Author(s):	Sumo S. Momolu - Mining Engineering Consultant	
Date:	26/11/2024	
Version / Status:	FINAL	
Print Date:	26/11/20224	
Copies:	Environmental Protection Agency Western Cluster Limited	(8 hardcopies + 1 Flash Drive) (1 hardcopy + 1 Soft Copy)

Document Review and Sign Off

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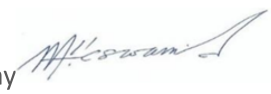
Walter S. McCarthy 

Checked by:

Document Change Control

Version	Description (section(s) amended)	Author(s)	Date

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ACRONYMS

^{o}C	Temperature in degrees Celsius
µg	Microgram
ADI	Area of Direct Influence
ADP	Agricultural Development Projects
AERMIC	AMS/EPA Regulatory Model Improvement Committee
AERMOD	AERMIC Dispersion Model
AfDB	African Development Bank
AHA	African Humanitarian Action
AHUs	Air Handling Units
AII	Area of Indirect Influence
Airshed	Airshed Planning Professionals (Pty) Ltd
AITB	Agricultural and Industrial Training Bureau
Al	Aluminium
ALARP	As Low As Reasonably Practicable
AMS	Artisan Mining Sector
ANFO	Ammonium Nitrate Fuel Oil
AoI	Area of Influence
AOO	Area of Occupancy
APELL	Awareness and Preparedness for Emergencies at Local Level
AQSR	Air Quality Sensitive Receptors
ARD	Acid Rock Drainage
ARI	Acute Respiratory Illness
ASG	Atmospheric Studies Group
ASPT	Average Score per Taxon
ASTM	American Society for Testing and Materials
ATSDR	Federal Agency for Toxic Substances and Disease Registry
BDI	Biological Diatom Index
BESU	Bengal Engineering and Science University
BID	Background Information Document
BIF	Banded Iron Formation
BMFR	Bomi Mines Feasibility Report
BMQ	Banded Magnetite Quartzite
BOD	Biochemical Oxygen Demand
BPHS	Basic Package of Health Services
CA	Certificate of Approval
CBL	Central Bank of Liberia
CDR	Crude Death Rate
CEAP	County Environment Action Plans
CEO	County Education Officer
CER	Certified Emissions Reductions
CH4	Methane
CHSWTs	County Health and Social Welfare Team

CITES	Convention on International Trade in Endangered Species
CLO	Community Liason Officer
CO	Carbon Monoxide
CO2	Carbon Dioxide
CO2e	Carbon Dioxide Equivalent
COD	Chemical Oxygen Demand
COP	Conference of Parties
CPRs	Common Property Resources
CR	Critically Endangered
CSR	Corporate Social Responsibility
CZ	Central Zone
dB	Decibels
DD	Data Deficient
DIN	German Deutsches Institut fuer Normung
DPM	Diesel Particulate Matter
DSO	Direct Shipping Ore
DSTV	Digital Satellite Television
DTM	Digital Terrain Model
EC	Electrical Conductivity
ECOWAS	Economic Community of West African States
EEC	Earth Environmental Consultancy Incorporated
EHS	Environmental, Health and Safety
EIA	Environmental Impact Assessment
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
EITI	Extractive Industries Transparency Initiative
EM	Environmental Manager
EMP	Environmental Management Plan
EMS	Environmental Management System
EN	Endangered
EOO	Total Extent of Occurrence
EPA	Environmental Protection Agency
EPAA	Environment Protection Agency Act
EPFI	Equator Principles Financial Institutions
EPHS	Essential Package of Health Services
EPML	Environmental Protection and Management Law of Liberia
EPRP	Emergency Preparedness and Response Plan
EPs	Equator Principles
EPSS	Essential Package of Social Services
ERC	Emergency Response Coordinator
ERM	Environmental Resources Management
ERT	Emergency Response Team
ESIA	Environmental Social Impact Assessment
ESMP	Environmental and Social Management Plan

EWD	Eastern Waste Dump
EZ	Eastern Zone
FAO	Food and Agriculture Organization
FDA	Forestry Development Authority
FDA	Food and Drug Administration (United States)
FDI	Foreign Direct Investment
Fe	Iron
FEED	Front End Engineering and Design
FGD	Focussed Group Discussion
FGM	Female Genital Mutilation
FIBLL	First International Bank Liberia
FONSI	Found of No Significant Impact
FoV	Field of Vision
FPIC	Free, Prior, and Informed Consent
FRP	Fibreglass Reinforced Plastic
FSNS	Comprehensive Food Security and Nutrition Survey
GDI	Gender Related Development Index
GDP	Gross Domestic Product
GEF	Global Environmental Facility
GHG	Greenhouse Gas
GIIP	Good International Industry Practice
GLCC	Global Land Cover Characterisation
GMCs	Grievance management Cells
GoL	Government of Liberia
GPS	Geographic Positioning System
GRC	Grievance Redressal Committee
GRM	Grievance Redressal Mechanism
GSM	Gravel, Sand and Mud
GTBL	Guaranty Trust Bank Liberia
GVs	Guideline Values
GWP	Global Warming Potential
HC	Hydro Carbons
HEMM	Heavy Earth Moving Machinery
HF	High Flow
HFCE	Household Final Consumption Expenditure
HFO	Heavy Fuel Oil
HH	Household
HPGR	High Pressure Grinding Roll
HSE	Health Safety and Environment
Hz	Hertz
IA	Impact Assessment
IBAs	Important Bird Areas
ICMM	International Council on Mining and Metals
ICP	Informed Consultation and Participation

IDPs	Internally Displaced Persons
IFC	International Finance Corporation
IFI	International Financial Institution
IH	Instream Habitat
IHI	Index of Habitat Integrity
ILO	International Labor Organization
IPCC	Intergovernmental Panel on Climate Change
IPDP	Indigenous People Development Plan
IRIS	Integrated Risk Information System
ISO	International Standards organization
ITCZ	Inter Tropical Convergence Zone
ITTA	International Tropical Timber Agreement
IUCN	International Union for the Conservation of Nature
IWRMP	Integrated Water Resources Management Plan
kg	Kilogram
km	Kilometer
KOP	Key Observation Point
KPIs	Key Performance Indicators
kWh	Kilowatt Hour
LAC	Liberia Agriculture Company
LBBC	Liberia Beverage and Bottling Company
LBDI	Liberian Bank for Development and Investment
LC	Least Concern
LF	Low Flow
LiDAR	Light Detection and Ranging
LIFE	Liberia Indigenous Forum for the Environment
LIMS	Low Intensity Magnetic Separators
LMC	Liberia Mining Company
Lmo	Monin-Obukhov length
LNP	Liberia National Police
LOM	Life of Mine
Lp	Sound Pressure Level
LPG	Liquid Petroleum Gas
LPP	Local Procurement Plan
LRRRC	Liberia Refugee Repatriation and Resettlement Commission
LSFRP	Liberian-Swedish Feeder Road Project
LTA	Liberia Telecom Authority
LVIA	Landscape and Visual Impact Assessment
LW	Sound Power Level
LWSC	Liberia Water and Sewage Corporation
m	Meter
m^2	Meter Squared
m^3	Meter Cubed
mamsl	Meters above mean sea level

MAP	Mean Annual Precipitation
mbs	Meters below surface
MCH	Maternal and Child Health
MCIMS	Mineral Cadastre Information Management System
MDA	Mineral Development Agreement
MEAs	Multilateral Environmental Agreements
mg	Milligram
ML	Mining Lease
MoA	Ministry of Agriculture
MoF	Ministry of Finance
MoH	Ministry of Health and Social Welfare
MoI	Ministry of Internal Affairs
MoJ	Ministry of Justice
MoLME	Ministry of Land, Mines and Energy
MoPW	Ministry of Public Works
MoT	Ministry of Transport
MRL	Minimum Risk Level
Mt	Million Tonnes
Mtpa	Million tonnes per annum
MW	Mega Watt
NEAP	National Environmental Action Plan
NEAP	National Environmental Action Plan
NEC	National Energy Committee
NECOLIB	National Environmental Commission of Liberia
NEP	National Environmental Policy
NEPC	National Environmental Policy Council
NFPA	National Fire Protection Association
NGO's	Non-Government Organizations
NHSB	National House and Savings Bank
NIOC	National Iron Ore Company
NLTCP	National Leprosy and Tuberculosis Control Program
NO	Nitrogen Monoxide
NO2	Nitrogen Dioxide
NOAEL	No Observed Adverse Effect Level
NoI	Notice of Intent
NOx	Nitrogen Oxides
NPA	National Ports Authority
NPI	Australian National Pollutant Inventory
NSR	Noise Sensitive Receptor
NSSRL	National Security Sector Strategy for the Republic of Liberia
NSSRL-IM	National Security Sector Strategy for the Republic of Liberia - Implementation Matrix
NT	Near Threatened
NTMP	National Transport Master Plan

NWWD	North Western Waste Dump
O3	Ozone
OECD	organization for Economic Co-operation and Development
OPD	Out-Patients Department
PAH	Polycyclic Aromatic Hydrocarbons
PAH	Project-Affected Household
PAP	Project Affected People
PAPs	Project Affected Parties
PBPK	Pharmacokinetic
PDF	Postscript Data File
PFC	Perflourocarbon
PLP	Project Linkage Plan
PM	Particulate Matter
PM10	Thoracic particulate matter with an aerodynamic diameter of less than 10mm
PM2.5	Thoracic particulate matter with an aerodynamic diameter of less than 2.5mm
POPs	Persistent Organic Pollutants
PPE	Personal Protective Equipment
ppm	Parts per Million
PPV	Peak Particle Velocities
PRS	Poverty Reduction Strategy
PS	Performance Standards
RAP	Resettlement Action Plan
RC	Resettlement Committee
RCC	Reinforced Cement Concrete
REL	Reference Exposure Level
RfCs	Inhalation Reference Concentrations
RH	Riparian Habitat
ROM	Run of Mine
RPF	Resettlement Policy Framework
RRAP	Resettlement and Rehabilitation Action Plan
RTA	Road Traffic Accidents
S	Storativity
SA DEA	South African Department of Environmental Affairs
SA	South African National Ambient Air Quality Standards
SABS	South African Bureau of Standards
SANS	South African National Standards
SAP	Social Action Plan
SASS5	South African Scoring System 5
SCUK	Save the Children UK
SDF	Social Development Fund
SEP	Stakeholder Engagement Plan
SIA	Social Impact Assessment

SIC	Stones in Current
SIDA	Swedish International Development Cooperation Agency
SMP	Soil Management Plan
SMU	Social Management Unit
SO2	Sulphur Dioxide
SOOC	Stones out of Current
SoW	Scope of Work
SRTM	Shuttle Radar Topography Mission
STDP	Skills and Technology Development Plan
STIs	Sexually Transmitted Infections
STP	Sewage Treatment Plant
SWWD	South Western Waste Dump
T	Transmissivity (m2/d)
TB	Tuberculosis
TC	Tolerable Concentration
TC	Tribal Certificate
TCE	Tata Consulting Engineers
tCO2e	Tonne of Carbon Dioxide Equivalent
TDS	Total Dissolved Solids
TOKTEN	Transfer of Knowledge through Expatriate Nationals
ToR	Terms of Reference
TS	Technical Standards
TSF	Tailings Storage Facilities
TSP	Total Suspended Particulate Matter
TWQR	Target Water Quality Range
UBALL	United Bank for Africa Liberia Ltd
UBN	Unmet Basic Needs
UGF	Upper Guinea Forest
UNCCD	United Nations Convention to Combat Desertification
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
UNMIL	United Nations Mission in Liberia
UNPOL	United Nations Police
URFs	Unit Risk Factors
USBM	United States Bureau of Mines Standard
USGS	United States Geological Survey
UTI	Urinary Tract Infections
VEG	Vegetation
VET	Vocational Education and Training
VOCs	Volatile Organic Compounds
VOD	Velocity of Detonation
WBCSD	World Business Council on Sustainable Development

NON-TECHNICAL SUMMARY

An Environmental and Social Impact Assessment (ESIA) has been undertaken to assess the potential environmental and social impacts associated with the proposed development of the Bomi Hills Mine in Liberia.

The report has been prepared for **Western Cluster Ltd (WCL)** by **Mac-Africa Consultants, Incorporated**, an EPA certified environmental consultancy firm, it and presents the objectives, methodology and outcomes of the ESIA.

The purpose of the ESIA is to update the initial environmental and social impact assessment report done in 2013 by assessing the direct and potential impacts of the project and project-related activities on the biophysical and socio-economic environments, including public health. The ESIA process assimilates the Environmental Protection and Management Law of Liberia (EPML) 2002 requirements as well as the international standards, Vedanta's own sustainability standards and the best practices.

The major project components under this ESIA are the mine operations – the production of 4 Million tonnes per annum (Mtpa). The ore produced is being transported via the existing road between Bomi Hills and the Freeport of Monrovia, and the alternative ore haul road alignment from Tubmanburg to Bamboja along the coast in Bomi County from where the ore will be transported by sea vessels to the Freeport of Monrovia.

Screening and scoping exercises were previously undertaken as part of the ESIA process. The scoping stage identified a number of key project activities that had the potential to interact with sensitive receivers/receptors and result in significant impacts. As such, assessments were undertaken to look at the potential impacts on surface and ground water, aquatic and terrestrial ecology, noise and vibration, air quality, landscape and visual resources and potential socio-economic resources.

STAKEHOLDER ENGAGEMENT

Stakeholder engagement and consultation was undertaken prior to and during the ESIA process. This allowed stakeholders to interact with the decision-making process, express their views and influence mitigation and technical solutions to concerns voiced during the process. The key steps involved in the stakeholder engagement are:

- Stakeholder identification process;
- Information dissemination to the stakeholders;

- Stakeholder engagement process;
- The outcomes of the consultations to date;
- Stakeholder analysis; and
- Way forward: stakeholder engagement plan and grievance response mechanism

Stakeholder engagement is considered as a continuous process during ESIA study and culminates into a Stakeholder Engagement Plan (SEP) that will guide project in identifying the stakeholder groups and the process to keep them engaged at an appropriate manner in future.

The key stakeholder groups identified include:

- national, regional and local government;
- local community and traditional leaders;
- community members including vulnerable sub-groups such as women, youth and elderly;
- international, national and local environmental and social nongovernment organizations (NGOs);
- potential contractors and service suppliers;
- local businesses/cooperatives and associations;
- universities, research institutes and academics; and
- labour unions.

These stakeholders outlined have been engaged through individual meetings, letters and press releases. The key findings from the stakeholder engagement are:

- Communities are happy for employment opportunities;
- Potential for water pollution;
- Loss of cash crops;
- Loss of residential structures, or crop and plantation losses;
- There are some key people who need to be consulted regarding various
- land issues;
- The land belongs to the head of the tribal reserve;
- Issues of resettlement and compensation; and
- Town Chief is the right person to establish the ownership of the land

BASELINE INFORMATION

Hydrology

The three major river systems or catchments which may be affected by the planned Bomi Hills Mine project are the Lofa River, the St. Paul River and a short coastal catchment (Po River). The Bomi Hills Mine will be located in the Lofa River catchment of which the Lawa and Mahe Rivers are the two main tributaries. The proposed Bomi Hills Mine project is situated mostly in the Small Mahe River catchment with an area of about 100 km^2. Drainage patterns vary considerably from the wet to the dry season, which corresponds with the rainfall records.

A number of catchments were delineated and studied for the purpose of this ESIA, these included:

- Catchment A (Bomi Creek);
- Catchment B (Unnamed Tributary);
- Catchment C (Weasain River);
- Catchment D (Unnamed);
- Catchment E (Unnamed);
- Catchment F (Small Mahe River); and
- Catchment G (Mahe River).

Hydrogeology

A total of 46 water supply wells and boreholes, used as a domestic water source, were identified in the vicinity of the project area. However, few settlements exist to the west, north and east of the proposed open pit and as a result, groundwater use is limited in the area. The towns of Bomi and Tubmanburg have a greater dependence on groundwater.

During the hydrocensus undertaken in November 2012 groundwater levels were observed to range between 0 and 17.62 mbs, with 90 percent of the measurements being less than 10 mbs. Interpretation of the water level data indicates that:

- At a local scale, the direction of groundwater flow mimics that of surface topography; and
- At a regional scale, groundwater flows in a southwest direction.

The pH levels in the hydrogeological test boreholes and existing pit lake ranged between 6.5 and 7, almost neutral, while pH values in the shallow, hand dug wells varied between 4.7 and 6.9, therefore slightly acidic. The slightly lower values observed in the wells may be as a result of organic acids and lack of minerals with a neutralising capacity. The majority of constituents analysed were in compliance with the WHO standards, with the exception of elevated metal concentrations, i.e. Al, Fe, Mn and Pb, analysed in some boreholes. Elevated metal concentrations are most likely due to natural reasons.

Given that effective rainfall is in the order of 2 000 mm/a and limited anthropogenic use, the aquifers are considered to be full and mostly in a pristine state. It is reasonable to expect that groundwater discharge in the drier months contributes a substantial portion of baseflow in the rivers.

Soils, land capability and land use

Soils

All four of soil groups identified (Plinthosols, Ferralsols, Stagnosols and Gleysols, and Anthrosols and Technosols) have an inherent low pH (ranging between 4.1 and 6.1) as a result of the combination of soil physical properties and the high rainfall of the area. Low pH levels naturally induce high aluminum content in soil which in turn results in inherent low fertility. Soil profiles with a high content of plinthic nodules and concretions are more susceptible to erosion than deep developed profiles with higher clay content.

Land capability

In terms of land capability of the area, an area of 989 ha has been classified as arable land capability and is suitable for crop production while 6 458 ha is marginally suitable for arable agriculture but would require proper soil fertility and conservation practices for high density crop production. A total area of 245 ha has wetland land capability and this area includes rivers, open pit lakes and wetland areas.

Land use

The area is dominated by human settlements and other wooded land where exotic plant species such as palm trees occur. Small patches of land are under temporary crops but it is mainly used for subsistence and not for income generation purposes. This is also the case with permanent crops such as fruit trees (no large orchards were identified and fruit trees mainly occur around the houses) for consumption by the inhabitants. Only one small site was identified where artisanal mining is currently taking place.

Terrestrial Ecology

Flora

Vegetation analysis culminated in the identification of 8 homogenous topographic-physiognomic units, each with unique characteristics and plant species composition. The two forest categories identified viz.

secondary and degraded forests were sub-divided based on vegetation structure. The secondary forest occurred as Tall Secondary Forest and Short Secondary Forest, based on recovery after disturbance. The degraded forest occurred as Short Degraded and Low Degraded Forest habitat based on the intensity of land-use in shifting cultivation and agriculture, respectively. The Urbanized area was considered a separate unit and heavily influenced by anthropogenic activities. The Transformed unit is restricted to the areas that represented the previous operations of Bomi mine concession, which shows poor signs of

recovery due to insufficient substrate to sustain germination of young seedlings. However, within this transformed habitat is a large tract of open water (Blue Lake) that now occupies the old excavation pit. Also within this unit is the expanse of water located to the northeast of Blue Lake. A river section bisects the areas currently showing intensive resource utilization from the secondary forest formations to the northeastern section of the Bomi mine concession area. Scattered throughout all these vegetation units are isolated wetland formations. A high prevalence of degraded habitat is characteristic of these areas as many drainage lines are obstructed due to infrastructure development and artificial damming of these drainage lines.

All vegetation units showed high infestations of alien species, both undesirable species and those cultivated as crops or for economic utilization. However, with the exception of the oil palm (*Elaeisguineensis*) found in the secondary forested areas, and the rubber tree (*Heveabrasiliensis*) and pine trees (*Pinusdensiflora*) in forested plantations, most of the other plants occur predominantly in the degraded, transformed and urbanized units. The prevalence of *Chromolaena odorata* in virtually all terrestrial vegetation units is a matter of concern as this species is extremely difficult to eradicate.

The only Red List plat species encountered during the survey is *Lofiraalata*, classified as Vulnerable based on the IUCN classification criteria. However, some epiphytic orchids have also been noted, but could not be identified to species level.

Based on species composition, presence and absence of IUCN Red-Data listed species. The presence and absence of alien species and perceived habitat connectivity, a sensitivity analysis was conducted. Analysis indicated that the Low Degraded Forest, areas Transformed by mining activity and Urbanized areas are all classified as Low sensitivity. The Short-Degraded Forest, despite intensive shifting cultivation practices being present, still retains some semblance of the natural vegetation with limited ecological ecosystem functionality. All secondary forest types are classified as being moderately sensitive.

Avifauna

A total of 187 bird species were confirmed during a wet and dry season investigation (October 2012 & January 2013) of the Bomi mine concession. It was evident that the concession shows the characteristics of an area with a long history of forest perturbation and disruption, which supported an avifaunal composition dominated by forest-edge species with widespread distribution ranges. The results are in support of degraded and secondary forest habitat, with an estimated 10 % of the composition comprising of savanna species. In addition, less than 50 % of the bird composition was

restricted to the Guinea-Congo forest biome.

The mine concession was poorly represented by species of global conservation concern (two near-threatened species) and species endemic to the Upper Guinea Forest (20 %). The Tall Secondary Forest and Wetland habitat (rivers, perennial drainage lines and natural freshwater ponds) were identified as sensitive bird habitat owing to high observed bird diversities and the presence of Upper Guinea forest endemics. These habitat types were considered as key dispersal corridors for bird species, thereby facilitating the movement of birds between the forest stands in the mine concession and those bordering the concession.

Herpetofauna

The Bomi mine concession provides potential habitat for 102 reptile and 66 amphibian species. Of these, only 7 reptile and 14 amphibian species were observed over two field surveys. The low species diversity detected is explained through the degraded nature of the habitats within the mine concession as well as sampling difficulties encountered during the surveys.

A total of 28 red data herpetofauna species (7 reptile and 21 amphibian) are expected to occur on the mine concession. Of these, only three species were observed, namely the Sierra Leone reed frog (*Hyperolius chlorosteus*), Chochran's running frog (*Kassina cochranae*) and the forest hinged tortoise (*Kinixys erosa*).

The Tall Secondary Forest, Short Secondary Forest and River habitat types were evaluated as sensitive from a herpetofaunal perspective. The combined sensitivity analysis revealed that the only as small portion of this sensitive habitat will be directly impacted upon by the mining infrastructure.

Mammals

A total of 23 mammal species were recorded within the Bomi mine concession during both the wet and dry season surveys out of the 112 mammal species are expected to occur within the Bomi mine concession. Of the species recorded, 3 IUCN red-data mammal species were confirmed on the concession, namely white–bellied tree pangolin *Manis tricuspis* (aka *Uramanis tricuspis*) (NT), African golden cat *Profelis aurata* (aka *Caracal aurata*) (NT) and sooty mangabey *Cercocebus atys* (VU).

Using the criteria of IUCN, CITES, Upper Guinea endemics and Liberian regislation, 6 species of mammal of conservation importance were confirmed on the Bomi mine concession out of a total of 29 expected species, representing 23% success rate. However, the low expected figure is due to the high significance of current habitat modification and other current impacts.

The overall mammalian scenario is one of a highly fragmented and modified habitat with a linear incursion of important mammalian habitat represented by the Mahe River. Connectivity of habitats is under severe pressure through habitat alteration; however, the eastern portion of the Bomi mine concession shows strong linkage to natural or semi-natural habitat. Subsistence hunting for bushmeat and habitat loss represents the greatest current risks to the mammalian assemblages.

Invertebrates

A rapid butterfly assessment was performed during a dry season survey to obtain an indication of the general butterfly richness on the Bomi mine concession. Species richness was generally low for the respective habitat types although a slight increase in species numbers was predicted for the secondary forest habitat. A strong dominance of forest-edge (generalist) species was recorded on the mine concession. Forest-interior species were restricted to secondary forest habitat. The forest along the Mahe River provided potential habitat for one Data Deficient butterfly species.

Aquatic Ecology and Water Quality

The habitat integrity of the systems within the vicinity of the mine was modified, largely due to activities of the local inhabitants, agricultural fields and from the Bomi Hills Mine (previous and current mining activities).

The results from the different water quality indicators which included; habitat integrity, water quality, diatoms, aquatic invertebrates and fish all indicate that the systems in the vicinity of Bomi Hills Mine are in a modified state. However, the presence of more intolerant species further downstream shows that the river is able to recover reasonably quickly downstream from these impacts.

Landscape and Visual

The Bomi Hills Mine is located at the transition between the coastal plain and rolling hills geomorphological landscapes. The landscape is tropical rain forest with topography gradually rising from the coast to an elevation of about 60 m at the base of Bomi Hills. The area is generally flat with gently rolling hills. Previous mining led to the creation of the disused mine pit which has filled with water and was in has been used as a recreational picnic area with boating and swimming facilities.

Air Quality

Meteorology

The wind field in the Project area is characterized by dominant south-south-westerly and south-westerly winds. Temperatures ranged between 21.6 °C and 31 °C. During the day, temperatures increased to reach maximum at around midday. Ambient air temperatures decreased to reach a minimum just before sunrise. Annual rainfall is approximately 3 500 mm.

Existing Ambient Air Quality

Existing sources of atmospheric emission within and around Bomi Hills were identified as:

- Sources of particulate emissions (TSP, PM_{10} and PM2.5) include: O Vehicle entrainment from paved and unpaved roads;
    - Vehicle exhaust;
    - Subsistence farming;
    - Charcoal manufacturing and domestic use; and
    - Small scale construction activities.
- Sources of gaseous emissions (CO, NOx, SO2 and VOCs) include: O Vehicle exhaust, mostly small cars and motorcycles; and
    - Charcoal manufacturing and domestic use.

Baseline dustfall rates sampled between 15 December 2012 and 15 March 2013. Dustfall rates for all three months at all four locations sampled were low and well below the dustfall limit considered acceptable for residential areas.

Climate Change

GHG emissions from the WCL Facilities

The carbon footprint has been estimated for 19 operational years and presents forecasted estimates for GHG emissions. At full production, the operational carbon footprint for WCL facilities is estimated to be approximately ***348 248*** tCO_2e per annum. The total operational carbon footprint for the WCL facilities is estimated to be approximately 6***.234*** $mtCO_2e$ for the life of the mine (19 years). The estimated total emissions are shown below.

WCL estimated operational carbon footprint

Emission Source	Annual Emissions (tCO_2e)	LOM Total Emissions (tCO_2e)	Percentage of Total Emissions
Mobile Combustion	81 252	1 454 415	23.33%
Stationary Combustion	264 427	4 733 241	75.93%
Non-Combustion	1 739	31 120	0.50%
Explosives	831	14 866	0.24%
Total CO_2e Emissions	**348 248.17**	**6 233 642**	**100.00%**

There is a significant level of uncertainty in the estimates given the early stage of project design. This report is based on the designs and assumptions available at the time of writing and the results may or may not correlate to the final design and operations of the facility.

Recommendations for potential emission reduction opportunities

Given the early stage in the design of the project, it was not possible to accurately estimate the abatement potential of each option. These activities will, however, contribute towards the sustainability of the project, reducing the greenhouse gas emissions, and reducing costs (e.g. fuel use for energy generation).

This section identifies a number of operational areas where best practice options can be considered by the WCL Project in order to improve energy efficiency and/or emissions intensity of its activities in Liberia and thereby reduce Scope 1, 2 and 3 emissions. These operational areas include:

- Stationary combustion, i.e. energy production
- Energy Efficiency and Renewable Energy
- Transport
- Waste management
- Business travel

- Reduced Deforestation and/or Offsets

Noise

Baseline noise samples were taken during a visit to site in October 2012. Measurements were conducted in accordance with South African National Standards SANS 10103 (2008) and the International Finance Corporation (IFC) General Environmental, Health and Safety (EHS) Guidelines (IFC, 2007) [(1)].

Noise dispersion is impacted by atmospheric absorption and meteorological conditions, as well as by terrain, ground absorption and reflection. From the noise measurements, it was concluded that:

- Noise levels were typical for rural and residential areas;
- In remote areas day-and night-time noise levels are comparable and mostly affected by natural noises such as wind, birds, frogs and insects;
- Baseline day-time noise levels are within the IFC guideline of 55 dBA;
- Baseline night-time noise levels frequently exceed the IFC night-time guideline of 45 dBA, this is mostly as a result of noise generated by insects and frogs;
- Calculations indicate that baseline noise levels in community areas are:
  - Day-time: 53 dBA;
  - Night-time: 52 dBA;
- Calculations indicate that baseline noise levels in remote areas are:
  - Day-time: 44 dBA; and
  - Night-time: 49 dBA.

Several communities, considered noise sensitive receptors (NSR) lie within a few kilometres from the proposed mining operations and may be affected by noise generated from the proposed operations.

Vibrations

When mining starts at Bomi Hills, there will be numerous mining related disturbances that impact on people and structures located in the vicinity of the operation. When blasts are set off ground vibration and air blast disturbances occur. These disturbances occur unexpectedly and for this reason often attract unwelcome attention. They do, however, diminish in intensity with an increase in distance. The following aspects of the blasting operation are assessed:

- Blast design and general safe blasting practice;
- Ground vibration,

- Airblast;
- Unwanted side effects such as fly rock, after blast fumes and dust;
- Pre blast surveys;
- Disturbance monitoring;
- Legal requirements; and
- Mitigation measures.

Ground vibration and airblast generally excite the greatest comment from people living in the neighborhood. Ground vibration disturbances will need to be measured and quantified to ensure compliance with recognized and accepted industry standards such as the internationally recognized USBM RI 8507 or the DIN 4150 standard.

The USBM limit is reached at a distance of 225 m when a single hole (212 kg of explosive) fires and at 315 m when two holes (424 kg of explosive) fire together. The closest communities are found at around 300 m from the mine.

As more holes fire together so the distance at which the USBM limit is reached increases. The limit is reached at a distance of around 630 m when eight holes (1 698 kg of explosive) fire together. At distances in excess of 1 000 m the levels fall off rapidly.

Ore blasts will cause the highest disturbance levels with waste blasts causing slightly lower levels of disturbance as less explosive is used in each hole.

Airblast is usually the main cause of blasting related complaints. Airblast is an atmospheric pressure wave consisting of high frequency sound that is audible and low frequency sound or concussion that is sub-audible and cannot be heard. The recommended maximum airblast level of 130 dB is exceeded at 150 m (ore blast) when a single hole fires. As more holes are fired together so the impact distance increases.

Side effects such as fly rock are undesirable and usually occur unexpectedly, sometimes for unknown reasons. As a safety precaution a minimum safe distance from the blast area must be cleared of people and animals before any blasting can take place. Dust is also an inevitable consequence of blasting

Social and Community Health Baseline

The area of influence of social impacts thus would range from project footprint area to national level on different issues.

The Local Area of Influence falls under Senjeh District of Bomi County and Bopolu District of Gbarpolu County; however, most part of the ML area falls under Senjeh District of Bomi County. There are 29 Towns/Villages of varying size within the Local Area of Influence including Tubmanburg. Approximately two thirds of the Towns/Villages have fewer than 20 households and are considered small in size. There are only 6 Towns/Villages which have 21-50 households, and 4 Towns/Villages have more than 50 households.

Liberia is among the poorest countries in the world and employment levels are quite low with a large proportion of the population dependent on growing crops for their own consumption. The unemployment rate is very high in Bomi County in particular. Apart from working with the government and international NGOs, formal employment is hard to come by. Services in Bomi and Gbarpolu County are also severely limited.

Ecosystem Services

Performance Standard 6 defines ecosystem services as “the benefits that people, including businesses obtain from ecosystems”. The contribution of the ecosystem services to the local economy and livelihood is through its contribution in four aspects, i.e. provisioning, regulating, supporting and cultural services.

The natural resource base for a subsistence community provides food, fresh water, wood, fibre and fuel. Deforestation and forestland degradation will further curtail an already limited supply or availability of these resources for local people. Natural sources plays a significant role in provisioning of food i.e. the meat of wild life in forests and fish from streams and creeks. Surveys revealed that some threatened faunal species are hunted for bush meat such as tortoises and crocodile, and many of the animals are restricted to natural habitats that are shrinking due to various land use pressures including timber harvesting.

Various other resources required by humans are expected to be impacted upon as the mine is developed and more people move into the area, these include:

- Charcoal production resulting in timber clearance;
- Slash and burn or shifting cultivation;
- Loss of lose aesthetic and spiritual value;

Changes in water filtration, flood and erosion control, pollination and climate stabilization are some of the ecosystems regulating services that could be disrupted; and Hunting grounds and places of recreation will be interrupted.

IMPACT ASSESSMENT

The Impact Assessment was undertaken assuming that various management controls would be incorporated into the mine design. Assuming these embedded controls, the potential Project related impacts identified during the ESIA are listed below. Where further mitigation measures are required to reduce the impact further the residual impact has also been assessed.

Topic	Description	Impact Direction	Before Mitigation	With Mitigation
Hydrology	Increase in sedimentation and general environmental degradation due to erosion	Negative	Minor	Negligible
	Sedimentation, silting of streams, rivers, wetlands and water bodies	Negative	Moderate	Minor
	General increase of bank instability	Negative	Moderate	Negligible
	Reduction in stream integrity and water quality	Negative	Moderate	Minor to Moderate
	Change in catchment yield	Negative	Moderate	Negligible
Hydrogeology	Potential loss of groundwater resources owing to dewatering	Negative	Moderate	Negligible
	Impact to groundwater discharge (baseflow) and stream flow	Negative	Minor	Negligible
	Impact to groundwater dependent ecosystems	Negative	Negligible	Negligible
	Impact on groundwater quality at the open pit	Negative	Minor	Negligible
	Potential water quality risk to the receptor	Negative	Negligible	Negligible
Soils, Land Use and Land Capability	Loss of nutrients through soil erosion during vegetation clearance	Negative	Moderate	Minor
	Soil compaction from movement of heavy vehicles on cleared soil	Negative	Moderate	Moderate
	Chemical soil pollution from fuel and oil spillages from construction vehicles leading to soil pollution	Negative	Moderate	Minor
	Soil erosion of top soil	Negative	Moderate	Minor
	Soil compaction due to unnatural load and increase in traffic	Negative	Moderate	Moderate
	Loss or sterilisation of top soil layer	Negative	Moderate	Minor
	Chemical soil pollution from accidental spillages or leakages from the tailings storage facility.	Negative	Moderate	Minor
Terrestrial Ecology	Terrestrial habitat loss and fragmentation	Negative	Minor	Negligible
	Habitat loss and fragmentation of downstream aquatic habitat due to increased runoff, pollution and sediment	Negative	Moderate to Major	Negligible
	Loss of Biodiversity	Negative	Minor	Negligible
	Spread of Alien Invasive Species	Negative	Moderate	Minor
	Chemical Spillages and massive sedimentation events	Negative	Moderate	Minor
Aquatic Ecology and Water Quality	Habitat loss and resultant loss of aquatic diversity	Negative	Moderate	Minor
	Change in water quality and associated impacts on aquatic ecology	Negative	Moderate	Minor
	Change in hydrology and associated impacts on aquatic ecology	Negative	Moderate	Minor

	Impacts from increase in human influx	Negative	Moderate	Minor
Landscape and Visual	Visual impact at KOP 1 at 19 years	Negative	Moderate	Moderate
	Visual impact at KOP2 during mining operation	Negative	Minor	Negligible
	Visual impact at KOP3 during mining operation	Negative	Minor	Negligible
	Visual impact at KOP 1 15 years after closure	Positive	Moderate	Moderate
	Visual impact at KOP2 15 years after closure	Negative	Minor	Negligible
	Visual impact at KOP3 15 years after closure	Negative	Moderate	Moderate
	Increased PM10 emissions from construction activities	Negative	Moderate	Minor
Air Quality	Nuisance impact as a result of dust fall	Negative	Minor	Negligible
	Increase in ambient air pollution during mining activities	Negative	Moderate	Moderate
	Nuisance as a result of increased dust fall	Negative	Minor	Minor
Noise	Nuisance impact as a result of increased environmental noise levels from construction activities	Negative	Negligible to Minor	Negligible
	Potential nuisance noise impacts as a result of operational activities	Negative	Negligible to Minor	Negligible to Minor
Vibrations	Blasting related disturbances – ground vibration, airblast, flyrock, dust and fumes and possible water pollution.	Negative	Major	Minor
Socio-economic	Revenue from Surface Rentals for the Government Land within Project Footprint	Positive		
	Impact from Economic Loss of Properties/Assets	Negative	Minor	Minor
	Psychological Stress from Uncertainty	Negative	Moderate	Moderate
	Impact on Regional Economy	Positive		
	Exploitation of Natural Resources	Negative	Minor	Minor
	Impacts of Labour Influx	Negative	Minor	Minor
	Workforce Health and Safety	Negative	Minor	Minor
	Labour Working Conditions and Human Rights	Negative	Minor	Minor
	Public and Community Health- Water Borne and Communicable Diseases	Negative	Minor	Minor
	Impact on Cultural Heritage	Negative	Negligible	Negligible
	Loss of Property and Assets attributable to Mining Operation	Negative	Minor	Minor
	Nuisance to social receptors attributable to mining operation	Negative	Minor	Minor
	Impact on Subsistence and Livelihood Strategies	Negative	Moderate	Moderate
	Public and Community Health	Negative	Minor	Minor
	Workforce Health and Safety	Negative	Minor	Minor
	Impact on Labour and Human Rights	Negative	Minor	Minor
	Impact of Migrated and Transient Population	Negative	Minor	Minor
	Impact on Governance and Administration	Positive		
	Impact on social Infrastructure and amenities	Negative	Moderate	Moderate
	Impact on Public and Community Security and Safety	Negative	Minor	Minor
	Impact on Cultural Heritage	Negative	Negligible	Negligible
	Multiple Impacts on Borbor and Zalakai Town	Negative	Moderate	Moderate

	Public and Community Health Containment Structure	Negative	Minor	Minor
	Maintenance (waste rock piles, mining slopes, tailing ponds etc)	Negative	Negligible	Negligible
	Retrenchment and Un-employment	Negative	Moderate	Moderate
	Impact on Natural Resource Services and Ecosystem Services	Negative	Minor	Moderate

CUMULATIVE IMPACTS

Cumulative impacts/effects generally refer to impacts that are additive or interactive (synergistic) in nature and result from multiple activities over time, including the project being assessed. This, the cumulative impact assessment considers the Project within the context of other similar land uses, in the local study area and greater regional context. There are, however, no other projects of this size in the area and as such in general the cumulative impacts are quite low.

Key cumulative impacts associated with the proposed Project include:

- Surface hydrology – impacts related to abstraction of water from the Mahe River, dewatering of the disused mine pit, siting of various facilities including WRDs and TSFs within existing catchment areas and diversion of water bodies;
- Terrestrial Ecology – impacts related to currently clearing of natural forest taking place due to commercial logging, subsistence agriculture and artisanal mining exacerbated by the influx of people in search of employment; and
- Socio-economic – impacts related to larger numbers of people such as health related issues and pressure on the provision of services.

ENVIRONMENTAL AND SOCIAL MANAGEMENT PLAN

This Chapter presents the Environmental and Social Management Plan (ESMP) for Bomi Hills Mine. The purpose of this ESMP is to specify the standards and controls, ensure compliance to all the relevant legislation, as well as identify roles and responsibilities of the various employees required to manage and monitor environmental and social impacts during Phase 1b (development of 4 Mtpa mine). To achieve this the ESMP identifies potential adverse impacts from the planned activities and outlines mitigation measures required to reduce the likely negative effects on the physical, natural and social environment.

This ESMP details all the management measures that need to be implemented in order to ensure that the impact of mining on the environmental and social receptors is kept to the minimum possible.

The ESMP also outlines all the monitoring that is required to be undertaken in order to ensure that the mitigation measures being implemented are reducing the impacts to residual levels and to early identify where there are potential issues. Clear records must be kept of all monitoring undertaken and reported on a frequent basis, as stipulated.

1. INTRODUCTION AND PURPOSE OF THE REPORT

1.1 Purpose of this Report

This Environmental Social Impact Assessment (ESIA) presents an assessment of the potential environmental and social impacts associated with the proposed development and operations of the Bomi Hills Iron Ore Mine in Liberia.

The report has been prepared for **Western Cluster Ltd (WCL)** by **Mac-Africa Consultants Inc.** and presents the objectives, methodology and outcomes of the updated ESIA of 2013 for the same project.

The purpose of the updating of the 2013 ESIA is to assess the direct and potential impacts of the project and project-related activities on the biophysical and socio-economic environments, including public health and provide mitigation and management to ensure residual impacts are kept to an acceptable level, and to include into the assessment those new components of the mining project not initially captured under the ESIA for the ultimate purpose of obtaining the necessary Environmental permit for said operations. The ESIA process which is followed for the project assimilates the Environmental Protection and Management Law of Liberia (EPML) requirements as well as applicable international standards and best practices. This process is further discussed in the following Chapters.

1.2 Project Background

WCL Liberia recognizes that comprehensive planning, management of environmental, socio-economic, and health issues are essential to the execution of any successful project and, therefore, intends to fully integrate environmental, socioeconomic and health management into the life cycle of the Project.

To support this, WCL Liberia has commissioned a detailed, integrated ESIA to be conducted in accordance with Liberian government regulations, company policies which are based on the International Finance Corporation (IFC) guidelines and standards, and the IFC's standards itself.

Brief History of Bomi Hills Mine

The Bomi Hills iron ore deposits were initially explored by Dutch interests in the late 1930s at which time a modest diamond core drilling program was undertaken. the Government of Liberia and United States Geological Survey undertook further exploration program in the 1940s mostly through geological mapping, and by 1951, the first shipment of iron ore was made through the Liberia Mining Company.

Production increased steadily over the next few years to more than one million tons per annum. The mine remained in operations up to the mid-eighties.

1.3 Overview of the Project

WCL has planned to execute its mining project in two stages known as Project 1 and Project 2, which are again divided into project phases to approach and complete the whole process strategically and economically. Details of both stages along with respective phases are covered below:

Project 1 – Rehabilitation, Development and Operation of Bomi Hills Mine

Production at Bomi Hills Mine commenced in October of 2016, and to meet the commitments as per the MDA, WCL has undertaken development of Project 1 in three phases, namely Phase 1a, Phase 1b and Phase 2.

Phase 1a –Enabling Works:

This phase comprised limited construction activities, principally refurbishing and rehabilitating existing infrastructure such as access roads, existing roads in need of repair, installation of portable processing equipment and temporary power generation devices and establishment of temporary working areas such as construction crew housing and laydown areas on existing brownfield sites.

This phase resulted in the enabling works for the project and did not involve the installation of permanent processing equipment or any physical or economic displacement or resettlement of Project Affected People (PAP). Exceptions were for the repairs or construction of a boundary wall, water distribution, storm water management measures, the rehabilitation of an accommodation camp at Bomi Hills Mine and road from Bomi Hills Mine to Tubmanburg; and the upgrade of two bailey bridges by replacing them with new RCC bridges along the existing road alignment.

Phase 1b –4 Mtpa iron ore product

This phase involves DSO mining and has seen the installation and operation of a dry crushing and screening processing plant for a production of high-grade ore known as Direct Shipping Ore (DSO), followed by the construction and operation of a 4 Mtpa wet processing beneficiation plant. The ore produced has been transported via the existing road between Bomi Hills and the Freeport of Monrovia (Port) subject to a road user permit granted by the Government of Liberia through the Ministry of Public Works.

This updated ESIA Report is specifically relevant to the development and operations of Bomi Hills Mine and associated facilities, which form part of *Phase 1b* and other activities and facilities not captured in the initial ESIA report of 2013.

Phase 2 –Expansion of Production Capacity:

This phase may involve ramping up of mining activities to a full capacity of 10 Mtpa concentrate based on results of further exploration in the Bomi Concession area, the operation of the wet and dry processing plants, rehabilitation, construction and operation of the ore transport haul roads between Bomi Hills mine and a jetty at Bamboja from where the ore will be transported by barge to the Freeport of Monrovia, and shipment of 10 Mtpa concentrate from the Port. In this phase, activities will be undertaken to expand the Mine in order to allow for production of 10 Mtpa of iron concentrate.

Project 2 - Rehabilitation and Development of all three concession areas (Bomi Hills, Bea Mountain and Mano River)

In order to increase the project's production capacity WCL has projected to ramp up its production to (30) Mtpa of concentrate from across the three concession areas (Bomi, Bea and Mano Mines), over a period of 25 years. WCL aims to expand the mining operations and construct infrastructure at the Bea and Mano River concession areas along with the establishment of transportation and shipping alternatives. This however are not subject to this updated ESIA report for Bomi Hills and shall be covered by a separate ESIA process.

1.4 Project Justification

Prior to the Civil War, the Liberian economy relied heavily on the mining of iron ore and on the export of natural rubber. Liberia was a major exporter of iron ore on the world market. In the 1970s and 1980s, iron ore mining accounted for more than half of Liberia's export earnings [(1)]. Following the coup d'etat of 1980, the country's economic growth rate slowed due to a decline in the demand for iron ore on the world market and political upheavals in Liberia.

In 2011 Liberia's economy recorded its-war eighth growth, expanding by an estimated 6.9% in the year . This was driven by the first iron-ore exports since the end of the war, strong rubber exports, and increased timber production. Foreign direct investment (FDI) in mine construction, rubber and timber exports, and recent investments in palm-oil plantations will contribute to growth in the coming years. GDP has steadily grown over the years as a result of increase in iron ore export.

Liberia has undergone transition from post-conflict reconstruction to medium-term growth and poverty reduction and is now in its next medium-term growth and development strategy with a vision becoming a middle-income country in the next ten years. Long-term growth is expected to be driven by natural-resource extraction, but the country must enable broad-based growth and increased employment creation. The government has simplified procedures for starting businesses but the general business climate remains difficult and development is constrained by poor energy infrastructure and transport, especially in rural areas. Liberia is susceptible to external factors including global iron-ore, rubber, and rice price shocks and the potential for reductions in FDI and donor contributions.

Bomi County, due to its proximity to Montserrado County, rendered it vulnerable during the war as various groups struggled at various times to take control of the capital, Monrovia. Bomi suffered during the war years incurring significant losses to private property and public infrastructure.

Bomi County is, however, well-situated to recover, being endowed with ample natural resources such as rubber, timber, diamonds, iron ore, gold, water, stone and sand, and fertile agricultural land. In addition, iron ore is in demand worldwide, largely driven by steel production. The iron ore was mined at Bomi Hills from 1951 to 1977, prior to hostilities breaking out. The proposed mine and associated infrastructure have been developed mainly around the old mine workings, therefore rendering this a brown field project with some green field development around residue deposits.

In Bomi County there is a need for job creation and local employment. Other than the employment of local labor where possible, goods and services are also been procured from local Liberian companies where possible. Further mine development has the potentially to result in better infrastructure (e.g. roads and other civil structures) and services (e.g. water provision, sanitation and waste management) in and around Tubmanburg.

1.5 Impact Assessment Objectives

The objectives of this impact assessment are to:

- Facilitate the updating of WCL's 2013 ESIA report with information pertaining to its current mining activities, and to provide an understanding of the elements of baseline conditions relevant to the resources/receptors that could be significantly impacted by the Project as identified in the initial ESIA Report;

- Document how stakeholders have been engaged during the Impact Assessment (IA) Process, and how stakeholder feedback has been considered in the IA;
- Predict and evaluate the significance of the impacts of the Project;
- Identify the environmental, social and health aspects of the Project that need to be managed, and recommend appropriate and justified mitigation and enhancement measures;
- Determine the significance of residual impacts, taking into account the implementation of mitigation measures; and
- Generate plans for the management and monitoring of impacts, including plans for ongoing stakeholder engagement.

1.6 Impact Assessment Scope

This report is focused on the *Phase 1b* development of the Bomi Hills Mine component. WCL intends to resume mining at Bomi Hills Mine to produce 4 Mtpa concentrate/DSO in a phased manner matching with infrastructure, and ramp-up plan. The concession area for Bomi Hills Mine is 114.42 km^2 (28,273.62 acres), the mineralized zone comprises of 18.45 km^2 and exploration has been carried out in approximately 4 km^2 area around disused mine pit and further exploration is in progress. Based on the exploration completed, the estimated resources evaluated in the initial resource report which covers an area around the disused mine pit is approximately 248.6 million tonnes (Mt). This report also includes the assessment of various infrastructure facilities that will be constructed for the day-to-day operation of the mine in a phased manner.

ESIA TEAM

The project team involved in this ESIA update include specialists from MacAfrica who were assisted by a technical staff. Details of the project team are provided in Table 1.

Table 1: Table 1: ESIA Team from MacAfrica

TEAM MEMBER	ROLE	ASPECT OF THE ESIA	ASSOCIATION
SUMO S. MOMOLU	Team Lead	Mine, Road, Port, Soil and Land Use	MacAfrica
GODWIN SENEGEH	Social Safeguard Specialist	Socio-economics and Public Consultation	MacAfrica

JACKSON MAH	Environmentalist	Water, Soil and Air Qualities	MacAfrica
LEVI N. PAYE	Geologist	Hydrogeology and Hydrology	Independent Consultant

1.7 Structure of this Report

An outline of the ESIA report is provided in Table 2

Table 2: Summary Outline of ESIA Report

Chapter	Title	Description
	Executive Summary	Brief Summary of the report
1	**Introduction**	Introduction to the Project; overview of stakeholder engagement activities; introduction to ESIA methodology and legislation and standards
2	**Project Description**	Technical description of the Project & related infrastructure and activities
3	**Legal and Policy framework**	Legislation and lender requirements and guidelines
4	**Environmental & Social process Impact Assessment Process**	Description of the impact assessment undertaken to identify potential environmental and social impacts.
5	**Screening and Scoping Outcomes**	Description of the Scoping outcomes previously undertaken as part of the ESIA process
6	**Stakeholder Engagement**	Provides an overview of the stakeholder engagement activities undertaken during the ESIA
7	**Environmental and Social Baseline**	Environmental and Social Baseline
8	**Surface Water Hydrology**	Surface Water Impact Assessment.
9	**Hydrogeology**	Hydrogeology Impact Assessment.
10	**Soils and Land Capability**	Soils and Land Capability Impact Assessment.
11	**Terrestrial Ecology**	Terrestrial Ecology Impact Assessment.
12	**Aquatic Ecology and Water Quality**	Aquatic Ecology and Water Quality Impact Assessment
13	**Landscape and Visual Impact**	Landscape and Visual Impact Assessment.
14	**Air Quality**	Air Quality Impact Assessment.
15	**Climate Change**	Carbon Footprint Impact Assessment.
16	**Noise**	Noise Impact Assessment.

17	**Blasting and Vibrations**	Blasting and Vibrations Impact Assessment
18	**Socio-economic Assessment**	Socio-economic Impact Assessment.
19	**Ecosystem Services**	Ecosystem Services Impact Assessment
20	**Cumulative Impacts**	Cumulative Impacts of the Project
21	**Environmental and Social Management Plan**	Outline of the Environmental and Social Management Plan (ESMP) taking into account identified impacts and planned mitigation measures and monitoring requirements.
21-A	**Emergency Response and Preparedness Plan**	Framework outlining procedures essential for effectively containing emergency situations for the proposed Project
21-B	**Stakeholder Engagement Plan**	Plan for engagement with external stakeholders during all phases of the Project
21-C	**Water Management Plan**	Plan for the management of water during all phases of the Project
21-D	**Soils Management Plan**	Plan for the management of soils during all phases of the Project
21-E	**Closure Plan**	Conceptual Mine Closure Plan to address rehabilitation and closure costs for premature and life of mine closure.

2. PROJECT DESCRIPTION

2. 1 Introduction

This *Chapter* provides a description of the Project in terms of the facilities and equipment required for the Bomi Hills Mine and associated project infrastructures and activities during all phases of the Project including manpower requirements and an analysis of project alternatives considered.

2. 2 Project Alternatives

This section describes the alternatives considered during the course of Project Design and the ESIA process. The following alternatives have been considered:

- Layout design and/ or technology alternatives.
- Location alternatives; and
- No-Go alternative.

2.2.1 Consideration of Design/ Technology Alternatives

Power generation technology alternatives

Due to the fact that Liberia does not at this stage have a power grid to supply Bomi Hills Mine with the required power, to arrive at the appropriate technology selection for power generation, a detailed evaluation of the different types of power source was carried out and the results can be seen in *Table 3*.

Table 3: Comparison of different types of power supply

No.	Type	Construction Time (months)	Capex (USD/MW)	Opex (USD/kW-hr)	Plant Efficiency (%)	Availability (%)
1	Coal fired	30	1,750,000	(0.10 to 0.13)	35	90
2	HFO fired DG	(14)	(830,000)	(0.21 to 0.24)	(43 to 47)	90
3	Diesel fired DG	(14)	(700,000)	0.35	45	90
4	Solar PV	8-10	2,884,700	0.17	17-18	Low
5	Hydro Power	60-72	1,923,100	0.23	85	Seasonal
6	Biomass	30	2,307,700	Variable	35	Uncertain
7	**Natural Gas**	(18 – 24) **	(1,000,000) ***	0.13 to 0.16	48 to 52	90

*****(Depends on time required for gas import infrastructure building)***
******(Excluding gas import infrastructure)***

It should be noted that from an economic point of view, an onsite coal fired thermal power station is the most feasible option, however, construction time is lengthy and the coal in Liberia is not readily available at this stage.

Hydro power, solar and biomass power sources cannot be relied upon for a consistent and reliable supply of power, and the use of diesel generators is very costly. Hence these options are also not considered further.

The Government of Liberia is planning for the augmentation of the port facilities and issuing a license and providing tax benefits for ensuring availability of HFO at a lower cost. On this basis the cost of generating using Heavy Fuel Oil (HFO) based generators is the most economic. The equipment required can be installed in line with the project time schedule. As such, the use of HFO-based generators has been found to be the best current option.

Water Storage Options

Water will be sourced from the Maher River and as a contingency from the disused mine pit. Various options were considered for the storage of water on site, these include:

- ✓ Option 1: Three (3) Day capacity open earthen lined tank lined with 1.5 mm HDPE lining.
- ✓ Option 2: One (1) day capacity Closed Concrete Storage Tank.
- ✓ Option 3: Half Day Capacity Closed Concrete Storage Tank. In this option the treatment plant may be avoided based on present water quality.
- ✓ Option 4: One (1) day capacity Closed Storage Tank. In this option treatment plant may be avoided based on present water quality.
- ✓ Option 5: Half Day Capacity Closed Structural Storage Tank. In this option treatment plant may be avoided based on present water quality.
- ✓ Option 6: One Hour Capacity Closed Storage Sump attached to make up water pump house. In this option the disused mine pit has to be retained with a barge pumping system for supply of water during emergencies created due to potential breakdown of the pumping system from the Mahe River.
- ✓ Option 7: Fibreglass Reinforced Plastic (FRP) tank of three days capacity, thirty-five (35) tanks.
- ✓ Option 8: One and half days' storage in an open concrete tank with a capacity of 38,358 m^3.

Option 1 was chosen as the preferred alternative.

2.2.2 Location of Alternatives

Location of major complexes

As considered in the Scoping Phase, the most suitable place to locate the various Project Units is to the south of the disused mine pit. Infrastructure will be located largely on previously disturbed land. This is still considered the most viable position for the erection of plants, crashers, townships and other major complexes. This infrastructure has all been located outside of the ultimate pit limit to avoid any infrastructure having to be moved at a later date. This infrastructure has been planned and considered in such a way that there will not be any resettlement.

2.2.3 No-Go Project Alternative

The no-go alternative implies that the proposed project would not be undertaken. This is highly unlikely at this stage since the project is well underway, however, an assessment of the no-go alternative is provided to present the relative trade-offs between the economic and social development benefits associated with the project against the environmental and social costs of the project.

A high-level no-go analysis is provided in the following sections.

Economic Benefits Not Realized

In 2011 Liberia experienced its eleventh post war year of growth, expanding by an estimated 6.9 percent in the year [1]. This growth was driven by the first iron-ore exports since the end of the war, strong rubber exports, and increased timber production. As such there is a huge potential for growth and economic benefits to be tapped into which could greatly benefit the country and Liberians themselves.

The initial 4 Mtpa DSO/ concentrate project has contributed to an increase in Gross Domestic Product (GDP) through its royalty, tax and equity rights (*Table 4*). Liberia will benefit from an increase in Government revenue for the next couple of decades as a result of the project expansion. This economic benefit could be used to improve the health, education and quality of life of the people of Liberia.

Table 4: WCL contribution to the Government of Liberia as of 2024

Contribution	Million USD
Upfront payments /Social/Medical & other funds	105.35
Royalty	298.58
Income Tax	335.28
Total	739.21

[1] http://www.africaneconomicoutlook.org/en/countries/west-africa/liberia/

Updated payments

As the volume of exports concentrate increases the economic benefits can be compounded several times.

Update Payments and Scenarios

Highlights about Western Cluster Limited (Liberia)'s operation

- WCL's MDA was signed and ratified by the Legislature in 2011 which allows the company to haul its products for the period of three years and find alternative means after the three years which include the construction of a new port, jetty or new roads working with the relevant government Ministries and Agencies, and in partnership with a third party.
- In 2014 Ebola hit Liberia and the company left as the result of the force majeure
- While the company was preparing to return after the Ebola, another force majeure occurred (COVID-19)
- In 2021 the company decided to return and started operations in 2022, subsequently signing an MOU with the government of Liberia. (Please see attached the MOU) for your reference. Please note that that the company has lived to all aspects of the MOU, but the company Road User Permit has been suspended four times in the last two years. The company has made the following contributions since 2021.

Contributions made by WCL

1. Social Contribution 2022-23 (USD 5,000,000.00)
2. Social Contribution 2023-24 (USD 5, 000,000.00)
3. Social Contribution 2024-25 (USD 2,000,000.00)
4. Road Works 2011-22 (USD 3,694,826.00)
5. Road Works 2023-24 (USD 4,500,000.00)
6. Road Works 2024-25 (USD 1, 229, 165.00)
7. Surface Rental 2024-25 (USD 379784.00)

- Over the past two years the company has provided over 700 direct and indirect employment to Liberian nationals and more than twenty-five Liberians Business Partners.
- The most recent Road User Permit Suspension was done on July 9, 2024 (please see attached).
- The Minister of Public Works Hon: Roland Layfette Giddings referred to communication received from EPA as his reliance to suspend WCL Road User Permit, the EPA has distanced itself from the suspensions of the Minister of Public Works (See attached communication from the EPA)
- The Minister of Public Works has been informed by the IMCC to reinstate the RUP of WCL since his arrival by his Deputy Minister of Public Works but has reneged to carry out the recommendation of the IMCC. He has intentionally ignored the instructions and recommendations of the IMCC.
- The current situation has led the company suspending all activities and operations of the Bomi Hill Mine, thereby leaving the fate of the employees in limbo (please see attached communication)
- The Minister of Public Works practice has been seen and felt by the employees and business partners of WCL.
- The company has request to intervene into the matter because the operation of the company is attached to social corporate responsibility that serves the communities in their area of responsibility.
- Western Clustern has imported a Concentrator Plant at the cost of Two Hundred and Fifty Million. Construction is expected to be concluded between now and December 2024. When constructed, additional one thousand jobs will be created.
- WCL has plans to construct a dedicated route for haulage of its ore. The company has also begun an assessment for the construction of a jetty along the Lofa River for shipping its ore and will subsequently build a port at Bomboja in Grand Cape Mount County. The company has begun informing all relevant government ministries agencies about the ongoing process.
- WCL has requested for permission to begin the exploration of the Mano Mines as well as the Bea Mines which are components of the MDA.

- WCL has made direct sponsorship to areas of sports, community, and youth. The company has provided sporting materials, and cash to the Bomi County team, engaged in community infrastructure developments.
- WCL is aiding the Liberian Government Hospital. The company provides the servicing of Ambulances, and fuel for Ambulance operations. Plans are being discussed with authorities of the Ministry of Health to procure and provide essential medical supplies and equipment to the Hospital.

Additionally, approximately 385 people of all levels (including local employment) have been employed on the mine thus creating much needed jobs for Bomi County. This number is expected to triple with the increase in production, commissioning of the beneficiation plant and other utilities, plus the upgrading of the Road and port facilities.

The no-go alternative would result in status quo conditions with large mineral resources remaining undeveloped and the loss of the substantial and long lasting social and economic benefits for Liberia.

Unmet Local Expectations

Local communities have expressed and voiced the need for socio-economic development in the form of training, employment and community development projects. Should the Project not go ahead, the local communities in both Bomi and Gbarpolu Counties lose investment in the local human resources and in the local economy. Potential positive socio-economic impacts are described and assessed in *Chapter 18.*

Negative Biophysical Impacts Averted

Potential impacts on the aquatic and terrestrial biophysical environments are detailed in the relevant assessment chapters. Potential biological impacts are associated with the degradation or loss of habitats and with a disturbance to, or loss of, sensitive or conservation-worthy plant and animal species. These impacts range from having a local scale (e.g. loss of a wetland) to a regional scale (potential impacts on migratory birds). In addition, the potential immigration of people into the Bomi and Gbarpolu Counties would also place additional pressure on natural resources (water, plants and animals) in the area.

From a physical perspective, the Project will affect air quality, ambient noise levels and will marginally increase Liberia's total global greenhouse contribution gas emissions. Should the Project not go ahead, these potential negative biophysical impacts would be avoided.

2.2.4 *Preferred Assessed Alternatives*

On the basis of the discussion above, the following project aspects were taken forward for assessment within this ESIA:

- HFO base generators used to provide onsite power.
- Water storage option 1 - Three (3) Day capacity open earthen lined tank lined with 1.5 mm HDPE lining

2. 3 Project Location

The Bomi Hills Mine project area is located near Tubmanburg, the provincial capital of Bomi County in north-western Liberia. It is located approximately 70 km north-west of Monrovia and is connected by a paved road. The concession area for Bomi Hills Mine is 114.42 km2 or 28,273.62 acres of land.

The mining concession area falls under the Senjeh District of Bomi County (*Map 2-1*) and Bopolu District of Gbarpolu County. However, most of the concession area falls under Senjeh District of Bomi County. There are 29 towns/villages of varying size within this area. The socio-economic screening was carried out within an area of up to 5 km from the boundary of the concession area. There are 23 towns/villages within a 1 km distance from the boundary and a further 93 towns/villages between 1 and 5 km's from the boundary. *Figure 2.3* shows the concession area and the 5 km extent.

Bomi Hills Mine is accessed by one main tarred road that runs from Monrovia through Tubmanburg. This road is proposed to be diverted around the town of Tubmanburg to reduce the impact of heavy vehicle movement. A railway line was built in the past to access Bomi Hills Mine; however, this has now deteriorated and is unsuitable for use as a form of transportation.

2. 4 Project Schedule

The implementation schedule for Bomi Hills Mine as it currently stands can be seen in Table 5.

Table 5: Project Implementation Schedule

Unit	**Proposed Target Completion**
Bamboja Roads & Bridges	Oct-25
Start Mining	Sep-13
Beneficiation Plant (1st Stream)	May-25
Beneficiation Plant (2nd Stream)	Feb26
Material Handling Plant (Primary Crusher, Stock Yard Equipment & Conveying System)	Jun-25

Water & Utility System	July-25
Power Generation & Distribution System	July-25
Township	Sep25
Port/Jetty	Dec25

2. 5 Description of Project Facilities, Components and Activities

This ESIA is focused on the Phase 1b development of the Bomi Hills Mine component. WCL intends to commence mining at Bomi Hills Mine to produce 4 Mtpa concentrate/DSO in a phased manner based on ramp up plan & infrastructure. Based on the exploration completed so far the estimated resources evaluated in the initial resource report which covers an area around the “old LMC Mining Pit” is approximately mined ore is required to be beneficiated to achieve the saleable grade of around 64 percent of ‘Fe’. It is 40 percent of mass recovery can be achieved, hence, to produce 4 Mtpa concentrated ore; 10 Mtpa of ROM (run of mine) is required. As the ore body is dipping, the waste rock will have to be at a strip ratio of 1:2. Thus to produce 10 Mtpa of RoM, 20 Mtpa of waste rock will be removed.

In order for mining to be able to take place the development of the following infrastructure is proposed:

- Permanent Facilities
  - Primary Crusher.
  - Conveyor.
  - Primary Crusher Ore Stockpile.
  - Beneficiation Plant.
  - Product Stockpile.
  - Power Plant.
  - Fuel Oil Storage.
  - Truck & Rail Loading System -.
  - Dedicated haul road corridor to Bomboja
  - Slurry Pipeline system
  - Truck parking area -.
  - Road Weigh Bridges (for mine and highway trucks).
  - Gate House 1, 2, 3 and 4.

- Plant Water System.
- Ancillary Building Complex (administrative building, canteen, project office, training center, medical facilities, environmental monitoring etc.)
- Township area.
- Repair shop and store complex.
- Heavy Earth Moving Machinery (HEMM) repair and maintenance complex.
- Waste disposal area.
- Magazine building.
- Mine site office.
- New WCL camp; and
- Geological shed.
- And Similar facilities required for any Iron ore Mining & Beneficiation plant

❖ Temporary Facilities

- Batching Plant / Storage of Civil construction materials.
- Steel Storage Yard.
- Lay down area for fabricated steel structures/equipment.
- Area for labor colony; and
- Area for Aggregate Crushing Plant.
- And other facilities required during construction of a similar Mining & Beneficiation project

2.5.1 Construction Activities

Site Preparation

The order for the major long lead equipment is scheduled to start from May 2025 and the balance by August 2025 to ensure there is sufficient time available for the construction / erection of the key items.

Some of the basic infrastructure that has to be developed to prepare the area for construction facilities includes:

- Construction of the crushers, conveyors, and mine plant and related facilities.
- Construction of security fencing/ boundary wall/perimeter road/watch towers for the proposed production area and retained production area.
- Site development includes area leveling and bush clearance, area lighting and related facilities.

- Set up WCL camp facilities with sanitary facilities.
- Construction of peripheral roads inside the plant boundary.
- Construction of water distribution and drainage system and toilet facilities with treatment facilities.
- Setting up an aggregate quarry and crushing plant in the mine area for course and fine aggregates for making concrete and related facilities.
- Setting up a batching plant for producing concrete and lay down area with related facilities.
- Existing disused mine pit water will be utilized for construction works.
- Drinking water during construction will be sourced from the disused mine pit or borehole and treated as necessary.
- Fuel storage facilities.
- Individual contractors will arrange for power during the construction phase using diesel generators.
- Development of construction yards, stores and construction offices; and
- Development of temporary camp facilities for construction labour and personnel.

The existing disused mine pit will be utilized for construction water as necessary. The water quality has been tested and found suitable for construction use. The peak requirement of construction water is estimated to be about 200-300 m^3/day. The following services will be established on site as part of the early activities and will expand as work progress. They include but are not limited to

- Site Security.
- Site Medical/ First Aid services.
- HSE staff and material; and
- Site quality control lab, including soil compaction, concrete testing and weld testing.

Construction Yards and Storage Yards

Space will be provided, within the mine/ plant area, to the Contractors for the aggregate crushing plant and quarry, batching plant, fabrication yard, construction equipment and machinery storage and a construction shed for materials.

Storage of Plant and Equipment

Equipment and materials will be stored in the open area adjacent to the individual units as required. For storage of electrical and other instrumentation covered storage with ambient controls will have to be built by respective executive agencies.

Construction Water

The existing disused mine pit will be utilized for construction water as necessary. The water quality has been tested and found suitable for construction use. The peak requirement of construction water is estimated to be about 200-300 m^3/day. Contractors will have to make further distribution and storage facilities as per their requirements.

Drinking water during construction will also be sourced from the disused mine pit or boreholes after suitable disinfection and treatment.

Construction Power

The individual contractors will arrange for power during the construction phase using diesel generators for all the site activities under their scope.

For construction area lighting, the contractor will make all the necessary arrangements for sufficient illumination of the working space.

2.5.2 Key Operational Facilities

Bomi Hills Mine will comprise an open-pit mine for iron ore extraction and surface facilities for ore transportation and processing; waste rock and tailings storage facilities; concentrate transportation; and utilities. The main facilities and their contents are detailed in *Table 6*. The locations of the individual Project facilities to be constructed related to the mining area were presented in *Map 2-2.*

Table 6: Summary of Key Project Facilities of the Mine

Key Project Facilities	Function and Contents
Concession Area	Project area –114.42 km^2
Mine footprint area	11 km^2 including waste rock dump & tailing storage facility area
Rate of Mining	9 Mtpa ROM, 18 Mtpa Waste rock
Strip Ratio	Approximately 1:2, but would vary according to the mine plan and ramp up plan
Mine Pits	Open pit Main pit max. 405m depth Pit slope as per Mine Plan
Blasting	Ammonium Nitrate emulsion
Working benches	Slope of 80-90^o and a minimum width of 30 m
Permanent benches	Multiple benches in the ore and overburden, bench height of 12 m

	and bench width of 5 m
Crushers	Primary crusher Secondary and tertiary –
Primary crushed ore	Permanent
stockpile	Two (2) days ROM. Two (2) stockpiles of 200 m x 50 m, height 11 m.
Beneficiation Plant	212,500 m^2
Product Stockpile	Capacity of 30,000-40,000 tons, area of 19,500 m^2
Tailings Storage Facility (TSF)	Average tailings disposal rate-19,000 tpd (6 Mtpa)
Waste Rock Disposal	20 Mtpa of waste rock
Facility (WDF)	Three areas identified, total capacity of 245.6 MT, 60 m in height Angle of Repose 40°
Ore Transportation System (OTS)	Truck
Explosives Magazine	Area of 200 m^2
Airstrip/ helipad	Refurbishing of existing airstrip/helipad.
Water Supply System	30,000 m^3/ day
Wastewater Treatment	Package type sewage treatment plant with Membrane Bio Reactor
Power Plant	HFO/other suitable fuel based, approx. 4-6 units of 5-8 MW each depending on manufacturer's recommendation Stack height around 20-30 m
Storm Water	Design to be finalized
Accommodation	Approximately 100 families initially Accommodation for approximately 800 contract workmen.

2.5.3 Mining

Out of the total concession area of 114.42 km^2 allotted for Bomi Hills Mine project, the mineralized zone comprises 18.45 km^2 and exploration has been carried out in approximately 4 km^2 area around the disused mine pit and further exploration is in progress. From work undertaken in the area it can be seen that the ore body resembles a truncated ladle trending in the East-West direction with moderate to steep northerly dips (*Figure 1)*. The ore body has been divided into a western (WZ - West of disused mine pit), a central (CZ - East of disused mine pit) and an eastern zone (EZ - Extreme Eastern side of disused mine pit).

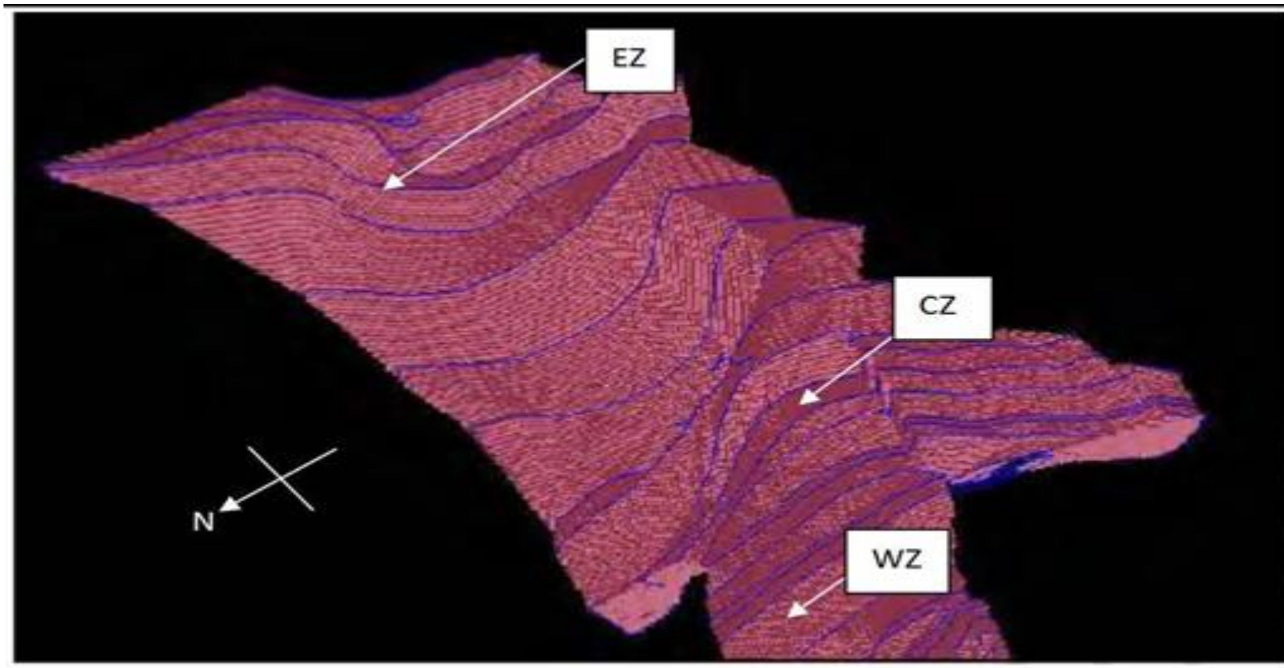

Figure 1: DTM Model of Bomi Hills Mine Orebody

Opencast mining has been identified as the most suitable mining method due to the occurrence of ore near the surface. Since the ore is medium hard, a drill and blast method with shovel and dumper equipment combination is the most suitable option for mining this deposit.

The mining method adopted for the Bomi iron ore deposit will consist of the following:

- Iron ore and waste rock will be excavated separately.
- A drill and blast method will be used.
- Blasting will be done using emulsion explosives.
- Shovel and dumper combination will be adopted for loading and hauling both ore and waste rock.
- Ore will be hauled at the rate based on ramp up plant max approximately 10 Mtpa to the primary crusher for crushing and further processing to produce 4 Mtpa of iron ore concentrate at a grade of ±62 percent Fe in a phased manner based on ramp up plan & infrastructure.
- Waste rock will be hauled at an average rate of 20 Mtpa and the waste will be dumped in pre-designated non-mineralized areas; and
- DSO (Direct Shipping Ore), wherever occurring, will be mined separately and crushed to obtain calibrated lumps and exported as such. The average grade for DSO is likely to be 62 percent Fe.

It is proposed that the Mining will start from east of the LMC disused mine pit and advance in a northerly direction until the main ore body is reached at which stage mining will continue in an easterly direction. It is also proposed that simultaneous mining will start from the northern end of the eastern flange (of the explored ore body) advancing towards the south and then towards west so as to merge with the pit advancing from the west. Mine fronts will eventually merge into a single mine pit. The actual mining will be commensurate with the detailed Mining Plan and ramp up plan.

While mining it is proposed that when a stripping ratio of 1:2, the optimized pit has a maximum depth occurring in the eastern side of the deposit reaching up to a depth of almost 405 m, while on the western side, the pit depth goes down up to almost 190 m. Since the thickness of the ore body decreases on the western side, going beyond 190m depth will increase the stripping ratio beyond 1:2. Thus the maximum pit depth will be approximately 405 m, with an ultimate pit slope angle of around 45°, a bench height of 12m, a bench width of 5 m and haul road width of 25m. The ultimate pit slope angle may be safely increased to approximately 50 °, according to the recent geotechnical study carried out by Bengal Engineering and Science University (BESU) (2012/2013).

The actual figures for Mining quantity, waste & recovery would vary depending upon the average grade of mining and actual recovery that would be possible from the beneficiation plant process. Considering a mass recovery of 40 percent from beneficiation plant to produce 4 Mtpa concentrate, Bomi Hills Mine will need to excavate 10 Mtpa of ore and 20 Mtpa of waste. Thus, the mine will need to excavate on average 30 Mtpa of rock which necessitates suitably large excavating machinery with matching dumpers. Based on this analysis it was found that for 12 m bench height an excavator of 10 m^3 bucket capacity and a matching dumper of 135-ton capacity would be the most suitable. Initially the mine operations will commence with smaller equipment. It is proposed that the minimum working bench width for this mine has been determined at 30 m.

Considering the above, Ore will be mined at a rate of approximately 28,000 tons per day (tpd) and therefore the generation of waste will be 56,000 tpd. The ore will be fed into the plant directly; however, while the plant shut down, the ore will be stockpiled at the ROM stockpiles.

The area where mining will take place is an area that has largely been previously disturbed due to mining activities in the past. Although the vegetation has to some extent recovered the area is still considered a brownfield site. The only portion that has not previously been impacted is the vegetated area in the northeast of the concession area. No mining is planned in this area at this stage.

Mine Sump

A sump will be required to keep my working faces free of water. As such, sumps have been proposed at two locations in the pit bottom of the eastern and western pits. Due to a shallower pit depth currently, a single sump is being operated.

Similarly, the existing disused mine pit water will be gradually lowered as the mining progresses, such that the water level is below the working mine level. This water can be utilized for various activities/ operations such as in the process plant, for dust suppression and other infrastructure.

Haul Roads

The haul road for ore comes out on the southern end towards the east of the disused mine pit at about 140 mRL (reduced level) to reach the primary crusher located south of the deposit. The haul road for the waste rock also emerges at about 140 mRL but moves towards the east from the east pit and for waste rock from west pit the road comes out on the extreme west side to be dumped on the southwest side of the pit. A spiraling haul road of 25m width/three times the width of the widest machinery at a gradient of 1 in 16 will be laid in the pit. The dumpers carrying ore will come out of the pit to the crusher, which lies to the east of the disused mine pit at about 140 mRL. All the haul roads will be designed at a slope of 1 in 16 with a gradient of 1 in 10 in case of a short ramp.

Ultimate Pit Slope Angle

The ultimate pit slop angle of 45° has been provisionally considered while the geotechnical studies are in progress. Upon receiving the results of the final geotechnical study report, the same will be utilized to optimize the pit shell and ultimate pit slope angle.

Operating Hours

Bomi Hills Mine operates on a schedule of 365 days per year at 24 hours per day, three (3) shifts of eight (8) hours each.

Life of Mine

Based on exploration and tests data, the total mineable reserves in the Bomi deposit have been estimated to be 222Mt. The targeted annual RoM production is 10 Mtpa. The life of mine, including 4 months of development period, has been determined to be 25 years. *Table 7* indicates ore and waste tonnages that are expected to be handled on an annual basis. Exploration activities are continuing, and the revised reserve and Mine life shall be updated from time to time based on results of exploration and actual mined quantity of the ore.

Table 7: Ore and Waste inventory for 25 years

Period	DSO	Fe%	BMQ + SMM + MM	Fe%	Total ore	Waste	Grand Total	Total Product
1	2.00	59.0	5.80	38.0	7.80	15.03	22.83	2.0
2	1.00	59.0	4.99	36.0	5.99	14.00	19.99	3.0
3	0.00	0.00	5.00	36.0	5.00	14.00	19.00	3.0
4	0.00	0.00	5.80	36.0	5.80	26.30	32.10	4.0
5	0.00	0.00	10.00	36.0	10.00	24.00	34.00	4.0
6	0.00	0.00	10.00	36.0	10.00	24.80	34.80	4.0
7	0.00	0.00	10.00	36.0	10.00	25.10	35.10	4.0
8	0.00	0.00	10.00	36.0	10.00	24.00	34.00	4.0
9	0.00	0.00	10.00	36.0	10.00	24.30	34.30	4.0
10	0.00	0.00	10.00	36.0	10.00	23.90	33.90	4.0
11	0.00	0.00	10.00	36.0	10.00	23.50	33.50	4.0
12	0.00	0.00	10.00	36.0	10.00	23.20	33.20	4.0
13	0.00	0.00	10.00	36.0	10.00	22.70	32.70	4.0
14	0.00	0.00	10.00	36.0	10.00	22.00	32.00	4.0
15	0.00	0.00	10.00	36.0	10.00	23.00	33.00	4.0
16	0.00	0.00	10.00	36.0	10.00	20.00	30.00	4.0
17	0.00	0.00	10.00	36.0	10.00	18.00	28.00	4.0
18	0.00	0.00	10.00	36.0	10.00	19.00	29.00	4.0
19	0.00	0.00	10.00	36.0	10.00	19.00	29.00	4.0
20	0.00	0.00	10.00	36.0	10.00	18.00	28.00	4.0
21	0.00	0.00	10.00	36.0	10.00	19.00	29.00	4.0
22	0.00	0.00	10.00	36.0	10.00	15.00	25.00	4.0
23	0.00	0.00	8.00	36.0	8.00	12.00	20.00	3.2
24	0.00	0.00	7.00	36.0	7.00	5.00	12.00	2.8
25	0.00	0.00	3.00	36.0	3.00	5.00	8.00	1.2
Total	3.00	59.0	219.59	36.1	222.59	479.83	702.42	91.3

Reference to current mining strip-ratio

DSO Mining

As per present exploration data & tests results, Total DSO resource (Massive Magnetite) is around 3.7 MT. The remaining resources will be mined in the course of Banded Magnetite Quartzite (BMQ) in a phased manner based on ramp up plan, matching with infrastructure.

2.5.4 Plant Infrastructure

WCL currently ships 4 Mtpa of concentrate/DSO after beneficiating the RoM ore. The final plant layout and equipment shall be as per detailed technical studies and as per the recommendations of the technological plant suppliers.

In general, the plant infrastructure has been divided into three zones:

- Technical zone with workshops, storage, fuel storage, heavy vehicle parking etc.
- Social zone with changing rooms, training center etc; and
- Office zone.

Thus the "noise-free" facilities are separated from the "noise-borne" facilities. These facilities will be separated by a green belt for the abatement of dust and noise.

The planned facilities are discussed in more detail in the following sections.

Primary Crusher

The primary crusher has been located on the south western side of the disused mine pit outside the mineralized zone on an area of 1,000 m^2 due to its proximity to the main mining area thus keeping the dumper haul distance to a minimum, to avoid tunnelling the conveyor towards the stock pile, there is sufficient area on the hill slope for dumper parking as well as stockpiling the RoM whenever the crusher is not in operation so that mining activity proceeds uninterrupted as well as being outside the ultimate pit limit, so that the crusher need not be shifted as mining progresses.

The capacity of the primary crusher is 1,200 -1,400 tons per hour (tph), and it is a jaw crusher. The RoM will be stockpiled in close proximity to the primary crusher. A RoM stockpile of almost 100,000 tons supply three days or more of feed in the event of a supply disruption at the mine or as number of days as per the process requirement considering the various factors including the rainy season and also to keep the crusher feeding during shift change. The RoM will be stockpiled during a temporary/maintenance shutdown of the primary crusher.

Primary Crushed Ore Stockpile

The crushed ore stockpile area has been located close to the beneficiation plant (refer to *Map 2-2*), thus reducing the transport distance. The proposed area can hold material for approximately three (3) days considering 10 Mtpa RoM or more as per the process requirement considering various factors including rainy season. The two (2) stockpiles will have dimensions of 200 m x 50 m, each with a height of 11 m. The intention of these stockpiles is to ensure uninterrupted operation of the Beneficiation Plant.

Beneficiation Plant

The low-grade magnetite ore mined cannot be used in metallurgical plants and needs to be upgraded to increase the iron content. The purpose of the beneficiation plant is to extract the iron ore from the ROM ore that has been crushed and thereby upgrade the Fe content from an average approximately 38 percent to +62 percent. This crushed ore will then be fed from the ore stockpiles to the High-Pressure Grinding Roll (HPGR) mill through an arrangement of conveyors and apron feeders. The feed to the beneficiation plant will be a combination of ROM ore and fine tailings from the old tailings pond. If possible, old tailings may be processed separately, as some of the old tailings have to be removed to mine the ore underneath. A diagram of the proposed Beneficiation process at this stage can be seen in *Figure 2.2*. The actual process and design shall be as per the detailed design of the process plant suppliers.

The main plant is divided into two parts, Comminution (grinding) Circuit and the Beneficiation Plant. These are described in more detail in the sections below.

Comminution Circuit

It is proposed that at this stage, the comminution circuit consists of a SAG mill/ High Pressure Grinding Roll (HPGR) mill with cone crusher (as a pebble crushing unit in an open circuit), grinding ball mill and screens. There is also an optional stage of secondary crushing and screening, and the oversize material has to be taken in the High-Pressure Grinding Roll (HPGR).

Beneficiation Circuit

The proposed Beneficiation Plant (212,500 m^2) is the main unit around which all the other units are designed and located. The process plant is designed for processing the lean ore to produce high grade Iron ore concentrate. The process plant contains different equipment to segregate the fine ground ore using its magnetic characteristics. The low-grade tailings from the process will be sent to thickeners and after recovering the process water the thickened tailings will be disposed of to the tailing's disposal facility (*Section 2.5.5*).

This Beneficiation Plant includes the beneficiation of the iron ore by classification and Low Intensity Magnetic Separators (LIMS). The mechanism of separation occurring within the cyclone is known as classification. Classification is a method of size separation of a mixture of minerals on the basis of the velocity with which the grains fall through a fluid medium (usually water). Cyclones utilize centrifugal force to accelerate the settling rate of particles. Although the aim of the cyclone operation is to separate particles by size; particle density, particle shape and other factors also affect the settling rate of particles and hence cyclone performance. Cyclones are used in preference to screens as a means of size separation in the grinding circuit as they are more efficient at fine separation sizes. Two product streams are generated by the cyclones; a fine 'overflow' stream which storage tanks for feeding to LIMS for conc stream that is fed to the ball mill for further liberation of ore.

The ground material is fed to the Rougher LIMS magnetic separation circuit. The magnetic product of the rougher LIMS is again ground to a finer size of 300 µm for further liberation of magnetite. The ground slurry is subsequently classified and treated in an intermediate LIMS further concentrating the magnetite. Then the final concentrate is aimed for further up grading in terms of total iron content and needs to be ground in a fine grinding mill to a particle size of 106 µm. Final concentrate slurry from the fine grinding mill shall pass through a final stage cleaner LIMS for final concentration. The magnetic product is pumped to the concentrate thickener. A suitable flocculant dosing system will be used for the dosage of flocculants. For tailing thickening, Nalco brand N83384 flocculants or equivalent shall be used. The typical flocculants dosing rate shall vary between 10 to 20 g/t. The concentrate thickener underflow is meant for dewatering to get the desired moisture in the final product.

The concentrate material from the pressure filter is stacked on the product stockpile via conveyors.

All the nonmagnetic products from the respective LIMS streams are collected in a sump and subjected to thickening in a tailings thickener. The nonmagnetic product, because of the low iron content, is non-profitable to process and is directly subject to safe disposal.

