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ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT (ESIA) FOR SAFER ROADS FOR SOCIO-ECONOMIC INTEGRATION IN MOZAMBIQUE (SRSEI) - MULTIPHASE PROGRAMMATIC APPROACH (MPA)

(Contract n° 140/GE-ANE/370/2021)

Environmental and Social Impact Assessment

ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT (ESIA) REPORT

Package 2: Gorongosa - Caia,
Lot 2 (km 84 - 168)

VOLUME 2B: MAIN REPORT

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Environmental and Social Impact Assessment for the Safer Roads for Socioeconomic Integration in Mozambique – Multiphase Programmatic Approach

This report consists of the following:

Volume 2A	Non-Technical Summary
Volume 2B	Main Report
Volume 2C	Annexes
Volume 2D	Public Consultation Report
Volume 2E	Environmental and Social Management Plan

EXECUTIVE SUMMARY

I. Introduction and Context

This Environmental and Social Impact Assessment (ESIA) has been prepared to support the environmental and social management process, as well as the implementation of the Safer Roads for Socio-Economic Integration of Mozambique Project – Multi-Phase Approach (SRSEI-MPA), particularly along the North-South corridor, National Road N1. The SRSEI-MPA will be implemented with funding from the World Bank and aims to unlock the potential across all sectors of the country's socio-economic development by, among other actions, promoting the rehabilitation of National Road N1 (EN1), using a phased approach.

This ESIA report prepared for the SRSEI-MPA aims to identify, assess, and propose measures for the effective management of potential environmental and social impacts associated with the Project, focusing on "Package 2 – Gorongosa to Caia, Lot 2 (km 84 – 168)". By evaluating the Project's consequences on the natural and human environment, the ESIA seeks to ensure that the Project complies with regulatory requirements, adopts good practices, and minimizes adverse effects while maximizing benefits for communities and the environment. The scope of the assessment covers the construction, operation, decommissioning, and maintenance phases, providing a comprehensive understanding of the Project's potential impacts throughout its life cycle.

II. Project Description

The conceptual design of the rural road includes the rehabilitation of EN1 section between Gorongosa – Caia (km84–168), along an existing road, so that the rehabilitated road will have a total cross-section of 12 meters in rural areas and 17 meters in urban areas. In rural areas, the cross-section is subdivided into a 7-meter width to accommodate two traffic lanes of 3.5 meters each (one for each direction), as well as 1.5 meters of paved shoulder and an additional 1 meter of unpaved shoulder on each side.

The cross-section for urban areas will have a reduced carriageway width (compared to the rural cross-section), with a minimum lane width of 3.2 meters, allowing for wider paved and unpaved shoulders of 2.0 and 2.5 meters, respectively. The narrower carriageway will encourage vehicles to travel at lower speeds and will provide wider shoulders, enabling many vehicles along the urban settlement Gorongosa to load and unload goods without encroaching onto the carriageway.

In addition, drainage ditches will be rehabilitated and paved to control runoff. Sharp curves and blind rises will be removed to establish an appropriate road alignment for traffic safety. Additional traffic calming measures will be implemented to protect wildlife, as the road sections to be rehabilitated pass near Gorongosa National Park and forest/hunting concessions, where wildlife crossing the EN1 has been observed at certain identified locations.

III. ESIA Methodology

This ESIA has been prepared in accordance with the environmental and social regulations and requirements of the Government of Mozambique, in particular the Regulation on the Environmental Impact Assessment Process (Decree No. 54/2015 of 31 December), as well as the World Bank's Environmental and Social Framework (ESF) and its Environmental and Social Standards (ESS), to address the Project's environmental and social concerns.

The World Bank ESS applicable to this Project, which require the preparation of this ESIA, include:

- ESS1: Assessment and Management of Environmental and Social Risks and Impacts;
- ESS2: Labor and Working Conditions;
- ESS3: Resource Efficiency and Pollution Prevention and Management;
- ESS4: Community Health and Safety;
- ESS5: Land Acquisition, Restrictions on Land Use, and Involuntary Resettlement;
- ESS6: Biodiversity Conservation and Sustainable Management of Living Natural Resources;
- ESS8: Cultural Heritage; and
- ESS10: Stakeholder Engagement and Information Disclosure.

Under ESS1, environmental and social screening is required for all projects, with the objective of assessing risks and impacts and providing guidance for an Environmental and Social Impact Assessment (ESIA) or Environmental and Social Management Plans (ESMPs) to mitigate and/or enhance the identified risks and impacts.

The environmental and social assessments involved several stages, including:

- Scoping exercise;
- Field reconnaissance visits;
- Review of Mozambican legislation and international guidelines;
- Consultations with local communities;
- Baseline data collection;
- Assessment of potential environmental and socio-economic impacts;

- Identification of significant impacts;
- Development of appropriate mitigation measures; and
- Preparation of an Environmental and Social Management Plan.

IV. Summary of the Main Positive Environment and Social Risks and Impacts of the Project

The implementation of construction structures will lead to some negative environmental and social impacts which must be mitigated. The ESIA identifies the potential impacts in the main phases of Pre-construction, Construction and Operation and Maintenance.

Pre-Construction Phase: Potential positive impacts during this phase include increased employment opportunities and skills transfer, business/trade opportunities, preparation of road technical designs with climate change resilient technologies, and revenue generation for the government while potential negative impacts during the pre-construction phase include solid waste generation, soil and water pollution, increased risk of transmissible diseases such as HIV and AIDS, including STIs.

Construction Phase: Potential positive impacts under this phase include increased employment opportunities and skills transfer, business/trade opportunities, increased revenue for the government, optimized use of energy and water due to energy efficient technologies put into use (e.g. solar panels, constructed rainwater harvesting reservoirs/tanks), enhanced road safety measures, and improved access and connectivity to markets and trade hub areas. Potential negative impacts include increased risks of higher levels of noise & vibration, air and water pollution, soil erosion, solid and liquid waste generation, creation of borrow pits and quarry sites, risks to loss of natural habitats and biodiversity, loss of land and property (e.g., structures for small markets, shops, houses), disruption of utility services (e.g. electricity, water, etc.,), increased risk of transmission of communicable diseases (e.g. HIV & AIDS and STIs), risks of climate change due to emission of Green Houses Gases (GHGs), increased use of energy and water, loss of employment (post-construction), traffic disruption. There are also increased risks of GBV/SEA/SH, increased risks of child abuse and forced labour due to labour influx, increased risks and hazards of occupational health and safety, community health risks, risk of exposure to hazardous wastes and toxic chemicals, disruption of traditional norms and family stability due to cases of promiscuity, and theft and vandalism of construction materials.

Demobilization and Decommissioning Phase: Positive impacts of this phase may include improved aesthetic beauty of the project sites, improved green environment at and around the project sites, and increased revenue for the government through taxes while some of the potential negative impacts may include increased air and water pollution, noise pollution and vibration, soil erosion, solid and liquid waste generation, risks of climate change, spread of transmissible diseases such as HIV and AIDS and STIs as well as Covid-19, risks of Occupational Health and Safety, community health risks, and risks of GBV/SEA/SH including child labour and abuse.

Operation and Maintenance Phase: Positive impacts under this phase will include improved road connectivity and access to potential markets, improved road safety and less consumption of fuel or gas by vehicles while the potential negative impacts may include increased deforestation along the N1 corridor, and risks of loss of wildlife (e.g. at Gorongosa National Park, and *coutadas* where the road section passes through and/or near these key biodiversity and protected areas).

V. Plans and/or Programs for Environmental and Social Management and Monitoring

The Environmental and Social Management Plan (ESMP) provides clear guidance to ensure that activities across the different phases of the proposed Project are implemented in accordance with environmentally acceptable standards, in full compliance with Mozambican environmental legislation and the World Bank Environmental and Social Standards (ESS). It encompasses a set of general and specific recommendations which, collectively, form the basis for environmental management (impact mitigation) and environmental control, while also defining the obligations and responsibilities of each party involved in the Project.

The analysis of the proposed Project description, together with the characterization of its impacts, indicates that the Project is environmentally viable. Most identified impacts are expected to be localized and of low to moderate intensity. The implementation of the mitigation measures identified in this study will minimize potentially significant adverse impacts, while enhancing the positive impacts identified.

Responsibility for the implementation of the environmental management measures, particularly those outlined in the ESMP, lies with ANE, IP. These measures are supported by the following plans and programs:

- Air Quality Monitoring Plan
- Noise and Vibration Monitoring Plan
- Soil and Erosion Monitoring Plan
- Water and Effluent Quality Monitoring Plan
- Waste Management Plan
- Biodiversity Management Plan

- Archaeology and Cultural Heritage Management Plan
- GBV/SEA/SH Prevention and Response Action Plan
- Labor Influx and Working Conditions Management Plan
- Community Health and Safety Management Plan
- Occupational Health and Safety Management Plan
- Traffic Management Plan
- General Guidelines for the Use of Security Personnel under the Project Safety and Security Management Plan
- Resettlement Plan
- Grievance Redress Mechanism (GRM)
- Emergency Preparedness and Response Plan

VI. Conclusion

The ESIA identifies that the Project is expected to have significant adverse environmental and social impacts which may include soil erosion, waste generation, risk to loss of natural habitats and biodiversity, resettlement, loss of land and property, risk to climate change, increased spread of HIV and AIDS and STIs, spread of Covid-19, risks to GBV/SEA/SH/VAC, risk to loss of or damage to cultural heritage, loss of livelihoods and risks to OHS hazards among others. The risks and impacts in this project that are classified as Moderate, High and Very High that shall be reduced to tolerable levels through project design, implementation of mitigation measures and Good International Industry Practices (GIIPs), extensive participation of project-affected people in the implementation of subproject activities as well as in the development of resettlement and compensation plans.

In order to effectively mitigate and enhance the potential impacts and risks identified for this road rehabilitation project, the ESMP has been prepared together with the ESMS and must be fully and rigorously implemented by the contractor and ANE, IP in line with relevant national legislations, regulations, standards and guidelines and the World Bank ESF and EHS Guidelines during the rehabilitation, maintenance and demolition/decommissioning phases of the project. The implementation of the ESMP must be on the other hand rigorously monitored by relevant independent institutions or a third party to ensure the contractor and ANE implement the strategies as required and verify their effectiveness.

Notwithstanding the identified negative risks and impacts on the biophysical and socioeconomic and cultural environment, the Project is, however, expected to bring potential positive impacts or benefits, which include improved road safety, improved road connectivity and access to markets, improved trade between regions, reduced road crash accidents and death, creation of employment (for both men and women, the youth and the vulnerable), skills transfer, and increased revenue to the GoM through taxes. Long-term and potential indirect benefits are anticipated, as a result of capacity building programs that will result in transfer of road rehabilitation and building skills to the local workers in the province and these workers would be able to stand on their own and implement similar small to medium scale infrastructure projects in Mozambique in future

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LIST OF ABREVIATIONS AND ACRONYMS

AADT	Annual Average Daily Traffic
ADT	Average Daily Traffic
ANE	Administração Nacional de Estradas
AP	Administrative Post
ARA	Regional Water Administration (*Administração Regional de Água)*
CBO	Community Based Organization
CERC	Contingency and Emergency Response
C-ESMP	Contractor Environmental and Social Management Plan
CoC	Code of Conduct
CoI	Corridor of Impact
CIA	Cumulative Impact Assessment
CPG	Civil and Planning Group
DPASA	Provincial/District Directorate of Agriculture and Food Security
DPOPHRH	Provincial Directorate of Public Works, Housing and Water Resources
DPTA	Provincial Directorate of Land and Environment
ESA	Environmental and Social Assessment
ESCP	Environmental and Social Commitment Plan
EHS	Environmental Health and Safety Guidelines
ESIA	Environmental and Social Impact Assessment
ESMF	Environmental and Social Management Framework
ESMP	Environmental and Social Management Plan
ESMS	Environmental and social management system
ESS	Environmental and Social Standards
GHGs	Greenhouse Gases
GIIPs	Good International Industry Practices
GoM	Government of Mozambique
GRM	Grievance Redress Mechanism
HQ	Headquarter
HIV	Human Immunodeficiency Virus
IBA	Important Bird Area
IDA	International Development Association
IFRDP	Integrated Feeder Roads Development Project
INATRO	National Institute of Road Transport
INGD	National Institute for Disaster Risk Reduction
LASA	LEA Associates South Asia
LMEs	Local Micro Enterprises
LMP	Labor Management Procedures
M&E	Monitoring and Evaluation
MCRS	Marromeu Complex Ramsar Site
MTC	Ministry of Transport and Communication
MAAP	Ministry of Agriculture, Environment and Fishing
NGOs	Non- Governmental Organizations
OHS	Occupational Health and Safety
PAHs	Project Affected Households
PAPs	Project Affected Persons
PBMC	Performance Based Maintenance Contract

PIU	Project Implementation Unit
PLC	Project Liaison Committee
PPE	Personal Protective Equipment
PPP	Public Participation Process
PPZ	Partial Protection Zone
PROSIR	Resettlement Implementation Service Providers
RAP	Resettlement Action Plan
RAT	Division of Cross-Cutting themes
RoW	Right of Way
RPF	Resettlement Policy Framework
SA	Social Assessment
SDPI	District Planning and Infrastructure Service
SDM	Species Distribution Models
SEA	Sexual Exploitation and Abuse
SEP	Stakeholder Engagement Plan
SA	Sexual Harassment
SRA	Security Risk Assessment
SRSEI	Safer Roads for Socioeconomic Integration
TA	Technical Assistance
USD	United States Dollar
VAC	Violence Against Children
VECs	Valued Environmental and Social Components
VPD	Vehicles Per Day
WBG	World Bank Group
WHO	World Health Organization
WII	Wetland of International Importance

1 INTRODUCTION

1.1 Project Background

The Environmental and Social Impact Assessment (ESIA) has been prepared to support the environmental and social management and implementation of the Safer Road for Socio-Economic Integration (SRSEI) Project in Mozambique, in particular the North-South N1 corridor aimed at unlocking potential in all sectors of socio-economic development.

With support from the World Bank (WB), GoM has developed a long - term program of socio-economic integration through resilient and safe upgrading of 1053 km of seven priority sections of N1 corridor. The Bank has agreed to prepare a US$850 million Multi-Phase Approach (MPA) operation over 3 IDA cycles, with a first phase of $480.00 million to be delivered in FY22 (including US$ 400.00 million IDA grant (80%) + US$ 80.00 million counterpart financing (20%). It is noted this amount is for all the 5 components under the Phase I, and not only for the civil works. Phases 2 and 3 planned for delivery in FY24 and FY26 to finance a Safer Roads for Social and Economic Integration project in Mozambique-Multiphase Programmatic Approach (SRSEI-MPA) to implemented along the N1 corridor.

Following up on the recommendations of the recently competed Advisory Services and Analytics (ASA) Prevention Human Capital through Improved Road Safety in Mozambique, the MPA for SRSEI will have an ambitious program of improving road safety. Road safety record in Mozambique is one of the worst in the world with roads killing between 5,000 and 9,000 people each year. To help the Government achieve Sustainable Development Goal (SDG) 3.6 of halving the number of deaths by 2030, the MPA will focus on both preventative measures and post-crash response. The post-crash response in Mozambique is one of the weakest links in the overall road safety delivery and the MPA is proposed to address that through a coordinated effort of Transport and Health Global Practices (GoM, 2021).

1.2 Project Objectives

The objectives of this project are:

- Improve road connectivity in N1 Corridor, increasing sections in good or fair condition;
- Improve road safety by decreasing of road fatalities and serious injuries (reduction by 50 percent by 2032 in absolute terms);
- Improve road resilience by increasing climate resilient road infrastructure.
- Improve access to markets, resources and services;
- Reduce vehicle operating and maintenance costs;

- Reduce transport costs for the private sector to facilitate investment and commercial traffic;
- Increase public transport access for individuals to take advantage of job and other economic opportunities;
- Improve the quality of transport services to promote a higher integration of the norther provinces; and
- Expand connectivity across the northern region and down towards the southern half of the country.

1.3 Project Components

The project components have been revised from concept stage and the current version is noted in the table below.

