Sierra Rutile Project Area 1 – Environmental, Social and Health Impact Assessment: Specialist Air Quality Impact Assessment

Report Prepared for

Sierra Rutile Limited

Sierra Rutile Limited

Report Number 515234

Report Prepared by

srk consulting

February 2018

Sierra Rutile Project Area 1 – Environmental, Social and Health Impact Assessment: Specialist Air Quality Impact Assessment

Sierra Rutile Limited

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SRK Project Number 515234

February 2018

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Executive Summary

Sierra Rutile Limited is an existing mining operation located in the Bonthe and Moyamba Districts of the Southern Province of Sierra Leone. The mine has been in operation for over 50 years and produces rutile, ilmenite and zircon rich concentrate. The SRL operation has an existing Environmental Licence (reference number EPA-SL030) and has undertaken two previous Environmental and Social Impact Assessment (ESIA) studies for their operations in 2001 followed by an update in 2012. When these studies where undertaken, the primary mining process was dredge mining (referred to as wet mining). During 2013, SRL commenced with a distinct open cast mining operation (referred to as dry mining) as an auxiliary method of ore extraction in conjunction with wet mining. In 2016, a second dry mining operation was commissioned. It is anticipated that, over time, dredge mining will cease and dry mining would be the primary mining method employed.

In 2015 the Environmental Protection Agency of Sierra Leone (EPA-SL) issued a notification to SRL (reference number EPA-SUHA.96/214/a/HNRM), instructing them to undertake an integrated Environmental, Social and Health Impact Assessment (ESHIA) and develop an Environmental, Social and Health Management Plan (ESHMP) for their current and proposed dry and wet mining activities, including the proposed expansion areas. This includes the Gangama and Lanti deposits and other deposits within SRL's current operating concession in Mining Lease Area 1 (SR Area 1).

The purpose of the Environmental Social and Health Impact Assessment is to update the previous ESIA and associated management plans to incorporate the dry mining process and associated activities, and include social and community health aspects.

SRK Consulting (South Africa) (Pty) Ltd was appointed by Sierra Rutile Limited to undertake the Environmental Social and Health Impact Assessment, which included a specialist Air Quality Impact Assessment to inform the ESHIA. The Air Quality Impact Assessment report (this document) provides a baseline description of the air quality and meteorological conditions for the SR Area 1 and assesses potential impacts that the Sierra Rutile Limited operations may have on the air quality. This information has, in turn, been used to identify measures to manage any potential impacts.

The objectives of this assessment were to:

- Provide a description of the baseline ambient air quality, climate and emission sources that are currently impacting on air quality in the SR Area 1 based on relevant information obtained from the client;
- Determine and assess the current and potential future impacts that the project may have on the local ambient air quality;
- Identify potential receptors and areas that may be affected by the operational and expansion phases with respect to air quality; and
- Identify and recommend air quality management measures.

The following scope of work was undertaken to meet the above objectives:

- Available project documentation was reviewed;
- Available climate data for the SR Area 1 (within a radius of 5 km from the SR Area 1) was reviewed and collated;
- An air emissions inventory, excluding a Greenhouse Gas (GHG) emissions inventory, was developed;
- An air dispersion model was set up and run for dust (PM_{10} and $PM_{2.5}$) with respect to operational conditions and, where applicable, gas;
- An impact assessment was conducted in terms of the following phases:
  - Operational phase: Historical and current dredge mining operations and associated infrastructure (i.e. included in the 2012 ESIA and approved via Environmental Licence number EPA-SL030);

  - Expansion phase: Construction, initial operational and expansion of the Lanti and Gangama dry mining operations (2013 onwards), including: site and vegetation clearing, grubbing, establishment of layout area, contractors camp, widening of existing haul roads, dry mining, scrubbers, expansion of Tailings Storage Facility (TSF), borrows pits and trucking of ore (haul roads); and
  - Decommissioning, closure and post closure phase.
- A report was compiled (this report) summarising the findings of this assessment including recommended management and mitigation measures.

The impact assessment focuses on the operational, decommissioning, closure and post closure phases of the Project. The change in air quality as a result of a change in ambient PM_{10}, $PM_{2.5}$ and gaseous emission levels during the operational phases of the mine were the only impacts that were assessed.

The significance of the impacts was assessed according to the following criteria:

- Magnitude – severity or intensity;
- Duration (temporal influence) – temporal influence; and
- Scale (spatial influence) – spatial influence.

Based on the findings of this assessment the following was concluded:

- According to the Koppen Climate Classification System, the study site is classified as a category "A" climate type which is characteristically hot and moist during summer and cool and dry in winter. Average temperatures associated with this classification are usually greater than 18ºC. Rainfall is usually above 1,500 mm per annum. The prevailing winds for the 3 period from January 2014 to December 2016 are from the southwest and west-southwest with lower occurrences from the south-southwest and west;
- The baseline air quality, as indicated through the available monitoring data, is a result of mine related activities, with contributions from the villages and surrounding activities, resulting in an existing cumulative impact;
- Dust fallout monitoring is currently being undertaken at SRL and began in July 2017. As the monitoring period falls in the wet season, the majority of dust fallout concentrations were below the Residential Area standard of 600 mg/m^2/day at the villages, except at SRLDM02 (September and November 2017) and Mogbwemo Village (November 2017). The dust fallout concentration at SRLDM02 for September 2017 is excluded as the material in the buckets were deemed to have been thrown in. The Non-residential Area standard was not exceeded during the monitoring period. Dust fallout is expected to increase during the dry season;
- 24-hour PM_{10} concentrations exceeded the WB / IFC EHS Guideline value of 50 µg/m^3, 16 times during the monitoring period from 29 July 2017 to 31 December 2017. The average 24-hour PM_{10} concentrations also showed one exceedances of the WB / IFC EHS Guideline value, in December 2017;
- 24-hour $PM_{2.5}$ concentrations exceeded the WB / IFC EHS Guideline value of 25µg/m^3, 31 times during the monitoring period from 29 July 2017 to 31 December 2017. The average 24-hour $PM_{2.5}$ concentrations also showed one exceedances of the WB / IFC EHS Guideline value, in December 2017;
- A comparison of the PM_{10} and $PM_{2.5}$ data shows that $PM_{2.5}$ concentrations are at an average of 83% of PM_{10} concentrations. Hence the majority of PM_{10} is made up of particulates that are less than 2.5 microns;
- SO_2 and NO_2 monitoring indicated concentrations that were below the applicable WB / IFC EHS Guideline values for the month of July 2017;
- With respect to PM_{10} and $PM_{2.5}$ from the operational phase, the impact of dust emissions was determined to be high without management and low with management measures in place;
- Similarly, with respect to PM_{10} and $PM_{2.5}$ from the expansion phase, the impact of dust emissions was determined to be high without management and medium with management measures in place;
- The impact of the vehicle entrainment of dust from haul roads, on villages in close proximity to the haul roads, is high when no management measures are in place, however the predicted

concentrations will decrease to below the WB / IFC EHS Guideline values once management measures are implemented;

- Dust and gaseous emissions from the Power Plant, SRL MSP dryer and medical incinerator are determined to be of low significance even without management measures in place;
- Human receptors are present in close proximity to the SR Area 1. Nearby villages and towns include Foinda, Moriba Town, Mogbewa and Mogbwemo amongst others. These villages and towns will be impacted by the mining operations, but dust and gas concentrations decrease substantially away from the mines operational activities, if management measures are implemented;
- Based on the impact ratings ranging from high to low, management measures are required especially during the dry season.

Based on the findings of the assessment undertaken by SRK the following management / mitigation measures are recommended:

- Maintain the current air monitoring network, making adjustments to accommodate the installation of new infrastructure as necessary, i.e. the addition of monitoring locations as activities expand;
- Stack emissions sampling should be undertaken at the Power Plant, MSP dryer and medical incinerators and thereafter the models should replicated using this data;
- The following key management measures should be considered as good practice to maintain low concentrations of dust and gas emissions within and around the SR Area 1:
  - SRL personnel should conduct quarterly site inspections in and around the mining operations and report observations on efficacy of ambient air quality monitoring and control actions;
  - Pave or treat road surfaces for ore delivery within the processing plant site to suppress dust entrained by vehicles. Surface treatment of roads should also be considered before and after a sensitive receptor;
  - Use dust suppression techniques such as wet suppression or chemical suppression to reduce dust on roads that exhibit an increase of dust emitted from the entrainment of dust;
  - Design road alignments to minimise travel distances and eliminate unnecessary traffic;
  - Speed limits within the SR Area 1 should be adhered for both treated haul roads and unpaved roads. Speed limits are 40 km/hr for haul trucks; 60 km for light vehicles, and 30 km for all SRL vehicles through villages;
  - If practical, grass should be planted along the boundary of the TSFs to lower the possibility of wind erosion. Re-vegetate or turf long side walls of the TSF to stabilise surfaces where required. Grass types planted along the boundary should be endemic to the area. Grass species that are not endemic to the area should not be considered as growing the grass may cause adverse effects to the natural flora in the area;
  - Maintain the current management measure of cladding with laterite. As the TSFs increase in height, the current management measures should continue;
  - If possible, keep the area of the sand TSF to a minimum and increase the area of active portions (wet state) to reduce windblown dust from this source during the dry season. Were required, apply a surface binder ((through the use of water cannons) on the TSFs, if monitoring indicates that dust is an issue from this source;
  - Attend to dust control when loading trucks by minimising drop heights and prevention of over loading;
  - Limit load size to reduce spillage and cover final product loads with tarpaulins where necessary;
  - When stockpiling ore, the design specification of equipment should be considered to determine a suitable drop height to control the fall of materials which will reduce dust emissions;
  - Regular maintenance will ensure that the abatement technology will continue to meet OEM specifications and acceptable international emissions standards;
  - Inline continuous monitors should be considered to monitor PM, SO_x and NO_x at the Power Plant and SRL MSP. At least one round of stack emissions tests should be undertaken to determine if arsenic and lead are present in the process.; and
  - Development and implementation of routine emissions and ambient air quality monitoring program to determine whether there are any significant increases in emissions and impacts at sensitive receptors.

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List of Abbreviations

DFO	-	Dust Fallout
DM	-	Dust Monitor
EHS	-	Environmental, Health and Safety
EIA	-	Environmental Impact Assessments
EPA	-	Environmental Protection Agency
EPA-SL	-	Environmental Protection Agency of Sierra Leone
ESHIA	-	Environmental, Social and Health Impact Assessment
ESHMP	-	Environmental, Social and Health Management Plan
GHG	-	Greenhouse Gas
GM	-	Gas Monitor
ITCZ	-	Inter-Tropical Convergence Zone
kt	-	Kilo tonne
MFO	-	Mineral Fuel Oil
MSP	-	Mineral Separation Plant
NEM:AQA	-	National Environmental Management Air Quality Act
NCAR	-	National Centre for Atmospheric Research
NO_2	-	Nitrogen dioxide
NPI	-	National Pollution Inventory
PM	-	Particulate matter
PM_{10}	-	Particulate matter <10 microns
$PM_{2.5}$	-	Particulate matter <2.5 microns
SO_2	-	Sulfur dioxide
SRL	-	Sierra Rutile Limited
TLV	-	Threshold Limit Values
tpa	-	Tonnes per annum
tph	-	Tonnes per hour
TSF	-	Tailings Storage Facility
US-EPA	-	United States Environmental Protection Agency
VOCs	-	Volatile Organic Compounds
WB / IFC EHS	-	World Bank/International Finance Corporation Environmental Health and Safety

Disclaimer

The opinions expressed in this Report have been based on the information supplied to SRK Consulting (South Africa) (Pty) Ltd (SRK) by Sierra Rutile Limited (SRL). The opinions in this Report are provided in response to a specific request from SRL to do so. SRK has exercised all due care in reviewing the supplied information. Whilst SRK has compared key supplied data with expected values, the accuracy of the results and conclusions from the review are entirely reliant on the accuracy and completeness of the supplied data. SRK does not accept responsibility for any errors or omissions in the supplied information and does not accept any consequential liability arising from commercial decisions or actions resulting from them. Opinions presented in this report apply to the site conditions and features as they existed at the time of SRK's investigations, and those reasonably foreseeable. These opinions do not necessarily apply to conditions and features that may arise after the date of this Report, about which SRK had no prior knowledge nor had the opportunity to evaluate.

1 Introduction and Background

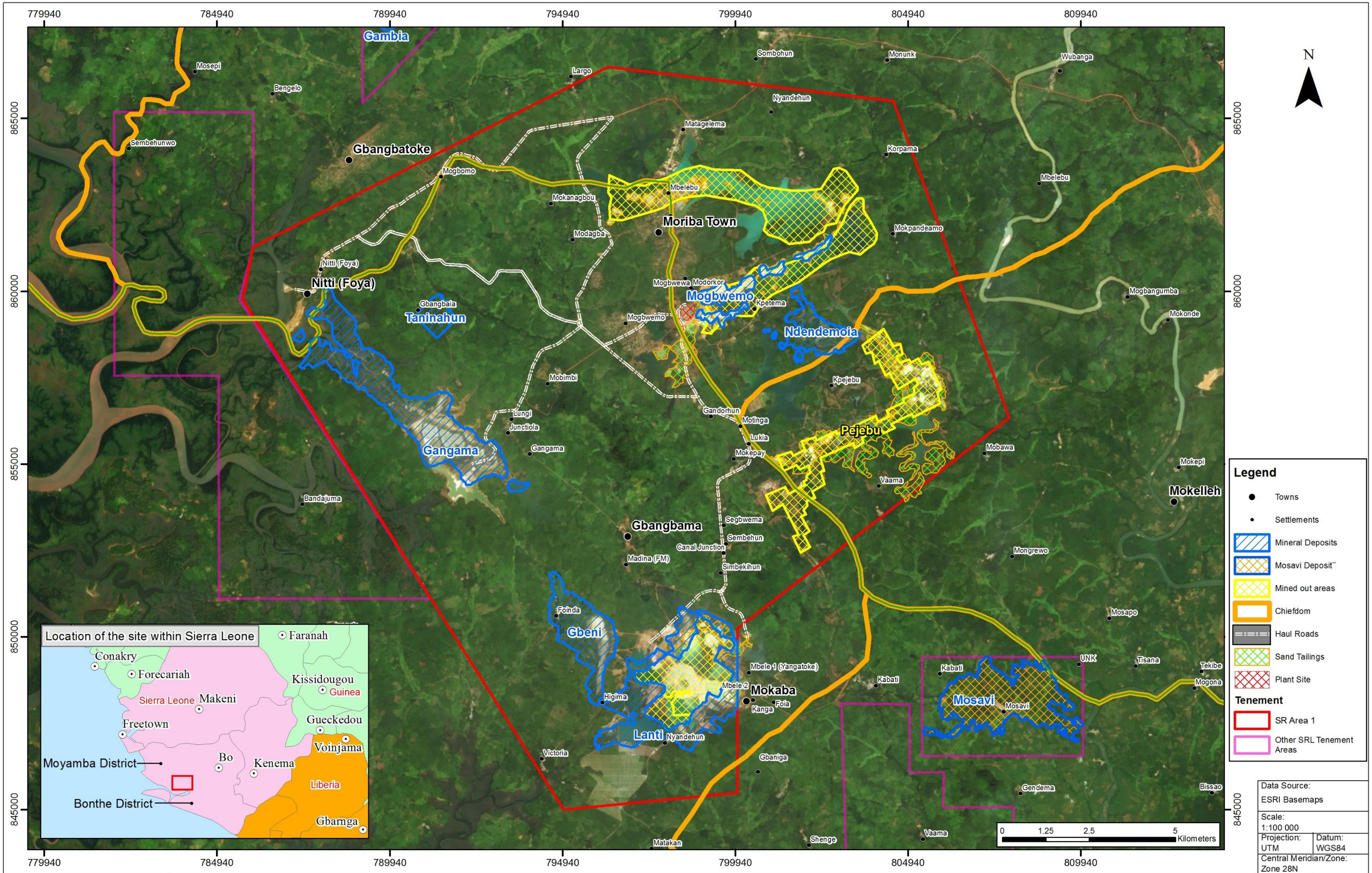
1.1 Introduction

Sierra Rutile Limited (SRL) is an existing mining operation located in the Bonthe and Moyamba Districts of the Southern Province of Sierra Leone (Figure 1-1). The mine has been in operation for over 50 years and produces rutile, ilmenite and zircon rich concentrate. The SRL operation has an existing Environmental Licence (reference number EPA-SL030) and has undertaken two previous Environmental and Social Impact Assessment (ESIA) studies for their operations in 2001 followed by an update in 2012. When these studies where undertaken, the primary mining process was dredge mining (referred to as wet mining). During 2013, SRL commenced with a distinct open cast mining operation (referred to as dry mining) as an auxiliary method of ore extraction in conjunction with wet mining. In 2016, a second dry mining operation was commissioned. It is anticipated that, over time, dredge mining will cease and dry mining would be the primary mining method employed.

In 2015 the Environmental Protection Agency of Sierra Leone (EPA-SL) issued a notification to SRL (reference number EPA-SUHA.96/214/a/HNRM), instructing them to undertake an integrated Environmental, Social and Health Impact Assessment (ESHIA) and develop an Environmental, Social and Health Management Plan (ESHMP) for their current and proposed dry and wet mining activities, including the proposed expansion areas. This includes the Gangama and Lanti deposits and other deposits within SRL's current operating concession in SR Area 1.

The purpose of the ESHIA is to update the previous ESIA and associated management plans to incorporate the dry mining process and associated activities, and include social and community health aspects.

SRK Consulting (South Africa) (Pty) Ltd (SRK SA) was appointed by Sierra Rutile Limited (SRL) to undertake the ESHIA, which included a specialist Air Quality Impact Assessment (AQIA) to inform the ESHIA. The AQIA report (this document) provides a baseline description of the air quality and meteorological conditions for the SR Area 1 and assesses potential impacts that the SRL operations may have on the air quality. This information has, in turn, been used to identify measures to manage any potential impacts.



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SR AREA 1 ESHIA & ESHMP

SITE LOCALITY

**Note
The Mosavi Deposit is not included in the SRL Area 1 Study, but is shown on the locality due to its proximity to Area 1.

Data Source: ESRI Basemaps	
Scale: 1:100 000	
Projection: UTM	Datum: WGS84
Central Meridian/Zone: Zone 28N	
Date: 21/09/2017	Compiled by: ALLK
Project No: 515234	Fig No: 1-1

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Revision: A Date: 23 02 2018

1.2 Project Description

Currently, SRL's primary operations consist of Lanti mining operations (both dredge and dry mining), processing operations (floating and land-based concentrators), Gangama dry mining operation (dry mining and land-based concentrator), Mineral Separation Plant (MSP) and the transport and export of product through the Nitti Port facilities (Figure 1-1). In addition, the mine maintains an extensive network of ponds (mine voids) and has power generation facilities, accommodation, offices, a clinic and roads.

Mining, scrubbing and screening occurs on board the Lanti dredge, with mineral concentrate produced on board the floating concentrator. The dry mines produce run of mine (ROM) ore for their respective concentrators, where de-sliming and primary heavy mineral concentration takes place. The separation of mineral concentrate into the various products takes place at the MSP. A simplified process flow of the current SRL mining operations and processes is shown in Figure 1-2.

The SRL operation intends to amend their current operations by implementing a more cost-effective mining method as well as by doubling the throughput of Lanti and Gangama dry mining operations and increasing the throughput capacity of the MSP. The latter expansion is driven by capacity constraints as well as occupational health and safety related considerations, and will coincide with the planned closure of the Lanti dredge during 2018. A list of current and proposed activities is provided in Table 1-1.

Table 1-1: List of current and proposed new activities

Stage	Activities
Operational Phase	• Site clearing; • Dredging; • Dam construction; • Ore extraction (earth moving); • Primary mineral processing; • Secondary mineral processing; • Tailings management; • Transporting and storage of ore and product; • Port handling and shipping; • Access road building and maintenance; • Waste management; • Power generation facility and transmission of power; • Potable water services; • Mine offices, workshops, storage, accommodation and associated facilities; and • Rehabilitation.
Expansion phase	• Site clearing; • Ore extraction (earth moving); • Access road building and maintenance; • Primary mineral processing; • Tailings management; • Transporting of ore • Waste management; • Power transmission services; • Potable water services; • Mine offices, workshops and storage; and • Rehabilitation.

1.2.1 Lanti Dry Mine

It is proposed that the current excavate and haul mining method be modified, by constructing an in-pit mining unit, followed by an ex-pit scrubber, before ore is pumped to the current concentrator. Lanti Dry Mine currently has a nameplate capacity of 500 tonnes per hour (tph), and the intent is to increase throughput to 1,000 tph.

This proposal will see the addition of the following infrastructure:

- In-pit mining unit;
- Ex-pit scrubber;
- Additional tailings containment facilities;
- Potential extensions to or new borrow pits;
- Potential extensions to roads; and
- Potential extensions to transmission lines.

1.2.2 Gangama Dry Mine

Construction of the Gangama Dry Mine commenced in April 2015 after the man-made dredge pond was drained. The construction activities focused on a dry mining concentrator plant and associated infrastructure such as roads. The plant was commissioned in May 2016. Similar to Lanti Dry Mine, the intention is to modify the mining method and increase the current throughput from 500 tph to 1,000tph.

This proposal will see the addition of the following infrastructure:

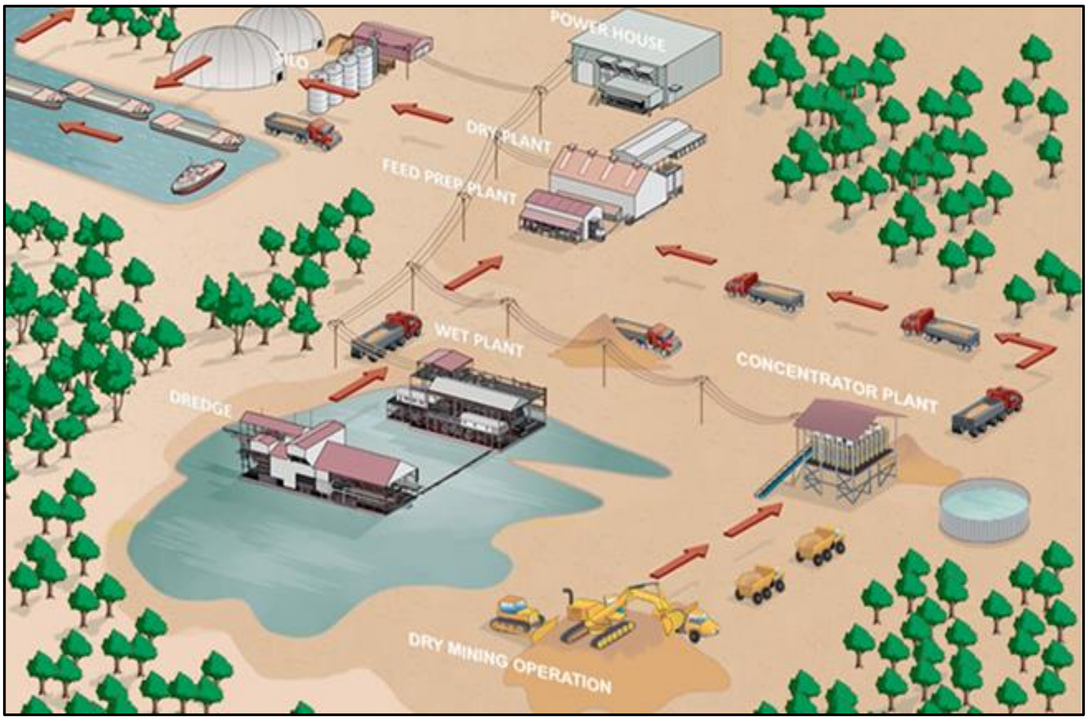
- In-pit mining unit;
- Ex-pit scrubber;
- Additional tailings containment facilities;
- Potential extensions to or new borrow pits;
- Potential extensions to roads; and
- Potential extensions to transmission lines.

1.2.3 Mogbwemo tailings

The Mogbwemo dry mine operates on the fringes of the Pejebu deposit that was historically wet mined. The process is similar to the Lanti and Gangama dry mining operations, with the exception that ore would be transferred to an existing concentrator.

1.2.4 Mineral Separation Plant

The MSP consists of a feed preparation plant and a dry plant. Flotation and completion of heavy mineral concentration will continue to be carried out in the feed preparation plant. The dry plant will be rebuilt to modern health and safety standards. Throughput will be increased from the current nominal 165-175 kilo tonne (kt) to 250 - 275 kt per annum.



srk consulting	**SR AREA 1 ESHIA & ESHMP** SRL current operations	Project No. 515234

Figure 1-2: Simplified current mining operations and processes

2 Objectives and Scope of Work

2.1 Objectives

The objectives of this assessment were to:

- Provide a description of the baseline ambient air quality, climate and emission sources that are currently impacting on air quality in the SR Area 1 based on relevant information obtained from the client;
- Determine and assess the current and potential future impacts that the project may have on the local ambient air quality;
- Identify potential receptors and areas that may be affected by the operational and expansion phase with respect to air quality; and
- Identify and recommend air quality management measures.

2.2 Scope of Work

The following scope of work was undertaken to meet the above objectives:

- Available project documentation was reviewed;
- Available climate data for the SR Area 1 (within a radius of 5 km from the SR Area 1) was reviewed and collated;
- An air emissions inventory, excluding a Greenhouse Gas (GHG) emissions inventory, was developed;
- An air dispersion model was set up and run for dust (PM_{10} and $PM_{2.5}$) with respect to operational conditions and, where applicable, gas;
- An impact assessment was conducted in terms of the following phases:

  - Operational phase: Historical and current dredge mining operations and associated infrastructure (i.e. included in the 2012 ESIA and approved via Environmental Licence number EPA-SL030);
  - Expansion phase: Construction, initial operational and expansion of the Lanti and Gangama dry mining operations (2013 onwards), including: site and vegetation clearing, grubbing, establishment of layout area, contractors camp, widening of existing haul roads, dry mining, scrubbers, expansion of Tailings Storage Facility (TSF), borrows pits and trucking of ore (haul roads); and
  - Decommissioning, closure and post closure phase.
- A report was compiled (this report) summarising the findings of this assessment including recommended management and mitigation measures.

3 Assumptions and Limitations

3.1 Assumptions

The following assumptions apply to this study:

- Dust (PM_{10}, $PM_{2.5}$ and dust fallout) and gases (sulfur dioxide (SO_2) and nitrogen dioxide (NO_2)) are the main pollutants of concern that have been identified and assessed in this study;
- As there are no standards and guidelines in Sierra Leone for ambient air quality, guidelines from the World Bank / International Finance Corporation (WB / IFC) Environmental, Health and Safety (EHS) General Guideline (2007) are used as compliance guidelines for ambient air quality results. As a comparison, South African dust fallout standards have also been used as a reference guideline as these standards were developed primarily for mining industry application.
- As there are no emission factor guidelines in Sierra Leone to determine emission rates from mining activities, emission factors from the United States Environmental Protection Agency (US EPA, 1995) and Australian National Pollutant Inventory (NPI, 2001) were used to determine the emission rates.

3.2 Limitations

The following limitations apply to this study:

- Modelled meteorological data was purchased from Lakes Environmental, as suitable on-site meteorological data for air dispersion modelling purposes was not available. The Lakes Environmental data file is designed to simulate or predict meso-scale atmospheric circulation using the MM5 model (NCAR, 2013). Long term data acquired from www,weatherbase.com (Weatherbase) was also reviewed and included as a comparison to site and Lakes Environmental data. SRK have also utilised the Koppen Climate Classification (Arnfield, 2017) to determine the climate type in the area to validate the data SRK have received from the site, Lakes Environmental and Weatherbase;
- All sources that were modelled were digitised and are representative of the sources at the existing SRL mine, based on information provided to the specialist by the client;
- The predicted ambient dust and gas concentrations reflect contributions from only the existing mining;
- A health risk assessment was not undertaken as part of the air quality impact assessment. However, it should be noted that a Health Impact Assessment was undertaken as a separate study and findings from this air quality study, will be taken into consideration as part of the Health Impact Assessment; and
- All data, modelled and monitored concentrations were compared against the WB / IFC EHS and South African dust and gas standards or guidelines were applicable.

4 Legislation and Guidelines

4.1 Sierra Leone Environmental Legislation Relating to Air Quality

4.1.1 Environmental Protection Agency Act, 2008

The *Environmental Protection Agency (EPA) Act, 2008*, is responsible for establishing a Sierra Leone Environmental Protection Agency (EPA-SL). Duties of the EPA-SL include reviewing and assessing Environmental Impact Assessments (EIAs) for projects that might lead to environmental disturbances, and also providing licences for such projects.

With respect to air quality, the following clauses have been identified in the *EPA Act*:

- Part III – Functions and management of agency:
  - Section 12 (f) – Issue environmental permits and pollution abatement notices for controlling the volume, types, constituents and effects of waste discharges, emissions, deposits or other sources of pollutants and of substances which are hazardous or potentially dangerous to the quality of the environment or any segment of the environment; and
  - Section 12 (h) – prescribe standards or guidelines relating to ambient air, water and soil quality, the pollution of air, water and land and other forms of environmental pollution including the discharges of wastes and the control of toxic substances.
- Part V – Ozone depleting substances, provides guidance on the control and use of ozone depleting substances. This section also makes provisions should an individual or entity contravene this Act;
- Part VI – Miscellaneous:
  - Section 58 (1) – The board may prescribe activities or substances which shall be considered toxic or hazardous;
  - Section 58 (5) - The discharge of any toxic and hazardous substance into the air or in, on or under the land and waters of Sierra Leone is prohibited; and
  - Section 58 (6) – Any person who contravenes subsections (3), (4) or (5) commits an offence and is liable on conviction to a fine not exceeding fifty million Leones or to a term of imprisonment not exceeding two years or to both the fine and imprisonment.

4.1.2 Minerals and Mines Act, 2009

The main purpose of the *Minerals and Mines Act, 2009* is to:

- Consolidate and amend the law on mines and minerals;
- Promote local and foreign investment in the mining sector by introducing new and improved provisions for exploration, mine development and marketing of minerals and mineral secondary processing for the benefit of the people of Sierra Leone;
- Ensure that management of the mineral sector is transparent and accountable in accordance with international best practice;
- Promote improved employment practices in the mining sector;
- Improve the welfare of communities adversely affected by mining; and
- Introduce measures to reduce the harmful effects of mining activities on the environment and to provide for other related matters.

With respect to air quality, the following applicable clauses have been identified in the Mines and Minerals Act:

- Part XV – Protection of the environment Section 133 (1) - In addition to any requirements set out in the *Environmental Protection Act*, an environmental impact assessment prepared by a small-scale mining license applicant shall be based on environmental baseline assessment work, and shall contain the types of information and analysis reflecting international mining best practice which shall include:
  - Clause (a) – A detailed description of the environment backed up with applicable measurements (air quality, water quality, etc.) to present a detailed documentation of the license area environment prior to any mining operations;

  - Clause (b) (ii) – Identification of the likely major environmental impacts, including but not limited to pollution.

4.1.3 Environmental and Social Regulations, 2013

With respect to air quality, the following clauses have been identified in the Environmental and Social Regulations:

- Part III – Environmental and social management principles and accountability:
  - Section 11 (1) Notwithstanding Section 62 of these Regulations, the holder of a mineral right shall be subject to the legal obligation to keep emissions and effluents resulting from its operations under the maximum level of pollutant concentration permitted by these Regulations and they shall manage and control residues, wastes, toxic substances and other contaminants in order to ensure that they will not cause adverse effects on the environment and public health;
- Part VII – Environmental standards:
  - Section (1) – Environmental quality standards establish the degree, level or concentration of the elements and substances, as well as physical, chemical and biological parameters, present in ambient air, water or soil that does not pose a significant risk on the public health and the environment;
  - Section (2) – Alterations of the environmental quality exceeding the above-mentioned standards are not legally imputable to the holder of a mineral right except if a direct cause-effect relationship between its operations and the violation of the environmental quality standards is proved;
  - Section 56 (1) – Effluent and emission quality standards establish the degree, level or concentration of elements and substances, as well as physical, chemical and biological parameters that characterises a particular effluent or emission from a mining operation, in excess of which public health, human wellbeing or the environment are or might be harmed;
  - Section 56 (2) – Effluent and emission quality standards are measured at their source, which shall include chimneys and waste water pipes;
  - Section 56 (3) – Compliance of effluent and emission quality standards is mandatory for the holder of a mineral right and violation of these standards shall be sanctioned as prescribed by law;
  - Section 57 (1) – Pursuant to Section 12 (h) and (t) of the *Environmental and Social Regulations Act*, the Board of the EPA is the competent authority to prescribe effluents and emission quality standards, and to recommend air, water and soil environmental quality standards;
  - Section 57 (2) – The Board is the competent authority to enforce effluent and emission quality standards, and to impose penalties in case of infringement;
  - Section 59 – In the mining sector, the prohibition established in Section 58 (5) of the Act to discharge any toxic and hazardous substance into the air or in, on or under the land and waters of Sierra Leone refers to the discharge from mining activities which infringe the effluent and emissions quality standards established in these regulations;
  - Section 63 – Gaseous emissions and particulate matter (PM) and quality standards (1) quality international standards for arsenic, lead and particulate matter emissions. (2) quality standards for sulfur dioxide;
  - Section 66 (1) - In order to ensure compliance with environmental quality standards established by the Agency pursuant to the Act and for the purposes of complying with the requirement to provide data on emissions pursuant to Section 133 (b) (i) of the *Mines and Minerals Act 2009*, the holder of an environmental licence shall measure the concentration of each regulated parameter not less than quarterly in order to determine pollutants concentration, as well as the volume of effluent and emission discharges;
  - Section 66 (2) - The holder of an environmental licence for a Category A or B project shall present a quarterly report to the Authorised Officer containing the effluents and emissions monitoring results for the last three months and an analysis and interpretation of these results;
  - Section 67 (1) - Effluent and emission sample collection and analysis shall be carried out according to the official monitoring guidelines approved by the Board; and
  - Schedule 8 – Environmental code of practice, Section IX: The holder of a mineral right shall ensure that at all times throughout the operations, any emissions to air, water or land are kept

to an absolute minimum and at levels that pose no risk whatsoever to the health of workers, local inhabitants or wildlife.

The emissions standards for arsenic, lead and particulate matter are presented in Table 4-1. It should be noted that these emission standards are for point sources and not for ambient air quality monitoring. As Sierra Leone does not have ambient air quality standards, the WB / IFC EHS Guideline was used as a compliance standard for ambient air quality monitoring.

Table 4-1: Emission standards

Parameter	Unit of measure	Limit of any pollutant
Arsenic	g/m^3	25
Lead	g/m^3	25
PM_{10}	g/m^3	100

4.1.4 Operational Regulations for Minerals Sector, 2011

With respect to air quality, the following clauses have been identified in the Operational Regulations for the Minerals Sector, 2011:

Part V1 – Workplace standards:

- Section 46: Workplace air quality (1) Mining right holders shall conduct periodic monitoring of workplace air quality for air contaminants which are relevant to an employee tasks and the plant's operations and shall maintain ventilation, air contaminant control equipment, protective respiratory equipment and air quality monitoring equipment; and
- Section 46 (2) - The Mine Manager shall ensure that protective respiratory equipment is used by employees when the exposure levels for welding fumes, solvents and other materials present in the workplace exceed local or internationally accepted standards, or the following Threshold Limit Values (TLVs) (Table 4-2).

Table 4-2: TLVs for the workplace

Pollutant	Threshold limit value (mg/m^3)
Arsenic	0.5
Carbon monoxide	29
Copper	1
Free silica	5.0
Hydrogen cyanide	11
Hydrogen sulfide	14
Lead, dusts and fumes	0.15
Nitrogen dioxide	6
Particulates	10
Sulfur dioxide	5

- Section 47 – Sampling of dust:
  - Section 47 (a) - A Competent Person[1] or a person under the direct supervision of a Competent Person takes samples of the dust present in the air throughout the mine at places determined by the Competent Person;

[1] Competent Person means a person who is:
a) Qualified by virtue of his or her knowledge of , and training, skills and experience in any matter in respect of which he or she is required to be a competent person: and or
b) Familiar with the provisions of the regulations or other law which apply to the work to be performed; and or
c) Trained to recognize any potential or actual danger to health and safety in performance of the work.

- Section 47 (b) - Sampling shall take place at regular intervals of not less than every three months; and
- Section 47 (c) - The Competent Person shall keep a detailed record and log of the time, place and results of sampling.

4.2 Ambient air quality guidelines

Guidelines published by the WB / IFC EHS Guideline are presented in this section as there are no ambient air quality guidelines in Sierra Leone. It should be noted that the WB / IFC EHS Guidelines, have been adopted from the World Health Organisation (WHO) Guidelines.

As Sierra Leone does not have standards or guidelines for dust fallout, standards from South Africa have been used as applicable reference guidelines to interpret the data and not as a compliance tool.

4.2.1 Particulate Matter

PM is airborne particles that include dust, smoke and soot. PM can either be emitted naturally (e.g. windblown dust of roads) or through human activity (e.g. stack emissions). PM is defined by size, with coarse particles being between 2.5-10 microns (µm), fine particles less than 2.5 microns, and ultrafine particles less than 0.1 microns.

PM has adverse effects on humans, such as respiratory illnesses (asthma, bronchitis) or cardiovascular diseases and is also considered as being carcinogenic. It can also affect vegetation in two ways. Firstly, by inhibiting the plant's photosynthetic properties by coating the leaves, thereby blocking the penetration of natural light. Secondly, various metals in the particulate matter could be deposited onto soils and absorbed by vegetation, hindering plant growth. The uptake of some metals by plants has the potential to contaminate the vegetables and fruit that may be consumed by humans and animals.

PM_{10}

Ambient air quality guidelines and standards for inhalable particles or PM_{10} (i.e. particulates with an aerodynamic diameter of less than 10 µm) are presented in Table 4-3. PM_{10} is important as it provides a measure of respirable dust, which has the potential to affect human health when inhaled.

Table 4-3: Air quality guidelines and standards for PM_{10}

WB / IFC EHS Guideline[1]	Maximum 24-hour concentration	Annual average concentration
Units	µg/m^3	µg/m^3
Interim Target 1[2]	150	70
Interim Target 2[3]	100	50
Interim Target 3[4]	75	30
Guideline[5]	50	20

1) WB / IFC, 2007. General EHS Guideline: Environmental. Air emissions and ambient air quality.
2) Interim target-1 (IT-1) – These levels are associated with about a 15 % higher long-term mortality risk relative to the Air Quality Guideline (AQG) level.
3) Interim target-2 (IT-2) – In addition to the other health benefits, these levels lower the risk of premature mortality by approximately 6% [2-11%] relative to the IT-2 level.
4) Interim target-3 (IT-3) – In addition to the other health benefits, these levels reduce the mortality risk by approximately 6% [2-11 %] relative to the IT-2 level.
5) Guideline (AQG) – In addition to the lowest levels at which total cardiopulmonary and lung cancer mortality have been shown to increase with more than 95 %confidence in response to long term exposure to $PM_{2.5}$
Interim targets are provided by WB / IFC in recognition of the need for a staged approach to achieving the recommended guidelines.

$PM_{2.5}$

Ambient air quality guidelines and standards for inhalable particles or $PM_{2.5}$ (i.e. particulates with an aerodynamic diameter of less than 2.5 µm) are presented in Table 4-4. $PM_{2.5}$ provides a measure of respirable dust which has the potential to affect human health and aesthetic impacts such as visibility and haze. The $PM_{2.5}$ particles when compared to PM_{10} are more harmful as particles have the potential to travel more deeply into the lungs due to the smaller size.

Table 4-4: Air quality guidelines and standards for $PM_{2.5}$

WB/IFC EHS Guideline[1]	Maximum 24-hour concentration	Annual average concentration
Units	µg/m³	µg/m³
Interim Target 1[2]	75	35
Interim Target 2[3]	50	25
Interim Target 3[4]	37.5	15
Guideline[5]	25	10

1) WB / IFC, 2007. General EHS Guideline: Environmental. Air emissions and ambient air quality.
2) Interim target-1 (IT-1) – These levels are associated with about a 15 % higher long- term mortality risk relative to the AQG level.
3) Interim target-2 (IT-2) – In addition to the other health benefits, these levels lower the risk of premature mortality by approximately 6% [2-11%] relative to the IT-2 level.
4) Interim target-3 (IT-3) – In addition to the other health benefits, these levels reduce the mortality risk by approximately 6% [2-11 %] relative to the IT-2 level.
5) Guideline (AQG) – In addition to the lowest levels at which total cardiopulmonary and lung cancer mortality have been shown to increase with more than 95 %confidence in response to long term exposure to $PM_{2.5}$.
Interim targets are provided by WB / IFC in recognition of the need for a staged approach to achieving the recommended guidelines.

4.2.2 Sulfur dioxide (SO_2)

Sulfur dioxide (SO_2) is a colourless gas and is characterised as having a sharp, irritant odour. It is a primary pollutant, which can react easily with other substances and form secondary pollutants such as sulfur trioxide and sulfuric acid, amongst others. SO_2 is formed by human activities through mainly industrial processes that contain sulfur, such as the combustion of coal, oil or gas.

SO_2 is damaging to the human respiratory function when inhaled, causing coughing and shortness of breath. Either long term exposure or exposure to a large dose can result in chronic respiratory disease and the risk of acute respiratory illness. With respect the impacts on vegetation, SO_2 can inhibit the photosynthetic properties of plants and in some cases, eliminate more sensitive species on the ecosystem level with continuous exposure. The relevant international guidelines and standards for ambient SO_2 levels are presented in Table 4-5.

Table 4-5: Ambient air quality guidelines and standards for SO_2

WB/IFC EHS Guideline[1]	Maximum 24-hour concentration
Units	µg/m³
Interim Target 1[2]	125
Interim Target 2[3]	50
Guideline[4]	20

1) WB / IFC, 2007. General EHS Guideline: Environmental. Air emissions and ambient air quality.
2) Interim target -1 (IT-1). These levels are associated with about a 15 % higher long- term mortality risk relative to the AQG level.
3) Interim target -2 (IT-2) – Intermediate goal based on controlling either motor vehicle emissions, industrial emissions and/or emissions from power production. This would be a reasonable and feasible goal for some developing countries (it would be achieved within a few years) which would lead to significant health improvements that, in turn, would justify further improvements (such as aiming for that AQG guidelines).
4) Guidelines (AQG).
Interim targets are provided by WB / IFC in recognition of the need for a staged approach to achieving the recommended guidelines.

4.2.3 Nitrogen dioxide (NO_2)

Nitrogen dioxide (NO_2) is a naturally forming gas, characterised as having an irritating odour. Small quantities can be produced by plants, soil and water, but anthropogenic activities, such as the combustion of fossil fuels and biomass, are the sources of most NO_2 in the air. Human respiratory tract irritation represents a direct effect of NO_2 exposures. Due to it being relatively insoluble (relative to SO_2), NO_2 can penetrate deep into the lungs, causing potential tissue damage. Effects of NO_2

exposure include alveolar tissue disruption and obstruction of the respiratory bronchioles. Long term effects of exposure include increased potential for lung infections. The relevant international guidelines and standards for ambient NO_2 levels are presented in Table 4-6.

Table 4-6: Ambient air quality guidelines and standards for NO_2

WB/IFC EHS Guideline[1]	Maximum 1-hour concentration	Annual average concentration
Units	µg/m^3	µg/m^3
Guideline	200	40
1) WB / IFC, 2007. General EHS Guideline: Environmental. Air emissions and ambient air quality.		

4.3 Dust fallout standards

Monitoring of Dust Fallout (DFO) is considered to be the most practical and cost-effective approach to obtaining an indication of baseline dust levels across the SR Area 1, and dust fallout was monitored during the baseline study for this ESHIA.

Since there are no local Sierra Leone standards or WB / IFC EHS Guidelines for DFO, the South African Dust Fallout Standards (*National Environmental Management Air Quality Act No. 39 of 2004 (NEM: AQA*)) were used as reference guidelines in this assessment. The South African Standard is presented in Table 4-7.

Table 4-7: NEM: AQA, 2004 Acceptable dust fallout standards

Restriction area	Dust fall rate (D) (mg/m^2/day, 30-day average)	Permitted frequency of exceeding dust fall rate
Residential Area	D < 600	Two within a year, not sequential months
Non-residential Area	600 < D < 1,200	Two within a year, not sequential months

5 Climate

5.1 General description of climate in Sierra Leone

Sierra Leone is located in West Africa, between the Tropic of Cancer and the Equator. The climate in Sierra Leone is tropical, with a wet season from May to October and a dry season from November to April.

The Inter-Tropical Convergence Zone (ITCZ) has a major influence on the climate of Sierra Leone. Throughout the year the ITCZ remains in the northern hemisphere in the eastern Pacific and Atlantic regions. Over Africa, the ITCZ migrates from the southern to the northern hemisphere between January and July (Tyson and Preston-Whyte, 2000). The hot weather during this period, heats the air in the ITCZ, increasing its humidity and making it buoyant. As the buoyant air rises as a result of the trade winds from the south west, it expands and cools, producing rainfall over Sierra Leone and surrounding regions. As the ITCZ moves south during September, the rainy season draws to a close.

The winds that originate during the dry season (winter), known as the Harmattan winds, consist of the northeast trade winds. These winds bring no precipitation apart from the occasional very light rain. The Harmattan winds transport dust from the Sahara Desert and usually blow from late November to mid-March. Average wind speeds in Sierra Leone are generally low.

There is little seasonal variation in mean air temperatures, with slightly hotter conditions in April and May. Altitude influences temperature as well as other weather variables, with temperatures generally decreasing with altitude.

5.2 General description of regional climate

According to the Koppen Climate Classification System (Arnfield, 2017), the SR Area 1 is classified as a Category “A” climate type, which is characteristically hot and moist during summer and cool and dry in winter. The region / site also falls into the subcategory “Am” which represents a tropical monsoon climate i.e. wet summers and dry winters. The ITCZ influences the climate in the summer period bringing rain and during winter, the trade winds dominate bringing a drier climate. Average temperatures associated with this classification are usually greater than 18ºC. Rainfall is usually above 1,500 mm.

