly monkeys. Historic record cited the presence of Hyenas, Lions, Warthogs, and Bush bucks. All the species are common and widespread and are not listed as endangered in the IUCN Redlist of endangered species.

Reptiles

The observed reptiles include lizards and snakes. The predominant species are *Varanus Albigularis* (Monitor lizard), *Agama agama* (Common lizard), *Bitis arietans* (puff Adder), (Philothamus irregularis (Bush snake), *Atractasis reticulata* (Viper) Python snake (*Python mulurus*), Cobra snakes (*Boulengerina annulata*), and Viper snake (*Crotalus basiliscus*) – seen occasionally.

Insects

The observed species include spiders (*Hysterocrates laticeps*), ants (*Camponotus pennsylvanius*), sand flies (*Diptera psychodidae*), Grasshopper (*Caelifera*), Wasps (*Polistes galicus*), Bees (*Anthophila*), Dragon Fly (*Anisoptera*), Green Mantis (*Sphodromatis virdis*), Termite (*Termitodae*), Ants (*Formicidae*), and long nose weevil (*Rhinotia hemistictus*).

Amphibians

The observed species include Flat Backed Toads (Amietophrynus macalutus), Subdesert Toads (*Amietophrynus xeros*), Grassland frogs (*Ptychadena tellinii*), Sand Frogs (*Tomopterna crytotis*), Newts (*Pleurodelinae*), Crab (*Liocarcinucinus vernalis*), Cane Toad (*Rhinella marina),*and Parsley Frogs (*Pelodytes punctatus*).

Birds

Birds recorded are listed in Appendix 2. They include birds of prey such as vultures, black kites, eagles, buzzards, and owls Red Eyed Doves (*Stretopelia semitorquata*), Guinea Fowl (*Numida meliagaris*), Cattle Egret (*Bubulcus igris*) which are migratory, Brown Quail (*Coturnix ypsilophora*), Village Weavers (*Ploceus cucullatus*), Canary (*Serinus canari domestica*), Curckoo (*Guira guira*), Crow (*Coryus*), African Hooded Vulture (*Necrosyrtes monachus*), Stork (*Cicconidae*) – an occasional visitor. Other species include rollers, doves, plovers, shirkes, bee-eaters, and finches. These species are classified as least concerned and are not threatened by the proposed project directly.

Fish and Fisheries

Information on the abundance and species composition of the fish is useful for assessing the quality of a water body. Fish occupies the peak of the aquatic food chain (barring predation by higher vertebrates); hence, their condition constitutes a summation of the condition of lower biological forms. Water quality factors that alter the ecological balance of the plankton and macro-invertebrate populations can also alter the fish population. Because fish and invertebrates have differing susceptibilities to certain toxins, the fish might be affected by certain pollutants that do not cause a demonstrable change in the invertebrates and plant communities.

During the field investigation, the fish species observed from catches by local fishermen were recorded. This is presented in Table 4.25. The families Bagridae and Cichlidae dominated the collections in terms of the number of taxa and abundance. The *Clarias gariepinus* (cat fish) and (*Tilapia zilli*) Tilapia dominated the catch. These fishes are predominantly freshwater species. The cichlids are of great economic value and are useful for mosquito control as they devour mosquito eggs and larvae (Olaniyan, 1975).

Table 4.25: Fish Species Composition, Distribution and Relative Abundance

Taxonomic List	Common Name	Total
Fishes		
Bagridae	**Cat Fish**	
Auchenoglanis occidentalis		**1**
Bagrus bayad		**2**
Chrysichthys auratus		**3**
Cichlidae	**Tilapia**	
Oreochromis niloticus		**3**
Sarotherodon galileus		**4**
Tilapia zilli		**4**
Clariidae	**Cat Fish**	
Clarias anguillaris		**2**
Clarias lazera		**2**
Mochokidae	**Cat Fish**	
Synodontis gambiensis		**7**
Momyridae	**Cat Fish**	
Gnathonemus senegalensis		**2**
Chromidotilapia guentheri		**3**
Mormyrops deliciousus		**2**
Abundance		**33**
Species number(S)		**12**
Margalef's Diversity index (D')		

4.4 Socio-economic Baseline

This socio-economic baseline survey was conducted in August–November 2013. It sought to determine the socio-cultural, demographic and quality of life of the population around the project site.

Structured questionnaire interviews and group discussions were used primarily to obtain necessary information from households and other target groups. Other sources of information included similar studies, existing records in the local government and other public institutions.

4.4.1 Study Communities

The study was conducted in Zongoro community in Ganjuma Local Government Area (LGA); and in Dungulbi; Runda, Waya and Yuli communities in Bauchi LGA. Ganjuwa LGA has Kafin Madaki as its administrative capital, while Bauchi LGA has the Bauchi Township. Figure 4.19 shows the types of Settlements and Hut in the area.

4.4.2 Population

Regional Overview

Population size: The population of Bauchi State in 2011 totaled 5,515,300 people. The populations of Bauchi and Ganjuwa in 2011 were 330,070 and 585,220 respectively.

Table 4.26 presents the population statistics for the regional study area (National Bureau of Statistics, 2010).

Table 4.26: Population Characteristics of Surveyed LGAs

S/N	Area	Number of Households	Number of People
1	Bauchi (LGA)	88,207	585,220
2	Ganjuwa (LGA)	52,496	330,070
3	Bauchi State	865,052	5,515,300

Family Size, Births and Deaths: National data (NBS, 2010) reveals that Bauchi State has a crude birth rate of 25.24%, and a crude death rate of 2.36%. Average family size, grew from 5.7 in 2005 to 6.3 in 2009, indicating an average family growth rate of 6.6%.

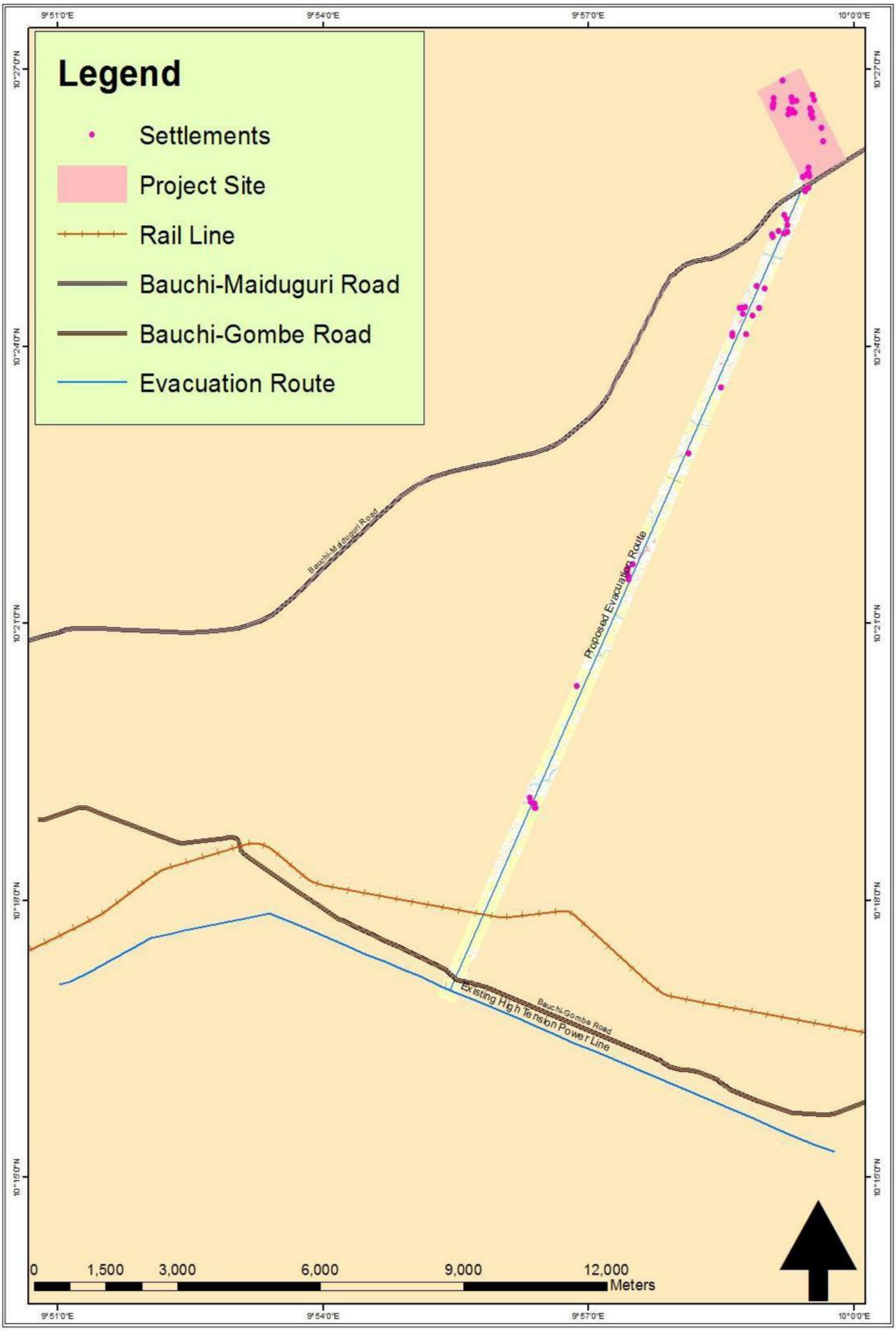


Figure 4.14: Settlement/Huts in the Project Area

4.4.3 Demography

Gender Distribution

Bauchi State has a gender distribution of 51% male and 49% female (National Bureau of Statistics [NBS] (2006).

Table 4.27: Gender Distribution of Surveyed LGAs

S/N	Area	Male	Female	Gender Ratio (M: F)
1	Bauchi (LGA)	252,420	241,310	1.05:1
2	Ganjuwa (LGA)	140,402	138,069	1.02:1
3	Bauchi State	2,369,266	2,283,800	1.04:1

Marital Status: Bauchi State has a percentage distribution by marital status (for persons aged over 14 years) of 68.6% married, 0.5% divorced, 0.9% separated, 1.9% widowed, and 28.1% single (NBS, 2006).

Age Distribution: As of 2011, Bauchi State has a population with a majority of its residents less than 18 years of age. 68.6% are aged 0-17 years, 36% are 18-40 years, 7.8% are 41-60 years, and 1.5% are over 61 years.

Religion: The predominant religion in Bauchi State is Islam.

Ethnicity: Bauchi State is home to 55 ethnic groups including Hausa, Fulani, Gerawa, Sayawa, Jarawa, Bulewa, Kare-Kare, Kanuri, Warjawa, Zulawa and Badawa. (Bauchi State Government, 2015).

Local Overview

Population Size: The population of the study communities totaled 700 households and 5,800 people. The largest community studied is Yuli, which has a total population of 1,256 people and the smallest, Anguwan Makeri, with a population of just 122 people.

Table 4.28: Census of Study Communities

Communities	Number of Houses	Number of Households	Number of People
Anguwan Sarki	66	86	611
Anguwan Bunu	6	9	409
Anguwan Galadima	50	66	462
Anguwan Makeri	11	14	122
Yuli	74	128	1,256
Runde Bin	48	136	996
Dungulbi	60	128	908

Waya	81	133	1,036

Family Size, Births and Deaths: The most common family size of respondents to the survey was between 4 and 6 persons. 10.4% of respondents had up to three persons in their families, 27.4% had between 4 and 6 persons, 23.9% had between 7 and 10 persons, 24.3% had 11 to15 persons, and 13.9% had a family size of 16 or more.

The findings of the survey show that over the last 12 months, 11.8% of the respondents had 1 birth in their families, 3.9% had 2 births, another 3.9% had 3 births, and 19.7% had 4 or more births. On the other hand, 25 (17.9%) respondents reported 1 death, 2 (1.4%) had 2 deaths, 4 (2.9%) had 3 deaths, and 1 (0.7%) had 4 or more deaths. The population of the communities is increasing, as the number of births exceeds the number of deaths (Table 4.29).

Table 4.29: Number of Births and Deaths in the Families in the last 12 months

Family Member Birth/Death	**Respondents (Birth)**		**Respondents (Death)**	
None	46	60.5%	108	77.1%
1	9	11.8%	25	17.9%
2	3	3.9%	2	1.4%
3	3	3.9%	4	2.9%
4 or more	15	19.7%	1	0.7%
Total	**76**		**140**	
No response	174		110	

Gender Distribution: Table 4.30 presents the gender distribution of respondents to the social survey. Males constituted the bulk (76.4%) of the respondents, while females constituted 23.6%. The gender distribution is a reflection of the patriarchal nature of the study communities: in general, it was head of households who completed the survey and males more likely to be identified as the heads of their households. In case of the death of a husband, the most senior male in the extended family assumes responsibility over the wife and the children of the deceased. The gender distribution also reflects the socio-religious system which makes females less visible in interaction with strangers.

As part of the social survey, respondents were asked about the gender profile of their family. The number of males per family ranged from 1 male to 21 males, with an average of 4.74 males per family. The number of females ranged from 1 to 30 per family, with a total average of 5.04 per family. This suggests that there are more females in the communities than males. An explanation for this is the tendency for adult males to leave the village for the town in search of income-earning employment opportunities.

Table 4.30: Gender Distribution of Respondents

Gender	Number	%
Male	191	76.4
Female	59	23.6
Total	250	100.0

Marital Status: The overwhelming majority of respondents (93.2%) to the social survey were married. 3.8% were single and 3% were either divorced or widowed.

Age Distribution: Respondents interviewed during the survey were within ages 10–75years. 27.6% were below 30 years, 27.2% were within 31–40 years, 20.8% were between 41 and 50 years, 13.2% were between 51 and 60 years, and 5.6% were above 60 years (Table 4.31).

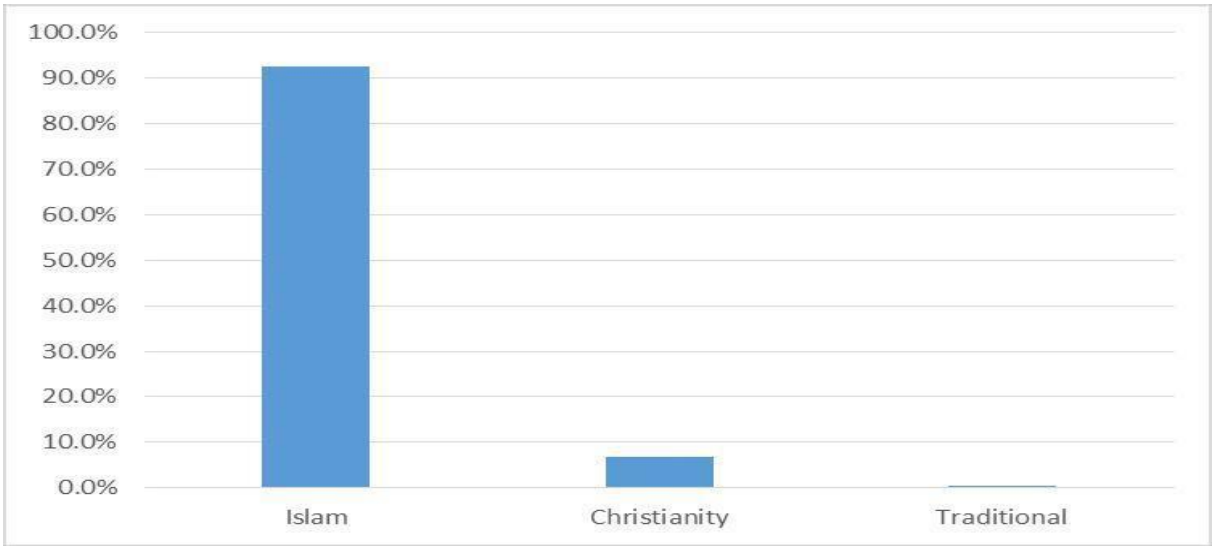
Further analysis shows that 94.1% of the respondents were within the working age from under 20 years to 60 years, while 80.1% may be said to be in the active working age (under 20 years to 50 years).

Table 4.31: Age Distribution of Respondents

Age	Number	%
20 years or less	15	6.0
21 – 30 years	62	21.6
31 – 40 years	68	27.2
41 – 50 years	52	20.8
51 – 60 years	33	13.2
61 – 70 years	8	3.2
71 years and above	12	2.4
Total	**250**	**100.0**

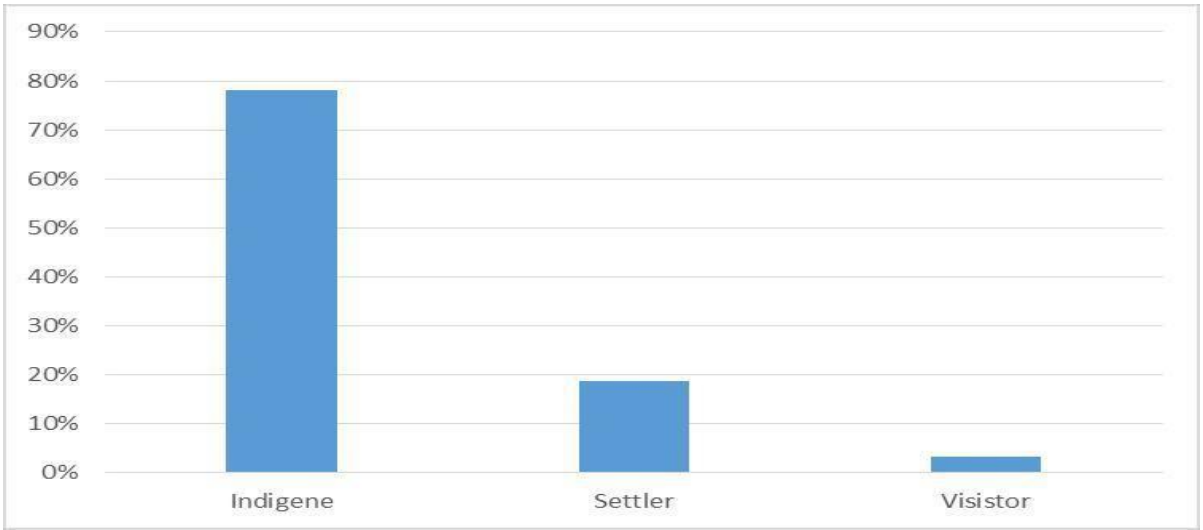
Religion: The results of the social survey showed that the majority (92.7%) of people are Muslims. Christians make up 6.9% of the population and traditional worshippers 0.4% (Figure 4.15).

Figure 4.15: Religious Background of Respondents



Ethnicity: Over three-quarter (78%) of the respondents described themselves as indigenes, 18.7% as settlers, and 3.3% as visitors (Figure 4.16).

Figure 4.16: Ethnicity of Respondents in their Communities



Length of Residence in Communities: Most (91.5%) of the respondents who provided information said they had lived in the study communities for five or more years, while only 8.5% had lived for less than five years. Overall, 78% of the respondents had lived in their communities for 11 or more years (Figure 4.17). This indicates a relatively high level of residential/population stability in the study communities.

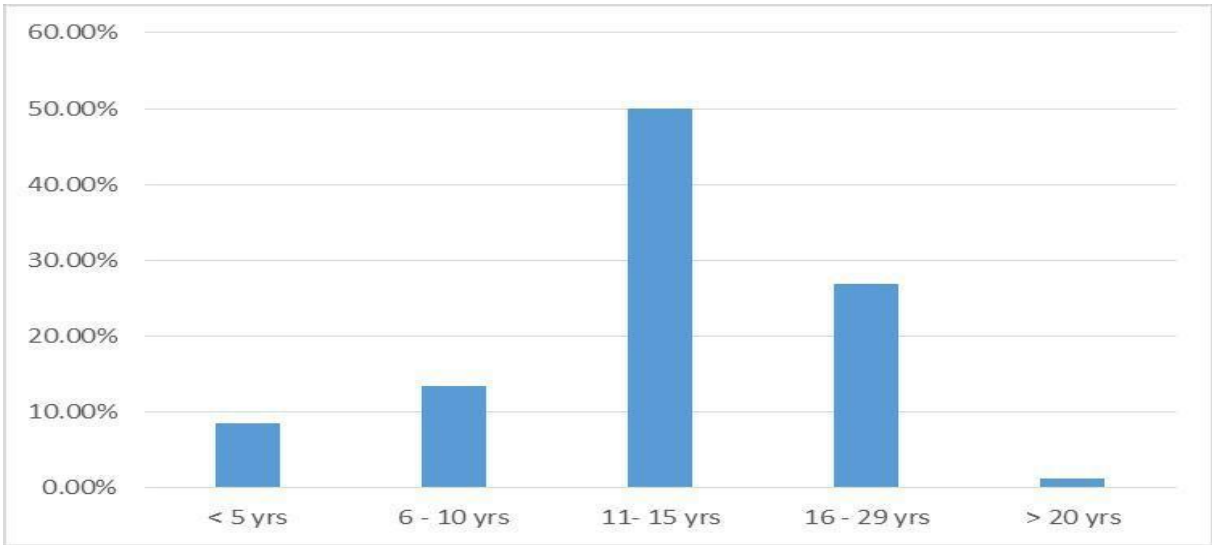


Figure 4.17: Tenure of Respondents in their Communities

4.4.4 Economy

Regional Overview

The economy of Bauchi state is dominated by agriculture. The most popular crops cultivated are maize, rice, millet, groundnut and guinea corn. Bauchi is one of Nigeria's main cotton producing states. Since the mid-1970s, irrigation schemes have helped to increase agricultural production and there are a number of dams, such as the Balanga, Gubi and Tilde-Fulani dams, that provide irrigation for farming. Livestock rearing e.g. cattle is also common. Although mineral resources exist in the state, these are largely unexploited.