Table 1-1 Project Components

Project components
Component 1: **Safe and Resilient Corridor Connectivity** This component will focus on safe and resilient rehabilitation, improvement, and maintenance of 1053 km in the most critical sections of the N1; it will finance simplified conceptual designs and supervision contracts for Output and Performance-Based Road Contracts (OPRC), design stage road safety audits of the road sections to be included in the project, and civil works under OPRC. The component will also finance design, supervision, and civil works for an improvement program of high crash risk locations, as well as design and implementation of the Safe Schools Program.
Component 2: Community Based Maintenance of Feeder Roads This component will finance the preparation of the community-based maintenance of feeder roads pilot connecting to or in areas near to the N1, as well as its implementation, including necessary consultancy services, works, and capacity building activities. Capacity building will be for ANE Provincial Delegations as well as the central ANE, RF, and local communities – in how to organize community groups to deliver routine maintenance of feeder / trunk roads organized in cooperatives or micro-enterprises and how to manage these from an ANE standpoint.
Component 3: Improved Road Safety This component will finance necessary TAs to support the Government's aspirations towards achieving Sustainable Development Goal 3.6 (decrease the number of road crash death by 50 percent by 2030). This component will finance a dedicated team of road safety professionals at the MOT/ National Road Transport Institute (INATRO), update of the Road Safety Strategy to align it with the safe system's approach; support the preparation of the Road Safety Action Plan, and other consultancy services including on vehicle inspections, speed management, driver licensing, post-crash response; and capacity building to improve long-term road safety expertise across all key road safety stakeholders, following recommendations from the recently concluded Road Safety Assessment Study.
Component 4: **Institutional Development and Project Management** This component will finance institutional development capacity building activities and project management costs.
Component 5: **Contingency Emergency Response Component (CERC)** This component will facilitate access to rapid financing by allowing reallocation of uncommitted project funds in the event of a natural disaster either by formal declaration of a national or regional state of emergency or upon a formal request from the Government of Mozambique (GoM). This component will use a project specific CERC mechanism. CERC arrangements will be part of the ESS instruments and a Country wide Emergency Manual currently in existence as coordinated by the Bank's disaster management team will be updated to reflect this new operation.

The sections selected for rehabilitation in the Sofala Province within the N1 corridor for the first Cycle of MPA-SRSEI - Phase I are:

- Package 1: Inchope - Gorongosa, (0 - 70km)
- Gorongosa - Caia, Lot 1 (0 - 84km) in Sofala Province, and
- Package 2: Gorongosa - Caia, Lot 2 (84 - 168km).

These sections add up to a total of 238 km.

It should be noted that in Sofala Province the rehabilitation of the last section of the N1 from Gorongosa to Caia is scheduled to be undertaken in Phase II of the SRSEI project, i.e. Package 4: Lot 3 Gorongosa – Caia Km 168-252 (84 Km).

As requested by the Financier, the original version of the ESIA submitted for all three packages of Phase I in Sofala, will now focus on Package 2: Gorongosa - Caia, Lot 2 (km84 - 168), a total of 84km.

1.4 Project Location

The North- South N1 corridor (Connecting to the fragile North) is the most important transport corridor for Mozambique in order to unlock development potential (in all sectors) in central and North Mozambique, which is the country's most fragile and critical region. The resilient (all weather access) and safe upgrading of N1 has been identified as the most important infrastructure need by the Government of Mozambique (GoM).

Historically, most of the investments have been directed towards multiple east-west corridors that focused on moving extractives/minerals from land locked countries to the Indian Ocean ports in Mozambique. The investment in the most critical North-South connection in comparison has been lacking. Currently more than half of the N1 corridor is in poor state of upkeep.

The map below depicts the project location in general and km84-168 Gorongosa to Caia of the N1 to be rehabilitated in Sofala Province in Phase I.

1.4.1 Sofala Province

Phase I of the project will be implemented on the N1 road between Inchope and Caia in Sofala Province, with a length of approximately 238km crossing the Districts of Gondola, Nhamatanda, Gorongosa and Maringue. This ESIA is now for Package 2: Gorongosa - Caia, Lot 2 (km84 - 168), a total of 84km, as shown in the map below.

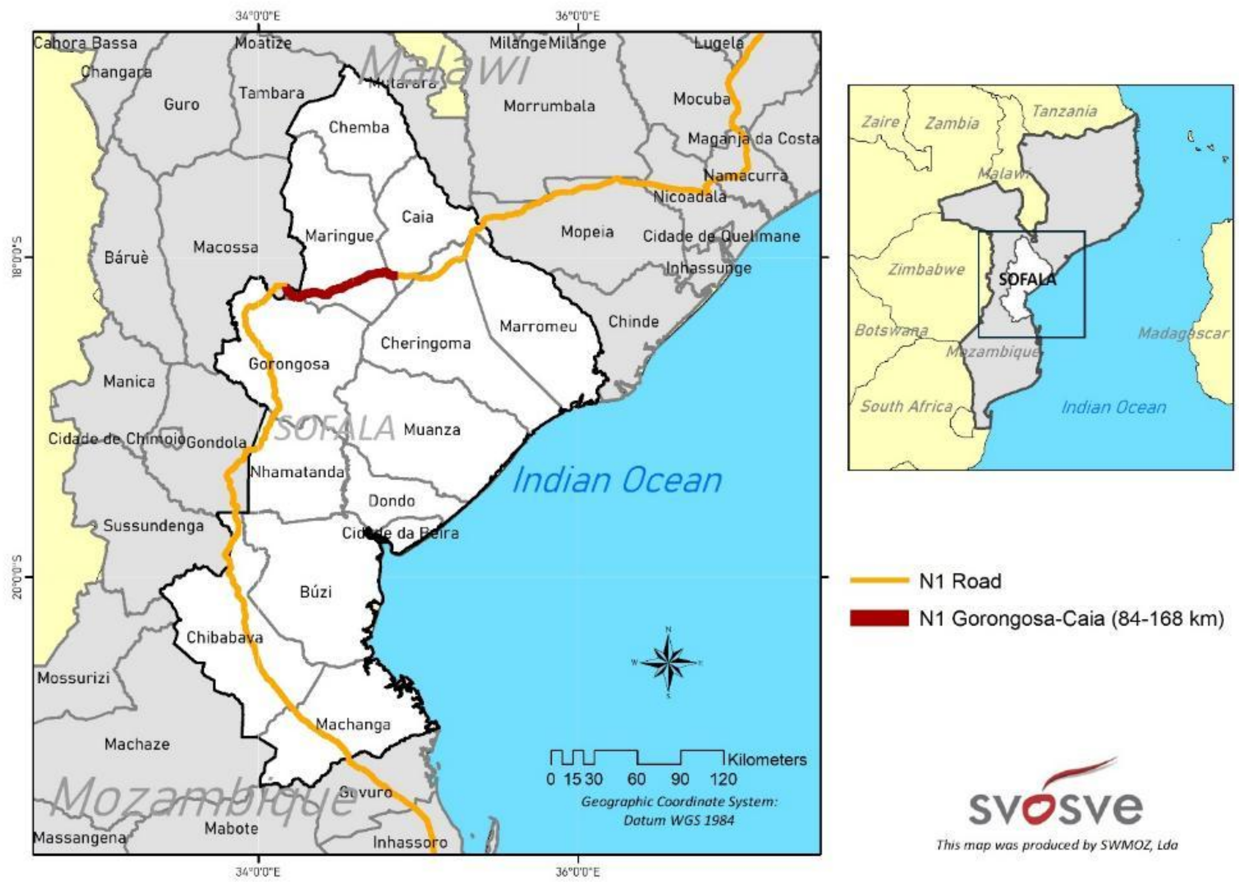


Figure 1 Geographic location of the N1 km84-168 Gorongosa to Caia, Sofala Province

Maríngué is a district in the province of Sofala, in Mozambique, based in the village of Maríngué. It is limited to the north by the district of Chemba, to the west by the district of Macossa (district of Manica province), to the south by the district of Gorongosa, to the southeast by the district of Cheringoma and to the east and northeast by the district of Caia.

Gorongosa is a district in the province of Sofala, headquartered in the village of Gorongosa. It is limited to the north and west by the district of Macossa, to the southwest by the district of Gondola (districts of Manica province), to the south by the district of Nhamatanda, to the east by the districts of Muanza and Cheringoma, and to the northeast by the district of Maringué.

Nhamatanda is a district in the province of Sofala, based in the village of Nhamatanda. It is limited to the North by the District of Gorongosa, to the West by the District of Gondola, to the south by the District of Busi and to the east by the District of Dondo.

Gondola is a district in the province of Manica, headquartered in the village of Gondola. It is limited to the north by the districts of Macossa and Bárue, to the west by the district of Vanduzi, to the south by the city of Chimoio and the districts of Macate, and Búzi of the province of Sofala, to the east by the district of Nhamatanda as well.

1.5 ESIA Approach and Structure

1.5.1 Purpose and Scope of the ESIA

The primary purpose of the Environmental and Social Impact Assessment (ESIA) for the SRSEI is to identify, evaluate, and effectively manage potential environmental and social impacts associated with the Project. By assessing the Project's consequences on the natural and human environment, the ESIA aims to ensure that the Project aligns with regulatory requirements, adheres to best practices, and minimizes adverse effects while maximizing benefits for the communities and the environment. The scope of the assessment encompasses the construction, operation, and decommissioning phases, providing a comprehensive understanding of the Project's potential effects throughout its lifecycle.

1.5.2 Methodology

According to World Bank Group (WBG) Environmental and Social Framework (ESF), in order to adequately manage environmental and social risks and impacts associated with the project, the Borrower will prepare and implement an Environmental and Social Impact Assessment (ESIA), including procedures for screening and excluding any intervention that could cause unprecedented environmental and social impacts to natural resources, communities and sensitive biodiversity ecosystems.

The ESIA for this project has been prepared in accordance with the ESF of the WBG and its Environmental and Social Standards (ESSs) and has considered the environmental and social regulations and requirements of the GoM, in particular the Regulation for the Process of Environmental Impact Assessment –EIA (Decree No. 54/2015, of December 31) to address the Project’s environmental and social concerns.

The ESS applied to this proposed Project which require preparation of this ESIA include:

- ESS1: Assessment and Management of Environmental and Social Risks and Impacts;
- ESS2: Labor and Working Conditions;
- ESS3: Resource Efficiency and Pollution Prevention and Management;
- ESS4: Community Health and Safety;
- ESS5: Land acquisition, Restrictions on Land Use and Involuntary Resettlement;
- ESS6: Biodiversity Conservation and Sustainable Management of Living Natural Resources;
- ESS8: Cultural Heritage; and

- ESS10: Stakeholder Engagement and Information Disclosure.

Under ESS1, environmental and social screening is required for all projects to assess the risks and impacts and provide guidance for an ESIA or Environmental and Social Management Plans (ESMPs) in order to mitigate and/or enhance the risks and impacts.

The environmental and social assessments involved a number of stages, as follows:

- Scoping exercise;
- Field reconnaissance visits;
- Review of Mozambican legislation and international guidelines;
- Consultations with local communities;
- Gathering of baseline data;
- Assessment of potential environmental and socio-economic impacts;
- Identification of significant impacts;
- Development of appropriate mitigation measures;
- Development of an Environmental and Social Management Plan.

1.5.3 Report Structure

The ESIA report is structured as follows:
VOLUME 2A: NON-TECHNICAL SUMMARY – presenting the project, significant impacts and required mitigation measures in non-technical layman's terms.

VOLUME 2B: MAIN REPORT – Consisting of the following chapters:

Chapter 1 - Introduction: background to the project, the terms of reference and scoping report, terminology, outline of the methodology to the ESIA and the report structure

Chapter 2 - Legal framework: description of applicable national legislation and international guidelines.

Chapter 3 - ESIA Process and Public Participation

Chapter 4 - Description of the Project

Chapter 5 - Analysis of Project Alternatives

Chapter 6 - Description of Environment and Social Baseline of the Project Area

Chapter 7 - Environmental and Social Impacts Mitigation Measures

Chapter 8 - Public Participation Process

Chapter 9 – Conclusion

Chapter 10 - References

VOLUME 2C: ANNEXES

VOLUME 2D: PUBLIC CONSULTATION/ PARTICIPATION REPORT

VOLUME 2E: ENVIRONMENT AND SOCIAL MANAGEMENT PLAN (ESMP)

2 POLICY, LEGAL, AND INSTITUTIONAL FRAMEWORK

This chapter offers a thorough exploration of both national (Mozambique) laws and regulations concerning environmental and social (E&S) aspects and the WBG Environmental and Social Standards (ESSs) and presents all relevant international treaties and conventions ratified by Mozambique. This dual perspective ensures that the Project is benchmarked against a broad spectrum of local and international guidelines, from national requirements to best international practices. The chapter undertakes an assessment to identify the most stringent framework from among these standards and guidelines, ensuring that the Project's E&S performance is held to the highest possible criteria and assuring legal compliance throughout the Project's lifecycle.

2.1 National Environmental and Social Legal Framework

The Constitution of the Republic of Mozambique lays the ground for the applicable environmental and social legal instruments. It provides that all the citizens have the right to a balanced and the duty to protect it. It also provides that the state is required to ensure: (i) the promotion of initiatives to ensure ecological balance and environmental preservation, and (ii) the implementation of policies to prevent and control pollution and integrate environmental concerns in all sectorial policies so as to guarantee the citizens the right to live in a balanced environment supported by sustainable development. The proposed project will be required to observe the legal requirements (both biophysical and social requirements) that may be relevant to the project throughout its life cycle.

Relevant environmental and social instruments and regulations required are presented in the next subsections. These sub-sections describe the regulations, major provisions, and their relevance for the project.

2.1.1 Environmental Assessment

National Environmental Policy (Resolution No. 5/1995, of December 6) - Provides the basis for various other environmental legislation. The instrument has been enacted to ensure sustainable development while maintaining an acceptable balance between socio-economic development and environmental protection. It stipulates that the integration of environmental considerations in socio-economic planning, the management of the country’s natural resources and the protection of ecosystems are essential ecological processes. The relevance of this instrument for the project is that the provision contained in it should be reflected in the project to minimize the project risks and impacts on natural resources and ecosystems.

Environmental Law (Law No. 20/1997, of October 1) - Establishes the basis for environmental management as a pre-requisite for a country's sustainable development. In terms of scope, this applies to public and private activities directly or indirectly affecting the environment. The project conformity with this provision is critical to contribute to the country's sustainable development.

Regulation for Environmental Impact Assessment - EIA (Decree No. 54/2015, of December 31) - It defines the fundamental instruments for environmental management, the EIA, which aims at mitigating the negative impacts that certain projects, in the public and private sectors, may cause to the natural and socio-economic environment, through the undertaking of environmental studies prior to commencement of the projects. This also sets out the environmental impact assessment process, required environmental studies, public participation process, the studies review process, project environmental viability decision process, and environmental license emission. So, any project should be submitted to a formal EIA process, under this regulation. So, for SRSEI an environmental license needs to be obtained from MAAP (ex-MTA), and the issuance of the environmental license precedes any other license or permit required for the subprojects.

Regulation on the Environmental Audit Process No.45/2024 of 26 June revokes Decree No. 25/2011, of June 15 – Relates to the need of a process for an environmental audit. It indicates that an environmental audit is a documented and objective instrument for management and systematic assessment of the management system and relevant documentation implemented to ensure the protection of the environment. Its objective is to assess compliance of work and operational processes with the environmental management plan, including the environmental legal requirements in force, as approved for a particular project through the environmental license issued. The proposed SRSEI should require independent environmental audits requested under this decree. The audits may be undertaken by the public entity responsible for environmental management, or a private entity, on an annual basis.

Regulation for Environmental Inspections (Decree No. 11/2006, of June 15) – It governs the supervision, control, and verification of compliance with environmental protection rules in the country. It may happen that, during project implementation, MAAP (ex-MTA) carries out inspections to verify compliance with environmental legislation and site management instruments (Environmental and Social Management Plan- ESMP). ANE shall allow for and facilitate the undertaking of such inspections.

General Directive for Environmental Impact Studies (Ministerial Order No. 129/2006, of July 19) – stipulates the environmental license procedures, its format, and outline and contents of an environmental impact assessment report. The ministerial order aims to standardize the process and the procedures followed by various players in the environmental impact assessment process. The SRSEI safeguards instruments (ESIA, ESMP, and Resettlement plans) reports for various subprojects, should be aligned with the provision of this regulation.

