DRAFT PROJECT REPORT

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Consulting Services for the Establishment of a Baseline Database of the Environmental Component of the CLSG Project Area in Sierra Leone

COTE D'IVOIRE, LIBERIA, SIERRA LEONE, GUINEA Interconnection Project (TRANSCO CLSG)

Submitted by:

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Signed by

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Prepared by Integrated Geo-information and Environmental Management Services (INTEGEMS)

INTEGEMS

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS AND ABBREVIATIONS

AQM	Air Quality Monitoring
BDEC	Baseline Database for the Environmental Component
BEDGIS	Baseline Environmental Database and Geographic Information System
BKPS	Bo-Kenema Power Services
BOC	Biochemical Oxygen Chemical
BOD	Biochemical Oxygen Demand
CALA	Canadian Association of Laboratory Accreditation
CBOs	Community-Based Organisations
CITES	Convention on International Trade in Endangered Species
CLSG	Côte d'Ivoire-Liberia-Sierra Leone and Guinea
CMS	Content Management System
COC	Chain of Custody
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
DQAs	Data Quality Assessments
DQOs	Data Quality Objectives
EBA	Endemic Bird Area
EC	Electrical Conductivity
ECOWAS	Economic Community of West African States
EDSA	Electricity Distribution and Supply Authority
EENRM	Energy, Environment & Natural Resource Management
EGTC	Electricity Generation and Transmission Company
EHS	Environmental Health and Safety
EIA	Environmental Impact Assessment
EP	Equator Principles
EPA	Environment Protection Agency
EPA-SL	Environment Protection Agency-Sierra Leone
ERM	Environmental Resources Management
ESHIA	Environmental Social and Health Impact Assessment
ESIA	Environmental and Social Impact Assessment
ESMP	Environmental and Social Management Plan
FOSS	Free Open Source Software
GIS	Geographic Information System
GoSL	Government of Sierra Leone

GPS	Global Positioning System
GSE	Gas Sensitive Electrochemical
HCV	High Conservation Value
HCVF	High Conservation Value Forest
IBA	Important Bird Area
ICT	Information and Communication Technology
IFC	International Finance Corporation
INTEGEMS	Integrated Geo-information and Environmental Management Services
IT	Information Technology
IUCN	International Union for Conservation of Nature
LWDD	Land and Water Development Division
MAFFS	Ministry of Agriculture, Forestry and Food Security
MDAs	Ministries, Departments and Agencies
MIS	Management Information System
MLCPE	Ministry of Lands, Country Planning and the Environment
MLGRD	Ministry of Local Government and Rural Development
MWR	Minister of Water Resources
NGO	Non-Governmental Organisations
NPA	National Power Authority
NRIS	National Risk Information System
OKNP	Outamba Kilimi National Park
ONS-DMD	Office of National Security, Disaster Management Department
ORP	Oxidation-Reduction Potential
PCBs	Polychlorinated biphenyls
PDF	Portable Document Format
PIM	Project Inception Meeting
PIU	Project Implementation Unit
PM	Particulate Matter
QA	Quality Assurance
QC	Quality Control
QMS	Quality Management System
RFP	Request for Proposal
ROW	Right-of-Way
RTC	Regional Transmission Company
SLECAD	Sierra Leone Chamber for Agribusiness Development
SLIEPA	Sierra Leone Investment and Export Promotion Agency

SLMD	Sierra Leone Meteorological Department
SOP	Standard Operating Procedures
TDS	Total Dissolved Solids
TOR	Terms of Reference
TSS	Total Suspended Solids
VOC	Volatile Organic Compound
WAPP	West Africa Power Pool
WB	World Bank
WBG	World Bank Group
WHO	World Health Organization

CHEMICAL SYMBOLS

Al	Aluminium
As	Arsenic
Ca	Calcium
Cd	Cadmium
CO	Carbon Monoxide
Co	Cobalt
CO_2	Carbon Dioxide
Cr	Chromium
Cu	Copper
Fe	Iron
H^+	Hydrogen Ion
Hg	Mercury
Mg	Magnesium
Mn	Manganese
Mo	Molybdenum
N	Nitrogen
NH_3	Ammonia
NH_4	Ammonium
Ni	Nickel
NO_2	Nitrites
NO_2	Nitrogen Dioxide
NO_3	Nitrates
NO_x	Nitrogen Oxide
O_3	Ozone
OH^-	Hydroxide
P	Phosphorous
Pb	Lead
PM_{10}	Particulate matter of aerodynamic diameter 10 microns
$PM_{2.5}$	Particulate matter of aerodynamic diameter 2.5 microns
PO_4	Phosphates
Sb	Antimony
Se	Selenium
SO_2	Sulphur Dioxide
VOC	Volatile Organic Compound
Zn	Zinc

UNITS OF MEASUREMENT

%	Percentage
°C	Degrees Celsius
Cal/cm^2	Calories per Centimetre Squared
cm	Centimetre
cm^2	Centimetre Squared
dB(A)	Decibels
ha	Hectares
Hz	Hertz
Kg	Kilogram
km	Kilometre
km^2	Square Kilometers
L	Litre
L min^{-1}	Litres per Minute
L_{10}	10-Percent Exceeded Level
L_{90}	90-Perecent Exceeded Level
LA_{eq}	A Weighted Equivalent Continuous Sound Level
LAF_{max}	A-weighted, Fast, Maximum, Sound Level
L_{eq}	Equivalent Continuous Sound Level
L_n	n-Percent Exceeded Level
Lp	Sound Pressure Level
m	Meter
m^2	Square Meter
mg/L	Milligram per Litre
mg/m^3	Miligrams per Cubic Metres
mm	Millimeter
ms^{-1}	Meters per Second
pH	Potential of Hydrogen
ppb	Parts per Billion
ppm	Parts per Million
µgm^{-3}	Microgram per Cubic Meter

1 INTRODUCTION

1.1 Background

TRANSCO CLSG, a Regional Transmission Company (RTC) set up under the West African Power Pool (WAPP) by an International Treaty signed and ratified among Cote D'Ivoire, Sierra Leone, Liberia and Guinea has been given the mandate to finance, construct, own, operate and further develop the Cote D'Ivoire-Liberia-Sierra Leone-Guinea (CLSG) Interconnection power transmission line with the aim of establishing a regional electricity market in West Africa through the appropriate development and implementation of key infrastructures so that all ECOWAS member states are given access to economic energy resources. TRANSCO CLSG has contracted Integrated Geo-information and Environmental Management Services (INTEGEMS) to undertake consulting services for the **Establishment of a Baseline Database of the Environmental Component of the CLSG Project Area in Sierra Leone**.

The establishment of the baseline database for the environmental component (BDEC) of the CLSG Project area in Sierra Leone covers specifically water quality of the specified watercourse crossed by the corridor of the transmission line, the preliminary characterization of the soils, vegetation and wildlife of the Project area, the air quality and noise level of the settlements of the Project area. The establishment of the BDEC includes activities in various areas ranging from data collection, storage, analysis, mapping and processing to the dissemination of information in form of hardcopy and electronic documents, services and reports to support TRANSCO in its mission to streamline baseline environmental data-flows and provide accurate, reliable and timely baseline environmental data and information to policy-makers and the public. The Project takes into account all environmental information in Sierra Leone to help streamline baseline data-flows, assist TRANSCO to meet its reporting obligations and comply with national and international treaties/conventions and standards.

TRANSCO CLSG is committed to complying with environmental requirements of CLSG countries, including relevant Sierra Leone laws and regulations, and international environmental requirements, including performance standards of the International Finance Corporation (IFC) of January 1st, 2012, the Environmental, Health and Safety guidelines (EHS) Guidelines of April 30, 2007), and finally the environmental, health and safety guidelines for energy transport distribution projects of April 30, 2007.

1.2 Project Objectives

The overall objective of the Project is to assist TRANSCO CLSG in developing a baseline database of the water quality of the watercourses crossed by the corridor of the line, the preliminary characterization of the soils, vegetation and wildlife of the project area, the air quality and noise level of the cities/towns of the Project area.

More specifically, the study objectives are to:

- Define the methodological approach, including sampling protocols, measurement protocols and analytical equipment used, and the working timetable;
- Describe and locate the sampling and measurement points (their surroundings, GPS coordinates, photographs, mapping, etc.);
- Provide numerical values of various parameters, interpret and compare with national and international standards, including those listed in the terms of reference (ToR); and
- Develop a study report constituting the database (object of the study) and attach all schedules (photographs, maps etc.).

1.3 Scope of Work

INTEGEMS worked under the guidance and supervision of the TRANSCO CLSG Project Implementation Unit (PIU) through the Project Manager, the Environmental Coordinator and the National Environmental Assistant, in order to perform the following tasks:

- Analysis of the quality of the specified watercourses crossed by the transmission line through in-situ measurements and sampling;
- Measurements of air pollutants in the towns of the Project area as specified in the ToR and interpretation of the measurement results;
- Environmental noise level measurements in residential and commercial areas within the specified Project towns and interpretation of the results;
- Preliminary characterization of the soils of the Project area through reviews of existing information and establishment of the history of the site with a particular focus on eco-sensitive regions of the Project area.
- Characterization of the flora and fauna of the Project area through the review of existing information on the flora and fauna inventory of the natural and human environment.

1.4 Deliverables

The schedule of reports and deliverables of the Project is presented below.

 **Deliverable 1**	**Submission of Project Inception Report:** Submission of the Project Inception Report to TRANSCO CLSG, including a detailed work plan and methodology for undertaking the Project, as well as any field work and meetings that would be undertaken during the Project.
 **Deliverable 2**	**Submission of Interim Baseline Database and Interim Project Report:** Submission of Interim Baseline Database and Interim Project Report on baseline data collection and indicating the progress achieved in baseline data collection/monitoring and the Baseline Environmental Database development, based on the original plan and indicating any issues faced and changes proposed. This presents the initial results to enable corrections and incorporation of comments and suggestion.
 **Deliverable 3**	**Submission of Final Baseline Database and Final Project Report:** Submission of the Final Baseline Database and Final Project Report on baseline data collection/monitoring, based on the comments and suggestions provided by TRANSCO during review of the Interim Baseline Database and Interim Project Report.

2 TRANSCO CLSG INTERCONNECTION PROJECT DESCRIPTION

2.1 Project Background and Overview

In 1982, the Heads of States of the Economic Community of West African States (ECOWAS) agreed to put in place a regional energy policy in order to promote a regional energy market and to optimize resources in West Africa. Subsequently, in 1999 the West African Power Pool (WAPP) was created and its Master Plan was put in place in 2000 with a view to provide electrical energy at competitive and affordable prices in the West Africa region to ensure a social and economic development. Within its Master Plan, WAPP planned to accelerate several regional interconnection line projects including a transmission line to interconnect the States of Côte d'Ivoire, Liberia, Sierra Leone and Guinea (CLSG).

In February 2012, the Summit of ECOWAS Heads of States and Government approved the revised ECOWAS Master Plan for the Generation and Transmission of Electric Power which identifies the Côte d'Ivoire, Liberia, Sierra Leone, and Guinea (CLSG) Interconnection Project as one of the five (5) priority projects of the West African Power Pool (WAPP) for the West African Sub-Region. The objective of the WAPP is to establish a regional electricity market in West Africa through the appropriate development and implementation of key infrastructures so that all ECOWAS member states are given access to economic energy resources. In order to accelerate the implementation of the CLSG interconnection project, WAPP uses Special Purpose Companies as a vehicle of achieving this objective. Accordingly, the four countries have duly signed and ratified an International Treaty establishing a Regional Transmission Company (RTC) known as TRANSCO CLSG with the mandate to finance, construct, own, operate and further develop the CLSG transmission interconnection line.[1]

The development objective of the project is to increase access of national power systems of Côte d'Ivoire, Liberia, Sierra Leone and Guinea to a more stable and reliable electricity as a means to alleviate power supply deficits and/or to reduce their collective vulnerability to drought induced power supply disruptions. The project will permit the interconnection of "Zone A" and "Zone B" of the WAPP through Côte d'Ivoire, thereby increasing opportunities for trade and the establishment of a regional power market. Thus, the project is expected to facilitate power exchanges among the countries in the West African sub-region.

The total length of CLSG interconnection line is approximately 1,411km and the section in Sierra Leone is 530km. Although the line route is 530km long, the actual area affected by the transmission line project is relatively small. The project will be carried out within a Right of Way (RoW) of 40 m that will span seven districts namely, Pujehun, Kenema, Kono, Tonkolili, Koinadugu, Bombali and Kambia for a distance of about 530km. The transmission line will enter Sierra Leone territory, crossing the Mano and Moa Rivers, through Bombohun, (after Mano on the Liberian border with Sierra Leone) in the Soro Gbema Chiefdom, Pujehun District in the South, follow the existing road network from Potoru, Barri Chiefdom, to enter Kenema Town, the Provincial Headquarter Town in the east of the country. In this section the proposed line route avoids the Gola Forest and other sensitive areas.

The Sierra Leone section of the project comprises the construction of five (5) substations and 530km of 225kV transmission line. The Project, among others, consists of the erection of steel transmission towers along the route. The height of the towers will be such as to provide a minimum of 8.0 meters clearance between the lines and open ground and 8.0 meters clearance for roads and houses. Typically, as with the existing system, the towers will be about 35 ~ 40 meters high.

Five (5) substations are being built each in a small area of 200m x 200m. These are being built on flat well drained land, thus no major topographical changes will occur; the land used will invariably have been used for cultivation. One substation (Kenema substation) will be constructed in Gofor, 2 km to Kenema on the Potoru – Kenema Highway. From Kenema substation, the transmission line continues to the north to enter Bikongor substation in the Nimiyama Chiefdom, Kono District. From Nimiyama Chiefdom it will go through Jaiama Nimikoro and then follow the existing road to Bumbuna, Kalansogoia Chiefdom. One substation (Bikongor substation) will be constructed in Ndoyorgbo 2 km from Jiaima Nimikoro along the existing road to Bumbuna. Another substation (Bumbuna substation) is being

[1] About TRANSCO CLSG, http://www.transcoclsg.org/overview/ (Accessed 17 October 2017)

constructed in Kabaray, 2 km to Bumbuna Town. From Bumbuna Town (Town of the Bumbuna Hydroelectric Plant), the line will enter Fadugu, Kasunko Chiefdom. Another substation (Yiben subsation) will be constructed at Kathadougbu Road, 1 km east of Fadugu. From Fadugu, the line will continue to enter Kamakwei, Sella Limba Chiefdom. In Sella Limba Chiefdom, another substation (Kamakwei substation) will be constructed 4 km from Kamakwei in a town called Kathirie, and the line detours the Outamba-Kilimni National Park to the south and crosses the Great Scarcies River to enter Guinea territory.

2.2 The Study Area

2.2.1 The Proposed Transmission Line

The proposed 225 kV high voltage transmission line covers a distance of approximately 530 km from Bombohun in the Sorogbema Chiefdom (Pujehun District), south of the country through Kenema (Eastern Province) on to Bikongor (Kono District), Bumbuna, Fadugu and then Kamakwei, in the north, and through Tambakka Chiefdom, Bombali District, then Kambia District to Guinea border (see Figure 2-1). It intends to pass through seven (7) districts. During its course in the Pujehun and Kenema District, it will pass along the Zimmi – Bambako-Sahun-Gofor-Kenema highway. The proposed line by-passes the Kambui Hills in Kenema District and the Nimini Hills in Kono District, East of Sierra Leone. It also bypasses the Outamba-Kilimi National Park in Bombali District in its path to Kamakwei onto Laya in Guinea. Furthermore, five new high voltage substations will be constructed along the transmission line route. Table 2-1 presents the substation sites, the Chiefdoms and Districts in which they are located.

Table 2-1: Substation Site Locations

No	Name of Substation	Location	Chiefdom	District
1.	Kenema	Gofor – 2 km to Kenema Town from Zimmy	Nongowa	Kenema
2.	Bikongor	Ndoyogbor – 2 km to Jiaima Nimikoro H/Q Town	Jiaima Nimikoro	Kono
3.	Bumbuna	Kabaray – 3 km to Bumbuna	Kalansogoia	Tonkolili
4.	Yiben	Kataadomgbu Road – Fadugu Town	Kasunko	Koinadugu
5.	Kamakwei	Kathirie – 4 km from Kamakwei Town going to Fintonia	Sella Limba	Bombali

2.2.2 Monitoring Locations

The monitoring towns for air quality and ambient noise were along the transmission line cutting across the entire country from Vaama close to the Liberian boarder in Pujehun district to Kamakwie in the north of Sierra Leone (see Table 2-2 and Figure 2-3). Road conditions from Freetown to some monitoring towns are generally good and surfaced (tarmac) while others like the road to Vaama Barri from Bo or from Mano Junction to Lago Jasawabu and Kangama, are laterite and are in need of serious repairs.

The water quality monitoring locations are in five major rivers cutting across the transmission line (see Table 2-3 and Figure 4-15 - Figure 4-17). The monitoring rivers are all rocky and torrential in their upper courses but open into wide estuaries which penetrate far inland and are bordered by mangrove swamps and floodplains.

- The Mano River originates in the Guinea Highlands in Liberia and forms part of the Liberia-Sierra Leone border. Diamond mining is a major industry in these areas.
- The Moa River arises in the highlands of Guinea and flows southwest, forming parts of the Guinea–Liberia and the Guinea – Sierra Leone borders. It flows into the Southern Province of Sierra Leone.
- The Little Scarcies begins in Guinea and flows into Sierra Leone, after which it empties into the Atlantic Ocean. It is surrounded by extensive marshlands.
- The Great Scarcies River forms a portion of the international border between Sierra Leone and Guinea. It empties into the Atlantic Ocean at Barlo Point, Sierra Leone.

Figure 2-1: Overview of the TRANSCO CLSG Transmission within West Africa

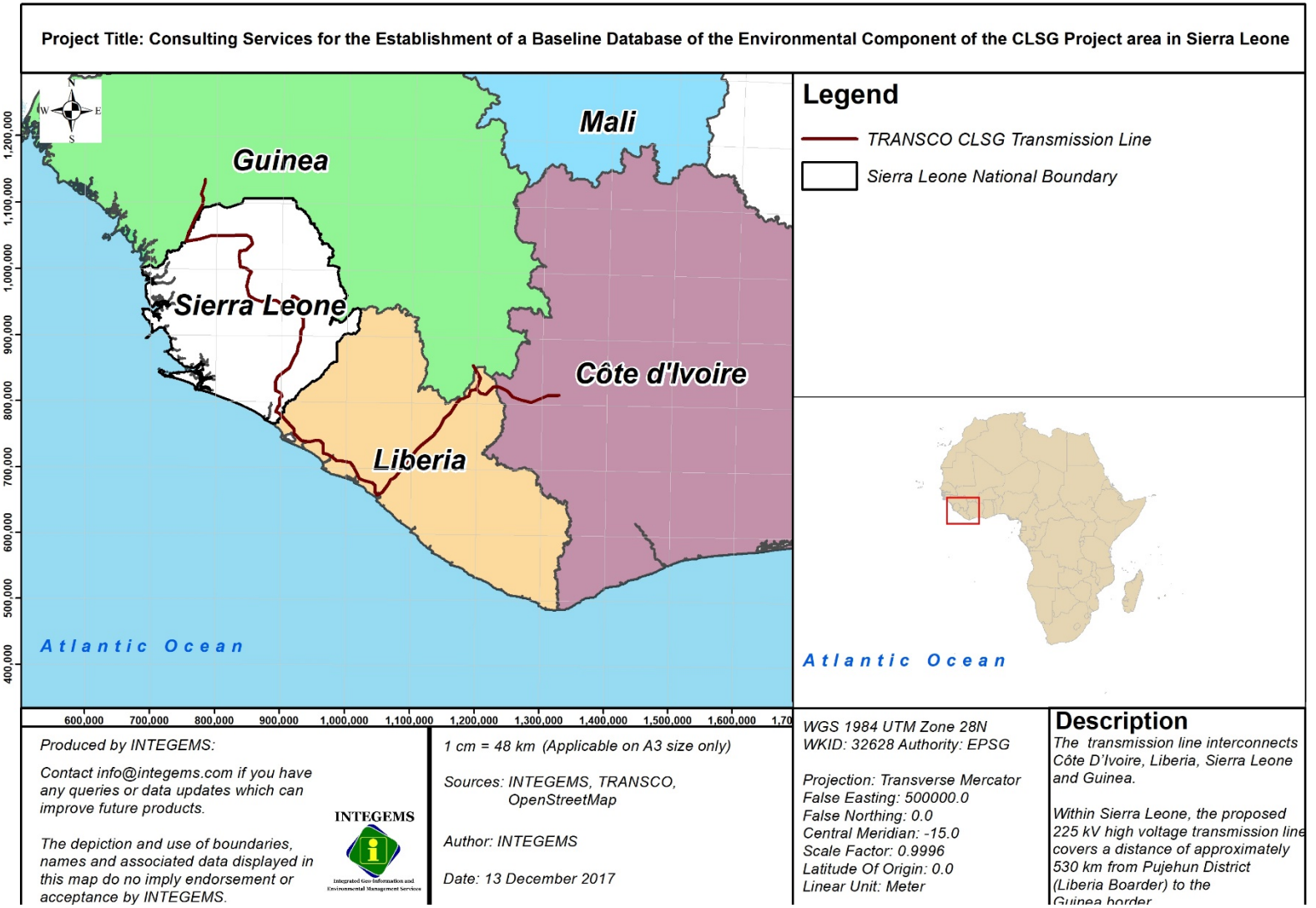


Figure 2-2: Overview of the TRANSCO CLSG Transmission within Sierra Leone

Figure 2-3: Overview of the Monitoring Locations

- Sewa River's furthest sources are the Bagbe River and Bafi River, which originates in the mountainous areas of the north-eastern part of the country, near the border with Guinea. From the confluence of Bagbe and Bafi in the Kono District Sewa flows 240 km in a south-southwestern direction and drains an area of 14,141 km^2. Close to the Atlantic coast the river joins Waanje River to form the Kittam River. Sewa River is navigable over shorter distances, but in the middle and upper reaches, rapids and cataracts dominate. The river has great commercial value for Sierra Leone. Sewa's upper reaches is being panned for diamonds on a large scale. Closer to the coast, rice cultivation and the cultivation of piassava, exported for the production of besoms, are important crops.[2]

Table 2-2: Air quality and noise monitoring locations along the transmission line in Sierra Leone

No	Towns	Section	Chiefdom	District	Coordinates		Approximate distance between the town and the corridor (km)
					X	Y	
1	Vaama (Barri)	Jougba	Barri	Pujehun	-11.41217	7.54294	2.9
2	Mano (Junction)	Kona Kpindibu	Nongowa	Kenema	-11.10476	8.02588	1.3
3	Lago (Jasawabu)	Kona Kpindibu	Nongowa	Kenema	-11.10461	8.05235	0.9
4	Kangama (Gorama)	Kangama	Gorama Kono	Kono	-11.05646	8.37579	1.6
5	Njagbwema Nimikoro	Gbogboafeh	Nimikoro	Kono	-11.14359	8.64171	1.1
6	Makoni Line	Mathonkara	Kunike Barini	Tonkolili	-11.57511	8.63826	0.9
7	Kajida (Near Bumbuna)	Lower Section	Kalasongoia	Tonkolili	-11.76282	9.02950	2.2
8	Kamabai	Kamabai	Biriwa	Bombali	-11.96035	9.14898	2.1
9	Fadugu	Kasunko	Kasunko	Koinadugu	-11.76894	9.39629	5.3
10	Kamakwie	Kamakwie	Sela Limba	Bombali	-12.24019	9.50492	1.7

Table 2-3: Water quality monitoring locations along the transmission line (Sierra Leone)

No	Rivers	Chiefdom	District	Coordinates		Approximate distance between the point and the corridor (km)
				X	y	
1	Mano	Soro Gbema	Pujehun	7.06897	-11.37588	0.5
2	Moa (Point 1)	Barri	Pujehun	7.36020	-11.41789	0.9
3	Moa (Point 2)	Koya	Kenema	7.66768	-11.26378	0.8
4	Sewa	Nimiyama	Kono	8.60477	-11.26573	2.0
5	Little Scarcies	Sela Limba	Bombali	9.52344	-12.38017	0.5
6	Great Scarcies	Bramaia	Kambia	9.44435	-12.68060	0.9

[2] http://www.wikiwand.com/en/List_of_rivers_of_Sierra_Leone List of rivers of Sierra Leone (accessed: 11 December, 2017)

3 LEGISLATIVE AND INSTITUTIONAL FRAMEWORKS

The baseline database must comply with environmental requirements of Sierra Leone and international environmental requirements, including the Performance Standards of the International Finance Corporation (IFC) of 1 January 2012, the Environmental, Health and Safety (EHS) Guidelines of 30 April 2007, and also the World Bank's Environmental, Health and Safety Guidelines for Energy Transport Distribution Projects of 30 April 2007.

3.1 Legislation and Policies in Sierra Leone

3.1.1 Environment Protection Agency Act, 2008 (No. 11 of 2008) as amended in 2010

The Environment Protection Agency (EPA) Act (Act No. 8 of 2008) established in 2008 and revised in 2010 (The Environment Protection Agency (Environmental Impact Assessment Licence) regulations 2010), is the primary legal framework for the establishment of the Environment Protection Agency - Sierra Leone (EPA-SL). The EPA Act defines the functions of the EPA-SL, its organization, powers and administration. The EPA Act defines and categorizes the development activities that may require an Environmental Impact Assessment (EIA) License and details the processes for acquiring such. The EPA Act further describes the obligations of the Licensee and the Board of the EPA-SL where the requirements for acquiring an EIA Licence has been met by the Project Proponent and the EIA Licence has been granted by the EPA-SL Board of Directors. Part IV of the Act exclusively deals with the activities requiring a full Environmental and social impact assessment and describes the permitting processes leading to the acquisition of an environmental licence.

3.1.2 National Electricity Act, 2011

This act provides for the establishment of the Sierra Leone Electricity Generation and Transmission Company which should be responsible for the generation, transmission and sale of electricity to the Authority (Electricity Distribution and Supply Authority) also established in section 25 of the act. The Company, headed by a Director General and Board of Directors, takes over ownership of all power generation and transmission assets of NPA, BKPS and Bumbuna Hydropower and is responsible for future development of national grids as determined by the government. The Act recognises role of Independent Power Producers in generating and selling electricity to the Authority for retail sale.

3.1.3 National Environmental Policy

The National Environmental Policy (1994) seeks to achieve sustainable development in Sierra Leone through the implementation of sound environmental management systems which will encourage productivity and harmony between man and his environment. It also promotes efforts which will prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of nationals, and serves to enrich the understanding of ecological systems and natural resources import ant to the Nation.

3.1.4 National Energy Policy

The objective of the National Energy Policy (2010) is to ensure the provision of modern energy services for increased productivity, wealth creation and improved quality of life for all Sierra Leoneans. The energy supply sub-sectors covered by this policy are electricity, petroleum and renewable energy, with a focus on increasing the supply of modern energy supplies for Sierra Leone. The policy is geared towards increasing supplies, through a comprehensive reform of the power sector, including liberalization of the sub-sector, attracting private investments and involvement and putting in place more effective mechanisms for monitoring and control. For the petroleum sub -sector, the upstream focuses on oil exploration, while the downstream addresses measures to reduce costs, without compromising security of supply.

3.1.5 The Draft Forestry and Wildlife Sector Policy for Sierra Leone 2003

The Draft Forestry and Wildlife Sector Policy for Sierra Leone document is still under review and awaiting parliamentary approval. The goal of the document is to support the development and exploitation of forests and wildlife of Sierra Leone in a sustainable manner for the material, cultural and aesthetic benefit of the people of Sierra Leone.

The main objectives of the forestry policy are to:

- Promote best practices in forest management so as to develop an environmentally friendly, self-sustaining forestry sector that is sensitive and responsive to the economic, social and cultural needs of those who live adjacent to or are dependent on the forest;
- Foster enabling environments for supervised production of sustainable volumes and quality of forest products that will create national wealth and contribute to food security; and
- Encourage the private sector to create employment opportunities for local populations thereby reducing rural poverty

3.1.6 National Land Policy (2015)

The National Land Policy promotes the objectives of equal opportunity and sustainable social and economic development. The principles guiding the Land Policy include: (1) protecting the common national or communal property held in trust for the people; (2) preserving existing rights of private ownership and (3) recognising the private sector as the engine of growth and development, subject to national land-use guidelines and rights of landowners and their descendants.

3.1.7 National Water and Sanitation Policy (2010)

This National Water and Sanitation Policy was developed in the light of the increasing challenges to the management to water resources in the country. The Policy covers water resources management, urban water supply and sewerage, rural water supply, hygiene and sanitation legal, regulatory and institutional framework. The Policy responds to the urgent need in Sierra Leone for integrated and cross-sectoral approaches to water management and development as well as the provision of safe and adequate water and adequate sanitation facilities. In particular, it advocates:

- The fundamental human right of access to safe and adequate water to meet basic human needs.
- Provision of education to improve hygiene practices and increased access to adequate sanitation facilities.
- Careful management of water as a socially vital economic good to sustain economic growth and to reduce poverty.
- A participatory approach that will help the conservation and protection of water resources.

3.1.8 Fisheries Management and Development Act, 1988 (Act No. 4).

This Act provides for the management, planning and development of the fisheries of Sierra Leone in the water over which fisheries jurisdiction is asserted from time to time. Authority and administration is covered by Part II; exclusive management and control over the fisheries and other aquatic resources is vested in the Government, with responsibility for administering the Act placed upon the Minister responsible for MAFFS, though a Department of Fisheries is also created by the Act.

3.1.9 Factories Act, 1974

This Act deals with health and safety measures as they concern the factory worker. It protects the worker through demands for all aspects of cleanliness, reports of all injuries, accidents, diseases and death. It makes provision for inspection of facilities, prescribes the powers of an inspector and sets penalties for defaulting parties.

3.2 Institutional Framework

There are several institutions which have various responsibilities directly or indirectly connected to the establishment of the baseline database of the environmental component of the CLSG project area in Sierra Leone. These include:

3.2.1 Environmental Protection Agency – Sierra Leone (EPA-SL)

The EPA Act 2008 (amended in 2010) established the EPA-SL and defines its functions and powers, provides for its organization and administration and provides rules for various matters regarding the environment in Sierra Leone. The EPA-SL is established as a corporate body managed by Board of Directors and an Executive Director. The Executive Chairperson, who is responsible to the Office of the President, executes the Board policies and oversees the day-to-day- professional and administrative activities of the Agency. The Executive Chairperson is assisted by the Executive Director and three Deputy Directors.

The EPA-SL Board of Directors comprises the Executive Chairperson and Representatives drawn from various following ministries and the private sector. At present, the Executive Board serving as the governing body of the EPA-SL, provides general policy guidance and advice as well as supervises the work of the EPA-SL.

The EPA-SL has a wide range of environmental management functions, including coordination of the activities of government agencies and other departments on matters relating to environmental protection and management. The EPA-SL is also responsible for ESHIA compliance and licensing. Part IV of the EPA Act exclusively deals with the activities requiring a full ESHIA and describes the permitting processes leading to the acquisition of an EIA Licence.

3.2.2 Ministry of Energy (MoE)

Ministry of Energy is responsible for the coordination of activities of the energy sector. The primary responsibility of the Ministry is to formulate and implement policies, projects and programmes on energy and provide oversight functions across the entire energy supply chain for all sub-sector agencies (which include electricity production, electricity transmission, electricity distribution and services). Following the passage of national electricity legislation, the Government of Sierra Leone (GoSL) in 2016 unbundled the National Power Authority (NPA) into two utilities – Electricity Generation and Transmission Company (EGTC) & Electricity Distribution and Supply Authority (EDSA) – and standing up an independent regulator.

3.2.3 Ministry of Agriculture, Forestry and Food Security (MAFFS)

The MAFF is mandated with the implementation of government's agricultural, forestry and food security policies. The mandate of the MAFFS spreads across crops, livestock and forest development and improvement policies, and related services. The MAFFS exercises its mandates over the environment through such Departments as Agriculture, Forestry, Land and Water Development, Planning, Evaluation, Monitoring and Statistics and the Livestock Unit. The current policy of the MAFFS includes higher productivity, self-sufficiency in staples and other products, diversified production, increased incomes, maximization of foreign exchange through export promotion and import substitution, increased rural employment, improved nutrition and soil fertility.

3.2.4 Ministry of Lands, Country Planning and the Environment (MLCPE)

The MLCPE's central role is to ensure the sustainable management and utilization of the nation's lands, proper planning and environmental management of the nation's natural resources for the country's socioeconomic growth and development. The MLCPE's policies and programmes are designed to contribute towards the realization of the national goals of wealth creation, revenue mobilization and employment generation within the framework of the poverty reduction. The MLCPE's programmes and projects are implemented by three in house Departments: Surveys and Lands, Country Planning and Environment.

3.2.5 Ministry of Local Government and Rural Development (MLGRD)

The MLGRD through the Paramount Chiefs holds control over lands in the provinces. Land is owned collectively by the community with the Paramount Chief as the sole custodian. The Director of Forests is the head of the Forestry Division and is responsible for the management and protection of forest reserves, game reserves and national parks. The communal forests, though they remain in the hands of the chiefdoms are also managed by the Chief Conservator of Forests (CCF). However, the Division lacks the capacity to professionally perform its duties and as a result the forests are exploited without attention to sustainable management.

3.2.6 Other Relevant National Institutional Frameworks

- Sierra Leone Investment and Export Promotion Agency (SLIEPA)
- Sierra Leone Chamber for Agribusiness Development (SLECAD)
- Land and Water Development Division (LWDD)
- Sierra Leone Roads Authority (SLRA)
- Human Rights Commission (HRC)

3.3 International Policies, Guidelines, Standards and Conventions

3.3.1 The World Bank Safeguard Policies

The World Bank environmental and social safeguard policies seek to address potential environmental risks and benefits associated with the Bank's lending operations. These safeguards policies are designed to avoid, mitigate or minimise adverse environmental and social impacts of projects supported by the Bank. The screening of the proposed project was carried out to determine the appropriate extent and type of environmental assessment to be undertaken and whether or not the project may trigger other safeguard policies.

3.3.2 International Finance Corporation (IFC) Performance Standards

IFC's Sustainability Framework articulates the Corporation's strategic commitment to sustainable development, and is an integral part of IFC's approach to risk management. The Sustainability Framework comprises IFC's Policy and Performance Standards on Environmental and Social Sustainability, and IFC's Access to Information Policy. TRANSCO will be guided by the IFC's Performance Standards on Social and Environmental Sustainability (2012). The eight Performance Standards are what IFC applies to manage social and environmental risks and impacts and to enhance development opportunities in its private sector financing.

- Performance Standard 1 (PS1): Assessment and Management of Environmental and Social Risks and Impacts
- Performance Standard 2 (PS2): Labour and Working Conditions
- Performance Standard 3 (PS3): Resource Efficiency and Pollution Prevention
- Performance Standard 4 (PS4): Community Health, Safety, and Security
- Performance Standard 5 (PS5): Land Acquisition and Involuntary Resettlement
- Performance Standard 6 (PS6): Biodiversity Conservation and Sustainable Management
- Performance Standard 7 (PS7): Indigenous Peoples
- Performance Standard 8 (PS8): Cultural Heritage.

3.3.3 Environmental, Health and Safety (EHS) Guidelines

The EHS Guidelines are technical reference documents that address IFC's expectations regarding the industrial pollution management performance of projects. This information supports actions aimed at avoiding, minimizing, and controlling environmental, health, and safety (EHS) impacts during the construction, operation, and decommissioning phase of a project or facility. Relevant for this project are:

- The General EHS Guidelines;
- The EHS Guidelines for Thermal Power Plants;
- The EHS Guidelines for Waste Management Facilities; and,
- The EHS Guidelines for Electric Power Transmission and Distribution.

3.3.4 African Development Bank's ESIA Procedures

The present study is part of the compliance process as detailed in the African Development Bank's Environmental and Social Impacts Assessment Procedures. The construction of the 225 kV transmission line and associated substation facilities classified as Category 1 of African Development that call for ESIA, because the Project will be implemented in broad areas and likely to have many impact on the project area.

3.3.5 High Conservation Value Forest (HCVF)

High Conservation Value Forest (HCVF): The forest necessary to maintain or enhance one or more High Conservation Values (HCVs):

- HCV1. Forest areas containing globally, regionally or nationally significant concentrations of biodiversity values (e.g. endemism, endangered species);
- HCV2. Forest areas containing globally, regionally or nationally significant large landscape level forests, contained within, or containing the management unit, where viable populations of most if not all naturally occurring species exist in natural patterns of distribution and abundance;
- HCV3. Forest areas that are in or contain rare, threatened or endangered ecosystems;
- HCV4. Forest areas that provide basic services of nature in critical situations (e.g. watershed protection, erosion control);
- HCV5. Forest areas fundamental to meeting basic needs of local communities (e.g., subsistence, health); and
- HCV6. Forest areas critical to local communities' traditional cultural identity (areas of cultural, ecological, economic or religious significance identified in cooperation with such local communities).

3.4 Relevant International Agreements

Sierra Leone has endorsed and signed several international conventions/protocols (see Table 3-1). These conventions and protocols are at different stages of implementation but in general implementation is slow as many have not been ratified or harmonised with the laws, policies and programmes of Sierra Leone. As a result Sierra Leone trails far behind in the implementation of the provisions of these conventions and protocols.

Table 3-1: Relevant International Conventions and Protocols

Policy/ Legislation	Summary	Year of Adoption	Year of Ratification
Abidjan Convention for Cooperation in the Protection, Management and Development of the Marine and Coastal Environment of the West and Central African Region	To protect the marine environment, coastal zones and related internal waters falling within the jurisdiction of the States of the West and Central African region. The Parties agree to take all necessary measures to prevent, reduce, combat and control pollution of the Convention area (art. 4). Parties undertake to prevent, reduce, combat and control coastal erosion (art.10) and protect and preserve rare or fragile ecosystems, as well as the habitat of depleted, threatened or endangered species and other marine life in specially protected areas (art. 11).	Adopted 1981, In force since 1984.	Ratified by Sierra Leone on 7 June 2005
Convention on Migratory Species (CMS)	Sierra Leone is not a signatory to CMS, although has signed a Memorandum of Understanding concerning Conservation Measures for Marine Turtles of the Atlantic Coast of Africa. This is a non - binding agreement under article IV (4) of CMS. It aims at safe guarding six marine turtle species that have declined in numbers in recent years.	Entry into force: 29 May 1999	

Policy/ Legislation	Summary	Year of Adoption	Year of Ratification
Ramsar Convention on Wetlands of International Importance, especially as Waterfowl Habitat (Ramsar Convention)	An international treaty that embodies the commitments of its member countries to maintain the ecological character of their 'Wetlands of International Importance' and to plan for their sustainable use. The criteria for identifying Wetlands of International Importance' include: sites containing representative, rare or unique wetland types; sites of international importance for conserving biological diversity, which includes specific criteria on species and ecological communities, water birds and fish (Ramsar Convention Secretariat, 2011a).	Entered into force 2nd February 1971.	Ratified by Sierra Leone 13 April 2000
Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972	To protect the marine environment from all sources of pollution and to prevent, reduce and where practicable eliminate pollution caused by dumping or incineration at sea of wastes and other matter.	Entry into force: March 24 2006.	Ratified by Sierra Leone March 10 2008.
United Nations Framework Convention on Climate Change	To regulate levels of greenhouse gas concentration in the atmosphere, so as to avoid the occurrence of climate change on a level that would impede sustainable economic development, or compromise initiatives in food production.	Entered into force globally 21 March 1994.	20 September 1995
Vienna Convention for the Protection of the Ozone Layer	Acts as a framework for international efforts to protect the ozone layer.	Signed in 1985	Came into force in 1988

Policy/ Legislation	Summary	Year of Adoption	Year of Ratification
Protocol on Substances that Deplete the Ozone Layer (Montreal Protocol)	To protect the ozone layer by taking precautionary measures to control global emissions of substances that depletes it. E.g. binding reduction goals for the use of CFCs.	Global Entry into force 1 January 1989.	
The Stockholm Convention on Persistent Organic Pollutants	To eliminate or restrict the production and use of persistent organic pollutants (POPs) – chemicals that are persistent bio-accumulates found in fatty tissues and are bio-magnified through the food chain, and adversely affect health and the environment.	22 May 2001	Sierra Leone became a signatory on the 27 August 2001. The convention came into force on 17 May 2004.
Aarhus Convention	Establishes a number of rights of the public (individuals and their associations) with regard to the environment.	25 June 1998	30 October 2001

3.5 Administrative Framework

Administratively, Sierra Leone is divided into various administrative areas/units. The administrative structure starting from the top to the bottom is: Country, Province/Area, District, Chiefdom, Section and Village/Town. At the time of contract signature (July 2017) Sierra Leone, was administratively divided into four areas: three Provinces and an Area, namely:

- Eastern Province, with its Headquarter in Kenema City;
- Northern Province, with its Headquarter in Makeni City;
- Southern Province, with its Headquarter in Bo City; and,
- Western Area (comprising the Peninsular), with the Capital City (Freetown), as its Headquarter.

The responsibility for provincial administrative matters is within the purview of the Ministry of Local Government and Rural Development. The Minister is assisted in his duties by a Resident Minister in each of the three provinces whose offices are in the respective provincial headquarter towns. The Resident Ministers are assisted by Provincial Secretaries at provincial level.

Each Province is divided into Districts; with 14 Districts in the entire Country (see Figure 3-1), namely:

- Bombali, Port Loko, Kambia, Koinadugu and Tonkolili Districts - all in the Northern Province;
- Bo, Moyamba, Pujehun and Bonthe Districts - all in the Southern Province; and
- Kailahun, Kenema and Kono Districts - all in the Eastern Province.
- Western Area Urban and Western Area Rural – all in the Western Area

Each District in the Provinces is divided into several Chiefdoms; there are a total of 149 Chiefdoms in Sierra Leone. Each of the chiefdoms in Sierra Leone has a traditional ruler called Paramount Chief, or a Regent Chief who is appointed upon the death of a Paramount Chief until a successor is elected. Paramount Chiefs constitute an important component of governance. They are elected for life-long terms by Chiefdom Councillors, who in turn are selected by the residents of their Chiefdoms.

The administration of the Chiefdom occurs through a hierarchical system of traditional authorities under the Paramount Chief. A Paramount Chief is responsible for general administration, the maintenance of law and order and the development of the chiefdom. The Paramount Chief also inherits custodian rights over land within his Chiefdom. There is a Chiefdom Speaker who assists and deputizes when the Paramount Chief is absent from the Chiefdom. The primary tasks of the Chiefdom structure are the distribution of land, collection of land taxes and the settlement of disputes. The Paramount Chief works with a Chiefdom Committee, Council of Elders and the Native Administration. The local government powers relate to raising and disbursing of funds.

The Ministry of Local Government and Rural Development in consultation with the respective Paramount Chiefs, appoints local Court Chairmen in the 149 chiefdoms in the country. The local court buildings are known as Court Barries, of which there are about 287 throughout the country. The Native Administration utilizes the services of the Chiefdom Police and “lock ups” for law enforcement purposes. Land is normally leased out to a company when an agreement is reached between the local authorities and the company. Surface rent payments are made to local authorities as compensation. The existing arrangement with the Government is that the Paramount Chief, the Native Administration and the land owners share the surface rent. Compensation is also paid for housing and cultivation within the surface rent area, should relocation of these be necessary. The holder of the right to leased land shall also on demand, pay compensation for any damage done to the land’s surface, to crops, buildings or any other infrastructure.

Each chiefdom is divided into Sections, which comprises a number of villages and towns. Each Section is headed by a Section Chief and each village/town by a Village Chief/Town Chief.

During the course of the Project (in late July 2017), the GoSL proclaimed the de-amalgamation of Chiefdoms and an attendant re-division of the Northern Region into two distinct Regions, namely: Northern Region and North-Western Region. Some 41 de-amalgamated chiefdoms have been created adding to the current 149, in a move the government has said is meant to right a historical wrong. Following nationwide consultations, the 41 Chiefdoms, mostly in the North, were de-amalgamated. With the de-amalgamation that has now come into effect with standard and informed criteria, the country has now got a total of 190 Chiefdoms with 16 Districts (see Figure 3-2**Error! Reference source not found.**).

Falaba in the northern Koinadugu District is now a district on its own with Mongor its district headquarter town; while Karene as well a new district under the new dispensation. The North now has seven Districts and is therefore divided into two Regions – Northern Region comprising of Bombali, Tonkolili, Koinadugu and Falaba, with Makeni as its city; while Kambia, Port Loko, and Karene form North-Western Region with Port Loko its new city.

Figure 3-1: Provinces and Districts in Sierra Leone (Pre De-amalgamation)

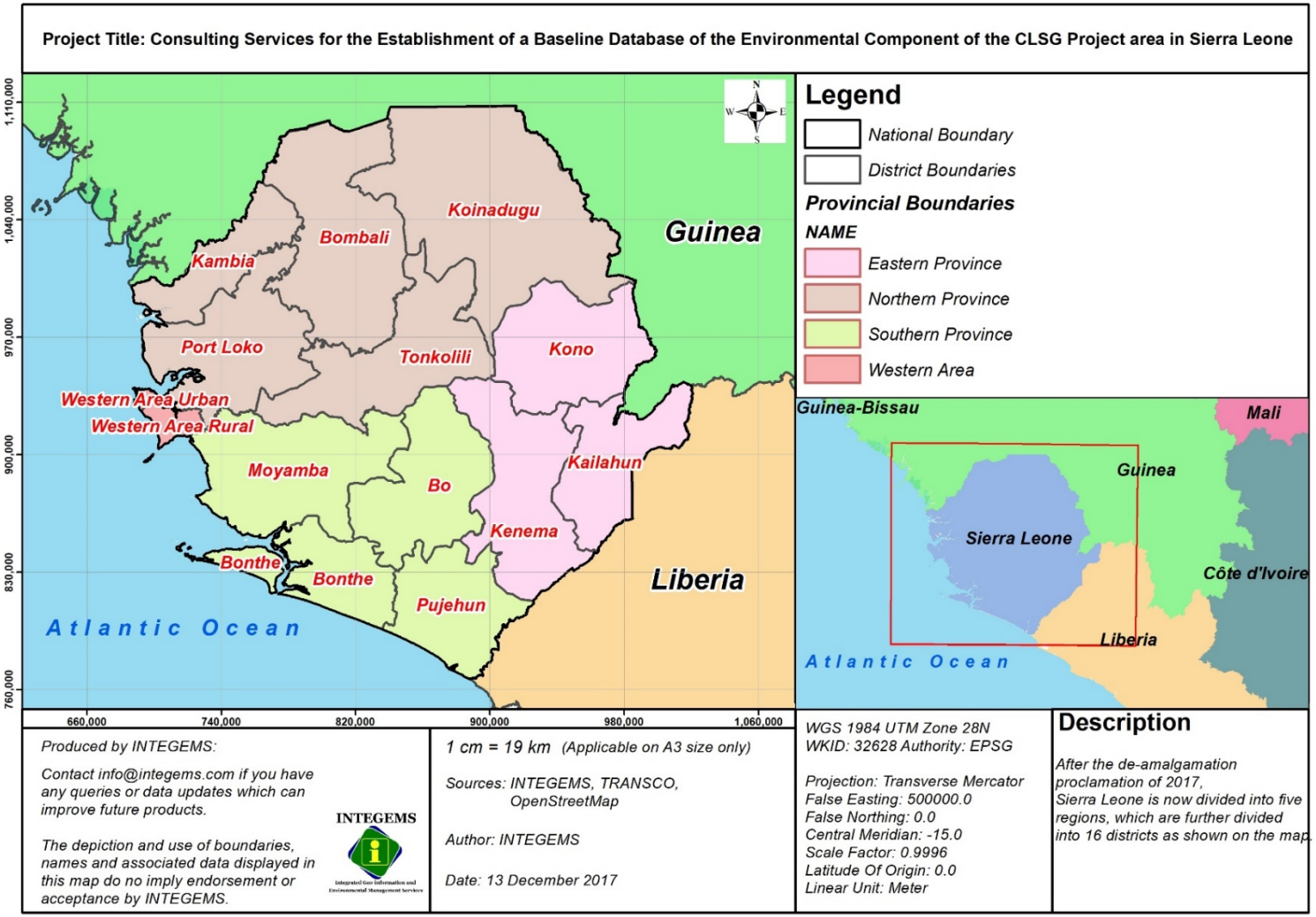
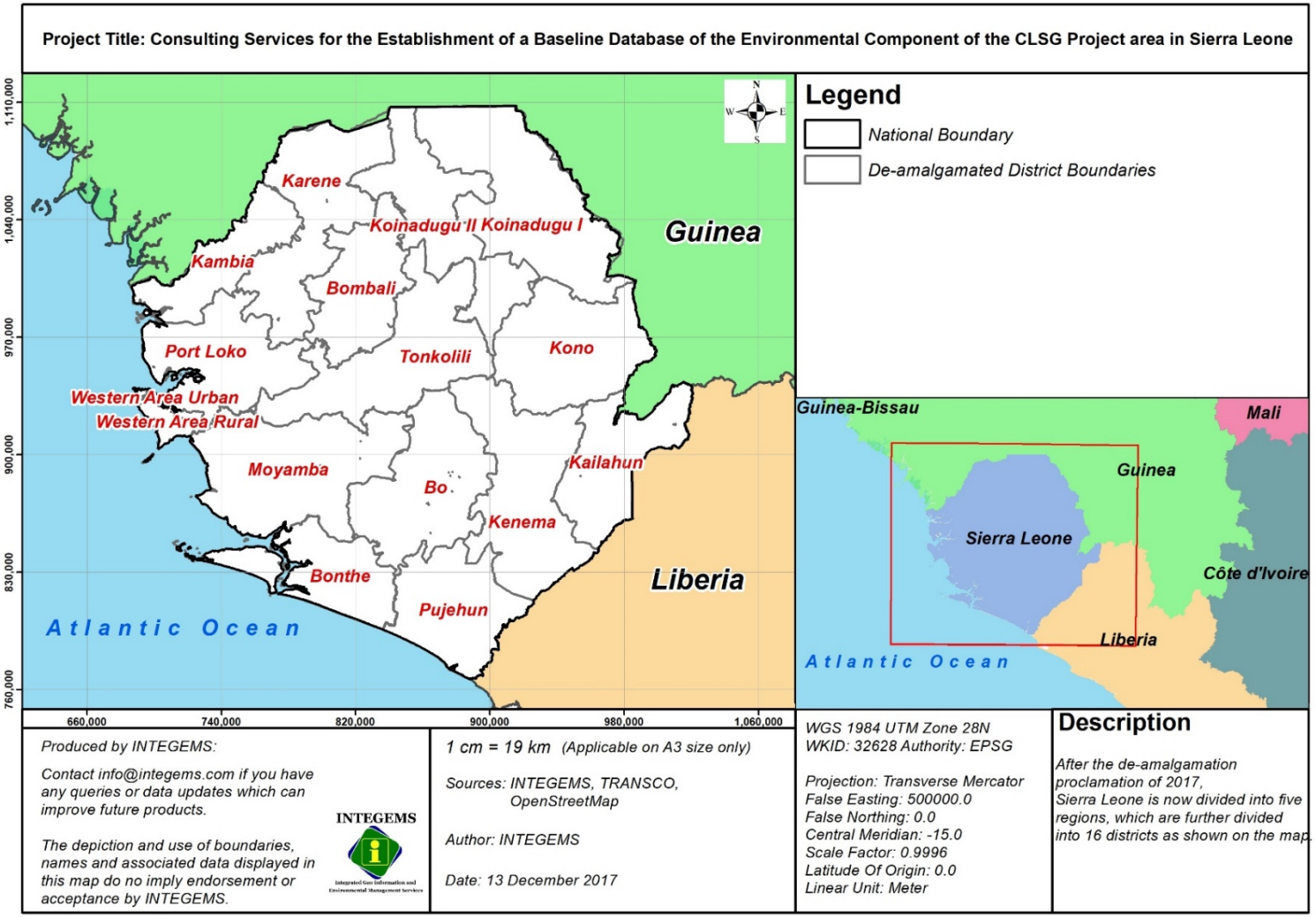


Figure 3-2: Districts in Sierra Leone (Post De-amalgamation)



4 STUDY METHODOLOGY

4.1 Project Inception, Desk Review, and Needs Assessment

A formal Project Inception Meeting (PIM) with the TRANSCO Environmental and Social Safeguard Team was convened in Freetown, Sierra Leone, on 23 June 2017 (before the start of the Project). At the PIM, the project methodology and draft work plan were presented and the scope of work fully clarified. The objectives of the PIM were to discuss the project methodology, scope of work and agree on/ finalise the project work plan, including confirmation of the required inputs, processes, outputs and the expected deliverables, milestones and timelines and other pertinent logistical issues. Furthermore, contract risks were identified and assessed. INTEGEMS formally requested from TRANSCO CLSG all the necessary data and reports on the environmental and social aspects (i.e., the TRANSCO CLSG ESIA, ESMP and RAP reports) in connection with the Sierra Leone transmission line corridor of the CLSG Interconnection Project, and any additional information helpful in the development of the environmental database. INTEGEMS also undertook a detailed desk review of useful project reports, data and information to gain a better understanding of the landscape in terms of Project implementation.

A brief Baseline Database Needs Assessment meeting was held with TRANSCO CLSG National Environmental Assistant in Freetown to understand and assess TRANSCO CLSG's information & communication technology (ICT) infrastructure and personnel in terms of environmental database and data management; data sharing, analysis and reporting; and ICT and human resource capacity. The brief Baseline Database Needs Assessment provided critical insight regarding the design and development requirements of the proposed Baseline Environmental Database & Geographic Information System (BEDGIS). This Need Assessment was required for the design, development and implementation of a functional baseline database system, including GIS and was helpful in identifying gaps in the personnel and computational resources of TRANSCO CLSG's potential end users.

A Project Inception Report was compiled and submitted to TRANSCO CLSG on 28 August 2017 and included a preliminary list of key project documents that were reviewed; detailed work plan and description of the approaches and methodologies that will be used; the activities and progress indicators that will guide the delivery of the Project; time frames of specific project activities, milestones; and dates for meetings and reporting on project progress.