Bauchi State is home to one of Nigeria's most popular tourist attraction, the Yankari Game Reserve /the Sumu Wildlife Park (the biggest game reserve in West Africa). The government is trying to boost its tourism potential to aid economic development. Other tourist attracts include the state museum, the open-air theatre and Abubakar Tafawa Balewa Tomb Complex (NBS 2015).

The majority of people in the state (1,438,399) work in the informal sector, especially females (905,045 versus 533,354 males) (Table 4.32). In regard to formal employment, most are engaged in the agriculture, forestry & farming sector (41%), followed by manufacturing (28%). When informal sector employment is taken into account, it is estimated that approximately 80% are engaged in agriculture (FOS, 2003).

Bauchi State has an unemployment rate of 29.7%. Females are disproportionately affected with 43.8% unemployed compared to 29.7% of males (NBS, 2010).

Table 4.32: Number and Percentage of People Employed by Sector in Bauchi State

Industry	Numbers	Percentage (%)
Agriculture, Forestry & Farming	238295	41.05
Mining & Quarrying	1615	0.28
Manufacturing	161374	27.80
Electricity, gas, steam & air conditioning supply	1014	0.17

Water Supply, Sewage, Waste Management and Remediation Activities	1076	0.19
Construction	6004	1.03
Wholesale & Retail Trade, Repair of Motor Vehicles & Motorcycles	118818	20.47
Transportation & Storage	15621	2.69
Accommodation & Food Services	34810	6.00
Information & Communication	1558	0.27
Financial & Insurance	321	0.06

Local Overview

As shown in Figure 4.18, farming (including agriculture and livestock rearing) was the predominant occupation of people in the study community (82% of the respondents). Other livelihood activities include trading/business (14.4%), civil service (3.1%) and industry worker (0.4%).

Farming is practiced on almost every available cultivable land. Cropping is mostly mixed and typical cultivated crops include onion, sorghum, millet, and guinea corn. Bush burning is usually employed for site clearing as it allows for the regeneration of green grass particularly in areas dominated by spear grass. The regenerates are subsequently fed upon by the live stocks (cattle, goats, chicken etc.). Agricultural productivity in the area of study is rainfall dependent and as such farming season is dictated by the amount of rainy days.

Livestock include cattle, goats, sheep, donkeys and pigs.

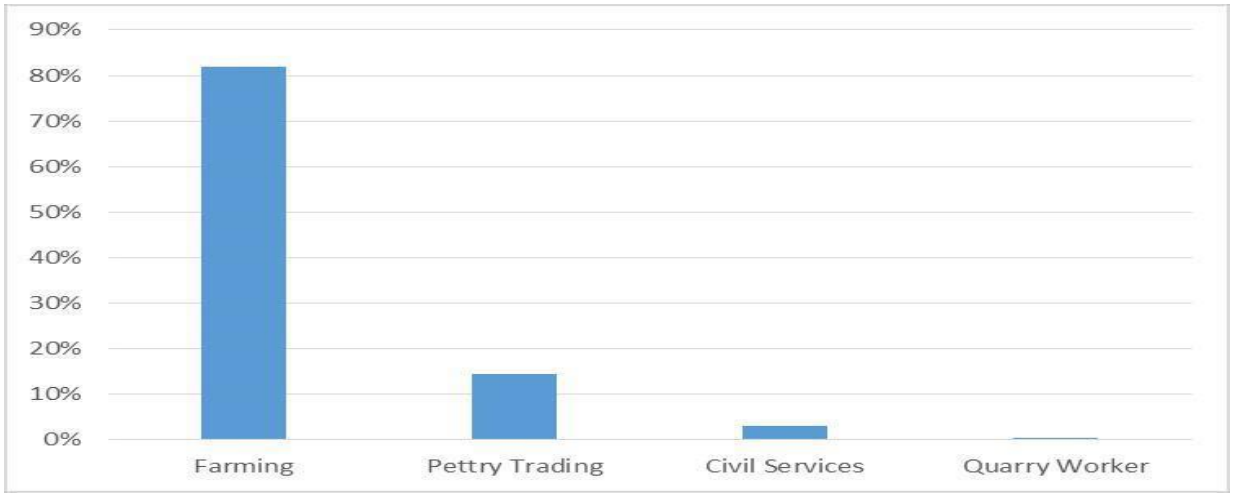


Figure 4.18: Occupation of Respondents

The farmers reported growing various types of crops as indicated in Table 4.33. The most popular crop was said to be maize which is grown by 62.4% of farmers. Other crops include beans (24.8%); millet (23.2%), ground nut 19.2%; rice 18.8%; guinea corn (8%), sorghum/cowpea (4.8%) and soya beans 0.8%.

Table 4.33: Types of Crops Grown by Farmers

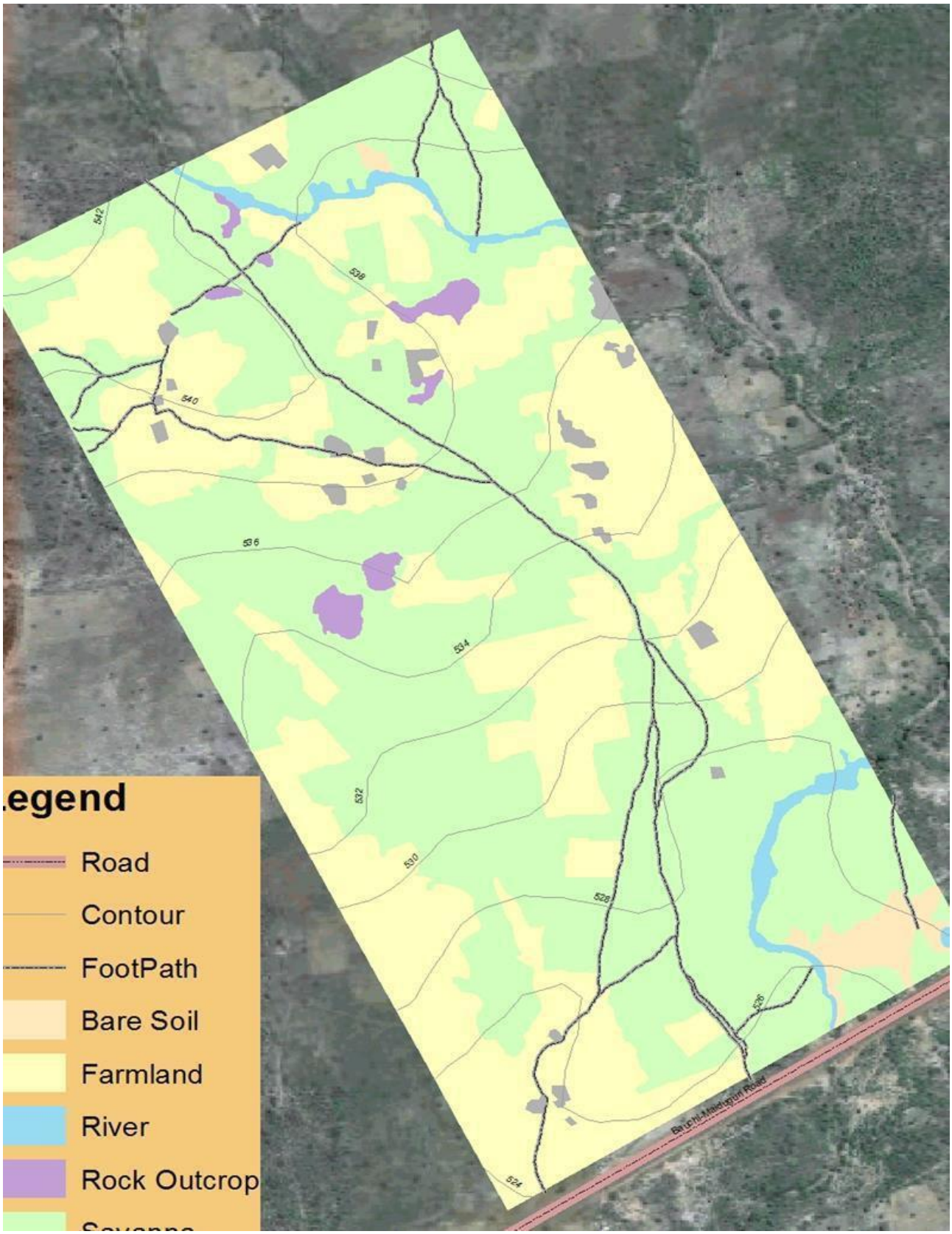
Crops	No. of Farmers	%

Crops	No. of Farmers	%
Maize	156	62.4
Millet	58	23.2
Rice	47	18.8
Beans	62	24.8
Ground nut	48	19.2
Guinea corn	20	8.0
Sorghum/cowpea	12	4.8
Soya beans	2	0.8

The annual quantity of farm produce in the last five years was reported to range from 2 bags to 150,000 bags (maize, millet, rice, beans, groundnut, guinea corn, cowpea and soya beans), with an average of 987 bags per annum around the study area. Land is put to predominantly mixed use as in Figure 4.19.

Figure 4.19: Mixed land use: farming and houses in Zongoro Village

Figure 4.20: Land use of the study area



4.4.5 Income and Expenditure

Regional Overview

The majority (85%) of households in Bauchi State have a monthly income/allowance below N20,000. The average household annual expenditure is reportedly N231,648.40 with 58% spent on non-food items (National Bureau of Statistics, 2010).

Local Overview

Income: Very few respondents provided information about their incomes. For instance, only 16 respondents provided information about their monthly incomes from farming. Of these, 56.3% stated that their monthly incomes were N250 or less per month. A further Sixty-three (63) respondents provided information about their incomes from other activities/sources per week, with 39.7% claiming to earn N500 or less per week from other sources/activities apart from farming. At the other polar end, only 12.7% said they earned more than N2, 000 per week.

Total annual income reported range from N11, 000 to N100, 000. More than one-third (34.4%) of respondents who provided information on their annual income reported that they earned N11,000 to N20,000 per annum; 11.1% of respondents earned N21,000 to N30,000 and 7.8% or respondents N31,000 to N40,000. The highest income earners in the communities (only 3.3%) said they earned N91, 000 to N100, 000 per annum.

Income levels also give an idea about the economic conditions of a people. Given that the national minimum wage is N18, 000 per month, it can be said that no respondent earned up to or higher than the national minimum wage, suggesting that the communities are relatively poor. More than half (53.3%) of the respondents earned N40, 000 or less per annum. This translates into about $250 per annum or $20.80 per month. In terms of international comparison, this is far less than the international benchmark poverty line of US$1.25 per day.

On the other hand, respondents reported spending an average between N250 and N3,500 per week on their families, with the modal expenditure category being N250 to N500 per week. More than half (57.5%) spend N1, 000 or less per week on their families (Table 4.34)

Women are usually engaged in the local processing of groundnut oil and cow milk with monthly range of N10, 000 – N12, 000 from the sale of these products.

Expenditure: Expenditure patterns provide an indication of the standard of living people have. Table 4.37 presents information about household expenditure on selected items, namely: food, clothing, healthcare, transportation, and education. The largest expenditure for households is clothing, followed by education. The data suggests that most of the respondents operate at the basic survival level.

Table 4.34: Weekly Household Expenditure Pattern

Expenditure Items	Amount
Food	N291.59
Household items	N388.26
Clothing	N567.65
Education of children	N460.44
Medical care	N275.07

Transport	N244.63

Savings: The majority of respondents (72.3%) confirmed they have no savings, while others save between N11, 000 and N60, 000 per annum (Table 4.35).

Table 4.35: Annual Income and Savings

Annual Income/Savings Band	% of Respondents (Income)	% of Respondents (Savings)
N11,000 to N20,000	34.4%	14.3%
N21,000 to N30,000	11.1%	0.8%
N31,000 to N40,000	7.8%	8.4%
N41,000 to N50,000	8.9%	2.5%
N51,000 to N60,000	7.8%	1.7%
N61,000 to N70,000	6.7%	-
N71,000 to N80,000	14.4%	-
N81,000 to N90,000	5.6%	-
N91,000 to N100,000	3.3%	-
None		72.3%
	Valid N=90	Valid N=90

Ownership of selected Household Items

Ownership of various property items could also be a pointer to the standard of living of a household/community. The survey showed that bicycles and motor cycles were the most common transportation property owned by the respondents (31.6% and 25.6% respectively), while only 2.8% reported to own motor vehicles. The other respondents (60%) did not report owning any transportation property.

4.4.6 Land and Home Ownership

Regional Overview

Land Ownership: Approximately 92% of Bauchi State residents own the house that they live in (NBS, 2010).

Home Ownership: According to NBS 2006 data, 95% of people in Bauchi State live in a house that is owned by a member of the household.

59% of houses in Bauchi State are mud houses and 39% of houses have thatched roofs.

Local Overview

The majority (86.6%) of respondents to the social survey said they owned land in their communities. Approximately 13% did not own any land (Figure 4.21).

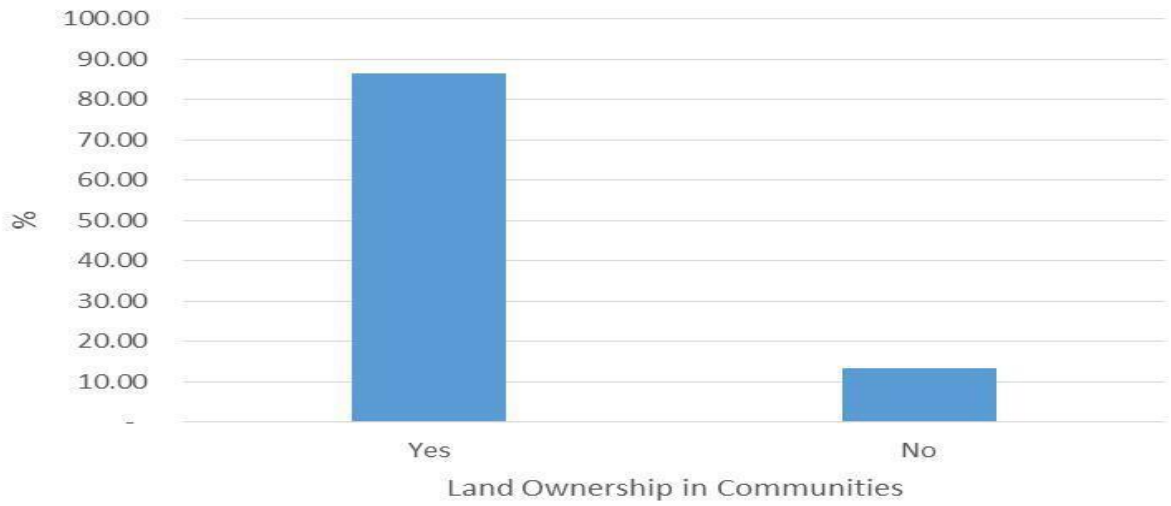


Figure 4.21: Land Ownership in Communities

Table 4.36: Hectares Owned by Respondents

Hectares owned	**No.**	**%**
1 or less	53	21.2
2 – 3	69	27.6
4 – 5	32	12.8
6 – 7	12	4.8
8 or more	18	7.2
Total	184	73.6
No response	66	26.4

The largest proportion of respondents (34.4%) who owned land said the land was owned personally; communal leasehold was mentioned by 23.2%; 14.8% said the lands were family lands, while 6.8% said they had leasehold over the land. Almost 21% of the respondents did not provide an answer (Figure 4.22).

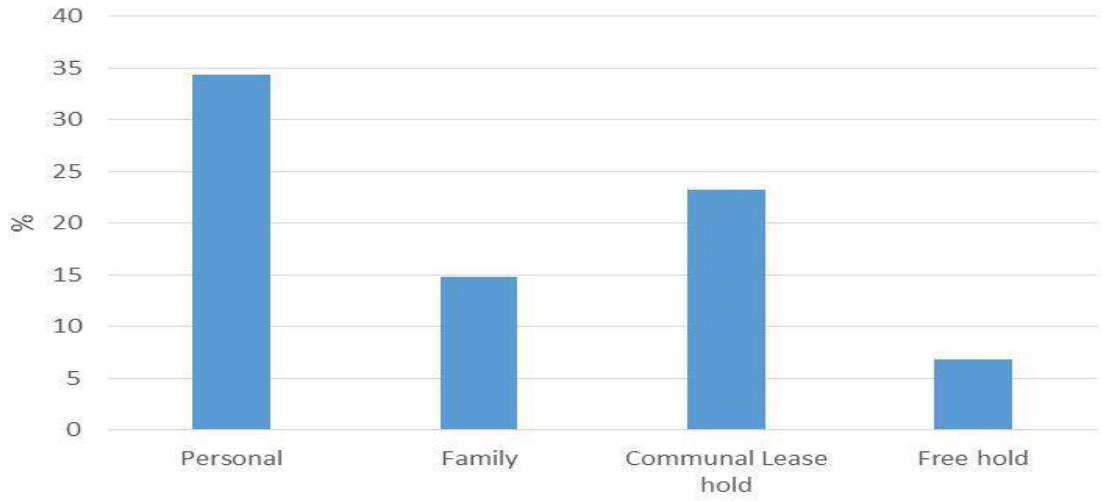
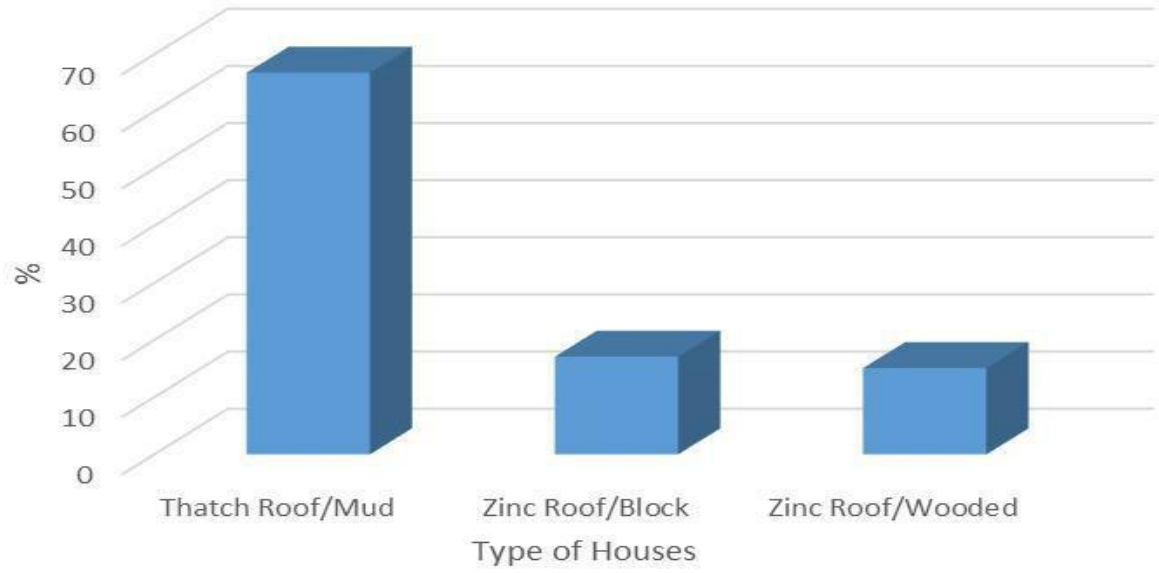


Figure 4.22: Nature of Land Ownership

House Ownership: The majority of the respondents (84.4%) reported that they owned the houses in their communities. The majority of houses (66.8%) are made from thatch/roof/mud. 17.1% have zinc roof/block warms and 16.1% zinc roof/wooden (Figure 4.23).