General Directive for Public Participation in the Process of Environmental Impact Assessment (Ministerial Order No. 130/2006) - Defines the basic principles related to public participation, methodologies, and procedures. Considers public participation as an interactive process that initiates at the design stage and continues through the lifetime of the project. It defines that Public Participation Process (PPP) for ESIA must conform to the guidelines provided in this Ministerial Order.

2.1.2 Air quality

Environmental law (Law No. 20/1997, of October 1) - Establishes the maximum standard of toxic substances allowed for discharge into the air. The emissions are further stipulated in Decree No. 18/2004, of June 2. This law is relevant for the project given the permitted level of emissions by law, so as not to harm the environment.

Regulation for Environmental Quality Standards and Effluents Emission (Decree No. 18/2004, of June 2 - as amended by Decree No. 67/2010, of December 31) - Establishes parameters for the maintenance of air quality; patterns of emission of gaseous pollutants for various industries; and standards for emission of gaseous pollutants from mobile sources - including light and heavy vehicles. The SRSEI-MPA project shall comply with the air quality standards, considering the admissible emissions by law, so as not to harm the environment.

Table 2-1 Air Quality Parameters according to the national legislation

Parameters (µg/m^3) = 1/1000 (ppm)	1 Hour		8 Hours		24 Hours		Annual Arithmetic Mean	
	Primary	Secondary	Primary	Secondary	Primary	Secondary	Primary	Secondary
Sulphur Dioxide (SO_2)	800				100		40	
Nitrogen Dioxide (NO_2)	190						10	
Carbon Monoxide (CO)	30000		10000					
Ozone	160		120		50		70	
Particulates ($PM_{2.5}$ / PM_{10})					150		60	

Source: Decree No. 67/2010, of December 31

2.1.3 Water quality

Regulation of Water Quality for Human Consumption (Ministerial Order No. 180/2004, of September 15) - Defines water quality standards for human consumption and defines measures for its control, to protect public health. Any project must meet water quality standards for human consumption.

Water Policy (Resolution No. 42/2016, of December 30) – It provides aspects of sanitation in urban areas, peri-urban and rural areas, hydrologic networks, development of new hydraulic infrastructure, and integrated management of water resources with the participation of interested parties.

Water Law (Law No. 16/1991, of August 3) – The policy seeks to protect ecological balance and environment. The use of water requires concession - for permanent or long-term water uses; or a water license – for short-term water uses.

Licenses are issued for a period of 5 renewable years, while concessions may go up to 50 renewable years. The law provides that any activity with the potential of contaminating or degrading public waters, in particular the discharge of effluent, is subject to a special authorization to be issued by the Regional Water Administration and payment of a fee. If the project requires the abstraction of water from natural sources, a water license must be obtained from the competent authority (Regional Administration of the Waters). If the project requires the discharge of effluents into water bodies (such as may be required by construction camps), a license must be obtained.

Regulation for Environmental Quality Standards and Effluents Emission (Decree No. 18/2004, of une 2 - as amended by Decree No. 67/2010, of December 31) – this defines that when an industrial effluent is discharged into the environment, the final effluent must comply with discharge standards established. The law also incorporates the discharge of domestic effluents.

2.1.4 Waste Management

Environment Law (Law No. 20/1997, of October 1) – in terms of pollution, the law forbids the production and deposition of any toxic or polluting substances on soils, sub-soils, water, or the atmosphere, as well as forbidding any activities which are likely to accelerate any form of environmental degradation beyond the legally established limits. The project needs to include measures to prevent pollution throughout its life cycle. Project compliance with regulation is critical.

Regulation on urban solid waste management (Decree No. 94/2014, of December 31) – Establishes the legal framework for the management of municipal solid waste. The key objective is to establish rules for the production, collection, or disposal of municipal solid waste to minimize their negative impacts on health and the environment. Municipal solid waste, under this regulation, is classified according to the NM339 Mozambican Standard - Solid Waste - Classification. Waste management obligations are assigned to Municipal Councils and District Governments in their respective areas of jurisdiction.

Regulation of Hazardous Waste Management (Decree No. 83/2014, of December 31) – Establishes the legal framework for hazardous waste management. The key objective is to lay down rules for the production, collection, or disposal of hazardous waste to minimize the negative impacts on health and the environment. MAAP (ex-MTA) is responsible for hazardous waste management, especially in licensing of management units. Only registered and licensed entities may collect and transport the waste outside the limits of the facilities. The project must conform to the regulation's requirements related to the management of hazardous waste during construction work and operation.

The environmental legal framework is overall referred to as the need for balanced development and recognized the vulnerability of Mozambique to Climate Change. In 2010 the country approves the National Climate Change Adaptation and Mitigation Strategy (NCCAMS), which represents a turning point in Mozambique's response to the challenges of climate change, indicating a clear set of strategic actions to be implemented so that Mozambique can ensure a more prosperous, resilient and sustainable future.

2.1.5 Land use and rights

Land Policy and Implementation Strategy (Resolution No. 45/2022, of November 28) – It sets out that the State must provide the land for each family to build or possess their habitation, and is responsible for land use and physical planning, although plans can be made by the private sector. The principle of this policy must be incorporated into the SRSEI-MPA project.

Land Law (Law No. 19/1997, of October 1) – Establishes the rights of land use, including details on customary rights and procedures for acquisition and use of land titles by communities and individuals. The law recognizes and protects the rights acquired through inheritance and occupation (customary rights and duties of good faith), except for legally defined reserves or areas where land has been legally transferred to another person or institution.

It provides that the 15 m corridor surrounding secondary and tertiary roads, and the 30 m corridor for primary roads, is defined as public domain. The land use in this corridor is thus reserved for the road infrastructure. The project compliance with this provision is critical and it should inform the resettlement and compensation process, if applicable.

Regulation for the Land Law (Decree No. 66/1998, of December 8) – It is a regulation that defines total protection areas, set aside for nature conservation and State defense, as well as partial protection zones, where land-use titles may not be granted, and where activities cannot be implemented without a license.

Partial protection zones, which include, amongst others: 50 m strip of land along lakes and rivers, 250 m strip of land surrounding dams and reservoirs, 100 m strip of land along the seafront and estuaries, a strip of 2 km along the terrestrial border, and a 50 m corridor of protection for the railway lines.

This regulation defines total and partial protection zones. In these zones, land use is restricted, and the project should consider the interferences with these protection zones so that the implementation does violate this provision of the law.

Regulation of the Use of the Roads and their Protection Zones (Decree No. 109/2014, of December 31)

Partial protection zones for road infrastructure are defined as a 15 m width along either side of secondary and tertiary roads, a 30 m width on either side for primary roads, and 50m for four lane highways. The land use in this corridor is reserved for road infrastructure.

Regulation for the Resettlement Process Resulting from Economic Activities (Decree No 31/2012, of August 8) – Stipulates rules and basic principles for resettlement processes from the implementation of public or private economic activities. Equally, it provides that the Resettlement Plan is part of the ESIA process and that its approval precedes the issuance of the environmental license. This regulation states that if a project results in physical or economic resettlement, a Resettlement Plan needs to be developed as part of the ESIA process and approved.

Technical Directive for the Process of Elaboration and Implementation of Resettlement Plans (Ministerial Order No. 156/2014, of September 19) – It provides the operation of the Regulations on the Resettlement Process and facilitates greater involvement and rapprochement between all parties involved, so that the resettlement does not have a social destructive character but takes the opportunity to develop well- structured and standardized new housing centers. It sets the conceptual framework for the development of Resettlement Action Plans. It equally presents guidelines of the process and identifies the different steps that characterize the development and implementation of the resettlement plan and sets out the content and the results required for each phase. The regulation provides that if a project results in physical or economic resettlement, it is necessary to develop a Resettlement Plan, as part of the ESIA process, and approved as defined in this Regulation. This plan identifies all potentially affected people by the project and characterizes the affected improvements.

Internal Regulation for Functioning of the Technical Commission for Monitoring and Supervision of the Resettlement Process (Ministerial Order No. 155/2014, of September 19) – Establishes the organization and functioning of the actors in the monitoring and supervision of resettlement.

Regulation of the Territorial Planning Law (Decree No. 23/2008, of July 1) – It establishes regulatory territorial planning measures and procedures, to ensure the rational and sustainable use of natural resources, regional potentials, infrastructure and urban centers, and to promote national cohesion and safety of the population. It deals with issues of procedures for expropriation of private property for national public interest reasons. The regulation provides that expropriation for territorial planning is considered to be of public interest if it aims to acquire areas to build economic or social infrastructure with great social positive impacts. Additionally, it states that expropriation should be preceded by just compensation. Most likely, the project will require the expropriation of land and land rights in the project area. The expropriation process should abide by the requirements stated in this regulation, namely the principle of just compensation for losses of property or goods. It also contains applicable procedures in case someone is opposed to the expropriation and/or wishes to contest the compensation amount. Expropriation requires the issuance of a declaration of public interest for the project.

Directive for the Expropriation Process of Territorial Planning (Ministerial Order No. 181/2010, of November 3) – Sets procedures for the expropriation processes resulting from territorial planning, including procedures for the issuance of a declaration of public interest, compensations for expropriation (including calculation methods) and the expropriation process itself. Under this project the expropriation decree will only be applicable to calculate compensation amounts for agricultural land as a basis, and not the total amount. Valuation based on the market value will also be undertaken. All land to be acquired for the project will follow Decree No. 31/2012, of August 8, guidelines from the project namely RPF and ESS5.

2.1.6 Cultural heritage

Cultural Protection Law (Law No. 10/1988, of December 22) – This seeks to protect material and non-material assets of the Mozambican cultural heritage. Material cultural assets include monuments, groups of buildings with historic, artistic or scientific importance, places or locations (with archaeological, historic, aesthetic, ethnologic or anthropologic interest) and natural elements (physical and biological formations with particular interest from an aesthetic or scientific point of view). If archaeological objects are found during subprojects implementation, this law shall apply and the subcontractor shall communicate the finding to the appropriate cultural heritage agency, immediately.

Regulations for the Protection of Archaeological Heritage and Composition of National Council of Cultural Heritage (Decree No. 27/1994 of July 20). Fortuitous Discovery, article 10 states the necessity to safeguard any remains of historical-cultural or archaeological value that may be found during excavations or removals.

2.1.7 Biodiversity

Environment Law (Law No. 20/1997, of October 1) – in terms of biodiversity protection this law covers aspects of guaranteeing the protection of biological resources, particularly of plant or animal species threatened with extinction or any similar issues, by their genetic value, ecological, cultural, or scientific, require special attention. Protection is extended to their habitats, especially those built-in areas of environmental protection. This law is in line with the conservation areas (Law No. 16/2014, of June 20), which stipulates that all activities that could result in changes to land and vegetation cover, or that could disturb flora, fauna, and ecological processes up to the point of compromising their maintenance, are forbidden within national parks, except if required for scientific reasons or management needs. It also indicates that activities can be approved within conservation areas, provided that a management plan is developed and approved.

Forest and Wildlife Law (Law No. 10/99, of July 7) – in terms of forest and wildlife protection this law provides the fundamentals and basic rules on protection, conservation, and sustainable use of forest and wildlife resources. Defines protection zones as territorial delimited areas, representative of the national natural heritage, designated for their biodiversity and fragile ecosystems, or the conservation of animal and plant species. It ensures that all activities that result in changes to land, disturbance to flora or fauna as well as water pollution are forbidden within national parks. The protection of forests and fauna under the SRSEI-MPA is paramount. Decree No. 12/2002, of June 6 which approves the regulation of Law No. 10/99, of July 7 is also applied to protection, conservation, use, exploration, and production activities of fauna and flora resources.

Law for Protection, Conservation and Sustainable Use of Biological Diversity (Law No. 5/2017 of May 11) in terms of conservation areas, Law No. 5/2017, of May 11 and Decree 89/2017, of December 29 are linked as the Decree No. 89/2017, December 29 regulates Law No. 16/2014, of June 20 that was amended and re-published by Law No. 5/2017, of May 11 and Decree No. 89/2017, of December 29 revokes all norms that contradict this decree.

Law No.5/2017, of May 11, which change and republish Law No. 16/2014, of June 20 stipulates that all activities that could result in changes to land and vegetation cover, or that could disturb flora, fauna and ecological processes up to the point of compromising their maintenance, are forbidden within national parks, except if required for scientific reasons or management needs. It also indicates that activities can be approved within conservation areas, provided that a management plan is developed and approved.

Furthermore, in Law No.5/2017, of May 11, the Article 11 states that a public or private entity exploiting natural resources in a conservation area, or its buffer zone must contribute financially to the protection of biodiversity in the conservation area in question and compensate for impacts to ensure there is no net loss of biodiversity.

Regulation of Law for Protection, Conservation and Sustainable Use of Biological Diversity (Decree No. 89/2017, of December 29) is applicable to the set of values and natural resources existing in the national territory and in waters under national jurisdiction, covering all public or private entities that may directly or indirectly influence the national system of the country's conservation areas, competing to the National Administration of Conservation Areas (ANAC). Protection zones are classified to guarantee the representative conservation of ecosystems and species and the coexistence of local communities with other interests and values to conserve. Protection zones are classified into: a) Total conservation areas; b) Conservation areas for sustainable use. In addition, it regulates the creation, modification and extinction of conservation areas, the administration and management of conservation areas, the management plans and closure program, the permitted and prohibited activities in conservation areas (including hunting activities), the exercise of activities in the conservation areas, including the environmental license, the recovery, restoration or rehabilitation of biodiversity, the mechanisms for compensating the conservation effort, the conservation of the natural habitat, and the protection and inspection of biodiversity, setting the sanctioning regime.

Articles 124 outlines the different types of compensation related to conservation: a) Compensation for ecological services provided by the conservation area and buffer zone; b) Compensation for anticipated and quantifiable impacts in environmental licensing, caused by the use of natural resources in conservation areas and buffer zones, and ensuring that there is no net loss of biodiversity; c) Compensation for unforeseen or unquantifiable impacts on biodiversity in the environmental licensing, in order to achieve no Net Biodiversity Loss; d) Payment for carbon stocks related to a conservation area and its buffer zone

Article 125 outlines requirements for no net biodiversity loss: 1. No net loss of biodiversity is a goal for a development activity or project, where impacts on biodiversity are fully offset by measures to prevent and minimize the loss of biodiversity. 2. No net loss of biodiversity implies that it should not reduce in the following cases: a) Within a species and between species or vegetation types; b) The long-term viability of species and vegetation types, ensuring the adequate size of their populations and areas of occupation; c) The functioning of groupings of species and ecosystems, including ecological and evolutionary processes.

The **Biodiversity Offset Directive, (Ministerial Order No. 55/2022, of May 19)** outlines the principles, methodologies, requirements, and procedures for the proper implementation of Biodiversity Offsets as part of environmental impact assessment processes. When a significant residual negative impacts on biodiversity remain or are expected after implementing measures to avoid, minimize, and restore affected areas, approval of biodiversity offset management plan is required for Category A+ or A projects. This applies to all activities needing an environmental license, including oil and mining operations. Non-compliance can lead to denial of the issuance or renewal of the environmental license. The types of biodiversity applicable under Decree No. 55/22, of May 19 are as follows (MTA, 2023):

- i) Legally protected species or ecosystem/habitat;
- ii) Species or ecosystem/habitat that is threatened or vulnerable;
- iii) Endemic species or ecosystem/habitat with a restricted geographic distribution;
- iv) Ecosystem/habitat of significant importance for threatened, endemic, or restricted distribution species and/or species protected in the country;
- v) Ecosystem/habitat that provides conditions for significant concentrations of migratory and/or congregatory species;
- vi) Location that corresponds to a key area for biodiversity;
- vii) Other species/ecosystems/habitats deemed important to preserve.

Based on the findings of the Road Permeability to Wildlife Study and further consultation with stakeholders, it is recognized that while construction-phase activities are not expected to result in significant residual biodiversity impacts requiring offsets under Decree No. 55/2022, of May 19, there remains a potential for operational-phase impacts, particularly related to wildlife-vehicle collisions. This risk is more pronounced in road sections intersecting or adjacent to ecologically sensitive areas such as the Gorongosa National Park Buffer Zone and the Gorongosa-Marromeu Key Biodiversity Area. In line with this precautionary principle and the requirements of both Decree No. 55/2022, of May 19 and the ESS6, an operational-phase wildlife monitoring program will be implemented to assess the extent of wildlife mortality and barrier effects along critical segments. Should the monitoring data indicate significant residual impacts, the implementation of biodiversity offset measures will be re-evaluated in coordination with the competent national authorities and relevant conservation stakeholders.