5.3 Climate conditions at the project site

Climate data for the SR Area 1 has been collected and reviewed from on-site weather stations (MSP and Lanti Dry Mine), and Weatherbase for the Mogbwemo village. The Mogbwemo village is located adjacent to the SRL MSP. Two additional weather stations were installed during the SRK site visit in July 2017, at Nitti Port and Gangama Dry Mine. The data for these weather stations are not presented in this report as only one month’s data has been collected. Modelled meteorological data from Lakes Environmental for the SR Area 1 is also presented in this section.

5.3.1 Rainfall

Rainfall is an important parameter with respect to air quality. During the rainy season, air pollution, and more specifically in this case, dust particles, are removed from the atmosphere. Dust emissions are suppressed due to increases in soil moisture content and increased vegetation cover during the rainy season. During the cooler dry and hot dry seasons, dust emission levels are generally higher.

Rainfall data obtained from the SRL MSP site for the period January 2001 to May 2017 were assessed. The average annual rainfall measured at the MSP was 2,827 mm, with the majority of rainfall falling from May to November. In comparison, low rainfall was measured during December to April. The weather station installed at the Lanti Mine Site measured rainfall from January 2001 to December 2007 and from August 2014 to August 2017. It should be noted that 10 months of wet season data was missing during the latter period (August 2014 to August 2017) due to unknown reasons. However due to the long-term data downloaded from the weather station this will not be an issue. The average annual rainfall for this period was 2,933 mm. Similarly, to the rainfall obtained from the MSP site, the majority of rainfall is measured from May to November, with low rainfall measured from December to April.

Rainfall data for the Mogbwemo area was sourced from Weatherbase. The average annual rainfall measured at Mogbwemo is 3,098 mm, which is slightly higher than at the weather stations located on the mine site.

In comparison to the measured rainfall data, the average annual rainfall from Lakes Environmental (for the SR Area 1) is considerably higher at 4,274 mm for the period January 2014 to December 2016. As with the measured data, the majority of rainfall occurs from May to November.

The average monthly rainfall for the on-site data and Lakes Environmental is presented in Figure 5-1. Similar trends are observed between the datasets.

Table 5-1: Comparison between on-site rainfall and Lakes Environmental data

Month	SRL MSP Site	Lanti Mine Site	Mogbwemo Village	Lakes Environmental
Units	mm	mm	mm	mm
January	6.5	3.7	3.8	74.4
February	10.6	27.6	15.4	30.6
March	50.2	44.9	28	18.0
April	92.7	139.4	85.7	140.1
May	240.5	199.0	285.8	405.0
June	375.6	396.4	408.7	569.9
July	515.1	556.8	651.6	567.0
August	636.6	686.4	690.3	754.2
September	450.2	443.5	448.3	732.5
October	278.2	271.9	328.3	543.5
November	146.8	154.0	121.7	373.4
December	24.0	9.7	30.1	64.8
Total	**2,827**	**2,933**	**3,098**	**4,274**

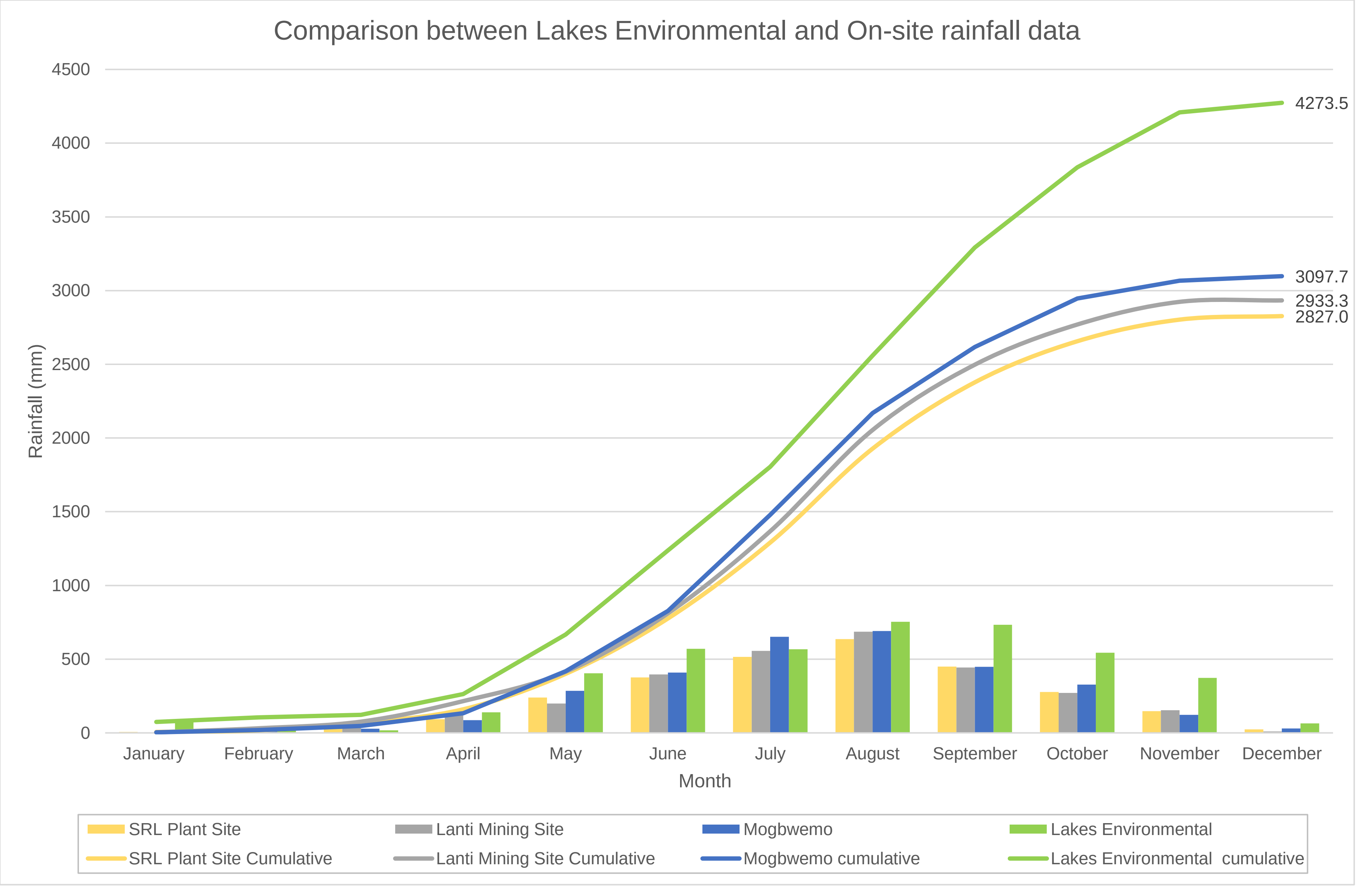


Figure 5-1: Comparison between Lakes Environmental and on-site rainfall data

5.3.2 Temperature and humidity

Similar to rainfall, temperature and humidity data were sourced from the on-site weather station at Lanti Mine Site, from Weatherbase and Lakes Environmental. The monthly average, average maximum and average minimum temperatures and average humidity are presented in Table 5-2 and Figures 5-2 to 5-4.

The data obtained from the Lanti Mine Site indicates average temperatures ranging from 24.7 - 28.1°C, with maximum temperatures reaching 37.3°C and minimum temperatures 18.8 °C. Relative humidity ranged from 67.4 - 84.6%, with higher humidity measured during the wet season and lower humidity measured in the dry season.

The average temperatures from the Weatherbase site (range 25.3 - 28.1°C) were comparable to Lanti Mine Site data. Average maximum temperatures reached 33.4°C and minimum temperatures 19.8 °C. Relative humidity ranged from 68.6 - 87.4%, with higher humidity measured during the wet season and lower humidity measured in the dry season.

The average temperatures for the Lakes Environmental dataset ranged from 25.2 - 28.2°C, with a maximum of 36.7°C and minimum of 16.6°C. Humidity ranged from 72.1 - 91.5% during the period from January 2014 to December 2016. The various datasets are comparable, with the slight differences in relative humidity between the datasets not considered significant.

Table 5-2 Comparison of Lakes Environmental and on-site temperature and humidity data

Month	Lanti Mine Site				Mogbwemo Village				Lakes Environmental			
	Average	Max	Min	Humidity	Average	Ave. Max	Ave. Min	Humidity	Average	Max	Min	Humidity
	°C	°C	°C	%	°C	°C	°C	%	°C	°C	°C	%
January	26.4	34.8	18.8	67.4	25.7	31.2	19.8	70.3	25.9	34.9	17.4	78.3
February	27.5	37.0	21.5	74.3	27.3	32.9	21.1	71.0	26.7	36.4	18.7	76.3
March	27.3	37.3	21.2	72.9	27.9	33.4	21.8	68.6	27.5	37.1	19.7	72.1
April	28.1	36.5	22.3	78.3	28.1	32.8	22.6	70.4	28.2	36.7	21.5	75.5
May	27.3	35.0	21.7	82.5	27.3	31.6	22.7	79.9	27.5	34.9	22.8	84.6
June	25.8	33.5	21.2	84.6	26.4	30.1	22.3	82.6	26.3	32.3	22.3	88.1
July	25.0	31.7	22.2	84.2	25.4	28.3	22.0	86.8	25.5	29.9	21.0	89.6
August	24.7	30.1	21.8	84.5	25.3	28.2	21.9	87.4	25.2	30.0	21.0	90.3
September	25.5	32.6	22.1	81.5	25.9	29.4	22.1	84.8	25.3	29.8	21.4	91.5
October	26.3	33.8	22.0	80.5	26.5	30.3	22.1	81.6	25.7	30.5	21.9	91.5
November	26.8	33.9	21.8	79.8	26.7	30.9	22.0	79.6	25.9	31.7	21.4	90.2
December	26.8	34.4	19.6	72.6	26.1	31.0	20.6	75.7	25.6	33.8	16.6	78.3

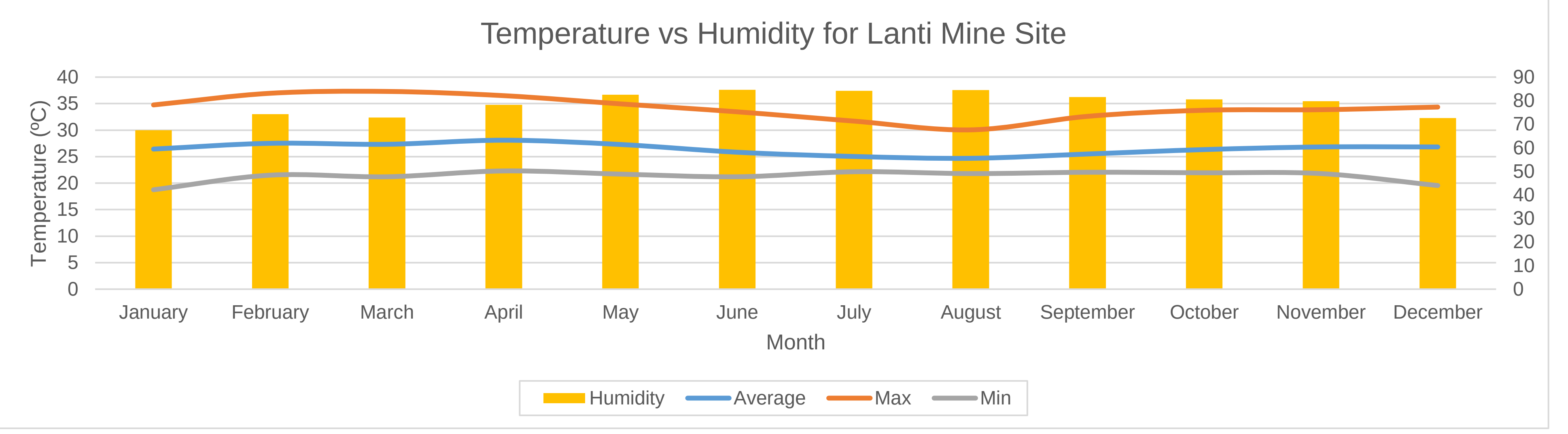


Figure 5-2: Average monthly temperature and humidity patterns for Lanti Mine Site for a 3-year period

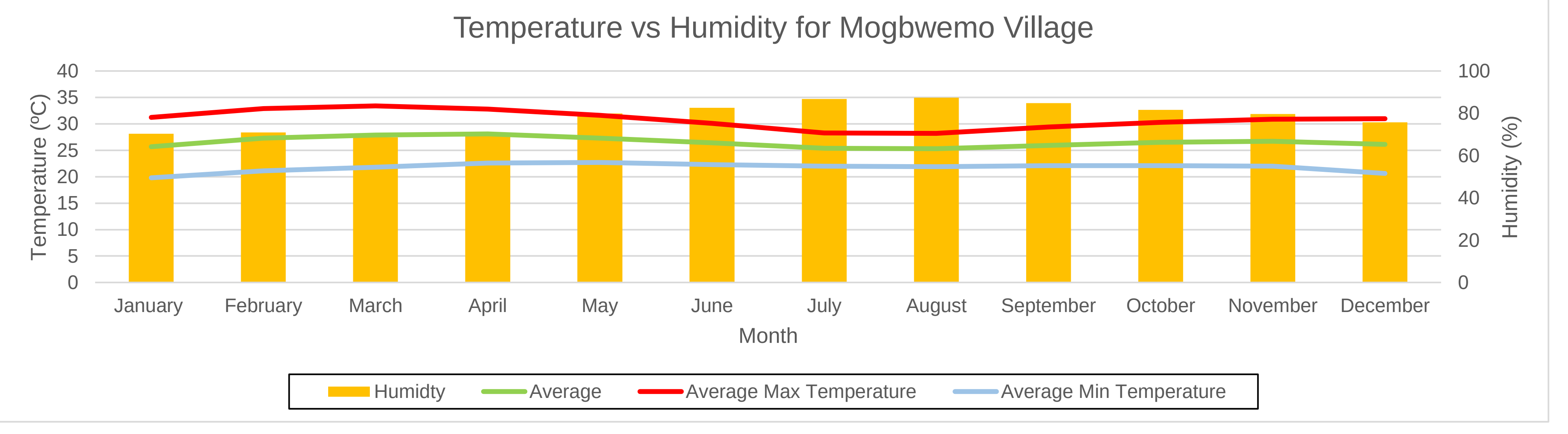


Figure 5-3: Average monthly temperature and humidity patterns for Mogbwemo Village for a 112-year period

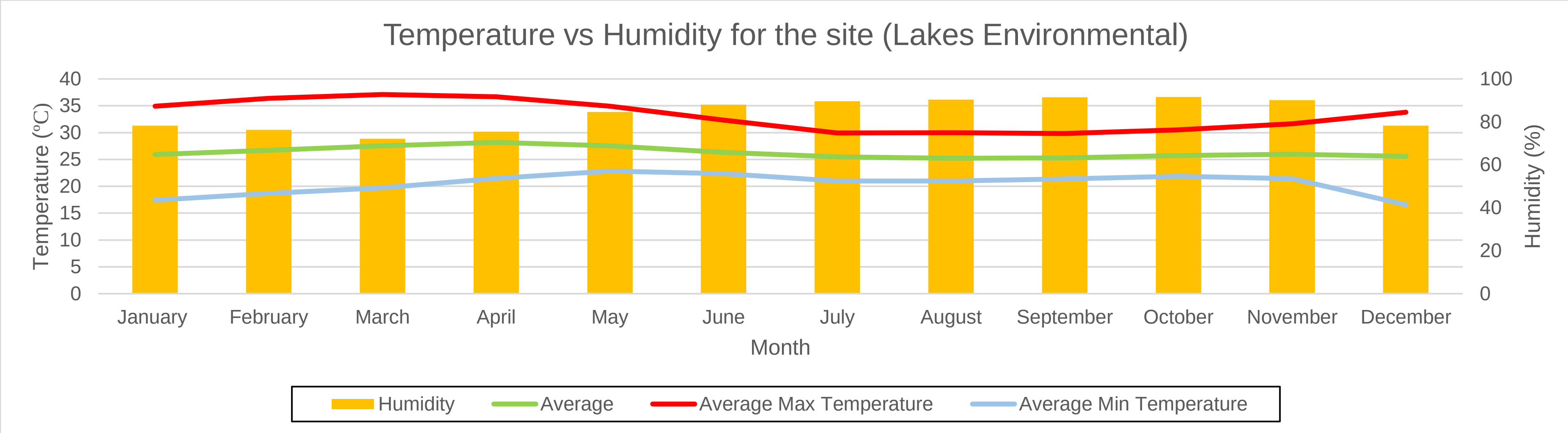


Figure: 5-4: Lakes Environmental average monthly temperature and humidity patterns for the site for a 3-year period

5.3.3 Wind Speed

The wind field for an area is an important parameter with respect to air quality and winds can generate dust emissions, as well as influence the dispersion of an emissions plume. The degree to which winds can influence dispersion depends on the wind speed. Higher wind speeds result in longer travel distance and dilution of the pollutants and lower, more stable wind conditions result in shorter travel distance and build-up of pollutant levels (especially gases) over a smaller area.

Lakes Environmental data

Hourly meteorological data for the period January 2014 to December 2016 was acquired from Lakes Environmental.

The wind roses for all hours, day and night time for the SR Area 1 are presented in Figure 5-5. The prevailing winds in the SR Area 1 are relatively constant throughout the year. Winds are predominantly from the southwest and west-southwest during the day (Figure 5-5b) and earlier (18h00-23h00) parts of the night (Figure 5-4c). Winds during the latter part of the night (Figure 5-5) are of lower speed and prevalent from all directions with the highest frequency of winds blowing from the northeast.

The average wind speed for all hours for the SR Area 1, is 2.64 m/s with maximum speeds less than 8.8 m/s and with calms (<0.5 m/s) of 2.97%. The average wind speeds for day time (06h00 - 18h00) during the year is 3.31 m/s with calms of 1.68%. The average wind speed during the earlier parts of the night (18h00 - 23h00) is 2.79 m/s with calms of 2.71%. The average wind speed decreases during the latter parts of the night to 1.42 m/s with calms prevailing 5.11% of the time.

Wind roses were also created for two distinct seasons i.e. wet season (May to October) and dry season (November to April) (Figure 5-6). The prevailing wind directions during the dry season are from the west-southwest and southwest with lower occurrences from the west and northeast. The influence of the Harmattan winds from the northeast is observed during the dry season. However, during the wet season the prevailing wind direction is from southwest with a lower occurrence from the west-southwest, south-southwest and south. The highest average wind speeds of 2.73 m/s occurs during the wet season with calms prevailing 3.93% of the time. The lowest average wind speed occurs during the dry season with an average wind speed of 2.56 m/s with calm conditions prevailing 1.99% of the time. The winds during the rainy season average 2.83 m/s with calms of 6.66%.

The wind class frequency distribution, presented in Figure 5-7, shows that 91.8% of wind speeds are below 5.7 m/s (low to moderate) with 8.2% of winds above 5.7 m/s.

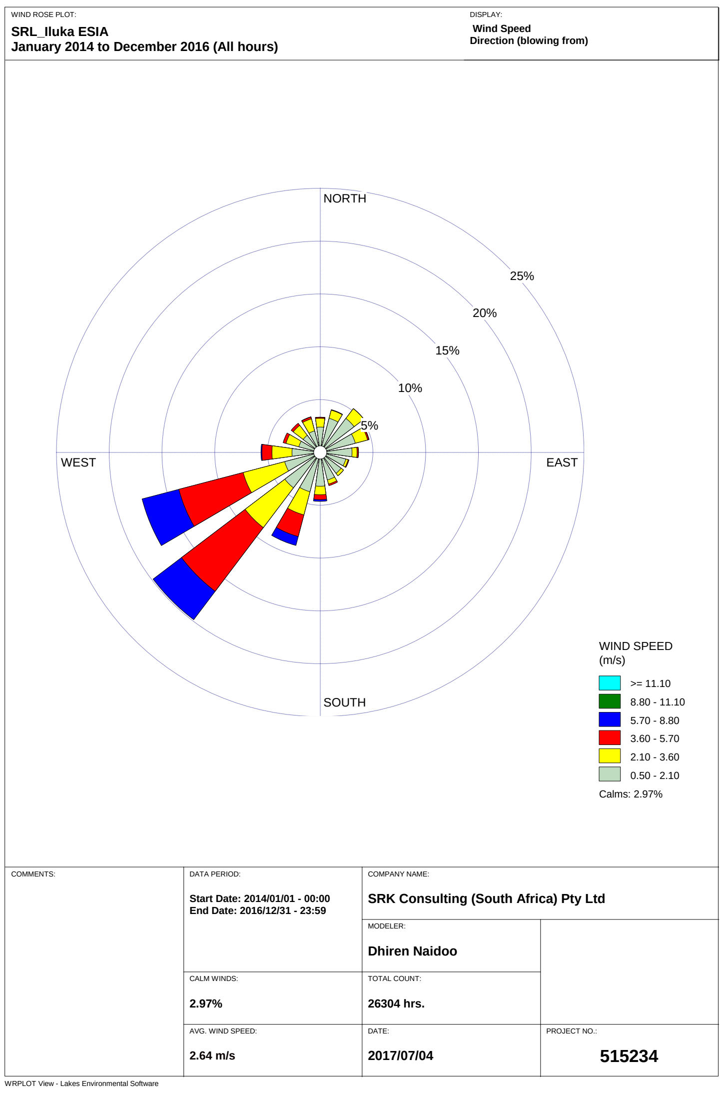


Figure 5-5a: January 2014 to December 2016 (All hours)

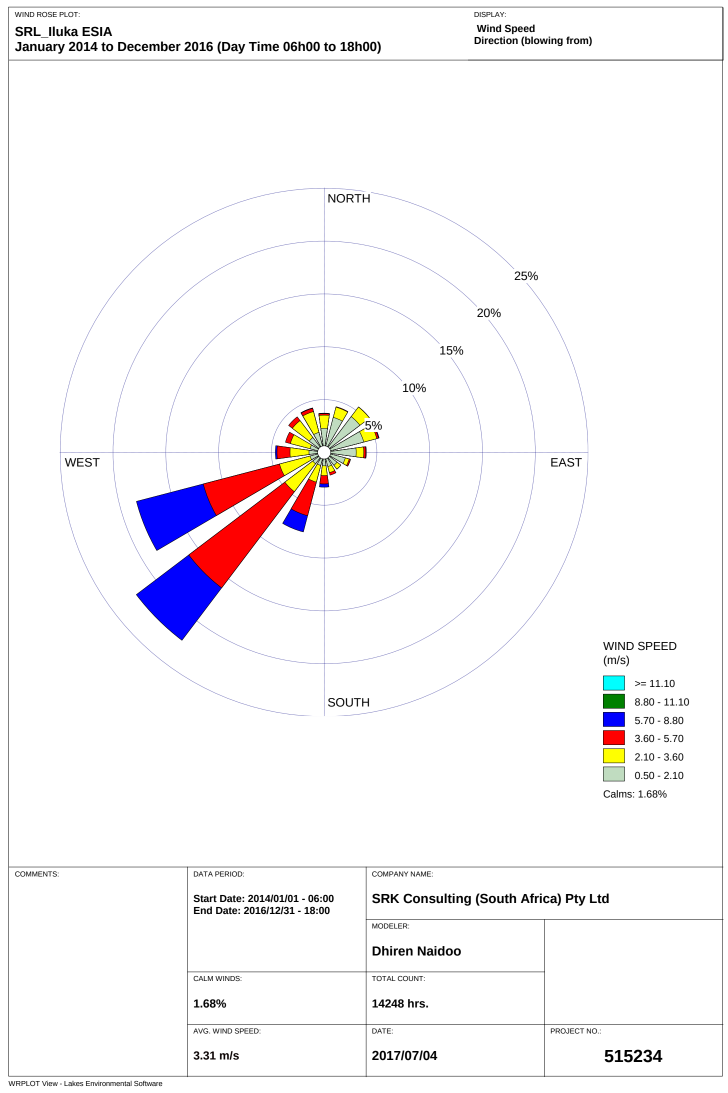


Figure 5-5b: January 2014 to December 2016 (Day Time 06h00-18h00)

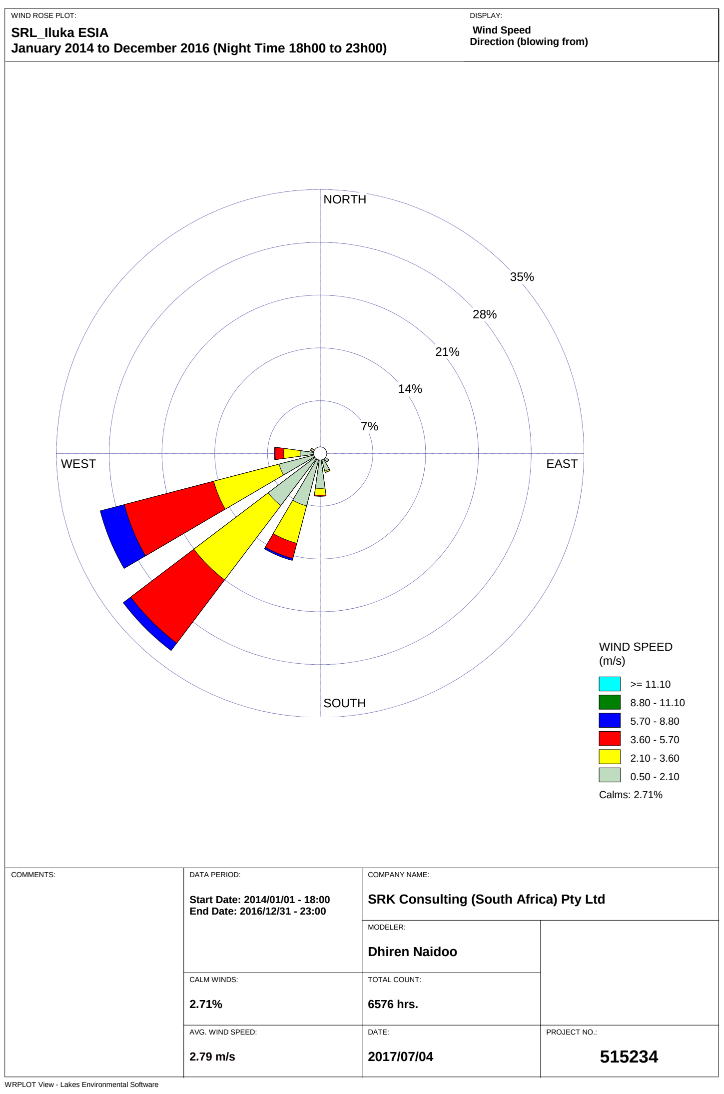


Figure 5-5c: January 2014 to December 2016 (Night Time 18h00-23h00)

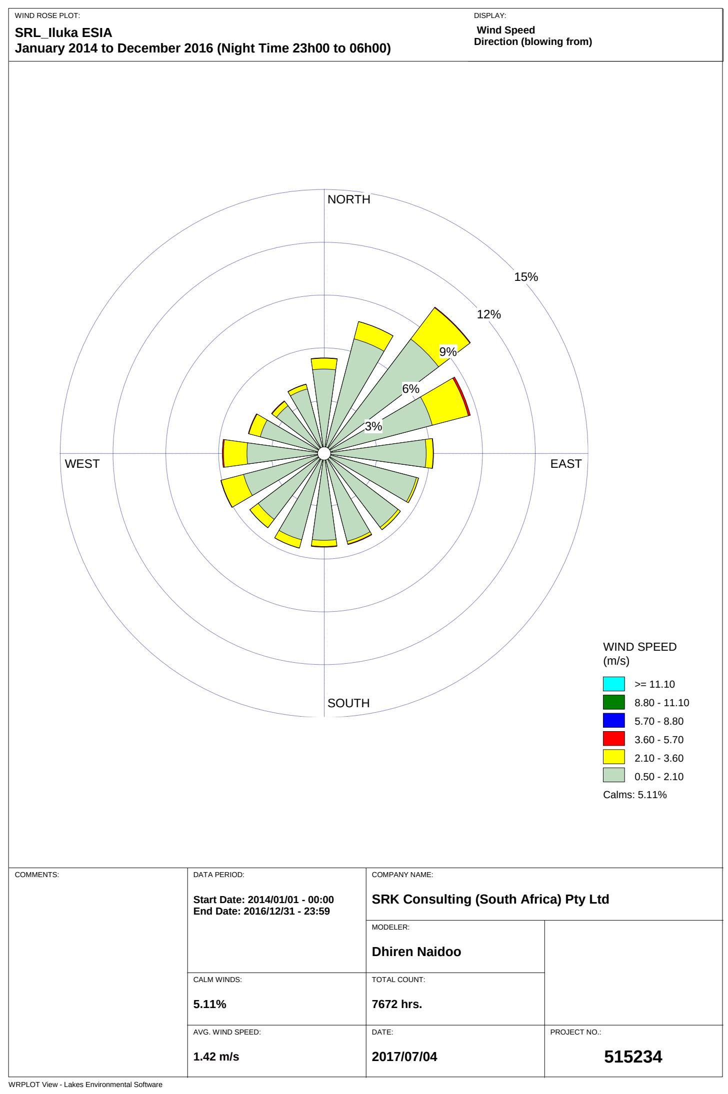


Figure 5-5d: January 2014 to December 2016 (Night Time 00h00-06h00)

srk consulting	SR AREA 1 ESHIA & ESHMP Lakes Environmental all hours, day time and night time wind roses	Project No. 515234

Figure 5-5: All hours, day time and night time wind roses from Lakes Environmental

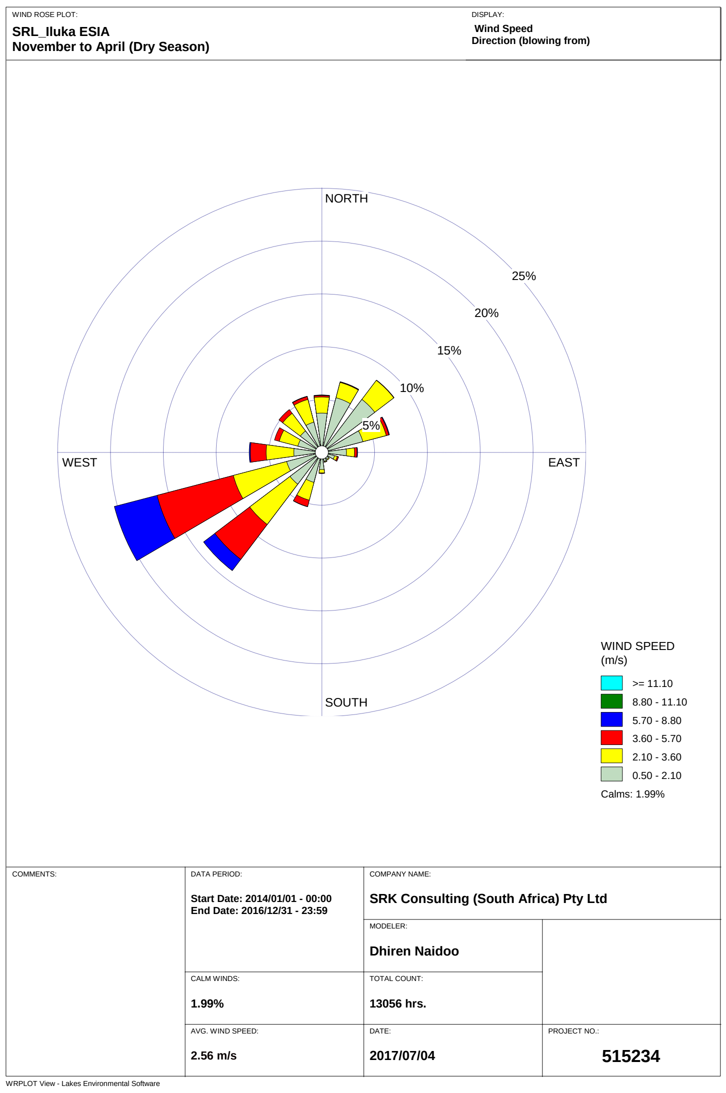


Figure 5-6a: Dry season (November to April)

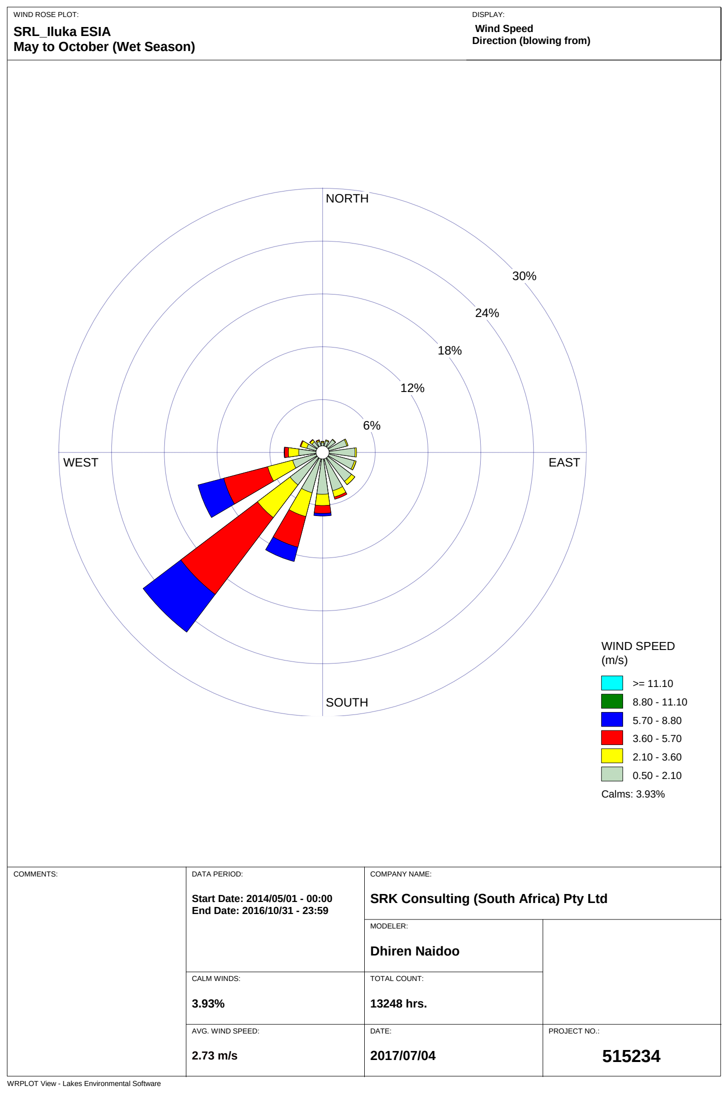
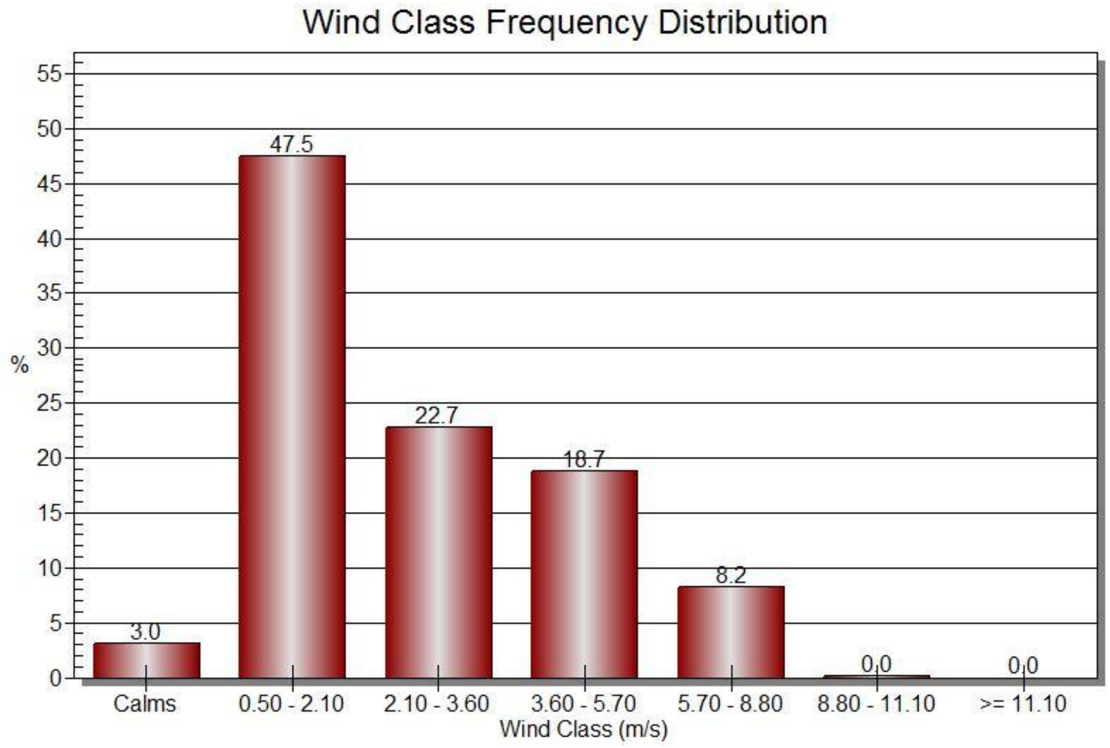


Figure 5-6b: Wet season (May to October)

srk consulting	**SR AREA 1 ESHIA & ESHMP** Lakes Environmental seasonal wind roses	Project No. 515234

Figure 5-6: Lakes Environmental seasonal wind roses



srk consulting	**SR AREA 1 ESHIA & ESHMP** Wind class frequency distribution	Project No. 515234

Figure 5-7: Lakes Environmental wind class frequency distribution

6 Ambient air quality monitoring

As part of the current dust and gas monitoring program for the SR Area 1, air quality monitoring data for the period July to August 2017 was available at the time of writing this report. The monitoring protocol for the ambient air quality study is presented in Appendix A. The monitoring locations are presented in Table 6-1, Table 6-2 and Figure 6-1.

The following datasets have been collated:

- DFO results for August 2017;
- Daily PM_{10} and $PM_{2.5}$ concentrations for the period 29 July 2017 to 31 August 2017; and
- Gas results for July 2017.

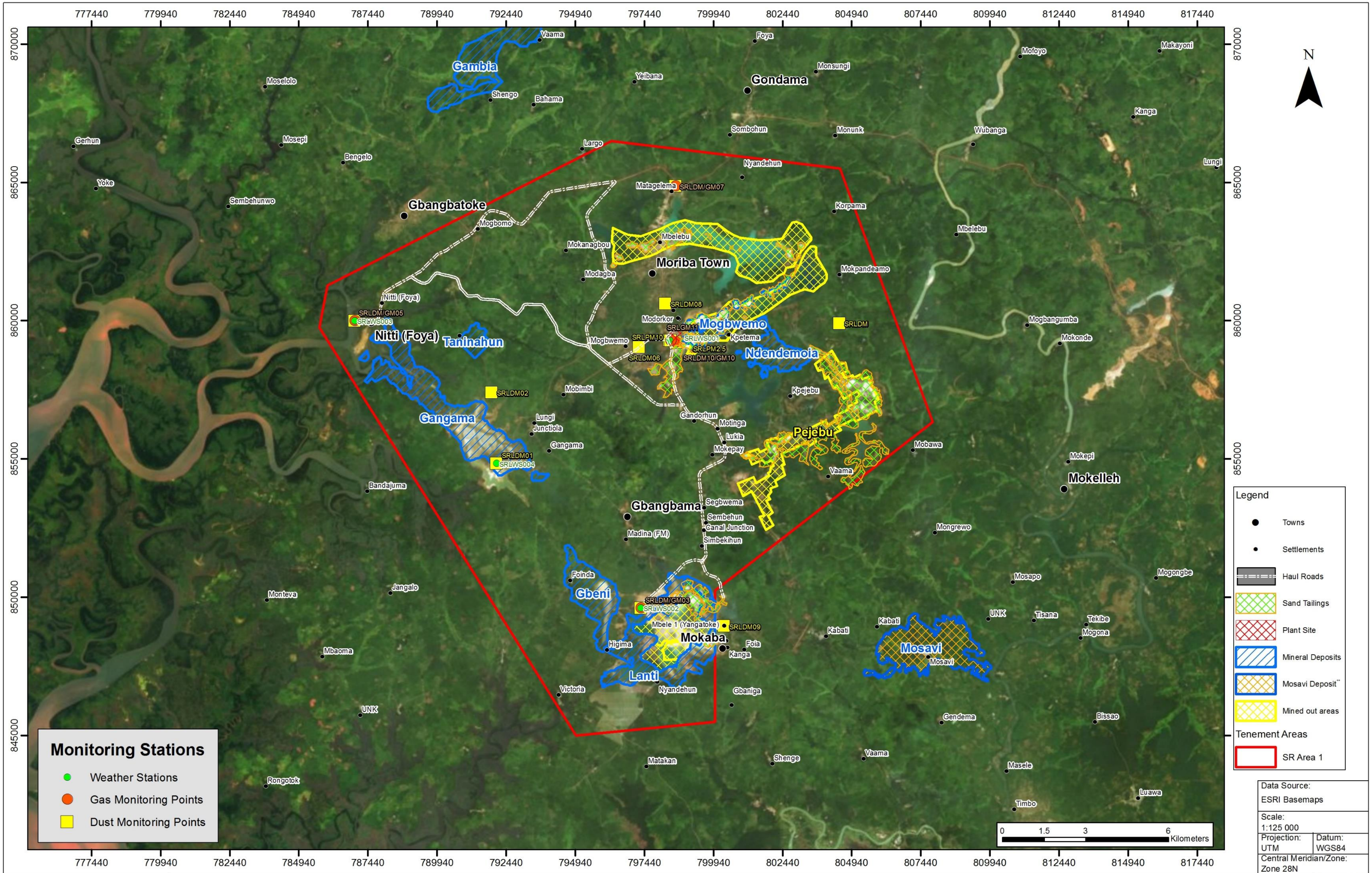
Table 6-1: DFO and gas monitoring locations

Field ID	Village / Area	Co-ordinates UTM	
SRLDM01[2]	Gangama MD2	792097	854837
SRLDM02	Semabu Village	791917	857409
SRLDM/GM03	Lanti MD 1	797319	849607
SRLDM	Mukaba Village	804497	859908
SRLDM/GM05	SRL Nitti Port	786957	860000
SRLDM06	Mogbwemo Village	797245	859043
SRLDM/GM07	Matagelema Village	798573	864867
SRLDM08	Moriba Town Police Station	798205	860620
SRLDM09	Yangatoke Village	800326	848958
SRLDM10/GM10	SRL MSP Site	798583	859223
SRLGM11	Plant Site Admin	798389	859286

Table 6-2: Monitoring locations for PM and weather stations at SRL

Field ID	Village	Co-ordinates UTM	
SRLPM10	Plant Site Admin	798389	859286
SRLPM2.5	Plant Site Admin	798389	859286
SRLWS001	Plant Site Admin	798389	859286
SRLWS002	Lanti MD 1	797319	849607
SRLWS003	SRL Nitti Port	786957	860000
SRLWS004	Gangama MD2	792097	854837

[2] DM refers to Dust Monitor and GM refers to Gas Monitor



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SR AREA 1 ESHIA & ESHMP

DUST AND GAS MONITORING STATIONS

**Note
The Mosavi Deposit is not included in the SRL Area 1 Study, but is shown on the locality due to its proximity to Area 1.

Path: G:\515234_ILUKA_SRK_ESIA_JNB\8GIS\GISPROJ\MXD\Feb2018\AQ\515234_F6_1_AQIA_monitoring_A3L_23022018.mxd

Revision: A Date: 23 02 2018

6.1 Dust fallout

The dust fallout results for August 2017 to November 2017 are presented in Table 6-3 and in Figure 6-2. Data for December is outstanding as a result of the time it takes the samples to be couriered to South Africa, hence, the analysis has not been completed at the time of report submission. There are six residential and four non-residential dust fallout monitoring sites. All four non-residential sites are below the South African Non-residential Area Standard of 1,200 mg/m^2/day, with the highest dust fallout rate measured at SRLDM10-MSP (454 mg/m^2/day in October 2017). Dust fallout at the six villages are below the South African Residential Area Standard of 600 mg/m^2/day for the majority of the period, except on 3 occasions. The exceedances occurred at SRLDM02-Semabu Village (September 2017 and November 2017) and SRLDM06-Mogbwemo Village (November 2017) with the highest concentration measured at SRLDM02-Semabu Village (2.536 mg/m^2/day). The exceedance at SRLDM02 should be excluded from the September 2017 monitoring round as it was noticed that material had been thrown into the bucket by the villagers. As expected, the results were low for the majority of the monitoring period which occurred during the wet season.