Figure 4.23: Types of Houses



4.4.7 Water Supply & Sanitation

Regional Overview

14.8% of houses in Bauchi have access to pipe-borne water, while 32.5% use bore-hole water. Well-water accounts for 23.3% of supply, while 27% of households access water directly from streams and ponds (National Bureau of Statistics, 2010).

Local Overview

The most common source of drinking water for survey respondents is hand-dug wells, used by 72% of respondents. Other sources of drinking water include streams (16.4%), boreholes (10.7%), and rain

(0.9%) (Figure 4.24). Access to safe water is problematic for communities in the region; it is estimated that only 20-24 % of rural communities have access to safe drinking water.

Figure 4.24: Sources of Water Supply

Figure 4.25: Public standpipe in Zongoro

Figure 4.26: Rural water scheme in Zongoro

Figure 4.27: Dysfunctional borehole in Zongoro

Figure 4.28: Functional borehole in Zongoro

4.4.8 Socio-Cultural Artefacts

Mosques (Figure 4.29) were said to be the main socio-cultural artefacts in the communities in the local study area (mentioned by 97.9% of the respondents), while one respondent reported the existence of sacred ground.

Figure 4.29: Community Mosque in Zongoro

4.4.9 Energy Sources

Regional Overview

In Bauchi State, 38.7% of households rely on the public source of electricity supplied through distribution companies, 2.8% rely on generators and 58.5% on other sources such as kerosene, wood and coal (NBS, 2009)

Local Overview

Wood was reported to be the most common source of energy (96.7%). Other sources of energy, such as kerosene and charcoal (for cooking) and petrol (for power generating sets) were reported to be used by less than 5% of the respondents (Figure 4.30).

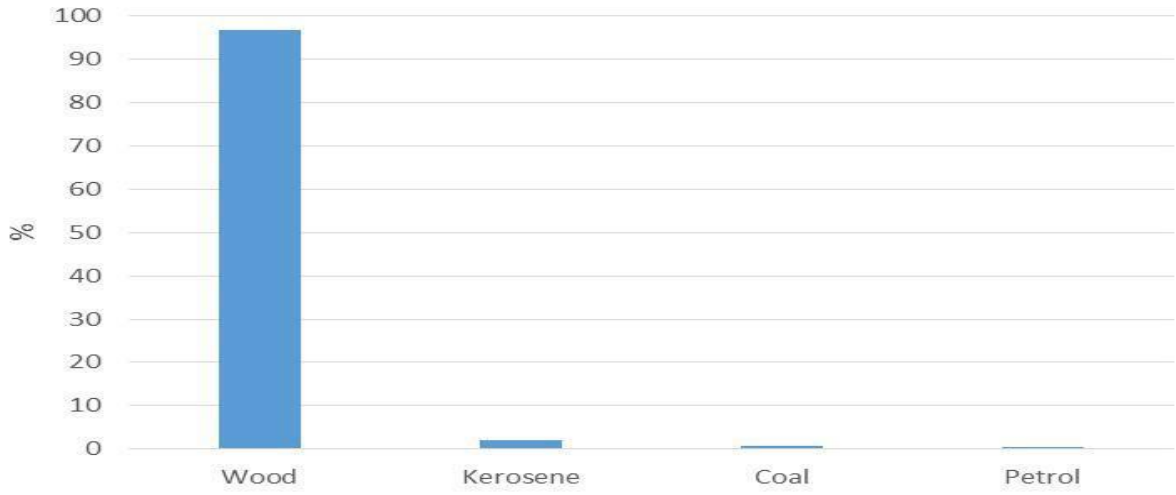


Figure 4.30: Sources of Energy

4.4.10 Education

Regional Overview

Educational Facilities: In 2010 Bauchi State had 2,894 public primary schools with over 19,842 teachers and 680,000 students. There are also 388 public secondary schools with 133,284 students (NBS, 2009). The number of primary private educational facilities in the state is significantly higher and totals 29,736, where the number of private secondary is 388 (NBS, 2012)

Literacy Rates: Literacy rates in Bauchi state are low in comparison to the average for Nigeria. Adult literacy in English in Bauchi State is 26.6% versus 57.9% at the national level. Literacy in another language is 65.7% for Bauchi State versus 71.6% at the national level. Literacy rates in Bauchi LGA are significantly higher than the state average: 58.4% are literate in English and 90% in another language. In contrast, in Ganjuwa LGA, literacy rates are significantly lower, with 15% and 39.3% being literate in English and another language respectively.

Males are more literate than females. In Bauchi State 35.3% of males are literate in English and 75.9% in another language, compared to 17.1% and 54.6% for females (NBS, 2011)

Boys are more likely to go to school than girls. Figure 4.34 shows the highest level of schooling for those in Bauchi State aged 6 years and over. Approximately 68% of females have never been to school compared to 57% of males. (National Population Commission, 2010).

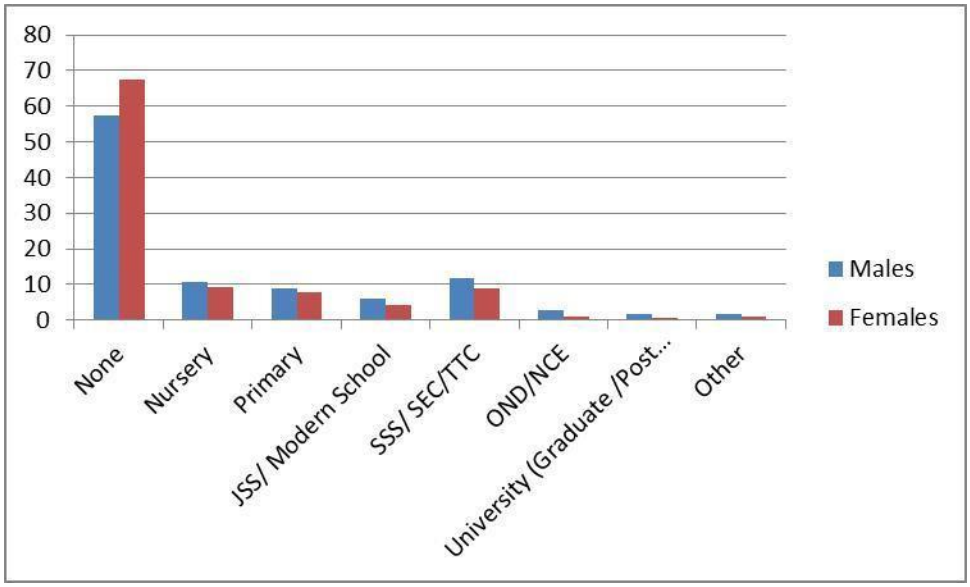


Figure 4.31: Highest Level of Schooling

Local Overview

Educational Facilities: The educational environment in the area is as depicted in Figure 4.32 and 4.33; which is 2 blocks of rooms used for primary school in the morning and secondary school in the afternoon. The school facility is about a 100-meter distance away from the project site on the opposite side of the road of Zongoro community. The primary school has 15 female and 24 male teachers. Total number of pupils is 238 with 109 females and 129 males.

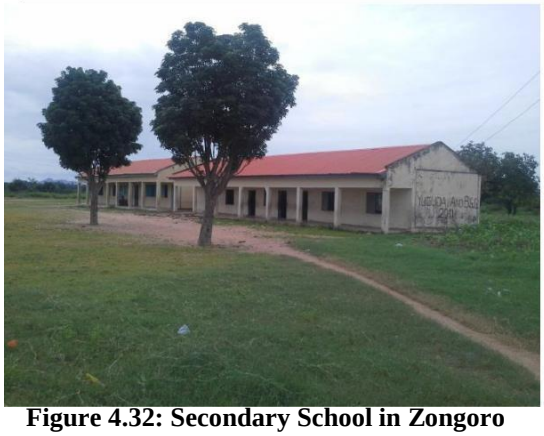


Figure 4.32: Secondary School in Zongoro

Figure 4.33: School Class-room in Zongoro

Literacy Rates: Educational level is one of the key determinants for measuring standard of living. About two-thirds (65.9%) of the respondents did not have any formal education, 19% had only primary level education; 10.6% had secondary level education, and only 4.4% had tertiary/post-secondary education (Figure 4.34). None of the female respondents to the survey had ever been to school. This indicates a relatively high level of illiteracy in the study communities.

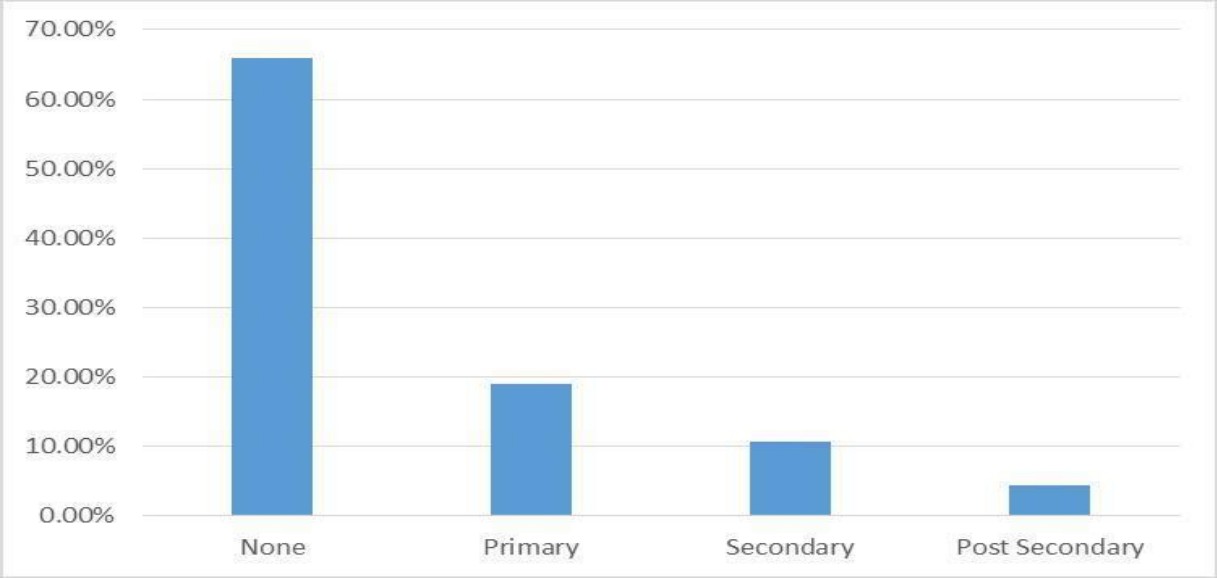


Figure 4.34: Educational Background of Respondents

4.4.11 Health

Regional Overview

Health Facilities: Bauchi State reportedly has over 660 public healthcare facilities (Ministry of Health, 2004).

Health Status:

According to Federal Ministry of Health 2003-2007 statistics, Diarrhea and Malaria are the leading causes of deaths from notifiable diseases across Nigeria.

Local Overview

Health Facilities: None of the communities around the project site have a primary health care facility, except for Gawa, which has a health centre.

Health Status: Malaria, cough, measles, yellow fever, dysentery/diarrhea were among the common health problems reported in the communities (Table 4.37). Malaria accounts for most illness at 75.6%. The FGD participants also mentioned typhoid, cholera and ulcer, high blood pressure, stomach ache and kidney problems as common health problems.

Table 4.35: Common Illnesses in the Communities

Illnesses	# of Respondents	%
Malaria	189	75.6
Yellow Fever	23	9.2
Dysentery/Diarrhea	22	8.8
Measles	13	5.2
Cough	47	18.8
Skin diseases/rashes	19	7.6
Other illnesses	8	3.2

4.4.12 Community Priorities

The following section describes community priorities in the local area only.

Residents reported that their community needs were:

Employment opportunities for youth
Employment opportunities for youth
Hospital
Potable water
Electricity
Improvement of facilities in the primary and secondary schools
Water source for livestock
Renovation of the palace of the community head
Upgrading of the Zongoro/Gango road
Provision/construction of a good market

Social problems: In terms of social problems, unemployment was cited most commonly (mentioned by 79.7% of the respondents), while 10.8% of the respondents also mentioned youth/juvenile delinquency, 2.6% reported land disputes, and 2.6% reported inter-family disputes. Other problems such as discord over Chieftaincy matters and inter-village problems were mentioned by 4.32% of the respondents.

Environmental and Economic Problems: Flooding was identified as the most common environmental problem in the communities. Other problems include lack/high cost of building materials, bad roads, poor sanitation, and deforestation (Table 4.38). Many respondents reported flooding and gully erosions in the farms.

Table 4.36: Common Environmental and Economic Problems in the Communities

Problems	# of Respondents	% of Respondents
Environmental		
Flooding	69	27.6
Deforestation	11	4.4
Bad Roads	51	20.4
Poor Sanitation	15	6.0
Economic		
High Cost of Building materials	62	24.8
Others	2	0.8

4.4.13 Community Associations

There were youth and livestock farmers' associations in the communities in the local area.

Stakeholder Views and Expectations about the Proposed Project

The following section describes views and expectations in the local area, based on primary data collection.

Willingness to Pay for Improved Electricity

There was a relatively high expression of willingness to pay for improved electricity (by 99.6% of respondents). The amount the respondents were willing to pay ranged from N1.00 to N6,000.00 per month, with an average of N722.88 (about US$4.38).

Awareness about the Project

There was a relatively high level of awareness about the proposed energy project in the communities with 70% of the respondents affirming their awareness of the proposed project, while only 27.6% were not aware and 2.4% did not provide an answer.

Respondents reported gaining awareness of the project through various sources, the most popular being local/village/traditional head (mentioned by 32.4%). Radio/electronic media were mentioned by 17.6%, and public/market place were mentioned by 4% of respondents. Others reported their sources as being neighbours (2%), friends (1.2%), husband/family members (0.8%) and project workers (0.8%).

Expected Benefits from the Proposed Project

Expected benefits from the project (Table 4.39) by the communities are basic infrastructures especially health care centers and improved employment opportunity for the indigenes. The views of the individual respondents were also in line with the views that were expressed by the Focus Group discussants regarding expectations.

Table 4.37: Expected Benefits from locating the project in the community

Expected Benefits	Population	%
Health Centers	54	21.6

Employment of indigenes	51	20.4
Electricity	21	8.4
School	17	6.8
Water project	16	6.4
Scholarship for indigenes	4	1.6
Other	1	0.4

Chapter Five: Environmental and Social Impacts

5.1 General

This chapter identifies and evaluates the potential environmental and social impacts of the proposed solar power project on the physical, social and human environment within the area of influence of the proposed project. The likely impacts were assessed for all activities in the construction; installation, operation and maintenance, and decommissioning/abandonment phases of the project development.

The identification and assessment of environmental and social impacts were based on American Society for Testing of Materials (ASTM), World Bank Environmental Assessment Sourcebook and ISO 14001/14004 guidelines, which include the following steps:

Identification of major activities of the project during the establishment of the proposed Solar power generating plant;
Identification of all the potential environmental and social aspects (hazards or sources of potential impacts) associated with each activity; and
Assessment of significance of identified environmental and social impacts.

Based on the above steps, major activities during the construction and operation phases of the project were identified. The associated environmental and social aspects were identified based on the project description.

All potential impacts from the proposed project have been evaluated as part of the ESIA process – effluent, ambient air quality, noise, surface water, and groundwater, geology, terrestrial and aquatic ecology and socio-economics.

5.2 Impact Evaluation Methodology

To ensure a comprehensive evaluation, a variety of measures to identify and weigh likely impacts, were considered. These included overlaying project components on maps of existing conditions to identify potential impact areas and issues; consultation with Nigerian experts and residents; experience from similar projects worldwide; and published and unpublished documents providing guidance on performing impact analysis for industrial development activities (such as the World Bank Environmental Assessment Sourcebook, and the EIA provisions of Nigerian's Environmental laws and regulations).

Impact Significance

Impact significance criteria were used to identify significant impacts in terms of environmental and social risks, public health and safety, environmental contamination and pollution, and asset/property damage, including land acquisition and involuntary resettlement. Taking into consideration the nature and extent of each activity, the following criteria were applied:

Magnitude – the level or intensity of the impact. An impact of high magnitude signifies that a large amount of the resource or population is affected.
Areal Extent – the area of coverage of an impact
Duration – estimated time for a population or resource to return to its initial state prior to the impact

Based on these criteria, the potential impacts of the project have been classified as negligible, minor, moderate or major. Criteria for defining these levels of significance are provided in Table 5.1. Using

the significance criteria to both screen and evaluate impacts enabled this EIA to identify and focus on those environmental components most likely to be impacted by the proposed project activities.

Table 5.1: Impact Significance Criteria[a]

Level	Definition
Biophysical Impact	
Negligible	Little or no change in natural environment, any effects are barely measurable above background conditions, much less significant than periodic stress by nature, measurable effects very temporary (a few days or less) before complete recovery.
Minor	Localized relatively isolated change in natural environment, lasting only a few days to a few months before recovery, with no observable residual effects. Areal extent only up to a total of 0.5 square kilometer.
Moderate	Local modification of considerable severity in atmospheric, surface or subsurface conditions, lasting from a few months to two years before recovery. Areal extent of affected area 0.5 to 5.0 square kilometers, or widespread modification of lesser severity.
Major	Widespread modification of considerable severity; areal extent of impact > 5 square kilometers.
Socioeconomic Impact	
Negligible	Little or no change in socioeconomic conditions or commercial activities any effects are barely measurable above background conditions, much less significant than periodic stress by on-going socioeconomic/commercial activities, measurable effects very temporary (a few days or less).
Minor	Localized relatively isolated change in socioeconomic conditions or commercial activities, lasting only a few days to a few months, with no observable residual effects.
Moderate	Local modification of considerable severity in less than 10 percent of those individuals affecting/affected by socioeconomic conditions or engaging in the commercial activities in the study area, lasting from a few months to two years. Widespread modification (more than 50 percent of those individuals affecting/affected by socioeconomic conditions or engaging in commercial activities in the study area) of lesser severity and duration.
Major	Widespread modification of considerable severity in socioeconomic conditions and commercial activities, lasting beyond two years duration.

Impact Risk

To objectively screen those issues warranting consideration as potential impacts and to determine the likely significance of those impacts, general consequence criteria covering natural (physical and biotic) and socioeconomic environmental components were developed. These consequence criteria (Table 5.2) were applied to all potential impacts to determine whether they would be positive or negative (negligible, minor, moderate, or major).

Table 5.2: Impact Consequence Criteria

Effect Level	Biophysical Environment	Socioeconomic Environment

Effect Level	Biophysical Environment	Socioeconomic Environment
Major Positive	There is a measurable improvement in the quality of environmental conditions (soil and vegetation) at the local and/or regional and/or national level. The effect could be of any duration, but it is likely to last throughout the duration of project.	There is a measurable improvement in the quality of socioeconomic conditions at the region's level. Such an improvement would result in an increase in the quality or availability of socioeconomic resources and reduction in poverty level of the region. The effect could be of any duration, but it is likely to last throughout the duration of the project.
Moderate Positive	There is moderate improvement in the quality of environmental conditions at the regional level. Such improvement would be optimized by the environmental sustainability of the area. The duration of the effect is likely to last the project life span.	There is moderate improvement in the quality of social conditions. Such improvement will result in an increase in the quality or availability of particular socioeconomic factor. The duration of the effect is likely to last for minimum of five years.
Minor Positive	There is a localized, isolated improvement in the quality of environmental conditions around the immediate project environment. The duration is likely to be short term, sustaining the biodiversity and ecology of the local environment.	There is a localized improvement in the quality of social conditions at the immediate project environment. Economy development of the host communities and hired personnel during activities such as construction, will be for short duration, i.e. the period of the activities.
Negligible	Little or no change in natural environment, any effects are barely measurable above background conditions, much less significant than periodic stress by nature The duration of the effect is likely to be totally reversible, naturally, within a few days.	Little or no change in socio-economic conditions or commercial activities (e.g., farming or trading etc.) any effects are barely measurable above background conditions, much less significant than periodic stress by on-going socioeconomic activities. The duration of the effect is likely to be totally reversible, naturally, within a few days.
Minor Negative	Localized and relatively isolated change in natural environment The duration of the effect is likely to be totally reversible, naturally or by intervention, within one year.	Localized and relatively isolated change in socioeconomic conditions or commercial activities. The duration of the effect is likely to be totally reversible, naturally or by intervention, within one year.
Moderate Negative	Local/regional modification of considerable severity in atmospheric, surface or subsurface conditions The duration of the effect is likely to last between one and two years.	Local modification of considerable severity in less than 10% of those individuals affecting socioeconomic conditions or engaging in the commercial activities in the study area. The duration of the effect is likely to last between one and two years.
Major Negative	Widespread modification of considerable severity in atmospheric, surface or subsurface conditions, The effect could be of any duration, but it is likely to last more than a couple of years.	Widespread modification of considerable severity in socioeconomic conditions and commercial activities. The effect could be of any duration, but it is likely to last more than a couple of years.