2.1.8 Labor management

Labor Law (Law No. 13/2023, of August 25) - is the main statute governing all aspects of the employment relationship. This law governs work relations between employers and domestic and foreign workers in all industries and includes principles of safety, hygiene and health of workers. Under the law, an employer must provide their employees adequate conditions to remain in good physical health in a decent working environment with high morale, inform them about the risks of their work, and instruct them about compliance with the standards for hygiene and safety at work. The employer must also provide first aid and medical treatment to workers in the event of accidents, acute illness, poisoning, or general ill health. This law shall be applied under the SRSEI project particularly to all contractors implementing activities under the project. Under this law, no child labor is permitted, as it does not allow employment of people below 18 years of age.

The labor law also determines minimum wages per sector. The Ministerial Order No. 72/2022, of June 24 established the minimum wage for the construction sector of 7,409.08 MZN (Seven thousand, four hundred and nine meticais and eight centavos). Minimum wages are periodically updated and should be followed closely during the project period to ensure the correct minimum wages are adhered to in labor contracts.

The legal framework for social protection was also established by Law No. 4/2007 of February 7. This Law defines Social Protection and outlines the Social Protection system. The social protection system has three levels, i.e.: a) Basic Social Security; b) Mandatory Social Security; c) Complementary Social Security. Mandatory social security ensures the livelihood of workers who lack or have a decreased capacity to work as well as to ensure the livelihood of surviving family members in case of the death of the aforementioned worker and to provide supplementary conditions for survival. Contributions to mandatory social security are distributed between employers and workers. Workmen's compensation for each worker is a requirement under this law for the contractor's civil works operations.

Law for Protection of People, Workers and Work Candidates Living with HIV and AIDS (Law nº 19/2014, of August 27) – It sets out general principles that aim to ensure that all employees and job applicants are not discriminated against in the workplace or when applying for jobs, for being suspected of having or having HIV and AIDS. Under the law, an employee who is infected with HIV and AIDS in the workplace, in connection with their professional occupation, in addition to the compensation which one is entitled to have, one must have adequate health care guaranteed to relieve one's health status, according to the labor law and other applicable legislation, funded by the employer. Under the same law, it is prohibited to test for HIV and AIDS in workers, job seekers, candidates to evaluate the training or promotion candidates at the request of employers, without the employee's or job seeker consent. The project must ensure that workers involved in the project, are aware of the law, and where workers are infected, they shall be placed in positions compatible with their residual capacities.

Regulation for the General Labor Inspection (Decree nº 45/2009, of August 14) – This regulation lays down the rules on inspections, under the control of the legality of work. It states the employer's responsibility for the prevention of occupational health and safety risks of the employee. These provisions must be enforced under the SRSEI especially concerning contractors implementing activities.

2.1.9 Gender Equality and Women´s Rights

Regarding gender issues, the Constitution of the Republic of Mozambique enshrines equal rights for men and women. In 1979, the country was one of the 189 signatories of the United Nations Convention on the Elimination of All Forms of Discrimination Against Women (CEDAW). This convention is an international treaty aimed at promoting women's rights and eliminating gender discrimination. Similarly, in 1995, Mozambique adopted the Beijing Platform for Action, an international document aimed at promoting women's rights and eliminating gender discrimination.

The Ministry of Gender, Children and Social Action (MGCAS) has developed policies and strategic plans to decrease gender-based inequalities within different sectors. Therefore, Gender is mainstreamed in different pieces of legislation. In recent years, the Parliament has approved the **Family Law (Law No. 10/2004, of August 25)**, which establishes equal rights and duties for family members and spouses towards each other and establishes gender equality, later on, approved the **Law of Domestic Violence Against Women (Law No. 29/2009, of September 29)** legislates on domestic violence against women, and aims to prevent domestic violence, sanction offenders, and provide necessary protection to victims. This law equips state bodies with the necessary tools to combat domestic violence effectively. The **Law for the Revision of the Penal Code (Law No. 24/2019, of December 24)**, which also repels Article 2 of Decree No. 182/74, of May 2, and the Penal Code approved by Law No. 35/2014, of December 31, legislates on crimes against sexual freedom in its Chapter 7. Regarding sexual assault, **Article 201** criminalizes anyone who engages in intercourse against another person's will, through physical violence or intimidation, including cases where the victim is deprived of reason or their senses.

The **Law on the Prevention and Combat of Early Marriages (Law No. 19/2019, of October 22)** establishes a legal framework to prohibit, prevent, and penalize early unions, protecting children involved in such unions. An early union is defined as a relationship where at least one party is under 18 years old, formed with the intention of creating a family. The law also addresses coercion, assistance for unions, and sexual acts with children, further safeguarding minors' rights and wellbeing. Sexual harassment is mentioned in Article 66. Article 202 of Law No. 24/2019, of December 24) considers any sexual contact with minors under 12 years old a crime. Furthermore, Article 203 legislates against sexual acts involving violence or serious threats with minors under 16 years old. This law serves as one of the legal instruments for the protection of children's rights.

As for minors, **Law No. 8/2002, of February 5**, updates the **1886 Penal Code (Decree of September 16)** on various issues. Article 405 criminalizes ascendants, stepfathers, stepmothers, and adoptive parents who encourage or facilitate the prostitution or corruption of their descendants or stepchildren. It also legislates on crimes of corruption of minors (Article 406) and mistreatment or overburdening of minors and incapacitated persons (Article 367). This law considers anyone under 21 years of age a minor.

Labor Law (Law No. 13/2023, of August 25), considers sexual harassment as a disciplinary infraction committed either in the workplace or outside of it, which interferes with job stability or career progression. In the revised **2019 Penal Code (Law No. 24/2019, of December 24)**, article no. 204 addresses indecent exposure while article no. 205 addresses sexual harassment. The practice of workplace harassment that harms the worker entitles the worker to compensation for material and non-material damages. Harassment in the workplace, or outside of it, encompasses a range of unacceptable behaviors and practices, as well as threats of such behaviors and practices. These acts can occur sporadically or recurrently, causing physical, psychological, sexual, or economic harm. They also include violence and gender-based harassment.

The Labor Management Program (LMP) prepared for SRSEI contains further details on applicable labor laws in Mozambique.

2.1.10 Covid19

Several laws were developed to manage Covid19, e.g., Decree No. 79/2020 of September 4, which enforced a state of public emergency and red alert, Decree No. 50/2021 of July 16, Decree No. 2/2022, of January 19, and Decree No. 4/2022, of February 18, which reviewed and updated measures to contain the spread of the pandemic and repealed certain requirements as the pandemic subsided in 2022.

2.2 International Standards and Guidelines

2.2.1 Air Quality and Dust

In regard to Air Quality Guidelines, it is important to note that Mozambique has established specific national standards for Air Quality. In accordance with the World Bank Group (WBG) Environmental Health and Safety (EHS) Guidelines, these national standards have been compared with the international standards as presented in the accompanying table. This comparison is crucial to ensure that the project aligns with both national and international environmental requirements, providing a comprehensive framework for air quality management.

Table 2- 2-2 WHO Air Quality Guidelines

Pollutant	Averaging Period	Guideline Value in µg/m^3
Sulfur Dioxide (SO_2)	24-hour 10-minutes	125 (Interim Target 1) 50 (Interim Target 2) 20 (Guideline) 500 (Guideline)
Nitrogen Dioxide (NO_2)	1-year 1-hour	40 (Guideline) 200 (Guideline)
Particulate Matter (PM_{10})	1-year 24-hour	70 (Interim Target 1) 50 (Interim Target 2) 30 (Interim Target 3) 20 (Guideline) 150 (Interim Target 1) 100 (Interim Target 2) 75 (Interim Target 3) 50 (Guideline)
Particulate Matter ($PM_{2.5}$)	1-year 24-hour	35 (Interim Target 1) 25 (Interim Target 2) 15 (Interim Target 3) 10 (Guideline) 75 (Interim Target 1) 50 (Interim Target 2) 37.5 (Interim Target 3) 25 (Guideline)
Ozone	8-hour Daily Max.	160 (Interim Target 1) 100 (Guideline)

Source: WHO Guidelines for Air Quality (2021)

Upon thorough comparison, it is observed that if the same period of measurement is compared for different parameters, e.g.,

- SO_2 for 24h period: National (100) is less demanding than WB EHS Guidelines (20, although interim targets are 50 and 125)
- NO_2 for 1h period: WB (200) is less demanding than National (190)
- PM_{10} for 24h period: National (150) is less demanding than WB (50, although interim target may range from 75-150)
- $PM_{2.5}$ for 24h period: National (nothing specified), WB 25, although interim target may range from 37.5-75)
- Ozone 8h period: National (120) is less demanding than WBG (100, although interim target 160)

In some instances, national legislation is more stringent, e.g., NO_2, and in others WBG EHS guidelines are more stringent. The more stringent shall apply to the air and dust management approach for the project.

Table 2-3 Air Quality Standards for the Project

Parameter	Measuring Period	Permissible Limit	Unit	According to:
SO_2	24 hr	100	µg/m^3	National Standards
NO_2	1 hr	190	µg/m^3	
CO	8 hrs	10,000	µg/m^3	
Ozone	8 hrs	120	µg/m^3	
PM_{10}	24hrs	150	µg/m^3	National & WHO Standard
$PM_{2.5}$	24hrs	25	µg/m^3	WHO standard

Source: WHO Air Quality Guidelines (2021)

2.2.2 Noise and Vibration Standards

In the absence of specific national standards pertaining to permissible noise levels in Mozambique, it is pertinent to adhere to the World Bank Group (WBG) Guidelines for environmental noise control in the context of the Project. Acceptable noise levels vary, e.g., occupational, campsite or work site, or noise levels at community receptors, i.e., houses, schools, etc. For example, WBG EHS Standards (page 65) state that occupational noise levels, i.e., workers at campsite or at work fronts must not be subject to noise levels over 85 d(B)A for more than an 8-hour period, without hearing protection (or peak noise levels reach 140 dB(C)). WBG EHS Guidelines (page 66), on-site noise levels, Road and Bridge rehabilitation is considered “Light Industry”, indicating the working environment (campsite or work fronts) shall not exceed noise levels over 50-65 dB(A), in an eight-hour period.

Off-site noise levels (page 53 of the WBG EHS Guidelines) near houses or schools, during daytime, should be below 55 dB(A), for a one-hour period measurement; as per Table 2-4 below. The adoption of these international standards ensures a robust approach to managing and mitigating noise pollution, thereby aligning the Project with globally recognized environmental practices.

Table 2-4 WBG Guidelines for Permissible Noise Levels

Receptor	One Hour L_{Aeq} (dBA)	
	Daytime (07:00-22:00)	Nighttime (22:00-07:00)
Residential, Institutional, Educational	55	45
Industrial, Commercial	70	70

Source: WHO Air Quality Guidelines (2021)

2.2.3 Wastewater and Effluent Quality Standards

According to WBG EHS standards in relation to wastewater, national standards are commonly used for specificity based on the design of the locally available system, however the following table outlines indicative values in case no specific standards are locally available. Since national standards outline standards for effluent quality for several specific industries but do not include a specific standard for general construction work, the following WBG guidelines should apply to effluent generated during this Project.

Table 2-5 WBG EHS - Indicative Values for Treated Sanitary Sewage Discharge with Decree No. 18/2004, of June 2 values for domestic liquid effluent

Pollutant	Units	Guideline Value	Guideline Value (Annex IV – Decree 18/2004, of June 2) Standards for domestic liquid effluent
pH	pH	6 - 9	6-9
BOD (Biological Oxygen Demand)	mg/l	30	-
COD (Chemical Oxygen Demand)	mg/l	125	150
Total Nitrogen	mg/l	10	15
Total Phosphorus	mg/l	2	10
Oil and Grease	mg/l	10	-
TSS (Total Suspended Solids)	mg/l	50	60
Total coliform bacteria	MPN/100mL	400*	

Source: WBG EHS and Decree No. 18/2004, of June 2

2.2.4 World Bank Group Environmental and Social Standards

The WBG has developed 10 environmental and social standards (ESSs). These set out the requirements for the proponent relating to the identification and assessment of environmental and social risks and impacts associated with the proposed projects. The application of these standards will be required to identify and manage environmental and social risks associated with implementation of this project.

The relevant ESSs for the proposed project are presented in table below:

Table 2-6: Analysis of ESS relevance in relation to the proposed SRSEI Project

ESS	Relevance in relation to the Project
ESS 1: Assessment and Management of Environmental and Social Risks and Impacts	**RELEVANT** The interventions proposed under SRSEI are not likely to result in significant adverse environmental or social impacts. However, the implementation of construction structures under Component 1, 2 and 5 may lead to some negative environmental and social impacts which must be mitigated. Potential positive impacts include increased employment opportunities and skills transfer, business/trade opportunities, increased revenue for the government, enhanced capacity for RF/ANE and MTC/INATRO in implementation of ESMS and road safety measures, and improved access and connectivity to markets and trade hub areas. The potential negative impacts include increased risks of higher levels of noise & vibration, air and water pollution, soil erosion, solid and liquid waste generation, creation of borrow pits and quarry sites, risks to loss of natural habitats and biodiversity, loss of land and property (e.g., structures for small markets, shops, houses), disruption of utility services (e.g. electricity, water, etc.,), increased risk of transmission of communicable diseases (e.g. HIV & AIDS and STIs, Covid-19), risks of climate change due to emission of Greenhouse Gases (GHGs), increased use of energy and water, loss of employment (post-construction), traffic disruption. There are also increased risks of GBV/SEA/SH/VaC, increased risks of child abuse and forced labor due to labor influx, increased risks and hazards of occupational health and safety, community health risks, risk of exposure to hazardous wastes and toxic chemicals, disruption of traditional norms and family stability due to cases of promiscuity, and theft and vandalism of construction materials. It is necessary to establish the principles, rules, guidelines and procedures for assessing environmental and social risks and impacts and to define the necessary measures to ensure that negative impacts are mitigated and positive ones are enhanced. For this purpose, the following Environmental and Social (ES) instruments are applicable to the project: RPF, ESMF, ESIA/ESMP, Social Assessment, GBV/SEA/SH/ VaC risk assessment.
ESS 2: Labor and Working Conditions	**RELEVANT** The Project will use different types of labor, including civil servants, direct workers, contract workers and primary supply workers, with various risks related to: health and safety of workers and surrounding communities; OHS/ES; labor disputes; discrimination against vulnerable groups; child labor and forced labor, as well as risks of GBV/VaC/SEA/SH in the workplace. Labor-related risks will have to be managed in accordance with the principles, rules and guidelines set out in the LMP drawn up for the project in accordance with the requirements of ESS 2 and existing national labor legislation.
ESS 3: Resource Efficiency and Pollution Prevention and Management	**RELEVANT** The potential negative impacts include increased risks of higher levels of noise & vibration, air and water pollution, soil erosion, solid and liquid waste generation. The implementation of environmental management plans specific to each sub project will allow adequate mitigation of issues related to the use of resources and pollution prevention and management. Potential positive impacts include optimized use of energy and water due to energy efficient technologies put into use (e.g., solar panels, constructed rainwater harvesting reservoirs/tanks)

ESS	Relevance in relation to the Project
ESS 4: Community Health and Safety	**RELEVANT** The project may lead to increased risks of GBV/SEA/SH/ VaC, increased risks of child abuse and forced labor due to labor influx, increased risks and hazards of occupational health and safety, community health risks which include water, soil, noise and air pollution to community members; potential increased risks of flooding and landslides. Poor road traffic management and insufficient road safety also create risks and hazards for community members;
ESS 5: Land Acquisition, Restrictions on Land Use and Involuntary Resettlement	**RELEVANT** Land will be required during the process of construction on the road either for access roads or detours (within the partial protection zone), as well as for establishment of camp sites of contractors, borrow pits and quarries. The RPF must be followed as resettlement plans are developed at sub project level to ensure that all project affected persons are adequately compensated for loss of assets.
ESS 6: Biodiversity Conservation and Sustainable Management of Living Natural Resources	**RELEVANT** The potential negative impacts include risks to loss of natural habitats and biodiversity and may include increased deforestation along the N1 corridor, and risks of loss of wildlife (e.g., at *Coutadas* (hunting concessions in Cheringoma) where the road sections passes through and/or near these key biodiversity and protected areas, such as Gorongosa National Park ecological corridors).
ESS 7: Indigenous Peoples/Traditional Local Communities Historically Disadvantaged in Sub-Saharan Africa	NOT RELEVANT This standard is not relevant to the Project. In the national context and the specific Project implementation areas there are no distinct social and cultural groups identified according to ESS7.
ESS 8: Cultural Heritage	**RELEVANT** While it is unlikely that the construction activities envisaged under the project will adversely affect the built heritage, intangible heritage or natural heritage, during the sorting of subprojects will also have to be identified and assessed their risks and potential impacts on cultural heritage and, where necessary, mitigation measures for the identified risks/impacts.
ESS 9: Financial Intermediaries	NOT RELEVANT The project does not involve financial intermediaries.
ESS 10: Stakeholder Engagement and Information Disclosure	**RELEVANT** A participatory, inclusive and culturally appropriate approach will have to be ensured during the project life cycle. A SEP has been prepared to identify key stakeholders in the project (affected parties and other parties), including independent consultations with

ESS	Relevance in relation to the Project
	vulnerable groups, and sets out guidelines and procedures to ensure that stakeholders are meaningfully informed about the status of the project and can contribute to and participate in its implementation. During the life cycle of the project it will also be necessary to respond in a timely manner to the questions and complaints of the parties affected by the project related to the environmental and social performance of the project. To receive and facilitate the resolution of such questions and complaints, a Grievance Redress Mechanism (GRM) will be developed and implemented, the requirements of which are described in this document. The GRM will include specific requirements for the receipt, treatment and ethical and confidential resolution of ES/GBV/VaC/SEA/SH-related complaints, including several accessible entry points, referral to survivor support services, and safe and confidential survivor-centered complaint management procedures.