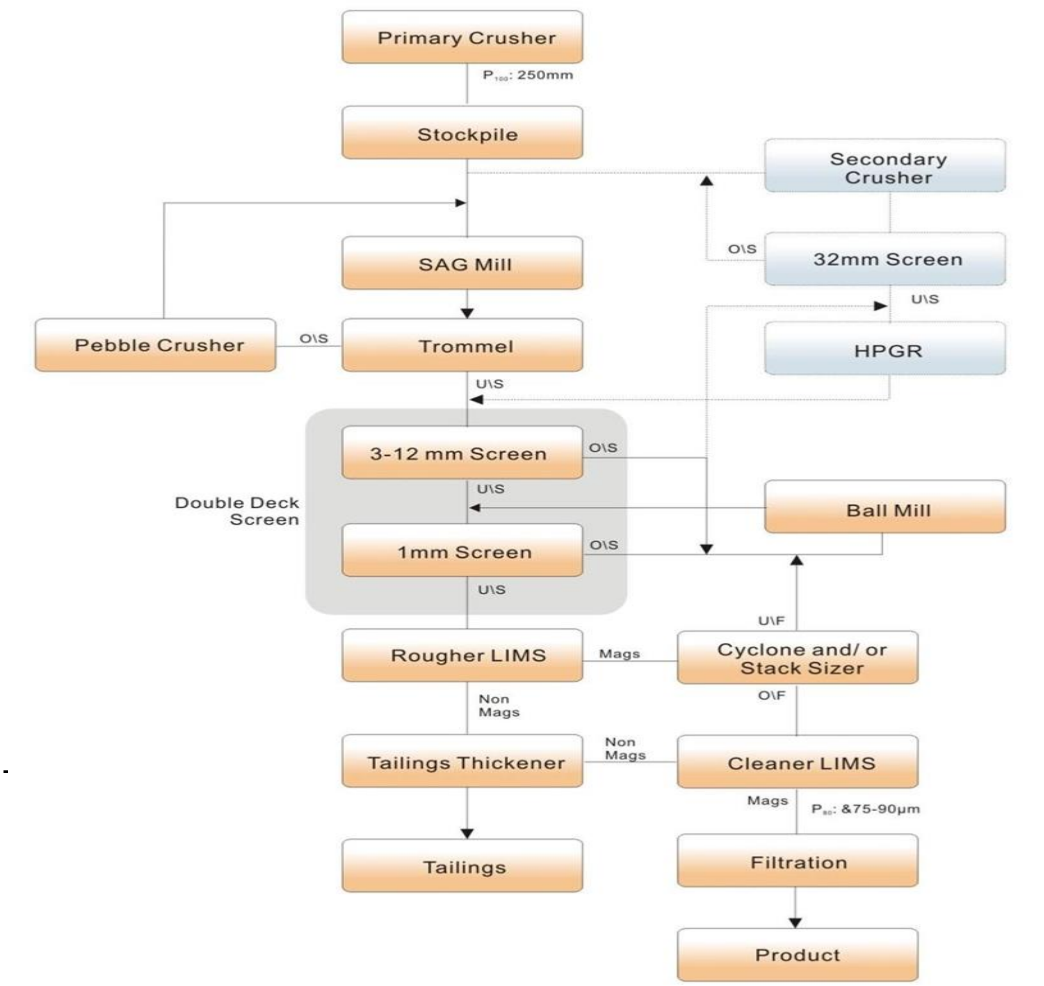

Figure 2: Ore beneficiation flow chart

Product Stockpile

Concentrate produced by the Beneficiation process is transferred via a conveyor to a covered stockpile with a capacity to stock approximately 30,000 tonnes (19,500 m^2), which is approximately five (5) days production. The stockpile will be located directly to the west of the Beneficiation Plant *(Map 2-2)*.

Initially the DSO and the concentrate will be transported by dump truck to the Port by using a manual equipment loading system until such time as the an alternative transport route and jetty facilities are developed or any other options become possible.

2.5.1 Waste Disposal Facilities

Waste Rock Dumps

Based on the exploration and tests results at this stage, the ore body at Bomi Hills Mine is East –West trending and dipping about 40°- 60° to the north, hence as the ore is mined associated waste rock needs to be excavated to maintain an overall pit slope of approximately 45°. An ore to waste ratios of 1:2 is considered, therefore for a project of 4 Mtpa of concentrate approximately 10 Mtpa of ore will have to be mined with the result that 20 Mtpa of waste rock will have to be excavated.

Locations for the proposed dumping of waste rock have been identified on the non-mineralised zones in Four locations namely, the Northeastern Waste Dump (NEWD), Northwestern Waste Dump (NWWD), Western West Dump (WWD) and South Eastern Waste Dump

The proposed final dimensions for the waste of the dumps can be seen in *Table 8* below:

Table 8: Proposed Waste Rock Dump Dimensions

	Dump Slope (^{0})	Dump Height (m)	Base area (km^2)	WRD Perimeter (km)	Capacity (million m^3)	Capacity (MT)
EWD	30	60	0.93	4.49	43.0	114.8
SEWD	30	60	0.55	2.9	24.5	65.4
NWWD	30	60	0.55	2.9	24.5	65.4
WWD	30	50	0.13	1.5	1.59	4.31

The total capacity of the four waste dumps is approximately 249.91 MT. This is less than the total volume of waste rock to be excavated over the life of mine and as such there is an excess of approximately 229 MT to be disposed of. A location(s) will need to be identified within the license area as the exploration progresses for the disposal of the excess waste rock. It is to be noted that the plant construction would also need rock aggregate including proposed road corridor.

Tailings Storage Facilities

Three (3) areas to the east of the mine pit have been proposed for the tailings storage facilities (TSF's) *Table 9* and *Map 2-2*. Duringare define beneficiation a mass recovery of 40 percent iron is expected as the ore is enriched to above 62 percent as saleable concentrate. As 10 Mtpa of ore is processed to produce 4 Mtpa of saleable concentrate, this means that 6 Mtpa of tailings is generated which needs to be disposed of.

The dimensions of the three (3) TSF's are outlined Table2.7below: in

Table 9: Proposed Tailings Storage Facilities

	Surface area (km^2)	Perimeter (km)	Height (RL)	Density (tones/m^3)	Volumetric capacity (million m^3)	Gravimetric Capacity
TSF 1	0.57	3.78	70	2.5	12.7	31.75
TSF 2	1.3	6.77	90	2.5	32.3	80.75
				2.5	8.61	21.5

A wet process has been selected for the beneficiation and concentration, largely for the safe disposal of tailings. The tailings from the thickener will be thickened to a solid concentration of 55-60 percent weight/weight (w/w) and pumped to the destined TSF with a suitable pumping mechanism. The TSF has been designed to cater for the maximum recovery of water from the system for reuse in the plant.

Dewatering Unit

The dewatering unit consists of thickener to thicken the magnetite slurry and pressure filtration systems to dewater the slurry. The ground and magnetically separated ore fines in slurry form are collected and pumped to the thickener unit to densify for filtration. A suitable flocculant solution is added to facilitate the flocculation of iron ore fines and collected as underflow. After thickening of the slurry in the thickener, the thickener underflow material is pumped to the filter press for further reduction of moisture from the ore. The material from the pressure filter is collected in the form of cake with a desirable moisture content suitable for downstream processes. The filter is collected in the sump and pumped back to process water clarifier tank for reuse.

The tailings from the Beneficiation plant will be collected in a tank and pumped into a tailing's thickener. After thickening the slurry, the thickener underflow material is pumped to the tailing's storage facility. Water from the tailing storage facility is recovered for reuse in the plant.

The major water recovery system has been incorporated at all points of discharge namely concentrate and tailing thickeners and the pressure filter which is collected in a process water clarifier tank. The recoverable water from tailing storage facilities shall also be taken into the main process water reservoir but not in the initial plant operation.

2.5.2 Power Requirements

Liberia does not have an electricity grid which is able to supply power to the 4 Mtpa project at Bomi Hills Mine. It is thus essential that WCL establish their own power generation plant to meet the power requirement of the Project.

The overall power demand for the proposed 4 Mtpa iron ore beneficiation project at Bomi Hills Mine has been calculated based on the requirement of power for individual plant units.

The tentative load requirement has been calculated as 45 MW; however, it is proposed that the power plant will be designed for an installed capacity of 70 MW in a phased manner based on ramp up plan for Mining and processing. The power plant is planned to be installed in phases with modular units, starting with an installed capacity of 30-35 MW for the first stream which will be augmented based on the requirement of the second stream of operation. The power plant will have sufficient expansion provision for the installation of further units to take care of additional load requirements, if any, at a later stage. In addition to the above installed capacity additional units have been planned for considering adequate stand-by units for ensuring availability as well as 90% loading on other units as per good power plant operational philosophy.

It is proposed to additionally install two 1.5 MW generators or as may be required based on the recommendation of the manufacturer for black starting and efficient load management of the power plant.

It is proposed that the generation voltage is envisaged at 11kV. Considering the load requirements, location of various sub-systems, results of the preliminary system study, 11kV is envisaged as primary transmission voltage from MRS (Main Receiving Station).

Proposed Site for Power Plant and Fuel Storage Area

A techno-economic study was carried out for HFO transportation from Monrovia to Bomi Hills by fuel oil tanker by road and transportation via pipelines. From this study, it was evident that HFO transportation by tankers would be the most economic. In view of this, the Power Plant will most likely be located at Bomi Hills with adequate HFO storage tanks to ensure uninterrupted operations.

It is proposed that fifteen days' storage of HFO will be provided, and the number of tanks and capacity will be dependent on the plant capacity. Tanks will be constructed in a tank farm area in a phased manner within a bunded area to avoid the oil spillage in case of any leakage from the tanks. The tank farm area shall have facilities for fire detection and prevention.

The proposed layout of the generators and fuel storage can be seen in *Map 2-2*.

Other auxiliary systems associated with the proposed power generation that will be required on site include:

- Fuel Oil unloading, storage with day tanks with pumping and transportation to the unit.
- Lube oil system.
- Compressed air system.
- Charge air and exhaust system.
- Cooling water system.
- Electrical systems.
- Control system; and
- Plant and buildings.
- Fire Fighting System and any other system as per the requirement.

It is proposed that the High engine exhaust temperatures in the HFO fired power station will be utilised for water heating for use in the HFO heating and tracing system. In addition, pollution abatement will be carefully considered in the design, construction and operation of the plant. Refer to *Map 2-2* for the proposed locations of the substations.

2.5.3 Water System and Mine Utilities

Water Requirements

Water is required for processing, in the beneficiation plant, in the power plant for process and equipment cooling purposes as well as for dust suppression, washing of heavy earth moving equipment, general washing and cleaning, and the firefighting system. In addition to water requirement for industrial uses, water is also required for drinking and sanitation needs of plant personnel, township population and drinking and sanitation for construction workers. During the construction phase water is also required for construction work. The estimated requirement of water by the various consumers is presented in *Table 10.*

Table 10: Water consumption requirements

Serial No.	Consumer	Proposed Water Requirement, (m^3/Day)
1	Process Water Make Up	23,520
2	Dust Suppression	480
3	Washing & Cleaning	180
4	Power Plant & Cooling Water Make Up	2 400
5	Drinking & sanitation for Plant Personnel	100
6	Drinking & Sanitation for Township	117
7	Construction Water	200
8	Drinking & Sanitation of Construction Workers	115
9	Miscellaneous & Contingency	300
10	Social Services	800
	TOTAL	30,000

Water sources

The area in which Bomi Hills Mine is situated has good rainfall, averaging 3,161 mm per year. Average monthly rainfall data for Monrovia and Bomi Mines are presented in *Chapter* 7 with the majority of that rainfall falling during the months of May to October. A perennial river, the Mahe River, flows through the lease area and is an important source of fresh water. There is an existing intake well on the Mahe River at Small Bopulu. Three (3) vertical turbine pumps (of which two (2) working and one (1) is on standby) are proposed to be installed. Each pump will be rated at 650 m^3/hr and suitable for head of 50 mWC (Water Column). It is proposed that a maximum of 30,000 m^3/day for 4 Mtpa stage will be extracted from the Mahe River on a daily basis. After two (2) years of operations water will be able to be recovered from the tailing's storage facilities and the make-up water required will be reduced to 14,400 m^3/day.

An alternate potential source of make-up water is the disused mine pit, however, from preliminary investigations it has been observed that the disused mine pit cannot be used as a permanent source of water on a sustainable basis. Based on the bathymetric study report submitted the two-dimensional area of the disused mine pit is 399,707 m^2 and the volume is 10,295,134.4 m^3. The water requirements for the 4 Mtpa project have been calculated at 30,000 m^3/day. The current capacity of the disused mine pit and the likely recharge volume through rainfall (about 75,000 m^3), will meet about a year's (432days) water requirement. In view of this, the disused mine pit cannot be considered as a sustained source of make-up water. It may be used as an emergency source to meet contingencies arising at the supply system from the Mahe River. This would avoid the need for large make up water storage at the mine site. As an alternative, the disused mine pit can be used for the emergency supply of water through the adoption of a barge pumping system during breakdown of the intake pumping system and thus major storage at the plant site could again be avoided.

Drinking water can be sourced from the ground water by drilling a sufficient number of boreholes. However, hydrogeological studies around the disused mine pit area reveal that the yield of 100 m deep wells is not expected to be more than 3 -5 m^3/hr. The water from the Mahe River or the disused mine pit can also be used as drinking water after chemical dosing, filtration and disinfection.

Water for the initial construction can be sourced from nearby streams, the Mahe River or disused by my pit. However, once the main water intake on the Mahe River is ready then this can be used for construction purposes as well.

Raw Water Treatment

The raw water treatment system proposed takes into account three (3) different water resources: the disused mine pit; the Mahe River and borewells. From tests carried out on these three (3) waters sources the following can be seen:

- The pH of the Mahe River water is 6.53 (1) indicating that it is mildly acidic in nature. The pH of the disused mine pit is approximately 7.09 which is within an acceptable range and may not need dosing.
- The water of the Mahe River and disused mine pit contains Coliform bacteria and disinfection through chlorination will be required.
- The quality of borehole water is not currently available.

Water Storage

The intake at the Mahe River is located approximately 6 km from the mine and plant site. As such an adequate storage of raw/make up water will have to be provided at the plant site to ensure that any supply problems associated with the pump and piping system at Mahe River can be overcome. Various options have been considered and it was decided as option 1 in the beginning of the chapter.

A separate storage tank of adequate capacity will be provided exclusively for the Fire Fighting System.

For drinking water, a separate tank of adequate capacity will be provided.

Make-up Water Pump House

For pumping water to the different consumers a makeup water pump house consisting of three (3) horizontal centrifugal pumps will be provided for pumping make up water from the storage reservoir to the various consumers.

Drinking Water System

It is proposed that Drinking water will be treated by removing iron, filtration and disinfection or by using borehole water for distribution to the various consumers in the mine, plant and township.

Recirculation Cooling Water System

Data received from various equipment suppliers has outlined the requirement for a cooling water system separate to the industrial recirculation cooling system which will be provided. This system will comprise pumps and a cooling tower with associated electrics and instrumentation. A separate cooling water system will be provided for the power plant.

Fire Fighting System

Fire hydrants will be provided in the process plant areas in line with the National Fire Protection Association (NFPA) standard. The fire hydrants will have a separate storage system comprising of one tank of 1,000 m^3 capacity. A separate pump house will be provided with two (2) electric and one (1) diesel engine driven pump. A fire water ring main will be provided covering the process units, beneficiation plant and the electrical installed power plant.

Dust Suppression

Three different dust suppression systems are envisaged for the mine and processing plant:

- mine haul road.
- stockpile.
- materials handling points; and
- transfer points.

For dust suppression of the mine haul roads, water sprinkler trucks are envisaged. The trucks will be filled at various specified points where water posts will be provided with a valve and hose system. The number of trucks will be determined on the basis of the haul road length.

For stockpiles, separate sprinkler system will be provided and complete with a pumping system. Sprinklers will be provided at a spacing of approximately 30 m around the stockpile.

A dry fog dust suppression system will be provided at all transfer points and crusher intake points and will be complete with pumps, compressors, and a control system. *Table 6* summarizes the water requirements for dust suppression.

Table 11: Water requirements for proposed dust suppression

Area	**Volume m^3/day**
Haul roads	320
Stockpiles	83
Transfer points	61
Total	464

Thus, the total water requirement for Dust Suppression works out to approximately 464 m^3/day. The actual capacity shall be calculated based on actual plant consumption worked out during detail engineering stage considering phase wise ramp up capacity of the plants.

Oil and grease trap

The wastewater generated in the service center and from floor washing of concentrator plants will be collected in a settling tank fitted with oil skimmers. The treated water will be reutilized for washing and cleaning.

Sewage Treatment Plant

The sewage generated in the main plant area and ablution block will either be treated in a package sewage treatment plant (STP) or using the septic tank and soak pits. For individual units in the mining area soak pits and septic tanks will be provided with upflow filters.

Solid Waste Management at the Mine

Solid waste will be managed at Mine through implementation of the Environmental and Social Management Plan (ESMP). A waste site will be identified for disposal of domestic waste which will be operated in accordance with the ESMP and international requirements [(1)]. This will be sited to avoid proximity to residential development, hospitals or schools or other sensitive receptors, avoid groundwater and surface water resources and will be designed to minimise the generation and impacts of leachate.

If hazardous waste is generated, it will be disposed of as per the applicable statutory requirement or international best practices.

2.5.4 Ancillary Facilities

An ancillary building complex has been envisaged to the southwest of the power plant and repair shop and stores. This complex comprises an administrative building, project office, training center, medical facilities and environmental monitoring.

Mine site office

The mine site office (could be a re-locatable facility) will be close to the actual mining area. It will consist of office facilities to accommodate necessary engineering and administrative personnel. Additional facilities such as a dining room, rest shelter, meeting rooms, security post, telecommunication facilities and ablution facilities will also be present.

Canteen

Considering the large operating areas for Mining and plant processing it is proposed that dining space will be provided near the working area instead of centralized Canteen. Ample dining space will be provided separately for the mining contractor personnel and departmental personnel preferably at their place of work.

Explosives Magazine

The explosives magazine is situated within concession in an isolated area far away from dwellings. The facility is well guarded with fencing and monitored by round-the-clock security. The storage area for the detonators and fuses approximately200 m^2.

Heavy Earth Moving Machinery (HEMM) Repair and Maintenance Complex

The equipment workshops will be sized to enable all routine maintenance of equipment to be carried out on site, but not major overhauls such as engine and transmission rebuilds. Routine maintenance includes daily maintenance, scheduled maintenance, minor repair and medium repair. Cleaning vehicles using high pressure hoses and steam cleaners will also be carried out in this facility. It is envisaged that major work that requires specialized skills, tools and conditions would be carried out.

Drainage of storm water will be handled by graded surface and sub-surface drains. All rainwater runoff from the workshop area will be collected in settling ponds complete with oil separation facilities before release to the environment.

It is proposed to have the following facilities and repair shops within the workshop area:

Major facilities:

- Maintenance office.
- Excavator shop (for the maintenance of hydraulic excavators and drills (but not wheel loaders).
- Dumper shop (maintenance of all off-road haulage vehicles, including water carts).
- Earthmover shop (maintenance of all earthmoving equipment, such as dozers, graders and wheel loaders); and
- Light vehicle and service workshops.

Other facilities:

- Wash down pad.
- Waste water treatment plant.
- Compressor house.
- Overhead tank.
- Tyre press and tyre storage.
- Open storage yard.
- Salvage storage yard.
- Lubricant storage.
- Security office; and
- Vehicle Park.

An area of 200 m^2 has been envisaged for fuel storage in mine area which will also include a separate area for lubricant storage.

The fuel storage area will be close to the HEMM workshop with a capacity of 200m^3 of diesel. This is for refueling of mining equipment.

Gates

The plant will assign one main gate and one heavy vehicle movement gate for regular operation. All other gates should be temporary for specific Maintenance or only operated during emergencies for speedy approach to designated place. Accordingly, four (4) gates have been planned for to and from the various my facilities. A separate emergency Gate House has been located close to the existing road going to Mano River. This gate will generally remain closed and will be used for emergency purposes only.

Weighbridge

Two (2) road weighbridges of approximately 100 tonne capacity and two weigh bridges of 300 tonne for mine will be used for weighment of both empty and loaded trucks.

2.5.5 Proposed Auxiliary Features

For Phase 1 – 4MTPA @Bomi – Existing EPA

We plan to build a 3MTPA Concentrator plant at Bomi Mine, for which a contract has been awarded. We plan to build a jetty at a suitable location and a dedicated road from Bomi Mine to the new jetty to transport and export 4 MTPA products (3MTPA Concentrate + 1 MTPA Occasional DSO).

Also, dedicated roads are planned from the Bea and Mano mines to the new jetty, which can transport the product from the mines to the jetty for export. The estimated jetty capacity is 7MTPA, catering to all three mines. A consultant from India is busy with technical work and engineering for this work.

Western Cluster currently also explore the option of partnering with Bao Chico to use their new jetty, which is under construction. Thorough due diligence is needed to evaluate this option. Western Cluster limited decide to proceed with this option, establishment of a dedicated road from Bomi Mine to the Bao Chico jetty. This road will have a common section from Bomi to Klay junction (25km) with the above road option to our new jetty. So, an additional 8 to 10km of road will be required in this option to connect Klay junction to Bao Chico jetty.

Phase 2 – 10MTPA @Bomi

The 10MTPA capacity is based on building two additional concentrator plants at Bomi Mine. For this, Western Cluster plan to build a environmental friendly dedicated slurry pipeline with a 10MTPA capacity from Bomi Mine to Monrovia port and upgrade the Monrovia port to increase its capacity to 10MTPA.

Currently, a technical feasibility and engineering for the slurry pipeline with a USA consultant and the Monrovia port upgrade with a German consultant. The outcome of the exercise will be available by March 2025.

2.5.6 Proposed Township

The township with an area of about 70,000 m^2 (7 hectares) has been planned to the southwestern side of the process plant, within the concession area, adjacent to the approach road from Monrovia/Tubmanburg town (*Map 2-2*). The proposed residential complex has been planned to accommodate approximately 100 families.

An area of 52,250 m^2 has been planned for the mining contractor housing to cater for a population of approximately 800 people consisting of a combination of dormitories and singles quarters.

The following sections outline the services to be provided in the Township.

Water supply

The township comprises mainly residential and commercial development for which a water supply system has been identified. Access to housing includes the provision of a clean and safe pipe-borne water system for all houses.

Additional hand pumps will be constructed, or other sources of water will be arranged at the workplaces to ensure a convenient and uninterrupted supply of clean and safe drinking water. All drinking water shall meet or exceed the approved Government Standards for drinking water quality (WHO) [(1)]. Potable water may be sourced through surface water or through ground water extraction.

Sewage generation and treatment

The following principles will be adopted during the detailed design of the sewer system:

- Each cluster or Building shall have separate septic tank & soak pit or the sewage water shall be collected from various buildings and shall be collected to an inspection chamber/manhole located nearby the respective buildings and shall be ultimately discharged to a plant sewerage system or septic tank or to a package sewage treatment system.
- In areas where there are no sewers, every house will have arrangements for their sewage being treated in a septic tank, effluent which will undergo secondary treatment either in a biological filter, upflow anaerobic filter in a sub-surface disposal system.
- The total sewage generated is considered to be in the order of 85 percent of total net water demand as seen in *Table 11* Considering the quantity of sewage generation it is assumed that only one Sewage Treatment Plant will be required. The location of the sewage treatment plant has not yet been finalized.

Table 12: Sewerage generation in the proposed township

Sewerage Generation	MLD
Population	1003
Water Demand (million litres per day)	0.117
Average Sewage Flow (million litres per day) *	0.094
Average Sewage Flow including Infiltration 10% (million litres per day)	0.103

*Sewage generated from hospital is not considered while arriving at the above figure. This will depend on the type and nature of up-gradating of the hospital.

Solid Waste Management

Solid waste management is one of the basic essential services to be provided to the township dwellers. The objective of solid waste management is to reduce the quantity of solid waste disposed of.

In order to plan, design and operate a solid waste management system, a thorough knowledge of the quantity of waste generated, its composition and characteristics are essential. For the purpose of preliminary assessment of waste generated, the following assumptions have been made:

- Residential refuse generation rate is considered as 0.5 kg per capita per day and works out to a total of 362.50kg/day.
- Refuse generation rate for floating population is considered as 0.2 kg per capita per day and works out to a total of 55.60kg/day.
- Hospital waste has not been considered in this assessment. Waste generated would depend on the type and nature of the proposed up-grading of the hospital.

The estimated quantity of waste generation considering the above assumptions and classifying them as organic, recyclable, combustible and inert is shown in *Table 13.*

Table 13: Solid waste generation

Type of Waste	Total quantity (in kg/day)
Organic	229.96 kg/day
Recyclable	83.62 kg/day
Combustible	62.72 kg/day
Inert and non-recyclable	41.81 kg/day
Total	418.10 kg/day

Further to the above:

- Generated hospital waste will be treated and handled according to best practice standards. This may include incineration, disposed of through a deep burial technique or transported to authorized vendor / Liberian Government's common hazardous waste landfill. The disposal method will need to be decided upon at a later stage taking all potential impacts into consideration.
- Liquid waste (waste generated from laboratory and washing, cleaning, house- disinfection and other disinfection activities) may be treated and discharged into drains.
- Hazardous waste generated, if any, may be transported to an authorized vendor / Liberian government's common hazardous waste landfill. Potentially hazardous waste generated due to blasting could include ammonium nitrate and diesel, and sodium nitrites as well as the potential for hydraulic fluid spillages from the trucks.

2. 6 Manpower Requirements

In this section the preliminary manpower requirements for the 4 Mtpa Iron ore Mine at Bomi Hills are estimated to determine the labor requirements for the Project, from construction to closure.

WCL Recruitment Policy

WCL will encourage local employment and ensure that jobs that can be performed by locals, are taken up by local Liberians. The Company will ensure that contractors comply with this policy by ensuring that only specialized jobs which cannot be done by Liberians are taken up by expatriates. The Company will also ensure that Liberians are trained to take up these positions after adequate training.

None of the Company nor any other contractor or sub-contractor may hire individuals who are not citizens of Liberia for unskilled labor positions (MDA).

Construction Resources

Construction resources in Bomi Hills and Liberia in general are limited and will not be able to meet all of the construction activity requirements for a project of this size. A significant component of heavy construction including a skilled workforce, equipment, tools, consumables, materials and services will have to be provided to the project from outside of Liberia. The project will promote the participation of the local community, including labor and local contractors as far as possible, and will provide training to the local communities enabling them to participate in the project, particularly for the mining operations.

As part of their contractual obligation, the international contractors will also utilize local labor. The peak manpower requirements during the construction phase have been estimated in *Table 2.12.*

Table 14: Construction labor requirements

Category	Civil Concrete (Man-day)	Erection (Structural, Equipment, Electro-Mechanical, piping) (Man-day)	Miscellaneous Construction Work (Man-day)	Total (Man-day)
Skilled	160	600	10	770
Semiskilled	615	525	10	1150
Unskilled	150		20	170
Total	2090			

In addition to the above approximately 200 personnel will also be mobilized for supervisory and administrative work by different contractors, consultants etc.

Operational Resources

Table 15: Operational Phase Labor Requirement

Sl No.	Manpower Category	Mines	Beneficiation Plant	Utilities	Road *	Port	Total
1.	Company	20	10	20	10	17	82
2.	Outsourced	442	70	55	10	20	592
	TOTAL MANPOWER	462	80	75	20	37	674

**These figures have been estimated considering a seven (7) day working week and three (3) shift operations*

The total manpower of approximately 674 as seen above is for the Bomi Hills Mine, beneficiation plant, crushing and conveying systems, power plant, water supply system and the Port only. Additionally, approximately 100 laborers will also be required for the services such as the canteen, horticulture, security, township maintenance and other miscellaneous activities. Considering about 80 trucks/tippers are required for transportation of concentration/ore to the Port about 100 drivers and helpers will also be required.

2. 7 Health, Safety (H&S) and Security

All WCL employees will be provided with the relevant Personal Protective Equipment (PPE). Contractors will also ensure that they provide their employees with adequate PPE and a proper work environment which does not subject employees to inhuman and deplorable working conditions.

The following will be ensured as standard:

- ✓ Proper safety equipment (safety boots, work suits and hard hat, dust/gas masks, harnesses, etc.).
- ✓ Safe working environment; and
- ✓ Hygienic surroundings (adequate sanitation facilities in work areas).

2. 8 Project Embedded Environmental Controls

During the development and design of the proposed project a number of embedded environmental controls were included (referred to as *embedded controls*). Embedded controls are defined as physical or procedural controls that are planned as part of the project design (i.e., not added solely based on a mitigation need identified by the impact significance assignment process). The embedded controls for the WCL Bomi Hills Mine are described in *Table 16*.

Table 16: WCL Bomi Hills Mine Embedded Environmental Controls

Design Principle	Design Criteria
Best practice handling of hazardous waste.	Secondary containment will be designed and managed to ensure that rainwater does not reduce the minimum capacity requirements. This may include installation of roofs in smaller facilities to prevent rainfall ingress. Use of drip trays and other temporary measures during fuelling or servicing of vehicles and equipment on site. All spent solvents, liquid wastes and spent fuels / lubricants will be stored in lined and bunded areas and transported off-site for safe disposal.
Best practice handling non-mineral waste.	The Project will locate, design and operate waste management facilities (including the design of any upgrades to existing facilities) in accordance with the Mining plan and Mining Laws of Liberia or as per mining plan or as per feasibility report. Waste incineration carried out in modern packaged incinerator plant designed and operated to comply with emissions standards for hazardous and non-hazardous waste incinerators set out in IFC EHS Guidelines for Waste management facilities.

Dam, safety.	Design water containing structures (e.g. TSF) according to in accordance with mining laws of iberia or mining plan or as per feasibility report.
Maintain Biodiversity - species richness.	Creation and Implementation of bushmeat trade prohibition for all WCL employees and sub-contractors
Maintain stream baseflow.	Runoff water will be diverted to exhausted mine pit and allowed to settle, by use of flocculants if necessary. The clear water is recycled/reused for ancillary activities, dust suppression etc. Excess water (If any) will be discharged after necessary treatment.
Minimise dust fallout.	Water sprays will be used to control dust in the following areas: Pit, Haul roads, waste Rock Dumps, Product stockpiles, ROM Stockpiles, Dirt Roads. Maintenance of ore moisture at or above the Dust Extinction Moisture (DEM) level throughout the ore handling process (reducing emissions by 99% compared to dry ore). In case of Dry screening, adequate precautionary measures will be taken to reduce the dust.
Minimise exposure of slopes on Waste Rock Dumps.	Where benches are not warranted on Waste Rock Dumps slope lengths should be limited to 15m vertical lift. Contour walls should be created in these areas.
Minimise noise disturbance to sensitive receptors.	The Project will be designed and operated to meet IFC General Environmental, Health and Safety Guidelines for residential properties, that is: 75 dB(A) LAeq (daytime period) and 50 dB(A) LAeq (night-time period) during construction; and 55 dB(A) LAeq (daytime 1 hr.) and 45 dB(A) LAeq (night-time 1 hr.) during operation. Provision of necessary PPE as per the job requirement. Mobile plants (e.g. compressors, generators) and other noisy construction plants such as concrete batching will be located as far from the nearest potential sensitive receptors (people) as possible, plants will be oriented to direct noise emissions away from sensitive locations as far as possible, and on-site structures and terrain will be used to screen sensitive locations wherever practicable. Principal noise sources (e.g. exhaust fumes) will be directed away from noise-sensitive places as far as possible. Standard practices will be followed.
Minimise sedimentation in streams.	As per Mine Plan and applicable Mining Laws
Minimise stream water contamination.	Promote seed viability and reduce erosion.
Minimise the impact on fish species diversity and population numbers	WCL Employees and subcontractors will be prohibited from catching fish in the streams affected by the project. WCL employees & Sub-contractors will help in maintaining the balance in aquatic ecology.
Minimise visual impact on sensitive receptors	Colour of finishes for buildings and structures will be selected to minimize impact on visual receptors.
Minimise waste rock footprint.	Deposit waste rock back into the western zone of the pit after year 15 when this zone is mined out.

Minimize exposure of topsoils.	Construction plans to be augmented by land clearance sequencing / schedule.
Minimize exposure of topsoils.	If an area is to be exposed for more than 60 days during the rainy season (May to October) then it should be covered with a coarse waste rock layer of 200mm thickness, unless an extreme event triggers erosion that must be addressed immediately. Not required during the dry season (November to April).
Moderate runoff from Waste Rock Dumps.	Concave on top & limit valleys on sides, shape benches to slope inward.
Optimise deposition strategy for mine waste rock.	The properties of the material must be evaluated by a specialist once mining and deposition starts. Dump management practices will be employed.
Optimise runoff management associated with roads.	Construct suitable water control structures on roads to limit erosion, e.g. Side drains, Shoulders, regular discharge points, culverts, camber gravel road surface to outside to prevent potholes.
Optimise the use of waste rock.	Construct tailings starter walls or buttresses with waste rock material to improve engineering & ecological stability & reduce closure costs
Preserve and reinstate topsoils.	Topsoil stripping, stockpiling and management will be planned prior to ground disturbance works commencing. As per Mining Law of Liberia
Promote seed viability and reduce erosion.	Long term soil stockpiles will be height constrained and revegetated if required to promote seed viability and reduce erosion.
Reduce air pollutants.	The Project will be designed and operated to meet the Air Quality Guidelines as per IFC/WHO standards. Large electricity generating plant will meet IFC (2008) Environmental, Health, and Safety Guidelines for Thermal Power Plants and will be designed and operated to meet the Air Quality Guidelines as per IFC/WHO standards. Waste incineration plant will only be used where alternatives are not feasible and will be small, modern plants designed and operated to meet the emissions standards for incinerators set out in IFC (2007) EHS Guidelines for Waste Management Facilities. Low sulphur fuel will be used. Open burning of cleared vegetation and waste will be prohibited without specific prior authorisation from WCL HSE Head
Reduce groundwater contamination from TSF.	Intercept baseflow under tailings facility with cut-off drains based on the design of the applicable specialists (e.g. Geologist, Hydrogeologist, engineers) and according to applicable design standards
Reduce point emissions.	Use of enclosures and fabric filters on point emission sources
Reduce storm water flow velocities.	Storm water channels to be sized to accommodate 1:50 year peak flow velocities. Energy dissipation sumps to be included in design around the plant, ancillary buildings, township, truck parking area. Size and shape berms and diversion

	embankments to accommodate 1:50 year peak flow velocities. Intermediate check dams will be installed to reduce velocity and to arrest the silt.
Separate clean and dirty water.	Washing of WCL and contractor vehicles only in designated wash bays with dirty water handling facilities. Oil and grease trap for separation of oil from wash water. Diversions to be designed to accommodate 1:50 year peak flow conditions. Clean and dirty water will be separate, however no lining ponds are required (Iron ore mining generally does not contain heavy metals and toxic materials). Settling ponds will be installed. All the waste dump runoff or mine runoff will be channelized through garland drains or storm water drains to settling ponds/sumps/Mining pits. Sufficient capacity of settling ponds/sumps will be created to give the settling time to run-off/dirty water, necessary flocculants will be added in the same in case if required. Treated Water and sludge are reused.
Use community based activities to support closure objectives.	Implement community based nursery & seed harvesting initiative to ensure vegetation for rehabilitation. Community based livelihood generation initiatives. Implement community based manure or compost collection initiative to improve growth medium for rehabilitation

3. LEGAL AND POLICY FRAMEWORK

3. 1 Introduction

This *Chapter* summarizes the institutional framework applied to the Project, as well as the most relevant national legislation and applicable international best practice policies (including the Equator Principles, and the International Finance Corporation (IFC) Performance Standards) that have been taken into consideration in the preparation of the ESIA. In particular, this *Chapter* provides a description of the following:

- Liberian administrative and legislative organization;
- The Liberian environmental and social laws and regulations applicable to the Project;
- Status of protected areas and species that may have an effect on the proposed development;

- International conventions and standards to which Liberia is a signatory and which the Project must therefore take into account;
- Consideration where relevant, of other international conventions and standards with which the Project will also be consistent; and
- International treaties, conventions and protocols relevant to the Project relate to such issues as biodiversity, climate change, marine pollution and employment conditions.

3. 2 Liberian Government and Administration Framework

Historically in Liberia the most important institution dealing with environmental matters has been the Forest Development Authority (FDA), which was established in 1976 to replace the former Bureau of Forest Conservation and Wildlife. The FDA has the mandate to protect, manage and conserve government-owned forests and wildlife on a sustainable basis.

The Environmental Protection Agency (EPA) is the successor of the National Environmental Commission of Liberia (NECOLIB) which was first established in 1999. With support from the United Nations Development Programme (UNDP) and the United Nations Environment Programme (UNEP), the EPA has developed the infrastructure and staff to transform itself into a fully operational Environmental Protection Agency. The EPA also works closely with the Global Environmental Facility (GEF) and the Convention Secretariats of the various Multilateral Environmental Agreements (MEAs).

In November 2002, the Liberian Government adopted the National Environmental Policy (NEP), the Environment Protection Agency Act (EPAA) and the Environment Protection and Management Law. The three documents became law in April 2003 when they were published into leaflets as required by the Constitution of Liberia.

3.2.1 Environmental Protection Agency and Related Environmental Committees

The Environmental Protection Agency (EPA) is the agency responsible for coordinating, integrating and harmonizing the implementation of the Environmental Policy under the guidance of the National Environmental Policy Council (NEPC). The NEPC was established under Section 7 of the Environment Protection Agency Act (EPAA) (*Section 3.4.2*).

Key functions of the EPA are to:

- Propose environmental policies and strategies to the NEPC and ensure the integration of environmental concerns in overall national planning.
- Collect, analyse and prepare basic scientific data and other information pertaining to pollution, degradation, environmental quality, resource use and other environmental protection and conservation matters. This includes undertaking research and preparing and disseminating a report on the state of the environment in Liberia every two years.
- Ensure the preservation and promotion of important historic, cultural and spiritual values of natural resources heritage and, in consultation with indigenous authority, enhance indigenous methods for effective natural resource management.
- Encourage the use of appropriate environmentally sound technologies and renewable sources of energy and natural resources.
- Establish environmental criteria, guidelines, specifications and standards for production processes and the sustainable use of natural resources for the health and welfare of future generations.
- Review and approve environmental impact statements (EIS) and environmental impact assessment (EIA).
- Initiate and co-ordinate actions required in a state of environmental emergency or any other situation which may pose serious threat to the environment and public health.
- Function as the national clearinghouse for all activities relating to regional and international environment-related conventions, treaties and agreements, and as national liaison with the secretariat for all such regional and international instruments.
- Advise the state and participate in the process of negotiating, ratifying or acceding to relevant regional and international environmental agreements.
- The EPA also has a Board of Directors to oversee the implementation and successful operation of the National Environment Management Policy and functions of the EPA. The government constituted the NEPC, Board of Directors and the Executive Director.

3.2.2 National Environmental Commission of Liberia

The National Environmental Commission of Liberia (NECOLIB) was created in 1999 with the mandate to coordinate environmental management activities, including the conservation of biological diversity. NECOLIB is the focal institution for the Convention on Biological Diversity, the Cartagena Protocol on Biosafety, United Nations Framework Convention on Climate Change and its Kyoto Protocol, and the

Stockholm Convention on Persistent Organic Pollutants (POPs). See Table 3.1 for the International Conventions to which Liberia is a signatory.

3.2.3 *Forest Development Authority*

The Forest Development Authority (FDA) was established in 1976. The FDA is in charge of the sustainable management of the forest and associated resources, including forest lands and wildlife. It provides medium- and long-term planning within the forest sector, the preparation and promulgation of forest policy, law and administration, the release of forest concession agreements, monitoring activities of timber companies and managing protected area programs and wildlife and national parks. Other FDA activities include forest conservation, educational awareness, agro-forestry programs, environmental awareness-raising in communities surrounding protected areas and discussion of trans-border issues.

3.2.4 *Ministry of Mines and Energy*

The Ministry Mines and Energy ensure the sustainable management and judicious utilization of the country's resources.

There are two main departments at the Ministry (Department of Mines and Mineral Resources, and the Department of Energy). These are further described below.

Department of Mines and Mineral Resources

The Mineral Resources Department also acts as the National Geological Survey and Mines Department of the Republic of Liberia, with the mandate to look after the Mining Sector. Its two major operating areas are Mines Administration and Geological and Mineral Investigations, which address the following:

- Administration of exploration and mining tenements, processing of applications for grant and renewal, granting licenses, special site licenses or permits as well as certification of mining personnel and specific mining equipment;
- Monitoring mining and exploration activities, through regular inspections, for adherence to safe environmental practices, health and safety of workers and other specified conditions laid down in the licenses;
- Issuing of licenses for importation, possession and transportation of explosives and fireworks and granting of export permits for geological and mineral samples;
- Facilitating mining and exploration projects through assistance in negotiations with relevant Government and non-government agencies and providing support with landowner liaison; and

- Hydrogeological assessment and advice on groundwater potential, the siting of potential abstraction sites and drilling of abstraction wells for groundwater.

Energy Department

Beginning in 1981, the Energy unit within the Office of the President of Liberia was integrated into the then Ministry of Lands and Mines at that time.

The Department of Energy consists of the Bureau of Hydrocarbons and the Bureau of Energy Technology and Policy Development. The Ministry has reactivated the National Energy Committee (NEC) an inter-agency advisory body on energy matters comprising nine members including government ministries and public corporations. This is in agreement with the multi-sectoral approach being encouraged by the Economic Community of West African States (ECOWAS). The Department of Energy continues to serve and maintain linkages with energy-oriented organizations both state-controlled and privately owned. In addition, it continues to monitor and coordinate the energy sector (both conventional and non-conventional) in an effort to ensure effective and efficient utilization and management of energy resources. It encourages sustainable forestry, incl charcoal from such forests, with revenues used to support local communities, and to ensure that energy considerations are integrated with food and farming policies.

3. 3 Relevant Development Policy and Plans

3.3.1 National Environmental Policy (NEP)

The Constitution of Liberia (1986) provides for the protection and management of the environment and natural resources. The National Environmental Policy (NEP) provides a broad framework for the implementation of national objectives and plans. The policy aims at ensuring a sound management of resources and the environment.

The policy provides for:

- Integration of environmental considerations in sectoral, structural, regional, and socio-economic planning at all levels;
- Sound management of the environment and natural resources;
- Protection and maintenance of human habitats, the ecosystems, and ecological processes essential for the functioning of the biosphere;
- Guidance for national action plan and for healthy environmental practices on the national development effort;
- Sustainable development; and

- A common approach to environmental issues. The primary aim of this policy is pursued through harmonization and enforcement of relevant laws on environment protection. The NEP identifies that the EPA will operate under the guidance of the National Environment Council.

3.3.2 *The National Environmental Action Plan (NEAP)*

Under Section 30 of the Environmental Protection Agency Act (EPAA), the EPA will prepare a National Environmental Action Plan (NEAP) every five years in consultation with the Line Ministries and County Environmental Committees.

The National Environmental Action Plan will:

- Contain all matters affecting the environment and provide general guidelines for the management and protection of the environment and natural resources of Liberia as well as the strategies for preventing, controlling, or mitigating any deleterious effects;
- Be the basis for national environment planning and implementation of development programmes;
- Recommend appropriate economic and fiscal incentives as instruments for environmental protection to be incorporated into the planning and operational processes of the economy;
- Recommend areas for environmental research outlining methods of utilizing research information;
- Recommend methods for building national awareness on the importance of sustainable use of the environment and natural resources for national development;
- Take into account County Environment Action Plans (CEAP); and
- Identify and recommend policy and legislative approaches for preventing, controlling or mitigating specific as well as general adverse impacts on the environment.

3.3.3 *Mineral Policy, 2010*

The Mineral Policy was introduced in 2010. The policy is intended to provide adequate indications to the investment community (both national and foreign) of a competitive mineral regime in Liberia that is informed by international trends, adheres to international norms, is grounded in local conditions and is accountable to national common interests.

3.3.4 *Integrated Water Resources Management Plan (IWRMP), 2009*

The Integrated Water Resources Management Plan (IWRMP) (2009) provides an overarching approach to manage water resources in Liberia that is sustainable and beneficial to most people. This policy was designed to provide a broad-based charter that must be recognized by all concerned sector institutions, and be considered by all public and private projects and programs. Two broad areas are covered in this policy:

- Water Resources Management: this covers the management framework, including policy objectives, principles and strategies for monitoring, assessment, allocation and protection of resources; and
- Water Resources Use: this covers the policy objectives, principles and strategies for the development and use of water for people, water for food security, water for industry and other water uses such as hydropower, recreation, non-revenue water and water for maintenance of productive ecosystems.

3.3.5 *National Forestry Policy, 2006*

The National Forest Policy was published in 2006. The aim of the forestry policy of Liberia is to conserve and sustainably manage all forest areas, so that they will continue to produce a complete range of goods and services for the benefit of all Liberians. The conservation of these forest areas is also to contribute to poverty alleviation in the nation, while maintaining environmental stability and fulfilling Li international agreements and conventions.

3.3.6 *National Biodiversity Strategy and Action Plan, 2004*

The overall goal of the National Biodiversity Strategy and Action Plan (2004) is to sustainably use biodiversity on a long-term basis to meet the needs of both the present and future generations.

3. 4 Liberian Laws and Regulations

3.4.1 *New Constitution of Liberia*

The constitutional basis for environmental law is provided in Article 7 of the Constitution (1986). The Article provides for:

- environmental protection as a fundamental rule;
- public participation of all citizens in the protection and management of the environment and natural resources; and
- binds state organizations to adopt and activate environmental policy and formulate national development plans that are environmentally sustainable.

3.4.2 *Environmental Protection Agency Act (EPA)*

This act establishes the EPA as the principal authority in Liberia for the management of the environment. The role of the authority is to coordinate, monitor, supervise and consult with relevant stakeholders on all activities in the protection of the environment and sustainable use of natural resources.

If an EIA is required the proponent will be requested to carry out a public consultation termed scoping. The scoping exercises will identify what possible impacts there may be from the project and from alternatives considered. This process will also lead to the identification of a Terms of Reference (ToR) for preparation of the Environmental and Social Impact Statement of the proposed project. The EPA must approve the ToR prior to commencement of the ESIA study. Consultants for the ESIA must also meet the qualification criteria set by the Agency, and be in its Registry.

Because of the nature of the proposed Project activities, under the requirements of the EPAA, WCL is required to obtain environmental permits for the Project. This requires that WCL carryout an ESIA to include a Scoping phase. The Environmental and Social Impact Assessment (ESIA) process to be followed for this project is shown in Figure 2

3.4.3 *Environment Protection and Management Law*

The Environmental Protection and Management Law (EPML) provides for a wide-ranging responsibility for environmental management by the EPA. One of the most prominent issues is the need for development of administrative procedures for the preparation of the EIA to ensure effective environmental governance.

It establishes regulations for environmental quality standards; pollution control and licensing; guidelines and standards for the management of the environment and natural resources. It also addresses the protection of biodiversity, national heritage and the ozone layer. Other areas covered include environmental restoration orders, inspections, international obligations, information access, education and public awareness.

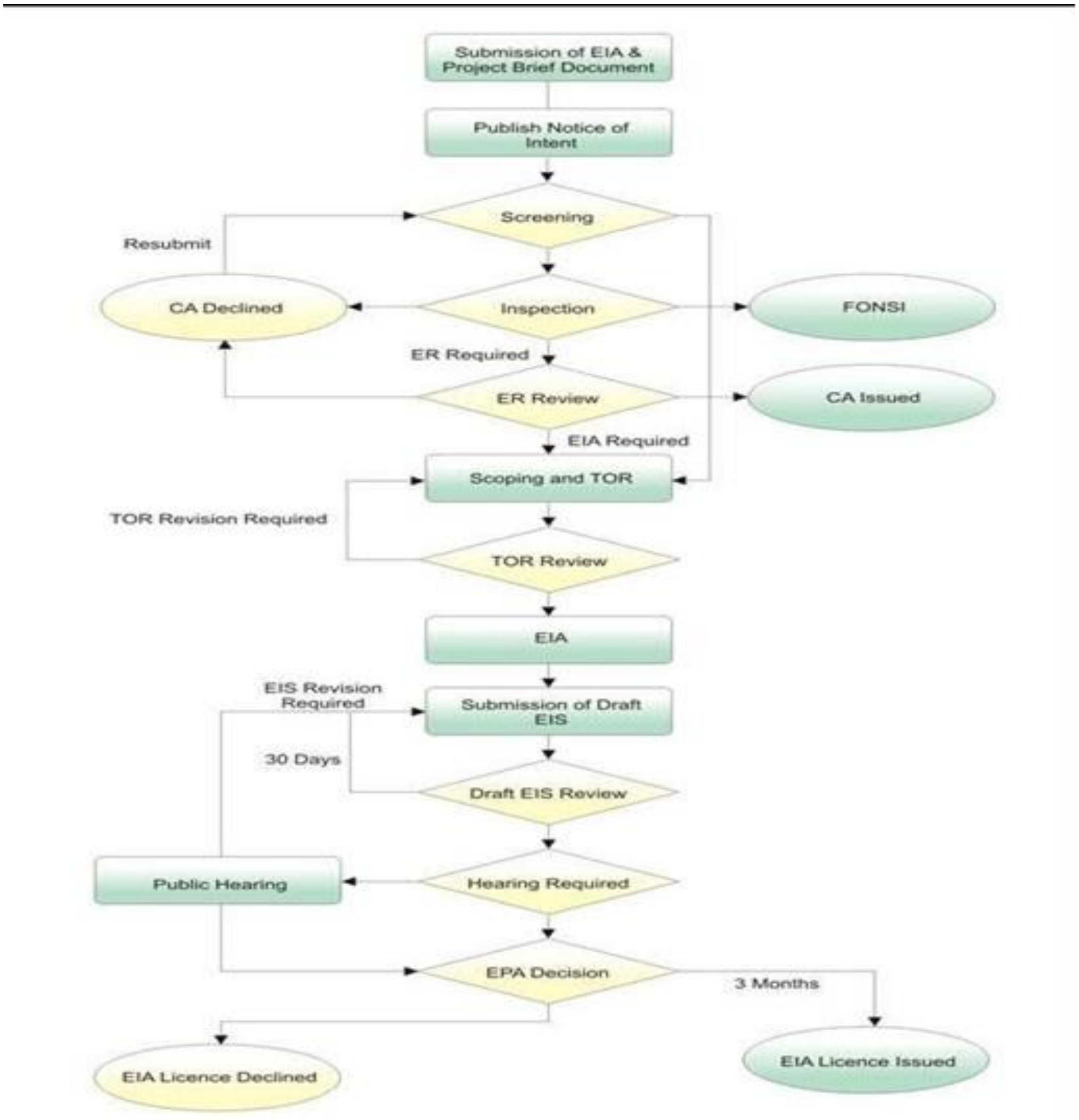

Figure 3:ESIA process flowchart

CA = Certificate of Approval	EIS = Environmental Impact Statement
EPA = Environmental Protection Agency	ER = Environmental Review
FONSI = Finding of no significant impact	

3.4.4 Public Consultation

Section 37 of the EPAA of Liberia requires the following public consultation process to be carried out:

- identify, inform and receive input from affected stakeholders and interested parties;
- determine and narrow the scope of the issues to be addressed in the EIA;

- identify and define, at an early stage of the EIA process, the significant environmental issues, problems and alternatives related to the different phases of the proposed Project or activity;
- ensure public participation early in the EIA process;
- ensure that all relevant issues and alternatives are adequately addressed in the environmental impact study;
- provide the applicant with the information necessary for formulating the terms of reference for the environmental impact study and impact statement; and
- guide the applicant's consultants in preparing the Environmental Impact Statement (EIS).

Section 5.8 (c) of the MDA signed between WCL and the Liberian Government mentions the requirement of public hearings on the Social Impact Assessment (SIA) and the Social Action Plan (SAP).

The public hearing should be conducted at least in Monrovia, in the county seat of each county in which a Proposed Production Area is located and in the county seat of each county in which the Railroad, Port, Power Plant or any road described in Section 6.6 is located or to be located.

It shall include a statement of the means taken to publicize the hearings, an indication of the numbers of persons who attended such hearings and, to the extent known to the Company, the names of the organizations such persons represent, a summary of the issues raised at such hearings, and a discussion of the actions taken by the Company in response to such hearings.

3.4.5 *Regulations Pertaining to Mining*

Minerals and Mining Act

The Minerals and Mining Act (2000) states that minerals on the surface of the ground or in the soil or subsoil, rivers, streams, watercourses, territorial waters and continental shelf are the property of Liberia. Section 3.4 allows for the establishment of a Minerals Technical Committee consisting of: Minister of Lands, Mines and Energy, Ministry of Justice, Ministry of Finance, Ministry of Planning and Economic Affairs, National Investment Commission, Ministry of Labor, Council of Economic Advisors, and Central Bank of Liberia. This committee has the power to negotiate agreements for Class A Mining Licences.

The Law, which is administered by the Ministry of Mines and Energy, has a clearly defined exploration and licensing system, as explained in the following sections:

Exploration Licenses

Exploration licenses are issued to exploration and mining companies at an initial term of three years and are renewable for a single two-year term upon written application of the holder who has fulfilled its work and expenditures obligations.

At or before the expiration of the initial period of the exploration license the holder may select the entire area or any part of a production area. If the holder does apply for an extension of the exploration license, 50% of the exploration area is surrendered at the end of the initial term.

At the end of the extension period, the holder can declare all or part of the entire remaining area as production area. The remaining area is surrendered to the government.

Class A Mining Licenses

Upon notice to the Minister that exploitable deposits were found under the exploration program, the Minister can grant a Class A Mining License.

A Feasibility Report is then to be submitted to the Minister. The initial terms of a Class A License is not more than 25 years; it can however be extended, if proven reserves are shown to exist, and upon submission of an updated feasibility report, for consecutive additional terms of up to 25 years. In order to receive an Exploration License or a Class A License, an applicant must conclude a Mineral Development Agreement (MDA) with the Government. The terms contained in the MDA are valid for no more than 25 years and are subject to periodic review every five years.

The surface rights granted under a license include the following:

- erection of habitations, office buildings, mill buildings, engine houses, store houses;
- building of dumps, ditches for drainage and roads within the surface boundaries of the production area;
- making trenches and open cuts for mining operation;
- cutting of timber only to clear for the construction of buildings and other infrastructure as required; and
- use of water and other resources necessary for the work.

Chapter 8 of this Law deals with environmental protection and states that an Environmental Impact Assessment Study for a Class A and Class B Mining License and Environmental Management Programs are to be prepared under Sections 8.5 and 8.6, respectively. Section 8.2 identifies the requirement for environmental restoration. These are further discussed below:

- Section 8.2 states that every holder of a mining license must restore the site disturbed by exploration of mining to its original state. If this is not possible, then it is to be restored to a state that is environmentally and socially desirable.
- Section 8.3 stipulates that all water polluted by exploration or mining is restored to its original state and that any water courses that have been closed are re-opened or a suitable water course opened to maintain natural runoff with minimal erosion. Reforestation is also required if exploration or mining resulted in large scale felling.
- Section 8.4 states that each applicant for a Class A and Class B License must submit, as a precedent to the granting of the license, an Environmental Impact Assessment Study. The study is to give special attention to potential impacts to nearby communities. The Minister of Mines will only grant a license after review of this study and confirm that the mitigation and reclamation procedures are adequate to protect the environment.
- Under Section 8.5, an Environmental Management Plan is to be submitted by the holder of a mining right for any affected land by exploration, mining or other operations and this plan will be submitted prior to the start of operations.

Chapter 11 addresses rights of owners and occupants of land affected by the Minerals and Mining Law, which is discussed further as follows:

- Section 11.3 provides for compensation to landowners or occupants diminution in the land value caused by the government to exercise its rights as owner of mineral rights, which supersedes any landowner or occupant rights with respect to exploration and mining.
- Any landowner or lawful occupant has the right of first refusal in any application for Class A or Class B Mining License against third parties (Section 11.4).
- Chapter 16 addresses health and safety requirements. Section 16.2 states that the permission to import, export, buy, sell, manufacture, store, handle purchase, use, dispose or otherwise deal with explosives needs to apply to the Ministry of State of Presidential Affairs.

3.4.6 Terms of Mineral Development Agreement (MDA)

Section 5.7 of the MDA states that the Environmental Impact Assessment Study Report and the Environmental Management Plan (EMP) shall comply with the requirements laid down by the EPA.

The EIA shall at a minimum identify pre-existing environmental conditions and set forth the potential adverse impact of the construction and operation of the Mining Plant and the Infrastructure proposed in the Feasibility Report shall take into account all activities or improvements to be undertaken by the

Company and referred to in Section 6.7(d), 6.7(e) or 11.6 of the Mining Law, and shall otherwise comply with applicable Law. The EMP shall at a minimum set forth detailed plans consistent with the EIA for the mitigation of environmental harm attributable to, and the restoration or remediation of the environment to the extent affected by, the implementation of the Development Plan and subsequent Operations, including the actions to be taken by the Company to comply with Sections 8.1 through 8.3 of the Mining Law, International Mining Standards and other applicable Law, and shall in any event comply with applicable EPA requirements and Section 5.7(b).

Section 5.7 (b) states that the EMP must include a closure management plan and a closure management budget designed to ensure that upon closure it shall not present any health or safety issues (including provision for the control of acid drainage and other long term environmental hazards). The proposed production area shall be restored to productive use or reforested or where restoration is impractical, suitably remediated. The closure management plan must include a list and assessment of risk and any uncertainties associated with the preferred closure option, address the social aspects of closure and rehabilitation, and provide a process for participation by the community and other stakeholders in closure management and monitoring.

Section 5.7(c) states that the EMP must also set forth the means by which the Company proposes to ensure the availability of funds to finance its environmental restoration and remediation obligations under Sections 8.2 and 8.3 of the Mining Law so that the cost of closure will be borne by the Company and not the public or the Government.

Section 5.7 (d) requires that the Company shall have held public hearings on the EIA and the EMP at least in Monrovia, in the county seat of each county in which a Proposed Production Area is located and in the county seat of each county in which the Railroad, Port, Power Plant or any Road described in Section 6.6 is located or to be located. Means must be taken to publicize the hearings, an indication of the numbers of persons who attended such hearings and their affiliates, a summary of the issues raised at such hearings, and a discussion of the actions taken by the Company in response to such hearings. The Ministry may set forth by regulation additional standards consistent with accepted practice in OECD countries for the location of, notification of and conduct of such hearings.

Section 5.8 (a) enlists the requirements to be covered under Social Impact Assessment (SIA) including the potential adverse impact of the construction and operation of each proposed Mine, and the related Mining Plant and Infrastructure on the individuals and community's resident in and around the Bomi Hills Mine and facilities; whether using Company provided infrastructure or equipment, or facilities or equipment provided by the Government or third parties.

Section 5.8 (b) of MDA enlists the requirements for the Social Action Plan (SAP) including reasonable measures, in light of the costs involved, for the mitigation of the adverse impact referred to in Section 5.8(a) as well as making provision for the continuing economic and social viability of enters of population that have formed and which may form as a result of Operations during the term of this Agreement.

Section 5.8 (b) also requires the inclusion of a Resettlement Action Plan (RAP) component if communes located in or adjacent to each Proposed Production Area or to Mining Plant or Infrastructure not located in the Proposed Production Area should under International Mining Standards be resettled for health or safety reasons. The RAP shall provide for (but not be limited to) suitable area(s) of resettlement to be undertaken at Company expense with key emphasis on shelter and livelihood continuity.

3. 5 International Conventions and Agreements

Liberia is a signatory to a number of international conventions, co-operative agreements and legal obligations concerned with environmental and social issues (see Table 11), which have contributed to shaping and influencing the development of the Liberian policy, guidelines and regulations that are applicable to the Project.

Table 17: Main International Conventions and Agreements Ratified by Liberia

No	Convention	Date of Ratification/Accession	Key Objectives
1	United Nations International Covenant on Economic, Social and Cultural Rights	1967	The granting of economic, social and cultural rights to individuals, including rights to adequate health, education and living standards.
2	Organization of African Unity's Convention on the Conservation of Nature and Natural Resources	21-Sep-78	Encourages action to conserve, use and develop soil, water, flora and fauna sustainably
3	Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)	11-Mar-81	Aims to ensure that international trade in specimens of wild animals and plants do not threaten their survival

4	United Nations Convention to Combat Desertification (UNCCD)	3-Mar-98	To combat desertification and mitigate the effects of drought through national action programs.
5	United Nations Convention on Biological Diversity	8-Nov-00	Conservation of biological diversity, the sustainable use of its components, and the fair and equitable sharing of the benefits from the use of genetic resources
6	UNEP Stockholm Convention on Persistent Organic Pollutants	24-Jun-02	Governs the use of 12 Persistent Organic Pollutant substances (including DDT).
7	UNESCO Convention Concerning the Protection of the World's Cultural Natural Heritage	25-Oct-02	To protect cultural and natural heritage of national and international value
8	UNESCO Ramsar Convention on Wetlands of International Importance	2-Nov-03	Protection and conservation of wetland resources.
9	United Nations Framework Convention on Climate Change (UNFCCC)	2003	Requires efforts to combat global warming and a key tool in promoting sustainable development
10	UNEP Convention on the Conservation of Migratory Species of Wild Animals	1-Dec-04	Aims to conserve terrestrial, marine and avian migratory species throughout their range.
11	UNEP Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)	1-Dec-04	Controlling the trade of endangered species.
12	UNCTAD International Tropical Timber Agreement (ITTA)	2006	The sustainable management of timber resources through improved forest management.
13	Extractive Industries Transparency Initiative (EITI)	2007	Strengthen governance by improving transparency and accountability in the extractives sector.
14	IMO Convention for Prevention of Pollution from Ships	1959	Covers accidental and operational oil pollution as goods in packaged form, sewage, garbage and air pollution.

15	UN Convention on Law of the Sea	25-Sep-08	Addresses Protection and Preservation of the Marine Environment and gives basic obligations to prevent, reduce and control pollution from land-based sources; pollution from sea-bed activities subject to national jurisdiction; pollution from activities in the Area; pollution by dumping; pollution from vessels; and pollution from or through the atmosphere.
16	Abidjan Convention and Protocol on Management and Protection of Coastal and Marine Environment in the Sub-Region	22-Mar-05	Provides a framework through which national policy makers and resource managers implement national control measures in the protection and development of the marine and coastal environment of the West and Central African Region.

3. 6 International Financial institution (IFI) Environmental and Social Performance Standards

International lending institutions provide guidance on their requirements for the ESIA process and place emphasis on achieving sustainable environmental, social and health outcomes. They also provide environmental standards and limits for emissions and discharges. A number of key project impact mitigation measures are also specified.

The overall project design and this ESIA are based on relevant guidelines published by the Environmental Protection Agency of Liberia, the World Bank and the IFC, and therefore is expected to meet the environmental requirements of these potential lending institutions. The proposal for this ESIA has been prepared following the Environmental Protection and Management Law of Liberia, the Equator Principles, which include both the IFC standards and the safeguard policies of the World Bank. These are all detailed in the sections and boxes below.

The relationships between the Equator Principles, the Performance Standards and the World Bank Group Guidelines are shown schematically in Figure 3.

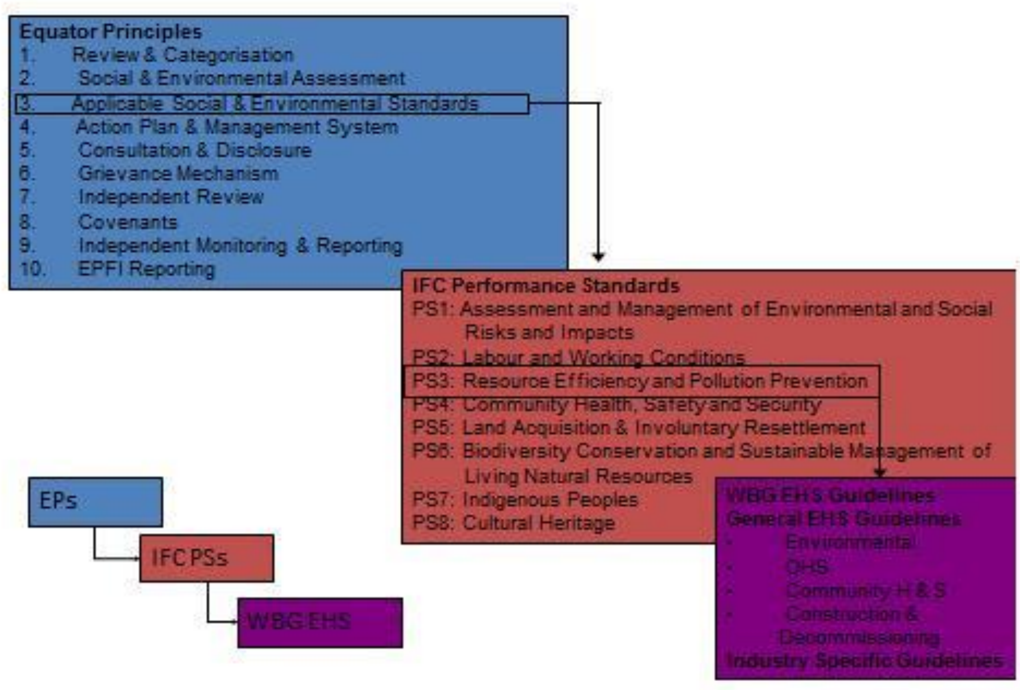

Figure 4: Financing requirements standards

3.6.1 Equator Principles

The Equator Principles (EPs) are an approach by financial institutions to determine, assess and manage environmental and social risk in project financing. The EPs emphasize that lenders will seek to ensure that the Project is developed in a manner that is socially responsible and reflects sound environmental management practices.

These Principles have been adopted by a wide range of banks and lenders all over the world in order to manage the social and environmental risks associated with their potential investments and are listed in Box 1 below.

Box 1 Equator Principles

The principles comprise the following:

- Principle 1 Categorisation of projects

- Principle 2 The borrower has to conduct an Environmental and Social Impact Assessment (ESIA)
- Principle 3 Applicable Social and Environmental Standards
- Principle 4 Action Plan and Management System
- Principle 5 Consultation and Disclosure
- Principle 6 Grievance Mechanism
- Principle 7 Independent Review
- Principle 8 Covenants
- Principle 9 Independent Monitoring and Reporting
- Principle 10 Equator Principles Financial Institutions (EPFI) Reporting

Principle 3 requires that the borrower apply the applicable social and environmental standards to the Project. In this regard, the Project references the Performance Standards' (PSs) summarized below and will apply these standards in the implementation of the Project.

3.6.2 *IFC Performance Sustainability Framework and Performance Standards*

The IFC Sustainability Framework (2012) comprises three elements:

- IFC's Policy on Environmental and Social
- the Performance Standards on Environmental and Social Sustainability; and
- IFC's Access to Information Policy.

The Performance Standards (PS) (January 2012) established by the IFC stipulate that the Project shall meet certain requirements throughout the life cycle of an investment by the IFC or other relevant financial institutions such as other DFIs (e.g. DEG, FMO) or commercial banks, which have adopted the Equator Principles.

The IFC released a Sustainability Policy and set of Performance Standards on Social and Environmental Sustainability (January 2012). These Standards replace the prior safeguard policies and will be used to evaluate any project seeking funding through the IFC. The Equator Principles, which reflect the application by major international banking institutions of IFC-inspired environmental and social best practice guidelines in the financing of large projects, have been revised to adhere to the new IFC Performance Standards (but do not reference the Sustainability Policy).

These PS and guidelines provide ways and means to identify impacts and affected stakeholders and lay down processes for management and mitigation of adverse impacts. A brief on the requirements as laid down in the performance standards is described further in the section.

Understanding the requirements of the specific PS is important, so as to set up the context for matching the requirements of these PS during the various stages of the life cycle of the Project. The standards and their objectives are shown below in Table 12.

Table 18: Performance

Performance Standards	Objectives
Performance Standard 1 underscores the importance of managing social and environmental performance throughout the life of a project (any business activity that is subject to assessment and management).	The social and environmental performance is a continuous process to be initiated by the management and would involve communication between the organization, its workers and local communities directly affected by the Project. The PS requires that the Project proponent initiate regular assessment of the potential social and environmental risks and impacts and consistently tries to mitigate and manage strategy on an ongoing basis. The main elements of PS 1 include:
	A Social and Environmental Assessment to understand the social and environmental impacts and risks
	Establishing and ensuring organizational capacity and requisite trainings to the staff to implement the Management Programme
	Identification and engagement with a range of stakeholders that may be interested in their actions;
	Development and implementation of a Stakeholder Engagement Plan that is scaled to the project risks and impacts and development stage and tailored to the characteristics and interests of the Affected Communities;
	Engagement and consultation with the affected communities, subject to identified risks and adverse impacts from a project;

	Informed Consultation and Participation (ICP) process for projects with potentially significant adverse impacts on affected communities; For projects with adverse impacts to Indigenous Peoples, requirement to engage them in a process of ICP and in certain circumstances requirement to obtain their Free, Prior, and Informed Consent (FPIC); · Implementation and maintenance of procedures for external communications to receive and register external communications from the public, and their Redressal; and · Adequate monitoring and reporting systems to measure and report the effectiveness of the Management Programs
Performance Standard 2 recognizes that the pursuit of economic growth through employment creation and income generation should be balanced with protection for basic rights of workers.	PS 2 is guided by the various conventions of the International Labour Organization (ILO) and outlines the minimum requirements of working conditions, protection to the workforce (including issues of child and forced labour) and ensuring occupational health and safety of both its employees'. PS requires: · Establishment of a sound worker-management relationship; · Encouraging equal opportunity and fair treatment of workers; · Encouraging equal opportunity and fair treatment of workers; · Management of accommodation services with provision of basic services; · Promoting healthy and safe working conditions for workers; and · Analysis of alternatives for retrenchment prior to implementing any collective dismissals.

	PS 2 requires project proponents to conduct its activities in a manner consistent with the four core labour standards (child labour, forced labour, non-discrimination, and freedom of association and collective bargaining). In addition, PS 2 also addresses other areas such as working conditions and terms of employment, retrenchment, and occupational health and safety issues. Some of these requirements refer to the applicable national law. Whereas national law establishes standards that are less stringent than those in PS 2, or are silent, the project proponent is expected to meet the requirements of PS 2.
Performance Standard 3 recognizes that increased industrial activity and urbanization often generate increased levels of pollution to air, water, and land that may threaten people and the environment at the local, regional, and global level.	PS 3 outlines a project level approach to resource efficiency and pollution prevention and control in line with internationally disseminated technologies and practices with objectives to: · Avoid or minimize adverse impacts on human health and the environment by avoiding or minimizing pollution from activities; · Promote more sustainable use of resources, including energy and water; and · Reduce project-related greenhouse gas (GHG) emissions.

	Key requirements of PS3 are to consider ambient conditions and apply technically and financially feasible resource efficiency and pollution prevention principles and techniques that are best suited to avoid or where avoidance is not possible, minimize adverse impacts on human health and the environment during the entire project life-cycle. In addition, a project needs to follow good international industry practice (GIIP), as reflected in various internationally recognized sources including the World Bank Group Environmental, Health and Safety Guidelines
Performance Standard 4 recognizes that project activities, equipment, and infrastructure often bring benefits to communities including employment, services, and opportunities for economic development. However, projects can also increase the potential for community exposure to risks and impacts arising from equipment accidents, structural failures, and releases of hazardous materials.	The performance standard details out project proponent’s responsibility to avoid or minimize the possible risks and impacts to community health, safety and security that may arise from project activities.
	· PS 4 concentrates on the responsibility that must be undertaken by the client to avoid or minimize the risks and impacts to the community’s hea security that may arise from project activities.
	· PS 4 requires a project to evaluate risks and impacts to the health and safety of the affected community during the Project life cycle and establish measures to avoid, minimize and reduce risks and impacts from the Project.

	A project needs to evaluate the risks and impacts to the health and safety of the Affected Communities during the project life-cycle and require establishing preventive and controlling measures consistent with good international industry practice (GIIP), such as in the World Bank Group Environmental, Health and Safety Guidelines (EHS Guidelines) or other internationally recognized sources.
Performance Standard 5 outlines that involuntary resettlement refers both to physical displacement (relocation or loss of shelter) and to economic displacement (loss of assets or access to assets that leads to loss of income sources or means of livelihood) as a result of project-related land acquisition	PS 5 require a project to consider various processes and systems to avoid /minimize social and economic impacts related to land acquisition and resettlement. The objectives of this PS are to: · Avoid, and when avoidance is not possible, minimize displacement by exploring alternative project designs; · Avoid forced eviction; · Anticipate and avoid, or where avoidance is not possible, minimize adverse social and economic impacts from land acquisition or restrictions on land use by (i) providing compensation for loss of assets at replacement cost, and (ii) ensuring that resettlement activities are implemented with appropriate disclosure of information, consultation and the informed participation of those affected; · Improve, or restore, the livelihoods and standards of living of displaced persons; and · Improve living conditions among physically displaced persons through the provision of adequate housing with security of tenure at resettlement sites.

This PS applies to physical or economic displacement resulting from the following types of land transactions:

· Land rights or land use rights acquired through expropriation or other compulsory procedures in accordance with the legal system of the host country;

· Land rights or land use rights acquired through negotiated settlements with property owners or those with legal rights to the land if failure to reach settlement would have resulted in expropriation or other compulsory procedures;

· Project situations where involuntary restrictions on land use and access to natural resources cause a community or groups within a community to lose access to resource usage where they have traditional or recognizable usage rights;

· Certain project situations requiring evictions of people occupying land without formal, traditional, or recognizable usage rights; or

· Restriction on access to land or use of other resources including communal property and natural resources such as marine and aquatic resources, timber and non-timber forest products, freshwater, medicinal plants, hunting and gathering grounds and grazing and cropping areas.

	This PS does not apply to resettlement resulting from voluntary land transactions (i.e. market transactions in which the seller is not obliged to sell and the buyer cannot resort to expropriation or other compulsory procedures sanctioned by the legal system of the host country if negotiations fail). It also does not apply to impacts on livelihoods where the project is not changing the land use of the affected groups or communities.
Performance Standard 6 recognizes that protecting and conserving biodiversity—the variety of life in all its forms, including genetic, species and ecosystem diversity—and its ability to change and evolve, is fundamental to sustainable development	PS 6 recognizes that protecting and conserving biodiversity—the variety of life in all its forms, including genetic, species and ecosystem diversity—and its ability to change and evolve, is fundamental to sustainable development. It reflects the objectives of the Convention on Biological Diversity to conserve biological diversity and promote use of renewable natural resources in a sustainable manner. The objectives of this PS are to: · Protect and conserve biodiversity; · Maintain the benefits from ecosystem services; and · Promote the sustainable management of living natural resources through the adoption of practices that integrate conservation needs and development priorities.

The components of biodiversity, as defined in the Convention on Biological Diversity, include ecosystems and habitats, species and communities, and genes and genomes, all of which have social, economic, cultural and scientific importance. This PS addresses how clients can avoid or mitigate threats to biodiversity arising from their operations as well as incorporate sustainable management of renewable natural resources1.

For the purposes of implementation of this PS, habitats are divided into modified, natural and critical. Critical habitats are a subset of modified or natural habitats. For the protection and conservation of biodiversity, the mitigation hierarchy includes biodiversity offsets, which may be considered only after appropriate avoidance, minimization, and restoration measures have been applied. A biodiversity offset should be designed and implemented to achieve measurable conservation outcomes that can reasonably be expected to result in no net loss and preferably a net gain of biodiversity; however, a net gain is required in critical habitats.

Performance Standard 7 recognizes that Indigenous Peoples, as social groups with identities that are distinct from dominant groups in national societies, are often among the most marginalized and vulnerable segments of the population.	PS 7 acknowledges the possibility of vulnerability of indigenous people owing to their culture, beliefs, institutions and living standards, and that it may be further compromised by one or other project activity throughout the life cycle of the project. The PS underlines the requirement of avoiding / minimizing adverse impacts on indigenous people in a project area, respecting the local culture and customs, fostering good relationship and ensuring that development benefits are provided to improve their standard of living and livelihoods. Objectives of PS 7 underscore the need to: · Ensure that the development process fosters full respect for the human rights, dignity, aspirations, culture, and natural resource-based livelihoods of Indigenous Peoples; · Anticipate and avoid adverse impacts of projects on communities of Indigenous Peoples, or when avoidance is not possible, to minimize and/or compensate for such impacts; · Promote sustainable development benefits and opportunities for Indigenous Peoples in a culturally appropriate manner; · Establish and maintain an on-going relationship based on Informed Consultation and Participation (ICP) with the Indigenous Peoples affected by a project throughout-cycle; · Ensure the Free, Prior, and Informed Consent (FPIC) of the Affected Communities of Indigenous Peoples when the circumstances described in this Performance Standard are present; and

	· Respect and preserve the culture, knowledge, and practices of Indigenous Peoples.
Performance Standard 8 recognizes the importance of cultural heritage for current and future generations. Consistent with the Convention Concerning the Protection of the World Cultural and Natural Heritage, this Performance Standard aims to ensure that clients protect cultural heritage in the course of their project activities.	PS 8 aims to protect the irreplaceable cultural heritage and to guide clients on protecting cultural heritage in the course of their business operations. In addition, the requirements of this PS on a project' are based in part on standards set by the Convention on Biological Diversity. PS 8 recognizes the importance of cultural heritage with an objective to: · Protect cultural heritage from the adverse impacts of project activities and support its preservation; and · Promote the equitable sharing of benefits from the use of cultural heritage in business activities. The PS requires the project proponent to comply with relevant national law on the protection of cultural heritage, including national law implement obligations under the Convention Concerning the Protection of the World Cultural and Natural Heritage and other relevant international law. The requirements of this Performance Standard apply to cultural heritage regardless of whether or not it has been legally protected or previously disturbed. The requirements of this PS do not apply to cultural heritage of Indigenous Peoples; PS 7 describes those requirements

3.6.3 IFC Environmental, Health and Safety (EHS) Guidelines

The IFC EHS Guidelines are technical reference documents, providing general and industry-specific examples of good international practice in environmental management. They are used by the IFC as reference documents as part of the appraisal of projects under the IFCs project evaluation mandate. The IFC EHS Guidelines represent the performance standards normally considered acceptable by the IFC, and generally considered to be achievable in new facilities at reasonable costs by using existing technology. When host country regulations differ from the levels and measures presented in the EHS Guidelines, the IFC recommends that projects should achieve whichever is more stringent.

The IFC EHS Guidelines considered relevant to the Project are listed below in Table 13

Table 19: IFC Guidelines Relevant to the Project

General Guidelines		
Environmental	**Community Health and Safety**	**Construction**
Air Emissions and Ambient Air Quality	Water Quality and Availability	Environment
Energy Conservation	Structural Safety of Project Infrastructure	Occupational Health and Safety
Wastewater and Ambient Water Quality	Life and Fire Safety (L&FS)	Community Health and Safety
Water Conservation	Traffic Safety	
Hazardous Materials Management	Transport of Hazardous Materials	
Waste Management	Disease Prevention	
Noise	Emergency Preparedness and Response	
Contaminated Land		
Industry Sector Guidelines		
Environmental, Health and Safety Guidelines for Mining		

3.6.4 *World Bank Group Guidelines*

Environmental Assessment is one of the ten environmental and social Safeguard Policies that the World Bank uses to examine the potential environmental risks and benefits associated with World Bank lending operations. The World Bank's Environmental Assessment policy and procedures are described in Operational Policy/Bank Procedures - OP/BP 4.01.

The World Bank screens projects based on their potential environmental impacts, in order to classify them as A, B or C. The WCL Liberia Project would be classified as a ‘Category A’ project, significant adverse environmental and social impacts, and this would trigger a full environmental assessment. Detailed advice and guidance on the conduct of environmental assessment is provided publicly by the World Bank in its Environmental Sourcebook and updates (1).

During project preparation, the World Bank examines the implications of the proposed project for a series of ‘safeguards:

- Environmental Assessment;
- Natural Habitats;
- Forestry;
- Pest Management;
- Physical Cultural Resources;
- Indigenous Peoples;
- Involuntary Resettlement;
- Safety of Dams;
- Projects in International Waterways; and
- Projects in Disputed Areas.

The World Bank's EHS Guidelines are technical reference documents that address the IFC's expectations regarding the industrial performance of projects. The updated EHS Guidelines serve as a technical reference source to support the implementation of the Performance Standards particularly in those aspects related to PS3: Resource Efficiency and Pollution Prevention, as well as certain aspects of occupational and community health and safety.

This information supports actions aimed at avoiding, minimizing, and controlling EHS impacts during the construction, operation, and decommissioning phase of a project or facility. The relevant World Bank Group EHS Guidelines that will apply to the Project are the following:

- EHS General Guidelines (World Bank Group, 2007); and
- EHS Guideline for Waste Management Facilities (World Bank Group, 2007).

EHS General Guidelines (World Bank Group, 2007)

The Environmental, Health and Safety (EHS) General Guidelines are technical reference documents, which promote Good International Industry Practice (GIIP). The General EHS Guidelines contain information on cross-cutting environmental, health, and safety issues potentially applicable to all industry sectors and should be used together with the relevant IFC industry sector guidelines.

When a member of the World Bank Group is involved in a project, the General EHS Guidelines are to be used in conjunction with the appropriate industry sector EHS Guidelines. Recommendations for the management of EHS impacts typical to most large industrial facilities are included in these Guidelines (World Bank Group, 2007a).

EHS Guideline for Waste Management Facilities (World Bank Group, 2007)

The Environmental, Health and Safety (EHS) Guidelines for Waste Management Facilities is applicable to facilities that are committed to the management of municipal solid waste and industrial waste, including waste collection and transport, waste receipt, unloading, processing and storage; landfill disposal, physico-chemical and biological treatment and incineration projects. The guidelines identify EHS issues that can arise during the operational and decommissioning phases of waste management and provide recommendations of their management in relation to the environment, occupational health and safety as well as community health and safety. These guidelines request the implementation of monitoring against identified performance indicators of all the activities that have been identified to have potentially significant impacts in order to monitor these impacts over time and to compare them to Industry Benchmarks (World Bank Group, 2007d).

3. 7 Vedanta Sustainability Framework

Vedanta's Sustainability (see Figure3.3) starts framework with (a) Vedanta Values and (b) Code of Conduct; and these are supported by more specific elements that include:

- Policies;
- Management Standards; and
- Operating Technical Standards.

The elements of the framework are based on international standards of institutions such as the International Finance Corporation (IFC), International Council on Mining and Metals (ICMM), United Nations Environment Program (UNEP) and Organization for Economic Co-operation and Development (OECD).

The Vedanta's sustainability has eight policies which the framework Management Standards (MS) are applicable to. These include:

- Biodiversity Policy;
- Energy and Carbon Policy;
- HIV/AIDS Policy;
- HSE Policy;
- Human Right Policy;
- Social Policy;
- Supplier and Contractor Management Policy; and

- Water Management Policy.

Figure 5: Vedanta's Standards

In the Vedanta's Sustainability Governance System, 14 Management Standards (MS) have been included to govern the sustainability of the company, which are:

- Leadership, Responsibility and Resources;
- Stakeholder Materiality and Risk Management;
- New Projects, Planning Processes and Site Closure;
- Compliance and Other Requirements;
- Objectives, Targets and Performance Improvement;
- Competency, Training and Awareness;
- Management of Change;
- Acquisitions, Divestment and Joint Venture Due Diligence;

- Documentation & Records Management;
- Performance Monitoring, Data Management and Reporting;
- Incident Reporting and Investigation;
- Auditing and Assurance;
- Corrective & Preventive Action Management; and
- Management Review and Continual Improvement.

These Vedanta's Group Policies have further been adopted by the Group's Companies. The Vedanta policies are further supported by 20 Technical Standards (TS), which include:

- Health Management;
- Safety Management;
- Environmental Management;
- Conducting ESHIA to International Standards (includes EMPs);
- Resource Use and Waste Management;
- Biodiversity Management (includes EMPs);
- Water Management;
- Energy and Carbon Management;
- Land and Resettlement Management;
- Security Management;
- Emergency and Crisis Management;
- Transport and Logistics Management;
- Sustainability Data Management;
- Cultural Heritage;
- Employee Consultation & Participation;
- Stakeholder Engagement;
- Social Investment Management;
- Grievance Mechanisms;
- HIV/Aids Management; and
- Site Closure.

3. 8 WCL Liberia Projects Standards

The Project will develop a set of environmental and social performance goals to guide the engineering and design. The goals will be set forth as a set of broad objectives supported by specific numerical standards for ambient environmental quality and emissions. The specific limits will be derived from Liberia regulatory requirements, international standards (e.g. IFC Performance Standards), as well as international best practices and in line with the Vedanta's Sustainability Framework.

In addition to this, Vedanta has also developed a set of standards against which the project will be carried out, this includes but is not limited to the following:

- A Technical Standard on Cultural Heritage;
- Management Standard New Projects, Planning Processes and Site Closure;
- Technical Standard on Stakeholder Engagement;
- Technical Standard on Biodiversity Management; and
- Technical Standard on Water Management.

4. IMPACT IDENTIFICATION AND ASSESSMENT

4. 1 Introduction

This Chapter presents the methodology used to conduct the ESIA. The ESIA methodology follows the overall IA approach illustrated in Figure 5 which was also used in the preparation of the 2013 ESIA Report. This ESIA has been undertaken following a systematic process that predicts and evaluates the impacts the Project could have on aspects of the physical, biological, social/ socio-economic and cultural environment, and it identifies measures that the Project will take to avoid, minimize/reduce, mitigate, offset or compensate for adverse impacts; and to enhance positive impacts where practicable. The stages of the ESIA process are described below.