Similarly, in order to obtain a measure of the risk associated with each potential impact, likelihood criteria (Table 5.3) estimating the probability of occurrence of each potential impact were estimated taking into consideration existing safeguards and controls to be put in place by the project proponent.

Table 5.3: Impact Likelihood Criteria

Likelihood Level	Definition
Negligible (0)	Occurrence of the effect is almost impossible (e.g., less than 1 or 2% likelihood of occurring, impact from risk unknown to have previously resulted in similar circumstances from related development projects)
Low (1)	Effect highly unlikely, given the controls to be put in place (e.g., less than 2-20% likelihood of occurring, impact from risk has been known to result, but only very rarely, in similar circumstances.)
Medium (2)	Effect could occur infrequently during normal operations, however following a failure of safeguards and controls this could occur more frequently (e.g., >20-70% likelihood of occurring, impact from risk has been known to result in many similar circumstances, but not routinely).
High (3)	Given the controls to be put in place, the effect is likely to occur during normal operations (e.g., over 70% likelihood of occurring, impact from risk has been known to result routinely, though not necessarily in all similar circumstances.)

The Leopold impact assessment matrix (Figure 5.1) is used for combining the two assessment criteria, i.e., the severity of impact and the likelihood of aspect occurrence. This matrix is prepared along the same lines of the widely used risk assessment matrix for qualitative risk assessment studies.

During the life of the proposed project, appropriate practices and measures will be put in place to mitigate all the potential adverse environmental impacts identified. Details of these mitigation plans, which are in conformity with Nigerian (FMEnv) and World Bank environmental guidelines, are addressed in Chapter Six: Mitigation Measures.

The potential impacts of each activity are ranked by combining the severity (significance) and likelihood criteria. A positive sign (+) denotes a positive impact and a negative sign (-) denote negative impacts on a scale of 0-3 (Negligible = 0, Minor = 1, Moderate 2, Major = 3).

Likelihood	Consequence/Severity			
	Negligible	Minor	Moderate	Major
High	Low	Moderate	High	High
Medium	Low	Moderate	Moderate	High
Low	Low	Low	Moderate	High
Negligible	Low	Low	Moderate	Moderate

Figure 5.1: Impact Risk Assessment Matrix

The overall level of an impact is determined by its position on the impact risk matrix. This qualitatively allows for the evaluation of the risk of each event. The use of risk (consequence and probability) to screen and evaluate impacts in this way enables this ESIA to systematically identify and focus on those resources most likely to be at risk by the proposed project.

For example, impacts placed within the red boxes indicate those with high probability of occurrence with major consequence; thus, they have a "high" risk rating. These high-risk impacts become high priority issues for further evaluation or management action. Impacts in the yellow category are

"medium" risk impacts, with a medium priority. Impacts in the green boxes indicate events with very minor probability of occurrence, and negligible significance; thus, they are of "low" significance, with low priority.

5.3 Potential Impact Generation Activities

The impacts of the project are envisaged during the pre-construction, construction, operational and decommissioning phases. The main project activities which may have an impact on environmental parameters are identified in Table 5.4.

Table 5.4: Impact Ranking of Project Activities aagainst Environmental Components

Project Phase	Project Activities	Environmental Components														
		Biophysical									Socio-economic					
		Vegetation	Surface Water	Groundwater	Wildlife	Aquatic Organisms	Air	Noise& Vibration	Soil	Sediment	Population Dynamics	Employment	Livelihoods	Community Infrastructure	Health& Safety	Security
Pre-Construction	Plant design	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
	Site Fencing & Equipment Mobilization	-1/1	0/0	0/0	-1/1	0/0	-1/1	-1/1	0/0	0/0	0/0	0/0	0/0	-1/2	-1/1	-1/1
Construction	Site Clearing & Leveling	-3/3	-3/2	0/0	-2/2	-2/1	-2/2	-2/2	-2/3	-2/2	-2/2	2/2	-2/3	0/0	-1/1	0/0
	Construction Material/Equipment Transportation	0/0	0/0	0/0	0/0	0/0	-1/2	-1/1	0/0	0/0	0/0	0/0	0/0	-2/1	-1/1	0/0
	Civil Construction	-2/2	-1/2	-1/1	-1/1	-1/1	-2/2	-2/2	-2/2	0/0	1/1	2/2	1/2	-1/2	-1/1	0/0
	Establishment of PV arrays and Electrical Components	-1/1	0/0	0/0	-1/1	0/0	-1/2	-1/1	-1/1	0/0	0/0	1/2	1/2	-1/1	-1/1	0/0
	Workers Influx & temporary housing	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	1/1	2/2	1/2	-1/2	-1/1	-1/1
	Debris Disposal	-2/3	-3/2	0/0	-1/1	0/0	-1/1	0/0	-2/2	-2/2	-1/1	2/2	1/2	-1/1	-1/1	0/0
Operations	Transportation/Traffic	0/0	0/0	0/0	0/0	0/0	-1/2	-1/2	0/0	0/0	0/0	2/2	0/0	-1/2	-1/2	0/0
	Water treatment & Storage Facility	0/0	0/0	0/0	0/0	-1/1	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0

	RoW Maintenance	-1/1	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	1/1	0/0	0/0	0/0	0/0
	Plant and Substation Operation	0/0	0/0	-1/1	-1/1	-1/1	0/0	-1/1	0/0	0/0	0/0	1/1	0/0	0/0	0/0	0/0
Closure	Removal of Structures	0/0	0/0	0/0	-1/1	0/0	-2/1	-2/1	0/0	0/0	0/0	1/1	0/0	0/0	0/0	0/0
	Site Restoration	2/2	0/0	0/0	2/2	0/0	0/0	0/0	2/2	0/0	0/0	1/1	0/0	0/0	0/0	0/0
	Spent Batteries	2/1	2/1	0/0	0/0	1/1	0/0	0/0	1/1	1/1	0/0	2/2	2/2	1/1	3/3	0/0
	Spent PV Cells	2/1	2/1	0/0	0/0	1/1	0/0	0/0	1/1	1/1	0/0	2/2	2/2	1/1	3/3	0/0

Key:

Severity: Major (3), Moderate (2), Minor (1), Negligible (0)

Likelihood: High (3), Medium (2), Low (1), Negligible (0)

5.4 Potential Impacts

Spatially, the impacts have been assessed over the study area of 2 km radius of the solar farm project site and 1km wide of the transmission line. These are considered the area of influence of the proposed project in quantitative terms.

The project has overall positive impacts by providing a competitive, cost-effective, pollution free, reliable power source. It will certainly help to meet the increasing demand for stable power supply and to reduce dependency on fossil fuels (Nigeria is currently over 78% dependent on oil for its energy needs). The project will also help to create jobs and add economic value to the local community. Nevertheless, there are few adverse environmental and social impacts associated with the project activities especially at the project construction phase.

5.4.1 Environmental Impacts

Air Quality

Pre-construction Phase

The potential sources of emissions during pre-construction phase are:

Site clearing, leveling, excavation and grading, unpaved roads, storage piles and material transfer points, which include both fallout dusts and high levels of respirable particulates;

Emissions (NO_x, SO_x, PM) from heavy trucks, generators and compressors; and

Construction equipment and material hauling could potentially affect traffic flow increase vehicular emissions.

The impact duration will be short-termed, the likelihood is classified as medium and risk level is moderate.

Construction Phase

Site preparation, road and drainage construction, excavation for tower erection and transmission line construction would generate dust which would temporarily degrade air quality.

Exposure to dust and other gaseous emissions may impact the health of the local people and construction workers. However, the magnitude of impact on air quality is low and areal extent is localized. The impact duration will be short-termed, the likelihood is classified as medium and risk level is moderate.

Operational Phase

There would be no significant air pollutants during plant operation as there is no emission. The proposed development represents an investment in clean, renewable energy infrastructure, which, given the challenges created by climate change, represents a positive social benefit for society as a whole as it would indirectly reduce/eliminate considerable percentage of air pollutants emissions due to consistent use of power generators by

individuals to support irregular power supply. The proposed project will not consume energy, but will instead provide a new source of clean, renewable electricity national grid.

Decommissioning Phase

Decommissioning activities will involve dismantling and disassembly of the components of the power plant, and site restoration and grading activities. Similar to the construction phase, this phase will generate dust, and gaseous emissions from vehicles and machinery including NOx, SOx, and particulate matter. The impact will be temporary and local to the site. The duration will be short-term, the likelihood is medium and the risk level is moderate.

Noise

Pre-construction Phase

Temporary elevated noise levels from equipment and vehicular traffic during mobilization of equipment and personnel to site. Noise levels will be transient and localized.

Construction Phase

Noise and attendant vibration effects from fabrication and associated welding equipments and vehicular traffic. The operation of the construction equipment will generate noise ranging between 75 dB (A)–90 dB (A). Noise levels will be transient and localized. The duration of impact will be short-term and severity is minor considering that workers working near high noise generating activities will be provided with protective instruments. Overall risk level is expected to be low.

Operational Phase

Plant operations will increase ambient noise level in few areas, mainly due to operation of the electrical components but the noise generated will not be audible at sensitive receivers, Low levels of noise will be generated during routine maintenance activities. The highest noise level will be from daily vehicular traffic movements. This impact will be localised within the site and the impact severity/risk level is considered to be low.

Decommissioning Phase

Increase in ambient noise levels above baseline conditions will occur from movement of vehicles and equipment, and other activities of decommissioning such as the dismantling and removal of ancillary facilities. Increased noise levels, though likely, are temporal and the severity/risk level is low.

Soil

Pre-construction Phase

Site clearing and site preparation activities (vegetation clearing, road and drainage construction) will result in loss of vegetation cover (grass and shrubs) and topsoil which could lead to soil erosion.

Construction Phase

During construction, soil compaction as well as other soil works such as excavation and trenching will lead to topsoil erosion, and surface water pollution and riverbed silting. Accidental spill of chemicals could result in soil contamination and in-fauna habitat's destruction. In addition, generation of waste material can also lead to soil degradation. Oil spill response measures are expected to be put in place by the contractor.

The likelihood of occurrence of impact is medium, the severity is moderate considering the impact mitigation and control measures to be put in place, and the duration is short-term. Overall impact risk level is therefore moderate.

Operational Phase

Soil impact is limited to the construction phase; this would get stabilized during operations. No appreciable negative impact is anticipated during project operation.

Decommissioning Phase

Decommissioning activities that may have an impact on the soil include accidental spillage of chemicals such as fuel and oil. The impact likelihood is medium, and the severity is moderate and short-term. The overall risk level is therefore moderate.

Land Use

Pre-construction Phase

Approximately 200 ha of cultivated land would be cleared during pre-construction; an additional 30 m wide corridor along the 18-km route would also be cleared as transmission line RoW. The change in land use from agricultural farm land to industrial will significantly impact on farming activities in the project area.

The impact of the project on land use is of high likelihood and moderate consequence as the farmers would be relocated while there would be an influx of construction workers and setting up of temporary residential quarters.

Construction Phase

The proposed site will be converted from farmland to built-up structure and landscaped for aesthetics. The potential land use impact is expected to be significant, and the overall risk level is high.

Operational Phase

The site will be used for energy generation via solar power for the duration of facility operation. The potential land use change impact still persists as consultation with the affected people will continue throughout the operational period. It is expected to be significant, and the overall risk level is high.

Decommissioning Phase

During the decommissioning phase, solar energy generation activities will cease and the plant's facilities will be dismantled and removed. The site will be restored, as close as

possible to its pre-construction state, taking into account any future changes in the land-use plan. The land use change impact and resulting risk level will therefore be reduced.

Landscape and Visual Amenities

Pre-construction Phase

During pre-construction, there will be significant alteration of the existing visual landscape due to loss of vegetation and natural habitat. The magnitude of the impact is considered significant.

Construction Phase

The installation of the solar panels, erection of buildings, etc will result in a major alteration to the visual landscape. The magnitude of the impact is considered significant as the components of the power plant will be a distinct dominant feature in the environment, affecting the rural sense of the locality.

Operational Phase

During operation, there will be reflection of PV panels leading to glint and glare. This is as a result of the reflection of the sun and can pose a potential distraction for viewers, motorists and aircrafts. The magnitude of the impact is considered moderate.

Decommissioning Phase

Once the facility is closed, the components of the power plant will be removed and the visual impacts will be reversed.

Solid Waste

Pre-construction Phase

Waste generated will include excavation waste and cleared vegetation. During site clearing, waste will be stockpiled in laydown areas on site before removal. The improper management and handling of solid waste could lead to erosion and siltation of surface water bodies.

Construction Phase

Solid waste comprising food waste, debris, and loose materials is anticipated during construction. Other waste from construction and installation activities include packaging, scrap metal, and contaminated soil from fuel or chemical spills.

The likelihood of the impact is high and severity is moderate since the effect is limited to the project site and given the controls to be put in place in accordance with the construction waste management plan.

Operational Phase

In general, operation and maintenance of the solar farm will produce negligible solid waste.

Decommissioning Phase

During the decommissioning Phase, solid waste generated will include municipal waste and litter, scrap metal, demolition waste, hazardous waste (fuel and oil) and contaminated soil. The likelihood of the impact is high and severity is moderate.

Surface Water

Pre-construction Phase

Runoff from site preparation activities could result in an increase in turbidity and organic load of surrounding water bodies. This will adversely affect the water quality and aquatic organisms. The likelihood of occurrence is high and severity is moderate, and the overall risk level is high.

Construction Phase

Alteration of soil structure during construction could lead to erosion and subsequent siltation in the surface water bodies at the downstream area. Changes in surface hydrology can in turn adversely affect conditions that maintain healthy biological resources especially the epifauna. Accidental spillage of hazardous materials, improper disposal of solid, liquid and hazardous wastes and contaminated surface runoffs from both the site and the construction personnel living quarters can also impact the aquatic environment.

Site preparation and construction activities will occur over a limited time and in a localized manner. The likelihood of occurrence is high, the severity of impact is moderate, and overall risk level is high.

Operational Phase

There would be minimal discharge from the quarterly cleaning of the PV modules. Wastewater would be routed to a pond from where they would be reused.

Accidental leakage of transformer oil can occur during transmission line and substation operation, which would cause contamination of nearby surface-water bodies. Substation transformers are normally located within secure and impervious areas with a storage capacity of 100 % spare oil.

The potential impact on surface water during the operation phase is negligible.

Decommissioning Phase

Runoff from decommissioning activities could result in an increase in turbidity and organic load of surrounding water bodies. This will adversely affect the water quality and aquatic organisms. The likelihood of occurrence is high and severity is moderate, and the overall risk level is high.

Groundwater

Pre-construction Phase

During site preparation, ground water resources may be impacted from spills and leaks of hazardous substances such as fuel and oil as a result of improper storage and handling of

these chemicals. The likelihood and severity is however low if implementation of a construction management plan is carried out. Thus, the overall risk level is low.

Construction Phase

There would be minimal release of oil spills and chemicals, but the ground water would not be significantly impacted. Since the soil contains clay fractions, these chemicals may be retained in the clay fractions for a while before impacting the groundwater.

The likelihood of occurrence of impact on groundwater is low and the effect on groundwater quality is negligible. The overall risk level is therefore low.

Operational Phase

The project would install six (6) boreholes for operational and domestic use. The likelihood of impact to groundwater is low and the severity is low, because the usage would be limited to the volumes estimated. Lowering of groundwater table will not be an issue. In addition, rainwater harvesting will be implemented at the proposed plant site to minimize ground water usage.

Decommissioning Phase

Contamination of groundwater resources could arise from the storage and handling of waste and hazardous chemicals during decommissioning activities. However, the likelihood, severity and overall risk level is low.

Ecological Resources

Pre-construction Phase

Potential impacts on vegetation include removal of native and cultivated vegetation during site clearing and conversion of natural habitats to an industrial environment (loss of habitat). Site preparation activities are expected to result in moderately severe impacts on habitat and biological resources at various locations across the project area. The impact risk is considered high.

Site clearing will also destroy wildlife habitat and cause migration out of the project area. Some of the displaced wildlife may return to areas surrounding the site after construction. The potential impact on wildlife is predicted to be moderately significant.

Construction Phase

During construction, soil disturbance during activities such as excavation and trenching, poses a risk to the natural vegetation and increases the risk of erosion. This disturbance could also leave the site vulnerable to alien plant invasion. In addition, noise from the presence of workers and the operation of heavy machinery will likely pose a disturbance to the wildlife species leading to their migration from the area. The impact significance is considered moderate.

Operational Phase

Vegetation will change from the current agricultural type to man-made landscape vegetation. The removal of vegetation from the soil and loosening of the top soil could lead to soil

erosion. However, such impacts would be primarily confined to the project site during initial periods of the construction phase. The likelihood of impact of operation phase on vegetation is negligible and the severity/risk level is negligible.

The impact of the plant operation on wildlife includes noise and reflections from the solar arrays while impacts from the transmission line may result in bird mortality through electrocution. This would disturb wildlife habitats and lead to subsequent migration of wildlife from the area. The likelihood of these impacts is medium, the area of influence is localized, and impact severity on wildlife is considered moderate.

Decommissioning Phase

The restoration of the site during decommissioning will include restoration of the vegetation cover and replenishment of the top soil once the solar plant components have been uninstalled. The significance of this impact is considered low as habitat loss cannot be fully mitigated or reversed.

5.4.2 Socio-economic Impacts

Demography/Population

Construction Phase

There will be an influx of workers to the area during the construction phase. Most of them will be local residents and therefore the project will have a positive socio-economic impact by increasing the labour force of the area and increasing the skills level of those employed. This impact is likely to have minimal effect due to the relatively small number of local employment opportunities. Change in population and demographic characteristics of the community are likely to be minimal.

Operational Phase

The project will require few workers during the operational stage as the solar panels are designed to operate continuously and unattended. Thus, the impact on demographics of the area during the operational phase is negligible.

Displacement

The proposed solar farm and transmission line will be set-up on cultivated land, which would require the resettlement and relocation of the existing inhabitants who lives on their farms. The whole of Anguwan Waziri (a settlement under Zongoro community) who currently resides on the site would need to be relocated.

Initial survey of the 18km transmission line RoW shows that it will pass through seven communities within Ganjuwa and Bauchi LGAs, namely: Zongoro, Yuli, Waya, Rundebin, Inkil, Kimni and Dungulbi. The RoW will pass through agricultural lands cultivated with maize, millet, groundnut, beans and rice. The total land take in each of the communities are Zongoro (13.68 ha), Yuli (4.8 ha), Waya (11.66ha), Runde (8.54 ha) and Dungulbi (6.77 ha). Approximately, 50 towers to be constructed will require 1 ha with each tower requiring about 120 m^2.

The preliminary survey observed that there are no proper houses along the transmission line but mud huts. The transmission lines may pass through private lands and towers may be erected on private lands. This may affect or limit future land use and potentially decrease the market value of privately owned properties. The acquisition of private land where applicable, will be conducted in accordance with the resettlement action plan (RAP).

Employment

Construction Phase

Construction of the solar farm and transmission line will generate employment opportunities for both skilled and unskilled local labour. There will also be an induced migration to project areas for people from nearby communities looking for employment. Sourcing of materials locally and demand for local goods and services will increase the earning capacity of local businesses. This will be limited to the construction period and is not expected to upset the local economy significantly (supply and demand price).

Operational Phase

The operation of the project would generate employment opportunities for some members of the communities. Indirect job opportunities will also be created outside the immediate project area. The impact will be moderate and mostly positive.

Livelihood

Construction Phase

Some existing farmlands will be acquired for the PV farm and the transmission line RoW. This will lead to loss of livelihood for some families.

Operational Phase

Employment opportunities as a result of the project could improve the quality of life in the community and introduce new commercial/trade and employment dynamics in the area. The likelihood of occurrence is considered high.

Socio-cultural Institutions

Construction Phase

Local customs, cultures, local languages and social relations are not likely to be impacted by the temporary influx of construction workers. There are no cultural resources on the project site. The project will not impact on the leadership

Operational Phase

The diverse ethnic groups in the communities have strong social relations having lived in the area for so long. The likelihood of conflicting lifestyles, culture and tradition with presence of strangers in the community is negligible and the impact is insignificant.