Table 6-3: Dust fallout for August 2017

Field ID	Village	Designation	Aug-2017	Sep-17	Oct-17	Nov-17
			mg/m^2/day			
SRLDM01	Gangama MD2	Non-residential	40	48	36	145
SRLDM02	Semabu Village	Residential	56	2,536	57	665
SRLDM03	Lanti MD 1	Non-residential	37	97	71	65
SRLDM04	Mukaba Village	Residential	59	51	66	85
SRLDM05	SRL Nitti Port	Non-residential	161	165	116	3
SRLDM06	Mogbwemo Village	Residential	138	309	526	624
SRLDM07	Matagelema Village	Residential	49	41	63	73
SRLDM08	Moriba Town Police Station	Residential	70	87	89	81
SRLDM09	Yangatoke Village	Residential	91	95	179	28
SRLDM10	SRL MSP Site	Non-residential	150	279	454	231
Residential Area Standard			600	600	600	600
Non-residential Area Standard			1,200	1,200	1,200	1,200

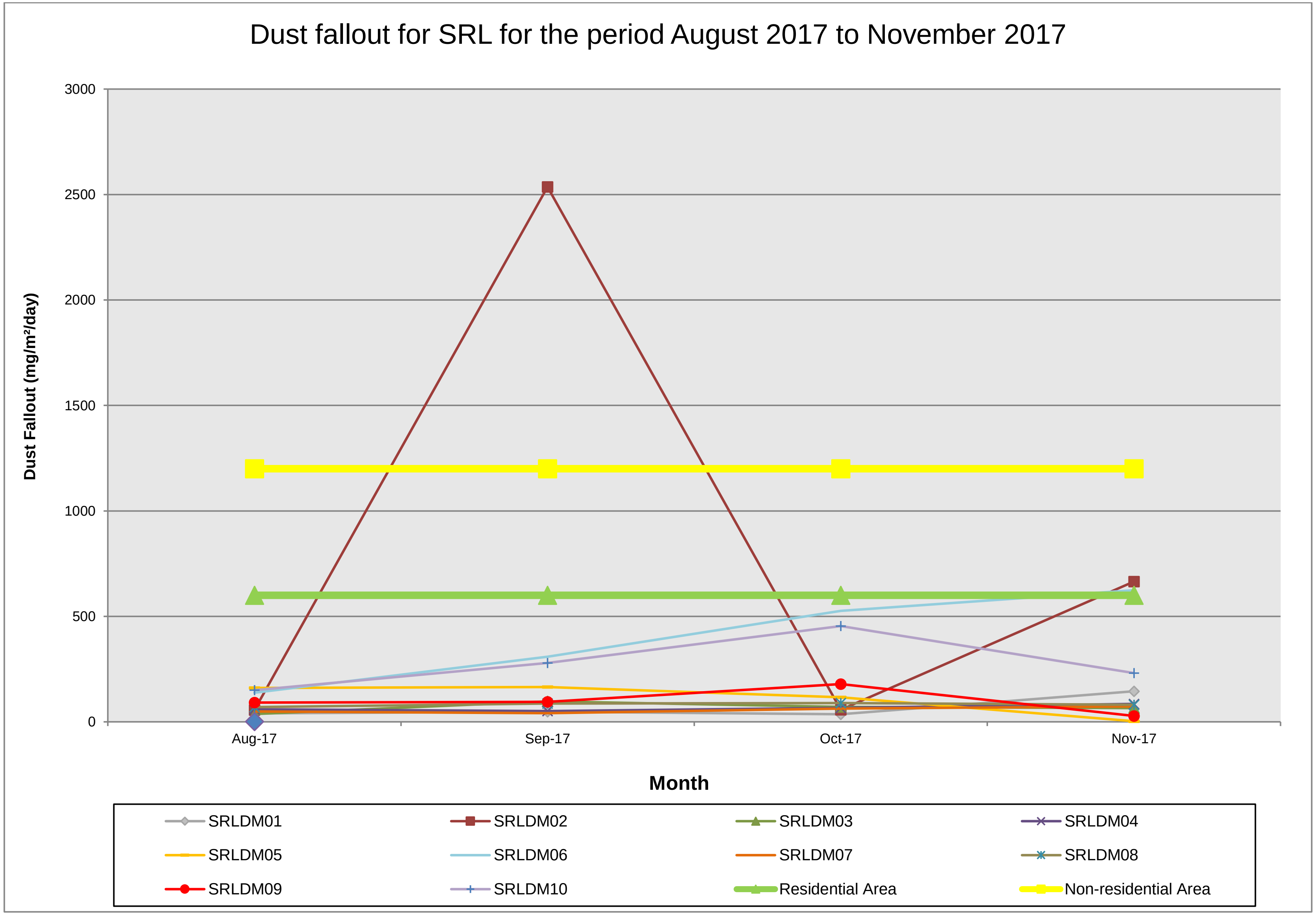

Figure 6-2: Dust fallout results for November 2017

6.2 Particulate Matter Results

PM data was collected for the period from 29 July 2017 to 31 December 2017. The PM_{10} and $PM_{2.5}$ monitors are located at the SRL mine offices as the location is secure with constant electricity supply (Figure 6-1). The PM_{10} and $PM_{2.5}$ data was validated for accuracy.

6.2.1 PM_{10}

The average 24-hour PM_{10} concentrations are presented in Table 6-4 and the daily concentrations are presented in Figure 6-3. The monthly average 24-hour PM_{10} concentrations were below the WB / IFC EHS Guideline of 50 µg/m^3 for the majority of period, except in December 2017 (74.5 µg/m^3). The PM_{10} concentrations for July 2017 represents data collected from 29 July 2017 (3 days). The daily concentrations, as presented in Figure 6-3, are below the WB / IFC EHS Guideline of 50 µg/m^3 during the wet season. However, once the dry season begins, concentrations exceed the WB / IFC EHS Guideline of 50 µg/m^3. There were 16 exceedances of the WB / IFC EHS Guideline of 50 µg/m^3 during the monitoring period from July to December 2017, with the majority occurring in December 2017.The highest 24-hour concentration measured occurred on the 24 December 2017 (176.5 µg/m^3) and may have been a factor of low rainfall and/or increased dust generation through on-site activities or the influence of Harmattan winds which blow from the northeast.

Table 6-4: Monthly average 24-hour PM_{10} concentrations

Month	PM_{10} concentration (µg/m^3)
July 2017	11.0
August 2017	9.0
September 2017	8.1
October 2017	16.5
November 2017	21.3
December 2017	74.5
WB / IFC EHS Guideline	50

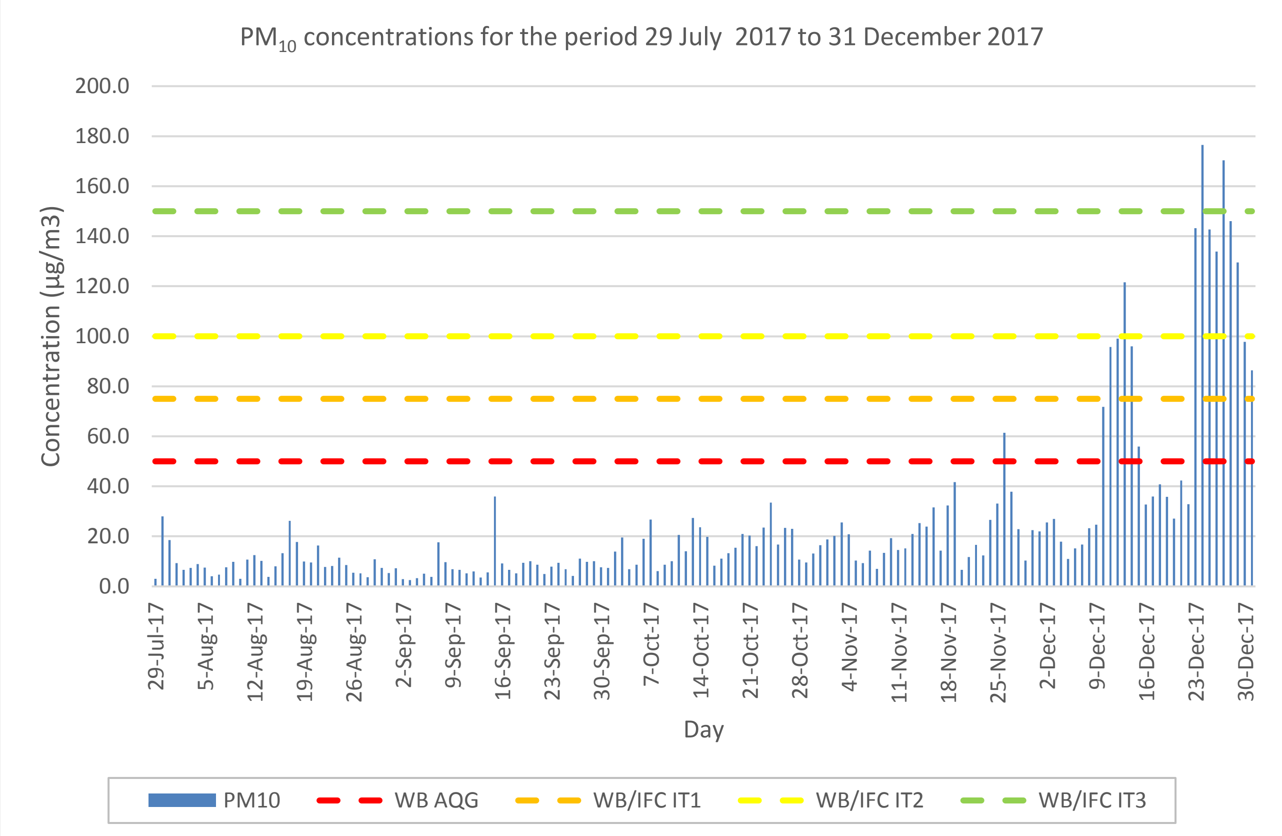

Figure 6-3: PM_{10} concentrations for the period July to December 2017

6.2.2 $PM_{2.5}$

The average 24-hour $PM_{2.5}$ concentrations are presented in Table 6-5 and the daily concentrations are presented in Figure 6-4. The average 24-hour $PM_{2.5}$ concentrations were below the WB / IFC EHS Guideline of 25 µg/m^3 for the period, except in December 2017 (70.8 µg/m^3). The daily concentrations, as presented in Figure 6-4, are below the WB / IFC EHS Guideline of 25 µg/m^3 during the wet season. Similar to PM_{10}, once the dry season begins, concentrations exceed the WB / IFC EHS Guideline of 25 µg/m^3. There were 31 exceedances of the WB / IFC EHS Guideline of 25 µg/m^3 during the monitoring period from July to December 2017.The highest 24-hour concentration measured occurred on the 27 December 2017 (146.7 µg/m^3) and may have been factor of low rainfall and/or increased dust generation through on-site activities and the influence of Harmattan winds which blow from the northeast.

Table 6-5: Monthly average 24-hour $PM_{2.5}$ concentrations

Month	$PM_{2.5}$ concentration (µg/m^3)
July 2017	9.5
August 2017	6.7
September 2017	5.8
October 2017	11.9
November 2017	18.4
December 2017	70.8
WB/IFC EHS Guideline	25

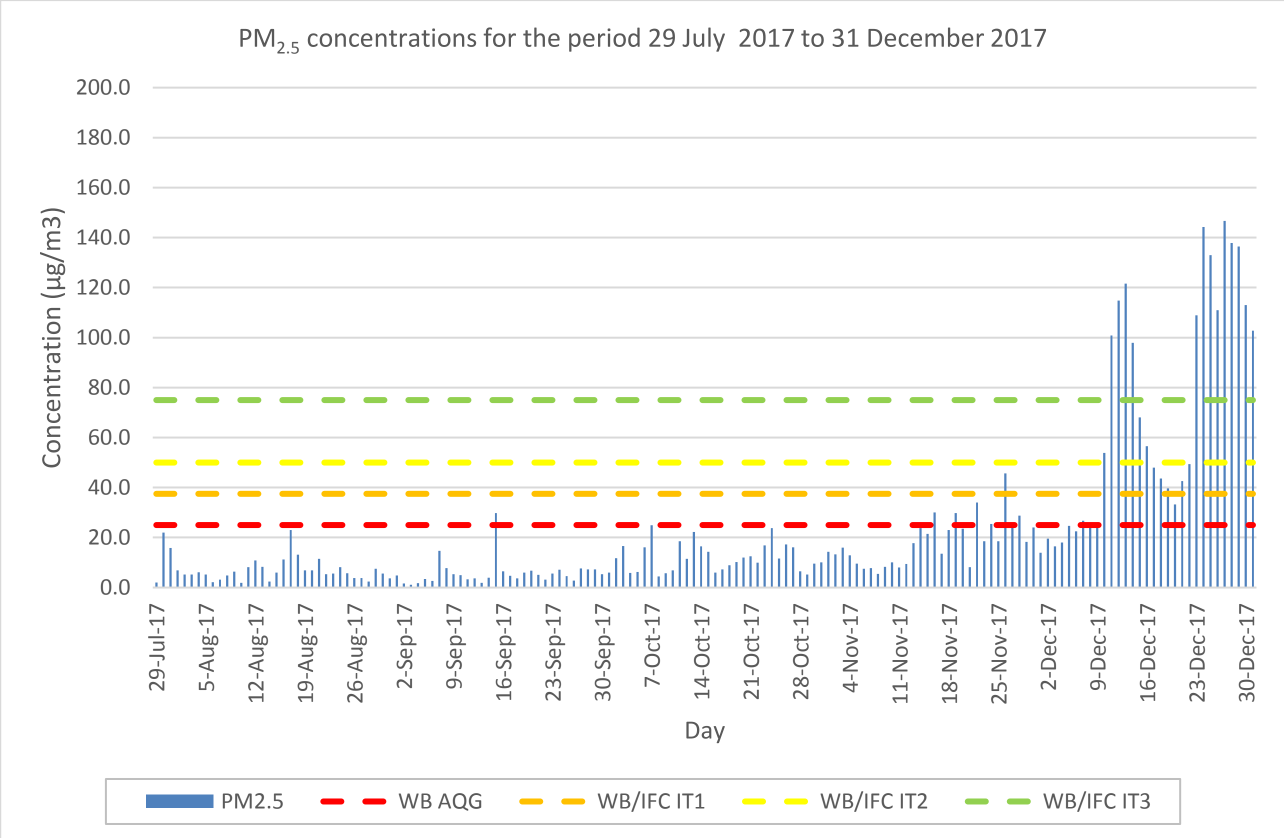

Figure 6-4: $PM_{2.5}$ concentrations for the period July to December 2017

6.2.3 PM_{10} and $PM_{2.5}$ comparison

A comparison of the PM_{10} and $PM_{2.5}$ data is shown in Figure 6-5. $PM_{2.5}$ concentrations are generally below the PM_{10} concentrations, except in a few instances where the $PM_{2.5}$ results are higher. Activities, such vehicle entrainment of dust and windblown dust, occurring near the $PM_{2.5}$ monitor have increased the concentration of $PM_{2.5}$ in the air.

Across the period from July to December 2017 the $PM_{2.5}$ concentrations are at an average of 83% of PM_{10}. Hence, the majority of PM_{10} consist of particulates that are less than 2.5 microns. For the monitoring period, high rainfall coincided with a decrease in PM concentrations and low rainfall with an increase PM concentrations.

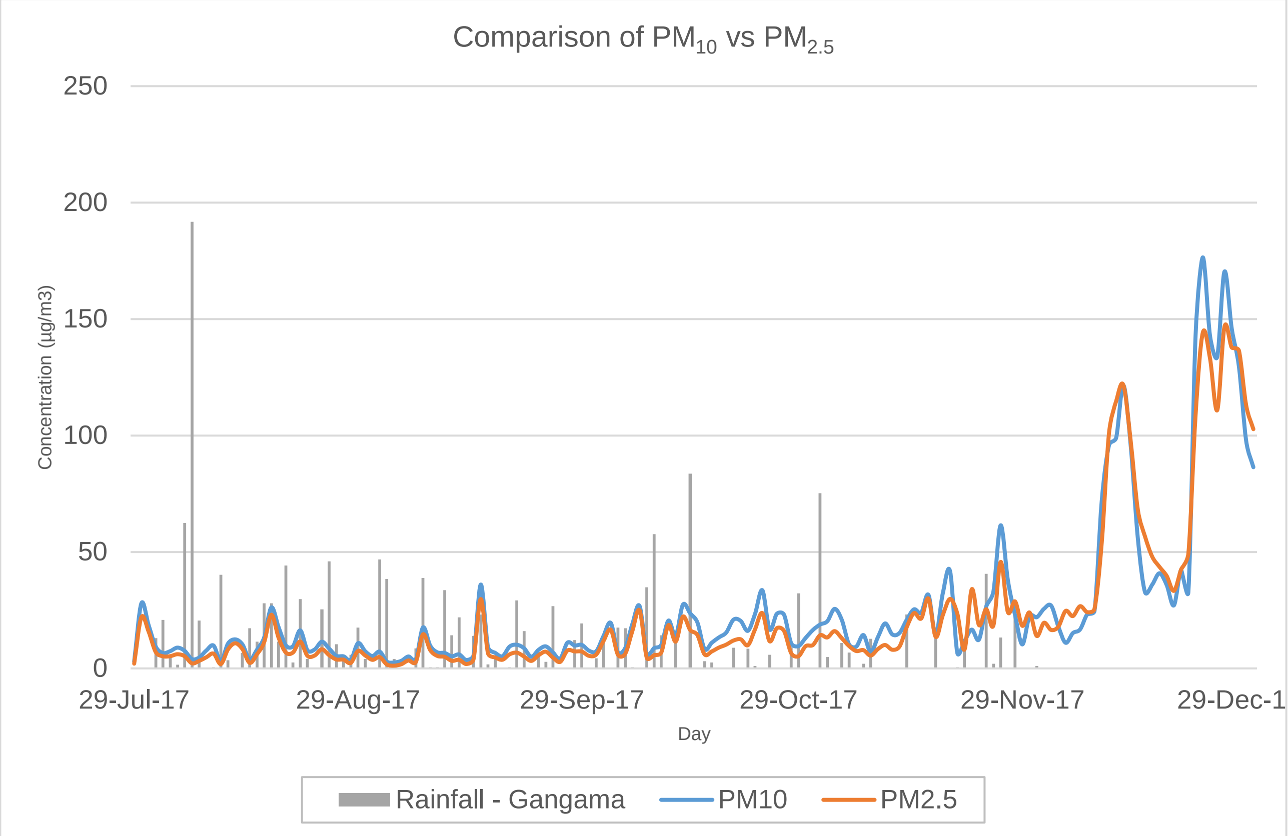

Figure 6-5: Comparison of PM_{10} and $PM_{2.5}$ concentrations[3]

6.3 Passive Gas Monitoring Results

SO_2 and NO_2 monitoring was conducted for July 2017 at the five locations within the SR Area 1 (Figure 6-2).

6.3.1 SO_2 monitoring

SO_2 monitoring was conducted using Radiello badges. The concentrations for all monitoring points were below the 24-hour period WB / IFC EHS Guideline of 20 µg/m³ (Table 6-6). The laboratory certificates are presented in Appendix B.

Table 6-6: 24-hour SO_2 concentrations

Field ID	July 2017
Units	µg/m³
SRLGM03	< 0.7
SRLGM05	1.5
SRLGM07	< 0.7
SRLGM10	< 0.7
SRLGM11	< 0.7
WB / IFC Guideline	20

[3] No rainfall recorded during December 2017

6.3.2 NO_2 monitoring

NO_2 concentrations for all monitoring points were below the 1-hour period WB / IFC EHS Guideline of 200 µg/m³ (Table 6-7). The laboratory certificates are presented in Appendix B.

Table 6-7: 1-hour NO_2 concentrations

Field ID	July 2017
Units	µg/m³
SRLGM03	0.7
SRLGM05	0.5
SRLGM07	0.6
SRLGM10	0.6
SRLGM11	0.7
WB / IFC EHS Guideline	200

7 Emissions Inventory

7.1 Emission Sources from SRL Mining Activities

Existing SRL mining activities that generate dust are land clearing, crushing, hauling, and materials handling (loading, handling and screening processes). The main pollutant of concern is dust (inclusive of respirable (PM_{10}, $PM_{2.5}$) and nuisance (DFO)) as it is has the potential to cause respiratory illnesses. Gaseous emissions (NO_x, SO_x VOCs, carbon monoxide (CO), Greenhouse Gases (GHGs) such as carbon dioxide (CO_2)) will also be present in and around the vicinity of the SRL MSP. There will also be emissions from the Power Plant, SRL MSP dryer as well as the two on-site medical incinerators.

Existing Operational Phase activities include:

- Site clearing for the mining areas;
- Construction of roads to mining areas;
- Storage of topsoil stockpiles;
- Vehicle exhaust emissions;
- Dredging;
- Dam construction;
- Ore extraction (earth moving);
- Primary mineral processing;
- Secondary mineral processing;
- Tailings management;
- Transporting and storage of ore and product;
- Product handling at the port and shipping;
- Access road building and maintenance;
- Waste management;
- Power generation facility and transmission of power; and
- Rehabilitation.

The expansion phase activities for the project are similar to the operational phase operations with the exception of, secondary mineral processing, dam construction and cessation of dredging operations.

Materials handling, wind erosion (e.g. tailings, roads) and vehicle-entrainment of dust by haul trucks transporting ore and product are expected to be the main sources of dust in the SR Area 1 during the operational phase.

A summary of emissions sources that are likely to emit dust and gas during all phases of the project is presented in Table 7-1.

Table 7-1: Summary of sources for all phases of the project

Source	Project phase	Pollutant type	Description of emissions generation
Roads and motor vehicles	Operational and Expansion	Dust, SO_2, NO_x CO, VOCs, lead	Vehicles used and to be used on-site include haul trucks or light motor vehicles. Source of dust resulting from the re-suspension of dust from the unpaved road surfaces.
Power generation	Operational and Expansion	Dust, SO_2, NO_x, VOCs, GHGs i.e. CO_2	The SRL Power Plant has four engine driven generators with Marine Fuel Oil (MFO) as a fuel source. The Power Plant is in operation 24/7/365 to supply electricity to the operations.
Ore processing	Operational and Expansion	Dust, SO_2, VOCs, GHGs	Processing activities such as crushing, milling and separation at the SRL MSP will generate dust.
Crushing	Operational and Expansion	Dust	Crushing will be done at the feed hoppers at each mine site. The feed hoppers are enclosed. It should be noted that trucks / front end loaders will tip ore into the feed hopper and this will be a source of dust.
Site Clearing	Operational and Expansion	Dust	The clearing of vegetation will generate dust. The soil stockpiles could create a source of windblown dust if dry. Numerous stockpiles are proposed.
Mining Areas	Operational and Expansion	Dust	The current mining areas within the SR Area 1 are the Gangama and Lanti mining areas. The depth of the pits will be near surface, and windblown dust from bare ground will be high during the dry season and will decrease during the wet season. Materials handling from haul trucks, excavators, bulldozers and front-end loaders will be sources of dust within the SR Area 1.
Run of Mine stockpiles	Operational and Expansion	Dust	ROM pad / stockpile will be located in proximity to the feed hoppers. Continuous materials handling at the ROM stockpiles will generate dust, however, this is dependent on weather conditions and moisture content. Stockpiling of the ore may also create dust.
Tailings Storage Facilities (TSF)	Operational and Expansion	Dust	TSFs are located at the mining areas and at the SRL MSP. Windblown dust will be evident from the sand tailings portions of the TSF.
SRL MSP dryers	Operational and Expansion	PM, SOx, NOx, VOCs, CO.	The dryers are fuelled by diesel and operate continuously. Emissions from the use of diesel are expected.
Medical incinerators	Operational and Expansion	Dust, SOx, NOx, VOCs, CO, Dioxins and Furans	Two medical mobile diesel-fired incinerators are located at the clinic. The unit has two chambers, with the first being a primary burning chamber, where waste is combusted. The second is an afterburner that cleans the emissions prior to discharge from the chimney. Gases and particulates are generated during combustion process. The medical incinerators are in operation twice a week. Dioxins and furans will be emitted from the medical incinerators, however in low to negligible quantities (Refer to Chapter 8)

7.2 Emission Sources from Non-mining Activities

The SR Area 1 experiences non-mining emission sources. However, sources such as roads are used both by mines and villagers. The SR Area 1 and surrounding land can be described as rural. The area is characterised by several populated villages and settled areas, subsistence cultivation and natural forest. The air emissions sources from non-mining sources in the SR Area 1 include:

- Traffic on the road network;
- Household fuel combustion;
- Fugitive dust sources (windblown dust from bare ground as well as dust being transported by the Harmattan winds, especially during the dry season);
- Biomass burning comprising of grass and bush burning during the dry season in preparation for crop planting ahead of the summer season;
- Vehicle tailpipe emissions; and
- Agricultural activities (e.g. windblown dust from bare agricultural areas, clearing of vegetation, soil cultivation).

7.2.1 Road Network

The SR Area 1 is located in a rural area and residents, other mining companies as well as local villagers use a network of unpaved roads in and around the SR Area 1. Vehicle use on the roads, especially during the dry season, causes dust emissions. Localised dust deposition i.e. dust deposition resulting from vehicle movements on roads usually fall within or close to (<50 m) the road edge. Trees on the side of the road act as a buffer for the entrainment of dust (Figure 7-1), thus ensuring it does not travel too far from the roadside.

Haul roads in the SR Area 1

Trees on the side of roadside act as buffers

Road network within the villages

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Figure 7-1: Road network with the SR Area 1

7.2.2 Household Fuel Combustion

Wood and charcoal are the primary domestic fuel sources in the SR Area 1. The combustion of these fuel sources is likely to be the greatest source of airborne particulates including airborne PM and gaseous pollutants (NO_x, SO_2, carbon monoxide (CO) and carbon dioxide (CO_2). Wood is readily available in the SR Area 1 and, therefore, likely to be the more common fuel source and is also part of the charcoal making process in the SR Area 1. Air pollution from these sources is limited to the villages and may have a significant detrimental impact on the regional air quality due to the high content of particulate matter. Household fuel combustion also has an adverse impact to human health, PM and gaseous emission such as CO, will impact on the lungs and respiratory airways. In poorly ventilated dwellings, indoor smoke can be 100 times higher than acceptable levels for fine particles (WHO, 2016). Exposure is particularly high among women and young children, who spend the most time near the domestic household (WHO, 2016).

7.2.3 Charcoal

Charcoal making is undertaken within the SR Area 1. Charcoal is used primarily as a domestic fuel. It is produced by cutting trees from the forest and burning the wood for long periods of time, forming charcoal (Figure 7-2). During this process, CO_2 and particulates are released into the air and will result in poorer air quality.

Charcoal manufacturing process 1

Charcoal manufacturing process 2

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Figure 7-2: Charcoal Manufacturing

7.2.4 Fugitive Dust Sources

All pollutants that arise from fugitive dust sources are termed primary pollutants as they are unlikely to undergo any physical or chemical reactions to form secondary pollutants. Fugitive dust sources can occur from vehicle entrained dust from gravel or unpaved roads and wind erosion of open areas (both in respect of mining activities, and community activities such as land clearance for farming) (Figure 7-3). Particulate emissions from roadways depend on the moisture content, particle size and the number of vehicles using the road. Windblown dust resulting from the erosion of bare ground depends largely on the velocity of the wind, the size of the exposed area, as well as the moisture and silt content of such areas. Areas that receive high rainfall will experience lower levels of fugitive dust being released into the air than areas that experience low rainfall, primarily because the higher moisture content makes the soil heavier and more compact resulting in the soil being more resistant to wind erosion.

In the SR Area 1, fugitive dust emissions are expected to increase during the dry season (November to April) and when wind speeds increase.

Sources (haul roads) of windblown dust

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Figure 7-3: Fugitive dust source within the SR Area 1

7.2.5 Biomass Burning

The burning of crop residue and field fires are sources of emissions that can be associated with densely vegetated areas. Biomass burning is an incomplete combustion process with carbon monoxide (CO), methane (CH_4), NO_2 and PM being emitted during the process. Biomass burning, including unintentional run-away fires, in and around the SR Area 1 is considered to be seasonal since these areas are used for subsistence agricultural practices and cleared using slash and burn methods. Biomass burning will contribute to air pollution. Due to the high temperatures within the region there is also a possibility of fires occurring naturally.

7.2.6 Vehicle Exhaust Emissions

Vehicle emissions can be classified into two groups, namely, primary and secondary pollutants. Primary pollutants from vehicle exhaust emissions include: CO, CO_2, SO_2, NO_x, PM and lead (Pb) depending on the type of fuel that is used. Secondary pollutants exist only because of the chemical reactions that take place in the atmosphere and include: NO_2, photochemical oxidants (e.g. ozone), sulfates and nitrates. The majority of the vehicles within the SR Area 1 run on diesel. Vehicles such as mining vehicles, motorcycles and on a smaller scale, trucks or vans, pass along the main roads in and around the villages (Figure 7-4). Currently, vehicle exhaust emissions are expected to be below the ambient WB / IFC EHS Guideline as a result of the low vehicle movements in the SR Area 1. Pollutants emitted from one vehicle will disperse adequately. However, in areas such as Nitti Port, exhaust emissions may increase with other mining companies also using the Nitti Port haul road network to reach their respective ports.

Motorcycles and light motor vehicles in the SR Area 1

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Figure 7-4: Vehicles within the SR Area 1

7.2.7 Agricultural Activities

Subsistence farming is one of the main sources of food in the SR Area 1 with activities such as ploughing done by hand. Apart from slash and burn described above, other agricultural activities are considered to be a minor or negligible source of dust, as the preparation of the land for planting is done manually and in small patches. A large-scale commercial pineapple farm is located within the SR Area 1 and harvesting activities may be a potential source of dust depending on the season (i.e. wet or dry) during which the area is cleared.

Pineapple farm in the SR Area 1

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Figure 7-5: Agricultural activities taking place within the SR Area 1

8 Dispersion modelling methodology

Dispersion models compute ambient concentrations and deposition levels as a function of source configuration, emission strengths and meteorological characteristics. It provides useful tools to ascertain the spatial and temporal patterns in the ground level concentrations and deposition arising from the emissions of various sources. The US-EPA AERMOD modelling software package was used to model PM_{10}, $PM_{2.5}$ and gaseous emissions resulting from the operational and expansion phases.

Input data required for the AERMOD model include the following:

- Meteorological requirements;
- Information on the nature of the receptor grid;
- Terrain data;
- Quantification of emissions; and
- Source emission data.

Each of these inputs is discussed in the following sections.

8.1 Meteorological requirements

The AERMOD model requires hourly average meteorological data as input, including wind speed, wind direction, a measure of atmospheric turbulence, ambient air temperature and mixing height. In the absence of suitable, reliable long term on-site data sets for all the input parameters required for modeling, a 3-year model ready meteorological dataset was obtained from Lakes Environmental. The Lakes Environmental data are based on synoptic weather data prepared using the MM5 model, which is used to forecast weather. For this model simulation exercise, hourly meteorological data for the period 1 January 2014 to 31 December 2016 were used.

8.2 Receptor grid

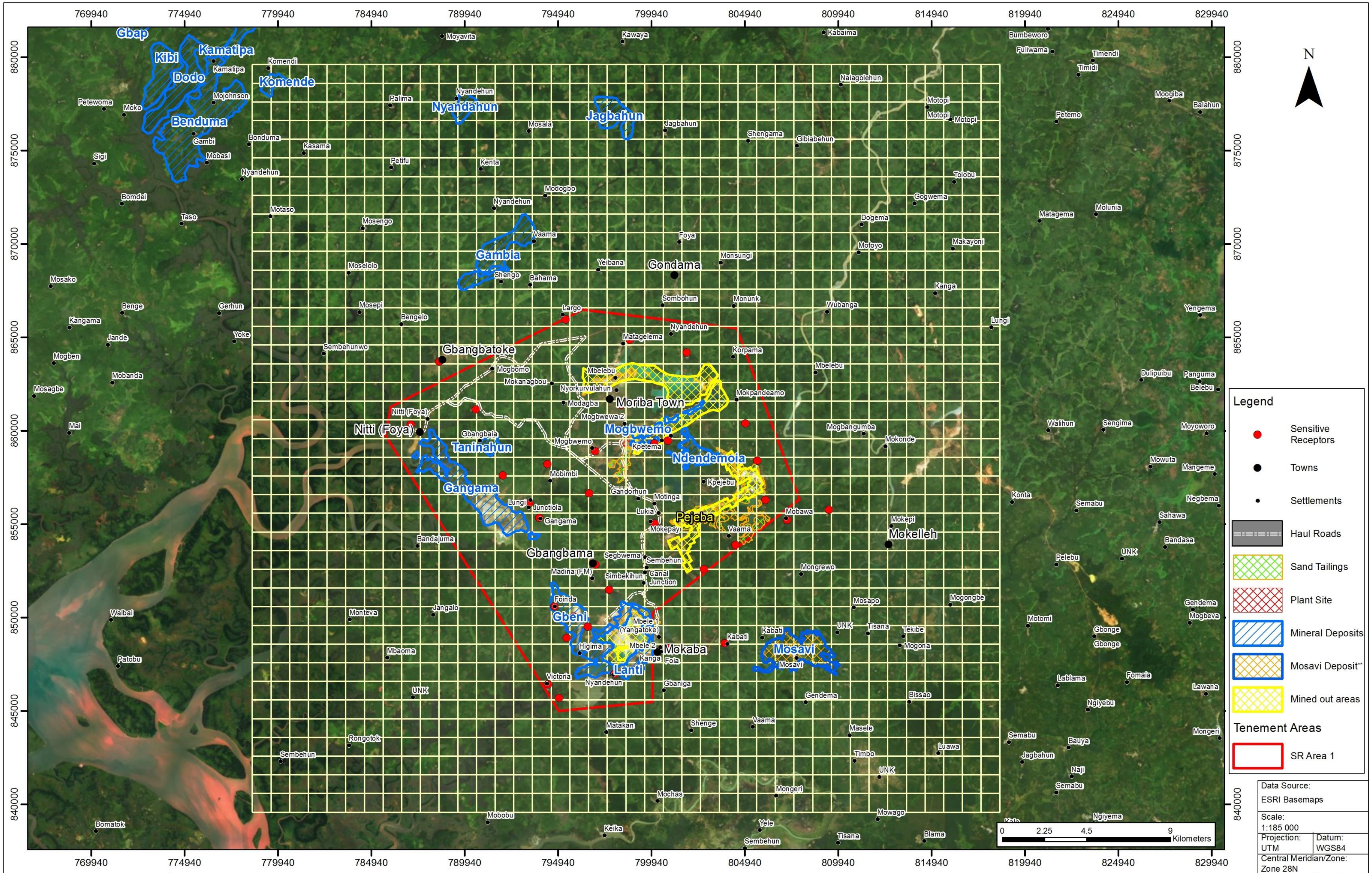
A key part of the dispersion modelling is to identify potential sensitive receptors for which impact predictions can be made. The identification of sensitive receptors is closely linked to the baseline surveys and description of baseline conditions The villages presented in Table 8-1 have been identified as potential sensitive receptors in close proximity to the mine area. The villages presented all fall within the dispersion modelling domain and have been included into the dispersion model as discrete receptors.

The receptor grid for the dispersion of dust emissions from the project, under various operating scenarios, covers an area of 1,600 km^2. The size of the Cartesian (X,Y) grid area is larger than the SR Area 1 so that the model can determine the extent of the concentration plume levels beyond the SR Area 1. The modelling domain extends for 40 km from east to west and 40 km from north to south, with the SR Area 1 located in the center.

The modelling domain and receptor grid together with the discrete receptors are presented Figure 8-1.

Table 8-1: Villages in close proximity to the mine

Name	Co-ordinates	
Kabati	803863.4	848630.9
Mokaba	800839.3	848362.0
Nyandehun	797961.0	846988.9
Teso	794987.6	845698.9
Victoria	794417.6	846427.5
Foinda	794744.2	850601.4
Yangatoke	797690.2	851497.1
Gbamgbama	796955.0	852835.7
Bonjema	802754.7	852601.9
Vaama	804456.4	853894.1
Bamba	801843.2	864196.6
Mokepay	800110.5	855051.1
Mombaya	807221.1	855236.6
Njagbahun	806053.8	856299.5
Mondokor	805606.6	858415.0
Pendembu	804977.6	860393.1
Moriba Town	798345.5	861393.9
Gondama	796608.1	856663.9
Gangama	793937.2	855349.5
Junctiola	793418.1	856132.9
Mobimbi	794381.2	858220.2
Mogbwemo	796939.6	858917.4
Matagiema	798788.2	864875.9
Gbangbatoke	788586.9	863712.0
Nitti Port	787056.2	860342.5
Gbangbama	790540.8	861161.5
Semabu	791988.4	857628.3
Fago	795348.2	865972.0
Mokpandi	809441.6	855773.1
Kpetema	800109.4	859325.6
Mogbewa	798657.4	860059.6
Ndendomoia	800812.7	859486.5
Total: 32 Villages		



Data Source:	ESRI Basemaps
Scale:	1:185 000
Projection: UTM	Datum: WGS84
Central Meridian/Zone:	Zone 28N
Date: 21/09/2017	Compiled by: ALLK
Project No: 515234	Fig No: 8-1

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RECEPTOR GRID AND DISCRETE RECEPTORS

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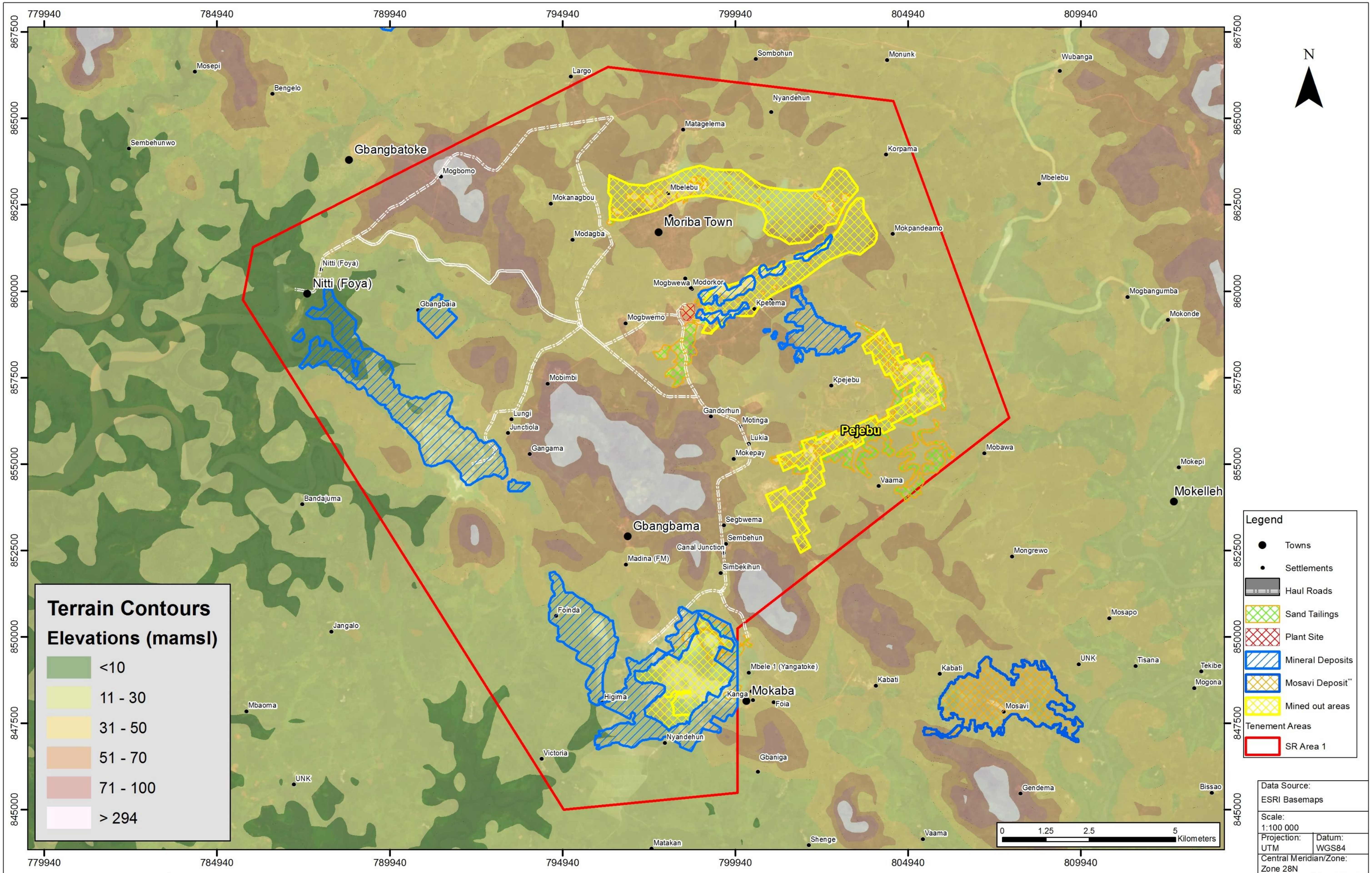
8.3 Terrain data

The AERMOD model incorporated the topography of the SR Area 1. Topography influences meteorological parameters (such as temperature inversions, local wind circulations, etc.) that may worsen or improve air quality on a local scale. Terrain data downloaded from WebGIS for the SR Area 1 were processed and imported into the model, yielding a 3D-model. The terrain image, Figure 8-2, shows that the SR Area 1 lies in an area with undulating topography. In a west to east direction the topography varies in elevation between 1.94 – 97.2 meters above mean sea level (mamsl). In a north to south direction, higher elevations are observed to the north and decrease towards the south. Elevations across the north to south profile range from 2.3 to 82.4 mamsl.

8.4 Quantification of emissions

Emission factors were used as they are the best surrogate measure available for quantifying emissions other than source specific emission tests. In order to calculate emission rates for the TSF, haul roads, mining areas, materials handling, and emissions from point sources (including the SRL MSP, Power Plant and medical incinerators), information regarding the project activities were used to determine emission factors. In this case, the US EPA emission factors in its AP 42 document, “Compilation of Air Pollution Emission Factors” (1995) as well as emission factors from the Australian National Pollution Inventory (NPI, 2001) were used. Both sets of emission factors are the most widely used in the field of air pollution and regularly subjected to review and revision as more effective modelling techniques are developed. Empirically derived, predictive emission factor equations are available for dust entrained by vehicles from both paved and unpaved roads, material handling operations and wind erosion as well as emissions from point sources.

The impact of fugitive dust on air quality depends largely on the extent of the drift potential of the particles. The drift potential of particles depends in turn on the initial height of the emission, the terminal settling velocity of the particle (which in turn is a function of the particle diameter) and the degree of atmospheric turbulence. Larger dust particles tend to settle out near the source, creating a local nuisance problem, whereas finer particles are more likely to be dispersed over greater distances since their settling rate is retarded by atmospheric turbulence. Predictive emission factor equations allow for the estimation of emissions for particular particle size ranges, i.e. PM_{10} and $PM_{2.5}$. Appendix C includes a detailed description of how the emissions used for the dispersion model were quantified.



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Scale: 1:100 000	
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Central Meridian/Zone: Zone 28N	
Date: 21/09/2017	Compiled by: ALLK
Project No: 515234	Fig No: 8-2

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SR AREA 1 ESHIA & ESHMP

TOPOGRAPHICAL/TERRAIN CONDITIONS WITHIN THE PROJECT AREA

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8.5 Emissions Estimation for Sources

8.5.1 Dust emissions for the operational and expansion phase

Two models were set up based on the project description for the operational and expansion phases. Two scenarios per phase / model were run; a scenario without the implementation of management measures (Scenario 1) and a scenario with the implementation of management measures for activities such as materials handling, windblown dust from TSF and pits, and the vehicle entrainment of dust from the haul roads (Scenario 2):

- Scenario 1 (without management measures / unmitigated):
  - For the operational phase, dust emissions were modelled for the pits, unpaved roads, windblown dust and materials handling including excavation activities;
  - Dust sources were modelled during the operational phase without any management measures in place and, hence, this scenario is viewed as the worst-case scenario;
  - The TSFs and pits were treated as sources that emit continuously dependent on the prevailing wind speeds exceeding the threshold wind velocity for tailings and the fine rock particles; and
  - No chemical suppressant or chemical sprayers used on unpaved haul roads.
- Scenario 2 (with management measures / mitigated):
  - It is assumed that during operations management measures will be used to reduce dust emissions within the SR Area 1;
  - Dust emissions from unpaved roads are suppressed using a sealant or wet suppression that will reduce dust by 50%, assuming an increase in moisture content of up to 2.0%;
  - Materials handling in and around the SR Area 1 will generate dust. The material will have a high moisture content i.e. 20% (*pers comm. Soils Specialist*) and this will decrease the potential for dust generation from materials handling facilities; and
  - The areas of the TSFs and pits that are dry, moist, or covered with water are equal in size i.e. one third (33.3 %) of the TSF. It assumed that portions of the TSFs and pits will be rehabilitated with vegetation which will reduce windblown dust.

The emission rates for grouped sources for each scenario are presented in Table 8-1 for operational phase and Table 8-2 for the expansion phase.

Table 8-2: Emission rates for the Operational Phase (tons per annum)

Source	Scenario 1 – without management		Scenario 2 – with management	
	PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$
Units	tpa	tpa	tpa	tpa
Excavation activities	1,702.9	258.6	264.9	40.4
Windblown dust (TSFs and pits)	3,377.8	507.1	608.0	91.5
Haul Roads	327.1	32.4	163.5	16.4
Materials handling	970.7	147.6	141.6	22.8

The windblown dust sources will remain the same as the footprint of these area will not change (Table 8-2). The haul road emission rates will decrease as the vehicle movements from the wet mining to SRL MSP cease.

Table 8-3: Emission rates for the expansion phase

Source	Scenario 1 – without management		Scenario 2 – with management	
	PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$
Units	tpa	tpa	tpa	tpa
Excavation activities	3,405.9	517.2	529.8	80.7
Windblown dust (TSF and pits)	3,377.8	507.1	608.0	91.5
Haul Roads	301.9	29.2	125.8	15.1
Materials handling	1,941.4	295.2	283.2	45.7

8.5.2 Power Plant

The Power Plant operates with Caterpillar MaK16CM32C power driven generators and is fuelled by Marine Fuel Oil (MFO). The emission factors used for quantification of emissions was obtained from the US EPA (1996), for power generation for industrial engines. Emissions expected from the Power Plant are CO, NO_x, SO_2, VOCs and PM. All emission rates for the fuel type was quantified and is presented in Table 8-3.

Table 8-4: Predicted annual emission rates for the Power Plant

Emission rate (tpa)				
CO	NO_x	SO_2	VOCs	PM_{10}
365	1,692	296	515	800

8.5.3 Mineral Separation Plant Dryers

The SRL MSP dryers are fuelled by diesel. Emissions expected from the dryers are CO, NO_x, SO_2, VOCs and PM. The emission factors used for quantification of emissions were obtained from the Australian National Pollution Inventory (NPI, 2001) for diesel boilers. All emission rates for the fuel type was quantified and are presented in Table 8-4.

Table 8-5: Predicted annual emission rates for the dryer

Emission rate (tpa)				
CO	NO_x	SO_2	VOCs	PM_{10}
1.65	6.61	0.04	0.06	0.34

8.5.4 Medical Incinerators

There are two medical incinerators on-site fuelled by diesel. The emission factors used for quantification of emissions were obtained from the US EPA (1993) for medical waste incineration and the fuel type used. Emissions expected from the medical incinerator are CO, NO_x, SO_2, VOCs, Dioxins and Furans and PM based on the fuel type used. All emission rates for one incinerator were quantified and are presented in Table 8-5. Due to the low to negligible dioxins and furans emission rates, models were run, however no isopleths were generated by the model. Hence no results are presented for dioxins and furans in Section 9. It is recommended that stack tests be undertaken to determine the concentration of dioxins and furans.