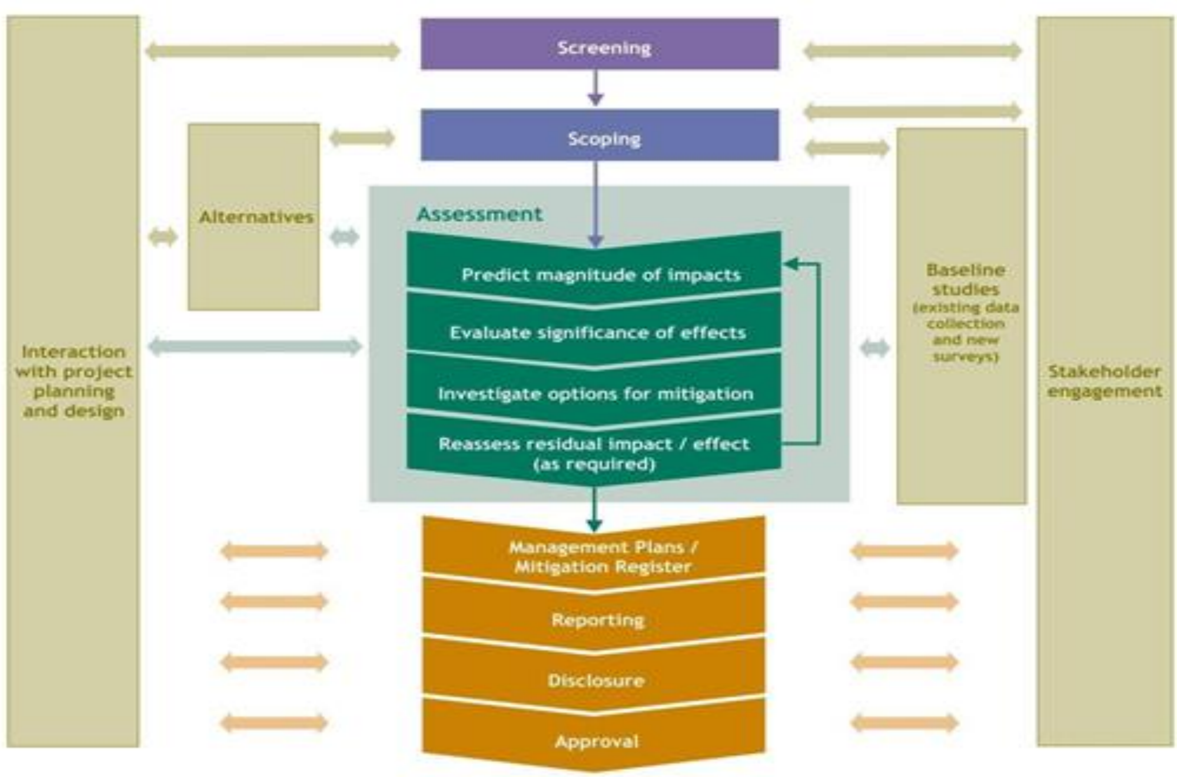

Figure 6: ESIA Process

4. 2 Screening

At the initial stage of the ESIA process, preliminary information was provided to aid in the determination of what legal and other requirements apply to the Project. This step was conducted utilizing a high-level description of the Project and its associated facilities.

MacAfrica reviewed the ESIA report from 2013 along with available environmental monitoring and other technical reports and data of the Project. Other secondary information in public domain was also reviewed to ensure reporting was accurate and current with regard to the Project, Project location and its surroundings. The ESIA team conducted a reconnaissance visit of the Project site and surroundings. The screening process was undertaken to identify environmental, social and other sensitivities and risks associated with the Project which were not part of the initial impact assessment in 2013. A review of the applicability of the reference framework with respect to the Project was also undertaken as part of the screening exercise.

4. 3 Scoping

Scoping has been undertaken to identify the potential Area of Influence for the Project (and thus the appropriate Study Area), to identify potential interactions between the Project and resources/receptors in the Area of Influence and the impacts that could result from these interactions, and to prioritize these impacts in terms of their likely significance.

The intent of this stage of the impact assessment was to focus on those issues which were not captured in the ESIA Report of 2013 but that are now most important for the design, decision making and stakeholder interest. The findings of the scoping exercise are reported in *Chapter 5* of this ESIA Report. Table 14 presents the resources/receptors considered in the scoping stage, together with the changes that might indicate a Project- related impact.

Table 20: Findings from scoping exercise

Resources/Receptors	Impacts
Environmental Receptors	
Geology & Soil	Changes to geology, geomorphology, topography and changes to physical and chemical properties and soil ecology
Benthic marine flora and fauna	Changes to marine flora and fauna composition
Water Quality (Surface, Groundwater, Marine)	Changes to physical, chemical or biological quality of surface, ground water and marine water bodies. Introduction of exotic species, changes in habitat quality, abundance and diversity.

	Effluent discharge.
Visibility	Change in visibility within surrounding environs.
Vegetation	Changes to vegetation population, health, species abundance and diversity, impact on endangered and economic species, food chain effects
Wildlife	Changes to wildlife assemblages, impact on endangered and economic species, food chain effects.
Carbon Footprint	Change in energy demand
Air Quality	Emissions of pollutants such as NO_x, SO_x, PM, CO, VOC, TSP etc
Noise and Vibration	Change in noise or vibration levels
Aesthetics	Physical presence of facilities, increased night time light
Heritage and Archaeology	Physical disturbances of shrines, burial grounds, archaeological resources or any other desecration.
Social Resources	
Demographics (including physical displacement)	Changes in population, total population, gender ratio, age distribution. Physical displacement from residence as a result of Project land take or activities.
Economy & Employment	Change in national/local economy, employment, standard of living, occupation
Education & Skills	Change in availability or quality of education or skills provision
Infrastructure and Public Services	Improvement or pressure on existing urban/rural infrastructure or services including: transportation, power, water, sanitation and waste handling facilities etc.
Community Health and Safety Resources	
Environmental Change	Changes in air quality, contamination of surface waters and potable ground water, changes in vibration and noise, changes in night time light beyond acceptable limits and changes to the visual environment.
Communicable & Non-Communicable Diseases	Change in incidence and/or prevalence of communicable and non-communicable diseases or disease-causing factors.
Vector Borne Diseases	Changes in the incidence and /or prevalence of vector borne diseases, the density of these vectors and their breeding grounds.
Sexually Transmitted Diseases	Changes in the incidence and/or prevalence of STD and the factors that contribute to this (external workforce, transport routes etc.).
Resource and Ownership	Temporary or permanent displacement from land or water-based livelihood activities; changes in ownership of such resources.

4.4 Determine the Project Description

In order to set out the scope of the Project features and activities, with particular reference to the aspects which has impact on the environment, a Project Description has been prepared. This is based on information included in the Feasibility Report, the 2013 ESIA Report, and other information as provided by the Project Proponent. This is presented in Chapter 2.

4.5 Baseline Conditions

To provide a context within which the impacts of the Project can be assessed, a description of the physical, biological, social/socio economic and cultural conditions that would be expected to prevail in the absence of the Project is presented. The Baseline includes information on all resources/receptors identified that have the potential to be significantly affected by the Project.

The baseline characterization is provided in the relevant assessment chapters of this ESIA report.

4.6 Study Area

The Study Area refers to the area that needs to be studied in order to adequately understand and describe the baseline conditions likely to be affected by the Project. This is different to the Project Footprint (as discussed below).

4.6.1 Project Footprint

The Project Footprint is the area that may reasonably be expected to be physically touched by Project activities, across all phases. The Project Footprint includes all the land used on a temporary basis such as lay down areas or construction haul roads, as well as disturbed areas in transport corridors, both public and private.

4.6.2 Area of Influence

The effects of the Project and its activities on a particular resource or receptor will have spatial (distance) and temporal (time) dimensions, the scale of which is dependent on a number of factors, including:

- Nature of the activity;
- Specific resource or receptor;
- Sensitivity of that resource or receptor; and
- Whether the impact is direct or indirect (e.g. a secondary effect).

These factors are all incorporated in the Area of Influence (AoI). For the ESIA, the definition of AoI used in the Performance Standards was applied (IFC, 2012):

This area of influence encompasses, as appropriate:

The area likely to be affected by: (i) the project and the client's activities and facilities that are directly owned, operated or managed (including by contractors) and that are a component of the project; (ii) impacts from unplanned but predictable developments caused by the project that may occur later or at a different location; or (iii) indirect project impacts on biodiversity or on ecosystem services upon which Affected Communities' livelihoods are dependent.

Associated facilities, which are facilities that are not funded as part of the project and that would not have been constructed or expanded if the project did not exist and without which the project would not be viable.

Cumulative impacts that result from the incremental impact, on areas or resources used or directly impacted by the project, from other existing, planned or reasonably defined developments at the time the risks and impacts identification process is conducted.

This Project covers the activities involved with the development of Bomi Hills Mine for the mining and processing of 4 mtpa of iron ore (DSO/Concentrate) for export and related auxiliary operations. The AoI of the mine development varies according to which aspect and its potential impacts are being analyzed.

Most of the impacts will occur within the project footprint area of 34 km2 (whereas the project concession area is 114.42 km2.) However, certain impacts can be further reaching in terms of expected impacts. Moreover, the AoI for a particular resource/receptor may vary depending on the nature of the change caused by the Project activities and the type of effect being considered, but in each case, it is defined to include all of the area within which it is likely that significant impacts could result.

The AoI with respect to the environmental and social resources will be considered as follows:

Surface Water

- Bomi Hill Mine concession area for Project 1 plus the possible dewatering of the Old LMC pit water to the Mahe River:
  - Drainage lines (tributaries) of the Mahe River;
  - The confluence of the Lofa River and Mahe River (although the Lofa drains directly into the Atlantic Ocean, the impacts of Bomi Hills Mine on the surface water hydrology will be diluted at major confluences);
  - It is assumed that surface water from the mine concession area has the potential to be:

        - Likely intercepted and contained on site –which may have an impact on the catchment yield;
        - Dewatering from open pit, i.e. increase in stream flows; and
        - Polluted and intercepted by the drainage lines reporting to the Mahe River - this has an impact on the quality of water for downstream water users.
- Water being drained from existing open pits into natural watercourses;
- Natural Drainage direction which is to the south west of the site:
    - The drainage from the mine concession area is predominantly towards the southwest; and
    - Drainage could further be affected by among others the following:
        - Water bodies (pans);
        - Roads ; and
        - Surface disturbances such as other mining and agricultural operations.
- Other considerations include existing on-going activities:
- Sand mining;
- Agriculture on floodplains;
- Water bottling plant at disused mine lake; and
- Villages and residential areas.

Groundwater

- Potential area of influence is largely limited to the catchment areas which have proposed mine infrastructure, i.e. the Bomi Creek (Small Mahe River catchment), Weasain River (Small Mahe River catchment), the unnamed tributary to the west of the pit (Small Mahe River catchment) and the unnamed Mahe River tributary to the east of the mine site.
- Dewatering of the pit likely to cause local drawdown of the aquifer as the mine develops and the pit expands, the extent of the area influenced by dewatering will extend, on average, by 500 m, to a maximum of 1500 m around the open pit.
- A contaminant plume, if one was to develop, would not leave the site and could even flow back to the pit owing to dewatering (a groundwater sink would be created which would draw groundwater into the pit from the surrounding area).

Air Quality

- Fine particulate matter (PM10) and gaseous pollutants likely impacts – maximum typically up to 1 km from operations; and

- Dust fall –maximum typically up to 500 m from operations.

Noise and Vibration

- Noise impact area (defined as the area over which an increase in environmental noise levels can be detected) –maximum typically between 500 m and 2 km from operations.
- Blasting noise would have an impact over a greater distance than the plant however, the impact would be lesser and at planned intervals.

Visual

- Due to the prominence of telecommunication tower/ UNMIL Point which can be seen from approximately 30 km away, the zone of visual influence (ZVI) has been defined as extending up to 30 km from the perimeter of the works (pits and waste emplacements). Other mine facilities (conveyors, roads, mine plant) will be smaller in scale and at a lower level and will not be seen from further away than the defined 30 km.

Flora and Fauna (Terrestrial and Aquatic)

- The direct footprint of the Project comprising the mine construction, pit, plant areas, township, and other areas used for mining purposes is likely to result in a loss of habitat. The direct AoI is determined to be the 11 km2 of the concession area.
- The areas immediately adjacent to the project footprint within which a zone of ecological disturbance is created through increased dust and human presence (e.g. trampling and wood collection). The AoI will be determined through the specialist investigations and is further discussed in *Chapters 11* and *12.*

Soils

- Impacts on soils will largely be contained within the 11 km^2 footprint of mine activities; however, there could be some losses due to erosion and dust.

Socio-economic/Social

The area of influence for social (including health) receptors has been developed based on reconnaissance site visits and stakeholder consultations with the community in the mine area and administrative representatives at county, district and town level.

The AoI in the context of socio-economic receptors is based on certain considerations which includes the following:

- The mining at this stage (Project 1, phase 1b) will be done in an area of 4 km^2 and hence it is assumed that this 4 km^2 and the area where the other temporary infrastructure will be developed (likely 1km) as the core zone of impacts at this stage. The Bomi Hills Mine (exploration area presently) concession area of 114 km^2, in addition to a radius of 1km around this area will be considered as buffer zone. This buffer zone of 1 km outside the concession area may or may not be expanded to 5 km from 1 km, depending upon the stakeholder consultations and focus group discussions in the Project area;
- The nearby areas in Bomi County where the mine is located will see an increase in the influx of opportunity seekers and unplanned development in the nearby areas of the project to serve the project and meet the emerging market needs that will come to serve the project needs like labour and services. These developments can be classified as induced activities, occurring at a later stage or at a different location. This will further increase the core zone as well as the buffer zone.

4. 7 Stakeholder Engagement

An effective ESIA Process requires engagement with relevant stakeholder throughout the key stages. This assists in understanding stakeholder views on the Project and in identifying issues that should be taken into account in the prediction and evaluation of impacts. Further detail is provided in *Chapter 6* for the approach undertaken for this ESIA.

4. 8 Impact Assessment

Impact identification and assessment starts with scoping and continues through the remainder of the ESIA Process. The principal ESIA steps are summarized in Figure 6 and comprise:

Impact prediction: to determine what could potentially happen to resources/receptors as a consequence of the Project and its associated activities.

Impact evaluation: to evaluate the significance of the predicted impacts by considering their magnitude and likelihood of occurrence, and the sensitivity, value and/or importance of the affected resource/receptor.

Mitigation and enhancement: to identify appropriate and justified measures to mitigate negative impacts and enhance positive impacts.

Residual impact evaluation: to evaluate the significance of impacts assuming effective implementation of mitigation and enhancement measures

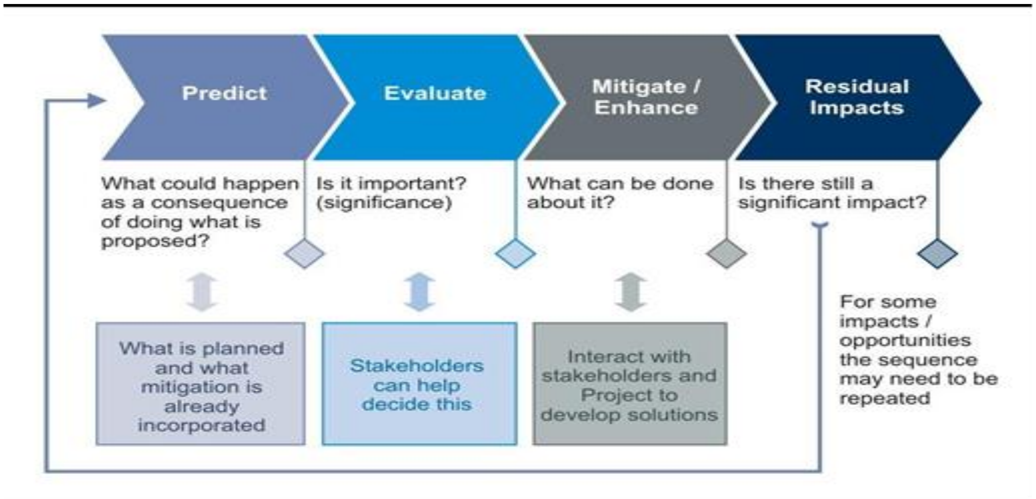

Figure 7: Impact prediction

4.8.1 Prediction of Impacts

Prediction of impacts is essentially an objective exercise to determine what is likely to happen to the environment as a consequence of the Project and its associated activities. From the potentially significant interactions identified in Scoping, the impacts to the various resources/receptors are elaborated and evaluated. The diverse range of potential impacts considered in the IA process typically results in a wide range of prediction methods being used, including quantitative, semi-quantitative and qualitative techniques.

4.8.2 Evaluation of Impacts

Once the prediction of impacts is complete, each impact is described in terms of its various relevant characteristics (e.g. type, scale, duration, frequency, extent). The terminology used to describe impact characteristics is shown in Table 15.

Table 21: Impact Characteristics Terminology

Characteristic	Definition	Designations
Type	A descriptor indicating the relationship of the impact to the Project (in terms of cause and effect).	Direct Indirect Induced

Extent	The "reach" of the confined to a small area around the Project Footprint, projected for several kilometers, etc.).	Local Regional International
Duration	The time period over which a resource /receptor is affected.	Temporary Short-term Long-term Permanent
Scale	The size of the impact (e.g., the size of the area damaged or impacted, the fraction of a resource that is lost or affected, etc.)	No fixed designations; intended to be a numerical value or a qualitative description of "intensity"
Frequency	A measure of the constancy or periodicity of the impact.	No fixed designations; intended to be a numerical value or a qualitative description.

The definitions for the type designations are shown in Table 13. Definitions for the other designations are resource/receptor-specific, and are discussed in the resource/receptor-specific impact assessment chapters presented later in this ESIA report.

Table 22: Impact Type Definitions

Designation	Definition
Type	
Direct	Impacts that result from a direct interaction between the Project and a resource/receptor (e.g., between occupation of a plot of land and the habitats which are affected).
Indirect	Impacts that follow on from the direct interactions between the Project and its environment as a result of subsequent interactions within the environment (e.g., viability of a species population resulting from loss of part of a habitat as a result of the Project occupying a plot of land).
Induced	Impacts that result from other activities (which are not part of the Project) that happen as a consequence of the Project (e.g., influx of camp followers resulting from the importation of a large Project workforce).

The above characteristics and definitions apply to planned and unplanned events. An additional characteristic that pertains only to unplanned events is *likelihood*. The *likelihood* of an unplanned event occurring is designated using a qualitative scale, as described in Table 15

Table 23: Description of Likelihood definition

Likelihood	Definition
Unlikely	The event is unlikely but may occur at some time during normal

	operating conditions.
Possible	The event is likely to occur at some time during normal operating conditions.
Likely	The event will occur during normal operating conditions (i.e., it is essentially inevitable).

Once an impact's characteristics are defined assessment phase is to assign each impact typically a function of some combination (depending on the resource/receptor in question) of the following impact characteristics:

- Extent
- Duration
- Scale
- Frequency

Additionally, for unplanned events only, magnitude incorporates the 'likelihood' factor discussed above.

Magnitude essentially describes the intensity of the change that is predicted to occur in the resource/receptor as a result of the impact. As discussed above, the magnitude designations themselves are universally consistent, but the descriptions for these designations vary on a resource/receptor-by-resource/receptor basis. The universal magnitude designations are:

- Positive
- Negligible
- Small
- Medium
- large

In the case of a *positive* impact, no magnitude designation (aside from 'positive') assigned. It is is considered sufficient for the purpose of the IA to indicate that the Project is expected to result in a *positive* impact, without characterizing the exact degree of positive change likely to occur.

In the case of impacts resulting from unplanned events, the same resource/receptor-specific approach to concluding a magnitude designation is utilized, but the 'likelihood' together with the other factor is impact characteristics, when assigning a magnitude designation.

In addition to characterizing the magnitude of impact, the other principal impact evaluation step is definition of the sensitivity/vulnerability/ importance of the impacted resource/receptor. There are a range of factors to be taken into account when defining the sensitivity/vulnerability/importance of the resource/receptor, which may be physical, biological, cultural or human. Other factors may also be considered when characterizing sensitivity/vulnerability/importance, such as legal protection, government policy, stakeholder views and economic value.

As in the case of magnitude, the sensitivity/vulnerability/importance designations themselves are universally consistent, but the definitions for these designations vary on a resource/receptor basis. The sensitivity/vulnerability/importance designations used herein for all resources/receptors are:

- Low
- Medium
- High

Once magnitude of impact and sensitivity/vulnerability/importance of resource/receptor have been characterized, the significance can be assigned for each impact. Impact significance is designated using the matrix shown in Figure 7.

		Sensitivity/Vulnerability/Importance of Resource/Receptor		
		Low	Medium	High
Magnitude of Impact	Negligible	Negligible	Negligible	Negligible
	Small	Negligible	Minor	Moderate
	Medium	Minor	Moderate	Major
	Large	Moderate	Major	Major

Figure 8: Matrix of impact designation

The matrix applies universally to all resources/receptors, and all impacts to these resources/receptors, as the resource/receptor-specific considerations are factored into the assignment of magnitude and sensitivity/vulnerability/ importance designations that enter into the matrix. Box 2 provides a context for what the various impact significance ratings signify.

It is important to note that impact prediction and evaluation take into account any embedded controls (i.e., physical or procedural controls that are already planned as part of the Project design, regardless of the results of the ESIA Process). An example of an embedded control is a standard acoustic enclosure that is designed to be installed around a piece of major equipment. The avoids the situation where an impact is assigned a magnitude based on a hypothetical version of the Project that considers none of the embedded controls.

Box 2 Context of Impact Significances

An impact of **negligible** significance is one where a resource/receptor (including people) will essentially not be affected in any way by a particular activity or the predicted effect is indistinguishable from natural background variations.

An impact of **minor** significance is one where a resource/receptor will experience a noticeable effect, but the impact magnitude is sufficiently small and/or the resource/receptor is of low sensitivity/ vulnerability/ importance. In either case, the magnitude should be well within applicable standards.

An impact of **moderate** significance has an impact magnitude that is within applicable standards, but falls somewhere in the range from a threshold below which the impact is minor, up to a level that might be just short of breaching a legal limit. Clearly, to design an activity so that its effects only just avoid breaking a law and/or cause a major impact is not best

practice. The emphasis for moderate impacts is therefore on demonstrating that the impact has been reduced to a level that is as low as reasonably practicable (ALARP). This does not necessarily mean that impacts of moderate significance have to be reduced to minor, but that moderate impacts are being managed effectively and efficiently.

An impact of **major** significance is one where an accepted limit or standard may be exceeded, or large magnitude impacts occur to highly valued/sensitive resource/receptors. An aim of IA is to get to a position where the Project does not have any major residual impacts, certainly not ones that would endure into the long-term or extend over a large

area. However, for some aspects there may be major residual impacts after all practicable mitigation options have been exhausted (i.e. ALARP has been applied). An example might be the visual impact of a facility. It is then the function of regulators and stakeholders to weigh such negative factors against the positive ones, such as employment, in coming to a decision on the Project.

4.8.3 Cumulative Impacts

A cumulative impact is one that arises from a result of an impact from the Project interacting with an impact from another activity to create an additional impact. Potential cumulative impacts are discussed in the relevant assessment chapters. How the impacts and effects are assessed is strongly influenced by the status of the other activities (e.g. already in existence, approved or proposed) and how much data is available to characterize the magnitude of their impacts.

The approach to assessing cumulative impacts in this ESIA is to screen potential interactions with other projects on the basis of:

- Projects that are already in existence and are operating;
- Projects that are approved but not as yet built or operating; and
- Projects that are a realistic proposition but are not yet built.

Table 18 summarizes projects have been identified in the vicinity that could contribute to cumulative impacts in the region.

Table 24: Other Projects

Name	Location	Status
New Liberty (Aureus) Gold Mine	Located on the Bea Mountain mining license, in north-west Liberia, it lies approx. 20 km north and north west of Bomi Hills.	ESIA approved
Bong Iron Ore Mine	Located approximately 150 km east of Bomi Hills.	In feasibility phase
Bea Iron Ore Mine	Located approximately 35 km north west of Bomi Hills.	In pre-feasibility phase
Mano Iron Ore Mine	Located approximately 60 km north west of Bomi Hills.	In pre-feasibility phase
Bomi East Iron ore mine (Bao Chico Resources Ltd.)	Located 30 kms in eastern side of Bomi Hills	In Feasibility & ESIA phase
Mano Oil Palm Plantation	The concession area is spread out in 4 counties: Grand Cape Mount, Bomi, Bong and Gbarpolu covering an area of 220000 hactres.	In Operational phase
EDASA Mining Company Inc. (Gold Mine)	Located approximately 15 km north west of Bomi Hills	In Operational Phase
Bomi South Iron Ore Project (West Peak Iron Limited)	Located just adjacent to south of Bomi Hills	In Exploration Phase
Green Ventures Recourses	Located approximately 15 km west of Bomi Hills	In Exploration Phase

Mambo Gold Mine (Endeavour Mining)	Located approximately 40 km north west of Bomi Hills	In Exploration Phase

4.8.4 Identification of Mitigation and Enhancement Measures

Once the significance of an impact has been characterized, the next step is to evaluate what mitigation and enhancement measures are warranted. For the purposes of this ESIA, the following Mitigation Hierarchy has been adopted:

- ✓ **Avoid at Source, Reduce at Source:** avoiding or reducing at source through the design of the Project (e.g. avoiding by siting or rerouting activity away from sensitive areas or reducing by restricting the working area or changing the time of the activity);
- ✓ **Abate on Site**: add something to the design to abate the impact (e.g. pollution control equipment, traffic controls, perimeter screening and landscaping);
- ✓ **Abate at Receptor**: if an impact cannot be abated on site, then control measures can be implemented off site (e.g. noise barriers to reduce noise impacts at a nearby residence or fencing to prevent animals straying onto the site);
- ✓ **Repair or Remedy**: some impacts involve unavoidable damage to a resource (e.g. agricultural land and forestry due to creating access, work camps or material storage areas) and these impacts can be addressed through repair, restoration or reinstatement measures; and
- ✓ **Compensate in Kind, compensate through Other Means**: where other mitigation approaches are not possible or fully effective, then compensation for loss, damage and disturbance might be appropriate (e.g. planning to replace damaged vegetation, financial compensation for damaged crops or providing community facilities, recreation and amenity space).

The priority in mitigation is to first apply mitigation measures to the source of the impact (i.e. to avoid or reduce the magnitude of the impact from the associated Project activity) and then to address the resultant effect to the resource/receptor via abatement or compensatory measures or offsets (i.e. to reduce the significance of the effect once all reasonably practicable mitigations have been applied to reduce the impact magnitude).

4.8.5 Residual Impact Evaluation

Once mitigation and enhancement measures are declared, the next step in the ESIA process is to assign residual impact significance. This is essentially a repeat of the impact assessment steps discussed above, considering the implementation of the proposed mitigation and enhancement measures.

4.8.6 Management, Monitoring and Audit

The final stage in the ESIA process is definition of the basic management and monitoring measures that are needed to identify whether a) impacts or their associated Project components remain in conformance with applicable standards; and b) mitigation measures are effectively addressing impacts and compensatory measures and offsets are reducing effects to the extent predicted.

A Register of Commitments, which is a summary of all actions which the Project Proponent has committed to executing with respect to environmental/social/ health performance for the Project, is also included as part of this ESIA. The Register of Commitments includes mitigation measures, compensatory measures and offsets and management and monitoring activities.

5. SCOPING

5. 1 Introduction

Potential environmental impacts have been identified through a systematic process whereby the activities (both planned and unplanned) associated with the Project have been considered with respect to their potential to interact with environmental and social resources or receptors. Scoping of potential impacts has been undertaken in two stages:

- First, potential interactions between project activities and environmental receptors have been identified; and
- Second, taking into consideration the information gathered on the extent and nature of project activities, and the existing condition/ sensitivities of the baseline, these potential interactions have been prioritized in terms of their potential to cause significant impacts.

The approach taken and results for each stage are presented below.

5. 2 Potential Interactions

Potential impacts have been classified in one of the three categories:

- **No interaction:** where the Project is unlikely to interact with the resource/receptor (e.g. wholly terrestrial projects may have no interaction with the marine environment);
- **Interaction likely, but not likely to be significant:** where there is likely to be an interaction, but the resultant impact is unlikely to change baseline conditions in an appreciable/detectable way; and
- **Significant interaction:** where there is likely to be an interaction, and the resultant impact has a reasonable potential to cause significant effect on the resource/ receptor.

As a tool for conducting scoping, the various Project features and activities that could reasonably be a source of impact were identified, and these have been listed down the vertical axis of a Potential Interactions Matrix. The resources/ receptors relevant to the Baseline environment have been listed across the horizontal axis of the matrix.

Each resulting cell on the Potential Interactions Matrix thus represents a potential interaction between a Project feature/activity and a resource/receptor.

The completed Potential Interactions Matrix is presented in *Figure 5.1*. Those cells that are coloured white are 'scoped out' of further consideration in the IA Process. Those interactions that are grey are also 'scoped out', but the IA report includes a discussion that presents the evidence base (e.g. past experience, documented data, etc.) used to justify the basis upon which this decision was made. Those interactions that are shaded black are retained for further consideration in the ESIA Process.

Interactions that are likely to lead to significant impacts are presented in *Table 5.1* and will be the focus of the impact assessment.

Table 25:Interactions of the project likely to lead to significant environmental and social impact

	Soil erosion	Soil pollution	Soil sterilisation	Soil compaction	Loss of vegetation	Loss of rare plants	Loss of fauna habitat	Loss of fauna biodiversity	Disturbance of fauna	Sedimentation of rivers	Pollution of rivers/ wetlands	Loss of instream biota	Decline in river health	Stream flow reduction	Dewatering	Groundwater contamination	Carbon footprint	Increased dust / air pollution	Increased energy demand	Loss of archaeology	Loss of historical heritage	Visual / aesthetic impact	Noise and vibration impact	Increased traffic accidents	Traffic nuisance / delays	Worse community potable water	Decline in community health from wate	Increased demand on community reso	Demographics (incl Physical Displaceme	Social and Cultural Structure	Economy and Employment	Resource Ownership and Use	Cultural Resources	Education and Skills	Infrastructure and Public Services	Mortality and Key Health Indicators	Environmental Change	Communicable & Non-communicable D	Vector Borne Diseases	Sexually Transmitted Diseases	Boost in national revenues
CONSTRUCTION																																									
General																																									
Labour recruitment																																									
Sourcing of materials																																									
Transport of equipment to site																																									
Site Preparation																																									
Excavation of topsoil																																									
Topsoil dumps																																									
Levelling of slopes																																									
Vegetation clearance																																									
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Construction of new Plant																																									
Construction of new office																																									
New camp/ accommodation																																									
Influx of people																																									
OPERATIONS																																									
Explosives Magazine																																									
Blasting																																									
Load and haul																																									
Pit expansion																																									
Plant																																									
Lighting at night																																									
Crushing of ore																																									

Project Phases and Activities																																									
	Terrestrial Impacts									Aquatic Impacts							Air			Heritag		Social and Health Impacts																			
	Soil erosion	Soil pollution	Soil sterilisation	Soil compaction	Loss of vegetation	Loss of rare plants	Loss of fauna habitat	Loss of fauna biodiversity	Disturbance of fauna	Sedimentation of rivers	Pollution of rivers/ wetlands	Loss of instream biota	Decline in river health	Stream flow reduction	Dewatering	Groundwater contamination	Carbon footprint	Increased dust / air pollution	Increased energy demand	Loss of archaeology	Loss of historical heritage	Visual / aesthetic impact	Noise and vibration impact	Increased traffic accidents	Traffic nuisance / delays	Worse community potable water	Decline in community health from water	Increased demand on community resources	Demographics (incl Physical Displacement)	Social and Cultural Structure	Economy and Employment	Resource Ownership and Use	Cultural Resources	Education and Skills	Infrastructure and Public Services	Mortality and Key Health Indicators	Environmental Change	Communicable & Non-communicable Diseases	Vector Borne Diseases	Sexually Transmitted Diseases	Boost in national revenues
ROM and temporary stockpiles																																									
Waste Residue																																									
Waste Rock Dump																																									
Tailings Storage Facility (TSF)																																									
Other infrastructure																																									
Storage of hazardous materials																																									
Storage of dirty water																																									
Storage of potable water																																									
EMV Workshops																																									
Sewage Treatment Plant																																									
Operation of generators																																									
Diesel storage																																									
Vehicle Wash Bay																																									
Waste storage yard																																									
Access roads																																									
Township																																									
Other activities																																									
Pit dewatering																																									
topsoil stripping and vegetation clearing																																									
Use of mine vehicles																																									
Abstraction of Process water from the Mahe River																																									

Table 26: Project activity justification for potential environmental and social impact

Interaction (between Project Activity and Resource/Receptor)	***Justification for Expectation of Potentially Significant Impacts***
Aquatic Diversity	· Increased sedimentation due to land clearing could lead to impacts on aquatic diversity. · Potential for spills, leaks etc could result in pollution of the watercourses. · Decanting of water-filled mining pits and tailings dams into natural systems. · Erosion of mining dumps and cleared areas leading to contamination of natural streams.
Surface Water	· Water quantity reduction in the Mahe and Lofa Rivers due to high rates and volumes of water being extracted for use by mine related activities. · Water quantity changed due to sediment deposits from reworking of tailings and impacts caused by dewatering of disused mine lake as well as increased runoff from plant areas. · Development of pit & dewatering will reduce runoff in total from catchment or increase runoff if groundwater influx into pit is also dewatered to this stream. · Water quality reduced due to sediment load increasing turbidity & release of nutrients from pit dewatering (nitrogen from blasting) may increase eutrophication · Stream diversions. · Changes in water quantity & quality impacts on utilization of water resource for drinking, fishing & cultivation. · Gradient of catchment will be lowered in general due to excavation of open pit in steeper gradient Bomi Hill area.
Groundwater	· Potential reduced recharge of aquifers due to water extraction for mine related activities from the Mahe River. · Storage and handling of hazardous materials (e.g., fuel and lubricant) and waste generated during construction and operations from equipment and machinery and their maintenance in the laydown areas may lead to ground water pollution. There is also potential for contamination plumes. · The radius of influence that could result from the dewatering of the disused mine lake) and future pits and the potential impact on other groundwater users (rural water supply, surface water -groundwater interaction and the environment).

	· The threat posed to groundwater quality by the opencast pit, the tailing storage facilities and the rock discard dump. as does the migration (direction and distance)
Soils	· Storage and handling of hazardous materials (e.g., fuel and lubricant) and waste generated from operation of construction equipment and machinery and their maintenance in the laydown areas may lead to soil contamination due to leaks/ spillage. · Clearance of soils for the construction of the plant and associated facilities could result in pollution and sterilisation of soils. · Long term use of the site will result in soil compaction. · Soils left exposed due to clearing are subject to erosion leading to loss of important topsoil and sedimentation of waterways. · Long term storage of topsoil in stockpiles could result in soil sterilization.
Air	· Airborne emissions may occur during the exploration, development, construction and operational phases of the mining cycle. The most significant sources include fugitive particulate matter (PM) from drilling, blasting, windblown dust from exposed surfaces such as tailings facilitates, stockpiles and waste dumps, haul roads and infrastructure (exacerbated in the drier months). · Gases from combustion of fuels in stationary and mobile equipment also add to airborne emissions but to a lesser extent.
Noise and Vibration	· Noise generation due to operation of plant and machinery. · Noise and vibration generated due to heavy vehicle movement. · Noise and vibrations caused by blasting.
Waste	· Large amounts of waste, including potentially hazardous wastes, will be produced by Bomi Hills Mine and all the associated facilities, which if poorly managed could impact on soil, water and a number of environmental and social receptors. · Leakage from the storage facilities for hydrocarbons used for vehicles may result in soil and groundwater contamination and this can have long-term deleterious effects on human and environmental health. Storage areas should be bunded to contain any accidental leakages. · Poor sanitation facilities in the camps may lead to surface water contamination through improper sewage handling.

Demographics (incl Physical Displacement)	The removal of the settlements for mining and for general health and safety of the community during the construction period, owing to movement of the heavy machinery and during operations period due to both, movement of the heavy vehicles for the transportation of ore and general mining operations will result in temporary or permanent displacement of the population. Construction of the lay down area, parking of the vehicles, nighttime movement of the trucks, and general storage of the equipment and machinery during the construction phase may also require temporary or permanent displacement of the community. · As per the Feasibility report the temporary land take will be required for Batching plant/storage of civil construction materials (100M x 100M), Steel storage yard (150M x 100M), Laydown area for fabricated steel structures/equipment (250M x 200M), Area for labour colony (250M x 200M). · The feasibility report also states that all temporary facilities required during construction will be dismantled and rehabilitated in original condition after project completion and all other permanent facilities will be dismantled and the entire land will be rehabilitated. · The following towns/villages will be either displaced or may be displaced by land acquisition (completely or to a limited extent) for the proposed Mineralised zones. -Mineralised Zone I: Zalakai, Borbor, Todemai, Jawajeh, -Mineralised zone II: Fahnsen and Small Bopolu. · Besides above, no other village/town seems to be affected by physical displacement because of any other project component as per the existing mine plan/layout of feasibility report. .The villagers here typically possess kitchen garden at the backyard, which is used for cassava cultivation or daily need based vegetables. Also, this area has good access to seasonal streams which not only provides fertility for the land but also provides food source and nutritional supplement through fishing.; .Permanent land take will result in the physical displacement of households. This will require resettlement and compensation for lost assets and income from loss of access to land currently used for subsistence and small scale and commercial agriculture.

.Temporary land take will result in the economic displacement of a currently unquantified number of households, and will require compensation for loss of access to land, assets and infrastructure, if any, upon which communities are dependent for livelihood activities. There are also many HHs in the nearby town of Tubmanburg, which though falls within the mining lease area (not within the present project mining area for 4 mtpa), is proposed to be left largely untouched at least in the initial stages i.e. 4 mtpa mining;

.Stakeholder consultations suggest that there are many HHs in Tubmanburg which have their agricultural land located in the project area;

.There could be some resettlement required to avoid impacts on noise and vibration as well as safety on the community living close to the mining activity;

· The whole area is endowed with good supply of seasonal drains and creeks which are likely to be affected due to the project and affect the livelihood of the people in the area in various ways. The houses are primarily temporary residences; however, would need to be compensated to be able to support them once the HHs are displaced owing to project;

· The nature of land ownership is primarily communal and individual ownership is minimal; this is either due to people preference for the communal ownership, ignorance, lack of access to fund for land registration, or the sheer complexity of the land registration process itself, lack of funds with the land department to ensure individual ownership, and many other reason which needs to form the context for issues surrounding land ownership in Liberia both in the social baseline and rehabilitation and resettlement framework. The permission for cultivating on a particular plot of land is given by the Village elders or the families which have access to traditional ownership of the land. The displacement would therefore have an impact on these HHs who lack access to individual ownership of the land, which is a common feature in the project area;

· Finding of alternate land for these HHs and availability of seed capital will be another challenge in such circumstances. The post-civil war era has actually seen increase in the land based vulnerability with people having been displaced owning to the war are trying to put pieces together. In such a scenario the displacement of such HHs may prove quite challenging both for the people and project too;

	· Also, the demand for agricultural land has resulted in people moving in these areas, though with the permission of the town chief in most of the cases. The displacement of such people without alternate land and enabling rehabilitation and resettlement package could have possible impact of increase in the food insecurity, as well as likely increase in the crimes cannot be overruled; · Lack of access to food in such cases too can result in overexploitation of the natural resources when people will have no other resort to depend upon. Increase in indebtedness or lack of access to credit under trying circumstances cannot be ruled out; · The talk of compensation for the land and asset loss is likely to exacerbate conflicts and tensions related to land ownership; this is also likely to increase cases of ascertaining of the ownership by the youth and individuals who see their rights being comprised owing to traditional ownership rights; · Stakeholder consultations in the community suggest that the traditional ownership is also trying to reinforce the ownership rights over the land as existing in the pre-civil war situation; · This may also result in lack of access to the cultural heritage resources (discussed below) · The impact assessment will therefore need to understand the land ownership patterns in the project areas, related issues, loss of plantation and assets and other livelihood opportunities related to land, shifting cultivation, charcoal production, wetlands, land preferences for cultivation etc. This will help understand the impact of the project in context to any temporary or permanent acquisition of land.
Social and Cultural Structure	Disruption of Cultural and Social Structure: The construction opportunities, construction of labour camp and deployment of the labour in the labour camp during the construction as well as related influx of migrant workers or opportunity seekers in the area (Construction activities, as well as employment opportunities during operations) is likely to result in changing the socio economic landscape of the nearby towns including the social and cultural structure. · Further dilution, alteration and erosion of local cultural systems and social networks in the project affected areas. Populations in Liberia are already relatively mixed and culturally diluted as result of population displacement during the war.

· Influx of foreign migrants and transient populations, and the corresponding weakening of traditional structures, social networks and norms may lead to irreversible changes in lifestyle and to an increase in antisocial behaviours, crime and prostitution.
· The civil war period as suggested in the stakeholder consultations to some extent also was formed on the ethnic lines and the identity. Each of the wards and districts can be categorised to an extent based on the tribal and ethnic identity they represent e.g., Gola tribes in the Bomi County. The rampant poverty in the country, especially when the infrastructure development and reconstruction works in the country are still in the nascent stages after the post-war period, has the possibility of mass migration of the people in the Bomi Hills Mine areas which the people expect to generate employment once the project starts.
· The Social structure with the traditional council at the county level forms an integral part of the existing socio-economic dynamics in the project area. The traditional council is the lead institution at the county level which shapes to a great extent the decision making and traditional beliefs of the community. This takes care of the certain specific tribes and the traditional beliefs that people have in the respective wards or county. These relationships to a large extent also shape the social structure of the community in the project area. The influx of the people in search of the employment opportunities is therefore likely to pose some kind of challenge, or at least discomfort to the existing traditional and social structure system. The impact assessment will therefore look at traditional ownership decision making, potential impacts on cultural identify and integrity etc. with influx of the workers and starting of the mining operations and transportation of the ore.
· Also the town areas are typically formed based on the presence of the lineage family which controls the allocation of the resources including land for cultivation, or construction of dwelling space; the mass influx of the people therefore will pose a challenge to the existing social structure system and traditional power equations in the community. Consultations in some of the community like Bola town, reinforces this thought process, which claims to be the lead, where the town chiefs of almost all the nearby towns report to; the rest of the independent towns as identified under the recent census of 2008, may not necessarily echo the same view; further development of the new settlements for influx migrants may accentuate

such conflicts over traditional control and power equation systems in the community.

Gender based impacts:

· The existing gender balance in the present socio-economic parlance needs to be studied to assess the existing gender relations in the present social structure. On the basis of the key parameters the various project components will need to be assessed whether they are likely to alter the social structure with a likely impact on the gender concerns.

Disruption of Cultural and Social Structure:

· The Project is likely to result in a significant increase in population both during the construction period as a result of the introduction of a foreign workforce which may be required due to the shortage of local skills, and through project induced migration by those attracted to the area by the prospect of jobs and other economic opportunities.

· High expectations for jobs and prosperity returning to the mining area are reportedly already triggering in-migration into Tubmanburg and to settlements along the old Railway. The tentative amount of local labour to be employed for the project is presently pegged at 985 which will be spread out at different skill level; Executive & supervisory category- 135, Skilled Category - 350, Unskilled category- 500.

· An informal economy is likely to grow up around the mine construction site and jetty area during the construction period. Increased commercial opportunities will bring short term economic benefits through new income streams (for example due to local procurement of supplies and services by the camp in Tubmanburg) but may also cause a peak in demand due to the presence of large numbers of workers and migrants. This could lead to an associated spike in the prices of goods and services which will impact on already economically marginalized and vulnerable communities.

· Land take in the concession area will have a negative economic impact on incomes from small scale economic activities of rural communities such fishing, charcoal production and rubber tapping. There is a general perception that the local economy suffered a major setback with the closure of mine in late 70s and further due to the onset of war, intermittently for almost 20 years. The reopening of the mine as per the local expectation will bring employment and prosperity in the area.

· The local contention is that in due course the population of the area has increased too along with simultaneous growth in the poverty in the area. With the change in the technology, the mining industry has become less labour intensive much oblivious to the expectation of the local people for labour intensive practices in mining like the previous mining operations during Liberia Mining company (LMC). The reduced requirement of labour and limited employment avenue with likely competition from the migrants over these labour opportunities may further cause dissatisfaction in the community.

· The Bomi Hills Mine during LMC operation used to be quite developed based on the review of the old records available and the reopening of the mines may not meet the same expectations.

Money economy (influx of cash)

· It is likely that with the influx of the money in the local economy with increased employment opportunity there could be perceived changes in the way the people interact. Presently the credit pattern, community support, and group saving schemes are operational which help people or the members in time of the need. Also the socio economic inequality is not too much in the project area, and hence the impact of increased income inequality will need to be assessed as part of the impact assessment.

Gender based impacts

· It is common for the mining operations to include more of women workforce. A quick understanding based on consultations indicates that women are more enterprising in the project area, with many of them involved in businesses. Also the difference in the wages is not much. The power equation and gender status depends a lot on the earning capacity of the men and women and nature of work they do. The increase in employment opportunities and increased income of the men may change the existing gender equations in the community. The impact assessment will try to understand the complexities surrounding the existing situation.

Resource Ownership and Use	Loss of Access and Use of Land, and Loss of and Increased Pressure on Natural Resources: · The Project will require permanent land take in the footprint of facilities within the concession area as discussed above. The scope of permanent land take required in the concession area will affect forested areas whose natural resources are currently used for agriculture, fishing, hunting and other subsistence activities, which are central to the livelihood strategies of local rural communities. The construction of the project facilities in the concession area is likely to require the introduction of skilled, semi-skilled and unskilled workers, many of whom are likely to come from outside the project area due to a lack of locally skilled labour. · The size and provenance of this workforce as earlier discussed is pegged to be around 1000, out of which nearly 500 are expected to be from unskilled category, which also has the highest potential for migration. The presence of large numbers of workers in the area may result in an increased pressure on demand for firewood, bush meat, fish, charcoal, and other natural resources from the surrounding forests and rivers. A large portion of the area being proposed for the early mining is already disturbed owing to previous mining activity, with huge population pressure to support. Only a limited part of the north west of the concession area in Bomi is actually little dense with potential for bush meat or other natural resources, which though previously exploited has developed into relatively better endowed secondary forest. This part of the concession area will need to bear most of the pressure and there will be conflict as well as pressure on these resources with the increased migrant population, if any. Such migration can be possibly distributed though, with the potential of many other mining companies like China Union, Arcellor Mittal also planning to start mining in the recent future.

· The water requirements for the project during infrastructure creation and operations are likely to be a cause of concern for the local community. The water for the township and other operational facilities and during the construction phase will be sourced from Mahe River, Bomi Lake and borewells in the project area. Most of the water source (in form of creeks, channels etc.), which are commonly used by the community and are characterised by ease of access are seasonal and turn dry by January. The borewells were far and few in these areas; WCL has recently increased the number of borewells of the community. However, impact on the water source availability for the community, is an issues which cannot be ruled out and the same will be based on the outcome of the hydrogeology studies to be carried out in the project area.

Downstream impacts on water bodies and potential impacts

· The existing contamination of the water bodies owing to legacy issues related to tailings deposit previously by LMC had already been documented. The present activities related to mining have the potential for exacerbating this existing impact. Though the project has integrated certain aspects into the project design itself, the impact of the present mining activity needs assessment especially in terms of the health impact and impact on livelihoods of people dependent on the river downstream.

Impact on Artisanal miners

· The Mineralised zone II and the area earmarked for township (legend no: 9 of the layout) is likely to involve some artisanal mining pits, affecting livelihood of those who are dependent on these pits. The location is other project component in concession area is likely to have little impact on artisanal mining because of low scale of mining activities to be carried out by project in these areas.

· Based on consultation with a local Mining chairman and preliminary ground truthing of the concession area, artisanal mining of gold and diamond is also practised in concession area, mainly in areas around the towns of Gorbla, Coffee Sua village, Barclay, Banana, Small Bopolu etc. Majority of miners are illegal (mining without license); however the scale of artisanal mining is much lower compared to Mano River and Bea Mountain concession areas. Majority of illegal miners in Bomi concession area are residents of Tubmanburg town. The proportion of aliens (Non-Liberian people) in Artisanal mining is almost negligible in Bomi concession.

· The impact however will need to understand the detailed scale of artisanal mining in the project core areas, and the likely number of legal license holders, people working under the licensee, income patterns and dependence on artisanal mining as source of livelihood.

Increase in land prices in the area

· The land will be acquired in phases, presently for this project and later for the next phase of Mining which will have ramped up capacity of 10 mtpa and evidently an expanded project area. The compensation in the present phase of the project for the loss of land can brew up expectations of the people in the neighbouring communities for the sheer scale of the compensation. Also presently based on the stakeholder consultations it would be safe to say that there is limited land transaction that takes place in the project area; it may be because there is limited individual ownership. It is however likely that the compensation dynamics may alter the complete land transaction market in the project area, if any. This land pricing is understood to have the potential to change the complete land market which is practically non-existent in the project area.

· The impact assessment will therefore need to assess whether the existing system of the land transaction has a chance to lead to a pricing based land transaction in the project buffer area. In such a situation, the capacity of the locals to actually own land over a period of time based on the current buying capacity will need to be assessed. The impact assessment will concentrate on first understanding the present context before understanding the likely impact that the project may have.

Gender based impacts

· The decreased access to resource or obstruction created towards ease of access for natural resources including firewood, daily needs, or income source owing to temporary land take or permanent land take for the project as discussed above.

· The impact assessment will therefore assess the women access, control and dependence over the natural resources including forest, bushes, streams and other manifestations of the natural resources having direct interaction with the gender needs. The impact assessment with proper understanding of such inter-linkages will then assess the likely impact the project may have owing to reduced or complete lack of access to control over the natural resources.

Cultural Resources	· The land take for the temporary and permanent usage for various facilities already discussed above is likely to have impact on the cultural heritage resources for the local population. · There is the potential for the loss of sites of archaeological and cultural heritage value in the concession area, through project land take and construction activities. Examples of cultural sites and resources which may be present but are as yet unidentified are the sacred sites used by Poro (male) and Sande (female) cultural societies and animists in parts of rural Liberia, as well as other sacred natural features and ancestral graves. Stakeholder consultations in the project area suggest that there are varied level of affiliations shown for these cultural resources. · There is a perceived reluctance in the project area in easily sharing of the information towards existence and the exact location of such traditional forests. However, without questioning the allegiance of the various groups towards these cultural resources, it would be safe to assume that there is likely impact envisaged on the cultural resources. · The exact position of these traditional forests cannot be ascertained; however preliminary consultations and reconnaissance suggests that three traditional forests exist in and around the concession area. One is near Malley Town (toward east side and very near to concession boundary), second is near Gboa town (towards western side and near to concession boundary) and third one was reported to be near Manna town which is located between 5 km radius of the concession boundary towards south east side of the concession area. The first two traditional forest, although is located outside the concession boundary, but it might involve impact on access route passing through project areas causing impact on movement of people from surrounding areas. It would be safe to assume that the core project area does not have any traditional forest; however the same will need to be confirmed during the impact assessment.
Education and Skills	· To meet the growing opportunity of manpower requirement in the mining area, there may be stress on the growth of Education and skills in the project area. · The project may also think of starting programs aimed at improving the education and skill levels of the local population. The increase in the CSR activity and Social Development fund (SDF) is likely to result in the improvement in the education and skills in the area.
Infrastructure and Public Services	Pressure on Social Services and Infrastructure:

	· The increased influx of the workers (across various categories) during the construction and operation period of the project (approximately 1000) is likely to put pressure on the existing infrastructure and social services in the core and buffer of the project areas. · The Project Area, in particular Tubmanburg and surrounding is characterized by severe poverty and a lack of public services with inadequate schooling and health facilities for the local population, and decrepit transport infrastructure and road networks. The influx of in-migrants and increase in traffic and mine workers could place a greater strain on already extremely limited facilities and infrastructure. There is very little government and local institutional capacity at a local, regional or national level to either deliver or improve the delivery of services in the project affected areas, inherently implying high expectation from the private sector actors such as mining companies to provide essential infrastructure and public services and maintain these over the long term, creating dependencies. This impact will need to be studied as part of the Impact assessment process. Gender based impacts · Experiences suggest that increase in the pressure on the infrastructure services, in some of the cases is accompanied with gradual inherent reduction in the level of access for women folk. This could be possibly due to gender based discrimination at HH level or in the public domain and can be exacerbated owing to factors such as increased cost, safety and security of women etc. The impact assessment will therefore need to see the present level of access to services by women, and also how are these curtailed or restricted in case there is a pressure on these infrastructure services.
Mortality and Key Health Indicators	· During the operation phase of the project as well as during the construction phase, community exposure to hazards from the use of machinery and negative interactions between local residence and workers cannot be ruled out. Construction site and the operations site do have the potential to increase fugitive dust generation, which is likely to increase the TB afflicted population in the neighbouring community and nearby areas.

	· The movement of the waste or other operational materials (owing to incessant rains in Liberia for almost 6 months), if not controlled can particularly lead to choking of the natural or man-made drains and culverts during wet season. Storm water drains, ditches, and stream channels are therefore likely to be impacted, resulting in health concerns for the local community. Runoff from the construction areas have the potential to contaminate storm water, groundwater or any nearby streams, in case suitable siting and design related consideration are not included in the project in the early stage. · Community Safety: The construction of project related infrastructure and facilities will result in a significant increase in movement of project related traffic, and heavy plant and machinery including the increased use of the access roads, and jetty. These activities will increase potential for interactions between project activities and communities in the vicinity resulting in potential safety hazards such as pedestrian road and rail accidents. Communities currently living in or close to the concession area boundaries and access roads, and the large number of communities living along the old Railway corridor or in settlements adjacent to the Road will be at particular risk. · The construction of the mine and ancillary facilities in the concession area will require large quantities of building material and other supplies (fuel, supplies to the construction village etc.), some of which could be delivered to the site by trucks that may pass in close proximity to homesteads. Some of these settlements are small, rural and isolated in nature increasing their susceptibility to disturbance and safety risks. Gender based impacts · The existing health indicators especially with respect to women will need assessment. Increase in the mortality and other health indicators has direct impact on the women, both directly and owing to the vulnerability they are prone to in case of the death or disability of the male members of the family.
Environmental Change	Increased pressure on natural resources: · The presence of large numbers of job seekers in the area may result in an increased demand for firewood, bush meat, fish, charcoal, and other natural resources from the surrounding forests and rivers.
Communicable & Non-communicable Diseases	· In the context of already poor to non-existent health services certain communicable and other diseases could be exacerbated by the presence of the project and induced migration during project operations. Malaria is a serious risk in the remote areas of Bomi County.

	· Other critical concerns cited by local communities and government point to high prevalence of acute respiratory infections and tuberculosis (TB); HIV/AIDS, Hepatitis B and C, and other sexually transmitted infections the risk of which may increase with the presence of a mine based workforce. · The construction of the labour camp and the movement of the working population along with the Road up-gradation work can have potential impact of the spread of the communicable diseases in case the waste disposal (especially the sewage waste etc.) is not taken care of properly or are directly disposed of in the water source etc. · Lack of access to proper infrastructure along the habitation, where the migrant labour may likely reside spread of communicable and non-communicable diseases cannot be ruled out. Pollution from tailings can create a health impacts · As earlier discussed the existing impacts on the health of the people particularly in the downstream will need to be assessed keeping in context the pollution of water bodies due to improper tailing dump. This is presently understood to be a legacy issue; however the present project has the potential to likely induce such pollution again with limited mining activity either in the project phase or in future. · The project will therefore need to assess the likely chances of such an impact on the health of the community downstream.
Vector Borne Diseases	· The increase in the incidence related to vector diseases due to increased exposure of the working population to the dense vegetation areas etc., apart from creation of artificial stagnation of waste, etc. may accentuate instances of vector Borne diseases. · Such instances would need to be assessed for baseline conditions and the nature of the present project related activity would be assessed for the impact in terms of their potential for increasing instances of vector borne diseases in the project area of influence.
Sexually Transmitted Diseases	· With the increased migration of the work force to the mine area and the ore transportation traffic has the potential to increase the spread of the sexually transmitted diseases especially in context to the behaviour practice of such population, as can be easily assessed from past experiences. The instance of sexually transmitted diseases is also likely to see increase in the project area.

	· Transportation in consonance with the mining activity, processing and the transportation of the ore, during the transportation stage, will result in movement of the population of the drivers and the helpers and related population. · Experiences from similar projects suggest that with the increase in such population, the instances of sexually transmitted diseases generally increase. This impact will need to be considered for impact assessment in Mine ESIA. Gender based impacts · Increase in unprotected sex and potential market situation for such behavioural practices owing to rampant poverty, influx of the migrant workers and the labourers housed in the labour camp, added to the mobile truck drivers and helpers in the project and buffer area cannot workers and the labourers housed in the labour camp, added to the mobile truck drivers and helpers in the project and buffer area cannot be ruled out. This has huge risk for the local women not only directly but also indirectly in case the male of the HHs contract STDs. In such a situation the impact area will be quite huge, with the potential risk of spread of STDs in the drivers and helper families. · The impact assessment will therefore also need to understand the existing protected (safe)/ unprotected sex and STD awareness in the project area and the scale of such an impact, if any in the future stages of this project.
Nutritional Status	· The increase in income of the locals owing to direct or indirect employment or business opportunities generated by the project is likely to find its way to the increase in the nutritional level of the people in the project areas. · This however is not always the case, and experiences suggest that it may also increase instances of substance abuse in the local areas owing to the nature of the activity and increased inflow of money in the local economy. · Substance abuse has been found to be matter of concern not only in case of abject poverty, but also in similar circumstances as mentioned above. · The impact assessment at this stage will need to understand the existing baseline conditions, and the way the project is likely to impact this segment of the population which is also linked to neonatal deaths, mortality rate etc. The project would anticipate reduction in the malnutrition related cases etc., and overall health access and improvement in the project areas. The project should impact the nutritional impacts positively; however improvement in the nutritional status of the women and children will need to be assessed in the long run.

Health Care/ Recreational Facilities	· The MDA stipulates that the Project will need to take care of the health care facilities in the project areas which in due course of time, with the progressing project stage will grow bigger and bigger within the existing concession area and related transportation options (first Road and then Railway). The Bomi Hospital, which is the biggest health care facility, as evident from the stakeholder consultations, presently takes care of almost the whole of western Liberia, owing to the geographical alignment and the single access route to further areas in Bea Mountain and Mano River Mountain areas. This hospital earlier was developed by Liberia Mining Company (LMC), which was further taken up by the government, and then was taken over by various international NGOs working in the area of health. Most of the health services, like other services is heavily funded or is dependent upon the grant of the International NGOs. Now as per the obligation under MDA, the project may either work on, strengthening the capacity of the same hospital or may develop a new facility, which is likely to increase the access to better health care facilities for the locals. · The project impact assessment will need to capture this positive impact by assessing the present level of health care access to the community at present and also whether the suggested improvement in the health care services is likely to create any positive impact or not. The impact assessment will also need to understand whether this capacity will be suitable to manage the pressure of the influx of the workforce owing to the project. Gender based impacts · Improvements to women'shealth access need to be better understood · The construction and operation of the mines is likely to have some source of irritant and discomfort to the community. The incessant noise, if not properly checked, movement of the vehicles, blasting operations and movement of the heavy earth equipment and machinery accompanied with the influx of the migrant population is likely to bring some positive and negative impact.

Psychosocial/ Lifestyle Factors	· On the whole with the increased income and business and more flow of money in the local economy is likely to change. To many having been exposed to the earlier mining experience, all these developments may not mean something unexpected; however there is a whole new generation in the post-war era, who have never seen such level of operations in this area. Such unexposed population to earlier mining operations definitely outnumber the ones who had seen the same. The level of technology involvement is likely to be a surprise even for those few who had seen the earlier mining operations. The change in the labour laws and the ways companies operate now will be subject to a lot of debate and discussions and is likely to impact the psychosocial make-up of the existing population in the project area of influence. · Effect of long period of civil war in terms of psycho- social trauma on the whole population having suffered through the whole period is not well known, as lack of access to such services capturing such changes in the project area make such assessment difficult. In such a situation, the project may have to manage certain issues in this context while starting the project operations. · The impact assessment will therefore need to focus on such aspects, and the impact on the social structure, migration etc. will need to be assessed keeping this aspect in consideration.

6. STAKEHOLDER ENGAGEMENT, CONSULTATION, ANALYSIS AND DISCLOSURE

6. 1 Introduction

This section presents the outcome of preliminary Stakeholder Engagement process and consultation for the Project undertaken so far as a part of the Impact assessment process.

This included the process of identifying and engaging the relevant stakeholders as a part of ESIA study. This section describes the activities undertaken so far to engage and consult with key stakeholders during right from the beginning of the ESIA process, including the scoping and the final impact assessment process. Stakeholder engagement plan will look into the realm of stakeholder consultations post ESIA.

6.1.1 Regulatory Requirement related to Stakeholder Consultation

The requirements related to stakeholder consultations for any project in Liberia undergoing through the ESIA process is laid out in the Environmental protection Agency Act of Liberia, 2003 as well as in the Mineral Development Agreement signed between Government of Liberia (GoL) and Western cluster Limited (WCL).

6.1.2 Environmental Protection Agency Act of Liberia, 2003

Section 37 of the EPA of Liberia requires the following public consultation[1] process to be carried out:

- identify, inform and receive input from affected stakeholders and interested parties;
- determine and narrow the scope of the issues to be addressed in the EIA;
- identify and define, at an early stage of the EIA process, the significant environmental issues, problems and alternatives related to the different phases of the proposed Project or activity;
- ensure public participation early in the EIA process;
- ensure that all relevant issues and alternatives are adequately addressed in the environmental impact study;
- provide the applicant with the information necessary for formulating the terms of reference for the environmental impact study and impact statement; and
- guide the applicant's consultants in preparing the Environmental Impact Statement (EIS).

6.1.3 Mineral Development Agreement (MDA) between WCL and GoL

At the PFS stage the social professionals on the project team will also commence the compilation of a stakeholder register. The stakeholders will include government agencies, non-government organisations (NGO's) and key members of the local communities.

In addition, a consultation strategy and a stakeholder engagement plan (SEP) will be developed and implementation of the consultation plan will also commence at this stage.

The closure management plan will include a list and assessment of risk and any uncertainties associated with the preferred closure option, address the social aspects of closure and rehabilitation, and provide a process for participation by the community and other stakeholders in closure management and monitoring.

6.1.4 Defining Stakeholder Engagement

A stakeholder is defined as a person, group, or organization that has direct or indirect stake in a project/organization because it can affect or be affected by the Project/organization's actions, objectives, and policies. Stakeholders are categorized in terms of degree of interest, influence and control they have over the Project.

Stakeholder engagement is an on-going process of sharing project information, understanding stakeholder concerns, and building relationships based on collaboration. Stakeholder consultation is a key element of engagement and essential for effective project implementation. Disclosure of information is equally as vital.

If there a risks or adverse impacts from a project, consultation must be inclusive and culturally appropriate and provide stakeholders with opportunities to express their views. In line with current guidance from the FC, consultation should ensure *"free, prior and informed consent of the affected communities* (1)*."* In other words, effective consultation requires the prior disclosure of relevant and adequate project information to enable stakeholders to understand the risks, impacts, and opportunities.

6.1.5 Stakeholder Engagement: Identification, Engagement & Analysis Overview

The stakeholder engagement process is designed to conform to the Liberian public consultation and disclosure requirements under Section 37 of the EPA of Liberia and international standards, including the IFC Performance Standards and Vedanta's sustainability standards.

This section is aimed at presenting the stakeholder analysis for the project. The various stages or the process followed to arrive at proper stakeholder analysis for the purpose of this project is as follows. *Figure 6.1* below sums up the complete stakeholder process for the project. The key steps are:

- Stakeholder identification process;
- Information dissemination to the stakeholders; and
- Stakeholder engagement process;
- the outcomes of the consultations to date; and
- Stakeholder analysis.
- Way forward: stakeholder engagement plan and grievance response mechanism

This section also covers information incl of project related information, identifying and consolidation of the comments of the various stakeholders including but not limited to the various Government departments, traditional leadership, opinion leaders, regional and international NGO's, interested Community, groups (Forest and o user groups, traditional groups, livelihood groups, farmers, etc.). While some of the stakeholder groups are easily identified, others either get identified during further consultations or during the comment seeking process. Also, depending upon the stage of the project and issues emerging out of the project, there is emergence of new stakeholders from time to time with varied interest in the project.

Based on the stakeholder analysis from 2013, 2022, and 2024 a stakeholder engagement plan (SEP) has been developed for the project which is being used for engagement with the various stakeholder groups associated with the project.

This stakeholder engagement has formulated a key relationship between the mines and the stakeholders, thus resulting in a continuous relationship that is formed. The engagement has spread over the boundaries of impacted and affected communities to the four districts of Bomi County.

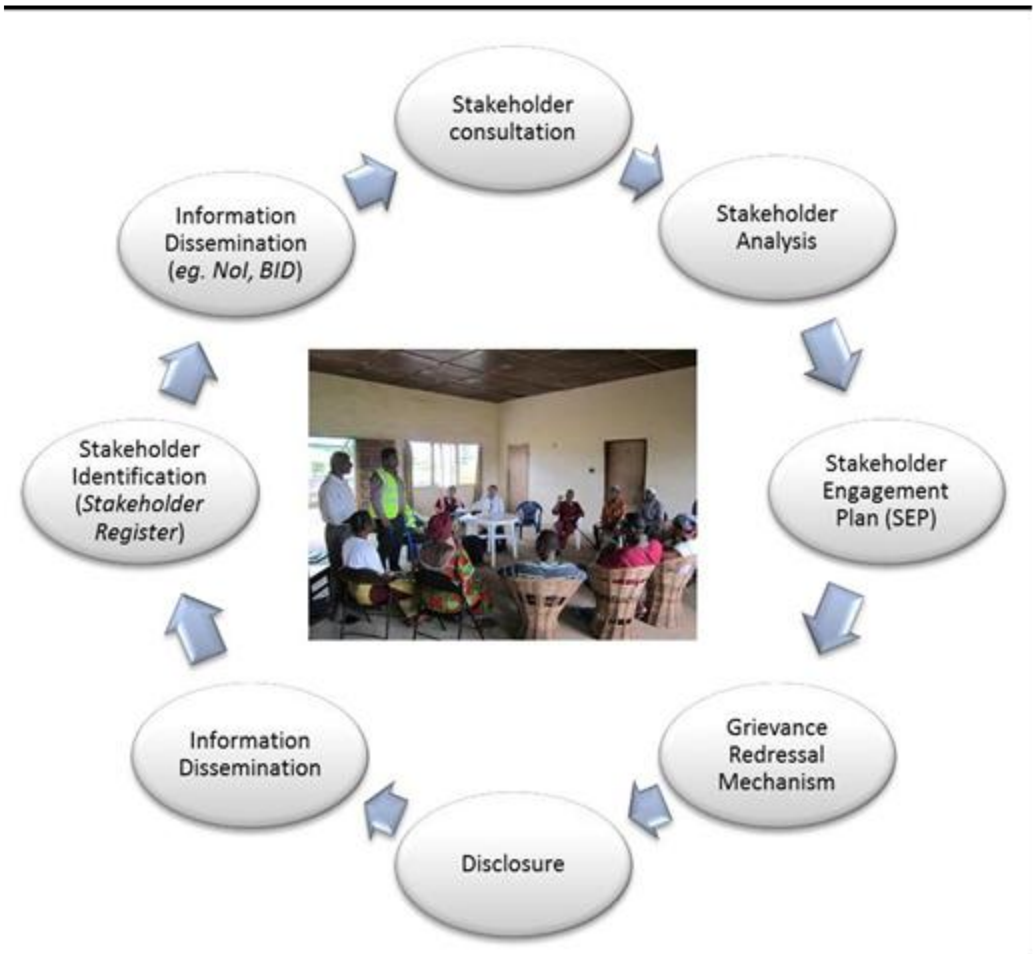

Figure 9: Stakeholders with project affected persons

Objectives

Stakeholder engagement is considered as a continuous process during ESIA study and culminates into a Stakeholder Engagement Plan (SEP) that will guide project in identifying the stakeholder groups and the process to keep them engaged at an appropriate manner in future. The main objectives of stakeholder engagement being proposed for the project are:

- to inform and educate stakeholders about the Project and to ensure that adequate and timely information is provided to those likely to be affected by the Project;
- to gather local knowledge to improve the understanding of the environmental and social context;
- to provide these groups with sufficient opportunity to voice their opinions and concerns; and

- to help them better understand locally-important issues;
- to ensure that the comments are received in a timely manner so that they can be taken into account for appropriate decisions;
- to take into account the views of stakeholders in the development of effective mitigation measures and management plans; and
- to lay the foundation for future stakeholder engagement.

6. 2 Stakeholder Identification

Identification of stakeholders and their engagement through appropriate medium in the decision-making process can help in prioritizing, analyzing and addressing issues; and create management systems and strategies to address their concerns/ expectations.

During the scoping stage a preliminary list of project stakeholders had been identified. These consisted of individuals, groups and organizations that may be affected by or may influence project development. The list was developed using international guidance and considered the following groups:

- ✓ national, regional and local government;
- ✓ local community and traditional leaders;
- ✓ community members including vulnerable sub-groups such as women, youth and elderly;
- ✓ international, national and local environmental and social non-government organizations (NGOs);
- ✓ potential contractors and service suppliers;
- ✓ local businesses/cooperatives and associations;
- ✓ universities, research institutes and academics; and
- ✓ labor unions.

6.2.1 Key Stakeholder Groups for the Project & their Profile

An attempt has been made to cover a broad range of these representatives and a brief description of the broad stakeholder groups with likely stakeholders is presented below.

<u>Concerned Ministries/Departments of Government of Liberia</u>

The following ministries and departments including the county authorities and local government representatives were identify as regulatory stakeholders to be approached to initiate discussions regarding the project. Some of them are:

- o Ministry of Mines and Energy

- The Environmental Protection Agency
- Ministry of Justice
- Ministry of Agriculture
- Ministry of Public works
- Ministry of Finance
- Ministry of Internal Affairs
- Ministry of Transport
- Ministry of Health
- Ministry of Labor
- Liberia Revenue Authority
- The National Port Authority
- Liberia Land Authority

Some other departments falling under different ministries mentioned above are important in terms of engagement and deserve special mention:

Departments and Bureaus under various Ministries

Each of these ministries has various departments and bureaus as well as branches / representation at local levels. The information on the existing practices and precedents on handling various issues related to mine operations (including acquiring surface rights, displacement, valuation of assets, compensation, and resettlement practices etc.), road development and port development was discussed with the various agencies as under;

- Bureau of Mines;
- The Geological Survey;
- The Mining Cadastre Office;
- The EPA Department of Compliance; and
- Resident County Surveyor for Bomi County

Commissions and Key Agencies

Apart from the various Ministries and departments there are standalone commissions which have important stakes in the policy making for future; land and resettlement being one of the paramount issues being presently addressed through the Liberia Land Authority (LLA) which was once a commission. Owing to ambiguity surrounding the issue of land ownership pattern in the concession area and elsewhere and the habitation pattern especially after the civil war has made the role of the LLA very important. The consultations aimed at understanding the various developments in the respective fields which may have implication for the project are:

- Liberia Refugee Repatriation and Resettlement Commission (LRRRC); and
- National Investment Commission.

Particularly the land commission has been spearheading the discussion and way forward towards shaping the new land policy for Liberia. Various issues surrounding the communal ownership and tribal certificates validity is likely to be addressed through the land commission.

Local Administrative Units

The local administration in the project area was informed before starting any kind of consultations or baseline data collection in the area. The communication in the community follows a hierarchy which is amalgamated with the existing administrative leadership in the community at various levels. The consultations and community engagement followed the established precedents and norms as commonly practiced in Liberia.

- County Administration;
- City Corporations & Borough;
- District commissioners;
- Paramount Chiefs;
- Clan Chiefs and town chiefs; and
- Security and Police representatives;

Customary and traditional aspects related Stakeholders

For addressing issues related to customs and practices and cultural heritage, especially *Poro* and *Sande* Forest, it was considered important to engage with the various institutions mandated traditionally as well as administratively to manage and address issues associated with them. The communities (women and men) were separately also consulted through focused group discussions to understand their beliefs and practices.

- National Traditional Council;
- Director of Culture and Custom under Ministry of Internal affairs;
- Paramount chiefs; and

- General community (men and women groups).

Security Agencies

The role of the security agencies was also given importance during the stakeholder consultations. The LNP was also consulted to understand its preparedness to enforce the law through the prevention of crime, and d identifying options for better coordination and management of traffic during the construction and operation phase of the project considering the many concerns and issues related to the transportation of ore by road.

Community likely to be affected by Project

Mine: There are six (6) communities that are within close proximity with the mine, and leaders and community members were invited to a general stakeholder's consultation at the offices of the Superintendent. This consultation was more of a follow-up to previous engagement meetings carried out since the 2013 ESIA.

Road: There have been ongoing consultations with the communities along the Tubmanburg to Monrovia highway regarding its use by WCL for haulage of ore to the Freeport of Monrovia. The team from MacAfrica also engaged and survey several influential community leaders in towns along the route for their impression with WCL's ore transport through their communities and their expectations for its continued use. Background information documents were also provided to the communities to ensure that people are informed about the project.

Port: No Consultative meeting was held with the port or the community within the vicinity of the port as a result of the short time period for preparation of this updated ESIA, however, the team relied on previous results from consultative meetings held since 2013 ESIA process and the fact that WCL has been continuously using the port for exporting ore.

Academia & NGOs

NGOs and civil society primarily associated with the development activities in the project area were invited to a county stakeholders' engagement. Bomi County currently has a community college which was also invited to form part of the county stakeholder's engagement.

6.2.2 Stakeholder Register for the Project

As per the MDA requirements, a stakeholder register has been prepared which follows from the stakeholder analysis being further developed in the section. The stakeholder register not only classifies the stakeholders on the basis of key concerns and expectation, their role in the project, but also the impact and influence rating with respect to the project. The registry had been updated to include stakeholders not inexistence at the time of the 2013 ESIA report and also to remove non-existing stakeholders.

6. 3 Stakeholder Engagement Process Alignment with EPA Requirements

The stakeholders outlined above (national, regional and local government, NGOs, private sector, research institutions and the general public/media) have been engaged through meetings, interviews, letters and press releases.

6.3.1 Information Sharing & Request for comments

Release of the Notice of Intent

A Notice of Intent (NoI) was prepared for the project as per the requirement mentioned in the EIA procedural guidelines published by EPA, 2006: *A proponent whose undertaking requires an EIA must prepare and publish a Notice of Intent that provides information to enable stakeholders to identify their interest in the proposed project.*

The notice was published in a major national and regional newspapers and was broadcasted on selective radio channels especially targeted at the geographical area where the proposed project is located. The publishing and broadcasting were scheduled to be continued with repetition at regular intervals.

The notice of intent provides the opportunity to the interested parties to communicate and raise their concerns/ suggestion or grievances through various modes (e.g. by letter, in person, through mails, on call etc.). Presently the concerns/ comments/ suggestions/ grievances etc. is directly taken up by project proponent itself through its community relations team.

6.3.2 Overview of the Consultation Process

Engagement activities carried out in the ESIA study stage included consultations designed to inform local stakeholders about project design, to obtain their key concerns and issues and to inform the development of mitigation for the Project.

These consultations enabled the ESIA team to refine the ESIA analysis by generating additional feedback on the EIA approach, key issues and analysis of potential impacts (such as assessment of their relative significance).

At the same time, it should be stressed that consultation was carried out in a sensitive manner so as not to raise the expectations of local stakeholders or to unduly raise the visibility of the project.

The engagement was done with the various stakeholders through individual interviews and group discussions as a follow-up to previous and on-going stakeholders' engagements. This was primarily done to assess the understanding of the issues related to this project and other projects implemented in the country and the aim was to generate first-hand information on the key procedures and practices related to the various activities which are being undertaken as a part of the project.

As done for the past SIA, a broad range of stakeholders were identified, and the following activities were taken forward under these engagement proceedings:

- Focused engagement by the project proponents on issues raised by the stakeholders and not included in the current Stakeholder Engagement Plan (SEP).
- Assessment of the adequacy of:
    - Community Relations and Resettlement Committee within WCL;
    - Communication and Grievance Systems.

In addition, a number of tools were prepared including stakeholder analysis tools and data collection tools (Influential community leaders survey questionnaires, focus group discussion guides, etc.) to update the existing SEP to help deal with stakeholders and their concerns effectively.

WCL has in place a dedicated team to oversee the implementation of the SEP and handle issues arising out of these public engagements, and it has attempted to ensure maximum participation at this stage of its operations.

6.3.3 Specific Strategy for Consultations for the Mine

Consultation was done with the Bomi County Administration and affected communities' leaders. This also included the mayor office, superintendent office, paramount chiefs and the clan chiefs. Other agencies like regional agricultural department offices, and other NGOs working with them were also contacted.

The discussions were able to capture the various facets of their socio-economic profile, including livelihood, health, education, cultural heritage- beliefs & practices, concerns and expectations and their perception of the positive and negative impact emanating from the mines.

6. 4 Stakeholder Analysis

The stakeholders identified and consulted as in the previous ESIA of 2013 have been categorized based on the stages of the project development owing to the fact their influence and relevance to the mine operations at a particular point in time.

Influence represents the ability and capability to persuade or coerce others and/or the ability to impact (positively or negatively) on the success of a project. The figure below depicts this matrix.

The top right-hand group of stakeholders are referred to as “players” - they are stakeholders that have high influence and interest; the owners of a project, highly influential NGOs, directly impacted people and key government ministries etc will fall in this category.

“Referees”, the group below “players”, are those that also have very high influence, however may not be as interested (this group often contains many of the regulatory authorities as well as key opinion formers such as NGOs and the media).

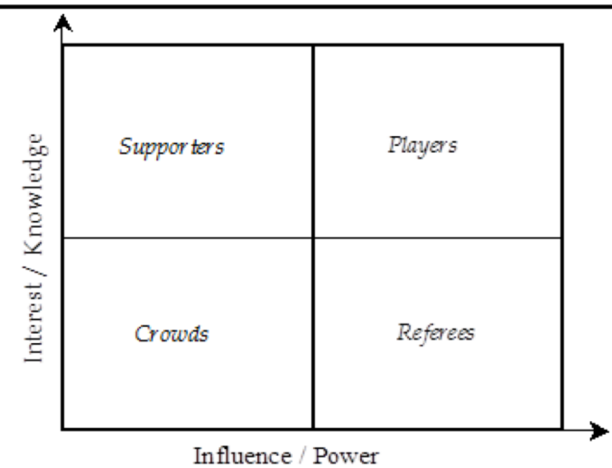

Figure 10: Stakeholder's categorization

“Supporters” are groups with a keen interest in the project, but little power or influence; poorly organized local communities would usually fall into this category.

“Crowds” comprise stakeholders with only a peripheral interest in the project such as local academics or the more marginal NGO groups. The matrix has been re-depicted in this particular context below.

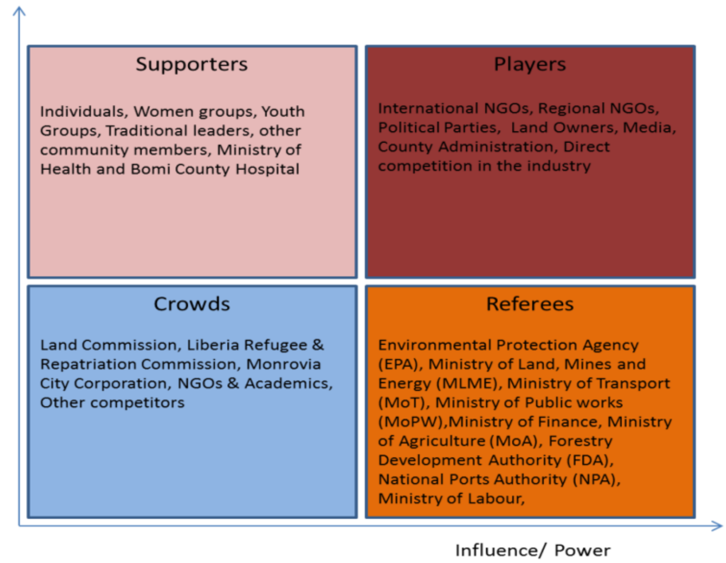

Figure 11: Stakeholders

In practice, some stakeholders are "players" for one issue, while they can be "crowds" for another.

The above identification process is more applicable to larger scale operations.

Each stakeholder group has been analyzed separately in the stakeholder analysis table. The analysis also reviews the stakeholder engagement process till date and raises critical issues in the process that requires attention.

This section extensively deals with external stakeholders and their specific aspirations, interests and needs in order to formulate a comprehensive stakeholder engagement plan.

Some of the key concerns with respect to each of the stakeholder group is being summarized in the stakeholder register cum stakeholder analysis table as shown *in Table 21* and *Table 22**.***

Table 27: WCL's Bomi Hills Iron Ore Mining Project Government Stakeholders Registry and Analysis

S. No.	Stakeholder Group	Stakeholder Details	Brief profile & interaction with Project	Issues discussed & Expectation	Level of Involvement
	Government	• Environmental Protection Agency (EPA)	• Responsible for giving environmental Permit for the project • Regular monitoring of the performance against Environmental and Social Management Plan (ESMP)	• The Project should conduct the Environmental and social impact assessment for project following Local laws and regulations and following best practices, wherever required as per IFC and WB standards. • The company should act in an environmentally sustainable and socially responsible manner.	High
		• Ministry of Mines and Energy (MME)	• Key Ministry responsible mining and energy etc. • Issuance of Mining lease for the project;	• The compensation for the crops and infrastructure or other kind of losses will need to be taken care by the project management; • Community engagement and negotiation will be the key for the company to do business in a conducive environment; • Artisanal miners are to be considered at par with the farmers engaged in subsistence farming; • The artisanal miners with valid licenses will need to be compensated.	High
		• Land Authority	• Not directly related to the project; • The findings and policy suggested by the Authority on land may have implications for land access in future	• The land Authority expects the corporates to respect the communal rights of the community over the land; • The land Authority also expects the corporates to adhere to consideration the land and policy in the country.	Low to Medium

S. No.	Stakeholder Group	Stakeholder Details	Brief profile & interaction with Project	Issues discussed & Expectation	Level of Involvement
				while in the rural areas communal ownership is common.	
		• Ministry of Finance	• Establishing value for the infrastructure and immovable assets;	• The market rates followed by the MoF may not necessarily reflect the correct market rate, as MoF generally does the assessment of the property for taxation purposes; • Local market rates may be considered for compensation and that generally figures in the negotiation based compensation.	Medium
		• Ministry of Agriculture (MoA)	• Agriculture survey; • Department has tried to streamline the agriculture compensation and bring uniformity for compensating various categories of crop losses; •	• Ministry of Agriculture does the assessment of the crops and plantation itself and should be involved in case crop or plantation related losses are expected in the mining lease area; • Rates for various trees are finalised based on market assessment and should be followed at minimum;	Medium
		• Forestry Development Authority (FDA)	• Responsible for Protection of forests and biodiversity associated with it; • Management of any forestry related issue in the project area, if any; • It is also the responsible agency for the community forestry in some of the areas; • FDA will be the partner to WCL, for any biodiversity conservation activity, it may plan to take up in future.	• The practices of other mining operations should be emulated by the rest of the concessions in Liberia; • Other mining operations have a dedicated separate expert for Biodiversity conservation and has given scholarship to many students to study on biodiversity related issues; • FDA expects the concessions/ companies in the country to support the biodiversity conservation activity.	