Community Infrastructure

Construction Phase

Construction activities may cause disruption of utility services such as electricity, if cables are damaged. This could impact the living conditions in the communities who depend on this resource.

The impact will be minor and temporal in duration with no long-term residual effects.

Operational Phase

The plant start-up would encourage erection of new buildings to meet accommodation needs of project workers and service companies. Housing characteristics in the area will change to reflect the socio-economic profile of the emerging population.

This is a positive impact that will be gradual and long-termed. This will bring about an improvement in land use, aesthetics and infrastructural development.

Public Health and Safety

Construction Phase

During construction, health and safety of workers and the general public is at risk. Contractor's occupational safety procedures will mitigate against impact to the safety of workers during construction. The likelihood of occurrence of impact on the safety of workers is high, however given the measures to be put in place, the severity ranking is low.

The influx of workers may also impact on local security as armed robbers and hoodlums may be attracted to the area. The likelihood is low and impact minor. Influx of construction workers may also lead to an increase in prevalence sexually transmitted diseases among the local population.

The influx of construction workers to the area may also increase the incidence of HIV/AIDs. However, due to the low population density of the area, and the relatively small size of the labour force, the potential risk to family structures and social networks is regarded as low.

Mobilization of equipment including heavy duty trucks will pose a risk for road accident to workers, community people and other road users. The impact is however, expected to be minor and the likelihood is low. Increase dust level may lead to an increase in respiratory diseases among the local population.

Possible exposure to electromagnetic interference could occur during these activities. The impact will be high if not adequately mitigated through awareness campaign.

Operational Phase

The safety of workers and the public around the project area may be impacted during operation due to exposure to occupational hazards on-site. However, the likelihood of occurrence of such incidents is low taking into consideration the mitigation measures and occupational safety procedures to be implemented.

Traffic /Transportation

Construction Phase

The project will result in increased vehicular movement during construction phase which will give rise to increased traffic flow, dust emissions, and possible traffic congestion. A traffic management plan will be implemented to minimize obstructions to road users and residents. The likelihood of occurrence is high and the severity of impact is moderate. Overall, the impact risk is high.

Operational Phase

The maintenance substations and transmission line will pose a risk of traffic disruption to the communities and general public. The likelihood of these impacts is medium, the area of influence is localized and severity of impact is low. Overall, the impact risk is low.

Risk/hazard studies of developing a PV solar farm in the area

Political Instability

Risk

Northern Nigeria has been beset by political instability, inadequate infrastructure, and poor macroeconomic management, as well as an ongoing threat from the terrorist group Boko Haram.

Mitigation

NSCP/Globeleq/ARM-Harith has carefully selected the States in Northern Nigeria to work and develop projects in paying close attention to the security updates made available by the State Department as well as the British Foreign Office.

Whilst there is a complex geo-political struggle going on in the North and an influx of Al Qaeda activity in certain states neighboring Bauchi State, NSCP/Globeleq/ARM-Harith also recognizes that many of the risks are heavily linked to socio-economic hardship. NSCP/Globeleq/ARM-Harith will ensure the employment of local stakeholders in Bauchi throughout the lifecycle of the development and operation of the solar plant. In this vein NSCP/Globeleq/ARM-Harith is also developing a Corporate Social Responsibility program which will seek to provide power to the local hospital and clinic as well as the local school in the city center.

NSCP/Globeleq/ARM-Harith has also engaged the services of Garda World (http://www.garda-world.com) to provide an independent survey that assesses the real threat in the region along with the associated mitigation measures required to manage the operational risk from the build out phase through to the commissioning and operation of the asset. We are also working closely with the Bauchi State Governor and chief of police to protect the interests of our project.

NSCP/Globeleq/ARM-Harith is pursuing political risk insurance through OPIC and MIGA to cover an event of default due to force majeure resulting from any act of vandalism or terrorism

Chapter Six: Analysis of Alternatives

6.1 General

This chapter presents the justification for the proposed 100 MW solar power project. It also discusses the various technology and site location options that were considered as alternatives during project planning.

6.2 Need for the Project

Epileptic power supply due to inadequate generation has been a major challenge in Nigeria. This has impacted on both social and technological development, despite the abundance of natural gas. The national economy is underdeveloped and characterized by over-reliance on oil exports. The decline in electrical output is directly linked to low investment and maintenance of existing power generating plants which has triggered the continuing degradation of power supply over the last 30 years. Due to high power cost from operating individual power generators, Nigerians are limited to an average of 4 to 8 hours of constant power supply in a day.

The establishment of a solar power plant and other planned power generating projects would redress this trend by improving productivity through availability and accessibility to regular power supply. This project will also promote the Federal Government's strategic plan to optimally utilize available renewable energy resources (solar, geothermal, wind etc) for economic development and further strengthen linkages between the power sector and the real economy.

Project Justification

As the demand for energy continues to rise, Nigeria is looking for alternative sources of energy in addition to the existing hydroelectric and gas-fired generating plants. Therefore, the federal government has initiated a renewable energy policy to access additional energy sources to reduce the demand-supply gap and reliance on fossil fuel while strategically diversifying the country's energy security.

Electricity consumption in Nigeria has more than doubled in the last 40 years, outpacing economic growth. Despite capacity additions, electricity demand continues to outstrip power generating capacity, compelling the Federal Government to release the National Electricity Policy, 1991, enact Electricity Act, 2003 and spell out the targets for the Vision 2020. The said Act and the Vision 2020, while giving due importance to electricity generation through conventional sources, have recognized the need to increase power generation through renewable sources too. Nigeria has realized additional advantages of curbing worldwide pollution and formulated strategies to explore renewable energy resources like hydro, wind and solar.

In view of above, the 100 MW Solar PV Power Project at Zongoro community in Ganjuwa Local Government Area (LGA) of Bauchi State, is justified.

Site Justification

The siting of the solar complex at Ganjuwa, Bauchi State, was mainly due to strong sunshine characteristic amongst other regions. With a DNI (Direct Normal Irradiation) of more than 6500 Wh/m^2/year, the area has adequate solar radiation.

Several other technical and socio-economic criteria have contributed to the siting. They are listed below:

6.2.1 Proximity to the Zongoro River;

6.2.2 The energy produced by the plant can be evacuated via an existing 132 kv transmission line which is about 18 km to the site;

6.2.3 Site topography is ideal (flat/plain over its entire surface except for a few rock outcrops);

6.2.4 The installation of a solar farm at the site belonging to the community would likely generate some conflict because the site currently is cultivated with maize and sorghum. Economic displacement of population or economic activity is therefore envisaged;

6.2.5 The site is located away from the main living areas (i.e. site is not densely populated); and

6.2.6 The site is located outside of any natural protected habitat, or tourist attracted area. Therefore, no co-visibility impact is to be expected.

Socio-economic Mitigation Measures

The resettlement plan

The RAP requires the project developer to compensate, either in cash or in kind approximately 220 people who will be directly impacted by the project construction. Of these, approximately 150 will require resettlement assistance and livelihood restoration, while the remainder will require just livelihood restoration.

Compensation and re-insertion measures

The preference and plan of the project developer is to compensate the Project Affected Persons (PAPs) in kind by constructing for them a village with housing on a significantly higher level than their current dwellings and including water, sanitation, electricity and health care facilities. NSCP/Globeleq/ARM-Harith is committed to a voluntary offering of socio-economic development projects in the area that meet the residents' key needs, focusing on the areas of health, energy, water and education. The village will include a house per family, public buildings, a medical clinic, clean water provision, good sanitation and electricity. Land is expected to be provided by Bauchi State close to the project area

Public consultations

There have been extensive consultations between NSCP/Globeleq/ARM-Harith's RAP team and residents in the area. Residents have a positive disposition towards the project; they welcome the potential economic developments that would come from it including employment opportunities and improved power supply etc. There are however some concerns from affected households over loss of farmlands and social networks.

Consultations have also been held with representatives of the Ministries of Lands, Special Duties, and Environment during which they were informed of project activities and their likely impacts. These institutions are aware of the project and have provided the required support to the project developers RAP team. The contacted agencies have resourceful in engaging all identified stakeholders. Furthermore, a Public Information Booklet is to be distributed to all PAPs and will contain the following information:

Brief description of the project and its impacts

Implementation schedule

Entitlement and rights of the PAP

Resettlement and rehabilitation or assistance polices for all types of impacts

Institutions responsible for the resettlement

Information dissemination and consultations with PAP

What to do when PAP have further questions, concerns or problems

Grievances redress procedure etc.

implementation schedule monitoring and evaluation procedures

Fears/Concerns about the Project

The inhabitants of the study area expressed concerns that siting the proposed energy project in their neighborhood, would result in land acquisition/loss of land (64.4%), followed by damage to agricultural/farm land (24.6%), cultural interference (5.2%), noise nuisance from working equipment (3.7%), pollution of fishing water (2.1%) as in Figure 4.35. These fears/concerns were also confirmed by the FGD sessions. As some female FGD discussants further clarified, some people inherited their houses from their parents and grand-parents, and would not want to just lose such inheritance.

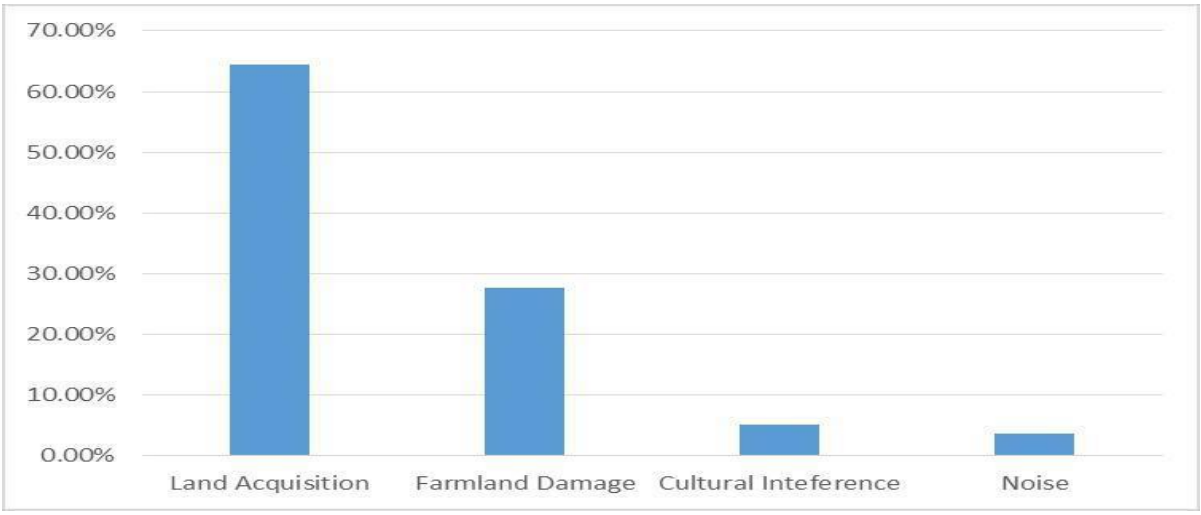


Figure 6.1: Fears/Concerns about the Proposed Energy Project

Concerns such as impact on daily activities were expressed by 12.8% of the respondents. 12.8% mentioned possible effects on their economic activities, and 2.4% possible effects on their social activities. However, the majority (72%) did not mention any possible effects on them as individuals.

On the possible effects on their communities, 25.2% of the respondents mentioned possible effects on farm land (e.g. loss of land through land acquisition), effects on daily life activities (3.6%), effects on economic activities (2.4%), effects on water sources (2%), effects on social activities in the communities (1.6%), effects on grazing land (0.8%), and effects on accommodation – e.g. loss of accommodation through land acquisition, increases in rent, etc. (0.4%).

Most of the respondents (71.2%) did not think proposed project could bring any problems to their community. However, possible problems mentioned by a few respondents include loss of accommodation/high rent (20.8%), pressure on social facilities and infrastructure (3.6%), loss of farm land (3.2%), and effects on economic activities and sources of livelihood (1.2%).

Possible Conflict between the Indigenes and the Project

The avoidance of conflict between the indigenes and the hosted company is important for a successful operation, thus the respondents were asked about areas of possible conflict between the indigenes and the project. The majority of the respondents (98.3%) did not foresee any conflict between the indigenes and the project, while only four respondents (1.7%) thought there could be some problems

This indicates massive support for the proposed project in the community. However, the few respondents who said there could be a problem between the indigenes and the project suggested adequate compensation for losses to avoid conflicts.

Preferred Modes of Compensation

If their lands were to be acquired for the project, 28.1% of the respondents expressed preference for financial compensation, 16.1% material compensation, and 55.8% both financial and material compensation as in Figure **6.3.2**.

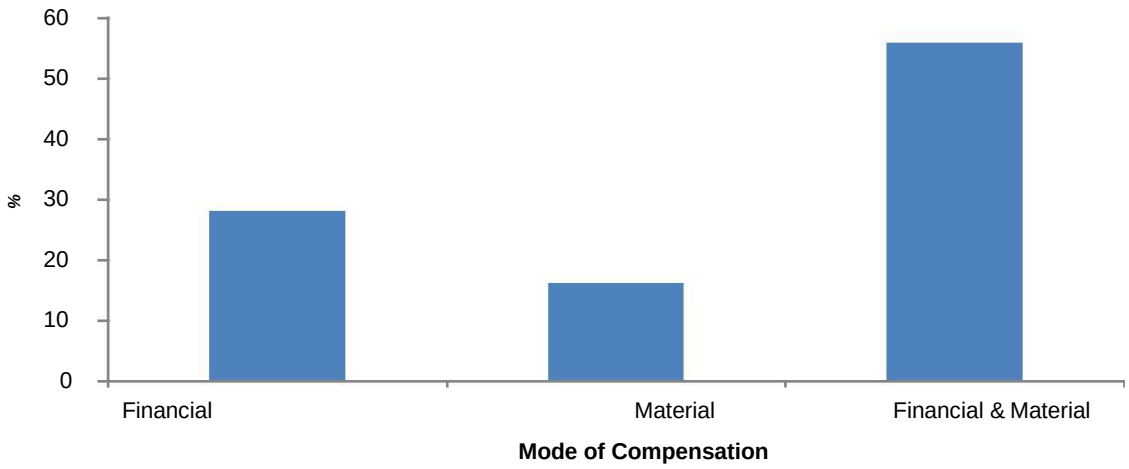


Figure 6.2: Preferred Modes of Compensation

It was also stated that access to necessary facilities such as a mosque, adequate water supply, schools, health centers, good roads, markets, etc. be provided for the communities to be relocated.

Implementation schedule and monitoring and evaluation procedures

An initial enumeration survey was conducted in August– November 2013. The survey focused on demographic characteristics, health, income and livelihoods, housing conditions, access to social amenities and general quality of life of the population in the project area.

A further asset valuation survey will be undertaken in spring/summer 2015 to establish the full replacement cost indices of all assets belonging to the PAPs. A social survey will also be conducted to gain further understanding of the community makeup and livelihood patterns. A team of specialist with experience of carrying out social surveys to IFC standards will be engaged to develop the field

Each PAP will complete a profile form with a picture attached, and have their details documented in a register. On completion of the PAP audit list, the project director will set-up a committee that will carry out compensation and relocation from the project affected area. All PAPs will be provided with a census registration card. It is expected that implementation of the RAP will begin in the Autumn of 2015.

The overall responsibility for overseeing the resettlement process lies with the Special Implementation Committee (SIC), which will be set up by the Bauchi State Government under the Ministry of Special Duties (MoSD). This committee will be an advisory/supervisory, strategic body which will coordinate and supervise all activities from a government perspective from pre-implementation through to monitoring and evaluation. The Compensation and Relocation Committee (CRC) will be responsible for the planning, coordination and monitoring of compensation and relocation activities.

The monitoring framework consists of three components: internal monitoring by SIC/MoSD; Impact Monitoring; External Monitoring and Completion Audit.

Internal monitoring by SIC/MoSD -The SIC will be responsible for monitoring the following key indicators, in keeping with World Bank requirements:

timely disbursement of compensation;

compensation disbursement to the correct parties;

public consultation and grievance redress procedures in place and functioning;

physical progress of resettlement and rehabilitation, where applicable.

Impact monitoring -The SIC/MoSD will commission socio-economic survey for the purpose of:

determining the extent to which quality of life and livelihood has been restored

determining whether PAPs have experienced any hardship as a result of the project.

reviewing grievance redress mechanism outputs

External Monitoring and Completion Audit - which will verify results of internal monitoring, by field check of delivery of acquisition, compensation and rehabilitation measures, such as:

payment of compensation, including its levels and timing;

infrastructure repair and relocation;

housing reconstruction, if applicable;

land reinstatement and restoration;

enterprise relocation, compensation and its adequacy;

assess overall compliance with the RAP;

identify any areas of non-compliance and agreed corrective actions;

verify that project affected people's incomes and livelihoods have been restored or enhanced (if income or livelihoods are affected by the resettlement action;)

verify the functioning of the grievance redress mechanism;

report on completion of RAP timetable.

6.3 Project Benefits

The potential benefits of the project include amongst others:

6.2.7 Increased electricity generation - when operational, the project is expected to generate around 166,240 GWh of electricity per year, and to increase Nigeria's generating capacity by 2.5%.;

6.2.8 Improved power supply for domestic and industrial use – the electricity generated will be sufficient to power approximately 2,750,000 additional households;

6.2.9 Multiplier effect from spin-off opportunities;

6.2.10 Manpower skills development and training - local engineers and technicians will attend training programs to teach them how to properly manage the solar field;

6.2.11 Strengthen economic productivity;

6.2.12 Local employment opportunities - during the construction period an estimated 500 construction workers will be employed part time, most of who will be Nigerians. An estimated 100 full time maintenance jobs will be created for the upkeep of the solar field;and

6.2.13 Reduced dependence on fossil fuel power generation – this will result in the inhibition of an estimated 2,469,000 tons of CO2 per year

6.4 Value of the Project

The total cost is estimated at about US$100,000,000 (One Hundred Million United States' Dollars).

6.5 Envisaged Sustainability

Fundamental factors that will contribute to the sustainability of the proposed project are as follows:

Environmental Sustainability

Implementation of the Environmental Management Plan contained in this report to ensure mitigation of adverse impacts on the environment;

Protection of biodiversity and natural ecosystems to protect water sources and control diseases during construction and operation; and

Improvement of local air quality through elimination of greenhouse gas emissions from local energy sources.

Social Sustainability

Ongoing consultation with community stakeholders throughout the project life-cycle to ensure social support and acceptability.

Economic Sustainability

Development of the electricity market through institutional support and policy implementation;

Local and regional economic development through job creation, capacity building, and infrastructural development;

Private sector ownership of the project to ensure effective execution; and

Comprehensive evaluation and management of the project life-cycle costs to ensure financial viability.

Technical Sustainability

- Adequate technical training on plant operations and maintenance; and
- International collaboration, partnerships, and knowledge sharing on the operation of large scale solar power plants.

6.6 Analysis of Alternatives

Alternatives scenario for meeting the aspiration of government and the proponent in the provision of improved power generation were evaluated. In particular, alternatives in relation to the type, scale and location of the project were reviewed. The options considered were:

Do nothing;

Generation technology options;

Site selection options

Option 1: Current Situation ("No Action" Option)

The no-action alternative assumes that the project will not be carried out. This would result in the continued low power generation and epileptic power supply in Bauchi State and in the Country at large. The attendant impact from epileptic supply will continue and the expected economic development in the state and nation will be delayed. In addition, the continued use of traditional fossil fuel sources will have great adverse effect on the environment.

As a result, the "no action" option is not considered a viable or acceptable alternative.

Option 2: Alternative Solar Technology

The major existing technologies for solar energy are solar Photovoltaic (PV) and Concentrated Solar Power (CSP). CSP systems use lenses or mirrors and tracking systems to focus a large area of sunlight into a small beam, whereas PV converts light into electric current using the photoelectric effect.

Concentrated Solar Power

Concentrating Solar Power (CSP) systems use lenses or mirrors and tracking systems to focus a large area of sunlight into a small beam. Various techniques are used to track the Sun and focus light. In all of these systems a working fluid is heated by the concentrated sunlight, and is then used for power generation or energy storage.

The main characteristics of CSP systems are:

Requirement for high direct normal solar radiation as it uses concentrated rather than diffuse radiation

Capable of generating electricity many hours after sunlight availability

Ability to store energy for up to 16 hours

High maintenance and complex system being a combination of equally critical components

Requirement for very large land area with limited cloud cover. A typical CSP plant requires 5 to 10 acres of land per MW of capacity.