2.3 GAP Analysis between National Instruments and World Bank Group Environmental and Social Standards

With respect to ESS1, it is mandatory for all projects supported by the Bank through Investment Project Financing (including SRSEI) to have the environmental and social assessment and management of social risks and impacts carried out. Thus, all projects are subjected to Environmental and Social screening process under this standard. Additionally, there is a possibility that the rehabilitation and improvement works, and construction of associated temporary facilities such as the camp yards and offices for workers are likely to cause negative environmental and social impacts and hence, need for subjecting the project sub-components to Environmental and Social screening process.

The use of only the Mozambican legal framework does not cover all WBG ESF requirements, hence the table below identifies some of the gaps in the national legislation in comparison to the ESSs.

Table 2-7 Comparison between Mozambican legislation and World Bank Group E&S Standards

World Bank Group ESS provisions	Mozambican Legislation	Gaps Identified	Mitigation Measures
ESS 1: Assessment and Management of Environmental & Social Risks and Impacts	EIA required by Environment Law Nº 20/97 of October 1[t], and Decree Nº 54/2015, of December 31. The Regulation for the EIA process classifies the projects into 4 Categories: A full EIA, A+ category subject to review by professional assessors, is also required for Category A. A Simplified EIA is required for category B and category C only a best practices guideline	EIA required by Environment Law Nº 20/97 of October 7, and Decree Nº 54/2015, of December 31 do not indicate the need to prepare ESMF for projects whose exact locations are not known. Only EIA process is discussed. Categorization does not follow the same criteria. Under the WBG ESF: High, Substantial, Moderate and Low categories are used instead.	Despite minor differences there are no conflicts between the two sets of legislation. The Mozambican legislation does not have any instruments above the project. The instruments are only prepared for the implementation of the project that the site is known. Both systems have to be followed/addressed since subproject screening since both systems have one common element of project screening.
ESS2: Labor and Working Conditions	The Labor Law (Decree No. 23/2007) and Labor inspection (Decree nº 45/2009) mention the labor working conditions, Labor Law no. 13/2023 mentions sanctions related to sexual harassment. Employers are responsible for the establishment of a safe working environment free of sexual harassment in their activities and operations	National legislation does not mention the need to develop Labor Management Procedures including the requirement for Grievance Redress Mechanism (GRM) to be established as early as possible in the project development phase. The WBG Environmental, Health and Safety Guidelines sets, in some cases, different standards for Occupational Health & Safety for workers.	SRSEI Project has followed ESS2 and developed Labor Management Plan with relevant provisions, including GRM and OHS Emergency Preparedness and Response, OHS management plan to include WBG EHS Guidelines standards for air quality, dust, noise, to bridge the gaps.
ESS 3: Pollution Prevention and Resource Efficiency	Environmental Law (Law No. 20/97, of October 1), Regulation for Environmental Standards and Effluent Emission (Decree No. 67/2010, of December 31), Pollution (Law No. 20/97, of October 1), Regulation on urban solid waste management (Decree No. 94/2014, of December 31), Hazardous Waste Management (Decree No. 83/2014, of December 31) & NM339 Mozambican	The national legislation mostly focuses on pollution prevention and less on aspects of resource efficiency. The WBG Environmental, Health and Safety Guidelines outlines different standards for water, wastewater, soil,	SRSEI Project will follow provisions of ESS3 on resource efficiency including the project screening its activities for cumulative impacts can be assessed.

World Bank Group ESS provisions	Mozambican Legislation	Gaps Identified	Mitigation Measures
	Standard are some laws and standard enacted to prevent environmental pollution from solid and liquid wastes, greenhouse gases and hazardous/toxic chemicals	waste, air, noise and energy management, in some instances.	C-ESMP should include additional references and follow the most stringent.
ESS 4: Community Health and Safety	The Labor Law (Decree No. 13/2023, of August 25); Social Protection Law (Law No. 4/2007 of February 7); Protection of Workers with HIV/AIDS (Law nº 19/2014, of August 27); and Labor relations (Decree No. 13/2023, of August 25) are national laws that promote safety, hygiene, health of workers and welfare of relatives of an employee when dead.	However, these laws do not focus much on community health and safety but that of workers. WBG Environmental, Health and Safety Guidelines sets different standards for water, wastewater, air, noise, energy and road safety management for communities, in some cases.	This gap has been addressed through the implementation of ESS4 which addresses potential risks and impacts on communities that may be affected by project activities, including training them on GBV/SEA/SH, Road Safety and communicable diseases (HIV, STIs)
ESS 5: Land acquisition, restrictions on land use and involuntary resettlement	Land use rights (Law No. 19/1997, of October 1); Decree No. 31/2012, of August 8; Technical Guideline of Planning and Implementation Process of Resettlement Plans (Ministerial Order No. 156/2014, of September 19) & Guidelines for the Expropriation (Ministerial Diploma No. 181/2010, of November 3), these Mozambican legislations regulate the condition and the compensation mechanisms that govern the land expropriation or acquisition for public and economic projects.	There is no significant Gap between National and WB requirements.	SRSEI-MPA Project will adopt the ESS5 principles, procedures and guidelines to ensure any impacts inflicted on restrictions on land use biodiversity are compensated for the losses.
ESS 6: Biodiversity conservation and sustainable management of living resources	Biodiversity protection (Law No. 20/97); Forest and wildlife protection (Law No. 10/99, of July 7); & Decree No. 12/2002, June 6 approves the regulation of Law No. 10/99, of July 7 focus on protection, conservation, use, production of flora and fauna resources, and conservation areas, including forest and wildlife.	There is no significant Gap between National and WBG requirements.	SRSEI-MPA Project will adopt the ESS6 principles, procedures and guidelines to ensure any impacts inflicted on biodiversity are compensated for to offset losses. It should follow the mitigation hierarchy: avoid, minimize, mitigate and offset.

World Bank Group ESS provisions	Mozambican Legislation	Gaps Identified	Mitigation Measures
	Conservation Law (Law No. 5/2017, of May 11), Article 11 states that a public or private entity exploiting natural resources in a conservation area, or its buffer zone must contribute financially to the protection of biodiversity in the conservation area in question, and compensate for impacts to ensure there is no net loss of biodiversity, Decree 89/2017, of December 29, Articles 124 and 125 apply to compensation related to conservation and requirements for no net biodiversity loss		
ESS 8: Cultural heritage	Cultural Heritage (Law No. 10/88, of December 22) & The National Heritage Protection Law (Decree No. 27/1994 of July 20).) focus on protection of material and non-material (antiques historical and cultural heritage) assets of the Mozambican cultural heritage.	The only gap that exists between the two legislations is that the national legislation does not focus on preparation of a chance finds procedure as part of the assessment instrument and does not focus on preparation of ESMF a part of the assessment tool	SRSEI-MPA Project will follow provisions of ESS8 on preparation of a chance finds procedures and ESMF as part of the tools for assessment of cultural heritage materials.
ESS 10: Stakeholder Engagement and information Disclosure	Articles 13 (No. 3) and 24 (No 1) of the Land Law (Law No. 19/1997, of October 1); Article 25 (No. 1) of the Land Law Regulations (Decree No. 66/1988, of December 8) & Article 27 (Nos. 2 and 3); and the Land Legislation Supplement (1998)1 in Article 50, 51, 52, and 53 focuses on stakeholder engagement on development projects that have risks and impacts on project affected persons and also on other interested parties.	The only gap that exists between the two legal frameworks is lack of GRM in national legislation useful to address grievances that may arise	A GRM for this Project has been developed and wherever necessary, World Bank Group GRM will be adopted for this Project if the GRM prepared is not sufficient to address all grievances which may arise.

3 ESIA PROCESS

The ESIA process commenced with an environmental screening conducted at the provincial level by the Provincial Services of Environment (SPA) of Sofala which resulted in a decision to classify the project as Category A according to Annex IV of Decree No. 54/2015, December 31, "Regulations for the Process of Environmental Impact Assessment". (Volume 2C Annex 1 contains copies of letters categorizing the project as being of category A):

- Sofala province: Letter Ref No. 140//DA/SPA/252

In accordance with Decree No. 54/2015, of December 31, a project scoping exercise was carried out with the following principal objectives:

- The identification of potential significant environmental impacts arising from the project; and
- To develop the Terms of Reference (ToR) for the ESIA process.

The ESIA scoping exercise included the following:

- Interviews and meetings with stakeholders;
- A review of selected relevant Mozambique legislation and WBG E&S Framework (ESF);
- Obtaining and reviewing information from key governmental and non-governmental institutions; and
- Specialist investigations in the fields of agriculture, air quality, archaeology and heritage, community and socioeconomics, ecology, noise and vibration, traffic and transportation, and water resources.

A Scoping Report and a Public Consultations Report were submitted to ANE IP and subsequently to SPA.

The approvals of the Scoping Reports (EPDA) were obtained from Ministry of Land and Environment (MTA) and a copy of approval letters is included in Volume 2C Annex 2:

- Sofala province: Letter Ref No.:401/MTA/183/GM/220/23, on 12th October 2023

The ESIA Scoping Reports established the environmental impacts considered to be potentially significant and therefore requiring detailed assessment. The specific methodology for the ESIA was developed to be consistent with the scope and potential environmental and socio-economic implications of the proposed project.

To inform findings from the field research, a literature review was carried out of applicable Mozambican legislation, ANE's environmental policy and relevant World Bank Group E&S Framework (ESF), EIA's for similar projects, Economic and Social Development Plans and consultation of the District Profile prepared based on 2017 Census for all project affected district.

3.1 Public Consultation and Disclosure

Public consultations for the ESIA process were conducted based on the national legislation guidelines and World Bank Group E&S Framework (ESF) (ESS 10: Stakeholder Engagement and Information Disclosure), as follows:

- Public engagement followed appropriate channels – initial contact was made with district administrations and local authorities followed by discussions with community leaders to members of affected communities.
- Public consultation: started in early stage – communities were engaged during the scoping exercise through individual and group meetings were held and were on-going throughout the fieldwork;
- Public consultation gave particular emphasis to women's participation – women were encouraged to participate through individual invitations, women-only group meetings and encouragement to speak during wider meetings; and
- Public participation influenced decision making – a number of major concerns noted during the public meetings informed actions proposed in the ESIA. These included the safety aspects of the road, the inclusion of rest areas for drivers, and a transparent selection process for employment during the construction phase.

The public consultations had the following key objectives:

- To demonstrate to those consulted that their input has been taken into account;
- To collect any further inputs; and
- To provide more information with respect to the project and the project status.

Details of the consultations undertaken are presented in ***VOLUME 2D – Public Consultations Report.***

4 DESCRIPTION OF THE PROJECT

4.1 Current Situation

The Concept Design consultant provided inception and interim reports with information about field assessments conducted in March 2024. All data or information about concept designs included in this report related to the section Gorongosa-Caia: Package 2 - Lot 2 (84 - 168km) the design report was prepared by LEA Associates South Asia – LASA (Design consultant).

4.1.1 Section between Gorongosa-Caia (km 84-168)

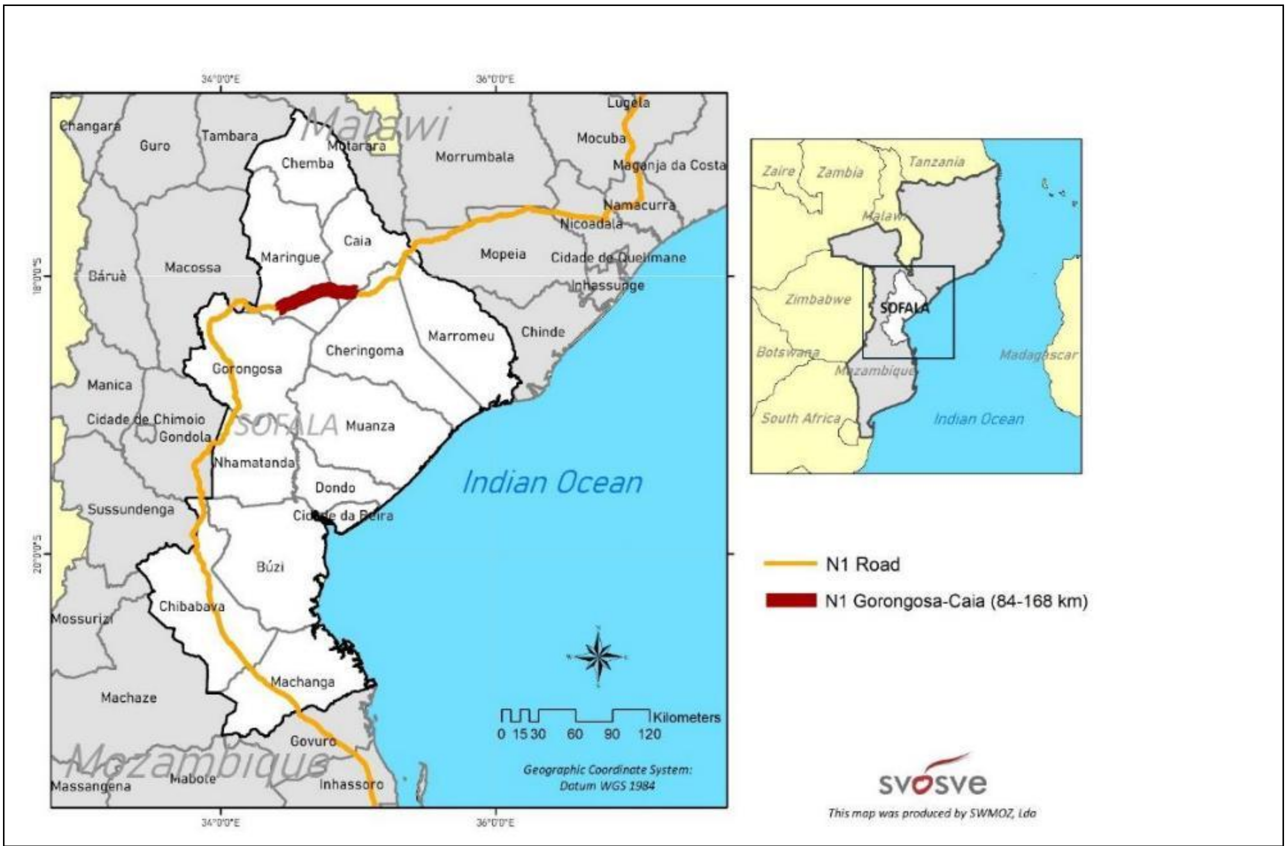


Figure 2 Location of project road Package 2 Gorongosa-Caia km 84-168 Lot 2

The project road section is exceptionally difficult to drive due to the poor condition of the road and currently takes up to three hours to complete the 84km.