Table 8-6: Predicted annual emission rates for the medical incinerators

Emission rate (tpa)						
CO	NO_x	SO_2	VOCs	PM_{10}	Dioxins	Furans
0.002	0.002	0.003	0.0002	0.003	4.93×10^{-13}	2.36×10^{-11}

9 Dispersion Modelling Results

Predicted 99th percentile daily and annual average concentrations for PM_{10}, $PM_{2.5}$ and gaseous concentrations were simulated using the US EPA approved AERMOD model. Isopleth maps showing PM_{10}, $PM_{2.5}$ and gaseous concentrations are presented in the following sections. The detailed dispersion modelling results are presented in Appendix C.

Modelled ambient ground level concentration isopleths represent interpolated values from the concentrations predicted by the AERMOD model for each of the receptor grid points. It should be noted that the plots reflecting daily averaging periods contain only the highest average predicted ground level concentrations over the entire period for which the simulations were undertaken. Therefore, a daily average concentration may be predicted to occur at a certain location; however, this may only be true for one specific day during the year. These high concentrations are usually associated with extreme meteorological conditions such as high winds and low-level inversions and may be considered as a worst-case scenario.

Prior to the interpretation of the results, it is important to reiterate the degree of uncertainty associated with emissions inventory preparation and dispersion simulation in general. Various assumptions have been made regarding the nature, location and extent of certain activities during the operational phase of the project. Of importance, however, are the trends and the areas that are likely to be impacted.

The 99th percentile values were chosen for predicted PM_{10}, $PM_{2.5}$ and gaseous emission concentrations, as this is a normal statistical method to exclude anomalous predicted concentrations. This in turn identifies emission concentrations in a range that is most likely to be observed during the project's operational phases and excludes outliers.

The detailed modelling results for all 35 villages are presented in Appendix D.

9.1 Operational phase

9.1.1 PM_{10}

The PM_{10} modelling results for the operational phase are presented in Table 9-1. The 10 highest predicted concentrations for villages located in close proximity to the mining activities are presented in Table 9-1, with the concentrations for the remaining villages presented in Appendix D. It should be noted that the results presented are only for the operational phase activities at the mine. A worst-case scenario (Scenario 1 - without management measures) and Scenario 2 – (with on-site management measures) were modelled for the operational phase.

Scenario 1 shows that the maximum 24-hour PM_{10} concentrations occur at both Gangama and Lanti mines as a result of the existing operational activities (Figure 9-1). The predicted concentrations for villages in close proximity (Foinda, Nyandehun, Teso and Kpetema) to these activities are all above the WB / IFC EHS Guideline value of 50 µg/m³ for Scenario 1. As shown in Figure 9-1, the villages to the southwest of the SR Area 1 will be impacted by the mining operations and exceed the WB / IFC EHS Guideline value of 50 µg/m³. The predicted PM_{10} concentrations for villages to the northeast are below the guideline.

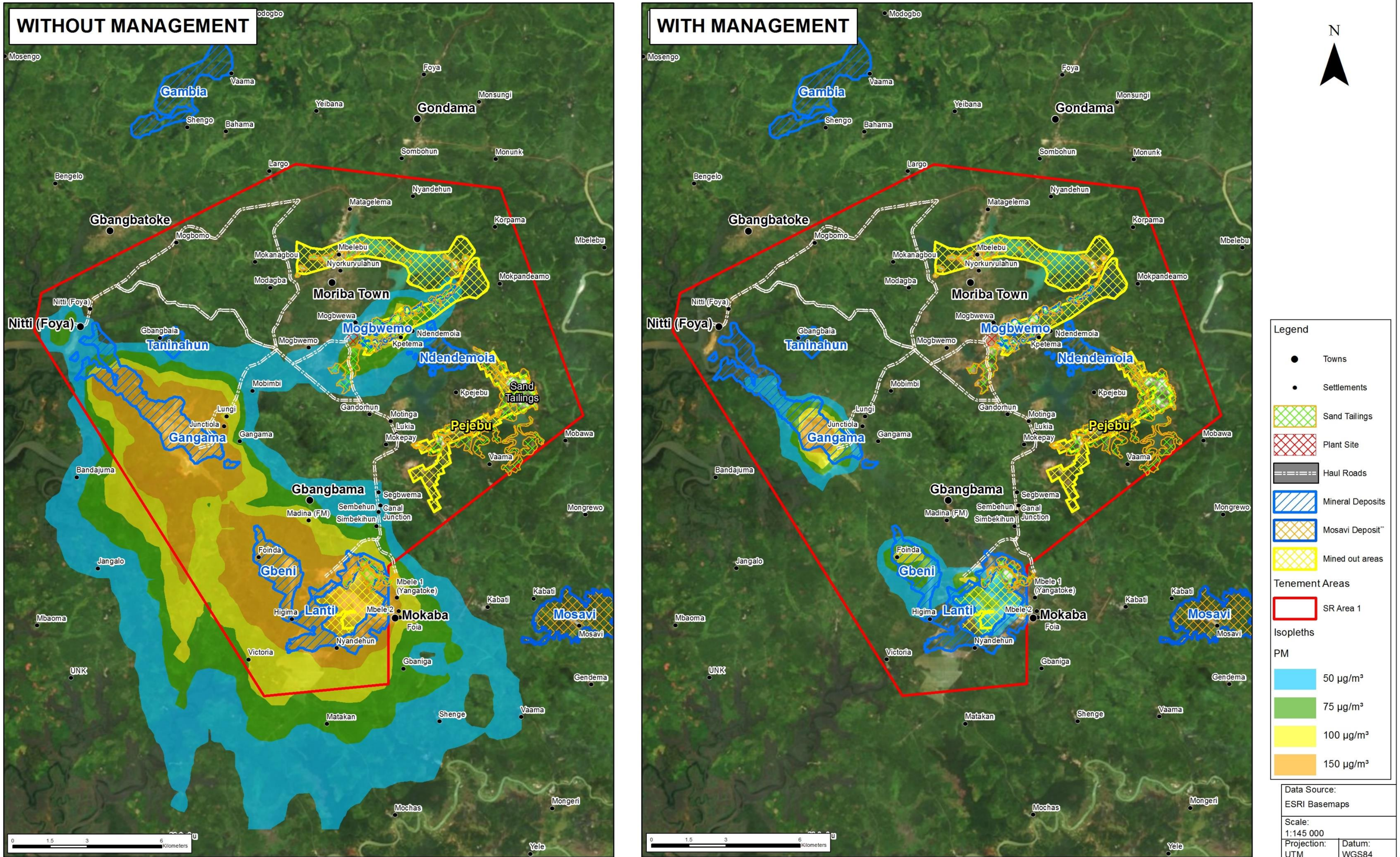
Villages in close proximity to the haul roads, namely Nyandehun, Junctiola, Mokaba, Nitti Port, Mobimbi, and Mogbwemo are impacted by the entrainment of dust on the roads. Predicted PM_{10} concentrations, without management measures, at theses villages range from 40.5 µg/m³ (Mokepay) to 225.9 µg/m³ (Nyandehun) (Appendix D).

Scenario 2 predicts that PM_{10} concentrations will decrease to levels below the guideline of 50 µg/m³ except at Foinda (129.9 µg/m³) which lies to the northwest of the Lanti mining operations. The maximum predicted concentrations at Foinda are a result of the mining operations and the location of the village. The footprint of the impacted area occurs around to the mine operational areas when compared to Scenario 1. The predicted concentrations at the villages in close proximity to haul roads are below the WB / IFC EHS Guideline and ranges from 11 µg/m³ (Mokepay) to 42.6 µg/m³ (Nyandehun) (Appendix D).

As with the 24-hour PM_{10} concentrations, the annual concentrations follow a similar trend whereby the village of Foinda is shown to be impacted by the mining operations (Figure 9-2).

Table 9-1: Modelled PM_{10} concentrations for the operational activities

Village	PM_{10} concentrations for operational activities			
	24-hour – Scenario 1 - No management	24- hour – Scenario 2 With Management	Annual – Scenario 1 No management	Annual – Scenario 2 With Management
Units	µg/m³	µg/m³	µg/m³	µg/m³
Foinda	814	129	133	21
Nyandehun	226	43	40	8
Teso	165	28	17	3
Kpetema	131	24	24	4
Junctiola	118	21	18	4
Mokaba	109	19	9	2
Yangatoke	108	18	13	2
Nitti Port	100	18	11	2
Victoria	92	16	16	3
Gbamgbama	79	13	9	2
WB / IFC EHS Guideline	50	50	20	20
WB / IFC EHS IT 1	150	150	70	70
WB / IFC EHS IT 2	100	100	50	50
WB / IFC EHS IT 3	75	75	30	30



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Central Meridian/Zone: Zone 28N	
Date: 21/09/2017	Compiled by: ALLK
Project No: 515234	Fig No: 9-1

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PREDICTED 24 HOUR PM_{10} CONCENTRATIONS FOR OPERATIONAL ACTIVITIES

Revision: A Date: 23 02 2018

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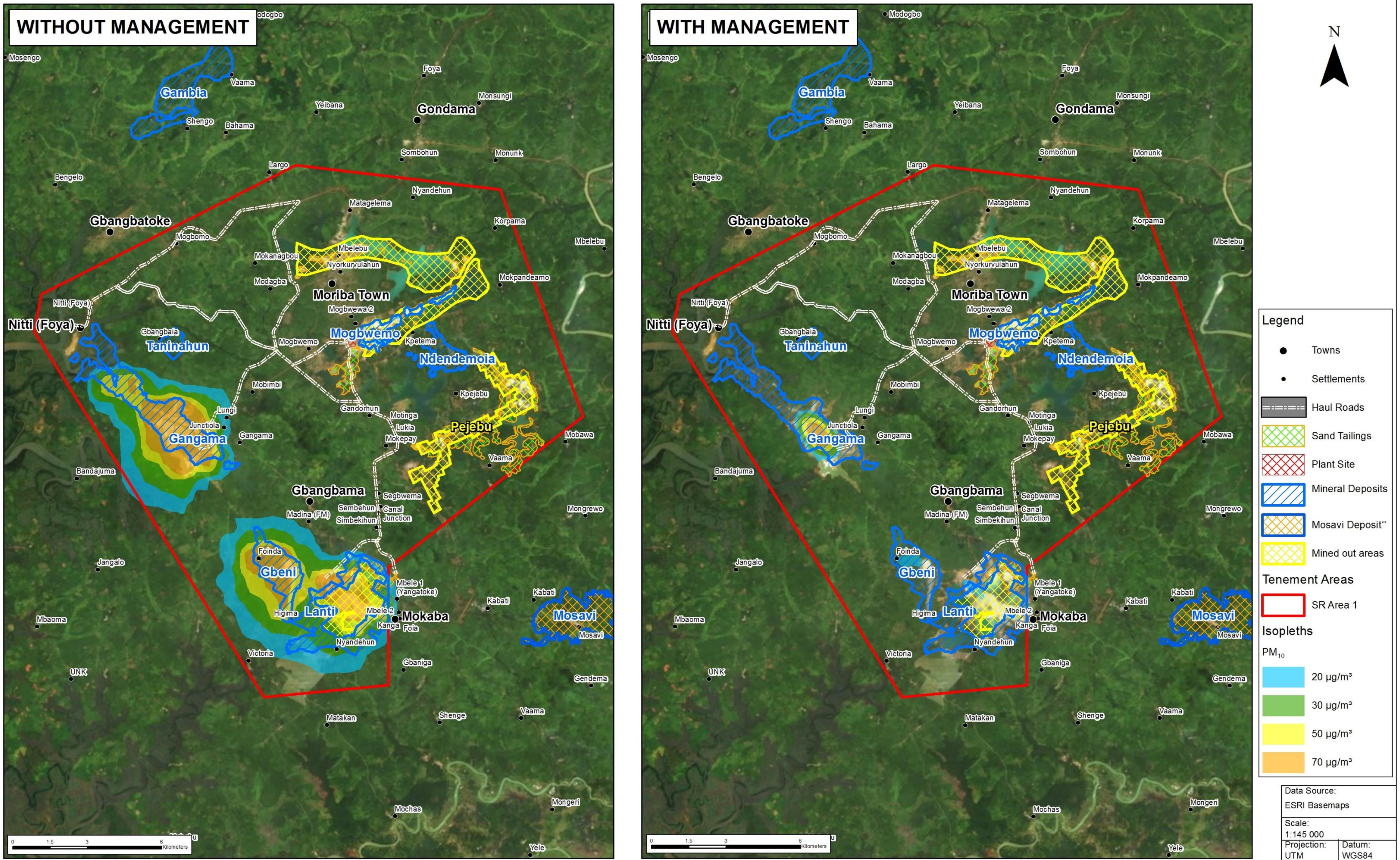

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Central Meridian/Zone: Zone 28N

Date: 21/09/2017 | Compiled by: ALLK

Project No: 515234 | Fig No: 9-2

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PREDICTED ANNUAL PM_{10} CONCENTRATIONS FOR OPERATIONAL ACTIVITIES

9.1.2 $PM_{2.5}$

The $PM_{2.5}$ modelling results for the operational phase are presented in Table 9-2. The 10 highest predicted concentrations for villages located in close proximity to the mining activities are presented in Table 9-2 with the concentrations for the remaining villages presented in Appendix D.

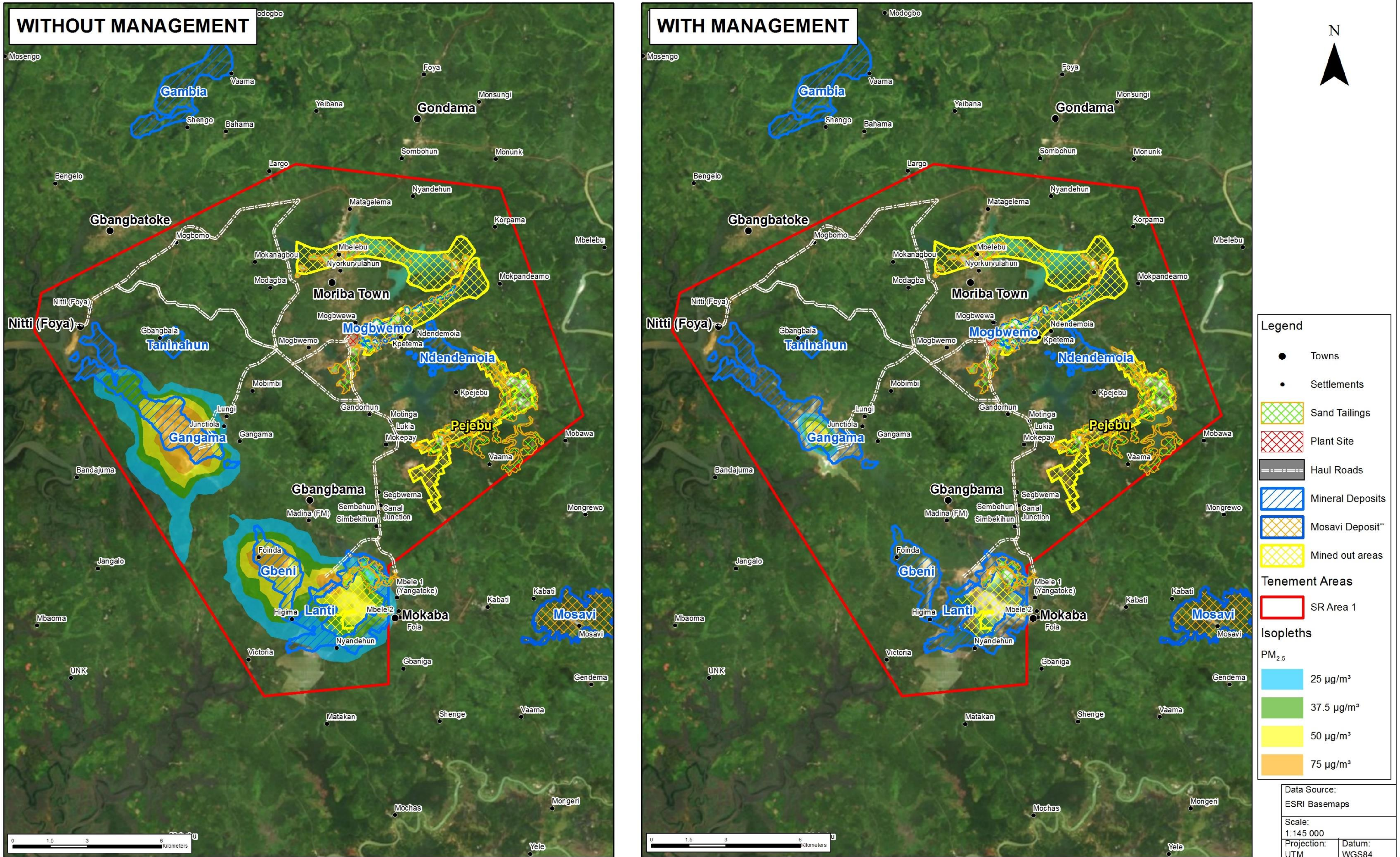
Scenario 1 shows that the maximum 24-hour $PM_{2.5}$ concentrations occur at both Gangama and Lanti mines as a result of the existing operational activities (Figure 9-3). Villages in close proximity, namely Foinda and Nyandehun predict concentrations above the WB / IFC EHS Guideline value of 25 µg/m³ for $PM_{2.5}$. Nyandehun is the only village near a haul road where concentrations are predicted to exceed the WB / IFC EHS Guideline value of 25 µg/m³. Predicted 24-hour concentrations for villages along the haul roads range from 5.7 µg/m³ (Mokepay) to 33.7 µg/m³ (Nyandehun) (Appendix D).

Scenario 2 shows that predicted $PM_{2.5}$ concentrations will decrease to levels below the 24-hour $PM_{2.5}$ WB / IFC EHS Guideline value of 25 µg/m³, at all villages. The highest predicted concentration occurs at Foinda (19.8 µg/m³). The predicted footprint of the impacted area will decrease to the Gangama mining area when compared to Scenario 1. The predicted concentrations at villages along haul roads range from 1.3 µg/m³ (Mokepay) to 5.9 µg/m³ (Nyandehun) (Appendix D).

The annual concentrations follow a similar trend whereby the village of Foinda is shown to be impacted by the mining operations in Scenario 2 (Figure 9-4). The annual $PM_{2.5}$ concentration with management is well below the WB / IFC EHS Guideline value of 10 µg/m³.

Table 9-2: Modelled $PM_{2.5}$ concentrations for the operational phase

Village	$PM_{2.5}$ concentrations for the operational phase activities			
	24-hour – Scenario 1 - No management	24- hour – Scenario 2 With Management	Annual – Scenario 1 No management	Annual – Scenario 2 With Management
Units	µg/m³	µg/m³	µg/m³	µg/m³
Foinda	121	20	20	3
Nyandehun	34	6	6	1
Teso	25	3	4	0.5
Kpetema	20	4	4	0.6
Junctiola	18	3	3	0.5
Mokaba	16	1	3	0.3
Yangatoke	16	2	3	0.4
Nitti Port	14	2	2	0.3
Victoria	14	2	2	0.4
Gbamgbama	12	1	2	0.2
WB / IFC EHS Guideline	25	10	25	10
WB / IFC EHS IT 1	75	35	75	35
WB / IFC EHS IT 2	50	25	50	25
WB / IFC EHS IT 3	37.5	15	37.5	15



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Central Meridian/Zone: Zone 28N

Date: 21/09/2017 | Compiled by: ALLK

Project No: 515234 | Fig No: 9-3

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PREDICTED 24 HOUR $PM_{2.5}$ CONCENTRATIONS FOR OPERATIONAL ACTIVITIES

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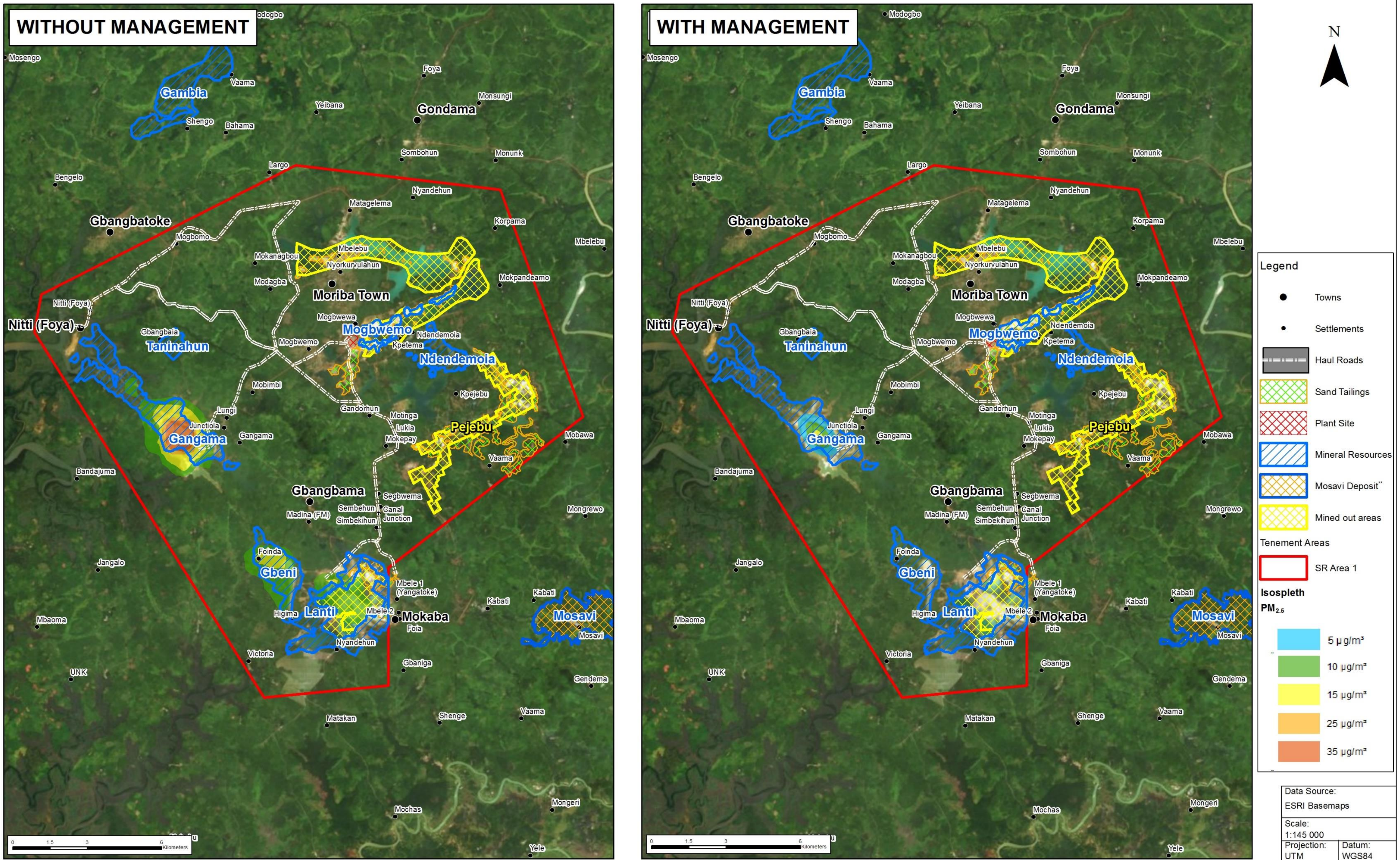

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Project No: 515234	Fig No: 9-4

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PREDICTED ANNUAL $PM_{2.5}$ CONCENTRATIONS FOR OPERATIONAL ACTIVITIES

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Revision: A Date: 23 02 2018

9.2 Expansion phase

9.2.1 PM_{10}

The PM_{10} modelling results for the expansion phase (i.e. increase in throughput to 1,000tph at Lanti and Gangama mines) are presented in Table 9-3. The 10 highest predicted concentrations for villages located in close proximity to the mining activities are presented in Table 9-3 with the concentrations for the remaining villages presented in Appendix E.

Scenario 1 shows the maximum 24-hour PM_{10} concentrations that occur at both Gangama and Lanti mines as a result of the operational activities (Figure 9-5). In comparison to the results for the operational phase activities, the impact of the expansion phase activities will increase the distance of the plume from the mining activities. The plume will extend further south, impacting villages to the south of the SR Area 1. Villages in proximity to these activities, namely Foinda, Nyandehun, Teso and Kpetema will be impacted should management measures for dust not be implemented. The predicted concentrations for the villages presented are all above the WB / IFC EHS Guideline value of 50 µg/m³ for PM_{10}. As shown in Figure 9-5, the villages to the southwest of the SR Area 1 will mostly be impacted by the mining operations and exceed the WB / IFC EHS Guideline value of 50 µg/m³. The predicted PM_{10} concentrations for villages to the northeast will be below the guideline value. Villages that are located in close proximity to haul roads are predicted to have concentrations above the WB / IFC EHS Guideline value of 50 µg/m³ (Appendix D). Predicted concentrations will range from 52.5 µg/m³ (Mokepay) to 290.3 µg/m³ (Nyandehun).

Scenario 2 shows that predicted 24-hour PM_{10} concentrations will decrease to levels below the WB / IFC EHS Guideline value of 50 µg/m³, except at Foinda (238.3 µg/m³) which lies to the northwest of the Lanti operations. The footprint of the impacted area will decrease to the Lanti and Gangama areas when compared to Scenario 1. With management measures in place, villages in proximity to haul roads will have predicted concentrations below the WB / IFC EHS Guideline value of 50 µg/m³, with the highest predicted concentration at Nyandehun (48.8 µg/m³).

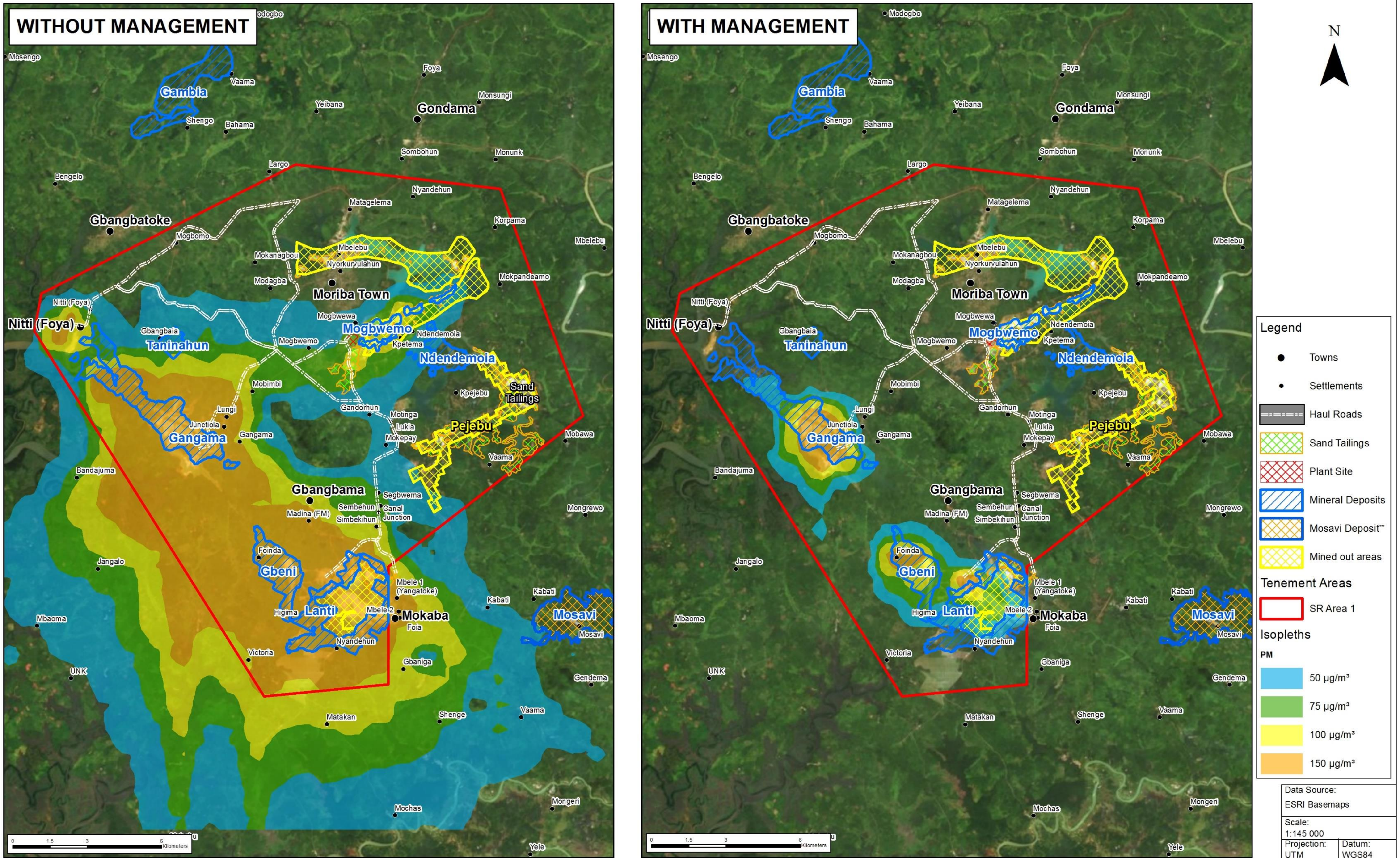
Under Scenario 1, annual concentrations do not follow a similar trend to the 24-hour predicted concentrations. Annual PM_{10} concentrations at some of the 10 villages presented in Table 9-3, do decrease to levels below the WB / IFC EHS Guideline value of 20 µg/m³ for PM_{10}.

Under Scenario 2, the predicted concentrations at the village of Foinda exceed the WB / IFC EHS Guideline value of 20 µg/m³. The annual predicted plume decreases and occurs within the footprint of the mining areas at Lanti and Gangama (Figure 9-6).

Overall, when compared to the operational phase, the PM_{10} concentrations for the expansion phase will increase, however with management measures in place, the predicted concentrations will be below the guidelines at most villages.

Table 9-3: Modelled PM_{10} concentrations for expansion activities

	PM_{10} concentrations for expansion activities			
Village	**24-hour – No management**	**24-hour – Management**	**Annual – No management**	**Annual – Management**
Units	µg/m³	µg/m³	µg/m³	µg/m³
Foinda	1,503	238	249	39
Nyandehun	290	49	48	8
Teso	263	43	25	4
Junctiola	208	31	30	4
Nitti Port	197	51	21	6
Mokaba	158	26	12	2
Yangatoke	153	25	20	3
Kpetema	139	25	26	5
Victoria	137	23	22	4
Gbamgbama	125	20	13	2
WB / IFC EHS Guideline	50	50	20	20
WB / IFC EHS IT 1	150	150	70	70
WB / IFC EHS IT 2	100	100	50	50
WB / IFC EHS IT 3	75	75	30	30



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Date: 21/09/2017	Compiled by: ALLK
Project No: 515234	Fig No: 9-5

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PREDICTED 24 HOUR PM_{10} CONCENTRATIONS FOR EXPANSION PHASE

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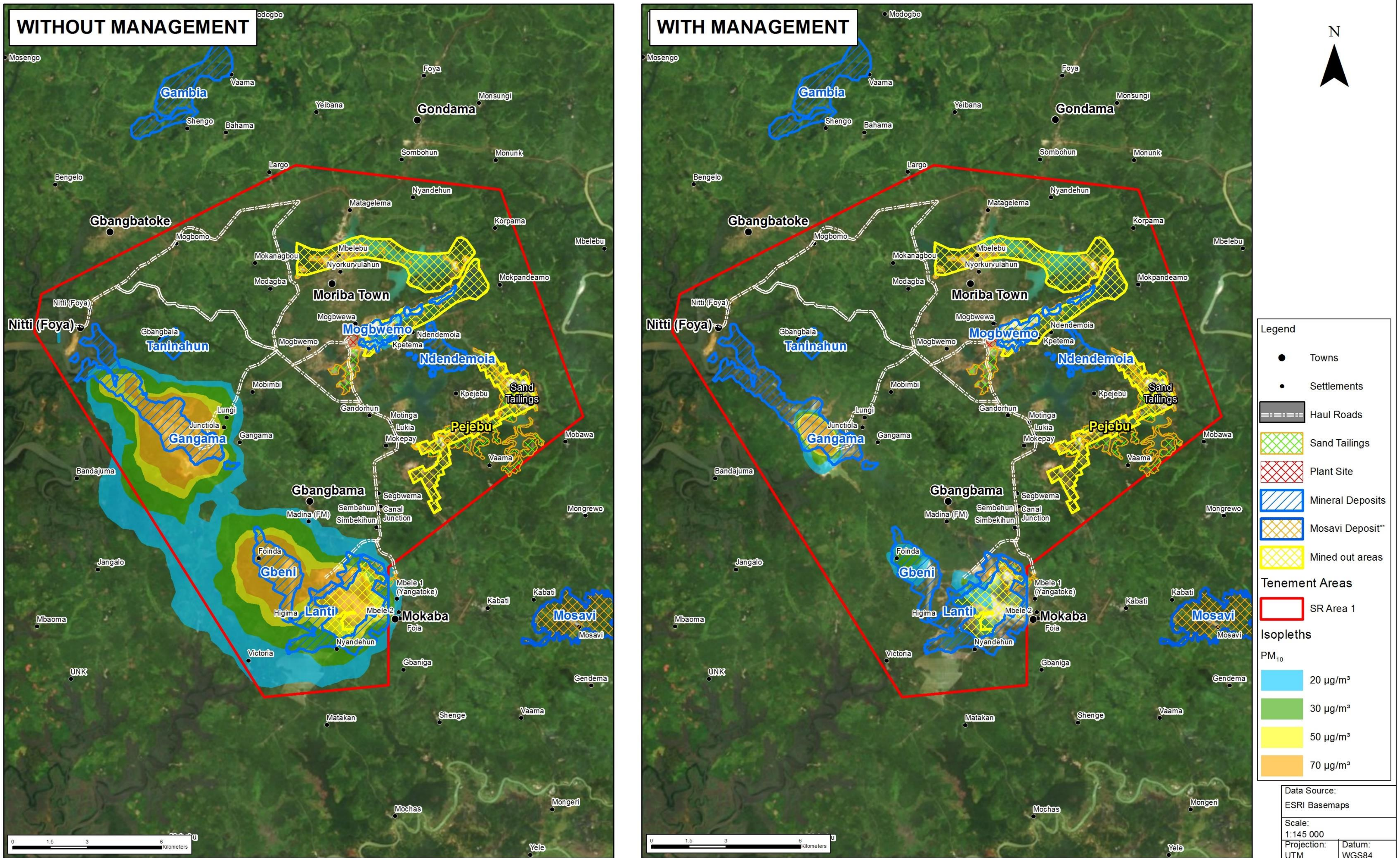

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Projection: UTM | Datum: WGS84

Central Meridian/Zone: Zone 28N

Date: 21/09/2017 | Compiled by: ALLK

Project No: 515234 | Fig No: 9-6

Revision: A Date: 23 02 2018

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PREDICTED ANNUAL PM_{10} CONCENTRATIONS FOR EXPANSION PHASE

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9.2.2 $PM_{2.5}$

The $PM_{2.5}$ modelling results for the expansion phases (i.e. increase in throughput to 1,000tph at Lanti and Gangama mines) are presented in Table 9-4. The 10 highest predicted concentrations for villages located in proximity to the mining activities have been selected, with the predicted concentrations for the remaining villages presented in Appendix D.

Scenario 1 shows that the maximum 24-hour PM_{10} concentrations occur at both Gangama and Lanti as a result of the mining activities (materials handling) taking place within these areas (Figure 9-7). In comparison to the model for the operational phase activities, the expansion phase activities will increase the distance of the plume from the mining activities. Villages in close proximity to these activities, namely Foinda, Nyandehun, Teso and Kpetema will be impacted by mining activities should management measures for dust not be implemented. The predicted concentrations for the villages presented, show that nine villages are above the WB / IFC EHS Guideline value of 25 µg/m³ for $PM_{2.5}$. As shown in Figure 9-7, the villages to the southwest of the SR Area 1 will mostly be impacted by the mining operations and exceed the WB / IFC EHS Guideline value of 25 µg/m³. Three villages will be impacted from the vehicle entrainment of dust on the haul roads i.e. Nyandehun (43.2 µg/m³), Junctiola (31.4 µg/m³) and Nitti Port (28.2 µg/m³).

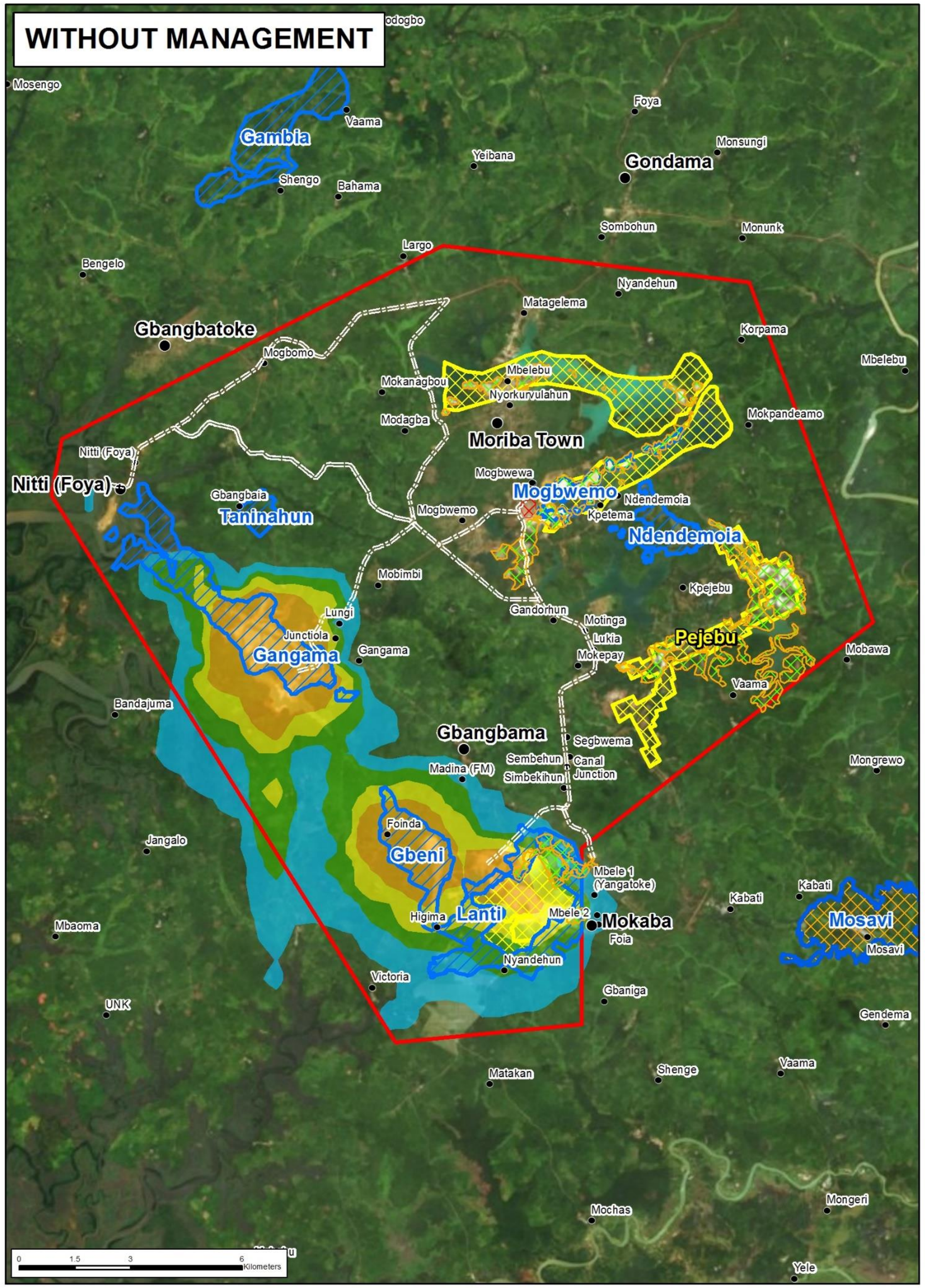
Scenario 2 shows that predicted $PM_{2.5}$ concentrations will decrease to levels below the WB / IFC EHS Guideline value of 25 µg/m³, except at Foinda (36.3 µg/m³) which lies to the northwest of the Lanti operations. The footprint of the impacted area will decrease to the mine areas when compared to the Scenario 1 without management. Predicted concentrations away from the SR Area 1 will be below the WB / IFC EHS Guideline value of 25 µg/m³ and this is also the case with villages in close proximity to the haul roads.

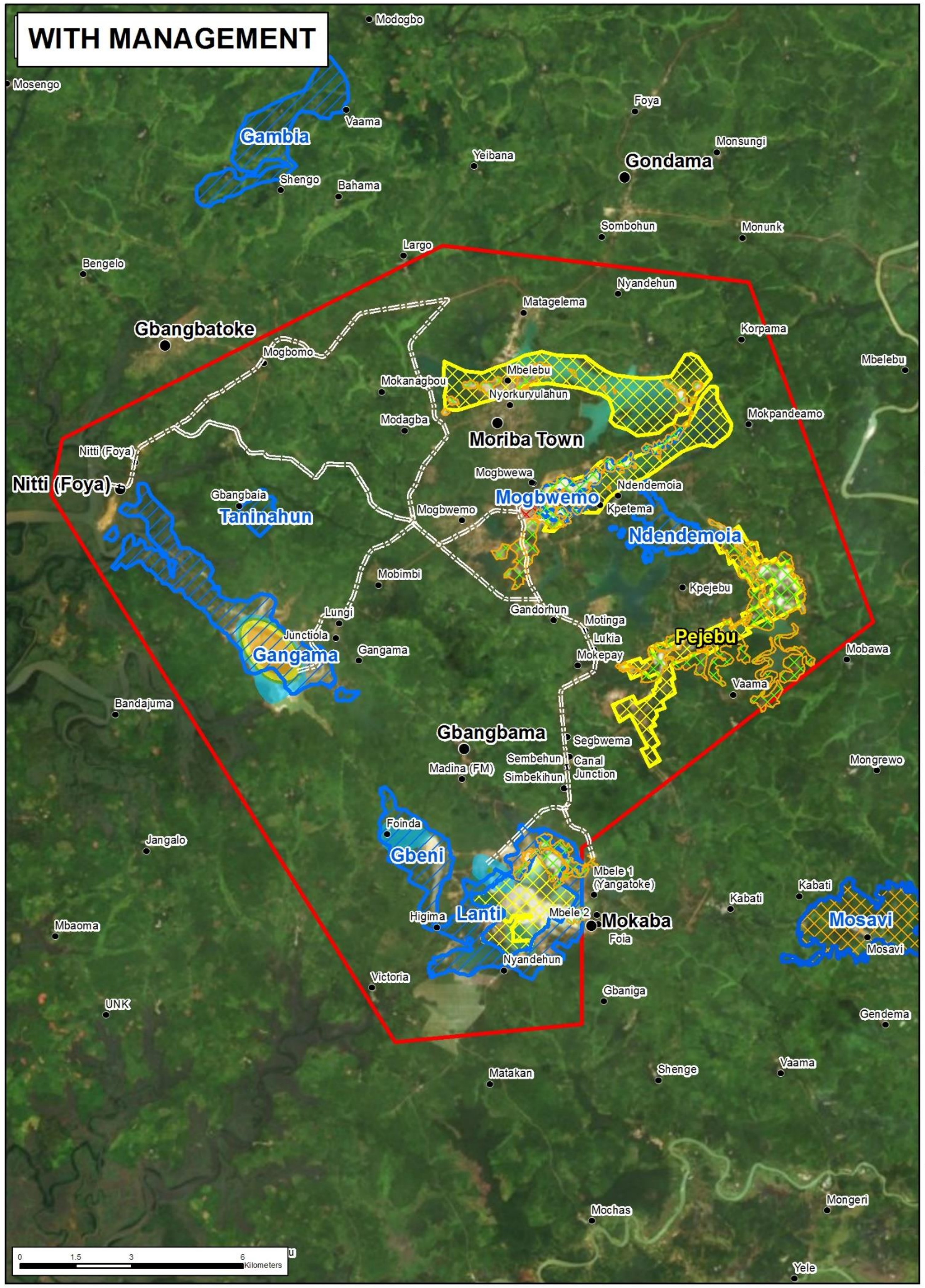
Annual $PM_{2.5}$ concentrations at all of the villages, except Foinda (37.0 µg/m³) are below the annual WB / IFC EHS Guideline value of 10 µg/m³. With management measures in place, the predicted concentrations at all villages are below the WB / IFC EHS Guideline value of 10 µg/m³. The annual predicted plume decreases and occurs within the footprint of the SR Area 1 at Lanti and Gangama (Figure 9-8).

Overall, when compared to the operational phase, the $PM_{2.5}$ concentrations for the expansion phase will increase, however with management measures in place, the predicted concentrations will be below the WB / IFC EHS Guideline values at all villages, except Foinda.