4.2 Preparation of Sampling Plans, QA/QC Plans and SOPs

The preparation of a sampling plan was an integral part of the Project. Site-specific information were gathered to ensure that the plan will be logical, meet the required objectives and the course of action will be achievable. The purpose of developing a sampling plan was to detail a "plan of action". The following factors were considered to determine the number of samples required for site characterization:

- Exposure pathways;
- Statistical performance objectives;
- Data quality objectives;
- Quality assurance objectives;
- Background samples;
- Sampling objectives; and
- Site-specific conditions.

Quality Assurance (QA)/Quality Control (QC) plans were also prepared and associated with each sampling and analysis event as an additional measure of control to assure that the sample collected and delivered for analysis was representative of site conditions. The sampling plan outlined how the representative quality of the samples were assured.

4.3 Preparation of Monitoring Toolkits and Tools

INTEGEMS field staff were responsible for dealing with a broad spectrum of environmental baseline issues; hence, INTEGEMS developed authoritative information and guidance on the environmental issues within the Project area. The comprehensive set of resources provided in the monitoring toolkit assisted field staff in managing the environmental issues; it provided information on:

- pollution, its sources and impacts;
- the regulatory framework for protecting the media;
- general information about management procedures and technologies; and
- specific information in the form of guidelines for managing a number of polluting activities that have been identified by field staff as priority issues.

The monitoring toolkits were prepared with the needs and backgrounds of field staff in mind so that the information could be easily understood and used for monitoring at the local level. As well as making use of the guidance material on specific topics, field staff were encouraged to explore the comprehensive range of information on air quality, water quality, noise, soils and biodiversity pollution, regulatory measures and monitoring generally. While seeking to be thorough in its discussion of the environmental issues, the toolkit were not a design manual nor did it attempt to give a detailed scientific or engineering treatment of the matters covered.

4.4 Instrument/Equipment Testing, Inspection and Maintenance

Prior to field monitoring all monitoring equipment underwent thorough testing, inspection and maintenance routines, field staff were assured that all equipment were capable of operating at acceptable performance levels. Due to the many types of equipment that were used in the field during the Project, INTEGEMS provided general guidance on testing, inspection and maintenance procedures for all the equipment that were taken to the field.

4.5 Calibration

Since calibration was associated with an adjustment in either the instrument or software, these adjustments were minimized as much as possible. Verifications were implemented at reasonable frequencies to avoid invalidating significant amounts of data. Calibrations were carried out at the field monitoring site by allowing the Technicians to sample test known pollutant concentrations.

4.6 Travel and Mobilization

After identifying the locations of the villages/towns where the field teams will carry out the environmental baseline surveys, INTEGEMS made firm arrangements to travel to the relevant towns/villages.

4.7 Identification of Monitoring Sites, Data Acquisition and Data Management

Final placement of the monitors at a selected site depended on physical obstructions and activities in the immediate area, accessibility/availability of utilities and other support facilities in correlation with the defined purpose of the specific monitor and its design. Because obstructions such as trees and fences can significantly alter the behaviour of pollutants, monitors were placed away from obstructions. Detailed information on physiography (e.g., buildings, street dimensions) were determined through visual observations, aerial photography and surveys. Such information were important in determining the exact locations of pollutant sources in and around the prospective monitoring site areas.

How closely a measurement represents the actual environment at a given time and location is a complex issue that was considered during development of the sampling design. Each sample was checked for conformity to the specifications.

4.8 Air Quality

Existing and potential sources of air emissions (pollutants) and sensitive receptors were tentatively identified in the Project area. Thus, the pollutants for which air quality monitoring was undertaken are carbon monoxide (CO), carbon dioxide (CO_2), nitrogen dioxide (NO_2), ozone (O_3), sulphur dioxide (SO_2), volatile organic compounds (VOC_s), particulate matter with aerodynamic diameter of 10 micrometres (PM_{10}), and particulate matter with aerodynamic diameter of 2.5 micrometres ($PM_{2.5}$). These pollutants are characteristic of power generation and transmission operation sites, widely recognized as posing a potential risk to population health and the environment, and are commonly regulated at both national and international levels.

An air quality monitoring network that measures air pollutants in the outdoor ("ambient") air was set up and operated in two locations (residential and commercial) in each of the towns/villages within the specified buffer zones along the transmission line (see Table 4-1). In each monitoring town/village, the two station locations were setup based on population density and distribution, the location of stationary and mobile sources, and the historic concentration (where available) of particular pollutants. The air quality monitoring equipment were located at specific points (see Figure 4-4 to Figure 4-10) within the specified towns along the transmission line corridor at a height of about 1.5 -1.7 metres from the ground level and sufficiently away from the disturbance or direct obstacle from the source(s) under consideration to ensure that the air that was monitored is representative of the air that most residents/visitors were breathing. The air quality monitoring was designed to ascertain the average concentrations of the aforementioned pollutants in the specified towns along the transmission line over a one-and-half-day period. Each station was equipped with the requisite equipment (i.e., Casella CEL712 Microdust Pro and Aeroqual Series 500 portable air quality monitor) to measure the concentration of particular pollutants in the outdoor air.

The Casella CEL712 Microdust Pro - Real Time Dust Monitor was used for both gravimetric and real-time dust measurements, including the use of foam inserts to select the PM_{10} and $PM_{2.5}$, fractions. To ensure optimum accuracy, prior to making measurements the CEL 712 Microdust Pro probe was purged with clean air to expel fine dust particles trapped within the probe assembly followed by a ‘zero’ and ‘span’ check. The Aeroqual Series 500 Portable Air Quality Monitors that accurately measure in real-time the concentrations of multiple outdoor air pollutants were set to measure the concentration of CO, CO_2, NO_2, O_3, SO_2, and VOC_s (see Figure 4-1 and Figure 4-2).

During the monitoring period in each town, INTEGEMS’ field staff were stationed on the sites on a daily basis to perform routine data checks, performance audits, and scheduled maintenance. The field technicians carried out QA/QC duties, including change of filters (where necessary), and retrieval/download of raw data.

Figure 4-1: TRANSCO CLSG Baseline Environmental Database Field Air Quality Monitoring

INTEGEMS Staff setting up the CEL712 in Vaama

INTEGEMS Staff performing routine check in Vaama

INTEGEMS Staff setting up the S500 in Lago Jasawabu

Dust monitoring with the CEL712 in Lago Jasawabu

INTEGEMS Staff setting up the S500 in Kangama

INTEGEMS Staff setting up the CEL712 in Kangama

Figure 4-2: TRANSCO CLSG Baseline Environmental Database Field Air Quality Monitoring

Real-time air quality monitoring in Njagbwema

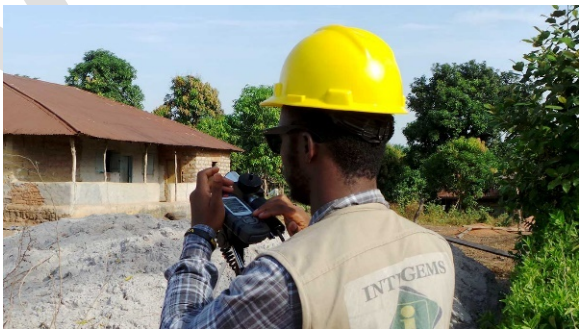
INTEGEMS Technician setting up the CEL712 in Makoni Line

INTEGEMS Technician setting up the S500 in Kajida

Real-time air quality monitoring in Kamabai

Real-time air quality monitoring in Fadugu

INTEGEMS Technician setting up the CEL712 in Kamakwie



4.9 Ambient Noise

The purpose of the baseline noise monitoring was to describe, both quantitatively and qualitatively, the ambient noise environment at noise sensitive receptors during the baseline environmental study periods in towns/village traversed by or near the transmission line (see Table 4-1 and Figure 4-4 - Figure 4-10). Baseline noise measurements were undertaken in proximity to key noise sensitive receptors. Two locations (commercial and residential) were selected in each town/village to monitor the background noise level representative of that town/village. The monitoring locations were selected on-site based on the specified proximity to the proposed transmission line and subjected to site access and security constraints. The geographic coordinates of all noise sampling locations were verified and captured using GPS receivers and site characteristics of the sampling locations were documented, with photographic references recoded (see Figure 4-3).

The Casella CEL 633A Digital Sound Level Meters, a Class 1 integrating-averaging type, capable of the simultaneous measurement and logging of the required noise measurement parameters (LAeq and LA90) in the towns/villages, were used. Periodic A-weighted LAeq (the average sound level) and statistical values such as L10 and L90 (percentiles) were captured. This was particularly important when monitoring in an environments like Mano Junction and Kangama Gorama with generally low noise levels and occasionally high ones - for example when vehicles pass. The CEL633A Sound Level Meter equipment were calibrated with a field calibrator immediately before and after the noise surveys.

The CEL633A Sound Level Meter equipment were set to log the following A-weighted broadband statistical noise descriptors at each measurement location every 5 minutes during the measurement:

- LAeq (Ambient Noise Level)
- LA90 (Background Noise Level)
- LA10 (Commonly used to quantify road traffic noise)
- LAFmax (Maximum noise levels, fast time response)
- LAFmin (Maximum noise levels, fast time response)

The CEL633A Sound Level Meter equipment were set to measure linear 1/1 and/or 1/3 octave band noise descriptors in addition to the A-weighted broadband noise descriptors. Spreadsheets containing the raw data and configuration for each measurement were employed to enable post-processing of results. The duration of the noise survey was on average one hour at each measurement location (security permitting). Measurements at a location were made continuously over the monitoring period (typically unattended) or regular attended measurements were undertaken. The objective in either situation was to build a picture of how noise levels at each location vary during the day, evening and night. Measurements were taken 1.2 – 1.5m above the ground. The sound level meters were mounted on a standard camera tripod.

Measurements were either taken under free-field conditions (more than 3.5m from any reflecting surface) or at 1m from the facade of a building and results treated accordingly. The Leq (the average sound level) and the periodic Leq (five Ln values for statistical analysis of the noise), including detailed time history, audio recording and automatic measurement times when measuring environmental and community noise, were captured. Attended measurements were conducted over a one-and-half-day period to gather sufficient data whilst allowing adequate rest periods for the staff undertaking the measurements. The sound level meters automatically logged environmental noise measurement parameters including LAeq, LA90, LA10, LA_{max} and LA_{min} parameters.

The environmental noise monitoring periods at the towns, including their environs, were:

- Daytime: from 07:00 until 22:00 (15 hours)
- Evening: from 22:00 to 07:00 (9 hours)

Table 4-1: Air quality and noise level monitoring locations in the vicinity of the transmission line

No	Towns	Monitoring Points	Location Type	Coordinates		Approximate distance between the town and the corridor (km)
				X	Y	
MT 01	Vaama (Barri)	MP 01	Residential	-11.41217	7.54294	3.1
		MP 02	Commercial	-11.41102	7.54339	
MT 02	Mano (Junction)	MP 03	Residential	-11.10476	8.02588	1.3
		MP 04	Commercial	-11.10497	8.02680	
MT 03	Lago (Jasawabu)	MP 05	Residential	-11.10461	8.05235	0.9
		MP 06	Commercial	-11.10518	8.05193	
MT 04	Kangama (Gorama)	MP 07	Residential	-11.05646	8.37579	1.6
		MP 08	Commercial	-11.05693	8.37627	
MT 05	Njagbwema Nimikoro	MP 09	Residential	-11.14359	8.64171	1.1
		MP 10	Commercial	-11.14356	8.64080	
MT 06	Makoni Line	MP 11	Residential	-11.57511	8.63826	1.2
		MP 12	Commercial	-11.57510	8.63692	
MT 07	Kajida (Near Bumbuna)	MP 13	Residential	-11.76282	9.02950	2.2
		MP 14	Commercial	-11.76275	9.03030	
MT 08	Kamabai	MP 15	Residential	-11.96035	9.14898	2.1
		MP 16	Commercial	-11.95962	9.14891	
MT 09	Fadugu	MP 17	Residential	-11.76894	9.39629	5.3
		MP 18	Commercial	-11.76768	9.39117	
MT 10	Kamakwie	MP 19	Residential	-12.24019	9.50492	1.7
		MP 20	Commercial	-12.24114	9.50453	

Because of very high security risk to monitoring personnel, noise monitoring at night (22:00 07:00) was only fully undertaken in Makoni, Kajida, Kamabai, and Fadugu. Noise surveys are susceptible to adverse wind conditions. Measurements were not conducted wind speeds exceeded 5m/s or in extremely foggy condition.

The following protocols were put in place to ensure proper measurement;

- Prior to and after each noise measurement, the meters were calibrated using a Calibrator for 114 dB at 1,000 Hz. Where the difference in the calibration level before and after a measurement was more than 1 dB, the measurement was considered invalid and a repeat of noise measurement was required after re-calibration or repair of the equipment.
- The battery condition was checked to ensure the correct functioning of the meter.

- The Sound Level Meter was set on a tripod at a height of 1.5 – 1.7 m above the ground and at least 3m from a wall or any other reflective surface to reduce the interference with the readings.
- The measurement location was cordoned off to any and all traffic (human, animal, vehicular and/or other) so as to reduce the interference with the readings that were taken.
- Environmental conditions (temperature and humidity) were recorded during the measurements.
- Noise monitoring was cancelled in the presence of fog.
- A wind shield was used at all times to prevent interference of reflecting noise.
- Parameters such as frequency weighting, the time weighting and the measurement time were set accordingly.
- Site conditions and noise sources were recorded on a standard record sheet.

Figure 4-3: TRANSCO CLSG BEDGIS ambient noise level monitoring

INTEGEMS Staff Setting Up Noise Level Meter in Vaama

INTEGEMS Staff Setting Up Noise Level Meter in Mano

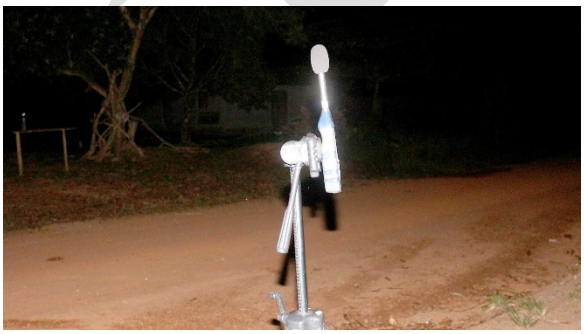
INTEGEMS Staff Setting Up Noise Level Meter in Lago

INTEGEMS Staff Setting Up Noise Level Meter in Kangama

Noise monitoring location in Njagbwema Nimikoro

INTEGEMS Staff Setting Up Noise Level Meter in Makoni

Real-time noise monitoring in Kajida (near Bumbuna)



Real-time noise monitoring in Fadugu

Figure 4-4: Air quality and noise monitoring locations (full transmission line length)

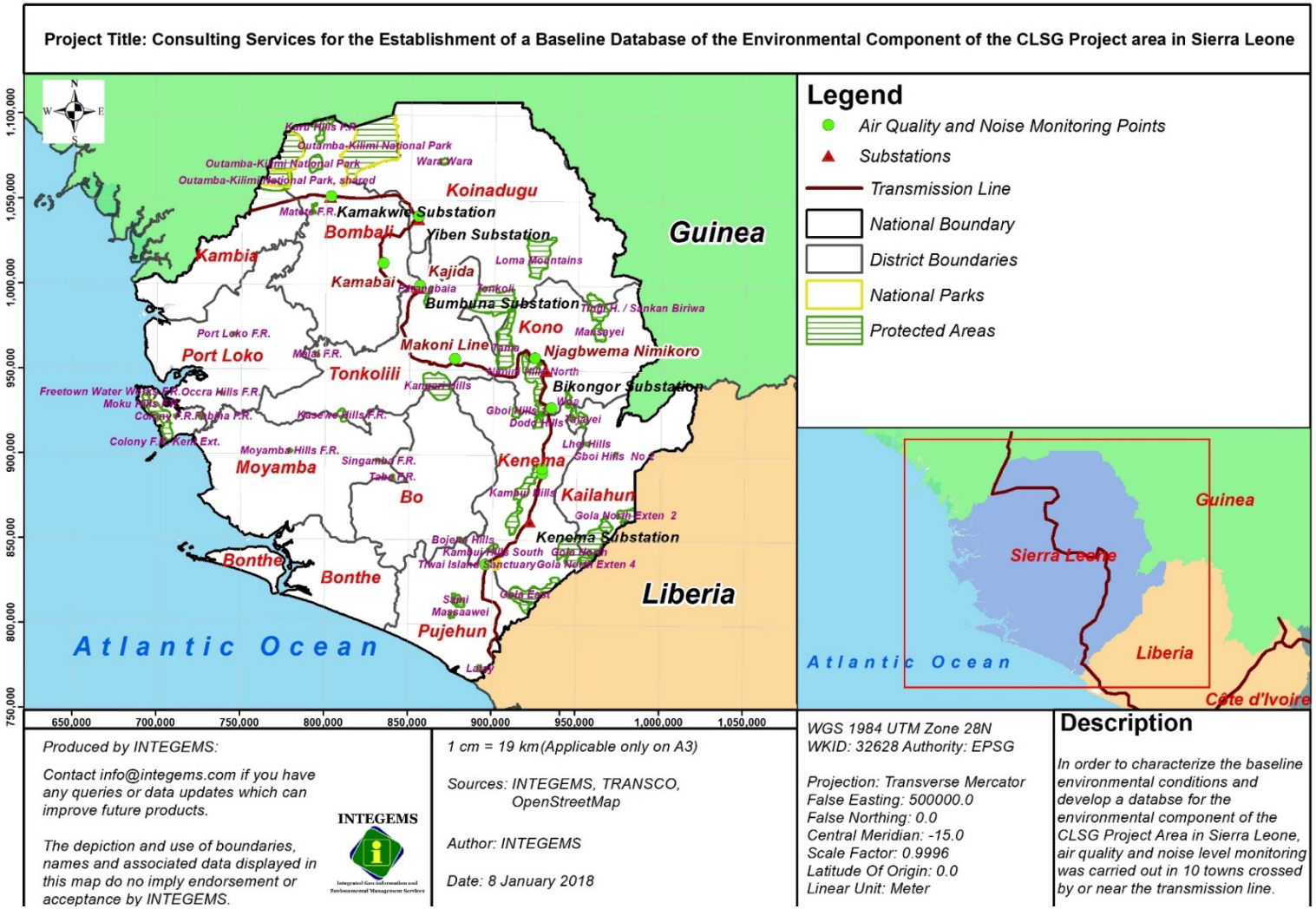


Figure 4-5: Air quality and noise monitoring locations (Liberian Border– Kenema Axis)

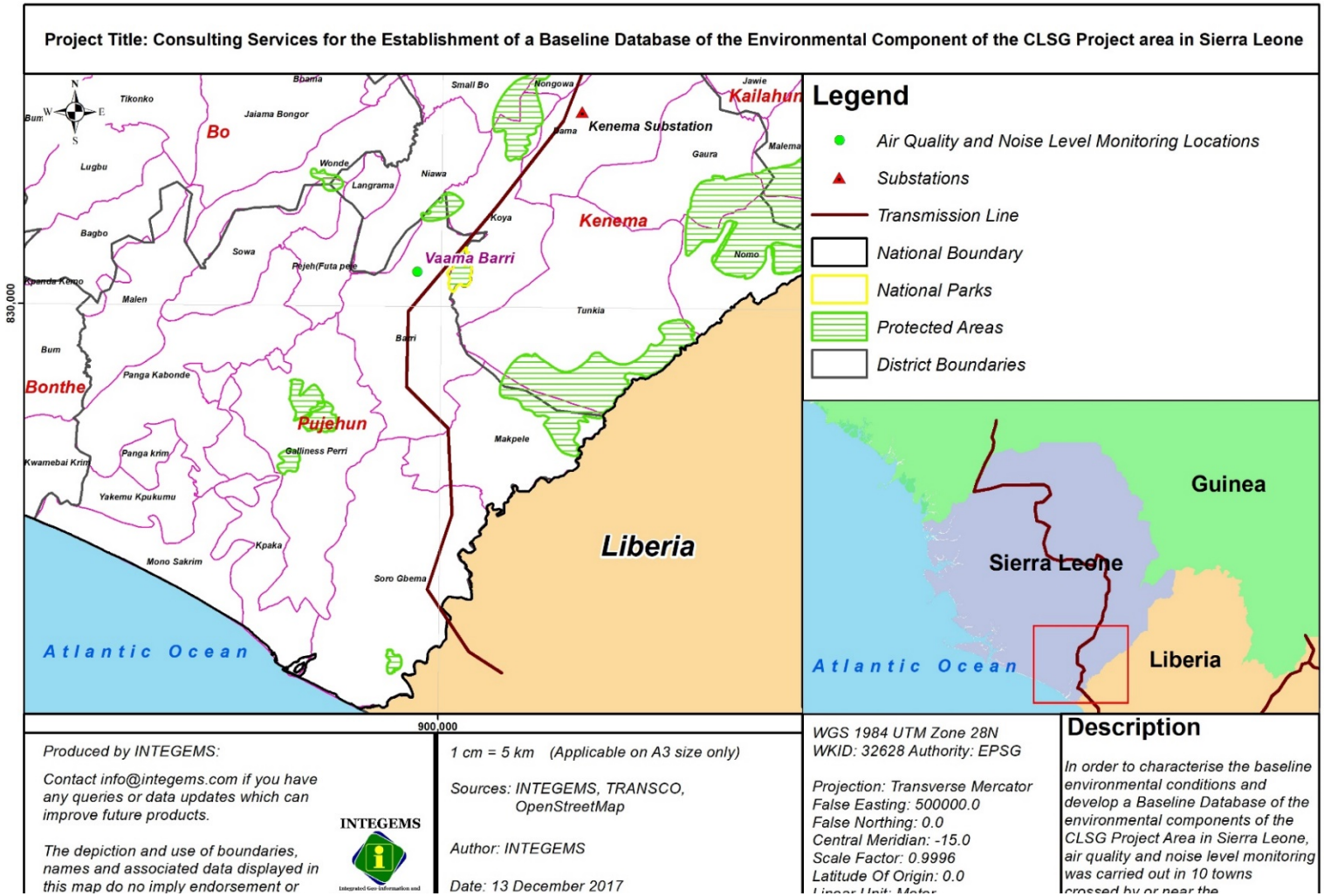


Figure 4-6: Air quality and noise monitoring locations (Kenema – Bikongor Axis)

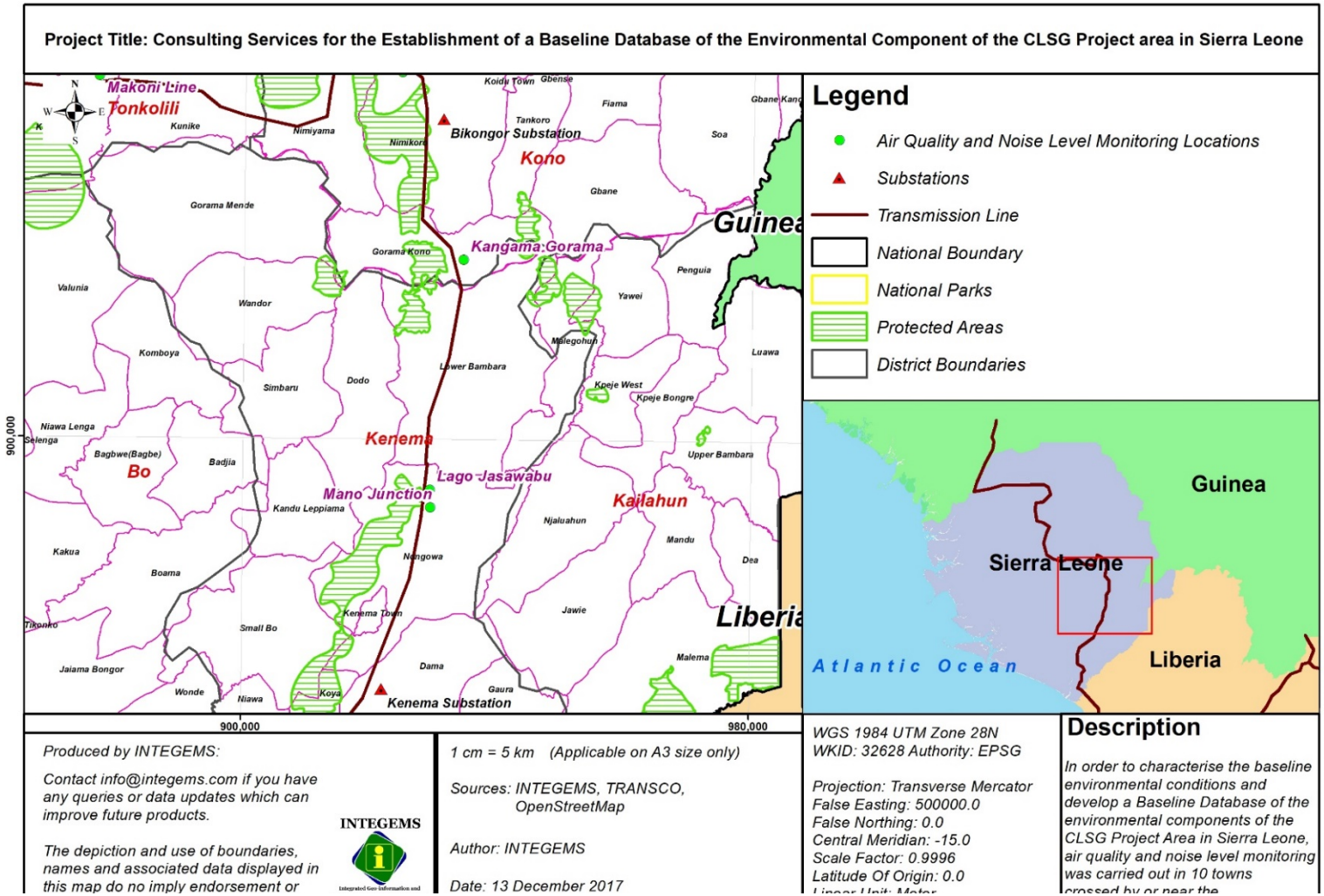


Figure 4-7: Air quality and noise monitoring locations (Bikongor – Bumbuna Axis)

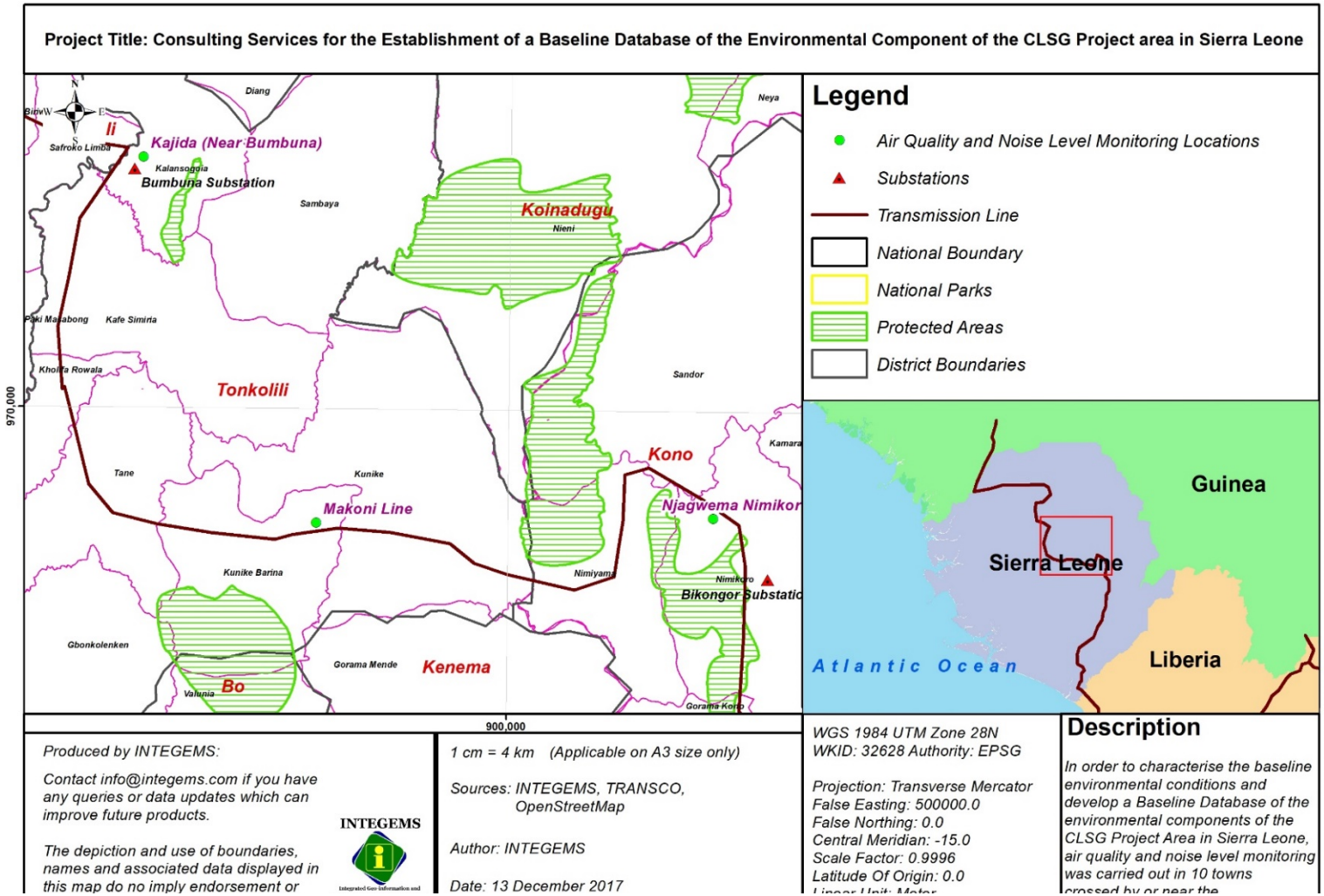


Figure 4-8: Air quality and noise monitoring locations (Bumbuna – Yiben Axis)

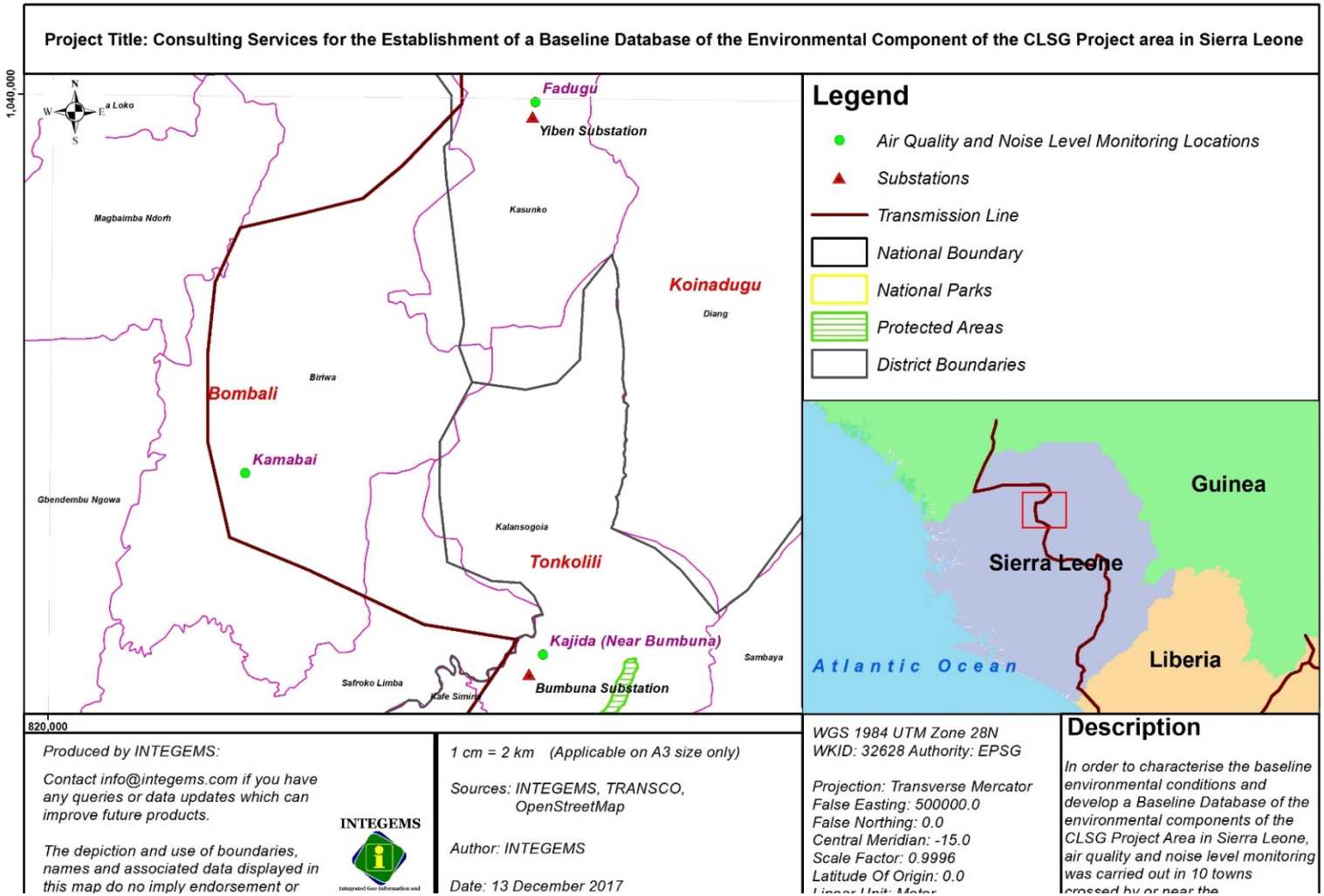


Figure 4-9: Air quality and noise monitoring locations (Yiben – Kamakwie Axis)

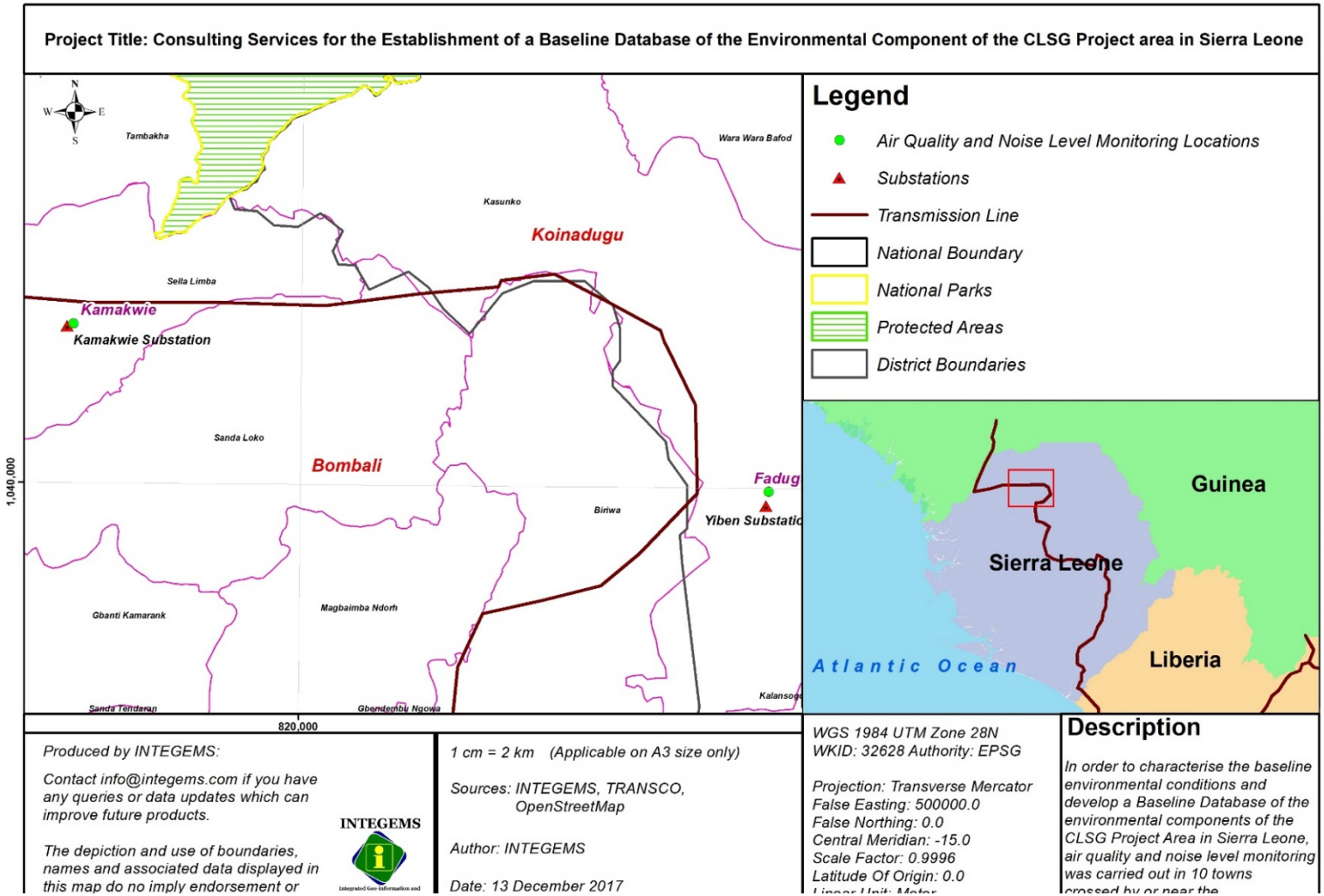
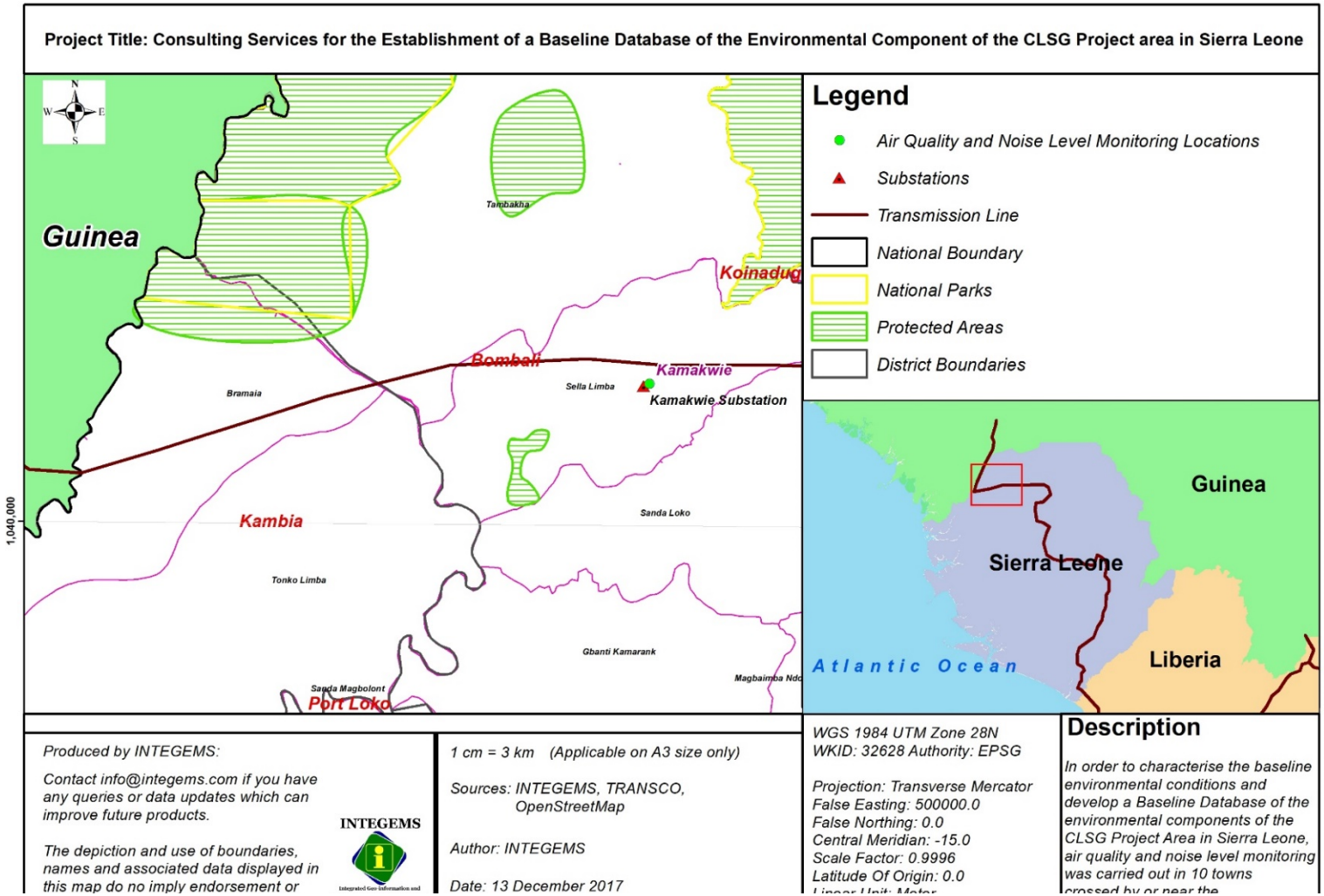


Figure 4-10: Air quality and noise monitoring locations (Kamakwie – Guinea Border Axis)



4.10 Water Quality

A water quality monitoring network that measures various water quality parameters as specified in the request for proposal (RFP) was setup and operated at each monitoring location where the transmission line crosses the relevant water course (see Table 4-2) in order to assess compliance with international and national water quality standards. Profiling and logging water quality data was captured to provide timely information on continually changing conditions – profiling to provide instantaneous real-time feedback, logging to track trends and demonstrate compliance.

Water quality monitoring locations were captured using GPS receivers (see Table 4-2 and Figure 4-15 - Figure 4-17) at the sample location. Visual observations of the water colour, transparency and some characteristic properties of the state of water bodies (streams/rivers, etc.) were also undertaken. Physico-chemical parameters were assessed in-situ using the Hanna 9829 Multiparameter handheld water quality probe, which has the latest sensor and electronics technology to collect, interpret and respond in a timely fashion with the convenience of a laboratory-quality measurement instrument for field use, providing true in-situ monitoring of water level and water quality. The Hanna 9829 portable logging multiparameter system was set up and calibrated to monitor in-situ for: electrical conductivity, pH, temperature, dissolved oxygen, oxidation reduction potential and total dissolved solids.

Table 4-2: Water quality monitoring locations within the Project Area

No	Rivers	Chiefdom	District	Coordinates		Approximate distance between the point and the corridor (km)
				X	y	
1	Mano	Soro Gbema	Pujehun	7.06897	-11.37588	0.5
2	Moa (Point 1)	Barri	Pujehun	7.36020	-11.41789	0.9
3	Moa (Point 2)	Koya	Kenema	7.66768	-11.26378	0.8
4	Sewa	Nimiyama	Kono	8.60477	-11.26573	2.0
5	Little Scarcies	Sela Limba	Bombali	9.52344	-12.38017	0.5
6	Great Scarcies	Bramaia	Kambia	9.44435	-12.68060	0.9

4.10.1 Sample Collection, Handling, Documentation and Transfer

Water samples were collected and delivered to the SGS Laboratory in Ghana[3] for analysis within days of sample collection in transport containers (carrying case, cooler, shipping box, etc.) for protection from breakage, contamination, and loss. Documentation ensuring that proper handling occurs throughout these activities was part of the custody record. Information describing the enclosed samples were placed on the bill of lading. The unopened and undamaged package was hand-delivered to the SGS Laboratory in Ghana by an INTEGEMS staff. The container was sealed using an appropriate tamper-evident method (custody tape). In transporting samples, precautions were taken to eliminate the possibility of tampering, accidental destruction, and/or physical and chemical action on the sample. After delivery to the SGS Laboratory, the samples were kept in a secured place with restricted access. Upon arrival at the laboratory, the samples were first checked and their integrity confirmed. The contents of the shipment were checked against the Chain of Custody Form to ensure that all samples listed were included in the shipment.

[3] SGS Laboratory in Ghana is a Canadian Association of Laboratory Accreditation (CALA) accredited laboratory

4.10.2 Laboratory Analysis

Laboratory analysis was undertaken at the SGS Laboratory and results were provided within 15 working days. Prior to submitting samples to the SGS Laboratory for analysis, the certification status of the Laboratory was determined - SGS Laboratory submitted its current certification to INTEGEMS for verification. INTEGEMS ensured the laboratory analyses met the following four basic requirements:

- Equipment were frequently and properly calibrated and maintained;
- Personnel were qualified to make the analysis;
- Analytical procedures were in accordance with accepted practice, properly documented and received peer and management review; and
- Complete and accurate records must be kept.

SGS Laboratory was fully responsible for preparing reference materials, testing and certifying instruments, and performing other activities necessary to collect and report measurement data.

Figure 4-11: INTEGEMS staff setting up the HI 9829 Multi-parameter Meter along Mano River

Figure 4-12: INTEGEMS staff with water samples collected from the Great Scarcies

Figure 4-13: INTEGEMS staff collecting water samples from Little Scarcies River

Figure 4-14: INTEGEMS staff calibrating the HI 9829 Multi-parameter Meter along the Sewa River

Figure 4-15: Water quality monitoring locations in Project Area (Liberian Border Kenema Axis)

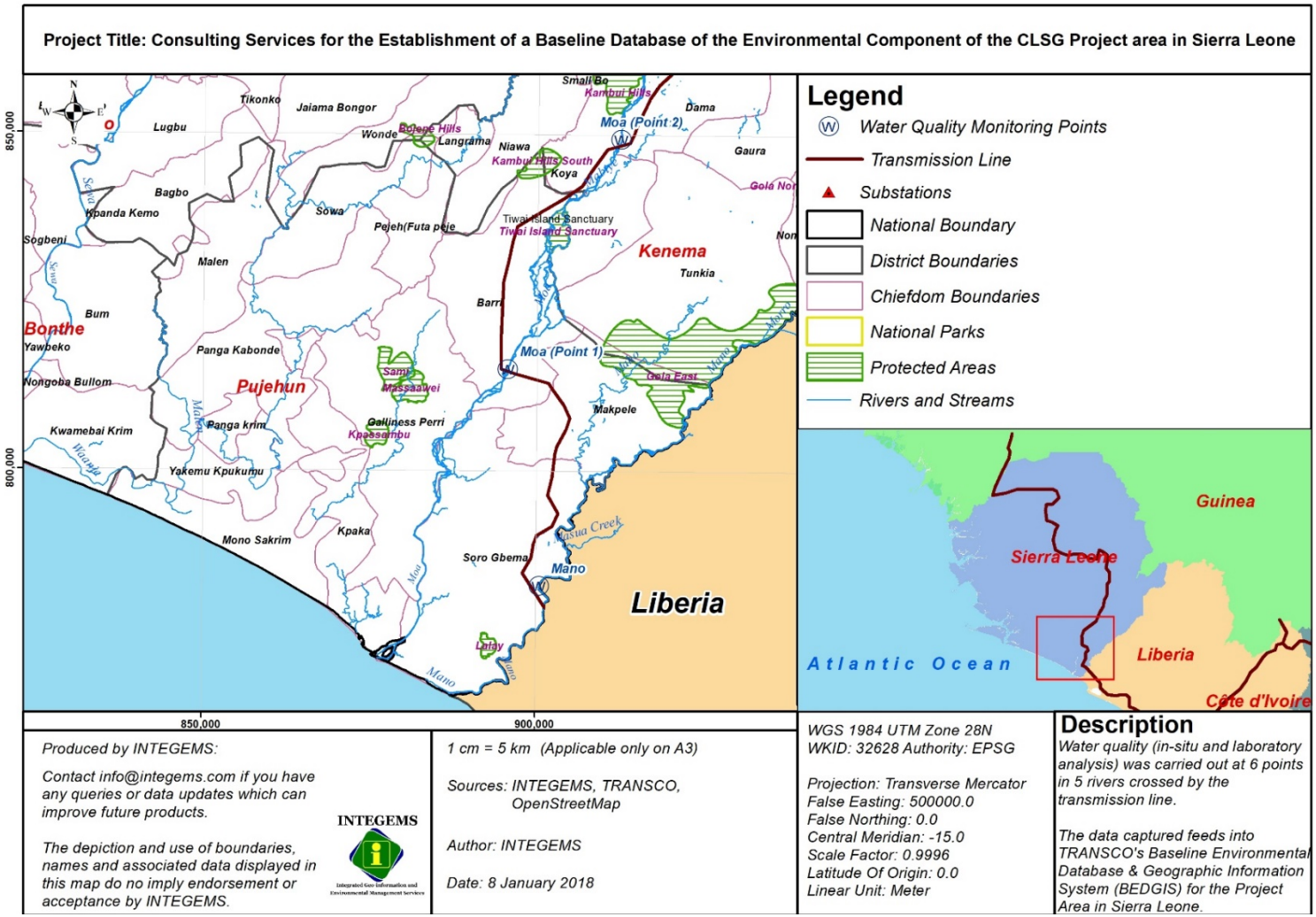


Figure 4-16: Water quality monitoring locations in Project Area (River Sewa)

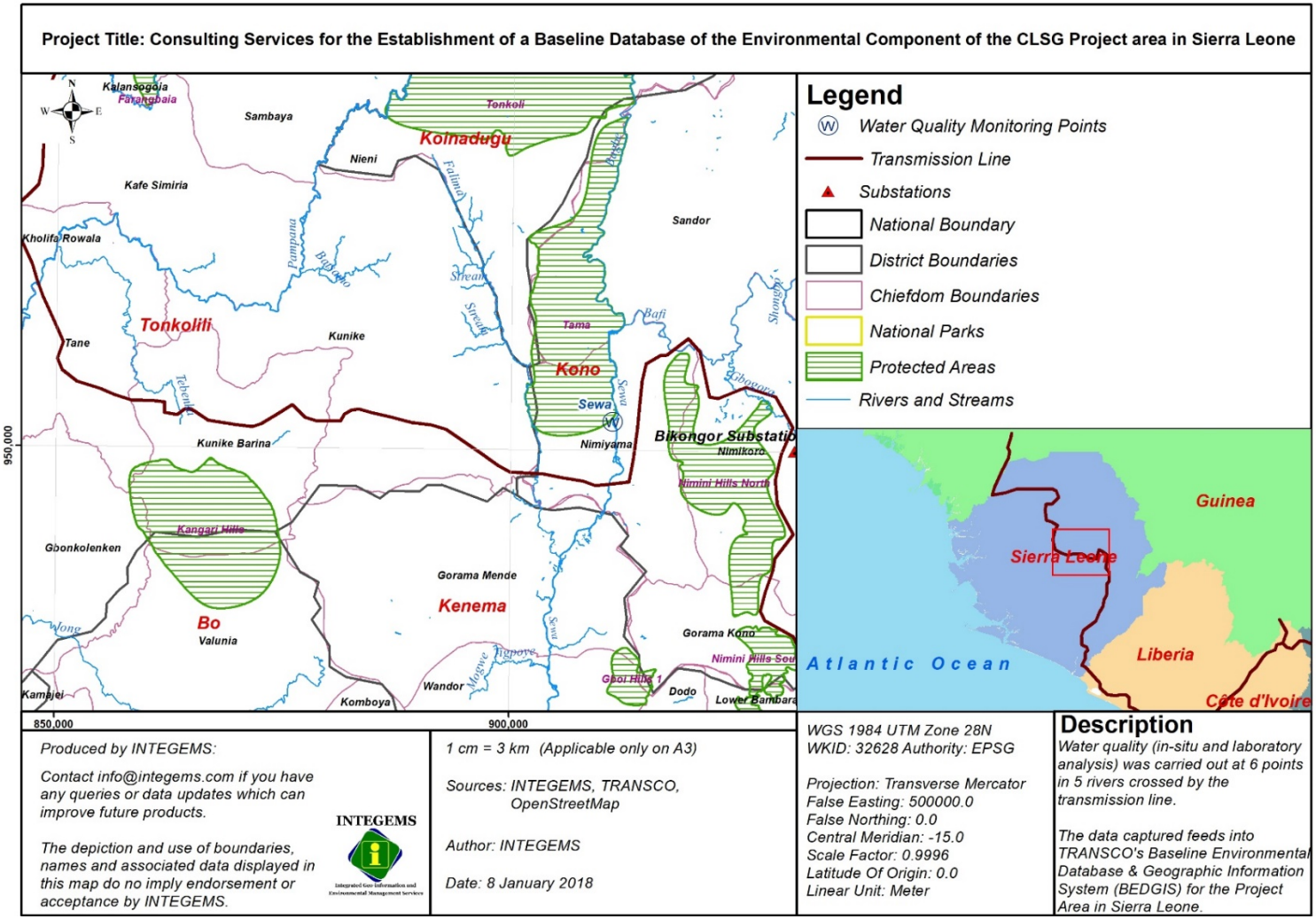
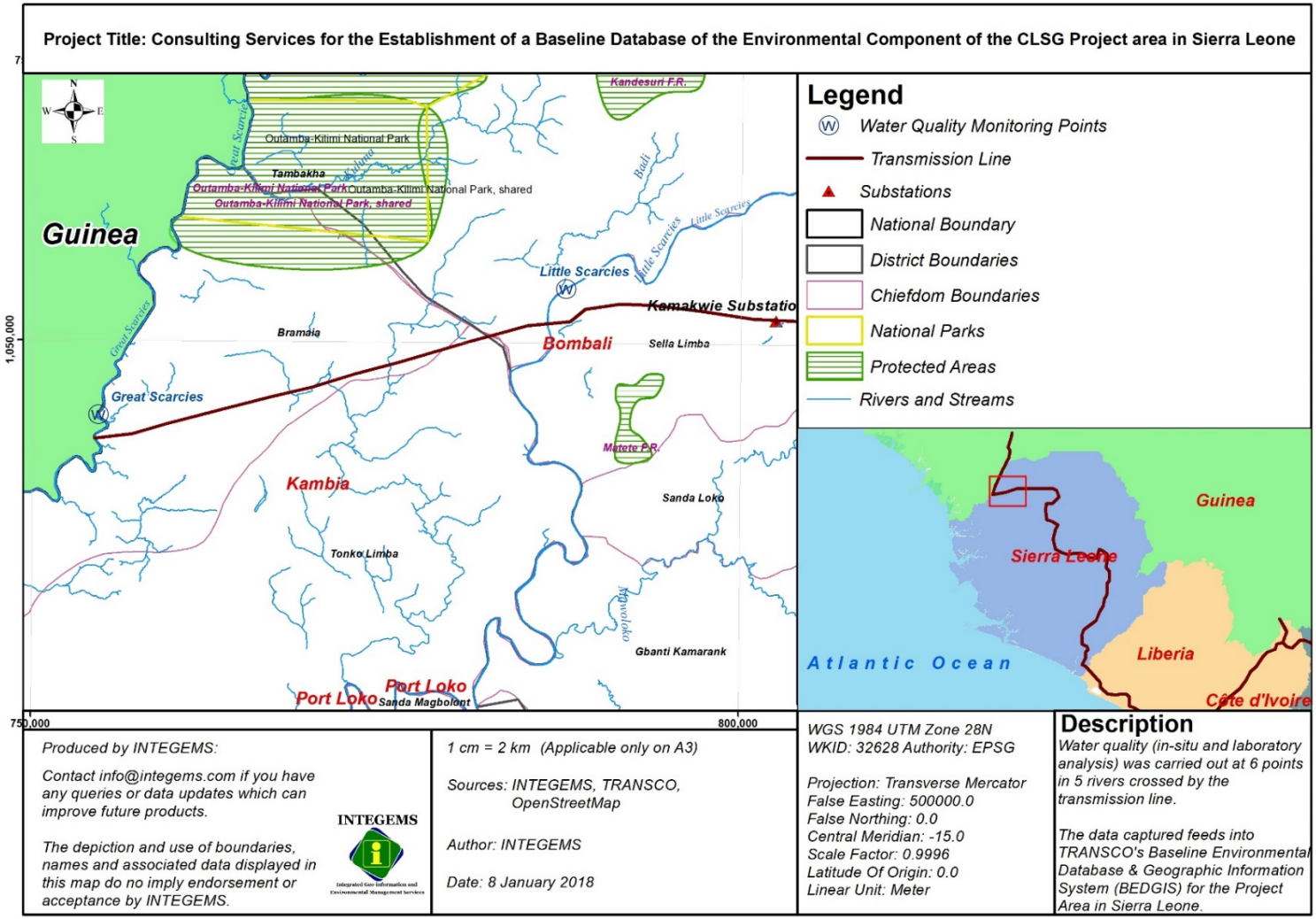


Figure 4-17: Water quality monitoring locations in Project Area (Little Scarcies – Great Scarcies)



4.11 Soil Study

The characterization of the soils of the project area included an extensive desk review of existing document and information, including information on the history of the site. The desk review focused on the eco-sensitive regions of the Project area, with particular focus on the types of soil within those eco-sensitive regions, the activities likely to pollute the soil and the areas likely to be polluted, including the potential impacts on the soils (i.e. potential soil pollution type).