Condition of road start of project (Km84)

Condition of road end of project (Km168)

Images of terrain and road condition

Figure 3 Condition of N1 road sections captured by design consultant,
Source: Inception report, LASA, March 2024

There are five bridges crossing the main rivers Nhapherua, Nhamapaza, Mombezi, Nhanzaza, and Fudza and appear to be in fair condition from visual assessment but will require further investigation.

Nhapherua River (Km 101+260)

Nhamapaza River (Km 126+260)

Mombezi River (Km 133+260)

Nhanzaza River (Km 143+680)

Fudza River (Km155+320)

Figure 4 Pictures of existing bridges Km 84-168 captured by design consultant, LASA, March 2024
Source: Inception report, LASA, March 2024

The condition of the existing culverts found was fair to poor. Based on the Hydrological and Climate Resilient study, it will be proposed that the culverts are widened and improved to accommodate increased water flow from extreme climate events.

Table 4-1 Existing box culverts noted by design consultant LASA, March 2024

Type of Structure	Span	Details of Existing Span	Total No.
Box Culvert	Single Span	1x2.0x2.0	3
		1x2.4x2.0	2
		1x3.0x2.0	2
		1x3.0x3.0	1
		1x4.0x4.0	1
	Double Span	2x1.5x1.5	1
		2x2.0x1.0	1
	Triple Span	3x2.0x1.2	1
	Four Span	4x2.0x1.2	1
		4x3.0x3.0	1
		Grand total	**14**

Source: Interim report, LASA, March 2024

Table 4-2 Existing pipe culverts noted by design consultant, LASA, March 2024

Type of Structure	Span	Details of Existing Span	Total No.
Pipe Culvert	Single Span	1x0.6	3
		1x0.75	1
		1x0.8	5
		1x0.85	27
		1x0.9	48
		1x1.0	9
		1x1.2	5
		1x1.5	1
	Double Span	2x0.85	4
		2x0.9	7
		2x1.0	8
		2x1.2	2
	Triple Span	3x0.85	2
		3x1.0	2
		Grand total	**124**

Source: Interim report, LASA, March 2024

Single pipe

Single cell box

Double pipe

Double cell box

Triple pipe

Triple cell box

Four cell box

Figure 5 Pipe and box culvert examples noted by design consultant LASA, March 2024
Source: Inception report, LASA, March 2024

The existing road is essentially a bitumen road and the existing geometry is consistent with the same class. As it is located in rolling and plain topography, both existing horizontal and vertical geometry are consistent with the existing topography. Sharp bends are quite frequent in certain sections of the road and the existing carriageway width is 6.8-7.2m throughout the project corridor. The condition of existing pavement throughout the project road is not good as patches, complete surface failure, edge failure and potholes were observed, and some of the sections seem to be in poor to fair condition.

Patches

Complete surface failure

Edge breaks

Potholes

Figure 6 Existing pavement conditions noted by design consultant LASA, March 2024
Source: Inception report, LASA, March 2024

The condition of the existing traffic sign boards are fair. However, the longitudinal gradients along with sub-standard vertical curves seem to be a major safety hazard.

4.2 Design Phase – Proposed Roads

Pavement Rehabilitation Design

ARUP consultants produced a detailed design report in 2017 and outlined the following options for rehabilitation of the pavement:

- Option 1: Cement Treated Base with material supplement, or
- Option 2: Bitumen Stabilized Base, BSM, with material supplement, or
- Option 3: Crushed Stone Base on Cement Treated Subbase, or
- Option 4: BSM Base with Geocell Reinforced Subbase.

At that time, ANE, IP selected Option 3, Crushed Stone Base with Double Bituminous Surface Dressing (DBSD) with cemented sub-base. This option will be verified by the current design consultants and finalized in the detailed design report (not yet available as of early May 2024).

Geometric Design

The existing cross section is same as has been observed and given by the ARUP Detailed Design Report, which is typically 2x3.5m lanes with variable paved shoulder of 0.3m minimum width and unpaved shoulders.

It is proposed to improve the existing cross section to achieve a preferred roadway of 2 x 3,5m lanes, 1,5m surfaced shoulders with gravel shoulders of 1,3 m. It is desirable to provide a consistent cross section over the entire length of the Project. Intersections will be improved to a standard consistent with either a major or minor intersecting junction road. As per site conditions, LASA proposed curve improvement at the following locations:

Table 4-3 Proposed curve improvements Km84-168 (Source: Interim Report, LASA, April 2024)

Si. No	Chainage (km)	Earlier Radius	Improved Radius
1	87+450	400	500
2	89+850	400	600
3	97+400	400	510
4	103+300	400	510
5	105+800	1000	1250
6	109+800	1000	2000
7	123+800	1000	1550
8	135+100	1000	1500
9	137+200	1000	2000
10	141+200	1000	1700
11	161+300	1000	1200

Drainage Design

The following drainage improvements are recommended:

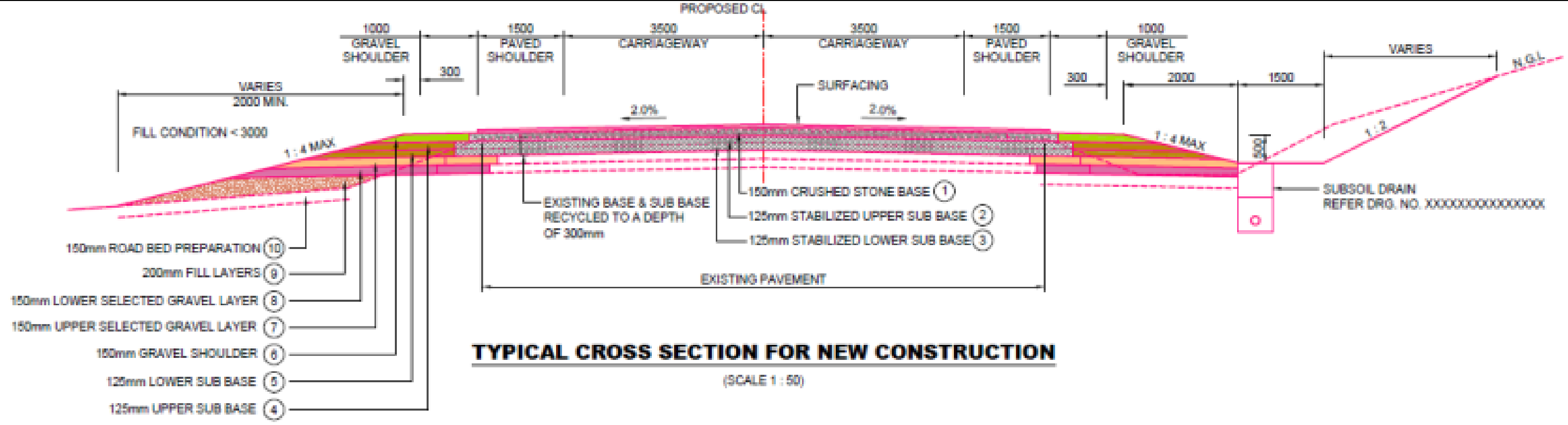
- Re-construction of lined and unlined side drains to suit new road levels where required,
- Clearing of existing culverts and channels,
- Lengthening of existing culverts and reconstruction of headwalls to cater for the widening of the carriageway.
- Replacement of any culverts where their hydraulic capacity is considered inadequate to pass the design flows.

There is no evidence of failure of existing subsoil drains. However, it should be established during construction if subsoil drains have been provided in all cuttings. Where these were omitted during original construction, the designer will consider if it is beneficial for them to be provided, and if so, include these in the contractor's detailed design. (this information is still outstanding).

Hydrology And Hydraulic Analysis

The hydraulic analysis of the bridges has been done using HecRas® software. The cross sections of the river crossings were taken from the SRTM 90 x 90m elevation data for the area. The bridges have been modelled with the 1:50 and 1:100-year return floods.

The figure below shows applicable typical cross sections as shown in the Inception Report by LASA/COTOP, however whether it is rural or urban is not defined



TYPICAL CROSS SECTION FOR NEW CONSTRUCTION

(SCALE 1 : 50)

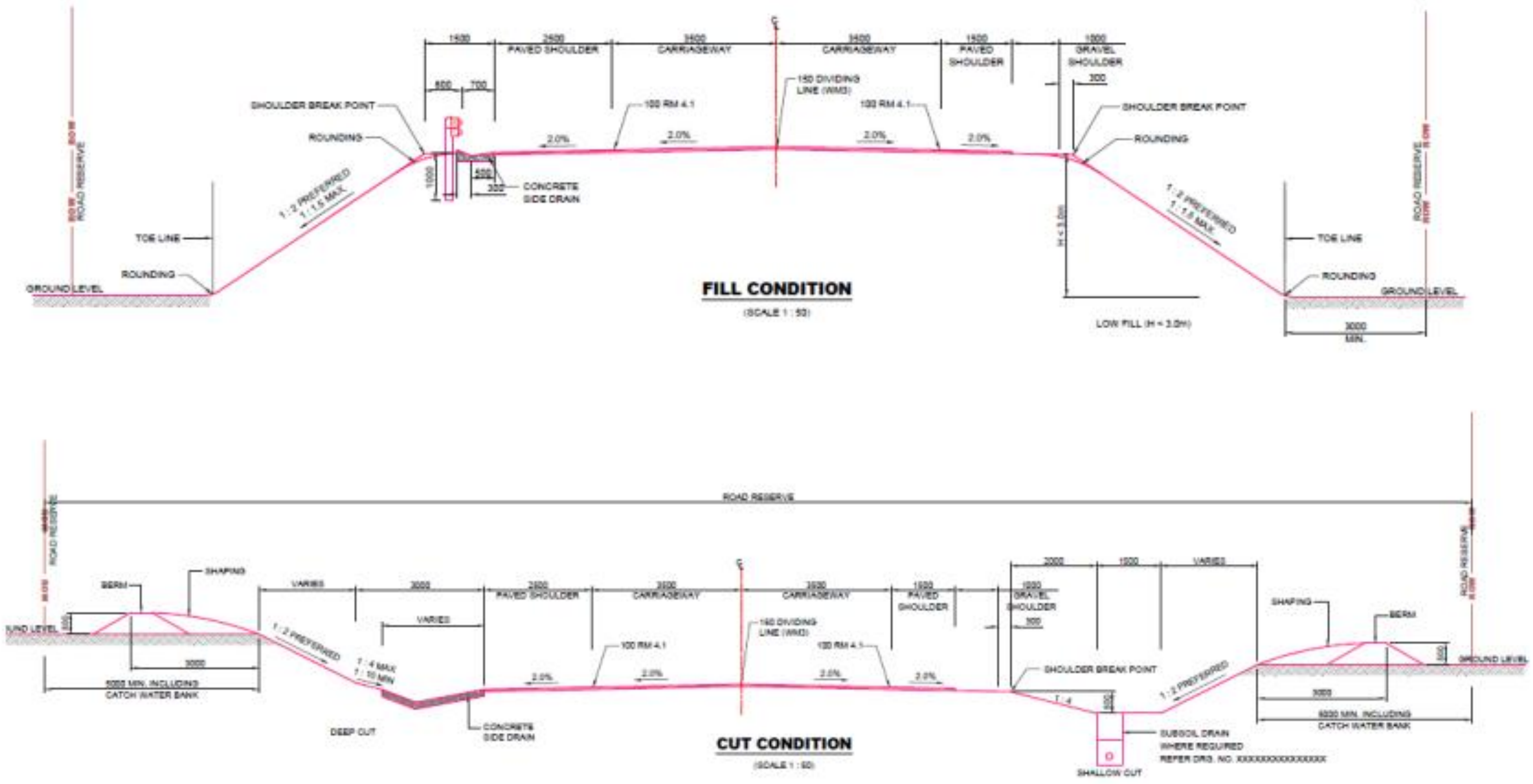


Figure 7 Typical applicable cross sections for road design (Source Inception Report, LASA, March 2024)

Bridges

Five bridges were observed along the Gorongosa-Caia sections.

Table 4-4 Pictorial representation of bridges in section Km84-168 (Source: Inception Report, LASA, April 2024)

Bridge Name	**Existing Span Arrangement**	**Pictorial Representation of Bridges**				
		Deck View	**Upstream**	**Downstream**	**Abutment**	**Pier**
Nhapherua River	3x20.6m =61.8m					
Nhampaza River	15x25.0 m=375.0 m					
Mombeze	3x20.6m =61.8m					

Bridge Name	**Existing Span Arrangement**	**Pictorial Representation of Bridges**				
		Deck View	**Upstream**	**Downstream**	**Abutment**	**Pier**
Nhanzaza River	2x20.6m =41.2m					
Fudza River	3x20.6m =61.8m					

The table below shows the findings and recommendations for rehabilitation at all bridge locations by LASA.

Table 4-5 Findings and recommendations at bridge locations Km84-168

Bridge Name	Existing Span Arrangement	Existing Deck Width (m)	Proposal LASA (Initial)	Remarks
S-20 (Nhapherua River)	3x20.6m =61.8m	7.2 (CW) +2x1.2m (Footpath) =9.6m	Existing + Eccentric Widening (2x3.5 CW+2x0.45 Railing =7.9m)	As per visual inspection widening can be done on either side
S-21 (Nhampaza River)	15x25.0m =375.0m	7.2 (CW) +2x1.2m (Footpath) =9.6m	Existing + Eccentric Widening (2x3.5 CW+2x0.45 Railing =7.9m)	As per initial observation, this Bridge has been overtopped by 1.0 to 1.5m as per local inquiries suggest, however, to be confirmed from respective Authority
S-22 (Mombeze)	3x20.6m =61.8m	7.2 (CW) +2x1.2m (Footpath) =9.6m	Existing + Eccentric Widening (2x3.5 CW+2x0.45 Railing =7.9m)	As per initial observation vibration of superstructure is observed.
S-23 (Nhanzaza River)	2x20.6m =41.2m	7.2 (CW) +2x1.2m (Footpath) =9.6m	Existing + Eccentric Widening (2x3.5 CW+2x0.45 Railing =7.9m)	Condition of existing structure is good
S-24 (Fudza River)	3x20.6m =61.8m	7.2 (CW) +2x1.2m (Footpath) =9.6m	Existing + Eccentric Widening (2x3.5 CW+2x0.45 Railing =7.9m)	Condition of existing structure is good

*CW=Carriageway

Source: Interim report, LASA, April 2024

Culverts:

The Scenario by RCP 8.5 [Long Term Period 2081-2100] has been taken into consideration based on baseline 1995-2014.

Due to climate change considerations, there are 6 new box culverts also proposed as improvement works:

Locations: km 129+965, km 141+590, km 142+099, km 156+981, [km 126+275, km 125+890- at approached of major bridge G-21 and river training works on both upstream and downstream]

4.3 Construction Phase

4.3.1 Preliminary activities

These include construction of the Contractor's and Consultant's temporary camps and temporary production facilities and site clearance at the commencement of construction.

4.3.2 Roadworks

Indicative construction methodology (source, Concept Design report, CPG, June 2024)

a) Clear and grub roadbed and road prism;

b) Remove to fill existing unpaved shoulder to a depth of 640 mm below final road level ("FRL");

c) Construct widening of road prism to a level of 640 mm below FRL;

d) Construct 150 mm G9 selected subgrade to a level of 490 mm below FRL;

e) Breakdown existing surface treatment together with underlying stabilized base to a depth of 490 mm below FRL and spread uniformly across the full width of subbase layer. This operation is to be carried out with a road reclaimer/recycler (If FRL is more than 490 mm above existing road level this step will not be applicable);

f) Import G5/G6 quality material in the necessary quantity from borrow and spread evenly over the full width of the subbase layer so as to permit construction of 150 mm C4 subbase to a level of 340 mm below FRL;

g) Stabilize 150 mm subbase with cement to achieve C4 order of cementation. This operation is to be carried out with a road reclaimer/recycler;

h) Import G5/G6 quality material in the necessary quantity from borrow and spread evenly over the full width of the C4 subbase layer so as to permit construction of 150 mm C3 subbase to a level of 190 mm below FRL;

i) Import 150 mm graded crushed stone base and construct G1 quality layer;

j) Prime G1 base with MC-30 or inverted emulsion prime;

k) Apply tack coat of SS60 stable-grade anionic emulsion diluted to have a bitumen content of 30% at a nominal rate of 0.5 l/m^2;

l) Construct 40 mm thick hot mix asphalt surfacing.