Table 9-4: Modelled $PM_{2.5}$ concentrations for the expansion activities

	$PM_{2.5}$ concentrations for expansion activities			
Village	**24-hour – No management**	**24-hour – With Management**	**Annual – No management**	**Annual – With Management**
Units	µg/m³	µg/m³	µg/m³	µg/m³
Foinda	224	36	37	6
Nyandehun	43	7	7	1
Teso	39	7	4	1
Junctiola	31	5	4	1
Nitti Port	28	5	3	1
Mokaba	24	4	2	0.3
Yangatoke	23	4	3	1
Kpetema	21	4	4	1
Victoria	20	3	3	1
Semabu	19	3	2	0.3
WB / IFC EHS Guideline	25	25	10	10
WB / IFC EHS IT 1	75	75	35	35
WB / IFC EHS IT 2	50	50	25	25
WB / IFC EHS IT 3	37.5	37.5	15	15





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Legend

- Towns
- Settlements
- Haul Roads
- Sand Tailings
- Plant Site
- Mineral Deposits
- Mosavi Deposit
- Mined out areas

Tenement Areas

- SR Area 1

Isopleths

PM

- 25 µg/m³
- 37.5 µg/m³
- 50 µg/m³
- 75 µg/m³

Data Source: ESRI Basemaps	
Scale: 1:145 000	
Projection: UTM	Datum: WGS84
Central Meridian/Zone: Zone 28N	
Date: 21/09/2017	Compiled by: ALLK
Project No: 515234	Fig No: 9-7

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PREDICTED 24HOUR $PM_{2.5}$ CONCENTRATIONS FOR EXPANSION PHASE

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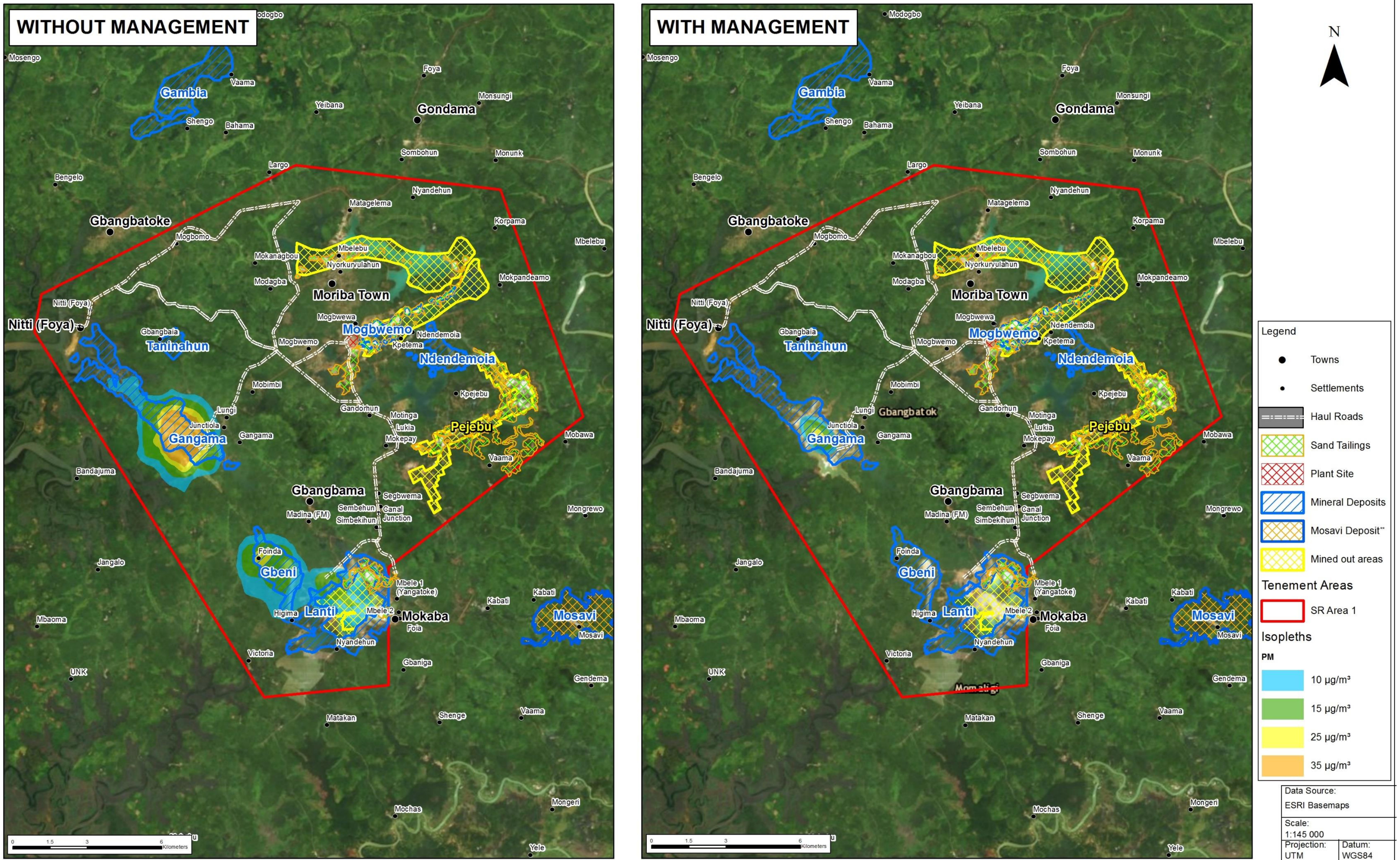
Revision: A Date: 23 02 2018



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Central Meridian/Zone: Zone 28N

Date: 21/09/2017 | Compiled by: ALLK

Project No: 515234 | Fig No: 9-8

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PREDICTED ANNUAL $PM_{2.5}$ CONCENTRATIONS FOR EXPANSION PHASE

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Revision: A Date: 23 02 2018

9.3 Power Plant

The Power Plant is one of three point sources located within the SR Area 1. A dispersion model was run for the Power Plant as emissions from power generating activities may be significant. Emissions modelled included NO_x, SO_2, PM_{10}, CO and VOCs. The 10 highest concentrations at the villages are presented in Table 9-5, with a detailed description of the predicted concentrations presented in Appendix E. Table 9-5 presents the results for NO_x, SO_2 and PM_{10}, with the CO and VOC results presented in detail in Appendix E.

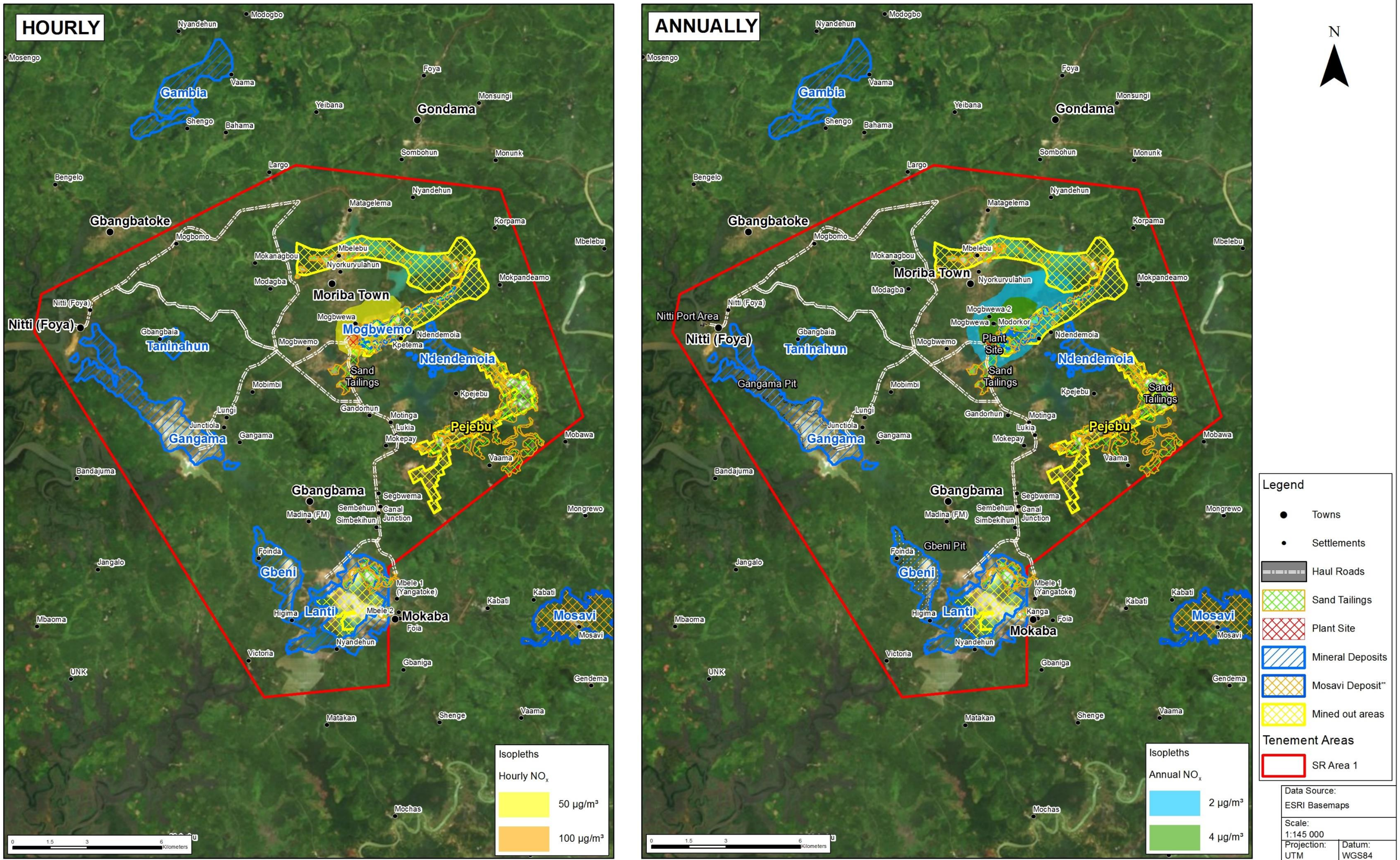
The NO_x concentrations are compared to the WB / IFC EHS1-hour NO_2 guideline value of 200 µg/m³. If NO_x concentrations are below the guideline it can be assumed that NO_2 concentrations will also be below the guidelines as NO_2 forms part of NO_x. Predicted NO_2 concentrations at the villages are below the 1-hour guideline of 200 µg/m³, with the highest predicted concentration at Mogbewa (140.32 µg/m³). The predicted NO_2 concentration at Mogbewo is an indication of the highest predicted at the sensitive receptors, however, it should be noted that the impact will be low as the predicted concentration is below the WB / IFC EHS Guideline of 200 µg/m³. The predicted concentrations decrease away from the Power Plant (Figure 9-9). The annual NO_x concentrations at the villages are below the annual guideline of 40 µg/m³.

The predicted 24-hour SO_2 concentrations at the villages are below the WB / IFC EHS Guideline value of 20 µg/m³. Mogbewa, which is in close proximity to the Power Plant, shows the highest concentration at 10.34 µg/m³. Similar to the predicted NO_x concentrations, SO_2 concentrations decrease away from the Power Plant (Figure 9-10).

The predicted 24-hour PM_{10} concentrations emanating from the Power Plant at the villages are below the WB / IFC EHS Guideline value of 50 µg/m³. As with the models for NO_x and SO_2, Mogbewa which is in close proximity to the Power Plant, shows the highest concentration at 17.98 µg/m³. Similar to the predicted NO_x concentrations, PM_{10} concentrations decrease away from the Power Plant (Figure 9-11).

Table 9-5: Predicted emissions from the Power Plant

Village	NO_x emissions		SO_2 emissions		PM_{10} emissions	
	1 hour	Annual	24-hour	Annual	24-hour	Annual
Units	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³
Mogbewa	140.3	8.6	10.3	1.5	18.0	2.6
Kpetema	26.0	1.8	2.0	0.3	3.5	0.6
Ndendomoia	25.8	1.4	1.6	0.2	2.7	0.4
Bamba	17.5	0.9	0.6	0.2	1.1	0.3
Mogbwemo	16.7	0.9	1.2	0.2	2.1	0.3
Moriba Town	15.2	0.8	1.1	0.1	1.8	0.3
Gondama	10.8	0.5	0.6	0.1	1.1	0.2
Junctiola	10.6	0.4	0.5	0.1	0.9	0.1
Pendembu	9.7	0.5	0.5	0.1	0.9	0.2
Gangama	8.9	0.4	0.5	0.1	0.8	0.1
WB / IFC EHS Guideline	200	40	20	-	50	20
WB / IFC EHS IT 1	-	-	125	-	150	70
WB / IFC EHS IT 2	-	-	50	-	100	50
WB / IFC EHS IT 3	-	-	-	-	75	30



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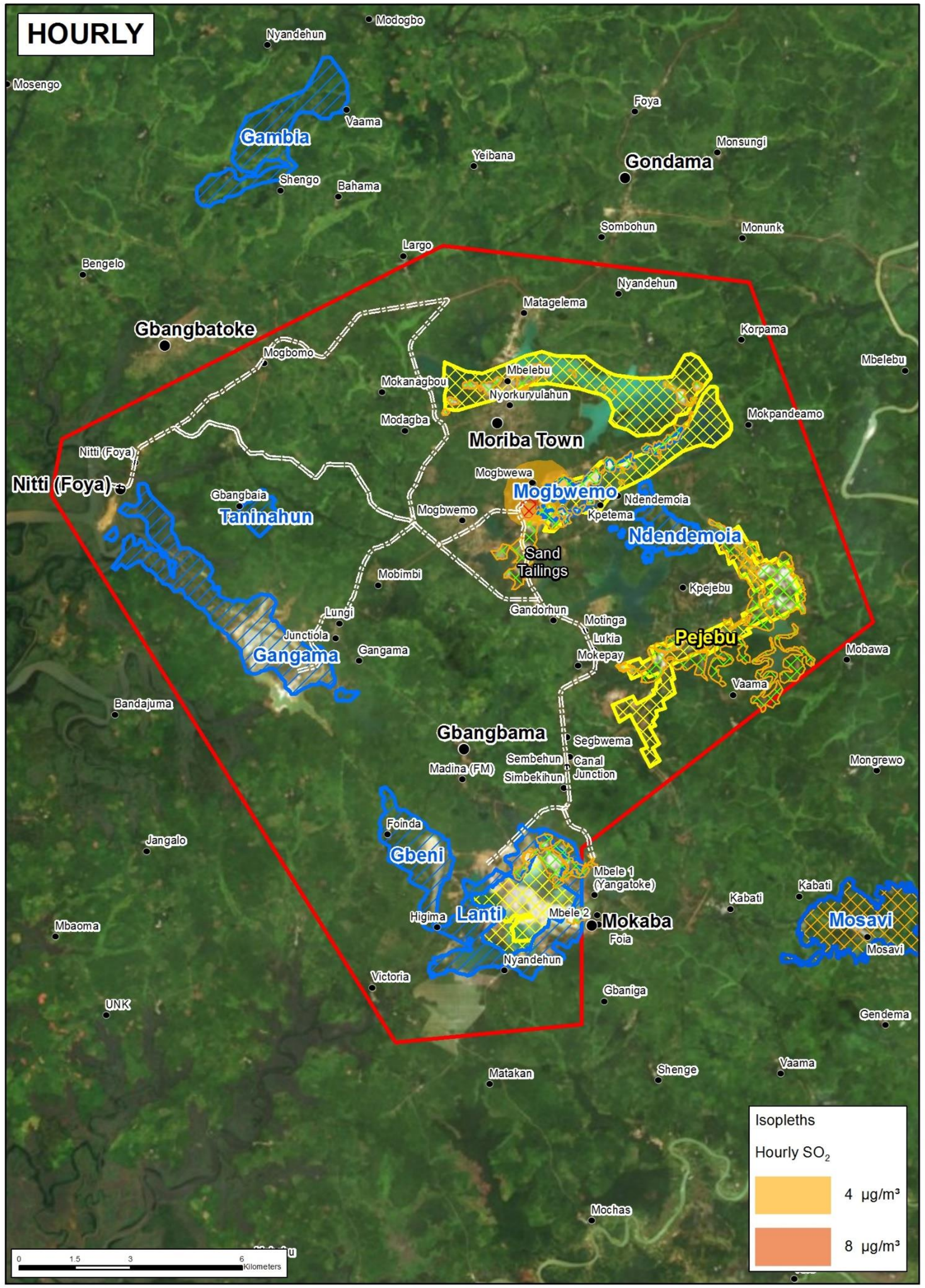
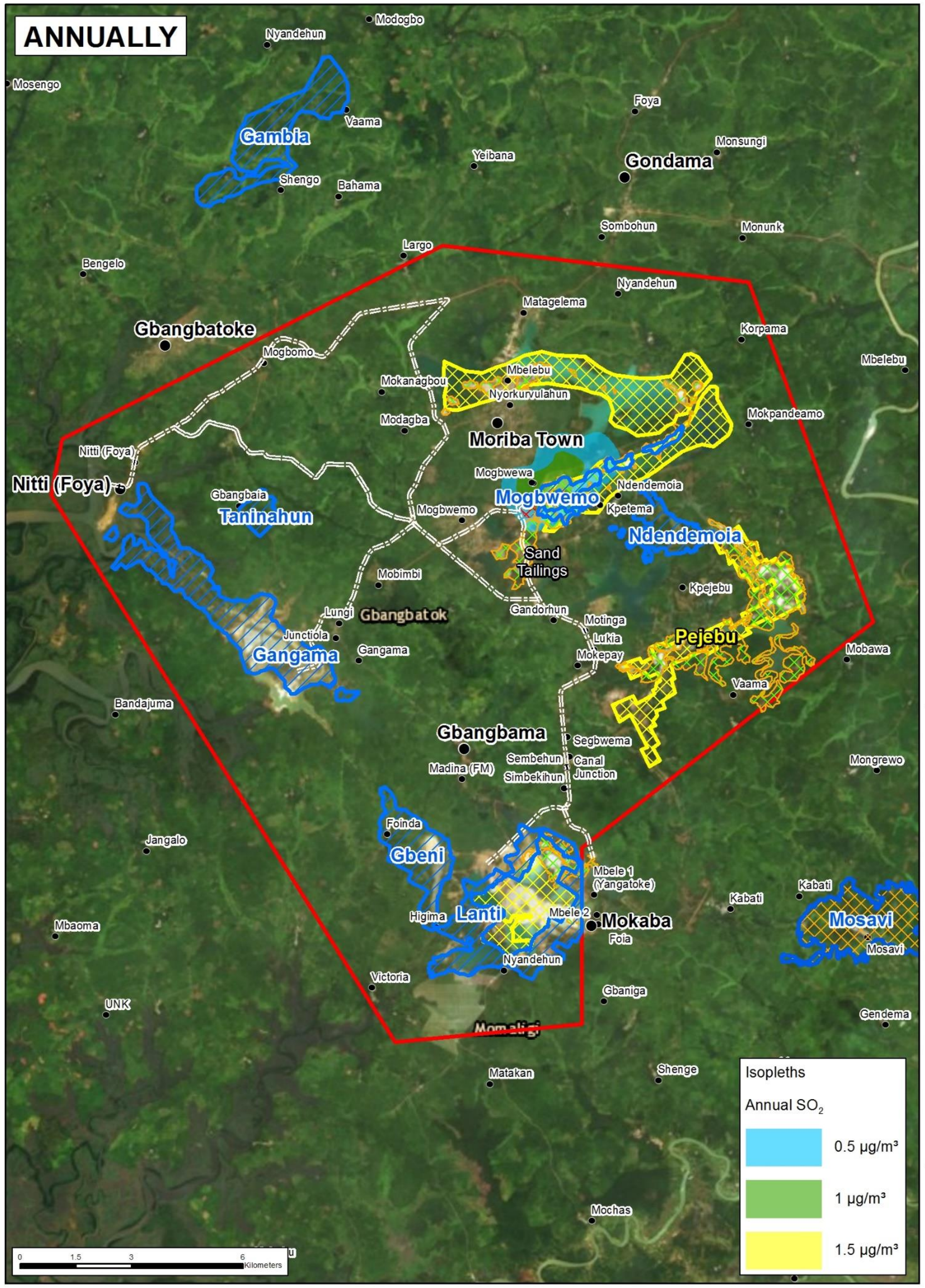
SR AREA 1 ESHIA & ESHMP

PREDICTED NO_X CONCENTRATIONS AT THE POWER PLANT

Path: G:\515234_ILUKA_SRK_ESIA_JNB\8GIS\GISPROJ\MXD\Feb2018\AQ\515234_F9_9_AQIA_NOx_Prediction_A3L_23022018.mxd

Revision: A Date: 23 02 2018





N

Legend

- Towns
- Settlements
- Haul Roads
- Sand Tailings
- Plant Site
- Mineral Deposits
- Mosavi Deposit**
- Mined out areas

Tenement Areas

- SR Area 1

Data Source: ESRI Basemaps	
Scale: 1:145 000	
Projection: UTM	Datum: WGS84
Central Meridian/Zone: Zone 28N	
Date: 21/09/2017	Compiled by: ALLK
Project No: 515234	Fig No: 9-10

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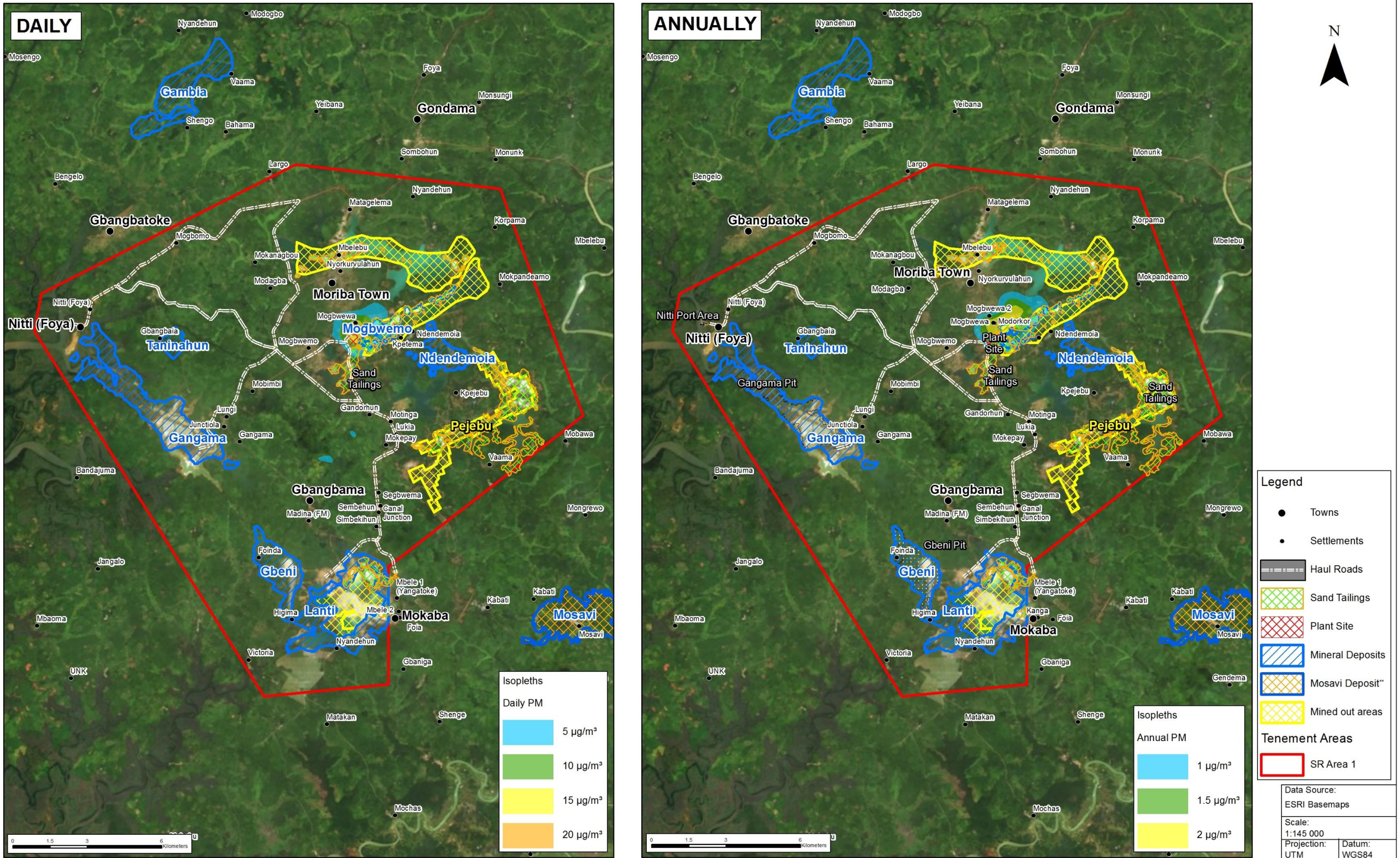
SR AREA 1 ESHIA & ESHMP

PREDICTED SO_2 CONCENTRATIONS AT THE POWER PLANT

Path: G:\515234_ILUKA_SRK_ESIA_JNB\8GIS\GISPROJ\MXD\Feb2018\AQ\515234_F9_10_AQIA_SO2_Prediction_A3L_23022018.mxd

Revision: A Date: 23 02 2018



Data Source: ESRI Basemaps	
Scale: 1:145 000	
Projection: UTM	Datum: WGS84
Central Meridian/Zone: Zone 28N	
Date: 21/09/2017	Compiled by: ALLK
Project No: 515234	Fig No: 9-11

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SR AREA 1 ESHIA & ESHMP

PREDICTED PM_{10} CONCENTRATIONS AT THE POWER PLANT

Path: G:\515234_ILUKA_SRK_ESIA_JNB\8GIS\GISPROJ\MXD\Feb2018\AQ\515234_F9_11_AQIA_PM10_Prediction_A3L_23022018.mxd

Revision: A Date: 23 02 2018

9.4 SRL MSP Dryers

A dispersion model was run for the SRL MSP dryer to determine emissions from the combustion of diesel and compared to WB / IFC EHS Guidelines. Emissions modelled for the SRL MSP dryer included NO_x, SO_2, PM_{10}, CO and VOCs. The 10 highest concentrations at the villages are presented in Table 9-6, with a detailed description of the predicted concentrations presented in Appendix E. Table 9-5 presents the results for NO_x, SO_2 and $PM_{10,}$ with the CO and VOC results and maps are presented in detail in Appendix E.

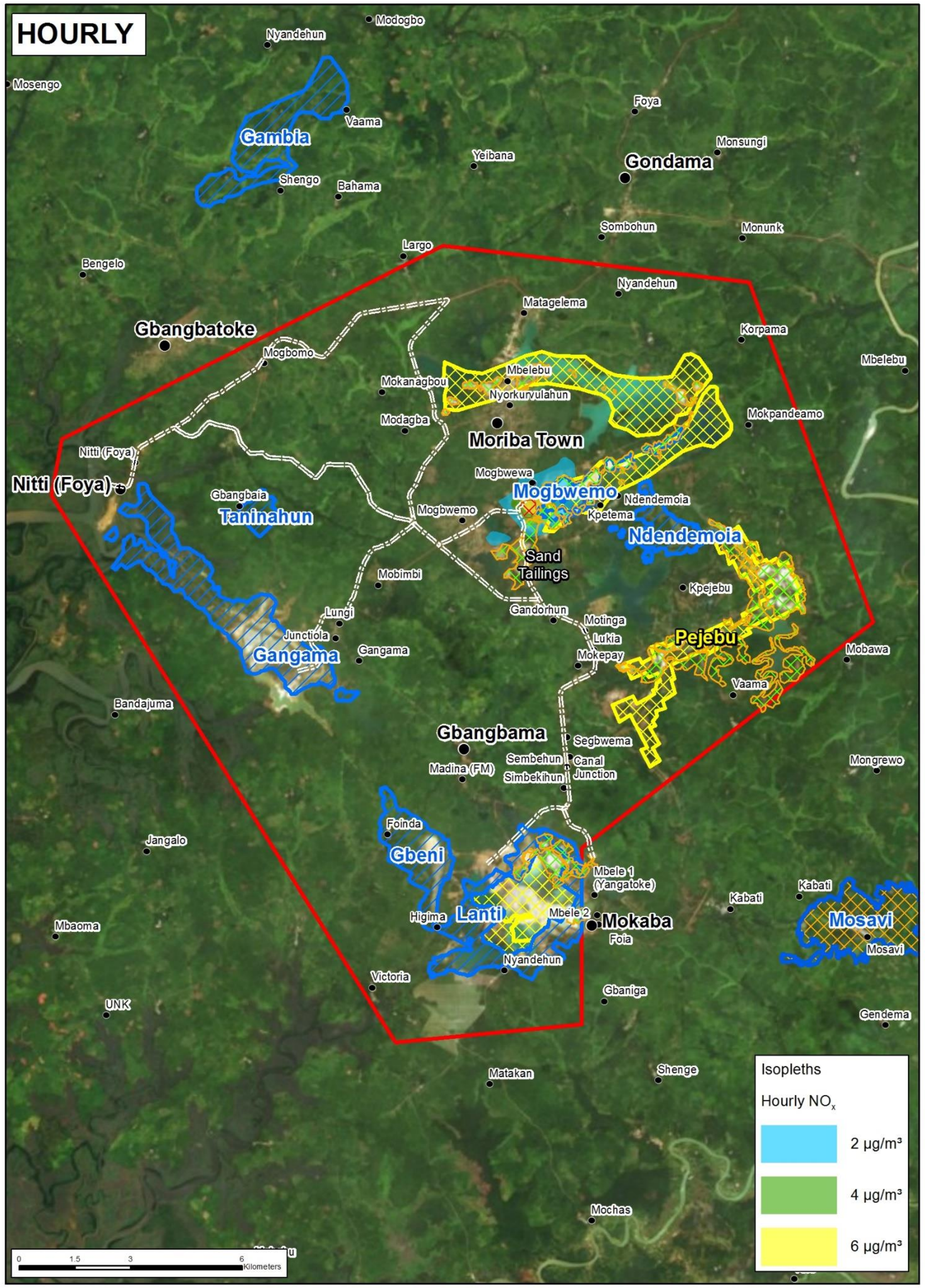
Similar to the Power Plant, the dryer NO_x concentrations are compared to the WB / IFC EHS 1-hour NO_2 guideline value of 200 µg/m³. Predicted concentrations at the villages are well below the guideline of 200 µg/m³, with the highest predicted concentration at Mogbewa (2.801 µg/m³). The predicted concentrations decrease away from the SRL MSP dryer (Figure 9-12). The annual NO_x concentrations at from the SRL MSP dryer are low to negligible and below the WB / IFC EHS annual guideline value of 40 µg/m³ at the villages.

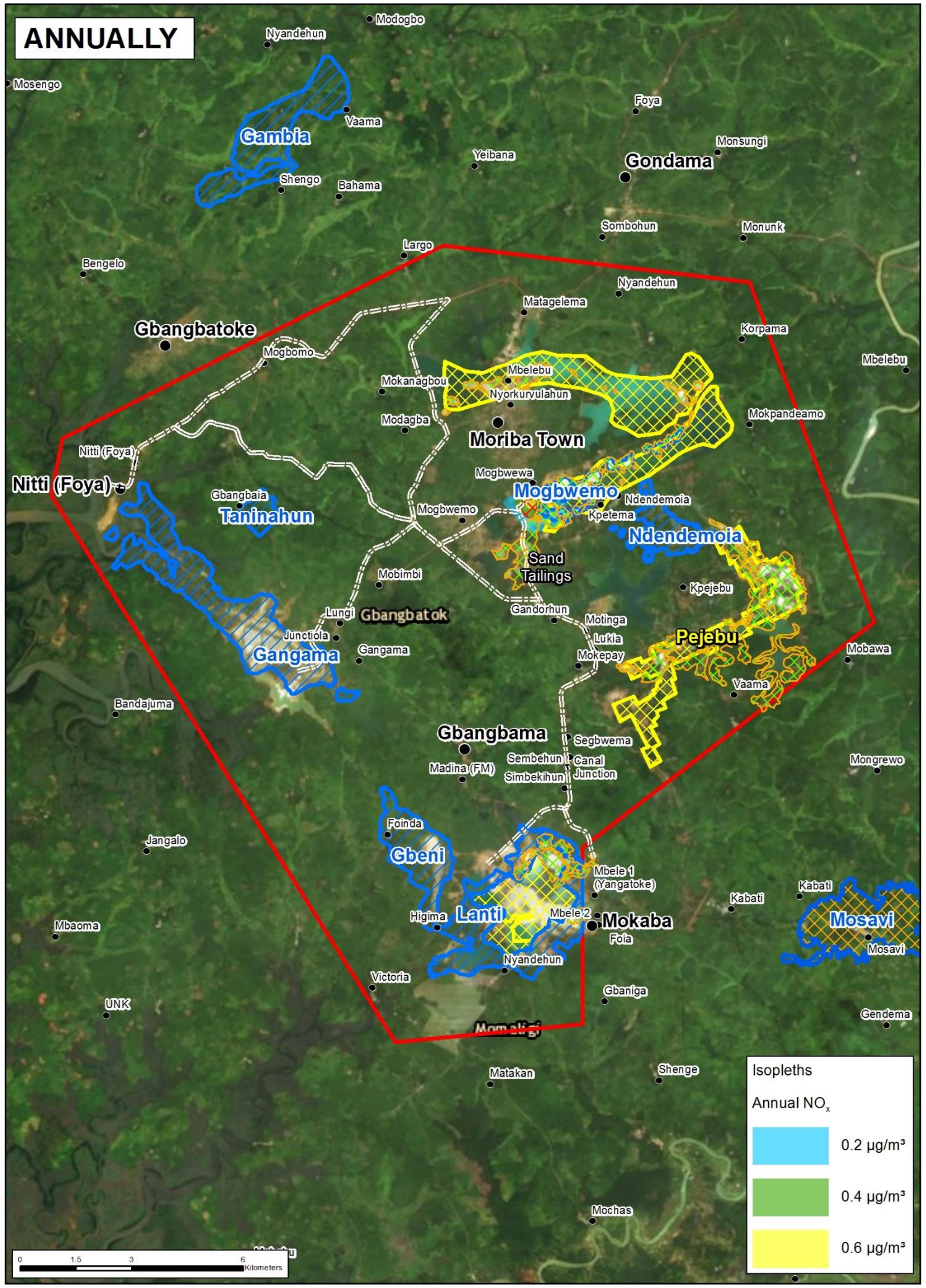
The predicted 24-hour and annual SO_2 concentrations at the villages are below the respective WB / IFC EHS Guidelines. Mogbewa which is in close proximity to the SRL MSP dryer, predicts the highest concentration at 0.008 µg/m³ (Figure 9-13). Similar to the predicted NOx concentrations, SO_2 concentrations decrease away from the SRL MSP dryer.

The predicted 24-hour PM_{10} concentrations at the villages are below the WB / IFC EHS Guideline value of 50 µg/m³. As with the models for NO_x and $SO_{2,}$ Mogbewa which is in close proximity to the SRL MSP dryer, shows the highest concentration at 0.060 µg/m³ (Figure 9-14). Similar to the predicted NO_x and SO_2 concentrations PM_{10} decrease away from the SRL MSP dryer.

Table 9-6: Emissions from the dryer at the SRL MSP

Village	NO_x emissions		SO_2 emissions		PM_{10} emissions	
	1 hour	Annual	24-hour	Annual	24-hour	Annual
Units	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³
Mogbewa	2.801	0.189	0.008	0.0013	0.060	0.010
Kpetema	1.137	0.062	0.002	0.0004	0.018	0.003
Ndendomoia	0.751	0.039	0.002	0.0003	0.012	0.002
Mogbwemo	0.575	0.029	0.002	0.0002	0.015	0.002
Gondama	0.524	0.021	0.001	0.0002	0.009	0.001
Junctiola	0.326	0.012	0.001	0.0001	0.006	0.001
Bamba	0.321	0.017	0.001	0.0001	0.004	0.001
Moriba Town	0.312	0.021	0.001	0.0002	0.011	0.001
Gangama	0.299	0.012	0.001	0.0001	0.006	0.001
Mobimbi	0.196	0.009	0.001	0.0001	0.004	0.000
WB / IFC EHS Guideline	200	40	20	-	50	20
WB / IFC EHS IT 1	-	-	125	-	150	70
WB / IFC EHS IT 2	-	-	50	-	100	50
WB / IFC EHS IT 3	-	-	-	-	75	30





N

Legend

- Towns
- Settlements
- Haul Roads
- Sand Tailings
- Plant Site
- Mineral Deposits
- Mosavi Deposit**
- Mined out areas

Tenement Areas

- SR Area 1

Data Source: ESRI Basemaps	
Scale: 1:145 000	
Projection: UTM	Datum: WGS84
Central Meridian/Zone: Zone 28N	
Date: 21/09/2017	Compiled by: ALLK
Project No: 515234	Fig No: 9-12

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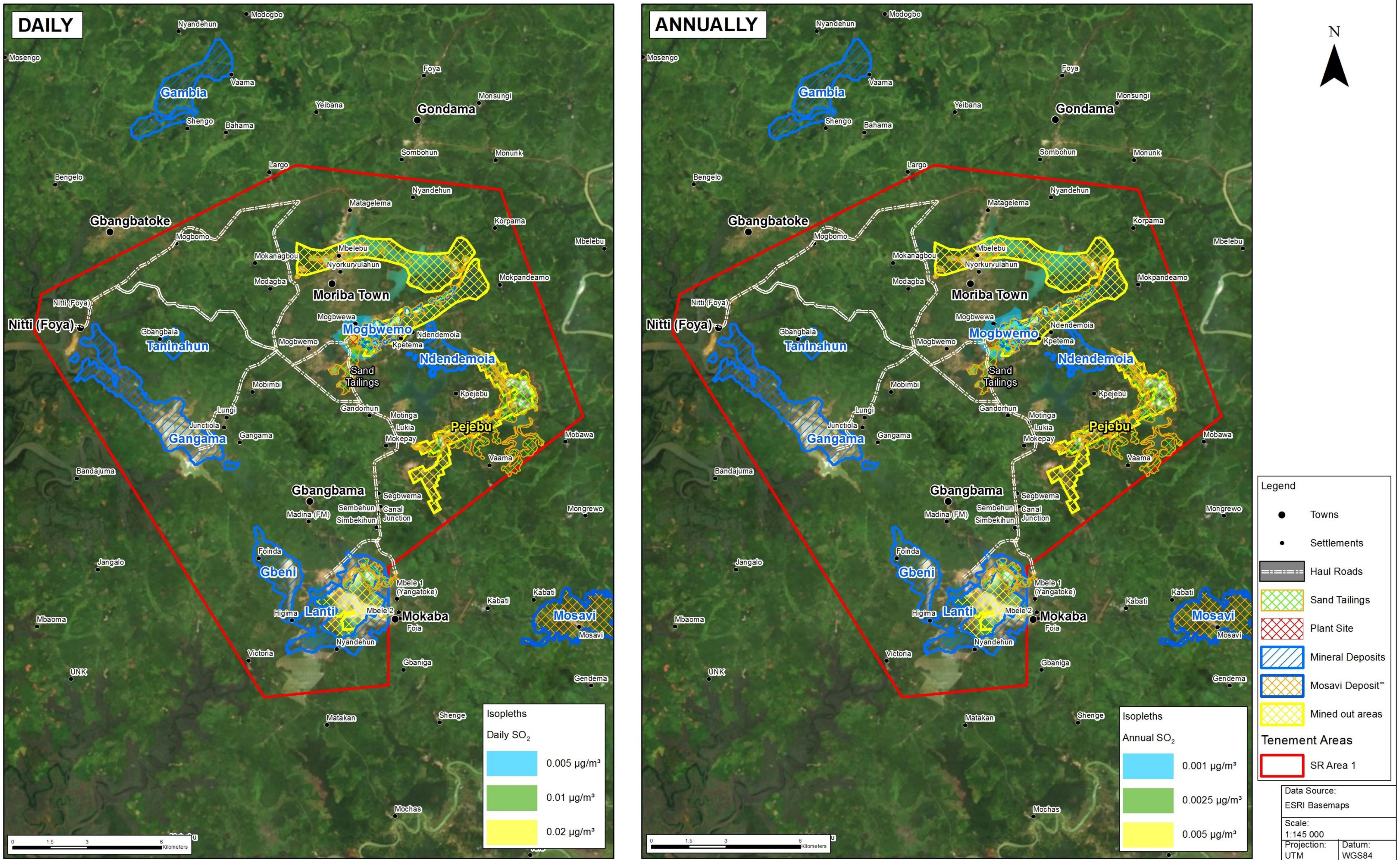
SR AREA 1 ESHIA & ESHMP

PREDICTED NO_X CONCENTRATIONS AT THE MPS DRYER

Path: G:\515234_ILUKA_SRK_ESIA_JNB\8GIS\GISPROJ\MXD\Feb2018\AQ\515234_F9_12_AQIA_NOx_MPS_A3L_23022018.mxd

Revision: A Date: 00 00 2011



Data Source: ESRI Basemaps	
Scale: 1:145 000	
Projection: UTM	Datum: WGS84
Central Meridian/Zone: Zone 28N	
Date: 21/09/2017	Compiled by: ALLK
Project No: 515234	Fig No: 9-13

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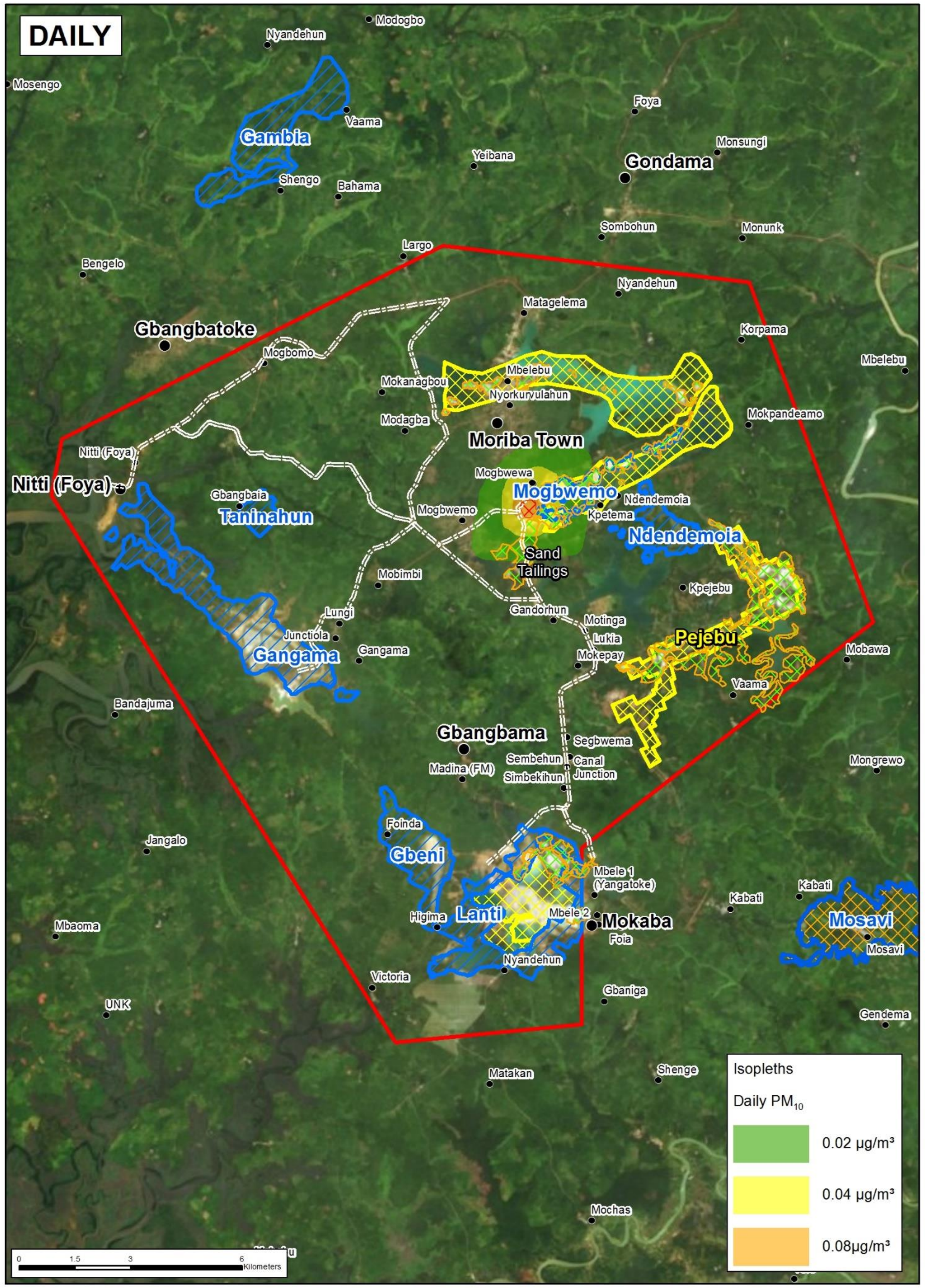
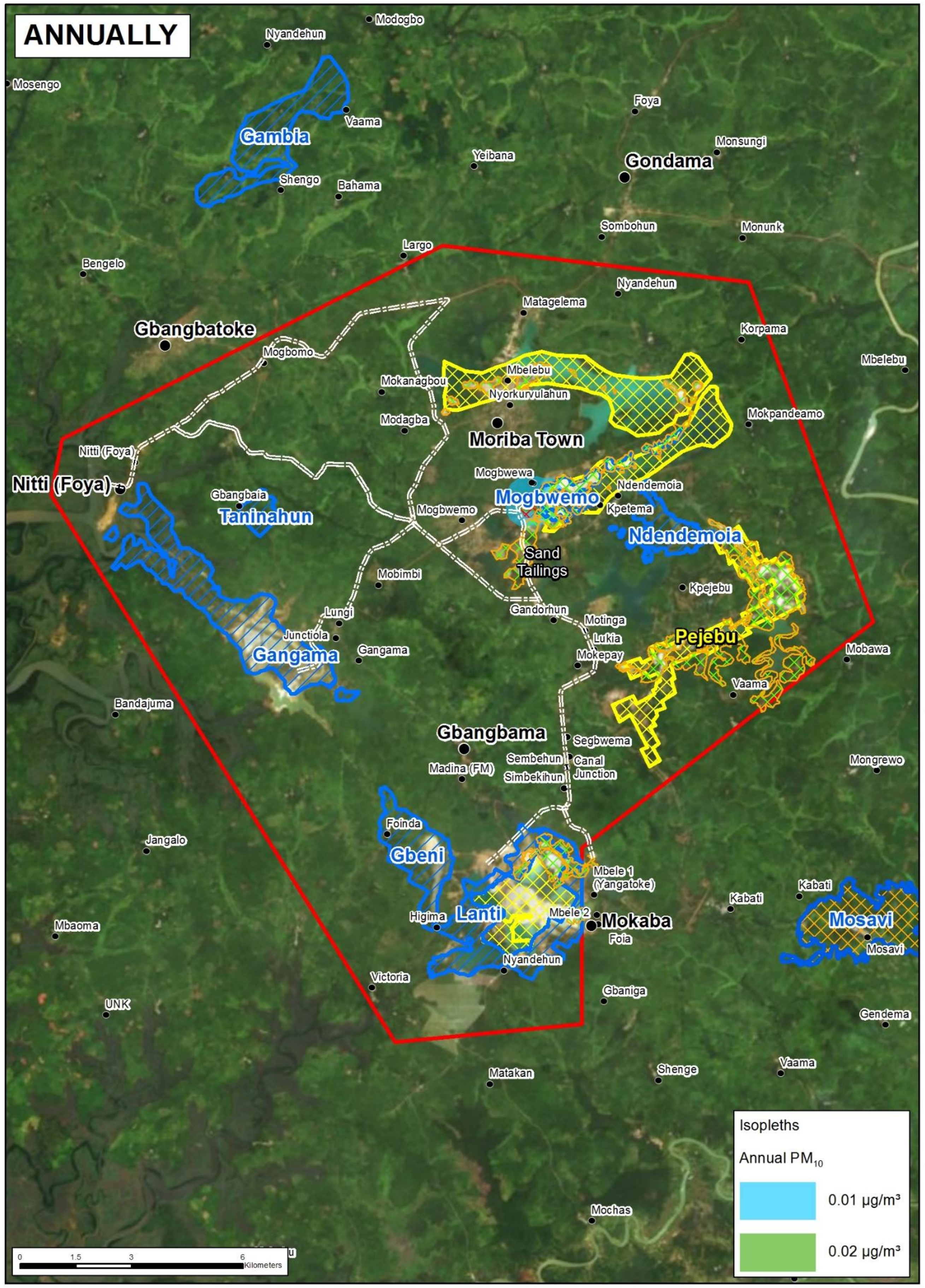
SR AREA 1 ESHIA & ESHMP

PREDICTED SO_2 CONCENTRATIONS AT THE MPS DRYER

Path: G:\515234_ILUKA_SRK_ESIA_JNB\8GIS\GISPROJ\MXD\Feb2018\AQ\515234_F9_13_AQIA_SO2_MPS_A3L_23022018.mxd

Revision: A Date: 23 02 2018





N

Legend
- Towns
- Settlements
- Haul Roads
- Sand Tailings
- Plant Site
- Mineral Deposits
- Mosavi Deposit**
- Mined out areas

Tenement Areas
- SR Area 1

Data Source: ESRI Basemaps	
Scale: 1:145 000	
Projection: UTM	Datum: WGS84
Central Meridian/Zone: Zone 28N	
Date: 21/09/2017	Compiled by: ALLK
Project No: 515234	Fig No: 9-14

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SR AREA 1 ESHIA & ESHMP

PREDICTED PM_{10} CONCENTRATIONS AT THE MPS DRYER

Path: G:\515234_ILUKA_SRK_ESIA_JNB\8GIS\GISPROJ\MXD\Feb2018\AQ\515234_F9_14_AQIA_PM10_MPS_A3L_23022018.mxd

Revision: A Date: 23 02 2018

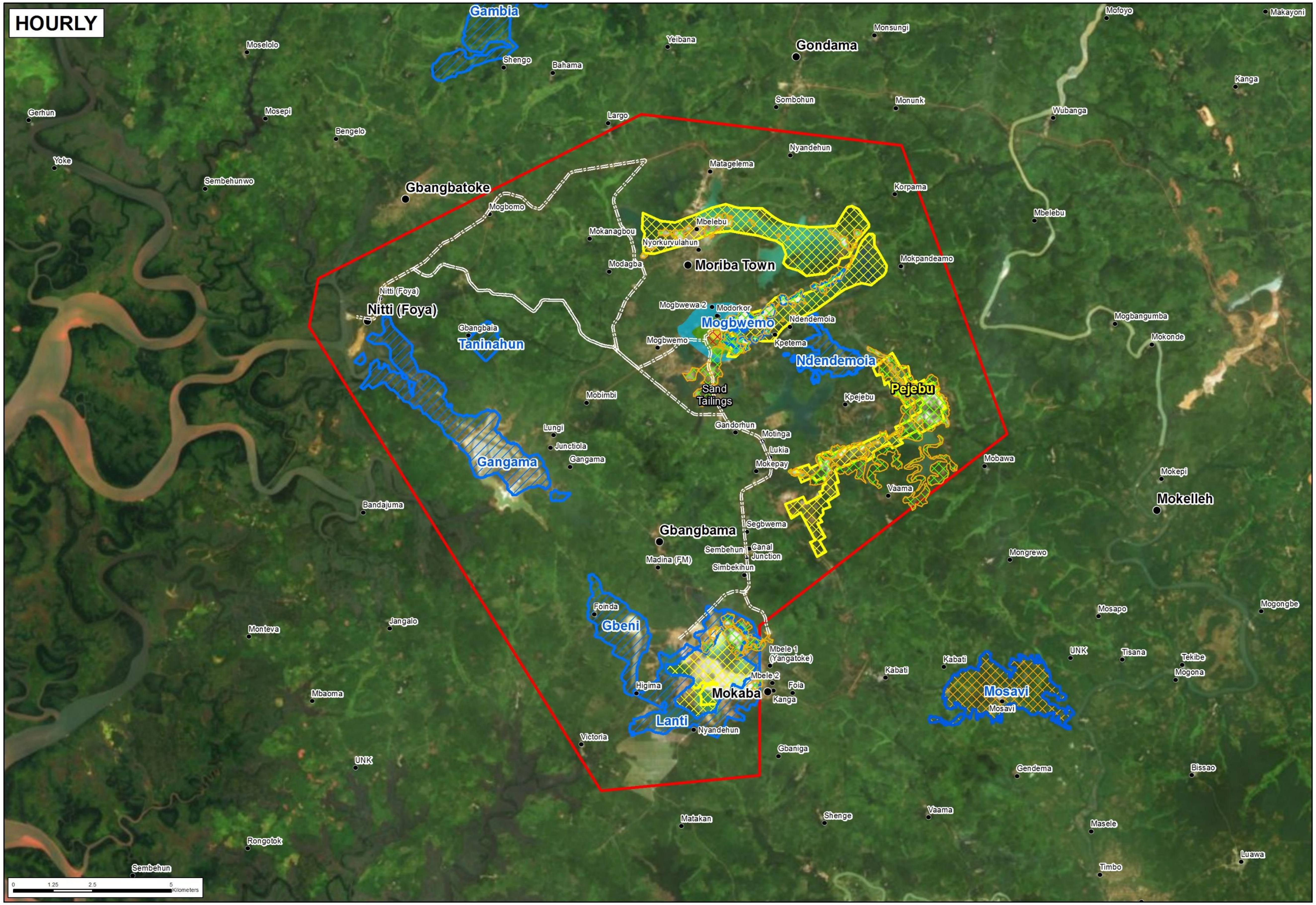
9.5 Medical Incinerators

A dispersion model was run for the two medical incinerators located at the clinic in the SR Area 1. The incinerators are operated twice a week and was modelled as such. The predicted concentrations for NO_x, SO_2 and PM_{10} are presented in Table 9-7, with the CO and VOC results and maps are presented in detail in Appendix E. Models were run for dioxins and furans, however due to the low emission rates, isopleth concentration maps could not be generated by the model, hence no results are presented. When no isopleths are generated in the model, concentrations are deemed to be 0 µg/m³.