Solar PV Technology

Solar photovoltaic can recover and convert sunlight directly into electricity by silicon panels. The photovoltaic cell can absorb solar radiation and produce energy using "photovoltaic effect". Several cells are connected together to form a photovoltaic solar module, several modules are combined to form a solar installation. The main characteristics of PV systems are:

High reliability of the system with no moving parts (except systems trackers, the movement is however, very slow)

Silent system with negligible noise impact

Associated low maintenance and low operating costs

Electricity storage difficult (due to loss of load over time)

The PV technology option was selected for the proposed solar plant due to:

Favourable project financing due to relatively lower costs than other solar technologies;

Technology is most suitable for power plants up to 100 MW;

Existing transmission infrastructure is adequate to deliver the energy produced from the plant; and

Process involves a simple design with few technical components which reduces operation and maintenance costs and in general makes the plant more efficient.

Option 3: Alternative Sites Location

Alternative site/location option was not considered due to the suitability of the proposed site in Bauchi state based on the following factors:

Proximity to an existing national power grid which is 18 km distance away on Gombe road

Optimal solar radiation of the area

Adequate availability of the required land resources, and

Ready market for electricity off-take via an existing transmission line

Chapter Seven: Environmental and Social Management Plan (ESMP)

7.1 Introduction

An Environmental and Social Management Plan (ESMP) is an important component of an ESIA as it provides an important tool that can be used to measure and check, in a continuous mode, the efficacy of the mitigation measures and project commitments incorporated in the ESIA to minimize or eliminate identified negative impacts. In addition, the ESMP may also be used to ensure compliance with statutory requirements, and corporate safety & environmental and social management policies.

The key features of an ESMP, drawing from relevant existing guidelines as well as the Nigerian ESMP experience, are that it:

is applicable to a range of types and scales of projects or developments, from projects with a low level of environmental risk to those with high environmental risk;

assumes a broad understanding of the term "environment", that includes the biophysical, social and economic components;

includes the enhancement of positive impacts (benefits) as well as the mitigation of negative impacts; and

should not be viewed as a prescriptive and inflexible document.

An ESMP is, therefore, a tool which ensures continuous assessment of the environmental and social impact of a project operation as well as proactive response to the impacts to reduce their overall effect on the identified environmental parameters. It makes an organization to do the right thing at the right time rather than responding to situations borne out of statutory or legal compulsion. This essential tool is contained in the International Standards Organization (ISO) Environmental Management ISO 14000.

In this section, an ESMP is presented to be used throughout the life span of the proposed project in Bauchi. This ESMP will facilitate environmental and social management of the proposed project and procedures are provided to help prevent, avoid or minimize negative environmental impacts that may occur from the project planning phase through construction and operations.

7.2 ESMP Objectives

The objectives of the ESMP for the proposed project are to:

monitor the project proponent's compliance with all the mitigation measures and commitments in the ESIA report;

monitor the project proponent's compliance with legal standards and limits for waste discharge and emissions;

provide early warning signals on potential environmental changes, so that appropriate actions can be taken to prevent or minimize environmental and social impacts;

put in place a sound and cost-effective contingency plan that can be activated for prompt response to any accidental occurrence;

encourage and achieve the highest environmental and socio-economic performance and response from individual employees and contractors throughout the duration of the project; and

routinely check all measures/devices put in place for effective monitoring of project functions and activities.

7.3 Proffered Mitigation Measures

7.3.1 Environmental Mitigation Measures

7.3.1.1 Air Quality

Preconstruction phase

The main potential sources of emission are fugitive dust produced by the movement of soils during site clearing, grading and filling, and emission from internal combustion engines of construction equipment.

Water shall be sprinkled on roads and other conveying routes and stockpiles to suppress dust. These emissions are short-termed and localized to the immediate site area. Regular maintenance of vehicle and construction equipment (regular emission control and inspection) shall be ensured by NSCP/Globeleq/ARM-Harith to greatly reduce emission from internal combustion engines.

Construction phase

The main potential sources of emission are fugitive dust produced by the movement of vehicles on dusty roads and emission from internal combustion engines of construction equipment.

Water shall be sprinkled on roads and other conveying routes and stockpiles to suppress dust. These emissions are short-termed and localized to the immediate site area. Regular maintenance of vehicle and construction equipment (regular emission control and inspection) shall be ensured by NSCP/Globeleq/ARM-Harith to greatly reduce emission from internal combustion engines.

Operation phase

There will be no emission from the plant operation. With the implementation of renewable energy into the energy system, there will be a decrease in diesel generation resulting in a reduction in air pollution.

Decommissioning phase

The main potential sources of emission are localised gaseous emissions from machinery and vehicles used for decommissioning activities. Fugitive dust emissions are also anticipated from adjacent areas.

These emissions are short-termed and localized to the immediate site area. Regular maintenance of vehicle and construction equipment (regular emission control and inspection) shall be ensured by NSCP/Globeleq/ARM-Harith to greatly reduce emission from internal combustion engines.

7.3.1.2 Noise

Preconstruction phase

Nuisance (noise and vibrations) due to movement from heavy duty equipment and vehicles affecting public and wildlife.

Machinery, vehicles and instruments that emit high levels of noise should be used on a phased basis to reduce the overall impact. Workers should be supplied with ear plugs and ear muffs to reduce the risk of hearing impairment. Prolonged exposure to this impact should be

reduced where possible. Plan work activities to avoid heavy duty movement during peak hours should be encouraged. Proper consultation with host communities to plan project activities accordingly while movement and work activities to daytime only.

Construction phase

Construction shall be restricted to day time so as to avoid disturbance to nearby communities during night hour rest. All noise generating equipment shall be fitted with noise control as well as vibration devices, and properly maintained.

Operation phase

There will be no noise produced during the daily operation of the solar plant and therefore no significant increase in noise levels is envisaged. With the implementation of increased renewable energy into the energy system, there will be a decrease in the use of diesel generators resulting in a reduction in noise pollution.

Decommissioning phase

Nuisance (noise and vibrations) due to movement from heavy duty equipment and vehicles affecting public and wildlife.

Machinery, vehicles and instruments that emit high levels of noise should be used on a phased basis to reduce the overall impact. Workers should be supplied with ear plugs and ear muffs to reduce the risk of hearing impairment. Prolonged exposure to this impact should be reduced where possible. Plan work activities to avoid heavy duty movement during peak hours should be encouraged. Proper consultation with host communities to plan project activities accordingly while movement and work activities to daytime only.

7.3.1.3 Soil

Preconstruction phase

Construction personnel shall adhere to the recommended erosion and sedimentation control practices such as management of excavations to avoid the generation of drainage pathways to underlying aquifers, provision of bunded areas for storage of hazardous materials (e.g. fuel) and equipment maintenance to prevent absorption of spillages and stockpile topsoil for site rehabilitation as contained in this report.

Construction phase

To minimize soil erosion and soil quality degradation, construction personnel shall adhere to the recommended erosion and sedimentation control practices as contained in this report. Construction crew shall be properly trained in handling and disposal of solid and liquid wastes to avoid accidental spills, and the use of appropriate clean-up procedures in case of accidental spills shall be ensured by NSCP/Globeleq/ARM-Harith.

Using local species, a buffer zone shall be planted post-construction, under and around the solar arrays, to minimize soil erosion.

Drainage works and road construction shall be done in a manner that minimizes erosion risk.

– Operation

Chemicals used during substation maintenance such as transformer oil, lubricants, etc. shall be stored and handled appropriately to minimize spills or leaks. Adequate hazardous materials handling programme shall be put in place to avoid poor handling and disposal and to reduce incidence of surface run-off and soil contamination where chemicals are spilled. Workers

handling hazardous materials shall be trained about proper storage and handling techniques and shall be made to study and understand the MSDS accompanying each chemical.

Decommissioning phase

During decommissioning, minimal surface area disturbance shall be ensured. Grading activities shall be limited to areas previously disturbed and the site shall be re-graded to leave it stabilized and maintain natural drainage patterns. Backfilling of open gaps from the removal of structures shall be carried out with topsoil and subsoil.

Appropriate erosion control measures will be adopted according to best practices including soil de-compaction and re-contouring to blend with the surrounding areas.

7.3.1.4 Surface Water

Preconstruction phase

During site clearing and civil works, soil surfaces would be exposed and an elevated level of suspended particles would be present in the surface run-off. Sediment laden runoff may carry pollutants (adsorbed onto the particle surfaces) into the storm water drainage system. Other potential source of contamination includes release of cement materials with rain wash, wash water from dust suppression sprays, fuel (diesel and gasoline) and lubricants from construction equipment maintenance.

Measures should be taken to ensure that excavated materials are stacked properly to reduce turbidity effect on surface runoffs and cleared materials should stacked properly to reduce turbidity effect on surface runoffs.

Construction phase

Adequate environmental hygiene, coupled with good construction practices and site management shall be ensured by NSCP/Globeleq/ARM-Harith to ensure that litters, fuels and solvents do not enter nearby streams and storm water drains. The water from the drains shall be channeled to an oil/water separator and treated to FMEnv acceptable level before discharge.

Operation phase

The project is a potentially significant consumer of water due to the washing of the solar pannels, in accordance to the resource efficiency requirements of the IFC Performance Standard 3; NSCP/Globeleq/ARM-Harith shall adopt measures to reduce water consumption so that the project's water usage does not have significant adverse impacts upon others. These measures shall include, but are not limited to conducting technical feasible water conservation measures within the project's operations and the use of alternative water supplies.

Wastewater from PV modules' washing and domestic waste water will be routed to a wastewater treatment plant. Waste water shall be treated and its properties shall be monitored to ensure that it meets the FMEnv set standard before discharge. Hazardous materials spill contingency plan shall be developed prior to start-up. Sanitary waste treatment facilities shall also be provided prior to project's commissioning, while sewage shall be collected for off-site disposal through government approved and licensed third party waste management contractor.

Fueling and maintenance of vehicles shall be conducted in a concrete paved and bunded area in order to contain any spills that may occur, and shall not be conducted within 30m of any water resources. All potential sources of leaks from operation and maintenance activities and equipment shall be blocked through regular maintenance and inspection. Adequate maintenance of drainage systems shall be carried out to prevent any overflow.

Decommissioning phase

Increased turbidity and contamination from soil nutrients may occur due to decommissioning activities. Disturbed areas are shall be leveled, restored, and re-vegetated in order to minimize soil erosion. Adequate spill protection should also be employed during decommissioning.

7.3.1.5 Groundwater

Preconstruction phase

During preconstruction activities oils, lubricant, and diesel fuel can seep into the ground, posing a real source of groundwater contamination. The handling, storage and disposal of materials and wastes during construction shall be done in an environmentally safe manner with bunded wall and concrete floor as well as other measures recommended in the ESMP. Hazardous material storage areas shall be built with impervious materials.

Construction phase

During construction activities oils, lubricant, and diesel fuel can seep into the ground, posing a real source of groundwater contamination. The handling, storage and disposal of materials and wastes during construction shall be done in an environmentally safe manner with bunded wall and concrete floor as well as other measures recommended in the ESMP. Hazardous material storage areas shall be built with impervious materials.

Operation phase

Reduce groundwater usage by recycling wastewater from the periodic cleaning of PV modules for landscaping of the site. Training on safe practices for personnel involved in handling, storage and disposal of materials and wastes shall also be provided.

Decommissioning phase

During decommissioning activities oils, lubricant, and diesel fuel can seep into the ground, posing a real source of groundwater contamination. The handling, storage and disposal of materials and wastes during construction shall be done in an environmentally safe manner with bunded wall and concrete floor as well as other measures recommended in the ESMP. Hazardous material storage areas shall be built with impervious materials.

7.3.1.6 Vegetation Resources

Preconstruction phase

Adequate measures should be taken to ensure minimal vegetation losses and re-planting of economic vegetation species around the site perimeters should also be carried out, while land clearing and site grading should be well planned to avoid excessive land take beyond what is actually required.

Construction phase

Movement of construction equipment and workers shall be restricted to the construction site.

During construction, a buffer of natural vegetation at the site boundary shall be maintained to serve as shelter belt and or wind break and further provide a milder microenvironment for the project site.

Strict control on site clearing activities shall be implemented to minimize loss of vegetation and clearance shall be strictly limited to target vegetation.

Operation phase

A plan for vegetation restoration shall be put in place by NSCP/Globeleq/ARM-Harith. Furthermore, there will be a positive impact on the flora and fauna of the region by the addition of renewable energy; the Solar PV project will result in a decrease in the share of traditional, polluting sources of energy. An estimated 2,469,000 tons of CO2 per year will be inhibited.

Decommissioning phase

Re-vegetation of the area using native species should be carried out after decommissioning.

7.3.1.7 Wildlife Resources

Preconstruction phase

The clearance of the 200-ha plant footprint and increased noise level from construction activities would affect wildlife habitat.

Noise levels shall be minimized by restricting construction activities to daytime hours and the use of low-noise generating equipment/materials.

Construction

Construction workers shall be prohibited from hunting, killing, or collection of animals from the project area. Bird flight diverters shall be installed along the transmission line to minimize the risk of electrocution.

During construction, NSCP/Globeleq/ARM-Harith shall ensure the use of available access roads only so as to prevent unnecessary bush clearing/disturbance to the natural habitat beyond the transmission line corridor. At night, should there be need to work along the transmission line, then, low-UV lights such as LEDs shall be used to prevent attracting insects.

Operation

NSCP/Globeleq/ARM-Harith shall install anti-reflective coating or glass to reduce the sunlight that is reflected and increase the amount of sunlight that is absorbed.

Decommissioning phase

Noise levels shall be minimized by restricting decommissioning activities to daytime hours and the use of low-noise generating equipment/materials.

7.3.1.8 Cultural Resources

Although there are no known historical or archaeological sites within the project site, if archaeological resources are found during construction, a qualified archaeologist shall be retained to evaluate the find.

7.3.1.9 Solid and Hazardous Waste Management

Fuels and other hazardous materials shall be stored in an area with secondary containment; spill clean-up materials shall be located at appropriate locations. Solid waste shall be segregated or sorted and stored separated. Hazardous wastes shall be disposed of by a government approved licensed third party contractor.

7.3.1.10 Occupational Health and Safety

Implementation of HSE procedures shall be made a condition of employment for all contractors and sub-contractors. There shall be clear definition of the HSE roles and responsibilities of contractors and their personnel.

The following measures shall be implemented to minimize HSE impact on the workers and public:

Implementation of a Fire Safety Plan prior to plant commissioning

Personnel shall be provided with safety appliances such as face shields, helmets, safety goggles, safety shoes, hand gloves etc., as per the job requirement. Safety training for workers and contractors shall be conducted for all project workers

Noise intense areas shall be clearly marked during construction with appropriate warning signs. Hearing protection such as ear plugs, earmuffs, etc., shall be provided

to all workers working in high noise areas to minimize their exposure to noise, and the use of all PPEs issued out to project workers shall be ensured by NSCP/Globeleq/ARM-Harith.

NSCP/Globeleq/ARM-Harith shall also ensure the provision of appropriate regular inspection, review and recording of HSE performance; and the maintenance of a high standard of housekeeping at all times and regular removal of litter and waste shall be ensured

In addition, site security shall be reinforced by fencing, and manned at entry/exit points, to prevent entry of unauthorized personnel and ensure proper control of hazardous materials on site.

7.4 Socio-economic Mitigation Measures

7.4.1 Demography/Population

Identifiable negative impacts relate to increase in population of non-residents in the event that youths and local people are not recruited into the labour force during construction. There is also the likelihood of gender imbalance. NSCP/Globeleq/ARM-Harith will however, mitigate this impact by localizing employment opportunities as much as possible.

NSCP/Globeleq/ARM-Harith proposes to provide employment to Nigerian nationals, and actively recruit among locals, at all phases of development of the project and throughout its lifetime. During the construction period, it is estimated that 500 construction workers will be employed part time, most of whom will be Nigerians. We estimate that 100 full time maintenance jobs will be required for the upkeep of the solar field. Local engineers and technicians will benefit from this project, as training programs will be implemented to teach them how to properly manage the solar field.

Additionally, certain jobs will be subcontracted out to local businesses.

7.4.2 Income/Livelihoods

The potential impact on the incomes and livelihoods of potentially affected persons through loss of farmlands and loss of structures will be adequately mitigated with appropriate compensation plan and adjustment measures for affected persons. Resettlement and compensation of Displaced Persons (DPs) and other Project Affected Persons (PAP) will be carried out in accordance with the RAP.
Furthermore, livelihoods will be positively impacted by the enhanced provision of electricity and reliability of supply.

7.4.3 Community Infrastructure

Construction activities interference with community infrastructure will be minimized through proper planning. As part of corporate social responsibility, the company shall restore damaged infrastructure and provide additional amenities to support the projected population increase in the area.

7.4.4 Socio-cultural Institution

NSCP/Globeleq/ARM-Harith's Community Relationship Officer (CRO) shall sensitize the construction workers to local norms and values to avoid cultural conflict.

Youth and community organizations shall be adequately notified prior to site mobilization to prevent delays in project execution. Adequate consultation shall be held with relevant authorities and community groups, especially the community relationship committee (CRC). Throughout the project life-cycle, periodic community consultation meetings shall be held to address issues and challenges as they may occur.

7.4.5 Public Health & Safety

Potential hazards identified shall be adequately mitigated through implementation of best management practices (BMP). These include:

- Sensitization programme on HIV/AIDS shall be conducted in communities to discourage wide spread of the disease through unprotected sex and related matters.
- Traffic management plan, traffic barriers, and speed limit signs, shall be implemented for road users to avoid accidents.
- Appropriate security measures such as police patrol and organized local vigilante could be used to check the surety impact due to influx of prospective employees.
- Operation of heavy equipment and vehicles shall be restricted to low traffic period of the day.
- Effluents from the site shall be treated prior to discharge.

7.5 Environmental and Social Management Plans

The Environmental and Social Management Plan for the proposed project is as follow:

Site Clearance

All site clearance works shall be carried out within defined perimeters and only when necessary. The maximum permissible time lapse between site clearing and initiation of construction operations shall be reduced to the barest minimum. Clearing of vegetation shall be kept to the barest minimum necessary to permit safe operations. Trees felled from the project site shall be made available to the host communities for re-use.

Health and Safety of Workers

All NSCP/Globeleq/ARM-Harith contractors, staff and third party shall be well informed and trained on all HSE issues at site. All facilities shall be designed to enhance safety planning. All activities shall be executed within the confines of the relevant Nigerian legislation (including FMEnv guidelines) as well as stakeholders' interests. All project activities shall be properly managed through careful planning and the application of relevant safety policies such as:

- Use of Permit to Work (PTW);
- Job Hazard Analysis and toolbox meetings before embarking on a job;
- Use of appropriate personal protective equipment (PPE);
- Prohibition of alcohol in the project area;
- Proper journey management;
- Regular emergency drills; and
- Use of appropriate caution signs.

Control of Atmospheric Emissions

Dirt roads and exposed construction areas shall be moisturized during the dry season to prevent and minimize dust emissions. Construction equipment shall be well maintained to minimize exhaust emissions into the atmosphere in accordance with FMEnv and World Bank standards.

Noise and Vibration Control

Noise levels shall be established for each noise source and targets. The personnel as well as environment that shall be affected by any established noise source shall be provided or equipped with appropriate protective or corrective device to ameliorate noise effect.

Waste Management

The proposed solar power generation project is not expected to generate significant quantity of waste, nevertheless, adequate waste management guideline and disposal facility have been integrated into the implementation of the proposed project. The principle of waste reduction, recycling, recovery and re-using shall be practiced. All wastes, which cannot be reused, will be managed and disposed off in accordance with the FMEnv regulatory standards. Some of the waste management options and waste disposal systems that will be considered for this project are highlighted below:

1. Solid Waste / Used Containers (Garbage and Inert Materials)

NSCP/Globeleq/ARM-Harith shall apply the following principles in handling of general garbage (wood, plastics, paper, and food wastes):

- Segregate components such as wood, plastic and paper, for recycling or reuse.
- Reduce packaging wastes such as paper and plastic by the use of bulk handling systems.
- Dispose all wastes at approved municipal dumps.
- Refilling and reusing of containers.

Sanitary Waste

Appropriate mobile septic tanks shall be provided during installation/pre-construction and construction phases. Sewage during the pre-construction, construction and operation phases shall be treated with residual chlorine level of 0.8-2.0 mg/l before disposal at appropriate sites.

In order to manage the waste generated on site, the following guideline and principle will be applied:

Waste Handling Guidelines

Wastes handling and disposal procedures shall be well defined at source and a waste inventory register kept. The general information required, as a minimum, for adequate definition of wastes include:

Waste stream identification;
Proper waste categorization;
Waste segregation;
Appropriate handling and disposal practice; and
Recommended Management practices.
Waste Minimisation Guidelines

The four principles of waste minimization process; recycle, reduce, reuse and recovery shall be adopted as applicable, to ensure reduction to the possible extent, of the volume or relative toxicity of liquid or solid wastes.