S. No.	Stakeholder Group	Stakeholder Details	Brief profile & interaction with Project	Issues discussed & Expectation	Level of Involvement
		• Ministry of Labour	• Management of labour related issues especially employment, working conditions, minimum wages, employment benefits for the workers and staffs engaged in the WCL project • Management of conflict in case of deadlock between management and working class	• The local laws and regulations related to labour should be strictly followed by any business entity and otherwise; • Should there be any gaps in the local laws and regulations ILO guidelines should be followed; • All the labour related conventions to which Liberia is a party, either through ratification or by signing should be complied with.	Medium
		• Ministry of Health and Bomi County Hospital	• Collaboration on provision of health facilities in the project area;	• Strengthening of existing infrastructure and services facility in the county and in the project area; • Bomi county Hospital has infrastructure and equipment requirements which could be considered by WCL; • The increased activity in the project area will also increase risks associated with the spread of the communicable diseases; • Presently the health facilities are free and the health services are accessed by the people; however once the funders move away there is likely to be many issues faced by the health services. These should be appropriately considered by the local project proponent.	Low to Medium
	Culture & Custom	Director of Culture and Custom	• Significance of local culture and customs in the project area;	• It is important to understand local administrative system for management of culture and customs. • Culture and tradition is very strong in Liberia;	Medium
		National Traditional Council	• Management of issues surrounding traditional forest etc. in the project area, if any; • Significance of sacred sites in and around concession areas	• Traditional & sacred sites to be identified, protected and suitably managed in case of land acquisition; • Local traditional leaders should be consulted in resettlement process; • Expectation from WCL to provide financial support for a project regarding identification of traditional forest location and other sacred sites all around the project area.	Medium

S. No.	Stakeholder Group	Stakeholder Details	Brief profile & interaction with Project	Issues discussed & Expectation	Level of Involvement
		• County Inspector – enforces local management regulations • County Cabinet – Heads of Line Ministries	• Main Coordination Platforms for new/upcoming projects to engage with the local population in general • County level administrative issues and land related issues	losses suffered by the people if any; • Compensation and resettlement are separate issues Local employment opportunities will need to be created; • Town chief should be involved in the land ownership identification and establishing entitlement.	
		District (a) • District Commissioner • Township Commissioner	• Supervises and monitors all administrative matters in the district • Responsible for all development management issues, initiation of projects, as need be, coordination with partners • Adjudicates appeal cases from the paramount Chiefs • DC is the Head of the DDC	• Issue of land ownership and displacement related issues in the project area, if any should be taken up with the District commissioner office, should all other efforts at local level fail; • Company should engage with the town chief, paramount chiefs, clan chiefs in resolving local disputes.	High to Medium
		Districts (b) • Paramount Chiefs • Clan Chiefs • General Township	• Paramount Chiefs, through the Clan and Township Chiefs are responsible for law and order under customary law, with ad hoc responsibilities pertaining to welfare within his tribe • Important partnership with project proponent in initiation of development projects	• There is an traditional procedure of community entry in any part of Liberia, and the project proponent should follow the same for any community entry; • After the war people are very cautious and concerned about any kind of development in their area and effective communication should be done through traditional agencies; • Land, ownership, compensation, and traditional forest issues should be tackled through town chiefs, clan chiefs and paramount chiefs, and only when the option fails, then alternate mechanisms should be explored.	High to Medium

Table 28: WCL's Bomi Hills Iron Ore Mining Project Communities and NGOs Stakeholders Registry and Analysis

S. No.	Stakeholder Group	Stakeholder Details	Key issues	Issues discussed & Expectation	Level of Influence	Level of Interest	Level of Involvement	Impact
	Communities	Community in mining areas	• Potential compensation and resettlement related issues; • Health and safety of the community due to mining operations; • Displacement related issues; • Employment avenues for the community	• Payment of the compensation in case of loss of land, house and other assets • Timing and process related to land acquisition and resettlement • Those having private deed land prefer to have cash compensation and self-resettlement. Those living on family/communal/tribal land, are inclined towards option of resettlement by project and expect community development benefits in lieu of their land acquisition ; • Possible influx of the people from other areas in search of employment and the locals loosing on the opportunity of employment; • Health and safety of the community during the transportation of the ore and the related movement of the vehicles	Low	High	Medium to Low	High to Medium
		Women Groups	• Gender concerns. • Living condition; • Displacement and resettlement owing to the project; • Employment opportunities	• Compensation and resettlement details and involvement of the community, in case any displacement happens; • Increased employment opportunity for the men and youth; • Support for vegetable gardens and other agricultural activity; • Welfare and development activity for the community including livelihood, health and education etc. • Improved quality of life of the people because of the surge of the economy in the area.	Low	Low to Medium	Low	High to Medium
		Youth Groups	• Engagement on possible training and capacity building opportunities for the youth once the project	• Employment opportunities for the youth; • Preference to the local population in employment, trainings and capacity building;	Low to Medium	High	Medium	High to Medium

S. No.	Stakeholder Group	Stakeholder Details	Key issues	Issues discussed & Expectation	Level of Influence	Level of Interest	Level of Involvement	Impact
			implementation starts; • Avenues of employment generation and other livelihood opportunities with preference for the locals	• Promotion of youth oriented programmes; • Youth to be involved during negotiations ; • Compensation and resettlement related negotiation, if any, should have representation of the youth too.				
	NGOs and academics	University of Liberia, Anthropology Department	• Impact on land ownership, customs and tribal identities; • Studying project impact on the people in the context of the previous war and development process in Liberia;	• Not much time has passed after the war, and it is therefore suggested that companies should be cautious before venturing into these areas and most importantly work with them to build a relationship on trust. This will ensure that the companies are able to carry on with their work without disturbances. • A lot of study is being concurrently done and there is a lot of discussion going on regarding the land, ownership and community rights and also among the various ethnic groups. • In some of the communities they have clearly marked areas for *Poro* and *Sande* groups and the community is in a position to tell that; however t disclose it to the outsiders, and in some cases not even to the people of other clans. • Some work has been done on the traditional education system in Liberia and which could be referred.	Medium to Low	Medium	Low	Medium to High

S. No.	Stakeholder Group	Stakeholder Details	Key issues	Issues discussed & Expectation	Level of Influence	Level of Interest	Level of Involvement	Impact
				process; ➢ War induced resettlement & rehabilitation of the affected people is being managed by LRRRC. It is being implemented in consonance with Kampala Convention.				
		NGOs involved in developmental activities or working with community in project areas (e.g. Agriculture development)	• Information sharing about development works and coordination; • Engaging on displacement and resettlement related issues, as some of them are working on agriculture promotion in the project area (especially mine)	• The project proponent may consult the NGOs on any kind of activity especially related to displacement and resettlement, as people are being engaged in agriculture and farm development programmes; • Displacement may undermine the efforts of these NGOs; • NGOs may be investing in the developmental activities around the project areas and they need to be aware of any kind of initiatives affecting people in the project area, so that they can adequately prepare.	Medium	Medium	Low	Medium to High

6.4.1 Consultation Findings by Issue

Stakeholder engagement is a key element of the IA process. The purpose of stakeholder engagement is to allow the stakeholders to interact with the project proponent, to express their views and concerns for devising proper mitigation and technical solutions. The Project's consultation program is intended to ensure that stakeholder concerns are considered, addressed and incorporated in the development process, especially during the EIA.

Key findings for Project Area

The Concession area comprise of approximately 30 human settlements most of them are classified as towns. Tubmanburg City is the largest human settlement that fall within Bomi Hills Concession area. About 15 human settlements fall within 1 km radius of the concession area.

- The key issue as observed during the stakeholder consultations in the project mining area in Bomi is as follows: The community and the local representatives informed that the people in this area have been waiting for this project to happen, as the employment opportunities in this area substantially dried up owing to closure of the LMC mine in 1970s. The local administration informed that the water pollution especially due to beneficiation of ore will impact the water quality in the nearby water bodies and hence prevention of the same will be one of the crucial aspects to be targeted at. It is important for the community and the county administration to know, what are the measures that company will take to reduce such impact? The issue of water was discussed previously with LMC when it was in operation.
- The general concern of the villagers is about losing their cash crop.
- The community at Zalakai and Borbor shared their concern that in case of loss of residential structures, or crop and plantation losses, how will the company deal with the issue of resettlement? Project should note that the resettlement of the people is a separate issue apart from the compensation.
- There are some key people who need to be consulted for understanding the various issues related to the project including the land and related issues:
  - Superintendent
  - District commissioner
  - Land Commissioner
  - Paramount Chief- Traditional Chief
  - City Mayor
  - Clan Chief
  - Town Chief
- The Superintendent office at Bomi informed that, any person is free to construct a house in the tribal reserve or any such property. Such property is developed with the permission of the head of the tribal reserve. The cultivation is also done in the tribal reserve with the permission of the head

of the tribal reserve. The land however belongs to the particular head of the tribal reserve. The compensation for the assets and the crops need to be paid to the person who has these assets and crops in possession. The people will welcome the project but such issues need to be addressed by the project before the project progresses. These views were shared in the Zalakai village too.

- The consultations at the Superintendent office including the land inspector suggested that the existing situation in the country after the civil war makes the issue of compensation for the asset loss as well as the resettlement to be looked into by the companies who are responsible for the same. The Government has not laid down clear rules; however the responsibility will vest with the company.
- There are very few people especially in the rural areas with proper deeds document of their property and land registration process; however the community hopes that they will not be displaced without any compensation that the government will recognise their rights, even without the deeds.
- Town Chief is the right person to establish the ownership of the land and to present the correct picture. Any conflict related to the ownership first reaches the town chief and only when the situation cannot be handled at that level people come to higher authorities. In the present set up town chief is the most accessible person and respected by the common people. Land Commissioner does not issue a tribal certificate; however, he is the right person to know the status of the land. Surveyor is responsible for identifying the exact area of the land plot. For settling the land ownership issues in the mine area especially for the purpose of paying compensation, town chief should be consulted.

6. 5 Stakeholder Engagement Plan (SEP)

To fulfil the objectives for stakeholder engagement, the Project is developing a stakeholder engagement plan (SEP) for the Project life-cycle. The SEP shall lay out a process for consultation. This plan will address the mitigation of key concerns of stakeholder groups identified as relevant for the ESIA process as also the overall project and its components. Public consultation and disclosure of information as well as regular monitoring of meetings and grievance will be a part of the SEP. The views of stakeholders shall be recorded through the consultation process.

The SEP will be a live document and will need to incorporate the findings of the stakeholder consultations. At this stage when the scoping for the project is being completed, based on a different types of stakeholder consultations, the SEP has broadened its base and to an extent getting strengthened from the feedback process.

The following Sections describe the stakeholder engagement activities already carried out as well and those that are planned for each of the above-mentioned stages.

6.5.1 Existing Process towards Formulation of SEP

The consultants have led the initial identification of stakeholders, which includes the likely affected/displaced families, Federal/County/ District administration, regional and local government representatives, civil society organizations, artisanal mining, livelihood groups, etc. The consultations with these group of stakeholders will continue to be taken forward, while new range of stakeholders with possible interest in the project, or likely to be impacted will be brought within the ambit of the stakeholder consultations.

Keeping the above-mentioned approach in practice, the project is continuously being updated of the findings of a range of stakeholder consultations done till now. The project itself is also undergoing a range of consultations with the various departments as part of the project design, which though not a part of the impact assessment process, also culminates into strengthening the SEP for the project.

The stakeholder analysis done as a part of ESIA will feed in to the SEP for the project. This will help aligning the engagement strategy with the assessed stakeholder needs, aspirations, concerns and expectations keeping in context their power and influence over the project.

6.5.2 On-going Engagement Activities Post-ESIA: Project Execution

This section provides a brief description of the activities that will be undertaken after the completion of the updating of the ESIA. Today, the term “Stakeholder Engagement” is emerging as a means of describing a broader, more inclusive and continuous process between a company and those potentially impacted that encompasses a range of activities and approaches, and spans the entire life of a project. In fact, engaging with stakeholders from the start enables a proactive cultivation of relationships that can serve as “capital” during challenging times.

6.5.3 On-going Engagement

Stakeholder participation is fundamental to the success of Project implementation, and stakeholder feedback will be a key component in monitoring the success of mitigation measures. On-going engagement after submission of the ESIA will be taken forward within the framework of a Stakeholder Engagement Plan (SEP) being developed by the Project.

6. 6 EIA Disclosure

The Environmental Impact Assessment Procedural Guidelines, released by EPA, 2006 suggests that, *“Once the draft EIA report has been submitted, the EPA will study the report to ensure that it is of standard and addresses the scope of work outlined in the terms of reference. If the report is satisfactory in all respects, the Agency will distribute copies of it to relevant line ministry/agency and other relevant public agencies, and communities for comments. Comments from the public will be received within 30 days of the publication of notice in respect of the report. If deemed appropriate, on consideration of comments from public and* *sector agencies/ministries the EPA may determine the need for a public hearing to be held at a location suitable to persons who are likely to be affected by the project."*

6.6.1 Public Disclosure

It is clear from local regulations that public consultations and public hearing will need to be done through prior information to the public about the project and related impacts at the different stages of the Impact assessment process. Typical process to be followed for public hearing/ consultations is detailed in *Box 6.4.*

Typical process to be followed for public hearing/ consultations

At any of these stages, the independent consultants will follow approach as under:

- Issuing of notification with complete details mentioned in the point below, with publication in newspapers of mass readership and broadcasting on local radios at regular intervals for the complete duration period of six weeks:
- a brief description of the Project;
- a list of venues where the EIA report is on display and available for review (*presently the same process has been adopted for the Notice of intent, and project briefs available with the EPA has been informed to the community*);
- duration of the display period; and
- contact information for comments.

6.6.2 Review by Environmental Assessment Committee

After receiving comments from stakeholders on the report, the EPA will constitute a Committee (Environmental Assessment Committee) to review the report. The committee will comprise technical experts from the Agency and sector agencies /ministries, a representative from the project, and also a representative from the project area. The body will give its opinions to the Agency for consideration.

6.6.3 Issuance of EIA Permit

Following the review of the EIA Report and considering comments received during the review period, the EPA in Pursuance of Section 21 of the EMPL will make a decision on the proposed project regarding the environmental permit for the project.

6. 7 Grievance Response Mechanism

Grievances are any complaints or suggestions about the way a project is being implemented. They may take the form of specific complaints for damages/injury, concerns about routine project activities, or perceived incidents or impacts. Identifying and responding to grievances supports the development of positive relationships between projects and the communities, and other stakeholders, they may affect. Grievance mechanisms therefore provide a formal and on-going avenue for stakeholders to engage with the company, whilst the monitoring of grievances provides signals of any escalating conflicts or disputes.

Grievances can be an indication of growing stakeholder concerns (real and perceived) and can escalate if not identified and resolved. The management of grievances is therefore a vital component of stakeholder management and an important aspect of risk management for a project.

The IFC Performance Standards outline requirements for grievance mechanisms for some projects. Grievance mechanisms should receive and facilitate resolution of the affected communities' concerns and grievances. The IFC states the concerns should be addressed promptly using an understandable and transparent process that is culturally appropriate and readily acceptable to all segments of affected communities, at no cost and without retribution. Mechanisms should be appropriate to the scale of impacts and risks presented by a project.

The grievance response mechanism will be developed by the project as part of this updated EIA report and will also become part of the Stakeholder Engagement Plan.

7. BASELINE STUDIES

7. 1 Introduction

This chapter presents the baseline biophysical and social conditions associated with the Bomi Hills concession area. Each of the topics below will be assessed in detail in the respective Impact Assessment Chapters.

7. 2 Hydrology

7.2.1 Methodology and Approach

A desktop study was done to obtain and gather all relevant information concerning the environment of the Bomi Hills Mine Concession. This included inter alia:

- A digital terrain model (DTM) generated by digitizing contour data of the mine concession area in shapefile (.shp) format with 5m contour intervals;
- Satellite and other layout images supplied by the client;
- Landscape features generated on the DTM from copies of topographical maps supplied by the client;
- Previous studies of related projects and project briefs;
- Feasibility studies as commissioned by the client;
- High resolution photos from the LiDAR survey data and contour plans with 0.5 m contours and survey points obtained during February 2013 and the DTM updated, this provided updated and more accurate information to delineate catchment, chart drainage lines and wetlands and conduct further planning; and
- Standards and guidelines related to the project were studied.

7.2.2 Baseline Conditions

The major basins within Liberia (66 percent of the country) are drained by major rivers, to the northeast and southwest, which include the Mano, St. Paul, Lofa, St. John, Cestos and Cavalla River (Republic of Liberia, 2008). A further 3 percent of Liberia is drained by short coastal watercourses, which include the Po, Du, Timbo Farmington and Sinoe Rivers (Republic of Liberia, 2008).

There is no local evaporation data available, however it is estimated that the annual evaporation per year at Monrovia is 985 mm. The highest evaporation occurs during January (99 mm/month) and the lowest evaporation occurs in July (68 mm/month) and September (68 mm/month) (Golder Associates, 2012).

The three major river systems or catchments which may be affected by the planned Bomi Hills Mine project (mine, road and port) are the Lofa River, the St. Paul River and a short coastal catchment (Po River) *(Map 7-1*). The Bomi Hills Mine will be located in the Lofa River catchment. The Lofa River has an estimated catchment area of 11,000 km^2 of which 9 600 km^2 falls within Liberia. The Lawa and Mahe Rivers are the two main tributaries of the Lofa River. The St. Paul River basin is one of the largest within Liberia with a total catchment of 20,500 km^2 of which 11,500 km^2 falls within Liberia. The Via and Tuma Rivers are the main tributaries of the St. Paul River.

Key Findings

Drainage Patterns

The proposed Bomi Hills Mine project is situated mostly in the Small Mahe River catchment with an area of about 100 km^2. To the east of this catchment is the Mahe River catchment, which is considerably larger and covers an area of about 1 273 km^2. The Mahe and Small Mahe rivers join to the south of the mine site and are a tributary of the Lofa River that drains into the Atlantic Ocean (*Map* 7-2).

A prominent finding was that the drainage patterns changed considerably from the wet to the dry season, which corresponds with the rainfall records. A wet and dry season drainage pattern was therefore developed and is presented in *Map 7-3*, *Map 7-4* and *Map 7-5* respectively.

Catchment Description

Catchment A (Bomi Creek):

Catchment A is located north of Bomi Hills and is approximately 790 Ha in total as assessed from the original 5 m contour data. The catchment has an overall low gradient, except for the portions to the south that includes the north slopes of the Bomi Hills. The catchment has been extensively disturbed by old mining activities, i.e. the old disused pits, mining terraces, waste dumps and tailings areas, as well as bush clearing and cultivation by local communities. The soil of the steeper slope areas will have lower infiltration values, although it is highly weathered which will result in a higher infiltration than solid, unweathered, rock. The waste dumps will have high infiltration rates. The waste dumps are vegetated with trees and shrubs that have established through succession, except for some of the slopes which are very coarse and without any vegetation. The soils of the lower lying areas are predominantly sandy and will have high infiltration rates. Exposed soil areas only occur on the cultivation areas, the old mining terraces and to an extent on the old tailings dumps in the dry season. The rest of the catchment is covered with grass species only on the lower lying old tailings areas and trees on the remainder of the areas. Some vegetation has also established on the old waste dumps and on some of the flatter areas on the old mining terraces. The LiDAR data provided more information and together with additional information gathered during the dry season site visit, the catchment was further divided into smaller sub-catchments as indicated in Table 23. Refer to *Map 7-6* for more information.

Table 29: Sub-catchments of Catchment A (Bomi Creek)

Sub-catchment Number	Area (ha)
Catchment A1	490
Catchment A2	150
Catchment A3	36
Catchment A4	5
Catchment A5	129
TOTAL	**746**

Sub-catchment A1 is drained by the Bomi Creek which predominantly flows west and discharges into the Small Mahe River. Bomi Creek originates in sub-catchment A2 towards the northwest of Bomi Hills. The drainage line is fairly well defined with predominantly sandy beds and banks. The river banks are unstable in many places. Most of the natural vegetation, ie trees and shrubs have been cleared along the river banks. The streambed carries a high sediment load and there is clear evidence of sediments from the old mine activities, especially the tailings material. Bomi Creek was flowing in the dry season, but only in the lower reaches (*Map 7-6*). The proposed open pit will be developed partially in the southern portions of the catchment. The waste rock dump (NWWD) will be situated in total in the lower portions of the catchment.

Sub-catchment A2 was apparently formed by the old mine tailings that blocked the flow of the Bomi Creek and diverted the flow further north. A large wetland or lake was formed that covers a large portion of the catchment. During the wet season this lake drains to the Bomi Creek near the village of Zalakai, but in the dry season there is no visible surface outflow, making this an endoreic catchment periodically. The wetland has a high-water level during the dry season. It is very likely that there is base flow through the very permeable tailings material that was originally (during early mining at Bomi Hills) dumped into Bomi Creek thus diverting and ponding the water. This assumption is supported by the flow that was noted in the lower reaches of Bomi Creek during the dry season. Large cultivation areas are visible on the southern shores of the wetland on the old tailings area. The proposed open pit will be partially within the southern portions of this sub-catchment. It is assumed that this water body will have to be drained to prevent seepage into the open pit that must be dewatered again to reduce the risk of slip failures of the pit sides closest to the wetland. The village of Todemai is just outside this catchment to the northeast. The villages of Jawajeh, Reeves and TK Town are further north.

Sub-catchment A3 was formed by the old mine tailings that blocked the flow of the Bomi Creek and diverted the flow further north. A large wetland or lake was formed that covers a large portion of the catchment. The wetland has a high-water level during the dry season. It is very likely that there is base flow through the very permeable tailings material that formed the division between this and the wetland in Sub-catchment A2. It could not be ascertained that the two wetlands are physically connected during the wet season. This wetland is considered endoreic. Large cultivation areas are visible on the southern shores of the wetland on the old tailings area. The proposed waste dump EWD (19a) will cover a large portion of this catchment. The village of Borbor is on the southern watershed of this catchment.

Sub-catchment A4 was also formed by the old mine tailings and it appears that this area also drained north and northwest previously. Several smaller wetlands were formed by the previous mine activities and one of these by the elevated access road to Borbor. The latter was dry and the other wetlands much smaller during the dry season. It is expected that all these wetlands may be dry towards the end of the dry season. This catchment is endoreic in total. Large cultivation areas are visible over most of the catchment. This catchment is situated between the proposed open pit and waste dump EWD. Very little original vegetation is visible in this catchment.

Sub-catchment A5 is an endoreic catchment formed by the old mine activities. The smaller of the two disused mine pits is situated in this catchment. The filled pit was almost decanting on surface during the wet season and seepage was visible towards the larger disused mine pit, presumably from this pit. The area around the pit is disturbed due to historical mine activities, as well as recent exploration activities.

Catchment B (Unnamed Tributary):

Catchment B is located south of the Bomi Hills and is approximately 212 ha in extent. The catchment is drained by an unnamed tributary of the Small Mahe River and originates towards the center of the project area just south of Bomi Hills and flows west to discharge into the Small Mahe River just after it crossed the old railway track west of the project area. The catchment has a low to moderate gradient, except for the portions to the north that includes the south slopes of the Bomi Hills. The upper portions of the catchment (north and east) have been disturbed by old mining activities, ie mining terraces and waste dumps, as well as bush clearing and cultivation by local people from Tubmanburg. The soils of the steeper slope areas will have lower infiltration values only on small portions on the old mine benches. The waste dumps will have high infiltration rates. The waste dumps are vegetated with trees and shrubs through succession, except for some of the slopes which are very coarse and without any vegetation. The soils of the lower lying areas are predominantly sandy and will have high infiltration rates. Exposed soil areas only occur on the cultivation areas and the old mining terraces. The rest of the catchment is covered with trees and shrubs, while the lower portions of the catchment towards the old railway track to the west seems to have natural vegetation, but definitely a higher density of trees. Trees and shrubs have also established on the old waste dumps and on some of the flatter areas on the old mining terraces. There was a large wetland visible during the wet season. In the dry season there was still a wetland visible next to the old railway track with a small stream flowing in the lower reaches of the drainage line. The upper reaches were dry enough to allow cultivation. The nearest village is on the western side of the Small Mahe River where large cultivation areas were visible, so it is unlikely that they utilize this water source. People from Tubmanburg cultivate the fields.

Catchment C (Weasain watercourse):

Catchment C is located south and to the east of the Bomi Hills and is approximately 1 900 Ha in total. The town of Tubmanburg is located in this catchment. The catchment has been extensively disturbed through bush clearing and cultivation by local communities, habitations and to a lesser extent old mining activities, i.e. mining terraces and some waste dumps, as well as foundations of old mine buildings. The soil of the steeper slope areas will have lower infiltration values, although due to the highly weathered state of the base rock there will be higher infiltration than expected for unweathered material. The waste dumps will have high infiltration rates, although these are the minority of the area. The runoff from the catchment in general will be more intense due to the low infiltration of roof, road and other compacted areas, as well as the larger portion of bare areas. The catchment has been divided in four sub-catchments as indicated in Table 24.

Table 30: Sub-catchments of Catchment C (Weasain watercourse)

Sub-catchment Number	Area (ha)
Catchment C1	729
Catchment C2	665
Catchment C3	462
Catchment C4	44
TOTAL	**1,900**

Sub-catchment C1 is the upper portion of the Weasain watercourse. The Weasain watercourse originates east of the Bomi Hills, flows south and then turns west through the town of Tubmanburg to the Small Mahe River. In the upper reaches along the main gravel road to Bea Mountain there are three distinct permanent wetlands. The village of Fanseh is near the uppermost wetland. The levels of the wetlands clearly dropped during the dry season, but they still seem permanently wet and a prominent resource to surrounding villages. In the lower portions of the sub-catchment where the Weasain watercourse flows westwards, there are also up to six large wetland areas. Four of the wetlands are still visibly wet in the dry season, although the levels are much lower. In this portion the floodplains are wide and used to a great extend for cultivation during the dry season. Sub-catchment C1 has a moderate gradient in the northern or higher portions and a low gradient in the lower portions. The northern reach of the drainage line is well defined with rocks or boulders visible on the surface in many places. The river banks are stable with some natural vegetation up to the flow area, although it has been removed to some extent. More natural vegetation is visible in the upper portions of the catchment, while the lower portions have been cleared for cultivation and habitations. The villages of Small Borbor and Cooper are situated in the lower portions of the catchment next to Tubmanburg. The mine plan proposes a Tailings Storage Facility 1 (28a) in the valley of the south flowing reach of the Weasain watercourse to the east of the proposed plant area. TSF 1 will block the natural flow of the Weasain watercourse and several tributaries. TSF 3 will be situated in another tributary valley from the east and almost fill it in total. Sub-catchment C1 will also be crossed by the water supply pipeline from the Mahe River and the tailings pipeline and return water lines from the TSFs. The villages of Barkley, Gorbla, Banana, Wilson and Coffee Suah are situated to the east of the Weasain watercourse. They are all to the east, northeast and southeast of the proposed tailings facilities.

Sub-catchment C2 is the middle reach of the Weasain watercourse flowing west. This portion of the catchment is disturbed to a great extent with many bare and compacted areas. Runoff will be high, although it may be attenuated to some extent by the many wetlands and wide floodplains along the Weasain watercourse. The sub-catchment has a low gradient along the river and a moderate gradient to the north portion that borders with the Bomi Hills in the south. There are many wetlands in this portion of the catchment, although some of them were formed by the historical mining activities, ie excavations and spoil dumps that prevented free drainage of the area. The floodplains along the Weasain watercourse form large wetlands in the wet season. During the dry season most of the floodplains were dry and were being cultivated by the local communities. There were a number of wetlands still visible in the dry season, eg near the new guesthouse and northeast of the FTI office. Despite this the flow of the Weasain watercourse was minimal in this section. A large portion of the town of Tubmanburg is located in the southern portion of this sub-catchment. Most of the major plant infrastructure is proposed in the northern portion of this sub-catchment, including the beneficiation plant, HEMM workshop, power plant, repair shop, plant water system, ancillary services building and the contractor housing area.

Sub-catchment C3 is the lower portion of the Weasain watercourse catchment. The Weasain watercourse flows west to the confluence with the Small Mahe River just upstream from the village of Larmin. Most of the sub-catchment has a low gradient and is disturbed with bare and compacted areas, except for the westernmost or lowest section. In this section more natural vegetation is visible, although cleared areas and cultivation are prevalent along the river on the floodplains. Many large wetlands are present in the lower section of the area in the wet season. Flow in the river reduces substantially in the dry season. The main facilities that will be situated in this area will be truck parking areas and township area.

Sub-catchment C4 could also be seen as a portion of sub-catchment C1. It was also formed by the old mine tailings and it appears that this area also drained north and northwest previously. Several smaller wetlands were formed by the previous mine activities and one of these by the elevated access road to Borbor. The latter was dry and the other wetlands much smaller during the dry season. It is expected that all these wetlands may be dry towards the end of the dry season. This catchment is endoreic in total. Large cultivation areas are visible over most of the catchment. This catchment is situated between the proposed open pit and waste dump EWD. Very little original vegetation is visible in this catchment. This sub-catchment can probably be drained to sub-catchment C1 if needed.

Catchment D (Unnamed):

Catchment D is similar in condition to the lower portions of Sub-catchment C3 and covers 250 Ha. It also covers part of the Tubmanburg town in the upper reaches. Major facilities that are situated in this catchment are the Bomi Hospital and the old airstrip. There are large cultivation areas on the floodplains next to the drainage line. There is still a good tree cover to the western and south-western portions of the area, although already disturbed and not natural any more. The overall gradient of the catchment is low. No mine activities planned in this catchment, stream in the lowest or western portion of the catchment, as well as the geological shed (Bomi Wood) near the boundary of the northern watershed of the catchment.

Catchment E (Unnamed):

Catchment E (532 Ha) is the southernmost catchment that will be affected by the mining activities, but to a lesser extent. The planned mining activities for this area is the alternative bypass route for ore trucks and the old geological office and guest house that the WCL exploration team used. A portion of the Tubmanburg town is situated towards the eastern portions of the area. Apart from the town and cultivated areas that are already cleared of trees, there is also the old golf course with no tree cover. The central, western and southern portions of the area show a relatively good tree cover. The overall gradient of the catchment area is low, with isolated moderately hilly areas to the west and south.

Catchment F (Small Mahe River):

Catchment F1 (6882Ha) is the remainder of the catchment of the Small Mahe River north and east of the project area that was not initially planned to be impacted by the mining activities directly. All the other mining activities and catchments as described above fall within the Small Mahe River catchment. The above catchments drain into the Small Mahe River mainly to the west of the project area. The latest mine planning indicates that there is a need to have an additional waste dump. This waste dump, EWD, is therefore sited to the northeast of the pit in the upper reaches or tributaries of the Small Mahe River in Sub-catchment F2 (3486Ha). The gradient of the catchment slopes where the EWD will be constructed are considered moderate and the area has a reasonable vegetation cover. Some bush clearing and cultivated areas are visible. The villages of Todemai, Jawajeh, Reeves and TK Town are situated downstream of the waste dump position.

Catchment G (Mahe River):

The adjacent catchment to the east of the project site falls within the larger Mahe River catchment, which is about 127,631 Ha (1 273 km^2) in extent. The Mahe River is a major river in the area. The concession area across the Mahe River to the east falls within an area with higher ecological value as indicated by other specialists. Two activities are planned in this catchment and part of the concession area at this stage, namely the abstraction point and pump station for process water from the Mahe River and the construction of a TSF in a valley to the east of the Weasain watercourse. There was a historical abstraction point on the banks of the Mahe River and it seems to still provide a good calm water area. The TSF area will drain to the east to the Mahe River which increases the project area of influence significantly.

Field Measurements and Observations

Flow Measurements (Local River profiles)

The measurement of stream profiles and flow velocity, in combination with general field observations was used to describe seven river sections within the Bomi Hills Mine Concession. The seven measuring points selected are within rivers which may be affected by the project. Accessibility was also taken into consideration in selecting the location of the measuring points.

A description of the monitoring points is presented in Table 25. The seven monitoring points consist of the following:

Table 31: Description of measuring points

Point	Stream	Coordinates		Flow direction	Flow area at section (m2)		Flow velocity (m/s)		Flow rate (m3/s)		River bed characteristics:	Banks characteristics
		N (°)	W (°)		Dry season	Wet season	Dry season	Wet season	Dry season	Wet season		
1	Stream flowing north from project site towards Small Mahe River; before village of Jawajeh	6.92	10.81	North	0.03	1.8	0.22	0.8	0.01	1.44	Well defined flow area. Mostly coarse gravel with isolated boulders	Dense vegetation
2	Bomi Creek, discharge point from project area	6.90	10.85	West	0.43	2.5	0.22	1.32	0.1	3.29	Well defined flow area. Mostly sand particles	Grassland covering /cultivated areas. Clear evidence of historical iron ore tailings (sediment) on banks & riverbed
3	Mahe River, upstream of concession area	6.94	10.76	South	8.4	77	0.4		3.36	48.12	Well defined flow area. Mostly coarse gravel with isolated boulders	Dense vegetation /forest
4	Mahe River just upstream of proposed abstraction point	6.92	10.76	East	3.2 + 0.04	21.3 + 5.8	1.12	2.37	3.63	64.28	Well defined flow area. Mostly coarse gravel with	Dense vegetation

											isolated boulders	
5	Weasain water course; discharge point from project area	6.88	10.85	North	0.3	6	0.6	0.6	0.18	16.45	Well defined flow area. Mostly coarse gravel with isolated boulders	Grassland mostly on upstream banks. Forest at measuring point
6	Small Mahe River, downstream from project area	6.87	10.85	South	5.8	42.4	0.1		0.58		Well defined flow area. Mostly sand particles and clay	Dense vegetation with sugarcane plantation. Clear evidence of historical iron ore tailings (sediment) on banks & riverbed
7	Small Mahe River, upstream of project area	6.91	10.85	West	3.3	32	0.36		0.12	17.62	Well defined flow area. Mostly coarse gravel with isolated boulders	Dense vegetation

The following must be noted for the interpretation and further use of the data presented above:

* The wet season flow velocities and flow rates in Table 25 above are a very rough estimate and only indicative of relative stream sizes. Flow areas were estimated from evident high-water marks that could be observed on the river banks. Therefore, it may be closer to extreme runoff events and not the "normal" wet flow regime. The w only be measured in isolated cases. For the wet flow rate estimates the river flow parameters were calculated for Mannings formula for open channel flow and used to estimate flow rates during the wet season.
* The parameters for Mannings formula are in themselves very difficult to measure either on site or from the latest survey data. Typical drainage line slopes are in some cases difficult to measure due to the very undulating nature of the water courses.
* The cross sections for the river stretches were extracted from the latest survey data. From this and field observations it is clear that the river / stream profiles are in most cases very varied. This further lead to the large variance in shape of the river / stream profile between the wet and dry season. For this reason, the estimated wet season flows are only indicative at that measuring point.
* There was no survey data for the Mahe River measuring point upstream of the project area, because it is just outside the concession area. This introduces a further unknown factor in the wet season estimate.

7.2.3 Existing Water Management Structures

The following information was gathered with regard to existing culvert structures:

- The culvert where the Small Mahe River crosses the old railway track: four corrugated iron pipe culverts; diameter 4.3 m; some of the culverts already show signs of severe corrosion in the bottom with undermining of bedding material;
- The culvert where the Bomi Creek crosses the old railway track: one corrugated iron pipe culvert; diameter 4.3 m; and
- The culvert where the Weasain watercourse crosses the old railway track: two corrugated iron pipe culverts; diameter 4.3 m.

7.2.4 General findings

The following general observations were made in and around the Bomi Hill Mine concession area.

Disturbed wetlands and river banks

Several wetlands were found to be disturbed by mining, economic or agricultural activities. The disturbance of the wetlands is more evident during the dry season when the water has retracted. The latest impacts were noted to the north east of the historical mining area and the proposed EWD.

Artisanal Mining

Several sand mining operations were observed along the Mahe River (Figure 11). Sand mining operations cause several environmental problems, e.g. bank instability which results in an increase of erosion and therefore sedimentation. Artisanal gold or diamond mining was also visible in the upper reaches of the Weasain watercourse near the town of Barkley.

Figure 12: Artisanal sand mining

7.2.5 *Project Area of Influence (AOI)*

During the delineation of the surface water area of influence, the following was considered (*Map 7-8*):

- The Bomi Hills Mine Concession area as provided on the latest mine layout plans including the possible abstraction from the Mahe River;
- The footprint of the mine infrastructure as indicated in the Feasibility Study Report and on the mine layout plans;
- The mine activities e.g. open pit, waste storage facilities and related activities like dewatering of seepage into pit, diversion of clean storm water around activities;
- The drainage patterns of the study area - the drainage from the mine concession area is predominantly towards the southwest, drainage could further be affected by the following:
  - Water bodies (wetlands & flood plains) that plays a large role in attenuating floods and reducing flow peaks and ensuring base flow in dry conditions;
  - Roads; and
  - Surface disturbances such as mining and agricultural operations.

Based on the above the AOI was delineated as indicated in *Map 7-8*. The AOI includes and extends up to:

- ✓ The sub-catchments as were delineated and discussed earlier, i.e. Catchments A (Bomi Creek), B, C (Weasain watercourse), D and the portion of Catchment E where there are new activities planned;
- ✓ The portion of Catchment F2 (Small Mahe River) where the waste dump EWD is proposed and the streams immediately downstream;
- ✓ The upper tributary of the Small Mahe River in Catchment F2 downstream up to the confluence of the Small Mahe River based on the possible migration of impacts downstream;
- ✓ The riverbanks and a strip along the Small Mahe River from the Bomi Creek confluence down to the confluence with the Mahe River.; and
- ✓ The portion of Catchment G (Mahe River) where the TSF 3 is proposed to be located and the streams downstream of the road and pipeline to the intake pumphouse. It also includes a strip along the Mahe River down to the confluence with the Small Mahe River.

As indicated earlier the Mahe River drains into the Lofa River and the Lofa River discharges into the Atlantic Ocean. Impacts are not expected beyond the confluence of the Mahe and Small Mahe River due to the high rainfall and runoff, dense river banks downstream, many low-lying areas or wetlands and the resultant attenuation of floods.

- The western flange of the Bomi Hill Mine has been blocked as proposed tailings storage – currently this dam wall has locked the water with a overflow trench on the East West of the wall, this allow the water flow to continue to the small Mahe River. This water locked in the valley is to be used for the commissioning of the washing plant and concentrator plant, this will gradually be replaced by the make up water abstraction from the Mahe River.

Transportation of iron ore

- **For Phase 1 – 4MTPA @Bomi – Existing EPA**
  - We plan to build a 3MTPA Concentrator plant at Bomi Mine, for which a contract has been awarded.
  - We plan to build a jetty at a suitable location and a dedicated road from Bomi Mine to the new jetty to transport and export 4 MTPA products (3MTPA Concentrate + 1 MTPA Occasional DSO).
  - Also, dedicated roads are planned from the Bea and Mano mines to the new jetty, which can transport the product from the mines to the jetty for export. The estimated jetty capacity is 7MTPA, catering to all three mines. A consultant from India is busy with technical work and engineering for this work.

  - Western Cluster currently also explore the option of partnering with Bao Chico to use their new jetty, which is under construction. Thorough due diligence is needed to evaluate this option. Western Cluster limited decide to proceed with this option, establishment of a dedicated road from Bomi Mine to the Bao Chico jetty. This road will have a common section from Bomi to Klay junction (25km) with the above road option to our new jetty. So, an additional 8 to 10km of road will be required in this option to connect Klay junction to Bao Chico jetty.

- **Phase 2 – 10MTPA @Bomi**
  - The 10MTPA capacity is based on building two additional concentrator plants at Bomi Mine.
  - For this, Western Cluster plan to build a environmental friendly dedicated slurry pipeline with a 10MTPA capacity from Bomi Mine to Monrovia port and upgrade the Monrovia port to increase its capacity to 10MTPA.
  - Currently, a technical feasibility and engineering for the slurry pipeline with a USA consultant and the Monrovia port upgrade with a German consultant. The outcome of the exercise will be available by March 2025.

7.2.6 *Uncertainties and Limitations*

- ✓ The copy of the topographical map of the area with 10-20 m contour interval that was available was not always clear and the delineation of catchment boundaries or watersheds outside the concession areas is approximated.
- ✓ Although the “Line Mapping” data was use the following was found:
  - Mapping of the drainage lines is not accurate; and
  - The drainage lines and wetlands had to be updated using the LiDAR data (ie contour and survey point data), the aerial imagery and the observations during the site visits. The delineated drainage lines as presented in this report and the accompanying layout maps should be used for further reference and studies.
- The following assumptions were made and limitations found concerning flow monitoring and the calculation of river / stream profiles:
- The wet season flow velocities and flow rates as in Table 25 are a very rough estimate and only indicative of relative stream sizes. Flow areas were estimated from evident high-water marks that could be observed on the river banks; therefore, it may be closer to extreme runoff events and not the “normal” wet flow regime. The wet season flow velocities could only be measured in isolated cases. For the wet flow rate estimates the river / stream flow parameters were calculated for open channel flow and used to estimate flow rates during the wet season.

- The parameters for open channel flow formulas are very difficult to measure either on site or from the latest survey data. Typical drainage line slopes are in some cases difficult to measure due to the very undulating nature of the water courses.
- The cross sections for the river stretches were extracted from the latest survey data. From this and field observations it is clear that the river profiles are in most cases very varied. This further lead to the large variance in shape of the river profile between the wet and dry season. For this reason, the estimated wet season flows are only indicative at that measuring point.
- There was no survey data for the Mahe River measuring point upstream of the project area, because it is just outside the concession area. This introduces a further unknown factor in the wet season estimate.

7. 3 Hydrogeology

This Section details the Hydrogeological Baseline Conditions for the proposed Bomi Hills Mine. The Water Management Plan for the project, based on the potential groundwater impacts identified, can be found in Annex 21-C.

7.3.1 Limitations

General limitations associated with the hydrogeological study are:

- Limited hydrogeological information exists for the site and regional area.
- The understanding and quantification of the hydrogeology of the study area was formed largely by the results of drilling and testing of 11 hydrogeological test boreholes which were done in late 2012 and early 2013. The depth of the boreholes was limited to 100 m.

7.3.2 General Physiographical and Geological Description

Topography

The area is generally flat with gently rolling hills. The iron ore deposits form prominent topographical features with the Bomi Hill crest attaining an elevation of 222 m amsl and the surrounding area about 60 m amsl.

Geology

Liberia forms part of the West African Shield, a rock formation ranging between 2.7 and 3.4 billion years old and comprising mostly of granite, schist and gneiss. This shield has been intensely folded and faulted and is interspersed with iron bearing formations. Remnants of slightly younger supracrustal rocks of sedimentary and volcanic origin are aligned predominantly in a NE-SW direction.

Wahl (2007)[2] describes the regional basement geology as comprising biotite-rich granitic gneiss, hornblende-bearing granodiorite to diorite gneiss and syenite (Map 7-9). The ore zone, surrounded by basement rock, has a general ENE - WSW trend over a length of some 16 km. It consists of: Proterozoic banded iron formations (BIF), containing quartz and the iron oxide minerals hematite and magnetite. Weathering and replacement products such as martite and limonite are also present. The Upper BIF is located above a chlorite schist horizon and is a banded rock consisting of alternating layers of iron oxides (magnetite and hematite) and quartz. The upper 30 m to 60 m is weathered, soft, has a medium-grade iron ore content (48 percent to 50 percent), medium to coarse grained and capped by a hard re-crystallized lateritic cover. The Lower BIF contains a high-grade ore (< 65 percent Fe) and lies below the chlorite schist horizon and above the basement granite gneiss. At the proposed mine, rock generally dips to the north. Amphibolite zones were logged.

Geological structures are difficult to map because of the thick weathered zone, the dense vegetation characteristic of the area and the deposition of tailings across the site. Two NW –SE trending lineaments were identified from the aerial magnetic data, just west of the proposed open pit mine. Regionally a number of NW –SE diabase dykes of Precambrian/Jurasssic age were mapped in the vicinity of the proposed mine by Wahl (2007). Diabase dykes of Jurassic age have also been identified in the exploration drill cores, with thicknesses ranging from 1 m to 57 m. Pegmatite and quartz veins were also observed in the drill cores, with thickness ranging from 0.5 m to as thick as 20 m. Refer to *Map 7-9* for the location of geological structures.

Geophysical data and observations from the drill core provide sufficient evidence of thrust and other faults within the area. Faults and fractures may have provided the pathway for late stage fluid ingresses and caused hydrothermal alteration of some units.

The land surface has been exposed to intense weathering, resulting in thick lateritic saprolite and residual soil cover. This zone can be up to 20 m thick.

7.3.3 Methodology

Desktop Study

A desktop study was undertaken to source existing hydrogeological information from the client, the internet and published literature. This task was moderately successful. Information presented by Burnet and Romanenko (2010)[3] and Golder Associates (2012a)[4] were particularly helpful.

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[2] Wahl, RR (2007) Geological, geophysical, and mineral localities map of Liberia –a digital compilation; United States Geological Survey, Denver

[3] Burnet, B and Romanenko, T (2010) Western Range DSO Iron Ore Project - Volume 3 Part 3.1 - Hydrogeological and groundwater baseline conditions in relation to Phase I DSO; Final report prepared for ArcelorMittal Liberia Limited, URS / Scott Wilson in asso

[4] Golder Associates (2012a) New Liberty Gold Mine project ESIA –Hydrogeological assessment; Report GHA1044 submitted to Aureus Mining Inc., Golder Associates.

Field Visit and Hydro census

A hydro census was undertaken within 5 km of the proposed open pit mine to collect hydrogeological information and identify groundwater users.

Hydro census data is summarized in Table 26. The locality of boreholes identified during the hydro census is shown in Map 7-10.

A total of 46 shallow water supply wells and boreholes (35 localities) were identified, mostly equipped with hand pumps. water level data was obtained for 46 Bomi Hills exploration boreholes from WCL's Exploration Department.

Only a few depths to groundwater level measurements could be made because of the sealed nature of the hand pumps. Water samples were collected from 9 of the boreholes visited and submitted to the Environmental Laboratory Services for analysis. The results of analyses are presented in Annex 7-A.

Development of a Preliminary Conceptual Model

Based on the limited information gleaned from existing reports and the hydro census and observations made during the field visit, a preliminary conceptual model of the Bomi Hills concession areas was compiled.

Table 32: Hydrocensus Data Collected

Borehole Number	Locality Description	Coordinates (UTM 29N, WGS84) Latitude	Longitude	Elevation (mamsl)	Borehole Depth (m)	Borehole Type (mm)	Equipment	Use	Yield (L/s)	Water Level (mbs)	EC (mS/m)	TDS (mg/l)	pH	Sample Taken	Contact Persons/ Owner
Bomi Hills 01	Kamana Town/Village	295133	762427	70	-	Hand Dug	Hand Pump	Municipal - Domestic	Low yielding, all year use		13	60	6.1	Yes	John Kue
Bomi Hills 02	Tapolin Village	305195	767929	76	9.6	Hand Dug	Hand Pump	Municipal - Domestic	Low yielding, runs dry	5.3	19	90	6.2	Yes	Flomo Saysay
Bomi Hills 05	Zalakai Villiage	298797	763986	68	-	Hand Dug	Hand Pump	Municipal - Domestic	Low yielding, all year use		14	120	5.4	Yes	-
Bomi Hills 06	Department of Agriculture	298161	761688	50	10.31	Hand Dug	Well with bucket-rope	Washing and cleaning	Low yielding, all year use	6.54	25	130	6.3	Yes	Christopher D. Momo
Bomi Hills 07	RRRE	298003	761359	34	-	Hand Dug	Well with bucket-rope	Washing and cleaning	Low yielding, all year use	7.29	16	100	5.9	Yes	Augustus Momo
Bomi Hills 08	Tubmanburg Village	300203	763400	38	10	-	Hand Pump	Municipal - Domestic	Low yielding, all year use	4.3	21	90	5.2	Yes	Thomas Guy
Bomi Hills 09	Be Mawi Village	296241	764582	52	10	-	Hand Pump	Municipal - Domestic	Low yielding, all year use	6	30	150	6.8	Yes	Jaliah Tufah
BCC01	Bomi Community College	297399	760266	54	9.8	Hand Dug	Well with bucket-rope	Municipal - Domestic	Low yielding, all year use	6.16	22	110	6.5	No	Myero Nyanway
SV01	Saube Village	294890	762671	70	-	Hand Dug	Hand Pump	Municipal - Domestic	Low yielding, runs dry		8	40	5.1	No	Charles Koha

Borehole Number	Locality Description	Coordinates (UTM 29N, WGS84) Latitude	Longitude	Elevation (mamsl)	Borehole Depth (m)	Borehole Type (mm)	Equipment	Use	Yield (L/s)	Water Level (mbs)	EC (mS/m)	TDS (mg/l)	pH	Sample Taken	Contact Persons/ Owner
CV01	Coffesueh Village	294663	762835	65	10.6	Borehole	Hand Pump	Municipal - Domestic	Low yielding, all year use	7.3	8	40	5.4	No	Veroney Goll
BJH01	Bomi Junior High	298078	760521	69	-	-	Hand Pump x 2	Municipal - Domestic	Low yielding, all year use		15	170	6.2	No	Cecilia Johnson
SV02	Stewl Village/camp	297926	760497	67	-	-	Hand Pump	Municipal - Domestic	Low yielding, runs dry		7	40	5.4	No	Satta Varney
GC01	Gbalasweh Community	297976	760255	67	9.9	Hand Dug	Well with bucket-rope	Municipal - Domestic	Low yielding, runs dry	6.65	18	90	4.7	No	Bendu Harris
UPS01	United Pentacostal School	298370	760302	71	-	Hand Dug	Hand Pump	Municipal - Domestic	Low yielding, runs dry		7	30	5.0	No	Varney K. Kpenkel
GT01	Gballasuah Town/village	298461	760000	75	-	Hand Dug	Hand Pump	Municipal - Domestic	Low yielding, runs dry		40	200	5.4	No	Sekou Kemokai
KV01	Kapatha Village	299287	759959	64	-	Hand Dug	Hand Pump	Municipal - Domestic	Low yielding, runs dry		8	40	5.5	No	-
VTV01	Vartam Two Village	298938	759950	56	-	Hand Dug	Hand Pump	Municipal - Domestic	Low yielding, all year use		55	280	4.6	No	Mary Sackey
VC01	Vallet Centre	298986	760116	52	-	Hand Dug	Hand Pump x 2	Municipal - Domestic	Low yielding, runs dry		17	80	5.3	No	William Karpu
KCNR01	Kollahung Community - New Road	299293	761257	59	8	Hand Dug	Hand Pump	Municipal - Domestic	Low yielding, all year use	5.3	7	30	5.1	No	Bernita Phelps
WCLG01	WCL Guesthouse	299688	761585	55	-	Hand Dug	Hand Pump	Municipal - Domestic	Low yielding, all year		8	40	5.9	No	WCL

Borehole Number	Locality Description	Coordinates (UTM 29N, WGS84) Latitude	Longitude	Elevation (mamsl)	Borehole Depth (m)	Borehole Type (mm)	Equipment	Use	Yield (L/s)	Water Level (mbs)	EC (mS/m)	TDS (mg/l)	pH	Sample Taken	Contact Persons/ Owner
DY01	Dukle Yard	299888	761373	56	12	6" Borehole	0.45Kw pump	Municipal - Domestic	Low yielding, all year use	4.14	5	20	6.0	No	Sekeh Kolleg
PY01	Prison Yard	300043	761613	64	-	-	-	Municipal - Domestic	Unknown				-	No	-
SV01	Samuel Village	305125	767823	50	-	Hand Dug	Hand Pump x 3	Municipal - Domestic	Low yielding, runs dry		8	40	5.1	No	Anny Yesee
YTMC01	Yomo Town Community Clinic	305016	768303	82	-	Hand Dug	Hand Pump x 4	Municipal - Domestic	Low yielding, all year use		7	40	5.4	No	Yeather Massaly
GV01	Gamala Village	299011	759442	69	11.2	Hand Dug	Hand Pump	Municipal - Domestic	Low yielding, runs dry	8.1	17	80	5.1	No	Marknay Ducle
KC01	Kondeh Community 01	299014	759321	32	10.6	Hand Dug	Hand Pump	Municipal - Domestic	Unknown	6	11	60	4.9	No	-
KC02	Kondeh Community 02	299129	758902	78	13.3	Hand Dug	Hand Pump	Municipal - Domestic	Low yielding, all year use	3.3	18	90	4.7	No	-
WC01	William Community 01	299034	758023	63	-	Hand Dug	Hand Pump x 4	Municipal - Domestic	Low yielding, runs dry		7	30	5.5	No	Joseph Sengbah
WC02	William Community 02	298969	757869	69	-	Hand Dug	Hand Pump	Municipal - Domestic	Low yielding, runs dry		7	40	5.7	No	Joseph Sengbah
WC03	William Community 03	298971	757789	70	9.3	Hand Dug	Hand Pump	Municipal - Domestic	Low yielding, runs dry	5.6	8	40	5.9	No	Joseph Sengbah
WC04	William Community 04	299050	757748	71	11.3	Hand Dug	Hand Pump	Municipal - Domestic	Low yielding, runs dry	7	5	30	5.7	No	Joseph Sengbah
ORS01	Oscar Romero School - Marys Meals	299468	758803	56	-	Hand Dug	Hand Pump x 2	Municipal - Domestic	Low yielding, runs dry		14	70	6.2	No	Martin Lissa

Borehole Number	Locality Description	Coordinates (UTM 29N, WGS84)		Elevation (mamsl)	Borehole Depth (m)	Borehole Type (mm)	Equipment	Use	Yield (L/s)	Water Level (mbs)	EC (mS/m)	TDS (mg/l)	pH	Sample Taken	Contact Persons/ Owner
		Latitude	Longitude												
TA01	Tubman Avenue 01	298721	759269	63	-	Hand Dug	Hand Pump	Municipal - Domestic	Low yielding, all year use		9	40	5.6	No	Edwin Foley Migill
TA02	Tubman Avenue 02	298678	759325	64	8.6	Hand Dug	Hand Pump	Municipal - Domestic	Low yielding, all year use	5.5	6	30	5.2	No	Hawa Nien
CE01	Coles Estate	298353	759655	54	6.6	Hand Dug	Hand Pump	Municipal - Domestic	Low yielding, runs dry	5	8	40	5.0	No	Famata Malbu
Bomi Hills 03	Bomi Hills Mine	297023	763295	69	0.9	Exploration hole	-	Ore Exploration	-	>0	44	240	6.5	Yes	WCL
Bomi Hills 04	Bomi Hills Mine	296651	762941	63	100	Exploration hole	-	Ore Exploration	-	11.0	30	90	5.6	Yes	WCL
X 04	Bomi Hills Mine	298391	762967	100	29.47	Exploration hole	-	Ore Exploration	-	*28**	-	-	-	No	WCL
X 09	Bomi Hills Mine	298000	763113	72	3.91	Exploration hole	-	Ore Exploration	-	*3**	-	-	-	No	WCL
X 17	Bomi Hills Mine	297065	763113	100	22.71	Exploration hole	-	Ore Exploration	-	*22**	-	-	-	No	WCL
X 18	Bomi Hills Mine	297065	763113	100	22.71	Exploration hole	-	Ore Exploration	-	*22**	-	-	-	No	WCL
X 22	Bomi Hills Mine	297066	763137	87	16.92	Exploration hole	-	Ore Exploration	-	11.33	10	80	5.7	No	WCL
X 30	Bomi Hills Mine	299396	763107	130	10.31	Exploration hole	-	Ore Exploration	-	*8**	-	-	-	No	WCL
X 31	Bomi Hills Mine	299512	763702	109	49	Exploration hole	-	Ore Exploration	-	*9**	22	90	6.0	No	WCL
X 32	Bomi Hills Mine	299513	763249	108	11	Exploration hole	-	Ore Exploration	-	*10**	-	-	-	No	WCL

Borehole Number	Locality Description	Coordinates (UTM 29N, WGS84) Latitude	Longitude	Elevation (mamsl)	Borehole Depth (m)	Borehole Type (mm)	Equipment	Use	Yield (L/s)	Water Level (mbs)	EC (mS/m)	TDS (mg/l)	pH	Sample Taken	Contact Persons/ Owner
X 33	Bomi Hills Mine	299506	763276	87	29.45	Exploration hole	-	Ore Exploration	-	9*	-	-	-	No	WCL
X 39	Bomi Hills Mine	299423	763453	32	100	Exploration hole	-	Ore Exploration	-	4.27	33	140	6.6	No	WCL
X 40	Bomi Hills Mine	299398	763502	38	12.4	Exploration hole	-	Ore Exploration	-	6*	-	-	-	No	WCL
X 41	Bomi Hills Mine	299240	763576	45	100	Exploration hole	-	Ore Exploration	-	0.1	25	130	6.8	No	WCL
X 43	Bomi Hills Mine	297105	763007	104	22.41	Exploration hole	-	Ore Exploration	-	17.62	29	110	6.4	No	WCL
X 44	Bomi Hills Mine	297200	763302	74	100	Exploration hole	-	Ore Exploration	-	2.64	35	130	6.5	No	WCL

Borehole information is presented in Table 27. Site information collected includes daily drilling records, lithology, depth of groundwater intersection (water-strike), blow-out yields and borehole construction.

Table 33: Information pertaining to the TCE Water Supply and Hydrogeological Test Boreholes Drilled during this Project

Borehole No.	Coordinates (UTM 29N, WGS84)		Ground Elevation (mamsl)	Borehole Depth (mbs)	Depth of Water Level (mbs)	EC (mS/m)	Water-strike depth (m)	Blow Yield (L/s)
	East	North						
B01 (H01)	298016	763102	72	101	3.75	10	10	1.5
B02	297617	762977	80	87	5.87	16	10, 45	1.1
B03	297284	764170	73	101	7.26	16	12, 25	2.5
B05	299181	763395	90	14	6.67	16	-	2.6
B06	299401	763506	87	101	5.37	12	22, 67	0.7
B07	299946	762721	71	101	5.40	15	12, 47	1.4
B08	298314	761796	62	35	3.01	20	21, 36	4.4
B09	298786	761006	58	100	27.46	-	-	<0.01
B11a	297095	762857	95	100	4.70	-	35	<0.01
B11b	287057	762908	95	100	17.69	14	65	0.3
B14	298127	763963	76	101	25.71	13	8, 16 ,36, 67	0.4
H02	298579	762924	114	101	3.75	18	20, 27	1.1
H03	298657	762551	119	101	5.87	-	25	<0.01

Seven (7) groundwater quality samples were taken during the drilling and testing phase of the project. The samples were taken directly before the end of pumping during the constant discharge tests. Samples were preserved and shipped to the lab for analysis. The results of the analyses are included in *Annex 7-A*.

Existing Pit Lake Water Quality

A bathometric survey was conducted in 2013 to survey the existing pit lake depth and to investigate the water quality with depth. The pit lake is up to 90 m deep in the central section. Subsequent aerial survey data indicated a pit lake level of about 68 to 70 mamsl.

An electrical conductivity (EC) probe was used, hanging from a canoe to take EC readings at depth, up to a 100 m below the pit water level. Four (4) water quality samples were also taken at different depths with a depth specific baler. The samples were collected and analyzed and the results are presented in *Annex 7-A*.

Numerical Groundwater Model

All data and information gathered during the project were combined and used as inputs to formulate a conceptual model and construct a numerical model of the study area. The numerical model was then used to assess potential environmental impacts due to dewatering of the mine workings.

The numerical model used to assess potential environmental impacts of the open pit mining was constructed using GUI Groundwater Vistas 6, a pre- and post- processing package for MODFLOW. MODFLOW is a modular three-dimensional groundwater flow model developed by the United States Geological Survey (Harbaugh et al., 2000)[5]. MODFLOW uses 3D finite difference discretization and flow codes to solve the governing equations of groundwater flow and solute transport. MODFLOW is a widely used simulation code and is well documented.

The calibration process was done by changing the model parameters of hydraulic conductivity and recharge. Thirty-two boreholes were used to calibrate the steady state groundwater flow model. The calibration objective was reached when an acceptable correlation was obtained between the observed and simulated heads (RMS=5.65).

A sensitivity analysis was conducted on the steady state model. The results of the sensitivity analysis showed the model to be sensitive to both hydraulic conductivity and recharge of the geological formations close to the mining area, and not sensitive to the regional aquifer characteristics.

The calibrated groundwater flow model was used in transient mode to predict mine inflows and the extent of dewatering due to mining. The mine stages with time were considered in this evaluation. The

[5] Harbaugh, AW, Banta, ER, Hill, MC and McDonald, MG (2000) Modflow-2000, the U.S. Geological Survey modular groundwater model –use guide to modularization concept and the groundwater flow process; Open-File Report 00-92, United States Geological Survey Report

uncertainties of aquifer parameters on the mine inflow and extent of dewatering was considered by varying the quantum of storage, hydraulic conductivity and recharge.

7.3.4 Baseline Hydrogeology

Groundwater Use

Liberia is endowed with abundant water resources, but suffers from a lack of infrastructure and management (MoLME, 2007)[6]. Brandolini and Taigani (2006)[7] (2) estimated large percentage of the people of Liberia depend on groundwater as a source of water. Most villages make use of surface water from nearby rivers and streams and shallow hand dug wells or boreholes, equipped with hand pumps.

A total of 46 water supply wells and boreholes, used as a domestic water source, were identified in the vicinity of the project area. The locality of these abstraction points in relation to proposed mine infrastructure is shown in *Map 7-10*.

Few settlements exist to the west, north and east of the proposed open pit and as a result, groundwater use is limited in this area. Water is sourced from hand pumps and streams by the villagers. To the south the towns of Bomi and Tubmanburg have a greater dependence on groundwater. During the hydrocensus it was attempted to visit as many hand pumps as possible in the area.

Except for a single motorised pumps located at the Dukle Yard (DY01), no deep boreholes or borehole equipped with motorised pumps were identified. All other groundwater points are equipped with hand pumps or in a few cases with a bucket system (mostly where hand pumps are out of order).

Except for hand pumps recently installed in boreholes by WCL, all hand pumps had been installed in hand dug wells which are on average about 8 m deep. Water flowing into these wells is from a deep weathered profile onto harder bedrock. Groundwater levels drop below the bottom of these wells during the dry season; and water then has to be sourced from the few wells that are deeper. Measurement of groundwater levels during the hydrocensus indicated that the water table is in the order of 7 m below surface.

Shallow hand dug wells are at risk of contamination due to the general lack of water and sanitation management, as well as the higher aquifer vulnerability of a shallow aquifer system. A number of

[6] Ministry of Lands, Mines and Energy (2007) National integrated water resources management policy for Liberia; Ministry of Lands, Mines and Energy, Monrovia.

[7] Brandolini, GV and Taigani, M (2006) Liberia environmental profile; Report prepared for the Government of Liberia and the European Commission by Agreco G.E.I.E.

community members complained that the water has a bad taste and these boreholes often have a slightly higher salt content than surrounding boreholes. However, this could also be due to natural causes and a more in-depth study is required to identify the source for the apparent poor water quality at some wells.

Surface water is also used to a large extent at the project area. The United Nations Peacekeeping forces deployed in the area also pump water directly from the existing pit lake and transport it by tanker to the points of need, while a bottle water plant also abstracts water from the lake.

Depth to groundwater level and flow direction

MacDonald et al (2011) [8]indicate depth to groundwater over much of the southern parts of West Africa to be less than 7 m below surface (mbs). Similar observations were made by Golder Associates (2012a) in the region of the project area.

During the hydrocensus undertaken in November 2012 groundwater levels were observed to range between 0 and 17.62 mbs, with 90 percent of the measurements being less than 10 mbs. This data was supplemented with that measured in the hydrogeological test boreholes drilled in January 2013 (Table 27). A similar trend was observed in the test boreholes, i.e. most water levels less than 10 mbs, with a range between 3 and 27.46 mbs.

Analysis of the data indicates a strong correlation between ground elevation and groundwater level (Figure 12). While the relationship weakens at higher elevations, it remains apparent.

Interpretation of the water level data indicates that:

- At a local scale, the direction of groundwater flow mimics that of surface topography; and
- At a regional scale, groundwater flows in a southwest direction.

[8] MacDonald, AM, Dochartaigh,B É Ó, Bonsor, HC, Davies, J and Key, R (2011) Developing quantitative aquifer maps for Africa; Internal Report IR/10/103, Groundwater Programme, British Geological Survey (BGS), Wallingford

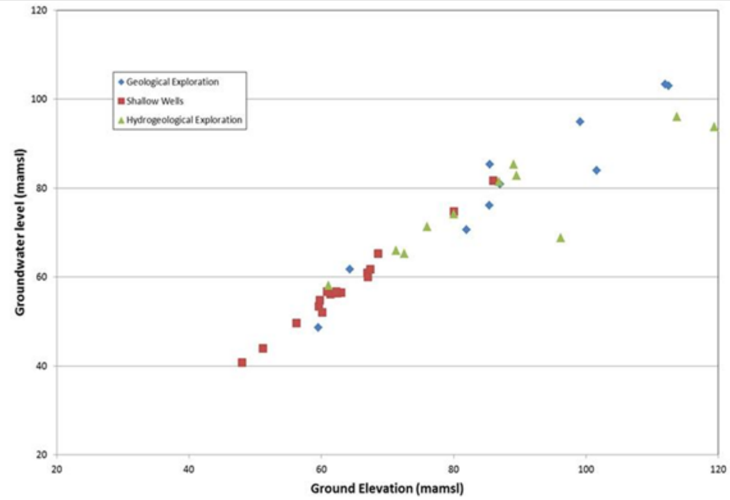

Figure 13: Correlation between Ground Elevation and measured Groundwater Levels in the Project Area

This relationship is also observed in the cross-sections in which the water level of disused mine pit is also considered (Figure 12). Interpreted groundwater elevations, using the calibrated groundwater model (*Annex 7-D*), are shown in *Map 7-13.*

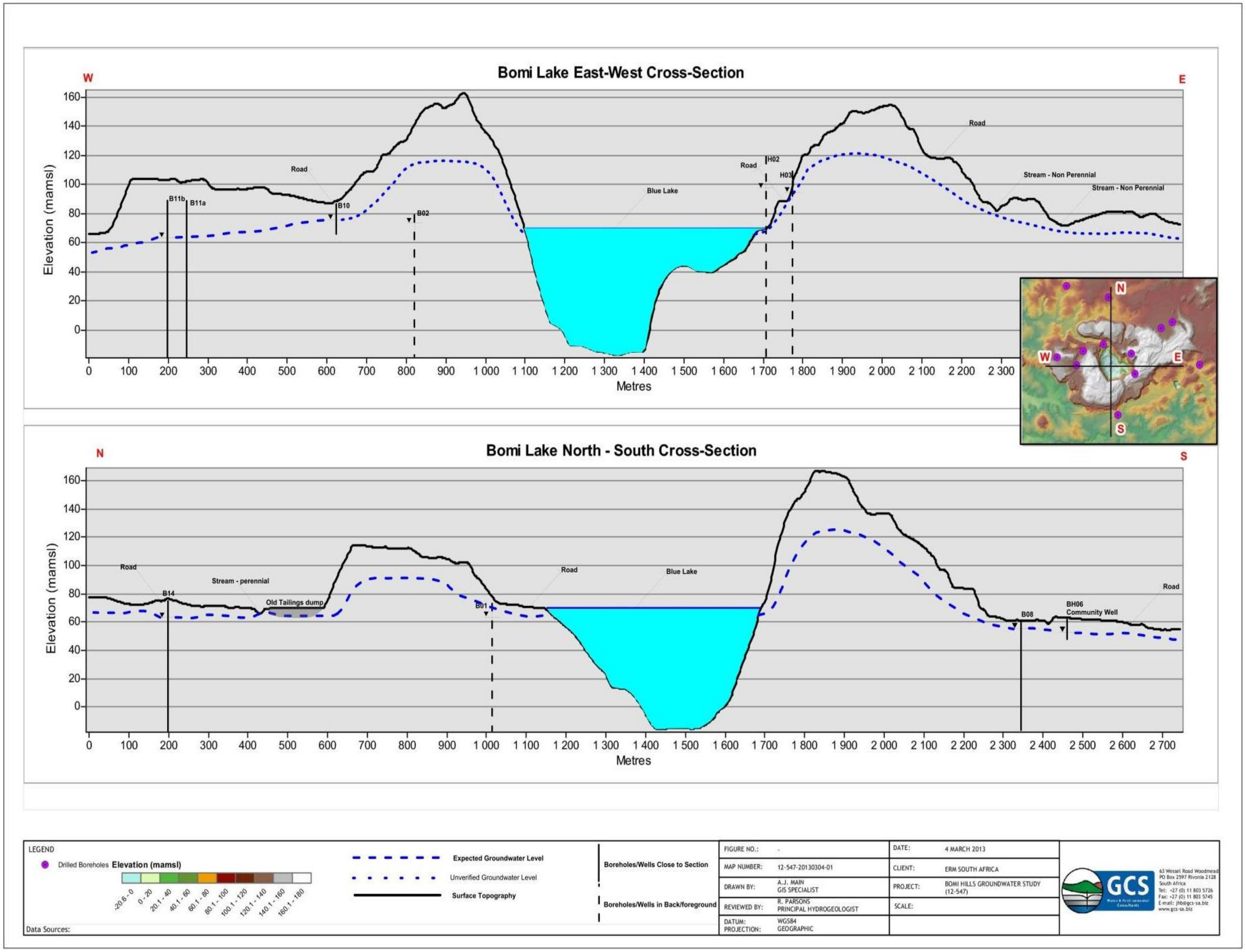

Figure 14: Groundwater Level Cross-section for Bomi Hills

General Aquifer Description

None of the aquifers in the study area have any significant primary porosity, and all owe their water-bearing properties to secondary properties that result from either fracturing (folding, faulting or diabase intrusions) or weathering processes (including laterite).

Based on the work undertaken during this study, as well as work undertaken within the region (Aquaterra (2012), cited by Golder Associates, 2012(a), three aquifer units with depth are proposed, i.e.:

- *Shallow lateritic (saprolite) aquifer unit* - unconfined, comprising shallow lateritic saprolite. This unit is mainly exploited by hand dug wells and shallow boreholes;
- *The weathered - fractured aquifer unit* - unconfined to semiconfined, comprises medium to slightly weathered and fractured bedrock, exploited by shallow boreholes; and
- *Deeper (fractured) aquifer unit* –semi-confined, comprises deeper fractured bedrock material.

The continental-scale aquifer productivity map prepared by BGS (2011) [(1)] [9]indicated aquifers to be of low to moderate productivity, with borehole yields typically being in the range of 0.5 L/s to 1.0 L/s (*Map 7-11*). Hydrocensus data also suggests that the shallow lateritic aquifer zone is relatively low yielding and seasonal. No site-specific information was available regarding the potential of aquifers in the Bomi Hills concession area prior to the hydrogeological test drilling undertaken as part of this project. The reported presence of faults and dykes could result in localized reasonable borehole yields.

Blow-out yields obtained during hydrogeological drilling ranged between 0 L/s and 4.4 L/s (Table 25) with a median of 1.1 L/s and a 90th percentile of 2.6 L/s. Borehole B05 has a blow-out yield of 2.6 L/s, however, this borehole was drilled in old tailings material, and is therefore not representative of the surrounding aquifers. Figure 14 shows the groundwater intersection or water strike depth for different aquifer units versus measured blow-out yields. Most water strikes were obtained at depths less than 40 mbs, with only five water strikes being obtained deeper than this level (Figure 14). All five deeper water strikes were low yielding (< 0.4 L/s) and were encountered at depths between 40 and 70 mbs. In terms of individual water strikes, the median strike amounted to 0.3 L/s while 90 percent of the individual water strikes yielded less than 1.1 L/s.

[9] British Geological Survey (BGS): MacDonald, AM, Dochartaigh,B É Ó, Bonsor, HC, Davies, J and Key, R. 2011. Developing quantitative aquifer maps for Africa; Internal Report IR/10/103, Groundwater Programme, Wallingford

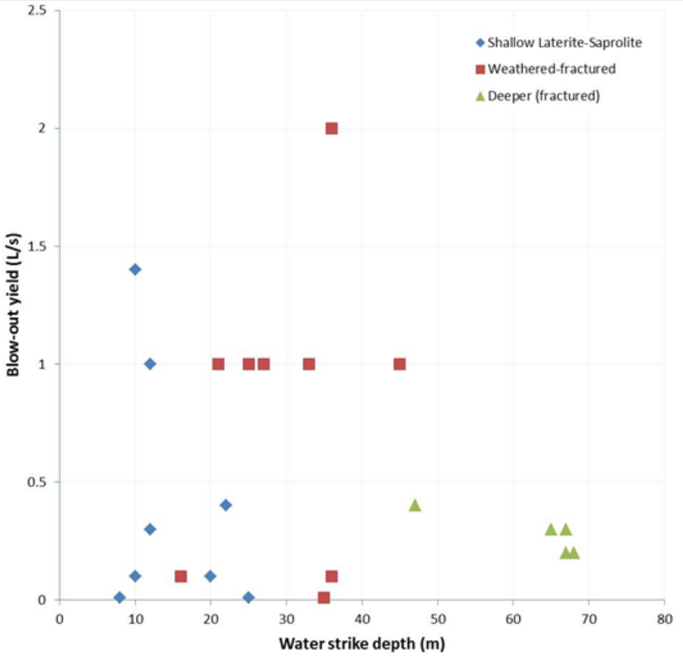

Figure 15: Depth of Groundwater Intersection (water strike) versus Blow-Out Yield

From the drilling logs and Figure 14 it can be concluded the shallow lateritic aquifer zone is generally less than 20 m in depth, while the weathered-fractured aquifer zone extends up to 40 mbs. Ore exploration data suggests that weathering might extend to a depth up to 60 m in the ore zone. Generally the frequency of groundwater intersection decreases with depth. The upper two (2) aquifer zones are the most productive while the deeper parts of the system have a low aquifer potential. This trend is often observed in similar basement –metamorphic rock aquifers. Drilling results showed no evidence of significantly enhanced water-bearing capabilities associated with faults or dykes. However, it is anticipated that some faults and/or dykes are present that could increase the yields of the lower two (2) aquifer units substantially.

The data from the hydrogeological test drilling showed no definite distinction between blow-out yields encountered in the ore zone (BIF, schist, and amphibolite) and the surrounding basement (gneiss, granite). However, hydrogeological data from other iron ore areas in Africa show that the potential exists that fractured BIF could have a greater aquifer potential compared to basement rocks. This will have to be investigated with further hydrogeological drilling and testing.

Using a classification developed by the National Rivers Authority (1992)[10] [(1)] and later adapted by Parsons (1995)[11] [(2)], the aquifers in the vicinity of the Bomi Mining Concession are considered to be minor aquifers. While the quality of the water is excellent, borehole yields are low.

Aquifer Test Results

[10] National Rivers Authority (1992) Policy and practice for the protection of groundwater; National Rivers Authority, Bristol

[11] Parsons, RP (1995) A South African aquifer system management classification; WRC Report KV77/95, Water Research Commission, Pretoria

Pumping test data was analyzed to obtain transmissivity[12] values using Theis/Cooper-Jacob analytical methods. The results are listed in Table 29.

From the blow-out yield data and aquifer test results it can be concluded:

- The upper lateritic aquifer zone has highly variable hydraulic parameters, depending on the hydraulic conductivity of the material and saturated thickness;
- Analysed transmissivity values for the weathered-fractured aquifer zone varies between 1 and 18 m^2/d; and
- No definite distinction could be made from the pumping test data for the deeper (fractured) aquifer unit. From the blow-out yield data, it can be concluded that transmissivity values are low, probably less than 2 m^2/d.

Table 34: Pumping Test Transmissivity Values

Borehole No.	Transmissivity (m2/d)		Comment/ Aquifer Unit
	Theis/Cooper-Jacob	Theis Recovery	
B01	45	-	Upper lateritic aquifer unit. Hydraulic conductivity (K) ~ 5 m/d Weathered/fractured aquifer unit (ore zone)
B02	6	3	Late T could be related to weathered-fractured aquifer unit (ore zone & basement
B03	4 (late T - 18)	4.6	Old saturated tailings material in Bomi Creek
B05*	418	-	Both Lateritic and weathered-fractured (ore zone) aquifer units
B06	1.7	1	Both Lateritic and deeper (fractured basement) aquifer units Weathered-fractured aquifer unit (schist) Late T could be related to weathered-fractured aquifer unit (basement) Weathered-fractured aquifer unit (ore zone
B07	3	2	
B08	6	3	
B14	1 (late T - 9)	1	
H02	4	8	

Table 35: Estimates of the hydraluic properties of the upper and deeper aquifer gneiss aquifer

Aquifer	Hydraulic Conductivity (m/d)	Specific Yield[13] (%)
Weathered gneiss rock	0.1 –0.43	1 –3
Deeper unweathered gneiss bedrock	0.01 –0.086	0.01 –1

[12]Transmissivity is a measure of the ease with which groundwater flows in the subsurface. It is defined as the rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient. It is expressed as the product of the average hydraulic conductivity and thickness of the saturated portion of an aquifer.

[13] This is a measure of the water released from an unconfined aquifer. It is the ratio of the volume of water that drains by gravity to that of the total volume of the saturated porous medium.

Groundwater Quality

Water samples were taken from the following points:

- Seven (7) shallow water supply wells equipped with hand pumps during the hydrocensus task (BH –series) –Bomi Hills 01, Bomi Hills 02, Bomi Hills 05, Bomi Hills 06, Bomi Hills 07, Bomi Hills 08 and Bomi Hills 09;
- Two (2) deeper Bomi Hills ore exploration boreholes during the hydrocensus task –Bomi Hills 03 and Bomi Hills 04;
- Four (4) water samples of the existing pit lake at different depths - Disused Mine Pit 01, Disused Mine Pit 02, Disused Mine Pit 03 and Disused Mine Pit 04; and
- Seven (7) borehole samples from the phase 2 hydrogeological test boreholes, taken during the constant pumping tests –B01, B02, B02, B05, B06, B07, B08 and B014.

The laboratory sheets are presented in *Annex 7-A*. Water quality results are summarized in Table 30 and is compared to Liberia Water Quality Standards Class I. The locality of boreholes sampled is shown in *Map 7-10* and *Map 7-12*.

The pH levels in the hydrogeological test boreholes and existing pit lake ranged between 6.5 and 7, almost neutral, while pH values in the shallow, hand dug wells varied between 4.7 and 6.9, therefore slightly acidic (Table 26). The slightly lower values observed in the wells may be as a result of organic acids and lack of minerals with a neutralizing capacity.

Table 36: Groundwater Quality Results

PoC	LWQS (Cl. 1)	BH01	BH02	BH03	BH05	BH06	BH07	BH08	BH09	DMP 01	DMP 02	DMP 03	DMP 04	BO1	B02	BO7	B14	B08	B05	B03	B06
pH	NS	6.5	4.7	6.8	5.1	5.9	5.8	5	6.8	6.6	6.6	6.7	6.7	6.6	6.8	6.5	6.6	7	6.7	7	6.7
EC (mS/m)	NS	12	6.8	24	4.6	18	14	9.5	26	9.2	10	9.5	9.9	11	17	14	11	17	16	24	12
Total Alkalinity	NS	60	25	100	BDL	75	40	15	150	30	30	30	25	85	70	75	55	100	40	140	50
Chloride (Cl)	250a	1.4	4.2	1.5	1.3	3.5	16	3.4	0.77	1.4	1.4	1.2	1.2	1.4	1.5	1.3	1.1	1.4	0.78	-	-
Sulphate (SO_4)	250a	1.4	2.5	0.93	8.2	3	0.71	0.14	2.3	18	15	15	15	21	8.4	0.79	0.94	1.4	40	-	-
Nitrate (NO_3)	50	2.5	14	0.1	1.8	10	1.5	24	<0.1	<0.1	1	0.1	0.3	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	-	-
Calcium (Ca)	NS	18	3.9	23	2.6	23	19	7.5	43	6	6	6	6.4	11	27	20	16	26	11	-	-
Magnesium (Mg)	NS	0.35	0.67	11	1.3	2	0.42	1.7	0.8	4.5	4.4	4.5	4.6	5.9	4.3	2.3	2.2	4.6	12	-	-
Sodium (Na)	200	1.5	4	6.5	1.2	5.1	3.5	2	1.7	1.3	1.2	1.3	1.5	1.9	8	6.1	2.7	3	1	-	-
Potassium (K)	NS	0.7	1.1	2.3	0.7	1.1	0.6	1.3	5.5	1.7	1.7	1.8	1.9	2	1.9	1.3	0.6	1.3	2.6	-	-
Aluminium (Al)	0.2	BDL	0.05	0.03	BDL	BDL	BDL	**0.29**	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	-	-
Iron (Fe)	2	0.28	0.094	0.94	0.14	**8.8**	0.35	0.19	0.61	0.059	0.092	0.074	0.1	BDL	0.075	BDL	BDL	0.087	BDL	0.1	BDL
Manganese (Mn)	0.4	0.002	0.022	0.1	0.24	**1.2**	0.1	0.089	0.005	BDL	BDL	BDL	**0.56**	BDL	0.12	0.081	0.069	**1.2**	**1.5**	**0.14**	0.079
Chrome (Cr)	0.05	BDL	BDL	0.003	0.002	0.004	BDL	BDL	0.002	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.04	0.02	BDL	BDL	BDL
Copper (Cu)	2	0.011	0.0084	BDL	0.0058	BDL	BDL	0.033	0.0096	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Arsenic (As)	0.01	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.0019	0.0018	0.0012	0.0012	0.0012	0.0013	0.0016
Lead (Pb)	0.01	BDL	0.0011	BDL	BDL	BDL	BDL	0.008	**0.012**	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Zinc (Zn)	NS	0.03	0.02	0.02	0.02	0.05	0.04	0.04	0.03	<0.01	0.01	<0.01	0.01	0.84	0.19	0.92	2.3	0.09	0.04	-	-
Silicon (Si)	NS	3.8	3.9	27	1.7	3.1	5.9	1.5	5.1	2.6	2.5	2.6	2.6	2.9	20	14	9.7	4	9.9	-	-
Vanadium (V)	NS	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.0016	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL

BDL - Below Detection Limit

NS - No Standard Specified

a –Aesthetic only

Indicated parameter exceeds the LWQS Class I standard limit

The majority of constituents analysed were in compliance with the WHO standards, with the exception of elevated metal concentrations, i.e. Al, Fe, Mn and Pb, analysed in some boreholes. Mn is more prevalent and is soluble over a wide pH –redox spectrum compared to the other metals. Elevated metal concentrations are most likely due to natural reasons.

Borehole B05 drilled into old tailings material had a SO_4 concentration of 40 mg/L and low metal concentrations. Generally, no definite remnant groundwater quality impacts from previous mining activities were observed.

Figure 16 shows electrical conductivity (EC) readings for different depth profiles. The EC values are generally low, with the exception of the muds at the pit floor. The data indicates no apparent water quality stratification with depth. Water quality samples from the disused mine pit were taken at varying depths below surface using a depth specific bailer:

- Disused mine pit 01 –0 m below surface;
- Disused mine pit 02 –30 m below surface;
- Disused mine pit 03 –60 m below surface; and
- Disused mine pit 04 –90 m below surface.

The water quality results (Table 30) show little variations with depth and none of the constituents analyzed, with the exception of Mn (disused mine pit 04) exceeded LWQS standards. The absence of groundwater contamination as a result of historic mining activities has an important bearing on predicting impacts that could result from proposed mining.

Figure 18 below shows the tri-linear piper diagram constructed for the site in order to assist in characterizing different water types. The dominant water type for the site is Ca-HCO_3, with the exception of the disused mine pit and borehole B05 which are Mg-HCO_3 water types. Both localities are associated with historical mining activities at the site (borehole B05 was drilled in to the old tailings storage area).

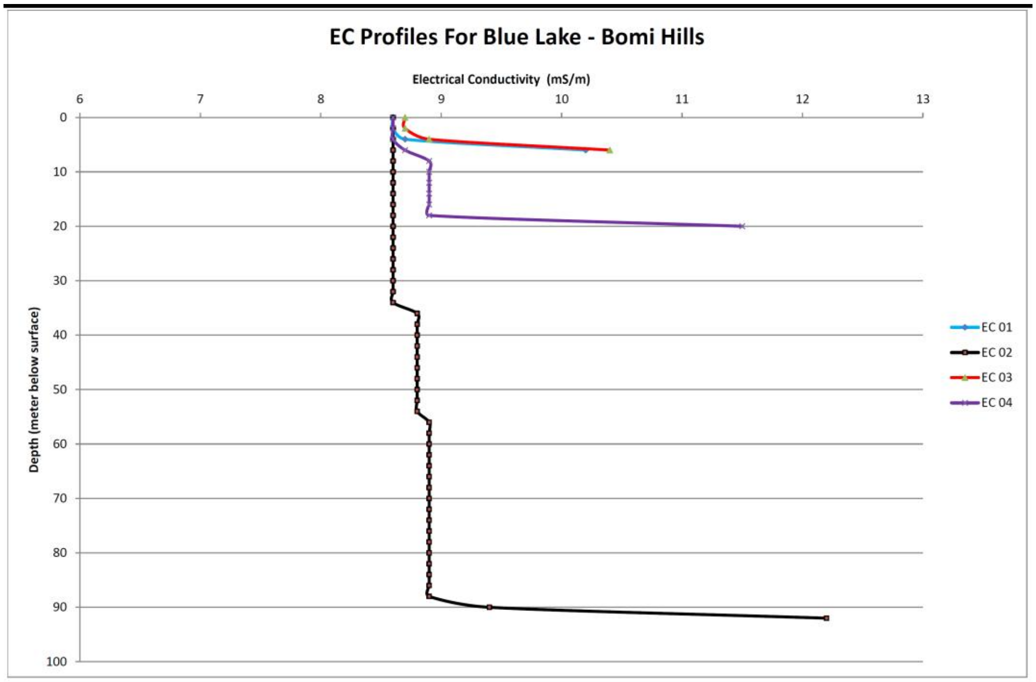

Figure 17: Electrical Conductivity Depth Profiling of the Existing Pit Lake

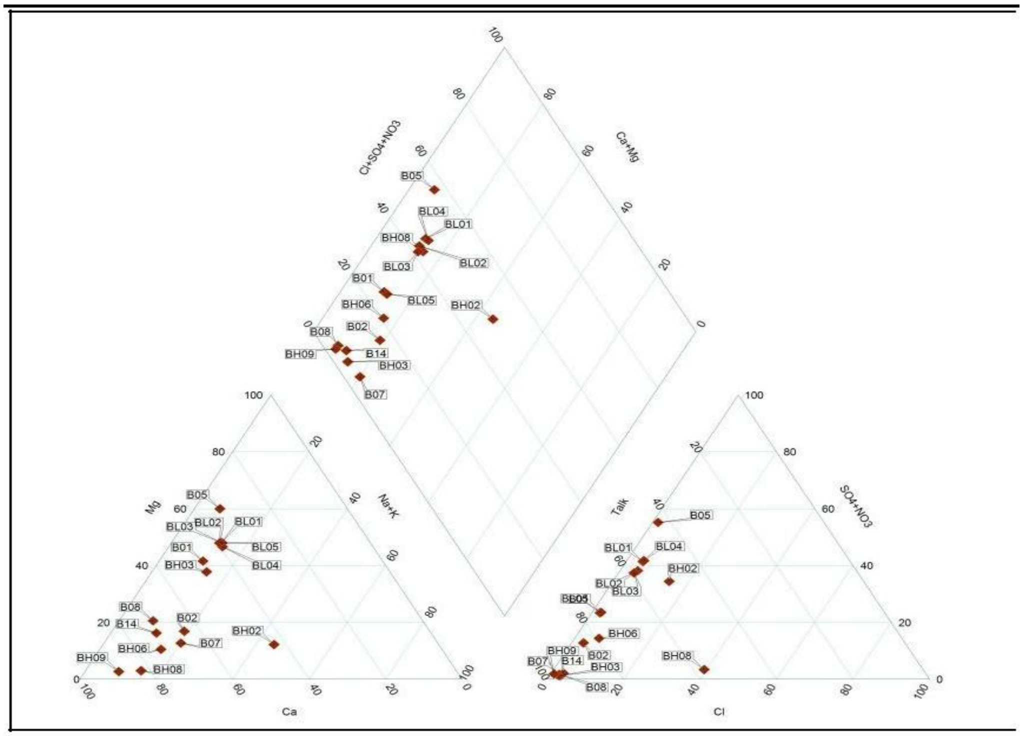

Figure 19: Piper Diagram

Conceptual Hydrogeological Model

The conceptual hydrogeological model represents an interpretation of the most significant components of the aquifer as well as the hydraulic properties.

The conceptual model represents a set of assumptions and simplification of the real aquifer and has sufficient information to construct the numerical model. The conceptual model was derived from desktop data, hydrocensus data, hydrogeological test borehole data and was refined during the calibration of the baseline numerical groundwater model (*Annex 7-D*).

In the absence of detailed spatial hydrogeological data, a simple three-layered conceptual model is proposed. The aquifers essentially comprise:

- A shallow, up to 20 m lateritic saprolite aquifer unit.
- A weathered and fractured aquifer unit for both the basement and ore zone rock. This zone is on average located between 20 to 40 mbs, with a range that probably varies between 5 to 60 mbs regionally.
- A deeper aquifer unit consisting of fracturing in the basement and ore zone. The frequency of groundwater intersection decreases with depth, with no recorded water strikes below 70 mbs. From similar hydrogeological terrains it is suggested that this zone is effectively less than 100 m deep. However additional hydrogeological drilling is required to confirm this, especially in the ore zone.