The predicted concentrations for NO_x, SO_2 and PM_{10} are well below the respective guidelines (Figures 9-15, 9-16 and 9-17). The predicted concentrations are low to negligible due to the nature of the combustion process within the incinerator and, therefore, will not impact on sensitive receptors.

Table 9-7: Emissions from the medical incinerator

	NO_x emissions	SO_2 emissions	PM_{10} emissions
Village	**1 hour**	**24 hour**	**24 hour**
Units	µg/m³	µg/m³	µg/m³
Mogbewa	0.0000420	0.0000065	0.0000145
Kpetema	0.0000055	0.0000017	0.0000038
Mogbwemo	0.0000050	0.0000022	0.0000050
Moriba Town	0.0000043	0.0000016	0.0000035
Ndendomoia	0.0000036	0.0000013	0.0000029
Bamba	0.0000030	0.0000008	0.0000019
Mokepay	0.0000016	0.0000016	0.0000035
Gondama	0.0000014	0.0000008	0.0000018
Pendembu	0.0000013	0.0000006	0.0000014
Matagiema	0.0000013	0.0000006	0.0000013
WB / IFC EHS Guideline	200	20	50
WB / IFC EHS IT 1	-	125	150
WB / IFC EHS IT 2	-	50	100
WB / IFC EHS IT 3	-	-	75



Legend

- Towns
- Settlements
- Haul Roads
- Sand Tailings
- Plant Site
- Mineral Deposits
- Mosavi Deposit
- Mined out areas

Tenement Areas

- SR Area 1

Isopleths

Hourly NO_x

- 0.00002 µg/m³
- 0.00004 µg/m³
- 0.00008 µg/m³

Data Source: ESRI Basemaps	
Scale: 1:120 000	
Projection: UTM	Datum: WGS84
Central Meridian/Zone: Zone 28N	
Date: 21/09/2017	Compiled by: ALLK
Project No: 515234	Fig No: 9-15

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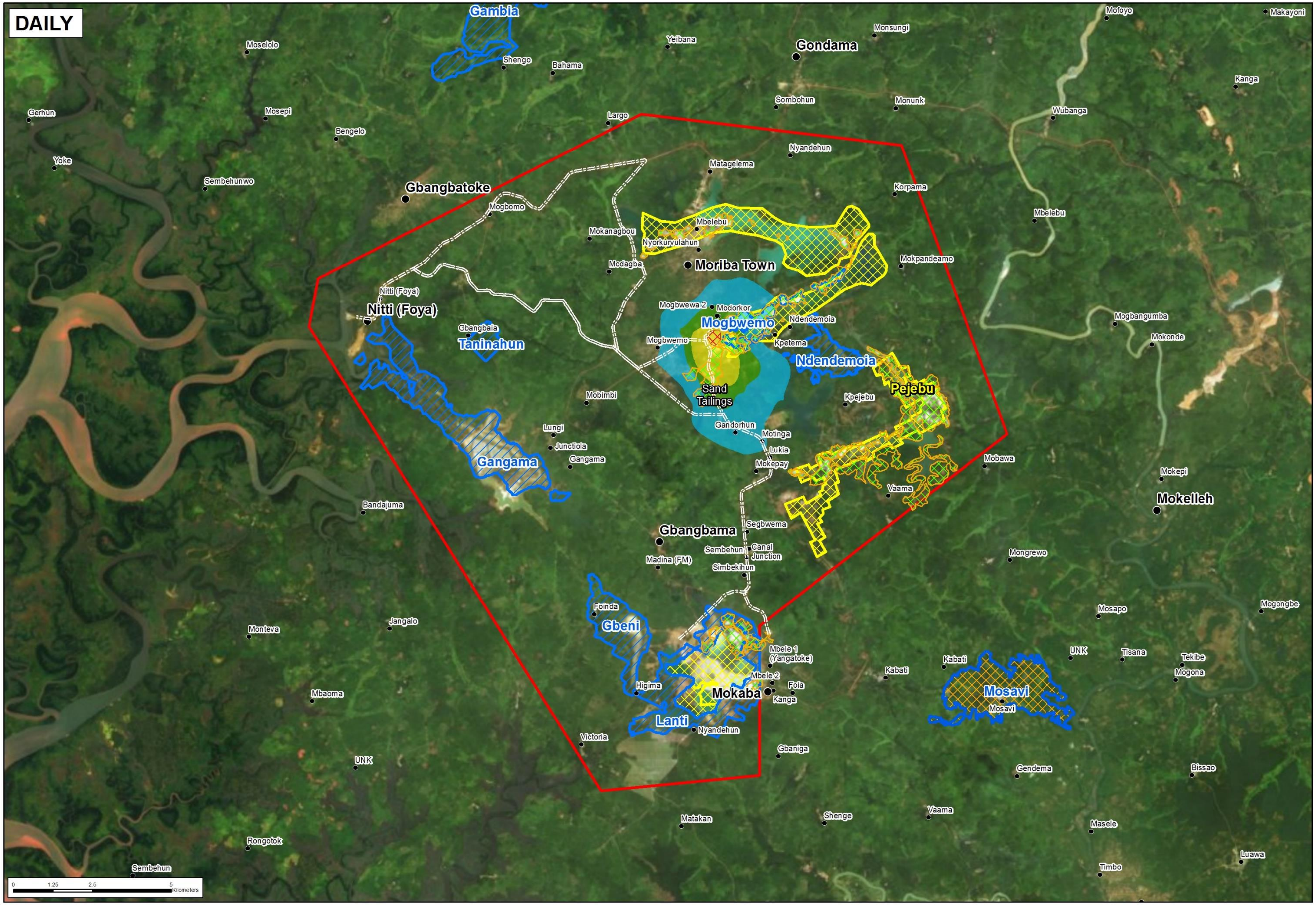
SR AREA 1 ESHIA & ESHMP

PREDICTED NO_X CONCENTRATIONS AT THE MEDICAL INCINERATOR

Path: G:\515234_ILUKA_SRK_ESIA_JNB\8GIS\GISPROJ\MXD\Feb2018\AQ\515234_F9_15_AQIA_NOx_Med_Inc_A3L_23022018.mxd

Revision: A Date: 23 02 2018



Legend

- Towns
- Settlements
- Haul Roads
- Sand Tailings
- Plant Site
- Mineral Deposits
- Mosavi Deposit**
- Mined out areas

Tenement Areas

- SR Area 1

Isopleths

Daily SO_2

- 0.000002 µg/m³
- 0.000004 µg/m³
- 0.000008 µg/m³

Data Source: ESRI Basemaps	
Scale: 1:120 000	
Projection: UTM	Datum: WGS84
Central Meridian/Zone: Zone 28N	
Date: 21/09/2017	Compiled by: ALLK
Project No: 515234	Fig No: 9-16

Revision: A Date: 23 02 2018

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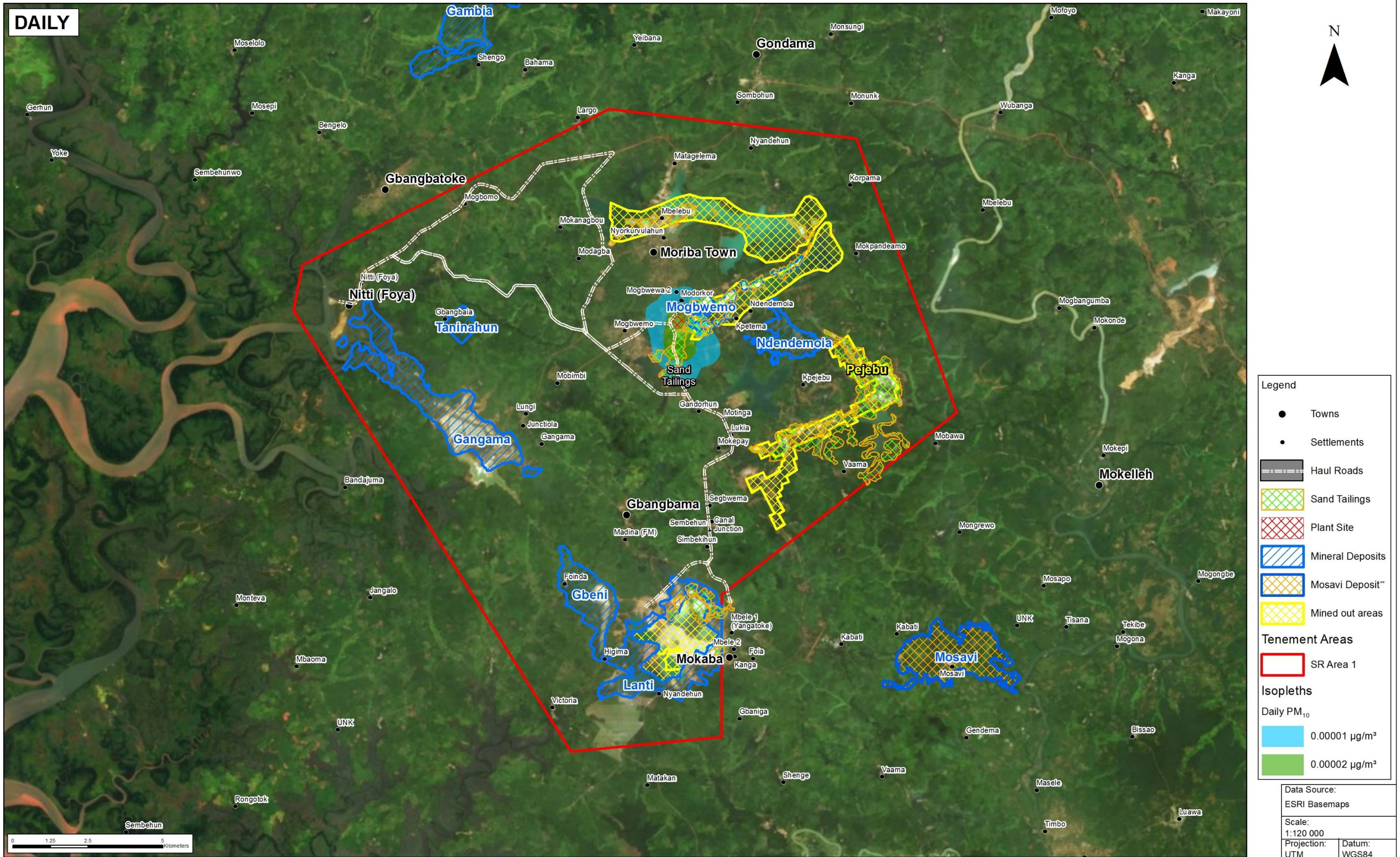
SR AREA 1 ESHIA & ESHMP

PREDICTED SO_2 CONCENTRATIONS AT THE MEDICAL INCINERATOR

Path: G:\515234_ILUKA_SRK_ESIA_JNB\8GIS\GISPROJ\MXD\Feb2018\AQ\515234_F9_16_AQIA_SO2_Med_Inc_A3L_23022018.mxd



Data Source: ESRI Basemaps

Scale: 1:120 000

Projection: UTM | Datum: WGS84

Central Meridian/Zone: Zone 28N

Date: 21/09/2017 | Compiled by: ALLK

Project No: 515234 | Fig No: 9-17

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SR AREA 1 ESHIA & ESHMP

PREDICTED PM_{10} CONCENTRATIONS AT THE MEDICAL INCINERATOR

Path: G:\515234_ILUKA_SRK_ESIA_JNB\8GIS\GISPROJ\MXD\Feb2018\AQ\515234_F9_17_AQIA_PM10_Med_Inc_A3L_23022018.mxd

Revision: A Date: 23 02 2018

9.6 Model Calibration

In order to determine the accuracy and consistency of the model, SRK modelled the location of the PM_{10} and $PM_{2.5}$ monitors as discrete receptors and compared the modelled concentrations at these points to monitored concentrations for the same period, i.e. 29 July 2017 to 31 August 2017. The monitored concentrations take into account baseline and operational dust, whereas the modelled concentrations only take into consideration operational dust. Hence the mining operations may contribute 83% of PM_{10} and 71% of $PM_{2.5}$ to the total ambient PM levels at these monitoring locations.

Table 9-8: Modelled vs monitored concentrations

Parameter	Modelled concentration	Monitored concentration	Percentage Difference
Units	µg/m³	µg/m³	%
PM_{10} (24hr)	23.3	28.0	83
$PM_{2.5}$ (24hr)	16.5	23.0	71

10 Impact Assessment

The impact assessment focuses on the operational, expansion, decommissioning, closure and post closure phases of the Project. It is expected that subsequent to rehabilitation, the ambient levels will decrease, and the impact will reduce to low. The change in air quality as a result of a change in ambient PM_{10}, $PM_{2.5}$ and gaseous emission levels during the operational phases of the mine were the only impacts that were assessed.

The significance of the impacts was assessed according to the following criteria:

- Magnitude – severity or intensity;
- Duration (temporal influence) – temporal influence; and
- Scale (spatial influence) – spatial influence.

10.1 Impact assessment rating

Practicable management measures are recommended that avoid, and if avoidance is not possible, then it is required to reduce, restore, compensate / offset negative impacts, enhance positive impacts and assist project design. The impact significance rating system is presented in Table 10-1 and involves three parts:

- Part A: Defines impact consequence using the three primary impact characteristics of magnitude, spatial scale and duration;
- Part B: Uses the matrix to determine a rating for impact consequence based on the definitions identified in Part A; and
- Part C: Uses the matrix to determine the impact significance rating, which is a function of the impact consequence rating (from Part B) and the probability of occurrence.

Table 10-1: Impact assessment rating

<table>
<tr><td colspan="6">PART A: DEFINING CONSEQUENCE IN TERMS OF MAGNITUDE, DURATION AND SPATIAL SCALE
Use these definitions to define the consequence in Part B</td></tr>
<tr><td>Impact characteristics</td><td>Definition</td><td colspan="4">Criteria</td></tr>
<tr><td rowspan="6">MAGNITUDE</td><td>Major -</td><td colspan="4">Substantial deterioration or harm to receptors; receiving environment has an inherent value to stakeholders; receptors of impact are of conservation importance; or identified threshold often exceeded.</td></tr>
<tr><td>Moderate -</td><td colspan="4">Moderate/measurable deterioration or harm to receptors; receiving environment moderately sensitive; or identified threshold occasionally exceeded.</td></tr>
<tr><td>Minor -</td><td colspan="4">Minor deterioration (nuisance or minor deterioration) or harm to receptors; change to receiving environment not measurable; or identified threshold never exceeded.</td></tr>
<tr><td>Minor+</td><td colspan="4">Minor improvement; change not measurable; or threshold never exceeded.</td></tr>
<tr><td>Moderate+</td><td colspan="4">Moderate improvement; within or better than the threshold; or no observed reaction.</td></tr>
<tr><td>Major+</td><td colspan="4">Substantial improvement; within or better than the threshold; or favourable publicity.</td></tr>
<tr><td rowspan="3">SPATIAL SCALE</td><td>Site or local</td><td colspan="4">Site specific or confined to the immediate SR Area 1</td></tr>
<tr><td>Regional</td><td colspan="4">May be defined in various ways, e.g. cadastral, catchment, topographic</td></tr>
<tr><td>National/ International</td><td colspan="4">Nationally or beyond</td></tr>
<tr><td rowspan="3">DURATION</td><td>Short term</td><td colspan="4">Up to 18 months</td></tr>
<tr><td>Medium term</td><td colspan="4">18 months to 5 years</td></tr>
<tr><td>Long term</td><td colspan="4">Longer than 5 years</td></tr>
<tr><td colspan="6">PART B: DETERMINING CONSEQUENCE RATING
Rate consequence based on definition of magnitude, spatial extent and duration</td></tr>
<tr><td colspan="3" rowspan="2"></td><td colspan="3">SPATIAL SCALE/ POPULATION</td></tr>
<tr><td>Site or Local</td><td>Regional</td><td>National</td></tr>
<tr><td>MAGNITUDE</td><td colspan="5"></td></tr>
<tr><td rowspan="3">Minor</td><td rowspan="3">DURATION</td><td>Long term</td><td>Medium</td><td>Medium</td><td>High</td></tr>
<tr><td>Medium term</td><td>Low</td><td>Low</td><td>Medium</td></tr>
<tr><td>Short term</td><td>Low</td><td>Low</td><td>Medium</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td rowspan="3">Moderate</td><td rowspan="3">DURATION</td><td>Long term</td><td>Medium</td><td>High</td><td>High</td></tr>
<tr><td>Medium term</td><td>Medium</td><td>Medium</td><td>High</td></tr>
<tr><td>Short term</td><td>Low</td><td>Medium</td><td>Medium</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td rowspan="3">Major</td><td rowspan="3">DURATION</td><td>Long term</td><td>High</td><td>High</td><td>High</td></tr>
<tr><td>Medium term</td><td>Medium</td><td>Medium</td><td>High</td></tr>
<tr><td>Short term</td><td>Medium</td><td>Medium</td><td>High</td></tr>
<tr><td colspan="6">PART C: DETERMINING SIGNIFICANCE RATING
Rate significance based on consequence and probability</td></tr>
<tr><td colspan="3" rowspan="2"></td><td colspan="3">CONSEQUENCE</td></tr>
<tr><td>Low</td><td>Medium</td><td>High</td></tr>
<tr><td colspan="2" rowspan="3">PROBABILITY
(of exposure to impacts)</td><td>Definite</td><td>Medium</td><td>Medium</td><td>High</td></tr>
<tr><td>Possible</td><td>Low</td><td>Medium</td><td>High</td></tr>
<tr><td>Unlikely</td><td>Low</td><td>Low</td><td>Medium</td></tr>
</table>

10.2 Impact AQ1: Dust emissions during the operational phase

Dust generating activities associated with the operational phase activities include materials handling at Lanti, Gangama, and Nitti Port, vehicle entrainment of dust on the haul roads, windblown dust from the SR Area 1s as well as TSFs. Without management measures dust emissions will affect the immediate SR Area 1 and some of the villages to the southwest of Lanti and Gangama, but will decrease with distance away from the sources and in areas beyond the SR Area 1. Based on the dispersion modelling results, predicted dust (PM_{10}, and $PM_{2.5}$) concentrations without management are above the WB / IFC EHS Guideline values. The significance of the impact is considered to be high at specific receptors, in close proximity to the operational activities if unmitigated. With mitigation, the majority of villages will show reduced concentrations that are below the WB / IFC EHS Guideline values, except at Foinda which is in close proximity to the Lanti. The significance of the impact with management measures is considered low as the predicted concentrations at the sensitive receptors will not impact over a longer term but instead is considered to be a short-term impact.

Table 10-2: Impact AQ1 – Dust emission during the operational phase

Impact AQ1: Impact of dust during the operational phase								
Activity	Impact of dust							
Project Phase	Operational							
Potential impact rating	Magnitude	Duration	Scale	Consequence	Probability	SIGNIFICANCE	+ /-	Confidence
Before Management	Major -	Long Term	Site or Local	High	Definite	High	-	High
Management Measures: • Pave or treat road surfaces for ore delivery within the MSP to suppress dust entrained by vehicles. Surface treatment of roads should also be considered before and after a sensitive receptor; • Use dust suppression techniques such as wet suppression or chemical suppression (must be environmentally friendly and non-polluting) to reduce dust on roads that exhibit an increase of dust emitted from the entrainment of dust; • Design road alignments to minimise travel distances and eliminate unnecessary traffic; • Speed limits within the SR Area 1 should be adhered to for both treated haul roads and unpaved roads. Speed limits are 40km/hr for haul trucks; 60 km/hr for light vehicles, and 30 km/hr for all SRL vehicles through villages; • Where necessary, grass should be planted along the boundary of the TSFs to lower the possibility of wind erosion. Re-vegetate or turf long side walls of the TSF to stabilise surfaces where required. Grass types planted along the boundary should be endemic to the area. Grass species that are not endemic to the area should not be considered as growing the grass may cause adverse effects to the natural flora in the area; • Maintain the current management measure of cladding with laterite. As the TSFs increase in height, the current management measures should continue; • If possible, keep the area of the sand TSF to a minimum and increase the area of active portions (wet state) to reduce windblown dust from this source during the dry season. Where necessary, apply a surface binder ((through the use of water cannons) on the TSFs, if monitoring indicates that dust is an issue from this source; • Attend to dust control when loading trucks by minimising drop heights and prevention of over loading; • Limit load size to reduce spillage and cover final product loads with tarpaulins where needed; • When stockpiling ore, the design specification of equipment should be considered to determine a suitable drop height to control the fall of materials which will reduce dust emissions; and • Development and implementation of routine emissions and ambient air quality monitoring program to determine whether there are any significant increases in emissions and impacts at sensitive receptors.								
After Management	Minor -	Short Term	Site or Local	Low	Unlikely	Low	-	High

10.3 Impact AQ2: Dust emissions during the expansion phase

Dust generating activities associated with the expansion activities include materials handling at Lanti, Gangama, and Nitti, vehicle entrainment of dust on the haul road, windblown dust from the SR Area 1 as well as TSFs. As a result of the increase in throughput at Lanti and Gangama to 1,000 tph, there will be an increase in dust emissions. Similar to the operational phase without management measures, dust emissions will affect the immediate SR Area 1 and the villages to the southwest of Lanti and Gangama, but will decrease with distance away from the sources and in areas beyond the SR Area 1. The significance of the impact is considered to be high with no management measure in place, as the predicted dust (PM_{10}, and $PM_{2.5}$) concentrations will exceed the WB / IFC EHS Guideline values. The majority of villages will show reduced concentrations with management measures in place. In this scenario, the predicted concentrations will below the WB / IFC EHS Guideline values, except at Foinda which is in close proximity to the Lanti Mining Operations. The significance of the impact with management is considered low as the predicted concentrations will not impact over a longer term but a medium term. As some of the predicted concentrations lie slightly below the WB / IFC EHS Guideline values, an anomalous event may result in an exceedance at the closest sensitive receptors, hence rating the probability of an impact as possible.

Table 10-3: Impact AQ2 – Dust emission during the expansion phase

<table>
<tr><th colspan="10">Impact AQ2: Significance of impact of dust emissions during expansion phase</th></tr>
<tr><td>Activity</td><td colspan="9">Impact of dust from mining related activities</td></tr>
<tr><td>Project Phase</td><td colspan="9">Expansion phase</td></tr>
<tr><td>Potential impact rating</td><td>Magnitude</td><td>Duration</td><td>Scale</td><td>Consequence</td><td>Probability</td><td>SIGNIFICANCE</td><td>+ /-</td><td>Confidence</td></tr>
<tr><td>Before Management</td><td>Major -</td><td>Long Term</td><td>Site or Local</td><td>High</td><td>Definite</td><td>High</td><td>-</td><td>High</td></tr>
<tr><td colspan="10">Management Measures:
• Pave or treat road surfaces for ore delivery within the processing plant site to suppress dust entrained by vehicles. Surface treatment of roads should also be considered before and after a sensitive receptor;
• Use dust suppression techniques such as wet suppression or chemical suppression (must be environmentally friendly and non-polluting) to reduce dust on roads that exhibit an increase of dust emitted from the entrainment of dust;
• Design road alignments to minimise travel distances and eliminate unnecessary traffic;
• Speed limits within the SR Area 1 should be adhered to for both treated haul roads and unpaved roads. Speed limits are 40km/hr for haul trucks; 60 km/hr for light vehicles, and 30 km/hr for all SRL vehicles through villages;
• Where necessary, grass should be planted along the boundary of the TSFs to lower the possibility of wind erosion. Re-vegetate or turf long side walls of the TSF to stabilise surfaces where required. Grass types planted along the boundary should be endemic to the area. Grass species that are not endemic to the area should not be considered as growing the grass may cause adverse effects to the natural flora in the area;
• Maintain the current management measure of cladding with laterite. As the TSFs increase in height, the current management measures should continue;
• If possible, keep the area of the sand TSF to a minimum and increase the area of active portions (wet state) to reduce windblown dust from this source during the dry season. Where necessary, apply a surface binder ((through the use of water cannons) on the TSFs, if monitoring indicates that dust is an issue from this source;
• Attend to dust control when loading trucks by minimising drop heights and prevention of over loading;
• Limit load size to reduce spillage and cover final product loads with tarpaulins where needed;
• When stockpiling ore, the design specification of equipment should be considered to determine a suitable drop height to control the fall of materials which will reduce dust emissions; and
• Development and implementation of routine emissions and ambient air quality monitoring program to determine whether there are any significant increases in emissions and impacts at sensitive receptors.</td></tr>
<tr><td>After Management</td><td>Minor -</td><td>Medium Term</td><td>Site or Local</td><td>Low</td><td>Possible</td><td>Medium</td><td>-</td><td>High</td></tr>
</table>

10.4 Impact AQ3: Emissions from the Power Plant

The predicted 24 hour and annual dust and gaseous emissions from the dispersion model show that concentrations at the closest sensitive receptors are below the respective WB / IFC EHS Guideline values. The significance of the impact before and after management measures will be low.

Table 10-4: Impact AQ3: Impact of dust and gaseous emission from the Power Plant

Impact AQ3: Significance of impact of dust and gas emissions from the Power Plant								
Activity	Emissions from the Power Plant							
Project Phase	Operational							
Potential impact rating	Magnitude	Duration	Scale	Consequence	Probability	SIGNIFICANCE	+/-	Confidence
Before Management	Minor	Short Term	Site or Local	Low	Possible	Low	-	High
Management measures: • Regular maintenance will ensure that the abatement technology will continue to meet OEM specifications and acceptable international emissions standards; • Development and implementation of routine emissions and ambient air quality monitoring program to determine whether there are any significant increases in emissions and impacts at sensitive receptors; • Inline continuous monitors should be considered to monitor PM, SO_x and NO_x at the Power Plant. At least one round of stack emissions tests should be undertaken to determine if the legislated arsenic and lead parameters are present in the process.								
After Management	Minor	Short Term	Site or Local	Low	Unlikely	Low	-	High

10.5 Impact AQ4: Emissions from the dryers at the SRL MSP

The predicted 24 hour and annual dust and gaseous emissions from the SRL MSP dryers show that concentrations at the closest sensitive receptors are below the respective WB / IFC EHS Guideline values. The significance of the impact before and after management measures will be low.

Table 10-5: Impact – AQ4 – Impact of dust and gaseous emissions from the SRL MSP dryer

Impact AQ4: Significance of impact of dust and gas emissions from the SRL MSP dryer								
Activity	Emissions from the SRL MSP dryer							
Project Phase	Operational							
Potential impact rating	Magnitude	Duration	Scale	Consequence	Probability	SIGNIFICANCE	+/-	Confidence
Before Management	Minor	Short Term	Site or Local	Low	Unlikely	Low	-	High
Management measures: • Regular maintenance will ensure that the abatement technology will continue to meet OEM specifications and acceptable international emissions standards; • Development and implementation of routine emissions and ambient air quality monitoring program to determine whether there are any significant increases in emissions and impacts at sensitive receptors. • Inline continuous monitors should be considered to monitor PM, SO_x and NO_x at the SRL MSP dryers. At least one round of stack emissions tests should be undertaken to determine if the legislated arsenic and lead parameters are present in the process.								
After Management	Minor	Short Term	Site or Local	Low	Unlikely	Low	-	High

10.6 Impact AQ5: Emissions from the medical incinerators

The medical incinerators are operational twice week with predicted emissions showing that emissions are well below the respective WB / IFC EHS Guidelines. Due to the nature in which the combustion process occurs, gases from waste and diesel fuel are volatilised within the process. The predicted model results show that concentrations are low to negligible at the closes sensitive receptors. Hence the significance of the impacts are considered low before and after management measures in place.

Table 10-6: Impact AQ5: Impact of dust and gas emissions from the medical incinerator

Impact AQ5: Impact of dust and gas emissions from the medical incinerator								
Activity	Emissions from the medical incinerators							
Project Phase	Operational							
Potential impact rating	Magnitude	Duration	Scale	Consequence	Probability	SIGNIFICANCE	+ /-	Confidence
Before Management	Minor	Short Term	Site or local	Low	Unlikely	Low	-	High
Management measures: • Regular maintenance will ensure that the abatement technology will continue to meet OEM specifications and acceptable international emissions standards; • Development and implementation of routine emissions and ambient air quality monitoring program to determine whether there are any significant increases in emissions and impacts at sensitive receptors. • At least one round of stack emissions tests should be undertaken to determine if the legislated arsenic and lead parameters as well as dioxins and furans are present in the process.								
After Management	Minor	Short Term	Site or local	Low	Unlikely	Low	-	High

10.7 Emissions from the Decommissioning Phase and Closure Phase

During the decommissioning and closure phases it is expected that all infrastructure will be demolished and removed. The areas will be revegetated after the demolition activities, hence leading into a closure phase. It is anticipated that the decommissioning activities will be staggered and will likely take place in phases with rehabilitation measures implemented during each phase. The major dust generating sources during the decommissioning and closure phases will be windblown dust from open and bare areas, materials handling and vehicle entrainment of dust. It is expected that these sources will be emitting until all rehabilitation measures have been implemented. Once rehabilitation measures are implemented, the air quality will begin to improve gradually, and the impact of the rehabilitation phase will be positive. Continuous air quality monitoring during these phases will determine the improvement in air quality.

The impact is considered to of medium (negative) significance before management and medium (positive) significance after management.

Table 10-7: Impact AQ6: Impact of dust and gas emissions during the Decommissioning and Closure Phase

<table>
<tr><th colspan="10">Impact AQ6: Impact of dust and gas emissions during the Decommissioning and Closure Phases</th></tr>
<tr><td>Activity</td><td colspan="9">Emissions from the medical incinerators</td></tr>
<tr><td>Project Phase</td><td colspan="9">Decommissioning and Closure</td></tr>
<tr><td>Potential impact rating</td><td>Magnitude</td><td>Duration</td><td>Scale</td><td>Consequence</td><td>Probability</td><td>SIGNIFICANCE</td><td>+ /-</td><td>Confidence</td></tr>
<tr><td>Before Management</td><td>Moderate -</td><td>Long Term</td><td>Site or local</td><td>Medium</td><td>Possible</td><td>Medium</td><td>-</td><td>High</td></tr>
<tr><td colspan="10">Management measures:
• Demolish all infrastructure and establish vegetation on the footprint exposed by demolition activities.
• Given that there is a likely to be a topsoil short fall, topsoil will not be used as “blanket” cover material or as an amendment to change soil structure. However, the planting regime, which will be conducted by hand, will be to excavate holes for the trees and fill these with topsoil to act as an inoculum to the growth medium on the footprints under consideration. This will be undertaken in all areas where vegetation will be established.
• Non-mining roads will remain in the landscape, however, the mining roads will be subjected to the following:
– Those that have no community benefit will be rehabilitated; and
– Those that the community can utilize will remain. However, the plan is to only leave 50% of the current width of the road, with the other 50% rehabilitated and vegetation established.
• Borrow pits will be rehabilitated by reshaping the high walls and then establishing vegetation on the reshaped walls and borrow pit base.
• The pond retaining dams will be lowered, thereby lowering pond level. If the lowered dam is not stable, reshaping will be undertaken to reduce the downstream slope to 1:5. Sand tails will be deposited upstream of dam to further enhance stability. The remaining walls will be revegetated, and engineered spillways constructed. The exposed sand, sand/slimes and slimes will be revegetated. As the slimes has the potential to generate acidity, lime will be mixed into the profile, prior to vegetation. As the sand has poor water retention capacity, slimes will be added to a depth of two meters. Where necessary, reshaping of the material will occur to obtain a slope of 1:3 prior to adding amendments and vegetation establishment.
• The residues associated with dry mining are expected to have classified under gravity, leaving discrete sand, sand/slimes and slimes bodies requiring vegetation establishment. These will be rehabilitated in similar manner to the drained ponds.
• Slimes dams will be rehabilitated by the establishment of vegetation. As these have been exposed to wetting and drying cycles, there is no need to include lime prior to vegetation establishment.
• Dredge mining sand tailings will be amended by mixing slimes to a 2m depth to improve water retention capacity prior to the establishment of vegetation.
• SRL MSP tails will be rehabilitated in situ, if they are not processed during operations or at the end of LoM. This will involve the placement of cover material, prior to vegetation establishment. The exception is the high sulfide tails, will be excavated and moved to an area where the acidity can be leached from the tails. Once leached, the tails will be replaced in the excavated footprint, covered and vegetation established.
• All stockpiles at the various locations around the mine will be reprocessed through a dry mining primary concentrator.
• Dry mining pit high-walls will be reshaped to 1:6 and vegetation established on the high-walls. Residues placed back in the pits will be rehabilitated as above, depending on textural/geotechnical properties. Exposed footprints not under residue will be re-profiled, ripped and vegetation established.</td></tr>
<tr><td>After Management</td><td>Minor +</td><td>Long Term</td><td>Site or Local</td><td>Medium</td><td>Possible</td><td>Medium</td><td>+</td><td>High</td></tr>
</table>

10.8 Emissions from the Post Closure Phase

It is anticipated that the post closure period will take place over 5 years for the monitoring and maintenance period to demonstrate achievement of relinquishment criteria. With the rehabilitation plans expected to be put in place during the Closure Phase, it is envisaged that the impact will be positive and that the rehabilitation measures will improve the air quality within the SR Area 1. Table 10-9 rates the significance as of medium significance before and after management with a positive outcome.

Table 10-8: Impact of dust and gas emissions during the Post Closure Phase

Impact AQ7: Impact of dust and gas emissions during the Post Closure Phase								
Activity	Emissions from the medical incinerators							
Project Phase	Closure							
Potential impact rating	Magnitude	Duration	Scale	Consequence	Probability	SIGNIFICANCE	+ /-	Confidence
Before Management	Major +	Medium Term	Site or Local	Medium	Unlikely	Medium	+	High
Management measures: • Continuation of monitoring and maintenance procedures to ensure rehabilitation measures have been implemented adequately.								
After Management	Major +	Medium Term	Site or Local	Medium	Unlikely	Medium	+	High

11 Requirements for Further Studies

The continuation of the existing monitoring program to determine seasonal trends for dust and gas is required. Monitoring during operational and expansion phases will assist in the determination of the levels and extent of impacts associated with the mining operation. Depending on the impacted zones, the current monitoring locations may be relocated to better monitor the impacts during the expansion phase activities. However, it should be noted that additional dust monitoring points will be needed with the expanded footprint of the expansion phase, especially where sensitive receptors are likely to exist.

A stack emissions assessment should be undertaken on the Power Plant, SRL MSP dryers and Medical Incinerators to determine if the emissions from these sources meet supplier specifications.

12 Conclusions

Based on the findings of this assessment the following were concluded:

- According to the Koppen Climate Classification System, the study site is classified as a category “A” climate type which is characteristically hot and moist during summer and cool and dry in winter. Average temperatures associated with this classification are usually greater than 18ºC. Rainfall is usually above 1,500 mm per annum. The prevailing winds for the 3 period from January 2014 to December 2016 are from the southwest and west-southwest with lower occurrences from the south-southwest and west;
- The baseline air quality, as indicated through the available monitoring data, is a result of mine related activities, with contributions from the villages and surrounding activities, resulting in an existing cumulative impact;
- Dust fallout monitoring is currently being undertaken at SRL and began in July 2017. As the monitoring period falls in the wet season, the majority of dust fallout concentrations were below the Residential Area standard of 600 mg/m^2/day at the villages, except at SRLDM02 (September and November 2017) and Mogbwemo Village (November 2017). The dust fallout concentration for September is excluded as the material in the buckets were deemed to have been thrown in. The

Non-residential Area standard was not exceeded during the monitoring period. Dust fallout is expected to increase during the dry season;

- 24-hour PM_{10} concentrations exceeded the WB / IFC EHS Guideline value of 50 µg/m^3, 16 times during the monitoring period from 29 July 2017 to 31 December 2017. The average 24-hour PM_{10} concentrations also showed one exceedances of the WB / IFC EHS Guideline value, in December 2017;
- 24-hour $PM_{2.5}$ concentrations exceeded the WB / IFC EHS Guideline value of 25µg/m^3, 31 times during the monitoring period from 29 July 2017 to 31 December 2017. The average 24-hour $PM_{2.5}$ concentrations also showed one exceedances of the WB / IFC EHS Guideline value, in December 2017;
- A comparison of the PM_{10} and $PM_{2.5}$ data shows that $PM_{2.5}$ concentrations are at an average of 83% of PM_{10} concentrations. Hence the majority of PM_{10} is made up of particulates that are less than 2.5 microns;
- SO_2 and NO_2 monitoring indicated concentrations that were below the applicable WB / IFC EHS Guideline values for the month of July 2017;
- With respect to PM_{10} and $PM_{2.5}$ from the operational phase, the impact of dust emissions was determined to be high without management and low with management measures in place;
- Similarly, with respect to PM_{10} and $PM_{2.5}$ from the expansion phase, the impact of dust emissions was determined to be high without management and medium with management measures in place;
- The impact of the vehicle entrainment of dust from haul roads, on villages in close proximity to the haul roads, is high when no management measures are in place, however the predicted concentrations will decrease to below the WB / IFC EHS Guideline values once management measures are implemented;
- Dust and gaseous emissions from the Power Plant, SRL MSP dryer and medical incinerator are determined to be of low significance even without management measures in place;
- Human receptors are present in close proximity to the SR Area 1. Nearby villages and towns include Foinda, Moriba Town, Mogbewa and Mogbwemo amongst others. These villages and towns will be impacted by the mining operations, but dust and gas concentrations decrease substantially away from the mines operational activities, if management measures are implemented;
- Based on the impact ratings ranging from high to low, management measures are required especially during the dry season.

13 Recommendations

Based on the findings of the assessment undertaken by SRK the following management / mitigation measures are recommended:

- Maintain the current air monitoring network, making adjustments to accommodate the installation of new infrastructure as necessary, i.e. the addition of monitoring locations as activities expand;
- Stack emissions sampling should be undertaken at the Power Plant, SRL MSP dryer and medical incinerators and thereafter the models should be replicated using this data;
- The following key management measures should be considered as good practice to maintain low concentrations of dust and gas emissions within and around the SR Area 1:
  - SRL personnel should conduct quarterly site inspections in and around the mining operations and report observations on efficacy of ambient air quality monitoring and control actions;
  - Pave or treat road surfaces for ore delivery within the processing plant site to suppress dust entrained by vehicles. Surface treatment of roads should also be considered before and after a sensitive receptor;
  - Use dust suppression techniques such as wet suppression or chemical suppression to reduce dust on roads that exhibit an increase of dust emitted from the entrainment of dust;
  - Design road alignments to minimise travel distances and eliminate unnecessary traffic;
  - Speed limits within the SR Area 1 should be adhered to for both treated haul roads and unpaved roads. Speed limits are 40km/hr for haul trucks; 60 km/hr for light vehicles, and 30 km/hr for all SRL vehicles through villages;

- If practical, grass should be planted along the boundary of the TSFs to lower the possibility of wind erosion. Re-vegetate or turf long side walls of the TSF to stabilise surfaces where required. Grass types planted along the boundary should be endemic to the area. Grass species that are not endemic to the area should not be considered as growing the grass may cause adverse effects to the natural flora in the area;
- Maintain the current management measure of cladding with laterite. As the TSFs increase in height, the current management measures should continue;
- If possible, keep the area of the sand TSF to a minimum and increase the area of active portions (wet state) to reduce windblown dust from this source during the dry season. Were required, apply a surface binder ((through the use of water cannons) on the TSFs, if monitoring indicates that dust is an issue from this source;
- Attend to dust control when loading trucks by minimising drop heights and prevention of over loading;
- Limit load size to reduce spillage and cover final product loads with tarpaulins where necessary;
- When stockpiling ore, the design specification of equipment should be considered to determine a suitable drop height to control the fall of materials which will reduce dust emissions;
- Regular maintenance will ensure that the abatement technology will continue to meet OEM specifications and acceptable international emissions standards;
- Inline continuous monitors should be considered to monitor PM, SO_x and NO_x at the Power Plant and SRL MSP. At least one round of stack emissions tests should be undertaken to determine if arsenic and lead are present in the process.; and
- Development and implementation of routine emissions and ambient air quality monitoring program to determine whether there are any significant increases in emissions and impacts at sensitive receptors.