4.3.3 Bridges

The potential scope of work required at the bridges is described in the table below: (source, Concept Design report, CPG, June 2024)

Item No.	Bridge work to be carried out
1	Provision of diversions at some bridges for rehabilitation work on the bridge
2	Provision of grouted stone pitching at abutments
3	Provision of gabions at abutments and piers
4	Re-surfacing of bridge deck and over approach slabs
5	Installation of guardrails on approaches
6	Painting of deck existing metal drain pipes and their metal supports and any other metals as directed by the Engineer
7	Construction of approach slabs
8	Construction of walkway ramps and parapets
9	Filling of cavities or voids under pile caps, footings and framed abutments with concrete
10	Reconstruction or repair of bridge deck, abutment and pier members or elements
11	Provision of new asphaltic plug seal joints
12	Provision of new strip seal joints
13	Provision of new elastomeric bearings
14	Provision of new steel railings
15	Provision of new number plates for bridges
16	Provision of concrete drain channels on embankment slopes at abutments
17	Tests on elastomeric bearings
18	Cleaning and repairing at abutments
19	Cleaning and repairing at piers
20	Cleaning and repairing at soffit and sides of deck
21	Partial or complete demolition of defective bridge concrete members or elements
22	Removal of metal sections and ferrules embedded in concrete
23	Surface and structural repair of decks, abutments and piers using cementitious mortar or concrete or epoxy mortar
24	Crack injection for decks, abutments and piers
25	Crack filling for decks, abutments and piers
26	Waterproofing for bridge decks
27	Protective coating on concrete surfaces with inadequate reinforcement cover
28	Removal of debris from expansion gaps
29	Clean and unblock deck drain pipes
30	Service and repair of strip seal expansion joints
31	Repair and seal expansion joints at walkways
32	Repair of handrails
33	Jacking bridge decks for replacement of bearings or repair of piers and abutments

4.3.4 Construction materials

Borrow Pits

The design consultant, LASA, identified new and existing potential borrow areas, belonging to the government and/or public as noted in the table below. The representative samples collected from these identified borrow areas will be tested to assess the possibility of utilizing the local soil as embankment fill, sub-grade and subbase.

Table 4-6 Potential borrow pits identified by design consultant LASA, March 2024

BORROW MATERIAL							
Site no.	**Chainage**	**Northing**	**Easting**	**Side**	**Quantity (m^3)**	**Distance from N1**	**Comments**
1	Km 158+300	7997892.19	691210.26	RHS	90,000	Approximately 173 m	Inside of GNP buffer zone
2	Km 139+500	7993661.32	674115.81	RHS	30,0000	Approximately 221 m	Inside of GNP buffer zone
3	Km 112+100	7983150.13	649599.23	RHS	40,0000	Approximately 157 m	Inside of intersection GNP buffer and Coutada 6
4	Km 103+300	7984891.87	641151.80	RHS	50,0000	Approximately 183 m	Inside of Coutada 6
5	Km 94+400	7981600.93	633512.88	RHS	150,000	Approximately 182	Inside of Coutada 6

As noted in the table above, sample points 1 and 2 are in the buffer zone of the Gorongosa National Park, point 3 is within the intersection of Coutada 6 and the buffer zone of GNP, while sample point 4 and 5 are inside of Coutada 6.

Figure 8 Images of borrow areas identified by design consultant LASA, April 2024
Source: Interim report, April 2024

Rock Quarry

Samples have been collected from two quarries to evaluate its properties and recommend using it in various pavement layers, i.e. sub-base, base, bituminous works and concrete works.

One location is noted below:

ROCK SOURCE				
Site no.	Location	Northing	Easting	Side
1	Covoe Village	8035952.5	763587.06	LHS

Figure 9 Images of quarries visited by design consultant LASA, April 2024
Source: Interim report, April 2024

<u>Sand Quarry</u>

The design consultant, LASA, identified potential sand sources and five samples have been collected from quarries to evaluate their properties for use in concrete works.

Table 4-7 Potential sand sources identified by design consultant LASA, March 2024

SAND SOURCE						
Site no.	**Chainage**	**Northing**	**Easting**	**Side**	**Distance from N1**	**Comments**
1	101+255	7984240.48	639086.10	RHS	Less than 3 m	Riverbank/water course, within buffer zone (GNP)
2	126+120	7988304.25	661781.92	RHS	Less than 3 m	Riverbank/watercourse, within buffer zone (GNP)
3	133+250	7991747.52	667946.72	RHS	Less than 3 m	Riverbank/watercourse, within Coutada 6
4	143+675	7995807.03	677368.60	RHS	Less than 3 m	Riverbank/watercourse, within Coutada 6
5	155+290	7998471.51	688369.30	RHS	Less than 3 m	Riverbank/watercourse, within Coutada 6

Source: Interim report, April 2024

As noted in the table above, all these sources were identified in a riverbank/watercourse either within the buffer zone of the GNP or within Coutada 6.

Figure 10 Images of potential sand sources identified by design consultant LASA, April 2024
Source: Interim report, April 2024

Water Source

Two water samples were collected from existing water sources by the design consultant, LASA, one location is noted below, however it was noted that the Contractor would be able to use any of the five perennial rivers flowing where bridges are to be rehabilitated.

WATER SOURCE				
Site no.	Chainage	Northing	Easting	Side
1	(5 km far from End Point)	7996227.83	709166.36	RHS

Figure 11 Images of water source identified by design consultant LASA, April 2024
Source: Interim report, April 2024

Toe samples

Roadside soil includes soil from the toe of the existing embankment. Samples have been collected for laboratory testing. To widen the road, it is very important to know the physical characteristics of the roadside soil and ascertain their suitability as the foundation of the embankment/sub-grade construction. Trial pits have been excavated at an interval of 10km in a staggered manner adjacent to toe of the existing embankment along all the link roads. A total of 8 trial pits were excavated. The samples were collected after removing the top strata. The toe samples have been tested to assess the possibility of utilizing the original ground soil as embankment / sub-grade construction.

Figure 12 Images of toe samples taken from road edge by design consultant LASA, April 2024
Source: Interim report, April 2024

Source of other Construction Materials

Bitumen will have to be imported from Dubai or Iran. Cement of various grades, from leading brands, can be procured either locally from suppliers or directly.

Estimate of earth works balance

Estimated earthwork quantity: 1,013,313.25 m^3

4.3.5 Potential camp site locations

The design consultant, LASA, identified two potential camp site locations as noted below, which are close to the N1 and one is situated inside of the buffer zone of the GNP.

Table 4-8 Potential camp locations km84-168 (Gorongosa to Caia)

CAMP LOCATION						
Site no.	**Chainage**	**Northing**	**Easting**	**Location**	**Distance from N1**	**Comment**
1	128+100	7989598.33	663285.12	Nhamapaza	17 m	Inside of buffer zone of GNP
2	118+860	7987612.17	659444.34	Nhamapaza	46 m	

Source: Interim report, LASA, April 2024

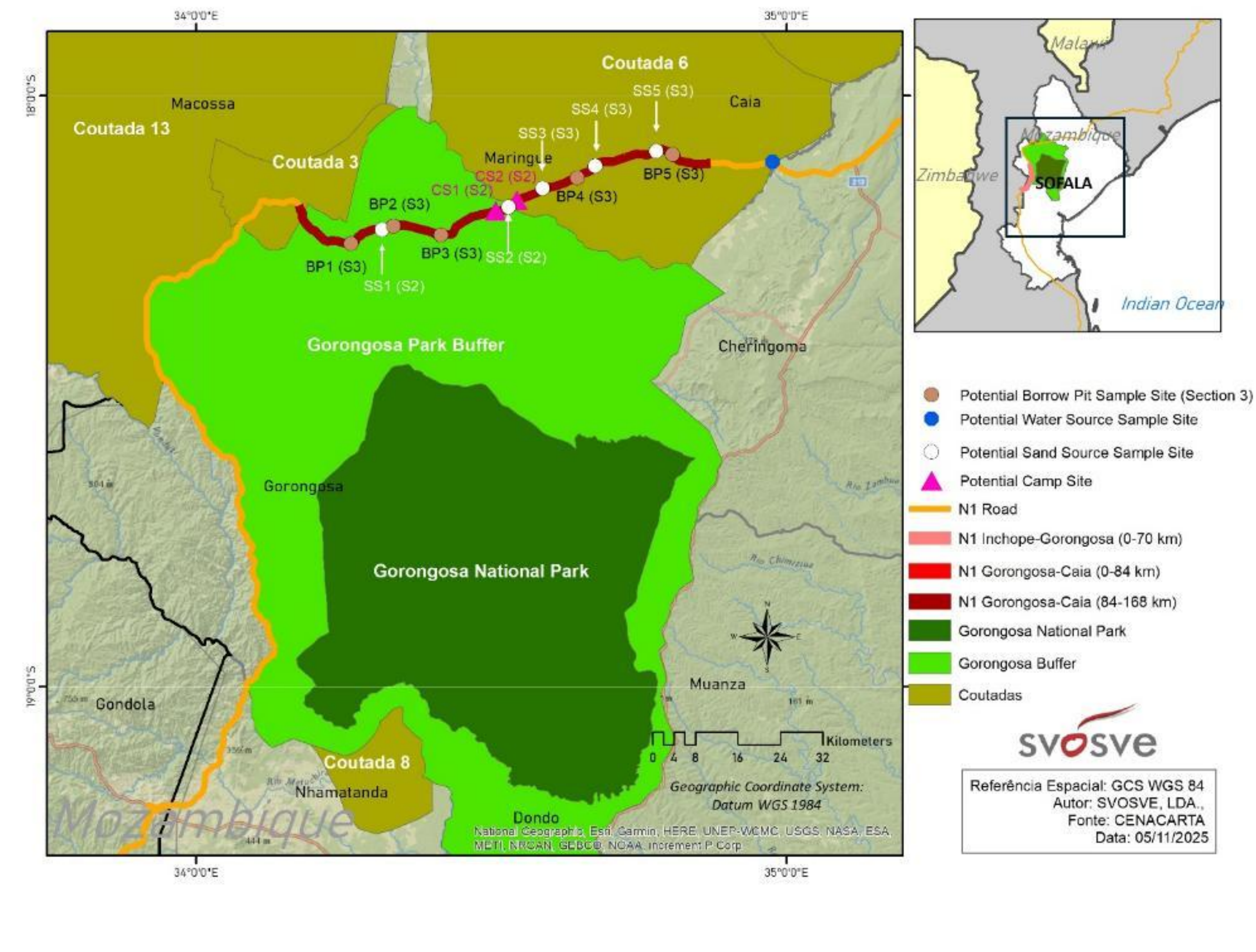
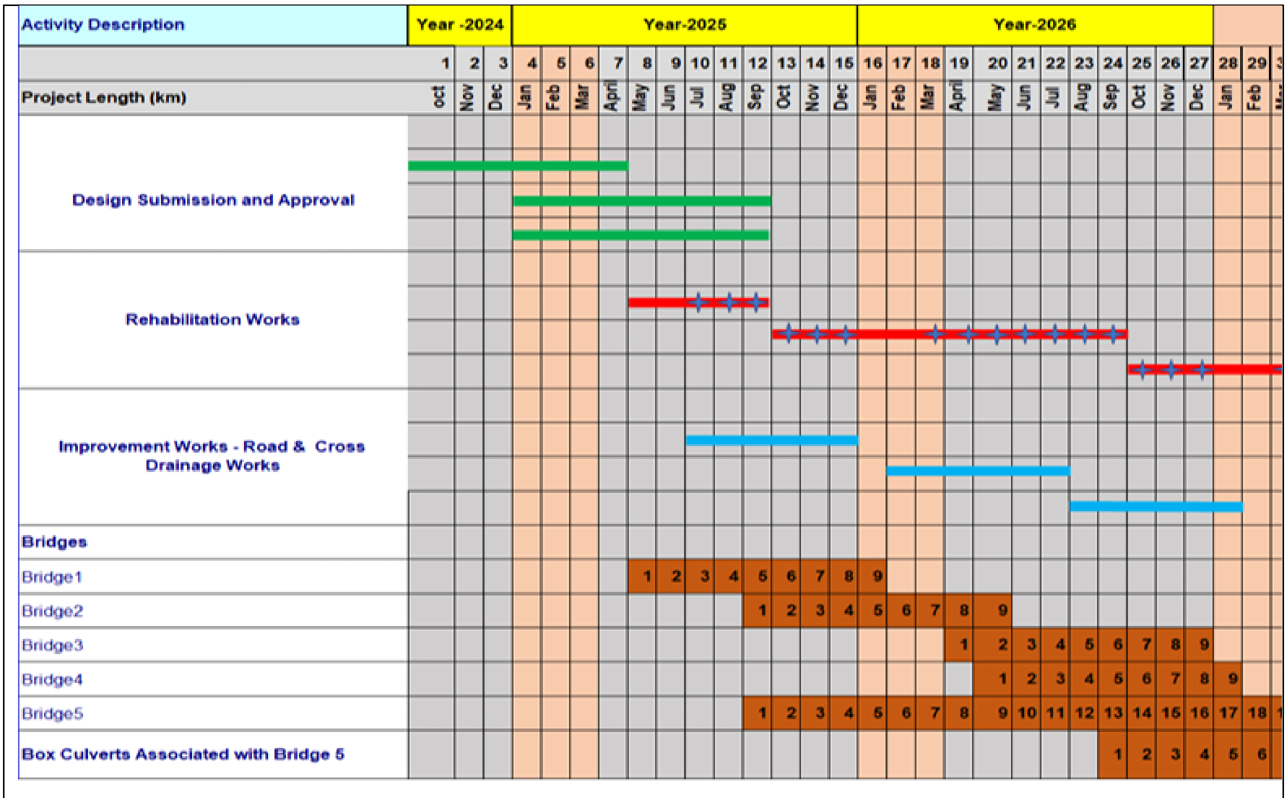


Figure 13 Sample points of potential borrow pits, sand sources, water source sample site and camp sites in concept design report km84-168 Gorongosa to Caia, Lot 2

The above map shows the sample sites of potential borrow pits and sand sources, potential water source sample site and potential camp sites identified by the design consultant in the concept design report. As noted in the above tables, some sites are inside the GNP buffer zone or Coutada 13.

4.3.6 Time vs. activities flowchart for Phase I road rehabilitation sections

Package 2: Gorongosa - Caia, Lot 2 (km 84 - 168)



Typical Conceptualized Milestones

4.3.7 Estimate on water, energy and raw materials needed/consumption for Phase I rehabilitation

Table 4-9 Estimate of consumption of materials for construction

Item	***Package 2: Gorongosa - Caia, Lot 2 (km 84 - 168)***
Water	577,800 t
Gravel	458,500,000m^3
Aggregates:	53,200 m^3
Crushed stone:	23,880,000 m^3

4.3.8 Estimated cost

The breakdown of the Contract Price for both road sections can be found in the Concept Design document prepared by LASA, or from the Employer. As the project has not yet gone out to tender, this price is confidential.