The transmissivity and/or bulk hydraulic conductivity of the three aquifer units decreases with depth:

- The bulk hydraulic conductivity of the shallow lateritic saprolite aquifer zone is in the order of 1 to 5 m/d.
- The weathered and fractured aquifer zone has highly variable hydraulic properties, typical of secondary aquifers. Analysed transmissivity values are in the order of 5 m^2/d, with a range between 1 and 18 m^2/d. For the numerical groundwater model (*Annex 7-D*), a higher transmissive zone was assigned for the ore zone compared to the surrounding basement in order to account for the potential higher aquifer potential of fractured BIF, as seen in a number of other iron ore projects across Africa. A hydraulic conductivity of 0.5 m/d (transmissivity of 10 m^2/d based on an average saturated thickness of 20 m) were assigned to the ore zone and 0.25 m/d for the basement gneiss/granite (transmissivity of 5 m^2/d based on an average saturated thickness of 20 m).

- The deeper (fractured) aquifer unit has a very low aquifer potential based on the frequency of water strikes and associated blow-out yield measurements. Transmissivity values are lower than 2 m^2/d, with a bulk hydraulic conductivity in the order of 0.01 to 0.03 m/d.
- More permeable zones, typically the result of faulting, folding or diabase intrusives, may be encountered at a local scale, but they are not expected to be well connected. A number of NW – SE trending diabase dykes were identified within the project area.

The hydraulic gradient mimics that of the topography, and suggests that gradients are flat in the low laying area. *Map 7-13* shows the interpreted groundwater level contours for the project area.

Based on estimates presented in the recharge map of Africa (BRGM, 2004)[14], recharge could amount to 6.5 percent of MAP (3 161 mm/a) or 205 mm/a. Burnet and Romanenko (2010) also argue effective rainfall (rainfall – evapotranspiration) is about five times greater than recharge, i.e. about 200 mm/a. Given that effective rainfall is in the order of 2 000 mm/a and the limited anthropogenic use (in relation to the extent of the groundwater resource) the aquifers are considered to be full and mostly in a pristine state. It is reasonable to expect that groundwater discharge in the drier months contributes a substantial portion of baseflow in the rivers. The estimated dry season measured flows (Redco, March 2013) for the project site towards the Small Mahe River is in the order of 25 000 m^3/d. However, this measurement was made in the beginning of the dry season (December 2012) and is probably still dominated by the surface water and inter-flow component.

Groundwater quality is on average very good, with EC being less than 20 mS/m. The water has a slight acidic character. Previous mining and waste disposal at the site has little impact on the hydro-geochemical regime.

[14]BRGM and others (2004). Hydrogeological Map of Africa: a prototype at 1: 10 000 000. GIS Africa Project. Réseau SIG Afrique/Africa GIS Network

7. 4 Soils, Land Use and Land Capability

The area where mining will take place is an area that has largely, been previously disturbed due to mining activities in the past. Although the vegetation has to some extent recovered the area is still considered a brownfield site. The only portion that has not previously been impacted is the forested area in the northeast of the concession area. No mining is planned in this area at this stage.

The soils, land capability, land use and agricultural potential study included the following:

- Conducting a desktop study for the proposed site to assess the soil and land use of the site and receiving environment;
- Performing a soil survey on site describing each sample point following the World Resources Base Guidelines;
- Sampling and analysis of soil samples to determine nutrient levels as a measure for agricultural potential;
- Performing a comprehensive detailed soil and land use impact assessment based on the predicted impacts resulting from the proposed activities. Impacts, their rating and the establishment of confidence limits are to be assessed and will need to take into account the nature of the impact, impact duration, possibility of occurrence, potential for mitigation/optimisation, impact significance and confidence;
- Recommend detailed mitigation measures which will reduce and ameliorate the soil and land use impacts identified in the comprehensive impact assessment; and
- Compile a comprehensive soil, land use, land capability and agricultural potential report.

During this visit, soil profiles were assessed by using a hand auger as well as by assessing existing open soil profiles. Soil samples collected were tested (*Annex 7-E*) by SGS South Africa (an ISO accredited laboratory).

7.4.1 Baseline Conditions

General Context

Land stability and soil erosion are particularly relevant in hilly, tropical terrain, where bedrock is weathered and hence weakened to considerable depths and very intense rainfall can trigger landslides and erosion in both natural and man-made slopes. Unfortunately, there are no formal records or catalogues of landslides and erosion problems in the Bomi Hill region from which statistical relationships between slope angle and landslides can be determined.

The following data was obtained and studied to prepare for the site survey and the baseline reporting:

- The aerial images as provided by WCL proved to be of value for desktop study purposes for determining land use.
- Climate graphs and data for the study area were extracted from the New Local Climate Estimator of the Food and Agricultural Organization of the United Nations (2005). Although this was studied, more recent climate data from the Final Scoping Report for the Bomi Hills Mine as submitted by ERM to the EPA of Liberia in 2012 was also used.

Site Context

Ground-truthing of the desktop assessments and more detailed appraisal of the terrain in the Bomi Hills Concession Area focused on representative locations where effects could be significant (such as the mine periphery, areas used by local communities, agricultural crop fields, undisturbed areas and in the vicinity of watercourses). The survey was conducted on a grid of one to five hectares, depending on the accessibility of the areas and a total of 143 soil pits were augured (*Map 7-14*). Profiles were observed to a depth of 1.5 m unless interrupted by rock or water. The soils are described using the World Resources Base parameters and the coordinates of the survey points were logged using a Global Positioning System and the results recorded in a database. Observations were made on landform position, topography, land cover, land use and soils information (color, structure, texture, drainage and depth).

The current soil conservation status of the area was evaluated with visual observations by visiting sites of existing soil erosion gullies (Figure 19) and areas previously disturbed by old mining activities. Areas of possible landslides were also evaluated. With regards to the land use survey, the area was scanned to determine all possible current land uses. Crop gardens were visited to establish what crops are cultivated by the local communities and the success of their agricultural practices.

Twenty soil samples were collected at the Bomi Hills study site, stored in perforated soil sampling plastic bags and sent to the SGS soil laboratory in Somerset-West (South Africa) for analysis. Samples were analysed for pH, phosphorus content (topsoil samples only), macro nutrients (calcium, magnesium, and potassium) and electrical conductivity. The pH of the soil is potentiometrically measured in a supernatant suspension of soil and liquid and in this case the pH of soil samples was measured in potassium chloride. Electrical conductivity (measured in milli siemens/meter or mS/m) is a measure of the ability of a soil saturation extract to conduct electricity and is a measure of the concentration of salts in solution.

Figure 20: Soil Erosion as a result of Steep Slopes and High Rainfall

7.4.2 Baseline Results

Soil Classification

A total study area of 11,508 ha was surveyed on a reconnaissance level. The soil forms were classified according to the World Resources Base system guidelines and different soil types identified were grouped together into soil-mapping units on the basis of soil form and surface features. Each soil-mapping unit has a unique color, which is identified in the map legend (*Map 7-15*). The discussion of each of the soil forms follows below.

Plinthosols (6,458 ha or 56.1 percent of the total area)

Plinthosols are soils with plinthite, petroplinthite or pisoliths. Plinthite is an Fe-rich (in some cases also Mn-rich), humus-poor mixture of kaolinitic clay (and other products of strong weathering such as gibbsite) with quartz and other constituents that changes irreversibly to a layer with hard nodules, a hardpan or irregular aggregates on exposure to repeated wetting and drying. Pisoliths are discrete strongly cemented to indurated nodules. Both petroplinthite and pisoliths develop from plinthite by hardening. It is crucial that sufficient Fe be present, originating either from the parent material itself or brought in by seepage water or ascending groundwater from elsewhere. Formation of plinthite is associated with level to gently sloping areas with fluctuating groundwater or stagnating surface water.

Plinthosols present considerable management problems. The main limitations of this soil form as a growth medium for food crops are low fertility and waterlogged conditions. These soils are very prone to erosion when vegetation cover is removed, especially when it occurs on steep slopes as is the case on the project site. Once the vegetation cover has been removed and topsoil erodes through water movement in the wet season or dries out in the dry season, the soil profile hardens irreversibly that limits the rehabilitation potential of the land and further aggravates soil erosion.

Ferralsols (989 ha or 8.6 percent of the total area)

Ferralsols are red and yellow tropical soils with a high content of sesquioxides that consist of strongly weathered material on old, stable geomorphic surfaces. These soils were identified on site in level to undulating land. The deep and intensive weathering has resulted in a residual concentration of resistant primary minerals (e.g. quartz) alongside sesquioxides and kaolinite. This mineralogy and the relatively low pH explain the stable microstructures (pseudo-sand) and yellowish (goethite) or reddish (hematite) soil colors.

The chemical fertility of Ferralsols is poor; weatherable minerals are scarce or absent, and cation retention by the mineral soil fraction is weak. Under natural vegetation, nutrient elements that are taken up by the roots are eventually returned to the surface soil with falling leaves and other plant debris. The bulk of all cycling plant nutrients is contained in the biomass; available plant nutrients in the soil are concentrated in the soil organic matter. If the process of nutrient cycling is interrupted, e.g. upon introduction of low-input sedentary subsistence farming, the rootzone will rapidly become depleted of plant nutrients.

Ferralsols on the project site are very well drained and have high water infiltration and percolation rate. As this soil form mostly occurs in relatively flat positions on site, it is less susceptible to erosion and soil loss than Plinthosols and Technosols. Good soil cover management is sufficient to control erosion in the areas of Ferralsols (*Chapter 21-D*).

The biggest impact of the proposed project on Ferralsols will be compaction as this soil form is highly susceptible to compaction due to the domination of the soil structure by macropores. Restricting traffic in the areas of Ferralsols is therefore of utmost importance and therefore haul roads and topsoil stockpiles should rather be constructed in areas of Plinthosols

Figure 21: Deeply Weathered Ferralsol Profile

Stagnosols and Gleysols (245 ha or 2.1 percent of the total area)

The water bodies (streams, rivers) and wetlands identified on the study site are situated in a combination of stagnosols and gleysols. Stagnosols occur in flat or gently sloping land and consist of soils with a perched water table showing redoximorphic features caused by surface water. Stagnosols are periodically wet and mottled in the topsoil and subsoil, with or without concretions and/or bleaching.

Gleysols are wetland soils that, unless drained, are saturated with groundwater for long enough periods to develop a characteristic gleyic colour pattern. This pattern is essentially made up of reddish, brownish or yellowish colours at ped surfaces and/or in the upper soil layer or layers, in combination with greyish/bluish colours inside the peds and/or deeper in the soil.

The agricultural suitability of both Stagnosols and Gleysols is limited because of their oxygen deficiency resulting from stagnating water above a dense subsoil. Therefore, they have to be drained. However, in contrast to Gleysols, drainage with channels or pipes is in many cases insufficient. It is necessary to have a higher porosity in the subsoil in order to improve the hydraulic conductivity. This may be achieved by deep loosening or deep ploughing. Drained Stagnosols can be fertile soils owing to their moderate degree of leaching.

Both the Stagnosols and Gleysols are situated in low-lying flat positions in the landscape resulting in a low erosion risk.

Figure 22: Gleysols Identified in a Riparian Zone

Anthrosols and Technosols (3,816 ha or 33.2 percent of the total area) Technosols combine soils whose properties and pedogenesis are dominated by their *technical* origin. They consist of all kinds of materials made or exposed by human activity that otherwise surface; pedogenesis in these soils is affected strongly by materials and their organization. This group includes soils from wastes (landfills, sludge, cinders, mine spoils and ashes), pavements with their underlying unconsolidated materials, soils with geomembranes and constructed soils in human-made materials. Technosols are often referred to as *urban* or *mine* soils. Technosols are affected strongly by the nature of the material or the human activity that placed it (Figure 21). They are more likely to be contaminated than soils from other groups. Many Technosols have to be treated with care as they may contain toxic substances resulting from industrial processes. All the old mine waste dumps and open pits in the study area that are now covered in vegetation or still barren, can be classified as Technosols.

Anthrosols comprise soils that have been modified profoundly through humans by long-continued cultivation. The influence of cultivation is normally restricted to the surface horizons; the horizon differentiation of a buried soil may still be intact at some depth.

Both Anthrosols and Technosols will be susceptible to erosion once vegetation clearance has taken place. However, Technosols on site have been identified in both flat and hillslope positions while Anthrosols are mainly found in flood plain areas which results in Anthrosols being less susceptible to erosion than Technosols.

Figure 23: Example of Technosols in the Bomi Hills Concession Area

Soil Chemical Characteristics and Soil Fertility

All four of these soil groups have an inherent low pH (ranging between 4.1 and 6.1) as a result of the combination of soil physical properties and the high rainfall of the area. Low pH levels naturally induce high aluminium content in soil which in turn results in inherent low fertility. The phosphor (P) levels are also very low (between 2 and 5 mg/kg) which indicates that the soil has not previously or is currently fertilized with a phosphate containing fertilizer, even in crop gardens and rice paddies. The cation levels of

Ca, Mg and K are low for conventional crop production and sodium levels are very low indicating no sodicity problems. Salinity levels are also sufficiently low.

Although not many areas with eroded soil profiles have been observed, intensive mining activities may aggravate soil erosion especially in areas with land clearance during the rainy season as well as on steep slopes. Soil profiles with a high content of plinthic nodules and concretions are more susceptible to erosion than deep developed profiles with higher clay content.

Land Capability of the Area

Following the land capability classification system above, the soil groups in the study area could all be classified into four land capability classes. Although industrial land capability is not defined in this system, it is now widely used internationally to describe the land capability of areas where human settlement, construction and mining activities have already impacted the surface area in such a way that cannot be classified as arable any longer. An area of 3,816 ha (or 33.2 percent of the total area) has been identified as land with industrial capability.

An area of 989 ha has arable land capability and is suitable for crop production while 6,458 ha is marginally suitable for arable agriculture and needs proper soil fertility and conservation practices for high density crop production. A total area of 245 ha has wetland land capability and this area includes rivers, open pit lakes and wetland areas.

Land Use

The area is dominated by human settlements and other wooded land where exotic plant species such as palm trees occur. Small patches of land are under temporary crops but it is mainly used for subsistence and not for income generation purposes. This is also the case with permanent crops such as fruit trees (no large orchards were identified and fruit trees mainly occur around the houses) for consumption by the inhabitants. Only one small site was identified where artisanal mining is currently taking place.

Agricultural Potential

Although there are currently agricultural activities in the form of subsistence farming, no formal agricultural production units were identified apart. Crops grown are rice, okra, green pepper, peppers, potato, cucumber, pumpkin, beans, tomato, sugarcane, cassava, yam, maize, coconut, guava, orange, lemon, banana, mango, pineapple, grape fruit and paw-paw (Figure 23 and Figure 24).

An old distillery was visited where the community distils alcohol from the sugar cane. Crop production depends on rainfall or flood irrigation from streams and river beds and no modern irrigation equipment was observed. Even though the soil may have inherent low fertility, it was evident that the community makes use of sustainable crop rotation practices and organic material build-up in soils to sustain their crop fields.

Figure 24: Planting a mixture of crops together is a common practice in the vegetable gardens

Figure 25:Rice farm in the Bomi Hills area

7. 5 Terrestrial Ecology

The assessment has focused on the potential impacts of mining and processing activities at Bomi Hills Mine on the Terrestrial Ecology of the area.

Some limitations experienced during the collection and analysis of data for the aquatic assessment include:

- Many animals occur at naturally low densities and are cryptic and very difficult to detect making it highly unlikely that all species occurring in a region will be detected. The majority of fauna are active during the wet season and therefore this is the optimal time for sampling, however, during the wet season survey the heavy daily rainfall limited surveys because of impassable roads, the inability to detect animals (e.g. with binoculars and sound recording equipment) and especially, the fact that most fauna (excluding amphibians) become inactive during heavy rain. A rapid assessment of diurnal butterfly species was conducted during the dry season survey.

- Due to time constraints, the invertebrate (or butterfly) survey was not stratified according to regional habitat types. There is a major lack of literature on the flora & fauna of West Africa, specifically regarding the geographic distributions of species.
- Several cryptic fauna species exist which cannot be identified without specific morphological and/or DNA tests (e.g. Hilliers 2009).
- The export of biological specimens beyond the Liberian border for later identification and sorting purposes are constrained by permitting requirements. Very poor trap success of small mammals in the forest systems is because many of the rodent/small mammal species are arboreal, living high in the forest canopy where most of the food resources are found.
- For the floral analysis, poor identification of plant species and incomplete data sets affected efficient data analysis, requiring modification of techniques in achieving the desired results.

7.5.1 Methodology

An overview of the methodologies used in order to obtain the baseline information for the Terrestrial Ecology Study for Bomi Hills Mine is below:

- Desktop studies including:
  - General information and GIS;
  - Flora;
  - Avifauna;
  - Herpetofauna;
  - Mammals; and
  - Invertebrates.
- Field Surveys including:
  - a wet and dry season survey was conducted during September 2012 and January 2013 respectively by implementing the following techniques (See *Map 7-17*):
    - A classification of the vegetation data is done using the TURBOVEG and MEGATAB computer programs[15];
    - Red Data Flora Assessment; and
    - Alien Invasive Plant Species assessment.

[15] Hennekens S M and Schaminee J H J (2001) TURBOVEG, A comprehensive database management system for vegetation data. Journal of Vegetation Science 12: 589-591.

- Avifauna (a wet and dry season survey was conducted during September 2012 and January 2013 respectively by implementing the following techniques:
    - Point count surveys (*Map 7-18*);
    - Random surveys;
    - Playback of bird calls/vocalizations; and
    - Detecting patterns in diversity.
- Herpetofauna (wet season September 2012 and dry season January 2013) (ERM 2013, *Map 7-19*).
- Mammals (wet season September 2012 and dry season January 2013) - due to the inherent complexity of the mammalian group, many techniques were employed to detect mammals during the field survey (ERM 2013, *Map 7-20*).
- Invertebrates.
- Sensitivity analysis - performed for each habitat type where the sensitivity of the floral and faunal groups was evaluated based on the ecosystem service (*ecological function*) and the preservation of diversity (*floral and faunal importance*).

All species lists referred to in this report can be found in *Annex 7-F*.

7.5.2 Baseline Conditions

Definitions[16]

A forest is a land area of more than 0.5 ha, with a tree canopy cover of more than 10 percent, which is not primarily under agricultural or other specific non-forest land use; where trees should be capable of reaching a height of at least 5 m in situ.

Primary Forest is considered old-growth forest with diversified tree structure and multi-layered canopies. These old-growth forests attained great age without significant disturbance, retaining unique ecological features and supports a higher bio-diversity.

A **secondary forest** is a forest that has been logged and has recovered naturally or artificially. Not all secondary forests provide the same value to sustaining biological diversity, or goods and services, as did primary forest in the same location.

[16] Chokkalingam U and De Jong W (2001) Secondary forest: a working definition and typology. International Forestry Review 3(1).

A **degraded forest** is a secondary forest that has lost, through human activities, the structure, function, species composition or productivity normally associated with a natural forest type expected on that site.

A **wetland** is a land area that is either permanently or seasonally inundated with water, such that it exhibits distinct characteristics. Wetland consists of hydric soils and supports aquatic plants.

Vegetation classification of the Bomi study area culminated in the identification of the following homogenous topographic-physiognomic units (*Map 7-21*).

- Tall Secondary Forest;
- Short Secondary Forest;
- Short Degraded Forest;
- Low Degraded Forest;
- Transformed/Mining;
- Urbanized;
- Wetlands; and
- Rivers/watercourse.

Each of these units was analyzed (Table 32) and discussed separately below:

Table 37: Vegetation units and their relative contribution to ecosystem functionality

Habitat Type	Area (Ha)	Proportion of Total	Area Destroyed by Infrastructure (Ha)	Proportion of Original Destroyed
Tall Secondary Forest	1275.9	11.1%	0.0	0.0%
Short Secondary Forest	3385.9	29.4%	69.9	2.1%
Short Degraded Forest	4286.7	37.2%	640.5	14.9%
Low Degraded Forest/Agriculture	1431.6	12.4%	122.2	8.5%
Urbanized	250.1	2.2%	29.8	11.9%
Transformed/Mining	481.2	4.2%	417.0	86.7%
Wetland	185.0	1.6%	55.8	30.2%
Open Water	77.9	0.7%	63.3	81.2%
River/Stream	134.7	1.2%	5.5	4.1%
Grand Total	11508.9	100.0%	1403.9	12.2%

Tall Secondary Forest

Habitat Description

This unit is characterized by a well-developed upper canopy structure, reaching heights of 10 to 20 m. The intermediate and lower canopy structures are also well represented. Access to the area is restricted to a single road and indicates road width suited for larger vehicles used in logging operations. Although it is evident that the natural progression in forest development has been interrupted by logging activities, it is also evident that natural recovery has taken place (Figure 25).

Although no old growth is present in this unit, remnants of the natural composition are present, with tree species such as the vulnerable *Lofiraalata*. Secondary forest growth indicators such as *Anthocleistanobilis, Anthocleistaprocera* and *Musangacecropioides* are dominant.

Figure 26: Tall Secondary Forest Habitat

Species Composition and Ecological State

Despite a relatively well-developed upper canopy structure with many natural forest species, a very high dominance of oil palm (*Elaeisguineensis*) indicates some degradation due to agriculture. Furthermore, active logging is still conducted with evidence of charcoal production. Alien plants species such as *Chromolaenaodorata* indicated continued disturbance and resource use. *Annex 7-F* lists the species identified.

The forest diversity is moderately high, and the presence of the protected *Lofiraalata* and *Terminaliaivorensis* indicates recovery after disturbance. However, the presence of *Ceibapentandra* and *Elaeisguineensis* remain as indicators of historic resource use. This unit is considered Natural Habitat in accordance with the IFC PS6 habitat classification data.

Short Secondary Forest

Habitat Description

Although this unit exhibits signs of historic utilization, and even current resource use, some semblance of the natural vegetation remains (Figure 26). Species composition is similar to the Tall Secondary Forest unit described above; however, the structure does not exceed 10 m in height. Logging is still practiced and charcoal production is evident. Remnants of Pine Forest plantations in some areas are also evident; however, only scattered individuals remained after harvesting.

Figure 27: Short Secondary Forest Habitat

Species Composition and Ecological State

Secondary growth is evident as is the presence of *Anthocleistanobilis, Anthocleistaprocera* and *Musangacecropioides* that is associated with secondary forest formations. The occasional presence of scattered individuals of *Lofiraalata* is considered a remnant of Primary Forest formations. However, oil palms (*Elaeisguineensis*) are now very prominent. The intermediate canopy is well developed with a dominance of *Alchorneacordifolia*, *Macarangaheterophylla* and *Zanthoxylumgilletii*. The lower canopy is dominated by *Combretum grandiflorum* and *Costusafer*.

The forest diversity is relatively high, and the presence of the protected *Lofiraalata* indicates moderate health despite disturbance of ecological functioning. This is especially evident in the *Pinusdensiflora* plantation that existed within this vegetation unit. This unit is considered Natural Habitat in accordance with the IFC PS6 habitat classification data.

Short Tertiary Forest

Habitat Description

This unit is relatively large and can be seen as an extension of subsistence farming outside the Low Tertiary Forest with Agriculture area. The vegetation is characterized by degraded forests with a structural height of between 5 to 10 m, and shifting cultivation practices. Lands are left fallow for a period of approximately 9 years before returning for another crop production. Due to this destructive practice, forest resources are decimated with little ecosystem functionality remaining (*Figure 7.32*).

Figure 28: Short Tertiary Forest Habitat

Species Composition and Ecological State

The tree component in the remaining forests is dominated by secondary growth and associated species such as *Anthocleistanobilis* and *Musangacecropioides* (*Annex 7-F*). The intermediate canopy structure is well developed and characterized by a dominance of *Alchorneacordifolia*, *Combretumgrandiflorum*, *Dichrostachysglomerata*, *Psychotriapenduncularis* and *Rauvolfiatetraphylla*. The lower canopy structure is also well developed with some alien or undesirable species associated with degraded areas. The grass layer is poorly developed in forested area, but more prevalent in the open cultivated areas.

This unit experiences high resource pressure as is evident by intensive logging operations and charcoal production. No protected tree species were encountered and it is presumed that these have been harvested. No other Red Data species were recorded in this unit. This unit is severely disturbed and the structure severely altered from its pristine state, and is thus considered Modified Habitat in accordance with the IFC PS6 habitat classification data.

Low Tertiary Forest/Agriculture

Habitat Description

This unit is located around the urbanized area and characterized by the virtual destruction of all forest ecosystem functionality by cultivation practices. The tree canopy seldom reaches 5 m in height and structure is more reminiscent of thicket formations, creating a fragmented mosaic within a predominantly cultivated area (Figure 28). Remnants of the natural forest vegetation are present as young trees and saplings.

Figure 29: Low Tertiary Forest Habitat

Species Composition and Ecological State

The tree or woody component is characterized by the dominance of the oil palm (*Elaeisguineensis*) and mango trees (*Mangiferaindica*), with scattered individuals of *Alchorneacordifolia*, *Dicrostachysglomerata,* the rubber tree (*Heveabrasiliensis*), *Nauclealatifolia* and *Psychotriapenduncularis* (*Annex 7-F*). Also prevalent is trifid weed (*Chromolaenaodorata*). Major crops of economic value importance rice (*Oryzasativa*), maize or corn (*Zea mays*), yam (*Dioscorea* Species), cassava (*Manihotutihissima*), ground nuts (*Arachishypogeae*), cow pea (*Vignaunguiculata*), cabbage (*Brassicaoleracea*), paw paw (*Caricapapaya*), banana (*Musa sapientum*) and avocado (*Perseaamericana*).

This unit is highly degraded with no Red Data species present and none expected. Due to active agriculture, the area is exposed severely degraded with a high prevalence of introduced alien plant species. Functional ecological processes are severely altered and thus considered to be Modified Habitat in accordance with the IFC PS6 habitat classification data.

Urbanized

Habitat Description

This unit is characterized by relatively high-density human settlement and associated infrastructure (Figure 29). The road network is poorly developed, degraded and of poor design. Water channeling and run-off control is virtually non-existent, resulting in surface erosion and gully formations.

Figure 30: Urbanized Habitat

Species Composition and Ecological State

Due to the dynamic nature of the surroundings, vegetation cover is very poor. Alien and undesirable plant species such as lantana (*Lantanacamara*) and trifid weed (*Chromalaenaodorata*) are most dominant (*Annex 7-F*). However, some alien trees such as Jack fruit (*Artocarpusheterophyllus*), mango (*Mangiferaindica*), cotton trees (*Ceibapentandra*) and calabash (*Crescentiacujete*) are also present.

No Red Data species are present and none are expected. This unit is totally transformed and thus considered to be a Modified Habitat according to the IFC PS6 habitat classification data.

Transformed/Mining

Habitat Description

The Bomi Hills Mine Concession is centered on an existing mining site that has been abandoned but now re-considered for exploitation. Although the impact of historic mining activities extends well beyond the old mining boundaries, the main impact area is restricted to the excavation pit and immediate surrounds (Figure 30). The excavated mining pit is now filled with water, creating an artificial habitat.

Due to a notable absence in reclamation measures applied after original mine closure, the area is badly scarified. Only fragments of the historic vegetation remain, with a dominance of alien plant species associated with degraded forest environments.

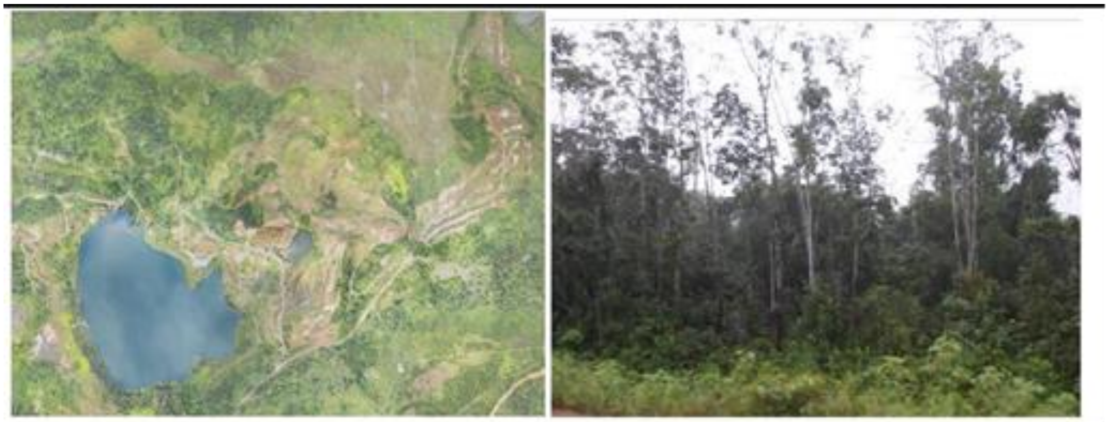

Figure 31: Transformed Habitat

Species Composition and Ecological State

The current vegetation on site is dominated by grass species such as *Hyparrheniadiplandra* and *Eragrostis* sp. and other relatively fast-growing woody species (*Annex 7-F*). However, relatively fast-growing tree species associated with secondary forest formations, such as *Anthocleistanobilis* and *Musangacercropioides* are germinating in pockets where suitable conditions exist. The dominance of alien plant species is an indication of severe habitat degradation.

No Red Data species were observed and no potentially suitable habitat was noted. This unit is totally transformed and thus considered to be a Modified Habitat according to the IFC PS6 habitat classification data.

Wetlands

Habitat Description

Although numerous drainage lines traverse the Bomi Hills Mine Concession, the formation of wetlands (Figure 30) are especially prevalent in the Low Tertiary Forested areas with Agriculture, but also found in the Short Tertiary Forest with shifting cultivation. This phenomenon can be attributed to obstructed water flow by manmade barriers such as raised roads and bridges. Furthermore, many of these areas are only waterlogged from May to October, where after they are cultivated. The natural vegetation is characterized by a unique set of plant species, with a gradual progression of unspecialized plant species merging with the surrounding vegetation unit. Due to the relatively small sizes of these units, they could not be mapped effectively. However, the locations of these wetlands are indicated on the vegetation map (Map 7-21, ERM 2013).

Figure 32: Wetland Habitat

Species Composition and Ecological State

The plant species that characterises wetlands in Liberia are *Lasimorphasenegalensis*, *Nymphaealotus*, *Clappertoniaficifolia* and the tree *Halleastipulosa* (*Annex 7-F*). The dominant tree species are the oil palm (*Eleaisguineensis*) and the raphia palm (*Raphiapalma-pinus*). The herbaceous layer is dominated by ferns, sedges and hydrophilic grass species.

No Red Data species has been recorded and due to the cultivation of rice in many of these wetlands, they are considered unsuitable as potential habitat. However, where these units are healthy ecological functional ecosystems, it is important that these be retained as a natural sump in filtering water run-off. These wetlands are considered natural habitat even though some seasonal rice cultivation is practiced.

Open Water

Habitat Description

This unit consists of open water, and although little vegetation is associated with this habitat it is an important resource to fauna, flora and humans. Furthermore, none of the above can function or survive without sufficient water. These open water areas (*Figure 7.37*) are associated with the disused mining pit and an area directly northeast of the old mine.

Figure 33: Open Water and River Habitat

Species Composition and Ecological State

Plant species from the surrounding vegetation units are often found along the periphery of the open water and will include the oil palm (*Eleaisguineensis*) and the raphia palm (*Raphiapalma-pinus*). Other plant species encountered (*Annex 7-F*) are *Clappertonia ficifolia*, *Panicum sp.* and *Cyperus sp.*

Although the open water area associated with the old mine is not highly productive it is considered an important resource for many faunal animals. However, based on the IFC PS6 habitat classification, these areas are modified environments.

River

Habitat Description

This unit forms a linear waterway, with a general north to south orientation. Although little vegetation is directly associated with water bodies the presence of surrounding vegetation units depends on this moisture regime. Furthermore, many plant species are opportunistic in their habitat requirements, where water requirements are one of the most important restrictions.

Species Composition and Ecological State

Species found along the embankment (*Annex 7-F*) are generally adapted to this very dynamic ecosystem that is prone to flooding and scarification. However, most of these plant species are opportunistic and can be considered incidental.

Based on the IFC PS6 habitat classification all riverine areas are classified as natural habitat.

7.5.3 Mapping

All of the described habitat types were mapped for the Bomi Hills Mine Concession (*Map 7-21, ERM 2013 report*).

7.5.4 Avifauna

Overview of Regional Taxonomic Richness

Approximately 251 bird species are expected to occur in the Bomi Hills Mine Concession (*Annex 7-F*) which equates to 41 percent of the approximate 615 species listed for Liberia[17]. Of the 251 species, 187 (75 percent) were confirmed and another 64 species are predicted to be present but were not observed during the surveys. Some of the species observed during the surveys undertaken in 2012 by ERM for the initial ESIA are presented in Figure 34 and described in Table 39.

Of the 251 bird species expected to be present, 103 (41 percent of potential occurrence) are restricted (endemic) to the Guinea-Congolian forest block (*Annex 7-F*). In other words, *c*. 56 percent of Guinea-Congolian forest endemics in Liberia could also be present in the Bomi Hills Mine Concession. Of these, 90 (49 percent) were confirmed in the Bomi Hills Mine Concession during the relevant surveys.

Table 38: Bird Identification Key to Figure

Photograph	Species Observed
A	Greyish Eagle-owl (Bubo cinerascens)
B	Village Weaver (Ploceus cucullatus)
C	Black-necked Weaver (Ploceus nigricollis)
D	Vieillot's Black Weaver (Ploceus nigerrimus)
E	Green-tailed Bristlebill (Bleda eximius) - a near-threatened species
F	Blue-throated Roller (Eurystomus gularis)
G	Velvet-mantled Drongo (Dicrurus modestus)
H	Capuchin Babbler (Phyllanthus atripennis)
I	Olive Sunbird (Cyanomitra olivacea)
J	Senegal Coucal (Centropus senegalensis)

[17] Robertson P (2001) Liberia. In Fishpool L D C, and Evans M I (Eds.) Important Bird Areas in Africa and associated islands: priority sites for conservation. Pisces Publications and BirdLife International, Newbury and Cambridge.

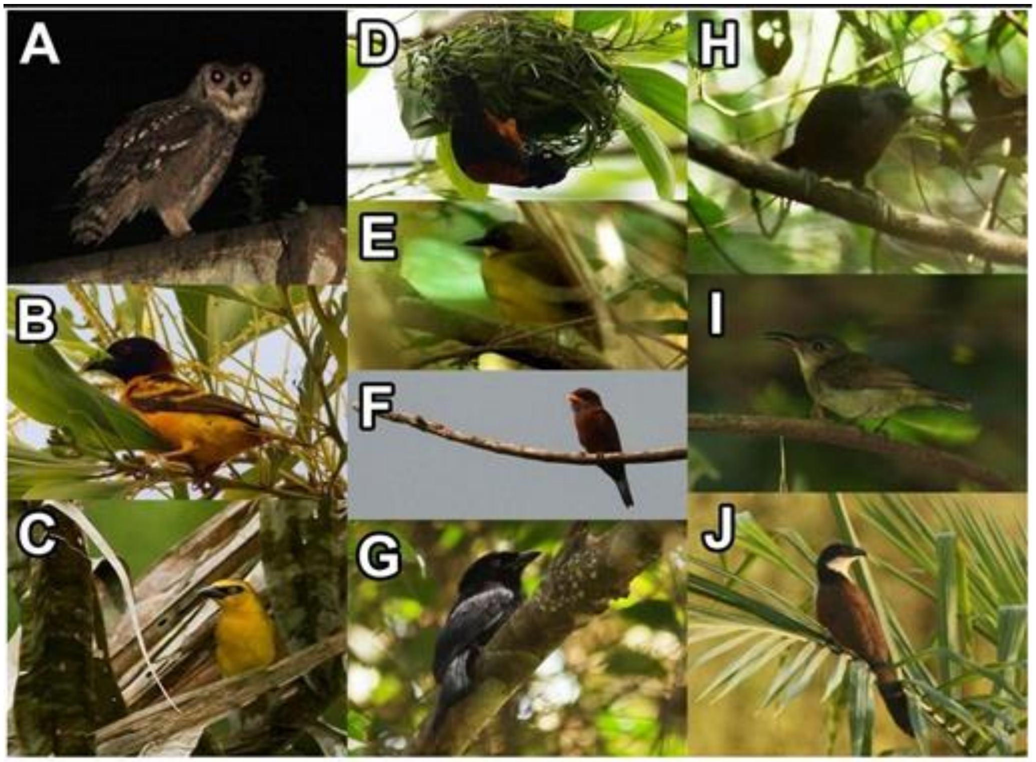

Figure 34: Photograp Avifauna observed during the study

Regional Dominance and Typical Species

The dominant bird species in the Bomi Hills Mine Concession are composed of forest species that reach high numerical values in secondary and degraded habitat types or along the edges of tall forest (*Annex 7-F*). The typical species in the Bomi Hills Mine Concession are the Little Greenbul (*Eurillas virens*), Yellow-whiskered Greenbul (*Eurillas latirostris*), Green Hylia (*Hylia prasina*) and Collared Sunbird (*Hedydipna collaris*).

The dominant bird composition in the mining concession consists of insectivorous and frugivore passerines which facilitate ecological processes such as pollination, seed dispersal and the maintenance of invertebrate prey numbers.

7.5.5 Herpetofauna

Comparatively low success in trapping and observations of herpetofauna was experienced during both wet and dry season surveys which was undertaken by ERM. The exception was a multitude of amphibian observations during the wet season, although these comprised of relatively few species (low diversity). Based on an extensive literature survey 102 reptile and 66 amphibian species were found to potentially to occur in habitats found in the mine concession. Of these only 7 reptile and 14 amphibian species were observed. A complete list of observed and expected reptiles is provided in Table 39 Similarly, the observed and expected amphibians are provided in Table 40. Photographic examples of some species observed during the surveys are shown for reptiles in Figure 35 and for amphibians in Figure 36. The precautionary principle was applied in the generation of these lists. Due to the lack of reliable geographic distribution information for herpetofauna, species listed as occurring in Liberian forested habitats were included in the expected species list. Therefore, the true number of herpetofauna species expected on the concession is expected to be slightly lower than that presented.

The low number of observed herpetofauna species is attributable to the degraded nature of the habitats within the mine concession. This area has been under anthropogenic pressure since the initial opening of the mine by LMC. No pristine habitats exist within the site and evidence of numerous current impacts are obvious and widespread. This constant pressure on the natural surroundings for timber, food (bushmeat and agriculture) and housing have created habitat conditions unsuitable for many species reliant on pristine primary forest. Direct mortality of snakes out of fear, superstition or for consumption, as well as from vehicle traffic have most likely contributed to the low density and diversity observed.

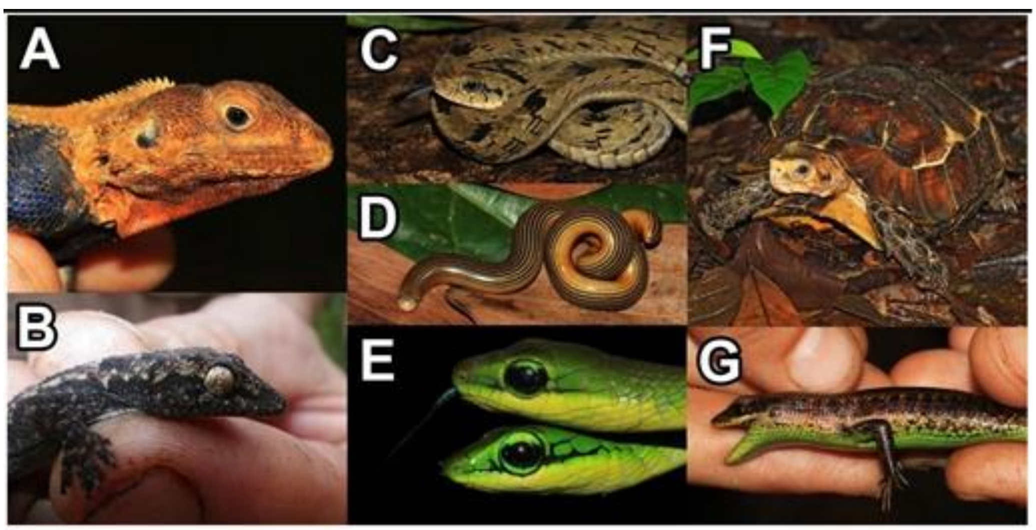

Figure 35: A collection of reptiles observed during the surveys of the Bomi Hills Mine Concession

Table 39: Key to Reptiles in Figure 36

Photograph	Description	Photograph	Description
A	Common Agama *Agama agama*	E	Emerald Snake *Hapsidophrys smaragdina*
B	Tropical House Gecko *Hemidactylus mabouia*	F	Forest Hinged Tortoise *Kinixys erosa*
C	Spotted Night Adder *Causus maculatus*	G	Western Forest Skink *Trachylepis paucisquamis*
D	Common Lined Worm Snake *Afrotyphlops lineolatus*		

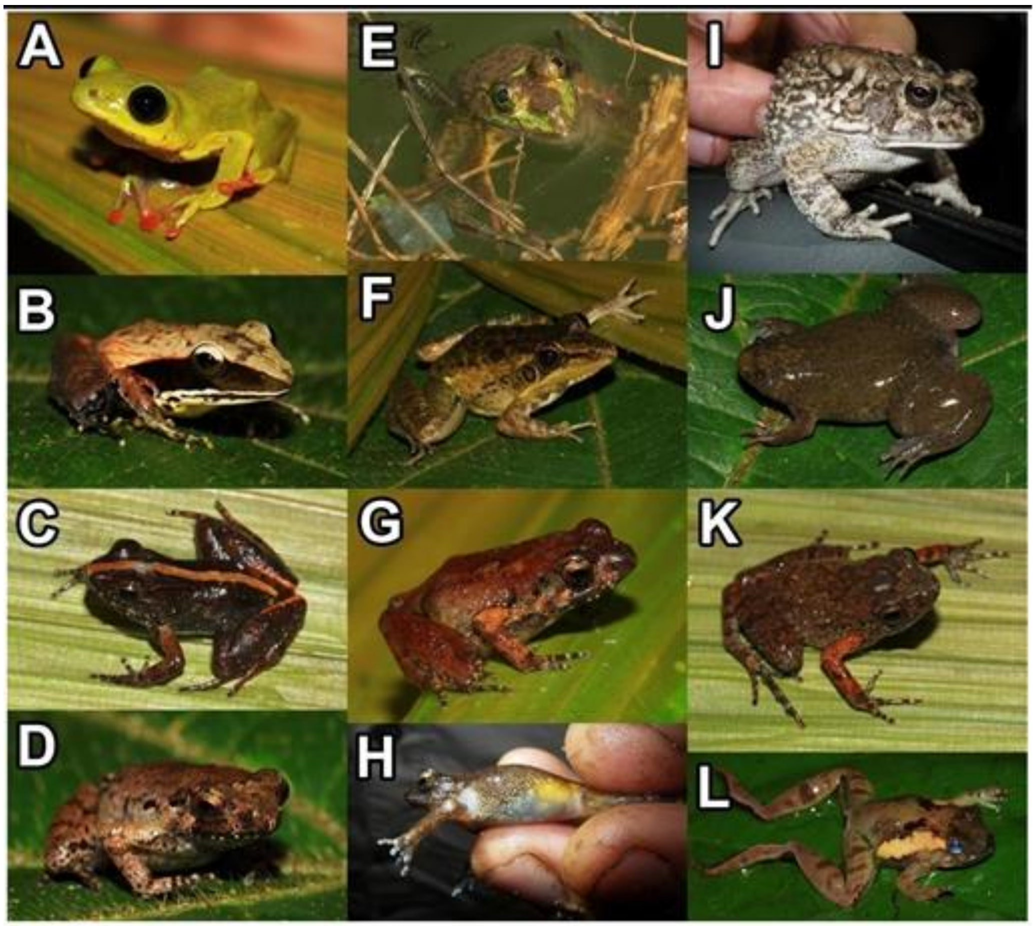

Figure 36: A collection of reptiles observed during the surveys of the Bomi Hills Mine Concession

Table 40: Key to Amphibians in Figure 37

Photograph	Description	Photograph	Description
A	Variable Reed Frog *Hyperolius concolor*	G	Screeching Frog *Arthroleptis sp.*
B	Snouted Grassland Frog *Ptychadena cf. longirostris*	H	Screeching Frog *Arthroleptis sp.*
C	Natal Dwarf Puddle Frog *Phrynobatrachus natalensis*	I	Egyptian Toad *Bufo regularis*
D	Buea Screeching Frog *Arthroleptis cf. variabilis*	J	Tropical Clawed Frog *Xenopus tropicalis*
E	Crowned Bullfrog *Hoplobatrachus occipitalis*	K	Screeching Frog *Arthroleptis sp.*
F	Broad-banded Grass Frog *Ptychadena bibroni*	L	River Frog *Phrynobatrachus sp.*

7.5.6 Mammals

Approximately 112 mammal species are expected to occur in the Bomi Hills Mine Concession (*Annex 7-F*), which equates to 62 percent of the approximate 180 species listed for Liberia (according to the IUCN, 2013). It must be stated that the expected species list used to calculate likelihood of occurrence for Liberia (and therefore the Bomi Hills Mine Concession) is reduced to 147, based on the elimination of species that have zero chance of occurring on site, such as whales, dolphins, manatees and species completely outside of their known distributions or habitat types. The relatively high number against which the likelihood ratings and sensitivities are based on the fact that Liberian mammal species, especially small mammal groups (shrews, rodents) and bats are under studied.

Twenty-three (23) mammal species were recorded within the Bomi Hills Mine Concession during both the wet and dry season surveys (ERM survey, 2013), representing 15.64 percent of the total number of (applicable) mammal species occurring in the region. The full list of mammal species acquired and list by habitat types identified on the study site is shown in *Annex 7-F*.

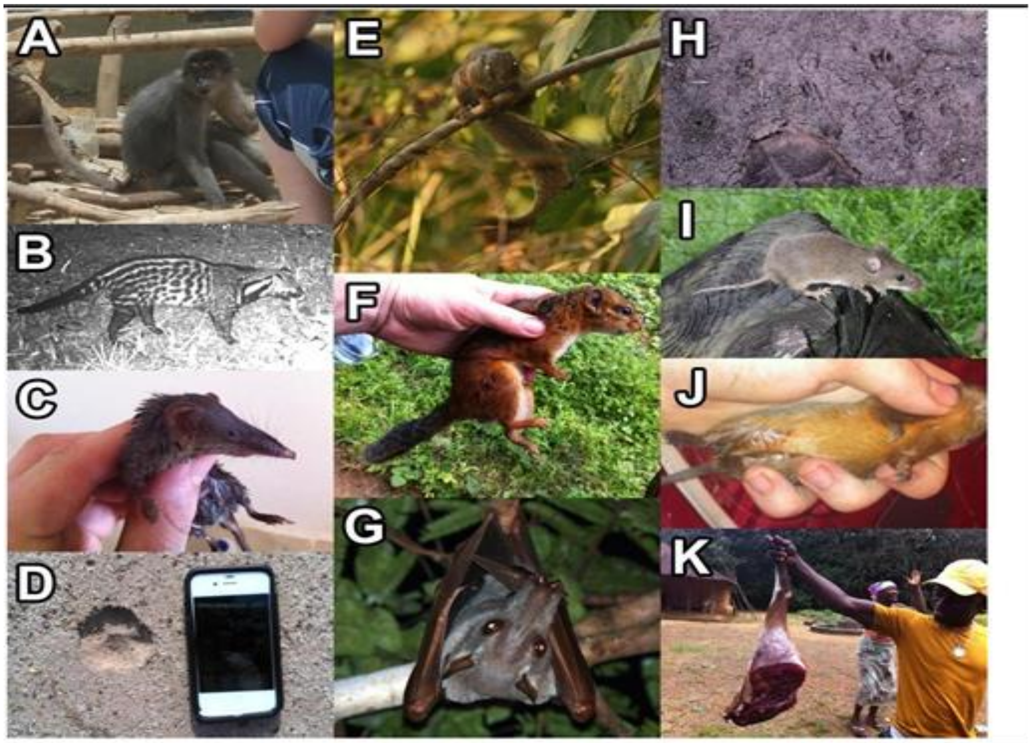

Figure 37: Mammals observed during the study

Table 41: *Key to the Mammals in Figure 37*

Photograph	Description	Photograph	Description
A	Sooty Mangabey *Cercocebus atys*	G	Hammer-head Fruit Bat *Hypsignathus monstrosus*
B	African Civet *Civettictis civetta*	H	Slender Mongoose *Galerella sanguinea*
C	Musk shrew *Crocidura olivieri*	I	Pygmy Mouse *Mus minutoides*
D	Large-spotted Genet *Genetta pardina*	J	Lophuromys sikapusi*Rusty Bellied Rat*
E	Slender-tailed squirrel *Epixerus ebii*	K	Bushbuck *Tragalephus scriptus*
F	Fire-footed rope squirrel *Funisciurus pyrrops*		

As mentioned above, the mammalian taxonomic group exhibits significant complexity due to vast differences in morphology, size, ecology and habitat preferences between families, orders, sub-orders, tribes (ungulates) and ecological categories[18]. Therefore, assessments such as sensitivity analysis for vegetation types must be assessed in detail for each mammalian category separately. The following provides a summary of each specific mammalian group found within the Bomi Hills Mine Concession hereafter referred to as mammalian categories.

Meso carnivores: These are medium sized carnivores occupying arboreal, terrestrial and aquatic niches. Relevant species include otters, tree civets, small to medium sized felids, larger mongooses, and large genets.

Small carnivores: Small carnivores are smaller predators found within arboreal and terrestrial niches. These species often weigh between 500 g and 3kg and are defined by their ecological roles as predators of smaller vertebrates, amphibians, reptiles, invertebrates, anthropogenic food sources and general forage.

Pangolins: These species from the Order PHOLIDOTA are specialist insectivores that occupy arboreal and terrestrial niches.

Primates: Relevant species in the Bomi Hills Mine Concession from this taxonomic group include vervet or green monkeys, dwarf galago, mangabey monkeys, Sykes' monkey and guenons.

Small mammals: The relevant species from these taxa include mammal species below 1 kg in mass. This includes most species of rodent, squirrels, lagomorphs, and shrews. Bats in the region are very under sampled and predictive analysis was used based on literature. Larger bats were identified through nocturnal surveys.

Large ungulates: Herbivores with a mass exceeding 50 kg are inherently rare in forest environments such as Liberia. However, this group is represented in the region by a number of species. The Bomi Hills Mine Concession shows extremely poor habitat potential, high levels of modification and unsustainable utilisation of bushmeat and the potential occurrence of large ungulates is very low. However, a bushbuck (*Tragalephus scriptus*) was killed adjacent to the Bomi Hills Mine Concession and brought into the markets for the purposes of consumption.

[18] Ecological category refers to the fact that animals of similar size or habitats are most likely sampled through similar techniques, despite the fact that they are not from the same Family or Order.

Small and medium sized ungulates: This group is represented by small ungulates (especially forest duikers) that occupy browsing niches in natural, semi natural and strongly vegetated areas. The mass of this group will not exceed 30 kg.

A number of categories are relevant to the region but were not recorded, nor are considered likely to occur within the Bomi Hills Mine Concession. Such categories may be eliminated from subsequent analysis. For the purposes of completion, the eliminated categories are defined as:

Hippopotamus species: Pygmy hippopotamus *Choeropsis liberiensis* (referred to in some texts as *Hexaprotodon liberiensis*) and common hippopotamus *Hippopotamus amphibius* are both present in the region but are extremely unlikely to occur within the Bomi Hills Mine Concession due to absence of suitable habitat.

Larger carnivores: The Bomi Hills Mine Concession is seen as highly modified and heavily populated. Although larger carnivores such as leopards have a tolerance for urban activity, the lack of prey availability, transformed environment and high hunting pressure represent near intolerable conditions for this group. On the whole, larger carnivores avoid heavily forested areas (Bothma and Walker 1999) and therefore, the Bomi Hills Mine Concession and surrounding areas represent sub-optimal habitat.

7.5.7 Invertebrates

The Upper Guinea Forest, referring to the area in Africa west of the Dahomey Gap, contains approximately 1 050 butterfly species, which represent 25 percent of the total Afrotropical richness (Klop *et al*., 2008). Although the total number of species in Liberia is unknown, it is probably estimated to be close or even more than the 750 species that occur in neighboring Sierra Leone. The majority of these species are all forest associates with a limited number also represented by savannah species.

It is predicted that the latter species will be common in the disturbed habitat types while typical forest-interior species are expected to be rare and restricted to the Tall and Short Secondary Forests. Therefore, the highest diversity of forest species is expected in the Tall and Short Forest habitat, followed by moderate diversities in the Short and Low Degraded Forests. The remaining habitat types are expected to host high numbers of forest-edge species, including savannah generalists.

During the 2013 survey conducted by ERM 24 species was observed (Table 42and Figure 38). This list describes the common and eurotropic (widespread) forest species that are prevalent in the secondary forest habitat.

The results showed that the diurnal butterfly community in the Bomi Hills Mine Concession was dominated by the Nymphalidae ("brush-footed" butterflies), representing 14 species, followed by three species of Lycaenidae (blues) and four species Papilionidae (swallowtails and swordtails), while the Pieridae (whites) consisted of one species. The majority of the Nymphalidae were restricted to forest edges. However, the genera *Euphaedra, Bebearia, Papilio* and *Graphium* are forest-interior species while the Lycaenidae and the genus *Bicyclus* were cosmopolitan and widely distributed along the edges of forest clearings, while the genus *Eurema* were indicators of the forest disturbance.

Table 42:

Photograph	Species
A	*Charaxes etheocles*
B	*Cerautola ceraunia*
C	*Bicyclus dubia*
D	*Neptis sp. nr. N. morosa*
E	*Acraea camaena*
F	*Bebearia abesa*
G	*Iolaus cf. iulus*
H	*Hypolycaena liara*
I	*Anthene lachares*
J	*Bicyclus dorothea*
K	*Cymothoe jodutta*
L	*Hypolimnas anthedon*
M	*Pyrrochalcia iphis*

7.5.8 Species of Conservation Concern

An overview of the taxon specific summary statistics of species of conservation importance that are likely to occur within the Bomi Hills Mine Concession are listed in Table 44.

Table 43: Species of Conservation Importance

Taxonomic Group	*Conservation Important Species*		*National*	*Global (IUCN)*			*Endemics*	
	Observed	***Potential Presence***	***Protected***	***NT / DD***	***VU***	***EN***	***Liberia***	***Upper Guinea Forests***
Flora	**4**	**121**	**46**	**70**	**4**	**1**	**103**	**469**
Fauna								
Mammals	6	22	7	16	3	1	0	2
Avifauna	32	38	36	2	-	-	-	3
Reptiles	1	7	5	4	3	-	1	13

Amphibians	2	21	-	18	1	2	-	32
Invertebrates	-	1	-	1	-	-	Unknown	Unknown
TOTAL	**41**	**89**	**48**	**41**	**7**	**3**	**1**	**50**

"Potential presence" is taken to mean the total number of within the concession

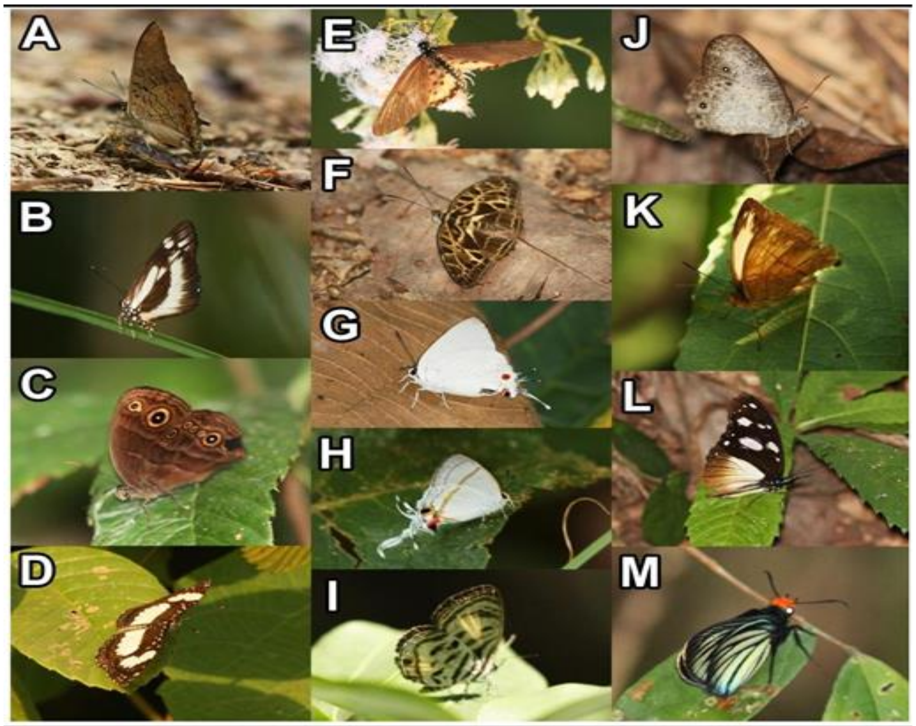

Figure 38: Photographic evidence of butterfly species observed during the dry season survey (ERM, 2012)

IUCN Relevant Definitions

- Home range: The entire (statistically quantifiable) area utilized (over time) by a species, in order to fulfill all resource needs (breeding, food, social structures, space).
- Migration: the regular and predictable movement of animals from one area to another, as driven by ecological factors (seasonality, food requirements, breeding).
- Circumstantial evidence: Any evidence not gathered from eye witness accounts.

The combined list of IUCN globally and Liberian threatened species, their Red Data status, habitat requirements, as well as the probability of occurrence in the Bomi Hills Mine Concession is discussed for each taxon below.

The Red-Data categories have been defined by the IUCN as:

- Critically Endangered (CR) - refers to species facing immediate threat of extinction in the wild.
- Endangered (EN) - Species facing a very high risk of extinction in the wild within the foreseeable future.
- Vulnerable (VU) - Species that face a high risk of extinction in the wild in the medium-term.
- Near Threatened (NT) - Species which do not qualify for higher categories but which are at risk of becoming Vulnerable or Endangered in the future, but currently are not threatened.
- Data Deficient (DD) - Species for which insufficient data is available for a proper assessment of conservation status to be made.

Flora

Only 75 plant species are currently classified based on the Red Data Species list criteria as promulgated by the IUCN. Of these plant species none are considered as “Critically endangered”, on “Endangered” *Tieghemellaheckelii*(-Cherry Mahogany), four (4) as “Vulnerable” *Lophiraalata*, *Khayaivorensis*(, *Turraeanthusafricanus* and *Miliciaregia*) and one (1) as *Irvingiagabonensis* “Near threatened”). These trees (are likely to occur in the North eastern section of the concession where there is no development planned for Project 1 Phase 1b. They are far less likely to occur in the area affected by Project 1 Phase 1b due to pre-existing anthropogenic impacts.

Important Timber Trees

Although 225 trees are known to be exploited as timber species, Jansen (1974)[19] identified 27 trees that are excessively logged in the timber industry. Of the Red List Species present in Liberia, only *Tieghemella heckelii* and *Lophira alata* are included on this timber list for Liberia, indicating that a shift in resource use is evidently driven by an increased demand.

Although many of these trees are not associated with primary old growth forest, a large number of these very large trees are considered indicative of pristine environmental conditions, undisturbed by human influence and exploitation.

Avifauna

Threatened and Near-threatened Bird Species

[19] Jansen J W A (1974) Timber Trees of Liberia. College of Agriculture and Forestry Project. University of Liberia.

Two globally near-threatened bird species (*Table 7.21*) were recorded in the Bomi Hills Mine Concession (IUCN, 2012). It was evident from the successional condition of the respective habitat types that none are likely to sustain any globally threatened (e.g. Vulnerable or Endangered) species. Of the two near-threatened species recorded on the Bomi Hills Mine Concession, the Black-headed Rufous-warbler (*Bathmocercus cerviniventris*) is the only species that could potentially be affected by the proposed mining activities. The high habitat fidelity of this species to drainage lines and forest streams and its patchy distribution in the concession area increase the risk that these species could become displaced from the Bomi Hills Mine Concession. In addition, any loss of forest habitat within the upper catchment of suitable habitat will displace this species due to increased run-off and subsequent habitat alteration. The remaining species, namely the Green-tailed Bristlebill (*Bleda eximius*), occupies a small part of the Tall Secondary and Short Secondary Forest stands that coincide with the north-eastern section of the concession area. This area falls outside the intended mining plan and are therefore is at a lower risk.

Table 44: Near-threatened bird species with declining population trends observed in the Bomi Hills Mine Concession (ERM, 2012)

Species	**Common Name**	**IUCN Status**	**Threat**	**Status on Bomi Hills Mine Concession**	**Habitat**
Bleda eximius	Green-tailed Bristlebill	NT	Deforestation (logging)	Highly localized; a rare resident in the north-eastern secondary forests.	TSF (optimal), SSF (sub-optimal)
Species	Common Name	IUCN Status	Threat	Status on Bomi Hills Mine Concession	Habitat
Bathmocercus cerviniventris	Black-headed Rufous-warbler	NT	Deforestation leading to catchment damage	Highly localized. Probably more abundant owing to skulking behavior.	R (all forested streams)

Tall Secondary Forest (TSF), Short Secondary Forest (SSF), Wetlands (W). Near-threatened (NT)

Status of the Black-headed Rufous-warbler on the Bomi Hills Mine Concession:

Bathmocercus cerviniventris is known from only two observations pertaining to secondary forest bordering perennial drainage lines.

The Black-headed Rufous-warbler is an uncommon resident along sections of small lowland streams. It is likely to be more abundant in the mine concession owing to the availability of small overgrown forest streams and its tolerance to secondary and degraded forests.

Bathmocercus cerviniventris is threatened by deforestation activities leading to catchment alteration. Therefore, deforestation upstream of its preferred habitat could lead to increased run-off and the catastrophic flooding of its habitat. The quality of its habitat is best preserved by implementing appropriate buffers to all perennial forest streams, thereby minimizing the adverse effects (e.g. forest clearing) caused by the proposed mining activities.

Status of the Green-tailed Bristlebill on the Bomi Hills Mine Concession:

Bleda eximius is known from only one observation pertaining to secondary forest on the north-eastern parts of the Bomi Hills Mine Concession. It is considered uncommon to rare in the Tall Secondary and Short Secondary Forests.

The Green-tailed Bristlebill is considered as a rare, although widespread, resident of old growth secondary forests. The population is currently surviving in a forest fragment that is already isolated from the large intact Upper Guinea forests further north. It is unlikely that the proposed mining activities will have a detrimental impact on the resident population, although the presence of these activities could open access to the area and attract more humans which could lead to unsustainable logging of the remaining forests.

Herpetofauna

Twenty-eight (28) Red Data herpetofauna species (7 reptiles and 21 amphibians) could possibly occur within the Bomi Hills Mine Concession. Many species are data deficient (DD) with unknown population sizes and trends because of a poor sampling history in West Africa. Almost all of these species are threatened by deforestation (habitat loss), which is the major threat to herpetofauna in Africa. Only three species of international conservation concern were observed on the mine concession during the surveys.

None of the Red Data herpetofauna species observed are listed as Critically Endangered or Endangered. Expected species in these categories are highly unlikely to be resident within the mining concession and will most likely be associated with the rivers and the riparian habitat during dispersal events.

Nevertheless, it should be mentioned as a management recommendation that the Tall Secondary Forest and the River habitats be afforded a measure of protection in order to help maintain ecological functionality within the region.

Mammals

An overview of the Red Data species that are expected to occur on the Bomi Hills Mine Concession is shown in *Annex 7-F*. The following species of conservation concern require further detailed explanation.

Sooty Mangabey *Cercocebus atys* (IUCN Vulnerable)

The sooty or white-napped mangabey was not recorded in the wild during the study period. However, a specimen was observed in the Bomi Hills market, adjacent to the WCL main office building. Interviews with the owner stated that the animal was captured in the Bea Mountain area and that he intended to sell the animal for consumption at a later date, most probably in Monrovia. A permanent population of the species is highly unlikely to occur in the Bomi Hills Mine Concession.

African Golden Cat *Profelis aurata* (IUCN Near Threatened)

African golden cats are an extremely low-density species which occur in primary and secondary forest systems. A single spoor observation was obtained in the Tall Secondary Forest habitat, which represents some of the only suitable habitat for the species within the Bomi Hills Mine Concession.

White-Bellied Tree Pangolin *Manis tricuspis* (aka *Uramanis tricuspis*) (IUCN Near Threatened)

The pangolin found within the Bomi Hills Mine Concession (white-bellied tree pangolin) are highly sought after species frequently harvested by most of the communities within the region for the purposes of trade, traditional medicine or consumption. In comparison to other areas in the region, pangolin occurrence in markets was relatively infrequent and no captured specimens were recorded as having been harvested directly from the concession.

Invertebrates

According to the latest IUCN (2012) assessment, six (6) insect species (Class: Insecta) of conservation concern are known to occur in Liberia. Five of these are Odonate taxa (dragonflies and damselflies), while one is a forest butterfly species. According to the table in *Annex 7-F*, the only species with a moderate probability of occurrence on the Bomi Hills Mine Concession is *Papilio antimachus* (African Giant Swallowtail).

The highlighting of Data Deficient species and taxa in the present assessment is an application of the precautionary principle in light of the relative lack of reliable information on arthropods in Liberia.

African Giant Swallowtail (*Papilio antimachus*):

Papilio antimachus is the largest butterfly in Africa (*Figure 7.44*) where it inhabits the high canopy of intact forest (Gimenez Dixon, 1996)[20]. Although it is much rarer in the western part of its distribution range it is regarded as an irregular visitor to the Bomi Hills Mine Concession that will be utilizing the Tall Secondary Forest and the riverine forest along the Mahe River when dispersing between forests in the region. Nevertheless, the tall canopy structure of the riverine forest of the Mahe River provides potential suitable habitat for this species to occur.

Figure 39: The dorsal views of a male (left) and female (right) Papilio antimachus (images taken from Vande weghe, 2010; © G.R. Vande Waeghe).

7.5.9 Endemic Species

Flora

Liberia is an important botanical biodiversity hotspot, reaching from Sierra Leone in the north to the southwest coast that more than 2 450 different plant species have been recorded in Liberia, it must also

[20] Gimenez Dixon M (1996) Papilio antimachus. In: IUCN 2012. IUCN Red List of Threatened Species. Version 2012.1.

be accepted that large areas of this country are still relatively unexplored and many more plant species are yet to be discovered. Currently 469 plant species are considered endemic to Upper Guinea Forests, with 103 plant species that are endemic to Liberia; of which 46 of these are considered to be threatened. However, the list of endemic plant species is very dynamic and is updated frequently. Some important plant species include *Alsodeiopsisvillosa*, *Gilbertiodendronobliquum*, *Heckeldorajongkindii*, *Jollydoraarmandui*, *Tetraberliniatubmaniana*, *Dactyladeniaglobosa*, *Jasminumcuneatum*, *Pavettamicheliana* and *Pavettaplatycalyx*; and the near endemics *Cola angustifolia*, *Dactyladeniawhytei*, *Pseudoprosopissericea* and *Sericantheadamii*.

Avifauna

Three endemic bird species are expected to occur in the Bomi Hills Mine Concession. These species are restricted to the Upper Guinea forest block. However, it is evident that previous forest clearances caused by mining and current logging activities are responsible for the poor presence of avifaunal endemics. The Sharpe's Apalis (*Apalis sharpei*) are widespread and tolerant to a variety of forest habitat (from riverine forest to Short Degraded Forest). The Green-tailed Bristlebill (*Bleda eximius*) and the Black-headed Rufous-warbler (*Bathmocercus cerviniventris*) are highly localized and restricted to the Secondary Forests and Riverine Forest respectively.

Herpetofauna

The Upper Guinea forest (UGF) has a rich diversity of herpetofauna which are restricted to this forest. 32 amphibian and 13 reptile species endemic to the UGF may be found on the mine concession. As mentioned above, several species are unlikely to be permanently resident within the concession area. Liberia has only one endemic herpetofauna species, the Liberia worm snake (*Letheobia leucostictus*).

Mammals

Two UGF endemic species recorded on the site were the western cussimanse (*Crossarchus obscurus*) and the slender-tailed squirrel *(Epixerus ebii*). The cussimanse is a highly fecund, synanthropic small carnivore which is not of conservation concern. Although being a habitat specific resident, the slender-tailed squirrel is a fairly common secondary forest resident in the area. It must be stated that the low predicted list for the endemics can be explained by the fact that (i) few Upper Guinea endemics occur in the Bomi Hills Mine Concession region and (ii), the Bomi Hills Mine Concession shows almost no suitable habitat type for the Upper Guinea endemics that are found in abundance, adjacent to the site. Such species include the West African chimpanzee *(Pan trolodytes versus*) and pygmy hippopotamus (*Choeropsis liberiensis)*.

Invertebrates

Approximately 13 percent of all the butterfly species in West Africa are endemic to the UGF region (Klop *et al*., 2008)[21]. There are two areas of butterfly speciation within the UGF block, of which one is centered in Liberia, SierraLeone and western Côte d'Ivoire (known as the Liberian Subregion) with 113 butterfly species that are endemic to it. Of the 113 endemic species, 70 are widespread in West Africa while a further 32 are restricted to the Liberian Subregion, for example *Cymothoe hartigi.*

7.5.10 Nationally Protected Species

Flora

A schedule of 65 tree species for which utilization is restricted is provided by the Forestry Development Authority (FDA). Only two (2) species listed on the FDA schedule were identified in the Bomi Hills Mine Concession (*Ceiba pentandra* and *Lophira alata)*. Both of these protected species were identified in the Tall Secondary and Short Secondary Forests.

Avifauna

The FDA of Liberia has compiled a schedule of bird species that are protected in Liberia. The schedule strives to control and regulate the exploitation of these species to prevent overutilization. A total of 36 protected bird species are expected to occur in the Bomi Hills Mine Concession, consisting of two (2) anatids (ducks), three (3) francolins, the osprey, 13 accipitrinid birds of prey, one (1) falcon, three (3) turacos, four (4) hornbills and nine (9) weavers (including the malimbies).

Herpetofauna

The FDA lists only five (5) reptile species as protected, all of which are expected to occur within the Bomi Mining concession (*Crocodylus niloticus; Mecistops cataphractus; Osteolaemus tetraspis, Python regius* and *Python sebae*). No amphibian species are protected.

Mammals

The Liberian conservation authority that is responsible for listing the nationally protected mammal species is known as the FDA. These species are not necessarily driven by IUCN or CITES assessments but take into account national interests, protected areas and sustainable wildlife management. The relevant legislation

[21] Klop E, Lindsell J & Siaka A (2008). Biodiversity of Gola Forest, Sierra Leone. A survey of Gola's mammals, birds, butterflies, dragonflies & damselflies, trees & non-woody plants and forest structure.

is known as the National Protected Forest Areas Network in accordance with Chapter 9 Section 1 of the National Forestry Law of 2006. However, this legislation is currently under review and is constantly changing in accordance with increases in national development and increased political stability. The only nationally protected species which does not fall under the areas of conservation concern (Upper Guinea endemic/IUCN Red Data) was the Demidoff's *Galagoides* Dwarf *demidovii* Galago). This species is a common arboreal small primate which is not of conservation concern, and is fairly abundant within the Bomi Hills Mine Concession.

Invertebrates

Approximately 13 percent of all the butterfly species in West Africa are endemic to the UGF region (Klop *et al*., 2008). There are two areas of butterfly speciation within the UGF block, of which one (1) is centered in Liberia, Sierra Leone and western Côte d'Ivoire. It forms a distinct speciation center (known as the Liberian Subregion) with 113 butterfly species that are endemic to it. Of the 113 endemic species, 70 are widespread in West Africa while a further 32 are restricted to the Liberian Subregion, for example *Cymothoe hartigi.*

7.5.11 Sensitivity Analysis

Flora

It is evident from the analysis that the Tall Secondary Forest and Short Secondary Forest has high potential for sustaining Red Data species; however, the score is moderated by the presence of alien invaders, diversity and connectivity. The Short-Degraded Forest with shifting cultivation has a similar trend, but a higher prevalence of alien invader plant species, resulting in a slightly lower sensitivity score. All three units mentioned are considered of Moderate Sensitivity (Table 46).

The Low Degraded Forest with agriculture, the area Transformed by Mining and the Urbanized unit shows Low Sensitivity. This trend can be attributed to low habitat diversity, high alien infestations and poor connectivity.

The Wetlands and Open Water units are inherently low in species diversity, but high in ecosystem functionality; and although both units are classified as Moderately sensitive, its impact on other functions necessitates protection of these resources.

Table 45: Flora Sensitivity Analysis

Habitat	Suitability	Sensitivity	Status	Diversity	Connectivity	Significance score
Tall Secondary Forest	4	3	3	3	3	16
Short Secondary Forest	4	3	3	3	4	17
Short Degraded Forest	3	2	2	3	3	13
Low Degraded Forest/Agriculture	3	2	2	1	2	10
Urbanized Transformed/	1	1	1	1	1	5
Mining	2	1	1	1	1	6
Open Water	1	4	2	1	3	11
Wetland	2	4	2	1	4	13
River	2	4	3	2	4	15

Significance Score	
5 to 10	Low sensitivity
11 to 20	Moderate sensitivity
21 to 25	High sensitivity

Avifauna

The Tall Secondary Forests, Wetlands and the river and drainage lines were identified with high avifaunal sensitivities.

The Short Secondary Forest and Open Water habitat comprising of old tailings facilities were identified with moderate avifaunal sensitivities.

The Short-Degraded Forest, Low Degraded Forest/Agriculture, Transformed/Mining and Urbanized habitat were identified with low avifaunal sensitivities.

The outcome of the avifaunal sensitivity analysis is summarized in Table 47.

Table 46: A summary of the bird species richness and the number of species of conservation concern for each habitat type on the Bomi Hills Mine Concession

Habitat	Bird Species Diversity				Guinea-Congo Forest (%)	Avifaunal Sensitivity
	Observed richness	Predicted richness	Red Data species	Upper Guinea Forest		
Tall Secondary Forest	87	19	1	2	73%	High
Short Secondary Forest	100	16	1	2	67%	Moderate
Short Degraded Forest	93	15	0	1	49%	Low

Low Degraded Forest/Agriculture	56	10	0	0	13%	Low
Transformed/Mining	41	13	0	0	4%	Low
Urbanized	11	1	0	0	1%	Low
Wetland	38	26	0	0	8%	High

Habitat	Bird Species Diversity				Guinea-Congo Forest (%)	Avifaunal Sensitivity
	Observe richness	Predicted richness	Red Data species	Upper Guinea Forest		
Open Water	26	17	0	0	2%	Moderate
River/Stream	81	20	1	1	39%	High

Herpetofauna

Habitats of importance for fauna are almost always those that are limited or rare in the landscape and those that are linear in nature and aid with dispersal and migration. For herpetofauna (which are particularly poor dispersers), the latter habitat type is crucial. As mentioned above, rivers and streams serve to channel herpetofauna through the landscape and promote connectivity between distant habitat types. Moreover, rivers occupy a limited area in the landscape and therefore are inherently sensitive.

Despite the long-term anthropogenic disturbance in the concession, the Tall Secondary Forest and Short Secondary Forest habitat types provide habitat potential for a great diversity of herpetofauna species, many of which are Red Data species. The fact that these habitat types are rare in the landscape due to habitat degradation increases their conservation value.

The Short-Degraded Forest and Wetland habitat types fulfill important ecological roles of 1) connectivity and 2) provision of habitat for amphibians serving as a lower tier on the food chain. This habitat is therefore assigned a moderate sensitivity.

All other habitat types found on the mine concession represent poor herpetofauna habitat due to their degraded or disturbed nature. An overview of the herpetofaunal habitat sensitivity is provided in Table 48.

Table 47: A summary of the amphibian and reptile species richness, the number of species of conservation concern and the habitat sensitivity for each habitat type on the Bomi Hills Mine Concession.

	Amphibian species			Reptile species			
Habitat	**O**	**P**	**RD**	**O**	**P**	**RD**	**Herpetofaunal Sensitivity**
Tall Secondary Forest	2	50	18	0	91	5	High
Short Secondary Forest	8	49	16	2	91	5	High
Short Degraded Forest	9	27	4	5	88	3	Moderate
Low Degraded Forest/Agriculture	7	20	1	3	50	1	Low
Urbanized	5	8	0	3	7	0	Low
Transformed/Mining	9	11	0	4	17	0	Low
Open Water	6	9	0	0	14	0	Low
Wetland	8	28	4	1	49	2	Moderate
River/Stream	3	33	9	4	101	7	High

Observed (O), Predicted (P), Red Data (RD))

Mammals

Overall, the Bomi Hills Mine Concession exhibits a very low sensitivity. This is perhaps due to the strong current impacts from local communities in what is essentially, a highly modified area. The only habitat exceptions are the Tall and Short Secondary Forest habitat which not only show higher observed species, but also a higher number of potential species occurring within the Bomi Hills Mine Concession. Finally, the River habitat shows a high expected value, due to its intact habitat integrity and functionality as a corridor system. However, the observed number of species is slightly lower, due to the limitation of access during the wet-season survey as well as the limited time available for the Bomi Hills study.

An important determinant of the habitat sensitivity in the Bomi Hills Mine Concession is the habitat integrity of the concession as well as connectivity to surrounding areas of optimal mammalian habitat. The Bomi Hills Mine Concession is strongly connected to regional forests to the north (of the eastern block of the concession). Therefore, it is vital to understand that although the Bomi Hills Mine Concession area exhibits high levels of current disturbance, habitat of important mammalian integrity still connects to the concession and therefore requires prevention and mitigation of potential future impacts.

The outcome of the mammal sensitivity analysis is summarized in Table 48.

Table 48: A summary of the mammal species richness and the number of species of conservation concern for each habitat type on the Bomi Hills Mine Concession

	Mammalian species				Sensitivity
Habitat	**Observed**	**Predicted**	**Possible Red Data**	**Recorded Red Data**	
Tall Secondary Forest	12	89	18	1	High
Short Secondary Forest	13	90	32	1	High
Short Degraded Forest	5	96	21	2	Moderate
Low Degraded Forest/Agriculture	7	56	17	1	Low
Urban	4	50	7	0	Low
Open Water	2	23	4	0	Low
Transformed/Mining	3	50	8	0	Low
Wetland	2	49	4	0	Moderate
River	5	94	34	1	High

Summary

A combined output of the sensitivity ratings for each habitat type is desired to illustrate the overall ecological sensitivity of the Bomi Hills Mine Concession.

This was achieved but applying a numerical value to each of the sensitivity classes where Low sensitivity =1, Moderate sensitivity = 2 and High sensitivity = 3. Summation of the sensitivity scores across the floral and faunal categories could therefore produce habitat scores between 4 and 12, representing a spread of 9 different possible outcomes. Scores of sensitivities were divided equally between the spread as follows:

- Low sensitivity = 4-6
- Moderate sensitivity = 7-9
- High sensitivity = 10-12

This summative approach assigns equal weight to each of the individual sensitivity evaluations and the equal spread of sensitivity classes removes bias from the interpretation. The results of this combined sensitivity analysis are shown in *Map 7-22* and it is clearly visible that the mine infrastructure placement is predominantly on low sensitivity habitat. Very little of the sensitive habitat is therefore likely to be directly influenced by infrastructure development.

7.5.12 Ecological Overview

Current Impacts

Bushmeat

Utilization of bushmeat represents one of the main existing environmental pressures to almost all the faunal assemblages within the Bomi Hills Mine Concession and indeed much of sub-Saharan Africa. As the main direct impact on biodiversity within the concession, bushmeat in Liberia has historically been an integral part of obtaining protein resources in the country. In addition, Liberia generated more than $ 42 million in revenue from the trade in bush meat, pre-civil war (Anstey 1991)[22]. Post-war, this figure has reduced in numeric value but is said to have increased in overall volume due to the reduction in protein availability. Demand has also increased in urban areas where protein availability has decreased, which has served to shift much of the market from subsistence or trade utilization to a more commercial approach (Hoyt 2004)[23]. This equates to a marked increase in hunting pressure on vertebrate biodiversity. Assessments of the extent and impacts of bushmeat utilization is often difficult, although estimates in Central and West Africa suggest that annual use may be up to 5 million tons (Davies 2002)[24].

During both the scoping study and the detailed survey, numerous incidences of subsistence hunting were observed within the concession area and the surrounding region. In addition, lack of government resources and elements of corruption have dramatically reduced the ability of local authorities to enforce local legislation. For the purposes of this study, hunters and animal collectors were interviewed to obtain reliable data on the bushmeat trade. It must be stressed that in no way was the search for subsistence hunting incidences or long-term patterns of use used to encourage such activities. Candidates for the study were briefed that deliberate harvesting for the purposes of the study will not be met with financial reward and is prohibited. Instead, candidates were subjected to a series of interviews as well as requested to assist in identifying locations of major regional trade centers.

The following summarizes the outcomes of the study undertaken:

- Extensive subsistence utilization of mammals by local communities takes place throughout the concession area and the region as a whole. However, the Bomi Hills Mine Concession is a relatively poor source of utilizable species, and much of the actual harvests are obtained from surrounding areas.

[22] Anstey S (1991) Wildlife Utilisation in Liberia. World Wildlife Fund and Liberian Forestry Department Authority, Gland, Switzerland

[23] Hoyt R (2004) Wild Meat Harvest and Trade in Liberia. Managing Biodiversity, Economic and Social Impacts, ODI Policy Briefing Number 6

[24] Davies G (2002) Bushmeat and International Development. Conservation Biology 16 (3).

- Larger antelope species, primarily bushbuck, black duiker and red-river hogs are mostly absent in the Bomi Hills Mine Concession. Small forest ungulates and primates were also targeted but are very scarce within the concession.
- All the local communities interviewed utilize small mammals as a staple food source. Methods of acquisition vary slightly between communities but encompass burning of the basal layer in order to isolate mice inside burrows, which are then dug out of the burrow systems. A point of interest was that as larger faunal species were largely absent from the Bomi Hills Mine Concession, even small arboreal species such as squirrels were heavily targeted.
- Significant conflict exists between local communities and mammalian crop pests such as brush tailed porcupines, rats and marsh cane rats. These species are heavily targeted for the bushmeat trade and the use of illegal capture techniques (snares and spring traps) are the primary method of hunting.
- Reptiles were not observed as being consumed on a regular basis.
- Birds are targeted by many local community members. Species are selected based on size and no regard is given to rarity or protected status.
- The cost of the bushmeat found in both markets and urban areas was strongly correlated to the end user of the product. However, unlike other regional studies, the Bomi Hills Mine Concession seemed to be a focal point for bushmeat distribution to Monrovia.
- Finally, the interview with members of the FDA revealed many of the limitations in regards to the bushmeat situation in Liberia. Although the mandate strictly states that authorities must strive to enforce the ban on utilization of protected species, as well as regulate the methods by which all species are acquired, it is apparent that resources to aid enforcement are almost non-existent. Solutions proposed by the FDA regarding the challenges facing the bushmeat trade in Liberia centers around increased funding, increased use of NGO's and cons increased education as to legislation as well as provision of alternative protein sources for the country as a whole.

One of the key components in the bushmeat issue is the utilization of protected species. According to Hoyt (2004) it is now estimated that prohibited or fully protected wildlife species account for approximately 35 percent of bushmeat sales. Partially protected species (in accordance with national legislation developed by the FDA) account for a further 40-50 percent of bushmeat use. Of the recorded harvested animals in the overall Bomi Hills Mine Concession and area of influence, 14 different harvested species (or general groups of species) were recorded. Of these, 7 species were either nationally protected or listed by the

IUCN. This represents 10.99 percent of all the harvested species, which is lower than expected from the known literature.

It must be noted that in no way has the research on subsistence hunting incidences or long-term patterns of use encouraged such activities. This is stipulated in the Western Cluster Bushmeat Policy developed by Peter Buckley.

Other Current Impacts

Several current impacts within the Bomi Hills Mine Concession were observed during the scoping survey. These impacts negatively affect flora and fauna species, especially in combination with each other. These are:

- Shifting/Slash and burn agriculture - the common practice of felling tracts of vegetation which is subsequently left for a period of time to dry and then burned. The high agricultural yields for razed tracts of land will only last between two and three growing seasons, causing further clearances of vegetation and a repeat of this cycle. The cleared portions of land shift to a pioneer succession stage which is characterized by high disturbance levels and greater susceptibility to colonisation from alien/invasive species.
- Destruction of sensitive natural vegetation by mining practices. This equates to a loss of floral and faunal habitat and creates large degrees of fragmentation.
- Open trenches/pits capable of trapping animals - Bomi Hills Mine Concession provides habitat for assemblages of small animals (such as rodents, amphibians and reptiles) which may be trapped in open trenches and pits. Such impacts will increase during the construction phase of the mine.
- Vehicle traffic - vehicle traffic within the concession area is high, even in areas where the vegetation was considered to be natural. This may serve to displace many vertebrate species from the area due to the effects of collisions, noise and the fact that vehicles provide significant access for hunters to operate over a wider area.
- Uncontrolled charcoal production - many local inhabitants generate income through charcoal production and also utilize the product on a subsistence basis, for cooking fires (Figure 40).
- Logging/timber production - tree loggers preferentially select certain hardwood species which are felled and then cut into planks to be used for building material and furniture (Figure 40). This process removes natural habitat and opens up access paths for charcoal producers and hunters which cause further impacts.

- Water pollution of streams/water courses and wetlands - local inhabitants appear uneducated regarding practises to maintain clean streams for safe water consumption. Many streams are utilized simultaneously for bathing, washing of clothes, cars and motorbikes (Figure 40), defecation and urination. Pollution and eutrophication of streams and other watercourses can lead to major changes in the composition of fauna and in severe cases can cause localized extinctions.
- Livestock - only sheep and goats were observed and relatively infrequently (Figure 40), however, local livestock farming represents a significant potential impact on fauna nonetheless, as poor grazing practices can lead to the loss of habitat utilized by fauna. Sheep and goat feeding is characterized by strong, non-discriminate grazing practices and also creates high trampling effects, which can severely impact both vegetation successional recovery (from previous disturbance) as well as sensitive wetlands.
- Exploration Roads - roads that have been opened and improved for mining exploration or drilling purposes allow access to areas that would otherwise be extremely inaccessible. This allows local communities and commercial companies to access more natural areas and cut down trees, engage in subsistence agriculture and hunt for bushmeat that would otherwise not be exposed to hunting pressure.