Waste Segregation Guidelines

All wastes to be generated from the project shall be segregated at source, into clearly designated bins at strategic locations. Colour code shall be used to differentiate the different waste bins.

Waste Disposal Guidelines

All debris, spoilt materials, rubbish and other waste, shall be cleared from the site during construction and disposed off accordingly at Government designated dump/landfill sites for such wastes.

All wastes in transit shall be tracked by waste consignment note. The waste consignment note records shall be kept and would include as a minimum the following information:

- Date of dispatch.
- Description of waste.
- Waste quantity/container type.
- Designated disposal site and method.
- Consignee /driver name and means of transportation.
- Confirmation of actual disposal (time and date).

Corporate Social Responsibility - *community development plan*

The proposed corporate social responsibility plan is anticipated to be implemented under the following programme:

Hospital and Schools

NSCP/Globeleq/ARM-Harith, together with our partner GE, will establish a solar powered small storage facility of a minimum of 1 MW to power the local hospital and schools and also appoint a local team to train them on installation and maintenance. We expect to be able to match funds for this with funding from the GE Foundation.

Solar Training

NSCP/Globeleq/ARM-Harith would arrange for advanced training in solar PV for a group of engineers and technicians from the Nigerian utility in order to empower them to operate and maintain the solar field. A similar program is underway for Rwandan engineers through Gigawatt Global's project in Rwanda.

Solar Powered Water Pumping

NSCP/Globeleq/ARM-Harith has identified a particular need for potable water in Bauchi State. NSCP/Globeleq/ARM-Harith would partner with a leading European company to provide solar powered water pumping and treatment facilities in order to increase supplies of drinking water and reduce the incidence of water- borne diseases.

Public Consultation

A range of stakeholders including community leaders, household heads, business owners, landlords, structure owners, local authorities and leaders from various administrative levels were consulted as part of the preliminary phase of this project. Appendix 4 presents details of consultation process implemented.

The objective of the consultations undertaken were to:

Disseminate information among potentially affected communities about the intended project;
Identify attitudes of communities towards the project;
Identify the degree of community participation in the project;

Identify anticipated project impacts on the socio-economic and cultural life of the community; and
Identify stakeholders and their roles in project activities.

Consultation with Community Representatives

Consultations were held with representatives of communities to sensitize them on the project and related issues, as well as identify their perception towards the project. Individuals, groups, organizations, and institutions interested in and potentially affected by the project were engaged in a stakeholder's forum where issues relating to the project impacts were discussed.

Key stakeholders identified in the community include:

Community leaders;
Households heads;
Structure owners; and
Farmer/youth associations.

Detailed information on the cut-off-date for the census of affected individuals, assets, and resources were provided to them, as well as the intended socio-economic survey. Annex 1 presents the minutes of meetings and records of community concerns.

Perception of Impacts of the Project by Local Residents

Residents in the area have a positive disposition towards the project. They welcome the potential developments that would come from the projects – employment, improved power supply etc. There are however some concerns from affected households over loss of farmlands and social networks. Worries were also expressed over the possibility of inadequate notice from the authorities in charge of relocation. The most important issues over which all PAP raised concerns were compensation for affected assets, and restoration of livelihoods.

Consultation with Local Administration

Consultations were also held with representatives of the Ministries of Lands, Special Duties, and Environment during which they were sensitized of project activities and their likely impacts. These institutions are aware of the project and provided the required support to the community engagement activities and development of Resettlement Action Plan for the proposed project. The contacted agencies were resourceful in engaging all identified stakeholders.

7.6 Environmental Management System (EMS)

The key components of the EMS that will be developed for this project include:

Commitment by leadership at all levels to foster excellence in all operations by assuring alignment of vision, expectations, resources and accountabilities;

Comprehensive identification of high-level issues, risks, opportunities and gaps in system and operating practices that can impact current or future ability to achieve the required level of performance;

Establish clear metrics to measure statistically significant performance improvement areas towards goals and targets;

Establish processes to ensure documents and records that are critical to operational excellence are current, controlled and accessible;

- Establish and maintain appropriate processes for management to regularly monitor company's HSE performance, conduct regular HSE audits and evaluations to ensure that the system is implemented and maintained and remains effective.

7.7 Reporting Procedures

7.7.1 Internal (HSE

Department)

Any observation of an environmental problem, such as non-compliance or adverse impacts will be reported immediately to the HSE Manager. On a monthly basis, the HSE Manager will prepare a summary HSE report. Any non-compliance or safety issues will be highlighted with proposed corrective actions.

7.7.2 External (Governmental Agencies)

Periodic HSE report summarizing the status of the environment in the plant will be submitted to FMEnv. The reports will summarise the results of all tests performed for the project. Any values exceeding regulatory limits will be specifically identified, together with an explanation of the circumstances involved and corrective measures to ensure compliance in the future.

7.8 ESMP

Implementation

7.8.1 Management

Arrangements

NSCP/Globeleq/ARM-Harith will ensure that the EPC contractor complies with the requirements outlined in the ESMP and any other requirements. NSCP/Globeleq/ARM-Harith Project Manager (PM) will coordinate with the EPC contractor to ensure that the latter develops and implements an effective environmental and social management system (ESMS) for the construction period. The EPC contractor shall be responsible for ensuring that its subcontractors also establish an ESMS to effectively implement the requirements of this ESMP.

Figure 7.1, presents the ESMP implementation arrangement. NSCP/Globeleq/ARM-Harith's External Relations department will be responsible for communicating necessary information to the people of the nearby villages, managing their various concerns especially with regard to disturbances to them due to increased level of activity at the site, noise, vehicular traffic, and presence of construction workers.

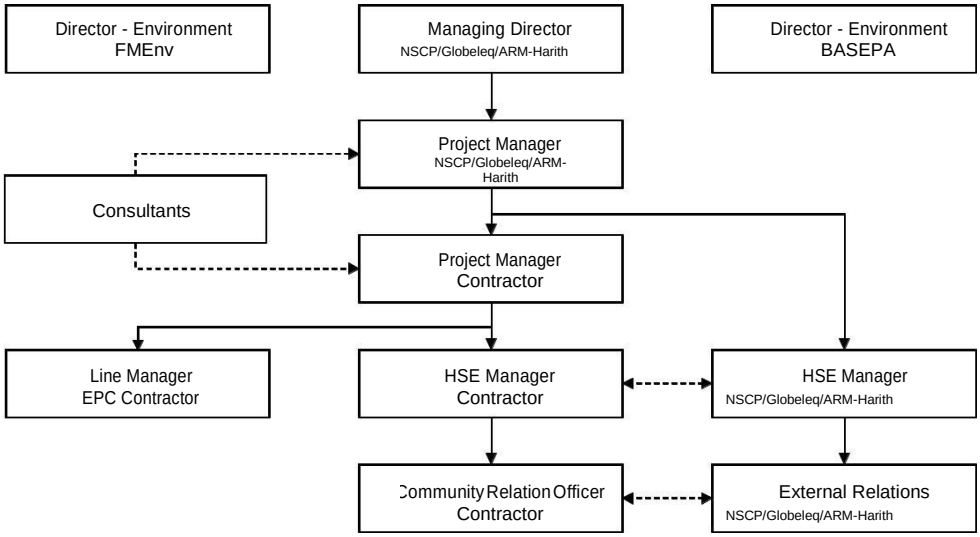


Figure 7.1: ESMP Implementation Arrangement

7.8.2 Capacity Building and Training Programme

Environmental, Health and Safety

NSCP/Globeleq/ARM-Harith will train employees in environmental management programs, plans and procedures. The training will educate employees on the occupational and environmental hazards associated with the work. All staff employed will be trained in the following:

General operation of the plant;
Environmental management;
Specific job roles and procedures;
Occupational health and safety; and
Contingency plans and emergency procedures.

Training will include:

Induction training on appointment;
Specialist training (as required for specific job role); and
Refresher training as required.

In addition, special environmental training will be given to the HSE personnel. They will receive training in the following:

Day-to-day monitoring activities;
Collection and analysis of air quality samples;
Monitoring the water effluents;
Collection and analysis of water quality information;
Use of monitoring equipment, operation and maintenance;
Industrial hygiene;
Occupational health and safety; and
Emergency and contingency procedures.

Social and Community Engagement

To ensure effective engagement with communities around the project area, public officials and NSCP/Globeleq/ARM-Harith public relation team may require refresher trainings to develop skills to facilitate relationships with communities for continuous stakeholder engagement and peaceful co- existence with the project host communities.

Appropriate training should be conducted to develop skills and knowledge related to the following:

- Listening to and understanding the opinions and perspectives of a diversity of stakeholders;
- Negotiation and partnership contracting;
- Interpersonal communication;
- Relationship-building;
- Facilitation;
- Principles of cross-cultural awareness and cross-cultural communication;
- Equity and diversity principles; and
- Public sector values and codes of conduct.

7.8.3 Implementation Schedule and Cost Estimate

The ESMP will be implemented in line with the finalised overall project schedule, as all activities are integrated into the project design. The total cost of implementing the ESMP is estimated at US$ 1.554 million (Table 7.1).

Table 7.1: Summary of Implementation Cost of the ESMP

No.	Phase of Implementation	Estimated Cost (US$)
1	Pre-construction Phase	14,000
2	Construction Phase	300,000
3	Operation Phase	30,000
4	Decommissioning Phase	30,000
5	Training	150,000
6	Community Development Plan	150,000
7	RAP Implementation & Monitoring	830,000
8	Contingency	50,000
	Total	**1,554,000**

The mitigation measures, monitoring plan, implementation arrangement and cost estimates are summarized in Tables 7.2, together with respective environmental management arrangements.

Table 7.2: Environmental and Social Management Plan

Pre-construction Phase

Issue/Impact	Mitigation Measures	Monitoring	Responsibility		Training	Cost (US$)
			Mitigation	Monitoring		
Air Quality						
Dust and air emissions caused by site clearing, grading, levelling, boring of holes and vehicular traffic	– Removal of debris and clearance of stockpiles at frequent intervals – Appropriate siting and maintenance of stockpiles of friable materials so as to minimize dust blow – Wetting of roads via a water sprinkler tanker – Compacting roads where necessary and repair of damaged roads once construction is completed – Restricting onsite vehicle speed limits to <20 km/h – Use of well maintained vehicles and equipment	Monthly monitoring for NO_2, SO_2, CO, and PM Daily observation of dust generation Log of respiratory tract infection among workers Incident reporting system Complaints register	All contractors on site	NSCP HSE Manager, FMEnv	Basic training of persons employed to operate and maintain the monitoring system All employees are given basic induction training on good site management practice	1,000
Noise						
Nuisance (noise and vibrations) due to movement from heavy duty equipment and vehicles affecting public and wildlife.	– Machinery, vehicles and instruments that emit high levels of noise should be used on a phased basis to reduce the overall impact. – Workers should be supplied with ear plugs and ear muffs to reduce the risk of hearing impairment. – Prolonged exposure to this impact should be reduced where possible.	Quarterly monitoring of noise pressure level in dB(A) near noise sources Continuous monitoring is required to ensure contractor complies with ESMP	Contractor and subcontractors	NSCP HSE Manager	All employees are given basic induction training on good site management practices	5,000

	– Plan work activities to avoid heavy duty movement during peak hours – Consult with host communities and plan project activities accordingly – Limit movement and work activities to daytime only – Ensure equipments are properly maintained					
Water Quality						
Water quality impact from surface run-off Accidental spill of lubricant, chemicals or oil Sediment contamination	– Design site drainage to reduce flow velocity and sediment load – Proper site management to minimize surface water run-off, soil erosion and the impacts of sewage effluents – Temporary channels to facilitate run-off discharge into the suitable watercourses, via a silt retention pond – Temporary water/toilet facilities will be provided	Monthly monitoring pH, BOD, TSS, TDS, Turbidity, metals, microbiology, oil & grease, nitrate, conductivity & total nitrogen Implementation of good management practices	Contractor.	NSCP HSE Manager, FMEnv	All employees are given basic induction training on good demolition and site management practices	1,000
Flora & Fauna						
Vegetation loss during clearing and site excavation and wildlife habitat disturbance	– Good site management practices will be observed to ensure that disturbance of habitats off-site are minimized – Restricting personnel and vehicles to site boundaries, lay down areas, and access roads – Minimise vegetation clearance during site preparation – Re-vegetation of native species in open spaces post-construction – Prevention of animal hunting by construction workers – Bird-friendly tower designs to minimise electrocution	Good site management practices Monitor loss of vegetation during site preparation	Contractor and sub-contractors	NSCP HSE Manager	Training on good management practices. Contractor and staff are trained in site restoration Basic training in horticultural practices and tree planting	1,000
Soil Impact						

Erosion, contamination from hazardous waste disposal, oil spillage of chemicals Change in topography	– Development of effective site drainage systems – Restriction of access only to site areas. – Disposal of waste materials at appropriately licensed/approved sites – Management of excavations to avoid the generation of drainage pathways to underlying aquifers – Provision of bunded areas for storage of hazardous materials (e.g. fuel) and equipment maintenance to prevent absorption of spillages – Hazardous wastes must be disposed of by a licensed contractor – Stockpile topsoil for site rehabilitation	Soil & groundwater sampling where contamination is suspected Monthly site inspections Records of compliance with site management plans and mitigation measures	Contractor and subcontractors	HSE Manager	All employees are given basic induction training on good management practices.	3,000
Traffic and Transport						
Increased traffic, heavy equipment and machinery transport	– Schedule of traffic to avoid peak hours on major local roads – Implement traffic management plan optimize/schedule material movement to non peak hours	Continuous monitoring to ensure compliance with traffic management plan	Contractor and subcontractors on site	HSE Manager	Traffic management	1,000
Socio-Economic						
Demography/Population						
Influx of skilled and unskilled workers	Localisation of employment opportunities	Employment records	Contractor	NSCP	Trainings for semi-skilled labours	1,000
Income/Livelihoods						
Loss of livelihood due to loss of farmlands from acquisition of transmission line corridor	– Job creation (contract, temporary and permanent) – Average income and local economy improvement – Resettlement and compensation of	Number of local residences loyed as skilled and unskilled labour Monitor the results of the	Contractor and subcontractors	HSE Manager/NSCP		830,000

	affected people	resettlement action plan and impact on livelihood				
Community Infrastructure						
Disruption of community infrastructure (electricity, water supply, etc) Deterioration of access roads	– Maintain minimal interference with community infrastructure – Replacement of any damaged infrastructure. – Implement a code of conduct for construction workers	Monitoring of infrastructure state in the area	Contractor	NSCP	Not required	60,000
Socio-cultural Institutions						
Violation of socio-cultural values, Social tension and violence	Sensitisation of construction workers to community cultural values	Complaint log	Contractor/ local resource persons	NSCP	Sensitisation programme	10,000
Public Health & Safety						
Increased prevalence of sexually transmitted diseases including HIV/AIDS, Road accidents Increase noise level by equipment Slips, trips and falls, Fires	– Public health awareness – Traffic control and speed limits – Specifications for noise level for heavy equipment – Curfew on operation of heavy equipment and vehicles – Use of personal protective equipment for workers – Provision of adequate fire-fighting equipment onsite – Emergency response/evacuation plan – Implementation of HSE procedures as a condition of contract – Implementation of a Fire Safety Plan prior to starting activities at the site – Clear marking of worksite and hazard recognition	Health records Noise complaint register Periodic inspection of noise monitoring log Regular inspection, review and recording of HSE performance	Contractor	NSCP	Training on emergency preparedness Fire-fighting training HSE talks and toolbox talks Training on use of protective equipment	10,000

	– Maintenance of a high standard of housekeeping at all times					
Hazardous and Solid Waste Management						
Site contamination from litter Soil and ground water contamination from spill of hazardous waste	– Designated waste storage areas for solid wastes – Waste disposal trucks must be adequately covered to minimize windblown litter – Storage areas for hazardous materials must be sealed and bunded – Regular collection and proper disposal of solid waste at a licensed disposal site – Provision of spill kits for on-site management of accidental spills and leaks of contaminants	Monitoring the implementation of waste management plans Record quantities of wastes generated, recycled and disposed	Contractor and subcontractors on site	HSE Manager	Hazardous material handling	15,000

Construction Phase

Issue/Impact	Mitigation Measures	Monitoring	Responsibility		Training	Cost (US$)
			Mitigation	Monitoring		
Air Quality						
Dust and air emissions caused by vehicular movement and delivery of construction materials such as sand and excavation	– Wetting of roads via a water sprinkler tanker – Compacting roads where necessary and repair of damaged roads once construction is completed – Restricting onsite vehicle speed limits to <20 km/h – Use of well maintained vehicles and equipment	Monthly monitoring for NO_2, SO_2, CO, and PM Daily observation of dust generation Log of respiratory tract infection among workers Incident reporting system Complaints register	All contractors on site	NSCP HSE Manager, FMEnv	Basic training of persons employed to operate and maintain the monitoring system All employees are given basic induction training on good site management practice	30,000

Noise						
Use of heavy construction equipment and vehicles	– Enforcement of vehicle speed limits – Strict controls of vehicle routing – Vehicles/equipment to be fitted with silencers	Quarterly monitoring of noise pressure level in dB(A) near noise sources Continuous monitoring is required to ensure contractor complies with ESMP	Contractor and subcontractors	NSCP HSE Manager	All employees are given basic induction training on good site management practices	10,000
Water Quality						
Water quality impact from surface run-off Accidental spill of lubricant. chemicals or oil Sewage discharge from construction camp Sediment contamination	– Design site drainage to reduce flow velocity and sediment load – Proper site management to minimize surface water run-off, soil erosion and the impacts of sewage effluents – Temporary channels to facilitate run-off discharge into the suitable watercourses via a silt retention pond – Temporary water/toilet facilities will be provided	Monthly monitoring pH, BOD, TSS, TDS, Turbidity, metals, microbiology, oil & grease, nitrate, conductivity & total nitrogen Implementation of good management practices	Contractor.	NSCP HSE Manager, FMEnv	All employees are given basic induction training on good demolition and site management practices	35,000
Flora & Fauna						
Vegetation loss during clearing and site excavation and wildlife habitat disturbance	– Good site management practices will be observed to ensure that disturbance of habitats off-site are minimized – Restricting personnel and vehicles to site boundaries, lay down areas, and access roads – Minimise vegetation clearance during	Good site management practices Monitor loss of vegetation during site preparation	Contractor and sub-contractors	NSCP/Globeleq/AR Manager	Training on good management practices. Contractor and staff are trained in site restoration Basic training in horticultural practices and	30,000

	site preparation – Re-vegetation of native species in open spaces post-construction – Prevention of animal hunting by construction workers – Bird-friendly tower designs to minimise electrocution				tree planting	
Soil Impact						
Erosion, contamination from hazardous waste disposal, oil spillage of chemicals Change in topography	– Development of effective site drainage systems – Restriction of access only to site areas. – Disposal of waste materials at appropriately licensed/approved sites – Management of excavations to avoid the generation of drainage pathways to underlying aquifers – Provision of bunded areas for storage of hazardous materials (e.g. fuel) and equipment maintenance to prevent absorption of spillages – Hazardous wastes must be disposed of by a licensed contractor – Stockpile topsoil for site rehabilitation	Soil & groundwater sampling where contamination is suspected Monthly site inspections Records of compliance with site management plans and mitigation measures	Contractor and subcontractors	HSE Manager	All employees are given basic induction training on good management practices.	60,000
Traffic and Transport						
Increased traffic, heavy equipment and machinery transport	– Schedule of traffic to avoid peak hours on major local roads – Implement traffic management plan optimize/schedule material movement to non peak hours	Continuous monitoring to ensure compliance with traffic management plan	Contractor and subcontractors on site	HSE Manager	Traffic management	10,000
Socio-Economic						
Demography/Population						
Influx of skilled and	Localisation of employment	Employment records	Contractor	NSCP/Globeleq/ARM-Harith	Trainings for semi-skilled	30,000

unskilled workers	opportunities				labours	
Income/Livelihoods						
Loss of livelihood due to loss of farmlands from acquisition of transmission line corridor	– Job creation (contract, temporary and permanent) – Average income and local economy improvement – Resettlement and compensation of affected people	Number of local residences employed as skilled and unskilled labour Monitor the results of the resettlement action plan and impact on livelihood	Contractor and subcontractors	HSE Manager/NSCP		830,000
Community Infrastructure						
Disruption of community infrastructure (electricity, water supply, etc) Deterioration of access roads	– Maintain minimal interference with community infrastructure – Replacement of any damaged infrastructure. – Implement a code of conduct for construction workers	Monitoring of infrastructure state in the area	Contractor	NSCP/Globeleq/ARM-Harith	Not required	60,000
Socio-cultural Institutions						
Violation of socio-cultural values, Social tension and violence	Sensitisation of construction workers to community cultural values	Complaint log	Contractor/ local resource persons	NSCP/Globeleq/ARM-Harith	Sensitisation programme	10,000
Public Health & Safety						
Increased prevalence of sexually transmitted diseases including HIV/AIDS, Road accidents	– Public health awareness – Traffic control and speed limits – Specifications for noise level for heavy equipment – Curfew on operation of heavy equipment and vehicles – Use of personal protective equipment	Health records Noise complaint register Periodic inspection of noise monitoring log	Contractor	NSCP/Globeleq/ARM-Harith	Training on emergency preparedness Fire-fighting training HSE talks and toolbox	10,000