4.12 Biodiversity Study

The methodology of the biodiversity study entailed the characterization of the flora and fauna of the project area through a review of the existing information on the flora and fauna inventory of the natural and human environment of the project area. Specifically, the methodology entailed defining the types of vegetation and faunal composition of the project area; evaluating activities that could adversely impact the fauna and flora of the project area; identifying threatened protected and/or vulnerable species; and identifying species likely to be threatened and/or are vulnerable.

4.13 Baseline Environmental Database & GIS Development and Mapping

4.13.1 Baseline Database System Analysis and Design

The logical and physical system design of the Baseline Environmental Database & GIS (BEDGIS) provided the framework and configuration for the integration of database and geographic information system (GIS) technology and computing infrastructure necessary for efficient and reliable baseline environmental data management and mapping. Unlike the logical system design, which was purely conceptual, the physical system was highly dependent on the integration of specific software and hardware components.

A three-tier system for the BEDGIS was used: 1) storage/database (Microsoft SQL Server and Microsoft Access); 2) GIS application server (ArcGIS Server); and 3) clients (Web browser, desktop/laptops and mobiles). A primary goal for the physical system design was to achieve high availability of servers and storage devices through redundancy. Criteria were developed for high availability and all potential causes of failure, impact to data access, and response plans were considered to minimize system downtime.

4.13.2 Development of BEDGIS Web Mapping Application

A GIS Web Mapping Application of the BEDGIS (accessed on www.bedgis-sl.website) was developed using ArcGIS for JavaScript to allow users to rapidly and effectively create, edit, publish, review, and collaborate on environmental baseline data mapping, updating and managing the monitoring locations and attributes through a robust, easy-to-use web browser. TRANSCO CLSG personnel do not need any specialized or commercial GIS software to work with the BEDGIS Web Mapping Application's GIS services; it can consume the services within any compatible Web browser or custom application.

All the captured and post-field processed baseline data and laboratory results were uploaded into the BEDGIS database.

4.14 Mapping, Documentation and Reporting

A preliminary data review was performed to uncover potential limitations of using the data, to reveal outliers, and generally to explore the basic structure of the data. The first step was to review the QA/QC reports, followed by calculations of basic summary statistics, generation of graphical presentations of the data, and review of summary statistics and graphs. Particular attention was directed to looking for anomalies in monitored data, missing values, and any deviations from standard operating procedures.

4.14.1 Production of Cartographic Maps

The locations of all captured baseline data and other relevant spatial datasets were cartographically mapped at the appropriate spatial scales (districts, chiefdoms and wards, etc.), including all pertinent and relevant socio-demographic and topographic/geographic data and information. Relevant and pertinent baseline data were mapped using ESRI ArcGIS for Desktop 10.5 in an ArcGIS geodatabase format.

4.14.2 Documentation and Recording

The data and information were documented, recorded and archived to provide a mechanism for integrating the various spatial and non-spatial data and information into a coherent structure for the BEDGIS.

5 ENVIRONMENTAL BASELINE STUDY RESULTS AND ANALYSIS

5.1 Air Quality

Ambient air quality monitoring was undertaken for CO, CO_2, NO_2, O_3, SO_2, VOC_s, PM_{10}, and $PM_{2.5}$. These measurements were undertaken in order to determine the background/baseline air quality concentration for use in the air quality assessment. 'Background' is the average concentration of pollutants present in the ambient air and is a concept used to enable assessment of the impacts of particular emission sources to air without the need for all sources in the area to be considered explicitly.

5.1.1 Carbon Dioxide (CO_2)

Carbon dioxide is a colourless, odourless gas that has a faint acid taste. When people breathe, they exhale carbon dioxide. Sources of carbon dioxide emissions, which contribute to climate change, include fossil fuel burning, electricity generation, transportation vehicles, waste burning and natural gas flaring, etc.

From the analysis of the data captured, the CO_2 levels in the study area were relatively low compared to the national and international standards. The measurement values range between 370.1 mg/m^3 (Kangama Gorama) and 466.3 mg/m^3 (Kamakwie).

Table 5-1: Average concentration of CO_2

Towns	CO_2, mg/m^3	
	Residential	Commercial
Vaama Barri	410.5	466.5
Mano Junction	373.7	374.7
Lago Jasawabu	400.2	474.3
Kangama Gorama	370.1	380.3
Njagbwema Nimikoro	428.0	607.5
Makoni line	387.5	383.1
Kajida (Near Bumbuna)	414.6	505.0
Kamabai	431.8	447.6
Fadugu	412.7	457.5
Kamakwie	466.3	442.9
Standard (Guideline) Values		
WHO Guideline		
EPA-SL		
IFC/WBG		
US-EPA		

5.1.2 Volatile Organic Compounds

Volatile organic compounds (VOCs) are organic compounds that easily become vapours or gases. Along with carbon, they contain elements such as hydrogen, oxygen, fluorine, chlorine, bromine, sulphur or nitrogen. Volatile organic compounds are released from burning fuel, such as gasoline, wood, coal, or natural gas. They are also emitted from diesel exhaust and released from solvents, paints, glues, etc. VOCs, when combined with nitrogen oxides, react to form ground-level ozone, or smog, which contributes to climate change.

From the analysis of the data captured, the VOC levels in the study area were relatively low compared to the national and international standards (see Table 5-2). The measurement values range between 1 mg/m^3 (Mano Junction) and 4 mg/m^3 (Vaama Barri).

Table 5-2: Average concentration of VOCs

Towns	VOC, mg/m^3	
	Residential	Commercial
Vaama Barri	2	4
Mano Junction	2	1
Lago Jasawabu	3	2
Kangama Gorama	2	2
Njagbwema Nimikoro	2	2
Makoni line	2	2
Kajida (Near Bumbuna)	2	2
Kamabai	3	4
Fadugu	2	3
Kamakwie	4	2
Standard (Guideline) Values		
WHO Guideline		
EPA-SL		
IFC/WBG		
US-EPA		

5.1.3 Carbon Monoxide (CO)

Carbon monoxide is a colourless, odourless, highly toxic gas that displaces oxygen in human blood, causing oxygen deprivation. The commonest source of carbon monoxide is motor vehicle emissions, where it results from the combustion of petrol in the presence of insufficient oxygen. It is also a result of some fuel-consuming industries and domestic fires.

From the analysis of the data captured within the towns, the CO levels in the study area were relatively low compared to the national and international standards (see Table 5-3). The measurement values for residential locations ranged between 0 ug/m^3 (Mano Junction, Kajida, and Kamakwie) and 498 ug/m^3 (Vaama Barri), while the CO concentration for commercial locations ranged from 0 ug/m^3 (Kamabai and Fadugu) to 727.9 ug/m^3 (Njagbwema Nimikoro).

Table 5-3: Average concentration of CO

Towns	CO, ug/m^3	
	Residential	Commercial
Vaama Barri	498.0	611.0
Mano Junction	0.0	0.9
Lago Jasawabu	352.0	506.0
Kangama Gorama	129.0	372.8
Njagbwema Nimikoro	215.8	727.9
Makoni line	306.0	186.0
Kajida (Near Bumbuna)	0.0	270.4
Kamabai	231.4	0.0

Towns	CO, ug/m^3	
	Residential	Commercial
Fadugu	95.8	0.0
Kamakwie	0.0	487.0
Standard (Guideline) Values		
WHO Guideline		
EPA-SL	29	
IFC/WBG		
US-EPA	9 ppm	

5.1.4 Nitrogen Dioxide (NO_2)

Nitrogen dioxide (NO_2) is one of a group of gases called nitrogen oxides (NOx). While all of these gases are harmful to human health and the environment, NO_2 is of greater concern. NO_2 primarily gets in the air from the burning of fuel in vehicles, power plants, and off-road equipment.

The data captured in the towns shows that the NO_2 levels in the study area were relatively low compared to the national and international standards (see Table 5-3 and Table 5-4). In residential locations, the recorded values range between 0 (Fadugu, Kamakwie) and 13.9 ug/m^3 (Njagbwema Nimikoro), whereas in commercial locations the measurements ranged between 0 (Vaama, Makoni Line, Fadugu and Kamakwie) and 15.8 ug/m^3 (Mano Junction).

Table 5-4: Average concentration of NO_2

Towns	NO_2, ug/m^3	
	Residential	Commercial
Vaama Barri	1.2	0.0
Mano Junction	4.1	15.8
Lago Jasawabu	6.3	3.6
Kangama Gorama	6.3	3.5
Njagbwema Nimikoro	13.9	4.5
Makoni line	10.0	0.0
Kajida (Near Bumbuna)	6.8	0.1
Kamabai	6.3	7.2
Fadugu	0.0	0.0
Kamakwie	0.0	0.0
Standard (Guideline) Values		
WHO Guideline	200	
EPA-SL		
IFC/WBG		
US-EPA	**100 ppb**	

5.1.5 Ozone

Ozone is formed in the atmosphere by photochemical reactions in the presence of sunlight and precursor pollutants, such as the oxides of nitrogen (NOx) and volatile organic compounds (VOCs). Ozone is the major constituent of photochemical smog, which is a complex mixture of also containing oxidised organics.

From the analysis of the data captured, the O_3 levels in the study area were relatively low compared to the national and international standards (see Table 5-5). The measurement values range between 0.4 ug/m^3 (Kangama Gorama – commercial location) and 9.9 ug/m^3 (Kamakwie and Fadugu – residential locations).

Table 5-5: Average concentration of O_3

Towns	O_3, ug/m^3	
	Residential	Commercial
Vaama Barri	0.9	1.2
Mano Junction	3.1	1.1
Lago Jasawabu	0.5	2.3
Kangama Gorama	2.4	0.4
Njagbwema Nimikoro	2.4	1.3
Makoni line	8.1	1.7
Kajida (Near Bumbuna)	8.0	1.4
Kamabai	1.4	9.2
Fadugu	9.9	6.0
Kamakwie	9.9	2.8
WHO Guideline	100	
EPA-SL		
IFC/WBG		
US-EPA		

5.1.6 Sulphur Dioxide

Sulphur dioxide (SO_2) is a criteria pollutant, which is often produced by the industrial processes that involve burning of coal, fuel oil and diesel. Being a corrosive acidic gas, sulphur dioxide damages buildings and other materials. Short-term exposure to SO_2, ranging from 5 minutes to 24 hours, is linked with adverse respiratory effects including bronchoconstriction and increased asthma symptoms. SO_2 is also a major precursor to acid rain. Sulphur Dioxides sources include fossil fuel combustion, industrial processes such as extracting metal from ore, and the burning of high sulphur-containing fuels.

The measurement values range between 0 ug/m^3 (residential locations in Lago, Kangama, Fadugu, and Kamakwie) and 55.8 ug/m^3 (Lago). The recorded levels were relatively low compared to the national and international standards (see Table 5-6).

Table 5-6: Average concentration of SO_2

Towns	SO_2, ug/m^3	
	Residential	Commercial
Vaama Barri	11.4	1.9
Mano Junction	14.0	16.0
Lago Jasawabu	0.0	55.8
Kangama Gorama	0.0	26.2
Njagbwema Nimikoro	19.6	16.7
Makoni line	0.0	3.3
Kajida (Near Bumbuna)	5.8	6.7

Towns	SO_2, ug/m^3	
	Residential	Commercial
Kamabai	2.3	23.3
Fadugu	0.0	54.2
Kamakwie	0.0	5.0
Standard (Guideline) Values		
WHO Guideline	125	
EPA-SL		
IFC/WBG		
US-EPA		

5.1.7 Particulate Matter PM_{10} and $PM_{2.5}$

Airborne particulate matter (PM) is categorised into different size fractions. PM_{10} (particles ≤ 10 microns) is a criteria pollutant and is a serious health risk because PM_{10} particles can penetrate the lungs. $PM_{2.5}$ (particles ≤ 2.5 microns) is also a criteria pollutant which has even greater health impact due to the risk of penetration deeper into the respiratory system.

From the analysis of the data collected the PM_{10} and $PM_{2.5}$ levels in the study area were relatively low compared to the national and international standards (see Table 5-6). The measurement values for PM_{10} range between 0 (Mano Junction, Kangama, and Njagbwema) and 159 ug/m^3 (Kamabai), while $PM_{2.5}$ values range from 0 to 219 ug/m^3 (Kajida). The PM_{10} and $PM_{2.5}$ concentrations in some areas were relatively low compared to international standards (see Table 5-7).

The low PM values (except in the case of Kajida) could be attributed to the wet surfaces because of the rains prior to the monitoring and high humidity during the period of the baseline survey. It is important to note that during the rainy/wet season (May – November) the roads are full of potholes and are almost always wet and/or flooded and therefore significant dust generation is unlikely. However, this very high proportion of un-tarred/un-surfaced roads could lead to significant dust generation during the deep dry season (March). Another reason for the relatively low dust (PM_{10} and $PM_{2.5}$) levels in the surveyed settlements is because of low vehicular movements and there are not many activities that generate dust in the settlements from the people's daily normal activities. The access roads leading to the villages like Vaama Barri, Lago Jasawabu, Kangama Gorama, residential areas of Fadugu and Kamakwie are in poor state (not tarred or hard surfaced along the entire route) and attract relatively moderate proportions of heavy and commercial vehicles accessing neighbouring facilities.

The other key sources of air pollution which influence air quality in the Project area are domestic and commercial-scale power generators (especially in commercial locations of Mano Junction, Lago Jasawabu, Kamabai, and Kamakwie); burning of agricultural, household and commercial wastes; and burning of residential wood and charcoals. Due to unreliable power sources, domestic and commercial power generators, running on petrol/diesel are common in towns like Kamabai, Fadugu and Kamakwie. This may lead to increased emissions of pollutants associated with combustion in addition to those emitted by road traffic.

Table 5-7: Average particulate matter concentration

Towns	PM2.5, ug/m^3		PM10, ug/m^3	
	Residential	Commercial	Residential	Commercial
Vaama Barri	0.0	0.0	0.3	1.0
Mano Junction	0.0	0.0	0.0	0
Lago Jasawabu	2.0	31.0	0.0	5.0
Kangama Gorama	0.0	0.4	0.0	0

Towns	PM2.5, ug/m^3		PM10, ug/m^3	
	Residential	Commercial	Residential	Commercial
Njagbwema Nimikoro	0.0	1.0	0.0	0
Makoni line	81.0	0.0	0.0	0.6
Kajida (Near Bumbuna)	0.0	219.0	92.0	2.0
Kamabai	109.0	94.0	159.0	104.0
Fadugu	75.0	28.0	19.0	62.2
Kamakwie	2.0	86.0	0.0	18.0
WHO Guideline	75		150	
EPA-SL				
IFC/WBG				
US-EPA	35		150	

5.1.8 Temperature and Relative Humidity

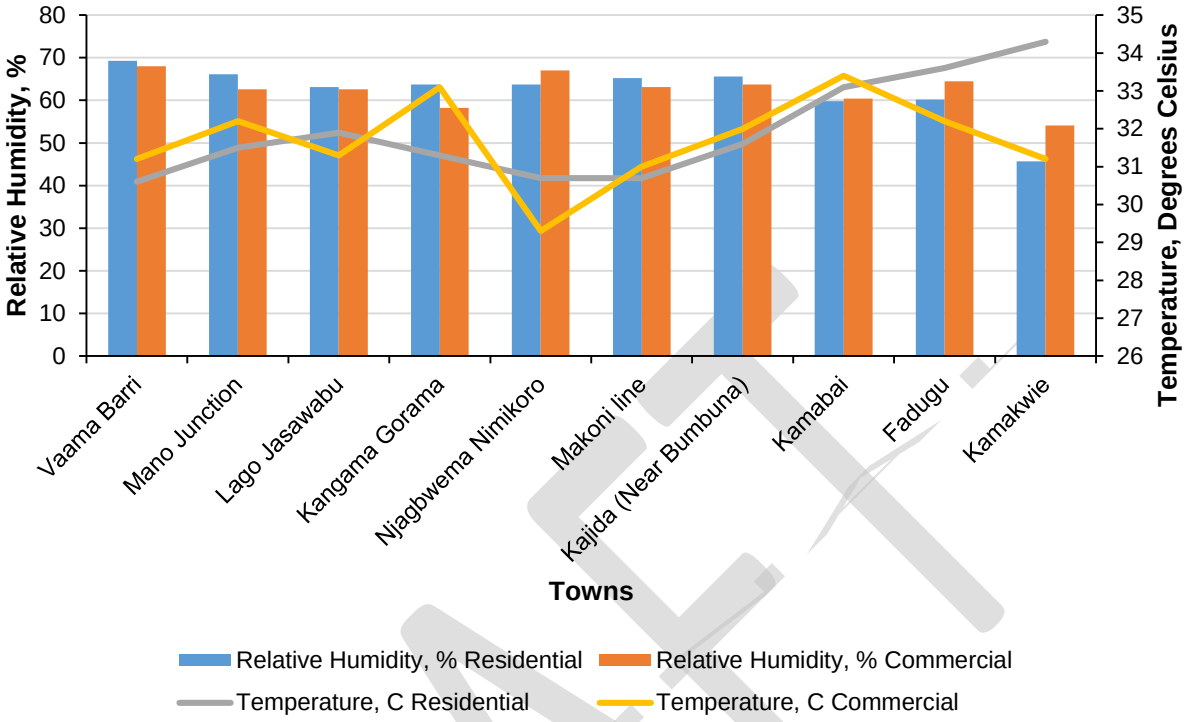
Air pollutants are emitted into the atmosphere from a variety of sources and the concentration of pollutants in the ambient air depends not only on the quantities that are emitted but also the conditions and ability of the atmosphere, either to absorb or disperse these pollutants. Understanding the behaviour of meteorological parameters is important because the atmosphere is the medium in which air pollutants are transported away from the source, which is governed by the meteorological parameters such as atmospheric wind speed, wind direction, pressure and temperature.

The average temperature recorded in the town over the monitoring duration ranged from 29.3 ^{o}C (Njagbwema Nimikoro) to 34.3 ^{o}C (Kamakwie). The minimum average relative humidity of 45.7% was recorded in Kamakwie and the maximum of 69.3% in Vaama Barri (see Table 5-8).

Table 5-8: Average temperature and relative humidity recorded

Towns	Relative Humidity, %		Temperature, C	
	Residential	Commercial	Residential	Commercial
Vaama Barri	69.3	68.5	30.9	30.8
Mano Junction	64.3	61.8	31.9	32.2
Lago Jasawabu	63.2	63.4	31.7	31.0
Kangama Gorama	61.9	55.4	31.2	33.3
Njagbwema Nimikoro	61.9	65.5	30.6	29.2
Makoni line	62.4	68.8	31.4	32.0
Kajida (Near Bumbuna)	64.7	63.0	31.7	31.9
Kamabai	60.0	58.7	32.9	33.9
Fadugu	60.2	64.0	33.7	32.4
Kamakwie	44.2	53.4	34.8	31.4

Figure 5-1: Average temperature and relative humidity recorded



5.2 Ambient Noise

Desk review and observations made prior to and during the field visit showed that the Project area is predominantly rural with extensive agricultural land use and mixed residential/commercial and road traffic environment. The existing ambient noise environment was therefore influenced by noise from residential and commercial activities, and local road traffic movements. During the field monitoring, noise from local roads, generators and other residential sources was noted. Potential noise sensitive receptors/areas were also identified and these include:

- Residential and commercial properties along the main motor roads in Mano Junction, Lago Jasawabu, Kangama Gorama, Njagbwema, Makoni Line, Kamabai, Fadugu, Kamakwie
- Forested areas around Vaama Barri, Kangama Gorama, Njagbwema Nimikoro, and Makoni Line.
- Commercial properties along the main motor ways leading to/from the transmission line, houses, schools, sheds, and residential premises.

A-weighted equivalent continuous sound energy level (LAeq) monitoring (steady level that would contain the same amount of noise energy as in the actual noise) which was undertaken alongside the air quality monitoring exercise showed that the levels representing the average daytime residential noise levels measured during the sampling period range from 56 dB (in Kamakwie, Bombali) to 70 dB (in Fadugu, Koinadugu District). Night-time monitoring was undertaken between 22:00 and 07:00 in Makoni Line, Kajida, Kamabai, and Fadugu. Monitoring was also carried out during the night in Vaama from 22:23 to 0:00 and in Kamakwie from 21:47 to 23:17. The monitored night-time ambient residential noise levels measured range from 50 dB (in Kajida, Tonkolili District) to 61 dB (in Kamabai, Bombali). All the monitored noise levels were found to be outside the WBG/IFC General EHS Guidelines permission level for both daytime and night-time residential area of 55.0 dB(A) and 45 dB(A), respectively (see Table 5-9, Table 5-10 and Table 5-11).

Noise monitoring in commercial areas was limited to daytime and was found to be within the range of 62 dB (in Kangama Gorama, Kono District) to 72 dB (in Mano Junction, Kenema District), with all the towns, except in Mano Junction, where recorded noise levels were lower than the WBG/IFC General EHS Guidelines permission level for daytime commercial area of 70 dB(A) respectively (see Table 5-9).

Whilst not explicit, the WBG/IFC guidelines in practice are commonly applied to the noise from the development only and not to the cumulative level of background plus development related noise.

The statistical functions L10 and L90 show the sound pressure levels that are exceeded for 10 % and 90 % of the measurement period, respectively.

Table 5-9: WBG/IFC General EHS Guidelines: Noise Level Guidelines (dB)

Receptor	Daytime 07:00-22:00 hrs ($L_{Aeq\ 1hr}$)	Night-time 22:00-07:00 hrs ($L_{Aeq\ 1hr}$)
Residential and institutional	55	45
Industrial; commercial	70	70

Table 5-10: Daytime residential area ambient noise level

Town	LAeq, dB	LA90, dB	LA10, dB	LAFMax, dB	LAFMin, dB
Vaama Barri	59	50	61	94	32
Mano Junction	67	65	68	94	38
Lago Jasawabu	60	57	63	88	37
Kangama Gorama	60	55	62	87	33
Njagbwema Nimikoro	60	50	62	90	38
Makoni Line	60	48	62	94	35
Kajida (Near Bumbuna)	63	48	66	96	33
Kamabai	61	52	63	89	39
Fadugu	70	56	67	94	34
Kamakwie	56	45	56	90	34

Table 5-11: Night-time residential area ambient noise level

Town	LAeq, dB	LA90, dB	LA10, dB	LAFMax, dB	LAFMin, dB
Vaama	51	48	51	83	38
Makoni Line	54	48	57	88	37
Kajida	50	43	52	89	39
Kamabai	61	54	63	92	32
Fadugu	59	60	75	89	37
Kamakwie	52	49	53	77	43

Figure 5-2: Day-time residential area ambient noise level

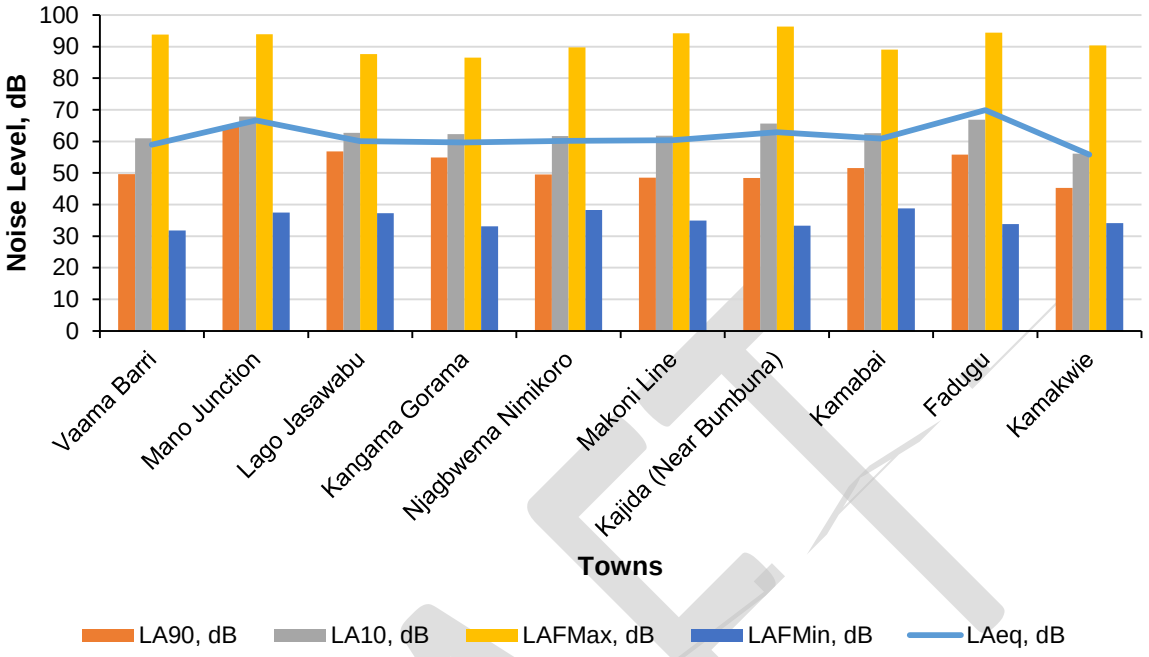


Figure 5-3: Night-time residential area ambient noise level measurements result

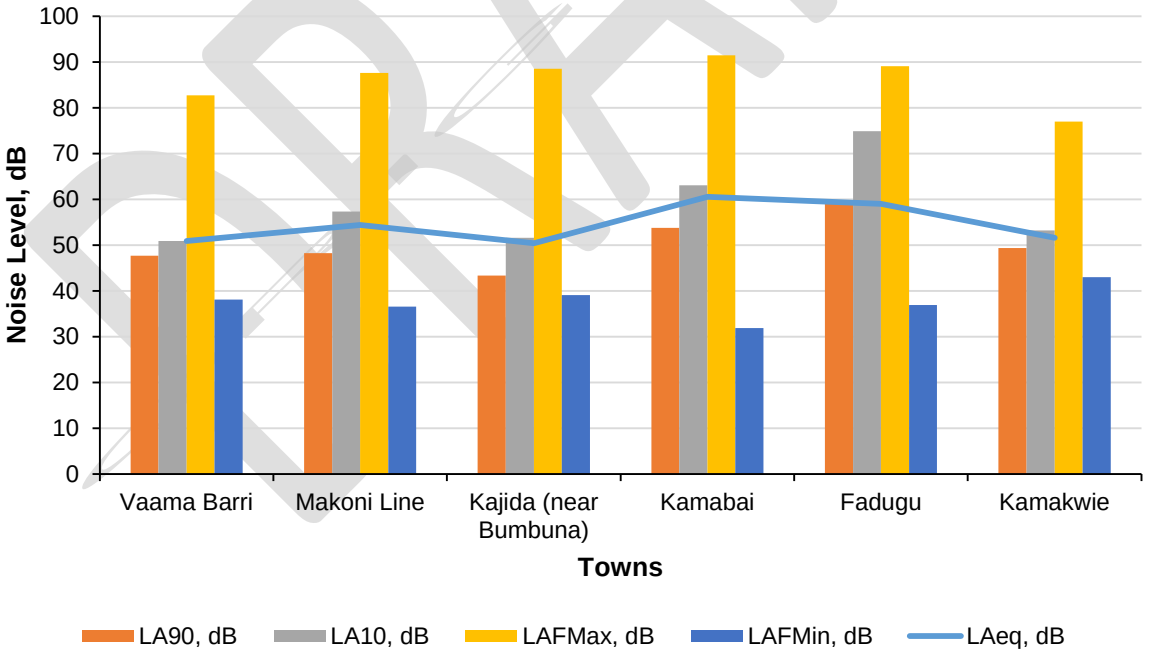
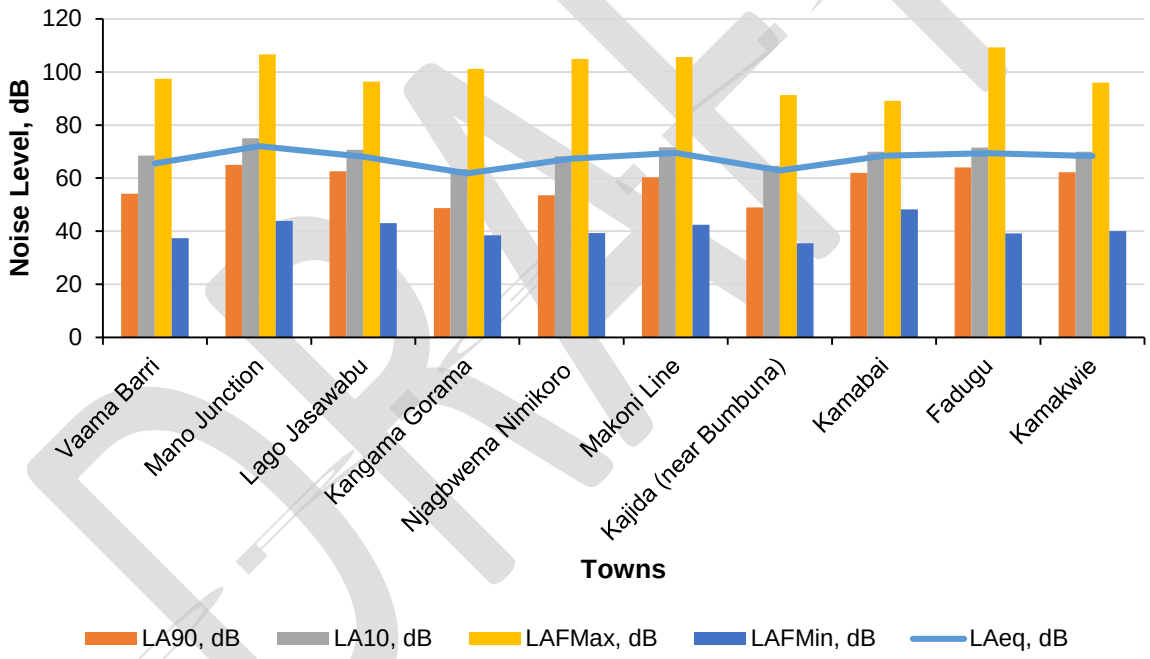


Table 5-12: Day-time commercial area ambient noise level

Town	LAeq, dB	LA90, dB	LA10, dB	LAFMax, dB	LAFMin, dB
Vaama	66	54	68	97	37
Mano Junction	72	65	75	107	44
Lago Jasawabu	68	63	71	96	43
Kangama	62	49	63	101	39
Njagbwema	67	54	68	105	39
Makoni Line	70	60	72	106	42
Kajida	63	49	65	91	36
Kamabai	68	62	70	89	48
Fadugu	69	64	71	109	39
Kamakwie	68	62	70	96	40

Figure 5-4: Day-time commercial area ambient noise level



5.3 Water Quality

The surface water quality of the specified rivers in the TRANSCO CLSG Project Area in Sierra Leone was studied by carrying out *in-situ* measurements, and grab sampling for laboratory analysis in order to characterize the hydrology of the major rivers and to generally assess the quality of surface water in the project area.

Water quality monitoring parameters (e.g., electrical conductivity, pH, temperature, total dissolved solids, oxidation-reduction potential, etc.) revealed much about the presence and movement of natural and unnatural components of water – potential water pollution sources, depletion of nutrient requirements for aquatic life, salt-water intrusion into fresh water bodies, changes in water level or temperature that can alert to the onset of an "event" that can adversely affect the quality of the resource.

Water quality standards or guidelines for the parameters analysed are listed in Table 5-13 and Table 5-14. These standards are from the International Finance Commission (IFC)/World Bank Group (WBG), World Health Organization (WHO) and Environment Protection Agency-Sierra Leone (EPA-SL). The IFC/WBG "effluent" based standards are applicable to any discharges that might occur from the TRANSCO CLSG project. Table 5-14 shows the recommended WHO standard limits for potable water.

Table 5-13: International Water Quality Guidelines

Parameter	Units	IFC/WBG Guideline	WHO Guideline	US EPA	EPA-SL
Temperature	°C	< 3 degree differential	NA		
pH	S.U.	6-9	NA	6.5-8.5	
Colour	CU	NA	NA	15	
Turbidity		NA	NA		
Total Dissolved Solids	mg/L	NA	<1,000	500	
Total Suspended Solids	mg/L	50	NA		
Conductivity	µS/cm	NA	250		
Chemical parameters and nutrients					
Total hardness		NA	NA		
Alkalinity		NA	NA		
COD	mg/L	125	NA		
BOD_5	mg/L	30	NA		
Nitrates (NO_3)	mg/L	NA	50	**10**	
Nitrites (NO_2)	mg/L	NA	50	**1**	
Phosphates (PO_4)					
Heavy metals					
As (Total – dissolved)	mg/L	0.1	0.01	0.01	
Sb (Total – dissolved)	mg/L	NA	0.005	0.006	
Se (Total)	mg/L	NA	0.01	0.05	
Hg (Total – dissolved)	mg/L	0.002	0.006	0.002	
Fe (Total)	mg/L	3.5	NA	0.3	
Mn (Total)	mg/L	NA	0.5	0.05	
Cu (Total)	mg/L	0.5	2.0	1.3	
Zn (Total)	mg/L	0.5	NA	NA	
Pb (Total)	mg/L	0.2	0.01	0.015	

Parameter	Units	IFC/WBG Guideline	WHO Guideline	US EPA	EPA-SL
Cr (Total)	mg/L	Hexavalent 0.1 Total 0.5	0.05	0.1	
Ni (Total)	mg/L	0.5	0.07	NA	
Cd (Total)	mg/L	0.1	0.003	0.005	
Al (Total)	mg/L	NA	0.2	0.2	
Mo (Total)	mg/L	NA	0.07	NA	
Co (Total)	mg/L	NA	NA		
Oils and fats	mg/L	10	NA	NA	
Microbiological parameters					
Total coliforms	MPN/100 ml	< 400	NA	5%	
Faecal coliforms	MPN/100 ml	NA	NA	NA	

Table 5-14: Recommended WHO standard limits for potable water

Parameter	Unit	Limit
Aluminium	mg Al/l	0.2
Arsenic	mg As/l	0.05
Barium	mg Ba/l	0.05
Beryllium	ug Be/l	0.2
Cadmium	ug Cd/l	5.0
Calcium	mg Ca/l	200.0
Chromium	mg Cr/l	0.05
Copper	mg Cu/l	1.0
Iron Total	mg Fe/l	0.3
Lead	mg Pb/l	0.01
Magnesium	mg Mg/l	150.0
Manganese	mg Mn/l	0.1
Mercury	ug Hg/l	1.0
Selenium	mg Se/l	0.01
Sodium	mg Na/l	200.0
Zinc	mg Zn/l	5.0
Chlorides	mg Cl/l	250.0
Cyanide	mg Cn/l	0.1

Parameter	Unit	Limit
Fluorides	mg F/l	1.5
Nitrates	mg NO_3/l	10.0
Nitrites	mg NO_2/l	-
Sulphates	mg SO_4/l	400.0
Suphides	mg H_2S/l	0
TOTAL "drins"	ug/l	0.03
TOTAL "ddt"	ug/l	1.0
Hydrocarbons	mg/l	0.1
Anionic Detergents	mg/l	0
pH		9.2
Total dissolved solids	mg/l	1500
Total hardness	mg/l	500
Alkalinity	mg/l	500
Microbiological Parameters		
Total Bacteria	Count/ml	100
Coliform	Count/100ml	0
E. Coli	Count/100ml	0
Salmonella	Count/100ml	0

NB: ug = microgram or ppb; mg = milligram or ppm

5.3.1 Temperature

Water temperature plays an important role in water chemistry, which in turn influences the biological activity and growth of aquatic organisms. In general, the higher the water temperature, the greater the biological activity and the rate of chemical reactions. An important example of the effects of temperature on water chemistry is its impact on oxygen. Warm water holds less oxygen than cool water; the maximum amount of oxygen that can be dissolved in the water decreases as water temperature increases. Artificially high temperatures are often referred to as “thermal pollution,” which may result from discharge of municipal or industrial wastewater.

Knowledge of water temperature is essential to the measurement of dissolved oxygen, conductivity (salinity), pH, and many other water quality parameters. The average temperature values for the samples range between 26.13^{o}C and 28.13^{o}C (see

Table 5-15).

Table 5-15: Water temperature of rivers monitored

River	Temperature, °C
Mano	26.86
Moa (Point 1)	28.13
Moa (Point 2)	28.02
Sewa	26.13
Little Scarcies	27.37
Great Scarcies	27.82
Standard (Guideline) Values	
WHO Guideline	
IFC/WBG Guideline	< 3 degree differential
US-EPA	
EPA-SL	

5.3.2 pH

A pH value indicates the amount of hydrogen ion that is present in an aqueous environment. The hydrogen ion concentration gives an indication of the acidity of a substance. pH is an important measurement in natural waters because most chemical and biochemical processes are pH dependent. The physiological chemistry of most living organisms can tolerate only small changes in pH and still provide the chemical reactions that sustain life. The solubility of many chemicals is pH dependent. Thus, pH determines their availability to living organisms.

The pH values for the rivers monitored range between 6.4 and 7.0. The pH values of all the samples (except for Mano River) tested fall within the IFC/WBG guideline values is of 6 -9 (see Table 5-16).

Table 5-16: pH of water in rivers monitored

River	pH, S.U.
Mano	6.42
Moa (Point 1)	6.48
Moa (Point 2)	6.96
Sewa	6.97
Little Scarcies	6.83
Great Scarcies	6.7
Standard (Guideline) Values	
WHO	
WBG/IFC	6 – 9
US-EPA	6.5 – 8.5
EPA-SL	

5.3.3 Colour

Colour in water is usually due to the presence of coloured organic matter (primarily humic and fulvic acids) associated with the humus fraction of soil. Colour is also strongly influenced by the presence of iron and other metals, either as natural impurities or as corrosion products. It may also result from the contamination of the water source with industrial effluents and may be the first indication of a hazardous

situation. High colour from natural organic carbon (e.g. humics) could also indicate a high propensity to produce by-products from disinfection processes. If sewage solids are present, pathogens may be encased in the particles and escape the action of chlorine during disinfection, with the presence of living microscopic organisms, or decaying organic matter, including weeds, algae; or industrial wastes containing ammonia, phenols, halogens, hydrocarbons.

The apparent (the colour of the whole water sample, including colour from both dissolved and suspended components) and true colour (colour measured after filtering the water sample to remove all suspended material) of the water samples collected from the rivers were analysed in the laboratory and reported in Table 5-17 and Appendix I (Section 8.2). From the laboratory analysis the apparent colour by specification of the samples ranged from 36 Pt/Co colour (Little Scarcies River) to 66 Pt/Co colour (Moa River – Point 2), while the true colour by spec of the water samples ranged from 13 Pt/Co colour (Great Scarcies River) to 24 Pt/Co colour (Mano River).

No internationally recognized health-based guideline value exists for colour in water. However, the colour at which water is objectionable to consumers is variable and dependent on individual and local factors, including the quality of the water to which the community is accustomed and a variety of social, economic, environmental and cultural considerations.

Table 5-17: Water colour of the rivers

River	Apparent Colour by spec, Pt/Co colour	True Colour by spec, Pt/Co colour
Reporting Limit	3	3
Mano	58	24
Moa (Point 1)	55	22
Moa (Point 2)	66	17
Sewa	65	18
Little Scarcies	36	15
Great Scarcies	48	13
Standard (Guideline) Values		
WHO		
IFC/WBG		
US-EPA		15
EPA-SL		

5.3.4 Barometric Pressure

Barometric pressure influences the measurement of water levels in water bodies that are open to the atmosphere. It also determines the amount of atmospheric gases that can be dissolved in water; more oxygen, for example, can be dissolved in water at higher barometric pressure (lower altitude). Barometric pressures additionally influences other water-quality parameters such as pH. The barometric pressure values for the samples range between 14.22 psi (Sewa River) and 14.6 psi (Great Scarcies River).

Table 5-18: Barometric pressure of water in the rivers

River	Barometric Pressure, psi
Mano	14.60
Moa (Point 1)	14.56
Moa (Point 2)	14.48
Sewa	14.22
Little Scarcies	14.58
Great Scarcies	14.60
Standard (Guideline) Values	
WHO	
WBG/IFC	
US-EPA	
EPA-SL	

5.3.5 Turbidity

Turbidity is an indirect measure of the clarity or transparency of water, and thus an important indicator of its condition and productivity. Created by suspended matter and microscopic organisms, turbidity causes light to be scattered and absorbed rather than transmitted directly through water. Turbidity is the physical characteristic of the solution that causes light scattering. Turbidity is the opposite of clarity.

Turbidity measurements:

- can provide a reasonable estimate of the TSS concentration in water.
- can tell us about the health of a natural water body. Clear water lets light penetrate more deeply into a lake or stream than does murky water. This light allows photosynthesis to occur and oxygen to be produced.
- can be a useful indicator of run-off into surface water systems

Higher turbidity levels make it more costly to treat surface water for use as drinking water. Controlling turbidity may be an effective way to protect against pathogens in drinking water. The results show turbidity measurements ranging from 5.8 FNU (Great Scarcies River) to 33.1 FNU (Sewa River).

Table 5-19: Turbidity of water in the rivers

River	Turbidity, FNU
Mano	21.77
Moa (Point 1)	15.69
Moa (Point 2)	12.25
Sewa	33.12
Little Scarcies	11.29
Great Scarcies	5.83
Standard (Guideline) Values	
WHO	
WBG/IFC	
US-EPA	
EPA-SL	

5.3.6 Electrical Conductivity (EC)

Electrical conductivity measures the ability of a material to carry an electric current. Lakes, rivers, and underground aquifers are typically good conductors because they contain dissolved salts and minerals. These salts and minerals dissociate in the presence of water to form negatively and positively charged particles called anions and cations. Anions and cations provide a pathway for the transportation of electrical charges throughout the aqueous medium. For the most part, the higher the concentration of dissolved salts and minerals in water, the better the conductor and the higher the electrical conductivity. De-ionized/distilled water is a poor conductor because almost all anions and cations are removed during the deionization/distillation process.

Changes in the conductivity of a body of water are often used to indicate an environmental event. For example, an increase in the electrical conductivity of a small lake that is completely surrounded by farmland may simply be the result of runoff from a recent rain.

The results show EC measurements ranging from 19.9 µS/cm (Mano River) to 39.0 µS/cm (Little Scarcies River). The results also show these figures to be lower than the maximum standard value for drinking water, which is 250 µS/cm (WHO water quality standards).

Table 5-20: Electrical conductivity of water in the rivers

Parameter	Electrical Conductivity (EC), µS/cm
Mano	19.9
Moa (Point 1)	25.0
Moa (Point 2)	27.4
Sewa	23.2
Little Scarcies	39.0
Great Scarcies	25.0
Standard (Guideline) Values	
WHO	250
WBG/IFC	
US-EPA	
EPA-SL	

5.3.7 Total Dissolved Solids (TDS)

Dissolved solids refer to any minerals, salts, metals, cations or anions dissolved in water. Total dissolved solids (TDS) comprise inorganic salts (principally calcium, magnesium, potassium, sodium, bicarbonates, chlorides and sulphates) and some small amounts of organic matter that are dissolved in water. In general, the total dissolved solids concentration is the sum of the cations (positively charged) and anions (negatively charged) in the water. An elevated total dissolved solids (TDS) concentration is not a health hazard. The TDS concentration is a secondary drinking water standard and therefore is regulated because it is more of an aesthetic rather than a health hazard.

The TDS values for the rivers monitoring range from 10 ppm (Mano River) to 20 mg/L (Little Scarcies River), which is below the maximum limit permissible for safe drinking water of <1000 mg/L (WHO Water quality standards).

Table 5-21: TDS of water in the rivers

River	Total Dissolved Solids, mg/L
Mano	10.0
Moa (Point 1)	12.8
Moa (Point 2)	11.9
Sewa	11.9
Little Scarcies	19.9
Great Scarcies	12.0
Standard (Guideline) Values	
WHO	<1000
WBG/IFC	
US-EPA	500
EPA-SL	

5.3.8 Oxidation-Reduction Potential (ORP)

Oxidation-Reduction Potential (ORP) is a measure of a water system's capacity to either release or gain electrons in chemical reactions. The process of oxidation involves losing electrons while reduction involves gaining electrons. Oxidation and reduction (redox) reactions control the behaviour of many chemical constituents in drinking water and aquatic environments. The reactivity and solubility of critical elements in living systems is strongly dependent on redox conditions. ORP values are used much like pH values to determine water quality. While pH values characterize the relative state of a system for receiving or donating hydrogen ions (acting as a base or an acid), ORP values characterize the relative state of a system for gaining or losing electrons. ORP values are affected by all oxidizing and reducing agents, not just acids and bases.

The results show ORP measurements ranging from 115.6 mV (Little Scarcies River) to 301.5 mV (Moa River (Point 1). Natural waters need a much lower ORP value in order to support life.

Table 5-22: ORP of water in the rivers

River	ORP, mV
Mano	245.97
Moa (Point 1)	301.53
Moa (Point 2)	258.89
Sewa	183.11
Little Scarcies	115.58
Great Scarcies	214.30
Standard (Guideline) Values	
WHO	
WBG/IFC	
US-EPA	
EPA-SL	

5.3.9 Dissolved Oxygen (DO)

The amount of dissolved oxygen (DO) in both natural water and wastewater is a function of several parameters. DO is highly dependent on temperature and atmospheric pressure. An increase in temperature causes a decrease in the amount of oxygen that can dissolve in water. On the other hand, higher atmospheric pressures result in higher DO values. Salinity is also a factor. Oxygen solubility is greater in freshwater than in saltwater. There are also chemical and biochemical processes that affect DO. Most of the dissolved oxygen in water comes from the atmosphere, but oxygen from the photosynthesis of aquatic plants is also a key source. DO levels in lakes and other surface water will actually follow a cyclic or diurnal pattern over the course of a day, rising and falling as light intensity changes from dawn to dusk.

Most aquatic life requires an average DO value greater than 5.0 milligrams dissolved oxygen per litre of water (mg/L) in order to survive. Although the amount of dissolved oxygen in a water body fluctuates due to natural processes, large deviations from the norm are usually a result of human activity. Changes in DO levels are usually the result of a build-up in organic waste. Organic waste can enter surface water from sewage treatment facilities, runoff from agricultural feed lots or domestic areas and from industrial discharge. Depending on the temperature of the water, the DO content in quality water will be in the range of 8 to 15 mg/L for adequate fish population.

DO logs were undertaken for Moa River (Point 2), Sewa River, Little Scarcies River, and Great Scarcies River. The DO in the surface water bodies investigated were low ranging from 29.85 % (Great Scarcies River) to 35.45 % (Sewa River).

Table 5-23: DO of water in the rivers

River	DO, %
Mano	NA
Moa (Point 1)	NA
Moa (Point 2)	34.74
Sewa	35.45
Little Scarcies	32.15
Great Scarcies	29.85
Standard (Guideline) Values	
WHO	
WBG/IFC	
US-EPA	
EPA-SL	

5.3.10 Total Suspended Solids (TSS)

Total Suspended Solids (TSS) are solids in water that can be trapped by a filter. TSS can include a wide variety of material, such as silt, decaying plant and animal matter, industrial wastes, and sewage. High concentrations of suspended solids can cause many problems for stream health and aquatic life. High TSS can block light from reaching submerged vegetation. As the amount of light passing through the water is reduced, photosynthesis slows down. Reduced rates of photosynthesis causes less dissolved oxygen to be released into the water by plants. If light is completely blocked from bottom dwelling plants, the plants will stop producing oxygen and will die. As the plants are decomposed, bacteria will use up even more oxygen from the water. Low dissolved oxygen can lead to fish kills.

High TSS can also cause an increase in surface water temperature, because the suspended particles absorb heat from sunlight. The decrease in water clarity caused by TSS can affect the ability of fish to see and catch food. Suspended sediment can also clog fish gills, reduce growth rates, decrease

resistance to disease, and prevent egg and larval development. When suspended solids settle to the bottom of a water body, they can smother the eggs of fish and aquatic insects, as well as suffocate newly hatched insect larvae. Settling sediments can fill in spaces between rocks which could have been used by aquatic organisms for homes. High TSS in a water body can often mean higher concentrations of bacteria, nutrients, pesticides, and metals in the water.

TSS analysis of the samples taken from the specified rivers were undertaken in the laboratory at a temperature 103-105 ^{o}C. The TSS in the surface water bodies investigated were low ranging from 7 mg/L (Little and Great Scarcies Rivers) to 14 mg/L (Mano River).

Table 5-24: TSS of water in the rivers

River	TSS at 103-105 ^{o}C, mg/L
Reporting Limit	1
Mano	14
Moa (Point 1)	8
Moa (Point 2)	12
Sewa	12
Little Scarcies	7
Great Scarcies	7
Standard (Guideline) Values	
WHO	
IFC/WBG	50
US-EPA	
EPA-SL	

5.3.11 Total Hardness

Hardness caused by calcium and magnesium is usually indicated by precipitation of soap scum and the need for excess use of soap to achieve cleaning. Consumers are likely to notice changes in hardness. Public acceptability of the degree of hardness of water may vary considerably from one community to another. The taste threshold for the calcium ion is in the range of 100–300 mg/l, depending on the associated anion, and the taste threshold for magnesium is probably lower than that for calcium. In some instances, consumers tolerate water hardness in excess of 500 mg/l.

The total hardness of the water samples collected from the rivers were analysed in the laboratory and reported in Table 5-25 and Appendix I, Section 8.2. The total hardness in the surface water bodies investigated were ranged from 5 (Mano River) to 12 (Sewa River).

Table 5-25: Total Hardness of water in the rivers

River	Hardness by Calculation, mg/L
Reporting Limit	5
Mano	5
Moa (Point 1)	7
Moa (Point 2)	8
Sewa	12
Little Scarcies	6
Great Scarcies	9

River	Hardness by Calculation, mg/L
Standard (Guideline) Values	
WHO	
IFC/WBG	
US-EPA	
EPA-SL	

5.3.12 Total Alkalinity

Alkalinity refers to the total amount of bases in water expressed in mg/l of equivalent calcium carbonate. A base is a substance that releases hydroxyl ions (OH-) when dissolved in water. In most waters these bases are principally bicarbonate (HCO_3) ions and carbonate ions (CO_3^{2-}). These ions are the buffers in water; that is they buffer the water against sudden changes in pH. They can do this by absorbing hydrogen ions when the water is acid and releasing them when the water becomes basic. Waters of low alkalinity (<20 mg/l) are poorly buffered, and the removal of carbon dioxide (CO_2) during photosynthesis results in rapidly rising pH. Waters, with greater than 20 mg/l alkalinity have greater buffering capacity and prevent large fluctuations in pH during photosynthesis. If alkalinity is high and hardness low, pH may rise to very high levels (greater than 10.5) during periods of rapid photosynthesis.

Alkalinity and hardness are not greatly affected by biological activity or aquacultural operations, and the initial concentrations in rivers are determined by their level in the water supply; any changes are largely the result of rainfall and evaporation. Desirable levels for fish culture generally fall within the range of 20-300 mg/l. If total alkalinity and total hardness are too low, they may be raised by liming. However, there is no practical way of decreasing alkalinity and hardness when they are above desirable levels. As a general rule, the most productive waters for fish culture have a hardness and alkalinity of approximately the same magnitude.

The alkalinity of the water samples collected from the rivers were analysed in the laboratory as $CaCO_3$ and reported in Table 5-26 and Appendix I, Section 8.2. The alkalinity in the surface water bodies investigated were ranged from 8 mg/L (Mano River) to 18 mg/L (Little Scarcies River).