7.5.13 Protected Areas

Protected and Key Biodiversity Areas

An analysis of forest systems in Africa and Madagascar conducted by Burgess *et al.* (2006)[25] found that Liberia rated as globally outstanding for biological distinctiveness. This analysis took into account country-wide estimates of species richness, degree of endemism, migrations, biodiversity threats and levels of fragmentations. The outcome of this analysis placed Liberia into the highest conservation priority class, partly because there is currently a lack of biodiversity protection in Liberia. Roughly 21 percent of Liberian land is demarcated as nationally protected, while 54 percent is considered to belong to key biodiversity areas (*Map 7-23*; Christie *et al.* 2007[26]; Conservation International 2007[27]; Kouame *et al.* 2012[28]). Only 8

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[25] Burgess N D, saD'Amico J,Ricketts, TH and Hale Dinersteina, E (2006) Factoring species, non-species values and threats into biodiversity prioritisation across the ecoregions of Africa and its islands Biological Conservation. 127: 383–401.

[26] Christie T, Steininger M K, Juhn, D and Peal A (2007) Fragmentation and clearance of Liberia's forests during. 1986-2000 Oryx 41: 539-543.

[27] Conservation international (2012) http://www.conservation.org

[28] Kouame O M L, Jengre N, Kobele M, Knox D, Ahon D B, Gbondo J, Gamys J, Egnankou W, Siaffa D, Okoni-Williams, A and Saliou, M (2012) Key Biodiversity Areas identification in the Upper Guinea forest biodiversity hotspot. Journal of Threatened Taxa 4(8): 274

Figure 40: Photographic evidence of current impacts encountered during the surveys on the Bomi Hills Mine Concession (ERM, 2013)

percent of the key biodiversity areas are protected and only 3.5 percent of the land currently enjoys active conservation enforcement by the government, with this being restricted to the National Parks. Due to this inadequate protection of the rich national biodiversity, developments should attempt to minimize environmental impact and thereby ensure some measure of biodiversity protection.

Yomo National Forest (managed timber purposes) is situated ±4.5 km to the north of the Bomi Hills Mine Concession and is also the closest key biodiversity area. The mine concession is favourably situated for development in the regional context as it is not located within a protected area, a key biodiversity area and it is not situated within a remaining portion of the Upper Guinea Forest.

Endemic and Important Bird Areas

Information regarding the distribution and the diversity of bird species in Liberia is scant and incomplete. Gatter (1997)[29] provides the only exhaustive outline of Liberia's avifaunal richness which was compiled during 15 years of research between 1981 and 1997. However, the published work of Gatter (1997) is largely outdated and in dire need of revision, especially when considering the alarming rate at which Liberia's lowland forests are deforested (mainly logging and agriculture).

Although Liberia is known to support to more than 615 bird species, it has only one true endemic namely the Liberian Greenbul (*Phyllastrephus leucolepis*) (Robertson, 2001)[30]. Nevertheless, Liberia lies entirely within the Guinea-Congo Forest biome of Central and West Africa (see Vande Weghe, 2004)[31], with 184 species (Table 49) restricted to this biome. Fifteen (15) of these species are restricted to the Upper Guinea Forest Endemic Bird Area (EBA 084), which highlights the Upper Guinea Forests as an important conservation entity. It covers approximately 40 percent of Liberia and nearly 43 percent of the remaining intact Upper Guinea Forest in West Africa. Nearly all of the high Upper Guinea forest that once covered a large part of the Bomi Hills Mine Concession was lost due to post-mining and human activities (e.g. logging, agriculture and exotic plantations) with only a small area in the north-east of the concession area persisting as secondary forests.

Table 49: Important bird families showing high species diversities restricted to the Guinea-Congolian forest biome in Liberia

Family	Common Name	Number of taxa
Bucerotidae	Hornbills	9
Lybiidae	African Barbets and Tinkerbirds	8
Pycnonotidae	Bulbuls, Greenbuls and Bristlebills	19
Muscicapidae	Old World Flycatchers & chats	16
Nectariniidae	Sunbirds	12
Ploceidae	Weavers and Malimbies	10

According to Robertson (2001), there are nine Important Bird Areas (IBAs) in Liberia with a combined surface area of *c*. 5 806 km^2. The only IBA that is formally protected is the Sapo National Park (LR008), while the remaining IBAs are either unprotected or they coincide with National Forests. The Bomi Hills Mine Concession does not overlap with any IBA. The nearest IBA to the Bomi Hills Mine Concession is Cape Mount (LR005 - *c*. 46 km south-west) and Lofa-Mano (LR003 - *c*. 82 km north-east) (*Map 7-23*).

[29] Gatter W (1997) Birds of Liberia. Sussex UK, Pica Press.

[30] Robertson P (2001) Liberia. In Fishpool L D C, and Evans M I (Eds.) Important Bird Areas in Africa and associated islands: priority sites for conservation. Pisces Publications and BirdLife International, Newbury and Cambridge.

[31] Vande Weghe J M (2004) Forests of Central Africa: Nature and Man. Protea Book House, Pretoria, South Africa.

7. 6 Aquatic Ecology and Water Quality

The assessment has focused on the potential impacts of mining and processing activities during high flow and low flow.

Some limitations experienced during the collection and analysis of data for the aquatic assessment include:

- ✓ Some of the river sections were too deep and the current too strong to be considered safe when sampling during the high flow survey (wet season), and as a result only low flow data regarding aquatic ecology are available for these sites (B8 and B9);
- ✓ Habitat integrity techniques are subjective; and

7.6.1 Baseline Conditions

General Context

From an aquatic, surface water context it is important to note that the Bomi Hills proposed project site is a typical "brownfield" environment in the north-western section of the concession with the majority of the eastern portion of the concession currently less impacted upon.

The Concession area is drained by the Mahe River along with a number of seasonal streams. The seasonal streams and rivers flow in a number of directions that eventually lead southward to the Atlantic Ocean. Other surface water environments within the concession consist of large man-made lakes.

Baseline data surveys were undertaken to aid the understanding of the baseline aquatic conditions. Aquatic areas were primarily selected based on the position of the proposed activities, including upstream and downstream of proposed impacted areas. Sites were focused around the north-western part of the concession area where the majority of mine activities are to take place. The specific sites within these areas were selected based on the following:

- ➢ Habitat that was representative of the present aquatic resources;
- ➢ Accessibility and safety;
- ➢ Avoidance of sites representing alternative impacts that may influence the interpretation of results;
- ➢ Proximity to anthropogenic activities in the catchment; and
- ➢ Proximity to confluences.

The layout of aquatic sampling points is illustrated in *Map 7-27* and Table 50 below.

Table 50: Aquatic Sampling points from initial study by ERM in 2012

Site	River/ Tributary	Location	Reasons for Selection
River/Stream Sites			
B1	Unknown	N 6° 52. W 10° 50	Downstream of mining activities, next to the old railway
B2	Unknown	N 6° 54 W 10° 49	Downstream of mining activities
B4	Unknown	N 6° 52. W 10° 49	Site in Tubmanburg town, downstream of mine, perennial upstream sites for B1
B5	Unknown	N 6° 54. W 10° 51	Site downstream of mining activities, downstream of B4 next to the old railway
Lakes			
B3	-	N 6° 54. W 10° 48	Upper reaches of large lake upstream of mining activities, sampled for biodiversity
B6	Blue Lake	N 6° 53.9 W 10° 49	Disused Mine Pit filled with rain water, planning to be emptied when mining commences

Water Quality

A range of physico-chemical constituents making up the water chemical characteristic were measured, as anthropogenic activities can render these naturally occurring constituent's toxic under certain conditions. These include the standard physical water quality variables measured *in situ* namely, temperature (℃), dissolved oxygen (mg/l and total dissolved solids (TDS) (ppm), which were all measured using a pre-calibrated Hanna 9828 multi-parameter hand-held water quality meter. For chemical analysis, water samples were collected in polyethylene bottles, stored at 4℃ and were analyzed by SGS La following variables were evaluated: pH, electrical conductivity, TDS, total alkalinity, chloride, sulphate, nitrate, ammonium, orthophosphate, turbidity, total hardness as well as an OES-MS metal scan for all metals some of which include fluoride, nitrite, calcium, magnesium, sodium, potassium, aluminium, iron and manganese.

These results were compared against South African Water Quality guidelines DWAF (1996)[32] as well as Canadian WQ guidelines (CCME, 1999)[33], Australian guidelines (NRMMC, 2000)[34], and international toxicological benchmarks [lowest chronic effects, Suter & Tsao (1996)][4], as guidelines are not available for

[32] DEPARTMENT OF WATER AFFAIRS AND FORESTRY (DWAF). 1996. South African water quality guidelines, volume 7: Aquatic Ecosystems.

[33] CCME (Canadian Council of Ministers of the Environment). 1999. Canadian water quality guidelines for the protection of aquatic life. Canadian Council of Ministers of the Environment, Winnipeg

[34] SUTER, G.W. & TSAO, C.L. 1996. Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota. Department of Energy. Report ES/ER/TM-96/R2

Liberia or other West African countries. These were used as guidelines to give an indication of ecosystem deterioration and results are summarized in *Annex 7-G.*

Habitat Integrity

The impacts on the aquatic and surrounding habitats of each site were assessed using the Index of Habitat Integrity (IHI) assessment protocol used in South African monitoring and described by Kleynhans (1996)[1]. This index was developed for South African ecosystems, but would still be suitable to identify the extent of impacts on the instream and riparian habitat in a Liberian context and therefore was used in this impact assessment study. Although the weightings were done for South African systems, the criteria are applicable to instream and riparian habitats of all freshwater systems and therefore it is assumed that the same weightings can be applied in Liberian systems. The index is based on a set of 12 weighted disturbances that are analyzed for both the instream (IH) and riparian (RH) habitats separately (Table 51).

Table 51: Criteria and Weightings used for the Assessment of Instream and Riparian Habitat Integrity (Kleynhans, 1996)

Instream Criteria	Weight	Riparian Criteria	Weight
Water abstraction	14	Vegetation removal	13
Water quality	13	Exotic vegetation	12
Flow modification	13	Bank erosion	14
Bed modification	13	Channel modification	12
Channel modification	14	Water abstraction	13
Inundation	10	Inundation	11
Alien aquatic plants	9	Flow modification	12
Alien fauna	8	Water quality	13
Rubbish dumping	6		

Macro-Invertebrate Habitat Availability

Different biotope diversities were evaluated i.e. stones in current (bedrock, cascade, chute, boulder rapid, riffle and run), stones out of current (bedrock, backwater, slackwater and pool), instream vegetation, marginal vegetation and GSM (gravel, sand and mud) were scored and rated (Dallas, 2005).

Fish Habitat Availability

A fish habitat assessment was carried out to provide a measure of the fish refuge potential associated with each of the sampling sites quantified on a scale from 0 to 5, being absent (0), rare (1), sparse (2), common (3), abundant (4) or entire (5) (Dallas, 2005).

Diatoms

Diatoms were collected from all aquatic sampling sites and analysed according to the procedures described by Taylor *et al.* (2005) and Fore and Grafe (2002).

All slides and material have been archived in the Diatom Collection of the North-West University should any material be required for independent verification. Data was interpreted in terms of species present, abundances, number of species with deformed valves and characterised into three (3) different indices calculated using OMNIDIA ver. 5.3 (Table 52) (Lecointe et al. 1993; database updated March 2009)[3] and each was classified into a class ranging from deteriorated to high quality as defined by Eloranta and Soininen (2002) (*Table 7.30*)

Table 52: Diatom indices implemented in this assessment

Index	Index Abbreviation	Reference
Specific Pollution sensitivity Index	SPI	CEMAGREF (1982)
Biological Diatom Index	BDI	Lenoir & Coste (1996)
Percentage Pollution Tolerant Valves	%PTV	Kelly & Whitton (1995)

Macro-Invertebrates

The macro-invertebrates were collected and identified to family level. As Liberia has no type of macro-invertebrate scoring system, the standardised SASS5 protocol derived by Dickens & Graham (2002)[1] was used. The resulting data set from each site was then analysed using the following metrics:

- Occurrence of macro-invertebrates: The number and abundances of families sampled were used to determine the overall family richness. These two measures are simple and were used as an indicator of contaminant stress on macro-invertebrates.
- EPT richness: This evaluates the total number of families occurring in the order Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies) (Marshall et al., 2001).

Biotic indices: The utilisation of the South African Scoring System 5 (SASS5) and Average Score per Taxon (ASPT) was included in this study as a guide to identify impacts as family tolerances have been shown to have similar trends throughout the world Table 53

Table 53: Descriptions of general SASS5 scores with standardized color coding (adapted from Kleynhans and Louw, 2008)

Category	SASS5 Score	ASPT Score	Short Description	Long Description
A	>120	>/=5.6	Natural	Unmodified state with no impacts, conditions natural Largely natural with few modifications.
B	80-120	>/=4.8<5.6	Largely natural	A small change in natural habitats and biota may have taken place but the ecosystem functions are essentially unchanged
C	60-79	>/=4.6<4.8	Moderately modified	Moderately modified - loss and change of natural habitat and biota have occurred, but the basic ecosystem functions are still predominantly unchanged
D	40-59	>=4.2<4.6	Largely modified	Largely modified - a large loss of natural habitat, biota and basic ecosystem functions has occurred
E	20-39	<5.2	Seriously modified	Seriously modified - the loss of natural habitat, biota and basic ecosystem functions are extensive
F	<20	<5.2	Critically modified	Critically/Extremely modified - modifications have reached a critical level and the system has been modified completely with an almost complete loss of natural ecosystem functions have been destroyed and the changes are irreversible

7.6.2 Fish

The fish communities were sampled according to the methodologies recommended by Kleynhans (2008)[35]. Photographs were taken of all fish species sampled and were identified using identification keys for species from the IUCN database (2012)[36] and FishBase (2012)[37] as well as various published articles and Skelton (2001).

7.6.3 Baseline Results

General Habitats

The habitats sampled for this survey were divided into the following:

- River and stream sites; and
- Lake and disused mine pit.

The man-made lake and disused mine pit were sampled only to assess the biodiversity at these sites as the various macro-invertebrate and fish analysis techniques used can only be applied to flowing systems. The disused mine pit was used as a water source for a water bottling plant but is no longer operable. Dewatering of the pit is ongoing. A large man-made lake upstream of previous mining activities and is being used by local inhabitants for fishing, bathing, washing and also as a water source for their plantations and livestock.

Habitat Availability

The habitat availability for macro-invertebrates, fish and diatom communities were assessed by ERM in 2012 at each of the nine sites, and it was observed that both the high and low flow surveys do not have good habitat diversity regarding available biotopes. The most abundant habitats available were GSM and vegetation (VEG). More biotope diversity was available during the dry season survey which included stones in current (SIC) and stones out of current (SOOC).

[35] KLEYNHANS, C.J., 2008. River EcoClasification manual for ecostatus determination (version 2) Module D: Volume 1, Fish Response Assessment Index (FRAI). Pretoria, South Africa: Water Research Commission no TT 330/08

[36] IUCN. 2010. Red list of threatened species. Available at: www.iucnredlist.org.

[37] FISHBASE 2012. A World Wide Web electronic database of fish. Editors: FROESE, R. & D. PAULY. Available at: www.fishbase.org

Table 54: Habitat and biotopes available for macro-invertebrate, diatom and fish communities at each site during the Low flow survey (ERM, January 2013)

Site	Biotopes				Fish Habitat			
	SIC	SOOC	VEG	GSM	SD	SS	FD	FS
River / Stream Sites								
B1	3	3	2	3	3	3	0	0
B2	2	3	3	2	0	4	0	0
B4	0	0	3	3	3	3	0	0
B5	0	0	3	4	2	4	0	0
B7	0	0	0	0	0	0	0	0
B8	3	3	0	3	2	3	0	2
B9	4	4	0	3	3	3	2	3
Lake and Disused Mine Pit								
B3	0	0	4	3	4	3	0	0
B6	0	4	0	3	4	2	0	0

0=absent, 1=rare, 2=sparse, 3=moderate, 4=abundant and 5=very abundant,
GSM = Gravel, sand and mud; SOOC = Stones out of current; SIC = Stones in current; SD = Slow deep, SS=Slow shallow, FD=Fast deep, FS=Fast shallow

Table 55: Habitat and biotopes available for macro-invertebrate, diatom and fish communities at each site during the High flow survey (September 2012)

Site	Biotopes				Fish Habitat			
	SIC	SOOC	VEG	GSM	SD	SS	FD	FS
River / Stream Sites								
BR1	0	0	2	2	4	1	4	0
BR2	0	0	3	4	3	1	3	0
B1	0	0	2	3	3	3	0	0
B2	0	0	3	2	0	4	0	0
B4	0	0	3	3	3	3	0	0
B5	0	0	3	4	2	4	0	0
B7	0	0	0	0	0	0	0	0
Lake and Disused Mine Pit								

B3	0	0	4	3	4	3	0	0
B6	0	0	0	3	4	2	0	0

0=absent, 1=rare, 2=sparse, 3=moderate, 4=abundant and 5=very abundant,
GSM = Gravel, sand and mud; SOOC = Stones out of current; SIC = Stones in current; SD = Slow deep, SS=Slow shallow, FD=Fast deep, FS=Fast shallow

Habitat Integrity

The habitat integrity of the systems within the vicinity of the mine was modified (Figure 41). The majority of the impacts observed in this study were associated with activities from the local inhabitants, agricultural fields and from the Bomi Hills Mine Concession (previous and current mining activities).

In comparing the high and low flow habitat integrity for the sites, the loss of habitat during different seasons can be observed (Figure 42). Although sites B8 and B9 were only sampled during the low flow survey, both sites showed the highest habitat integrity and impacts were largely due to activities from local communities, with no impacts from mining activities. This was also represented in the macro-invertebrate assemblages at these sites (Figure 42).

The sites B1, B2 and B5 were situated within streams directly downstream from the current and previous mining activities. There were also impacts upstream and downstream of the sites which consisted of large agricultural fields that could possibly be the source of the extreme levels of siltation.

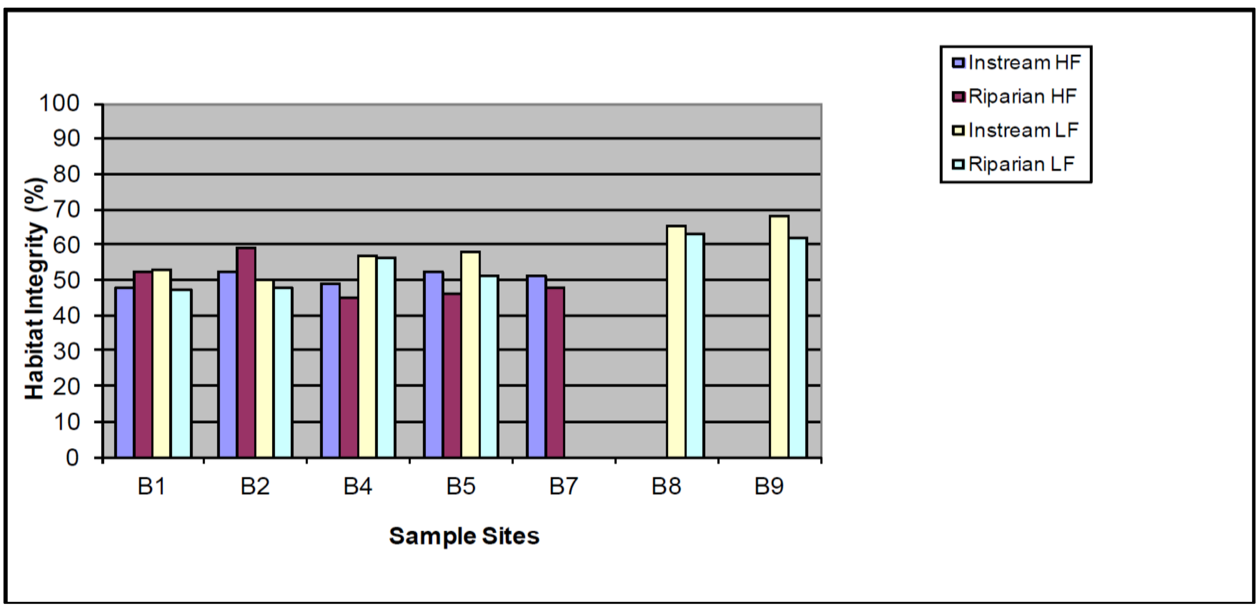


Figure 41: Index of Habitat Integrity for the river and stream sites assessed in the high (HF) and low (LF) flow surveys

The habitat integrity at site B7 was higher than site B4, which were both situated within the town of Tubmanburg. Site B7 is considered a non-perennial stream which dries up in the drier season and impacted by the floods during the wet season. The habitat integrity at site B4 was shown to be less affected during the low flow season. This may be due to less siltation present during the dry season. The agricultural activities taking place adjacent to site B4 also have a significant impact on the turbidity and siltation observed at the site.

Figure 42: Images showing Agricultural Activities around Sites B2 and B4, respectively

7.6.4 Water Quality

The results of the water quality variables measured in the high flow and the low flow are detailed in the *Annex 7-G and is compared to the Liberian Water Quality Standards Class III.*

At sites B1 and B4 oxygen levels were detected to be low only during the high flow survey and at site B7 during both high and low flow surveys. Site B1 also showed high levels of iron (Fe), which may also be a contributing factor to the low oxygen levels observed during the high flow survey. As site B4 is situated in the city of Tubmanburg, the low oxygen levels may be as a result of organic waste which is washed down during the high flow. Both B1 and B4 were fast flowing during the high flow survey. At site B7 low oxygen levels were recorded during both surveys. This site (B7) was characterized by very shallow, slow flowing water with lots of vegetation growing on the banks and in the channel of the stream as well as upstream of the site, which can affect the oxygen levels. Oxygen levels fluctuate considerably depending on numerous factors and the low flow and excessive plant growth in the stream channel at B7 can be the main contributor to the low oxygen levels present. This site also did not flow during the low flow survey and seemed to dry up during the drier seasons, thus being a non-perennial stream.

Aluminium (Al) usually results from industrial and mining activities; however, it is also abundant in the earth at all sites. The presence of high levels of Al (>10ug/l) in areas un-impacted from the Bomi Hills Mine Concession may be natural for this area. Zinc occurs in rocks and ores and is readily refined into a pure stable metal. It can enter aquatic ecosystems through both natural processes such as weathering and erosion, and through mining activity. The presence of high levels of Zinc (<50ug/l) in all the sites and all within the same value range perhaps indicate these levels could be natural. This was found to be the same with high levels of Iron (Fe) which were found to be present at all sites except for B6 and B7. The high Fe levels are associated with the high iron deposits in the area and also the previous iron mining activities at the mine.

The dependence of the local villages on streams and rivers also has an impact on the water quality of the streams and rivers at the sites sampled. Washing and bathing occurs at most river or stream sites which includes B1, B2, B4, B5, B7, B8 and also B9. This has an impact on the oxygen concentrations and also chemical variables. However, the significance of these impacts was not seen in the water quality results probably due to the dilution effect from the water flow at the sites. Alkalinity can also be a contributing factor to the low oxygen concentrations as alkalinity often indicates eutrophication from nutrients. High alkalinity levels were present at sites B1, B5, B6 and B7.

Sites B1 and B5 are situated on streams downstream of the mining activities and both are next to local agricultural fields. The high levels of turbidity that were detected during the high flow survey are possibly as result of local agricultural activities upstream and also possible runoff from the mining area.

The majority of water quality impacts from the previous mining activities are increased turbidity and Fe levels with no water quality impacts from the road observed during the survey. Eutrophication and oxygen depletion were evident in streams sampled within the town (B4 and B7) and is indicative of high nutrient levels possibly caused by run off from the City of Tubmanburg.

Diatoms

This updated assessment has relied on the previous study conducted by ERM in 2012 for diatoms which found that diatom community composition for the high flow survey was analysed by DIAMON Specialized Water Quality Analysis CC (Potchefstroom, South Africa) at sites B1, B2, B3, B4, B5, B6 and B7 and for the low flow survey by ECOTONE Freshwater Consultants (Johannesburg, South Africa) for sites B1, B2, B3, B4, B6, B7, B8 and B9. The results obtained during the high flow 2012 and low flow 2013 is summarised in Table 56 and Table 57 respectively, and discussed below and presented fully in the *Annex 7-G*.

The sites that were analysed for the high flow survey had a total of 87 species identified, ranging from 16 species at B4 and 26 species at B1. The diatom assemblages indicate that the systems are in a relatively natural state, and the SPI scores showed that the water of the systems was of a Good to High quality. The sites analysed for the low flow survey had a total of 85 species identified, ranging from 15 species at B3 and 33 species at B2 (Table 57). The diatom assemblages indicate that the systems are in a relatively natural state, and the SPI scores showed that the water of the systems was of a Good to High quality. In general, as observed in the high flow results, the sites were all considered to have a typically acidic nature and a large percentage of tropical African endemic species.

Site B7 had a high abundance of only one species *Achnanthidium spp.* during the high flow season. The most relevant ecological feature of these diatoms (*Achnanthidium*) is an extraordinary ability to colonize any system submitted to some kind of perturbation that leads to the desperation of the flora of a site (Deniseger et al., 1986; Genter et al., 1987; Medley & Clements, 1998; Ivorra et al., 1999; Gold et al., 2002, 2003; Cattaneo et al., 2004; Ferreira da Silva et al., 2009)[38]. However, the presence of *Achnanthidium minutissimum is* considered indicative of clean water by the diatom indexes (Gonzalo and Maria de los Reyes, 2012). Thus, the genus *Achnanthidium* has a wide tolerance range and it is therefore important to be aware of the discrepancies surrounding this genus when inferring water quality based on diatom assemblages in impacted areas. *Achnanthidium* occurred at 7 sites sampled (B2, B3, B4, B6, B7, B8 & B9) for the low flow and was dominant at four of these sites (B6, B7, B8 & B9).

Site B6 had high levels of *Gomphonema* genera, which are present due to the dominance of low flowing, swamp type habitats with acidic waters and low conductivity. *Gomphonema parvulum* was dominant at B7 during both high and low flow surveys and occurs in a range of waters, but generally is considered to be tolerant of extremely polluted conditions (Taylor et al., 2007). During the low flow survey, *Gomphonema minutum* were dominant at B1, and are found in eutrophic waters, and *G. gracile* (dominant at B1 and B4) in electrolyte rich waters, but both taxa are not tolerant to more than moderate levels of pollution. It can therefore be assumed that the water quality at B1 and B4 is not negatively affected.

During the high flow survey, sites B1 and B2 demonstrated an abundance of *Eunotia* genera that are naturally found in low flowing, swamp type habitats with acidic waters and low conductivity (Taylor et al.,

[38] Deniseger, J., Austin, A. & Lucey, W.P. (1986). Periphyton communities in a pristine mountain stream above and below heavy metal mining operations. Freshwater Biology, 16: 209–18.

Genter, R.B. (1996). Ecotoxicology of inorganic chemical stress to algae. VII. Response of algal communities to inorganic stressors. In: Stevenson RJ, Bothwell ML, Lowe RL, editors. Algal Ecology. Freshwater Benthic Ecosystems. San Diego, CA: Academic Press

2007). *Eunotia* spp. occurred at all the sites during the low flow survey and was the most diverse genera recorded. Even though the genus *Eunotia* has a cosmopolitan distribution, numerous species are restricted to tropical areas due to their environmental water preferences, which include low pH and conductivity. Abdallah et al. (2004) found *Eunotia* spp. in an upland tropical African stream of which the water was nutrient poor, with low pH and conductivity, and where nitrate was undetectable.

Diadesmis contenta a species tolerant of low light conditions was found regularly in the samples with very high levels in B1, possibly indicating that terrestrial sediments are entering the studied site (Taylor et al., 2007). Current water quality results (*Annex 7-G*) showed high turbidity at site B1 during the high flow survey. The heavy rains during the rainy season might be the reason for the abundance of this diatom species at sampled sites. Sites B2 and B7 showed very high levels of *Diadesmis contenta* during the low flow survey.

From Table 57 it can be seen that a high percentage of tolerant valves were present during the high flow survey at sites B1, B5 and B7. The values were high above levels of concern, especially for sites B1 and B5. This may be due to the high abundance of tolerant *Diadesmis contenta* at some of these sites.

The high rainfall during the rainy season, washing sediment into rivers and streams, may be the reason for this occurrence as the high levels at these sites, except for B7, were only present during the high flow survey (Table 57*)*. Both these sites (BR1 and B1) showed values above levels of concern for tolerant valves, which can be attributed to the high levels of *D. contenta* present during the low flow. Site B2 had very low flow during the low flow survey and the high levels of *D. contenta* at this site may be contributed to the agricultural activities which are present upstream of this site. No, turbidity issues were observed at sites B2 or B7 during the low flow survey. Site B7 was not flowing during the low flow survey and is considered to dry up totally during the dry season.

Table 56: Results of Diatom Analyses for the High Flow Survey (NWU)

Site	NWU No. (Count)	No. Species	SPI*	%PTV*
LEVELS OF CONCERN		**-**	**<13**	**>10**
B1	12-663/648 (402)	26	14.3	**65.9**
B2	12-664/649 (300)	24	18.5	5.0
B3	12-665/650 (400)	16	17.7	0.3
B4	12-666/651 (200)	16	16.1	0.5
B5	12-667/652 (100)	26	15.8	**42.0**
B6	12-668/653 (400)	16	18.1	1.2
B7	12-669/654 (400)	18	15.0	**11.5**

Table 57: Results of Diatom Analyses for the Low Flow Survey (Ecotone)

Site	Count	No. Species	SPI*	%PTV*
LEVELS OF CONCERN		**-**	**<13**	**>10**
B1	400	19	18,8	0,3
B2	402	33	18,1	**18,9**
B3	400	15	19,8	0,0
B4	400	27	18,8	0,0
B6	402	21	16,9	2,0
B7	402	26	14,2	**24,4**
B8	401	26	17,7	1,0
B9	402	23	17,3	0,5

7.6.5 Aquatic Invertebrates

The macro-invertebrate integrity was assessed based on the family composition observed at each site. In *Annex 7-G*, the presence and abundance of each family are listed as identified during the study. As can be seen in Table 58 and *Table 59* the EPT and ASPT scores were low at most of the sites sampled during the high flow and low flow surveys, which indicated that the community structures consisted of a low number of sensitive taxa. This can be due to the lack of adequate habitat availability for these taxa during high flow. The high percentage of air breathers and the general lack of families may, however, attest to the fact that the macro-invertebrates at the sites are continuously exposed to water adverse quality impacts. During the low flow survey, the EPT and ASPT scores were high at most of the sites sampled, which indicated that the community structures consisted of a higher number of sensitive taxa. This can be due to the higher availability of adequate habitat and lower water levels.

Table 58: The Macro-Invertebrate Metrics assessed during the High Flow

Site	No. Families	EPT Richness	No of Air Breathers (% of Total)	ASPT Score	SASS5 Score	Interpretation al
River / Stream Sites						
B1**	10	2	50	5.3	53	Largely natural
B2*	9	4	22	4.8	44	Largely modified
B4**	6	1	66	4.0	24	Seriously modified
B5*	12	2	41	4.2	51	Largely modified
B7*	12	0	66	4.3	52	Largely modified
Lake and Disused Mine Pit						
B3*	13	2	46	4.1	54	-
B6***	4	0	25	3.7	15	-

** Only Veg and GSM microhabitats sampled; ** Only veg sampled; *** Only GSM sampled; - not assessed*

The river and stream sites that were sampled in and around Bomi Hills Concession during the survey indicated fluctuations within macro-invertebrate assemblages between the high and low flow samples. A much higher number of air-breathers and low numbers of sensitive families were sampled at the sites during the high flow season. This can be contributed to the high flowing waters causing siltation and impacting the availability of habitats for the more sensitive families. The stream sites within Tubmanburg (B4 and B7) were largely modified due to the impacts of the surrounding town and human activities. Site B7 showed a very high number of air-breathing families which suggests a chronic lack of oxygen perhaps due to the high levels of instream vegetation present upstream of the site or possible organic pollution. Site B7 was not flowing during the low flow survey and were mostly dry indicating this stream only flows during the wet season.

Sites B8 and B9 were only sampled during the low flow survey and are situated upstream of any mining impacts currently. There is a definite increase in the macro-invertebrate communities at both these sites due to better habitat availability. B8 was situated on the same perennial river downstream from B9. The macro-invertebrate community was composed of families with preferences to a diverse number of microhabitats, including water column, slow flowing and fast flowing biotopes, corresponding to the high biotope availability, except for vegetation biotope, at these sites.

The presence of sensitive taxa from the *Ephemeroptera* (mayflies), *Trichoptera* (caddisflies) and *Plecoptera* (stoneflies) indicates that there are fewer disturbances to the macro-invertebrate assemblages at sites B8 and B9. Good habitat availability may be the major cause however any possible disturbances from upstream were mitigated, possibly due to the dilution effect of the river. Sand mining by local villagers do, however, occur downstream of B8, which may have an effect on water quality as result of possible siltation.

Table 59: The Macro-Invertebrate Metrics assessed during the Low Flow

Site	No. Families	EPT Richness	No of Air Breathers (% of Total)	ASPT Score	SASS5 Score	Interpretation al
River / Stream Sites						
B1	11	3	36	5.1	56	Largely modified
B2	8	3	25	4.5	36	Largely modified
B4*	13	4	30	4.4	58	Largely modified
B5*	17	2	35	5.3	91	Largely

						natural
B7	-	-	-	-	-	-
B8	10	4	20	6.8	68	Natural
B9	12	5	16	7.4	89	Natural
Lake and Disused Mine Pit						
B3*	11	2	36	5.0	55	-
B6**	3	0	33	3.3	10	-

** Only Veg and GSM microhabitats sampled; ** Only GSM sampled; - not assessed*

Sites B3 and B6 (disused mine pit) were mainly sampled to assess the biodiversity present during both seasons. The overall macro-invertebrate assemblages at both these sites were found to be low, due to the lack of suitable habitats. The low EPT richness indicates more tolerant families were present and B3 is situated at the top of a man-made lake upstream of the mining activities, whilst B6 is a disused mine pit. Site B6 is planned to be emptied when mining operations commence at Bomi Hills Mine Concession.

Seasonal correlations between sites showed in many cases an increase in the macro-invertebrate assemblages during the low flow. *This* is related to the lower flow and greater habitat availability at the sites. Site B4 showed a large increase in macro-invertebrate assemblage as well as for B5. These sites are also connected as B4 is upstream from B5 on the same stream, with similar habitats available.

Site B7 was dry during the low flow survey which indicates that it was a non-perennial stream and was probably the reason for the low macro-invertebrate score obtained during the high flow survey. This site is also affected by anthropogenic impacts showing a low water quality during both the high and low flow surveys (*Annex 7-G*).

7.6.6 Fish

According to Paugy *et al.* (1990) and the IUCN database (2012), there are approximately 78 fish species expected to occur within the Mahe River system, including numerous barbs, killifish and tilapia (*Annex 7-G*). From this list 14 species have been identified on the IUCN database (2012) as having a conservation important status in the river systems in the vicinity of the mining activities (Table 60). This includes two (2) Endangered, six (6) Vulnerable, three (3) Near Threatened and three (3) Critically Endangered fish species. These fish species of conservation concern are presented in *Table 7.34* with their habitat preferences, distribution and the existing threats on the population. None of the fish species were sampled during this study possibly due to the high flow conditions at the time. Although none of these species have been sampled during this survey the possibility of their presence within and around the study area must be taken into consideration.

Table 60: Conservation Important Fish Species expected in the Mahe River and tributaries

Species and Red Data status	Habitat Preference	Distribution and Threats
Barbus parawaldroni (Carp) NT	This is a bentho-pelagic fish. Permanent & seasonal rivers/tributaries	The species is found in six to eight locations and is threatened by deforestation and mining in Liberia. However, the EOO is greater than 20,000 km² and the AOO is greater than 2,000 km².
Barbus eburneensis (Carp) VU	This is a benthopelagic species.	This species is found from Guinean region of MountNimba in the basins of Cavally, Nipoué, Niger and St. Paul. The estimated extent of occurrence and area of occupancy are less than 20,000 km² and 2,000 km², respectively. It is known from five locations. The extent and quality of habitat is undergoing continuous decline due to deforestation and past civil conflicts.
Epiplatys hildegardae (killifish) VU	A non-migratory and benthopelagic fish. The species inhabits the quiet parts of brooks and streams.	This species is known only from a restricted area around N'Zérékore in sout upper drainage systems of the Saint John/Mani and Saint Paul/Oulé riversPotentially threatened from water pollution due to mining and untreated sewage.
Epiplatys roloffi (killifish) EN	This species occurs in brooks, swamps and small streams.	Known from swamps and small streams of the Upper Saint Paul and UpperLofaRiver systems and southeastern Guinea and Liberia, where the species populations are declining through deforestation and sedimentation.
Epiplatys Lamottei (Redspotted panchax) VU	This species is found in brooks and small streams.	This fish occurs in south eastern Guinea and northern Liberia, in the upper Niger River basin and in the upper parts of the Lofa, Saint Paul and Saint John river systems in Northern Liberia and south eastern Guinea. Deforestation and mining in Liberia threaten the species.
Epiplatys ruhkopfi (killifish) CR	This species is found in brooks.	This fish is only known from its type locality, the upper Saint John River in northern central Liberia, an area with a lot of mining and agricultural activities. There are indications of continuing decline in quality of habitat.
Callopanchax monroviae (killifish) VU	This species inhabits temporary swamps and pools, and swampy parts of forest creeks in the humid coastal	This species is endemic to Liberia. The range of distribution extends from the drainage system of the Lower Mano River to that of the Lower Saint Paul River in southern and southwestern Liberia. The estimated extent of occurrence and area of occupancy are less than 10,000 km² and 2,000 km², respectively. It is only known from five locations from Liberia. The extent and quality of habitat is undergoing and

	rainforest	continuous decline due to urbanisation, mining, agriculture and deforestation developments.
Sarotherodon occidentalis (Tilapia) NT	This is a demersal species. Detritivore and oviparous. Permanent rivers	*Sarotherodon occidentalis* occurs in coastal areas, from the River Casamance in Senegal to the St John in Liberia. The species has a wide distribution (EOO). But is found in a limited number of locations (but more than 10) and has widespread threats, particularly from drought, deforestation, overfishing and dams. The species is close to meeting Vulnerable status.
Scriptaphyosemion liberiense (Killifish) NT	This species occurs in brooks, swamps, pools and small streams in the coastal rainforest.	The species is found in more than 10 locations in Liberia and Sierra Leone. The area suffers from deforestation and past conflicts have affected the vegetation. The species is close to meeting Vulnerable status.
Scriptaphyosemion roloffi (Killifish) NT	Mainly found in the shallow and stagnant parts of pools, brooks, swamps and small streams in the coastal rain forest.	This species is known from 10 or more locations, the Little Scarcies River drainage system in Western Sierra Leone southward to the drainage system of the Lower Lofa River in Western Liberia. The threats to the species are from deforestation, human settlements and mining leading to sedimentation and pollution.
Tilapia coffea (Tilapia) CR	This is a demersal fish species.	This species is restricted to one location, the Saint Paul River in Liberia where it is probably endemic. The estimated EOO is less than 1,000 km^2 and the AOO is less than 10 km^2. There is ongoing decline in habitat quality due to sedimentation and pollution from deforestation and mining.
Aphyosemion viride (Killifish) VU	This killifish is found mainly among vegetation, or between fallen leaves, in brooks and small streams of the forested savannah.	This species occurs in the drainage systems of the upper Saint Paul and upper Saint John rivers in eastern Guinea and northwestern Liberia. This species is threatened by degradation of its habitat due to deforestation in all its locations.
Labeo curriei CR	This is a benthopelagic species.	This species is reliably known only from the locality, River Via, Saint Paul drainage in Liberia. There are indications of continuing habitat degradation by deforestation, farming and mining with possible decline in population.
Paramphilius firestonei EN	This is a demersal species.	This endemic species to Liberia is restricted to two to three locations, St. Paul, Du and Borlor rivers near the coastline in Liberia. The estimated EOO is less than 5,000 km^2 and AOO is less than 500 km^2. Ongoing decline in habitat quality due to siltation and pollution from deforestation and mining.

Total extent of occurrence (EOO) is the area contained within the shortest continuous imaginary boundary, which can be drawn to encompass all the known, inferred or projected sites of present occurrence of a taxon.

Area of Occupancy (AOO) is a parameter that represents the area of suitable habitat currently occupied by the taxon.

In comparison with the expected species lists (Paugy *et al.* 1990) (*Annex 7-G*), 60 fish species were not seen during sampling within the study area. The extent and source of impacts could not be identified with certainty in this study due to the very few studies associated with the sensitivities, natural population structures and preferences. Despite this, some of the surrounding anthropogenic activities are expected to threaten the fish communities and could have contributed to the lack of fish sampled in this study. The local communities are highly dependent on the aquatic resources and thus large species are under pressure from overfishing.

Apart from this, it should be noted that the absence of the fish specimens does not necessarily indicate that there were impacts on the fish community integrity. Many of the absent species are in families that are generally expected to have a low frequency of occurrence, including predators and larger specimens such as those in the MORMYRIDAE (snoutfish), CHARACIDAE (characins), SCHILBEIDAE (butter catfish), CLARIIDAE (catfish), MOCHOHIDAE (squeakers), and MALAPTERURIDAE (electric catfish) families, which drastically minimised the chances of sampling.

Further to this, the likelihood of sampling adult specimens is further reduced by the fact that many of the expected species have preferences to deep habitats, which were difficult to sample, so their presence could not be confirmed.

A total of 18 fish species were sampled during the high and low flow survey. It was observed that a higher diversity of species were sampled during the low flow survey, with only five (5) species sampled in the high flow and 13 species sampled during the low flow survey. This was mainly due to more habitats available for sampling in the low flow. The *Cyprinid* genera dominated the fish species sampled during both surveys. These species are hardy and mostly tolerant to potential impacts in the system. The important fish taxa that could potentially be threatened by anthropogenic impacts were noted based on the general family biology and ecology with reference to Skelton (2001) and the IUCN database (2012). Some examples are illustrated in *Figure 7.49* below. More photos of fish species sampled are presented in *Annex 7-G*.

Tilapia louka (Tilapia) | *Nannocharax fasciatus* (nomi comuni) | *Hemichromis fasciatus* (Cichlid)

Figure 43: Example of fish species sampled

The integrity of the fish communities was not scored into an ecological category in this study due to the lack of appropriate reference data. However, the occurrence, species richness and diversity could be used to identify areas of concern.

During the low flow survey, a high diversity of sensitive species were sampled which included *Nannocharax fasciatus* (nomi comuni) (B4), *Brienomyrus brachyistius* (snout fishes) (B4) and *Mormyrus tapirus* (snout fishes) (B8). Most of these species are characterised as intolerant or moderately intolerant to aquatic impacts in the water and their habitats. As such their presence indicates that the impacts upstream do not significantly influence the fish community richness.

Sites B1, B2, B5 and B7 were dominated by cichlid genera with *Hemichromis fasciatus* and *Tilapia louka* being the most abundant species present at all the sites. Both these species are fairly tolerant to water quality impacts.

Ctenopoma kingsleyae was sampled at B5 during the low flow survey also indicating an increase in water quality and habitat availability. The killifish, *Epiplatys dageti,* were sampled at site B7 during the high flow season. This species is sensitive to impacts in the system. However, the presence of this fish species at B7 may also be as a result of the high flow observed during the rainy season causing the little fish to be washed from more suitable habitat upstream.

In comparison with the rest of the sites sampled, site B8, which is a site on the Mahe River upstream from the mining activities, showed a definite increase in species richness and diversity. The presence of the killifish species *Epiplatys olbrechtsi*, at site B9, which is situated downstream of B8 on the same river, indicates the system has a fairly natural fish community with currently no detectable large impacts. Both sites, B8 and B9, had good habitat diversity during the low flow survey (*Table 7.33*). A possible concern is the presence of the common carp, *Cyprinus carpio*, that were sampled at site B8. This species is not on the expected fish species list however, it has been recorded previously in Liberia and is currently considered native to the area (IUCN, 2012). The presence of *C. carpio* may have detrimental effects on other more sensitive fish species within the system in future, as this species is linked to increased turbidity of water sources within which they occur.

The habitats at sites B3 and B6 consisted only of non-flowing shallow- and deep-water habitats. The two sites were dominated by species preferring these types of habitats and included *Tilapia brevimanus, Tilapia guineensis* and *Hemichromis fasciatus*.

Figure 44: Image of the Exotic Fish Species Samples, Cyprinus carpio

Table 61: Fish species identified in high flow (HF) and low flow (LF)

Fish Species	Common Name	River & Stream Sites												Lake Site & Disused Mine Pit				Abundance of species
		B1		**B2**		**B4**		**B5**		**B7**		**B8**	**B9**	**B3**		**B6**		
Sampling Season		HF	LF	HF	LF	HF	LF	HF	LF	HF	LF	LF	LF	HF	LF	HF	LF	
*Heterobranchus isopterus**	Catfish										-	x						1
*Tilapia louka**	Tilapia							x	x	x	-			x		x	x	20
*Tilapia brevimanus**	Tilapia										-				x			6
*Hemichromis fasciatus**	Cichlid		x					x	x		-			x	x	x	x	18
Barbus ablabes	-										-						x	10
*Sarotherodon tournieri tournieri**	Tilapia							x			-					x		9
*Tilapia guineensis**	Tilapia										-					x		7
Mormyrus tapirus (1)	Snout fishes										-	x						1
*Labeo coubie**	African Carp										-	x						1
Barbus macrops	-										-	x						10
Cyprinus carpio	Common Carp										-	x						1
Awaous lateristriga	Goby				x		x				-							6
Chrysichthys johnelsi	Catfish											x						1

Brienomyrus brachyistius (1)	Snout fishes							x			-							2
*Ctenopoma kingsleyae**	Grunt-Grunt								x		-							5
Nannocharax fasciatus (1)	Nomi comuni						x				-							4
Epiplatys olbrechtsi (1)	Killifish										-		x					8
Epiplatys dageti(1)	Killifish									x	-							6
Number of fish species sampled		0	1	0	1	0	3	3	3	2	0	6	1	2	2	4	3	18
*populations under pressure from over fishing; (1) Sensitive to impacts in the system; na –not assessed																		

7. 7 Landscape and Visual

'Landscape and visual resources' are defi topography, geology, forests, woodland, biodiversity, ridgelines, water courses and coastlines which contribute to landscape through the visual, aesthetic or scenic quality of the environment.

7.7.1 Methodology

Study Area and Zone of Theoretical Visibility

The study area for landscape and visual impact assessment is defined as the area within which the Project could be discernible by the human eye from the center of the mine concession out to 30km, depending on the presence of intervening local topography, meteorological conditions and features such as vegetation and buildings. The study area is referred to in this section as the Zone of Theoretical Visibility (ZTV).

Legal and Other Requirements

There are no local or international standards for undertaking landscape and visual impact assessment. The scope and methodology for assessment of the Bomi Mine has therefore been developed drawing from a number of sources for guidance. These are summarized below.

- ✓ IFC Environmental Health and Safety Guidelines for Mining;
- ✓ IFC Performance Standard 6 with regard to Sustainable Natural Resource Management and its relationship with landscape resources and Performance Standard 8 Cultural Heritage with regard to historic landscapes and visual sensitivities;
- ✓ Guidelines for Landscape and Visual Impact Assessment (2002)[39]; and
- ✓ Visual Landscape Planning in Western Australia, A Manual for Evaluation, Assessment, Siting and Design (2008)[40].

Characterizing the Baseline

The baseline characteristics, conditions and attributes of the landscape were determined as follows.

39 Guidelines for Landscape and Visual Impact Assessment (2002), published by the United Kingdom Landscape Institute and the United Kingdom Institute of Environmental Management and Assessment

40 Visual Landscape Planning in Western Australia, A Manual for Evaluation, Assessment, Siting and Design (2008)

- Landscapes were mapped and characterized at a local scale through a review of existing data sources, an examination of satellite and aerial photography and verification through field work.
- The character of the landscape was described based on the shape, texture, colours, and the way in which these various components combine to create specific patterns and pictures that are distinctive to a particular area.
- Understanding landscapes also includes understanding underlying influences such as geology and soils, topography, archaeology, landscape history, land use and management, ecology, architecture and cultural associations, all of which can explain the ways in which landscape resources are experienced and valued.
- Sensitivity was determined by taking into account the value placed on the landscape by people, from local communities, to regional and national or even international populations, and the ability of the landscape to accommodate change of the types envisaged. Sensitivity can be influenced by the place a particular landscape plays in the culture and traditions of local people, by its recognition as an important aesthetic resource through tourism, or by its recognition as a valued landscape through designation at local, national or international level.

7.7.2 Baseline

Regional Landscape and Landscape Value

Liberia is situated on the southwest corner of the West Coast of Africa bordered to the west by Sierra Leone, the north by Guinea, the east by Côte d'Ivoire and the south by the Atlantic Ocean.

There are four geomorphological landscape regions at different altitudes, each with distinct physical features. These include the coastal plain, a belt of inundated plateau followed by the belt of high lands and rolling hills in the north and northwest.

The Bomi Hills Mine Concession is located at the transition between the coastal plain and rolling hills geomorphological landscapes. The landscape is tropical rain forest with topography gradually rising from the coast to an elevation of about 60 m at the base of Bomi Hills. Before mining, the Bomi Hill crest attained an elevation of 222 meters above mean sea level. The area is generally flat with gently rolling hills. Previous mining led to the creation of the disused mine pit which was filled with water and also known as Blue Lake.

Figure 45: Aerial view from Telecommunication Tower

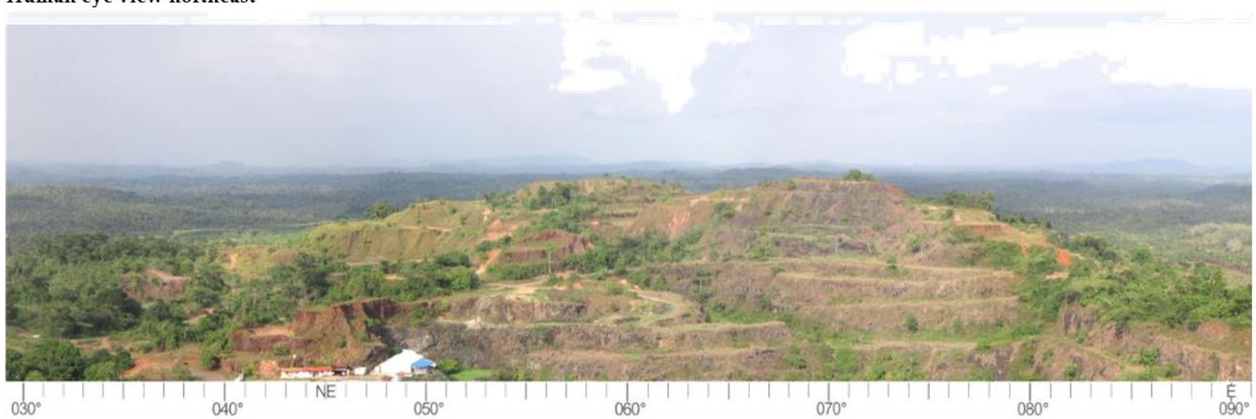
KOP Telecommunication Transmission Tower Point

The KOP for this Project is from Telecommunication transmission Tower Point and broken down into three viewpoints with the following attributes:

- KOP1 –Panoramic horizon view from Telecommunication Tower Transmission Point facing northeast;
- KOP2 –Panoramic horizon view from Telecommunication Tower Transmission Point facing south and southeast; and
- KOP3 –Downward view from Telecommunication Tower Transmission Point facing northeast (as seen in Figure 45).

Table ___ illustrates the KOP location and each viewpoint, and summarizes the evaluation of the sensitivity. The KOP1 and KOP2 viewpoints are illustrated by two images. The first image is a panorama using a wide-angle lens to capture the context of the location. Wide angle panoramas do not represent what the human eye sees and tend to exaggerate the size of objects in the foreground and reduce the size of objects in the background and therefore cannot be used to assess visual impact. Therefore, the second image illustrates what the central field of vision of the human eye would see from exactly the same location. The assessment of visual impact was based on photomontages using the second image. The KOP3 viewpoint encompasses a downward view to include the lake and is not panoramic.

Table 62: Evaluation of SVR Sensitivity with in the Mine ZTV

	Main Visual Characteristics of SVR Location				**Sensitivity of Visual Receptor**
KOP and Viewpoint	**Name and Typical Attributes of View Group**	**Foreground**	**Middle ground**	**Background**	**(High, Medium, Low, Negligible)**
KOP1 Northeast Refer to *Annex 7-H* and *Map 7-25*.	**180 degree panoramic view northeast**  **Human eye view northeast** 				
	SVR1 –View from Telecommunication Tower Point Northeast	Previously mined land comprises a prominent part of the foreground	The middle ground is blocked by previously mined land except to the north where undulating land cover is visible.	The Bomi Hills are discernible in the background.	Low

	Main Visual Characteristics of SVR Location				Sensitivity of Visual Receptor
KOP and Viewpoint	**Name and Typical Attributes of View Group**	**Foreground**	**Middle ground**	**Background**	**(High, Medium, Low, Negligible)**
KOP2 South and southeast Refer to *Annex 7-H* and *Map 7-26.*	**180 degree panoramic view southeast** 				
	Human eye view south 				
	KOP2 –View from Telecommunication Tower Point South and Southeast	A tower, dense shrubbery, and trees dominate the foreground and slightly block the middle ground.	Visible in the middle ground is a slightly rolling landscape interspersed with buildings.	The Bomi Hills are discernible in the background.	Low

	Main Visual Characteristics of SVR Location				Sensitivity of Visual Receptor
KOP and Viewpoint	Name and Typical Attributes of View Group	Foreground	Middle ground	Background	(High, Medium, Low, Negligible)
KOP3 Downward view facing northeast Refer to *Annex 7-H* and *Map 7-25*.	**Downward view facing northeast** 				
	KOP3 –View from Telecommunication Tower Point downward view facing Northeast	The foreground is comprised of light shrubbery and a downward slope.	The Bomi Mine and Bomi Lake are visually dominant in the middle ground.	The Bomi hills and undulating landscape are discernible in the background.	Low

7. 8 Air Quality

This *Section* presents an assessment of potential air quality impacts associated with the construction and operation of the Bomi Hills Mine. Specifically, this *Section* provides:

- A review of proposed operations at Bomi Hills Mine from an air quality perspective;
- A review of local and international guidelines and standards against which ambient air quality and inhalation health impacts are assessed and (or) screened;
- A description of the site from an air quality perspective including a description of meteorological conditions governing site-specific atmospheric dispersion potential;
- The assessment of existing ambient air quality based on the results of the ambient monitoring campaign conducted in comparison with ambient air quality guidelines and standards;
- The quantification of atmospheric emission;
- Atmospheric dispersion modelling to determine ambient air quality concentrations as a result of proposed operations in comparison with air ambient air quality guidelines and standards; and

7.8.1 Assumptions and Limitations

The main assumptions are summarized below:

- *Meteorological data*: In the absence of representative on-site hourly sequential meteorological data, use was made of modelled (MM5) meteorological data for the project area for the period January to December 2011.
- *Predicted air concentrations*:
  - Hourly air NO_2 concentrations assumed 20 percent (Howard, 1988[41]) of total emitted NOx emissions.
  - Annual and daily average air concentrations assumed 75 percent conversion rate to NO_2 (Janssen, 1988[42]). This is due to sufficient time for oxidation from NO to NO_2 to occur, as well as the establishment of photochemical equilibrium.
- Baseline air quality: A baseline air quality monitoring data was collected for the Project in for the purposes of establishing current air quality in the study area. Baseline dust-fall data is included in this report.

Legislative Requirements

Prior to assessing the air quality impact of the proposed Bomi Hills Mine operations on the atmospheric environment, reference needs to be made to the environmental regulations governing the impact of such operations i.e. emission standards and ambient air quality standards.

[41] Howard, J. B. (1988). Internal Combustion Engine Fundamentals. Singapore: McGraw-Hill Book Co.

[42] Janssen, L. H. (1988). Reactions of Nitrogen Oxides in Power-plant Plumes. Models and Measurements.

Emission standards are generally provided for point sources and specify the amount of the pollutant acceptable in an emission stream and are often based on proven efficiencies of air pollution control equipment.

Air quality guidelines and standards are fundamental to effective air quality management, providing the link between the source of atmospheric emissions and the user of that air at the downstream receptor site. Ambient air quality standards and guideline values indicate safe daily exposure levels for the majority of the population, including the very young and the elderly, throughout an individual's lifetime. Air quality guide normally given for specific averaging or exposure periods.

It should be noted that the air quality impact assessment was conducted to meet Liberian Ambient Air Quality Standards.

Emission Standards

The Liberian Ambient Air Quality Standards is incomplete does not clearly specify emissions guidelines for point sources. The only point sources at Bomi Hills Mine are expected to be associated with the 50MW heavy fuel oil (HFO) power generation plant.

Table 63: Liberian Ambient Air Quality Standards

Pollutant	Unit	Time weighted Average	Industrial Area	Residential, Rural & Other Area	Controlled Areas***
Sulphur oxides (SOX)	µg/m3	Annual Average*	80.0	60.0	15.0
		24 hours**	120.0	80.0	30.0
		Annual Average	-	50.0	-
		Month Average	-	-	-
		24 Hours	-	125.0	-
		One Hour	-	-	-
		Instant Peak	-	500.0	-
		Instant Peak (10 min)	-	0.191 ppm	-
Oxides of Nitrogen (NOX	$\mu g/m^3$	Annual Average*	80.0	60.0	15.0
		24 hours**	120.0	80.0	30.0
		8 hours	-	-	-
		Annual Average		0.2 ppm	-
		Month Average		0.3 ppm	-
		24 Hours		0.4 ppm	-
		One Hour		0.8 ppm	-
		Instant Peak		1.4 ppm	-
Nitrogen Dioxide	ppm	Annual Average		0.1	-

		Month Average		0.1	-
		24 Hours		0.1	-
		One Hour		0.2	-
		Instant Peak		0.5	-
Suspended particulate matter (SPM)	µg/m3	Annual Average*	360.0	140.0	70.0
		24 hours**	500.0	200.0	100.0
		Mg/Kg	-	-	-
		Annual Average****	-	100.0	-
		24 hours***	-	180.0	-
Suspended particulate matter (<10 µg/m3) (SPM)	µg/m3	Annual Average*	120.0	60.0	50.0
		24 hours**	150.0	100.0	75.0
Lead (Pb)	µg/m3	Annual Average*	1.0	0.8	0.5
		24 hours**	1.5	1.0	0.8
		Month Average	-	-	-
Carbon monoxide (CO)/carbon dioxide (CO2)	µg/m3	8 hours**	5.0	2.0	1.0
		1 hour	10.0	4.0	2.0
Hydrocarbons (HC)		24 hours**	-	-	-
VOC		24 hours**	-	-	-
Ozone	ppm	1-Hour	-	0.12	-
		Instant Peak	-	1.25	-

**Annual Arithmetic mean of minimum 104measurements in a year taken twice a week 24 hourly at uniform interval.*

*** 24 hourly/8 hourly values should be met 98% of the time in a year. However, 2% of the time, it may exceed but not on two consecutive days. The 24-hour limit may not be exceeded more than three times in one year.*

**** Not to be exceeded more than once per year average concentration*
Whenever and wherever two consecutive values exceed the limit specified above for the respective category, it would be considered adequate reason to institute regular/continuous monitoring and further investigations.

The Liberian Environmental Protection Agency has published an ambient air quality standard, and it was used in the assessment of the air quality impacts.

Dust Deposition Limits

There is no local dustfall criteria, thus, dustfall Hs been gauged according to the standards published by the South African Department of Environmental Affairs (SA DEA).

South Africa's Draft National Dust Control Regulations were published in May of 2011. The purpose of the regulations is to prescribe general measures for the control of dust in all areas including residential and light commercial areas.

The draft regulations state that:

No person may conduct any activity in such a way as to give rise to dust in such quantities and concentrations that –

1) The dust, or dustfall, has a detrimental effect on the environment, including health, social conditions, economic conditions, ecological conditions or cultural heritage, or has contributed to the degradation of ambient air quality beyond the premises where it originates; or
2) The dust remains visible in the ambient air beyond the premises where it originates; or
3) The dustfall at the boundary or beyond the boundary of the premises where it originates exceeds –
    a. 600 mg/m^2-day averaged over 30 days in residential and light commercial areas measured using reference method ASTM 01739; or
    b. 1 200 mg/m^2-day averaged over 30 days in areas other than residential and light commercial areas measured using reference method ASTM 01739

7.8.2 Scope of the Assessment

Airborne emissions may occur during the construction and operational phases of the mining cycle. The most significant sources include fugitive particulate matter (PM) from drilling, blasting, bulk earthworks, windblown dust from exposed surfaces such as tailings facilities, stockpiles and waste dumps, hauls roads and infrastructure. Gases from combustion of fuels in stationary and mobile equipment also add to airborne emissions but to a lesser extent.

In the estimation of PM emissions and impacts a distinction is made between different particle size fractions, *viz*. TSP, PM10 and $PM_{2.5}$. PM_{10} is defined as particulate matter with an aerodynamic diameter of less than 10 µm and is also referred to as thoracic particulates. Inhalable particulate matter, $PM_{2.5}$, is defined as particulate matter with an aerodynamic diameter of less than 2.5 µm. Whereas PM_{10} and PM2.5 fractions are taken into account to determine the potential for human health risks, total suspended particulate matter (TSP) is included to assess nuisance dustfall.

Combustion emissions include PM_{10} and $PM_{2.5}$, carbon monoxide (CO), nitrogen oxides (NOx), sulphur dioxide (SO_2), polycyclic aromatic hydrocarbons (PAH) and volatile organic compounds (VOCs) such as formaldehyde. PM emitted from diesel combustion will mostly be in the form of black carbon, commonly referred to as diesel particulate matter (DPM).

7.8.3 Baseline Conditions

Description of the Site and Atmospheric Conditions

Meteorological mechanisms govern the dispersion, transformation, and eventual removal of pollutants from the atmosphere. The analysis of hourly average meteorological data is necessary to facilitate a comprehensive understanding of the atmospheric dispersion potential of the site.

Meteorological Modelling

In the absence of representative on-site hourly sequential meteorological data at Bomi, reference was made to modelled MM5 meteorological data for the project area. A wind field simulation model was applied to determine *site specific meteorological conditions*. For this purpose, it was decided to use the US EPA CALMET wind field model. This model is able to simulate the complex nature of the study area and atmospheric interaction over land and sea. A short discussion on each of the most important meteorological parameters from an air pollution dispersion point of view (wind field, temperature, rainfall and atmospheric stability) is provided in this section.

Surface Wind Field

Wind roses comprise 16 spokes, which represent the directions from which winds blew during a specific period. The colours used in the wind roses Figure 46 *reflect* the different categories of wind speeds; the red area, for example, representing winds in between 3 and 4 m/s. The dotted circles provide information regarding the frequency of occurrence of wind speed and direction categories. The frequency with which calms occurred, i.e. periods during which the wind speed was below 1 m/s are also indicated. The period wind field and diurnal variability in the wind field are shown in Figure 47. Day-time is considered sunrise to sunset i.e. 06:00 to 18:00. Night-time wind roses represent hours from 18:00 to 06:00.

The wind field in the Project area is characterized by dominant south-south-westerly and south-westerly winds. Calm conditions prevailed 22 percent during the period with a period average wind speed of 2 m/s with little variation in the diurnal wind field. The strongest winds (> 6 m/s) were also from the south-south-west. Wind speeds decreased during the night. The average wind speed of 2.3 m/s during the day, decreased to 1.9 m/s during the night.

The West African region is influenced by the movements of the Inter Tropical Convergence Zone (ITCZ) which is a region of pronounced convective activity. In Africa, north of 20° south, three major near surface airflows influence the climate, these are equatorial westerly winds which consist of the low level movement of Atlantic air over the central parts of the African continent; the East African monsoon airflows that cross the continent from the northeast, these may impact the location of the ITCZ; and the deep tropical easterly flows originating from the tropical Indian Ocean, which move across the African continent in a north westerly direction.

The two air flow patterns that directly cross Liberia do so predominantly as south westerly winds. The modelled wind field confirms macro scale wind flows prevalent in this region.

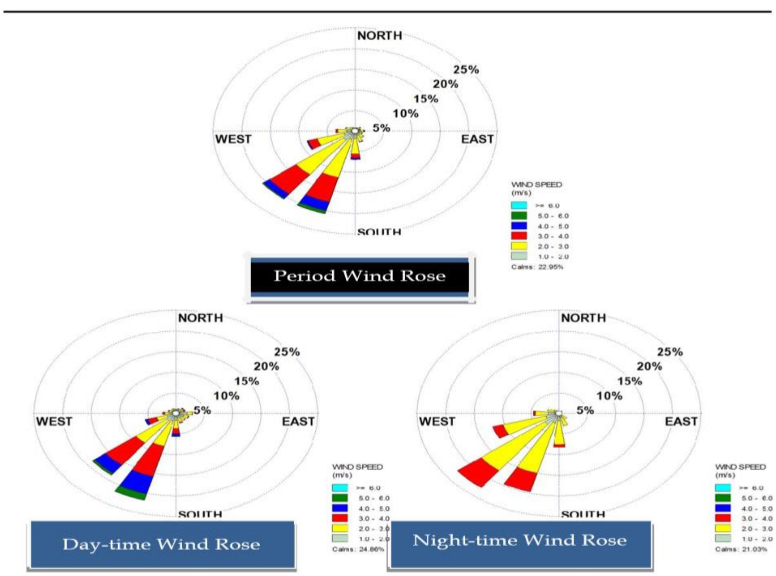


Figure 46: Period, day and night-time wind roses for Bomi (CALMET data, 2011. Source ERM)

Temperature

Air temperature is important, both for determining the effect of plume buoyancy (the larger the temperature difference between the emission plume and the ambient air, the higher the plume is able to rise), and determining the development of the mixing and inversion layers.

Diurnal and average monthly temperature trends are presented in Figure 47. Monthly mean and hourly maximum and minimum temperatures are given in Table 64. *Temperatures* ranged between 21.6 °C and 31 °C. During the day, temperatures increased to reach maximum at around midday. Ambient air temperatures decreased to reach a minimum at around 06:00 i.e. just before sunrise.

Table 64: Hourly minimum, hourly maximum and monthly average temperatures at Bomi

Hourly Minimum, Hourly Maximum and Monthly Average Temperatures (°C) Extracted from Regional CALMET Model Data, 2023												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Minimum	20.4	21.5	23.2	22.3	23.5	22.4	21.2	20.6	20.9	21.6	21.5	20
Maximum	32.3	33.5	32.2	33	34.3	33.1	31.4	30.3	31.2	31.6	32	32.9
Average	**26.2**	**26.7**	**27**	**27.3**	**27.6**	**26.7**	**25.3**	**24.8**	**25.6**	**25.9**	**25.9**	**25.9**

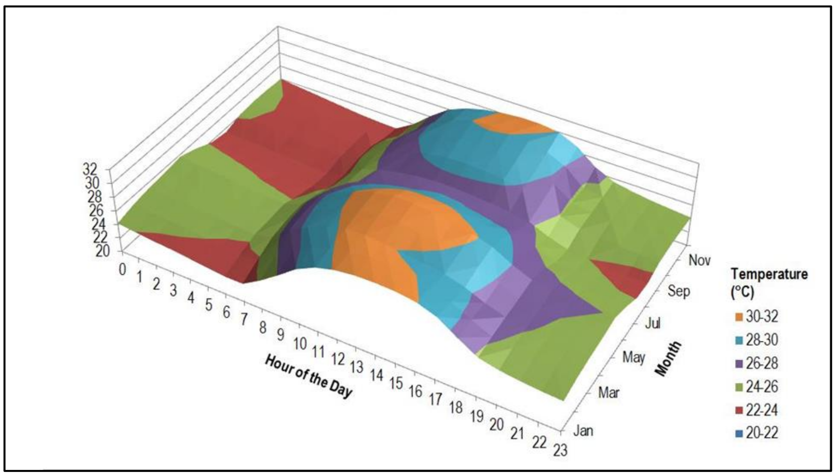


Figure 47: Monthly, diurnal average temperatures at Bomi (CALMET data. Source ERM)

Precipitation

Precipitation is important to air pollution studies since it represents an effective removal mechanism of atmospheric pollutants. Monthly rainfall as obtained from regional CALMET model data is presented in Figure 48. Annual rainfall was 3,500 mm.

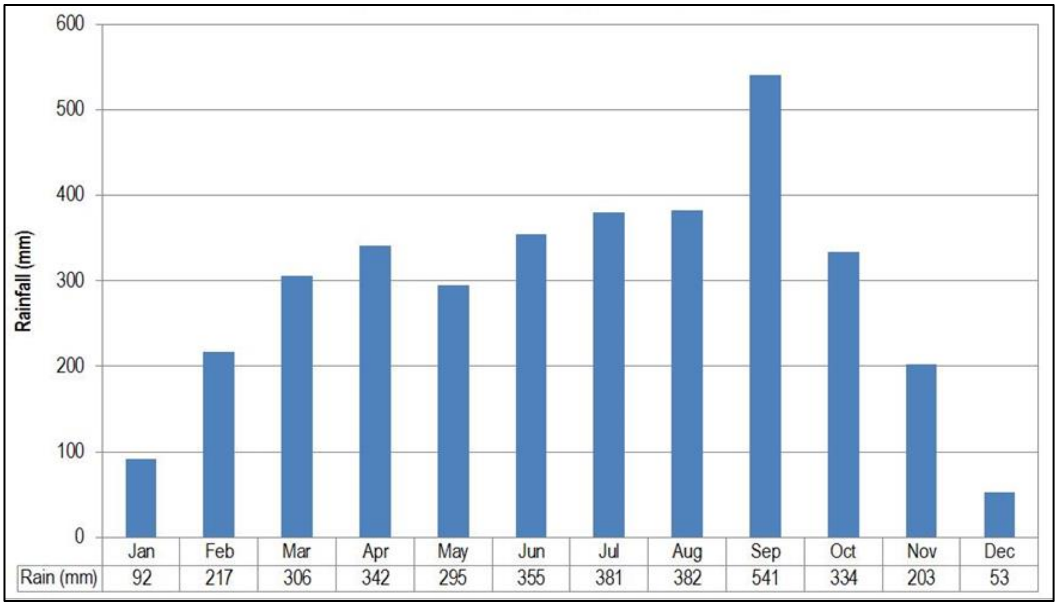


Figure 48: Monthly precipitation at Bomi (CALMET data, Source ERM)

Existing Ambient Air Quality

The objective of any ambient air quality assessment is to understand the current air quality in a specific region and to identify the main contributing sources to concentration levels. It also enables the assessment of the potential for cumulative air quality impacts associated with the instruction of a new source of emission in an airshed.

Existing Sources of Atmospheric Emissions

Existing sources of atmospheric emission within and around Bomi Hills were identified during two visits to site. The following was observed:

- The Bomi Hills area can be described as rural.
- Sources of particulate emissions (TSP, PM_{10} and $PM_{2.5}$) include:
    - Vehicle entrainment from paved and unpaved roads;
    - Vehicle exhaust; Subsistence farming;
    - Charcoal manufacturing and domestic use; and
    - Small scale construction activities.
- Sources of gaseous emissions (CO, NOx, SO2 and VOCs) include: o Vehicle exhaust, mostly small cars and motorcycles; and o Charcoal manufacturing and domestic use
- High rainfall reduces the potential for fugitive PM generation to a large extent.

Sampled Ambient Air Quality

A baseline air quality monitoring network was set up at Bomi and it included:

- Dustfall monitoring at four locations (Location 1, 2, 3 and 4, *Map 7-28*) conducted in accordance with the American Society for Testing and Materials standard method for collection and analysis of dustfall (ASTM D1739-98);
- PM_{10} monitoring at one location (Location 2, *Map 7-28*) conducted in accordance with British Standards (BS EN 12341); and
- SO_2/NO_2 Radiello passive diffusive monitoring at one location (Location 2, *Map 7-28*)

(a) Location 1 –Bomi Guesthouse (Dustfall Monitoring)

(b) Location 2 –Bomi Wood (Dustfall, PM10 and SO2/NO2 Monitoring)

(c) Location 3 –Bomi Exploration Guesthouse (Dustfall Monitoring)

(d) Location 4 –Boart Longyear (Dustfall Monitoring)

Figure 49: Baseline sampling sites in the project area

Figure 7-50

Sampled baseline dustfall rates around Bomi Hills Mine at the Bomi Guesthouse (Location 1), Bomi Wood (Location 2), the Bomi Exploration Guesthouse (Location 3) and Drilling Camp (Location 4) are graphically presented in Figure 49.

Dustfall rates for all three months at all four locations were low and well below the dustfall limit considered acceptable for residential areas. Results also indicate a slight increase in dustfall rates in the third week. Although still considered low, the highest dustfall rate was sampled at Site 4 during in the third week.

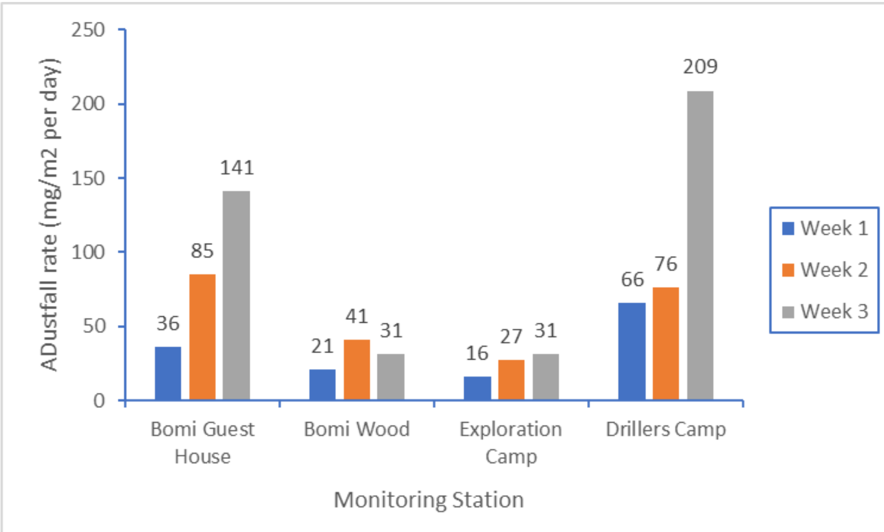


Figure 51: Sampled baseline dustfall rates at Bomi Hills Mine

Baseline for PM_{10} concentrations at Bomi Hills Mine relied on the 2013 ESIA reported baseline data which is graphically presented in Figure 52.

The data shows that daily PM_{10} concentrations were in exceedance of the Liberian Ambient Air Quality Standards in most instances, but it should be noted that the monitoring period was during the dry season for Liberia and dust fallout and PM_{10} concentrations will be higher.

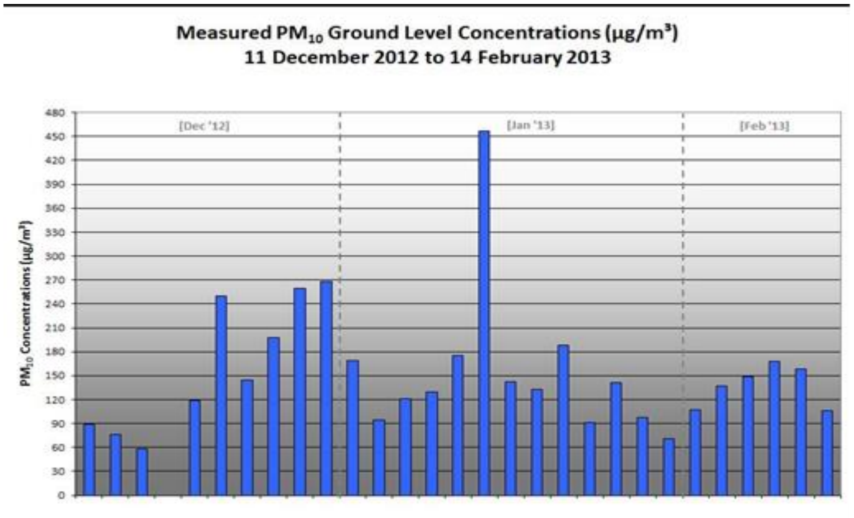


Figure 52: Sampled Baseline PM10 Concentrations at Bomi Hills Mine (ERM, 2013)

7. 9 CLIMATE CHANGE

The GHG Specialist Study has been produced through desktop assessment of international and national climate change literature (science and policy), review of relevant WCL documentation and communications with WCL representatives. No field work was undertaken.

7.9.1 Carbon Footprint Calculation

Methodology

A carbon footprint is a measure of the estimated greenhouse gas (GHG) emissions caused directly and indirectly by an individual, organization, event or product. The calculation of a carbon footprint generally involves the following equation:

Carbon footprint emissions = activity data x emissions factor x global warming potential

- *Activity data* relates to the emission causing activity e.g. the combustion of a quantity of diesel or the use of a explosives for blasting activities;
- *Emission factors* convert the activity data collected and consolidated into tonnes of the relevant greenhouse gas; and
- *Global warming potentials* are applied to non-CO_2 GHG to convert the result to carbon dioxide equivalent (tCO_2e).

The carbon footprint has been estimated in accordance with the *GHG Protocol: Corporate Accounting & Reporting Standard* developed by the World Business Council for Sustainable Development (WBCSD) and the World Resources Institute (WRI). The *GHG Protocol* provides comprehensive guidance on accounting and reporting corporate GHG emissions. It is the most widely used standard for mandatory and voluntary GHG programmes and makes use of the Intergovernmental Panel on Climate Change (IPCC) GHG inventory guidelines for specific heating values, carbon content, densities and emission factors.

The calculation using these standards ensures that the Carbon Footprint is aligned with international standards.

Emissions Boundary Definition

The scope of the carbon footprint depends on the definition of two boundaries relating to the organizational and operational aspects of the project as outlined below. The boundaries drawn for the purposes of this project are discussed further in *Section 7.9.2*.

Organizational boundaries determine whether reporting is done according to the "equity share approach" (different economy being wholly owned, incorporated or non-incorporated join ventures or subsidiaries) or the "control approach" (operations under the direct operational control of the parent company).

Operating boundaries determine which emission causing activities will be included in the carbon footprint. The GHG Protocol divides emissions into three categories as described below and illustrated I Figure 53.

- *Scope 1 –direct emissions* from sources owned or under the operational control of the company;
- *Scope 2 –indirect emissions* from the consumption of purchased electricity; and
- *Scope 3 –indirect emissions* an optional reporting category allowing for other indirect emissions associated but not controlled by the company to be included such as contractor activities.

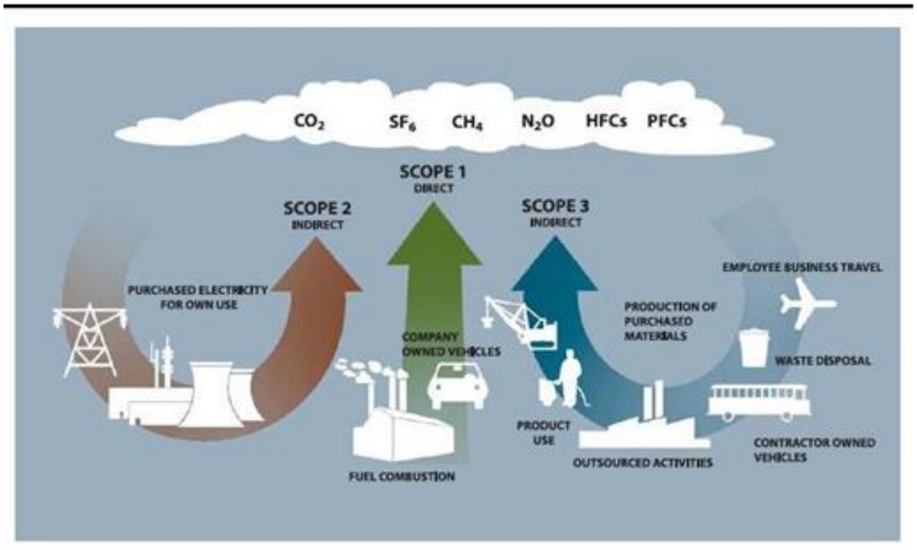


Figure 53: GHG Protocol Emission Scopes

7.9.2 Scope of the Carbon Footprint

This section defines the scope of the WCL carbon footprint in terms of emission boundaries and an overview of emission causing activities. The results of the carbon footprint calculation are presented in *Section 7.9.6.*

Organizational and Operational Boundary

The organizational boundary has been defined according to the control approach where emissions from sources under the direct operational control of WCL will be included in the carbon footprint as illustrated in Figure 54.

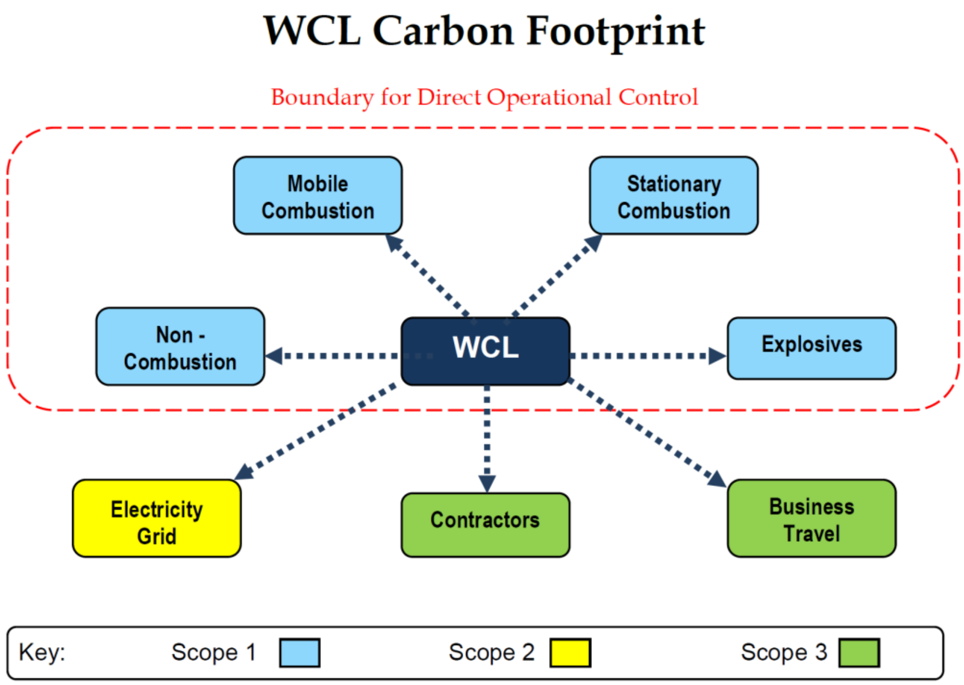


Figure 54: WCL's Carbon Footprint

It is assumed that WCL will pay for the fuel used by contractors on site and therefore the emissions associated with their activities have been included under Scope 1. All electricity is generated on site (Scope 1) and Scope 2 emissions will be from purchased electricity since the national grid is now available in Tubmanburg through the Liberia Electricity Corporation.

Scope 3 (indirect) emissions would typically be from outsourced activities, such as contractor activity and employee business travel. These emissions have been excluded for the purposes of this study due to the fact that there is considerable uncertainty with respect to estimating contractor activity and employee business travel.

7.9.3 Overview of WCL emission causing activities

Key emission sources occurring on site and those which are included in the carbon footprint are summarized in Table 66.

Table 65: Summary of Key Emission Sources (all Scope 1)

Emission Scope	Emission Source
Mobile combustion	Fuel used in terrestrial vehicles –e.g. cars, utility vehicles, buses
Stationary combustion	HFO used for power generation
	Diesel/HFO used for stationary equipment
Non-Combustion	Lubricants - Use of lubricant oils and greases in machinery
Explosives	Explosives used in the blasting activities

7.9.4 Timeframe

Construction at the Bomi Hills Mine is due to begin in 2013 with production beginning in 2014. The extraction at the Bomi Hills Mine will be continuous until depletion. The life of the Mine (LOM) is anticipated to be 19 years, mining at an annual rate of 4 million tons iron ore concentrate at ±62 %Fe.

7.9.5 Assumptions made in estimating operational activity data

Good practice for calculating a carbon footprint dictates that actual activity data (e.g. litres of diesel consumed) for a financial year is used. Given that this project involves an estimation of a future carbon footprint for activities yet to begin, a series of assumptions have been made in order to obtain the activity data required to undertake this calculation.

Data was obtained from the 2013 ESIA Report and WCL personnel. The carbon footprint has been estimated in accordance with current design options and these may well change following completion of the ESIA. *Annex 7-I* provides a detailed account of the assumptions that have been made in relation to each aspect of the carbon footprint calculation.

The carbon footprint is an estimate of direct emissions (Scope 1) from activities associated with the project. All electricity is generated on site (Scope 1) and therefore there are no Scope 2 emissions from purchased electricity.

Emissions associated with the business travel and contractor transportation are regarded as Scope 3 and not included due to considerable uncertainty of data and information, and are thus outside the scope of this project.