Prepared by

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All data used as source material plus the text, tables, figures, and attachments of this document have been reviewed and prepared in accordance with generally accepted professional engineering and environmental practices.

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Appendices

Appendix A: Dust and gas monitoring protocol

Dust and Gas Monitoring Protocol

Report Prepared for

Sierra Rutile Limited

Protocol Number 515234/1

Report Prepared by

August 2017

Dust and Gas Monitoring Protocol

Sierra Rutile Limited

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Disclaimer

The opinions expressed in this Report have been based on the information supplied to SRK Consulting (South Africa) (Pty) Ltd (SRK) by Sierra Rutile Limited (SRL). The opinions in this Report are provided in response to a specific request from SRL to do so. SRK has exercised all due care in reviewing the supplied information. Whilst SRK has compared key supplied data with expected values, the accuracy of the results and conclusions from the review are entirely reliant on the accuracy and completeness of the supplied data. SRK does not accept responsibility for any errors or omissions in the supplied information and does not accept any consequential liability arising from commercial decisions or actions resulting from them. Opinions presented in this report apply to the site conditions and features as they existed at the time of SRK's investigations, and those reasonably foreseeable. These opinions do not necessarily apply to conditions and features that may arise after the date of this Report, about which SRK had no prior knowledge nor had the opportunity to evaluate.

1 Introduction

These guidelines have been compiled by SRK Consulting South Africa (Pty) Ltd (SRK) and are intended for use by Sierra Rutile Limited. (SRL) for the monitoring of dust fallout, Particulate Matter (PM) (PM_{10} and $PM_{2.5}$) and gas (SO_2 and NO_2) at SRL's operations, *c*.131 km southeast of Freetown, Sierra Leone. The purpose of these guidelines is to ensure reproducible sampling by using techniques which are consistent and suitable to each site. The data so obtained can be confidently used to assess dust and gas levels in the receiving environment.

The guidelines are presented in terms of the following:

- Equipment.
- Monitoring installations.
- Procedures.
- Laboratory information.
- Quality Control.

1.1 Project location

The SRL project is located 131 km southeast of Freetown (capital city) in Sierra Leone (site co-ordinates: 7°45'59.10"N 12°17'38.63"W).

1.2 Objectives

The principle objective of this protocol is to provide guidance on establishing an ambient air quality monitoring network in and around the project area and subsequent collection of gas and dust fallout samples. Some of the specific objectives are to provide guidance on:

- Designing and establishing an air quality monitoring programme, measuring appropriate parameters such as dust fallout, particulate matter (PM_{10} and $PM_{2.5}$) and gas (SO_2 and NO_2).
- Collection of ambient air quality data for the proposed project.

2 Equipment

The following is a list of essential equipment required for the collection of samples. All items listed below must be packed prior to departure for the sample collection.

- This document.
- Site map/s.
- Fully charged laptop with the appropriate PM and weather station software loaded and data cables (only for PM and weather stations monitors).
- Radiello gas badges if gas monitoring is scheduled.
- Plastic sampling containers (e.g. dust buckets).
- Sampling stand (should have been installed).
- Pens/pencils/eraser.
- Padlocks and keys.
- Field logbook.
- Deionised water (or distilled or any available clean water without suspended solids).
- Sodium Hypochlorite/bleach (if required).
- A step ladder.

3 Contact Personnel

The key personnel who can be contacted in the event of any difficulties, emergencies or uncertainties are listed in Table 3-1 below:

Table 3-1: Key Personnel

Company	Person	Telephone	Email
SRL	Clovie Erasmus	+232 79997339	Clovie.Erasmus@iluka.com
SRL	Mohamed Kamara	N/A	mohamed.kamara@sierra-rutile.com
SRL	Anthony Amara	N/A	Anthony.amara@sierra-rutile.com
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4 Monitoring Locations

The dust and gas monitoring points are presented in Table 4-1 and 4-2 and in Figure 1. The decision to locate the monitoring points at the proposed locations was based on mine infrastructure, dust generating activities, receptors, etc. Security at the sampling locations has been considered and, wherever possible, access to the general public must be restricted.

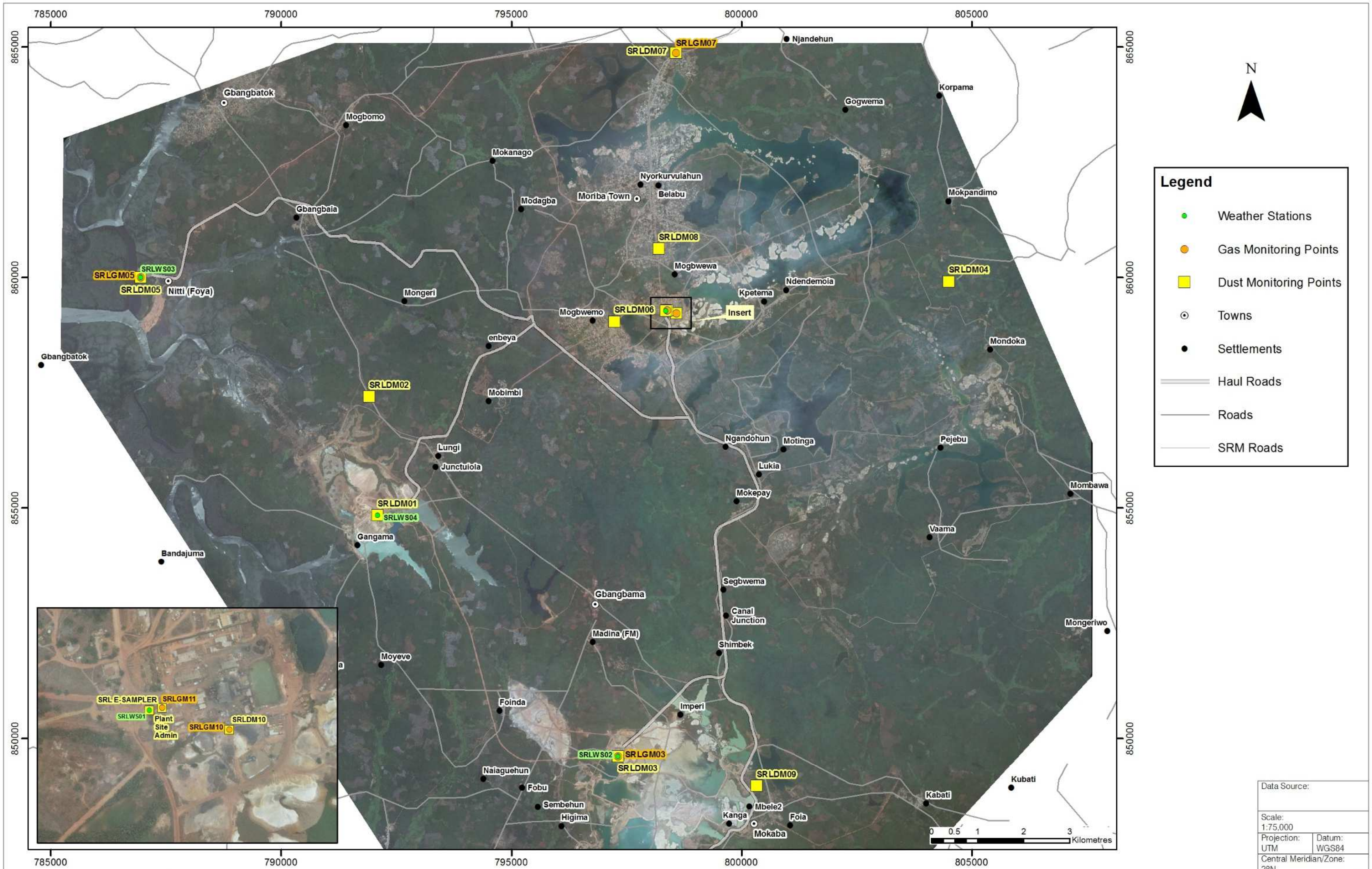
Table 4-1: Sampling locations for dust and gas monitoring at SRL

Field ID	Village/Area	Co-ordinates UTM	
SRLDM01[1]	Gangama MD2	792097	854837
SRLDM02	Semabu Village	791917	857409
SRLDM/GM03	Lanti MD 1	797319	849607
SRLDM	Mukaba Village	804497	859908
SRLDM/GM05	SRL Nitti Port	786957	860000
SRLDM06	Mogbwemo Village	797245	859043
SRLDM/GM07	Matagelema Village	798573	864867
SRLDM08	Moriba Town Police Station	798205	860620
SRLDM09	Yangatoke Village	800326	848958
SRLDM10/GM10	Plant Site MSP	798583	859223
SRLGM11	Plant Site Admin	798389	859286

[1] DM refers to Dust Monitor and GM refers to Gas Monitor

Table 4-2: Sampling locations for PM monitors and weather stations at SRL

Field ID	Village	Co-ordinates UTM	
SRLPM10	Plant Site Admin	798389	859286
SRLPM2.5	Plant Site Admin	798389	859286
SRLWS001	Plant Site Admin	798389	859286
SRLWS002	Lanti MD 1	797319	849607
SRLWS003	SRL Nitti Port	786957	860000
SRLWS004	Gangama MD2	792097	854837



Data Source:	
Scale: 1:75,000	
Projection: UTM	Datum: WGS84
Central Meridian/Zone: 28N	
Date: 18/08/2017	Compiled by: LOUA
Project No: 515234	Fig No: 1

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SIERRA RUTILE MINE

AIR QUALITY MONITORING LOCATIONS

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Revision: A Date: 00 00 2011

5 Installation and Sampling Methodologies

5.1 Dust fallout monitoring

5.1.1 Installation of dust monitors

The following instructions must be followed during installing of the dust monitors:

- Bolt the bucket holder to the pole.
- Select an appropriate monitoring point that is in an open and secure area (e.g. field or security hut, etc.).
- Dig a hole at the point selected (approximately 50 cm deep).
- Mix the amount of cement mix required and pour a portion into the hole.
- Place the pole and bucket holder into the hole, keeping as vertical as possible, and fill the hole with the remaining cement and soil.
- Label the bucket, for example, as "SRLDM01" (this depends on the site and location number).
- Place the bucket in the bucket holder and secure the bucket to the holder using the security clamps and key-alike lock.
- During the dry (wet) season pour 3.5 L (2.5 L) bottled/distilled or deionised water and 90 ml (60 ml) bleach/sodium hypochlorite solution into each bucket. NOTE: the bleach or hypochlorite is added to prevent bacterial and algal growth in the buckets. Chemicals such as bleach or hypochlorite should never be added to the buckets if chemical analysis of the dust is required.
- During the dry season, water levels in the buckets should be monitored and replenished if the buckets are dry or water levels have dropped by more than 50%. The regularity of the inspection will depend on the evaporation rate in the area.
- A photograph and GPS reading must be taken once the monitor has been installed.
- On the sampling schedule, record the bucket number, the date and time when the bucket was installed.

5.1.2 Preparation of sample containers for dust monitoring

Each point has a set of two containers, where one is installed and the second one is used as a replacement container at the end of each sampling period. The following instructions must be followed prior to departing for the field:

- Thoroughly rinse the containers and lids using detergent solution.
- Rinse the containers and lids twice with the water to be used as a medium for the dust collection.
- The cleaned replacement containers must be closed prior to departing for the field.

5.1.3 Sample Collection

Dust samples are generally collected at 30 day (± 2) intervals. The following steps must be followed during sample collection:

- Record the date and identification number of the container installed and the container being replaced in the field notebook (e.g. SRLDM01 or SRLDM02, etc.).
- Use the chair or ladder if the bucket is too high, ensuring that these are in good working condition and placed on the ground correctly.
- Unlock the padlock for the bucket holder and carefully remove the bucket taking care not to spill any of the contents.
- Inspect the contents of the bucket and note the condition of the bucket and the contents within the bucket (dust, foreign objects such as leaves, insects, etc.) in the field notebook.
- Remove large foreign objects, especially biological objects such as insects, birds, etc. as well as sticks, stones and leaves.

- Reseal this container using a lid and place in a cooler box or any other container that will be used to transport the samples.
- **Do not** discard any water present in the sample container when it is collected from the site. If sufficient rain has fallen at a site and the container is filled with water to the extent that it has overflowed, note this in the field notebook and seal the bucket as is for submission to the laboratory.
- Install the replacement bucket (ensuring that it contains sufficient water, and disinfectant solution if required) and lock the bucket holder.

5.1.4 Site records

The following site records must be kept:

- Records must be maintained and updated after every site visit to change the sample containers for each site.
- The site log sheet included in Appendix A must be completed during each site visit.
- Unusual events that emit large amounts of dust (particulate matter) in the vicinity of the site must be recorded. These could be meteorological conditions i.e. heavy rains, winds, fires. etc.
- Site photographs must be taken and if possible include photographs of the surrounding area and any significant event/s that may influence dust levels.
- A detailed description of the conditions in the surrounding area must be recorded and changes around the site must be noted over the duration of the sampling period. These changes could include the clearing of vegetation, construction activities, burning activities, etc.

5.1.5 Sample handling

The following procedures must be followed when handling the sample:

- Do not remove any material from within the containers.
- A log of containers being taken to the field and those containers returning from the field must be kept. The outgoing and incoming records must be reconciled immediately and any discrepancies investigated prior to the samples being dispatched to the laboratory.

5.1.6 Sampling frequency and duration

The following sampling frequencies and durations must be followed:

- For the purposes of this investigation, the dust sampling period shall be monthly (30 days $\pm$ 2 days).
- The sample buckets must be replaced on the 1st day or the first working day of every month as far as possible.
- No additional sample preservation is required. Ensure that the buckets are sealed immediately on site after the buckets are removed from the stands and the sample has being inspected.
- The sealed buckets must be dispatched to the laboratory for analysis (See Section 6).
- The samples must be dispatched on a monthly basis.
- A dust sampling schedule is presented in Appendix D.

5.2 PM Monitoring

5.2.1 Maintenance

The following maintenance schedule must be followed (Refer to section 3.3 in E-Sampler operations manual for more detail):

- A leak check must be done once every three months as per instructions in the E-sampler operation manual (Section 7.6 of E-Sampler Operation Manual).
- The inlet cleaning must be done on a monthly basis, and requires the use of compressed air, isopropyl alcohol, and a lint free cloth to clean the inlet head and cyclone (Section 3.3.4 of E-Sampler Operation Manual).

- Check purge filter and pump filter every two months for any blockages e.g. dust collection. The filters must be replaced if there are any blockages.
- If the flow rate falls below 2.0 LPM and the normal checks cannot correct the problem, contact the SRK Consulting contact persons detailed in Table 3-1 (this could indicate that the purge and/or pump filters are blocking; this is likely to occur in very dusty environments).

5.2.2 Data Download

The following method must be followed when downloading the data:

- Turn the monitor off or select stop sample. The pump would have stopped.
- Connect the downloading cable to the monitor and connect the USB to Serial cable adaptor to the downloading cable and the laptop.
- Should you have issues connecting the laptop and the PM monitors the following need to be looked at:
  - The software for the serial cable adaptor could be out of date and an upgrade to the software would be required;
  - The baud rate for the port should be set to 9600. This can be done through the communication port properties under Device Manager; and
  - Similarly once the baud rate is changed, click on the “Advanced” button on the same window and make sure the box for “Use FIFO buffers” is unchecked.
- Open the Comet software on the laptop and select the existing station which should be $SRLPM_{10}$_0001 or $SRLPM_{2.5}$_0001.
- On the left hand side of the Comet software window, click retrieve data and a smaller window should open up with four options; select data and new and then click retrieve.
- After this has been completed, download the settings and alarm files as per the description above.
- The data will be downloaded to a directory that has already been setup on the laptop and this data must be emailed to Mr. Dhiren Naidoo and copied to Mr. Bish Sahadeo of SRK.

5.2.3 Data Management

The hourly results obtained from the PM monitors will be downloaded on a monthly basis, at which point the data should be stored in a database for interpretation at a later stage.

5.2.4 Data Storage

The PM_{10} and $PM_{2.5}$ monitors can store data for at least 6 months after which the memory will have to be cleared. The steps below show the process for which data should be erased[2] from both the data logger and the alarm log.

- Step 1: On the monitor push the menu/select button.
- Step 2: Scroll down to “Memory” using the arrow keys and press select.
- Step 3: On the screen it will show Alarm Log, push the soft key on the left hand side under “Clear” to clear the alarm log. Select yes at the next prompt screen to clear the alarm log.
- Step 4: After clearing the Alarm Log, go back to the memory select screen and push the down arrow key which will select “Data Logger”. Follow step three to clear the data logger.
- Step 5: Once this has been completed the monitor will run for an additional six months before it has to be cleared.
- Return to the main screen and turn the monitor on.

[2] Erasing of data should only be done after the data has been sent to SRK and a backup is available on a local laptop or desktop computer.

5.3 Weather Station

5.3.1 Maintenance

The following maintenance schedule must be followed:

- The rain gauge bucket needs to be routinely checked to ensure no debris is prohibiting rain from flowing through to the sensor.
- The battery powering the solar panel needs to be checked every 6 months to ensure it is powering the panel.
- Should batteries be used in the weather station console, then these batteries would need to be replaced every 3-4 months. A detailed description is provided on Page 42 of the user manual.

5.3.2 Data Download

The following method must be followed when downloading the data:

- Connect the downloading cable to the laptop/desktop computer and thereafter open the weatherlink software.
- Click file, open weather station and thereafter downloading of data will begin.
- Once data is downloaded, click on the yellow notepad icon on the ribbon at the top. This will preview all of the data.
- Thereafter click on “Browse” (heading at the top of the program and then click on export records. Click on the month you use to download data for and thereafter click on “OK”. All data will downloaded to a directory on the laptop/computer.
- The data will be downloaded to a directory that has already been setup on the laptop and this data must be emailed to Mr. Dhiren Naidoo and copied to Mr. Bish Sahadeo of SRK.

5.3.3 Data Management

The weather results obtained from the weather stations will be downloaded on a monthly basis, at which point the data should be stored in a database for interpretation at a later stage.

5.4 Gas monitoring

5.4.1 Preparation of Radiello badges

The following should be noted with respect to preparation of the Radiello® badges:

- No preparation is needed (badges can be assembled in the field) (Table 5.1).
- Follow instructions (Appendix C) to assemble the badge.

5.4.2 Sampling frequency and duration

The following sampling frequencies and durations must be followed:

- The gas sampling duration is 24 hours, and samples must be collected 24 hours after installation.
- Assemble the shield and holder and attach to the dust bucket handle or any other part of the bucket holder.
- Open the cartridge holder, and carefully transfer the white cartridge into the blue holder, taking care not to touch the cartridge.
- Close the cartridge holder and attach to the bucket or bucket holder.
- The gas cartridge must be returned to the original vial marked with the sample location on the side of the vial. Do not touch or drop the cartridge when transferring back into the vial.
- Gas sampling should be undertaken on a quarterly basis e.g. August 2017, November 2017, February 2018, May 2018, etc.
- The start and end time and date must be recorded on the field sampling log sheet (See Appendix A).

- No sample preservation is required other than keeping the samples cool (out of direct sunlight).
- The gas samples can be transported to the laboratory (See Section 6 for details) as hand luggage or together with the dust samples.
- Record field conditions.
- A gas sampling schedule is presented in Appendix D.

Table 5-1: Equipment requirements for each gas sampled

Gas	Cartridge	Diffusive Body	Supporting Plate
SO_2 and NO_2	Chemi adsorbing cartridge code 166	Blue diffusive body code 120-1	Supporting plate code 121

6 Laboratory Services

For this baseline monitoring program, the gas and dust samples must be sent to M&L Laboratory Services (Pty) Ltd in Johannesburg, South Africa. A representative from SRL must package the samples with the necessary labelling and forwarding address and arrange for a courier to send the samples to the lab. A chain of custody form attached in Appendix B must be completed for each batch of samples and must be sent to the laboratory together with the samples. A copy of the form must be scanned and e-mailed to Mr. Dhiren Naidoo and cc to Mr. Bish Sahadeo from SRK.

Bureau Veritas M&L Laboratory Services

Ms. Allison Ackerman

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Ormonde

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Gauteng

South Africa

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The gas samples will be analysed for the specific gases based on the cartridges used i.e. SO_2 and NO_2, whilst the dust samples will undergo a gravimetric analysis. The results will be sent to Mr. Dhiren Naidoo and Mr. Bish Sahadeo from SRK via e-mail (dnaidoo@srk.co.za and bsahadeo@srk.co.za).

Should the gravimetric analysis for the dust fallout samples be undertaken at the in-house laboratory, then the following process should be followed:

Table 6-1: Gravimetric analysis procedure

Gravimetric Analysis Procedure	
Principle	A well-mixed sample is filtered through a pre-weighed filter paper, and the residue retained on the filter paper is dried to a constant weight at 103-105ºC. The increase in weight of the filter paper represents the dust fallout.
Scope	This test method applies to the measurement of dust in dust fallout samples.
Safety precautions	Wear safety gloves. Remove foreign objects such as bird droppings, sticks, stones, leaves, insects, animals or other unfamiliar foreign objects. Be cautious when transferring samples to and from hot ovens.
Sample preparation	Analyse samples as soon as possible after collection. If this is not possible, refrigerate at 4ºC (± 2ºC) to minimise microbiological decomposition. Samples containing bleach may be stored in a cool, dark place in the original containers, for example, dust buckets.
Interferences	Exclude large floating particles or submerged non-homogenous materials from the sample if it is determined that their inclusion is not desired in the final residue. This may include: sticks, stones, bird droppings, animals (insects, birds), branches, leaves or any other foreign object that does not constitute dust. THIS CAN BE DONE BY USING A SIEVE PROVIDED THE SIEVE DOES NOT HOLD BACK THE DUST PARTICLES. For samples high in Total Dissolved Solids (may be evident as crusting on the filter paper), thoroughly wash the filter to ensure the removal of dissolved material. Prolonged filtration times resulting from filter clogging may produce high results owing to increased colloidal materials captured on the clogged filter.
Apparatus	Glass fibre filter paper or equivalent Filtration apparatus including vacuum pump, Buchner flask and funnel. Desiccator, with a desiccant (silica gel) containing a colour indicator of moisture concentration. NOTE: AN ORANGE COLOUR INDICATES THAT THE SILICA BEADS CAN BE USED FOR DRYING PURPOSES. IF THE BEADS ARE BLUE, THIS INDICATES SATURATION WITH WATER – IN THIS CASE THE BEADS MUST BE DRIED AT 105ºC BEFORE USE, OR NEW BEADS CAN BE USED. Drying oven, for operation at 105ºC (± 2ºC). SWITCH ON THE DRYING OVEN TO ENSURE THAT IT REACHES THE REQUIRED TEMPERATURE BEFORE COMMENCING WITH ANY ANALYSES. Analytical balance, capable of weighing to 0.1mg and mass pieces for checking the operation of the balance. REMEMBER TO CHECK WHETHER THE BALANCE IS WORKING CORRECTLY BEFORE USE. DO THIS EVERY TIME THAT THE BALANCE IS USED. ENSURE THAT THE LEVEL BUBBLE IS IN THE CENTRE, THUS ENSURING THAT THE BALANCE IS LEVEL WEIGH THE CHECK MASSPIECES 0.5000g, 1.0000g AND 10.0000g AND RECORD THE MASSES ON THE EXCEL SPREADHSEET. THE MASSES MUST NOT BE GREATER THAN 10% OF THE EXPECTED MASS FOR EACH MASSPIECE.

Gravimetric Analysis Procedure	
	DO NOT MOVE OR BUMP THE BALANCE. CLOSE ALL BALANCE DOORS WHEN WEIGHING. WAIT FOR THE READING TO BE STABLE (MASS PIECES AND SAMPLES) BEFORE RECORDING THE MASS.
Reagents	De-ionised water
Method	
Preparation of filter paper	Using a permanent marking pen, label a filter paper with a unique identification number on the outside edge of the filter paper, for example, DM01, DM02, etc. Insert the filter paper with wrinkled side up into filtration apparatus. USE A TWEEZER, however be careful not to pierce the filter paper. Wet the filter paper with some deionised water. Connect the vacuum pump. Wash the filter paper with 100mL de-ionised water while applying a vacuum. THE VACUUM MUST NOT BE SO STRONG THAT IT CAUSES THE FILTER PAPER TO BREAK. Place the filter paper on a watch glass and dry in an oven at 105ºC (103-107ºC) for 1 hour. Cool in a desiccator for 1 hour and weigh on the balance before use. Record the mass (M1) of the filter paper on the Excel spreadsheet provided. A BATCH OF FILTER PAPERS CAN BE PREPARED AS ABOVE PRIOR TO ANALYSIS. THE FILTER PAPERS CAN BE STORED IN A DESSICATOR.
Measurement	Place the pre-weighed filter paper in the Buchner funnel. Wet the filter paper with a small volume of de-ionised water and apply a vacuum. THE VACUUM MUST NOT BE SO STRONG THAT IT CAUSES THE FILTER PAPER TO BREAK. Filter the sample from the sampling bucket through the SIEVE into a clean bucket so that all foreign objects will be excluded from the sample. Rinse the sample bucker well with deionised water and add the washing into the collection bucket. Filter the sample in the collection bucket through the filter paper while the vacuum is on. Rinse the bucket a few times with de-ionised water and filter the contents through the same filter paper after each rinse. Do this until there is no more dust in the bucket. Continue suction/vacuum until complete drainage has occurred, that is, the filter paper and sample on the paper looks dry and no water is dripping into the flask. Switch the vacuum off. Release the vacuum by removing the tube connected to the Buchner flask. Carefully remove the filter paper using a tweezer and place the filter paper onto a watch glass. Label the watch glass with the same number as the filter paper label, for example, DM01, DM02, etc. Carry out the above procedure for all the dust samples.

Gravimetric Analysis Procedure	
	When all samples have been filtered, place the watch glasses with the filter papers into the drying oven. Close the oven door. Wait until the temperature in the oven records105ºC (+ 2ºC) and record the temperature on the Excel spreadsheet. Dry the filter papers for 2 hours at 105ºC (+ 2ºC) in the oven. After 2 hours, very carefully remove the watch glasses with the filter paper from the oven and immediately place in the dessicator. Cool in the desiccator for 1 to 2 hours. Remove the filter paper and watch glass from the dessicator. WEIGH ONLY THE FILTER PAPER BY PLACING ON THE BALANCE, CLOSE ALL THE BALANCE DOORS AND NOTE THE MASS OF THE FILTER PAPER CONTAINING THE SAMPLE. Record the mass (M2) of the filter paper on the Excel spreadsheet.
Results	Calculate the mass of the dust on the filter paper by using the following formula. Mass of dust = M2 – M1 Where: M1 = mass of filter paper before filtration M2 = mass of filter paper after filtration (i.e. with sample)
Reporting	Express results as g (g). If the results are required in milligrams (mg), then multiply the result by 1000.
References	Standard Methods for the Examination of Water and Wastewater, Clesceri, Greenberg, Eaton, 20th Edition, 1998, Method 2540D, Page 2-57 to 2-58

7 Calculation

The following steps must be followed:

Calculate the deposition rate D in grams/m^2 (g/m^2):

$$D = \left(\frac{W}{A}\right) \mathrm{gm}^{-2}$$

Where: D – Deposition rate;

W – Total mass of particulate matter (soluble and insoluble); and

A – Cross sectional area of the inside diameter of the top of the sampling container.

Should the user need to determine the daily rate of deposition then the deposition rate D from above needs to be divided by the number of days that the dust monitor has been exposed to the atmosphere; and

To obtain a monthly rate of deposition the daily rate of deposition needs to be multiplied by 30 days to give a deposition rate in grams/m^2/month (g/m^2/month).

Prepared by

D. Naidoo (Pr.Sci.Nat)

Senior Scientist

Reviewed by

V.S. Reddy (Pr.Sci.Nat)

Partner

All data used as source material plus the text, tables, figures, and attachments of this document have been reviewed and prepared in accordance with generally accepted professional engineering and environmental practices.

8 References

ASTM Designation: D1739 – 94, Standard Method for Collection and Measurement of Dustfall.

Metone, 2011. E-sampler Particulate Monitor Operation Manual, Revision J.

Davis Instruments, User Manual for Vantage Pro 2

Appendices

Appendix A: Field Log Sheets

DUST MONITORING FIELD LOGSHEET				srk consulting
Client: SRL				Project Name:
Site:				
Sample ID	Installation Date	Removal Date	Samplers Name	Observations/Comments
SRLDM01				
SRLDM02				
SRLDM03				
SRLDM04				
SRLDM05				
SRLDM06				
SRLDM07				
SRLDM08				
SRLDM09				
SRLDM10				

GAS MONITORING FIELD LOGSHEET						srk consulting	
Client: SRL						Project Name:	
Site:							
Sample ID	Barcode Label	Installation Date	Time Installed	Removal Date	Time Removed	Samplers Name	Observations/Comments
SRLGM03							
SRLGM05							
SRLGM07							
SRLGM10							
SRLGM11							

Appendix B: Chain of Custody

CHAIN OF CUSTODY RECORD AND ANALYTICAL REQUEST FOR DUST FALLOUT

Project No: 515234	Analytical Lab.: M&L Contact: Alison Ackerman Alison.ackerman@za.bureauveritas.co.za E-mail address: dnaidoo@srk.co.za or bsahadeo@srk.co.za			Matrix Type			TYPE OF ANALYSIS					SAMPLE PRESERVATION	SAMPLE CONTAINER	SAMPLER	ANALYTICAL LABORATORY TO RETAIN COPY
				DUST FALLOUT			Gravimetric Dust Analysis								
Sample Date			Sample ID												COMMENTS
Day	Month	Year													
			SRLDM01	x			x					None	Bucket		
			SRLDM02	x			x					None	Bucket		
			SRLDM03	x			x					None	Bucket		
			SRLDM04	x			x					None	Bucket		Please sign and fax to (031) 279 1204 for attention Dhiren Naidoo
			SRLDM05	x			x					None	Bucket		
			SRLDM06	x			x					None	Bucket		
			SRLDM07	x			x					None	Bucket		
			SRLDM08	x			x					None	Bucket		
			SRLDM09	x			x					None	Bucket		srk consulting
			SRLDM10	x			x					None	Bucket		

Relinquished by Signature:	Date	Time	Received by Signature:	Date	Time	RECEIVED FOR LABORATORY BY: SIGNATURE:
Relinquished by Name:			Received by Name:			CUSTODY SEAL INTACT: YES/NO
Relinquished by Signature:			Received by Signature:			RECEIVING LABORATORY TO SIGN CHAIN OF CUSTODY RECORD AND FAX TO CLIENT

CHAIN OF CUSTODY RECORD AND ANALYTICAL REQUEST FOR GAS ANALYSIS

Project No: 515234			Analytical Lab.: M&L Contact: Alison Ackerman alison.ackerman@za.bureauveritas.com SRK e-mail address: dnaidoo@srk.co.za or bsahadeo@srk.co.za		Matrix Type			TYPE OF ANALYSIS					SAMPLE PRESERVATION	SAMPLE CONTAINER	SAMPLER	ANALYTICAL LABORATORY TO RETAIN COPY
					SO_2 and NO_2			Analyze for SO_2 and NO_2								
Sample Date			Sample ID	Barcode ID												COMMENTS:
Day	Month	Year														
			SRLGM03		x			x								Please sign and fax to (031) 279 1204 for attention Dhiren Naidoo
			SRLGM05		x			x								
			SRLGM07		x			x								
			SRLGM10		x			x								
			SRLGM11		x			x								

Relinquished by Signature:	Date	Time	Received by Signature:	Date	Time	RECEIVED FOR LABORATORY BY: SIGNATURE:
Relinquished by Name:			Received by Name:			CUSTODY SEAL INTACT: YES/NO
Relinquished by Signature:			Received by Signature:			RECEIVING LABORATORY TO SIGN CHAIN OF CUSTODY RECORD AND FAX TO CLIENT

Appendix C: Radiello Instruction Form

how to use *radiello*

before sampling

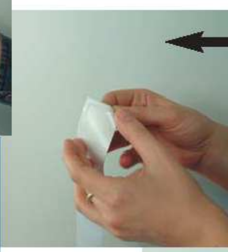
assembling the supporting plate

Before using ***radiello***, you have to assemble the supporting plate with the clip, necessary to suspend it, and the adhesive label pocket.

(1) insert the clip strip in the slot, with the peg facing upwards

(2) ply the strip and insert the peg into the hole

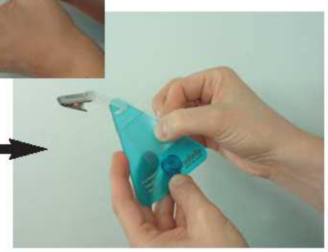
(3) peel off the transparent pocket



user tip

assemble the supporting plate in your laboratory before the sampling campaign: on the field they are uselessly time-consuming.

(4) and stick it onto the plate in a central position;



if you prefer, the pocket can be applied to the rear of the plate, but BE CAREFUL, always with the label insertion slot on the side (otherwise, if it starts raining the label can get wet)

on-field

to start the sampling

(1) open the plastic bag, draw the cartridge out from the tube and put it in the diffusive body. ***Keep the glass or the plastic tube and stopper in the original plastic bag.***

The lower part of the diffusive body holds a seat for the central positioning of the cartridge. **A correctly centered cartridge should not stick out even by half a millimeter. If it is not so, the cartridge is not correctly positioned and is out of axis.**

As a consequence, when the diffusive body is screwed onto the supporting plate the cartridge is bent, the geometry of the sampler is disturbed and the results obtained become unreliable.

To place the cartridge centrally you need only to tap on the diffusive body.

(2) keeping the diffusive body in a vertical position, screw it onto the supporting plate

BE CAREFUL: do not hold the diffusive body horizontally when you screw it onto the plate, otherwise the cartridge could come out from its seat and stick out.

user tip

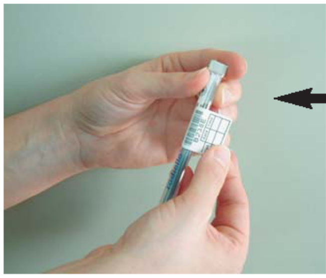
Do not touch the cartridge with your fingers if possible, particularly if it is impregnated with reactive

(3) Insert a label in the pocket without peeling it off. Keep note of the date and time and expose ***radiello***. Sampling has started.

user tip

even if you can write date and time of the sampling start and end on the adhesive label, we suggest you to keep note of these parameters also separately: after a week exposure with bad weather conditions, your writings could become illegible!

DO NOT USE MARKING PENS to write on the label: they contain solvents that are sampled by ***radiello***!



after the sampling

Keep note of the date and time of the end of exposure.

4 Place the cartridge into the tube, peel off the label and stick it onto the tube **such that the barcode is parallel to the axis of the tube**.

If you have performed the sampling of different polluting compounds at the same time, ***BE CAREFUL NOT TO MIX UP THE TUBES***: place the exposed cartridge in its original tube, identified by the code printed on the plastic bag.

IMPORTANT

Always stick the label such that the barcode is parallel to the axis of the tube: any other position will compromise the barcode automated reading by the optic reading device.

radiello maintenance

When exposed outdoors or in a workplace environment, the diffusive body may get dirty from airborne dust. Fine particles (PM_{10}) are especially harmful to yellow diffusive bodies since they can obstruct the pores. When the diffusive bodies are dirty you can wash them as follows.

Immerse the diffusive bodies in a beaker with a soapy solution (e.g. dish detergent) and sonicate them for 20 minutes. As the diffusive bodies float, you may make them sink by putting a smaller beaker on them, with water inside enough to dip it a few centimeters.

Rinse the diffusive bodies with plenty of water and then deionized water; let them finally dry in the air.

IMPORTANT: NEVER USE SOLVENTS TO CLEAN THE DIFFUSIVE BODIES!!!

After four or five washings, diffusive bodies need replacing: repeatedly adsorbed dust may have penetrated the pores such deeply to be undisturbed by washing.

The following table shows the advised washing schedule:

PM_{10} concentration ($\mu g \cdot m^{-3}$)	<30	40	>50
Washing after days of exposure	45	30	15

Appendix D: Sampling Schedule

Dust Monitoring Sampling Schedule

Dust fallout, PM_{10}, $PM_{2.5}$ and weather stations					
Sampling Event	**Start Date**	**End Date**	**Sampling Month**	**No. of Days**	**Completed**
1	27-28/07/2017	31/08/2017	August 2017	35	
2	31/08/2017	30/09/2017	September 2017	30	
3	30/09/2017	31/10/2017	October 2017	31	
4	31/10/2017	30/11/20117	November 2017	30	
5	30/11/20117	31/12/2017	December 2017	31	
6	31/12/2017	30/01/2018	January 2018	31	
7	30/01/2018	28/02/2018	February 2018	30	
8	28/02/2018	31/03/2018	March 2018	29	
9	31/03/2018	30/04/2018	April 2018	30	
10	30/04/2018	31/05/2018	May 2018	31	
11	31/05/2018	30/06/2018	June 2018	30	
12	30/06/2018	31/07/2018	July 2018	31	

NB: Dust Sampling may be completed 2 days prior or 2 days after the proposed dates.

Gas Monitoring Sampling Schedule

Gas Sampling Schedule				
Start Date	**End Date**	**Month**	**Year**	**Completed**
27/07/2017	11/08/2017	July	2017	✔
16/11/2017	30/11/20117	November	2017	
14/02/2018	28/02/2018	February	2018	
17/05/2018	31/05/2018	May	2018	

NB: Gas sampling should coincide with the dust sampling dates if possible.

Appendix B: Laboratory Certificates

M and L Laboratory Services (Pty) Ltd
Reg No. 1974/001476/07 VAT No. 478013505
P O Box 82124
Southdale, 2135
40 Modulus Road
Ormonde, 2091
T: +27 11 661 7900
F: +27 11 496 2238
E: joanne.barton@za.bureauveritas.com
W: www.bureauveritas.com

M&L LABS

Certificate/Report

RESULTS REPORTED RELATED ONLY TO ITEMS TESTED

Ref No. : 10347659

Issued at : Johannesburg

Date : 06/09/2017

COMPANY NAME	:	SRK CONSULTING – DURBAN
ADDRESS	:	PO BOX 1969, WESTVILLE, 3630
SUBJECT	:	ANALYSIS OF 5 RADIELLO TUBES
MARKED	:	AS BELOW
INSTRUCTED BY	:	DHIREN NAIDOO
ORDER NO	:	N/A
RECEIVED ON	:	08/08/2017
LAB NO(S)	:	H04346-H04350
DATE ANALYSED	:	22/08/2017

Test: Gases for SO_2 and NO_2

Test Ref.: Radiello Method

Results: µg/sample

SAMPLE MARKS	Nitrogen Dioxide NO_2	Sulfur Dioxide SO_2
SRLGM03	0.55	<0.27
SRLGM05	0.40	0.55
SRLGM07	0.45	<0.27
SRLGM10	0.50	<0.27
SRLGM11	0.55	<0.27

B.D.L. = Below Detection Limit
NO_2 = 0.35 µg/sample
SO_2 = 0.27µg/sample

Note: The results were supplied by a sub contracted laboratory

ALISON ACKERMAN
OPERATIONAL MANAGER

Authorised Signature (original blue ink)

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Appendix C: Quantification of Emissions

Quantification of Emissions

Data used in the modelling of emissions should ideally come from source-specific emission tests or continuous emission monitors. However, in the case of the proposed development such data were not available. Emission factors were therefore used in this case, as they are the best surrogate measure available for quantifying emissions. In order to calculate emission rates information regarding the site activities and processes used to calculate the rates of emission from the emission factors.

In this case, the US-EPA in its AP-42 document, “Compilation of Air Pollution Emission Factors” was used. The AP-42 emission factors are the most widely used in the field of air pollution, and are regularly subjected to revision and review as more effective modelling techniques are developed. Empirically derived, predictive emission factor equations are available for dust entrained by vehicles from both paved and unpaved roads, material handling operations and industrial wind erosion.

The impact of fugitive dust on air quality depends to a large extent on the drift potential of the particles. The drift potential of particles depends in turn on the initial height of the emission, the terminal settling velocity of the particle (which in turn is a function of the particle diameter) and the degree of atmospheric turbulence. Larger dust particles tend to settle out near the source, creating a local nuisance problem, whereas finer particles are more likely to be dispersed over greater distances, since their settling rate is retarded by atmospheric turbulence. Predictive emission factor equations allow for the estimation of emissions for particular particle size ranges, i.e. PM_{10}, $PM_{2.5}$ and TSP (US-EPA, 2000).

Dust Entrainment from Road Surfaces

Vehicle-entrainment from unpaved roadways has frequently been found to represent one of the largest sources of fugitive dust emissions at sites. The force of the wheels of vehicles travelling on unpaved roadways causes the pulverisation of surface material. Particles are lifted and dropped from the rotating wheels, and the road surface is exposed to strong air currents in turbulent shear with the surface. The turbulent wake behind the vehicle continues to act on the road surface after the vehicle has passed. The quantity of dust emissions from unpaved roads varies linearly with the volume of traffic.

In addition to traffic volumes, emissions also depend on a number of parameters, which characterise the condition of a particular road and the associated vehicle traffic. Such parameters include average vehicle speed, mean vehicle weight, average number of wheels per vehicle, road surface texture, and road surface moisture (US-EPA, 2000). These parameters have been assigned values based on reference values listed in the US-EPA AP-42 emission factor inventory.

The extent of particulate emissions from unpaved roads is a function of the silt content present on the road surface. The measurement of silt content was not undertaken for this study as they require very specific sampling techniques. In the absence of site specific silt content measurement in road dust, a silt load content of 8.3 percent was used as it is the typical mean silt content, given by Airchief, for a haul road which runs to or from a pit.

To quantify emissions from unpaved industrial haul roads, the following equation is used:

$$E = k\left(\frac{sL}{12}\right)^{a}\left(\frac{W}{3}\right)^{b} x281.9 \qquad \text{(Equation 1)}$$

where,

E = emissions in grams of particulates per vehicle kilometre travelled (g/VKT)

k = particle size multiplier (1.5 for PM_{10}, 4.9 for TSP and 0.15 for $PM_{2.5}$) (dimensionless)

a = empirical constant (0.9 for PM_{10} and $PM_{2.5}$, 0.7 for TSP)

b = empirical constant (0.45 for PM_{10}, $PM_{2.5}$ and TSP)

sL = silt content of road surface material (percent)

W = mean vehicle weight (tonnes)

According to the US EPA (US EPA, 2005) for publicly accessible roads where light vehicles dominate the vehicle population, vehicle speed and moisture content are important factors in controlling dust emissions whereas on industrial roads (dominated by heavy vehicles travelling at low speeds) vehicle weight controls dust emission loads.

Wind erosion

Dust emissions due to the surface erosion of open stockpiles and exposed tailings areas occur when the threshold wind speed is exceeded (US-EPA 1992). The threshold friction velocity is defined as the minimum wind velocity that is required to initiate particle motion. It is influenced by the particle size and wind shear stress on the surface (Figure B.1). Small particles, with a diameter less than 60 microns (µm), form strong cohesion forces between other particles; therefore a higher threshold friction velocity exists. Larger particles, with a diameter greater than 60 microns, experience a trend where the threshold friction velocity decreases as the diameter of the particle decreases.

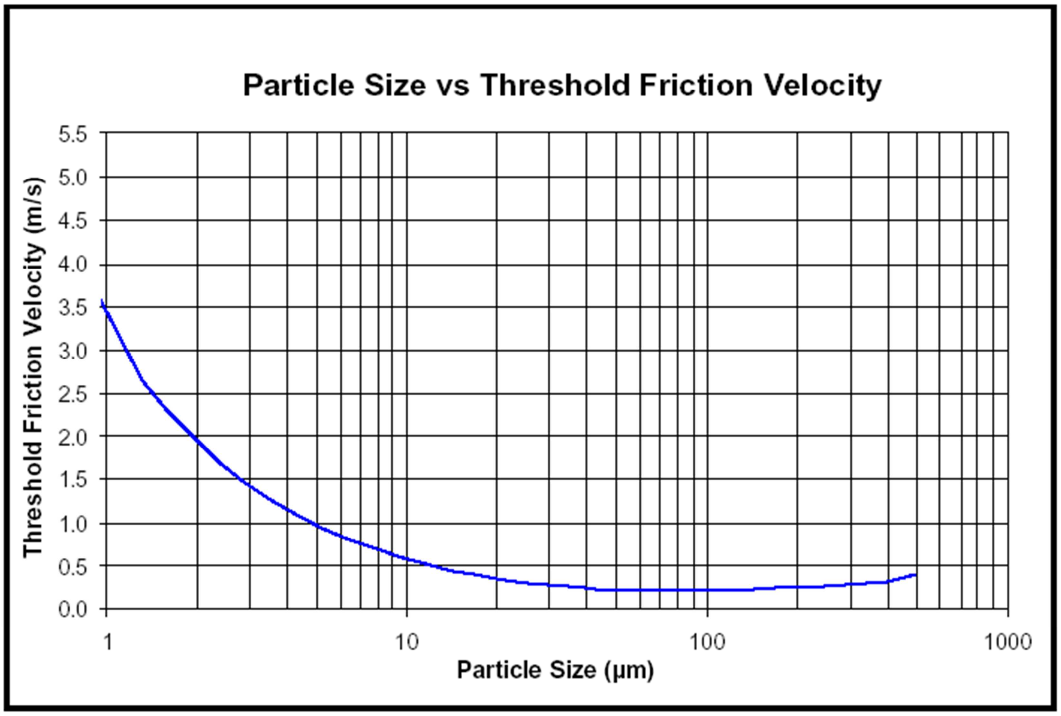


Figure B.1: Relationship between particle sizes and threshold friction velocities (Source: Airshed 2006)

Field testing of exposed materials using a portable wind tunnel (EPA, 2000) has shown that:

- Threshold wind speeds exceed 5 ms^{-1} at 15 cm above the surface or 10 ms^{-1} at 7 m above the surface; and
- Particulate emission rates tend to decay rapidly (half-life of a few minutes) during an erosion event. In other words, these aggregate material surfaces are characterised by finite availability of erodible material (mass/area) referred to as the erosion potential. Any natural crusting of the surface binds the erodible material, thereby reducing the erosion potential.