Table 5-26: Total alkalinity of water in the rivers

River	Total Alkalinity as $CaCO_3$, mg/L
Reporting Limit	2
Mano	8
Moa (Point 1)	11
Moa (Point 2)	12
Sewa	11
Little Scarcies	18
Great Scarcies	11
Standard (Guideline) Values	
WHO	
IFC/WBG	
US-EPA	
EPA-SL	

5.3.13 Biological Oxygen Demand (BOD)

Biochemical Oxygen Demand is the measure of the oxygen required by micro-organisms whilst breaking down organic matter. BOD is normally measured over a period of 5 days, and shows how much oxygen is needed by the water to completely oxidize its organic pollution load. DO, on the other hand, gives an indication of how much oxygen is present and thus shows how much the oxygen is being utilized. BOD measurements were carried out in a laboratory. The BOD of the water samples collected from the rivers were analysed in the laboratory and reported in Table 5-27 and Appendix I, Section 8.2.

5.3.14 Chemical Oxygen Demand (COD)

Chemical Oxygen Demand is the amount of oxygen consumed by organic matter as determined by chemical oxidation using a boiling solution of potassium dichromate and concentrated sulphuric acid. Typically the COD is larger than the BOD. The COD of the water samples collected from the rivers were analysed in the laboratory and reported in Table 5-27 and Appendix I, Section 8.2.

Table 5-27: BOD and COD of water in rivers monitored (laboratory analysis)

River	BOD (BOD_5), mg/L	COD, mg/L
Reporting Limit	5	5
Mano	<5	6
Moa (Point 1)	<5	<5
Moa (Point 2)	<5	17
Sewa	<5	<5
Little Scarcies	<5	<5
Great Scarcies	<5	7
Standard (Guideline) Values		
WHO		
IFC/WBG	30	125
US-EPA		
EPA-SL		

5.3.15 Nitrate

Nitrogen is an essential nutrient for plants and animals. It exists in the environment in many different forms, constantly being replenished as part of the nitrogen cycle. Nitrate (NO_3^-) is one form of nitrogen in the ecosystem that is very soluble in water. Nitrate enters the water system when runoff from rainfall or irrigation washes through soils that contain nitrate. The nitrate dissolves in the water and is carried to nearby streams and lakes. It also permeates downward into the soil where it may enter underground aquifers. The concentration of nitrogen in a body of water depends mostly upon the land cover and soil type. Highest concentrations are associated with shallow groundwater and agricultural use of the land. Agriculture is a large contributor to the pollution of surface water and groundwater because of the use of fertilizers that contain nitrate. Also, densely populated livestock produce large quantities of manure that can be changed into nitrate upon decay. Nitrate remains in surface water until it is consumed as a nutrient by plants or other organisms.

The nitrite concentration of the water samples collected from the rivers were analysed in the laboratory and reported in Table 5-28. The rivers monitored have nitrate concentrations ranging from 0.43 mg/L (Great Scarcies River) to 0.79 mg/L (Sewa River).

5.3.16 Nitrite

Nitrites are found in natural waters as an intermediate stage in the nitrogen cycle, and are formed in water either by the oxidation of ammonia or the reduction of nitrates. Thus biochemical processes can cause a rapid change in nitrite concentrations. In natural waters, nitrites are normally present only in low concentrations (0.1 – 0.5 mg/l). However, higher concentrations may be present in sewage and wastewaters. Nitrites are harmful to aquatic life. The nitrite concentration of the water samples collected from the rivers were analysed in the laboratory and reported in Table 5-28 and Appendix I, Section 8.2. The rivers monitored have nitrite concentrations below the reporting limit of <0.05 mg/L.

Table 5-28: Nitrate and nitrite concentration of water in rivers monitored (laboratory analysis)

River	Nitrate, as NO_3, mg/L	Nitrite, NO_2, mg/L
Reporting Limit	0.06	0.05
Mano	0.65	<0.05
Moa (Point 1)	0.68	<0.05
Moa (Point 2)	0.77	<0.05
Sewa	0.79	<0.05
Little Scarcies	0.61	<0.05
Great Scarcies	0.43	<0.05
Standard (Guideline) Values		
WHO		
IFC/WBG	50	50
US-EPA	10	1
EPA-SL		

5.3.17 Phosphates

Phosphate is an essential nutrient for all living organisms. However, when phosphate levels rise above natural levels due to the activities of man, eutrophication of water bodies can occur. Phosphates are extensively used in detergents and washing powders, also in food processing industries and industrial water treatment processes. Phosphates can enter water-courses through a variety of routes – particularly via domestic and industrial effluent and from agricultural land run-off. Phosphate is an important control test for natural and drinking waters. Whilst phosphates are not considered harmful for human consumption, they do exhibit a widespread and complex effect on the natural environment.

The phosphate concentration of the water samples collected from the rivers were analysed in the laboratory and reported in Table 5-29 and Appendix I, Section 8.2. The rivers monitored (have phosphate concentrations below the reporting limit of <0.02 mg/L, except samples from the Little Scarcies River, which were analysed to have a phosphate concentration of 0.02 mg/L.

Table 5-29: Phosphate concentration of water in rivers monitored (laboratory analysis)

River	Phosphate as PO_4, mg/L
Reporting Limit	0.02
Mano	<0.02
Moa (Point 1)	<0.02
Moa (Point 2)	<0.02
Sewa	<0.02

River	Phosphate as PO_4, mg/L
Little Scarcies	0.02
Great Scarcies	<0.02
Standard (Guideline) Value	
WHO	
IFC/WBG	
US-EPA	
EPA-SL	

5.3.18 Oils and Fats

The concentration of dispersed oils and fats is an important parameter for water quality and safety. Oils and fats in water can cause surface films and shoreline deposits leading to environmental degradation, and can induce human health risks when discharged in surface or ground waters. Additionally, oils and fats may interfere with aerobic and anaerobic biological processes and lead to decreased wastewater treatment efficiency. The concentration of oils and grease in the water samples collected from the rivers were analysed in the laboratory and reported in Table 5-30 and Appendix I, Section 8.2. All the rivers monitored (have oil and grease (fats) concentrations below the reporting limit of <5 mg/L.

Table 5-30: Oils and fats concentration of water in rivers monitored (laboratory analysis)

River	Oil and Grease, mg/L
Reporting Limit	5
Mano	<5
Moa (Point 1)	<5
Moa (Point 2)	<5
Sewa	<5
Little Scarcies	<5
Great Scarcies	<5
Standard (Guideline) Values	
WHO	
IFC/WBG	10
US-EPA	
EPA-SL	

5.3.19 Total Coliform and Faecal Coliform

In general terms, the greatest microbial risks are associated with ingestion of water that is contaminated with faeces from humans or animals (including birds). Faeces can be a source of pathogenic bacteria, viruses, protozoa and helminths. Faecally derived pathogens are the principal concerns in setting health-based targets for microbial safety. Microbial water quality often varies rapidly and over a wide range. Short-term peaks in pathogen concentration may increase disease risks considerably and may trigger outbreaks of waterborne disease. Measurement of the faecal coliform concentration gives an indication of the relative presence of sewage in the water, and likelihood of the presence of associated viruses, more harmful bacteria and other dangerous microorganisms (all of which are difficult to measure individually). In raw sewage concentrations of faecal coliforms (as E coli) can vary between 1-50 million/100 ml. The coliform and faecal coliform in the water samples collected from the rivers were

analysed in the laboratory and reported in Table 5-31 and Table 5-30 and Appendix I, Section 8.2. All the rivers monitored (have oil and grease (fats) concentrations below the reporting limit of <5 mg/L.

Table 5-31: Total and faecal coliform concentration of water in rivers

River	Total Coliforms, MPN/100 mL	Faecal Coliforms, MPN/100 mL
Reporting Limit	1	1
Mano	2419.6	33.1
Moa (Point 1)	298.7	17.3
Moa (Point 2)	866.4	9.8
Sewa	9208	920.8
Little Scarcies	2,419.6	117.8
Great Scarcies	1,732.9	46.5
Standard (Guideline) Values		
WHO	NA	NA
IFC/WBG	<400	NA
US-EPA	NA	NA
EPA-SL	NA	NA

5.3.20 Heavy Metals

Heavy metals such as cadmium, zinc, copper, lead may be toxic to aquatic organisms if present at high concentrations. Health risks are principally caused by the consumption of affected fish etc., but they can also be created by absorption in crops irrigated with wastewaters. Bioaccumulation in the aquatic environment is principally due to organic metallic compounds. The heavy metals can be carried as aqueous salts in the water body, but most of the ions are adsorbed onto sediment particles. Although there is an equilibrium between the two forms, it is possible for heavy metals to be accumulated where sediment is deposited. The concentration of dissolved and total metals in the water samples collected from the rivers were analysed in the laboratory and reported in Table 5-32, Table 5-33 and Appendix I, Section 8.2.

Table 5-32: Concentration of dissolved metals in rivers monitored

River	As	Sb	Hg	Ca	Mg
Reporting Limit	0.0005	0.0001	0.0001	1	0.5
Mano River	<0.0005	0.0005	<0.0001	1	0.6
Moa River (Point 1)	<0.0005	0.0002	<0.0001	2	0.7
Moa River (Point 2)	0.0007	0.0004	<0.0001	2	0.8
Sewa River	<0.0005	<0.0001	<0.0001	3	1.4
Little Scarcies River	<0.0005	0.0003	<0.0001	1	0.5
Great Scarcies River	<0.0005	<0.0001	<0.0001	2	1.1
Standard (Guideline) Values					
WHO	0.01	0.02	0.006		
IFC/WBG					
US-EPA	0.01	0.006	0.002		
EPA-SL					

Table 5-33: Concentration of total metals in rivers monitored

River	As	Sb	Se	Hg	Mn	Cu	Zn	Pb	Cr	Ni	Cd	Mo	Co	Fe	Al
Reporting Limit	0.0005	0.0001	0.01	0.0001	0.002	0.001	0.005	0.0005	0.001	0.001	0.0001	0.0005	0.001	0.1	0.03
Mano River	<0.0005	0.0006	<0.01	<0.0001	0.016	<0.001	0.007	0.0005	<0.001	<0.001	<0.0001	<0.0005	<0.001	1	0.24
Moa River (Point 1)	<0.0005	0.0002	<0.01	<0.0001	0.011	<0.001	0.005	0.0006	<0.001	<0.001	<0.0001	<0.0005	<0.001	1.1	0.18
Moa River (Point 2)	<0.0005	<0.0001	<0.01	<0.0001	0.014	<0.001	0.007	0.0006	<0.001	<0.001	<0.0001	<0.0005	<0.001	1.3	0.31
Sewa River	0.0015	<0.0001	<0.01	<0.0001	0.021	0.002	0.01	0.0008	0.002	0.001	<0.0001	<0.0005	<0.001	1.4	0.41
Little Scarcies River	<0.0005	<0.0001	<0.01	<0.0001	0.025	<0.001	0.006	0.0008	<0.001	<0.001	<0.0001	<0.0005	<0.001	1.3	0.17
Great Scarcies River	<0.0005	<0.0001	<0.01	<0.0001	0.018	<0.001	0.007	0.0005	<0.001	<0.001	<0.0001	<0.0005	<0.001	0.8	0.09
Standard (Guideline) Values															
WHO	0.01	0.02	0.04	0.006		2		0.01	0.05	0.07	0.003				0.9
IFC/WBG															
US-EPA	0.01	0.006	0.05	0.002	0.05	1.3	5	0.015	0.1	0.5	0.005			0.3	0.2
EPA-SL															

5.4 Soil

5.4.1 National Context

Sierra Leone is situated in the humid tropics on the west coast of Africa. It consists of four broad physiographic regions: the Peninsula Mountains, the Coastal Plain, the Interior Plain and the Interior Plateaux and Hill Region. Each of these broad physiographic regions is subdivided into soil provinces on basis of differences in soil forming factors given a total of 16 Soil Provinces.

The Peninsula Mountains (Soil Province A), located near the capital Freetown, are the result of a large basic intrusive body of norite and gabbro. It consists of a strongly dissected mountain range. The coastal plain (Soil Provinces B, C, D and E) is a strip about 40 km in width adjoining and parallel to the coast. Most of it occurs at elevations less than 18m above sea level. It is built up of marine, deltaic and fluvial deposits of Pleistocene and recent age. The topography is nearly flat with many swamps. The Coastal Plain is subdivided into four soil provinces: Sandy Beach Ridges (B), Mangrove Swamps (C), Alluvial Grassland Flood Plains (D) and Raised Beaches and Coastal Terraces (E).

The Interior Plain (Soil Provinces F, G, H and I) is a strip about 95 km in width adjoining and parallel to the coastal plain. It is a gently undulating peneplain that was probably formed during the late Tertiary (Stobbs, 1965). Its elevation rises from 15 m in the west to about 152 m in the east. It is broken by a number of isolated hills which are monadnocks, remnants remaining from an earlier plateau. The western part of the Interior Plain is underlain by acid igneous and metamorphic rock (Soil Province F), the eastern part by sedimentary rocks. The latter is subdivided into three Soil Provinces on basis of climate, vegetation, and drainage. The northern part (Soil Province H) is the driest and has savanna vegetation. The middle part (Soil Province I) are the Bolilands, an area consisting mainly of inland swamps. The southern part (Soil Province G) receives the most rainfall and is covered by secondary bush vegetation.

The Interior Plateaux and Hill Region (Soil Provinces J, K, L, M, N, O, P) covers the eastern half of Sierra Leone. It consists of elevated plateau country lying primarily between elevations of 305 m and 610 m. Other plateaux and remnants of plateaux rise above this general level especially near the Guinea border. Most of the area is underlain by granite and acid gneiss which is covered by savanna in the north (Soil Province N) and by secondary bush and forest more to the south (Soil Province M). Some smaller areas consist of basic schist, amphibolite and serpentine (Soil Province P). The Interior Plateaux and Hills are separated from the Interior Plain to the west by an escarpment which is rather sharp in the north where it is covered by savanna (Soil Province K). Further south the escarpment is much less clearly defined, more dissected and covered by secondary bush and forest (Soil Province I). In the south eastern part along the upper part of the Moa river erosion and denudation have been so extensive that the scarp face is replaced by an undulating to gently rolling erosion surface (Soil Province L). Table 5-34 and Figure 5-5 show the soil types and provinces in Sierra Leone and their description to give a better understanding of the soil classification and distribution.

Table 5-34 Soil provinces and types

Soil Provinces	Soil Types
A	Peninsula Mountains from norite and gabbro
B	Sandy beach ridges and lagoons
C	Coastal swamps
D	Alluvial grassland floodplains
E	Raised beaches and coastal terraces
F	Interior plain from acid igneous and metamorphic rocks
G	Rokel River series under secondary bush

Soil Provinces	Soil Types
H	Rokel River series under savanna
I	Bolilands
J	Escarpment from granite and acid gneiss under secondary bush and forest
K	Escarpment from granite and acid gneiss under savanna
L	Upper Moa Basin
M	Plataeux from granite and acid gneiss under secondary bush and forest
N	Plataeux from granite and acid gneiss under savanna
O	Hills and mountains from granite and acid gneiss
P	Hills and mountains from Kambui schists

For ease of analysis and brevity, the transmission line has been divided into eleven segments to determine the variation of soil types from one monitoring location to another (see Table 5-35). This helps to give a better understanding about the soil distribution within the transmission line buffer zones.

Figure 5-5 Maps shows the soil classification in Sierra Leone

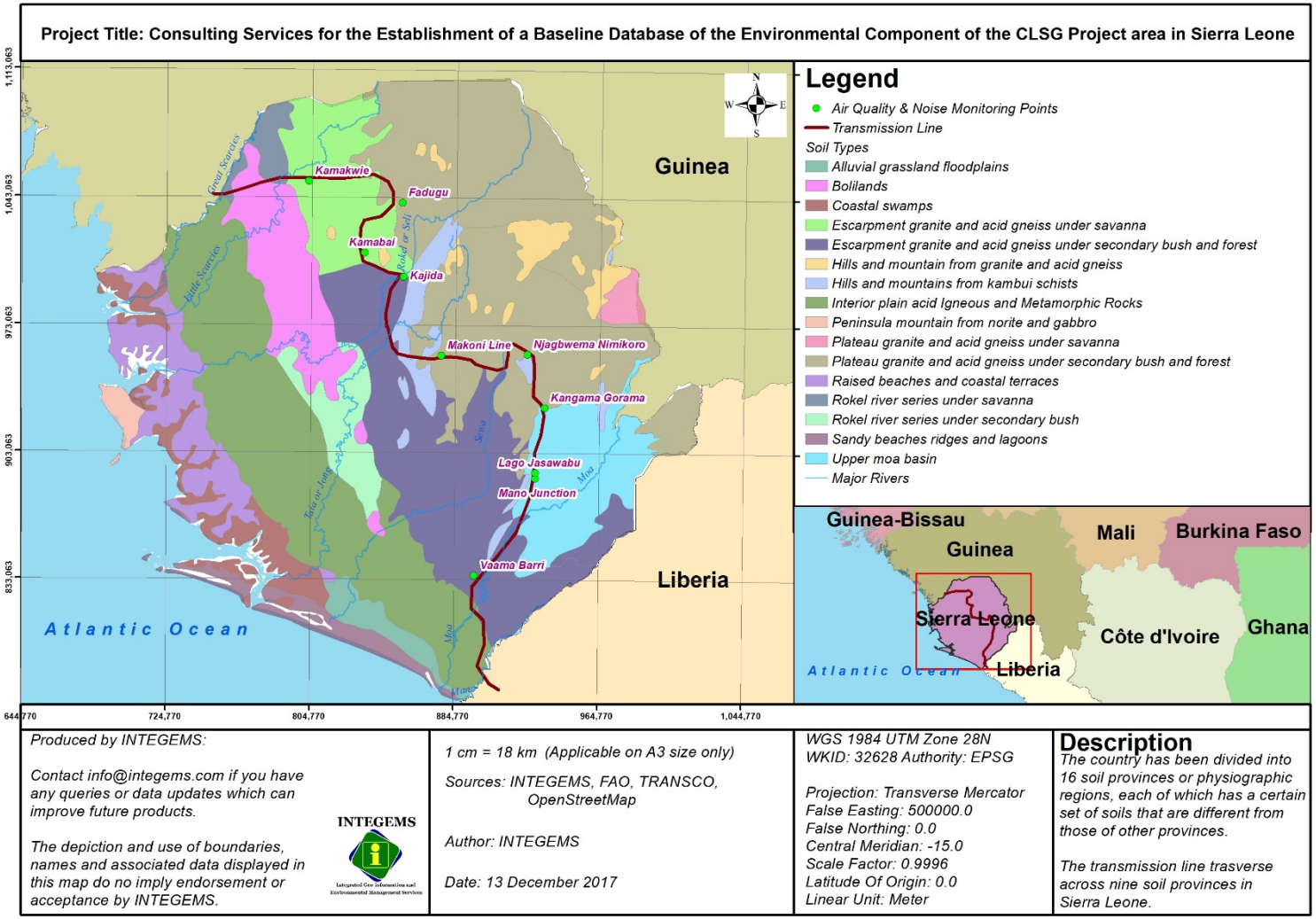


Table 5-35: Soil types and provinces divided into segment among monitoring points

Segment No	Segment Length (km)	Segment	Soil Province	Soil Description
SG01	58.2	Liberian Border to Vaama Barri	F, J	F - Interior plain from acid igneous and metamorphic rocks. J - Escarpment from granite and acid gneiss under secondary bush and forest.
SG02	63.3	Vaama Barri to Mano Junction	J, L, P	J - Escarpment from granite and acid gneiss under secondary bush and forest. L - Upper Moa Basin. P - Hills and mountains from kambui schists.
SG03	2.9	Mano Junction to Lago Jasawabu	L	L - Upper Moa Basin.
SG04	36.6	Lago Jasawabu to Kangama Gorama	L, M	L - Upper Moa Basin. M - Plataeux from granite and acid gneiss under secondary bush and forest.
SG05	33.3	Kangama Gorama to Njagbwema Nimikoro	M, P	M - Plataeux from granite and acid gneiss under secondary bush and forest. P - Hills and mountains from kambui schists.
SG06	61.3	Njagbwema Nimikoro to Makoni Line	J, M	J - Escarpment from granite and acid gneiss under secondary bush and forest. M - Plataeux from granite and acid gneiss under secondary bush and forest.
SG07	70.3	Makoni Line to Kajida	J, K, M, P	J - Escarpment from granite and acid gneiss under secondary bush and forest. K - Escarpment from granite and acid gneiss under savanna. M - Plataeux from granite and acid gneiss under secondary bush and forest. P - Hills and mountains from kambui schists.
SG08	26.7	Kajida to Kamabai	J, K, O	J - Escarpment from granite and acid gneiss under secondary bush and forest. K - Escarpment from granite and acid gneiss under savanna. O - Hills and mountains from granite and acid gneiss.
SG09	38.9	Kamabai to Fadugu	K, N	K - Escarpment from granite and acid gneiss under savanna. N - Plataeux from granite and acid gneiss under savanna
SG10	57.9	Fadugu to Kamakwie	K, N	K - Escarpment from granite and acid gneiss under savanna. N - Plataeux from granite and acid gneiss under savanna
SG11	49	Kamakwie to Guinea border	H, I, K	H – Rokel River series under savanna I – Bolilands K – Escarpment from granite and acid gneiss under savanna.

5.4.2 Overview of Soil Types within the Transmission Line Buffer

Three buffers (400 m, 600 m, and 1,000 m) were delineated along the transmission line using GIS to get the soil types that are within the transmission line buffers. The soil dataset was clipped with the buffers and various soil types within the transmission line buffers were then extracted. However, the area that will be affected varies among the 400m, 600m, and 1,000 m buffer ranges. This was used to determine the soil types that will be affected by the transmission line (see Table 5-36).

Table 5-36 Soil types and provinces traversed by the transmission line

Soil Province	Soil Types
F	Acidic igneous and metamorphic rocks.
H	Rokel river series under savanna.
I	Bolilands.
J	Escarpment granite and acid gneiss under secondary bush and forest.
K	Escarpment granite and acid gneiss under savanna.
L	Upper moa basin.
M	Plateau granite and acid gneiss under secondary bush and forest.
N	Plateau granite and acid gneiss under savanna.
P	Mountains from Kambui schists.

5.4.2.1 Soil Province F: Acidic Igneous and Metamorphic Rocks

This soil province occurs in a southeast-northwest belt about 32 to 48 km wide, just behind the coastal plain, stretching from the Liberian to the Guinean border, and including the towns of Pujehun, Moyamba, and Port Loko districts and also Sumbuya town. It is part of the interior plain, a gently undulating peneplain that was probably formed during the late tertiary. A few monadnocks, remnant hills of earlier plateaux like the Moyamba, Mokanji, Imperri and Gbonge hills, are also present. Remnant erosion surfaces are reported at heights of 76, 120, 160, and 215 metre (Dixey, 1922).

Annual rainfall varies from 4,060 mm in the southeast to 2,540 mm in the northwest. About 90 to 95% of the rain falls between May and November, except for the extreme north western part which receives over 95 % of the annual rainfall during that period. The Western part of this soil province is underlain by crystalline schists and gneisses of the Kasila series. The remainder of the province has granite and acid gneiss bedrock except for some small areas of Marampa schists. These acid and intermediate igneous and metamorphic rocks contain more weather able minerals than the sedimentary rocks of the Rokel River series to the east, and consequently the soils should have higher nutrient status, especially those soils that occur on steep slopes.

Soil surveys have been carried out in Soil Province F at Sorogbwema (Allbrook and Bakshi, 1960) and at Mange Bureh (Allbrook, 1962 a). On gentle convex slopes, there are well and moderately well drained soils that have 50 to 80 % volume of gravel. These soils have low nutrient status and very poor water-holding capacities. They are unsuitable for most agricultural crops. On the fiat summits, these gravelly soils usually have a hard, indurated plinthite sheet within depths of four feet. On steep slopes, more productive soils are present that usually contain weathering bedrock pieces in the subsoil. Because the bedrock contains a moderate amount of weather able minerals, the nutrient status of these soils is rather good. On the concave lower slopes, soils are present with a deep gravel free, colluvial layer over a gravelly lower subsoil. With adequate fertilization, these soils can be made productive for a great variety of crops, including rubber, oil palm and coffee. However, hard plinthite occurs at shallow depths at some places, especially at the foot of steep slopes where much seepage water rich in iron comes down. In the swamps, poorly drained sandy clay loam soils are present. They are best used for rice in the wet season and vegetables in the dry season. Very productive gravel free alluvial soils occur along the banks of the major rivers. They are suitable for a great variety of agricultural crops, although occasional flooding may be a hazard.

5.4.2.2 Soil Province H: Soils from the Rokel river series under savanna

This soil province is in the north western part of Sierra Leone between the Little Scarcies and the Great Scarcies Rivers. It differs from Soil Province G in the predominance of savanna and a smaller amount of annual rainfall. The area is part of a gently undulating peneplain which extends into Guinea. Swamps are present but to a much lesser extent than in the Bolilands of Soil Province I. The main annual rainfall is between 2,032 mm and 2,540 mm. Over 95% of this rain falls between May and November. The soils are derived from sandstones, mudstones, and siltstones. Because these sedimentary rocks are poor in weatherable minerals, the soils developed from them are very poor in plant nutrients. No detailed data are available for the soils in this area. They are probably similar to the soils of the Bolilands except that the proportion of well drained soils is much greater.

5.4.2.3 Soil Province I: Bolilands

The Boliland region is a seasonally swampy area in a belt about 20 miles wide stretching from Yonibana through Batkanu to the Guinea border. It is a low lying, flat or very gently undulating grassland area that is thought to be a former delta formed by the merging of the Mabole, Rokel and Pampana rivers at a period of higher sea level. A swampy area east of Taiama and one south of Bumpe also have been included in Soil Province I. The vegetation is predominantly derived from savanna resulting from the destruction of forest vegetation by human activity and fire. Medium and tall grasses are common in the swamps, savanna woodland and Lophira bush predominate on the uplands. Mean annual rainfall is between 2,794 mm and 3,048 mm, 90% to 95% of which falls between May and November. The area is underlain by sandstones, mudstones, and siltstones of the Rokel River series.

A reconnaissance soil survey of the main part of the Bolilands was made by Stobbs (1963). The seven landscape units that he recognized are: uplands, river terraces, old river levees, recent river levees, old river channels, riverine Bolis, and inland Bolis. The soils are in general quite similar to those of Soil Province G, but the relative proportion of swamps and river terraces is much greater. The very gravelly upland soils differ from those of Soil Province G in the lighter coloured surface and lower content of organic matter, which is probably caused by its development under savanna. These upland soils are poor and can only be used for shifting cultivation, pasture, or possibly groundnuts.

On the extensive river terraces, some soils have a strongly developed, indurated or unindurated plinthite sheet in the subsoil, and other terrace soils have no plinthite. The mamalia soil is an example of a somewhat poorly drained terrace soils that has an indurated plinthite sheet in the lower subsoil. It is a rather poor soil that is locally used for cassava, beans and sweet potatoes. The plinthite free terrace soils are more productive and can be used for oil palm, tobacco, or other cash crops if properly fertilized.

Riverine Bolis or contemporary sloughs are swamps of the present day floodplain. Inland Bolis or old sloughs are swamps of former floodplains. Soils of the riverine Bolis are younger and more fertile than those of the inland Bolis. The Romkane soil is an example of an inland Boli soil that has abundant soft plinthite in the subsoil. In the Bolis, swamp rice must be the principal crop. Fertilization and water control by bunding are essential for high fields. During the dry season, the swamps can be used for vegetables or pasture.

5.4.2.4 Soil Province J: Escarpment granite and acid gneiss under secondary bush and forest

The interior plateaux and hills of the eastern part of Sierra Leone are separated from the low lying interior plain to the west by an escarpment region in which the elevation increases from 61 m in the west to 309 m in the east. Soil Province J consists of that part of the escarpment region which is under secondary bush or forest. It consists of a northwest southeast strip, 24 km to 80 km wide, through central Sierra Leone, including the towns of Makeni, Magburaka, Yele, Bo, Blama, and Zimmi. The escarpment is most abrupt in northern Sierra Leone. In central Sierra Leone, the erosion of the scarp is more advanced, and there are many large dome shaped hills (inselbergs) near Makeni. Farther south of the escarpment region is much broader, highly dissected, and less clearly defined than in the north.

Annual rainfall ranges from 2,540 mm to 3,556 mm. In the north western part of this Soil Province, 90% to 95% of the rain falls from May to November, while in the south eastern part 85% to 90% of the precipitation falls during that period. Thus, the severity of the dry season decreases in a south eastern direction. The vegetation consists mainly of secondary bush, but in the south eastern part old forests

are present, especially in the Gola Forest Reserve. The bedrock is acid gneisses and granite. It contains a moderate amount of weather able minerals, thus soils developed from it have a moderate nutrient status, especially the soils on steep slopes where fresh minerals are exposed.

In the northern part of this Soil Province near Makeni a soil survey has been carried out by van Vuure and Miedema (1968). They recognize four distinct landscape units; uplands, alluvial river terraces, valley bottoms, and inselbergs. The uplands contain mainly very gravelly and shallow soils that are unsuitable for most agricultural crops. Some lower upland areas however have gravel-free colluvial soils that are more suitable for agriculture. Soils on steep slopes have some weatherable minerals and are therefore slightly more fertile. Erosion, however, is a great danger thus they are best adapted to tree crops.

The alluvial terraces consist of soils that with subsequent lower elevations have an increasingly thicker gravel-free layer over a gravelly subsoil or bedrock. With increasing depth of the gravel-free layer the soils are better adapted to a great variety of crops. Especially promising are the deep alluvial terrace soils along the Mabole River.

The valley bottoms consist of deep gravel free, poorly drained, rather sandy soils that have low water and nutrient holding capacities. Possible crops are swamps rice in the rainy season and irrigated vegetables in the dry season.

The inselbergs have very shallow soils with numerous rock outcrops. Because of the steep slopes of these dome shaped- hills, erosion danger is very great. They should be kept under forest on places where still some soil is left.

5.4.2.5 Soil Province K: Escarpment granite and acid gneiss under savanna

Soil Province K consists of a northwest-southeast strip, about 48 km wide, in north-central Sierra Leone. It is similar to Soil Province J but differs from it in having savanna vegetation, lower annual rainfall, and a more severe dry season. The annual rainfall is 1,778 mm to 2,540 mm, of which 90% to 95% falls between May and November. Little is known about the soils of this area because of the savanna vegetation, soils are probably lower in organic matter and less fertile than those of Soil Province J. Waldock et al. (1951) report that soil erosion in this area is serious, especially where upland rice is grown on steep slopes. These slopes are probably better used for forest, tree crops of pasture.

5.4.2.6 Soil Province L: Upper Moa Basin

In the south eastern part of Sierra Leone, erosion and denudation of the escarpment between the interior plateaux and hills in the northeast and the low lying interior plain in the southwest have been so extensive that the scarp face is replaced by an undulating to gently rolling erosion surface. This is especially true in the Moa Basin, an area about 48 km wide and 120 km long along the Moa River, including the towns of Kenema, Daru, and Pendembu. In this area, the erosion surface rises from about 12 m to 243 m above sea level and is broken by numerous monadnocks (isolated hills of earlier plateaux) of elevations generally between 182 m and 305 m. The area is underlain by granite and acid gneiss. Annual rainfall ranges between 2,540 mm and 3,084 mm, and about 85 % of which falls between May and November. The dominant vegetation is secondary bush with some areas of older forests. The moa basin is the main cocoa growing region in Sierra Leone.

5.4.2.7 Soil Province M: Plateaus granite and acid gneiss under secondary bush and forest

This Soil Province is located in east central Sierra Leone and includes Kono district and the eastern part of Tonkolili District. It consists of a series of plateau between elevations of 304 m and 610 m. This plateau region, which is part of the Guinea highlands, is far from flat and comprises numerous steep sided valleys, monadnocks, and dome shaped granite hills. Annual rainfall is between 2,540 mm and 2,794 mm, 85% to 90% of which falls during the rainy season. The greater part of the area is under secondary bush, but extensive areas of forest also are present. The bedrock consists of granite and acid gneiss.

Little is known about the soils, as no soil surveying has been done in this area. Flat erosion surfaces usually have hard indurated plinthite that may attain a thickness of up to 12 m (Clarke, 1966). On steep slopes, plinthite is usually absent and bedrock is close to the surface. Waldock et al. (1951) report that

some of the hills have been completely denuded of soil and vegetation because of the severe erosion that takes place when they were used for upland rice. They recommended a considerable increase of the area under forest reservations and a more intensive use of the inland valley swamps.

5.4.2.8 Soil Province N: Plateaux granite and acid gneiss under savanna

This soil province is located in north eastern Sierra Leone and includes the greater part of Koinadugu district. It is similar to Soil Province M, but it has a savanna vegetation, a lower annual rainfall, and a more severe dry season. The annual rainfall ranges from 1,778 mm to 2,540 mm 90% to 95 % of which falls between May and November. Crops grown in this area include cassava, groundnuts, pigeon peas, onions, guinea corn, fundi, tobacco, tomatoes, and vegetables. This Soil Province is also the main cattle rearing region of Sierra Leone.

No detailed soil information for this area is available. Soils are probably similar to those of Soil Province M, but lower in organic matter and available nutrients because of the savanna vegetation. Around Kabala, soil fertility has declined considerably because of excessive farming. Waldock et al. (1951) recommend that the steeper slopes should be reforested or used for growing economic tree crops, the lower slopes should be used more intensively, and dry season irrigation should be practiced where possible, while more use should be made of cattle manure and compost from towns.

5.4.2.9 Soil Province P: Hills and mountains from the Kambui schists

In eastern Sierra Leone, some high hills and mountains are present that are underlain by basic rocks such as amphibolites, serpentines, and basic schists belonging to the Kambui geological series. This Soil Province includes the Sula Mountains and the Kangari, Nimini, Gori, and Kambui hills. The elevation ranges from 305 m to 915 m. Vegetation is mainly forest and secondary bush, but on the flat erosion surfaces where hard laterite pan is close to the surface, short grasses usually are present. Annual rainfall varies between 2,540 mm and 3,048 mm, 85% to 95 % of which falls between May and November.

Unlike granite, the basic rocks of the Kambui schists are high in sesquioxides and weather rapidly. Pollett (1951) noted that the Kambui schists are blanketed with a covering of residual laterite as much as 30 m thick. This residual laterite may be in the form of an indurated laterite hardpan, as is the case on the 610 m erosion surface of the Sula mountains (Wilson, and Marmo, 1985). This indurated laterite hardpan usually is present on flat surfaces, but in the Sula Mountains it has been found on slopes as steep as 25°. At the foot slopes in the valleys, colluvial and alluvial laterites are usually present. They consist of laterite boulders and gravel cemented by sesquioxides. In the Kangari Hills, laterization is much less widespread than in the Sula mountains (Marmo, 1962). It is mainly limited to flat terraces and minor flat areas within the mountains.

5.4.3 Activities with Potential to Impact Soils

Soils are assessed as a high sensitivity receptor due to their value as a natural resource; hence, this section describes the direct and indirect impacts associated with the TRANSCO CLSG project on soils. GIS-based maps were evaluated to identify geology issues and assess soil types along the 530 km transmission line corridor, within the delineated buffer zones. There are nine specific soil types impacted by the TRANSCO CLSG project as described in Section 5.4.2.

The main impacts on soils are likely to arise during the various site preparation and construction activities associated with the TRANSCO CLSG project. However, soils will also be vulnerable during the operation and maintenance phases. Project activities with the greatest potential to impact soils include clearing and grubbing of vegetation for transmission line ROW and access roads, excavation for tower and substation foundations, and ongoing operations and maintenance. These activities are described below:

- **Clearing and grubbing.** Clearing of trees and shrubs make the soil more susceptible to erosion and dust generation as the soils under these plants are now exposed to wind and precipitation. ROW and access road clearing also increase sedimentation carried in storm water runoff. As a result, these areas may also become susceptible to landslides and mudslides over time.

- **Excavation**. Excavation for transmission tower and substation foundations removes grass and vegetation, exposes soil and makes it prone to erosion from wind and rain. Disturbance potential is greatest during excavation for transmission line tower structures since these can be up to 10 m deep, while substation foundations are more shallow and impact less volume of soils. Blasting may be required to set tower foundation in rocky terrain. Blasting activities produce seismic waves which could locally produce rockslides, landslides, or mudslides in areas that are geologically unstable.
- **Operations and maintenance.** There is a potential impact for soil erosion and compaction associated driving maintenance vehicles over the ROW during operations and maintenance. Additionally, there is a potential for soil contamination during this activities associated with leaks of insulating oils from transformers and fuel and oil spills from maintenance vehicles.

5.4.3.1 Construction Impacts

Damaged foundations and towers would be repaired or replaced as necessary. Restoring access to these areas where clearing of forested areas and shrub land in steep-slope areas would be required could expose soils to erosion and mass movement. Restoration and rehabilitation work would not be expected to require blasting or other seismic disturbances except perhaps few foundation replacements, and would not have any significant impact to geology or seismic conditions. There can be a potential for damage to the project in areas prone to seismic events, downhill of areas prone to mass movement of soils.

The main impact on soils during construction will be the increase in vulnerability to erosion and potential for soil contamination. The following types of construction activity could lead to potential soil erosion and contamination:

- Vehicle and other construction equipment traffic along access roads and ROW during construction may cause soil compaction, soil rutting, and dust generation. Additionally, mud could be carried off the site on vehicle tyres and could result in sedimentation in off-site areas. This will be a short-term impact with a potential to become a long-term impact without mitigation measures.
- Vegetation will be cleared and at least some soil will be removed for the construction camps, the substation and expansions, tower foundations and work areas, and access roads. Clearing of trees and shrubs make the soil more susceptible to erosion, mass movement, and dust generation as the soils under these plants are now exposed to wind and precipitation. Right-of-way and access road clearing also increase storm water runoff. This will be a long-term and permanent impact for towers and substations as these areas will no longer have accessible soil after construction. Impacts from construction camps will be short-term and temporary, as these areas will only be used during construction activities.
- The installation of tower foundations in rocky terrain/granite outcrops may require blasting activities. Blasting in high slope areas could generate sound and seismic waves that could trigger mass movement of soils. In addition, blasting could fracture supporting bedrock and produce mass movement of overlying soil in high sensitivity areas. Blasting for tower foundations will also result in the removal of vegetation and topsoil and near- surface rock. This will remove the natural erosion and wind control elements and make the soil susceptible to increased erosion and dust generation. If not repaired, this could be a long-term and permanent impact for towers and substations as these areas will not be accessible after construction.
- The installation of tower foundations and towers in inaccessible terrain may require the use of helicopters. Rotor vibration and noise from the helicopters could trigger mass movement of soils.
- Soil contamination can occur from the use, improper handling and spills of hazardous materials, such as insulating oils, wood preservatives, paints, and other toxic substances which could be used during the construction of the project. This will be a short-term impact with a potential to become a long-term impact without mitigation measures.

5.4.3.2 Operation and Maintenance

The main impact on soils during operation and maintenance of the project will be the increase in vulnerability of soils erosion and potential for soil contamination. The following types of operation and maintenance activity could lead to potential soil erosion and contamination:

- Vehicle traffic along access roads and ROW during construction may cause soil compaction, soil rutting, and dust generation. Additionally, mud could be carried off the site on vehicle tires and could result in sedimentation in off-site areas. This will be a short-term impact likely to occur every five years with a potential to become a long-term impact without mitigation measures.
- Rotor sound/vibration impacts associated with operations and maintenance in areas that require helicopter access.
- Periodic clearing of vegetation as part of normal right-of-way and access road maintenance activities may make the soil more susceptible to erosion. Right-of-way and access road clearing also increase storm water runoff. This could be a long-term and permanent impact along right-of-way areas that are presently shrub land and forest as these areas will not be allowed to fully revert to these habitats.
- Soil contamination can occur from the use, improper handling and spills of hazardous materials, such as insulating oils, wood preservatives, paints, and other toxic substances which could be used during the operation and maintenance of the project. Vegetation control techniques that use herbicides can introduce environmental contaminants into the soil and adjacent habitats. This will be a short- term impact with a potential to become a long-term impact without mitigation measures.

Once construction is complete, there should be minimal need for vehicles to travel along the right-of-way and access roads except for periodic vegetation management activities and response to tower/line damages from vandalism or natural causes. The extent of soil impact during operation and maintenance will be substantially lower than during construction and has been characterized as negligible.

5.4.4 Potential Soil Pollution Types within the Project Area

5.4.4.1 Soil Erosion Impacts

Loss of vegetation and soil compaction increases the vulnerability of the soils to erosion. It is difficult for vegetation to re-colonize bare and compacted areas, so once vegetation is lost, the areas affected by erosion tend to spread through the effects of wind and rain. Soils will be particularly vulnerable during wet weather, when vehicle traffic is likely to cause the greatest damage.

Erosion of exposed soil and the resulting sediment that is produced can occur from project development, causing air (from dust) and water pollution (from sedimentation). As indicated above, earthmoving activities such as vegetation clearing, grading and grubbing for site preparation, and heavy equipment hauling over unpaved ground, may loosen soils and cause fugitive dust and particulate matter to become airborne. Soil erosion can adversely affect water quality and biological communities in receiving water bodies due to increases in turbidity and rates of sediment deposition. The potential risk for erosion is increased by siting project components in areas with steep slopes, unstable soils such as peat, humus and alluvial soils, and clays which are fine-grained and susceptible to dust and erosion in dry conditions. Additionally, the potential risks to water quality are increased with proximity to stream, rivers, and lakes.

Damage to soils has further effects on land-use. When soil is compacted, it cannot support the native grasses, and this in turn reduces the pasturage that can be used by the livestock of local herders. In addition, the loss of grass affects biodiversity, since grassland is a food source for small mammals, which in turn provide food for predators.

5.4.4.2 Soil Contamination Impacts

Soil contamination can occur from the use, improper handling, and spills of hazardous materials, such as insulating oils, wood preservatives, paints, herbicides/pesticides, and other toxic substances which could be used during the construction, operation, or maintenance of the project. Substations will use transformers and may also use treated wood poles. Paints, fuel, and other hazardous materials are often stored at substations as well in maintenance shops. Vegetation control methods at substations and along rights-of- way may use herbicides and pesticides.

The towers and conductors should not present a significant impact with respect to soil contamination. The conductors are Aluminum, which is a naturally occurring element in soils. The towers are made of steel, a composite of iron and carbon which are both also naturally occurring elements. Additionally, the leaching potential for these elements from these structures is extremely low. Paint, if used on the towers, could present a potential impact to soil, if spilled or applied improperly.

- **Insulating oils.** Polychlorinated Biphenyls (PCB) were widely used as a dielectric fluid to provide electrical insulation, most commonly found in transformer equipment. Although their use has been largely discontinued due to potential harmful effects on human health and the environment, some of the equipment for this project could contain PCB insulating oils.
- **Wood pole preservatives**. While wood preservatives should not pose a risk along the transmission route due to the use of steel tower structures, there may be some soil contamination impact from leaching of preservative treated wood used at the substations. Poles are typically treated with creosote or Chromated copper arsenate.
- **Petroleum fuels and lubricants**. Liquid petroleum fuels and lubricants for vehicles and other equipment pose a risk of contaminating soils if spilled or leaked during construction as well as during operations and maintenance activities.
- **Herbicides and Pesticides.** All vegetation control along the right-of-way and at the substations will be done mechanically; so there will be soil contamination. However, should this practice be changed, herbicides and pesticides could pose a considerable risk to the soils and adjacent water bodies carried on eroded particles. If herbicides and pesticides are to be use, mitigation measures should be applied to ensure they do not impact nearby soils or water bodies.
- **Paints**. Paints are likely to be used on substation components and buildings and may be used on the towers. Spills of stored paint and drips from painted equipment could directly contaminate the soils.

5.4.5 Areas Likely to be Polluted

The areas likely to be polluted are areas where there is active construction, installation, storage and maintenance activities (see Table 5-37). These areas include the substation and the construction storage sites and the possible pollutants are lubricants and fuel. A 50m buffer was designed around the five substations using ArcGIS software to determine the Soil Province that are likely to be polluted. Each substation is located within one Soil Province as shown below:

Table 5-37: Areas vulnerable to soil contamination

Substation	Soil Province
Kamakwie	K - Escarpment granite and acid gneiss under savanna.
Yiben	N - Plateau granite and acid gneiss under savanna.
Bumbuna	J - Escarpment granite and acid gneiss under secondary bush and forest.
Bikongor	M - Plateau granite and acid gneiss under secondary bush and forest.
Kenema	L - Upper moa basin

5.5 Biodiversity (Flora & Fauna)

The desk study describes the impacts to ecosystems, flora, and fauna from construction, operation and maintenance of the project. Impacts to dominant flora, known fauna, and potential species of special concern (for example, from the International Union for Conservation of Nature (IUCN) Red Lists) are assessed for each ecosystem, and a description of the specific habitat requirements for each protected species is provided. Furthermore, the desk study specifically describes the direct and indirect impacts of the project with respect to habitat alteration, the increased risk of forest fires (an impact to habitats/ecosystems), and avian and bat collision/electrocution (an impact to fauna) consistent with the IFC/WBG Environmental, Health, and Safety Guidelines for Electric Power Transmission and Distribution (IFC/WB, 2007).

5.5.1 National Context

The main eco-zones in Sierra Leone can be divided into two categories: terrestrial and aquatic. Forest, montane, savannah and agricultural ecosystems fall under terrestrial; whilst, wetlands, freshwater, coastal and marine ecosystems are classified under aquatic systems. Of all these ecosystems, there is evidence that the lowland rainforest ecosystem is the most endowed in species richness, diversity and endemism. Half of Sierra Leone is a low-lying plain with swampy areas, inland, the terrain rises to a hilly plateau extending northward to the Guinea border. The eastern flank of the country has important mountains – mount Bintumani (about 1,940 m) is the second highest point in West Africa, and Sanka Biriwa (1,715 m) in the Tingi Hills. Sierra Leone has 295,950 ha of forest, game reserves and national parks and 32,000 ha of community forest. Approximately 15,000 plants species have been identified with an estimated 5,250 species are found useful[4].There are six main ecosystems in Sierra Leone; namely: Forest, Montane, Savannah, Agricultural, Wetlands and Freshwater, and Coastal and Marine Ecosystems (NBSAP 2003).

5.5.1.1 Vegetation

Tropical moist evergreen forest and moist semi-deciduous forest form the two types of forests in Sierra Leone and are found in the south-east and north of the country, respectively. The tropical moist evergreen forest is subdivided into lowland rainforest and montane. The Gola Forest Reserve is predominantly lowland tropical moist evergreen rain forest with small areas of moist semi-deciduous forest. The moist semi-deciduous forest needs less total rainfall, 2,000-2,500 mm annually with a four to five months long dry season. There are more deciduous trees (shedding leaves annually) but the total diversity of plants is less than in the tropical moist evergreen forest.

The Loma Mountains, Tingi Hills and Tama Tonkolili forest Reserve all have moist semi-deciduous forests. Widely spaced trees and tall grasses characterize savannah woodlands. These trees are fire resistant that grows only 7 m to 9 m. high. The abundant elephant grass can grow as high as 3 to 4m. Open savannah woodland supports a more limited variety of wildlife than the forest. Bolilands are depressions in the drainage areas of large rivers that flood in the rainy season, and by March are dry grasslands again. These areas provide fine grazing for buffalo because the soil is too moist for coarse elephant grass. Migratory waterfowl are attracted to the Boli when the water regime begins to recede in December. The flooding and drying of the soil offers a wonderful environment for the tiny invertebrates, snails, and worms that the birds eat. However, Bolilands are also attractive for rice cultivation.

[4] https://www.cbd.int/doc/world/sl/sl-nbsap-01-en.pdf Biodiversity: Strategic Action Plan (Accessed 4 January 2018)

5.5.1.2 Wetlands and Freshwater

There are two types of aquatic environments in Sierra Leone: fresh water lakes and rivers. There are 8 major river basins and 11 fresh water lakes in the country. The major river systems in Sierra Leone are the Great Scarcies, Jong (Maboleh) River, Little Scarcies, River Rokel (Seli), Kpamgbai River, Sewa River and Mano River. These rivers are usually bordered by palisade forests. It is designed to protect the water bodies from excessive evaporation and subsequent alteration of the hydrologic cycle including depletion of the water table. Because of the palisade forest, there is a dynamic food chain existing ranging from foragers and larger herbivores as well as carnivores. The rivers and streams themselves are rich in aquatic life such as scaled and non-scaled fish. Some common fish varieties include tilapia, catfish, eel, electric fish, crabs, and shrimps. They are a ready source of the protein component of the diet of the local communities. The lacustrine environments are rather small. The largest lake in Sierra Leone Sonfon. Most of the lakes are fed by fresh water streams. The others are: Lake Mape, Mabesi, Popei, Baiama, Masatoi, Kamason, Tibi, Kenema, Kwako, and the Gambia.

5.5.1.3 Agricultural Biodiversity

Agricultural biodiversity in Sierra Leone, as in the African region, has had a history of unique challenges. The crop cultivars that are currently grown are largely exotic breeds introduced into the farming systems unlike the livestock species and medicinal plants which are largely indigenous and well adapted to the agricultural biodiversity ecological systems. Rice mainly sativa species and the interspecific breeds (NERICA varieties), cassava, sweet potatoes, maize are some of the introduced staples. Sorghum and millet are little used cereal staples which together with Tabae beans, cowpea, pigeon pea, bambara ground nut, benniseeds and some vegetables (landraces) are indigenous to Sierra Leone. Fruit trees, namely citrus, mango, cashew and avocado, plantain, pineapple and banana are amongst the most recent introductions to the country. Some introduced commercial perennial crops are coffee, cacao, piassava, rubber, coconut and oil palm. Several indigenous wild tree species producing edible fruits and nuts exist in the agricultural biodiversity system.

In the livestock sector very little success has been recorded in terms of genetic improvement for beef and milk production. Most high yielding introduced breeds of animals intended for use in hybridization programmes across the country perished as a result of disease infestations. The indigenous livestock are N'dama cattle, West African dwarf and Djalonke sheep and Goats that are tolerant /resistant to both Trypanosomiasis and Streptothricosis. Other livestock are pigs (local and exotic), poultry (local and exotic), rabbits and Guinea pigs.

5.5.1.4 Fauna

The transmission line traverses and bypasses numerous forest reserves, most prominently the Kambui Hills, Nimini Hills, and Outamba Kilimbi, which houses many animals, including large mammals both vulnerable and endangered, and are designated Important Bird Areas (IBA) in Sierra Leone. Comprehensive species list for the Project site is yet to be established but however, based on previous extensive studies within Sierra Leone's forests, the following species list are those that are of conservation concerns within the project site.

5.5.1.4.1 Birds

The avifauna of the West African sub-regional level mainly comprises species restricted to the Guinea-Congolian forest biome, which extends from southern Republic of Guinea to the Democratic Republic of Congo, and the Sudan-Guinea savanna biome, which extends between the Republic of Guinea and Republic of Sudan. The Guinea-Congo biome, covers a total land area of 3,630,000 sq. km and supports approximately 274 species of birds restricted to it across 24 countries (Fishpool and Evans, 2001). These species are mainly associated with forest biomes, comprising species that are exclusively forest-dependent to those that can tolerate and survive in degraded or secondary forests. According to Fishpool and Evans (2001), 160 sites (accounting for 7% of the Guinea-Congo forest biome land area) have been identified across this region as Important Bird Areas on the basis that they support a significant assemblage of species restricted to the Guinea-Congo forest biome.

BirdLife International Endemic Bird Area (EBA) concept identifies the Upper-Guinea forest (EBA 08) as an endemic bird area, which extends into Sierra Leone. According to BirdLife (1998), an EBA is an area

that contains habitats that supports a unique assemblage of avian communities, including species with global range equal to or less than 50,000 sq. km. EBAs cover about 5% of the world land surface, but their biological richness makes them high priorities for ecosystem conservation. The natural habitat of most EBAs is forest, especially tropical lowland forest and highland closed forest, often comprising islands or mountain ranges, and varying in size from a few square kilometres to over 100,000 km^2. There are many other EBAs in Africa, but the Upper-Guinea Forest is the only one in West Africa, supporting 15 known endemic species. Sierra Leone has 14 of the 15 endemic bird species that occur in the Upper-Guinea Forest.

A significant number of bird species found in the biomes and related ecosystems are considered as species of global conservation concern, including species categorised as threatened (Critically Endangered, Endangered and Vulnerable) and those that are near threatened and data deficient. Fishpool and Evans (2001) identified 324 species of global conservation concern distributed in 824 sites in Africa. Within the Upper Guinea many of the restricted range species are also species of global conservation concern. In Sierra Leone for instance, 12 of the 14 Upper Guinea endemics are globally threatened and one is near threatened. The entire south-eastern region of the country incorporates areas within the western extent of the Guinea-Congo forest biome and the Upper Guinea forest. Thus, the list of species found in the project is expected to reflect the biogeographic setting of this zone and the avifauna associated with the forest ecosystem that predominate the ecology of the area. Table 8-15 gives data on the species of global conservation concern in Sierra Leone:

5.5.1.4.2 Mammals

According to the Important Bird Area (IBA), (Okoni-Williams 2004, et al) record, there are 178 known mammal species, including 15 species of primates, of which six are globally threatened in Sierra Leone. However, ERM (2013) consolidated sources states the presence of approximately 226 mammal species in Sierra Leone of which 20 are globally threatened. This is clearly indicating the need for a national effort in rectifying these inconsistencies in records on mammals of the country. Due to the fact that mammals use a variety of habitats and sometimes forage in stretches of forest and adjacent areas, it is expected that the mammal diversity of the project site may be greatly influenced by forests along the transmission lines.

5.5.1.4.3 Amphibians and Reptiles

Present IUCN record for amphibians in Sierra Leone is 55, but from 2012 to 2015, the Reptile and Amphibian Program - Sierra Leone (RAP-SL) has added eight species to the list. This is now summing up the total of amphibian species to 63 known to occur in Sierra Leone.

For reptiles, their number and the understanding of their distributions are incomplete as there is no comprehensive record of the species for the country. Reviews of different reptile genera have been published that include species occurring in Sierra Leone (e.g. Hoogmoed, 1974; Böhme, et al. 2000). Unlike the IUCN internet-based database for amphibians, there are several claims of lists of reptiles of Sierra Leone. Internet based Wikipedia is stating 67 reptile species where as a desperate review by ERM (2013), indicates the presence of 115 reptile species. The RAP-SL has so far (in two years' time), recorded 60 reptile species in the country.