7.9.6 GHG Emissions in Liberia and WCL

GHG Emissions in Liberia

Liberia produced **0.01%** of global greenhouse gas emissions in 2021 (the latest date with complete emissions data). This amounted to 1.83m metric tonnes of carbon dioxide equivalent, or $MtCO_2e$. These emissions represented an increase from 2020 by 2.5% (https://www.emission-index.com/countries/liberia)

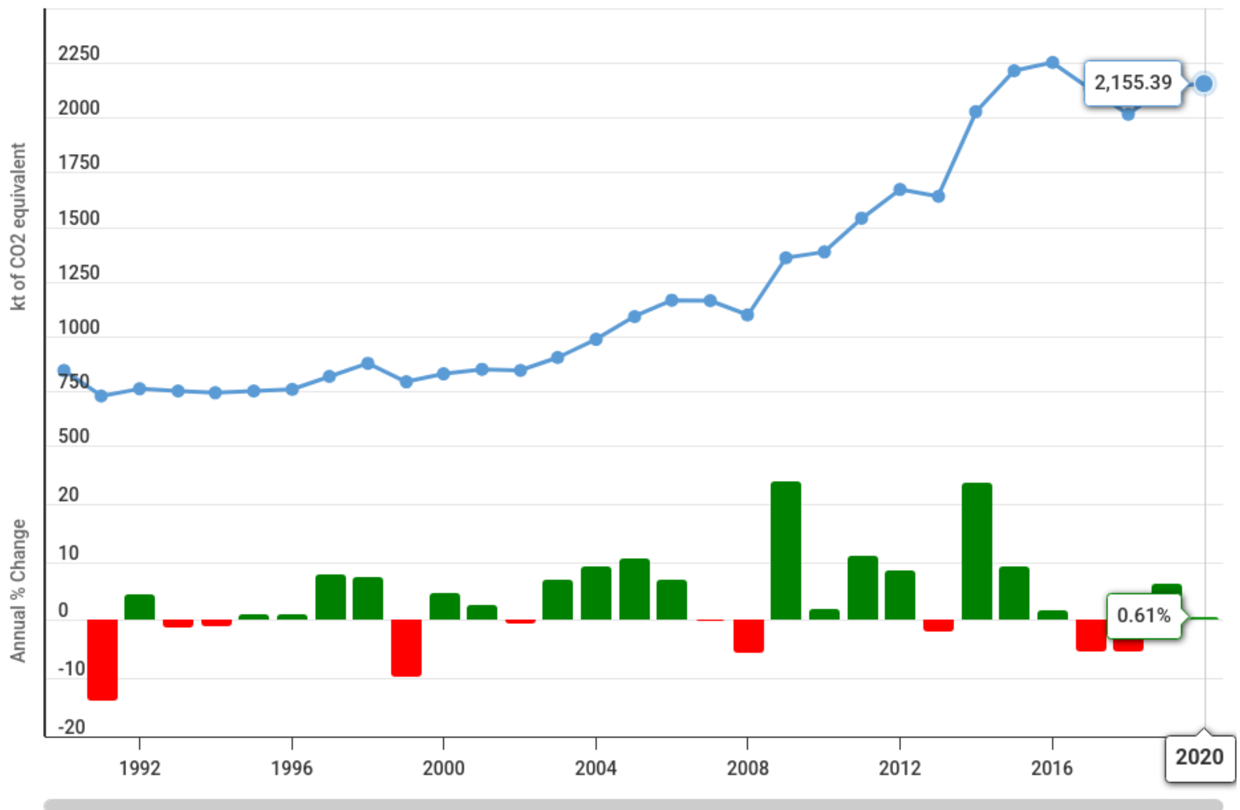


Figure 55: Liberia Greenhouse Gas (GHG) Emissions 1990-2024 (https://www.macrotrends.net/global-metrics/countries/LBR/liberia/ghg-greenhouse-gas-emissions)

Liberia's emissions ar subscribed to the low economic and technical activity of the country. Contributing factors include inadequate infrastructure, low institutional capacity and inadequate data monitoring capability. In addition, Liberia does not have a national electricity grid supply.

In the absence of current actual emissions data, GDP growth has been used as a proxy for emissions growth. Figure 56 illustrates the variation in GDP growth rate from 2003 to 2032, with the 2005 to 2011 average GDP being used as an estimate for the GDP growth for 2012 to 2032.

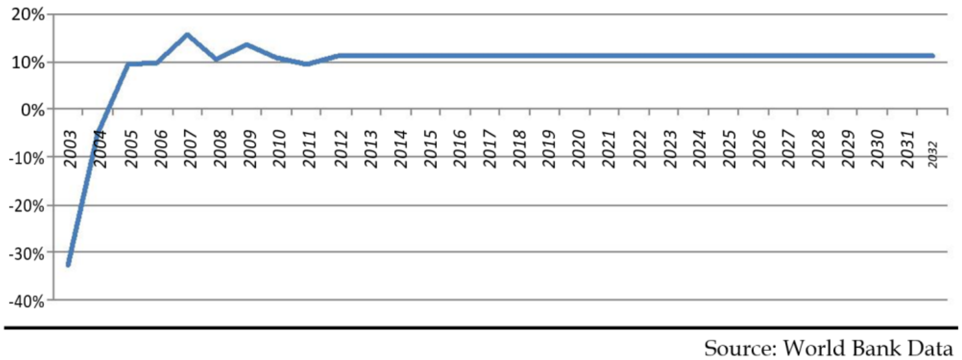


Figure 56: Liberia GDP growth rates 2004 - 2032

Liberia has shown a negative growth rate between 2003 and 2004, but has varied between 9 percent and 16 percent from 2005 to 2011. Due to the variations in the GDP growth data, only the positive GDP growth of 2005 to 2011 has been used to make a conservative estimate of the GDP growth. The average over these years (i.e. 2005 to 2011) of 11 percent per annum has been used to project emissions from 2010 to 2032. The extent of the increase in national emissions is somewhat dependent on the policy, legislative framework, the type of development (e.g. mining, manufacturing) and GDP growth in Liberia, and the timing thereof. It is, however, the best estimate of potential future emissions in the country. Figure 56 illustrates Liberi estimated historic and projected national emissions based on a 2009 baseline and past and predicted GDP growth.

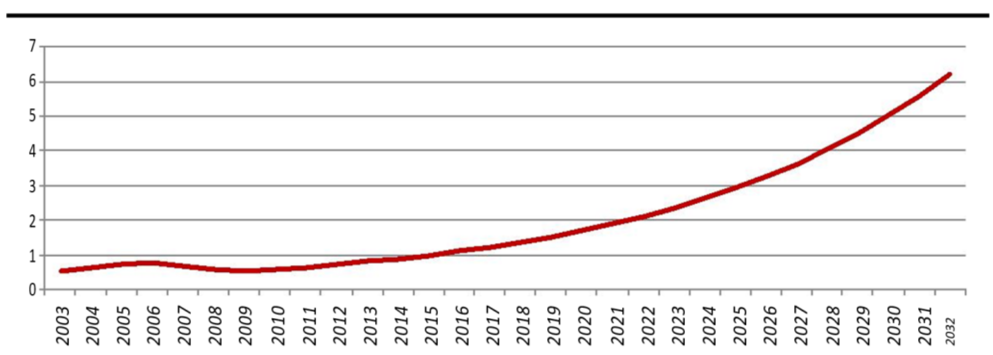


Figure 57: Liberia National Emissions (MtCO2e) based on GDP Growth

Table 66: WCL Estimated Operational Carbon Footprint

Emission Source	Annual Emissions (tCO2e)	LOM Total Emissions (tCO2e)	Percentage of Total Emissions
Mobile Combustion	81 252	1 454 415	23.33%
Stationary Combustion	264 427	4 733 241	75.93%
Non-Combustion	1 739	31 120	0.50%
Explosives	831	14 866	0.24%
Total tCO2e Emissions	**348 248.17**	**6 233 642**	**100.00%**

Estimated GHG Emissions by Source

The emissions associated with WCL facilities can be estimated as follows:

<u>Mobile Combustion</u>

Mobile combustion emissions result from transport related activities. At full production, the annual emissions from mobile combustion are estimated to be 81,252 tCO2e.

The total emissions from mobile combustion during the operational phase of Bomi Hills Mine (i.e. 2014 - 2032) are estimated to be 1,454,415 tCO2e, which is 23.3 percent of the overall emissions.

<u>Stationary Combustion</u>

The electricity required to run operations will be provided by generators which will utilise Heavy Fuel Oil (HFO). It is understood that generators with a capacity of producing 40MW and a maximum of 60MW of power would be installed to power all WCL facilities, requiring the consumption of approximately 90,000 kilolitres of HFO per annum. At full production, the annual emissions from stationary combustion are estimated to be 264,427 tCO2e. Figure 58 illustrates the step change in stationary combustion emissions over time (i.e. annual emissions).

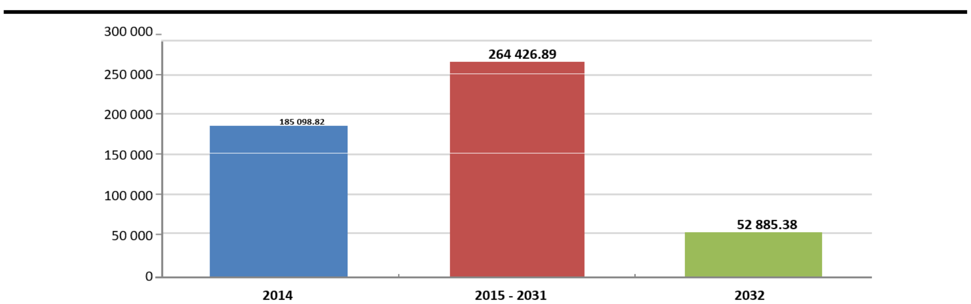


Figure 58: Annual Stationary Combustion Emissions (tCO2e)

The total emissions from stationary combustion during the operational phase of Bomi Hills Mine (i.e. 2014 - 2032) are estimated to be 4,733,241 tCO2e, which is 75.9 percent of the overall emissions.

Non-Combustion

The total emissions from non-combustion activities (i.e. lubricants such as oils) utilised during the mining process and/or in vehicles and equipment are estimated to be 1 739 tCO2e per annum at full production.

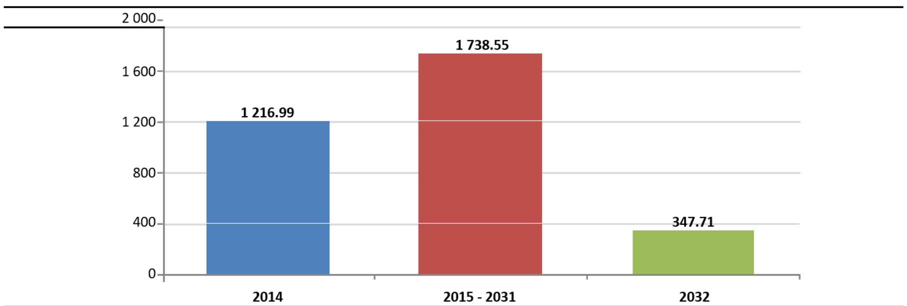


Figure 59: Annual Non-Combustion Emissions (tCO2e)

The total emissions from non-combustion emissions during the operational phase of Bomi Hills Mine (i.e. 2014 - 2032) are estimated to be 31,120 tCO2e, which is 0.5 percent of the overall emissions.

Explosives

Explosives to be utilized for blasting activities annually was provided by WCL. According to current design, Ammonia Nitrate Emulsion will be used for blasting activities. At full production, the annual emissions from explosives are estimated to be 831 tCO2e. Figure 60 illustrates the step change in emissions from explosives over time (i.e. annual emissions).

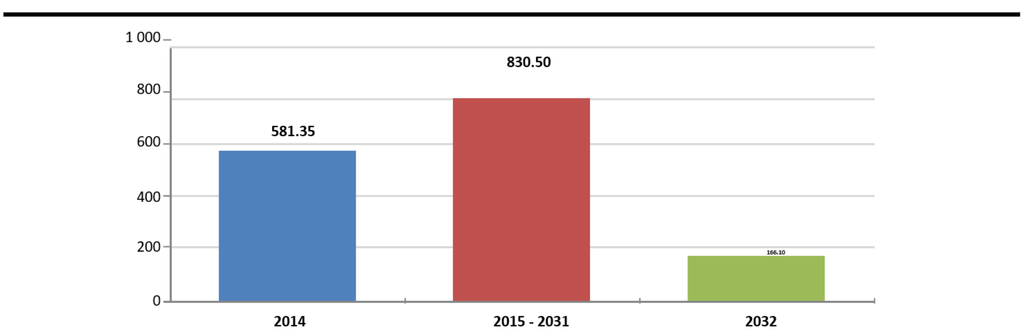


Figure 60: Annual Explosive Usage Emissions (tCO2e)

The total emissions from explosives during the operational phase of Bomi Hills Mine (i.e. 2014 - 2032) are estimated to be 14,866 tCO_2e, which is less than 0.2 percent of the overall emissions.

Uncertainty and Gaps

The significant direct emission sources have been included in the estimated carbon footprint of the operations of the WCL Project. There is a significant level of uncertainty in the estimates given the early stage of project design and data availability. This report is based on the designs and assumptions available at the time of writing and the results may or may not correlate to the final design of the facility.

Additional potential emission sources may include land use change, refrigerants and waste water emissions which have not been quantified in the carbon footprint. Further detail on the exclusions and the broad assumptions that have been made in calculating emissions are outlined in *Annex 7-I*.

7. 10 Noise

7.10.1 Methodology

Individual aspects of the noise impact assessment methodology, as required by the terms of reference, are subsequently discussed in more detail.

Noise Defined

As background to the noise impact assessment, the reader should take note of some important definitions and conventions used in the measurement, calculation and assessment of environmental noise.

Noise is generally defined as unwanted sound transmitted through a compressible medium such as air. Sound in turn, is defined as any pressure variation that the ear can detect. Human response to noise is complex and highly variable as it is subjective rather than objective.

Noise is reported in decibels (dB). “dB” indicated as 10 times a logarithmic ratio of quantities that have the same units, in this case sound pressure. The relationship between sound pressure and sound pressure level is illustrated in the following equation:

$$L_p = 20 \cdot \log_{10}\left(\frac{p}{p_{ref}}\right)$$

Where:
Lp *is the sound pressure level in dB;*
P *is the actual sound pressure in Pa; and*
Pref *is the reference sound pressure (pref in air is 20 µPa)*

Perception of Sound

Sound has already been defined as any pressure variation that can be detected by the human ear. The number of pressure variations per second is referred to as the frequency of sound and is measured in hertz (Hz). The hearing of a young, healthy person ranges between 20 Hz and 20 000 Hz (20 kHz).

In terms of sound pressure level, audible sound ranges from the threshold of hearing at 0 dB to the pain threshold of 130 dB and above. Even though an increase in sound pressure level of 6 dB represents a doubling in sound pressure, an increase of 8 to 10 dB is required before the sound subjectively appears to be significantly louder. Similarly, the smallest perceptible change is about 1 dB (Brüel & Kjær Sound & Vibration Measurement A/S, 2000)[43].

Frequency Weighting

As human hearing is not equally sensitive to all frequencies, a 'filter' has been developed to simulate human hearing. The 'A-weighting' filter simulates the human hearing characteristic, which is less sensitive to sounds at low frequencies than at high frequencies. "dBA" is the descriptor that is used to indicate 10 times a logarithmic ratio of quantities, that have the same units (in this case sound pressure) that has been A-weighted.

Adding Sound Pressure Levels

Since sound pressure levels are logarithmic values, the sound pressure levels as a result of two or more sources cannot just simply be added together. To obtain the combined sound pressure level of a combination of sources such as those at an industrial plant, individual sound pressure levels must be converted to their linear values and added using the following equation:

$$L_{p\_combined} = 10 \cdot \log\left(10^{\frac{L_{p1}}{10}} + 10^{\frac{L_{p2}}{10}} + 10^{\frac{L_{p3}}{10}} + \cdots 10^{\frac{L_{pi}}{10}}\right)$$

This implies that if the difference between the sound pressure levels of two sources is nil the combined sound pressure level is 3 dB more than the sound pressure level of one source alone. Similarly, if the difference between the sound pressure levels of two sources is more than 10 dB, the contribution of the quietest source can be disregarded (Brüel & Kjær Sound & Vibration Measurement A/S, 2000).

[43] Brüel & Kjær Sound & Vibration Measurement A/S. (2000). www.bksv.com. Retrieved October 14, 2011, from Brüel & Kjær: http://www.bksv.com

Environmental Noise Propagation

Many factors affect the propagation of noise from source to receiver. The most important of these are:

- The type of source and its sound power;
- The distance between the source and the receiver;
- The extent of atmospheric absorption (attenuation);
- Wind speed and direction;
- Temperature and temperature gradient;
- Obstacles such as barriers or buildings between the source and receiver;
- Ground absorption;
- Reflections;
- Humidity; and
- Precipitation

To arrive at a representative result from either measurement or calculation, these factors must be taken into account (Brüel & Kjær Sound & Vibration Measurement A/S, 2000).

Environmental Noise Indices

In assessing environmental noise either by measurement or calculation, reference is made to the following indices:

- **LAeq (1 hour)** –The A-weighted equivalent sound pressure level, where noise is averaged over one (1) hour (calculated or measured).
- **LA90** – The A-weighted 90 percent statistical noise level, i.e. the noise level that is exceeded during 90 percent of the measurement period. It is a very useful descriptor which provides an indication of what the LAeq could have been in the absence of noisy single events and is considered representative of background noise levels.

7.10.2 Approach

Baseline noise measurements were conducted in accordance with the Liberian Noise Pollution Control Standards and Regulation of 2017. The Objectives of these Regulations are to ensure the maintenance of a healthy environment for all people in Liberia, the tranquility of their surrounding and their psychological well-being by prescribing standards, regulating noise and vibration levels, and to improve the standard of living by:

1) Providing standards for noise and vibrations
2) Prescribing the maximum permissible noise and vibrations levels from a facility or activity to which a person may be exposed; and
3) Providing for the control of noise and for mitigating measures for the reduction of noise;

Sound power levels (noise 'emissions') from activities associated with the project were estimated from sound power level predictions for industrial machinery as published in the *'Handbook of Acoustics'* (Crocker, 1998) (2) and SANS10210, *'Calculating and predicting road traffic noise'* (SANS 10210, 2004) (3). Reference was also made to general sound power data obtained from Francois Malherbe Acoustic Consulting cc.

The propagation of noise from proposed operations was calculated according to *'The calculation of sound propagation by the Concawe method'* (SANS 10357, 2004) (4). The Concawe method makes use of the International Organization for Standardization's (ISO) air absorption parameters and equations for noise attenuation as well as the factors for barriers and ground effects. In addition to the ISO method, the Concawe method facilitates the calculation of sound propagation under a variety of meteorological conditions. Average meteorological parameters obtained from readily available and modelled MM5 data were applied in calculations.

Predicted noise impacts were calculated both in terms of total ambient noise levels as a result of Bomi Hills operations as well as the effective increase in ambient noise levels. Impacts were assessed according to reference values published by the EPA.

7.10.3 Assumptions and Limitations

The following should be noted:

- As a conservative measure the mitigating effects of pit walls and waste dumps were not accounted for.
- The extent and character of construction phase noise will be highly variable as different activities with different equipment will take place at different times, periods, combinations, sequences and parts of the construction site. In the absence of a detailed construction schedule, this phase is assessed qualitatively.

Environmental Noise Regulations

Prior to assessing existing baseline levels or the impact of mining operations on the surrounding area, reference needs to be made to the environmental regulations governing the impact of such operations i.e. ambient noise level guidelines.

The EPA guidance on the assessment of noise impacts beyond the project boundaries of industrial facilities, and it states that noise impacts should not exceed the levels presented in *Table 68*.

Table 67: Environmental Noise Level Guidelines

Nos.	Facility	Noise Limits B (A) (Leq)	
		DAY	NIGHT
A	Any building used as hospital, convalescence home, home for the aged, sanatorium and institutes of higher learning, conference rooms, public library, environmental or recreational sites.	45	35
B	Residential buildings	50	35
C	Mixed residential (with some commercial and entertainment)	55	45
D	Residential + industry or small-scale production + commerce	60	50
E	Industrial	70	60

Time Frame: use duration

Day: 6.00 a.m. 10.00p.m.

Night: 10.00p.m - 6. 00a.m

7.10.4 Baseline Conditions

Atmospheric Absorption and Meteorology

Atmospheric absorption and meteorological conditions have already been mentioned with regards to its role in the propagation of noise from source to receiver. Meteorological parameters affecting the propagation of noise are similar to those affecting atmospheric dispersion of air pollutants. It should, however, be noted that when assessing noise, day- and night-times are defined as being from 06:00 to 22:00 and 22:00 to 06:00 respectively.

Average wind speed, wind direction, temperature, relative humidity and pressure data for day- and night-times are summarized in Table 68.

Table 68: Average day- and night-time meteorological parameters

Meteorological Parameter	Day-time (07:00 –22:00)	Night-time (22:00 –07:00)
Average wind speed[(a)]	2.3 m/s	1.5 m/s
Wind Direction (° from)[(a)]	South-west (225°)	South-west (225°)
Average temperature[(a)]	27.5 (°C)	24.1 (°C)
Relative Humidity[(b)]	95 (%)	71 (%)

Air Pressure[c]	101 (kPa)	101 (kPa)
Solar Radiation[c]	700	Not applicable
Cloud Cover[c]	3/8	3/8

Notes:

a) Extracted from modelled MM5 data
b) 'Weather base'(Canty Media, 2013)
c) Assumption

It is well known that wind speed increases with altitude. This results in the 'bending' of the path of sound to 'focus' a 'shadow' on the upwind side of the sour the downwind level may increase by a few dB but the upwind level can drop by more than 20 dB (Brüel & Kjær Sound & Vibration Measurement A/S, 2000).

Wind roses indicating prevailing wind directions in the area during the day and night are provided in Figure 61. Except for a reduction in wind speed, there is very little variation in the diurnal wind field. From a maximum noise impact perspective (expected to occur at winds speeds of between 1 and 5 m/s), it can be concluded that noise impacts will be most significant to north-east and north-north-east of Bomi Hills mining operations.

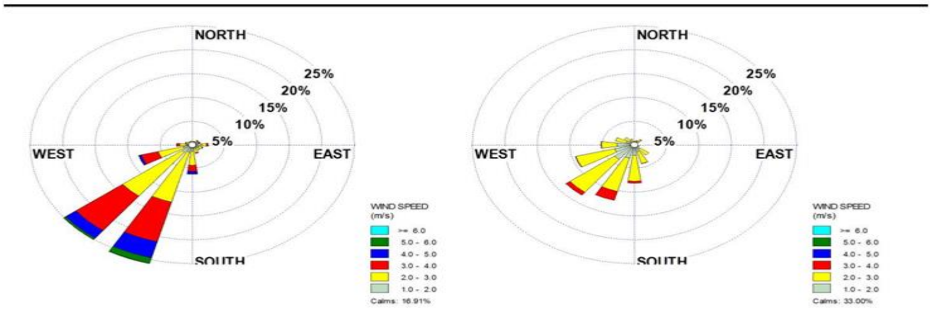


Figure 61: Day and night-time wind roses at Bomi Hills (ERM, 2012)

Temperature gradients in the atmosphere create effects that are uniform in all directions from a source. On a sunny day with no wind, temperature decreases with altitude and creates a 'shadowing' effect for sounds. On a clear night, temperatures may increase with altitude thereby 'focusing' sound on the ground surface. Noise impacts are therefore generally more significant during the night.

Terrain, Ground Absorption and Reflection

Noise reduction caused by a barrier (natural terrain or installed acoustic barrier) feature depends on two factors namely the path difference of the sound wave as it travels over the barrier compared with direct transmission to the receiver and the frequency content of the noise. Low frequency noise is difficult to reduce with barriers (Brüel & Kjær Sound & Vibration Measurement A/S, 2000).

Terrain features like the various hills present in the area may act as acoustic barriers and shield communities from noise generated at the proposed Bomi Hills Mine.

Sound reflected by the ground interferes with the directly propagated sound. The effect of the ground is different for acoustically hard (e.g., concrete or water), soft (e.g., grass, trees or vegetation) and mixed surfaces. Ground attenuation is often calculated in frequency bands to take into account the frequency content of the noise source and the type of ground between the source and the receiver barriers (Brüel & Kjær Sound & Vibration Measurement A/S, 2000). At Bomi Hills, the dense vegetation is considered acoustically soft i.e. conducive to noise attenuation.

7.10.5 Measured Baseline Noise Levels

Baseline noise measurements were conducted in accordance with EPA guidelines 2017. Noise monitoring locations were selected to establish the following:

- Baseline noise levels within community areas; and
- Baseline noise levels in remote mining areas where human activity is currently limited.

To achieve this, monitoring was conducted at various sites within the Bomi Hills Concession and the results are summarized in Table 69. During measurements, existing sources of noise and the physical environment, including weather conditions, were noted.

Table 69: Summary of sound level measurement

Site Description	Site Type	Day-time		Night-time	
		L_{Aeq} (dBA)	L_{A90} (dBA)	L_{Aeq} (dBA)	L_{A90} (dBA)
Bomi Hills Blue Lake	Remote	43.1	38.0	-	-
Bomi Hills Exploration Guesthouse	Community	53.1	48.1	-	-

From the noise measurements, the following was concluded:

- Measured noise levels correspond to typical noise levels reported for rural and residential areas;
- In remote areas, where human activity is limited, day-and night-time noise levels are comparable and mostly affected by natural noises such as wind, birds, frogs and insects;
- Baseline day-time noise levels are within the EPA guideline of 70 dBA;
- Baseline night-time noise levels frequently exceed the EPA night-time guideline of 60 dBA, this is mostly as a result of noise generated by insects and frogs;
- Calculations indicate that baseline noise levels in community areas are:
  - Day-time: 53 dBA;

    - Night-time: 52 dBA;
- Calculations indicate that baseline noise levels in remote areas are:
    - Day-time: 44 dBA; and
    - Night-time: 49 dBA.

Existing sources of noise and the physical environment, including weather conditions, were noted during measurements.

7.10.6 Noise Sensitive Receptors

Several communities, considered noise sensitive receptors (NSR) lie within a few kilometres from the proposed mining operations and may be affected by noise generated from the proposed operations. The locations of the NSRs are shown in *Map 7-30*.

7. 11 Vibrations

Blasting is a mining related disturbance that impact on people and structures located in the vicinity of the operation. When blasts are set off ground vibration and air blast disturbances occur. They, however, diminish in intensity with an increase in distance. Fly rock, after blast fumes, and dust will also occur.

To help manage this situation a systematic approach to the drill and blast operation needs to be adopted. This approach should initially assess the potential environmental impact of the drill and blast operation and then control and manage the day-to-day operations to ensure that the impacts are kept to acceptable levels. The aim of this assessment is to review the possible impact of the drill and blast operation and to provide guidelines to help ensure that the blasting process is correctly implemented so as to cause the lowest levels of disturbance.

7.11.1 Objectives

The possible impact of the blasting operations on the surrounding neighborhood is considered with an assessment of the disturbance levels that may be experienced at various distances from the mine. The preliminary work that should be carried out prior to the start of blasting is described below.

The following aspects of the blasting operation are assessed:

- Blast design and general safe blasting practice;
- Ground vibration,
- Airblast;
- Unwanted side effects such as fly rock, after blast fumes and dust;
- Pre blast surveys;
- Disturbance monitoring;

- Legal requirements; and
- Mitigation measures.

7.11.2 Methodology

Blast Design

Prior to the start of blasting proposed blast design is modelled to determine the firing sequence, number of holes firing together and the combined charge mass per delay. Based on these figures the PPVs can be calculated at the points of concern. These predictions are then compared to recognized standards - such as the United States Bureau of Mines Standard (USBM RI 8507) and / or the German Deutsches Institut fuer Normung (DIN 4150) standard - to ensure compliance. It is recommended, in this case, that the DIN standard be used where third world structures are found as it is a lot more conservative than the USBM standard.

The distances from the proposed mine to the various communities in the vicinity were determined using the final mine layout plan (*Chapter 2*) together with Google Earth. The measured distances are given *Table 71* below. Measurements were made from the boundary of the mine closest to the particular community (*Map 7-30*).

Table 70: Distance of Community from Mine Boundary

Measured from	Measured to	Distance (m)
Mine boundary	Zalakai, N of the mine.	300m
Mine boundary	Be Tape N of the mine.	3,170m
Mine boundary	Malia N of the mine.	3,520m
Mine boundary	Borbor, E of the mine.	460m
Mine boundary	Wesing ESE of the mine.	4,200m +
Mine boundary	Various houses SE of the mine.	1,290m
Mine boundary	Various areas around the disused mine pit. These appear to be used for relaxation.	0m to 450m
Mine boundary	Various houses S of the disused mine pit	835m
Mine boundary	Tubmanburg S of the mine.	2,000m +
Mine boundary	Be Mawi W of the mine. This location appears on Google Earth. The location must be confirmed.	300m

Ground Vibration

Ground vibration and air blast generally excite the greatest comment from people living in the neighborhood. Ground vibration disturbances will need to be measured and quantified to ensure compliance with recognized and accepted industry standards such as the internationally recognized USBM RI 8507 or the DIN 4150 standard since Liberia does not have its own standards or guidelines.

Factors Affecting Ground Vibration and Prediction of Ground Vibration Levels

Ground vibrations are an undesirable consequence of blasting activity. The intensity of the vibrations depends on a number of factors some of which can be managed and controlled to help reduce the impact.

The two principal factors that control vibration levels are distance and charge weight. Vibration levels will increase as the charge weight increases. The larger the charge mass the higher the amplitude of the vibration. The charge weight can be controlled by reducing the blasthole diameter or limiting the number of holes (i.e. the explosive mass) that fire together.

Vibration energy is attenuated by the rock mass so normally lower amplitudes are experienced further from a blast.

Vibration Control

Effective vibration control can be exercised by making use of a propagation law developed by the US Bureau of Mines, which relates peak particle velocity (vibration), charge weight and distance. This is referred to as the "Scaled Distance Relationship" which takes the following form:

$$Sd = D/\sqrt{E}$$

and

$$PPV = a(Sd)^{-n}$$

Where;

Sd = Scaled distance (Sd should be greater than or equal to 31 where no monitoring is carried out)
PPV = Peak Particle Velocity (mm/sec)
D = Distance to property of concern (m)
E = Mass of explosive per delay (kg)
a = Site specific constant, which is a function of the rock mass n = Site specific constant, which is a function of the rock mass

Human Response

Human beings are easily disturbed at low levels of vibration. Levels of 0.76 to 2.54 mm/sec are quite perceptible, but the probability of damage is almost non-existent. Levels between 2.54 and 7.62 are disturbing and levels above 7.62 can be very unpleasant.

Vibration Levels – Predictions

The following drill and blast design parameters were provided for ore and waste in the Feasibility report.

Table 71: Drill and Blast Design Parameters

Description	Ore	Waste
Density (t/m3)	3.6	3.0
Hole diameter (mm)	165	165
Burden (m)	4.5	5
Spacing (m)	5.5	6.5
Bench height (m)	12	12
Subgrade (m)	1	1
Explosive column (m)	9	8
Stemming length (m)	4	5
Explosive / hole (kgs)	212	188
Powder factor (kg/m3)	0.71	0.48
Explosive type	Bulk	Bulk
Explosive density	1.1	1.1

Blasting is being done during the day time and the stemming material used is drill cuttings. The parameters above were used in the modelling exercise. The purpose of the modeling exercise is to predict the ground vibration and airblast levels that could be expected at various distances from the mine for different charge masses fired. The prediction is based on desktop theoretical model. The actual blast design is carried out in consultation with the explosive supplier/blasting service provider. The distances are based on those given in *Table 72* above. A bulk emulsion explosive with a density of 1.1 was used in the calculation.

The calculated PPV determined at various distances from the mine and for increasing charge masses is shown in the tables below. The worst-case scenario (i.e. ore blasts) is reviewed in detail as these blasts will cause the highest disturbance levels. The waste blasts will cause slightly lower levels of disturbance as less explosive is used in each hole.

Airblast

Airblast is usually the main cause of blasting related complaints. Airblast is an atmospheric pressure wave consisting of high frequency sound that is audible and low frequency sound or concussion that is sub-audible and cannot be heard. Either or both of the sound waves can cause damage if the sound pressure is high enough.

Airblast results from explosive gasses being vented to the atmosphere that results in an air over pressure pulse. This occurs as a consequence of stemming ejections or hole blowouts, direct rock displacement through face ruptures or surface cratering, the use of high Velocity of Detonation (VOD) accessories that are left unconfined and / or uncovered (e.g. detonating cord on surface), by ground vibration or by various combinations of the above.

Airblast levels will be aggravated by local weather conditions such as cloud cover (cloud base height above ground and percentage cover), temperature inversions and wind strength and direction. *Figure 7.45* (Chiappetta, 2000) illustrates the possible impact of temperature profiles. If these temperature conditions are accompanied by strong wind the situation can be exacerbated. To ensure that the airblast impact is minimised, rigorous control of the blasting operation must be implemented. This includes postponing blasts when temperature inversions occur and when the cloud base is low, especially if the prevailing wind is blowing towards a sensitive area.

It is difficult to predict air blast levels with certainty due to unknown blast conditions as well as varying atmospheric conditions. However, airblast can usually be successfully contained below 130 dB by precise control of the charging operation (overcharged holes can generate amplitudes that exceed 142 dB). Airblast amplitudes up to 135 dB should not cause damage but it is recommended that the airblast be kept below the 130 dB level. Suggested threshold limits for air blast have been proposed by Personn et.al.[44] (*Table 7.60*).

[44] Persson, P-A, Holmberg, R and Lee, J, 1994, Rock Blasting and Explosives Engineering. CRC Press, USA.

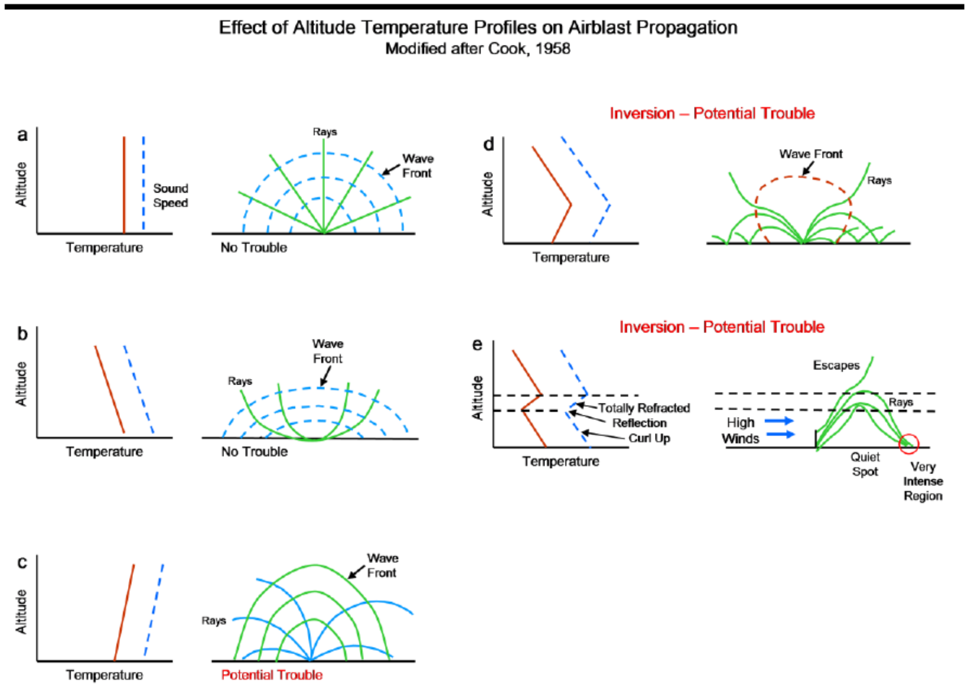


Figure 62: Effect of altitude temperature profiles on airblast propagation (Chiappetta, 2000)

Table 72: Damage Threshold for airblast

120 dB	Threshold of pain for continuous sound
	Resonant response of large surfaces (roofs, ceilings).
>130 dB	Complaints start.
150 dB	Some windows break
170 dB	Most windows break
180 dB	Structural Damage

Chiappetta [45] (personal communication) recommends that a maximum threshold level of 125 dB be used, to try and avoid all complaints.

Airblast Prediction

45 Chiappetta, R.F., 2000, Vibration/airblast controls, Damage criteria, record keeping and dealing with complaints. The Institute of Quarrying, Southern Africa, Symposium, Durban

Given the variables associated with airblast any attempt to predict air blast levels can only be regarded as subjective. There are a number of equations that can be used to try and predict airblast. Airblast is scaled according to the cube root of the charge weight:

$$K = D/W^{0.33}$$

The following equation can be used for the calculation of air blast:

$$L = 165 - 24 \text{ Log10 } (D/W^{0.33})$$

Where:

K = Scaled distance value;
L = Airblast level (dB);
D = Distance from source (m); and
W = Charge mass per delay (kg).

Airblast levels have been calculated using the same charge masses used for the prediction of ground vibrations.

The recommended maximum airblast level of 130 dB is exceeded at 150 m (ore blast) when a single hole fires. As more holes are fired together so the impact distance increases.

The number of holes detonated per delay is increased to illustrate the impact of more holes firing together. The legend in the graph refers to the number of holes firing together and to the Personn limit (130 dB).

The applicable airblast limit must be confirmed with the Liberian authorities. In this report it has been assumed that it will be similar to the 130 dB limit accepted in South Africa and other countries. This being the case, the graph shows that the airblast levels reach or exceed the 130 dB limit at distances of 300 m when eight holes fire together. It is also clear that the airblast impact will be greatest at the communities closest to the mine even for single hole firing.

7.11.3 Baseline Conditions

The location of the proposed Bomi Hills iron ore mine and the area surrounding the mine are shown in *Map 7-31* below.

A number of communities found to the west, north and east of the mine are located within 500 m of the mine boundary as well as various facilities belonging to the mine. All of these areas fall into the Area of Direct Influence (ADI).

There are also a number of communities (Be Tape, Malia, Wesing, Tubmanburg etc) located 800 m and further, from the proposed mine boundary. These areas fall into the Area of Indirect Influence (AII).

The ADI in terms of blasting impacts is a difficult one to quantitatively describe as there are a number of factors that could affect the distance at which the impacts are felt e.g. weather can affect how far airblast and noise are heard/ felt. As such one site could be an ADI on some occasions and an Area of Indirect Influence (AII) on other occasions.

At present, given the fact that no mining activity is taking place, the areas in question, are undisturbed. In the future, blasts will have an impact on these surroundings.

7.11.4 Description of Affected Environment

Infrastructure

Brick and mortar structures (buildings) should be capable of tolerating ground vibrations up to the levels specified in the USBM RI 8507 recommendations. If these levels are exceeded, then minor cosmetic damage may occur. It must be made clear that exceeding the limit does not automatically mean that damage will occur, but that the likelihood of damage occurring increases.

The roads in the area appear to be gravel roads. None of these roads will be adversely affected by ground vibrations as they can tolerate high vibration levels.

Roads, concrete structures, pylons etc, can all tolerate much higher vibration levels than houses. The houses surrounding Bomi Hills Mine are the most sensitive receptors in terms of impacts due to blasting and vibrations and so by default the acceptable limit for houses must be applied as the limiting threshold in those areas where houses could be affected by blasting.

Humans and Animals

Humans are very sensitive to vibrations and react at low levels of disturbance. The human response to blasting is difficult to quantify. Typically, they react to the airblast (which is often misconstrued as ground vibration) as airblast can be felt at levels well below those required to produce damage to structures.

Metal roof sheets or roof tiles squeak or rattle and window panes may also rattle in response to airblast. This can be very disturbing especially if one is inside the building at the time. This is likely to affect the people living in the houses (formal/ informal).

Animals may also be affected by blasting related disturbances. No long-term negative effects were noticed.

Dust is an inevitable consequence of blasting. This can become a major source of irritation especially for people and animals that live downwind of the mine. However, the dust generated by blasts is a small component of the overall dust levels caused by mining activities. Dust from haul roads and soil stockpiles will be the major sources.

7. 12 Social & Community Health Baseline

7.12.1 Introduction

This chapter evaluates the significance of the social and community health impacts of the Bomi Hills Mine. The evaluation was conducted in accordance with the overall impact assessment process described in Chapter 4 and applied specifically to social and community health impacts by:

7.12.2 Defining the Area of Influence

Major steps

The major steps for defining the area of influence for social resources and receptors are shown in *Figure 63.*

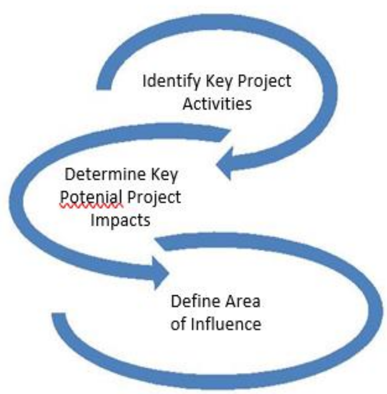


Figure 63: The major steps for defining the area of influence

Identification of Key Project Activities and Processes

Refer to Chapter 2 for a detailed project description including key activities. The key project activities and processes relevant to social and community impacts will be:

- Pre-construction;
- Construction;
- Operation; and
- Closure.

Determine Key Potential Project Impacts

The key potential project impacts derived from project activities and processes will be:

- Pre-construction –physical displacement, impact from economic and livelihood loss, psychological stress from uncertainty;
- Construction - impact on regional economy, exploitation of natural resources, labour influx and in-migration, workforce health and safety, labour working conditions and human rights, communicable diseases, impact on cultural heritage,
- Operation - public and community health, workforce health and safety, impact on labour and human rights, impact of in-migration and transient population, impact on governance and administration, impact on social infrastructure, impact on natural resources and eco-system services, impact on public and community safety and security, impact on cultural heritage
- Closure - public and community health, containment structure maintenance, retrenchment and un-employment, impacts on public infrastructure

Defining Area of Influence

The area of influence is summarized in *Table 73* and illustrated on *Map 7-32*.

Table 73: Summary of AoI

Key Impacts	**Project Footprint**	**Local**	**County**	**National**
Pre-Construction Stage				
Physical Displacement	√	√		
Impact from Economic Loss	√	√		
Psychological Stress from Uncertainty	√			
Construction Stage				
Impact on Regional Economy	√	√	√	√
Exploitation of Natural Resources	√	√		
Labour Influx and In-Migration	√	√		
Workforce Health and Safety	√			
Labour Working Conditions and Human Rights	√	√		
Public and Community Health- Communicable Diseases		√	√	
Impact on Cultural Heritage	√			
Operation Stage				
Public and Community Health	√	√		
Workforce Health and Safety	√			
Impact on Labour and Human Rights	√	√		
Impact of In-Migration and Transient Population	√	√		
Impact on Governance and Administration		√	√	√

Impact on Social Infrastructure		√	√	
Impact on Natural Resources and Eco-System Services	√	√		
Impact on Public and Community Safety and Security	√	√		
Impact on Cultural Heritage	√			
Closure Stage				
Public and Community Health	√	√		
Containment Structure Maintenance	√	√		
Retrenchment and Un-employment		√	√	√

The area of influence of social impacts thus would range from project footprint area to national level on different issues. The project footprint area would include its associated facilities.

The local area of influence includes a standard distance to which air, soil, water and noise pollutions can be experienced. As the proposed production area is limited to approximately 10% of the total Mine Lease Area, this is considered as the mine lease area and Tubmanburg city as local influence area.

The county level is taken as Bomi County as the Mine Lease Area falls within its boundary. Though, ore transportation and port are associated components to Bomi Mines operation, the impacts associated with these components will not be discussed in details, as special ESIA studies being conducted for these components.

These geographical boundaries are kept in mind while preparing the social and community health baseline of the project. Hence, the social and community health profile is presented for project footprint area, local area, Bomi County, and national level. The level of disaggregated information and analytical understanding of the social and community health baseline is presented matching these geographic extents of identified social and community health impacts.

7.12.3 Description of the Area of Influence

Project Footprint Area of Influence

The location of different plant components were planned with due consideration of their technical requirements and existing habitations, isolated houses, roads and other public infrastructure. Wherever, there was a chance of directly affecting any of these structures, alternatives were considered and were incorporated to the extent possible.

The layout map was superimposed with satellite image. Each of the planned components in the layout map was closely examined to find out existence of social receptors within the boundary of these components. Other social receptors existing in adjacent areas where the influence of the particular project component may impact them was also examined and noted. Thereafter, the ground situation was verified during field visit to all components where social receptors lived close enough. The summary of the footprint area and the possible social and community health impact is provided in *Table 74* below.

Table 74: Summary of possible community health and social impact of the project

Ref No (Layout Map)	Facility Name	Total Area (in Sqmt)	Adjacent Social Receptors	Potential Impacts
PERMANENT FACILITIES				
1	Primary Crusher House	40 x 25 = 1000	None	
2	Conveyor (from primary crusher to crushed ore stock)		None	
3	Primary Crushed Ore Stock Pile	200 x 33.3 = 6660	Bomi to Bea Road	
5	Beneficiation Plant	500 x 425 = 212500	New Road colony of Tubmanburg	
5a	Conveyor (From Beneficiation Plant to Product Stock Pile)		None	
6	Product Stock Pile	130 x 150 = 19500	Police Camp center, Agriculture building	Moving population at these places may be impacted by air pollution caused by dust in Stock pile area
6a	Conveyor from Stock Pile		None	
7	Power Plant	350 x 150 = 52500	None	
7a	Fuel Oil Storage	125 x 75 = 9375	None	
8	Rail Loading System	30 x 30 = 900	None	
9	Gate House for Township Entry		Mountain view Club	Increased Traffic
10	Truck Parking Area	8000	None	
11	Road Weigh Bridge		None	
12	Gate House No-1 (Official Entry)		LRRRC office	Increased Traffic
13	Gate House No-2 (Commercial Entry)		BMI office,	Increased Traffic
14	Plant Water System	200 x 370 = 74000	Some settlements along the road of	Economic Loss

15	Ancillary Building Complex	600 x 125= 75000	New road colony, Tubmanburg Civil Service Agency Settlements of New Road colony, Tubmanburg	The access road to few households falls within its boundary. New access to be provided.
15a	Parking area for light vehicle		None	
16	Township Area	280 x 250 = 70000	Mountain view Club	Increased business opportunity for mountain view club restaurant
17	Repair shop and store complex	300 x 170 = 51000	Settlements of New Road colony,	

Thus, the project footprint area does not appear to have any human habitation, and physical displacement has been avoided owing to careful planning. Although, the project footprint does not have any human presence currently, it would be populated during operation period; most of this population would consist of workers, and township, labour camp and guest houses will have non-worker residents as well. The social and community health assessment presumes their presence and takes them into account.

Local Area of Influence

The local area is defined as the Mining Lease (ML) Area plus a buffer zone out to five kilometres. The Local Area of Influence falls under Senjeh District of Bomi County and Bopolu District of Gbarpolu County; however, most part of the ML area falls under Senjeh District of Bomi County. There are 29 Towns/Villages of varying size within the Local Area of Influence including Tubmanburg. Approximately two thirds of the Towns/Villages have fewer than 20 households and are considered small in size. There are only 6 Towns/Villages which have 21-50 households, and 4 Towns/Villages have more than 50 households.

Table 75: Sizes of the Towns in Local Area of Influence

Size of Town/ Village	No of Towns in Bomi County, Senjeh Dist	No of Towns in Gbarpolu County, Bopolu Dist	Total Number of Towns
< 5 Households	5	2	7
5-10 Households	4		4
11-20 Households	6	2	8
21-50 Households	5	1	6
>50 Households	4		4

ML Area Total	24	5	29

Thus, the Local Area of Influence is defined as Senjeh District of Bomi County and Bopolu District of Gbarpolu County. The total population is 2,535 (2,302 in Senjeh District of Bomi County and 233 from Bopolu district of Gbarpolu County). The population living the Senjeh District's Local Area of Influence is 7.7 percent of the total district population; however, the population living in Bopolu District's Local Area of Influence constitutes only 1.3 percent of the total district population

Within the five kilometer buffer zone there are 9,645 people which constitute 11.1 percent of the combined population of the concerned districts. Hence, the potential of the direct impact of the Bomi Mines project would cover 2.9 percent of the population of the districts within which the project is located.

County Area of Influence

The project is mostly located in Bomi, though a small part also falls in Gbarpolu County. The County Area of Influence is defined as the Bomi and Gbarpolu administrative county boundaries.

National Area of Influence

The National Area of Influence is defined as the international borders of Liberia.

7.12.4 Area of Influence - Governance

National Governance System

Liberia is a unitary sovereign state divided into counties for administrative purposes. The form of government is Republican with three separate coordinate branches: the Legislative, the Executive and Judiciary (Constitution of Republic of Liberia, 1986, pp. Article-3).The Republic of Liberia is governed by elected senators and representatives. Each county elects two Senators. The Senator securing the highest vote is appointed as senior senator for nine years and the other is elected for six years. The number of representatives at county level may vary depending upon population, but each serve for 6 years.

The Executive Power of the Republic is vested in the President who is Head of State, Head of Government and Commander-in-Chief of the Armed Forces of Liberia. The president is elected by universal adult suffrage of registered voters in the Republic for a term of six years. The President nominates with the consent of the Senate, cabinet ministers, deputy and assistant cabinet ministers; the Chief Justice and Associate Justice of the Supreme Court and judges of subordinate courts; superintendents, other county officials and officials of other political sub-divisions; members of the military from the rank of lieutenant of its equivalent and above; and marshals, deputy marshals, and sheriffs.

County Governance System

The traditional structure meets the formal (that is, government appointed or elected) structure at the county level and goes parallel with it upwards in various policy and administrative bodies/structures. The County administration is headed by a County Superintendent and officers of line Ministries as well as Central Government Ministriesand supported by district commissioners for administrative purpose.At the district level, locally elected positions also exist in hierarchy and they are primarily responsible for intervention related to development works in their area. The administrative hierarchy is further divided in terms of District Superintendents and District Officers.

Local Governance System – Rural Communities

Management of local rural communities is achieved through partnership of the governmental system, traditional chiefs, and councils of elders. Every two to three towns (15 to 100 households make a town) make a clan. Every three to five clans make a district. Every two to eight districts make a county. There are 15 counties in the country and a total of 74 districts. The paramount chief, clan chief and general town chief are elected for six years. The Election Commission of Liberia is responsible for conducting elections at all of these levels; however, no formal election has been conducted for the past two decades and most of the existing chiefs at these levels are retaining their position for more than six years. Town chief or village chief level positions are filled following customary practices. Members of the town sit together and elect one of them as their chief with active participation of the clan chief.

The key officials and community representatives involved in administrative function at county level1 could be summed up as follows:

 County Superintendent: is the executive head of the county;

 District Commissioner: Represents superintendent at the district level;

 Tribal Governor: is representative of tribal people within given area, investigates all tribal matters between his tribal men and settle all disputes as the case may be from time to time. He is also responsible to the superintendent through the city mayor, township or district commissioner;

 Paramount Chief: is head of the chiefdom, clan, zones, elders and indigenous administrators within the chiefdom. He acts as the middle man between the central government and the indigenous people within the chiefdom, adjudicates all domestic and cultural matters, including relevant matters from the chiefdom and to the clan chief's office;

Clan Chief: is head of the clan and represents the paramount chief within his clan, investigates all indigenous matters from his clan and reports to the paramount chief;

 General Town Chief: is usually head of a cluster of households which may vary from a few households to 250 households and reports to the clan chief.

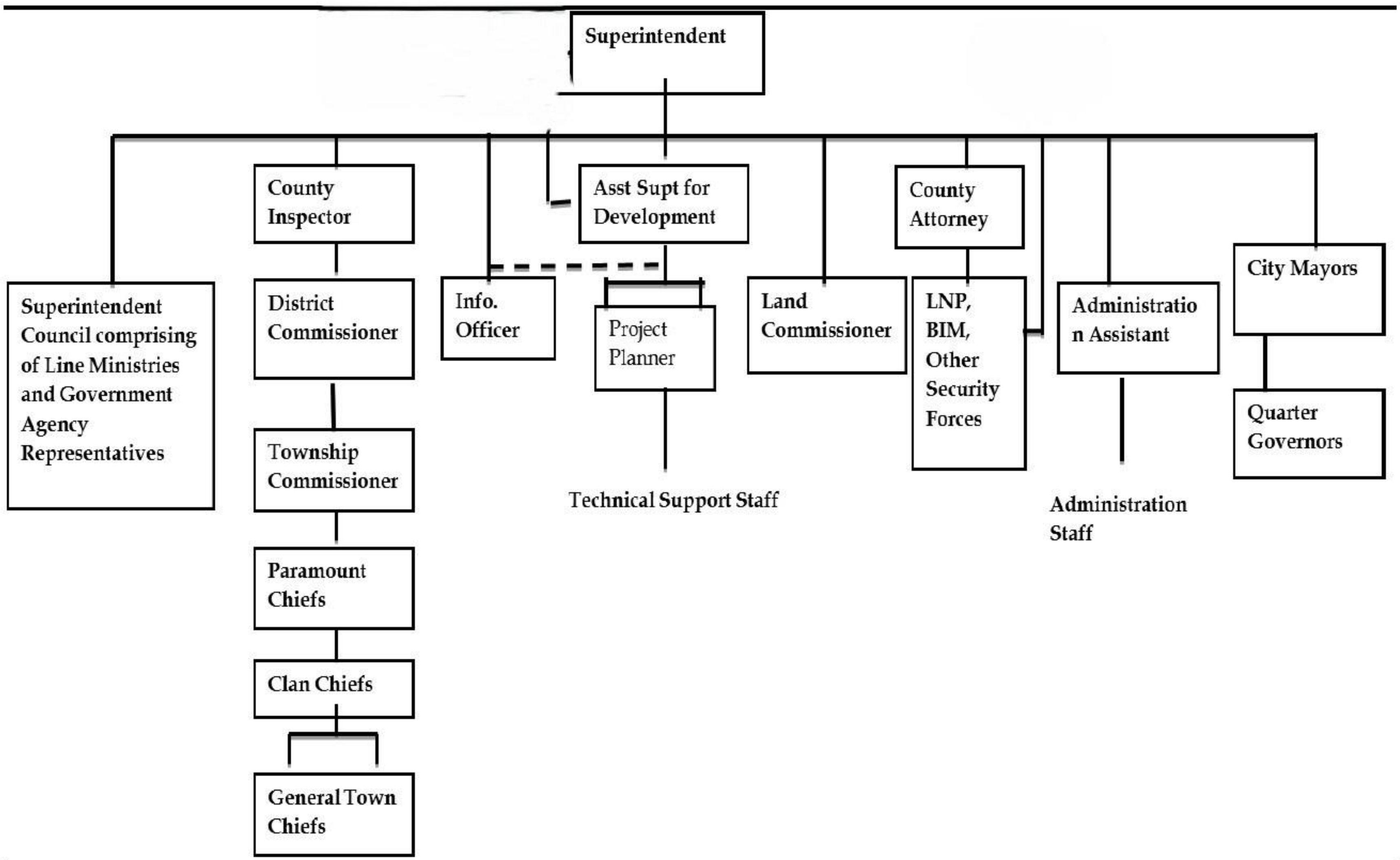


Figure 64: Local administrative structure organogram

Local Governance System –Urban Communities

Mayors are elected in principal cities in Liberia. Some of the bigger urban settlements of the country are administered by a township commissioner which is appointed by the President of Liberia directly. Tubmanburg in Bomi County and Kongo Town in Grand Cape Mount are urban areas and administered by a township commissioner. The local elected positions are described as follows:

Table 76: Positions in local administration that should be elected

Local Position	Command area
Mayors	City Level
Township Commissioner	Smaller Urban Areas
District Commissioner	District

7.12.5 National Area of Influence –Socio-Economic, Cultural & Demographic History and Trends

The Development Policy Context

As per the 2022 census the total population of Liberia is approximately 5.4 million persons. The average annual increase rose between 1974 and 1984 but declined slightly by 2008.

The Mineral Policy of Liberia recognizes that management of Liberia's natural resources is a critical aspect of Liberia's reconstruction and development program. The mineral policy is guided by strategies for diverse linkages of the mining sector activities to other sectors of Liberian economy. The policy states: 'Mining in itself is clearly not sustainable, as it depletes a finite national asset. However, mineral extraction can indirectly become sustainable in so far as it catalyzes sustainable economic activity in other, sustainable, sectors, through maximizing the economic "linkages" whilst the resource is still extant." (Mineral Policy of Liberia, Mar 2010, p. 5)

The Mineral Policy therefore envisages several strategic provisions to beat the 'enclave effect' of the mining operations. Such provisions include greater infrastructure linkages, development of small micro and medium-scale enterprises especially in procurement of goods and services, promotion of forward linkages, and more importantly linkage into the local human capital (skilling, technology transfer and development of education and training institutions).

Liberia has gone through a critical process of mineral governance reform and has established transparent procurement systems, mineral cadastre information management system (MCIMS), and a set of new mineral exploration regulation. The policy and regulations recognize the importance of Artisan Mining Sector (AMS) which would co-exist with larger Mining Concessions. The capacity building for artisanal miners and the organization and development of mining communities for sustainable growth of the AMS is seen as an area of concern. The citizens of Liberia obtain Class-B and C Mining Licences and constitute the AMS sector. The large Foreign Direct Investments (FDI) in mining sector are through Class-A Mining Licences. They are obtained through entering into a Mineral Development Agreement (MDA) with Government of Liberia. The MDA contains provisions of linkages to economic, ecological, infrastructural, social and human capital and thereby provide an integrated and transparent framework for achieving desired objectives.

Labor and Working Conditions

As new job opportunities emerge in the formal economy, a sound industrial relations system will be necessary, but it will not be easy to establish and maintain. Understandably, a number of interests have to converge and appropriate choices must be made to strike the balance between attracting investors and creating jobs, while safeguarding working conditions and labour rights. To set the legal framework for employment creation and economic recovery, it should be stressed that the country has ratified most of the fundamental International Labor Organization (ILO) Conventions and is planning to ratify Conventions 100 (Equal Remuneration Convention, 1951) and 182 (Worst forms of child labour Convention, 1998). Liberia is also the first country to ratify the convention 185 (Seafarers' Identity Documents Convention (Revised), 2003).

The law allows workers to form or join freely independent unions of their choice without prior authorization or excessive requirements. The law also provides workers, except members of the military, police, and civil service, the right to associate in trade unions. The law allows unions to conduct their activities without interference, and the government protects this right in practice. The law prohibits unions from engaging in partisan political activity. Workers, except members of the civil service, have the right to strike. It does not prohibit retaliation against strikers. There are requirements to notify the Ministry of Labor of the intent to strike. Collective bargaining is protected by law, and these laws are effectively enforced. With the exception of civil servants, all workers have the right to organize and bargain collectively.

The law prohibits forced or compulsory labor; however, there are still reports that such practices occur. Families living in the interior sometimes send young women and children to stay with relatives in Monrovia or other larger cities with the promise that the relatives will assist them in pursuing educational or other opportunities. In some instances, these women and children are forced to work as street vendors or domestic servants.

The law prohibits the employment and apprenticeship of children under the age of 16 during school hours; however, child labor is widespread in almost every economic sector. The government does not effectively enforce child labor laws, and there are inconsistencies between the minimum employment age and compulsory educational requirements.

In urban areas children assist their parents as vendors in markets or hawk goods on the streets. There are reports that children tap rubber on smaller plantations and private farms and that children work in conditions that are likely to harm their health and safety, such as stone cutting or work that requires carrying heavy loads. Some children are engaged in hazardous labor in the alluvial diamond industry and in agriculture.

The Child Labor Commission is responsible for enforcing child labor laws and policies; however, the commission is understaffed and underfunded. The Child Labor Commission coordinates efforts to provide scholarships for children to enrol in school. The Ministry of Labor's Child Labor Secretariat, the Ministry of Justice's Human Rights Division, the Ministry of Gender and Development's Human Rights Division, the Ministry of Health and Social Welfare's Department of Social Welfare, and the Liberia National Police’s (LNP') Women and Children Protection Section are also charged with investigating and referring for prosecution allegations of child labor.

National law requires a minimum wage of 15 Liberian dollars (0.30 USD) per hour, not exceeding eight hours per day, excluding benefits, for unskilled laborers. The minimum wage laws apply only to the formal economic sector. The law does not fix a minimum wage for agricultural workers but requires that they be paid at the rate agreed to in the collective bargaining agreement between workers' unions and their management, excluding benefits. Skilled labor has no minimum fixed wage, and the minimum wage for civil servants is 5,600 Liberian dollars (114 USD) per month. The national minimum wage does not provide the minimum standard of living for a worker and family.

Many families dependent on minimum wage incomes also engage in subsistence farming small scale marketing, and begging.

The Labour law 1956 (amended in 1986) provides for a 48-hour, six-day regular workweek with a 30-minute rest period for every five hours of work. The six-day workweek may be extended to 56 hours for service occupations and to 72 hours for miners, with overtime pay beyond 48 hours. The law also provides for pay for overtime, and it prohibits excessive compulsory overtime. The law provides for paid leave, severance benefits, and safety standards.

The Ministry of Labour's Inspection Department enforces government established health and safety standards. Officials conduct unannounced visits to improve standards; however, enforcement of standards and inspection findings are not always consistent. Moreover, laws do not give workers the right to remove themselves from dangerous situations without risking loss of employment. Due to the country's continued severe economic problems, most citizens are forced to accept any work they could find regardless of wages or working conditions.

Human Rights Context

The United Nations Secretary-General has observed that, "Not only are development, security and human rights all imperative; they also reinforce each other... We will not enjoy development without security, we will not enjoy security without development, and we will not enjoy either without respect for human rights." The Constitution of Liberia prohibits torture, cruel, inhuman or degrading treatment or punishment.

Human rights organizations have reported1following human rights abuses:

- ritualistic killings;
- incidents of trial by ordeal;
- police abuse, harassment, and intimidation of detainees and others;
- harsh prison conditions;
- arbitrary arrest and detention;
- judicial inefficiency and corruption;
- lengthy pre-trial detention and denial of due process;
- official corruption and impunity;
- violence against women, including rape, and widespread domestic violence;
- female genital mutilation (FGM);
- child abuse and sexual violence against children;
- human trafficking; continued racial and ethnic discrimination; and
- child labor.

Rape continues to be a widespread problem. As mandated by the 2008 Gender and Sexually-Based Violence Bill, the special court for rape and other violence has exclusive original jurisdiction over cases of sexual assault including abuse of minors in Montserrado County, which includes Monrovia. The Sexual and Gender Based Violence Crimes Unit within the Ministry of Justice coordinates with the special court and collaborates with NGOs to increase sensitization of sexual and gender based violence issues. Outside of Montserrado Country, the stigma of rape contributed to the pervasiveness of out-of-court settlements and obstructed prosecution of cases. Inefficiency in the justice system also prohibits timely prosecution of cases, although local NGOs push for prosecution and sometimes provide lawyers for victims.

Female genital mutilation (FGM) is common and traditionally performed on young girls in northern, western, and central ethnic groups, particularly in rural areas. The most extreme form of FGM, infibulation1, was not practiced. The law does not specifically prohibit FGM. Traditional institutions, such as the secret *Sande* Society, often perform FGM as an initiation rite, making it difficult to ascertain the number of cases. To combat harmful traditional practices like FGM, the government trains community leaders and women's groups during the year and provides training in alternative income generating skills to FGM practitioners.

The Human Rights Watch World Report 2011 for Liberia states that lack of public confidence in the police and criminal justice system led people to take justice into their own hands, resulting in mob attacks on alleged criminals and others, causing several deaths. Liberian police continue to engage in unprofessional and sometimes abusive and criminal behavior, including frequent absenteeism, extortion, bribery, assault, and rape. They frequently fail to adequately investigate alleged criminals, and when they make arrests, suspects are often freed. Lack of funding for transportation and communications equipment further undermines the effectiveness of the national police, especially in rural areas. However, the police demonstrated some improvement in 2010. Crime levels in Monrovia, the capital, dropped somewhat as a result of more proactive patrolling.

Judicial System and Crime Rates

In the judicial system, Liberia has a Supreme Court, criminal courts, and appeals court and magistrate courts in the counties. There also are traditional courts and lay courts in the counties. Trial by ordeal2 is practiced in various parts of Liberia. The basic unit of local government is the town chief. Apart from this traditional justice system, the modern judicial system co-exists. A judicial magistrate and attorneys help judicial administration at the county and district level.

per the County Attorney of Bomi County, 'Bomi County has a high crime rate especially in terms of rape, theft of property and burglary'. Most frequent crimes include rape, theft of property, and burglary, amongst others. Crime is attributed to the high level of unemployment.

Though LNP is vigorously working in order to drastically reduce the high rate of crimes in the county, the delay in the trial of cases at the courts is also responsible for the high velocity of crimes. The cases are delayed because complainants do not pursue their cases and there is an unwillingness of witnesses to testify. Despite the challenges the judicial authorities in the county are working very assiduously and diligently in order to ensure that citizens have trust and confidence in the justice system. (Heritage, 2012)

Natural Resources and Livelihood

Water Resources

Liberia has a surface area of about 111,400 km2, of which 14 percent is covered by water. Liberia has one of the highest precipitations (4 000 to 5 000 mm/year) in the world and its capital supply of water amounts to 71,000 km3/year, while the total renewable water amounts to 232 km3/year. The total water withdrawal in 2000 was estimated at 106.8 million m3, of which agriculture took 57 percent, and followed by the domestic sector with 28 percent and industry with 15 percent (FAO, 2005). Liberia is endowed with abundant water resources, but the proper management and planning of these remain crucial to meeting the national priorities and goals and reducing conflicts between competitive uses.

The four line ministries/agencies responsible for water resources in Liberia are the Ministry of Lands, Mines and Energy (MLME), the Ministry of Public Works (MPW), the Ministry of Health and Social Welfare (MOH) and the Liberia Water and Sewage Corporation (LWSC). National integrated water management policy states that water allocation shall be done considering the economic, social and environmental value of the water as well as other demands from other sectors.

The industrial growth of Liberia in the manufacturing, mining and processing industries shall undoubtedly play a key part in the sustainable development of the nation. The water available to be allocated in a manner which is determined based on understanding of the available yield in a catchment and allocations reserved for domestic needs and for ecosystem maintenance. The decisions will be taken with stakeholder involvement, emphasizing the continued security of existing allocations.

Generally, groundwater is available and can be exploited in most parts of the country in amounts needed for rural water supply, which relies on dug wells and to some extent on drilled boreholes. Data from the rural water supply program indicate that the depth to the water table in shallow wells can be less than one meter. Drilled boreholes can be as deep as 100 meters.

Though water allocation across sectors is a lesser challenge, Upstream-downstream issues in terms of decreased water quality occur more and more frequently and urbanized areas contribute to the degradation. The degraded water quality leads to health risks as reliable water supply and sewerage infrastructures are lacking and as domestic water often are taken directly from surface water bodies. The vast and valuable productivity of the ecosystems of coastal lagoons, estuaries, deltas and mangroves needs to be maintained, not least because they are a rich source of fish protein. (National Integrated Water Resources Management Policy, November 2007)

Wildlife and Biodiversity

Liberia has been lauded for its extensive and unique biodiversity, including the largest remaining tract of Upper Guinean Forest in West Africa and a stunningly diverse range of wildlife and plant species. However, the nation's biodiversity faces serious threats from a wide range of activities, including logging, fuel wood and charcoal production, subsistence agriculture, hunting, mining, and rubber plantations. These threats are compounded by the subsistence struggles of a population that ranks as one of the most impoverished in the world, in part resulting from more than a decade of civil conflict.

Liberian communities traditionally manage their surrounding natural resources according to customary codes that provided for communal ownership and regulation of access and responsibilities. However, the development of laws that assigned ownership of these same resources to the state, without recognizing their importance to community survival, has contributed to a conflict between subsistence needs and biodiversity conservation. The creation of protected areas that effectively excluded communities from resources to which they previously enjoyed access, without providing alternative sources of income such as tourism revenue, has exacerbated this situation. Because a failure to address the subsistence needs that drive resource exploitation (such as the bush meat trade) is likely to undermine the success of any biodiversity conservation strategy, successful legislation must balance community subsistence needs with the effective protection of forest and wildlife resources.

Another way to meet community subsistence needs and alleviate pressure on wildlife sources is through the development of alternative protein sources. The Wildlife Conservation Issue Paper mentions several such projects, including participatory community wildlife farming, artisan (small-scale) fisheries, and larger aquaculture facilities. (Assessment of the Legal, Scientific, and Institutional Frameworks for Biodiversity Protection in the Republic of LIberia, 2007)

Customarily, forests are an integral part of community property and this itself is quitewell defined in discrete land areas held by each village (town) or by clusters of towns referred to as clans or chiefdoms. However, the status of forest ownership under national law is unclear and the community is often at conflict with the Government on this issue of ownership of forest resources. Though, the recent legislations have tried to address this issue and have granted communities greater control on these resources with which their subsistence lifestyle integrated. Many of the critical assets within those domains are traditionally community owned pastures and forests. Forested land continues to make up the larger proportion of most community land areas in Liberia's Hinterland.

Conflict of land ownership and control of natural resources in forest and wildlife sector have mirrored property relations in the mining sector, but with perhaps less justification. With the exception of near surface gold and iron mining, minerals have not played a role in traditional livelihoods. In contrast, forests are and always have been a profoundly integral element of rural land tenure, land use and livelihood. They have never been constitutionally declared national property, unlike minerals. (Wily, November 2007)

Liberia is a party to several international agreements1 that address community based natural resource management. Conservationists once focused exclusively on natural resource protection to the detriment of local people. It has since been recognized that active community participation is critical to the sustainable management and use of natural resources, for the benefit of both these resources and the communities they have historically sustained.

Ecosystem Services and Genetic Resources

The subsistence lifestyle of Liberians is weaved into the forest ecosystem both in terms of resource base and cultural landscape. The slash and burn cultivation of the forest slopes and marshland, fish from streams, production and sale of rattan chairs, processing of wild foods, preparation of herbal medicines were part of the subsistence activities2. The modernisation and development process which claims a share on the eco-system within which Liberians live disturbs this status quo. Hence, conflicts with local community interests need a careful attention for any proposed development activity. The sentiments of the community over these commercialization and modernization of the eco-system can be judged from the statement below:

"Loggers came and broke all our rules even though we begged them not to. They felled our sacred trees, our prayer trees, our medicine trees. They opened the forest and took it from us. Now the winds blow". (Wily, November 2007, p. 220)

Another important concern is the scrupulous link of the limitations of the subsistence life with the monetary prospects of earning cash through wildlife trade. The international wildlife trade, which is estimated to run in the billions of dollars and involve hundreds of millions of plants and animals, adds pressure to already-depleted plant and animal populations. This trade includes, in addition to live animals and plants, products derived from wildlife, such as food, leather, and medicines. Another potential area of interaction of modernity with the traditional subsistence lifestyle is those genetic resources which hold significant commercial potential. The genetic resources that lack commercial potential are often allowed to extinct even though they held a significant ecological value.

Nonetheless, genetic resources may provide important alternative sources of income for rural communities, if its sustainable use is ensured. The management and sustainable use of genetic resources raises a number of legal issues, including questions of intellectual property rights, benefit sharing, and the proper balance between traditional and contemporary concepts of "access." It is important that regulation in this area strike a balance between restricting uncontrolled access and enabling access for research that can contribute to food security and other public uses.

Liberia Indigenous Forum for the Environment (LIFE) and other NGOs are now actively working to build environmental awareness, empowerment, and benefit-sharing in local communities. They advocate for the preservation and use of traditional knowledge in biodiversity conservation, with a particular focus on medicinal plants, timber species, and plants linked to dietary habits.

Natural Resources Base for Subsistence Lifestyle

In 1950s and 60s there were no meaningful attempts to integrate the monetized export/industry economy and the subsistence/food-producing economy. In 1970s, there was a strategy shift from large scale mechanised farming to the establishment of Agricultural Development Projects (ADPs), mainly directed at rice production from irrigated lands, and development of swamps for small producers. The 1980s saw much greater focus placed on food self-sufficiency and improvement of traditional agriculture, but the onset of conflict prevented realization of the envisaged results. Armed civil conflict pervaded Liberia from 1989 to 1997 and later through 2003. During this period, it was difficult to establish meaningful longer term policy perspectives for the economy. This was a period of emergency, rehabilitation and recovery in the sector as a result of the devastating civil war in the country.

In 1974, Liberia produced 87 percent of its grain consumption requirements, but rice production fell 76 percent between 1987 and 2005.While production of rice, the staple crop, has improved since 2006, Liberia still relies heavily on food imports to meet domestic requirements of staples, vegetables, pulses, chicken, meat, and condiments1. Agriculture productivity is very low, with upland rice yields averaging just over 1 metric ton per hectare. The yield rate of cassava crop is estimated to vary in the range of 6-10 metric ton per hectare.

Additionally, post-harvest losses are exceptionally high, reaching up to 45 percent in some areas, and value chains are severely underdeveloped. Notwithstanding these significant constraints, agriculture remains the mainstay of Liberian economic activity. Agriculture accounted for one half of GDP in the post-war period, and more than two-thirds of Liberians depend on agriculture for their livelihood; women and children are particularly dependent on the sector. Subsistence producers constituted a very large majority of the population, and produced over 60 per cent of the country's staple foods, particularly rice. Approximately 63 percent of subsistence households produce rice (exclusively on the uplands) following traditional technology of slash and burn shifting cultivation. (From Subsistence to Sufficiency: Food and Agriculture Policy and Strategy, July 2008)

Liberia's agriculture sector is forest based, dominated by traditional subsistence farming systems mainly in the uplands, characterized by labor intensity, shifting cultivation, low technologies and productivity. The farming systems are primarily forest based and they cover the largest portion of cultivated land area, are concentrated in the central belt of the country, and account for almost half (50 percent) of the total land area and almost 90 percent of arable land.

Currently over 95 percent of Liberia's farms are located on uplands, which are far less productive and contribute to environmental degradation. Most of the swamp/lowland areas on which subsistence farmers cultivate rice comprise narrow inland valleys and widely scattered small swamps, which are cleared manually, and which make extensive use of water control structures. Small acreages of tree crops are maintained for generating cash income while rice, intercropped with vegetables and other food crops, occupy the major portion of cultivated land (about 87 percent), which is on upland. Currently over 95 percent of Liberia's farms are located on uplands, which are far less productive and contribute to environmental degradation. A secondary root and tuber based farming system (involving some cereals) is concentrated in the northern region, and a third farming system occurs in the costal belt with fishing as a major activity complemented with mixed cropping.

Coffee and cocoa are produced mainly by smallholders and exclusively for export. Value addition is limited and done for both rubber and oil palm. Fish farming in Liberia is largely subsistent. The number of people engaged in inland fisheries is not known, so is the volume and value of production but it is an important seasonal subsistence activity of riverside communities, using mainly traditional fishing gears and traps. There are about 3,581 fish farmers nationwide engaged in some form of fish culture on part-time basis. As per the Ministry of Agriculture, there are 449 pounds of various sizes with a total area of 17.47 hectares are distributed in 159 communities around the country. Most of these ponds have been dormant since 1990 and are now being rehabilitated although the process of rehabilitation is slow and laborious.

Production of rice and vegetables occupy about 87 percent of cultivated land, but below national requirements. Small acreages of tree crops are maintained for generating cash income. Commercial agricultural activities are almost exclusively plantation estates of rubber, oil palm, coffee and cocoa, the latter two are produced exclusively for export, with little value addition done for rubber and oil palm. Besides the plantation estates, very little private sector investment has been made in the agriculture sector, except for limited commodities trading which has persisted over the years. (From Subsistence to Sufficiency: Food and Agriculture Policy and Strategy, July 2008)

Land-use and Ownership

Land is key to peace and security, since the majority of conflicts are around land. Land and complementary production factors such as technology, markets and credits are crucial. Consequently, the majority of families who depend on land and land resources contribute to and benefit from growth and development. In Liberia, land tenure is derived from the broader notion of natural resource tenure, which determines the terms and conditions under which natural resources are held and used (Sustainable Development Report on Africa: Managing Land-based Resources for Sustainable Development, 2011, p. 12). Prior to the arrival of Europeans, land in Liberia was owned communally, with members of a certain community having rights of access to the land. While the levels of status and wealth depended on one's ability to attract dependents and followers, access to land was guaranteed to all members of the community. 'Strangers' were also welcome to settle and acquire rights accorded to other members of the community, subject to adherence of rules binding the community. As a result, customary tenure facilitated a livelihoods framework that supported rural multi-ethnic communities in Liberia.

Forests, pasturelands and wildlife resources were common property resources, which were used by a group collectively. The nature of these resources and their use make them difficult to partition among users. The Liberia Government faces challenge in the management of pasture, forestry and wildlife resources is to adopt a policy framework of either individualizing the resources through partitioning or strengthening community institutions for better governance of these resources. In this time of transition, the land tenure in Liberia recognizes the following categories:

- *Freehold land:* mainly a western concept denoting a situation where rights to land include the control, management, use and disposal of land.
- *Leasehold land:* involves a contractual arrangement between the owner of land (lessor) and the user (lessee) over a specified period of time
- *Statutory land allocations:* where the state allocates land and land rights based on statutory provisions
- *Customary system of tenure:* where land rights are controlled and allocated based on traditional practices

plantations – for rubber and other tropical tree crops – are an important feature of the Liberian economy. Plantations require substantial capital investment in machinery, materials and installations. The war halted most large-scale plantation activities, but renovation and capital reinvestment are proceeding in some cases. Some major plantations are joint ventures, and levels of post-war investment will depend on confidence in the peace process by overseas investors. Several of the commercial plantations are joint ventures, involving overseas investment and management input. These concessions are granted by the executive on land not considered necessary for “tribal purposes”. The generous terms on which these concessions were at times granted have drawn much criticism. In certain areas, villagers contest the ownership of land granted in concessions. For example, controversy surrounds land granted to the Liberia Agriculture Company (LAC) in forests some fifty kilometres north of Buchanan. (Paul Richards, Feb 2007) is one such case.

Unlike commercial plantations, peasant holdings, by contrast, involve little investment in the land itself, other than forest clearance and adoption of superior planting materials (e.g. dwarf hybrid oil palms). An exception to this is the intensive development of inland valley swamp land for rice agriculture. Levelling and water control is stimulated by shortage of land for fallow agriculture. The government of Liberia is making efforts to intensify rice cultivation and running programs to increase the productivity of the small peasant holdings.

Low wages, poor and unhealthy working conditions, low agricultural productivity, and widespread poverty are conditions often associated with economic insecurity. These problems are aggravated by the deficient regime of property rights that has characterized Liberia since its creation. When governance fails or is perceived to have failed, land users (individuals and communities) sometimes take matters into their own hands and decide on the ownership and use of land. Land users who are politically allied with those in power tend to receive more fertile and larger tracts while those in opposition parties or who are members minority groups are pushed to marginal lands. Such practices create the potential for conflict. Thus, putting in place a sound land use and tenure policy is clearly one of the biggest needs in post-conflict Liberia if reconstruction and development are to be successful. (Ejigu, 2006)

Employment

Liberia's 14 years of civil war and the consequent internal displacement of thousands civilians and a variety of events directly linked to the crisis resulted widespread job loss, for example timber sanctions resulted in losses of 25,000 jobs, and diamond sanctions lost another 12,000 jobs. Prior to sanctions, timber accounted for 18 percent of the GDP, and 60 percent of the exports. The ban on timber and diamonds is estimated to have lowered the GDP by 31 percent. Deterioration in the rubber plantations has shrunk 50,000 jobs to 10,000. (Employment Strategy for Decent Work in Liberia, 2006, p. 6) Hence, employment creation is seen as the most crucial building block of forthcoming social progress, economic growth and human security.

Unemployment among household heads was estimated at about 14 percent and most of the unemployed were urban based. The proportion of urban unemployed household heads was 19 percent while it was only 9 percent in rural areas. The distribution of the unemployed heads varied widely among the counties. As per 2008 Census, Bomi had 9.5 percent and Gbarpolu had 6 percentof household heads unemployed. The overall unemployment in Liberia was reported at 13.8 percent.

Poverty

As per World Bank, Liberia continues to be one of the world's poorest countries, ranked 162 out of 169 countries in the 2010 United Nations Development Program (UNDP) Human Development Index. Depending on source and definition, between 64 percentand 84 percentof the population live below the national poverty line or on less than $1.25 day. (LISGIS Core Welfare Indicators Questionnaire Survey 2007, 2012). Food insecurity is widespread with 42 percentof the population considered food insecure, children being especially hard-hit. Government of Liberia (GOL) capacity is weak and its presence in rural areas and districts inadequate, one consequence of which is limited availability of public services. The country is highly aid dependent with foreign aid accounting for significantly more than GOL spending; U.S. bilateral assistance in 2010 alone was equivalent to two-thirds of the GOL budget. (US Government Document, Jun 2011)

The Population and Housing Census in 2008 used the Unmet Basic Needs (UBN) approach to measure the poverty level in the country. The use of access to basic needs as a proxy for poverty measurement has captured the world's attention because it identifies areas of social services deficiency1.As per this methodology poverty is defined as not having enough resources to meet the basic needs or not being able to consume enough food, shelter, health care, education etc. (World Bank Institute, Aug 2008) UBN is defined as lacking ownership of essential amenities (radio, mattress and furniture), housing, proper sanitary conditions, water, education, health services and employment.

A household was classified as deficient of an indicator or not based upon the following criteria:

- Essential assets - Not owning mattress, furniture and radio;
- Housing - Living in a house made of temporary building materials;
- Energy - Not using electricity for lighting; - Not using electricity for cooking;
- Not using piped water as main source of drinking water;
- Waste disposal - Not using flush toilet for human waste disposal;
- Education - Literacy of the household head; Children aged 6–12 years not in school
- Health - Taking 40 or more minutes to reach nearest health Facility;
- Employment- Dependency ratio (Employed/in-active population).

A household is classified as deficient if the household does not own essential assets, the type of building materials for the housing unit are temporary, electricity is not used as main source for lighting or for cooking, source of drinking water is not safe, head of household is illiterate, time taken to the nearest health facility is more than 40 minutes, household head is unemployed (high dependency ratio) and non-use of flush toilet for waste disposal. Poverty status is classified by a number of household heads characteristics so as to determine the sections of society most affected. A household was classified as poor on the basis of basic needs deficiency in any one of the indicators.

Poverty ranking was used as a means of arranging the counties from the most deficient to the least deficient in terms of the selected indicators. An arithmetic mean of the individual rankings of the counties was used in deriving an overall poverty ranking of the counties. Table below summarizes the proportion of households with each dimension of unmet basic need by county. The overall UBN Index value and the number of poor in each county of Liberia are provided in Table.77.

Table 77: County Poverty Rankings in 2011 (ERM, 2012)

County Name	Ordinal Ranking	UBN Index	Population	Number of Poor
Bomi	11	69.6	82,032	57,094
Bong	9	71.8	3,28,107	2,35,540
Grand Bassa	5	74	2,13,480	1,57,975
Grand Cape Mount	8	72.2	1,24,540	89,933
Grand Gedeh	10	71.7	1,23,372	88,504
Grand Kru	2	78.4	57,402	45,003
Lofa	7	73	2,73,031	1,99,415
Margibi	14	60.7	2,07,437	1,25,862
Maryland	13	63.7	1,34,778	85,854
Montserrado	15	45.4	10,93,150	4,95,743
Nimba	12	65.7	4,52,110	2,97,037
Rivercess	1	82.3	69,905	57,523
Sinoe	6	73.7	1,01,306	74,637
River Gee	4	74.7	63,843	47,659
Gbarpolu	3	75	81,385	61,018
National	NA	61.5	34,05,878	21,18,797

Household Consumption Expenditure

Household Final Consumption Expenditure[46] (HFCE) for the year 2009 was compiled from 49 member countries by African Development Bank (AfDB). HFCE is considered a key aggregate for assessing household welfare. The real expenses for different expenditure items in LRD and per cent share of these expenses for each item is provided in the table below.

Table 78: Expenditure Item

Sl No	Expenditure Items	Real Expenses in Regional Currency (in Billions)	Per Capita Real Expenditures in Regional Currency	percen t share
1	Food and Non-Alcoholic Beverages	0.13	36.84	28.66
2	Alcoholic Beverages, Tobacco and	0.02	4.79	4.44

[46] 1Household final consumption expenditure (formerly private consumption) is the market value of all goods and services, including durable products (such as cars, washing machines, and home computers), purchased by households. It excludes purchases of dwellings but includes imputed rent for owner-occupied dwellings. It also includes payments and fees to governments to obtain permits and licenses.

	Narcotics			
3	Clothing and Footwear	0.06	17.91	13.63
4	Housing, Water, Electricity, Gas and Other Fuels	0.07	19.43	19.96
5	Furnishings, Household Equipment and Routine Household Maintenance	0.03	7.22	5.78
6	Health	0.01	1.59	1.37
7	Transport	0.01	3.50	2.67
8	Communication	0.02	5.02	3.94
9	Recreation and Culture	0.01	2.36	1.82
10	Education	0.04	12.43	9.72
11	Restaurants and Hotels	0.0	0.72	0.71
12	Miscellaneous Goods and Servies	0.04	10.01	7.31
13	Net Purchases of Residents			0.0
	Total	0.44	121.83	100%

The share of food of beverages in household expenses is 28.66 percent, 19.96 percent for housing and energy consumption. The next most expenditure head is clothing (13.63 percent) and 9.72 percent for education.

Gender Equity

The population and housing census 2008 enumerated 1,739,945 males and 1,736,663 females and the calculation of the overall sex ratio gave a result of 100.2 males per 100 females. The sex-ratio for Bomi and Gbarpolu is provided in the Table 79. Gbarpolu has a higher sex-ratio than Bomi County.

Table 79: Sex Ratio by County in Liberia 2008

	2008 Population		Sex Ratio (males per 100 females)	
County/ Country Name	**Male**	**Female**	**1984**	**2008**
Bomi	42,940	41,179	108	104.3
Gbarpolu	43,906	39,482	101.7	111.2
Liberia	1,739,945	1,736,663	102	100.2
Montserrado	549,733	568,508	117.8	96.7

Gender Related Development Index

The Human Development Report for Liberia reports the Gender Related Development Index (GDI). The GDI measures the average achievement using the same indicators as the HDI (life expectancy, educational attainment and income) in the context of the disparity between females and males. The greater the downward disparity in basic human development.

Ethnic composition

Ethnicity is defined as a segment of a society whose members are thought of by themselves and or others to have a common origin and to share important segments of a common culture. They in addition, take part in shared activities in which common origin and culture are of significant ingredients. These are inscriptive differences in terms of colour, appearance, language, religion, or some other indicators of common origin or some combination seen as salient to their identity. (Population and Housing Census 2008, Sep 2011, p. 18)

The 2008 Census classified Liberians into seventeen well-defined major ethnic groups and a number of other Liberian and African tribes. Ethnic composition of the Liberian population is provided in the figure below. The Kpelle were the largest single tribe (20.3 percent) followed by the Bassa with 13 percent, while Grebo was the third largest (10 percent).

Liberia's sixteen ethno-linguistic groups, although characterized as tribes, have never constituted unified, historically continuous political entities. In the north-western section, Mande-speaking groups formed multiethnic chiefdoms and confederacies that coordinated trade and warfare, especially during the period of the slave trade. Although there were no pre-colonial states, the north-western peoples were united in two pan-ethnic secret societies: *Poro* (for men) and *Sande* (for women). The structure of *Poro* and *Sande* lodges could in theory mobilize the entire population under the authority of elders.