Increase noise level by equipment Slips, trips and falls, Fires	for workers – Provision of adequate fire-fighting equipment onsite – Emergency response/evacuation plan – Implementation of HSE procedures as a condition of contract – Implementation of a Fire Safety Plan prior to starting activities at the site – Clear marking of worksite and hazard recognition – Maintenance of a high standard of housekeeping at all times	Regular inspection, review and recording of HSE performance			talks Training on use of protective equipment	
Hazardous and Solid Waste Management						
Site contamination from litter Soil and ground water contamination from spill of hazardous waste	– Designated waste storage areas for solid wastes – Waste disposal trucks must be adequately covered to minimize windblown litter – Storage areas for hazardous materials must be sealed and bunded – Regular collection and proper disposal of solid waste at a licensed disposal site – Provision of spill kits for on-site management of accidental spills and leaks of contaminants	Monitoring the implementation of waste management plans Record quantities of wastes generated, recycled and disposed	Contractor and subcontractors on site	HSE Manager	Hazardous material handling	15,000

Operational Phase

Issue/Impact	Mitigation Measures	Monitoring	Responsibility		Training	Cost (US$)
			Implementation	Supervision		
Water Quality						
Discharge of PV module wash-water, domestic waste water,	– Treatment of wash water before discharge – Off-site disposal of sewage by appropriate waste collection and disposal authority	Monitor water quality for temperature, pH, COD, BOD, TOC, DO,	NSCP /Globe leq/A PM	BASEPA		10, 000

Issue/Impact	Mitigation Measures	Monitoring	Responsibility		Training	Cost (US$)
			Implementation	Supervision		
sewage Over abstraction can lead to rivers drying up thereby leading to mortality of fish and invertebrates or the level of groundwater aquifers reducing unacceptably	– Regular maintenance of site drainage system to ensure efficient operation – All discharges will comply with national and World Bank guidelines – Groundwater study will be required to assist NSCP in taking informed decision on controlled abstraction limit on the amount of water that can be extracted per time. – Water conservation measures through recycling and reuse	TSS, heavy metals Records of wastewater monitoring and compliance with standards				
Flora and Fauna						
Habitats disturbance as a result of noise, vehicle and personnel movement, Bird mortality along the Transmission line	– Restrict personnel and vehicle movements to site boundaries only	Annual inspections of wildlife, native habitats and agricultural crops in surrounding areas	NSCP /Globe leq/A RM-Harith	BASEPA	Re-vegetation where required	5,000
Visual Impact						

Issue/Impact	Mitigation Measures	Monitoring	Responsibility		Training	Cost (US$)
			Implementation	Supervision		
Visual image of solar plant from surrounding areas.	– The visual effect of the solar plant will be improved through creation and maintenance of landscaped boundary around the plant	No monitoring is envisaged	NSCP/Globeleq/ARM-Harith	BASEPA	Contract a firm to manage landscaped areas.	
Soil and Hydrology						
Spillage of oils, chemicals or fuels on site	– Regular checks of bunds and drainage systems to ensure containment and efficient operation – Develop an oil spill contingency plan	Continuously monitoring and good site management practices	NSCP/Globeleq/ARM-Harith	BASEPA	Spills Response	500
Solid Waste	– Good disposal practice	Records of final disposal of waste Log of waste generated	NSCP/Globeleq/ARM-Harith	BASEPA	Training on good operation and site management practices	500
Demography/population						
Influx of contractors and business workers	– Proper recruitment process – Maximise local employment opportunities	Periodic survey of business services in project area	NSCP/Globeleq/ARM-Harith	Local regulatory authorities	Not required	Included in bidding document
Community Infrastructure						
Pressure on social amenities	– Provision of additional amenities to support the increasing population	Periodic monitoring of state of infrastructure on service delivery	NSCP/Globeleq/ARM-Harith			1,000
Socio-cultural values						
Social conflict & tension	– Sensitize staff on community cultural values – Periodic community consultation meeting	Community complaint log	Contractors/ local resource	Regulatory authorities	Sensitisation programme	2,000

Issue/Impact	Mitigation Measures	Monitoring	Responsibility		Training	Cost (US$)
			Implementation	Supervision		
			persons/ NSCP/Globeleq/ARM-Harith			
Public Health & Safety						
Traffic & Accidents Contamination of water bodies Crime	– Proper traffic control – Standard operating procedures to keep waste parameters within permissible limit – Police patrol and organised community vigilante	Health records Period checks for compliance to health and safety procedures Crime rate records	NSCP/Globeleq/ARM-Harith	Regulatory authority		1,000
Occupational Health and Safety						
	– Standard International HSE Practice shall be employed on site – Use of protective equipment – Clear marking of work site hazards and training in recognition of hazard symbols – Development of site emergency response plans	Regular on-site HSE training, fire drill etc Regular staff checks, system checks and field tests of emergency procedures by on-site management	NSCP/Globeleq/ARM-Harith	Regulatory authority	Induction training on H&S policies and procedures, Emergency Response, Spills Response Training on use of protection equipment and chemical handling	10,000

Decommissioning/Abandonment Phase

Issue/Impact	Mitigation Measures	Monitoring	Responsibility		Training	Cost (US$)
			Mitigation	Monitoring		
Air Quality						

Temporary elevated noise levels from equipment and vehicular traffic Localised gaseous emissions from machinery and vehicles Fugitive dust emissions in adjacent areas	– Ensure work is restricted to day-time hours – Use of well maintained vehicles and equipment	Daily observation of dust generation Log of respiratory tract infection among workers Incident reporting system Complaints register	All contractors on site	NSCP/Globeleq/AR Manager, FMEnv	All employees are given basic induction training on good site management practice	1,000
Noise						
Use of heavy equipment and vehicles	– Enforcement of vehicle speed limits – Strict controls of vehicle routing – Vehicles/equipment to be fitted with silencers	Continuous monitoring is required to ensure contractor complies with ESMP	Contractor and subcontractors	NSCP/Globeleq/AR Manager	All employees are given basic induction training on good site management practices	500
Water Quality						
Water quality impact from surface run-off Accidental spill of lubricant, chemicals or oil Sediment contamination	– Ensure disturbed areas are levelled, restored, and re-vegetated in order to minimise soil erosion – Ensure electrical components are properly isolated and demolished – Ensure adequate spill protection is employed during decommissioning	Implementation of good management practices	Contractor.	NSCP/Globeleq/AR Manager, FMEnv	All employees are given basic induction training on good demolition and site management practices	500
Flora & Fauna						
Vegetation loss during clearing and site excavation and wildlife habitat disturbance	– Good site management practices will be observed to ensure that disturbance of habitats off-site are minimized – Restricting personnel and vehicles to site boundaries, lay down areas, and access roads – Re-vegetation of native species in	Good site management practices	Contractor and sub-contractors	NSCP/Globeleq/AR Manager	Training on good management practices. Contractor and staff are trained in site restoration Basic training in horticultural practices and	1,000

	open spaces post-construction				tree planting	
Soil Impact						
Reversal of land use from construction and operation Erosion of soil due to surface disturbance and exposure from removal of structures Exposure of land surface	– Ensure minimal surface area disturbance during decommissioning. Grading activities should be limited to areas previously disturbed – Ensure site is re-graded to leave it smooth, regular and maintain natural drainage patterns – Ensure open gaps from the removal of structures in the ground are backfilled with topsoil and subsoil and graded to ensure adequate drainage – Ensure appropriate erosion control measures are adopted according to best practices including soil de-compaction and re-contouring to blend with the surrounding areas.	Records of compliance with site management plans and mitigation measures	Contractor and subcontractors	HSE Manager	All employees are given basic induction training on good management practices.	1,000
Traffic and Transport						
Increased traffic, heavy equipment and machinery transport	– Schedule of traffic to avoid peak hours on major local roads – Implement traffic management plan optimize/schedule material movement to non peak hours	Continuous monitoring to ensure compliance with traffic management plan	Contractor and subcontractors on site	HSE Manager	Traffic management	1,000
Socio-Economic						
Demography/Population						
Influx of skilled and unskilled workers	Localisation of employment opportunities	Employment records	Contractor	NSCP/Globeleq/ARM-Harith	Trainings for semi-skilled labours	5,000
Income/Livelihoods						
Loss of livelihood due to	– Ensure early disengagement notification	Monitor post decommissioning	Contractor and	HSE		

disengagement of personnel Availability of land for alternative uses	– Relevant government agencies together with stakeholders shall work out processes for land relinquishment or alternative uses as at the time of decommissioning.	state of the environment	subcontractors	Manager/ NSCP/Globeleq/ARM-Harith		
Community Infrastructure						
Disruption of community infrastructure (electricity, water supply, etc) Deterioration of access roads	– Maintain minimal interference with community infrastructure – Replacement of any damaged infrastructure. – Implement a code of conduct for construction workers	Monitoring of infrastructure state in the area	Contractor	NSCP/Globeleq/ARM-Harith	Not required	60,000
Visual Amenity						
Increased activity over de-commissioning period Removal of solar plant infrastructure and facilities	– Ensure site is adequately fenced off during decommissioning – Ensure site is restored to its near pre-construction state and to match the surrounding environment after de-commissioning	Complaint log	Contractor/ local resource persons	NSCP/Globeleq/ARM-Harith	Sensitisation programme	10,000
Public Health & Safety						
Increased prevalence of sexually transmitted diseases including HIV/AIDS, Road accidents Increase noise level by equipment Slips, trips and falls	– Public health awareness – Traffic control and speed limits – Specifications for noise level for heavy equipment – Curfew on operation of heavy equipment and vehicles – Use of personal protective equipment for workers – Provision of adequate fire-fighting equipment onsite – Emergency response/evacuation plan – Implementation of HSE procedures as a condition of contract	Health records Noise complaint register Periodic inspection of noise monitoring log Regular inspection, review and recording of HSE performance	Contractor	NSCP/Globeleq/ARM-Harith	Training on emergency preparedness Fire-fighting training HSE talks and toolbox talks Training on use of protective equipment	10,000

Fires	– Implementation of a Fire Safety Plan prior to starting activities at the site – Clear marking of worksite and hazard recognition – Maintenance of a high standard of housekeeping at all times					
Hazardous and Solid Waste Management						
Site contamination from litter Soil and ground water contamination from spill of hazardous waste	– Ensure recycling of solar modules at the end of their useful life through an approved facility or contractor – Ensure reusable materials are transferred to an approved contractor or offtaker – Ensure complete removal of waste materials and adequate disposal through an approved contractor	Monitoring the implementation of waste management plans Record quantities of wastes generated, recycled and disposed	Contractor and subcontractors on site	HSE Manager	Hazardous material handling	15,000

7.8.4 Proponent and Regulatory Agencies' Requirements

The proposed solar power generation is not likely to have any negative impacts on the biophysical and social environment within and around study area. However, the onus of maintaining a sustainable environment in the proposed project area lies on NSCP/Globeleq/ARM-Harith and the various institutions / agencies that are involved in this project. This section apportions roles and responsibilities to all the various parties involved in the implementation of the project.

– ***Staffing and Training***

NSCP/Globeleq/ARM-Harith shall ensure that for the purpose of the proposed project, every category of its personnel is adequately trained on the various aspects of the job. Personnel will be trained on effective maintenance of all equipment on site.

NSCP/Globeleq/ARM-Harith shall also reinforce staff training with regular induction courses and refresher courses/programmes.

– ***Emergency Response Plan (ERP)***

NSCP/Globeleq/ARM-Harith shall develop an Emergency Response Plan (ERP) that shall cover actual and potential incident/accident (including fire outbreak) that might occur in the course of the operation activity. The development of the emergency response plan will provide NSCP/Globeleq/ARM-Harith with a framework for responding to emergency incidents. Drills will be conducted regularly to ascertain the efficiency of the ERP.

– ***Facilities Surveillance***

This is a very important requirement for the environmental sustainability of the proposed project. Constant surveillance of the PV panels will be necessary so as to detect on time, its malfunctioning or deterioration, with the aim of taking prompt corrective/repair measures, as well as to protect them from intruders.

NSCP/Globeleq/ARM-Harith shall put in place a sound surveillance schedule plan that will be operative throughout the life span of the project.

– ***Environmental Monitoring Requirements***

Environmental monitoring is the systematic collection of environmental data through a series of repetitive measurements. It is essentially a process aimed at measuring the accuracy of predicted impacts of the project as well as measuring the efficacy of recommended mitigation measures. It serves as an early-warning tool to take actions for any residual/new impacts and improvement of mitigation measures. For the proposed project, the main focus of the environmental monitoring shall be on ambient air quality and noise level management as there would be no effluent discharge from the facility.

The baseline for the environmental monitoring shall be the database contained in chapter four (4) of this report while standards shall be in accordance with FEPA 1998 now FMEnv. The environmental monitoring schedule and requirements for the proposed project activities in Bauchi is presented in Table 7.3.

– ***Future Consultations Plan***

The Bauchi State Ministry of Special Duties (MoSD) has the responsibility for conducting future Public Consultation and Disclosure Plans in conjunction with the proponent as

presented Community Engagement Plan detailed in Appendix 6. The goal of the plan will be to improve decision-making through dialogue with individuals, groups and organizations having legitimate interest in the project. The plan will include key features such as:

- Creation of multi-stakeholder committees to identify and address project impact and community concerns including compensation modalities and resettlement time lines;
- Ensure that affected persons are knowledgeable of resettlement policies and capable of responding to questions/comments appropriately in local dialects or English;
- Choosing the venue for Public Consultations;
- Hosting regular documented meetings between PAP and their representatives;
- Maintenance of an open-door policy through which PAP can seek advice and lodge complaints; and
- Creation of a responsive management system for recording and responding to comments and concerns.

Resettlement Consultation and Disclosure Activities

The proponent (NSCP/Globeleq/ARM-Harith) in conjunction with the MoSD will undertake a comprehensive and formal negotiation process with PAP and other stakeholders to determine mutually agreed compensation policies, procedures and rates. The negotiation process will be complemented by series of consultation and disclosure activities. The activities will involve formal and informal dialogue with stakeholders and relevant agencies on regular basis to ensure that all Stakeholders are engaged in the resettlement planning and implementation process.

This process will involve:

The formation of a Resettlement Negotiations Committee, involving all stakeholders;

Collaboration between stakeholder groups at the Resettlement Negotiation Committee;

An agreement on the compensation principles, policies, procedures and rates described in this document;

Alleviating pressures, fears and anxieties of both impacted persons/households; and

Promoting broad community support for the Project.

The Resettlement Negotiation Committee meetings will serve as the primary vehicle for negotiating compensation principles, policies, procedures and rates.

Importantly, these meetings will also:

Promote a spirit of cooperation between the proponent, Bauchi State Government and the representatives of impacted people / households.

Enable the committee to resolve contentious resettlement issues, and assess individual complaints on a case-by-case basis;

Ensure that information is disclosed in a transparent, culturally appropriate way.

Table 7.3: Environmental Monitoring Schedule for the Project

Environmental Attributes	Schedule	Parameters	Sampling Location	Sampling Frequency	Sampling Method	Responsible Officer
Air Quality	Construction and operation phase	TSP, CO, NO_2, SO_2, VOC	1. Around the project site 2. Around the settlement	Weekly during the construction phase and monthly during operation phase for a period of 2 years	Portable Air Monitoring Equipment	NSCP Environmental Officer
Noise	Construction and operation phase	Noise level	1. Around the project site 2. Around the settlement	Weekly during the construction phase and monthly during operation phase for a period of 2 years	Portable Sound level meter	NSCP Environmental Officer
Water Quality	Operation phase	pH, BOD, COD, Dissolved Oxygen, Salinity, Temperature, Total Suspended Solids, Total Dissolved Solids, Exchangeable Cations (Ca^{2+}, K^+, Mg^{2+}, Na^+) and Anions (CI^-, SO_4^{2-}, NO_3^-, PO_4^{3-}), Total Petroleum Hydrocarbon, Heavy Metals	1. Around the project site 2. Around the settlement	Monthly during operation phase	Insitu/Laboratory Analysis	NSCP Environmental Officer

Environmental Attributes	Schedule	Parameters	Sampling Location	Sampling Frequency	Sampling Method	Responsible Officer
Bird Mortality	Operation phase	Bird mortality	1. Along the transmission line	Monthly during operation phase	Visual count	NSCP Environmental Officer

Chapter Eight: Decommissioning and/or Abandonment Plan

8.1 Introduction

Most development projects have useful lives, beyond which they are no longer economically viable either as a result of depleted feed stock or competing technology. Upon the completion of useful life cycle, there is a need to abandon and/or decommission such projects.

The proposed solar power generation is expected to have a life span of 25 years. It is envisaged that technology and environmental policies could have changed so drastically by then, hence a definite decommissioning plan cannot be put in place for now. However, it is of importance that abandonment activities be planned in advance. The planning shall be done in accordance with the Nigerian regulatory requirements.

8.2 Decommissioning

During decommissioning, NSCP/Globeleq/ARM-Harith shall ensure that the project sites are returned to a safe and environmentally acceptable condition. The process of decommissioning shall, amongst others, include the following tasks:

- restore the environment to allowable baseline conditions and monitor the process in line with legislative and regulatory requirements and best industry standards; and
- assess the residual impacts, if any, that the project has on the environment; and specifically if there are any future restrictions for other activities.

8.3 Abandonment Plan

In the event of the project being abandoned, this shall be done in accordance with strict compliance with legislative requirements and international best practices. The abandonment process shall be carried out as follows:

Relevant stakeholders shall be duly informed;

Physical Asset Verification (PAV) of the facilities shall be carried out;

National Sectoral Regulations, as they affect the abandonment of the project, shall be strictly complied with to ensure:

- Restoration and rehabilitation of the environment;
- Management of residual impacts of the project in strict compliance with extant National/FMEnv sectoral regulations.

In addition, a site close-out permit shall be obtained as appropriate.

Chapter Nine: Conclusion and Recommendations

9.1 Summary and Conclusion

This Environmental and Social Impact Assessment (ESIA) Report was prepared in accordance with the requirements of the FMEnv. The impact assessment, based on interactions between project activities and the recipient environment, has been well documented in this report.

The proposed 100MW solar power generation in Bauchi State, Nigeria by NSCP/Globeleq/ARM-Harith is justifiable and will have a number of significant positive values including:

Reduce Environmental Pollution;

Minimize global warming and climate change;

Ensure uninterrupted power supply, which will boost commercial and industrial activities in the area;

Contribute to national power generation.

Create employment opportunities for the people of the area.

The overall impacts associated with the activities of the proposed project can demonstrably be managed within reasonable and acceptable limits by applying all the recommended mitigation measures.

In addition to the identified mitigation measures, there are a number of other commitments to be followed:

Undertake a Best Practicable Environmental Option (BPEO) for the transmission line and access roads;

Define and undertake monitoring for atmospheric emissions, water discharges and social impacts;

Regular audits to be undertaken on the environmental performance of the project operational elements;

Studies will be undertaken to determine the best decommissioning strategy towards the end of the project lifecycle; and

Implement a CDP (Community Development Plan) and commit to supplying bordering communities with basic utilities such as electricity, running water, roads, schools, or health care.

An Environmental and Social Management Plan (ESMP) has also been drawn up to manage residual impacts, ensure compliance with regulatory requirements and the incorporation of environmental controls throughout the project life cycle.

In view of all that had been documented in this ESIA report and the commitment by NSCP/Globeleq/ARM-Harith to ensure strict compliance with this EIA, NSCP/Globeleq/ARM-Harith hereby requests the National Regulatory body, the FMEnv, for its Approval to enable the commencement of the proposed project.

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