Studies in the Gola Forest in 2009 indicate the presence of at least 41 frog and 12 reptile species, including two first national records (*Amietophrynus superciliaris* and *A. taiensis*). In combination with the results of previous surveys in the region, the number of species known to occur in the Gola area, including Tiwai Island, sums up to 43 amphibian and 13 reptile species (Hillers, 2009). Most of the amphibian and reptile species recorded are forest species and are interestingly noted to be restricted to the Upper Guinea Forest zone.

Of the 43 amphibians recorded, 14 are of IUCN conservation concern, while two of the reptile species are protected by CITES (Table 8-17).

5.5.1.4.4 Fish

According to records of the www.fishbase.org (2007, 2014), there are 167 freshwater fish species of 38 families in Sierra Leone but so far, research efforts in the country have documented 16 families comprising 100 species. The major fish species include *Brycinus longipinnus, Epiplatys fasciolatus, Hepsetus odoe, Ctenopoma kingsleyi, Hemichromis fasciatus, Tilapia sp., Clarias lazera, Clarias laeviceps and Mormyrus macrophaalus*. There are also several species of catfish *(Bagrus bayad, Synodontis nigrita, Clarias platycephalas, Clarias lazera and Chysichthys furcatus)* found in lakes, rivers and Lagoons (Payne, 1986 cited in NBSAP, 2003). Over the years, bulk of the freshwater fishes in sub Saharan Africa were not classified under IUCN- red-listing criteria but recent intervention has classified majority of the fish species within the region and almost certainly majority are regarded as Least Concern while few are regarded as Data Deficient or Not unevaluated species.

5.5.2 Project Area Baseline

5.5.2.1 Flora

The vegetation along the TRANSCO CLSG transmission line shows a high variety of different habitats ranging from mixture of primary forest, shrubs, wetlands and patches of cultivated areas including plantations (cocoa, coffee, kola-nut and oil palm), vegetables and rice farms by locals. The transmission line cuts across contiguous parcel of land with patches of areas that are of locally High Conservation Value (HCV) areas. The locally HCV areas within the corridor include patches of secondary and riverine forests, swamp edges and watersheds. Around the Moa and the east is Gola West, the Lowland Rainforest dominates the north of Pujehun District which is interspersed with some moist semi-deciduous forests. Towards the north, protruding into Kenema District around Kambui South, are forest reserves (Dodo and the Nimini Hills) and further north is the Outamba Kilimi National Park (OKNP) in Bombali District. The areas of designated reserves (276,800 ha) indicate that they constitute only about 5% of the total land area of the country Sadly enough, even these reserves are subjected to deforestation and resource degradation just like off-reserve areas, for satisfying man's insatiable demand for forest products.

Moist closed evergreen forest - occurs at low to medium altitude where rainfall is over 3000mm with 7-9 wet months. It is now largely restricted to forest reserves. Typical tree species include *Heriteira utilis, Uapaca guineensis, Cryptosepalum tetraphyllum, Lophira alata, Diospyrus elliota, Brachystegia leonensis, Pentachetra macrophylla, Mimusops heckelli, Parinari excelsa, Funtumia africana, Xylopia aethiopica* and *Erythrophylum ivorensis.* within the project area, this type of forest is found as gallery forest and in sacred groves in all the eleven segments from the Liberian border in the southeast to the Guinea border in the northwest of the transmission line This forest types is an important stabilizer of local climate as well huge genetic reservoirs for flora and fauna that are important to the local community and the country as a whole in perpetuity.

Moist semi-deciduous forest - occurs mainly between 300 m and 1000 m and constitutes the predominant vegetation types on most of the mountains (Loma 86.3km from the transmission close to Kamabai). It is found associated with forest-savanna mosaic and gallery forest of the southern Guinea savanna. The common tree species are *Chlorophora regia*, *Terminalia ivorense*, *Piptadinia africanum*, *Entandrophragma* sp, *Afzelia* sp, *Oldfieldia africana*, and *Daniella thurifera*. Moist closed evergreen and semi-deciduous forest together currently cover only about 5% (ca 365,200 ha) of the country's land area. Some portions of this king of forest occur around the Gisinolo village. Moist semi-deciduous forests are equally important to local communities and the country as moist closed evergreen forest.

Moist secondary forest - found across the interior plain and in most cases contiguous with closed canopy forests. Oil palm *Elaesis guineensis* is usually associated with this forest type. Coffee and cacao plantations occupy large portions in the southeast (SG01 to SG05). Other tree species include *Anisophyllea* sp, *Musanga smithii*, *Chlorophora regia*, *Terminalia* sp, *Macrolobium dawei*, *Bridelia ferruginea*, *Berlinia* sp and *Uapaca* sp. This accounts for 3.6% (ca 261,000 ha) of the country's land area. This is among the most common forest types across the entire expanse of the project concession area and is usually contiguous with farmbush. The local people get most of their timber, building poles, wild fruits and medicinal herbs from moist secondary forest.

Farmbush/forest regrowth - occurs in proximity to all other forest formations especially in unprotected areas. It has replaced most of the original forest, mainly as a result of unplanned agricultural activities and occupies up to 52% (ca 3,774,400 ha) of the country's total land area. Common tree species are *Carapa procera, Musanga cercopoides, Anthocleister nobilis*, *Canthium globiglorum* and *Parinari excelsa*. Oil palm *Elaeis guineensis* is very common. Farmbush is the most common vegetation types, occupying large portions of land in the project concession and inundating most secondary forest. Farmbush vegetation is one that is usually under a cyclic fallowing system whereby they are cleared for farming over a one to two year period and subsequently left to fallow for a longer period. This cyclic system of bush fallowing, which replenishes nutrient in upland agriculture is very important for sustaining crop yield for the local people; invariably, farmbush with longer fallow produce higher crop yield. The farmbush is also important for the supply of wood, charcoal, medicinal herbs and wild tuber and fruits to the local communities.

5.5.2.1.1 Diversity of Plant Species

A total of 175 species belonging to 60 vascular plant families have been recorded by various studies. This includes six species of trees that are listed by IUCN (2015) – *Afzelia africana, Copaifera salikunda, Hallea stipulosa, Lophira alata, Nauclea diderrichii* and *Terminalia ivorensis*, all of which are categorized as vulnerable (VU). The diversity of plant species also includes 21 species of fruits, and 19 species used as medicinal plants (see Table 8-14). The 175 species of plants recorded can be subdivided into five different growth forms as presented in (see Table 8-14), with trees constituting nearly 50% (83 species) of the growth forms recorded. Trees are generally the most utilised of all growth forms for purposes such as timber, wood, medicines and food, although shrubs constitute the most common plants among the wild fruits plants identified.

5.5.2.1.2 The diversity of Fruit Trees

Previous studies within the areas in close proximity to the project area have recorded twenty-one species of fruit trees (see Table 8-14), among which at least 15 species are commercialized and/or domesticated. Fruit trees such as oil palm *Elaeis guineensis*, coffee *Caffea liberica* and cacao *Theobroma cacao* produce major cash crops that determine the socioeconomic status of farming families and they also constitute important agro-based future investment of the family. Most of the farmbush ecologies are inundated by oil palm stands, an indication of the importance of oil pam to the local economy, which is also a reflection of what obtains generally among local farming communities in the country. Small-scale plantations of oil palm, coffee and cacao were also encountered close to the village settlements visited.

5.5.2.1.3 Diversity of Medicinal Plants

In total, 38 species of plants of 18 families used for medicinal purposes have been recorded around the project area. Trees (21 species) make up the most common medicinal plant species recorded, one of which *Nauclea diderrichi* is globally threatened; followed by shrubs. Medicinal plants are very important to the health of the inhabitants of the local communities in and around the project concession zone. The inhabitants of these communities make concoctions from roots, barks or leaves of these plants for their health needs and these are used to treat a wide range of diseases and ailments, from common fever-related ailments to bone fracture and abortion (Lebbie and Guries, 1995). Lebbie and Guries (1995), identified 82 species of plants in sacred groves used by people in southern Sierra Leone for preparation of 75 different medicinal remedies; 25 of these medicinal plant species were recorded during this survey. The report underlies the importance of sacred groves to the maintenance of biodiversity and ecosystem services in local ecologies.

5.5.2.1.4 Diversity of timber trees

In total, 38 species of plants of 18 families used for medicinal purposes are common within the project area. Trees (21 species) make up the most common medicinal plant species recorded, one of which *Nauclea diderrichi* is globally threatened; followed by shrubs. Medicinal plants are very important to the health of the inhabitants of the local communities in and around the project concession zone. The inhabitants of these communities make concoctions from roots, barks or leaves of these plants for their

health needs and these are used to treat a wide range of diseases and ailments, from common fever-related ailments to bone fracture and abortion (see Lebbie and Guries (1995). Health clinics are very few and far between in these communities and so they heavily rely on medicinal plants to address their health needs. Lebbie and Guries (1995), identified 82 species of plants in sacred groves used by people in southern Sierra Leone for preparation of 75 different medicinal remedies; 25 of these medicinal plant species were recorded during this survey. The report underlies the importance of sacred groves to the maintenance of biodiversity and ecosystem services in local ecologies.

5.5.2.2 Fauna

The transmission line bypasses numerous forest reserves, most prominently the Gola forest, Kambui Hills, Nimini Hills, and Outamba Kilimbi, which houses many animals, including large mammals both vulnerable and endangered, reptiles, amphibians, birds, and fish (fresh water fishes). Comprehensive species list within the Project site is yet to be established but however, based on previous extensive studies within Sierra Leone's forests, the following species list are those that are of conservation concerns within the project site.

5.5.2.2.1 Mammals

A totat of 18 mammal species are known to be popular within the project area. Of the 18 species, two (*Cercocebus atys and Hydrictis maculicollis* are species of IUCN conservation concern). The *Cercocebus atys* is Vulnerable while the *Hydrictis maculicollis* is near threatened. About seven primates' species were recorded within the boundary area between the Nimini Hills, leakage belt and the Gola forest. Three of the primates species including Diana Monkey, Sooty Mangabey and Chimpanzee were heard from a pocket of forest located to the north east (Tama &Tonkoli) in the concession and along the Mano river to the south east.

5.5.2.2.2 Herpetofauna (Reptiles and Amphibians)

Amphibians and reptiles are found in almost all the habitat types within the project area, from forests to grasslands. Many species use different habitats during different times of the year. Amphibians often require both aquatic and terrestrial habitats because of their unique life cycles. Depending on the species and geographical area, they may require damp areas (creeks, streams, swamps, mud puddles, and ponds – especially in SG01), moist soil, and/or places to burrow in order to keep their skin moist. they generally breed and lay eggs in wetlands and other aquatic habitats, some of which exist for only short periods during the year (after rains), and then move to terrestrial areas. Amphibians use a wide range of terrestrial habitats adjacent to wetlands and streams, typically consisting of leaf litter, coarse woody material, boulders, small mammal burrows, crack in rocks, spring seeps, rocky pools, and even grasslands.

Some reptiles have general habitat requirements, while others have specific ones. They can live in terrestrial, aquatic, or riparian habitats. Those that inhabit riparian habitats are not considered aquatic, but they are strongly associated with riparian-upland transitional zones. Some reptiles live and forage in aquatic habitats most of the year but move to upland habitats to nest. Within grasslands, woodlands, and wetlands, reptiles require habitats that provide thermal gradients ranging from cool shelters to warm basking areas that receive exposure to full sun. Reptiles also require suitable aestivation habitats to which they can escape during times of environmental extremes. Thermal and aestivation habitats may be present in the form of large woody material, brush piles, rock piles or outcroppings, animal burrows, or huts. These same habitats provide nesting habitat for many snakes and lizards, while nesting habitat for turtles may be found within areas of loose or sandy soil exposed to full sun and protected from flooding. Amphibians and reptiles are a diverse group and their habitat requirements vary greatly from species to species.

The project area generally constitutes some appropriate habitats for reptiles and amphibians (SG01, SG04) owing to the fact that all required habitat types for the species' survival are present in these areas. The habitats include secondary forests, farm bush, wetlands (swamps and streams) and grasslands.

5.5.2.2.3 Birds

A range of 140-146 species distributed into 36 avian families are common within the project area. Four species of global conservation concern were recorded: the endangered Hooded Vulture *Necrosyrtes monachus*, the vulnerable Yellow-casqued Hornbill *Ceratogymna elata* and African Grey Parrots *Psittacus erithacus,* and the near threatened Rufous-winged Illadopsis *Illadopsis rufescens*. Two species restricted to the Upper Guinea forest were encountered: Sharpe's Apalis *Apalis sharpie* and Rufous-winged Illadopsis *Illadopsis rufescens*. Sixty-seven species restricted to the Guinea-Congo forest biome and two species restricted to the Sudan-Guinea savanna were recorded. Of the total number of species recorded 91% (134 species) are residents with proof of breeding, whilst 9% (2 species) are migratory, four of which are Palaearctic migrants and six are intra-African migrants.

5.5.2.2.4 Fish

A total number of 16 families of fish comprising 100 species have so far been documented from the freshwater ecosystem. However, record from www.fishbase.org for Sierra Leone freshwater fish species is 167 (Eagbayani, 2007; Dsantos, 2014). Efforts by Sierra Leoneans in documenting freshwater fish species in the country have largely been from the Rokel and Taia Rivers since these two are the most widely studied rivers in the country. The two rivers are located in the northwest of the project site and are both connected to the Atlantic coast either directly (Rokel River) or in directly (Taia River) via the Jong River. It is very likely that their accessibility might have resulted in the extensive studies carried out by both students and scientists (local and international). There are about 27 rivers in the country among which are brackish and fresh water ecosystems. Most of the fish species that occur within the rivers include *Brycinus longipinnis, Epiplatys fasciolatus, Hepsetus odoe, Ctenopoma kingsleyi kingsleyae, Hemichromis fasciatus, Tilapia sp., Clarias gariepinus, Clarias laeviceps and Mormyrus macrophaalus.* Important families, as in most African rivers, include Cichlidae, Cyprinidae, Mormyridae, Characidae and Clariidae (Payne et al, 2006 cited in BHEP, 2006). Several species of catfish including *Bagrus bayad, Synodontis nigrita, Clarias platycephalas, Clarias lazera* and *Chysichthys furcatus* also occur in the rivers, lakes and lagoons (Payne, 1986, NBSAP, 2013).

5.5.3 Biodiversity Transversed by Transmission Line

Three buffers (400m, 600m, and 1km) were delineated along the transmission line using GIS to get the land cover types that are within the transmission line. The land cover dataset was clipped with the three buffers and eight land cover types within the transmission line were extracted. Table 5-39 shows the land cover types trasversed by the transmission line, including the segment identification.

The Protected areas of Sierra Leone, include national parks, game reserves, conservation areas and wetlands. In total there are about 55 of them; five of which (Gola Forest, Tiwai Island Sanctuary, Kambui Hills, Nimini Hills and Outamba-Kilimi) are sensitive areas and are in close proximity to the proposed transmission line. The transmission line transverse five major rivers Great Scarcies, Little Scarcies, Rokel, Sewa and Moa) at six different points and nine open water bodies (lakes and reservoir) in six segments (SG04, SG05, SG6, SG7, SG8 and SG9) using the 1km buffer.

Table 5-38: Transmission line segment identification

Segment ID	Segment Name
SG01	Liberia Border to Vaama Barri
SG02	Vaama Barri to Mano Junction
SG03	Mano Junction to Lago Jasawabu
SG04	Lago Jasawabu to Kangama Gorama
SG05	Kangama Gorama to Njagbwema Nimikoro
SG06	Njagbwema Nimikoro to Makoni Line
SG07	Makoni Line to Kajida
SG08	Kajida to Kamabai
SG09	Kamabai to Fadugu
SG10	Fadugu to Kamakwie
SG11	Kamakwie to Guinea Border

Table 5-39: Land cover types along the transmission line segments

Segment ID	Segment Name	Classification	Description
SG01	Liberia Border to Vaama Barri	A,B,C,D,E,F,H	**A** - Tropical moist evergreen and moist semideciduous forest **B** - Dense group of bushes and trees **C** - Sparse trees and Boli land **D** - Shrub and small tree that grows in coastal saline or brackish water **E -** Thick deposits of clays and silt at the foot of terraces **F** - Mud, burnt farm land and rocks **H** - Rivers
SG02	Vaama Barri to Mano Junction	A,B,C,E,F,H	**A** - Tropical moist evergreen and moist semideciduous forest **B** - Dense group of bushes and trees **C** - Sparse trees and Boli land **E -** Thick deposits of clays and silt at the foot of terraces **F** - Mud, burnt farm land and rocks **H** - Rivers
SG03	Mano Junction to	A,B,C,E,F	**A** - Tropical moist evergreen and moist semideciduous forest

Segment ID	Segment Name	Classification	Description
	Lago Jasawabu		**B** - Dense group of bushes and trees **C** - Sparse trees and Boli land **E -** Thick deposits of clays and silt at the foot of terraces **F** - Mud, burnt farm land and rocks
SG04	Lago Jasawabu to Kangama Gorama	A,B,C,E,F,G	**A** - Tropical moist evergreen and moist semideciduous forest **B** - Dense group of bushes and trees **C** - Sparse trees and Boli land **E -** Thick deposits of clays and silt at the foot of terraces **F** - Mud, burnt farm land and rocks **G** - Lakes and reservoir
SG05	Kangama Gorama to Njawema Nimikoro	A,B,C,F,G	**A** - Tropical moist evergreen and moist semideciduous forest **B** - Dense group of bushes and trees **C** - Sparse trees and Boli land **F** - Mud, burnt farm land and rocks **G** - Lakes and reservoir
SG06	Njawema Nimikoro to Makoni Line	A,B,C,E,F,G,H	**A** - Tropical moist evergreen and moist semi-deciduous forest **B** - Dense group of bushes and trees **C** - Sparse trees and Boli land **E -** Thick deposits of clays and silt at the foot of terraces **F** - Mud, burnt farm land and rocks **G** - Lakes and reservoir **H** - Rivers
SG07	Makoni Line to Kajida	A,B,C,E,F,G,H	**A** - Tropical moist evergreen and moist semideciduous forest **B** - Dense group of bushes and trees **C** - Sparse trees and Boli land **E -** Thick deposits of clays and silt at the foot of terraces **F** - Mud, burnt farm land and rocks **G** - Lakes and reservoir **H** - Rivers
SG08	Kajida to Kamabai	A,B,C,E,F,G,H	**A** - Tropical moist evergreen and moist semideciduous forest **B** - Dense group of bushes and trees **C** - Sparse trees and Boli land

Segment ID	Segment Name	Classification	Description
			E - Thick deposits of clays and silt at the foot of terraces **F** - Mud, burnt farm land and rocks **G** - Lakes and reservoir **H** - Rivers
SG09	Kamabai to Fadugu	A,B,C,E,F,G	**A** - Tropical moist evergreen and moist semideciduous forest **B** - Dense group of bushes and trees **C** - Sparse trees and Boli land **E -** Thick deposits of clays and silt at the foot of terraces **F** - Mud, burnt farm land and rocks **G** - Lakes and reservoir
SG10	Fadugu to Kamakwie	A,B,C,E,F	**A** - Tropical moist evergreen and moist semideciduous forest **B** - Dense group of bushes and trees **C** - Sparse trees and Boli land **E -** Thick deposits of clays and silt at the foot of terraces **F** - Mud, burnt farm land and rocks
SG11	Kamakwie to Guinea Border	A,B,C,E,F,H	**A** - Tropical moist evergreen and moist semideciduous forest **B** - Dense group of bushes and trees **C** - Sparse trees and Boli land **E -** Thick deposits of clays and silt at the foot of terraces **F** - Mud, burnt farm land and rocks **H** - Rivers

Table 5-40: Eco-sensitive zones within the Project Areas

Segment ID	Segment Name	Sensitive Area
SG01	Liberian Border - Vaama Barri	Tiwai Island Sanctuary
SG02	Vaama Barri - Mano Junction	Gola Forest
SG03	Mano Junction - Lago	Kambui Hills
SG05	Kangama Gorama - Njagbwema Nimikoro	Nimini Hills
SG11	Kamakwie to Guinea Border	Outamba-Kilimi

5.5.3.1 Segment SG01

SG01 stretches approximately 58.2 km along the transmission line, extending from the Bomborhun at the Liberian border in the south of Sierra Leone northwards through Zimmi in Makpele Chiefdom to Vaama Barri. Within this segment lies some forest and game reserves in the south-east of the country (Tiwai Island Sanctuary – 2.8 km; Lalay – 10.9 km; Massaawei – 13.2 km; Sami – 15.5; and Kpassambu – 23.4 km from the transmission line) in Pujehun district and the Gola Forest in Kenema District, which extends into Kailahun District east of the proposed transmission line.

The segment is characterized by seven land cover types – Forest, Thicket, Grass, Mangrove, Swamp, Bare Ground and River. The most common feature in this segment is forest (tropical moist evergreen and moist semideciduous), thicket, and grass. Compressively the bare ground covers also a significant portion of this segment which comprises burnt farm land, mud and rocks. With hand full of mangrove and swamps the secondary forest, farm bush vegetation is the dominant type of vegetation that is periodically and strategically cleared for farming through the observation of local bush fallow system. The vegetation shows a high variety of different habitats ranging from mixture of shrubs, wetlands and patches of cultivated areas including plantations (cocoa, coffee, kola-nut and oil palm), vegetables and rice farms by locals.

Around the Moa River and east of the proposed transmission line is Gola (Forest) West, which is approximately 11 km away from the corridor; the Lowland Rainforest dominates the north of Pujehun District. This is interspersed with some moist semi-deciduous forests. Being close to the Gola Forest, the forest houses many animals including mammals both vulnerable and endangered. Different bird (Sierra Leone Prinia *Prinia leontica* etc) species and reptiles are also found in this segment.

5.5.3.2 Segment SG02

SG02 stretches along the route from Vaama Barri to Mano Junction, in Kenema District, with an approximate length of 63.3 km. Within the segment lie the Kambui Hills, and Kambiu Hills South on which a forest reserves in close proximity (approx. 1.9 km and 6.3 km, respectively) to the transmission line is situated. There are six land cover types in this segment (Forest, Thicket, Grass, Swamp, Bare Ground and River). The transmission within this segment traverses the Moa River at two points on its path towards Kenema District.

The vegetation of this segment shows a variety of habitats ranging from mixture of shrubs, wetlands and patches of cultivated areas including plantations vegetables and rice farms by locals. The forest, thicket and grassland vegetation types are the most common features in this segment. Moreover, the segment is also characterized by bare ground surfaces, including rocks, mud and farm bushes cleared for farming by locals in the area. In addition to agricultural land uses, prominent within this segment towards the north of country are commercial timber logging activities.

5.5.3.3 Segment SG03

SG03 extends from Mano Junction to Lago Jasawabu (both towns fall within Nongowa Chiefdom in Kenema District). Being the shortest segment along the transmission, SG03 stretches just about 2.9 km, bypassing the Kambui Hills.

The segment is characterized by five land cover types in this segment - Forest, Thicket, Grass, Swamp and Bare Ground.

Within the segment lies a couple of seasonal streams that support catchment areas for supply of water to surrounding communities. The vegetation in the reserve is closed forest belonging to the Upper Guinea forest zone. However, the hills have been extensively logged with the forest still accessible through existing logging roads.

5.5.3.4 Segment SG04

Stretching for approximately 36.6 km along the transmission line from Lago Jasawabu to Kangama Gorama, SG04 is characterized by seven land cover types, including Forest, Thicket, Grass, Bare Ground and Open Water. The mostly secondary forest vegetation consists of some fruit trees and economic tree crops mostly found close to the settlements. A diversity of forest tree species heterogeneously distributed is also characteristic of the secondary forest. The trees identified include

mango (*Mangifera indica*), oil palm (*Eleais guineensis*), banana (*Musa sapientum*), oranges (*Citrus sinensis*), breadfruit (*Artocarpus communis* var.), cacao (*Theobroma cacao*) and coffee (*Coffea* spp.) (which are cultivated under the shade of the taller trees close to the settlements).

East of the transmission line within the segment lies: Gobi Hills - 20.6 km , Lhei Hills – 24.9 km, Tajayei – 19.1 km, and Gafele – 13.9 km; and towards the line is Dodo Hills – 6.2 km, and Nimini Hills South – 10.8 km.

5.5.3.5 Segment SG05

SG05 stretches between Kangama Gorama to Njagbwema Nimikoro for a distance of 33.3 km along the transmission line. Within this segment, the transmission line bypasses the Nimini Hills North and is flanked on the east by Mansayei and Sankan Biriwa Forest Reserves.

The segment is characterised by seven land cover types. However, the predominant land cover type within this axis of the transmission line is forests. The vegetation type commonly represents a degraded form of the once existing rain forest vegetation that has been cleared using the slash and burn method of cultivation, or by logging or for mining purposes. It is generally dense with very tall trees of up to 30 m and moderately-closed to closed canopy. Seedling growth has formed a rather dense undergrowth of shrubs which do not, however, hinder penetration into the forest. Lianas are also evident and so is the sword/razor grass (*Scleria barteri*) which occurs in clumps. The vegetation found around settlements is also included in this category because of the heights of the trees and vegetation density. These mainly comprise fruit trees and economic tree crops.

5.5.3.6 Segment SG06

SG06 extends from Njagbwema Nimikoro to Makoni Line in Tonkolili District for a distance of approximately 61.3 km. Segment six is characterized by seven land cover types - Forest, Thicket, Grass, Swamp, Bare Ground, Open Water and River. Within this segment, the transmission line bypasses the Tama Forest reserve by a distance of approximately 3 km, the Tonkoli Forest Reserve by distance of about 30.4 km, and traverses the Sewa River - a major river in the country flowing from the northeast of the country to the southwest where it empties itself into the Atlantic Ocean.

5.5.3.7 Segment SG07

This axis along the transmission line stretches from Makoni Line through Maguraka to Kajida a small town about 4 km from Bumbuna. The segment extends for a distance of approximately 70.3 km. There are seven land cover types in this segment, including Forest, Thicket, Grass, Swamp, Bare Ground, Open Water and River.

Within SG07 southwest of the transmission line lies Kangari Hills forest reserve and northeast – the Farengbaia forest reserve. Here, the transmission crosses the Pampana River, which flows from Lake Sonfon in the north of the country to the southwest into the Atlantic Ocean.

5.5.3.8 Segment SG08

SG08 stretches from Kajida in Tonkolili District through Binkolo to Kamabai in Biriwa Chiefdom, Bombali District. The segment extends for a distance of about 26.7 km along the transmission line. This segment is characterised by seven land cover types, including Forests, Thickets, Grasses, Swamps, Bare Ground, Open Water and River. Within SG08, the transmission line traverses River Rokel a major river flowing across the country from the north to the west, where it empties itself into the Sierra Leone River Estuary.

Previous studies in communities that are in close proximity to this segment show that there are about 51 species, including 22 amphibians and 29 reptiles, with many occurring in a wide range of habitats. The 51 species include frogs, crocodiles, geckos, snakes, chameleons, aganids and a monitor lizard.

5.5.3.9 Segment SG09

This segment extends from Kamabai stretching for a distance of about 38.9 km to Fadugu in Koinadugu District. The area around the transmission line segment is characterized by seven land cover types, including Forests, Thickets, Grasses, Swamps, Bare Ground. However, the predominant land cover type SG09 is savanna grasslands.

5.5.3.10 Segment SG10

SG10 extends from Fadugu to Kamakwie in the north of the country. Within this segment the proposed transmission line bypasses the Outamba-Kilimi National Park in Bombali District in its path to Kamakwie. The land cover types within this segment include, forest, thicket, grass, swamp and bare ground. The vegetation comprises mixed tree savanna, forest regrowth, upland grass and riverain grassland and each habitat with its own unique complement of animals. Most of the plant species have thick barks and are mostly fire resistant trees, producing suckers or coppiced shoots after burning. They are deciduous in nature, shedding their leaves in the dry season. Tree species include *Daniella Olivieri*, *Pa rkia Biglobosa* and *Pterocarpus Erinaceus.*

Dwarf buffalos are occasionally seen in the project area but probably coming from Outamba-Kilimi National Park (OKNP). Giant forest hog and bush pig are said to exist (evidence of faeces, footprints) but their abundance are thought to have dwindled over time. However, anecdotal and oral evidences from the local residents indicate the presence of forest elephant, hippopotamus and chimpanzees. Birds are known to be particularly diverse in the area.

5.5.3.11 Segment Eleven SG11

SG11 stretches from Kamakwie to the international border with Guinea for a distance of approximately 49.0 km. The predominant land cover types in this area includes forest, thicket, grass, swamp, bare ground and river. The vegetation type here is typical of broad drainage depressions and within the segment, especially towards the Guinea border is evident in some depressions. The riverine grassland found in this segment consists of medium height grasses that could reach up to about 2 m. Species include *Anadelphia Leptocoma,* especially occurring around the edges, while *Paratheria Africana* occur in the lower areas where water could be evident.

5.5.4 Project Activities That May Cause Impacts

The main project activities with the greatest potential to impact ecosystems, flora and fauna include construction of transmission line right-of-way, access roads, and substations, installation of conductor wires, and maintenance activities along the transmission corridor.

5.5.4.1 Clearing and Construction

Construction of transmission line right-of-way and towers (including rehabilitation), access roads, and substations may transform habitats, depending on the characteristics of existing vegetation, topographic features, and installed height of the transmission lines. Examples of habitat alteration from these activities include destruction or fragmentation of forest, loss of wildlife habitat including nesting area, and establishment of non-native invasive plant species. In addition, animals and plants could be injured or crushed, and animals would be disturbed by noise visual and auditory disturbance due to the presence of machinery, construction workers, transmission towers, and associated equipment. Some impacts would be permanent (for example, tree removal on the right-of-way, use of land for foundations/towers) and some temporary (for example, vegetation removal/crushing in the laydown area, human activities).

5.5.4.2 Conductor Installation

Impacts from installation of transmission conductor wires would be relatively short-term and temporary. Vehicular traffic to pull the conductor wire and unloading activities at laydown areas can cause physical impacts, such as injuring or crushing animals and plants. Installation of conductor wires over the entire length of the transmission corridor will cause noise and visual disturbance that could temporarily disturb and displace various animal and bird species.

5.5.4.3 Maintenance Activities

Maintenance activities along the transmission corridor may cause erosion and adversely affect water quality. Disturbance from noise and physical presence of machinery and workers will occur during activities such as mowing, weed cutting, tree trimming, inspections, tower and foundation repairs, and maintenance of damaged/downed transmission wires.

5.5.5 Potential Physical Impacts to Fauna

5.5.5.1 Avian and Bat Collisions and Electrocutions

The combination of the height of transmission towers and distribution poles and the electricity carried can pose potentially fatal risk to birds and bats through collisions and electrocutions. Avian collisions with power lines and transmission structures can occur in large numbers if located within daily flyways or migration corridors, or if groups are traveling at night or during low light conditions such as dense fog. Bird and bat collisions with power lines may result in power outages and fires. If conductors (wires) are not spaced far enough apart to prevent birds from touching two wires at once, or if "bird-proofing" measures are not implemented, large perching birds (particularly raptors) can be electrocuted. Based on migratory patterns and known species of concern, areas of high risk include all the east-west sections of the route, which comprises most of the corridor. Bird species characterized by rapid flight and the combination of heavy body and small wings run a high risk of colliding with power lines because of their restricted speed of reaction to unexpected obstacles.

5.5.5.2 Den and Nest Destruction

Installation of foundations, towers, substations, access roads, and driving over areas of the right-of-way can potentially destroy or damage nesting and den areas for animals. In areas of known or potential breeding habitat for species of significant concern, which include protected areas, field surveys will need to be conducted to identify any breeding areas prior to access or construction activities begin. To the extent possible, construction and maintenance in these areas should not take place during breeding seasons, and other actions should be taken to avoid disturbance.

5.5.5.3 Destruction of Habitats of Herpetofauna

The construction activities would potentially affect movement of the species (especially in forest reserves where the power line passes eg. Tiwai Island Sanctuary, Kambui Hills and Nimini Hills). Most of the species hide in holes, under stones and rock crevices. Disturbance during construction by excavation and grading by earth movers might destroy habitats of this species. The speed at which vehicles move in the area will determine occasions of road kill accidents. Normally the herpetiles crawl and they are prone to road kills by vehicles. Species normally affected are snakes, lizards and geckos.

5.5.5.4 Temporary Obstruction of Movement of Wild-Herbivores

The landscapes along the Transmission Line which provides dispersal areas for wildlife during wet seasons. During dry season, wild animals move towards the Otamba Kilimi National Park. The forage conditions for the wild herbivores are adversely affected during this season, depriving them of feed. Only the isolation of woodland remains serving small mammals, reptiles and birds as a refugia.

Project development will potentially affect activities and behaviours of mammal species. The species depend on the area for habitats, foraging grounds and migration during dry season. Some of the mammals prefer woodlands or bushlands, riverine, grasslands and rocky areas. Activities leading to interference to movements of the animal are viewed as adverse to the species.

Generally, during the construction of the power line there will be movements of vehicles and noise generated by vehicles and construction equipment. The noise would potentially scare animals away from dispersal areas. Speed of the vehicles used in the area would be a concern to lives of animals that normally graze in a group and they tend to follow each other. A vehicle intercepting a group crossing road runs a risk of hitting individuals which normally tries to catch up with the rest.

5.5.5.5 Exposure of Wild Herbivore to Electric and Magnetic Fields

EMF is associated with the power transmission lines. EMF is invisible lines of force emitted by and surrounding any electrical device. Electric fields are shielded by materials that conduct electricity, and other materials, such as trees and building. Magnetic fields pass through most materials and are difficult to shield. Both electric and magnetic fields however, decrease with distance. There is concern over risks of electrocution and potential health associated with the exposure to EMF on human than wild animals though the evidence on the latter is weak.

Normally areas cleared for ROW experience dominance of grasses. The extensive area also provides wild herbivores with an open area safe from predators. The amount of time the herbivore spent under the pylon cables will determine how much they will be exposed. It is not clear how the EMF would affect wild mammals but a general fear is expressed on the unknown magnitude of impact.

5.5.5.6 Other Physical Impacts

Construction and maintenance work involving the clearing of vegetation, excavation of soils, movement of vehicles or equipment over roads, terrain or streams, loading and unloading of materials, deployment of conductor, and other activities can result in the injury or mortality of plants and animals. Crushing, suffocation, removal from protective habitat, destruction of seeding plants, destruction of nests and eggs, and other conditions usually result in the immediate or eventual death of affected organisms. Such impacts can be significant if they involve large numbers of organisms, occur on a regular basis, or affect plant or animal populations that are particularly sensitive, unable to reasonably compensate for losses, or already low in numbers. The surveys required for sensitive areas should reduce this significantly. In addition, most populations are able to recover, particularly if the project is planned to avoid as many critical areas and sensitive habitats as possible, and incorporates the appropriate design measures, such as raptor protection measures.

5.5.6 Potential Impacts on Terrestrial Habitat

The construction, operation and maintenance of substations and transmission line right-of-way, especially for sections that pass through or very close forested areas, will result in alteration and disruption to terrestrial habitat. Excavation, grading, and earthmoving activities physically disturb and remove topsoil which contains plant seeds and invertebrates which are critical for a healthy ecosystem. Erosion and associated loss of topsoil becomes a concern in terrestrial habitats due to construction activities. Work crews will gain access to tower locations by driving to existing road crossings and entering the right-of-way by driving over the ground or along dirt access roads. Neither permanent nor temporary paved/gravel access roads are proposed to be constructed in the right-of-way, which will greatly reduce potential impacts. In some locations, including that portion of the route that passes very close to the Nimini Forest Reserve, access may be made by helicopter. Maintenance activities for the project to control vegetation will be conducted mechanically with cutting activities occurring every six to eight years. Herbicides will not be used for vegetation control, which reduces the potential impacts to plants and to terrestrial habitat.

Adequate terrestrial habitat is critical for the survival of plant species, and must provide suitable food resources, territory, loafing areas, nesting sites, and reproduction dens for birds and animals which depend on the ecosystem. Major impacts of the project are expected to be loss of wildlife habitat including fragmentation of forest, potential for forest fires, and establishment of non-native invasive species due to site development and the presence of construction workers, vehicles and machinery, disturbance of soil and vegetation, and trimming and removal of trees. These are described in more detail below.

5.5.6.1 Terrestrial Habitat Modifications

Habitat modifications associated with transmission line construction can adversely affect wildlife populations but can also result in certain positive impacts. Right-of-way clearing during the transmission line construction process can result in a loss of suitable habitat, which is a leading cause of the decline of many plant and animal species, including threatened and endangered species. Biodiversity may be reduced in the construction areas because certain species of plants and animals may be unable to tolerate the disturbance and subsequently leave the area, at least temporarily. Migratory pathways can be affected such that seasonal migration patterns can be interrupted or modified, at least during the construction period. It is noted that the construction period at any one location will be relatively brief, one or two week or less, although construction along a particular section of the corridor could take place over several months. Conversely, in areas where forest, scrub-shrub, or similar communities dominate, habitat modifications can create additional “edge” habitat, increase the availability of forage area (at least for certain species), and improve overall habitat diversity. As such, the advantages and disadvantages to wildlife habitat must be assessed to arrive at an overall conclusion regarding impacts.

5.5.6.2 Forest Fires

If underlying growth is left unchecked, or if slash from initial construction or routine maintenance is left to accumulate within the right-of-way boundaries, sufficient fuel may be available to promote forest fires. Regular maintenance of vegetation (every six to eight years) within the right-of-way is necessary to avoid damage to overhead power lines and transmission towers. Vegetation maintenance is needed since unchecked growth of tall trees and accumulation of vegetation may result in power outages through contact of branches and trees with energized transmission lines, ignition of forest and brush fires, corrosion of steel equipment, and interference with critical grounding equipment. Forest fires may also be started by construction and maintenance activities if workers are not careful with use of flammable materials and fuels. Forested ecosystems along the project route would be particularly sensitive to fires, since these areas have the highest potential for fires. Due to the potential risk for forest fires in the forested habitats of the project, mitigation measures will be employed to minimize the potential for fires.

5.5.6.3 Invasive, Exotic Species

Intentional or accidental introduction of alien or non-native species of flora into areas where they are not normally found can be a significant threat to biodiversity, since some alien species can become invasive, spreading rapidly and out- competing native species. Clearing of forested habitats along the project route will be the only significant change in habitat type. Once the vegetation has been cleared away, the ground will naturally re- vegetate with native and non-native species. Due to the potential risk of introducing invasive exotic species in the forested habitats of the project, mitigation measures will be employed to minimize invasive colonization and propagation.

5.5.7 Potential Impacts on Aquatic Habitat

Construction and maintenance activities may negatively impact water quality of streams, water bodies and groundwater, resulting in potential impacts on local aquatic habitat and downstream river biota, communities, and fisheries. Impacts to water quality may result from erosion and accumulation of sediment and organic debris in water bodies (for example, at river crossings of the transmission line right-of-way and access roads. Chemical contamination may occur from use and spills of pesticides, liquid fuels or lubricants, equipment coolants, and transformer lubricants. Increased nutrient loads may result from erosion and use of fertilizers. Changes in stream flows may affect fish and aquatic biota populations. Preventing direct adverse impacts to water resources and maintaining riparian zones is critical to protect water quality, quantity and aquatic habitats.

5.5.7.1 Increased Turbidity and Sediment Deposition

Cutting and filling activities can result in accelerated surface erosion, channel scouring, and sediment transport, which can lead in turn to increased turbidity and sediment deposition in receiving water bodies. The same thing can occur when vehicles cross small streams or tributaries of rivers, or when vehicles traffic reduces vegetation cover near streams. Such impacts can adversely affect water quality and, in turn, the health of fish and aquatic invertebrates by interfering with respiration, feeding, and other activities. Depositions of large amounts of silt and sediment can also cover critical habitat and spawning grounds, making them unavailable for use, and can smother incubating eggs.

Impacts to water quality are not expected to be significant; therefore, the impacts to the wildlife that use these habitats will also be insignificant. However, impacts on a specific small stream or wetland could be significant. For that reason, project activities should avoid activities near and in water as much as is possible, and any damage to streambanks or streambeds should be repaired when work is concluded.

5.5.7.2 Disruption of Watercourse

Power lines and associated roads and facilities may require heavy machinery working in, or construction of crossings over, aquatic habitats. Such activities may disrupt affected watercourses and wetlands, physically uproot aquatic vegetation, and interrupt fish migration/spawning patterns. Slash and debris from construction and maintenance clearing can accumulate in ditches and other drainage structures, enter lakes, streams and wetlands, and block natural hydrologic flow and migratory pathways. Cutting and filling activities may disrupt surface and subsurface hydrologic flows and bring water to the surface

in new areas, including existing streams and rivers. Hydrologic changes (i.e., changes in flow rates; flow velocities; etc.) can result in conditions that are unsuitable for certain species or life stages.

Overall impacts to water flow are not significant; therefore, the impacts to the wildlife that use these habitats will also be insignificant. However, impacts on a specific small stream or wetland could be significant. For that reason, project activities should avoid activities near and in water as much as is possible, and any damage to streambanks or streambeds should be repaired when work is concluded.

5.5.7.3 Invasive and Exotic Species

Intentional or accidental introduction of alien or non-native species of flora and fauna into aquatic areas where they are not normally found can be a significant threat to biodiversity, since some alien species can become invasive, spreading rapidly and out-competing native species. Invasive, exotic species may force resident species out of the area, introduce diseases which existing species have no resistance to, compete with indigenous species, or lead to increased predation of resident plants and animals. There are no activities that will occur close to aquatic habitats that could introduce invasive exotic species into these habitats.

5.5.8 Potential Impacts on Health (Electric and Magnetic Fields)

Electric and magnetic fields (also known as electromagnetic fields) (EMF) are invisible lines of force emitted by and surrounding any electrical device, including power lines and electrical equipment. Electric fields are produced by voltage, they increase in strength as the voltage increases, and they are measured in volts per meter (V/m). Electric fields are blocked or shielded by materials that conduct electricity, and other materials such as trees and buildings. Magnetic fields result from the flow of electric current, they increase in strength as the current increases, and they are measured in units of gauss (G) or tesla (T), where 1T equals 10,000G. Magnetic fields pass through most materials and are difficult to shield. Both electric and magnetic fields decrease rapidly with distance.

Although there is public and scientific concern over the potential health effects associated with exposure to EMF (not only from high-voltage power lines and substations, but also from everyday household uses of electricity), there is limited empirical data demonstrating adverse health effects from exposure to typical EMF levels from power transmission lines and equipment. While the evidence of adverse health risks is weak, evaluation of EMF impact is still warranted in environmental assessments. Construction and operation of the TRANSCO CLSG project is not anticipated to have any significant impact to nearby residents or the environment due to electric and magnetic fields.

5.5.8.1 Activities that Generate EMF

Project activities that will generate EMF include operation of the energized transmission line and substations. EMF in the range of power line frequencies typically range from 50 to 60 Hertz (Hz) and are considered Extremely Low Frequency (ELF). The most common impact from nearby power transmission lines is electrical interference with sensitive equipment, such as computer monitors.

5.5.8.2 Potential Human Health Impacts

Over the last 30 years, extensive research has been conducted in the U.S. and around the world to examine whether exposure to EMF has adverse health or environmental effects. Exposure to EMF is affected by the types of electrical sources, the distance from these sources, and the amount of time spent near these sources. Scientific research has focused on magnetic fields, since objects such as trees and walls act as physical barriers that easily block and shield electric fields.

In most homes, background alternating current magnetic field levels average about 1 milligauss (0.001 gauss), resulting from wiring within the home, appliances, and power lines outside the home. Since the intensity of magnetic fields diminishes quickly with distance from the source, few homes are close enough to transmission lines for the lines to have an impact on the magnetic field level within the home. Rather, the major source of residential magnetic field levels comes from electrical appliances within the home. The average daily exposure is the composite of instantaneous, high exposures (such as driving under a power line) and long-term, low exposures (such as wiring within a home).

5.5.8.3 Environmental, Animal and Plant Impacts

Power frequency EMF in the 50 to 60 Hz range carries very little energy, has no ionizing effects, and usually has no thermal effects. Because EMF in the range of power line frequencies are far too weak to damage molecules or break up DNA, they cannot lead to mutational changes or cancer. EMF can cause very weak electric currents to flow in the body. In animal studies, scientists exposed rat and mice test subjects to electric or magnetic fields, some as high as 50,000 mG, and compared the amount of disease they observed to the amount of disease observed in animals that had not been exposed. WHO concluded in their June 2007 review of EMF and health (WHO, 2007) that no consistent adverse health effects, including cancer, were reported in animals even after exposure to high levels of electric and magnetic fields. Overall, the research does not establish that EMF exposure causes or contributes to any disease or illness.

5.5.9 Sensitive Areas (Ecosystem Hotspots) That Could Be Affected

In addition to the general impacts discussed above, the project was assessed with respect to the potential for impacting ecosystems (flora and fauna) in specific areas (protected areas, fauna and flora) in the vicinity and along the transmission line where the most significant impacts can be expected. The transmission line route bypasses legally constituted National Forest Protected Area in the East of the country (Gola Forest National Park), in the North (Outamba-Kilimi National Park), in the South East both (Tiwai Island Sanctuary and Kambui Hills) and one designated Protected Forest in the North East of the Country (Nimini Hills). There are areas where the line route will have to avoid or moved further away:

- Avoid the Nimini Hills Forest Reserve to the north because it is ecologically sensitive areas
- Avoid all the current segments of Gola Forest as well as future transboundary Park, which will be established between Sierra Leone and Liberia. It also ensures that Tiwai Island and Kambui Hills are avoided with a minimum distance of 2.2 km and 1.8 km, respectively.
- Avoid the Outamba-Kilimi National Park keeping a distance of at least 1.5km.

The following criteria were used for assessing sensitivity of ecological receptors.

- High Sensitivity: Rare or uncommon habitats, which increase national biodiversity; irreplaceable or take 10+ years to regenerate
- Medium Sensitivity: Habitats which are regionally or locally uncommon; increase regional biodiversity; take 2-10 years to regenerate
- Low Sensitivity: Common habitats; take less than 2 years to regenerate.

5.5.9.1 Gola Forest

The transmission line avoids all the current segments of Gola Foest (Figure 5-6) as well as future transboundary Park, which will be established between Sierra Leone and Liberia. It also ensures that Tiwai Island and Kambui Hills are avoided with a minimum distance of 2.2km and 1.8km, respectively.

Gola Forest is located in the Eastern Province of Sierra Leone, within the districts of Pujehun, Kenema and Kailahun. The forest spans seven chiefdoms: Koya, Gaura, Tunkia and Nomo chiefdoms in the Kenema district, Barri and Makpele chiefdoms in the Pujehun district, and Malema chiefdom in Kailahun district. The eastern boundary of Gola Forest follows the Moro and Mano Rivers, which form the border between Sierra Leone and Liberia. The Gola Forest reserves consist of several separate forest blocks which are orientated along a southwest – northeast axis. Gola West (67 km2) and Gola East (205 km2) are contiguous although a road runs between these two blocks. Gola North is the largest block, having an area of 417 km2 plus an extension of 61 km2 which is located northeast of Gola North.

Although no precipitation data is available from the forest itself, there are historic and recent data from villages and towns around the forest. Based on historic rainfall data, annual rainfall in Gola is likely to be 2,500–3,000 mm.

Gola East and West were gazetted forest reserves in 1926 and Gola North as a timber production forest in 1930, to supply both local and international markets. The reserve as a whole (including Tiwai) has been proposed as a biosphere reserve and parts of Gola North and Gola East have been proposed as strict nature reserves. However, the Gola Forest has been proposed as a biosphere reserve and parts of Gola North and Gola East have been proposed as strict nature reserves. The Gola Forest was declared as National Park in November and gazetted on December 16, 2010. On the January 14, 2011 it was presented to Parliament for the first hearing and deliberation.

Currently, the Across the River Transboundary Peace Park Project (AR_TBPPP) which is an international move towards the conservation of common resources around the border areas between Sierra Leone and Liberia is ongoing. With the establishment of the Transboundary Peace Park by the AR_TBPPP, the segment of the Gola forest in Sierra Leone will be connected to Lofa Forest in Liberia.

5.5.9.2 Nimini Hills Forest Reserve

The line route would pass outskirt of the hotspots, Nimini Hills Forest Reserve (Figure 5-8), which is an ecologically sensitive area. A minimum 1 km buffer zone to the Nimini Hills Forest Reserve was created. The Nimini Hills Forest Reserve is approximately 129 km^2 and located in the southwest of Kono District. Vegetation in the reserve is closed forest belonging to the Upper Guinea forest zone, but the reserve has been partially logged. The Nimini Hills Forest Reserve was surveyed in 2010 as part of the Sierra Leone National Chimpanzee Census Project. According to the Study, although no signs were found on transects, nests were found in the southwest of the reserve on recess. This indicates that there are some chimpanzees in the reserve, or at least at its periphery, though probably not in significant numbers. The Nimini Hills retain much of their forest cover, and inventory and management of the forest resources, so there are necessary to maintain this resource into the future.

The Nimini Hills Forest Reserve is already a deeply depleted and threatened forest. Very few signs of wildlife can be encountered, and human signs were found almost everywhere in the reserve. Chimpanzee nests are only found in the very southwest edge of the reserve, and probably those chimpanzees are utilizing areas outside of the reserve where hunting pressure might actually be less. It is illegal gold-mining and timber felling that probably poses the greatest threat for the remaining forest and wildlife here. Mining camps create a constant human presence in the reserve and encourage hunting and tree-felling to supply miners with meat and wood. Currently, small-scale logging with power-saws is rampant, with only a few of the saw owners obtaining a timber license. In 2008 the Trans-Atlantic logging company did a forest inventory in the Nimini Hills North Extension 1, but a 2009 logging ban temporarily shut down commercial logging in the district.

5.5.9.3 Outamba Kilimi National Park

Outamba Kilimi National Park is the first national park in Sierra Leone (Figure 5-9). Located in the far north of Sierra Leone on the border with Guinea, it is divided into the larger Outamba section (783km2) in the east and Kilimi section (274 km2) in the west of northern Bombali district. The terrain is relatively flat with low rolling hills or plateaus which offer excellent views across the spectacular landscape. The eastern side of Outamba is more varied, with more hills reaching 300-400m elevation. Vegetation is primarily southern Guinea savanna woodland with trees such as Lophira and Daniellia. A small proportion of the area is made up of forest, narrow riverine forest, or small patches of savanna. The savanna grasses are primarily a tall elephant grass which is burned annually by people in the park. Almost all areas of the park are affected by the burning.

The site supports at least nine species of primates including Western Chimpanzee, red colobus, black and white colobus, sooty mangabey, and olive baboons. The total number of bird species recorded in the park is 220. A small population of forest elephant occurs at Outamba. Other large mammals include leopard, pygmy hippopotamus, water chevrotain, Maxwell's duiker, and forest buffalo. Both sections of the reserve are located within one chiefdom (Tambakha, the least populated of all chiefdoms in the country).

The transmission line detours the Outamba-Kilimi National Park to the south and west. It includes the construction of 51.2km transmission line in the vicinity of the Outamna-Kilimi National Park, keeping a distance of at least 1.5km

5.5.9.4 Tiwai Island Sanctuary

Tiwai is a 12 km^2 forested island in the Moa River in southeastern Sierra Leone, at the western end of the Upper Guinea forest region of West Africa (Figure 5-7). This region has both high species richness and high levels of species endemism. The Guinean rain forest of West Africa is one of 25 'biodiversity hotspots' in the world, and has the highest mammalian diversity of any tropical forest Tiwai Island is a Wildlife Sanctuary under Sierra Leonean law, and hunting on the island is prohibited but limited forest-product harvesting is allowed under the current management plan. Historically there has been low-intensity slash-and-burn farming on the island that has created a mosaic of vegetation types, of which the most widespread is old secondary rain forest.

Tiwai is well known for its primates, including the endangered western chimpanzees, seven species of forest monkey, and two prosimians. However, to date, no inventory is available on avifauna of Tiwai.

5.5.9.5 Kambui Hills

The proposed transmission line passes close to the Kambui Hills (Figure 5-7). Located in the south-east of the country, Kambui Hills Forest Reserve comprises two major blocks, Kambui North (20,348 ha) and Kambui South (880 ha). The two areas are divided by the main road linking Kenema, 10 km to the east, with the town of Bo. The Forest Reserve occurs on steep slopes, reaching 645m in Kambui North. The reserve acts as a catchment area for a number of reservoirs that supply Kenema and surrounding communities.

The vegetation is predominantly mature secondary moist forest with semi-deciduous forest on the slopes, and farm bush and thicket on the lower plains and the fringes of the reserve.Over 200 species of bird have been recorded, including five species of global conservation concern. Non-bird biodiversity: The following primates occur: *Pan troglodytes verus* (EN), *Procolobus badius* (LR/nt), *Colobus polykomus* (LR/nt), *Cercocebus atys* (LR/nt) and *Cercopithecus diana* (VU). Other threatened mammals known include *Loxodonta africana cyclotis* (EN) and the duikers *Cephalophus jentinki* (VU), C. *niger* (LR/nt) and C. *maxwelli* (LR/nt).

Kambui North was officially designated a Forest Reserve in 1920, Kambui South in 1932. The reserve is primarily managed as a national production forest, i.e. is exploited commercially for timber, and acts as a buffer against the exploitation of the Gola Forest Reserve (IBA SL010), about 40 km to the east. The main threat to the reserve is illegal, unsustainable timber exploitation. A number of farms exist around the fringes of the reserve, especially in those areas closest to Kenema, but these currently pose little threat. A management plan was developed by one of the logging companies, mainly relating to purported sustainable logging operations.