South and east of the Saint John River, Kwa speaking peoples who migrated from the east lived in smaller, less stratified communities. As the Americo-Liberians (freed slaves from Americas) attempted to extend their control from the coast to the interior, they created administrative units that were thought to be coterminous with existing "tribes." For example, Maryland County in the southeast was treated as the home of the "Grebo tribe," even though the people there did not recognize a common identity or history beyond speaking dialects of the same language.

Americo-Liberian hegemony was established, primarily, on the basis of insidious distinctions between "civilized" settlers and "uncivilized" Africans. It was secured by superior weaponry and US intervention, and institutionalized when Liberia declared its independence in 1847. In time, assimilation occurred when Native Liberians took on attributes of "civilization," a process facilitated by President William V.S. Tubman's Integration and Unification Policy in the 1940s. During this period, indigenous participation in all aspects of Liberian life increased, but not sufficiently to break the continued political, economic, social, and cultural dominance enjoyed by the ruling Americo-Liberian elite. (Bruce 2004)

The settler group comprises of people at all class levels, from rich to poor, who continue to maintain a sense of prestige and entitlement. In the indigenous community, a distinction between "civilized" and "native" people emerged early in the nineteenth century as a result of mission education and labor migration along the coast. Civilized ("Kwi") status implies facility with English, a nominal allegiance to Christianity, a degree of literacy, and involvement with the cash rather than the subsistence sector. Although Kwi people maintain their ethnic identities as Grebo, Kru, Vai, or Kpelle, an undeniable prestige difference separates them from their native neighbors and kin. Civilized people, especially women, are distinguished by Western-style clothing and household furnishings. The association is so strong that native women are also known as "*lappa* women," a reference to the two pieces of cloth (*lappas*) that constitute native female dress.

The development experience of countries endowed with abundant natural resources varies greatly. Countries dependent on natural resources (particularly minerals and timber) tend to experience slow growth, unusually high corruption rates, abnormally low rates of democratization, and an exceptionally high risk of civil war (Ross 2003). Further, in such countries wealth tends to concentrate in the hands of the ruling elite or dominant class, and the economic management process centers around controlling the wealth and centrally allocating it to favored sectors rather than increasing productivity by finding the means to mobilize the creativity and ingenuity of citizens in order to lay a broader foundation for development.

Americo-Liberians, although they constitute only about 2.5 percent of the population, have dominated Liberian politics and economics for 150 years. Efforts by presidents Tubman and Tolbert to integrate indigenous Liberians into the political process through improved access to education were insufficient to end their deprivation. The political dominance of the Americo-Liberians seemingly ended when Samuel K. Doe, who had a Krahn (the Krahn are a Liberian minority group) ethnic background, assumed the presidency in 1980.

For most of Liberia's history, the primary meaningful division on the national level was between the tribal majority and the settler minority. After the military coup of 1980, however, a new tribalism or politically strategic ethnicity began to emerge1. The next Liberian leader, Charles Taylor, was of mixed Gola and Americo-Liberian ancestry. As practiced in many countries in the world, each leader brought into his government people of his own ethnic group whom he considered trustworthy. Although elements of ethnic tension were present, the desire to control political and economic power rather than ethnic domination per se seemed to be the prime drivers of political conflict and instability. At the end of the twentieth century, clashes between Americo-Liberians and African-Liberians were synonymous with clashes between the government and the governed and between the haves and the have-nots

Although, the Liberian constitution modelled after the United States, calls for equality, democracy, and freedom of expression, the reality was quite different; African-Liberians were required to pay higher taxes than Americo-Liberians and were denied the right to vote until 1951. The power structure was designed to marshal the wealth generated from the work of the natives into the hands of the Americo-Liberian ruling elite, in part by keeping wages low. Some serious forms of exploitation continue to this day.

A study by the United Nations Mission in Liberia focusing on human rights in rubber plantations reported "plantation workers are exposed to hazardous working conditions without adequate training or safety equipment …" and "…do not receive fair wages or equal remuneration...child labour is frequently used on the plantations" (UN Mission in Liberia 2006). Similar charges are the basis of a lawsuit filed in a California Court on April 21, 2006, by the International Labor Rights Fund charging Bridgestone with maintaining "conditions of slavery on plantations"2 (The Analyst-Monrovia 2006).

Displacement and Migration

Upto 500,000 people were internally displaced in Liberia during the 14 year civil war which ended in 2003. By the end of 2011, the Liberian Government and its international counterparts considered that the internal displacement situation has ended. (Global Overview 2011: People internally displaced by and violence, Apr 2012, p. 48) The fluctuating presence of refugees living in Liberia, mainly from Sierra Leone and Côte d'Ivoire, must further be added to these numbers. (State of the Environment Report for Liberia 2006, 2006, p. 29) This large scale displacement has impoverished individuals, families and communities. The displaced population has lost land, property, livelihoods and access to health services and education. The areas hosting Internally Displaced Persons (IDPs) have felt the pressure and exhausted available resources.

Thus, the displacement arguably has an integral relationship with development. On one hand, lack of development trigger instability, conversely, lack of development hinder the return of people to devastated areas. Displacement might also undermine or even reverse the development of a region and it always increases the risk of impoverishment and perceived marginalisation. (Internal Displacement in Africa: A Development Challenge, Sep 2010, p. 4) Recognising the significance of the displacement as a factor in development planning, 2008 census covered this as a significant objective. The 2008 census result showed that 2 out of every 5 persons in Liberia have been displaced since 1995. It is significant to note that it found about 4 out of every 5 persons have been resettled. (Population and Housing Census 2008, 2009, p. xi)

Cultural Heritage: Poro and Sande Groups

As most of the people lead a subsistence life style, both their livelihood and cultural practices are intimately connected to natural resources in the landscapes where they live. The cultural significance is attached to *Poro* and *Sande* bushes; cultural prayer sites; burial grounds; shrines; public meeting places; and churches/mosques. In addition, the folklore of the local people, revere a number of ancestors sites or sites where hunting or fishing is not allowed due to their sacred connections. (Cultural Heritage Assessment Report: NLGM Project EIS, Jun 2012, p. 21)

According to National Legislation1 'cultural societies such as *Poro* and *Sande* are permitted', however 'unlawful societies', such as the human Leopard Society, the *Neegee* Society, *Susha*, *Toya*, and *Yama Yama* and any other society whose purpose is to commit criminal acts, are illegal. The cultural societies are permitted as long as a permit is obtained from the Department of Interior Affairs if it is established in county area and from the District Commissioner if it is to be established in the hinterland. (Western Range DSO Iron Ore Project ESIA Report Vol 5: Socio-economic Baseline Study, Sep 2010, p. 78)

The *Poro* and *Sande* societies are fraternities/ sororities of men and women, organised in groups of people of the same age bands. Their purpose is to teach life skills, and reinforce cultural knowledge and practices. Membership of each society determines 'belonging' and acceptance in a community. The Poro and Sande societies are linked with each other through hierarchies of Zoes in a system that parallels that of the Chiefdoms in Liberia. Zoe1 is considered as guardian of the traditional wisdom and history. These societies in each town wherein groups of males and females are separately educated into cultural knowledge and history through age related initiation and reinforcement ceremonies. Ritual training and initiation occurs in secret forests in the forest near each settlement. Hence, the *Poro* and *Sande* groups have separate secret forests. The location of the secret forest is not easily disclosed to outsiders and can be violated accidentally through exploration because of unwillingness to identify specific sites.

The community cohesion in traditional society is manifested through the binding force of norms, practices of rituals and sharing of beliefs and values. These shared cultural practices are enforced by institutions such as the *Poro* and *Sande* societies, as well as by heads of extended families or clans. In Liberia, there are three kinds of Taboos: 1. those observed by individuals within the tribe as a condition resulting from intermarriage; 2. those sanctioned by the community; and 3. those observed by members of extended families and clans. Some taboos prohibit particular clans from eating certain fauna and flora. A clan taboo is observed by all of its members. Other taboos prohibit hunting in places regarded as abodes of ancestors and or evil spirits. Another kind of taboo prohibits fishing in certain bodies of water in which the fish are considered humans in fish form waiting to be conceived by barren women. (Brandolini & Tigani, Dec 2006, p. 42)

7.12.6 County Area of Influence – Socio-Economic and Cultural History and Trends

Historical and Political Overview

Bomi County, formerly known as Bomi Territory, was annexed from Montserrado County by decree during the military regime of Samuel Doe in 1983 and later recognized by an act of legislation. Bomi means "light" in the Gola language, symbolizing the County's uniqueness as the first cradle for iron ore mining in Liberia. Before the national crisis, iron ore mining flourished in Bomi County, starting in the 1950s. There are four Administrative Districts (Klay, Dewien, Suehn Mecca and Senjeh), comprising five Chiefdoms and 18 Clans.

Before the war, Bomi County enjoyed a vibrant socio-economic life, and it is still one of the richest in Liberia, boasting ample natural resources. The proximity of Bomi to Monrovia rendered it vulnerable during the war as the various fighting groups struggled at various times to take control of the capital. The County suffered extensive damage to infrastructure and basic social services as well as mass displacements and loss of life. (Bomi County Development Agenda 2008-12, 2008)

In Gbarpolu County the Kpelle form the majority ethnic group, with Belle and Gola making the next two largest groups. Kpelle and Gola are the main dialects spoken in the County. (Gbarpolu County Development Agenda 2008-12, 2008, p. 4)

In Bomi County the four largest ethnic groups in the County are the Gola, Vai, Kpelle and Mandingo, although all sixteen of Liberia's main ethnic groups (Dey, Gola, Gio, Vai, Kpelle, Mende, Bassa, Gbee, Grebo, Kru, Krahn, Mandingo, Sapo, Loma, Kissi and Gbandi) are thought to be represented. The Golas are in the majority, followed closely by the Vai and the Kpelle, who are mainly settled in the boundary region between Bomi and Gbarpolu. The Mandingo are found under various Clans. (Bomi County Development Agenda 2008-12, 2008, p. 4)

Composition

Religion is defined as a spiritual belief in and reverence for supernatural powers. It is a system of thought, feeling, and action that is shared by a group and that gives the members an object of devotion and a code of behaviour by which individuals may judge the personal and social consequences of their actions. It is a frame of reference by which individuals relate to their group and the universe. (Population and Housing Census 2008, Sep 2011, p. 20)

The religion of Bomi County can be roughly sub-divided into two groups: Christians, estimated at 40 percent of the population, and Muslims, estimated at 60 percent. (Bomi County Development Agenda 2008-12, 2008, p. 4). Gbarpolu County although is predominantly Christian, the County has a significant Muslim population and relationships between the religious groups and integration of traditional norms have been largely harmonious. (Gbarpolu County Development Agenda 2008-12, 2008, p. 4)

Language Distribution

English is the official language for Government of Liberia. The number of individual languages listed for Liberia is 31 (*Map 7-33*).

Of those, 30 are living languages and 1 is a second language without mother-tongue speakers. (Languages of Liberia, 2013). These languages1 can be grouped in four language families Indo-European, Kru, Mende and Gola/Atlantic. The linguistic division of Liberia in terms of language groups and individual languages is provided in the map below.

The Bomi County is multilingual. The major languages spoken are Gola, Dey and Kpelle. In Gbarpolu County major languages are Kpelle and Gola. The linguistic division of the County Population and their comparison to the national linguistic division is provided in table below.

Table 80: ethnic Groups

Language Groups	Liberia	Bomi	Gbarpolu
Bassa	13%	2%	0%
Belle	1%	0%	0%
Dey	0%	23%	0%
Gbandi	3%	0%	1%
Gio	8%	1%	6%
Gola	4%	36%	31%

Social Structure: Family, Marriage and Kinship1

Among the indigenous majority, marriage is ideally polygamous and patri-local, with the bride moving to her husband's compound to live with his extended family. Less than 30 percent of men actually have more than one wife at a time, and those marriages often fail because of conflicts between co-wives. Marriage is a process rather than an event, with bride-wealth payments made over many years and solidified by the birth of children. The increasing access of women to cash through the marketing of foodstuffs has resulted in some women freeing themselves from unwanted marriages by paying back the bride wealth. Bride wealth establishes the right of a husband to claim any children born to his wife regardless of their biological father.

The great value placed on women as agricultural workers and child-bearers ensures that no woman who wants a husband is without one for long. Among the civilized native and Americo-Liberian communities, statutory marriages are limited by the Christian insistence on monogamy. Most successful men, however, have one or more "country wives" who have been married through bride-wealth in addition to the "ring wife" who shares their primary residence. Children from secondary marriages often are raised by the father and his official wife and form junior lines within important families in Monrovia and other coastal cities. Before 1980, the most prominent settler families practiced formal endogamy2, resulting in a situation in which most important government officials were related by kinship and intermarriage. Among the indigenous people, groups in the northwest are organized into ranked lineages of "land owners," "commoners," and "slaves." Kinship is crucial in determining social status among these groups. The ranking of lineages is mirrored in the Poro and Sande societies and dictates the "secrets" that may be by initiates. Chieftaincy belongs to particular families, although succession does not follow a strict father-to-son transmission.

Legacy of Displacement and Migration

The broad profile of the displaced population for Bomi and Gbarpolu counties is provided in the table below. This shows that most of these populations are Internally Displaced Persons (IDPs) from other parts of Liberia.

Bomi County

The employment profile of Bomi County shows that the population comprises of 26 percent self-employed and 20 percent as contributing family workers. There are only 5 percent paid employees and 8 percent are household workers. It is significant to note that there are 3 percent population which is looking for work; and there are 5 percent population who are neither working nor looking for work. There are 2 percent incapacitated persons and a small section of them are retired pensioners.

Gbarpolu County

The employment profile of Gbarpolu County shows that full time student population comprises of 28 percent and 2 percent are looking for work. Only 3 percent are paid employees vis-à-vis 32 percent of self-employed. 19 percent report as contributing family workers.

The gender break-up of the employment profile shows that 85 percent of the paid employees are male. Among those who are looking for work, approximately 70 percent are male. 65 percent of household Age break-up of the employed population shows that child employment is prevalent in self-employed, contributing family worker, household worker and part time worker categories. Almost 50 percent of the people employed in other employments are less than 15 years old. Majority of the people looking for work are in 15-35 years age-group, though percentage of people of higher age-group looking for work is also significant. workers are female, and among part time workers females share is only 20 percent.

7.12.7 County Area of Influence – Urbanization, Infrastructure & Services

Urbanization

The Project is close to the Tubmanburg Town which is the head quarter for Bomi County. As of the 2008 census, Tubmanburg has an estimated population of 13,144. The town is populated predominantly by the Gola ethnic group, which hails from Bomi County. The town also has a significant Mandingo and Vai population. The town grew due to the mining operation by Liberia Mining Company in the 1970s.

As per the 2008 Census, Bomi County has 20.2 percent urban population and the rest of population lives in rural areas. The urban population in Gbarpolu is only 9.3 percent of the total population.

Transport and Road Network

It is important to mention that due to the crisis and years of neglect, the majority of Liberia's primary roads lie in total dis-repair. The Administration of Madam Ellen Johnson Sirleaf had no option but to prioritize through the Poverty Reduction Strategy (PRS) and invest heavily in infrastructure development beginning with roads, bridges and public buildings. The national Poverty Reduction Strategy 2008-2011, had identified investment in road infrastructure as the critical interventions needed to move toward realizing the MDGs. The strategy included paving of all primary roads and most secondary roads to connect agriculture communities to market.

The Ministry of Transport was established by an Act of National Legislature in 1987. The Ministry is the Agency of Government responsible to administer and implement the Transportation, Insurance and Maritime Laws and to plan executes policies related to Land, Rail, Sea and Air Transport services within the Republic of Liberia. The current administration, headed by Honorable Eugene Lenn Nagbe, took over the affairs of the Ministry on February 13, 20121.

The National Transport Master Plan (NTMP) was endorsed by Cabinet on May 15, 2012 and launched by the President on May 29, 2012.The NTMP provides for transport service and infrastructural planning and development. It recommends investment options or the various subsectors (modes of transport) and suggests the arrangements and procedures for multi-modal system to minimize the cost of transport.The Ministry is currently conducting a review process of all legal instruments establishing GOL transport related agencies, MOT, MPW, NPA, LMA, LCAA, LDAA, LAA, RIA and NTA for a mandate and option of MOT oversight responsibility.

The road network in Liberia is classified into three major categories: National Primary Road (major routes connecting County Capitals), National Secondary Road, Farm to Market Road and Neighbourhood road (community serving routes generally of short distance). In totality, Liberia's primary roads amount to 1,152.50 miles and connect various counties and regions to each other with road transportation being the easiest and dominant means of mobility.

Bomi County Development Agenda defined three priorities for development that are common to all the districts in the County are 1) roads, 2) health facilities and 3) educational facilities. (Bomi County Development Agenda 2008-12, 2008, p. 9). It is reported that from October 2006 to May 2007 the Ministry of Public Works in collaboration with UNMIL provided some 132 temporary jobs in the County, mainly roadside brushing and road maintenance on the Klay-Bo Waterside route. The problem is especially bad in the Suehn Mecca district. The Road Task Force has been instrumental in the assessment of about 30 farm-to-market (feeder) roads and has mobilized communities to rehabilitate these roads with WFP assistance. NGOs involved in road and bridge rehabilitation and construction include WVL, GAA and Peace Winds Japan. (Bomi County Development Agenda 2008-12, 2008, p. 19)

The NRC needs assessment report gives an insight on the road connectivity situation, documenting 23 villages in Senjeh District, 18 in Klay District, 37 in Suehn Mecca District and 27 in Dowein District that are all inaccessible. Similarly, the County Assessment and Action Report (CARR) estimates the number of persons without access to a passable road at 20,000. (Bomi County Development Agenda 2008-12, 2008, p. 20)

There is currently a free flow of transportation between Monrovia and Tubmanburg due to the good condition of the road. Transportation to other parts of the Bomi County is often severely hampered by bad road conditions. Taxis and other commercial transport are nearly always overloaded, posing a hazard to human life. Exact figures on the population centers that are inaccessible by vehicle are hard to come by.

Telecommunication

The Telecom policy of the Republic of Liberia states in its objective to ensure forty-five per cent (45 percent) of Liberians living in rural communities have the opportunities to use and interface with telecommunication systems and networks by 2013.

The ICT and Telecommunication sector in Liberia was scarcely developed prior to the outbreak of the civil war in 1989. Only Monrovia and the provisional capitols had access to telephone lines with most homes not connected. The total number of telephone lines was 6,000 for 2.5 million people. Then the war worsened the situation. Infrastructures were destroyed or vandalized leaving no fixed line service available. Liberia Telecommunications Corporation, the state owned service provider was unable to operate due to lack of funding or as a consequence of obsolete network equipment.

In recent years the mobile telecom was introduced and the mobile market is fully liberalized. It has 4 players: Cellcom, Comium, Libercell, and Libtelco. Liberia Telecom Authority1 (LTA) is responsible to regulate the sector. The current statistics about the mobile sector including the total number of subscribers for each of the companies, volume of calls remains less satisfactory.

Energy

In the Ministry of Lands, Mines and Energy2 three functional areas are clustered under a deputy minister of operations. There are three Government energy parastatals established by law – the Liberia Electricity Corporation, created in 1973, the Liberia Petroleum Refining Corporation, created in 1978, and the National Oil Company of Liberia, created in 2002.

It is significant to note that the war effectively privatized energy service delivery by destroying the capacity of the parastatals. In the petroleum sector, the LPRC is currently only issuing licenses and providing storage facilities to private sector importers. The retail sale of petroleum products and lubricants is dominated by the private sector. (National Energy Policy Liberia, 2009, p. 13)

Since 2004, Liberia has been in a transition phase, rebuilding slowly from a series of violent civil wars, which, among other things, ripped up most of the nation's existing energy infrastructure. The most of the population depends on unreliable and inefficient sources of energy such as small gasoline and diesel generators, firewood, charcoal, candles, kerosene, battery-powered LED torches and lamps, and palm oil. (Liberia: Giving Power Back to the People, 2013)

Under the current legislation, the Liberia Electricity Corporation is responsible for the generation, transmission, and distribution of electricity. Consequently, only about 10 percent of urban residents and less than 2 percent of rural Liberians have electricity access, largely produced by small private generator sets at prohibitive costs. (National Energy Policy Liberia, 2009, p. 14)

Almost 74 percent of Liberia's population resides in rural areas, and rural households expend a significant amount of their meager incomes on inferior forms of energy such as candles, flashlights, and kerosene or oil lanterns for lighting. Higher fuel costs result from long transportation distances, fragmented delivery systems, and absence of economies of scale. The source of lighting fuel for the households as enumerated during National Census in 2008 is provided in the table below for Liberia, Bomi and Gbarpolu County.

The Electricity Supply in Bomi County is limited to 1 percent of the urban and rural households. Only 2 percent in urban areas in Bomi county source electricity by own generator. Majority of the population in Urban areas in Bomi County depend on Kerosene (41 percent) and Candle (39 percent). Households in rural areas of Bomi county mostly use Palm Oil Lamp (45 percent) in addition to Kerosene (25 percent) and Candle (19 percent). A similar trend is also noticed in Gbarpolu County.

The power generation has dropped drastically in comparison to the capacity that existed before civil war1. At present, there is no generation capacity outside of Monrovia beyond privately-owned generators and scattered donor-funded pilot projects. A number of Government agencies, community organizations and private sector establishments in rural locations in several counties have been able to receive diesel generators and solar power systems through USAID, the United Nations Development Programme, and some NGOs.

Education Infrastructure

The 2008 census enumerated the access to education through time to reach the nearest school. 56 percent of the total population in Liberia lives within 20 minutes commuting distance from the nearest school. However, there are still 16 percent of the total population which need to travel more than one hour to reach nearest school. In Bomi County 49 percent of population has access to a primary school within a 20 minute commute; however 20 percent of the total population h needs to commute more than one hour to reach nearest primary school. In Gbarpolu County 57 percent of total population needs to commute less than 20 minutes to reach the nearest primary school. Conversely 22 percent of the population needs to commute more than one hour. There is a shortage of trained teachers in most of the schools. Hence, access to basic education in the project area is limited.

Table 81: Access to School Education-Time to reach nearest school

Time to School	Liberia Urban	Liberia Rural	Liberia Total	Bomi Urban	Bomi Rural	Bomi Total	Gbarpolu Urban	Gbarpolu Rural	Gbarpolu Total
< 20	2,10,519	1,66,195	3,76,714	2,235	7,761	9,996	1,213	7,130	8,343
Minutes	64%	48%	56%	54%	47%	49%	74%	55%	57%
20-39	69,752	50,557	1,20,309	995	2,752	3,747	238	1,485	1,723
Minutes	21%	15%	18%	24%	17%	18%	15%	12%	12%
40-59	19,980	27,506	47,486	306	1,780	2,086	56	1,050	1,106
Minutes	6%	8%	7%	7%	11%	10%	3%	8%	8%
60-79	9,160	25,519	34,679	113	1,130	1,243	40	813	853
Minutes	3%	7%	5%	3%	7%	6%	2%	6%	6%
80 and Over	8,772	67,040	75,812	331	2,602	2,933	79	2,240	2,319
Mutes	3%	20%	11%	8%	16%	14%	5%	17%	16%
Not	8,777	6,518	15,295	133	370	503	14	175	189
Stated	3%	2%	2%	3%	2%	2%	1%	1%	1%
TOTAL	3,26,960	3,43,335	6,70,295	4,113	16,395	20,508	1,640	12,893	14,533
	100%	100%	100%	100%	100%	100%	100%	100%	100%

Similarly, the education infrastructure in Gbarpolu was devastated by the civil crisis. Most schools were destroyed and are not yet fully functional. There is also a chronic lack of trained teachers. The Bopolu Central High school in Bopolu and Zuo Mission high school in Gbarma are the only senior high schools in Gbarpolu County. There are junior high schools in Gbarma and Belle Districts, and twenty-four elementary schools in Bopolu, nineteen in Gbarma, fourteen in Kongba, seventeen in Belle, sixteen in Bokomu and ten in Gou-Nwolala. Women and girls continue to have limited access to education, health services and judicial services, which has severely curtailed their participation in the formal economy. (Gbarpolu County Development Agenda 2008-12, 2008, p. 17)

Domestic Water supply

The piped water supply indoors is limited to 2 percent of the total households in Liberia. Majority of the households draw their household water supply from the piped or pumped water outdoors. The ownership pattern of the water supply facilities for households as enumerated during 2008 census operation is provided in *Table 7.92* below.

In Bomi County, indoor piped or pumped water to households is limited to 1 percent of households. Majority of the households (39 percent) receive water supply from piped or pumped water sources outdoors. Another 10 percent of the households receive water supply from public tap and 16 percent from closed well or protected springs. A sizable number of households (26 percent) depend on surface water sources such as rivers, lakes or springs.

Access to water was stressful because Bomi is among the counties of highest return for displaced persons and refugees. NGOs through its community empowerment projects have assisted with hand-pumps, wells and latrines, mostly in areas of high return. The NRC Needs Assessment Survey in 2007 found that number of people per hand pump is 727 (In Klay District it is 780

Table 82: Sources for water supply for domestic use

Ownership	Liberia			Bomi			Gbarpolu		
	Urban	Rural	Total	Urban	Rural	Total	Urban	Rural	Total
Piped or	11,718	4,109	15,827	71	84	155	6	84	90
Pump Indoors	4%	1%	2%	2%	1%	1%	0%	1%	1%
Piped or Pump	1,48,172	95,704	2,43,876	1,971	5,975	7,946	1,262	2,904	4,166
Outdoors	45%	28%	36%	48%	36%	39%	77%	23%	29%
Public Tap	37,802	26,292	64,094	610	1,494	2,104	29	561	590
	12%	8%	10%	15%	9%	10%	2%	4%	4%
Closed Well or Protected	59,601	19,119	78,720	820	2,522	3,342	172	465	637
Spring	18%	6%	12%	20%	15%	16%	10%	4%	4%
Open Well	40,404	42,643	83,047	450	550	1,000	100	460	560
	12%	12%	12%	11%	3%	5%	6%	4%	4%
River, Lake, or	7,342	1,47,106	1,54,448	99	5,151	5,250	52	8,172	8,224
Spring	2%	43%	23%	2%	31%	26%	3%	63%	57%
Water	16,864	4,691	21,555	22	486	508	4	105	109
Vendors	5%	1%	3%	1%	3%	2%	0%	1%	1%
Other	5,057	3,671	8,728	70	133	203	15	142	157
	2%	1%	1%	2%	1%	1%	1%	1%	1%
Total	3,26,960	3,43,335	6,70,295	4,113	16,395	20,508	1,640	12,893	14,533
	100%	100%	100%	100%	100%	100%	100%	100%	100%

In Gbarpolu County, 89 percent in urban areas and 80 percent in rural areas take less than 20 minutes to reach nearest water source. On the other hand, 7 percent in urban areas and 3 percent in rural areas take more than an hour to reach the nearest source of water supply for their household requirement. As per the County Development Plan Document, "majority of inhabitants depend solely on creeks for drinking and household use, and are therefore susceptible to waterborne diseases". (Gbarpolu County Development Agenda 2008-12, 2008, p. 18)

Sanitation and Waste Management

Sanitation and human waste management system is almost absent in Bomi and Gbarpolu County. The Flush toilets for private use of the households are limited to 3 percent of urban households and 1 percent of the rural household sin Bomi County. In Gbarpolu County flush toilet is used by 4 percent of urban households and 0 percent of the rural households. Most of the households use bush, beach or other open space for defecation. Some people have started using pit latrines (either cover or open) due to awareness campaigns run by NGOs and Government. The detail of the toilet facility available at households covered in census operation in 2008 is provided below.

Table 83: Access to toilet facilities

Type of Toilet	Liberia			Bomi County			Gbarpolu County		
	Urban	Rural	Total	Urban	Rural	Total	Urban	Rural	Total
Flush Toilet	48,262	2,934	51,196	118	102	220	71	40	111
for Housing									
Unit Only	15%	1%	8%	3%	1%	1%	4%	0%	1%
Flush Toilet	33,420	6,061	39,481	158	272	430	30	132	162
Shared	10%	2%	6%	4%	2%	2%	2%	1%	1%
Covered Pit	92,148	48,965	1,41,113	1,835	3,678	5,513	628	1,655	2,283
Latrine	28%	14%	21%	45%	22%	27%	38%	13%	16%
Open Pit	41,784	14,521	56,305	357	706	1,063	95	416	511
Latrine	13%	4%	8%	9%	4%	5%	6%	3%	4%
Bush	76,705	2,57,491	3,34,196	1,511	11,007	12,518	720	10,312	11,032
	23%	75%	50%	37%	67%	61%	44%	80%	76%
Beach	19,520	9,933	29,453	62	461	523	79	193	272
	6%	3%	4%	2%	3%	3%	5%	1%	2%
Others	15,121	3,430	18,551	72	169	241	17	145	162
	5%	1%	3%	2%	1%	1%	1%	1%	1%
Total	3,26,960	3,43,335	6,70,295	4,113	16,395	20,508	1,640	12,893	14,533
	100%	100%	100%	100%	100%	100%	100%	100%	100%

Source: (Liberia Population and Housing Census 2008, May 2009)

Therefore, access to safe mode of human waste disposition is not satisfactory. The Bomi County Development Agenda therefore mentions solid waste management as a priority area of intervention (Bomi County Development Agenda 2008-12, 2008, p. 57). Similarly, it is reported that sanitation condition in Gbarpolu County is 'desperate as there are few proper latrine facilities in most communities'. (Gbarpolu County Development Agenda 2008-12, 2008, p. 18)

Security infrastructure (police stations, law and courts)

Peace and security is considered as a significant pillar in poverty reduction strategy (Poverty Reduction Strategy Paper: Liberia, July 2008). Security is essential for peace stability and sustainable development in Liberia. Though the threat of an armed conflict has reduced, increases in armed robbery and related secondary crimes (particularly rape) and vigilantism are significant threats to individual and community security (Poverty Reduction Strategy Paper: Liberia, July 2008, p. 53)A range of issues related to land and property ownership, communal land boundary disputes, ethnic hatred and tension are some of the security threats.

Although the security situation has improved dramatically in the last few years, there is still a long way to go. The police force, the armed forces, and all other security forces need to be completely rebuilt. This is therefore the immediate focus of the National Security Sector Strategy for the Republic of Liberia (NSSRL) and its attendant Implementation Matrix (NSSRL-IM), which are inextricably linked with the PRS process. The government has renovated the Police Academy Training Facilities and concluded plans for the construction of 10 county headquarters and 15 police depots around the country.

The Bomi County Development Agenda mentions inadequate police presence as a concern along with poor records of prosecuting criminals. It also highlights poor public image, corruption, brutality during arrests, and check posts being used for extortion by Liberia National Police. (Bomi County Development Agenda 2008-12, 2008, p. 54). United Nations Police (UNPOL) provided training to Liberian National Police, and there are now 62 LNP officers in Bomi County. However, their work is hampered by lack of vehicles, communication equipment and office furniture. The head quarter of the LNP is located at Tubmanburg. There are two other LNP stations in Bomi County, they are Guthrie Plantation and Klay Junction. The county lacks a formal correction system and facilities. In most instances, local authorities are forced to improvise in order to detain and transport suspects, and are unbable to meet the minimum human/prisoner’s rights requirements. (Bomi County Development Agenda 2008-12, 2008, p. 10) There is a Magistrate and a Circuit Court operating in the County and a Justice of the Peace Court in Senjeh District, but the remaining three districts do not have courts at all. (Bomi County Development Agenda 2008-12, 2008, p. 12).

The Gbarpolu County is largely calm and stable. The police staffing in Gbarpolu in 2006 stood at 49 officers. The facilities for the LNP officers are inadequate. The head quarter of LNP for Gbarpolu is located at Bopolu City. There are three other NLP stations in the county, they are: Henry Town, Gbarma, Kumgbor. The correction and prison facilities are not present in the county. (Gbarpolu County Development Agenda 2008-12, 2008, p. 7)

Access to Credit (Finance and Banks)

In 1974, the government established the National Bank of Liberia. It became the exclusive banker and fiscal agent of the government, introduced reserve requirements for commercial banks, and undertook their supervision. Liberia's commercial banks had their main offices in Monrovia. The Liberian Bank for Development and Investment was established in November 1965 to provide additional medium-and long-term financial aid to worthwhile industrial projects. A National Housing and Savings Bank was established in 1972, with priority given to low-cost public housing. An Agricultural and Cooperative Development Bank provided credit to facilitate capital investment in agriculture.

Banks operating in 1999 included the International Trust Company of Liberia, the Liberia Bank for Development and Investment (LBDI), the National Bank of Liberia, the National House and Savings Bank (NHSB), and the Tradevco Bank. The current list of commercial banks operating in Liberia include Liberian Bank for Development and Investment (LBDI), Eco Bank Liberia (EBLL), International Bank Liberia Ltd (IBLL), First International Bank Liberia Ltd (FIBLL), United Bank for Africa Liberia Ltd (UBALL), Access Bank Liberia The Microfinance Bank, Guaranty Trust Bank Liberia (GTBL), Afriland First Bank.

Economic activity and self-sufficiency are hampered by a lack of access to credit, opportunities to accrue and mobilize savings, and business development products and services for micro- and small enterprises. Representing the majority of both the entrepreneurial class and the agricultural workforce, women in particular need access to these products and services. Bomi County provided land to the Central Bank of Liberia (CBL) for the construction of a branch office that now facilitates the encashment of civil servants' pay checks, in a project funded by UNMIL Quick Impact. (Bomi County Development Agenda 2008-12, 2008, p. 19)

7.12.8 Local Area of Influence – Demographic Profile

Approximately 800 households in 29 Towns were reported to live within Bomi Mining Lease Area in 2008 census. Total population living within ML Area is 2535 (2302 in Senjeh District of Bomi County and 233 from Bopolu district of Gbarpolu County). The average household size ranges from 5 to 6. This is exclusive of the Tubmanburg Town which also fall under Bomi concession area and is relatively more densely populated. The town is divided in 16 different communities, all of them located close by. Tubmanburg town claims to have about 2000 households while the total population will come down to a figure of 10000. Thus the entire population living in Bomi concession area is expected to be about 12500. A random sample of 635 people (5 percent approximately) were surveyed in between Dec 2012 to Mar 2013 to collect their current social and community health status. The finding from this social and community health survey is discussed in this section of the report.

Demographic Profile

On the basis of representative sampling, 551 persons in Senjeh District in Bomi County and 84 persons in Bopolu District of Gbarpolu County were covered during the sample survey. The sex-ratio in the entire concession area was found to be 101 males per 100 females. The sex-ratio in Bomi County is reported as 102 in comparison to 104 as per 2008 Census data.

7.12.9 Baseline Conditions

The contribution of the ecosystem services to the local economy and livelihood is through its contribution in four aspects, i.e. provisioning, regulating, supporting and cultural services. Each of these aspects is discussed here.

The natural resource base for a subsistence community provides food, fresh water, wood, fibre and fuel. Availability of food round the year wasexamined in the socio-economic sample survey within Local Area of Influence. The responses from the households indicate that food insufficiency is faced by households in Urban areas of Tubmanburg (*Figure 7.110)*. The people living in rural parts of both Senjeh and Bopolu District do not face insufficient food supply because of their access to edible items available in the forest. In Tubmanburg, the insufficient food supply is encountered by greater number of households from April to August. Deforestation and forestland degradation will further curtail the supply or availability of these resources for local people.

Apart from the food items produced in farm land and kitchen gardens, food supply from natural sources plays a significant role in provisioning of food. The meat of wild life in forests and fish from streams and creeks is obtained by male members using hunting and fishing practices. The availability of bush meat/fish was examined in project local area of influence as an indicator for dependency. The supply of wild meat is adequate in urban areas of Tubmanburg from January to March. An overview of the faunal species that were harvested for bush meat consumption is provided in *Chapter 10*.

A lower percentage of households in rural areas of Bopolu report adequate supply of bush meat/fish in comparison to that of rural areas of Senjeh District. The supply of bush meat in Bopolu District, however, shows less variation which indicates a steady dependence on this source. The rural areas of Senjeh District on the other hand show greater consumption of bush meat/fish from November to March.

The supply and consumption of edible parts of plants is comparatively less in the urban area of Tubmanburg. The consumption is reportedly higher in dry months from January to March. Correspondingly, the consumption is reported to be lower in dry months in adjacent rural areas falling into the Senjeh District. The consumption of the edible plant parts collected from the forest in rural areas shows a marginal increase in wet months from June to October. Some of the important plants which are exploited by local people are listed below in *Table 7.113*. The traditional herbalists who have a better knowledge of plants and their medicinal properties, though present in the area, the local people do not rely on them much. The use of some of the plant parts is, however

8. SURFACE WATER HYDROLOGY

8. 1 General

Potential sources of impacts that may arise during the construction, operational and decommissioning / closure phases of the Project have been identified and are presented in the following sections. All the identified sources of potential impacts are then evaluated and their impact significance is determined, considering the factors of the nature and magnitude of impacts and sensitivity of the water and sediment bodies.

If considered necessary (for impact significance of moderate or major), mitigation measures are recommended to ensure the compliance with relevant regulations, by minimizing any potential adverse impacts on hydrology, water and sediment quality to allowable levels. Water monitoring and audit requirements were developed, to ensure the effectiveness of the water and sediment pollution control and mitigation measures. Finally, residual impacts were summarized, which considered the net impacts of the Project given the recommended measures are appropriately employed.

For this surface water hydrology impact assessment, the following embedded controls has been incorporated into the Project design and operational activities considering the project has been in operation for several years:

- Diversion of clean storm water and other streams around the pit and dumps;
- Construction of paddock walls on crest of top level and benches of waste dumps to contain all runoff;
- Making top of waste dumps and benches to slope inward;
- Construction of toe paddocks around all waste dumps and stockpiles in such a way to avoid concentrating the sediment load in one area;
- Implementation of concurrent rehabilitation on lower lift slopes as far as possible to stabilize the disturbed waste areas;
- Construction of road side drains with regular discharge drains connected to the nearest drainage line;
- Design the river diversion structures for the 1:50 year flood peaks to reduce erosion in the newly constructed drain;
- Construction of lined water control structures where the flow velocities are high, eg around the plant and other hard stand areas;
- Do not leave large areas exposed for long periods of time during construction;
- Cover areas that may need to be exposed for long periods with coarse waste rock material, construct temporary contour walls or similar and provide siltation bunds where the sedimentation cannot be arrested within limits;
- Construction of large sedimentation areas, e.g. swales (low valleys) or wetlands, where runoff is discharged to act as attenuation structures and sediment traps; these areas must be vegetated;
- Provision of sufficient buffer areas between disturbed areas and receiving water bodies; a general guideline is to site activities further than 100m or outside the 1:100 flood line;
- Construction of sediment traps before discharging runoff into the receiving environment;

- Limiting traffic on exposed areas or areas outside the designated roads;
- Regularly clean sediment trap facilities when the capacity is being compromised; this is especially required for sediment traps at infrastructure areas, e.g. plants, offices, the sediment that is removed must be rehabilitated or consolidated with other waste dumps in a manner that it does not become a secondary source of sedimentation again;
- Spread the amount of water stored on dumps by constructing several paddocks;
- Diversion of all storm water from higher lying areas around the dumps;
- Minimize the disturbance to river banks through construction activities;
- Construction of appropriately sized culverts, bridges or drifts at river crossings;
- Do not construct tailings facilities or other with possible risk of failure upstream or in the hazard zone of habitations;
- Contain and treat all mine waste and process water if necessary before it is being released in the case of surplus water;
- Monitor water quality and only release when within parameters;
- Contain and treat (e.g. oil separator) all hydrocarbon contaminated water.;
- Do not discharge excess water to catchment with high ecological value or high receptor sensitivity;
- Design landfill or other solid waste site to divert all clean storm water upstream, contain any possible dirty runoff and seepage. Locate any landfill site at least 100 m away from streams;
- Design and construct entire sewage system such that the ingress of storm water is prevented. Locate any sewage system at least 100m away from streams;
- Divert all storm water in a planned way and with suitably sized structures past the mine facilities before construction starts;
- Implement concurrent rehabilitation strategies as discussed in the closure plan to discharge clean runoff back to the receiving environment;
- Optimize the re-use of process or dirty storm water in the beneficiation process and dust suppression;
- Construct check dams downstream of facilities with higher risk of failure (as an emergency control) e.g. TSF and upstream of habitations; and
- A concurrent rehabilitation plan will be implemented during the operation phase.

8. 2 Receptor Sensitivity

The receptor sensitivity of most of the catchments as impacted by the proposed mining activities is low due to existing impacts mainly from anthropogenic sources. The receptor sensitivity is higher to the eastern portions of the study area as discussed in *Chapter 11*.

8. 3 Impact Assessment

8.3.1 Erosion

Source of Impact

Erosion will occur in all catchments as this is a natural process (see also Chapter 10, Section 10.2.1). However, the severity of erosion will be increased by mining, agriculture, economic and social activities (e.g. vegetation stripping and construction of roads) which would cause an imbalance in natural processes. Severe erosion could lead to a loss in agricultural land and cause general environmental degradation. Erosion could increase the sediment load which will have a severe consequence on aquatic habitat and life.

The following activities could increase the severity of erosion:

- Construction activities;
- Stripping of vegetation;
- Compaction of soils owing to heavy traffic and other construction activities;
- River diversion (change in flow regime);
- Ineffective water management implementation; and
- Over-utilization of natural resources (eg over-grazing).

Potential Consequence

On the waste rock dumps, topsoil stockpiles, tailings slopes and other smaller dumps or embankments the following consequences could be expected owing to erosion:

- Erosion of topsoil stockpile dumps causing the loss of seeds and nutrients;
- Erosion on slopes between benches on the waste dumps causing loss of growth medium needed for rehabilitation and long-term ecological stability, which cause secondary erosion;
- Erosion along haul roads increasing the sediment load in nearby streams;
- Erosion along the pit face will increase sediment load in pit sumps;

- Erosion along Bomi Creek and NWWD;
- Erosion around plant infrastructure or near other water control structures causing the silting up or damage of the structures, thereby reducing the effectiveness; and
- Increase in safety risks owing to the decrease in bank stability

Significance of Impact

The impact significance of erosion, for all three project phases (i.e. construction, operational, decommissioning / closure) is considered to be minor (Table 8.1) as it is assumed that the embedded control listed in Section 8.1 are incorporated into the Project:

Table 84: Significance of erosion on water resources

Impact	Increase in sedimentation and general environmental degradation due to erosion.			
Impact Nature	Negative	Positive	Neutral	
	Loss of topsoil, general environmental degradation, habitat loss, loss of agricultural land and silting of streams, rivers, wetlands and waterbodies has a negative impact on the physical, biological and social environment.			
Impact Type	Direct	Indirect	Induced	
	Impact of erosion is direct on the physical, biological and social environment.			
Impact Duration	Temporary	Short-term	Long-term	Permanent
	Impacts are considered permanent if proper mitigation measures are not put in place and maintained during the operational phase and post mine closure.			
Impact Extent	Local	Regional	International	
	Impacts on the environment are regional as erosion occurs in all catchments, only severity of erosion differs.			

Impact Scale	The scale of the impact is estimated to be found within all catchments, but the most severe in catchments where mining activities take place (agricultural, economic and social activities will enlarge the scale of the impact).				
Frequency	Throughout the life time of the mining operations and post mine closure.				
Impact Magnitude	Positive	Negligible	Small	Medium	Large
	Impact magnitude is considered small as erosion can be mitigated and managed sustainably.				
Receptor Sensitivity	Low	Medium	High		
	The receptor sensitivity is considered as medium.				
Impact Significance	Negligible	Minor	Moderate	Major	
	Significance of impact is considered to be minor.				

Mitigation Measures and Monitoring

The following mitigation measures will be examined by the Project Proponent during the construction stage:

- Construct the NWWD on an alternative position against the northern slope of the Bomi West Hills. This will negate the need for large river diversion structures in the Bomi Creek.
- Combine the SWWD with the NWWD or construct against the southern slope of the Bomi Hills. This will reduce the number and perimeter of side slopes to be rehabilitated or stabilized, as well as move the waste dump out of the stream in catchment B.
- Move the EWD slightly south and southwest to be located on existing exposed or disturbed areas (eg. old tailings deposits east of Bomi Hills). This may reduce some of the slope lengths to the north.
- Construct the starter walls with waste rock material as large buttress embankments or at least armour the tailings dam slopes with a thick layer of waste rock.

Monitoring of erosion has been done visually by inspection of all areas prone to erosion, e.g. steep slopes of dumps, stockpiles, river diversions and drains or water control structures. The amount of sediment in sediment traps will also give an indication of erosion severity and duration. All the above are recorded on the site layout plans that are updated after every wet season and after the erosion damage has been repaired.

Significance of Residual Impacts

The significance of erosion can be negligible after the above-mentioned mitigation measures have been implemented and will reduce with time as rehabilitated areas stabilize.

8.3.2 Sedimentation / Silting of streams, rivers, wetlands and water bodies

Source of Impact

The construction of dams, weirs and other structures could cause significant changes to the downstream biophysical template of a river ecosystem, i.e. hydrology, geomorphological characteristics, sedimentation and channel type.

(Katz et al., 2005)[47]. The characteristics of the channel type immediately after a newly constructed dam or weir can undergo many morphological and hydrological changes (Katz et al., 2005). In return, these changes could eventually lead to the formation of a new channel type (Katz et al., 2005). In addition, an increase in sedimentation creates bars that are ideal for the establishment of alien vegetation (Foxcroft et al., 2008)[48].

The following Project activities could cause a change in existing sedimentation patterns and silting of streams, rivers, wetlands and water bodies:

- Erosion as described above;
- General construction activities, especially those close to drainage lines or within the 100 m flood line;
- Change in flow regime, through:
    - Water extraction;
    - Uncontrolled discharge;
    - Construction of dams, weirs and bridges; and
    - Ineffective storm water management structures causing erosion.

[47] Katz, G.L., Friedman, J.M. & Beatty, S.W. 2005. Delayed effects of flood control on a flood-dependent riparian forest. Ecological Applications, 15(3):1019-1035.

[48] Foxcroft, L.C., Parsons, M., McLoughlin, C.A. & Richardson, D.M. 2008. Patterns of alien plant distribution in a river landscape following an extreme flood. South African Journal of Botany, 74(3):463-475.

Potential Consequence

The consequence of changed patterns in sedimentation and silting could be:

- Loss of aquatic habitat and biodiversity owing to increase in turbidity, oxygen levels, temperature changes etc.;
- Changes in stream flow characteristics due to changes in river profiles;
- Destruction of vegetation;
- Reduction of the capacity of water control structures;
- Spreading of contaminants to downstream or receiving water bodies;
- Reduction of water quality used for human consumption; and
- Increase in safety risks due to the possible downstream inundation of habituated areas

Significance of impact

The impact significance of changed patterns in sedimentation and silting of streams, rivers, wetlands and water bodies, for all three project phases (i.e. construction, operational, decommissioning / closure) is summarized in Table 8.6 below. The significance of the impact is considered to be minor owing to embedded controls incorporated into the Project.

Table 85: Significance of sedimentation on water resources

Impact	Sedimentation / Silting of streams, rivers, wetlands and water bodies.			
Impact Nature	Negative	Positive	Neutral	
	Sedimentation / silting of streams, rivers, wetlands and water bodies has a negative impact on the physical, biological and social environment.			
Impact Type	Direct	Indirect	Induced	
	The impact of sedimentation / silting of streams, rivers, wetlands and water bodies has a direct effect on the physical, biological and social environment.			
Impact Duration	Temporary	Short-term	Long-term	Permanent
	Impacts are considered long-term but not permanent. High flood conditions will "flush",removingtheexcessivesystemsediment within streams and rivers. However silting of wetlands and water bodies may be permanent.			
Impact Extent	Local	Regional	International	
	Impacts on the environment are local.			
Impact Scale	The scale of the impact is estimated to be across all catchments; however excessive sedimentation will occur where mining activities take place.			

Frequency	Throughout the life time of the mining operations and post mine closure.				
Impact Magnitude	Positive	Negligible	Small	Medium	Large
	Impact magnitude is considered Small as changed sedimentation patterns and silting of streams, rivers, wetlands and water bodies will cause localized impacts on channel characteristics, environmental degradation and habitat loss.				
Receptor Sensitivity	Low	Medium	High		
	The receptor sensitivity is considered as Medium.				
Impact Significance	Negligible	Minor	Moderate	Major	
	Significance of impact is considered to be Moderate.				

Monitoring

Monitoring of sedimentation has been done visually by inspection of sediment load in sediment trap facilities. Keep record of the interval and amount of sediment removed throughout the lifetime of the operations to identify trends or measure effectiveness of measures. Monitoring must be done at all sediment trap facilities. The sediment load must be monitored downstream of the TSF and just upstream of the downstream communities in Tubmanburg. Monitoring should also be done where water control structures discharge near human activities, e.g. cultivation, water use.

Refer to the Closure Plan in Annex 21-E for recommendations on the dumping strategy and details on slope angles of repose.

8.3.3 General decrease in watercourse bank stability

Source of Impact

Riverbanks can be the dominant source of anthropogenic sediment in drainage basins. In some catchments, watercourse banks supply over 50 percent of sediment to the river system (e.g. Grimshaw and Lewin[49], 1980; Simon et al., 2000[50]). Watercourse bank instability is mostly caused by a combination of hydraulic-induced bank-toe erosion and bank mass failure (Simon and Collison, 2001[51]). Bank mass failure is further induced by the removal of riparian vegetation (Thorne, 1990)[52]; Simon and Darby, 1999

[49] Grimshaw, D.L., and Lewin, J. 1980. Source identification for suspended sediments. Journal of Hydrology, 47: 151-162.

[50] Simon, A., Curini, A., Darby, S.E. and Langendoen, E.J. 2000. Bank and near- bank processes in an incised channel. Geomorphology, 35:193-217.

[51] Simon, A., and Collison, A. 2001. Quantifying the mechanical and hydrological effects of riparian vegetation on streambank stability. Journal of Earth Surface Processes and Landforms, 27: 527-546

[52] Thorne, C.R. 1990. Effects of vegetation on riverbank erosion and stability, In Vegetation and Erosion: Processes and Environments, Thornes JB (ed.). John Wiley & Sons: 125–144.

[53]). There are three process groups active in watercourse bank erosion: subaerial, fluvial entrainment and mass failure processes (Abernethy and Rutherfurd, 1998[54]; Couper and Maddock, 2001[55]). The subaerial process is active throughout the watercourse system but is particularly dominant in headwater reaches (Abernethy and Rutherfurd, 1998), fluvial processes generally dominate in mid-basin reaches (e.g. Graf, 1983; Lawler, 1995) and mass failure processes tend to dominate in the downstream reaches (Lawler 1995; Lawler et al. 1999). In summary, watercourse bank collapse occurs when the driving forces (stress) exceed the resisting forces (strength) (Simon and Collison, 2001).

The following activities could result in the decrease in water course bank stability within the Project area of influence:

- Vegetation stripping;
- Change in flow regime (e.g. continuous increase in flow velocity and change in the position of influencing flow on a bend); and
- Alteration to bank characteristics (e.g. height, slope and curvature) through construction or mining activities

Potential Consequence

The consequence of watercourse bank instability could be:

- Increase in erosion and sediment load downstream;
- Slips or failure of banks of streams as well as tailings storage facilities and related safety risks; and
- Damage to stream integrity in case of bank failure

Significance of Impact

The impact significance of general decrease in bank stability is summarized in *Table* __. The significance of the impact is considered to be minor assuming the embedded controls as stipulated in Section 8.1 are incorporated into the Project design.

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[53] Simon, A. and Darby, S.E. 1999. The nature and significance of incised river channels. In Incised River Channels: Processes, Forms, Engineering and Management, Darby SE, Simon A (eds). John Wiley and Sons: London, 3–18.

[54] Abernethy, B., and I.D. Rutherfurd. 1998. Where along a river's length will vegetation most effectively stabilise stream banks? Geomorphology, 23: 55-75.

[55] Couper, P., and Maddock, I.P. 2001. Subaerial river bank erosion processes and their interaction with other bank erosion mechanisms on the river Arrow, Warwickshire,UK, Earth Surface Processes and Landforms, 26:631-646.

Table 86: Significance of mine activities on bank stability

Impact	General increase of bank instability due to vegetation stripping, construction activities and increase in flow velocity.				
Impact Nature	Negative	Positive	Neutral		
	General decrease of bank stability due to vegetation stripping, construction activities and increase in flow velocity has a negative impact on the physical, biological and social environment.				
Impact Type	Direct	Indirect	Induced		
Impact Duration	Temporary	Short-term	Long-term	Permanent	
	Impacts are considered permanent. If the bank stability is altered this will cause erosion, decrease the ability of the river banks to contain high flows, an alteration in channel type which will in return cause a loss in natural habitat and, create unsafe conditions for humans and animals.				
Impact Extent	Local	Regional	International		
	Impacts on the environment are local as only certain reaches of streams and rivers will be affected by bank instability. If the bank instability is severe enough and affects more downstream users, the impact extent will be regional.				
Impact Scale	The scale of the impact is estimated to be where mining and construction activities take place.				
Frequency	Throughout the life time of the mining operations and post mine closure.				
Impact Magnitude	Positive	Negligible	Small	Medium	Large
	Impact magnitude is considered Medium as bank instability can cause unsafe conditions for humans and animals (e.g. flooding can destroy villages and cause human injury and/or death), although these are some distance downstream. It is assumed villages in the immediate hazard zone will be relocated if required.				
Receptor Sensitivity	Low	Medium	High		
	The receptor sensitivity is considered as Medium.				
Impact Significance	Negligible	Minor	Moderate	Major	
	Significance of impact is considered to be Moderate.				

Embedded Controls, Mitigation Measures and Monitoring

The following additional measures may be required or can be considered to further reduce the indicated impacts:

- Consider alternative construction methods such as rock buttress starter walls, disposal of tailings and waste rock to increase stability, where required.

Bank stability must be monitored on the slopes of firstly the tailings facilities, but also on the waste dumps and pit slopes. The frequency will be dictated more by the monitoring for engineering stability for safety. Stream bank stability must be regularly (yearly after rain season) evaluated or inspected downstream of all discharge of diversion positions, as well as ad hoc per event that causes a change in stability.

Significance of Residual Impacts

The significance of the impact of bank instability can be reduced to negligible if the alternative construction methods (rock starter walls) are also considered. Without the implementation of these mitigation measures/ alternative construction methods the impact will remain minor.

Reduction in riparian corridor integrity and water quality

Source of Impact

A focus on protection of riparian corridors is well-grounded in current scientific **w**ater knowledge of land-water interaction (Naimanland & De´camps, 1990; Gregory et al., 1991) and the multiple mechanisms through which terrestrial ecosystems influence streams. The integrity of riparian corridors is vital in upholding the function, structure and composition of larger ecosystems. Thus, construction activities should be avoided as much as practically possible up to 100 m from a stream or river.

Human alteration of land affects river ecosystems through multiple processes that operate at different spatial scales (Allan et al., 1997). Some of the human alteration activities include:

- Mining activities;
- Construction within the buffer zone;
- Bank instability;
- Erosion;
- Agricultural activities;
- Vegetation stripping;
- Over utilization of natural resources; and
- Water quality will be affected by spillage of contaminants into the water source which may include sewage, hydrocarbons and other chemicals.

Potential Consequence

The consequence of a reduction in riparian corridor integrity within the Project's area of influence would be contribution to erosion, sedimentation and bank instability and a decrease in water quality, loss of aquatic life and a reduction in biodiversity.

Significance of Impact

The impact significance of a reduction in riparian corridor integrity, for all three project phases (i.e. construction, operational, decommissioning / closure) is considered to be moderate as it is assumed that even though all control and mitigation measures will be in place, the loss integrity will be inevitable. The overall significance of the impacts on stream integrity and water quality is considered moderate Table 87).

Table 87: Significance of mining activities on stream integrity

Impact	Reduction in stream integrity.				
Impact Nature	Negative	Positive	Neutral		
	Reduction in stream integrity has a negative impact on the physical, biological and social environment.				
Impact Type	Direct	Indirect	Induced		
	The impact of Reduction in stream integrity has a direct effect on the physical, biological and social environment.				
Impact Duration	Temporary	Short-term	Long-term	Permanent	
	Impacts are considered permanent.				
Impact Extent	Local	Regional	International		
	Impacts on the environment are local as a reduction in stream integrity will be localized, however if stream integrity is completely lost which may affect water availability and quality for downstream users.				
Impact Scale	The scale of the impact is estimated to be across all catchments that are likely to be affected by mining, agriculture and social activities.				
Frequency	Throughout the life time of the mining operations and post mine closure.				
Impact Magnitude	Positive	Negligible	Small	Medium	Large
	Impact magnitude is considered Medium as a decrease in stream integrity occurs over an extended period and can therefore be mitigated.				
Receptor Sensitivity	Low	Medium	High		
	The receptor sensitivity is considered as Medium.				
Impact Significance	Negligible	Minor	Moderate	Major	
	Significance of impact is considered to be Moderate.				

Embedded Controls, Mitigation Measures and Monitoring

Stream integrity will be monitored as a result of the monitoring required for the other discussed management measures as well as measures prescribed in *Chapter 11*.

Significance of Residual Impacts

The significance of residual impacts is expected to be minor to moderate. Some streams can be reinstated after closure, but certain stretches will be permanently lost (eg riparian corridors within the proposed TSF area).

8.3.4 Change in catchment yield

Source of Impact

The change in catchment yield can occur due to the following activities:

- Diversion of clean storm water around mining activities.
- Major diversion of streams due to the location of mine waste facilities.
- Diversion of Bomi Creek to prevent surface flow into the planned open pit, which is close to the watercourse.
- Diversion of the Weasain watercourse and tributaries around the proposed TSFs.
- Dewatering of the existing lakes to the northeast of the planned open pit to reduce seepage into the open pit during operation.
- Reduction in catchment yield due to the construction of waste dumps and tailings facilities blocking the natural flow of streams, especially if the diversion of upstream flow is not effective and some runoff is contained.
- The containment of runoff on the rehabilitated waste dumps to assist in vegetation establishment and growth and to reduce the need to have large water control structures from the dump.
- The destruction of wetlands and river sections due to the placement of waste facilities. Wetlands can act as sources for baseflow during dry periods.
- Yield will be reduced by abstraction of water from existing water sources for the process plant.

Potential Consequence

The consequence of the impact on yield will be:

- Increased stream flow can cause erosion.

- A change in catchment yield will affect the stream integrity with resultant impacts on aquatic life and water quality. This can be short term because river systems stabilize with time and distance from source of impact.

- A more serious concern is the total reduction in flow or yield and the loss of the resource for downstream users, whether it is for cultivation, food source (fishing) or human consumption. The pit only will cover about 137 Ha at end of LOM, which is about 21 percent of the catchment area of the free draining portion of Catchment A (Bomi Creek). For the immediate catchment it is therefore a major impact, but it reduces to only 2 percent of the catchment area of all catchments that will be impacted by the mine, i.e. Catchments A to E and F2. In addition to this there are the footprints of the other mine waste facilities where runoff will need to be contained for a period until clean runoff can be discharged. This does not, however, happen simultaneously but changes as the mine development progresses.

- Changes in flow regime may also change the normal seasonal changes in streams that may be required for the current functioning of the system.

- The destruction of wetlands and river sections due to the footprint of mine waste facilities will also have a negative impact on biodiversity and water quality. Wetlands act as important biological filters and can trap sediment.

Significance of Impact

The impact significance of changes in catchment yield is considered to be moderate during the operational phase of the project (Table 8.5). The impact significance of changes in catchment yield during the decommissioning / closure phase is moderate as there will be flow that can be returned to the system after rehabilitation

Table 88: Significance of mining activities on catchment yield

Impact	Change in catchment yield				
Impact Nature	Negative		Positive		Neutral
	A change in catchment yield has a negative impact on the physical, biological and social environment.				
Impact Type	Direct		Indirect		Induced
	The impact of a change in catchment yield has a direct effect on the physical, biological and social environment.				
Impact Duration	Temporary	Short-term	Long-term		Permanent
	Impacts are considered Long-term.				
Impact Extent	Local		Regional		International
	Impacts on the environment are regional as a change in catchment yield will affect multiple downstream users.				
Impact Scale	The scale of the impact is estimated to be across all catchments that are affected by mining, agriculture and social activities.				
Frequency	Throughout the life time of the mining operations and post mine closure.				
Impact Magnitude	Positive	Negligible	Small	Medium	Large
	Impact magnitude is considered Medium.				
Receptor Sensitivity	Low		Medium		High
	The receptor sensitivity is considered as medium.				
Impact Significance	Negligible	Minor	Moderate		Major
	Significance of impact is considered to be Moderate.				

Mitigation Measures and Monitoring

This study has indicated that there is lack of long-term hydrological data. WCL intends to construct monitoring facilities at selected points in the identified watercourse and commence with the collection of flow data immediately. The following water quality monitoring points are proposed:

- Bomi Creek just before it discharges into the Small Mahe River;

- Weasain watercourse upstream of Tubmanburg and just before it discharges into the Small Mahe River;
- Downstream of TSF3 that drains to the Mahe River; and

Construct simple measuring points in all constructed water control structures at the discharge to be able to measure occasional or instantaneous flows. This can be simple structures like Cipoletti or V-notches with a calibrated scale.

8.3.5 Other Considerations

It is assumed that the mitigation measures as discussed above will form part of an integrated surface and groundwater monitoring program. A framework for the water management plan is included in *Annex 8-A* of this report.

9.3.1 HYDROGEOLOGY

This Chapter details the Hydrogeological Impact Assessment of the Bomi Hills Mine. The Water Management Plan for the project, based on the potential groundwater impacts identified, can be found in *Annex 21-C.*

9. 1 Scope of Assessment

Major impacts were quantified using the knowledge of the baseline conditions, the compiled numerical groundwater model and applying the proposed mining activities as described in the Mine Feasibility Report. The numerical groundwater model used in quantifying the groundwater impacts are discussed in *Annex 7-D*. In summary:

Open pit dewatering was simulated, using estimated pit bench elevations for the 19 years of life-of-mine. In-pit dewatering was assumed and the predictive data are presented in *Section 9.4.1* and *Annex 7-D*; and

Potential groundwater quality risks associated with the proposed different waste rock dumps (WRD) and tailings storage facilities (TSF) areas were assessed. Mine waste seepage quality was obtained from geochemical testing undertaken by ERM (*Annex 9-A*).

Potential impacts from other mining components were undertaken on a more qualitative manner, based on the feasibility report details.

Embedded management controls and additional mitigation measures are then considered to reduce the impacts. This is followed by evaluation of the significance of residual impacts i.e. after implementation of management and mitigation measures.

Embedded management controls and additional mitigation measures are structured according to IFC standards with emphasis on: avoidance; containment, minimization and rehabilitation.

For the Impact Assessment carried out in the following Sections, the following embedded controls have been assumed:

- Where possible and practical, manage and prevent water ingress into and around the ore stockpiles, WRD and TSF. These management measures should be designed and implemented throughout construction, the operational life and closure of the mine. Potential measures include foundation levelling and compaction, stormwater control measures and remediation that will minimize ponding of water;

- A groundwater monitoring programme must be implemented at the proposed WRD and TSF. Workshops must have dedicated work areas lined with oil traps and these must be managed correctly;
- Drip trays must be used when changing oils;
- Fuel depots must be monitored and inspected for leaks;
- Hazardous/Toxic Substances must be stored in bunded areas which make provision for the capturing and containment of spills; and
- In-pit water should be used in the ore beneficiation process, dust suppression and other uses. Stormwater measures should be implemented to reduce the dirty water footprint;
- Horizontal borehole drains must be considered to drain groundwater without being exposed to suspended solids[56];
- The feasibility of additional water treatment options such as filtrations, flocculation, containment and settlement of suspended solids should be considered;

The hydro-census indicated that there are a number of villagers sourcing water from hand pumps and streams. To the south the towns of Bomi and Tubmanburg have a greater dependence on groundwater. Except for hand pumps recently installed in boreholes by WCL, all hand pumps had been installed in hand dug wells which are on average about 8 m deep. Water flowing into these wells is from a deep weathered profile onto harder bedrock. Groundwater levels drop below the bottom of these wells during the dry season; and water then has to be sourced from the few wells that are deeper. Measurement of groundwater levels during the hydrocensus indicated that the water table is in the order of 7 m below ground level.

Except for a single motorised pump located at the Dukle Yard, no deep boreholes or boreholes equipped with windpumps or motorised pumps have been identified. The United Nations Peacekeeping forces deployed in the area pump water directly from disused mine lake and transport it by tanker to the point of need, while a water bottling plant also abstracts water from the lake.

9. 2 Receptor Sensitivity

Groundwater receptors that could be impacted on by proposed mining activities include:

- Surrounding groundwater users;

[56] Horizontal boreholes, drains or weeping holes are drilled into open pit side wall at a slight angle, enabling water to drain under gravitation. Drilling is commonly undertaken with diamond core or RC drilling rigs. A steel starter casing is often added

  - Groundwater discharge areas (streams); and
  - Groundwater-dependent ecosystems.
- The receptor sensitivities could be interpreted such as:

Groundwater users are interpreted as being **highly** sensitive. A number of shallow wells are located across the project area, and are being used as a source of domestic water. However, Groundwater is not the only water source in the area owing to the abundance of surface water sources. The potential impact (or the perception thereof) if any on groundwater supply could impact on the relationship between the surrounding communities and the client's reputation. Furthermore, compensation would have financial impacts.

Groundwater discharge areas - Wetlands and streams are interpreted as being **moderately** sensitive. Wetlands and streams are mainly fed by direct rainfall –runoff and inter-flow. The groundwater contribution to the streams is small. The groundwater contribution only becomes noticeable during the short dry season of December, January and February. A preliminary assessment suggests that these receptors are not exclusively dependent on groundwater base flow during the dry season, however, groundwater can make up a substantial portion of this contribution. The sensitivity is rated as being ***generally small***, however, this could become moderate during the dry season.

Groundwater-dependent ecosystems are interpreted as of **low** sensitivity. It is considered unlikely that groundwater-dependent ecosystems are entirely dependent on groundwater, and the high rainfall (and almost continual recharge), perennial nature of surface water bodies and nature of the subsurface flow result in many systems being facultative or opportunistic in character.

9.2.1 Area of Influence

The spatial scope of the assessment is defined by the physical footprint of the project activities and the extent to which impacts extend beyond these boundaries. Groundwater gradients mainly mimic topography, with streams and wetland areas often representing groundwater discharge areas. The potential area of influence pertaining to potential groundwater impacts are therefore limited to the surrounding catchment areas where certain mine infrastructures have been proposed. The impact on the surrounding catchment area may influence the water bodies like, the Bomi Creek (Small Mahe River catchment), Weasain River (Small Mahe River catchment), the unnamed tributary to the west of the pit (Small Mahe River catchment) and the unnamed Mahe River tributary to the east of the mine site.

9. 3 Impact Assessment

9.3.1 Potential loss of groundwater resources due to dewatering

Source of Impact

Groundwater dewatering would be required when mining activities intersect underlying aquifers in order to ensure a safe workable environment. The impact of abstracting water from the open pit during mining was investigated using a numerical groundwater model (Annex 7-D). It is acknowledged that most of the water in the pit would be derived from both direct rainfall and groundwater, and that only a portion of the water abstracted would be derived from intersected aquifers.

Using output from the numeric groundwater model, it is predicted that the volume of groundwater to be dewatered would initially be small, however, it will increase to about 4 000 m^3/d over the first 5 years of operations; thereafter remaining constant at almost 4 000 m^3/d on average. The estimated yearly groundwater inflow rates are presented in Annex 7-A.

Potential Consequence

As the mine develops and the pit expands, so too will the zone of influence, i.e. lowering of the groundwater table and even dewatering aquifer units. However, much of the impact will remain localised. The estimated groundwater drawdown contours for different operational mine stages in year 5, year 10, year 15 and end of mining (year 19), are shown in Map 9-1, Map 9-2, Map 9-3 and Map 9-4 respectively. After 19 years, at the end of operations, the extent of the area influenced by dewatering will extend, on average, by 500 m, to a maximum of 1 500 m around the open pit (Map 9-4). Shallow water-supply wells that are potentially situated within this zone of impact include Bomi Hills (BH) 06 and Bomi Hills (BH) 08 as shown in Map 9-1.

Dewatering may either decrease the yield ***(***based on extraction and recharging), thereby impacting water supply to the community. It is estimated that up to 450 individuals (estimated during the hydro census)

within the zone of impact depend on groundwater to some degree. Shallow wells are currently stressed in the dry season and it is therefore critical to start with a monitoring programme to measure the extent of the potential impact.

On cessation of mining the groundwater level will rise back to pre-mining levels (as was the case when mining stopped in 1977). It is estimated that recovery will take 10 to 14 years before completion. Detailed water balance calculations are, however, required to confirm the pit flooding rate.

Significance of Impact:

The impact significance of dewatering on groundwater users is summarised in Table 9.1. This impact will predominately be limited to the operational phase and up to 10 - 14 years after cessation of dewatering. The impact is interpreted as being of moderate significance without applying mitigation measures. The scale of the potential impact is locally limited (between 500 m and 1 500 m) and the magnitude is medium, however, the receptors are interpreted as being of medium sensitive nature.

Table 89: Assessment of the impact of dewatering on groundwater users

Impact	Reduction in the yield of shallow wells/boreholes used for water supply as a result of the zone of influence of mine dewatering.				
Impact Nature	Negative	Positive	Neutral		
	Impact on aquifers and groundwater users are negative				
Impact Type	Direct	Indirect	Induced		
	Impact on aquifers and groundwater users are direct				
Impact Duration	Temporary	Short-term	Long-term	Permanent	
	Impacts are considered long-term, as the potential impact will continue past closure, 10 to 14 years after cessation of dewatering				
Impact Extent	Local	Regional	International		
	Impact on aquifers and groundwater users are local				
Impact Scale	The scale of the impact is estimated to be restricted to 0.5 to 1.5 km around the proposed open pit extent. Wells BH06 and BH08 are situated in the potential zone of impact.				
Frequency	Throughout the life-of-mine and continuing after cessation of dewatering, until a pit lake is established in +/- 10 - 14 years				
Impact Magnitude	Positive	Negligible	Small	Medium	Large
	Impact magnitude is considered medium as other sources of water, such as streams, are available.				
Receptor Sensitivity	Low	Medium	High		
	The receptor sensitivity is considered as medium since the Proponent will be able to supply water to the communities				
Impact Significance	Negligible	Minor	Moderate	Major	
	Significance of impact is considered to be **Moderate.**				

Existing Controls, Mitigation Measures and Monitoring:

Mitigation measures proposed, in order of importance, include:

- Implement a relocation program for community members within impacted areas if necessary. This will probably mitigate the potential impact to a large degree, since the groundwater zone of impact is close to the open pit and other mining infrastructure.
- Groundwater users are currently using shallow wells and boreholes. The drilling of deeper water-supply boreholes may, in most cases, mitigate the potential impact or at least delay the impact. This could be implemented to mitigate the impact on groundwater users.
- The mine could compensate impacted community members by supplying an alternative source of water should it be required.
- Training of community members for conservation of water resources and judicious usage.

Further monitoring should be carried out for quality and quantity to include:

- Monitoring boreholes (hydrogeological test boreholes and proposed boreholes);
- Selected community water supply wells/boreholes; and
- Dewatering volumes.

The proposed groundwater monitoring programme is discussed in Annex 9-B and must include the drilling of additional monitoring boreholes. Annual monitoring audit reports are proposed.

Significance of Residual Impacts

With the proper implementation of mitigation measures as described above, the significance of residual impacts on groundwater users becomes negligible.

9.3.2 *Impact to groundwater discharge (baseflow) and stream flow*

Source of Impact

The source of impact is mine dewatering as discussed in Section 9.4.1.

Potential Consequence

Mine dewatering could decrease the groundwater baseflow contribution to wetlands and streams. This potential impact is specifically relevant during the dry season.

Groundwater modelling results suggests 30 percent groundwater baseflow loss, as a result of dewatering, compared to the no-mining scenario (Annex 7-D). The calculation was done by taking the total groundwater baseflow contribution of the Bomi Creek, Weasain River and the unnamed tributary to the west of the pit into account.

No large-scale surface water abstraction was identified down-stream of the mine. It is furthermore understood that all streams are perennial. Dry periods are short and the potential impact will not totally stop groundwater baseflow. The potential is therefore unlikely to impact on surface water users.

Significance of Impact

The impact significance of dewatering on groundwater baseflow is summarised in Table 9.2. This impact will predominately be limited during the operational phase and only exist for short periods during the dry season. Available information suggests that there are no major impacts on receptors.

Table 90: Reduction in groundwater baseflow contribution to streamflow, due to mine dewatering

Impact	Reduction in groundwater baseflow contribution to streamflow, owing to mine dewatering and potential impacts on receptors				
Impact Nature	Negative	Positive	Neutral		
	The impact on stream flow is negative. Potential impacts on water users are unlikely.				
Impact Type	Direct	Indirect	Induced		
	Impacts on aquifers and streamflow are direct. Potential impacts on receptors could be classified as being indirect.				
Impact Duration	Temporary	Short-term	Long-term	Permanent	
	Impacts are considered short-term, mainly limited to the operational phase.				
Impact Extent	Local	Regional	International		
	Impacts on aquifers and streamflow are local, within the catchment areas of Bomi Creek and the unnamed tributary to the west of the pit, and to a lesser degree the Weasain River catchment.				
Impact Scale	The scale of the impact is restricted to the stream systems bordering the proposed open pit. Loss is about 30 percent of the baseline scenario and only measurable during the short dry season. The indirect impact on surface water abstraction is negligible.				
Frequency	Throughout operational phase. Measurable only during the dry season.				
Impact Magnitude	Positive	Negligible	Small	Medium	Large
	Impact magnitude is considered small because the impact is only for a short period during the year and it is unlikely to have large impacts on receptors.				
Receptor Sensitivity	Low	Medium	High		
	The receptor sensitivity is considered to be medium during the dry season. For most of the year the sensitivity of the receptor is negligible to **low**.				
Impact Significance	Negligible	Minor	Moderate	Major	
	Significance of impact is considered to be **Minor**				

Existing Controls, Mitigation Measures and Monitoring

Mitigation and monitoring measures must include:

- Regular monitoring of stream flow;

Additional investigations and monitoring if required to quantify the dry season stream flow, including the groundwater base flow contribution. The risk of this impact occurring must be updated to assess the impact on the community and the mitigation measures.

Significance of Residual Impacts

With the proper implementation of mitigation measures as described above, the significance of residual impacts on stream flow will be negligible.

9.3.2 Impact to groundwater-dependent ecosystems

Source of Impact

The source of impact is mine dewatering and subsequent lowering of the groundwater levels as discussed in Section 9.4.1.

Potential Consequence

The effect of dewatering on groundwater-dependent ecosystems is more difficult to assess because of uncertainty around the existence of groundwater-dependent ecosystems in the study area. It is considered unlikely that groundwater-dependent ecosystem are entirely dependent on groundwater, and the high rainfall (and almost continual recharge), perennial nature of surface water bodies and nature of the subsurface.

Significance of Impact

The impact significance of dewatering on groundwater-dependent ecosystems is summarized in Table 9.3. This potential impact will predominately be limited to during the operational phase. The impact is seen as unlikely, site-specific to the open pit area and of negligible magnitude. The significance of the potential impact is seen as negligible

Table 91: Potential impact to groundwater-dependent ecosystems due to mine dewatering

Impact	Potential impact to groundwater-dependent ecosystems owing to mine dewatering			
Impact Nature	Negative	Positive	Neutral	
	Dewatering could impact on the water source of groundwater-dependent ecosystems			
Impact Type	Direct	Indirect	Induced	
	Impacts on aquifers and available groundwater are direct			
Impact Duration	Temporary	Short-term	Long-term	Permanent

	Mainly restricted to the operational phase				
Impact Extent	Local	Regional	International		
	Potential impacts on groundwater-dependent ecosystems are site-specific to the proposed open pit				
Impact Scale	Local				
Frequency	Operational phase				
Impact Magnitude	Positive	Negligible	Small	Medium	Large
	Impact magnitude is considered negligible owing to the low likelihood of occurrence and small scale thereof.				
Receptor Sensitivity	Low	Medium	High		
	The receptor sensitivity is considered low.				
Impact Significance	Negligible	Minor	Moderate	Major	
	Significance of impact is considered to be **Negligible**				

Existing Controls, Mitigation Measures and Monitoring

No specific management and/or mitigation measures required.

Significance of Residual Impacts

The impact is classified as being **negligible** with the correct embedded controls and mitigation measures in place.

9.3.3 Impact on groundwater quality at the open pit and potential water

Source of Impact

Groundwater intersected by the open pit will flow over exposed rock particles of different sizes. These rock fragments are exposed to oxygen and other weathering processes which could impact on in-pit water quality.

Based on the geochemical assessment (Annex 9-A) it is expected that the rocks at Bomi Hills will not have acid rock drainage potential and will not result in any major groundwater contamination. However, the water might be naturally acidic as seen from baseline groundwater quality data. Some minor leaching of salts, for example sulphate, could result in an elevated salt content. This is, however, still within WHO Drinking Water standards. The iron, manganese, nickel and aluminium concentrations might occasionally exceed WHO Drinking Water standards and the IFC EHS Guidelines for Mining (2007) discharge guidelines. The non-compliance will be infrequent owing to seasonal, geological and pit operational factors. These metals are also often elevated in the natural groundwater of the area.

The use of ammonium-type explosives could introduce nitrate to the pit water. The high rainfall of the area is, however, likely to dilute the nitrate concentration.

Groundwater (and rainfall/ runoff) flowing into the open pit will potentially be impacted by fines in the pit, increasing the suspended solids load to potentially unacceptable levels. In-pit water with a high quantity of suspended solids could impact on stream water quality and/or could become an aesthetic issue.

Potential Consequences

Unmanaged discharge of mine water (operational phase) in the nearby water courses could impact on stream water quality, including aesthetic issues owing to suspended solids and associated coloring of water. The main constituent of concern is suspended solids. The overall salt concentration would not impact on receptors and dilution would further assist in mitigating potential water quality issues associated with salts and metals.

Significance of Impact

The impact significance rating is summarized in Table 9.4. This impact will be limited to the operational phase of the mine. The impact is only likely if in-pit water is discharged in an unmanaged manner into adjacent stream channels.

The impact is seen as possible and of a local scale. The resultant magnitude of this impact is seen as small.

A significance rating of 'moderate' is as on surface water receptors, mainly owing to potentially unacceptable suspended solids. The impact on aquifer water quality, operations and closure, associated with the open pit, is ***negligible***.

Table 92: Impact on groundwater quality at the open pit

Impact	Impact on groundwater quality at the open pit and potential water quality risk to receptor			
Impact Nature	Negative	Positive	Neutral	
	Impact on groundwater (in-pit) and stream water quality could be negative			
Impact Type	Direct	Indirect	Induced	
	Potential direct impact on groundwater and stream water quality			
Impact Duration	Temporary	Short-term	Long-term	Permanent
	Limited to the operational phase			
	Local	Regional	International	

Impact Extent	Impact on groundwater quality (in-pit) and surface water quality are local				
Impact Scale	Must be quantified, however, considered to be very local. Suspended solids are the main issue.				
Frequency	Only when open pit water is discharged into nearby streams. Dependent on the overall mine water balance and the load of suspended solids.				
Impact Magnitude	Positive	Negligible	Small	Medium	Large
	Impact magnitude is considered small: on a small scale and infrequent occurrence.				
Receptor Sensitivity	Low	Medium	High		
	The receptor sensitivity is considered as medium if unmanaged.				
Impact Significance	Negligible	Minor	Moderate	Major	
	Significance of impact is considered to be **Minor** on surface water receptors, mainly owing to potentially unacceptable suspended solids. The direct impact on aquifer water quality is *negligible*.				

Existing Controls, Mitigation Measures and Monitoring

Apart from the embedded controls to be included in project design, the following mitigation measure will reduce the significance of soil compaction:

- A mine water discharge management strategy must be developed; and
- Groundwater, in-pit water, discharge water and surface water quality monitoring must form an integral part of embedded control measures and should be used in future water management strategies.

Additional studies are required to quantify the potential impact of suspended solids on surface water features.

Significance of Residual Impacts

The impact is classified as being **minor** with the correct - embedded controls and mitigation measures in place.

9.3.4 Potential groundwater contamination from ore stockpiles and mine waste disposal

Source of Impact

Seepage from ore stockpiles, WRD and TSF areas often has the potential to contaminate underlying aquifers. Comparison of groundwater quality sampled from boreholes close to existing WRD and TSF area, established during previous mining of the site (e.g. B01, B05, B06, B08, B11, H03) and boreholes considered to reflect ambient conditions (e.g. B03, B07, B14) indicate no remnant quality impacts. No elevated levels of chemical parameters typically associated with mining contamination (EC, pH, SO_4, Fe) are observed in the data.

The geochemical assessment also suggests that the ore stockpiles, WRD and TSF seepage quality have low groundwater contamination potential (Annex 9-A). Some minor leaching of salts could result in a slightly elevated salt content (e.g. SO_4). However, this is still within WHO Drinking Water standards. The migration of metals in the aquifer would be limited to the general site area.

Potential Consequences

Waste seepage quality poses a low contamination risk to underlying aquifers. The potential impact risk of receptors owing to groundwater contamination is therefore also low.

Groundwater contaminant transport modelling was undertaken to quantify the extent of the groundwater quality risk posed by different ore stockpiles, WRD and TSF options, although this was interpreted as being low. Map 9-5 indicates the zone that could potentially be impacted on by ore and mine waste seepage.

The modelling conducted as part of this study indicates that a contaminant plume, if one were to develop, would not leave the site and could even flow back to the pit owing to dewatering.

Significance of Impact

The significance rating for the potential impact is summarized in Table 9.5. The ore and mine waste component poses negligible risk to groundwater quality and associated receptors.

Table 93: Assessment of the impact of groundwater water contamination resulting from the waste rock dumps and tailings storage facilities

Impact	Impact on groundwater quality owing to ore stockpile, WRD and TSF seepage and potential impact on down-gradient receptors (groundwater users, groundwater baseflow to streams)			
Impact Nature	Negative	Positive	Neutral	
	The nature of the potential impact on groundwater quality is negative.			
Impact Type	Direct	Indirect	Induced	
	Direct impact on groundwater (and stream/well) water quality			
Impact Duration	Temporary	Short-term	Long-term	Permanent
	Impacts are considered long-term, as the impacts will continue past closure			
Impact Extent	Local	Regional	International	
	Potential groundwater quality impacts will be site specific. No impact			

	on receptors foreseen				
Impact Scale	Potentially slightly elevated salts and metals such as Fe, Mg, Ni and Al.				
Frequency	On-going impact				
Impact Magnitude	Positive	Negligible	Small	Medium	Large
	The magnitude of the impact is considered negligible: low water quality risk, high dilution rates, site specific, no impact on receptors expected				
Receptor Sensitivity	Low	Medium	High		
	The sensitivity is considered low, because it is unlikely to impact on receptors				
Impact Significance	Negligible	Minor	Moderate	Major	
	Significance of impact is considered to be **Negligible**				

Existing Controls, Mitigation Measures and Monitoring

The following monitoring should be implemented:

- A groundwater monitoring program must be implemented at the proposed WRD and TSF.

Significance of Residual Impacts

The impact is classified as negligible with the correct - embedded controls in place.

9.3.5 Potential groundwater contamination from mine support infrastructure

Source of Impact

A number of potential contaminant sources are related to mine support infrastructure, including:

- Oil and grease spillages from the proposed workshop areas;
- Contamination from fuel depots; and

Potential Consequence

The above-mentioned sources, if undetected and unmanaged, could result in localized groundwater contamination. Such contaminant sources could impact locally on receptors, however, given that these impacts would occur within the precinct of the mine, there is little risk of groundwater resources used by surrounding communities being impacted.

Good management and the implementation of health and safety standards are key to reducing the risk and significance of these impacts.

Potential Significance of Impact

The impact significance of this potential impact is summarized Table 9.6. This impact will predominately be limited to the operational phase; remnant impacts extending post closure. The contaminant risk is localized and likely to occur if unmanaged, however the risk of impacting surrounding receptors is low.

Table 94: Assessment of the impact owing to potential groundwater contamination emanating from mine support infrastructure

Impact	Potential groundwater quality impact associated with oil, fuel and chemical spills and leaks. This could pose a risk to receptors.				
Impact Nature	Negative	Positive	Neutral		
	Impact on groundwater quality and surrounding receptors				
Impact Type	Direct	Indirect	Induced		
	Direct impact on groundwater quality				
Impact Duration	Temporary	Short-term	Long-term	Permanent	
	Impacts are considered long-term, as the impacts will continue past closure.				
Impact Extent	Local	Regional	International		
	Potential groundwater quality impacts will be localised within the mine property. No impact on receptors foreseen.				
Impact Scale	Hydrocarbon and chemical contamination could be once-off spillages or undetected leaks that could be active for an extended period.				
Frequency	Contamination could occur as single events or for extended periods during the construction and operational phases. Remnant plumes could remain in the long-term after closure.				
Impact Magnitude	Positive	Negligible	Small	Medium	Large
	The magnitude of the impact is considered a small to medium water quality risk, point source and site-specific, unlikely to impact on receptors.				
Receptor Sensitivity	Low	Medium	High		
	The sensitivity is considered low because it is unlikely to impact on receptors.				
Impact Significance	Negligible	Minor	Moderate	Major	
	Significance of impact is considered to be **Negligible**				

Existing Controls, Mitigation Measures and Monitoring

Mitigation measures other than embedded controls/ best practices for the development of the infrastructure to be implemented include:

- Remediation would be required in the event of spillages. Mine and contractor staff must be trained to identify potential contamination, health risks and basic clean-up procedures; and
- A groundwater and soil monitoring program must be implemented at the fuel depots, workshops, plant and other storage areas of hazardous material.

Significance of Residual Impacts

The impact is classified as negligible with the correct embedded controls in place.

It is recommended that the groundwater model should be updated on a regular basis as and when any impact is envisaged. Initially this should be done annually for the first two years and thereafter every second year to confirm the effects of drawdown on the receiving environment and receptors.