If typical values for threshold wind speed at 15 cm are corrected to typical wind sensor heights (i.e. 7 – 10m) then the resultant wind speeds exceed the upper extremes of mean hourly wind speeds. In other words, the mean hourly wind speeds are not sufficient to sustain wind erosion from flat surfaces of the types tested. However, wind gusts may quickly deplete a substantial portion of the erosion potential. Since erosion potential has been found to increase rapidly with increasing wind speed, estimating emissions should be related to gusts of highest magnitude (US-EPA, 2000).

It is anticipated that significant amounts of dust will be eroded from the dry sections of the tailings dam or waste rock stockpile at wind speeds greater than 8.3 ms^{-1} (i.e. standard threshold friction velocity of 8.3 ms^{-1}). Fugitive dust generation resulting from wind erosion under high winds (i.e. > 5.4 ms^{-1}) is directly proportional to the wind speed. The erosion potential function for a dry, exposed surface is given as:

$$P = 58(u^* - u_t^*)^2 + 25(u^* - u_t^*)$$ (Equation 2)

where,

P = Erosion potential for a dry, exposed surface

u* = Friction velocity (m/s)

u^*_t = Threshold friction velocity (m/s)

The threshold friction velocity (u^*_t) was taken to be 1.02 m/s, which is the figure presented by Airchief for overburden. The friction velocity (u*) is calculated using the following equation:

$$u^* = 0.053(u_{10}^+) \qquad \text{(Equation 3)}$$

where,

u* = Friction velocity (m/s)

u^+_{10} = Fastest mile (m/s) at 10 m for period between disturbances

The emission factor for wind generated particulate emissions from mixtures of erodible and non-erodible surface material subject to disturbance may be expressed in units of grams per square meter (g/m^2) per year as follows:

$$E = k\sum_{i=1}^{N} P_i \qquad \text{(Equation 4)}$$

where,

k = Particle size multiplier

N = Number of disturbances per year

P = Erosion potential for a dry, exposed surface

In calculating emission factors, each area of an erodible surface that is subjected to a different frequency of disturbance should be treated separately. This equation only applies to dry, exposed material with limited erosion potential i.e. sidewall and the top of the tailings dam. For top surface of the tailings dam the entire open area was not modelled as only a portion of the exposed open area is vulnerable to wind erosion. Therefore 43 percent of the open area and tailings dams were modelled for baseline conditions, while 30 percent of the tailings dams were modelled during the operational phase when the major portion of the tailings dam is submerged under water.

Figure B.2 shows a conical and an oval shaped pile with a flat top and a 37 degree side slope as used in wind tunnel tests by the US EPA. The contours show the areas across the stockpiles that possess the same $\left(\frac{Us}{Ur}\right)$ ratio, which were grouped together in order to calculate the emission load. The red and yellow areas with a $\left(\frac{Us}{Ur}\right)$ ratio, of 1.1 and 0.9 respectively denote the areas of highest erosion potential in stockpiles, while the green (0.2) and blue (0.6) areas have the lowest erosion potential. Round stockpiles have lower erosion potential than oval stockpiles as indicated in Figure B.2.

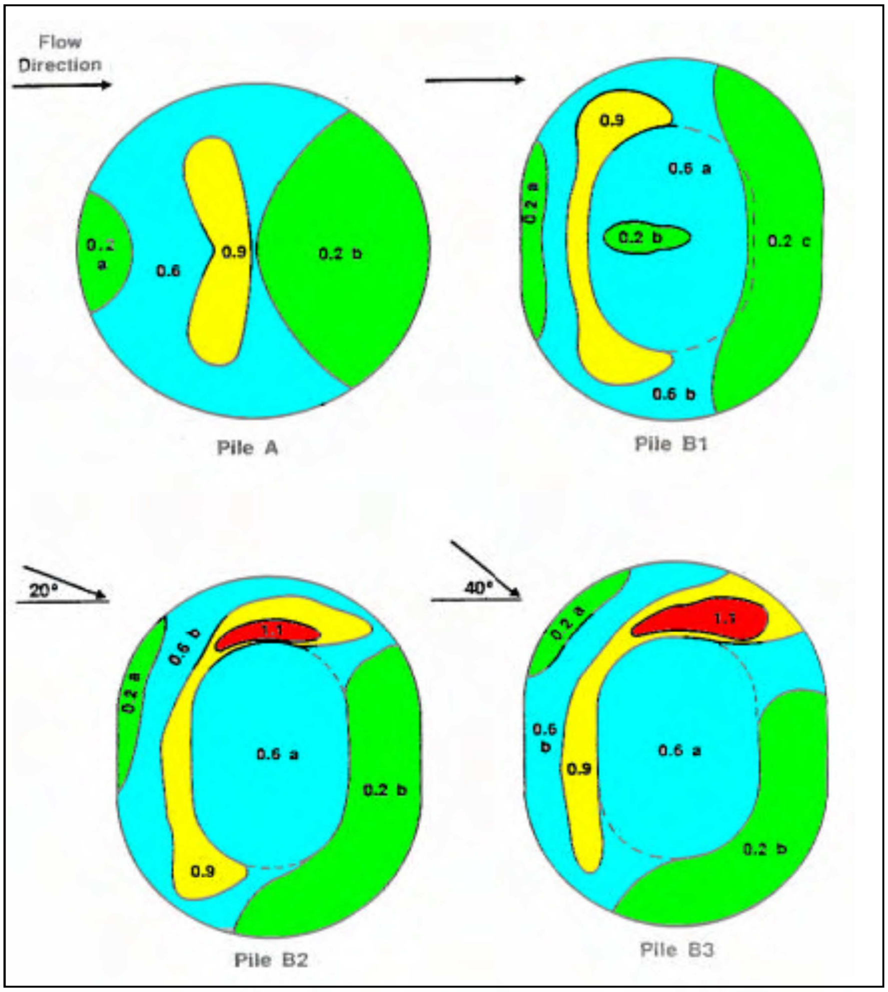


Figure B 2: Contours of normalised surface wind speeds (surface wind speed (Us) / approach wind speed (Ur)) (Source: USEPA, 2005)

Materials Handling

$$E = kx0.0016\frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}} \text{ (kg/ton)} \qquad \text{(Equation 5)}$$

Where,

E = Total PM_{10} Emissions (kg of dust / tonne transferred)

k = Particle size multiplier (0.35 for PM_{10} and 0.74 for TSP) (dimensionless)

U = mean wind speed (m/s)

M = moisture content of ore (%)

The value 0.0016 is a constant and 0.35 is the particle size multiplier for PM_{10}. The calculation of Total Suspended Particulates (TSP) dust emissions requires that the constant be multiplied by the TSP multiplier of 0.74 and for $PM_{2.5}$ the multiplier is 0.053. The particle size multiplier accounts for the varying physical and chemical characteristics associated with PM_{10}, TSP and $PM_{2.5}$. It should be noted that, whilst generic emission factors are available, Equation 4 was used to develop site specific emission factors to take account of site specific wind speeds and moisture content.

Appendix D: Detailed modelling results

Current Operations				
Village Name	**PM10_unmit**	**PM10_unmit_annual**	**PM10_mit**	**PM10_mit_annual**
Foinda	814.9	133.3	129.9	21.5
Nyandehun	232.2	41.7	45.2	8.5
Teso	166.4	17.5	27.7	3.1
Kpetema	131.9	24.4	24.4	4.6
Junctiola	119.3	18.8	21.3	4.0
Mokaba	109.7	9.8	20.3	2.0
Yangatoke	109.2	14.0	19.1	2.8
Nitti Port	99.9	11.3	18.0	2.4
Victoria	92.6	15.8	16.7	2.9
Gbamgbama	80.8	9.3	14.1	1.9
Semabu	73.7	8.4	12.7	1.8
Mobimbi	68.5	12.0	18.9	4.3
Ndendomoia	66.6	11.2	12.4	2.2
Mokepay	59.9	11.8	20.1	4.4
Mogbwemo	58.4	8.7	16.3	3.0
Gangama	56.0	8.1	9.6	1.6
Gondama	46.3	6.6	9.1	1.5
Mogbewa	46.3	5.4	9.5	1.2
Kabati	41.5	3.6	7.5	0.7
Gbangbama	41.0	6.7	13.3	2.6
Bonjema	40.2	4.8	8.0	1.0
Vaama	21.4	3.0	4.7	0.7
Moriba Town	20.9	2.6	4.4	0.6
Pendembu	17.8	2.1	3.3	0.4
Bamba	17.2	1.7	3.4	0.4
Njagbahun	16.5	2.3	3.2	0.5
Mombaya	15.8	2.0	3.0	0.4
Matagiema	15.2	1.5	3.1	0.3
Mondokor	15.2	2.2	3.0	0.4
Mokpandi	14.8	1.6	2.7	0.3
Gbangbatoke	14.1	1.4	2.9	0.3
Fago	13.2	1.2	2.5	0.3

Current Operations				
Village Name	**PM2.5_unmit**	**PM2.5_unmit_annual**	**PM2.5_mit**	**PM2.5_mit_annual**
Foinda	121.2	19.8	19.8	3.3
Nyandehun	33.9	5.9	6.2	1.2
Teso	24.8	2.6	4.2	0.5
Kpetema	19.8	3.7	3.6	0.7
Junctiola	18.0	2.7	3.3	0.5
Yangatoke	16.4	2.0	2.9	0.4
Mokaba	16.4	1.4	3.0	0.3
Nitti Port	14.3	1.6	2.4	0.3
Victoria	13.8	2.4	2.5	0.4
Gbamgbama	12.1	1.3	2.1	0.3
Semabu	11.1	1.2	1.9	0.2
Ndendomoia	9.9	1.7	1.8	0.3
Mobimbi	9.7	1.5	2.3	0.5
Gangama	8.5	1.2	1.5	0.2
Mogbwemo	8.1	1.1	1.9	0.3
Mokepay	7.4	1.4	2.2	0.5
Gondama	6.9	0.9	1.3	0.2
Mogbewa	6.8	0.8	1.3	0.2
Kabati	6.1	0.5	1.1	0.1
Bonjema	6.0	0.7	1.1	0.1
Gbangbama	5.4	0.8	1.5	0.3
Moriba Town	3.1	0.4	0.6	0.1
Vaama	3.1	0.4	0.6	0.1
Pendembu	2.6	0.3	0.5	0.1
Bamba	2.5	0.3	0.5	0.0
Njagbahun	2.4	0.3	0.5	0.1
Mondokor	2.2	0.3	0.4	0.1
Matagiema	2.2	0.2	0.4	0.0
Mokpandi	2.2	0.2	0.4	0.0
Mombaya	2.2	0.3	0.4	0.1
Gbangbatoke	2.1	0.2	0.4	0.0
Fago	1.9	0.2	0.4	0.0

Planned Operations				
Village Name	**PM10_unmit**	**PM10_unmit_annual**	**PM10_mit**	**PM10_mit_annual**
Foinda	1503.1	248.6	238.3	39.4
Nyandehun	290.3	48.3	48.7	8.3
Teso	263.4	24.5	43.0	4.1
Junctiola	207.5	30.0	32.2	4.9
Nitti Port	197.4	21.3	51.9	5.8
Mokaba	157.5	12.0	25.7	2.0
Yangatoke	153.0	20.2	25.1	3.3
Kpetema	139.3	25.5	24.7	4.6
Victoria	137.0	21.9	22.4	3.7
Gbamgbama	125.4	13.4	20.2	2.2
Semabu	124.8	11.1	19.3	1.9
Mobimbi	113.4	18.5	18.7	3.4
Gangama	96.5	12.4	14.7	2.0
Mogbwemo	81.9	12.7	15.2	2.3
Ndendomoia	68.6	12.2	12.5	2.2
Gondama	68.0	8.6	10.5	1.5
Kabati	62.6	4.8	10.2	0.8
Gbangbama	58.5	8.8	10.4	1.7
Mogbewa	55.2	6.6	9.2	1.1
Bonjema	52.7	5.9	9.1	1.0
Mokepay	52.5	8.8	9.8	1.8
Moriba Town	34.0	3.5	5.3	0.6
Vaama	32.8	3.8	5.2	0.7
Njagbahun	22.3	2.9	3.7	0.5
Pendembu	22.3	2.7	3.9	0.5
Mondokor	22.0	2.9	3.4	0.5
Bamba	21.9	2.3	3.7	0.4
Matagiema	21.7	2.1	3.6	0.4
Fago	20.8	1.7	3.5	0.3
Mombaya	20.3	2.6	3.4	0.4
Gbangbatoke	19.7	2.1	3.3	0.4
Mokpandi	18.2	2.0	3.2	0.3

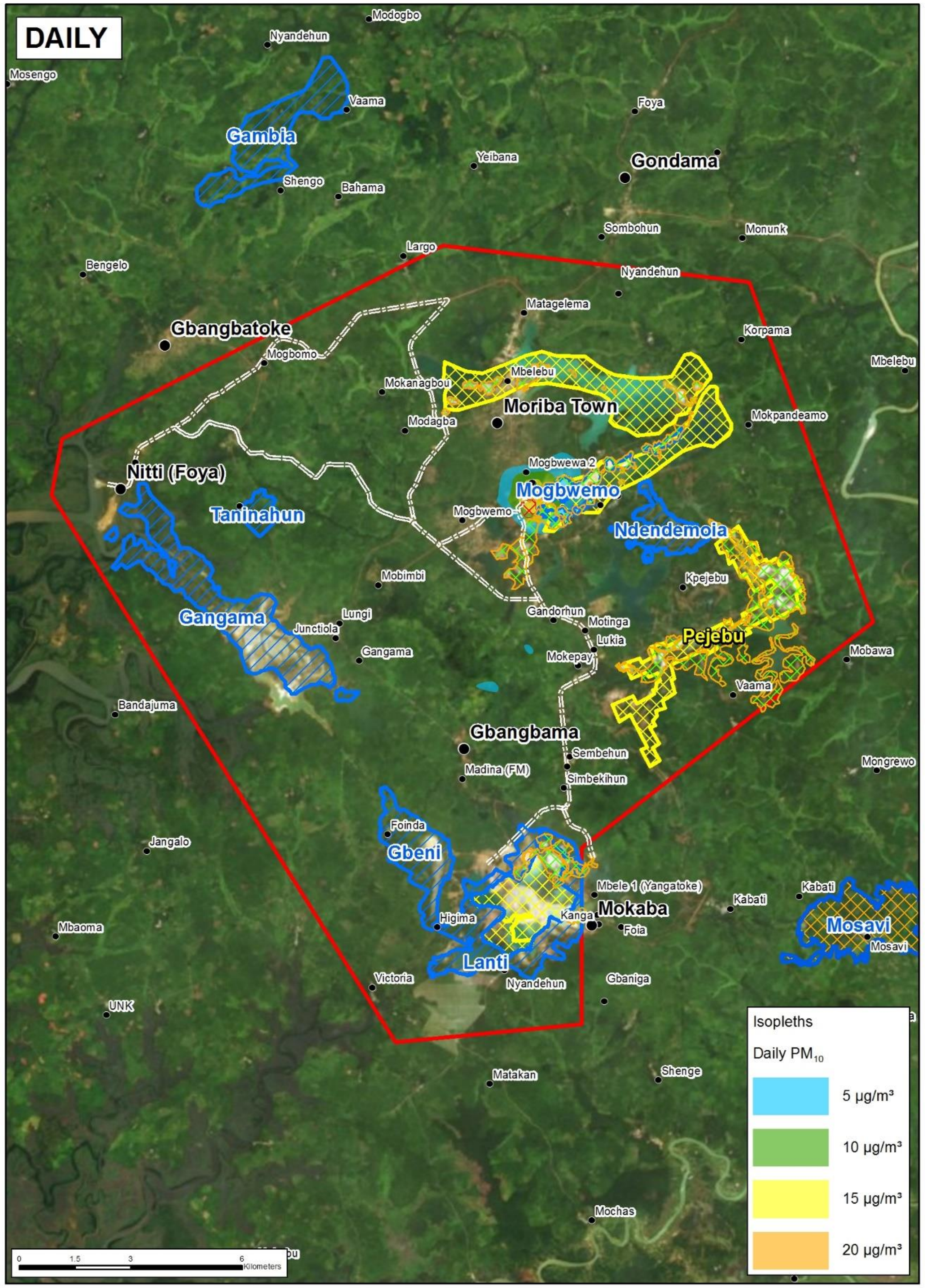
Planned Operations				
Village Name	PM2.5_unmit	PM2.5_unmit_annual	PM2.5_mit	PM2.5_mit_annual
Foinda	223.6	37.0	36.3	6.0
Nyandehun	43.2	7.2	7.1	1.2
Teso	39.2	3.7	6.5	0.6
Junctiola	32.0	4.4	5.0	0.7
Nitti Port	28.2	3.0	4.5	0.5
Mokaba	24.0	1.8	3.9	0.3
Yangatoke	22.9	3.0	3.8	0.5
Kpetema	20.9	3.8	3.7	0.7
Victoria	20.4	3.3	3.4	0.6
Semabu	19.0	1.6	3.0	0.3
Gbamgbama	18.8	2.0	3.0	0.3
Mobimbi	16.4	2.4	2.7	0.4
Gangama	14.8	1.8	2.3	0.3
Mogbwemo	11.2	1.7	2.0	0.3
Ndendomoia	10.3	1.8	1.8	0.3
Gondama	10.1	1.3	1.6	0.2
Kabati	9.5	0.7	1.6	0.1
Mogbewa	8.3	1.0	1.4	0.2
Bonjema	7.9	0.9	1.3	0.1
Gbangbama	7.8	1.0	1.3	0.2
Mokepay	7.5	1.2	1.3	0.2
Moriba Town	5.1	0.5	0.8	0.1
Vaama	4.9	0.6	0.8	0.1
Mondokor	3.3	0.4	0.5	0.1
Pendembu	3.3	0.4	0.6	0.1
Njagbahun	3.3	0.4	0.6	0.1
Matagiema	3.3	0.3	0.5	0.1
Bamba	3.3	0.3	0.6	0.1
Mombaya	3.1	0.4	0.5	0.1
Fago	3.0	0.2	0.5	0.0
Gbangbatoke	2.9	0.3	0.5	0.0
Mokpandi	2.6	0.3	0.5	0.1

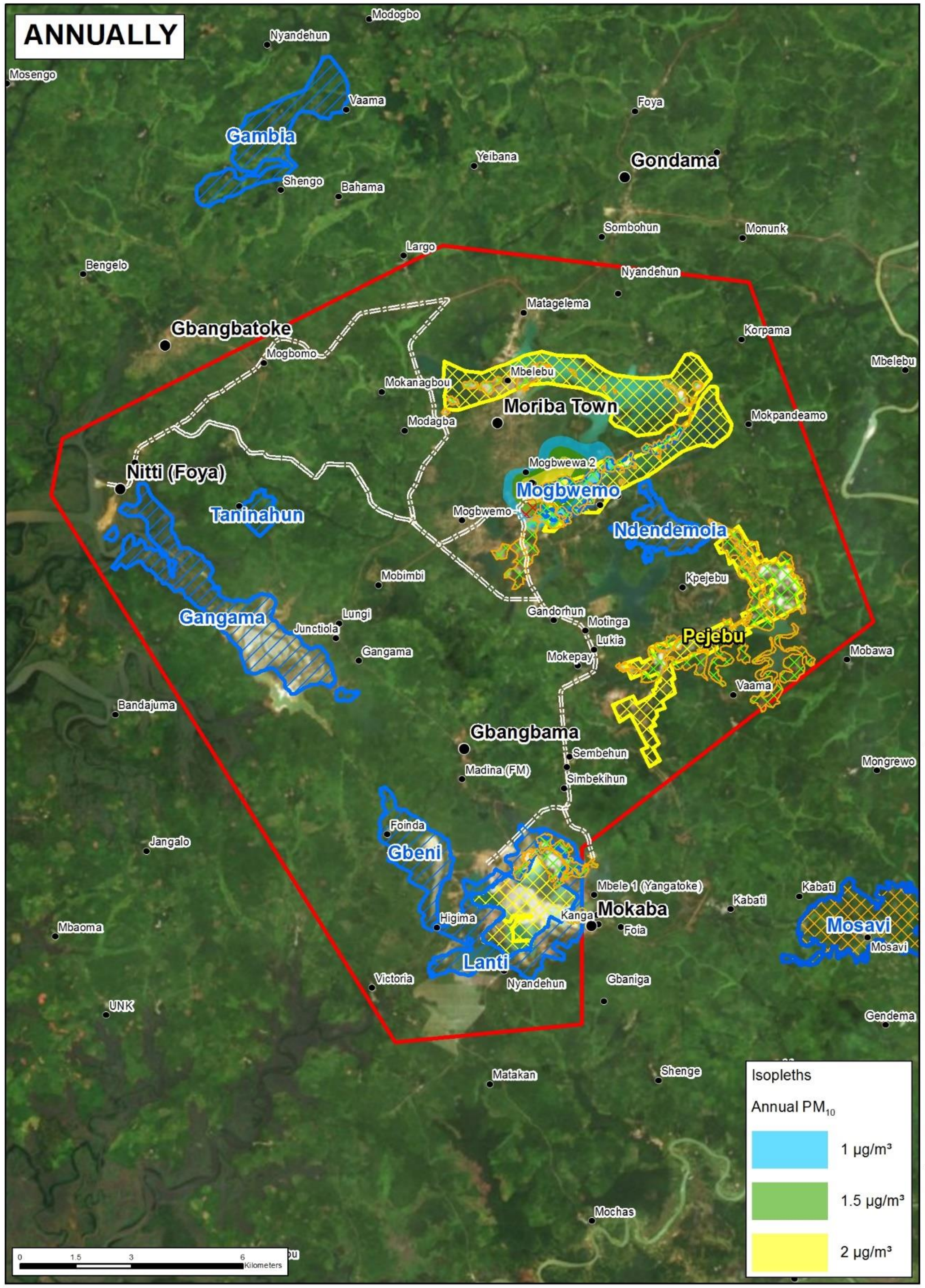
Power Plant						
Village Name	**1 hour Nox**	**Annual Nox**	**24 hour SO2**	**annual SO2**	**24 hour PM10**	**Annual PM10**
Mogbewa	140.32	8.64	10.34	1.51	17.98	2.63
Kpetema	25.95	1.83	2.01	0.32	3.49	0.56
Ndendomoia	25.77	1.38	1.55	0.24	2.70	0.42
Bamba	17.49	0.90	0.63	0.16	1.10	0.27
Mogbwemo	16.71	0.85	1.18	0.15	2.05	0.26
Moriba Town	15.24	0.82	1.05	0.14	1.82	0.25
Gondama	10.76	0.51	0.63	0.09	1.10	0.16
Junctiola	10.55	0.41	0.54	0.07	0.94	0.12
Pendembu	9.73	0.49	0.50	0.09	0.87	0.15
Gangama	8.87	0.37	0.48	0.07	0.83	0.11
Mobimbi	8.68	0.40	0.51	0.07	0.88	0.12
Mokepay	7.31	0.36	0.41	0.06	0.72	0.11
Gbamgbama	6.09	0.28	0.36	0.05	0.62	0.08
Matagiema	5.89	0.34	0.44	0.06	0.77	0.10
Semabu	5.34	0.27	0.39	0.05	0.68	0.08
Foinda	4.57	0.20	0.27	0.03	0.47	0.06
Yangatoke	4.28	0.22	0.28	0.04	0.49	0.07
Bonjema	4.19	0.21	0.25	0.04	0.44	0.06
Mondokor	4.14	0.27	0.35	0.05	0.61	0.08
Vaama	3.49	0.19	0.21	0.03	0.37	0.06
Njagbahun	3.12	0.19	0.29	0.03	0.50	0.06
Mokaba	3.05	0.16	0.23	0.03	0.40	0.05
Kabati	2.89	0.15	0.18	0.03	0.32	0.05
Teso	2.66	0.13	0.18	0.02	0.31	0.04
Victoria	2.65	0.14	0.21	0.02	0.37	0.04
Mombaya	2.56	0.16	0.24	0.03	0.41	0.05
Fago	2.52	0.16	0.22	0.03	0.38	0.05
Nyandehun	2.52	0.15	0.22	0.03	0.39	0.05
Mokpandi	2.28	0.15	0.24	0.03	0.42	0.05
Gbangbama	2.06	0.14	0.20	0.03	0.35	0.04
Nitti Port	1.49	0.11	0.16	0.02	0.27	0.03
Gbangbatoke	1.43	0.11	0.18	0.02	0.32	0.03

Dryer						
Village Name	**1 hour Nox**	**Annual Nox**	**24 hour SO2**	**annual SO2**	**24 hour PM10**	**Annual PM10**
Mogbewa	2.801	0.189	0.008	0.0013	0.0599	0.0097
Kpetema	1.137	0.062	0.002	0.0004	0.0178	0.0032
Ndendomoia	0.751	0.039	0.002	0.0003	0.0115	0.0020
Mogbwemo	0.575	0.029	0.002	0.0002	0.0149	0.0015
Gondama	0.524	0.021	0.001	0.0002	0.0093	0.0011
Junctiola	0.326	0.012	0.001	0.0001	0.0058	0.0006
Bamba	0.321	0.017	0.001	0.0001	0.0040	0.0009
Moriba Town	0.312	0.021	0.001	0.0002	0.0107	0.0011
Gangama	0.299	0.012	0.001	0.0001	0.0061	0.0006
Mobimbi	0.196	0.009	0.001	0.0001	0.004	0.000
Pendembu	0.178	0.010	0.000	0.000	0.003	0.001
Gbamgbama	0.138	0.006	0.000	0.000	0.003	0.000
Mokepay	0.133	0.008	0.001	0.000	0.004	0.000
Semabu	0.126	0.006	0.000	0.000	0.003	0.000
Matagiema	0.114	0.007	0.000	0.000	0.003	0.000
Foinda	0.096	0.005	0.000	0.000	0.002	0.000
Yangatoke	0.085	0.005	0.000	0.000	0.002	0.000
Victoria	0.081	0.004	0.000	0.000	0.002	0.000
Mondokor	0.081	0.005	0.000	0.000	0.002	0.000
Teso	0.071	0.004	0.000	0.000	0.002	0.000
Bonjema	0.068	0.004	0.000	0.000	0.002	0.000
Vaama	0.058	0.004	0.000	0.000	0.002	0.000
Njagbahun	0.056	0.004	0.000	0.000	0.003	0.000
Mokaba	0.055	0.004	0.000	0.000	0.002	0.000
Nyandehun	0.053	0.003	0.000	0.000	0.002	0.000
Nitti Port	0.051	0.003	0.000	0.000	0.002	0.000
Fago	0.050	0.004	0.000	0.000	0.002	0.000
Kabati	0.049	0.003	0.000	0.000	0.001	0.000
Mombaya	0.046	0.004	0.000	0.000	0.002	0.000
Gbangbama	0.044	0.003	0.000	0.000	0.001	0.000
Mokpandi	0.043	0.003	0.000	0.000	0.002	0.000
Gbangbatoke	0.037	0.003	0.000	0.000	0.002	0.000

Medical Incineration			
Village Name	**1 hour Nox**	**24 hour SO2**	**24 hour PM10**
Mogbewa	0.0000420	0.0000065	0.0000145
Kpetema	0.0000055	0.0000017	0.0000038
Mogbwemo	0.0000050	0.0000022	0.0000050
Moriba Town	0.0000043	0.0000016	0.0000035
Ndendomoia	0.0000036	0.0000013	0.0000029
Bamba	0.0000030	0.0000008	0.0000019
Mokepay	0.0000016	0.0000016	0.0000035
Gondama	0.0000014	0.0000008	0.0000018
Pendembu	0.0000013	0.0000006	0.0000014
Matagiema	0.0000013	0.0000006	0.0000013
Mobimbi	0.0000012	0.0000005	0.0000012
Mondokor	0.0000010	0.0000004	0.0000009
Bonjema	0.0000009	0.0000009	0.0000021
Njagbahun	0.0000008	0.0000007	0.0000016
Vaama	0.0000008	0.0000008	0.0000017
Junctiola	0.0000008	0.0000004	0.0000010
Gangama	0.0000007	0.0000003	0.0000008
Semabu	0.0000007	0.0000003	0.0000007
Gbamgbama	0.0000007	0.0000009	0.0000020
Mombaya	0.0000007	0.0000007	0.0000015
Fago	0.0000007	0.0000003	0.0000007
Yangatoke	0.0000006	0.0000010	0.0000022
Gbangbama	0.0000006	0.0000002	0.0000005
Mokpandi	0.0000006	0.0000004	0.0000010
Kabati	0.0000006	0.0000007	0.0000016
Mokaba	0.0000006	0.0000007	0.0000017
Foinda	0.0000005	0.0000003	0.0000006
Gbangbatoke	0.0000004	0.0000002	0.0000004
Nyandehun	0.0000004	0.0000004	0.0000009
Nitti Port	0.0000004	0.0000002	0.0000004
Victoria	0.0000004	0.0000002	0.0000004
Teso	0.0000003	0.0000002	0.0000005

Appendix E: Dispersion modelling maps





N

Legend
- Towns
- Settlements
- Haul Roads
- Sand Tailings
- Plant Site
- Mineral Deposits
- Mosavi Deposit**

Tenement Areas
- SR Area 1

Data Source: ESRI Basemaps
Scale: 1:145 000
Projection: UTM
Datum: WGS84
Central Meridian/Zone: Zone 28N
Date: 21/09/2017
Compiled by: ALLK
Project No: 515234
Fig No: E1

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SR AREA 1 ESHIA & ESHMP

PREDICTED PM_{10} CONCENTRATIONS AT THE POWER PLANT

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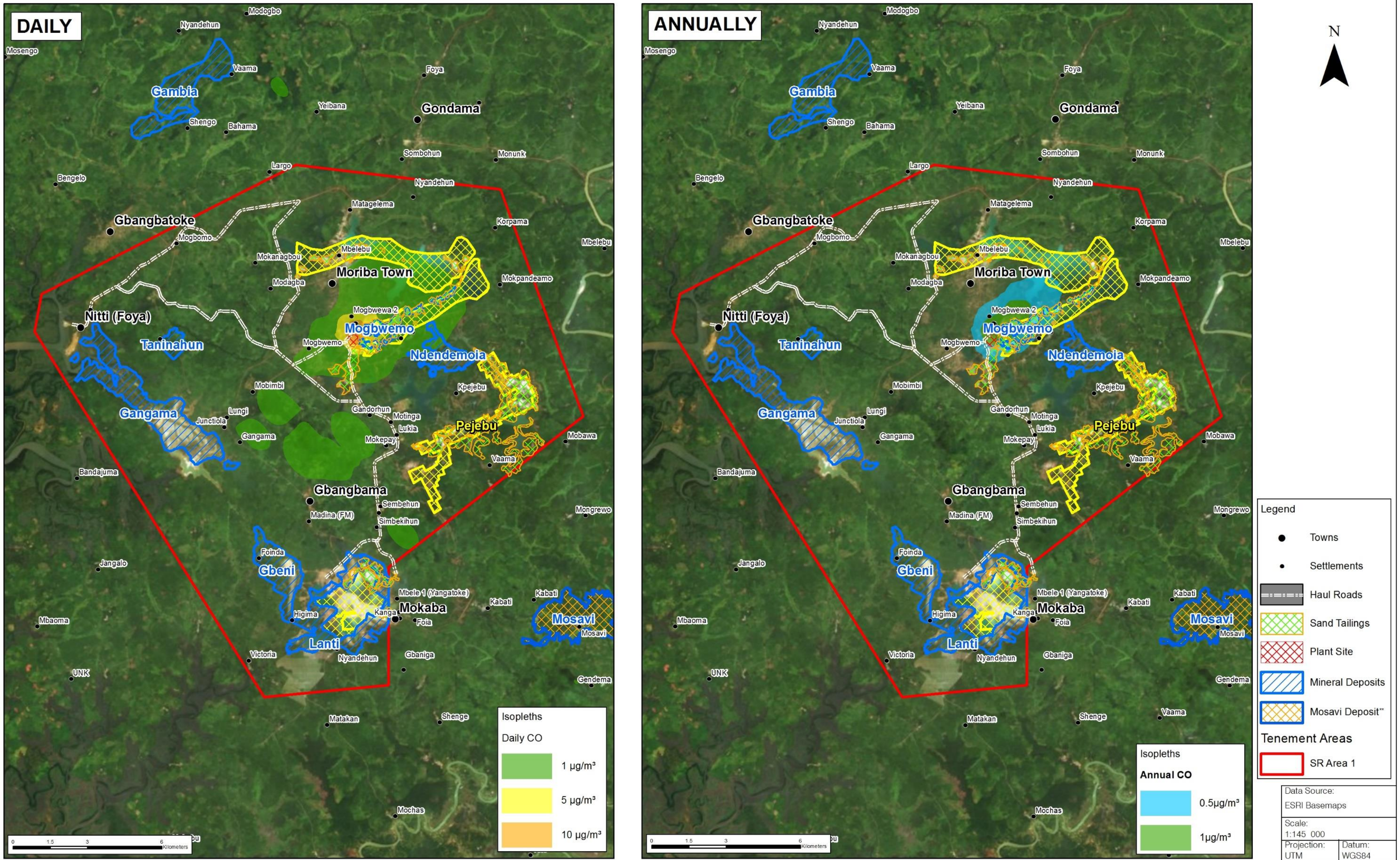
Revision: A Date: 26 02 2018



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Central Meridian/Zone: Zone 28N
Date: 21/09/2017 | Compiled by: ALLK
Project No: 515234 | Fig No: E2

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SR AREA 1 ESHIA & ESHMP

PREDICTED CO CONCENTRATIONS AT THE POWER PLANT

Path: G:\515234_ILUKA_SRK_ESIA_JNB\8GIS\GISPROJ\MXD\Feb2018\AQ\515234_APPE2_AQIA_VOC_Prediction_A3L_26022018.mxd

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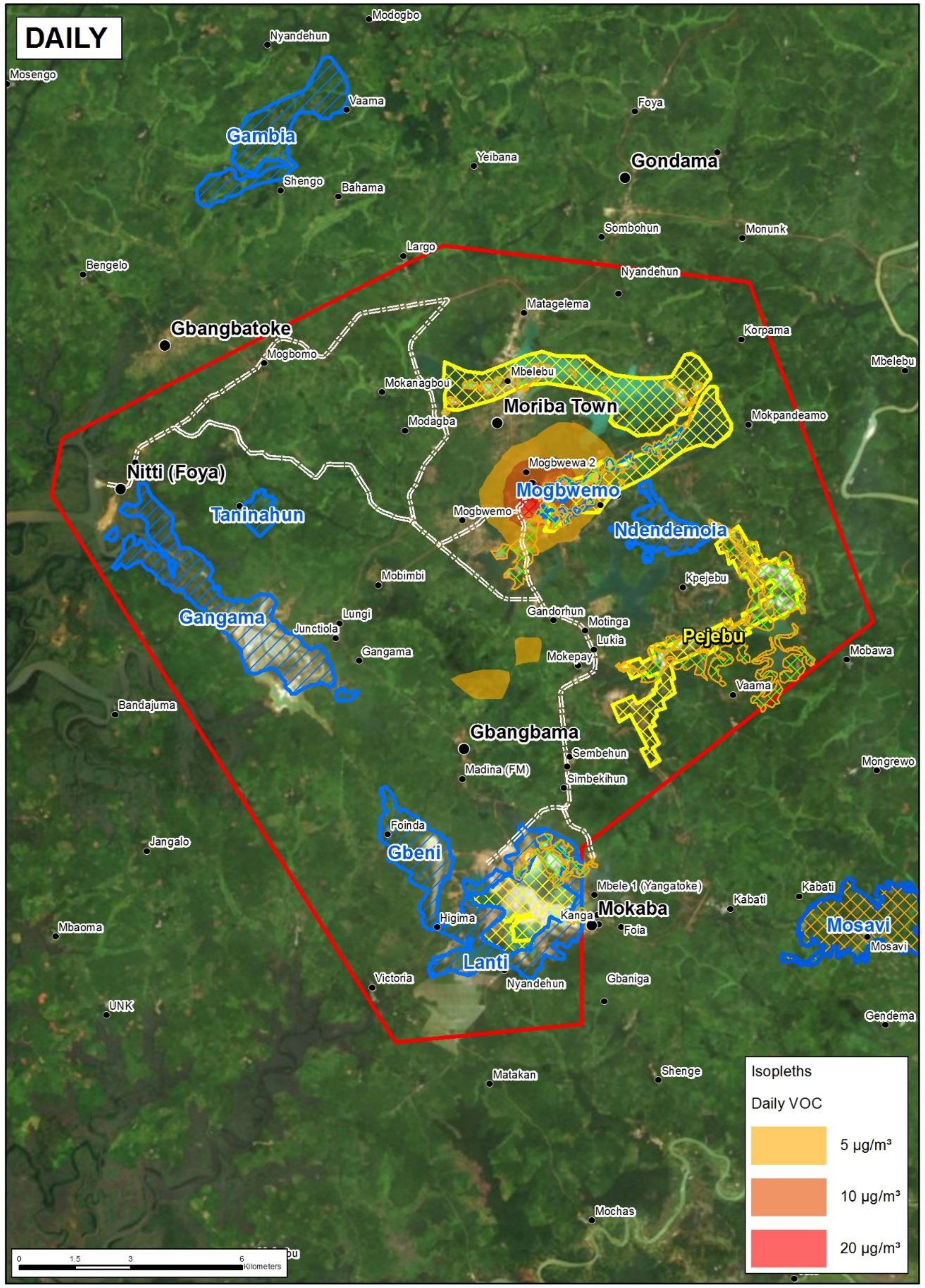

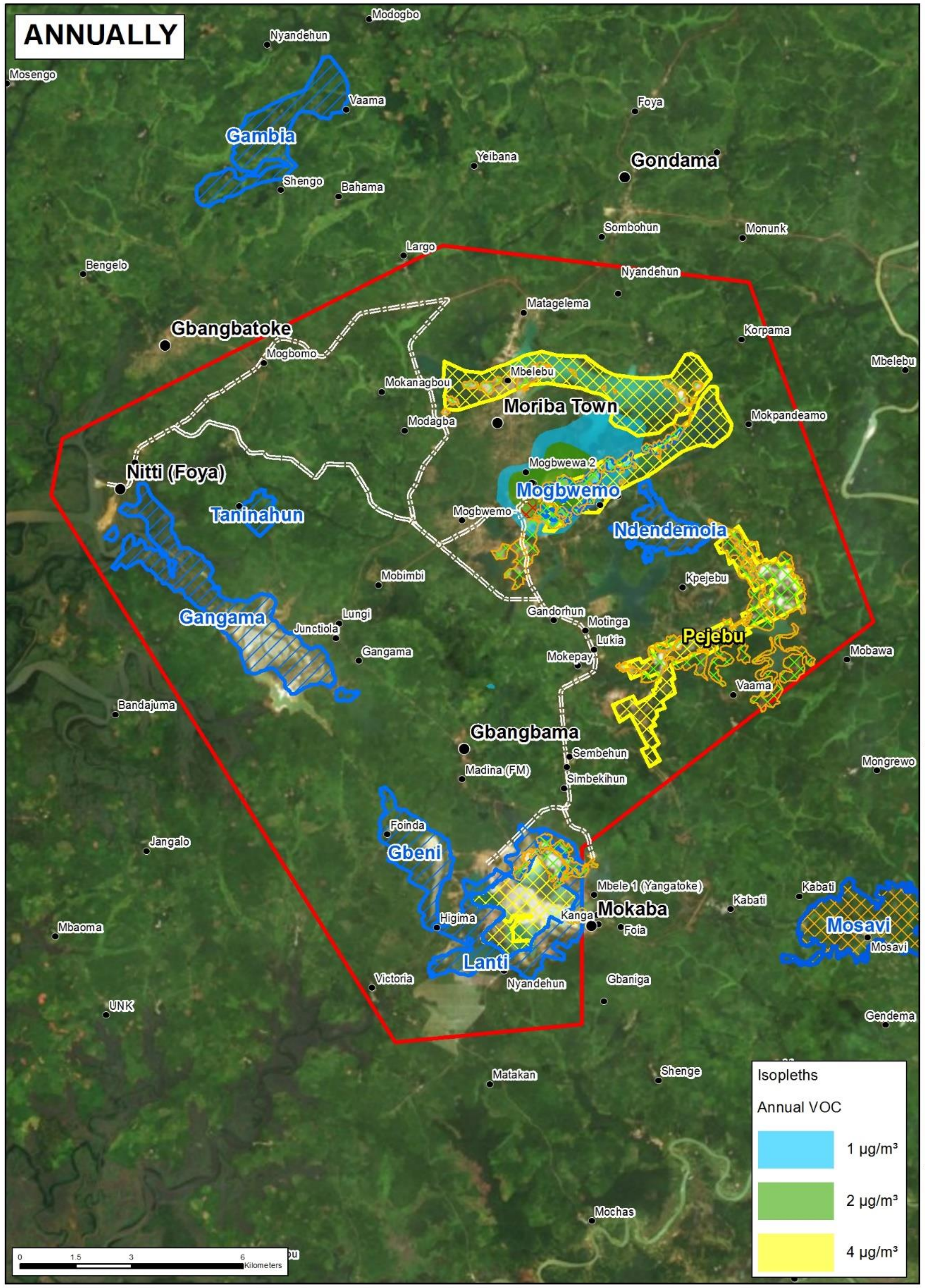

N

Legend

- Towns
- Settlements
- Haul Roads
- Sand Tailings
- Plant Site
- Mineral Deposits
- Mosavi Deposit**

Tenement Areas

- SR Area 1

Data Source: ESRI Basemaps	
Scale: 1:145 000	
Projection: UTM	Datum: WGS84
Central Meridian/Zone: Zone 28N	
Date: 21/09/2017	Compiled by: ALLK
Project No: 515234	Fig No: E3

Revision: A Date: 27 02 2018

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PREDICTED VOC CONCENTRATIONS AT THE POWER PLANT

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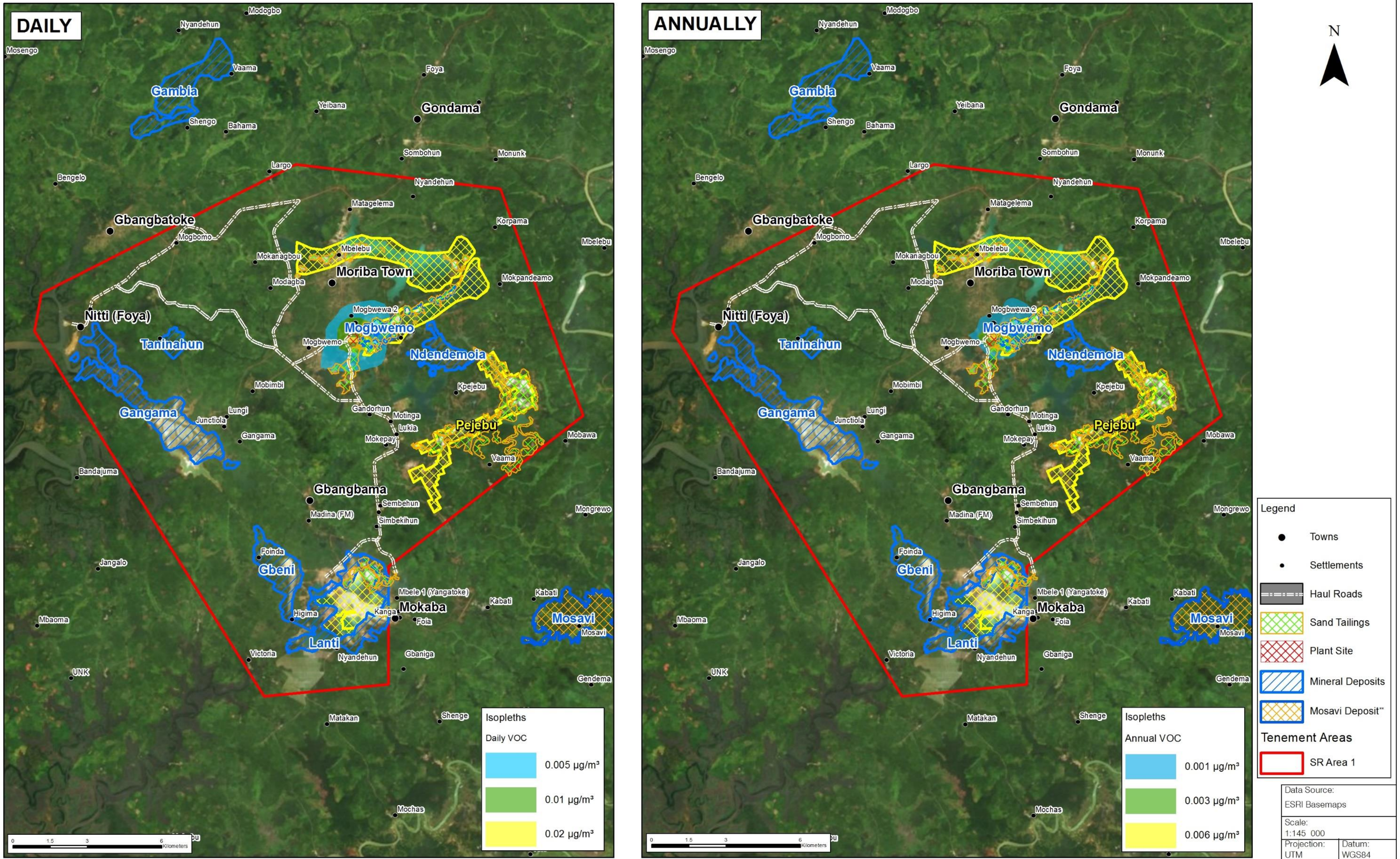

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Date: 21/09/2017	Compiled by: ALLK
Project No: 515234	Fig No: E4

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SR AREA 1 ESHIA & ESHMP

PREDICTED VOC CONCENTRATIONS AT THE MPS DRYER

Path: G:\510810_DTPC_HLAWE_IWULA\8GIS\GISPROJ\MXD\515234_AppE4_AQIA_VOC_Prediction_A3L_27022018.mxd

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