Figure 5-6: Eco-sensitive zones within the Project Area (Gola Forest Reserve)

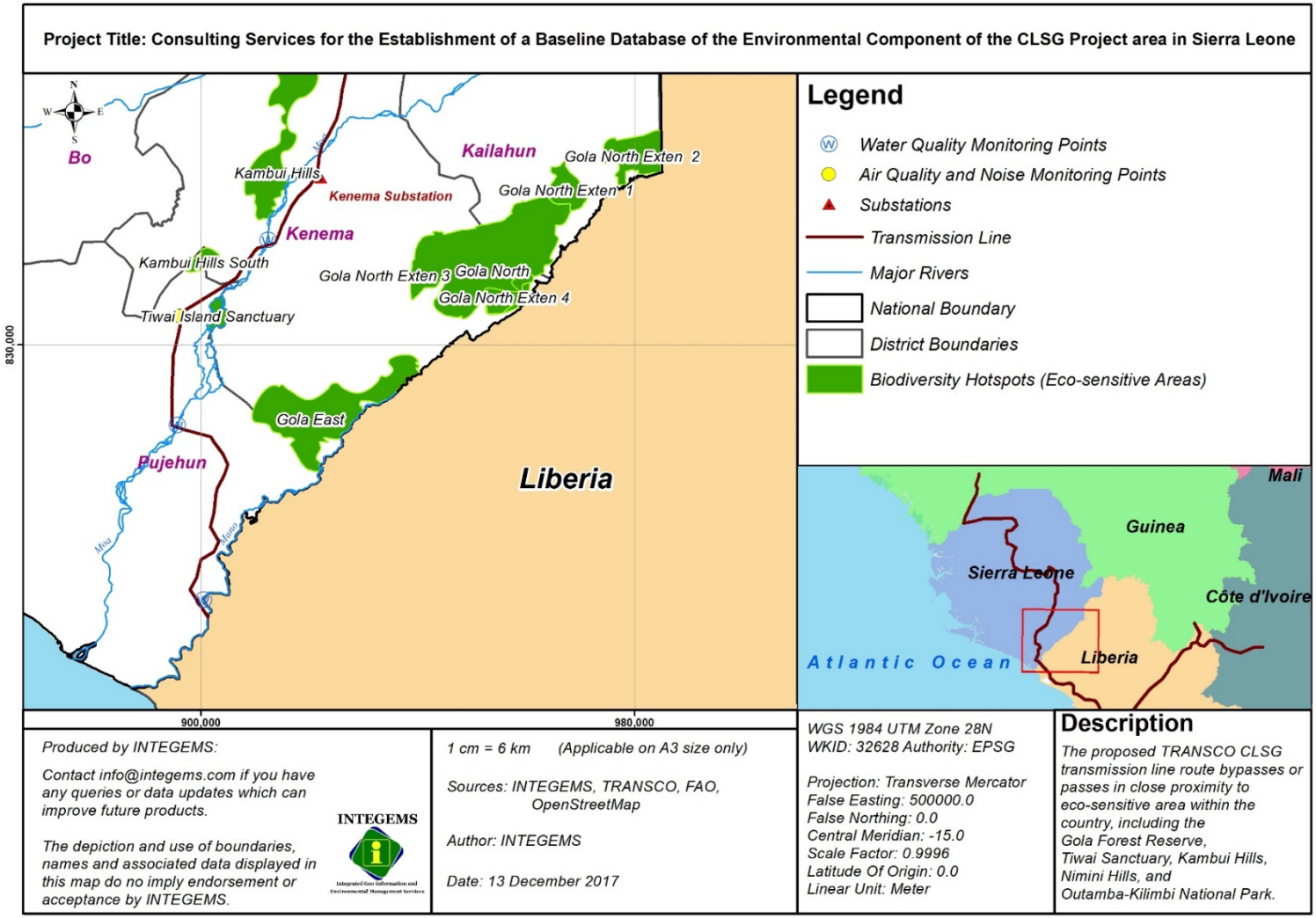


Figure 5-7: Eco-sensitive zones within the Project Area (Kambui Hills and Tiwai Sanctuary)

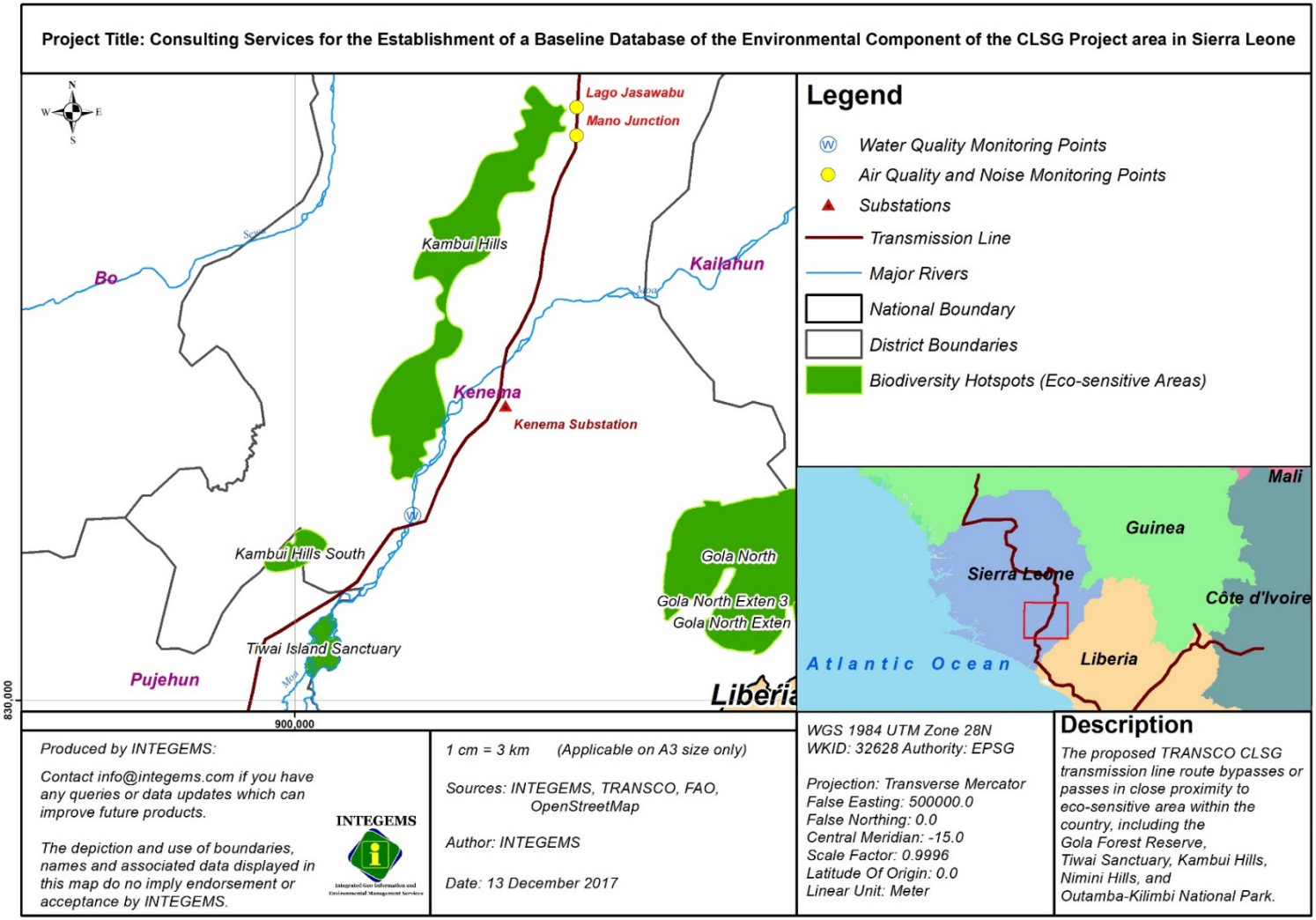


Figure 5-8: Eco-sensitive zones within the Project Area (Nimini Hills)

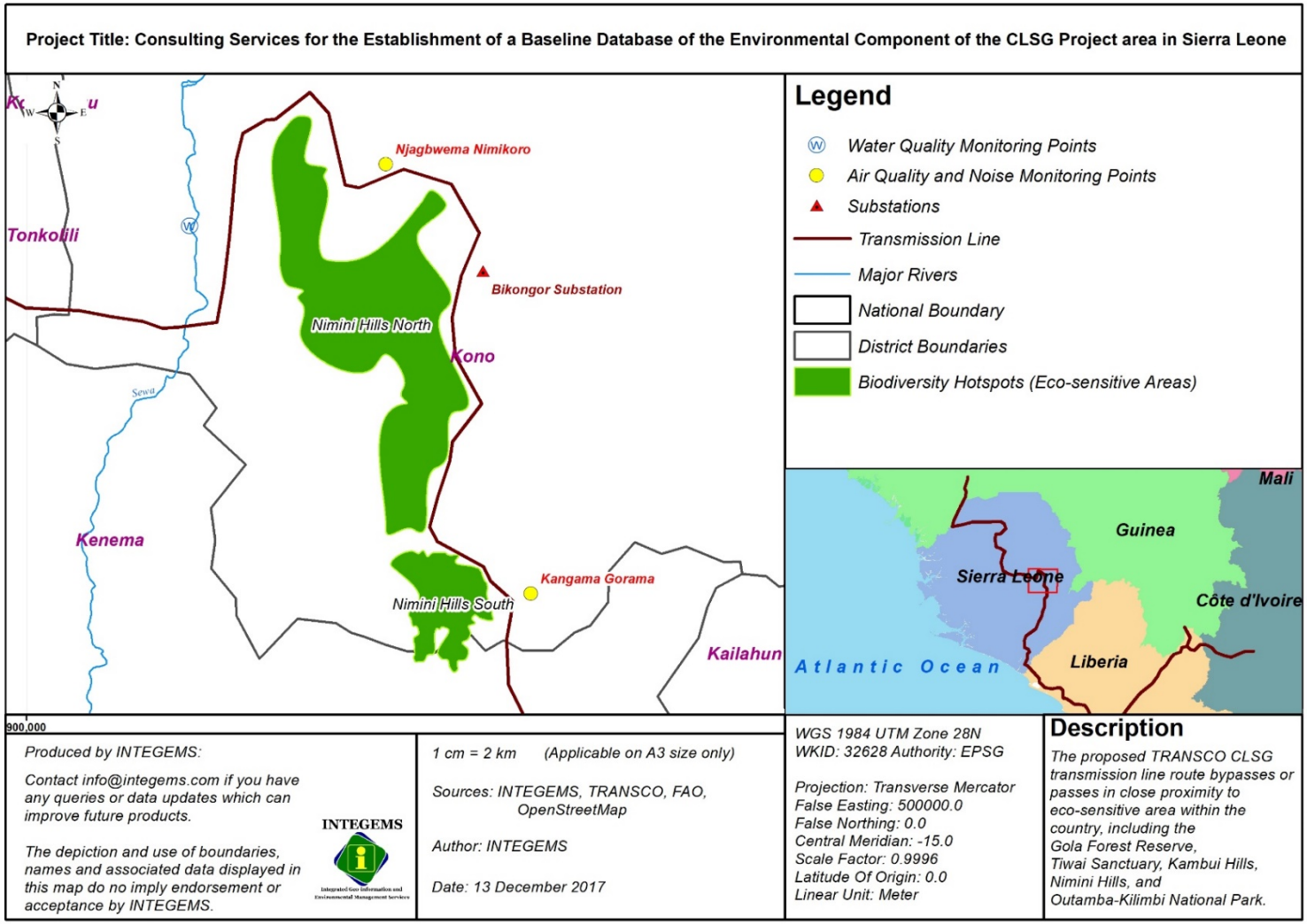
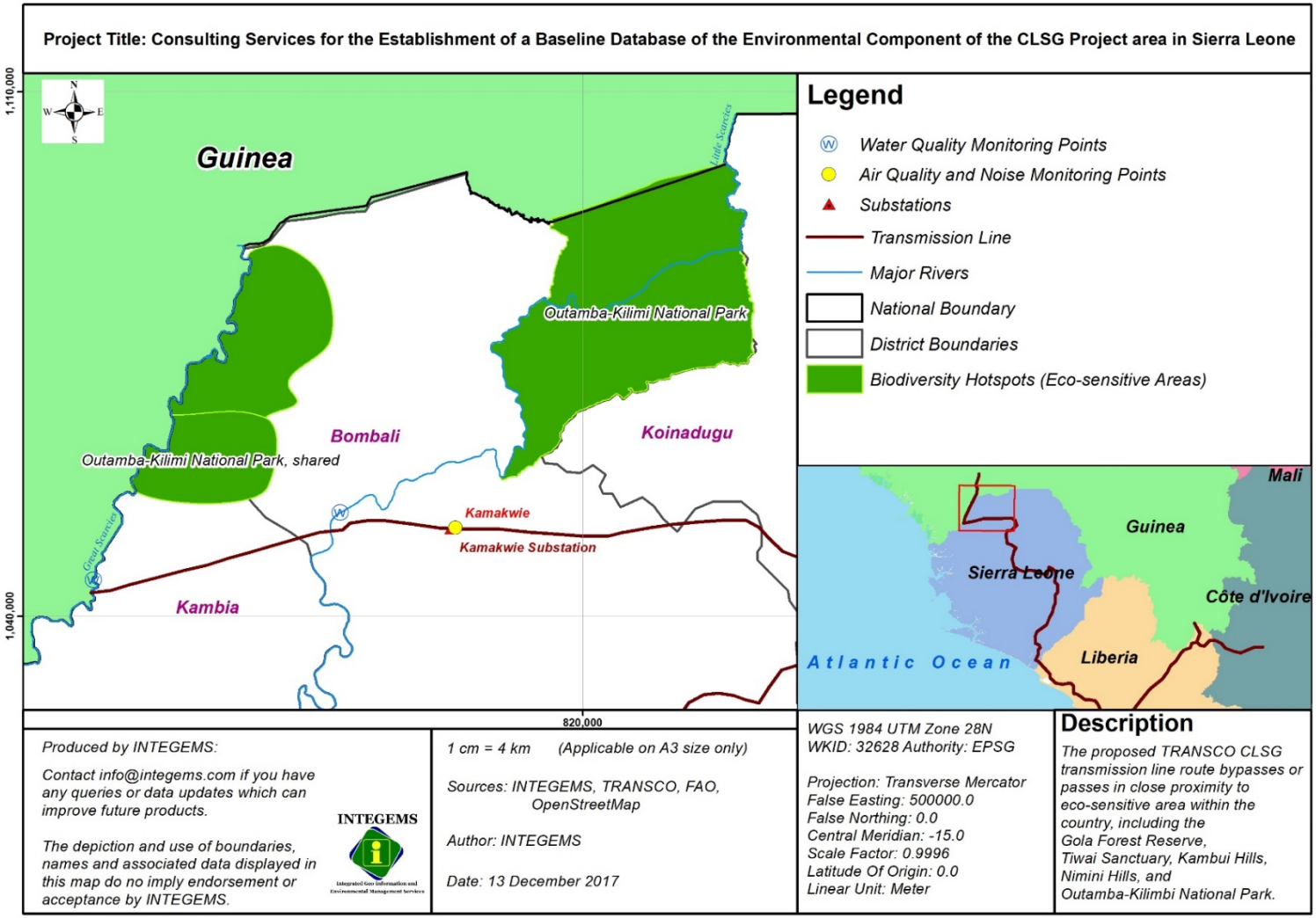


Figure 5-9: Eco-sensitive zones within the Project Area (Outamba-Kilimbi National Park)



6 BASELINE ENVIRONMENTAL DATABASE & GIS (BEDGIS)

The **Baseline Environmental Database and Geographic Information System – Sierra Leone** (**BEDGIS-SL**) integrates Geographic Information Systems (GIS) and Management Information System (MIS) systems and mobile data collection technology to provide a family of sophisticated tools and Web services for collecting, managing, visualizing, mapping, analysing, monitoring, evaluating and reporting on various environmental components of the TRANSCO CLSG Project Area in Sierra Leone.

6.1 Baseline Database System Analysis and Design

The BEDGIS-SL was designed, developed and deployed to standardize, interoperate, integrate and centralize information about the environmental component of the CLSG Project Area in Sierra Leone. The technical approach adopted was to:

- Build a robust, scalable, flexible and interoperable BEDGIS-SL with an integrated browser-based[5] MIS and high-quality production ready databases (on dedicated servers in the Cloud), for collecting, managing, visualizing, mapping, analysing and monitoring the environmental component of the CLSG Project Area in Sierra Leone.
- Build a network-enabled BEDGIS-SL that can be accessed over the Internet, local Intranet, as well as a locally installed system using the latest Information & Communication Technology (ICT) so that all project stakeholders can access accurate, timely, secured and reliable BEDGIS-SL resources from any device (desktops, smartphones/tablets and the Web), from any place, and at any time.
- Build interactive and user-friendly browser based interfaces, including dashboards and maps, using the latest MIS, GIS, mobile, server, network and Web technologies so that all stakeholders can access accurate, timely, secured and reliable BEDGIS-SL data and information right from any device (desktops, smartphones/tablets and the Web), from any place (both online and offline), and at any time.
- Build an integrated GIS and MIS System using a combination (i.e., hybrid approach) of commercial (proprietary) and free open source software (FOSS) and web services. This hybrid approach will help reduce risk and add value in several ways: avoiding single software vendor lock-in; reducing costs associated with licensing; and promoting interoperability with existing software and architecture.

6.2 Key Features of the BEDGIS-SL

The key features of the BEDGIS-SL are as follows:

- Provides a comprehensive data management solution based on data warehousing principles and a modular structure which can easily be customised to the different requirements of the Project's management information system, supporting analysis at different levels (national, district, chiefdom, section, town).
- Customisation and local adaptation through the user interface. No programming required to start using the BEDGIS-SL in a new setting within or outside TRANSCO CLSG.
- Serves as a data collection, recording and compilation tool, and all data (be it in numbers or text form) can be entered into it. Data entry can be done in lists of data elements or in customised user defined forms which will be developed to mimic paper based forms in order to ease the process of data entry. Provides data quality checks that help to improve the quality of the baseline environmental data being collected or entered.

[5] The only real requirement to interact with the System is with a web browser on any desktop or mobile device.

- Provides easy to use one-click reports with charts and tables for selected indicators or summary reports using the design of the data collection tools. Allow for integration with popular external report design tools to add more custom or advanced reports.
- Flexible and dynamic (on-the-fly) data analysis in the analytics modules and widgets. Dashboards to provide quick access to different analytical objects (maps, charts, reports, tables, etc.) to an individual user.
- Integrated GIS module to easily display temporal and spatial data on maps, both on polygons (e.g., districts, chiefdoms, sections) and as points, and either as data elements or indicators.
- Temporal data and periodicity are organised according to a set of fixed period types: daily, weekly, monthly, bimonthly, quarterly, six-monthly, yearly, etc. This becomes an important factor when analysing BEDGIS-SL data over time e.g. when looking at cumulative data, when creating quarterly or annual aggregated reports.
- A user-specific dashboard for quick access to the relevant tools, including indicator charts and links to favourite reports, maps and other key resources.
- User management module for passwords, security, and fine-grained access control (user roles). BEDGIS-SL allows for multiple users to access the system simultaneously, each with a defined set of permissions, which can be finely tuned so that certain users can only enter data, while others may generate reports. Multiple user roles can be created, each with their own set of permissions, and then assigned to users which grant them certain privileges within the system.
- Functionalities of export-import of data and metadata, supporting synchronization of online installations as well as interoperability with other applications.
- Using the Web-API, allows for integration with external software and extension of the core platform through the use of custom apps.
- Further modules can be developed and integrated as per user needs, either as part of the user interface or a more loosely-coupled external application interacting through the Web-API.
- The BEDGIS-SL can be deployed: offline; online; and hybrid. The GPRS/3G mobile module provides a mechanism for remote clients using mobile phones to enter data directly into the BEDGIS-SL.

6.3 GIS-enabled and Web-based

GIS-enabled and Web-based environmental database and decision support system like the BEDGIS-SL enables timely insights and better communication, thus making the information rapidly available for better preparedness and action. The BEDGIS-SL comprises geospatial databases for decision making and management to capture environmental data in a near real-time manner and automates the generation of reports to various stakeholders and end user communities.

6.4 Service-Oriented Architecture (SOA)

BEDGIS-SL involves the integration of a broad spectrum of free and open source software (FOSS) and proprietary software and hardware technologies, including database servers, Web servers, map servers, desktop and server GIS software, Web services, storage area networks, etc. Thus, a Service-Oriented Architecture (SOA)[6] technical approach has been successfully employed in delivering the

[6] Services-oriented architecture (SOA) is an approach for building distributed computing systems, based on encapsulating business functions as services which can be easily accessed in a loosely coupled fashion. The core components supporting a service-oriented architecture (SOA) are: Service Providers - developers provide component services available for consumption over the web; Service Consumers - Web applications are developed from the available component services; and Service Directory - connects web applications with available component services. Common web protocols and network connectivity are essential to support this type of architecture.

BEDGIS-SL. Building a BEDGIS-SL that leverages SOA to author, publish and serve intelligent data and maps empowers TRANSCO CLSG to utilize best-of-breed components in delivering the right data, information and services to the right beneficiaries at the right time in the right place in a robust, scalable and efficient manner. The SOA approach includes multiple access layers based on client/software technology and service communication tiers. With desktop (ArcGIS for Desktop) and enterprise server-based GIS (ArcGIS Enterprise) and database management solutions (PostgreSQL and MS SQL Server), TRANSCO and partners can now freely integrate mapping into their existing workflows and solve the challenges of providing Web and mobile access to MIS/GIS-based environmental data and information and mapping services.

The BEDGIS-SL is based on the integration of both open-source and proprietary software - ESRI ArcGIS Enterprise 10.5, ESRI ArcGIS for Desktop 10.5, and PostgreSQL/PostGIS 9.5 and Microsoft SQL Server 2014 Database Management Systems (DBMS), Joomla 3.3 Content Management System (CMS) and/or Microsoft Internet Information Services (IIS)/Apache Tomcat, employing a multi-tier server configuration. The backbone of the BEDGIS-SL is a cabled and wireless LAN/WAN interconnected via the Transmission Control Protocol (TCP)/Internet Protocol (IP). The foundation of the BEDGIS-SL's physical infrastructure and data storage architecture is a Cloud-based dedicated server (Windows Server 2012 R2) and storage device that has the capacity to store nine terabytes of data, utilize a RAID system and intelligent backup mechanisms.

In addition, various interactive maps and data are available from the BEDGIS-SL Website through various web browsers (e.g., IE, Safari, Chrome, FireFox, etc.). Compressed files of data, maps, and metadata are available by direct download from data catalogue and atlas/map gallery pages on the BEDGIS-SL Website, which also provides a gateway to interactive map services built with ESRI ArcGIS API for JavaScript, HTML, and CSS. Basic and advance map and geo-processing services allow visualization of pre-packaged sets of data layers (vector and raster) and metadata. Users are able to zoom and pan maps, turn on and off layers, and query the attribute tables associated with the data and metadata. The BEDGIS-SL Website also provides feature-streaming capabilities, in which data will be downloaded and/or streamed to the client machine to allow advanced GIS and MIS functionality, including data import/export capabilities, direct download of public-access data and maps, and interactive visualization of related spatial, non-spatial data, data management and environmental data and information.

6.5 BEDGIS-SL Website

The BEDGIS-SL Content Management System (CMS) Website (http://www.bedgis-sl.website) takes full advantage of the flexibility of features offered by Joomla CMS with an array of functions and modules that can be easily added to over time without costly redesigns to interfaces and templates (see Figure 6-1). Designed with end users in mind, the BEDGIS-SL Website's responsive web design (RWD) and multi-device design technologies uses the gantry framework to ensure the site is highly mobile-accessible and viewable on all screen sizes (from desktops to smartphones).

Visitors to the BEDGIS-SL Website site can access relevant BEDGIS-SL information in a timely and consistent manner. Baseline environment data and information are presented in a non-technical and visually appealing manner incorporating a well thought out site-flow and information architecture. Information is organised clearly to facilitate access to relevant information and content easily searchable. All pages feature similar and consistent navigation controls with a minimum number of clicks required for navigation. Clear and intuitive labels, controls are grouped into logical units.

An integrated and interactive BEDGIS-SL Web Mapping Application has been embedded in the BEDGIS-SL CMS Website's Home Page and menu to allow users to interactively and effectively create, edit, publish, review, and collaborate on baseline environmental mapping, updating and managing development project locations and attributes through a robust, easy-to-use Web browser.

6.6 BEDGIS-SL Mapping Application

The **BEDGIS-SL Mapping Application** (accessed via http://www.bedgis-sl.website) is a GIS Web mapping application that provides easy and convenient ways to collect, map, explore, query, analyse and securely share available baseline environmental data and information resources from any device, anywhere, at any time (see Figure 6-2 and Figure 6-3). A primary goal of the BEDGIS-SL is to allow people who are not GIS professionals to do self-service mapping on any device (i.e., desktop, tablets and smartphones using Internet browsers) and expand the creative use and sharing of baseline environmental management data and information resources about TRANSCO CLSG's project in Sierra Leone (see Figure 6-4 and Figure 6-5).

6.7 BEDGIS-SL Web Hosting and Management

An Internet Service Provider (ISP) provides Managed Services for deploying the BEDGIS-SL Website, which includes providing external HTTP/HTTPS access to the BEDGIS-SL Website, operational hosting and monitoring, and troubleshooting technical support incidents through Hosted Environment Support. The ISP has set up the base components comprising the underlying Hosting Environment infrastructure, including the relevant hardware, power, facilities and network infrastructure to enable external HTTP/HTTP access to the BEDGIS-SL Website.

To facilitate unified and secured (authorised) public access to the BEDGIS-SL data and data services, a combination of Joomla Content Management System (CMS) and Rich Internet Web Application (using ArcGIS API for JavaScript) technologies were developed and deployed within the IaaS (Dedicated Server). The interactive BEDGIS-SL Website allows TRANSCO CLSG to expose baseline environmental data and geospatial services from the server and stream the results to remote clients through a single consumer access point. The BEDGIS-SL Website expedites the discovery, transfer, and utilization of BEDGIS-SL data and information by TRANSCO CLSG and various stakeholders.

Figure 6-1: The BEDGIS-SL Website – Home page

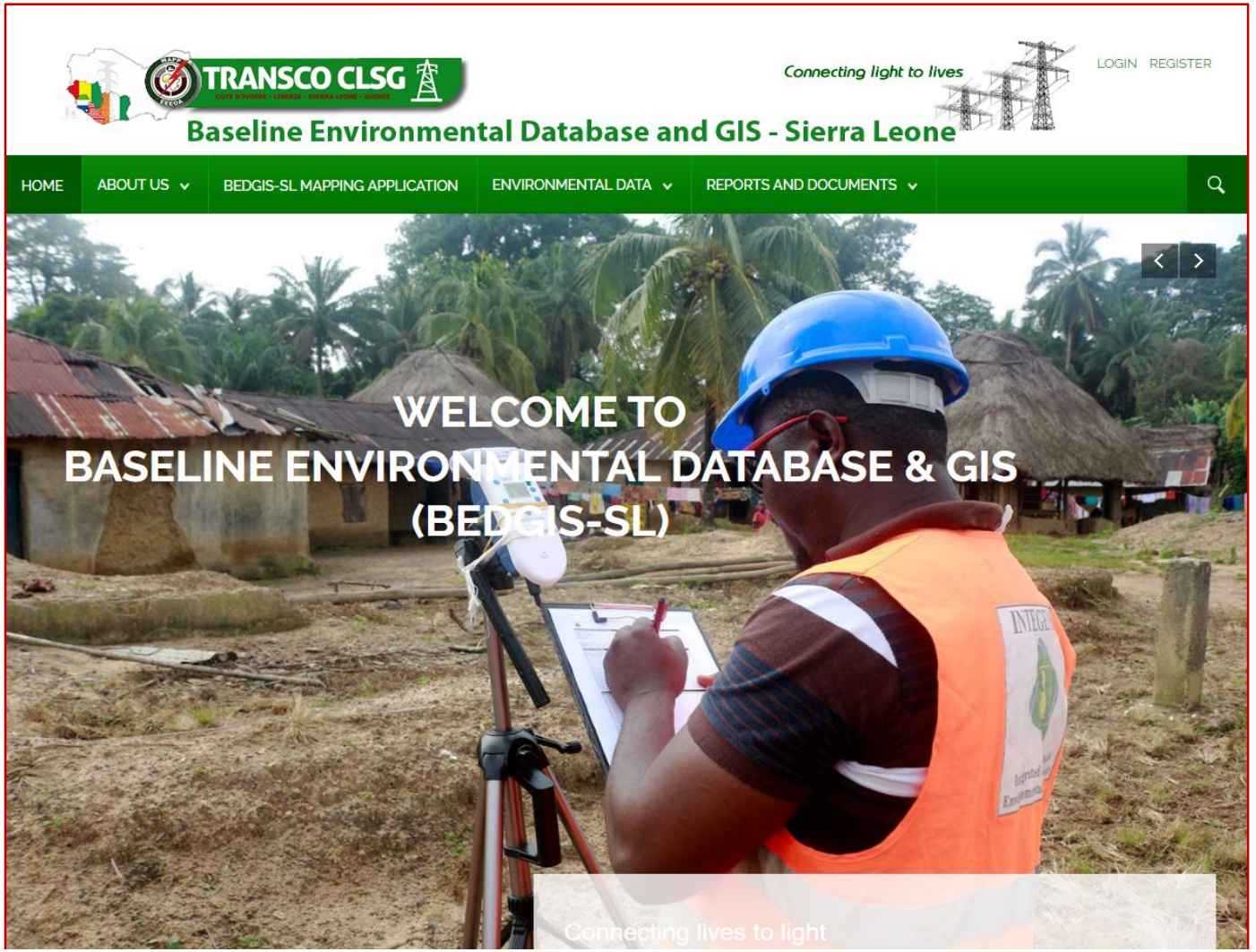


Figure 6-2: The BEDGIS-SL Web Mapping Application Interface

Figure 6-3: The BEDGIS-SL Web Mapping Application Interactive Map

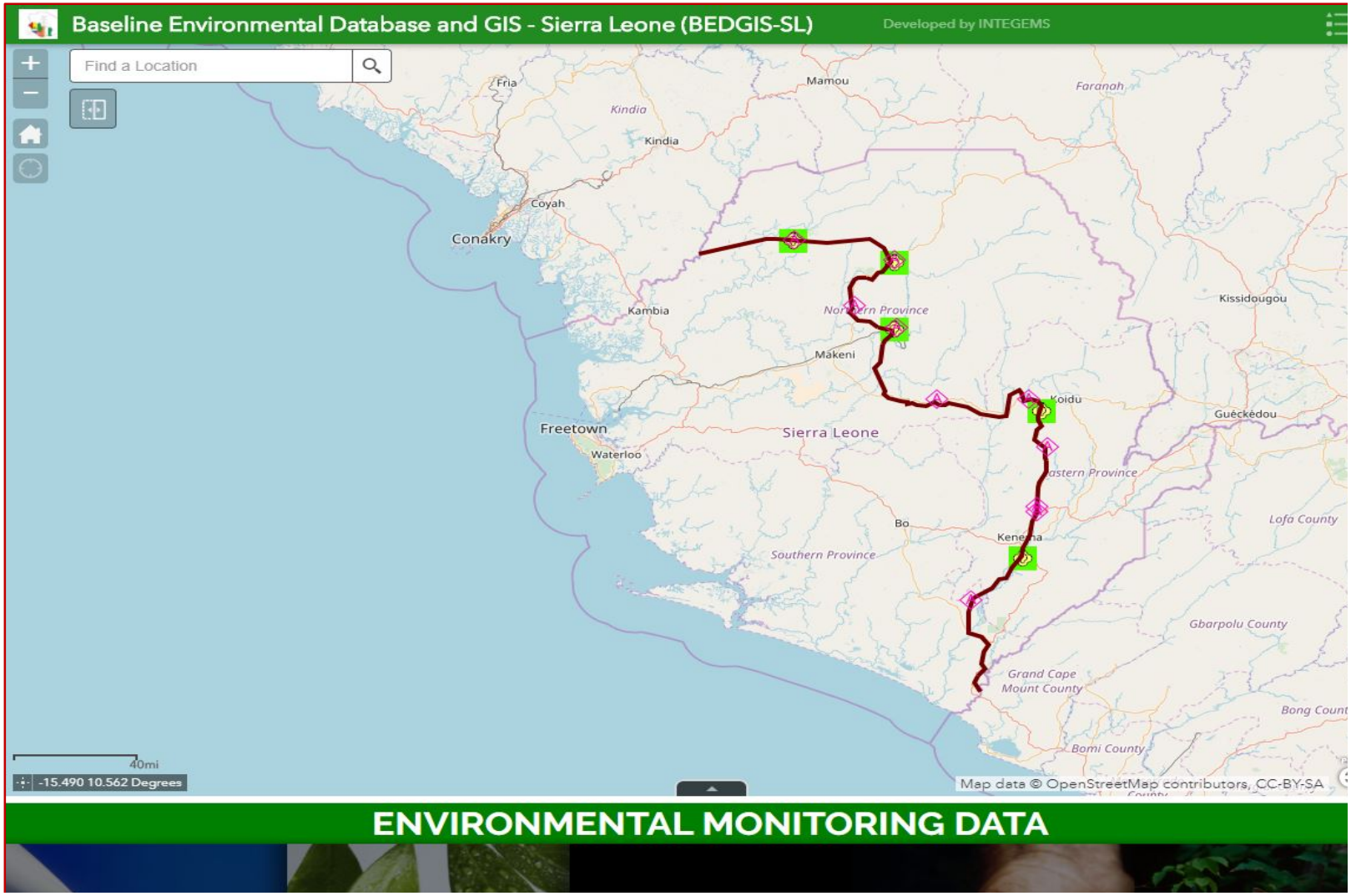
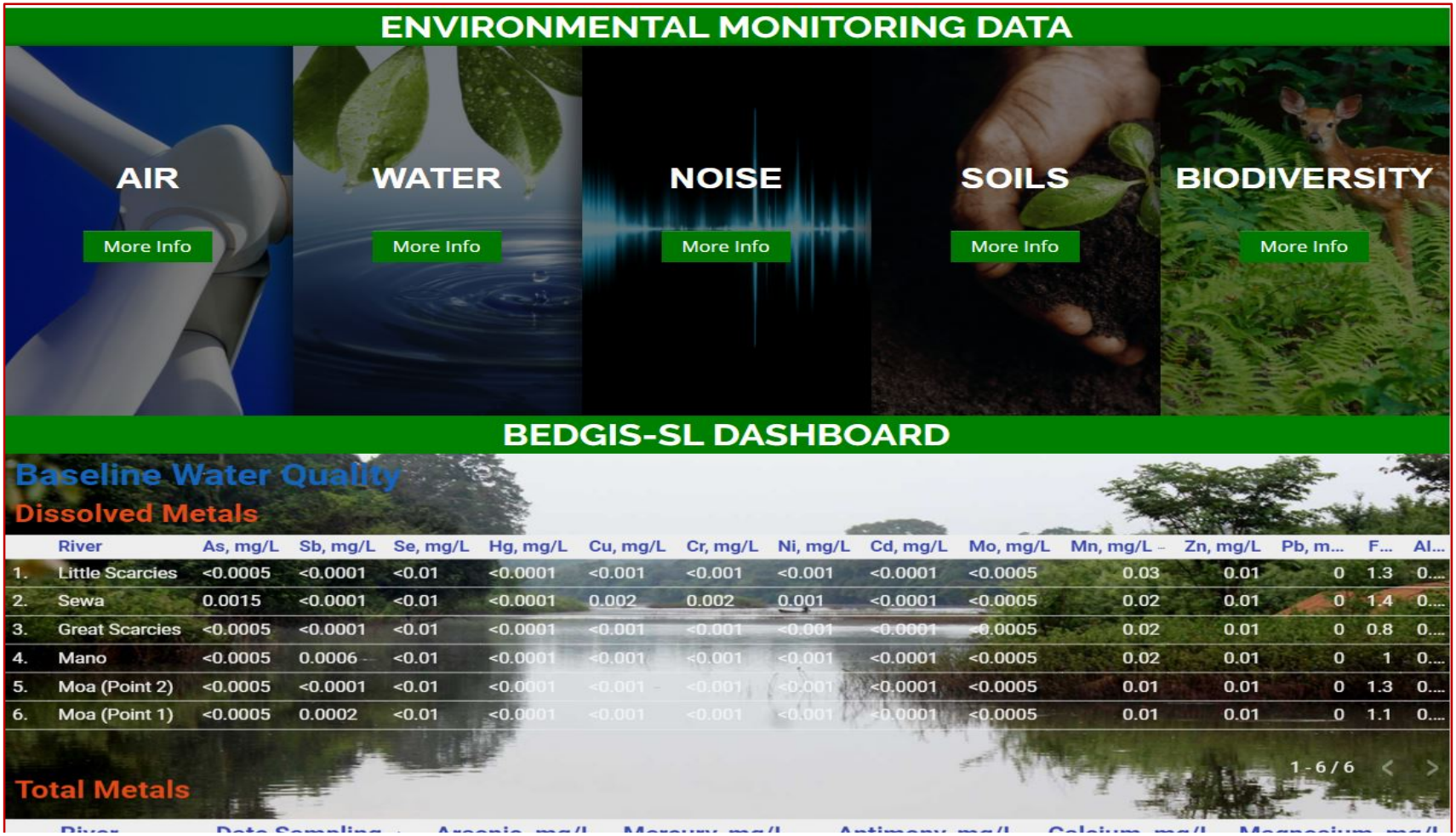
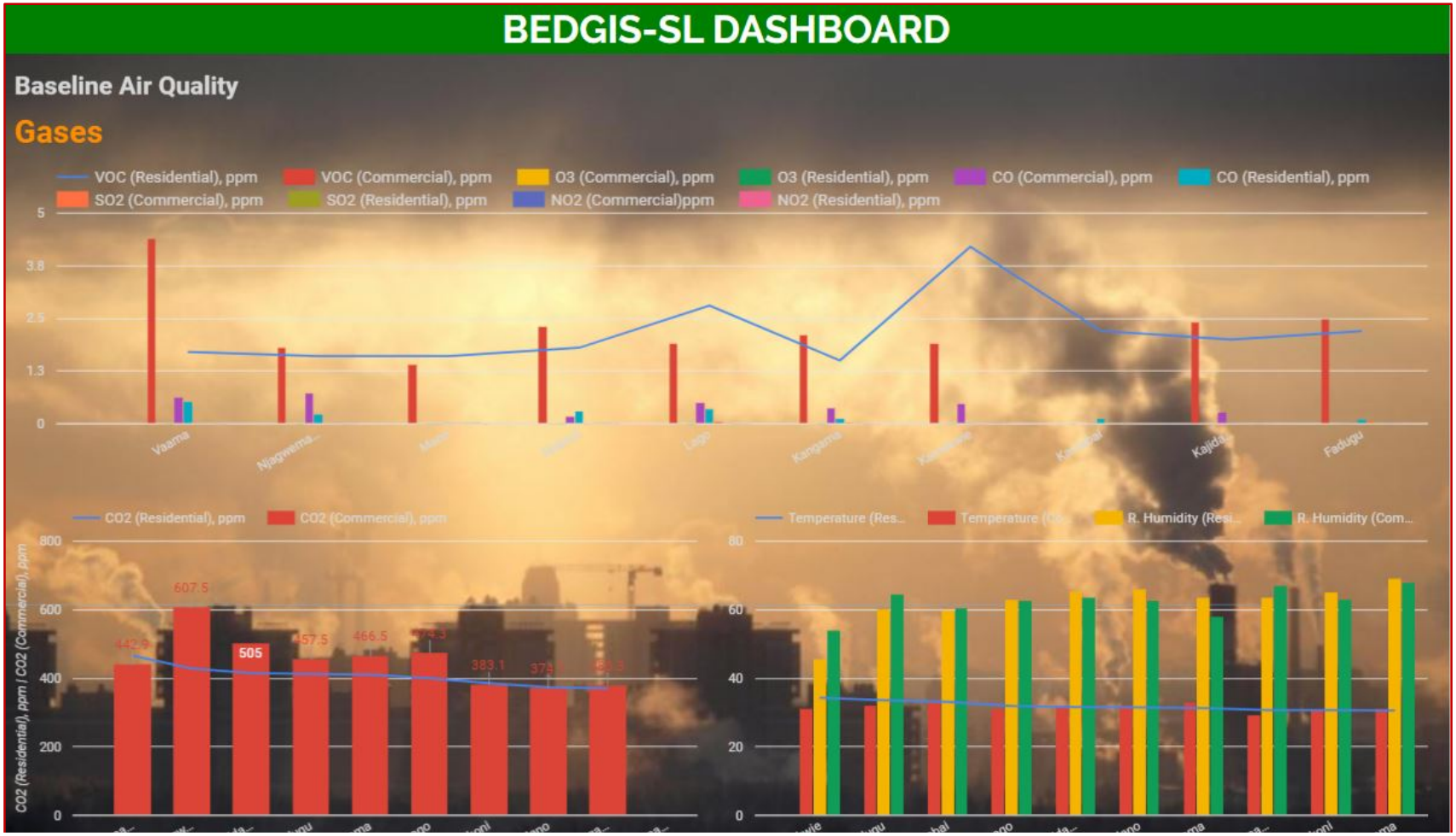


Figure 6-4: The BEDGIS-SL Environmental Monitoring Data Module



	River	As, mg/L	Sb, mg/L	Se, mg/L	Hg, mg/L	Cu, mg/L	Cr, mg/L	Ni, mg/L	Cd, mg/L	Mo, mg/L	Mn, mg/L	Zn, mg/L	Pb, m...	F...	Al...
1.	Little Scarcies	<0.0005	<0.0001	<0.01	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.0005	0.03	0.01	0	1.3	0....
2.	Sewa	0.0015	<0.0001	<0.01	<0.0001	0.002	0.002	0.001	<0.0001	<0.0005	0.02	0.01	0	1.4	0....
3.	Great Scarcies	<0.0005	<0.0001	<0.01	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.0005	0.02	0.01	0	0.8	0....
4.	Mano	<0.0005	0.0006	<0.01	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.0005	0.02	0.01	0	1	0....
5.	Moa (Point 2)	<0.0005	<0.0001	<0.01	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.0005	0.01	0.01	0	1.3	0....
6.	Moa (Point 1)	<0.0005	0.0002	<0.01	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.0005	0.01	0.01	0	1.1	0....

Figure 6-5: The BEDGIS-SL Infographics Dashboard



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8 APPENDIX I: ENVIRONMENTAL BASELINE DATA

8.1 In-situ Water Quality Monitoring Results

Table 8-1: In-situ water quality monitoring results

River	River ID	Date	Time	Temp.[°C]	pH	mV[pH]	ORP[mV]	EC[µS/cm]	EC Abs.[µS/cm]	RES[Ohm-cm]
Mano River	BEDGIS 001	2017-11-18	15:01:06	26.84	6.70	8.9	211.7	19	20	52600
Mano River	BEDGIS 001	2017-11-18	15:06:06	26.84	6.60	14.8	224.4	20	21	50000
Mano River	BEDGIS 001	2017-11-18	15:11:06	26.84	6.50	21.1	234.4	20	21	50000
Mano River	BEDGIS 001	2017-11-18	15:16:06	26.85	6.44	24.1	241.0	20	21	50000
Mano River	BEDGIS 001	2017-11-18	15:21:06	26.87	6.31	31.9	252.1	20	21	50000
Mano River	BEDGIS 001	2017-11-18	15:26:06	26.87	6.41	26.4	248.5	20	21	50000
Mano River	BEDGIS 001	2017-11-18	15:31:06	26.87	6.37	28.6	249.1	20	21	50000
Mano River	BEDGIS 001	2017-11-18	15:36:06	26.87	6.41	26.3	252.1	20	21	50000
Mano River	BEDGIS 001	2017-11-18	15:41:06	26.87	6.37	28.6	255.8	20	21	50000
Mano River	BEDGIS 001	2017-11-18	15:46:06	26.87	6.36	29.2	257.3	20	20	50000
Mano River	BEDGIS 001	2017-11-18	15:51:06	26.87	6.36	29.0	259.2	20	21	50000
Mano River	BEDGIS 001	2017-11-18	15:56:06	26.86	6.26	35.0	266.0	20	21	50000
Moa River Point 1	BEDGIS 002	2017-11-18	18:34:57	28.13	6.55	17.9	270.4	25	26	40000
Moa River Point 1	BEDGIS 002	2017-11-18	18:39:57	28.13	6.53	19.2	272.7	25	26	40000
Moa River Point 1	BEDGIS 002	2017-11-18	18:44:57	28.14	6.65	12.1	279.8	25	27	40000
Moa River Point 1	BEDGIS 002	2017-11-18	18:49:57	28.13	6.39	27.7	302.7	25	27	40000
Moa River Point 1	BEDGIS 002	2017-11-18	18:54:57	28.13	6.69	9.7	290.4	25	27	40000
Moa River Point 1	BEDGIS 002	2017-11-18	18:59:57	28.13	6.34	30.4	312.2	25	27	40000
Moa River Point 1	BEDGIS 002	2017-11-18	19:04:57	28.13	6.41	26.5	312.5	25	27	40000
Moa River Point 1	BEDGIS 002	2017-11-18	19:09:57	28.13	6.50	20.7	307.8	25	27	40000
Moa River Point 1	BEDGIS 002	2017-11-18	19:14:57	28.13	6.37	28.5	317.7	25	27	40000
Moa River Point 1	BEDGIS 002	2017-11-18	19:19:57	28.12	6.30	32.7	323.6	25	27	40000
Moa River Point 1	BEDGIS 002	2017-11-18	19:24:57	28.12	6.34	30.5	323.9	25	27	40000

River	River ID	Date	Time	Temp.[°C]	pH	mV[pH]	ORP[mV]	EC[µS/cm]	EC Abs.[µS/cm]	RES[Ohm-cm]
Moa River Point 1	BEDGIS 002	2017-11-18	19:29:57	28.12	6.65	12.0	304.7	25	27	40000
Moa River Point 2	BEDGIS 003	2017-11-19	10:15:35	28.29	7.03	13.0	190.1	2	3	500000
Moa River Point 2	BEDGIS 003	2017-11-19	10:15:55	28.31	7.03	13.0	190.0	2	2	500000
Moa River Point 2	BEDGIS 003	2017-11-19	10:22:00	27.96	7.08	10.1	257.3	19	20	52600
Moa River Point 2	BEDGIS 003	2017-11-19	10:27:00	27.97	7.00	15.1	258.0	27	29	37000
Moa River Point 2	BEDGIS 003	2017-11-19	10:32:00	27.96	6.97	16.8	261.8	27	29	37000
Moa River Point 2	BEDGIS 003	2017-11-19	10:37:00	27.96	6.94	18.3	265.7	28	29	35700
Moa River Point 2	BEDGIS 003	2017-11-19	10:42:00	27.96	6.99	15.3	264.9	28	29	35700
Moa River Point 2	BEDGIS 003	2017-11-19	10:47:00	27.96	6.98	15.9	267.2	28	29	35700
Moa River Point 2	BEDGIS 003	2017-11-19	10:52:00	27.96	6.92	19.5	271.7	28	29	35700
Moa River Point 2	BEDGIS 003	2017-11-19	10:57:00	27.97	6.92	20.0	275.3	28	29	35700
Moa River Point 2	BEDGIS 003	2017-11-19	11:02:00	27.97	6.94	18.8	273.7	28	30	35700
Moa River Point 2	BEDGIS 003	2017-11-19	11:07:00	27.98	6.89	21.6	277.8	28	30	35700
Moa River Point 2	BEDGIS 003	2017-11-19	11:12:00	27.99	6.92	19.5	275.1	28	30	35700
Moa River Point 2	BEDGIS 003	2017-11-19	11:17:00	28.01	6.86	23.0	277.3	30	32	33300
Moa River Point 2	BEDGIS 003	2017-11-19	11:22:00	28.01	6.88	22.2	277.4	29	31	34500
Sewa River	BEDGIS 004	2017-11-20	13:06:53	26.09	7.09	7.1	132.7	22	23	45500
Sewa River	BEDGIS 004	2017-11-20	13:11:53	26.08	6.99	12.8	165.0	23	23	43500
Sewa River	BEDGIS 004	2017-11-20	13:16:53	26.09	6.94	15.7	184.3	23	24	43500
Sewa River	BEDGIS 004	2017-11-20	13:21:53	26.09	6.97	13.6	184.3	23	24	43500
Sewa River	BEDGIS 004	2017-11-20	13:26:53	26.10	6.96	14.3	187.9	23	24	43500
Sewa River	BEDGIS 004	2017-11-20	13:31:53	26.11	6.97	13.7	184.7	23	24	43500
Sewa River	BEDGIS 004	2017-11-20	13:36:53	26.13	6.96	14.4	186.1	23	24	43500
Sewa River	BEDGIS 004	2017-11-20	13:41:53	26.14	6.95	15.2	184.6	23	24	43500
Sewa River	BEDGIS 004	2017-11-20	13:46:53	26.16	7.00	12.2	186.3	23	24	43500
Sewa River	BEDGIS 004	2017-11-20	13:51:53	26.16	6.91	17.4	196.1	23	24	43500
Sewa River	BEDGIS 004	2017-11-20	13:56:53	26.17	6.93	16.0	200.7	24	24	41700
Sewa River	BEDGIS 004	2017-11-20	14:01:53	26.17	6.94	15.4	195.8	24	24	41700

River	River ID	Date	Time	Temp.[°C]	pH	mV[pH]	ORP[mV]	EC[µS/cm]	EC Abs.[µS/cm]	RES[Ohm-cm]
Sewa River	BEDGIS 004	2017-11-20	14:06:53	26.18	6.97	14.0	191.9	24	24	41700
Little Scarcies River	BEDGIS 005	2017-11-21	07:35:46	27.74	6.83	29.1	113.1	39	41	25600
Little Scarcies River	BEDGIS 005	2017-11-21	07:40:46	27.34	6.82	29.4	110.2	39	41	25600
Little Scarcies River	BEDGIS 005	2017-11-21	07:45:46	27.34	6.79	31.0	116.4	39	41	25600
Little Scarcies River	BEDGIS 005	2017-11-21	07:50:46	27.34	6.96	21.7	104.8	39	41	25600
Little Scarcies River	BEDGIS 005	2017-11-21	07:55:46	27.34	6.76	33.0	118.9	39	41	25600
Little Scarcies River	BEDGIS 005	2017-11-21	08:00:46	27.34	6.81	30.3	119.0	39	41	25600
Little Scarcies River	BEDGIS 005	2017-11-21	08:05:46	27.34	6.76	33.0	120.2	39	41	25600
Little Scarcies River	BEDGIS 005	2017-11-21	08:10:46	27.34	6.94	22.8	110.9	39	41	25600
Little Scarcies River	BEDGIS 005	2017-11-21	08:15:46	27.34	6.75	33.4	119.1	39	41	25600
Little Scarcies River	BEDGIS 005	2017-11-21	08:20:46	27.34	6.77	32.2	120.4	39	41	25600
Little Scarcies River	BEDGIS 005	2017-11-21	08:25:46	27.35	6.80	30.4	119.8	39	41	25600
Little Scarcies River	BEDGIS 005	2017-11-21	08:30:46	27.35	6.97	20.7	110.9	39	41	25600
Little Scarcies River	BEDGIS 005	2017-11-21	08:35:46	27.36	6.83	28.7	118.8	39	41	25600
Great Scarcies River	BEDGIS 006	2017-11-21	12:14:51	27.74	6.86	27.0	217.7	25	26	40000
Great Scarcies River	BEDGIS 006	2017-11-21	12:19:51	27.74	6.80	30.8	222.2	25	26	40000
Great Scarcies River	BEDGIS 006	2017-11-21	12:24:51	27.77	6.70	36.2	215.7	25	26	40000
Great Scarcies River	BEDGIS 006	2017-11-21	12:29:51	27.82	6.66	38.6	205.8	25	26	40000
Great Scarcies River	BEDGIS 006	2017-11-21	12:34:51	27.81	6.68	37.5	217.7	25	26	40000
Great Scarcies River	BEDGIS 006	2017-11-21	12:39:51	27.78	6.69	37.0	223.1	25	26	40000
Great Scarcies River	BEDGIS 006	2017-11-21	12:44:51	27.81	6.64	40.0	203.6	25	26	40000
Great Scarcies River	BEDGIS 006	2017-11-21	12:49:51	27.78	6.72	35.0	215.1	25	26	40000
Great Scarcies River	BEDGIS 006	2017-11-21	12:54:51	27.79	6.72	35.1	226.4	25	26	40000
Great Scarcies River	BEDGIS 006	2017-11-21	12:59:51	27.74	6.71	35.7	218.2	25	26	40000
Great Scarcies River	BEDGIS 006	2017-11-21	13:04:51	27.96	6.68	37.6	226.1	25	26	40000
Great Scarcies River	BEDGIS 006	2017-11-21	13:09:51	27.94	6.66	39.0	201.9	25	26	40000
Great Scarcies River	BEDGIS 006	2017-11-21	13:14:51	27.98	6.60	42.3	192.4	25	26	40000

Table 8-2: In-situ water quality monitoring results (continued from Table 8-1)

River	River ID	Date	Time	TDS [ppm]	Sal.[psu]	Press.[psi]	D.O.[%]	D.O.[ppm]	Turb.FNU	Latitude	Longitude
Mano River	BEDGIS 001	2017-11-18	15:01:06	10	7.25E-03	14.606	0.0	NA	21.0	7.06897	-11.37592
Mano River	BEDGIS 001	2017-11-18	15:06:06	10	7.65E-03	14.603	0.0	NA	21.5	7.06896	-11.37581
Mano River	BEDGIS 001	2017-11-18	15:11:06	10	7.74E-03	14.600	0.0	NA	21.9	7.06899	-11.37584
Mano River	BEDGIS 001	2017-11-18	15:16:06	10	7.74E-03	14.599	0.0	NA	22.6	7.06893	-11.37577
Mano River	BEDGIS 001	2017-11-18	15:21:06	10	7.73E-03	14.600	0.0	NA	22.3	7.06892	-11.37572
Mano River	BEDGIS 001	2017-11-18	15:26:06	10	7.78E-03	14.600	0.0	NA	24.2	7.06897	-11.37589
Mano River	BEDGIS 001	2017-11-18	15:31:06	10	7.73E-03	14.596	0.0	NA	24.7	7.06896	-11.37592
Mano River	BEDGIS 001	2017-11-18	15:36:06	10	7.73E-03	14.600	0.0	NA	21.2	7.06894	-11.37593
Mano River	BEDGIS 001	2017-11-18	15:41:06	10	7.60E-03	14.603	0.0	NA	19.0	7.06900	-11.37591
Mano River	BEDGIS 001	2017-11-18	15:46:06	10	7.55E-03	14.600	0.0	NA	20.9	7.06895	-11.3759
Mano River	BEDGIS 001	2017-11-18	15:51:06	10	7.60E-03	14.601	0.0	NA	18.9	7.06903	-11.37593
Mano River	BEDGIS 001	2017-11-18	15:56:06	10	7.60E-03	14.599	0.0	NA	23.0	7.06899	-11.37596
Moa River Point 1	BEDGIS 002	2017-11-18	18:34:57	12	9.94E-03	14.556	0.0	NA	17.0	7.3602	-11.41788
Moa River Point 1	BEDGIS 002	2017-11-18	18:39:57	12	9.94E-03	14.557	0.0	NA	15.4	7.36021	-11.41794
Moa River Point 1	BEDGIS 002	2017-11-18	18:44:57	13	1.00E-02	14.556	0.0	NA	15.6	7.36021	-11.41788
Moa River Point 1	BEDGIS 002	2017-11-18	18:49:57	13	1.01E-02	14.556	0.0	NA	16.1	7.36019	-11.41788
Moa River Point 1	BEDGIS 002	2017-11-18	18:54:57	13	1.01E-02	14.561	0.0	NA	15.3	7.36016	-11.41789
Moa River Point 1	BEDGIS 002	2017-11-18	18:59:57	13	1.01E-02	14.561	0.0	NA	14.2	7.3602	-11.41787
Moa River Point 1	BEDGIS 002	2017-11-18	19:04:57	13	1.02E-02	14.563	0.0	NA	16.1	7.36019	-11.41787
Moa River Point 1	BEDGIS 002	2017-11-18	19:09:57	13	1.02E-02	14.562	0.0	NA	15.0	7.3602	-11.41788
Moa River Point 1	BEDGIS 002	2017-11-18	19:14:57	13	1.02E-02	14.555	0.0	NA	17.5	7.3602	-11.41792
Moa River Point 1	BEDGIS 002	2017-11-18	19:19:57	13	1.02E-02	14.554	0.0	NA	14.8	7.36018	-11.41793
Moa River Point 1	BEDGIS 002	2017-11-18	19:24:57	13	1.02E-02	14.560	0.0	NA	15.2	7.36016	-11.41793
Moa River Point 1	BEDGIS 002	2017-11-18	19:29:57	13	1.02E-02	14.558	0.0	NA	16.1	7.36024	-11.41781

River	River ID	Date	Time	TDS [ppm]	Sal.[psu]	Press.[psi]	D.O.[%]	D.O.[ppm]	Turb.FNU	Latitude	Longitude
Moa River Point 2	BEDGIS 003	2017-11-19	10:15:35	1	1.42E-04	14.481	0.1	0.01	1.2	7.66762	-11.26383
Moa River Point 2	BEDGIS 003	2017-11-19	10:15:55	1	2.99E-05	14.480	0.1	0.01	1.1	7.66757	-11.2638
Moa River Point 2	BEDGIS 003	2017-11-19	10:22:00	9	7.17E-03	14.480	46.7	3.60	12.7	7.66776	-11.26374
Moa River Point 2	BEDGIS 003	2017-11-19	10:27:00	13	0.01	14.480	42.9	3.31	13.9	7.66771	-11.26384
Moa River Point 2	BEDGIS 003	2017-11-19	10:32:00	14	1.11E-02	14.480	41.7	3.22	14.1	7.66777	-11.26378
Moa River Point 2	BEDGIS 003	2017-11-19	10:37:00	14	1.12E-02	14.479	40.5	3.13	13.2	7.6677	-11.26378
Moa River Point 2	BEDGIS 003	2017-11-19	10:42:00	14	1.12E-02	14.479	39.8	3.07	14.1	7.66772	-11.26381
Moa River Point 2	BEDGIS 003	2017-11-19	10:47:00	14	1.13E-02	14.479	40.0	3.08	15.2	7.66772	-11.26374
Moa River Point 2	BEDGIS 003	2017-11-19	10:52:00	14	1.13E-02	14.481	39.1	3.02	13.6	7.66762	-11.26362
Moa River Point 2	BEDGIS 003	2017-11-19	10:57:00	14	0.01	14.478	38.4	2.96	14.1	7.66766	-11.26384
Moa River Point 2	BEDGIS 003	2017-11-19	11:02:00	14	1.14E-02	14.479	38.5	2.97	14.0	7.66766	-11.26379
Moa River Point 2	BEDGIS 003	2017-11-19	11:07:00	14	1.14E-02	14.477	38.2	2.94	14.3	7.6677	-11.26378
Moa River Point 2	BEDGIS 003	2017-11-19	11:12:00	14	0.01	14.478	38.2	2.94	14.6	7.66768	-11.26373
Moa River Point 2	BEDGIS 003	2017-11-19	11:17:00	15	1.24E-02	14.480	38.6	2.97	13.6	7.66769	-11.26375
Moa River Point 2	BEDGIS 003	2017-11-19	11:22:00	14	1.18E-02	14.482	38.3	2.95	14.1	7.66767	-11.26381
Sewa River	BEDGIS 004	2017-11-20	13:06:53	11	8.71E-03	14.218	40.9	3.20	35.1	8.60477	-11.2657
Sewa River	BEDGIS 004	2017-11-20	13:11:53	11	9.03E-03	14.222	38.9	3.04	34.4	8.60477	-11.26568
Sewa River	BEDGIS 004	2017-11-20	13:16:53	12	9.17E-03	14.221	37.1	2.91	32.3	8.60477	-11.26572
Sewa River	BEDGIS 004	2017-11-20	13:21:53	12	9.26E-03	14.219	36.3	2.84	34.3	8.6048	-11.26575
Sewa River	BEDGIS 004	2017-11-20	13:26:53	12	9.30E-03	14.220	35.8	2.80	33.7	8.60479	-11.26575
Sewa River	BEDGIS 004	2017-11-20	13:31:53	12	9.30E-03	14.220	35.2	2.76	32.0	8.60476	-11.26574
Sewa River	BEDGIS 004	2017-11-20	13:36:53	12	9.29E-03	14.220	34.9	2.73	34.4	8.60474	-11.26574
Sewa River	BEDGIS 004	2017-11-20	13:41:53	12	9.34E-03	14.225	34.2	2.68	32.5	8.60476	-11.26577
Sewa River	BEDGIS 004	2017-11-20	13:46:53	12	9.33E-03	14.226	34.2	2.68	32.7	8.60476	-11.26572
Sewa River	BEDGIS 004	2017-11-20	13:51:53	12	9.33E-03	14.222	33.9	2.65	32.1	8.60477	-11.26571

River	River ID	Date	Time	TDS [ppm]	Sal.[psu]	Press.[psi]	D.O.[%]	D.O.[ppm]	Turb.FNU	Latitude	Longitude
Sewa River	BEDGIS 004	2017-11-20	13:56:53	12	9.38E-03	14.217	33.5	2.62	32.1	8.60478	-11.26573
Sewa River	BEDGIS 004	2017-11-20	14:01:53	12	9.38E-03	14.213	33.1	2.58	32.7	8.60479	-11.26575
Sewa River	BEDGIS 004	2017-11-20	14:06:53	12	9.37E-03	14.210	32.9	2.57	32.2	8.60478	-11.2657
Little Scarcies River	BEDGIS 005	2017-11-21	07:35:46	19	1.65E-02	14.580	34.8	2.73	11.6	9.52345	-12.38013
Little Scarcies River	BEDGIS 005	2017-11-21	07:40:46	20	1.67E-02	14.574	33.8	2.66	10.9	9.52346	-12.38016
Little Scarcies River	BEDGIS 005	2017-11-21	07:45:46	20	1.67E-02	14.576	33.5	2.63	11.8	9.52347	-12.38017
Little Scarcies River	BEDGIS 005	2017-11-21	07:50:46	20	0.02	14.575	32.8	2.58	12.1	9.52345	-12.38016
Little Scarcies River	BEDGIS 005	2017-11-21	07:55:46	20	1.68E-02	14.573	32.5	2.55	11.6	9.52345	-12.38017
Little Scarcies River	BEDGIS 005	2017-11-21	08:00:46	20	1.68E-02	14.582	32.2	2.53	11.6	9.52342	-12.38019
Little Scarcies River	BEDGIS 005	2017-11-21	08:05:46	20	1.67E-02	14.579	31.8	2.50	10.8	9.52343	-12.38015
Little Scarcies River	BEDGIS 005	2017-11-21	08:10:46	20	1.67E-02	14.589	31.5	2.48	11.1	9.52342	-12.38016
Little Scarcies River	BEDGIS 005	2017-11-21	08:15:46	20	1.67E-02	14.590	31.4	2.47	10.7	9.52341	-12.38018
Little Scarcies River	BEDGIS 005	2017-11-21	08:20:46	20	1.67E-02	14.594	31.2	2.46	11.7	9.52341	-12.38019
Little Scarcies River	BEDGIS 005	2017-11-21	08:25:46	20	1.67E-02	14.597	31.0	2.44	10.9	9.52344	-12.38018
Little Scarcies River	BEDGIS 005	2017-11-21	08:30:46	20	1.66E-02	14.590	30.8	2.42	11.1	9.52346	-12.38019
Little Scarcies River	BEDGIS 005	2017-11-21	08:35:46	20	0.02	14.595	30.6	2.41	10.9	9.52345	-12.38018
Great Scarcies River	BEDGIS 006	2017-11-21	12:14:51	12	9.86E-03	14.599	29.7	2.32	5.8	9.44435	-12.68058
Great Scarcies River	BEDGIS 006	2017-11-21	12:19:51	12	9.90E-03	14.603	29.2	2.28	5.6	9.44434	-12.68058
Great Scarcies River	BEDGIS 006	2017-11-21	12:24:51	12	9.94E-03	14.602	31.7	2.47	5.8	9.4443	-12.68064
Great Scarcies River	BEDGIS 006	2017-11-21	12:29:51	12	9.93E-03	14.605	30.0	2.34	5.4	9.44433	-12.68058
Great Scarcies River	BEDGIS 006	2017-11-21	12:34:51	12	9.93E-03	14.606	30.1	2.35	5.5	9.44434	-12.68059
Great Scarcies River	BEDGIS 006	2017-11-21	12:39:51	12	9.94E-03	14.605	27.4	2.14	5.8	9.44432	-12.68058
Great Scarcies River	BEDGIS 006	2017-11-21	12:44:51	12	9.93E-03	14.608	29.7	2.32	5.7	9.44433	-12.68066
Great Scarcies River	BEDGIS 006	2017-11-21	12:49:51	12	9.89E-03	14.608	29.8	2.33	5.8	9.44434	-12.68061
Great Scarcies River	BEDGIS 006	2017-11-21	12:54:51	12	9.94E-03	14.609	29.9	2.34	5.9	9.44436	-12.68069

River	River ID	Date	Time	TDS [ppm]	Sal.[psu]	Press.[psi]	D.O.[%]	D.O.[ppm]	Turb.FNU	Latitude	Longitude
Great Scarcies River	BEDGIS 006	2017-11-21	12:59:51	12	9.95E-03	14.606	30.9	2.42	6.5	9.44436	-12.68055
Great Scarcies River	BEDGIS 006	2017-11-21	13:04:51	12	9.94E-03	14.603	31.0	2.41	5.9	9.44439	-12.68063
Great Scarcies River	BEDGIS 006	2017-11-21	13:09:51	12	9.94E-03	14.603	28.1	2.18	5.8	9.44441	-12.68059
Great Scarcies River	BEDGIS 006	2017-11-21	13:14:51	12	9.98E-03	14.603	30.6	2.38	6.3	9.44434	-12.68057

8.2 Laboratory Water Quality Monitoring Results

Table 8-3: Water quality monitoring results from laboratory analysis

Parameter	Units	Reporting Limit	River					
			Mano BEDGIS 001	Moa (Point 1) BEDGIS 002	Moa (Point 2) BEDGIS 003	Sewa BEDGIS 004	Little Scarcies BEDGIS 005	Great Scarcies BEDGIS 006
			Result					
Hardness by Calculation	mg/L	5	5.	7.	8.	12.	6.	9.
Total Alkalinity as $CaCO_3$	mg/L	2	8.	11.	12.	11.	18.	11.
Apparent Colour by spec	Pt/Co colour	3	58	55	66	65	36	48
True Colour by spec	Pt/Co colour	3	24	22	17	18	15	13
Biochemical Oxygen Demand (BOD5)	mg/L	5	<5	<5	<5	<5	<5	<5
Chemical Oxygen Demand	mg/L	5	6.	<5	17.	<5	<5	7.
Nitrate, NO_3 as NO_3	mg/L	0.06	0.65	0.68	0.77	0.79	0.61	0.43
Nitrite, NO_2 as NO_2	mg/L	0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Phosphate as PO_4	mg/L	0.02	<0.02	<0.02	<0.02	<0.02	0.02	<0.02
Oil and Grease	mg/L	5	<5	<5	<5	<5	<5	<5
Total Coliforms	MPN/100 mL	1	2419.6	298.7	866.4	9208	2419.6	1732.9
Faecal Coliforms	MPN/100 mL	1	33.1	17.3	9.8	920.8	117.8	46.5
Arsenic dissolved	mg/L	0.0005	<0.0005	<0.0005	0.0007	<0.0005	<0.0005	<0.0005
Antimony dissolved	mg/L	0.0001	0.0005	0.0002	0.0004	<0.0001	0.0003	<0.0001
Mercury dissolved	mg/L	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Calcium dissolved	mg/L	1	1.	2.	2.	3.	1.	2.
Magnesium dissolved	mg/L	0.5	0.6	0.7	0.8	1.4	0.5	1.1

Parameter	Units	Reporting Limit	River					
			Mano BEDGIS 001	Moa (Point 1) BEDGIS 002	Moa (Point 2) BEDGIS 003	Sewa BEDGIS 004	Little Scarcies BEDGIS 005	Great Scarcies BEDGIS 006
			Result					
Arsenic total	mg/L	0.0005	<0.0005	<0.0005	<0.0005	0.0015	<0.0005	<0.0005
Antimony total	mg/L	0.0001	0.0006	0.0002	<0.0001	<0.0001	<0.0001	<0.0001
Selenium total	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Mercury total	mg/L	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Manganese total	mg/L	0.002	0.016	0.011	0.014	0.021	0.025	0.018
Copper total	mg/L	0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001
Zinc total	mg/L	0.005	0.007	0.005	0.007	0.01	0.006	0.007
Lead total	mg/L	0.0005	0.0005	0.0006	0.0006	0.0008	0.0008	0.0005
Chromium total	mg/L	0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001
Nickel total	mg/L	0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001
Cadmium total	mg/L	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Molybdenum total	mg/L	0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Cobalt total	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Iron total	mg/L	0.1	1.	1.1	1.3	1.4	1.3	0.8
Aluminium total	mg/L	0.03	0.24	0.18	0.31	0.41	0.17	0.09
Total Suspended Solids at 103-105 ^{o}C	mg/L	1	14	8	12	12	7	7

8.3 Noise Monitoring Results

Table 8-4: Detailed noise level measurements in Vaama Barri

Summary of residential ambient noise measurement(s)									
ID	**Start Time and Date (h:m:s)**	**End Time and Date (h:m:s)**	**Duration (h:m:s)**	**LAeq dB**	**LA90 dB**	**LA10 dB**	**LAFMax dB**	**LAFMin dB**	**Time of Day**
001	11/18/2017 6:59	11/18/2017 9:02	2:02:44	60.4	46.0	62.6	88.8	36.0	Day
002	11/18/2017 12:00	11/18/2017 14:00	2:00:27	60.3	41.8	63.3	87.7	31.8	Day
003	11/18/2017 16:58	11/18/2017 18:59	2:00:32	60.5	55.7	61.6	93.8	37.5	Day
004	11/18/2017 22:23	11/19/2017 0:00	1:37:25	50.9	47.7	51.3	82.7	38.1	Night
005	11/19/2017 8:22	11/19/2017 9:26	1:04:00	56.3	43.0	56.4	85.1	36.9	Day
006	11/19/2017 10:56	11/19/2017 12:00	1:04:00	54.1	40.6	56.3	80.4	33.1	Day
Day Average				**59.0**	**49.6**	**61.0**	**93.8**	**31.8**	**Day**
Night Average				**50.9**	**47.7**	**51.3**	**82.7**	**38.1**	**Night**
Summary of commercial ambient noise measurement(s)									
ID	**Start Time and Date (h:m:s)**	**End Time and Date (h:m:s)**	**Duration (h:m:s)**	**LAeq dB**	**LA90 dB**	**LA10 dB**	**LAFMax dB**	**LAFMin dB**	**Time of Day**
001	11/18/2017 9:29	11/18/2017 11:31	2:01:03	62.5	51.4	65.5	90.3	37.4	Day
002	11/18/2017 14:31	11/18/2017 16:09	1:37:45	63.2	51.5	65.9	87.3	43.0	Day
003	11/18/2017 16:11	11/18/2017 16:36	0:25:13	67.5	56.5	71.3	87.2	45.9	Day
004	11/18/2017 19:39	11/18/2017 21:49	2:10:00	65.7	56.6	69.6	88.1	49.8	Day
005	11/19/2017 7:00	11/19/2017 8:04	1:04:00	65.2	54.1	66.8	97.4	44.3	Day
006	11/19/2017 9:39	11/19/2017 10:43	1:04:00	66.7	53.5	69.1	92.3	43.4	Day
007	11/19/2017 12:09	11/19/2017 13:13	1:04:00	65.7	51.4	68.1	95.8	41.0	Day
Day Average				**65.5**	**54.1**	**68.5**	**97.4**	**37.4**	**Day**

Table 8-5: Noise level measurements in Mano Junction

Summary of residential ambient noise measurement(s)									
ID	**Start Time and Date (h:m:s)**	**End Time and Date (h:m:s)**	**Duration (h:m:s)**	**LAeq dB**	**LA90 dB**	**LA10 dB**	**LAFMax dB**	**LAFMin dB**	**Time of Day**
001	11/20/2017 7:34	11/20/2017 9:38	2:04:00	60.5	48.9	62.4	91.0	40.5	Day
002	11/20/2017 12:02	11/20/2017 14:06	2:04:00	59.3	46.5	60.5	88.7	37.5	Day

003	11/20/2017 16:45	11/20/2017 18:49	2:04:00	72.9	71.9	74.2	93.9	43.7	Day
004	11/21/2017 9:41	11/21/2017 10:43	1:01:08	59.1	46.3	59.6	89.0	37.7	Day
005	11/21/2017 12:09	11/21/2017 13:15	1:05:34	58.5	43.9	59.2	89.4	37.9	Day
Day Average				**66.6**	**64.9**	**67.9**	**93.9**	**37.5**	**Day**

Summary of commercial ambient noise measurement(s)

ID	Start Time and Date (h:m:s)	End Time and Date (h:m:s)	Duration (h:m:s)	LAeq dB	LA90 dB	LA10 dB	LAFMax dB	LAFMin dB	Time of Day
001	11/20/2017 9:50	11/20/2017 11:54	2:04:00	71.9	59.6	74.4	106.6	47.2	Day
002	11/20/2017 14:19	11/20/2017 16:23	2:04:00	67.6	60.5	70.3	91.7	49.6	Day
003	11/20/2017 19:13	11/20/2017 21:03	1:50:08	72.1	65.1	74.9	96.4	56.3	Day
004	11/21/2017 8:07	11/21/2017 9:12	1:04:11	64.4	53.4	67.2	88.7	43.9	Day
005	11/21/2017 10:56	11/21/2017 12:01	1:05:42	69.5	58.5	73.1	93.6	45.6	Day
006	11/21/2017 13:22	11/21/2017 14:25	1:03:36	76.7	71.0	79.9	92.9	53.0	Day
Day Average				**72.0**	**65.0**	**75.0**	**106.6**	**43.9**	**Day**

Table 8-6: Noise level measurements in Lago Jasawabu

Summary of residential ambient noise measurement(s)

ID	Start Time and Date (h:m:s)	End Time and Date (h:m:s)	Duration (h:m:s)	LAeq dB	LA90 dB	LA10 dB	LAFMax dB	LAFMin dB	Time of Day
001	11/22/2017 7:42	11/22/2017 9:46	2:04:00	58.3	47.1	61.2	87.5	39.9	Day
002	11/22/2017 12:09	11/22/2017 14:13	2:04:00	54.6	45.9	57.0	80.4	39.5	Day
003	11/22/2017 16:35	11/22/2017 18:39	2:04:00	59.3	51.9	61.6	87.7	42.9	Day
004	11/22/2017 21:02	11/22/2017 21:24	0:22:05	65.7	64.1	68.4	74.4	45.3	Day
005	11/23/2017 9:36	11/23/2017 10:36	1:00:32	54.3	44.1	57.6	78.8	37.3	Day
006	11/23/2017 11:42	11/23/2017 12:44	1:01:30	55.4	46.8	56.2	87.3	40.0	Day
Day Average				**60.1**	**56.8**	**62.7**	**87.7**	**37.3**	**Day**

Summary of commercial ambient noise measurement(s)

ID	Start Time and Date (h:m:s)	End Time and Date (h:m:s)	Duration (h:m:s)	LAeq dB	LA90 dB	LA10 dB	LAFMax dB	LAFMin dB	Time of Day
001	11/22/2017 9:59	11/22/2017 12:03	2:04:00	67.2	60.7	69.6	92.0	47.9	Day
002	11/22/2017 14:22	11/22/2017 16:26	2:04:00	65.1	56.7	67.8	91.2	51.7	Day
003	11/22/2017 18:51	11/22/2017 20:55	2:04:00	73.2	68.0	76.0	96.3	60.0	Day

004	11/23/2017 8:33	11/23/2017 9:34	1:01:12	61.0	53.8	63.3	88.3	46.0	Day
005	11/23/2017 10:39	11/23/2017 11:40	1:00:42	64.0	57.3	67.0	92.7	43.1	Day
006	11/23/2017 12:48	11/23/2017 13:50	1:01:44	67.6	63.2	69.2	95.2	52.0	Day
Day Average				**68.1**	**62.5**	**70.7**	**96.3**	**43.1**	**Day**

Table 8-7: Noise level measurements in Kangama Gorama

Summary of residential ambient noise measurement(s)									
ID	**Start Time and Date (h:m:s)**	**End Time and Date (h:m:s)**	**Duration (h:m:s)**	**LAeq dB**	**LA90 dB**	**LA10 dB**	**LAFMax dB**	**LAFMin dB**	**Time of Day**
001	11/24/2017 6:59	11/24/2017 8:58	1:58:57	55.6	44.8	58.7	81.8	39.8	Day
002	11/24/2017 11:30	11/24/2017 13:32	2:01:58	52.6	40.2	53.6	86.5	33.1	Day
003	11/24/2017 17:00	11/24/2017 19:01	2:01:00	56.7	49.4	59.6	82.3	41.9	Day
004	11/24/2017 21:40	11/24/2017 23:31	1:51:20	63.0	62.1	64.7	83.1	48.0	Day
005	11/25/2017 7:59	11/25/2017 9:01	1:01:54	54.9	45.6	56.9	81.0	40.1	Day
006	11/25/2017 10:15	11/25/2017 11:16	1:01:49	63.4	48.1	66.9	85.2	37.6	Day
Day Average				**59.6**	**54.9**	**62.3**	**86.5**	**33.1**	**Day**
Summary of commercial ambient noise measurement(s)									
ID	**Start Time and Date (h:m:s)**	**End Time and Date (h:m:s)**	**Duration (h:m:s)**	**LAeq dB**	**LA90 dB**	**LA10 dB**	**LAFMax dB**	**LAFMin dB**	**Time of Day**
001	11/24/2017 9:15	11/24/2017 11:19	2:04:00	61.4	49.6	65.6	87.9	42.7	Day
002	11/24/2017 14:40	11/24/2017 15:33	0:53:23	65.0	49.9	65.4	93.0	42.1	Day
003	11/24/2017 15:35	11/24/2017 16:45	1:09:47	63.0	49.0	66.1	89.5	42.0	Day
004	11/24/2017 19:13	11/24/2017 21:14	2:01:49	62.9	50.7	64.5	101.2	43.0	Day
005	11/25/2017 6:50	11/25/2017 7:10	0:20:07	59.8	45.1	65.8	92.3	38.5	Day
006	11/25/2017 7:11	11/25/2017 7:49	0:37:49	56.9	48.7	58.8	78.9	39.9	Day
007	11/25/2017 9:10	11/25/2017 9:45	0:34:53	58.9	49.3	59.8	89.3	42.4	Day
008	11/25/2017 9:46	11/25/2017 10:11	0:24:36	59.9	49.6	62.0	91.4	42.5	Day
009	11/25/2017 11:20	11/25/2017 12:00	0:40:41	65.0	45.9	56.9	96.3	38.6	Day
010	11/25/2017 12:02	11/25/2017 12:25	0:23:42	54.7	46.5	57.3	76.0	39.6	Day
Day Average				**61.8**	**48.8**	**63.4**	**101.2**	**38.5**	**Day**

Table 8-8: Noise level measurements in Njagbwema Nimikoro

Summary of residential ambient noise measurement(s)									
ID	**Start Time and Date (h:m:s)**	**End Time and Date (h:m:s)**	**Duration (h:m:s)**	**LAeq dB**	**LA90 dB**	**LA10 dB**	**LAFMax dB**	**LAFMin dB**	**Time of Day**
001	11/26/2017 7:39	11/26/2017 9:40	2:01:00	59.7	50.5	61.9	84.0	41.0	Day
002	11/26/2017 11:54	11/26/2017 13:56	2:02:00	57.7	46.3	60.3	87.2	38.3	Day
003	11/26/2017 16:30	11/26/2017 17:11	0:41:00	61.6	49.8	62.0	88.2	44.1	Day
004	11/26/2017 17:14	11/26/2017 18:37	1:23:00	61.1	50.2	62.0	88.4	42.6	Day
005	11/26/2017 19:56	11/26/2017 21:58	2:02:00	60.5	50.3	62.6	89.3	44.6	Day
006	11/27/2017 7:59	11/27/2017 8:59	1:00:00	61.7	50.9	62.6	89.8	43.4	Day
007	11/27/2017 10:14	11/27/2017 11:17	1:03:00	56.2	46.0	59.2	79.8	39.2	Day
Day Average				**60.2**	**49.5**	**61.7**	**89.8**	**38.3**	**Day**
Summary of commercial ambient noise measurement(s)									
ID	**Start Time and Date (h:m:s)**	**End Time and Date (h:m:s)**	**Duration (h:m:s)**	**LAeq dB**	**LA90 dB**	**LA10 dB**	**LAFMax dB**	**LAFMin dB**	**Time of Day**
001	11/26/2017 9:45	11/26/2017 11:46	2:01:15	64.4	52.2	67.1	88.9	40.7	Day
002	11/26/2017 14:05	11/26/2017 16:06	2:01:09	64.3	50.3	66.2	92.1	39.3	Day
003	11/26/2017 18:48	11/26/2017 19:52	1:03:04	65.8	56.2	68.2	90.7	51.4	Day
004	11/27/2017 6:51	11/27/2017 7:52	1:01:41	70.9	51.0	67.5	104.9	40.9	Day
005	11/27/2017 9:05	11/27/2017 10:07	1:01:52	65.6	52.6	68.5	89.1	42.3	Day
006	11/27/2017 11:25	11/27/2017 12:29	1:04:10	68.7	55.7	70.7	96.7	46.0	Day
Day Average				**67.3**	**53.6**	**68.3**	**104.9**	**39.3**	**Day**

Table 8-9: Noise level measurements in Makoni Line

Summary of residential ambient noise measurement(s)									
ID	**Start Time and Date (h:m:s)**	**End Time and Date (h:m:s)**	**Duration (h:m:s)**	**LAeq dB**	**LA90 dB**	**LA10 dB**	**LAFMax dB**	**LAFMin dB**	**Time of Day**
001	11/28/2017 7:01	11/28/2017 9:03	2:01:25	62.4	48.6	62.0	94.2	39.1	Day
002	11/28/2017 11:20	11/28/2017 13:20	2:00:49	56.9	43.9	59.3	82.9	34.9	Day
003	11/28/2017 16:11	11/28/2017 18:13	2:02:01	61.1	49.1	63.7	90.1	42.0	Day
004	11/28/2017 21:39	11/28/2017 23:43	2:04:00	55.4	49.6	56.8	85.1	41.6	Night
005	11/28/2017 23:51	11/29/2017 1:52	2:01:32	52.0	51.5	52.7	76.9	41.5	Night

006	11/29/2017 1:55	11/29/2017 3:59	2:04:00	46.3	44.0	47.4	72.3	37.9	Night
007	11/29/2017 4:33	11/29/2017 6:36	2:02:51	57.4	40.4	61.7	87.6	36.6	Night
008	11/29/2017 7:59	11/29/2017 9:00	1:00:40	60.1	51.2	62.8	85.4	42.4	Day
009	11/29/2017 10:29	11/29/2017 11:30	1:00:37	59.6	46.4	59.5	91.6	39.4	Day
Day Average				**60.4**	**48.5**	**61.8**	**94.2**	**34.9**	**Day**
Night Average				**54.4**	**48.3**	**57.4**	**87.6**	**36.6**	**Night**

Summary of commercial ambient noise measurement(s)									
ID	**Start Time and Date (h:m:s)**	**End Time and Date (h:m:s)**	**Duration (h:m:s)**	**LAeq dB**	**LA90 dB**	**LA10 dB**	**LAFMax dB**	**LAFMin dB**	**Time of Day**
001	11/28/2017 9:11	11/28/2017 11:14	2:03:20	67.6	58.5	70.5	95.4	45.7	Day
002	11/28/2017 14:00	11/28/2017 15:32	1:31:27	70.6	63.0	73.6	93.8	50.9	Day
003	11/28/2017 15:33	11/28/2017 16:03	0:29:22	72.3	63.7	75.3	95.5	53.4	Day
004	11/28/2017 19:30	11/28/2017 19:49	0:18:59	68.6	60.7	70.2	95.4	54.6	Day
005	11/28/2017 20:36	11/28/2017 21:30	0:54:43	63.6	52.6	67.5	92.0	49.0	Day
006	11/29/2017 6:50	11/29/2017 7:50	1:00:20	66.4	57.5	68.4	98.7	42.4	Day
007	11/29/2017 9:13	11/29/2017 10:15	1:02:12	72.5	60.3	72.0	105.6	48.2	Day
008	11/29/2017 11:40	11/29/2017 12:40	1:00:13	67.5	57.3	69.4	99.4	46.5	Day
Day Average				**69.5**	**60.3**	**71.6**	**105.6**	**42.4**	**Day**

Table 8-10: Noise level measurements in Kajida (Near Bumbuna)

Summary of residential ambient noise measurement(s)									
ID	**Start Time and Date (h:m:s)**	**End Time and Date (h:m:s)**	**Duration (h:m:s)**	**LAeq dB**	**LA90 dB**	**LA10 dB**	**LAFMax dB**	**LAFMin dB**	**Time of Day**
001	11/30/2017 7:00	11/30/2017 9:00	2:00:00	62.4	46.6	63.6	96.4	36.7	Day
002	11/30/2017 11:15	11/30/2017 13:15	2:00:00	57.4	43.2	59.4	84.4	33.3	Day
003	11/30/2017 15:49	11/30/2017 17:49	2:00:00	59.8	44.8	62.7	90.3	35.4	Day
004	11/30/2017 20:20	11/30/2017 22:20	2:00:00	67.5	53.7	71.2	87.4	42.5	Day
005	11/30/2017 22:29	12/1/2017 0:29	2:00:00	51.9	44.7	52.8	79.7	40.2	Night
006	12/1/2017 0:30	12/1/2017 4:30	4:00:00	47.2	42.3	44.3	88.5	39.7	Night
007	12/1/2017 4:34	12/1/2017 6:34	2:00:00	50.9	42.6	53.4	75.9	39.1	Night
008	12/1/2017 8:10	12/1/2017 9:10	1:00:00	63.2	48.4	64.2	90.9	37.0	Day
009	12/1/2017 10:22	12/1/2017 11:22	1:00:00	58.4	43.2	60.6	86.3	33.7	Day

Day Average	**62.9**	**48.5**	**65.6**	**96.4**	**33.3**	**Day**
Night Average	**50.4**	**43.4**	**51.6**	**88.5**	**39.1**	**Night**

Summary of commercial ambient noise measurement(s)

ID	Start Time and Date (h:m:s)	End Time and Date (h:m:s)	Duration (h:m:s)	LAeq dB	LA90 dB	LA10 dB	LAFMax dB	LAFMin dB	Time of Day
001	11/30/2017 9:05	11/30/2017 11:05	2:00:00	62.5	50.6	65.1	90.9	37.6	Day
002	11/30/2017 13:40	11/30/2017 15:40	2:00:00	62.1	47.3	63.4	91.3	36.1	Day
003	11/30/2017 18:03	11/30/2017 20:03	2:00:00	62.6	50.6	64.3	91.1	40.9	Day
004	12/1/2017 7:03	12/1/2017 8:03	1:00:00	62.4	46.2	62.1	88.9	40.3	Day
005	12/1/2017 9:16	12/1/2017 10:16	1:00:00	64.2	49.2	66.0	90.1	38.6	Day
006	12/1/2017 11:30	12/1/2017 12:30	1:00:00	63.0	48.5	65.5	91.2	35.5	Day
Day Average				**62.9**	**49.0**	**64.6**	**91.3**	**35.5**	**Day**

Table 8-11: Noise level measurements in Kamabai

Summary of residential ambient noise measurement(s)

ID	Start Time and Date (h:m:s)	End Time and Date (h:m:s)	Duration (h:m:s)	LAeq dB	LA90 dB	LA10 dB	LAFMax dB	LAFMin dB	Time of Day
001	12/2/2017 7:16	12/2/2017 8:16	1:00:00	57.1	46.7	60.0	80.0	38.8	Day
002	12/2/2017 8:26	12/2/2017 9:26	1:00:10	60.5	48.1	62.8	86.5	39.7	Day
003	12/2/2017 11:35	12/2/2017 13:35	2:00:00	63.3	51.8	66.2	89.1	44.4	Day
004	12/2/2017 15:45	12/2/2017 17:45	2:00:00	61.0	50.2	62.1	84.3	43.1	Day
005	12/2/2017 20:00	12/2/2017 22:00	2:00:00	63.0	56.0	61.7	86.9	45.2	Day
006	12/2/2017 22:10	12/3/2017 0:10	2:00:00	65.2	58.4	67.8	91.5	34.8	Night
007	12/3/2017 0:12	12/3/2017 2:12	2:00:00	44.8	39.3	47.9	69.4	37.5	Night
008	12/3/2017 2:15	12/3/2017 6:15	4:00:00	49.4	42.4	49.3	87.6	31.9	Night
009	12/3/2017 8:05	12/3/2017 9:05	1:00:11	60.1	49.7	62.6	85.4	43.4	Day
010	12/3/2017 10:15	12/3/2017 11:16	1:00:40	57.6	51.9	59.3	82.3	43.4	Day
Day Average				**60.9**	**51.6**	**62.7**	**89.1**	**38.8**	**Day**
Night Average				**60.6**	**53.8**	**63.1**	**91.5**	**31.9**	**Night**

Summary of commercial ambient noise measurement(s)

ID	Start Time and Date (h:m:s)	End Time and Date (h:m:s)	Duration (h:m:s)	LAeq dB	LA90 dB	LA10 dB	LAFMax dB	LAFMin dB	Time of Day

001	12/2/2017 9:30	12/2/2017 11:30	2:00:00	68.5	63.0	70.2	98.0	55.6	Day
002	12/2/2017 13:40	12/2/2017 15:20	1:40:00	70.9	64.3	71.7	97.4	55.9	Day
003	12/2/2017 15:21	12/2/2017 15:41	0:20:00	69.9	64.4	70.3	92.1	57.7	Day
004	12/2/2017 17:50	12/2/2017 19:50	2:00:00	68.7	61.7	70.8	96.1	54.2	Day
005	12/3/2017 7:00	12/3/2017 8:00	1:00:00	66.3	58.9	69.0	89.1	48.2	Day
006	12/3/2017 9:10	12/3/2017 10:10	1:00:00	66.7	58.3	68.6	93.3	51.4	Day
007	12/3/2017 11:23	12/3/2017 12:23	1:00:00	65.7	58.8	67.8	86.7	54.0	Day
Day Average				**68.5**	**62.0**	**70.0**	**98.0**	**48.2**	**Day**

Table 8-12: Noise level measurements in Fadugu

Summary of residential ambient noise measurement(s)									
ID	**Start Time and Date (h:m:s)**	**End Time and Date (h:m:s)**	**Duration (h:m:s)**	**LAeq dB**	**LA90 dB**	**LA10 dB**	**LAFMax dB**	**LAFMin dB**	**Time of Day**
001	12/4/2017 7:05	12/4/2017 9:05	2:00:00	62.8	49.0	65.3	92.7	39.9	Day
002	12/4/2017 11:31	12/4/2017 13:31	2:00:00	61.7	46.7	63.7	91.5	33.8	Day
003	12/4/2017 18:23	12/4/2017 20:23	2:00:00	75.9	62.2	70.7	94.4	52.0	Day
004	12/4/2017 22:43	12/5/2017 0:43	2:00:00	63.4	63.8	79.5	89.1	36.9	Night
005	12/5/2017 0:50	12/5/2017 4:50	4:00:00	49.5	56.7	65.9	76.4	37.5	Night
006	12/5/2017 4:56	12/5/2017 5:56	1:00:00	51.0	45.9	51.5	78.4	40.4	Night
007	12/5/2017 8:56	12/5/2017 9:20	0:24:27	60.8	46.4	52.8	91.3	36.3	Day
008	12/5/2017 10:36	12/5/2017 11:36	1:00:00	67.5	47.1	68.0	91.2	37.5	Day
Day Average				**69.9**	**55.8**	**66.8**	**94.4**	**33.8**	**Day**
Night Average				**59.0**	**59.8**	**74.9**	**89.1**	**36.9**	**Night**
Summary of commercial ambient noise measurement(s)									
ID	**Start Time and Date (h:m:s)**	**End Time and Date (h:m:s)**	**Duration (h:m:s)**	**LAeq dB**	**LA90 dB**	**LA10 dB**	**LAFMax dB**	**LAFMin dB**	**Time of Day**
001	12/4/2017 9:20	12/4/2017 11:20	2:00:00	70.0	58.9	69.6	99.0	52.0	Day
002	12/4/2017 13:56	12/4/2017 15:21	1:25:04	70.8	62.6	71.9	95.3	48.5	Day
003	12/4/2017 15:22	12/4/2017 15:59	0:37:25	68.0	70.7	62.2	87.5	52.3	Day
004	12/4/2017 16:09	12/4/2017 18:09	2:00:00	64.7	63.6	75.1	95.1	39.2	Day
005	12/4/2017 20:35	12/4/2017 22:35	2:00:00	57.6	46.5	59.5	91.6	40.0	Day
006	12/5/2017 7:02	12/5/2017 8:02	1:00:00	71.3	45.8	62.5	93.8	49.8	Day
007	12/5/2017 9:28	12/5/2017 10:28	1:00:00	72.9	58.3	75.4	109.3	53.0	Day

008	12/5/2017 12:07	12/5/2017 13:07	1:00:00	66.8	64.4	72.4	92.9	49.9	Day
Day Average				**69.4**	**64.0**	**71.5**	**109.3**	**39.2**	**Day**

Table 8-13: Noise level measurements in Kamakwie

Summary of residential ambient noise measurement(s)									
ID	**Start Time and Date (h:m:s)**	**End Time and Date (h:m:s)**	**Duration (h:m:s)**	**LAeq dB**	**LA90 dB**	**LA10 dB**	**LAFMax dB**	**LAFMin dB**	**Time of Day**
001	12/6/2017 9:23	12/6/2017 10:53	1:30:00	54.8	41.9	55.3	87.0	34.1	Day
002	12/6/2017 12:33	12/6/2017 14:03	1:30:00	58.6	40.8	54.1	90.4	34.2	Day
003	12/6/2017 15:39	12/6/2017 17:09	1:30:00	55.4	44.1	57.2	84.9	36.4	Day
004	12/6/2017 18:54	12/6/2017 20:10	1:15:56	56.5	50.4	58.2	81.6	48.6	Day
005	12/6/2017 21:47	12/6/2017 23:17	1:30:00	51.6	49.3	53.2	77.0	43.0	Night
006	12/7/2017 7:44	12/7/2017 8:44	1:00:00	55.5	44.2	57.1	86.8	37.5	Day
007	12/7/2017 9:49	12/7/2017 10:49	1:00:00	55.8	41.8	52.6	89.5	36.4	Day
Day Average				**56.3**	**45.3**	**56.1**	**90.4**	**34.1**	**Day**
Night Average				**51.6**	**49.3**	**53.2**	**77.0**	**43.0**	**Night**
Summary of commercial ambient noise measurement(s)									
ID	**Start Time and Date (h:m:s)**	**End Time and Date (h:m:s)**	**Duration (h:m:s)**	**LAeq dB**	**LA90 dB**	**LA10 dB**	**LAFMax dB**	**LAFMin dB**	**Time of Day**
001	12/6/2017 10:56	12/6/2017 12:26	1:30:00	70.3	65.8	71.2	96.0	63.8	Day
002	12/6/2017 14:06	12/6/2017 15:36	1:30:00	68.1	64.7	68.7	92.4	62.8	Day
003	12/6/2017 17:13	12/6/2017 18:43	1:30:00	67.9	57.8	70.5	94.7	43.9	Day
004	12/6/2017 20:14	12/6/2017 21:44	1:30:00	68.0	62.9	70.3	91.6	60.3	Day
005	12/7/2017 6:41	12/7/2017 7:41	1:00:03	63.7	51.3	66.3	90.6	40.0	Day
006	12/7/2017 8:47	12/7/2017 9:47	1:00:00	67.8	55.9	69.9	91.0	45.9	Day
007	12/7/2017 10:52	12/7/2017 11:52	1:00:00	69.6	62.8	71.1	91.5	59.9	Day
Day Average				**68.3**	**62.2**	**70.0**	**96.0**	**40.0**	**Day**

8.4 Biodiversity (Fauna and Flora) Species List

Table 8-14: Plant species of conservation importance in the project area

Family	Species
Anacardiaceae	*Mangifera indica*
	Spondias mombin
	Trichoscypha arborea
Annonaceae	*Cleistopholis patens*
	Uvaria sp
	Xylopia aethiopica
	Xylopia quintasii
Apocynacaea	*Alstonia congensis*
	Rauvolfia vomitoria
Bignoniaceae	*Newbouldia laevis*
Bombacaceae	*Ceiba pentandra*
Burseraceae	*Canarium schweinfurthii*
	Santiria trimera
Caesalpiniaceae	*Afzelia africana*
	Amphimas pterocarpoides
	Cassia sieberiana
	Daniella thurifera
	Detarium senegalense
	Dialum pobeguinii
	Guobourtia leonensis
Chysobalanaceae	*Parinari excelsa*
Combretaceae	*Combretum sp*
	Terminalia ivorensis
Commelinaceae	*Palisota hirsuta*
Compositae	*Aspilia africana*
	Chromolaena odorata
Cyperaceae	*Rhynchospora corymbosa*
Dilleniaceae	*Tetracera alnifolia*
Ebenaceae	*Diospyros elliotii*
	Diospyros gabonensis
	Diospyros sp
Euphorbiaceae	*Alchonea cordifolia*
	Alchornea hirtella
	Drypetes sp
	Mareya micrantha
	Microdesmis puberula
	Phyllanthus discoideus
Gramineae	*Olyra latifolia*

Family	Species
Guttiferae	*Garcinia kola*
	Garcinia sp
Hypericaceae	*Harungana madagascariensis*
	Vismia guineensis
Irvingiaceae	*Klainedoxa gabonensis*
Loganiaceae	*Anthocleista nobilis*
	Anthocleista vogelii
Loranthaceae	*Pycnanthus angolensis*
Meliaceae	*Carapa procera*
	Turraenthus africanus
Mimosaceae	*Acacia pennata*
	Albizia adiantifola
	Albizia ferruginea
	Albizia zigia
	Piptadeniastrum africanum
	Samanea saman
	Samanea dinklagei
Moraceae	*Ficus capensis*
	Milicia regia
	Musanga cecropioides
	Myranthus libericus
Myrtaceae	*Psidium guajava*
Ochnaceae	*Lophira alata*
	Ochna multiflora
	Ouratea flava
Palmae	*Elaeis guineesis*
Pandanaceae	*Pandanus candelabrum*
Papilionaceae	*Baphia sp*
	Leptoderis fasciailata
	Millettia thonningii
Rutaceae	*Fagara macrophylla*
Sapindaceae	*Allophylus africanus*
Sapotaceae	*Chrysophyllum albidum*
	Chrysophyllum pruniforme
Sterculiaceae	*Cola chlamydantha*
	Cola nitida
	Heritiera utilis
	Sterculia tragacantha
Verbenaceae	*Premna hispida*
Zimgiberaceae	*Afromomum sp*
Rutaceae	*Fagara macrophylla*

Family	Species
Sapindaceae	*Allophylus africanus*
Sapotaceae	*Chrysophyllum albidum*
	Chrysophyllum pruniforme
Sterculiaceae	*Cola chlamydantha*
	Cola nitida
	Heritiera utilis
	Sterculia tragacantha
Verbenaceae	*Premna hispida*
Zimgiberaceae	*Afromomum sp*

Table 8-15: Bird species of conservation importance in the project area

Common Name	Scientific Name
Black Kite	*Milvus migrans*
Palm-nut Vulture	*Gypohierax angolensis*
Hooded Vulture	*Necrosyrtes monachus*
African Harrier Hawk	*Polyboroides typus*
Red-necked Buzzard	*Buteo auguralis*
Ahanta Francolin	*Francolinus ahantensis*
Double-spurred Francolin	*Francolinus bicalcaratus*
White-spotted Flufftail	*Sarothrura pulchra*
African Green Pigeon	*Treron calvus*
Tambourine Dove	*Turtur tympanistria*
Blue-spotted Wood Dove	*Turtur afer*
Western Bronze-naped Pigeon	*Columba iriditorques*
Vinaceous Dove	*Streptopelia vinacea*
Great Blue Turaco	*Corythaeola cristata*
Green Turaco	*Tauraco persa*
Red-chested Cuckoo	*Cuculus solitaries*
Black Cuckoo	*Cuculus gularis*
African Emerald Cuckoo	*Chrysococcyx cupreus*
Klaas's Cuckoo	*Chrysococcyx klaas*
Didric Cuckoo	*Chrysococcyx caprius*
Yellowbill	*Ceuthmochares aereus*
Senegal Coucal	*Centropus senegalensis*
African Wood Owl	*Strix woodfordii*
Plain Nightjar	*Caprimulgus inornatus*
African Palm Swift	*Cypsiurus parvus*
Common Swift	*Apus apus*
Little Swift	*Apus affinis*

Common Name	Scientific Name
Narina's Trogon	*Apaloderma narina*
African Pied Hornbill	*Tockus fasciatus*
Black & white casqued Hornbill	*Bycanistes subcylindricus*
Yellow-casqued Hornbill	*Ceratogymna elata*
Naked-faced Barbet	*Gymnobucco calvus*
Speckled Tinkerbird	*Pogoniulus scolopaceus*
Red-rumped Tinkerbird	*Pogoniulus atroflavus*
Yellow-throated Tinkerbird	*Pogoniulus subsulphureus*
Yellow-rumped Tinkerbird	*Pogoniulus bilineatus*
Hairy-breasted Barbet	*Tricholaema hirsute*
Spotted Honeyguide	*Indicator maculates*
Gabon Woodpecker	*Dendropicos gabonensis*
Fire-bellied Woodpecker	*Dendropicos pyrrhogaster*
Grey Woodpecker	*Dendropicos goertae*
Rufous-sided Broadbill	*Smithornis rufolateralis*
Square-tailed Saw-wing	*Psalidoprocne nitens*
Fanti Saw-wing	*Psalidoprocne obscura*
Red-rumped Swallow	*Hirundo daurica*
Red-chested Swallow	*Hirundo lucida*
Nectarinia cyanolaema	*Blue-throated Brown Sunbird*
Lamprotornis cupreocauda	*Cupper-tailed Glossy Starling*

Table 8-16: Mammal species of conservation importance in the project area

Common Name	Scientific Name
West African Chimpanzee	*Pan troglodytes verus*
Sooty Mangabey	*Cercocebus atys*
Campbell Monkey	*Cercopithecus campbelli*
Callithrix Monkey	*Cercopithecus (a) sabaeus*
Lesser Spot-nosed Monkey	*Cercopithecus petaurista*
Western Pied Colobus	*N/A*
Olive Colobus	*N/A*
Diana Monkey	*Cercopithecus diana*
Potto	*Perodictcus potto potto*
Demidoff's Galago	*Galagoides demidoff*
Chiroptera (Bats)	*N/A*
African Straw-coloured Fruit-bat	*Eidolon helvum*
Climbing Shrew	*Sylvisorex grantii*
Striped Ground Squirrel	*Xerus erythropus*
Fire-footed Rope Squirrel	*Funisciurus pyrropus*
Green Squirrel	*Paraxerus poensis*
Red-legged Sun Squirrel	*Heliosciurus rufobrachium*

Common Name	Scientific Name
Hystricidae (Porcupines)	*N/A*
Brush-tailed Porcupine	*Atherurus africanus*
Thryonomyidae (Cane-rats)	*N/A*
Marsh Cane-rat	*Thryonomys swinderianus*
Giant Pouched Rat	*Cricetomys sp*
Giant Pouched Rat	*Cricetomys emini*
Common Mice	*Mus sp*
Common House Rat	*Rattus rattus*
Typical Striped Grass Mouse	*Lemniscomys striatus*
African Clawless Otter	*Aonyx capensis*
Common Slender Mongoose	*Herpestes sanguineus*
Gambian Mongoose	*Mungos gambianus*
Marsh Mongoose	*Atilax paludinosus*

Table 8-17: Amphibian species of conservation importance in the project area

Common Name	Scientific Name
Brown Banana Frog	*Afrixalus dorsalis*
N/A	*Amietophrynus maculatus*
African Common Toad	*Amietophrynus regularis*
N/A	*Astylosternus occidentalis*
N/A	*Arthroleptis sp*
African Foam-nest Treefrog	*Chiromantis rufescens*
African Groove-crowned frog	*Hoplobatrachus occipitalis*
N/A	*Hylarana albolabris*
N/A	*Hyperolius concolor*
N/A	*Leptopelis spiritusnoctis*
N/A	*Leptopelis viridis*
Allen's River Frog	*Phrynobatrachus alleni*
Alh's River frog	*Phrynobatrachus latifrons*
Natal Dwarf Puddle Frog	*Phrynobatrachus natalensis*
N/A	*Phrynobatrachus phyllophilus*
N/A	*Phrynobatrachus tokba*
Broad-banded Grass Frog	*Ptychadena bibroni*
Mascarene Grass Frog	*Ptychadena mascareniensis*
N/A	*Ptychadena pumilio*
N/A	*Ptychadena sp*
N/A	*Ptychadena oxyrhynchus*
Tropical Clawed Frog	*Silurana tropicalis*

Table 8-18: Reptile species of conservation importance in the project area

Common Name	Scientific Name
N/A	*Agama africana*
N/A	*Agama agama*
Boulengeri's Agama	*Agama boulengeri*
N/A	*Agama lebretoni*
Insular Agama	*Agama insularis*
N/A	*Agama paraficana*
N/A	*Agama paragama*
N/A	*Agama wagneri*
African Brown Water Snake	*Afronatrix anoscopus*
Keeled Water Skink	*Cophoscincopus durus*
N/A	*Cophoscincopus simulans*
Western Green Mamba	*Dendroaspis viridis*
N/A	*Grayia smythii*
N/A	*Hemidactylus brooki*
N/A	*Hemidactylus mabouia*
N/A	*Mochlus fernandi*
N/A	*Naja melanoleuca*
N/A	*Naja nigricolis*
African Dwarf Crocodile	*Osteolaemus tetraspis*
Northern Green Bush Snake	*Philothamnus irregularis*
Striped-bellied Sand Snake	*Psammophis sibilans*
Royal Python	*Python regius*
N/A	*Python sebae*
N/A	*Riopa fernandi*
N/A	*Trachylepis affinis*
Benson's Mabuya	*Trachylepis bensonii*
N/A	*Trachylepis paucisquamis*
N/A	*Trachylepis perrotetii*

Table 8-19: Fish species of conservation importance in the project area

Family	Species
Notopteridae	*Notopterus afer*
Mormyridae	*Petrocephalus leveque*
Characidae	*Brycinus longipinnis*
Characidae	*Hydocynus forskalii*
Cyprinidae	*Barbus sacratus*
Cyprinidae	*Labeo parvus*
Cyprinidae	*Raiamas nigeriensis*
Bagridae	*Chrysichthys nigrodigitatus*
Claridae	*Clariaes buettikoferi*

Family	Species
Claridae	*Clarias laeviceps*
Claridae	*Heterobranchus isopterus*
Malapteruridae	*Malapterurus electricus*
Cichlidae	*Hemichromis fasciatus*
Cichlidae	*Sarotherodon occidentalis*
Cichlidae	*Tilapia brevimanus*
Cichlidae	*Tilapia louka*
Cichlidae	*Tilapia buettikoferi*
Anabantidae	*Ctenopoma kingsleyae*
Alistidae	*Brycinus macrolepidotus*
Polypteridae	*Polypterus sp*
Hepsetidae	*Hepsetus odoe*
Mormyridae	*Marcusenius meronai*
Cyprinidae	*Barbus liberiensis*
Schilbeidae	*Schilbe mandibularis*

9 APPENDIX II: CERTIFICATES, RESULTS AND CALIBRATION DOCUMENTS

Canadian Association for Laboratory Accreditation Inc.

Certificate of Accreditation

Monitoring & Analytical Services Laboratory (MASLAB)
SGS Laboratory Services Ghana Ltd.
SCOA Yard, Harbour Road, Plot No. B15 Tema, Community I,
Tema, GHANA

This laboratory is accredited in accordance with the recognized International Standard ISO/IEC 17025:2005.
This accreditation demonstrates technical competence for a defined scope and the operation of a laboratory quality management system (refer to joint ISO-ILAC-IAF Communiqué dated 8 January 2009).

Accreditation No.: A3699
Issued On: August 11, 2016
Accreditation Date: July 6, 2009
Expiry Date: February 9, 2019

President & CEO

LABORATORY NAME: Monitoring & Analytical Services Laboratory (MASLAB)

MATRIX

Fat and Oils

APPENDIX NO. / NAME

NEW 063 Peroxide Value - Food

METHOD	METHOD REFERENCE	LAB METHOD I.D.
TITRIMETRIC	modified from AOAC 965.33 AND ISO 3960	ME-GH-[ENVTST]AGR-TM-AN-617

Parameters:

Peroxide Value

NEW 065 Saponification Value - Fat and Oils

METHOD	METHOD REFERENCE	LAB METHOD I.D.
TITRIMETRIC	modified from ISO 3657 AND BS 684	ME-GH-[ENVTST]AGR-TM-AN-619

Parameters:

Saponification Value

Food (Inorganic)

APPENDIX NO. / NAME

NEW 058 Total Ash - Food

METHOD	METHOD REFERENCE	LAB METHOD I.D.
GRAVIMETRIC	modified from AOAC 942.05	ME-GH-[ENVTST]AGR-TM-AN-616

Parameters:

Total Ash

NEW 059 Crude Fat - Food

METHOD	METHOD REFERENCE	LAB METHOD I.D.
SOXHLET EXTRACTION METHOD	modified from AOAC 920.39	ME-GH-[ENVTST]AGR-TM-AN-604

Parameters:

Crude Fat

NEW 060 Free Fatty Acid - Food

METHOD	METHOD REFERENCE	LAB METHOD I.D.
TITRIMETRIC	modified from PEARSONS COMPOSITION AND ANALYSIS OF FOODS, 9TH EDITION, PAGES 349 AND 475	ME-GH-[ENVTST]AGR-TM-AN-601

Parameters:

Free Fatty Acid (FFA)

NEW 061 Iodine Value - Food

METHOD	METHOD REFERENCE	LAB METHOD I.D.
TITRIMETRIC	modified from 920.159, VOL II	ME-GH-[ENVTST]AGR-TM-AN-610

Parameters:

Iodine Value

NEW 064 Protein - Food

METHOD	METHOD REFERENCE	LAB METHOD I.D.
distiLLATION	modified from AOAC 988.05	ME-GH-[ENVTST]AGR-TM-AN-609

Parameters:

Protein

Food (Microbiology)

APPENDIX NO. / NAME

032 Aerobic Bacteria - Food

METHOD	METHOD REFERENCE	LAB METHOD I.D.
PETRIFILM	modified from AOAC OFFICIAL ANALYTICAL METHOD, 16TH ED., VOL. 1 986.33, 990.12	ME-GH-[ENVTST] MIC-TM-AN-401

Parameters:

aerobic bacteria

* CALA Proficiency Testing (PT) Program analyte

LABORATORY NAME: Monitoring & Analytical Services Laboratory (MASLAB)

MATRIX

034 Coliform bacteria - Food

METHOD	METHOD REFERENCE	LAB METHOD I.D.
PETRIFILM METHOD	modified from AOAC FFICIAL ANALYTICAL METHOD, 16TH ED. VOL. 1 986.33, 989.10, 991.14	ME-GH-[ENVTST] MIC-TM-AN-409

Parameters:

Coliform bacteria
E.coli

Soil (Inorganic)

APPENDIX NO. / NAME

042 Trace Metals - Soil/Sediment

METHOD	METHOD REFERENCE	LAB METHOD I.D.
ICP - DIGESTION	modified from EPA 3050	ME-GH-[ENVTST] MET-TM-AN-342, ME-GH-[ENVTST] MET-TM-AN-348

Parameters:

Aluminum*
Antimony*
Arsenic*
Barium*
Beryllium*
Boron*
Cadmium*
Chromium*
Cobalt*
Copper*
Iron*
Manganese*
Nickel*
Strontium*
Tin*
Titanium*
Vanadium*
Zinc*

043 Mercury - Soil/Sediment

METHOD	METHOD REFERENCE	LAB METHOD I.D.
	modified from EPA 7471B	AP3042, AP 3045

Parameters:

Mercury*

Solids (Inorganic)

APPENDIX NO. / NAME

022 pH - Soil

METHOD	METHOD REFERENCE	LAB METHOD I.D.
pH METER	modified from SM 4500-H+ B and ASTM D4972-4	ME-GH-[ENVTST] PHY-TM-AN-308

Parameters:

pH

NEW 062 Moisture - Food

METHOD	METHOD REFERENCE	LAB METHOD I.D.
GRAVIMETRIC	modified from AOAC 925.10 AND 930.15	ME-GH-[ENVTST]AGR-TM-AN-602

Parameters:

Moisture

Water (Inorganic)

APPENDIX NO. / NAME

001 Silicate - Potable, Groundwater, Wastewater, Effluent

METHOD	METHOD REFERENCE	LAB METHOD I.D.
COLORIMETRIC (AQUAKEM DISCRETE ANALYSER)	modified from SM 4500-SI02 D and 370.1, AQUAKEM	ME-GH-[ENVTST] PHY-TM-AN-301

Parameters:

Reactive Silica*

*** CALA Proficiency Testing (PT) Program analyte**

LABORATORY NAME: Monitoring & Analytical Services Laboratory (MASLAB)

MATRIX

002 Nitrate - Potable, Ground, Water, Wastewater, Effluent

METHOD	METHOD REFERENCE	LAB METHOD I.D.
COLORIMETRIC (AQUAKEM DISCRETE ANALYSER)	modified from SM 4500-NO3 H and EPA 353.1 AQUAKEM REFERENCE MANUAL	ME-GH-[ENVTST] PHY-TM-AN-302

Parameters:

Nitrate*

003 Sulphate - Potable, Ground, Water, Wastewater, Effluent

METHOD	METHOD REFERENCE	LAB METHOD I.D.
COLORIMETRIC (AQUAKEM DISCRETE ANALYSER)	modified from SM 4500-SO42- C and D and EPA 375.4 AQUAKEM REFERENCE MANUAL	ME-GH-[ENVTST] PHY-TM-AN-303

Parameters:

Sulfate*

004 Chloride - Potable, Ground, Water, Wastewater, Effluent

METHOD	METHOD REFERENCE	LAB METHOD I.D.
COLORIMETRIC (AQUAKEM DISCRETE ANALYSER)	modified from SM 4500-CL E and EPA 325.21 AQUAKEM REFERENCE MANUAL	ME-GH-[ENVTST] PHY-TM-AN-304

Parameters:

Chloride*

005 Nitrite - Potable, Ground, Water, Wastewater, Effluent

METHOD	METHOD REFERENCE	LAB METHOD I.D.
COLORIMETRIC (AQUAKEM DISCRETE ANALYSER)	modified from SM 4500-NO2 B and EPA 354.1 AQUAKEM REFERENCE MANUAL	ME-GH-[ENVTST] PHY-TM-AN-318

Parameters:

Nitrite*

006 Ammonia Nitrogen - Potable, Ground, Water, Wastewater, Effluent

METHOD	METHOD REFERENCE	LAB METHOD I.D.
COLORIMETRIC (AQUAKEM DISCRETE ANALYSER)	modified from SM 4500 - NH3 H and EPA 350.1 AQUAKEM REFERENCE MANUAL	ME-GH-[ENVTST] PHY-TM-AN-322

Parameters:

Ammonia*

007 Cyanide - Potable, Ground, Water, Wastewater, Effluent

METHOD	METHOD REFERENCE	LAB METHOD I.D.
SPECTROPHOTOMETRIC	modified from SM 4500-CN- I and OPERATORS MANUAL LACHAT INSTRUMENTS, 2000	ME-GH-[ENVTST] PHY-TM-AN-321

Parameters:

Cyanide (WAD)

009 Soluble Reactive Phosphorus - Potable, Ground, Water, Wastewater, Effluent

METHOD	METHOD REFERENCE	LAB METHOD I.D.
COLORIMETRIC (AQUAKEM DISCRETE ANALYSER)	modified from SM 4500 P-E and EPA 365.2 AQUAKEM	ME-GH-[ENVTST] PHY-TM-AN-334

Parameters:

Soluble Reactive Phosphorus

012 Conductivity - Potable, Ground, Water, Wastewater, Effluent

METHOD	METHOD REFERENCE	LAB METHOD I.D.
CONDUCTIVITY METER	modified from NATA, ISO/IEC 17024 APPLICATION DOCUMENT - CHEMICAL TESTING (FAD) NATA, 2005 and SM 2510	ME-GH-[ENVTST] PHY-TM-AN-307

Parameters:

Conductivity (25˚C)*

013 Solids - Potable, Ground, Water, Wastewater, Effluent

METHOD	METHOD REFERENCE	LAB METHOD I.D.
GRAVIMETRIC	modified from SM 2540 C, D	ME-GH-[ENVTST] PHY-TM-AN-309

Parameters:

Total Dissolved Solids*
Total Suspended Solids*

*** CALA Proficiency Testing (PT) Program analyte**

LABORATORY NAME: Monitoring & Analytical Services Laboratory (MASLAB)

MATRIX

014 Chemical Oxygen Demand (COD) - Potable, Ground, Water, Wastewater, Effluent

METHOD	METHOD REFERENCE	LAB METHOD I.D.
COLORIMETRIC (CLOSED REFLUX)	modified from SM 5220 D and HACH WATER ANALYSIS HANDBOOK	ME-GH-[ENVTST] PHY-TM-AN-311

Parameters:

COD*

015 Dissolved Oxygen - Potable, Ground, Water, Wastewater, Effluent

METHOD	METHOD REFERENCE	LAB METHOD I.D.
D.O. METER	modified from SM 4500-O G	ME-GH-[ENVTST] PHY-TM-AN-312

Parameters:

Dissolved Oxygen

016 Biochemical Oxygen Demand (BOD) - Potable, Ground, Water, Wastewater, Effluent

METHOD	METHOD REFERENCE	LAB METHOD I.D.
WINKLER	modified from SM 5210 B and SM 4500-O C	ME-GH-[ENVTST] PHY-TM-AN-313, ME-GH-[ENVTST]PHY-TM- AN-320

Parameters:

BOD (5 day)*

017 Alkalinity - Potable, Ground, Water, Wastewater, Effluent

METHOD	METHOD REFERENCE	LAB METHOD I.D.
TITRIMETRIC	modified from SM 2320 B, 2310B	ME-GH-[ENVTST] PHY-TM-AN-316

Parameters:

Alkalinity (pH 4.5)*

021 pH - Potable, Groundwater, Wastewater, Effluent

METHOD	METHOD REFERENCE	LAB METHOD I.D.
pH METER	modified from SM 4500-H+ B	ME-GH-[ENVTST] PHY-TM-AN-308

Parameters:

pH*

025 Hydride Metals - Potable, Groundwater, Wastewater and Effluent

METHOD	METHOD REFERENCE	LAB METHOD I.D.
FAAS HYDRIDE	modified from SM 3114 B and C	ME-GH-[ENVTST] MET-TM-AN-339, ME-GH-[ENVTST] MET-TM-AN-340

Parameters:

Antimony*
Arsenic*
Selenium*

029 Dissolved and Extractable - Potable, Groundwater, Wastewater and Effluent

METHOD	METHOD REFERENCE	LAB METHOD I.D.
ICP/OES	modified from EPA 200.7 and SM 3120 B	ME-GH-[ENVTST] MET-TM-AN-348

Parameters:

Aluminum*
Bismuth
Cadmium*
Calcium*
Chromium*
Cobalt*
Copper*
Iron*
Lead*
Magnesium*
Manganese*
Molybdenum*
Nickel*
Potassium*
Silica
Sodium*
Vanadium*
Zinc*

* CALA Proficiency Testing (PT) Program analyte

LABORATORY NAME: Monitoring & Analytical Services Laboratory (MASLAB)

MATRIX

039 Cyanide - Potable, Groundwater, Wastewater and Effluent

METHOD	METHOD REFERENCE	LAB METHOD I.D.
SPECTROPHOTOMETRIC	modified from SM 4500-CN- C and E	ME-GH-[ENVTST] PHY-TM-AN-315

Parameters:

Cyanide (SAD)*
Free Cyanide

044 Total Oil and Grease - Water

METHOD	METHOD REFERENCE	LAB METHOD I.D.
GRAVIMETRIC - EXTRACTION	modified from SM 5520 B	ME-GH-[ENVTST] PHY-TM-AN-326

Parameters:

Total Oil and Grease*

045 Cyanide - Water

METHOD	METHOD REFERENCE	LAB METHOD I.D.
AUTO COLOR	modified from SM 4500-CNC and 4500-CN E and 4500-CN I	ME-GH-[ENVTST] PHY-TM-AN-349

Parameters:

Cyanide (SAD)*
Free Cyanide

046 Total Phosphorus - Potable, Groundwater, Wastewater and Effluent

METHOD	METHOD REFERENCE	LAB METHOD I.D.
AUTO COLOR	modified from SM 4500-P-F	ME-GH-[ENVTST] PHY-TM-AN-352

Parameters:

Total Phosphorus*

047 Metals - Water

METHOD	METHOD REFERENCE	LAB METHOD I.D.
ICP/MS - DIGESTION	EPA 200.2 and EPA 200.8	ME-GH-[ENVTST] MET-TM-AN-350, ME-GH-[ENVTST] MET-TM-AN-351

Parameters:

Aluminum*
Antimony*
Arsenic*
Barium*
Beryllium*
Boron*
Cadmium*
Calcium*
Chromium*
Cobalt*
Copper*
Iron*
Lead*
Magnesium*
Manganese*
Mercury
Molybdenum*
Nickel*
Potassium*
Selenium*
Silver*
Sodium*
Strontium*
Thallium*
Tin*
Titanium*
Uranium*
Vanadium*
Zinc*

* CALA Proficiency Testing (PT) Program analyte

LABORATORY NAME: Monitoring & Analytical Services Laboratory (MASLAB)

MATRIX

049 Colour - Water

METHOD	METHOD REFERENCE	LAB METHOD I.D.
COLORIMETRIC	modified from SM 2120 C	ME-GH-[ENVTST]PHY-TM-AN-358

Parameters:

Apparent Colour
True Colour*

050 Turbidity - Water

METHOD	METHOD REFERENCE	LAB METHOD I.D.
NEPHELOMETRY	modified from SM 2130 B	ME-GH-[ENV]PHY-TM-AN-306

Parameters:

Turbidity*

055 Hexavalent Chromium - Water

METHOD	METHOD REFERENCE	LAB METHOD I.D.
COLORIMETRIC	modified from SM 3500 B	ME-GH-[ENVTST]PHY-TM-AN-356

Parameters:

Chromium VI

056 Fluoride - Water

METHOD	METHOD REFERENCE	LAB METHOD I.D.
SELECTIVE ION ELECTRODE	modified from SM 4500 F C	ME-GH-[ENVTST]PHY-TM-AN-357

Parameters:

Fluoride*

Water (Microbiology)

APPENDIX NO. / NAME

031 Aerobic Bacteria - Water

METHOD	METHOD REFERENCE	LAB METHOD I.D.
PETRIFILM METHOD	modified from AOAC OFFICIAL ANALYTICAL METHOD, 16TH ED., VOL. 1 986.33, 990.12	ME-GH-[ENVTST] MIC-TM-AN-407

Parameters:

aerobic bacteria

033 Coliforms - Water

METHOD	METHOD REFERENCE	LAB METHOD I.D.
PETRIFILM METHOD	modified from AOAC OFFICIAL ANALYTICAL METHOD, 16TH ED. VOL. 1 986.33, 989.10, 991.14	ME-GH-[ENVTST] MIC-TM-AN-403, ME-GH-[ENVTST] MIC-TM-AN-408

Parameters:

Coliform bacteria
E.coli

051 Coliforms - Water

METHOD	METHOD REFERENCE	LAB METHOD I.D.
IDEXX COLILERT-18	modified from SM 9221 D	ME-GH-[ENVST] MIC-TM-AN-410

Parameters:

Escherichia coli (E. coli)*
Total Coliforms*

054 Heterotrophic Plate Count (HPC) - Water

METHOD	METHOD REFERENCE	LAB METHOD I.D.
MOST PROBABLE NUMBER (SIMPLATE)	modified from SM 9215 E	ME-GH-[ENVTST] MIC-TM-AN-411

Parameters:

Heterotrophic Plate Count (HPC)*

* CALA Proficiency Testing (PT) Program analyte

LABORATORY NAME: Monitoring & Analytical Services Laboratory (MASLAB)

MATRIX

† "OSDWA" indicates the appendix is used for the analysis of Ontario drinking water samples, which is subject to the rules and related regulations under the Ontario "**Safe Drinking Water Act**" (2002).

PT REQUIREMENTS: All tests appearing in the scope of testing must be supported by PT testing where available. Therefore, analytes with a status of Withdrawn, Suspended, or not yet proficient, will NOT appear on the Final Scope of Testing. Once proficiency has been achieved, the affected analyte(s) will appear on the Scope of Testing. Please refer to P02-03 *CALA Program Description - Proficiency Testing (PT) Requirements for Accreditation.*

The list of tests and measurement capabilities for which a laboratory is accredited can change at any time due to circumstances such as scope extensions, voluntary withdrawal of tests by the laboratory and suspension. Scopes are published by the CALA via the Internet at http://www.cala.ca/cala_directories.html

* CALA Proficiency Testing (PT) Program analyte

SGS	**SAMPLE KIT REQUEST FORM**	Doc. No	PF-GH-[ENVTST]GEN-TM-AD-007
		Rev No	2.5
		Issued On	29/12/2016
		Approved by	Berko-Asamoah Boateng

SGS MASLAB is able to assist with the correct bottle and preservation choice for your required analysis. Please contact our office.

Client:	**Date Requested by Client:**
Contact:	**Time Required by Client:**
Telephone:	***SGS Office Use Only***
Delivery Address:	**Date Order Received:**
	Time Order Received:

SAMPLE CONTAINERS

Quantity	Type - Water	Size	Preservative	Determinations
	Glass Amber Bottle	1000mL	Nil	Oil and grease/TPH
	Glass Amber Bottle	1000mL	Nil	PAAH
	Sterile plastic sample bags	23cmx 15cm	Nil	Micro-24 hours of sampling

Quantity	Type - Water	Size	Preservative	Determinations
	Plastic Bottle - white	1000mL	Nil	For general and inorganic
	Plastic Bottle - white	500mL	Nil	BOD
	Plastic Bottle - black	500mL	NaOH	Cyanide
	Plastic Bottle - white	250mL	Nitric Acid	Unfiltered raw sample for total metals
	Plastic Bottle - white	250mL	To be preserved with HNO3 on receipt.	For dissolved metals (filter prior to submission)
	Plastic Bottle - white	100mL	Nil	COD
	Sterilized Plastic Bottle - white	120ml	Na2S2O3	Micro-24 hours of sampling

Other:

Quantity		Type	Size
		Ice chest Hard Plastic	Large
		Ice chest Hard Plastic	Small
		Ice Bricks	n/a
Tick	☐	Label for sodium hydroxide(NaOH) preserved bottles	n/a
	☐	Label for nitric acid(HNO3) preserved bottles	n/a
	☐	Label for sulphuric acid(H2SO4) preserved bottle	n/a
	☐	Label for bottle with no preservative	n/a

Please contact Sample Receipt at emmanuel.agyemang@sgs.com for your sample container requirements. Allow 5 days for interprovincial delivery.

Kindly see sample preservation guide below.

SAMPLE PRESERVATION GUIDE

INORGANICS						
	Water & Wastewater				Soil & Sludge	
Analysis	**Container**	**Volume**	**Preservation**	**Holding Time**	**Container**	**Holding Time**
Acidity	HDPE	100 ml	Cool, 4°C	24 Hours	--	N/A
Alkalinity	HDPE	100 ml	Cool, 4°C	7 days	--	N/A
Ammonia	HDPE	50 ml	Cool, 4°C H_2SO4 pH <2	28 Days	Glass Jar/Plastic bag	7 Days
BOD	HDPE	1000 ml	Cool, 4°C	48hrs/4 days	--	--
Chloride	HDPE	50 ml	Cool, 4°C	28 Days	Glass Jar/Plastic bag	7 Days
Chlorine	HDPE	50 ml	None	Analyse Immediately	--	--
COD	HDPE or Glass	100 ml	Cool, 4°C H_2SO4 pH <2	7/28 days	--	--
Colour	HDPE or Glass	100 ml	Cool, 4°C	48 Hours	--	--
Conductivity	HDPE or Glass	100 ml	Cool, 4°C	7 Days	Glass Jar/Plastic bag	7 Days
Cyanide - Free, Total, WAD	HDPE	250 ml	Cool, 4°C NaOH pH > 12	14 days	Glass Jar/Plastic bag	7 Days
Fluoride	HDPE	50 ml	Cool, 4°C	28 days	Glass Jar/Plastic bag	7 Days
Nitrate	HDPE	50 ml	Cool, 4°C H_2SO4 pH <2	28 days	Glass Jar/Plastic bag	48 Hours
Nitrite	HDPE	50 ml	Cool, 4°C	48 Hours	Glass Jar/Plastic bag	48 Hours
Kjeldahl Nitrogen	HDPE	250 ml	Cool, 4°C H2SO4 pH <2	7 Days	Glass Jar/Plastic bag	28 Days
Orthophosphate	HDPE	50 ml	Filter on site Cool, 4°C	48 Hours	Glass Jar/Plastic bag	48 Hours
pH	HDPE	50 ml	Cool, 4°C	Analyse Immediately	Glass Jar/Plastic bag	48 Hours
Phosphorus - Total	HDPE	100 ml	Cool, 4°C H2SO4 pH <2	28 Days	Glass Jar/Plastic bag	28 Days
Solids - Total	HDPE	100 ml	Cool, 4°C	7 Days	--	--
Sulphate	HDPE	50 ml	Cool, 4°C	28 Days	Glass Jar/Plastic bag	7 Days
Sulphide	HDPE	50 ml	Cool, 4°C Zinc Acetate + NaOH pH > 9	7 Days	Glass Jar/Plastic bag	7 Days
Total Diss. Solids	HDPE	100 ml	Cool, 4°C	7 Days	--	--
Turbidity	HDPE	200 ml	Cool, 4°C	24 Hours	--	--
Oil & Grease/ TPH	Glass	1000	Add HCl to pH < 2, Cool, 4°C	28 days	Glass Jar/Plastic bag	28 days

METALS						
Water & Wastewater					Soil & Sludge	
Analysis	**Container**	**Volume**	**Preservation**	**Holding Time**	**Container**	**Holding Time**
Boron	HDPE	250 ml	None	28 Days	--	--
Chromium VI	HDPE	100 ml	Cool, 4°C	24 Hours	Glass Jar/Plastic bag	7 Days
Metals	HDPE	250 ml	Cool, 4°C Filter* HNO3 pH < 2	6 Months	Glass Jar/Plastic bag	6 Months
Mercury	HDPE	100 ml	Cool, 4°C HNO3 pH < 2	28 Days	Glass Jar/Plastic bag	28 Days

HDPE: High Density Polyethylene; **Glass Jar/Plastic bag:** A 250ml glass jar with a Teflon lined plastic lid.

SAMPLING INSTRUCTIONS

- If possible, sample straight into sample bottle. If you can't, fill a bucket, scoop etc and then fill the bottle from this. Bucket/scoop must be rinsed with sampling water to reduce contamination risk.
- When sampling from well mixed, flowing sites (rivers), take the sample ~10 cm below the surface, as far away from the edge as possible and point the bottle opening upstream.
- Waste discharge points should be taken from where the effluent is well mixed and as close as is practicable to point of discharge. The discharge licence will usually specify the exact location.
- For microbiological analysis, fill sample containers without pre-rinsing with sample; pre-rinsing results in loss of any pre-added preservative and sometimes can bias results high when certain components adhere to the sides of the container.
- Depending on determinations to be performed, fill the container full (most organic compound determinations) or leave space for aeration, mixing, etc. (microbiological and inorganic analyses).
- If a bottle already contains preservative, take care not to overfill the bottle, as preservative may be lost or diluted and close bottle immediately after sampling.
- Make sure all lids on bottles are secure and labels are correct with date & time included on label.
- Store samples between 1-4 °C if possible. If in the field, place in an esky with frozen icebricks.
- Do not leave eskies in the sun or in the boot of the car for an extended length of time.
- Transport the samples to the lab by 5pm on day of sampling. **Contact SGS if you will be late.**
- For dissolved metals samples should be filtered through a 0.45µm on site prior to preservation. Nutrients at low levels (<50 µg/l) should be frozen and not preserved with acid.

SGS Environmental Services is not responsible for the accuracy of the information contained in this table. Users are encouraged to defer to the current regulations from which this information is obtained. The hold time listed the suggested time that samples may be held before analysis and still be considered valid. International references e.g., Standard Methods for the Examination of Water and Wastewater, 22nd Edition & USEPA SW 846, 3rd Edition plus updates provide alternative recommended holding times that may be considered valid.

ANALYTICAL REPORT

E016678 R0

Default Project

Prepared for

INTEGEMS

issued by:

CALA
Testing
Accreditation No. A 3699

First Page

CLIENT DETAILS		LABORATORY DETAILS	
Client	INTEGEMS	Manager	Peter Sarpong
		Laboratory	SGS Laboratory Services Ghana Ltd
Address	8G MAIN MOTOR ROAD TECHNICAL INSTITUTE DRIVE CONGO CROSS	Address	MASLAB, Plot No. B15, Community 1 Tema, P. O. Box 732. Accra . Ghana.
Contact	MANSA-MUSA KAMARA	Telephone	+233 501561114
Telephone		Fax	
Facsimile		Email	maslab.tema@sgs.com
Email	mm.kamara@integems.com	SGS Reference	E016678
Project	Default Project	Received	28/11/2017
Order n°	MASL - PFI 0435	Analysis Started	12/09/2017
Matrix/samples	Water(6)	Analysis Completed	13/12/2017
		Approved	13/12/2017
		Date Reported	13/12/2017
		Report n°	E016678 R0

SIGNATORIES

Peter Sarpong

Assistant Laboratory Manager

COMMENTS

Testing
Accreditation No. A 3699

TABLE OF CONTENTS

CALA
Testing
Accreditation No. A 3699

RESULTS

	Sample n°	E016678.001	E016678.002	E016678.003	E016678.004	E016678.005
	Sample Name	BEDGIS 001	BEDGIS 002	BEDGIS 003	BEDGIS 004	BEDGIS 005
	Sample Matrix	Water	Water	Water	Water	Water
Parameter	Units	RL	Result	Result	Result	Result	Result
[ME-AN-305]							
* Hardness by Calculation	mg/L	5	5	7	8	12	6
[APHA 4500-H,]							
* Total Alkalinity as CaCO3	mg/L	2	8	11	12	11	18
* Apparent Color by spec	Pt/Co colour	3	58	55	66	65	36
* True Color by spec	Pt/Co colour	3	24	22	17	18	15
[ME-AN-313]							
Biochemical Oxygen Demand (BOD5)	mg/L	5	<5	<5	<5	<5	<5
[ME-AN-311]							
Chemical Oxygen Demand	mg/L	5	6	<5	17	<5	<5
[ME-AN-301,302,303,304, 318, 322, 334,338, 354, 355 & 356]							
Nitrate, NO3 as NO3	mg/L	0.06	0.65	0.68	0.77	0.79	0.61
Nitrite, NO2 as NO2	mg/L	0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Phosphate as PO4	mg/L	0.02	<0.02	<0.02	<0.02	<0.02	0.02
[ME-AN-326]							
Oil and Grease	mg/L	5	<5	<5	<5	<5	<5
[APHA 9223B 22nd Edition]							
Total Coliforms	MPN/100 mL	1	2419.6	298.7	866.4	9208	2419.6
[0 + APHA 9221D 22nd Edition (2005)]							
Faecal Coliforms	MPN/100 mL	1	33.1	17.3	9.8	920.8	117.8
[ME-AN-351_Dissolved]							
Arsenic dissolved	mg/L	0.0005	<0.0005	<0.0005	0.0007	<0.0005	<0.0005
Antimony dissolved	mg/L	0.0001	0.0005	0.0002	0.0004	<0.0001	0.0003
Mercury dissolved	mg/L	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
[ME-AN-348_Dissolved]							
Calcium dissolved	mg/L	1	1	2	2	3	1
Magnesium dissolved	mg/L	0.5	0.6	0.7	0.8	1.4	0.5
[ME-AN-351_Total]							
Arsenic total	mg/L	0.0005	<0.0005	<0.0005	<0.0005	0.0015	<0.0005
Antimony total	mg/L	0.0001	0.0006	0.0002	<0.0001	<0.0001	<0.0001
Selenium total	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Mercury total	mg/L	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Manganese total	mg/L	0.002	0.016	0.011	0.014	0.021	0.025
Copper total	mg/L	0.001	<0.001	<0.001	<0.001	0.002	<0.001
Zinc total	mg/L	0.005	0.007	0.005	0.007	0.010	0.006
Lead total	mg/L	0.0005	0.0005	0.0006	0.0006	0.0008	0.0008
Chromium total	mg/L	0.001	<0.001	<0.001	<0.001	0.002	<0.001
Nickel total	mg/L	0.001	<0.001	<0.001	<0.001	0.001	<0.001
Cadmium total	mg/L	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Molybdenum total	mg/L	0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Cobalt total	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001
[ME-AN-348_Total]							
Iron total	mg/L	0.1	1.0	1.1	1.3	1.4	1.3
Aluminium total	mg/L	0.03	0.24	0.18	0.31	0.41	0.17

CALA Testing Accreditation No. A 3699

RESULTS

	Sample n°	E016678.006
	Sample Name	BEDGIS 006
	Sample Matrix	Water

	Parameter	Units	RL	Result
[ME-AN-305]				
*	Hardness by Calculation	mg/L	5	9
[APHA 4500-H,]				
*	Total Alkalinity as CaCO3	mg/L	2	11
*	Apparent Color by spec	Pt/Co colour	3	48
*	True Color by spec	Pt/Co colour	3	13
[ME-AN-313]				
	Biochemical Oxygen Demand (BOD5)	mg/L	5	<5
[ME-AN-311]				
	Chemical Oxygen Demand	mg/L	5	7
[ME-AN-301,302,303,304, 318, 322, 334,338, 354, 355 & 356]				
	Nitrate, NO3 as NO3	mg/L	0.06	0.43
	Nitrite, NO2 as NO2	mg/L	0.05	<0.05
	Phosphate as PO4	mg/L	0.02	<0.02
[ME-AN-326]				
	Oil and Grease	mg/L	5	<5
[APHA 9223B 22nd Edition]				
	Total Coliforms	MPN/100 mL	1	1732.9
[0 + APHA 9221D 22nd Edition (2005)]				
	Faecal Coliforms	MPN/100 mL	1	46.5
[ME-AN-351_Dissolved]				
	Arsenic dissolved	mg/L	0.0005	<0.0005
	Antimony dissolved	mg/L	0.0001	<0.0001
	Mercury dissolved	mg/L	0.0001	<0.0001
[ME-AN-348_Dissolved]				
	Calcium dissolved	mg/L	1	2
	Magnesium dissolved	mg/L	0.5	1.1
[ME-AN-351_Total]				
	Arsenic total	mg/L	0.0005	<0.0005
	Antimony total	mg/L	0.0001	<0.0001
	Selenium total	mg/L	0.01	<0.01
	Mercury total	mg/L	0.0001	<0.0001
	Manganese total	mg/L	0.002	0.018
	Copper total	mg/L	0.001	<0.001
	Zinc total	mg/L	0.005	0.007
	Lead total	mg/L	0.0005	0.0005
	Chromium total	mg/L	0.001	<0.001
	Nickel total	mg/L	0.001	<0.001
	Cadmium total	mg/L	0.0001	<0.0001
	Molybdenum total	mg/L	0.0005	<0.0005
	Cobalt total	mg/L	0.001	<0.001
[ME-AN-348_Total]				
	Iron total	mg/L	0.1	0.8
	Aluminium total	mg/L	0.03	0.09

QC SUMMARY

MB blank results are compared to the Limit of Reporting. LCS and MS spike recoveries are measured as the percentage of analyte recovered from the sample compared the the amount of analyte spiked into the sample. DUP and MSD relative percent differences are measured against their original counterpart samples according to the formula: the absolute difference of the two results divided by the average of the two results as a percentage. Where the DUP RPD is 'NA' , the results are less than the LOR and thus the RPD is not applicable.

LB26834

BOD5 [ME-AN-313]

Parameter	ES	QC Reference	Units	RL	MB	DUP %RPD	LCS %Recovery
Biochemical Oxygen Demand (BOD5)		LB26834	mg/L	5.0	<5	0 - 16%	91%

LB26841

Metals in Water (Tot) by ICP-OES [ME-AN-348_Total]

Parameter	ES	QC Reference	Units	RL	MB	DUP %RPD	LCS %Recovery
Iron total		LB26841	mg/L	0.10	<0.1	0%	101 - 102%
Aluminium total		LB26841	mg/L	0.030	<0.03	0 - 5%	100 - 103%

LB26850

Metals in Water (Diss) by ICP-OES [ME-AN-348_Dissolved]

Parameter	ES	QC Reference	Units	RL	MB	DUP %RPD	LCS %Recovery
Calcium dissolved		LB26850	mg/L	1.0	<1	1 - 5%	103 - 105%
Magnesium dissolved		LB26850	mg/L	0.50	<0.5	1 - 5%	111%

LB26854

Testing
Accreditation No. A 3699

QC SUMMARY

MB blank results are compared to the Limit of Reporting. LCS and MS spike recoveries are measured as the percentage of analyte recovered from the sample compared the the amount of analyte spiked into the sample. DUP and MSD relative percent differences are measured against their original counterpart samples according to the formula: the absolute difference of the two results divided by the average of the two results as a percentage. Where the DUP RPD is 'NA' , the results are less than the LOR and thus the RPD is not applicable.

COD in Water - Low level [ME-AN-311]

Parameter	ES	QC Reference	Units	RL	MB	DUP %RPD	LCS %Recovery
Chemical Oxygen Demand		LB26854	mg/L	5.0	<5	0%	NA

LB26870

Anions by Aquakem Discrete Analyser [ME-AN-301,302,303,304, 318, 322, 334,338, 354, 355 & 356]

Parameter	ES	QC Reference	Units	RL	MB	DUP %RPD	LCS %Recovery
Nitrate, NO3 as NO3		LB26870	mg/L	0.060	<0.06	1 - 8%	113%
Nitrite, NO2 as NO2		LB26870	mg/L	0.050	<0.05	0 - 8%	87%
Phosphate as PO4		LB26870	mg/L	0.020	<0.02	0 - 7%	90%

LB26903

Skalar Robotic Analyser [APHA 4500-H,]

Parameter	ES	QC Reference	Units	RL	DUP %RPD
Total Alkalinity as CaCO3		LB26903	mg/L	2.0	0 - 4%
Apparent Color by spec		LB26903	Pt/Co colou	3.0	2 - 5%
True Color by spec		LB26903	Pt/Co colou	3.0	5%

LB26944

QC SUMMARY

MB blank results are compared to the Limit of Reporting. LCS and MS spike recoveries are measured as the percentage of analyte recovered from the sample compared the the amount of analyte spiked into the sample. DUP and MSD relative percent differences are measured against their original counterpart samples according to the formula: the absolute difference of the two results divided by the average of the two results as a percentage. Where the DUP RPD is 'NA' , the results are less than the LOR and thus the RPD is not applicable.

Oil and Grease in Water [ME-AN-326]

Parameter	ES	QC Reference	Units	RL	MB	LCS %Recovery
Oil and Grease		LB26944	mg/L	5.0	<5	99 - 102%

METHOD SUMMARY

METHOD	METHODOLOGY SUMMARY
ME-AN-301,302,303,304, 318, 322, 334,338, 354, 355 & 356	Anions in water by Aquakem Discrete Analyzer
ME-AN-305	Hardness determination on water samples by calculation. This method is based on APHA 2340B
ME-AN-311	COD determination in water. This method is based on APHA 5220D
ME-AN-313	BOD determination in water by winkler. This method is based on APHA 5210B
ME-AN-326	Determination of Oil and grease in water. This method is based on APHA 5520B
ME-AN-348_Dissolved	Aqueous samples are filtered through a 0.45 um pore size filter, immediately acidified with HNO3 and then read on ICP-OES. Solutions are aspirated into an Argon plasma at 8000-10000K and emit characteristic energy or light as a result of electron transitions through unique energy levels. The emitted light is focused onto a diffraction grating where it is separated into components. This method is based on APHA 3120B.
ME-AN-348_Total	Acidified (nitric acid) aqueous samples are digested with HNO3 at 95°C +/- 4oC reducing interferences by organic matter and converting metals associated with particulates to the free metal form. This is read on the ICP-OES. Solutions are aspirated into an Argon plasma at 8000-10000K and emit characteristic energy or light as a result of electron transitions through unique energy levels. The emitted light is focused onto a diffraction grating where it is separated into components. This method is based on APHA 3120B.
ME-AN-351_Dissolved	This method is based on EPA_200.8
ME-AN-351_Total	This method is based on EPA_200.8

CALA
Testing
Accreditation No. A 3699

LEGEND

FOOTNOTES

^	Performed by external SGS laboratory.	IS	Insufficient sample for analysis.
^^	Performed by outside laboratory.	LNR	Sample listed, but not received.
RL	Reporting Limit	NA	The sample was not analysed for this analyte
↑	Raised Limit of Reporting	NVL	Result to be validated
↓	Lowered Limit of Reporting	TBA	Parameter not yet analysed

ACCREDITATION NOTES

*	This analysis is not covered by the scope of accreditation.

--- End of the analytical report ---

AMENDMENT ANALYTICAL REPORT

E016678 R1

Default Project

Prepared for

INTEGEMS

issued by:

Testing
Accreditation No. A 3699

First Page

CLIENT DETAILS		LABORATORY DETAILS	
Client	INTEGEMS	Manager	Peter Sarpong
		Laboratory	SGS Laboratory Services Ghana Ltd
Address	8G MAIN MOTOR ROAD TECHNICAL INSTITUTE DRIVE CONGO CROSS	Address	MASLAB, Plot No. B15, Community 1 Tema, P. O. Box 732. Accra . Ghana.
Contact	MANSA-MUSA KAMARA	Telephone	+233 501561114
Telephone		Fax	
Facsimile		Email	maslab.tema@sgs.com
Email	mm.kamara@integems.com	SGS Reference	E016678
Project	Default Project	Received	28/11/2017
Order n°	MASL - PFI 0435	Analysis Started	12/09/2017
Matrix/samples	Water(6)	Analysis Completed	19/12/2017
		Approved	13/12/2017
		Date Reported	19/12/2017
		Report n°	E016678 R1

SIGNATORIES

Peter Sarpong

Assistant Laboratory Manager

COMMENTS

This Report/Certificate cancels and supersedes the Report No.:

E016678 R0

TABLE OF CONTENTS

CASE NARRATIVE

This re-issued final report cancels and supersedes report number E0166781 R0 issued by SGS Maslab on 13/12/17. Report has been updated with TSS results.

CALA
Testing
Accreditation No. A 3699

RESULTS

		Sample n°	E016678.001	E016678.002	E016678.003	E016678.004	E016678.005
		Sample Name	BEDGIS 001	BEDGIS 002	BEDGIS 003	BEDGIS 004	BEDGIS 005
		Sample Matrix	Water	Water	Water	Water	Water
Parameter	Units	RL	Result	Result	Result	Result	Result
[ME-AN-305]							
* Hardness by Calculation	mg/L	5	5	7	8	12	6
[APHA 4500-H,]							
* Total Alkalinity as CaCO3	mg/L	2	8	11	12	11	18
* Apparent Color by spec	Pt/Co colour	3	58	55	66	65	36
* True Color by spec	Pt/Co colour	3	24	22	17	18	15
[ME-AN-313]							
Biochemical Oxygen Demand (BOD5)	mg/L	5	<5	<5	<5	<5	<5
[ME-AN-311]							
Chemical Oxygen Demand	mg/L	5	6	<5	17	<5	<5
[ME-AN-301,302,303,304, 318, 322, 334,338, 354, 355 & 356]							
Nitrate, NO3 as NO3	mg/L	0.06	0.65	0.68	0.77	0.79	0.61
Nitrite, NO2 as NO2	mg/L	0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Phosphate as PO4	mg/L	0.02	<0.02	<0.02	<0.02	<0.02	0.02
[ME-AN-326]							
Oil and Grease	mg/L	5	<5	<5	<5	<5	<5
[APHA 9223B 22nd Edition]							
Total Coliforms	MPN/100 mL	1	2419.6	298.7	866.4	9208	2419.6
[0 + APHA 9221D 22nd Edition (2005)]							
Faecal Coliforms	MPN/100 mL	1	33.1	17.3	9.8	920.8	117.8
[ME-AN-351_Dissolved]							
Arsenic dissolved	mg/L	0.0005	<0.0005	<0.0005	0.0007	<0.0005	<0.0005
Antimony dissolved	mg/L	0.0001	0.0005	0.0002	0.0004	<0.0001	0.0003
Mercury dissolved	mg/L	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
[ME-AN-348_Dissolved]							
Calcium dissolved	mg/L	1	1	2	2	3	1
Magnesium dissolved	mg/L	0.5	0.6	0.7	0.8	1.4	0.5
[ME-AN-351_Total]							
Arsenic total	mg/L	0.0005	<0.0005	<0.0005	<0.0005	0.0015	<0.0005
Antimony total	mg/L	0.0001	0.0006	0.0002	<0.0001	<0.0001	<0.0001
Selenium total	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Mercury total	mg/L	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Manganese total	mg/L	0.002	0.016	0.011	0.014	0.021	0.025
Copper total	mg/L	0.001	<0.001	<0.001	<0.001	0.002	<0.001
Zinc total	mg/L	0.005	0.007	0.005	0.007	0.010	0.006
Lead total	mg/L	0.0005	0.0005	0.0006	0.0006	0.0008	0.0008
Chromium total	mg/L	0.001	<0.001	<0.001	<0.001	0.002	<0.001
Nickel total	mg/L	0.001	<0.001	<0.001	<0.001	0.001	<0.001
Cadmium total	mg/L	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Molybdenum total	mg/L	0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Cobalt total	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001
[ME-AN-348_Total]							
Iron total	mg/L	0.1	1.0	1.1	1.3	1.4	1.3
Aluminium total	mg/L	0.03	0.24	0.18	0.31	0.41	0.17

CALA Testing Accreditation No. A 3699

RESULTS

			Sample n°	E016678.001	E016678.002	E016678.003	E016678.004	E016678.005
			Sample Name	BEDGIS 001	BEDGIS 002	BEDGIS 003	BEDGIS 004	BEDGIS 005
			Sample Matrix	Water	Water	Water	Water	Water
Parameter	**Units**	**RL**		**Result**	**Result**	**Result**	**Result**	**Result**
[ME-AN-309]								
Total Suspended Solids at 103-105'C	mg/L	1		14	8	12	12	7

CALA Testing Accreditation No. A 3699

RESULTS

	Sample n°	E016678.006
	Sample Name	BEDGIS 006
	Sample Matrix	Water

	Parameter	Units	RL	Result
[ME-AN-305]				
*	Hardness by Calculation	mg/L	5	9
[APHA 4500-H,]				
*	Total Alkalinity as CaCO3	mg/L	2	11
*	Apparent Color by spec	Pt/Co colour	3	48
*	True Color by spec	Pt/Co colour	3	13
[ME-AN-313]				
	Biochemical Oxygen Demand (BOD5)	mg/L	5	<5
[ME-AN-311]				
	Chemical Oxygen Demand	mg/L	5	7
[ME-AN-301,302,303,304, 318, 322, 334,338, 354, 355 & 356]				
	Nitrate, NO3 as NO3	mg/L	0.06	0.43
	Nitrite, NO2 as NO2	mg/L	0.05	<0.05
	Phosphate as PO4	mg/L	0.02	<0.02
[ME-AN-326]				
	Oil and Grease	mg/L	5	<5
[APHA 9223B 22nd Edition]				
	Total Coliforms	MPN/100 mL	1	1732.9
[0 + APHA 9221D 22nd Edition (2005)]				
	Faecal Coliforms	MPN/100 mL	1	46.5
[ME-AN-351_Dissolved]				
	Arsenic dissolved	mg/L	0.0005	<0.0005
	Antimony dissolved	mg/L	0.0001	<0.0001
	Mercury dissolved	mg/L	0.0001	<0.0001
[ME-AN-348_Dissolved]				
	Calcium dissolved	mg/L	1	2
	Magnesium dissolved	mg/L	0.5	1.1
[ME-AN-351_Total]				
	Arsenic total	mg/L	0.0005	<0.0005
	Antimony total	mg/L	0.0001	<0.0001
	Selenium total	mg/L	0.01	<0.01
	Mercury total	mg/L	0.0001	<0.0001
	Manganese total	mg/L	0.002	0.018
	Copper total	mg/L	0.001	<0.001
	Zinc total	mg/L	0.005	0.007
	Lead total	mg/L	0.0005	0.0005
	Chromium total	mg/L	0.001	<0.001
	Nickel total	mg/L	0.001	<0.001
	Cadmium total	mg/L	0.0001	<0.0001
	Molybdenum total	mg/L	0.0005	<0.0005
	Cobalt total	mg/L	0.001	<0.001
[ME-AN-348_Total]				
	Iron total	mg/L	0.1	0.8
	Aluminium total	mg/L	0.03	0.09

CALA Testing Accreditation No. A 3699

RESULTS

		Sample n°	E016678.006
		Sample Name	BEDGIS 006
		Sample Matrix	Water
Parameter	**Units**	**RL**	**Result**
[ME-AN-309]			
Total Suspended Solids at 103-105'C	mg/L	1	7

QC SUMMARY

MB blank results are compared to the Limit of Reporting. LCS and MS spike recoveries are measured as the percentage of analyte recovered from the sample compared the the amount of analyte spiked into the sample. DUP and MSD relative percent differences are measured against their original counterpart samples according to the formula: the absolute difference of the two results divided by the average of the two results as a percentage. Where the DUP RPD is 'NA' , the results are less than the LOR and thus the RPD is not applicable.

LB26834

BOD5 [ME-AN-313]

Parameter	ES	QC Reference	Units	RL	MB	DUP %RPD	LCS %Recovery
Biochemical Oxygen Demand (BOD5)		LB26834	mg/L	5.0	<5	0 - 16%	91%

LB26841

Metals in Water (Tot) by ICP-OES [ME-AN-348_Total]

Parameter	ES	QC Reference	Units	RL	MB	DUP %RPD	LCS %Recovery
Iron total		LB26841	mg/L	0.10	<0.1	0%	101 - 102%
Aluminium total		LB26841	mg/L	0.030	<0.03	0 - 5%	100 - 103%

LB26850

Metals in Water (Diss) by ICP-OES [ME-AN-348_Dissolved]

Parameter	ES	QC Reference	Units	RL	MB	DUP %RPD	LCS %Recovery
Calcium dissolved		LB26850	mg/L	1.0	<1	1 - 5%	103 - 105%
Magnesium dissolved		LB26850	mg/L	0.50	<0.5	1 - 5%	111%

LB26854

QC SUMMARY

MB blank results are compared to the Limit of Reporting. LCS and MS spike recoveries are measured as the percentage of analyte recovered from the sample compared the the amount of analyte spiked into the sample. DUP and MSD relative percent differences are measured against their original counterpart samples according to the formula: the absolute difference of the two results divided by the average of the two results as a percentage. Where the DUP RPD is 'NA' , the results are less than the LOR and thus the RPD is not applicable.

COD in Water - Low level [ME-AN-311]

Parameter	ES	QC Reference	Units	RL	MB	DUP %RPD	LCS %Recovery
Chemical Oxygen Demand		LB26854	mg/L	5.0	<5	0%	NA

LB26870

Anions by Aquakem Discrete Analyser [ME-AN-301,302,303,304, 318, 322, 334,338, 354, 355 & 356]

Parameter	ES	QC Reference	Units	RL	MB	DUP %RPD	LCS %Recovery
Nitrate, NO3 as NO3		LB26870	mg/L	0.060	<0.06	1 - 8%	113%
Nitrite, NO2 as NO2		LB26870	mg/L	0.050	<0.05	0 - 8%	87%
Phosphate as PO4		LB26870	mg/L	0.020	<0.02	0 - 7%	90%

LB26903

Skalar Robotic Analyser [APHA 4500-H,]

Parameter	ES	QC Reference	Units	RL	DUP %RPD
Total Alkalinity as CaCO3		LB26903	mg/L	2.0	0 - 4%
Apparent Color by spec		LB26903	Pt/Co colou	3.0	2 - 5%
True Color by spec		LB26903	Pt/Co colou	3.0	5%

LB26944

QC SUMMARY

MB blank results are compared to the Limit of Reporting. LCS and MS spike recoveries are measured as the percentage of analyte recovered from the sample compared the the amount of analyte spiked into the sample. DUP and MSD relative percent differences are measured against their original counterpart samples according to the formula: the absolute difference of the two results divided by the average of the two results as a percentage. Where the DUP RPD is 'NA' , the results are less than the LOR and thus the RPD is not applicable.

Oil and Grease in Water [ME-AN-326]

Parameter	ES	QC Reference	Units	RL	MB	LCS %Recovery
Oil and Grease		LB26944	mg/L	5.0	<5	99 - 102%

LB27093

Total Suspended Solids 103-105'C [ME-AN-309]

Parameter	ES	QC Reference	Units	RL	MB	DUP %RPD	LCS %Recovery
Total Suspended Solids at 103-105'C		LB27093	mg/L	1.0	NVL	NVL	NVL

METHOD SUMMARY

METHOD	METHODOLOGY SUMMARY
ME-AN-301,302,303,304, 318, 322, 334,338, 354, 355 & 356	Anions in water by Aquakem Discrete Analyzer
ME-AN-305	Hardness determination on water samples by calculation. This method is based on APHA 2340B
ME-AN-309	A well-mixed water sample is filtered through a weighed standard glass-fibre filter and residue dried in an oven to a constant weight at 103-105oC. This method is based on APHA 2540B
ME-AN-311	COD determination in water. This method is based on APHA 5220D
ME-AN-313	BOD determination in water by winkler. This method is based on APHA 5210B
ME-AN-326	Determination of Oil and grease in water. This method is based on APHA 5520B
ME-AN-348_Dissolved	Aqueous samples are filtered through a 0.45 um pore size filter, immediately acidified with HNO3 and then read on ICP-OES. Solutions are aspirated into an Argon plasma at 8000-10000K and emit characteristic energy or light as a result of electron transitions through unique energy levels. The emitted light is focused onto a diffraction grating where it is separated into components. This method is based on APHA 3120B.
ME-AN-348_Total	Acidified (nitric acid) aqueous samples are digested with HNO3 at 95°C +/- 4oC reducing interferences by organic matter and converting metals associated with particulates to the free metal form. This is read on the ICP-OES. Solutions are aspirated into an Argon plasma at 8000-10000K and emit characteristic energy or light as a result of electron transitions through unique energy levels. The emitted light is focused onto a diffraction grating where it is separated into components. This method is based on APHA 3120B.
ME-AN-351_Dissolved	This method is based on EPA_200.8
ME-AN-351_Total	This method is based on EPA_200.8

LEGEND

FOOTNOTES

^	Performed by external SGS laboratory.
^^	Performed by outside laboratory.
RL	Reporting Limit
↑	Raised Limit of Reporting
↓	Lowered Limit of Reporting
IS	Insufficient sample for analysis.
LNR	Sample listed, but not received.
NA	The sample was not analysed for this analyte
NVL	Result to be validated
TBA	Parameter not yet analysed

ACCREDITATION NOTES

*	This analysis is not covered by the scope of accreditation.

--- End of the analytical report ---

Certificate of Calibration

NoiseMeters

97 Brighton Road
Surbiton
KT6 5NF
United Kingdom

Tel: +44 845 680 0313
Fax: +44 845 680 0316
Email: accounts@noisemeters.com

Instrument Type	**Sound Level Meter**
Model	**CEL633A1**
Serial Number	**1950731**
Certificate Number	**2483/1950731**
Date	**October 12, 2015**

Applicable Standards

IEC 61672:2002 (Electroacoustics - Sound Level Meters)
IEC 60651:1979 (Sound Level Meters)
ANSI S1.4:1983 (Specifications for Sound Level Meters)

Test Summary

Self Generated Noise Test	**All Tests Pass**
Electrical Signal Test of Frequency Weightings	**All Tests Pass**
Frequency & Time Weightings	**All Tests Pass**
Level Linearity On The Reference Level Range	**All Tests Pass**
Toneburst Response Test	**All Tests Pass**
Overload Indication	**All Tests Pass**
Acoustic Tests	**All Tests Pass**

Test equipment and acoustic working standards used for conformance testing are subject to periodic calibration, traceable to national standards.

Declaration of Conformity

This certificate confirms that the instrument specified above has been produced and tested to comply with the manufacturer's published specifications and the relevant European Community directives.

Signed  Date October 12, 2015

Certificate of Calibration

NoiseMeters

97 Brighton Road
Surbiton
KT6 5NF
United Kingdom

Tel: +44 845 680 0313
Fax: +44 845 680 0316
Email: accounts@noisemeters.com

Instrument Type	**Class 1 Acoustic Calibrator**
Model	**CEL120/1**
Serial Number	**2651627**
Certificate Number	**2484/2651627**
Date	**October 12, 2015**

Applicable Standards

IEC 60942:2003 (Electroacoustics - Sound Calibrators)
ANSI S1.40:2006 (Specifications and Verification Procedures for Sound Calibrators)

Test Summary

Frequency	1kHz ± 2Hz
Total Harmonic Distortion	< 1 %
SPL at 114dB Setting	114.0 dB
SPL at 94dB Setting (CEL120/1 only)	94.0dB

Test equipment and acoustic working standards used for conformance testing are subject to periodic calibration, traceable to national standards.

Declaration of Conformity

This certificate confirms that the instrument specified above has been produced and tested to comply with the manufacturer's published specifications and the relevant European Community directives.

Signed  Date October 12, 2015