4.3.9 Climate resistant analysis

Climate Vulnerability Risk Assessment (CVRA)

Assessing the vulnerability of roads to climate change is crucial for ensuring their resilience and functionality in the face of changing environmental conditions. A comprehensive approach to conducting a climate vulnerability assessment for roads would entail consideration of the following:

- Identification of climate hazards that pose risks to roads in the area of interest. Common climate hazards include extreme temperatures, heavy precipitation, flooding, storms (including hurricanes, cyclones, and typhoons), sea level rise, and landslides.
- Determination of the exposure of roads to the identified climate hazards. This would involve mapping the road network and overlaying it with maps of climate hazards. Such factors as proximity to water bodies, elevation, and terrain would be considered.
- Evaluation of the sensitivity of roads to the identified climate hazards. Factors affecting sensitivity include road construction materials, design standards, drainage systems, and maintenance practices. Roads with poor drainage, inadequate slope protection, or built on unstable terrain are more sensitive to climate hazards.
- Assessment of the adaptive capacity of roads to withstand and recover from climate impacts. This involves considering factors such as the availability of maintenance resources, emergency response capabilities, institutional capacity, and community resilience.
- Utilization of climate models and projections to understand how climate change may alter the frequency and intensity of climate hazards in the future. This helps in anticipating long-term risks and planning adaptation measures accordingly.
- Engagement with relevant stakeholders including transportation agencies, local governments, communities, and experts in the vulnerability assessment process. Stakeholder input can provide valuable insights into local conditions, priorities, and potential adaptation strategies.
- Prioritization of risks based on their likelihood and potential impact on the road network. Consideration of factors such as the importance of roads for transportation, economic activities, emergency response, and social equity.
- Development of adaption strategies based on the vulnerability assessment findings. Adaptation strategies which enhance resilience of roads to climate change should be developed. This may include upgrading drainage systems, improving slope stabilization measures, raising road elevations, diversifying transportation options, and incorporating green infrastructure, design for less probable storm events (1.500 return period instead of 1:200 return period). Clarification of these figures by the design consultant are as follows. Drainage systems have been checked and where necessary augmented as noted in drawings. There is no section of the road in Package 1 which is prone to flooding. In some cases, water tends to pond at bridge approaches due to blocked and insufficient waterway

opening. Additional drainage measures were added to the bridge approaches, including concrete drain channels and chutes as noted in drawings. Slope stabilization measures such as stone pitching have been adopted to stabilize embankments in the areas susceptible to erosion. Similarly, erosion protection works at bridges have been specified where required (gabions, riprap) to protect the embankments and the bridge substructures as noted in drawings. The entire road section is being raised by about 300 mm to accommodate the stronger pavement. Further raising is not necessary and would be wasteful. Hydroseeding of embankments could be prescribed at the instance of the Employer for embankments with higher erosion risks and may be included by the Contractor in detailed designs/method statements.

- Implementation of the identified adaptation strategies and regular monitoring of their effectiveness. Adaptation is an interactive process, and adjustments may be needed over time as climate conditions evolve and new information becomes available.
- Building capacity within transportation agencies and other relevant organizations to integrate climate considerations into road planning, design, construction, and maintenance practices. This may involve training programs, knowledge sharing networks, and institutional reforms.

Mozambique grapples with substantial vulnerability to climate change and natural disasters, facing a combination of acute and chronic threats. The susceptibility of the country emanates from its delicate topography, diverse ecosystems, unpredictable rainfall-driven hydrology, inadequately planned settlements, and a deficiency in resilient infrastructure.

The recognition of climate risks can strengthen adaptation and mitigation actions and transitions that reduce risks. Taking action is enabled by governance, finance, knowledge and capacity building, technology and catalyzing conditions as addressed in the 2023 Country Climate and Development Report: Mozambique of the World Bank Group.

Design considerations

The approach to the design of climate resilient infrastructure can be divided into:

- Existing infrastructure: The approach involves the assessment of vulnerability of existing infrastructure and developing measures to enhance the resilience of such infrastructure against damage and wash away; and,
- New infrastructure: New infrastructure must be designed to be resilient to the impacts of climate change in order to reduce the vulnerability or risk of damage and wash away.

There are two key principles for the design of climate resilient roads, namely:

- Resilience against loss of strength when submerged; and,
- Resilience against flood damage or washaways

Vulnerability and flood risk

Vulnerability depends on the flood risk of the area. According to ANE IP's Drainage Manual, areas of high flood risk are in the basins of major rivers, for example the Zambezi River Basin. Also, coastal areas consisting of flat terrain are more prone to flooding.

The project road is mostly located in "No risk area" except the near the end of the Gorongosa – Caia Lot 1 section.

Climate projection data is modelled data from the global climate model compilations of the Coupled Model Inter-comparison Project (CMIP), overseen by the World Climate Research Program. The projected mean climate change effect on temperature and precipitation for long-term periods (80 years) is between 17.2% and 19.6%, respectively. ANE IP's Hydrology and Drainage Design Manual, 2019, approach to the design of climate resilient roads and structures is to increase the design return periods by one step up or 100% in the high-risk areas. ANE IP's design criteria for climate change and climate resilient roads and structures are in line with and even more stringent than the World Bank's Vulnerability and Climate Change Risk and are therefore adopted.

ANE IP Design Return Periods

The table below provides a summary of the ANE IP structure classification, and the design return periods required for each structure, for normal conditions and taking climate resilience into account.

Table 4-10 ANE IP Design Return Periods for normal and climate resilient conditions

STRUCTURE	DESCRIPTION	RETURN PERIOD (YEARS)			
		NORMAL		CLIMATE RESILIENT	
		QT (return for the design)	Q2T (return period for verification/checking)	QT (return for the design)	Q2T (return period for verification/checking)
GUTTERS AND INLETS		5	10	10	25
SIDE DITCHES		10	25	25	50
CULVERT	Pipe (Span < 2 m)	25	50	25	50
BOX CULVERT	Span between 2 m and 6 m	50	100	50	100
SHORT SPAN BRIDGE	Span between 6 m and 15 m	50	100	50	100
MEDIUM SPAN BRIDGE	Span between 15 m and 50 m	100	200	200	500
LONG SPAN BRIDGE	Span > 50 m	100	200	200	500

Source: Concept Design Report (CPG, June 2024)

Design Inputs and Proposed Measures as Engineering Adaptation

To ensure the all-year pass ability, the following design criteria were applied for the designing:

- Small to medium size bridges should be designed for a 50year flood/storm return period and checked on a 100-year flood;
- Large bridges shall be designed for 100-year flood/storm return period and checked on a 200-year flood and 500-year flood for zones of extreme flood risk (areas usually hit by tropical and cyclonic storms)
- Box culverts $\leq$ 10 m span: flood return frequency of 50 years;
- Pipe culvert < 2 m diameter: flood frequency of 25 years;
- Side drains and ditches: flood frequency of 25 years.

Pavement design

As noted previously, mitigation measures of climate change impacts due to extreme temperatures may include the use of appropriate layer coefficients, drainage coefficients, weather-resistant pavement surfacing materials and asphalt mix designs and revised pavement thicknesses which take into consideration the future temperatures and the use of advanced heat-resistant materials.

4.3.10 Hydrology

Bridges

The hydraulic analysis and design of bridges is primarily concerned with:

- Determining the opening size and configuration required to accommodate the required peak floods;
- Ensuring that adequate scour protection and sedimentation control is provided.
- The outputs from the hydraulic analysis and design are:
- The flow type - normal flow depth, subcritical flow depth, supercritical flow depth with hydraulic jump after the bridge and, supercritical flow depth with hydraulic jump before the bridge.
- The backwater effect to define the hydraulic jump position and set the principal of controlling of the flood.
- Scour design of piers and abutments.
- Sediment transport and depositing.
- Hydraulic forces on the bridge.
- Debris design and flow conditions.

Bridges are divided into three types described below:

- Small bridges – these have short spans up to 15 m on relatively narrow and low-volume streams.

- Medium bridges – these have medium size spans up to 50 m on a well-defined river channel.
- Large bridges – these have spans greater than 50 m and include cable stay bridges built on very wide rivers and flood plains.

In the present case all bridges fall under the classification of small span or medium span bridges.

HECRAS software was used to model the bridge structure and accompanying water surface profiles. The design was calibrated and checked against ANE IP's standards and specifications.

There are numerous measures that can be taken for scour protection. These measures include the provision of gabions, stone pitching, rip rap or the lining of the channel with concrete. The selection of the most appropriate method is based on many factors including the characteristics of flow at the location where the scour is required, and the cost of the protection measure and the availability of materials for the method at the required location. All these factors have to be considered when the scour counter measures are designed for a bridge structure.

Culvert Hydraulic Analysis and Design

Culvert hydraulic analysis is carried out to ascertain capacities of the existing and proposed new culverts have essentially involved Headwater-depth calculations for both 'Inlet Control 'and 'Outlet Control' considerations. The greater of the two has been considered as the governing headwater depth for the design purpose. The software HY-8 has been used to perform the aforesaid computations.

The following design standards should be met unless specific constraints require deviation from the standards.

- The minimum diameter/size of culverts should be 800 mm for ease of cleaning and de-siltation.
- Exceptions shall be made for culverts on access roads should have a minimum diameter/size of 700 mm for access to properties.
- To accommodate the design discharge calculated based on the Design return period of 10 yrs (checked on 25 yrs) for small culverts, 25 yrs (checked on 50 yrs) for medium size culverts and 50 yrs (checked on 100 yrs) for large culverts.
- The maximum level of the upstream side should not reach the subbase (wetting of the subbase from side drains should be avoided).
- The general arrangement of the culvert and wing walls should prevent the development of vortexes during flooding, which are the main cause of flood damage and washaways.

- The velocity/energy of the water downstream of the culvert should be controlled to prevent scour and avoid sedimentation. The standard shall be to include a drop inlet (catch pit) at the inlet and a stilling basin/tank and/or riprap at the outlet as necessary
- The velocity inside the barrel of the culvert should not be less than 0.7m/s.
- The gradient of the barrel should not be less than 1.5%.
- Where the potential for siltation is high such as in erodible sandy soils the inlets should have catch pits and the gradient of the outlet should be 3% – 5% and certainly steeper than the gradient of the culvert. The length of the outlet where this minimum gradient should be specified should not be less than 10m.
- Siltation tanks, which are easily accessible for cleaning should be designed and built upstream of the culvert inlet to catch silt.
- As a norm, all culverts should have protection works at the outlet, which include a stilling basin/tank and/riprap or normal lining of concrete or wet stone masonry. Exceptions may be made in flat terrain where outlet flow velocity is expected to be low (≤1m/s).

Susceptibility to erosion on the downstream side of the culvert depends on the erodibility of the material in the outlet drains.

Detailed design considerations for bridges and culverts are noted in section 4.2.1 for each of the road sections, for example in Km 84-168 (Gorongosa to Caia), due to climate change considerations, there are 6 new box culverts also proposed as improvement works at locations: Km 129+965, Km 141+590, Km 142+099, Km 156+981, Km 126+275, Km 125+890 at approaches of major bridge G-21 and river training works on both upstream and downstream.

4.3.11 Traffic Surveys and Analysis

Based on the interim report of LASA (April 2024), the traffic surveys were carried out in the month of March 2024 using formats prepared in line with ANE, IP's practiced formats on vehicle classifications, locations of survey stations, field survey durations etc. Surveys were conducted near (i) Nhamapaza Trading Centre.

<u>Classified Traffic Volume Counts</u>

Traffic count surveys were carried out for seven (7) continuous days (16 hours survey for 5 days and 24 hours survey for 2 days), 2 days of 24 hours included 1 weekday and 1 weekend day. Pre-designed proforma was used to capture a total of eight vehicle types.

Origin-Destination Survey

Origin-Destination (OD) survey, employing the road-side direct interview approach, was conducted for 16 hours continuous hours, recording identification of each vehicle sampled, vehicle category, trip purpose, origin and destination, travel distance, travel time, trip frequency etc. and the consignment carried in goods vehicles and their weight in tons.

Traffic Volume Analysis

Table 4-11 Average Daily Traffic (ADT) at Nhamapaza

Modes[1]/ Location	ADT based on 24 hrs Count
Class A (Saloon Cars and Taxis)	13
Class B (Light Goods, Vans, Pickups and 4WD)	86
Class C (Small Bus)	7
Class D (Standard Bus)	22
Class E (2 Axle Trucks)	44
Class F (3/4 Axle Trucks)	25
Class G (Multi Axle Trucks)	104
Class H (Tractor with or without Trailer)	1
Total Vehicles	**302**

Source LASA, April 2024

The estimated Seasonal Correction Factor (SCF) for the month of March has been applied to the ADT figures so as to estimate the Annual Average Daily Traffic (AADT) in vehicles/day.

Table 4-12 Annual Average Daily Traffic (AADT) for Gorongosa-Caia (km 84-168)

Modes/ Location	Nhamapaz
Class A (Saloon Cars and Taxis)	14
Class B (Light Goods, Vans, Pickups and 4WD)	77
Class C (Small Bus)	8
Class D (Standard Bus)	19
Class E (2 Axle Trucks)	41
Class F (3/4 Axle Trucks)	25
Class G (Multi Axle Trucks)	105
Class H (Tractor with or without Trailer)	1
Total Vehicles	**288**

Source LASA, April 2024

Future Traffic Growth on the Project Corridor

Table 4-13 Projected Traffic (AADT) at Nhamapaza on N1

Vehicle Type	2024	2029	2034	2039	2044	2049
Class A	14	19	27	38	53	72
Class B	77	107	150	207	286	391
Class C	8	11	16	22	32	45
Class D	19	31	50	74	109	150
Class E	41	58	82	108	143	180
Class F	25	38	58	81	114	143
Class G	105	156	232	318	436	540
Class H	1	1	1	1	2	2
Total Vehicles	**288**	**421**	**615**	**850**	**1,175**	**1,523**

Source LASA, April 2024

4.3.12 Road safety

Speed Management

The design consultant, LASA, identified the following locations for traffic calming measures:

Table 4-14 Location for adoption of traffic calming measures in schools

TRAFFIC CALMING			
School			
Site No.	Rumble strip	Speed hump	Rumble strip
1	92+640	92+840	93+040
2	105+530	105+730	105+930
3	113+670	113+870	114+070
4	117+080	117+280	117+480
5	122+480	122+680	122+880
6	128+760	128+960	129+160
7	135+650	135+850	136+050
8	144+890	145+090	145+290
9	149+680	149+880	150+080
10	163+045	163+245	163+445

Table 4-15 Location for adoption of traffic calming measures in villages

TRAFFIC CALMING				
Nhampaza settlement and TC				
Serial	Rumble strip	Speed hump	Speed hump	Rumble strip
1	125+400	125+600	127+640	127+840

Source: Interim report, LASA, April 2024

Pedestrian Facilities

Designated pedestrian crossings are proposed at all villages with prior sign boards. In general pedestrian crossings are proposed near the bus stops as per the guidance given in the Road Design Manual.

Table 4-16 Location of pedestrian crossings in Gorongosa-Caia (km 84-168)

Serial	Chainage	Side	Type	Remarks
1	88+970	RHS	-	Church
2	92+840	RHS	Mussicadzi-2 EP	School
3	105+730	RHS	EP- Mataus sansau mutenbe	School
4	113+870	RHS	EP Muerera	School
5	117+280	LHS	EP De Nsawa	School
6	122+680	LHS	EP Samnariano	School
7	128+960	LHS	Escola Secundaria De Nhamapaza	School
8	135+850	LHS	Escola Base Joaquim Alberto Chissauo Matombo	School
9	143+090	LHS	EP Igrau 25 De Setembro	School
10	149+880	LHS	EP Marcelino dos Santos Taupa	School
11	163+245	LHS	EPC-1 De Maio Caia	School

Source: Interim report, LASA, April 2024

Other Road Safety Measures

The following road safety measures are also proposed along the project road to enhance safety:

Table 4-17 Kerb locations km 84-168 Gorongosa-Caia

Sl. No.	From (km)	To (km)	Side	Length
1	126+690	127+020	BHS	330
2	126+376	126+440	LHS	64
3	126+976	127+040	RHS	64

Source: Interim report, LASA, April 2024

Table 4-18 Locations of 'intersection ahead signs km 84-168 Gorongosa-Caia

Serial	Chainage	Side	Width	Remarks
1	111+310	RHS	4m	Connecting to Gorongosa
2	119+680	LHS	3.5m	Going to EPC de Nhago
3	125+210	RHS	3m	Going to EPC Juchengi
4	126+80	LHS	7m	Going to Maringue Palame Senga Senga
5	126+860	RHS	7m	Going to Nnaminga
6	127+530	LHS	5m	Zona Neighbourhood
7	134+970	LHS	4m	Going to EP de Maguide (5km from road)
8	155+660	LHS	4m	Maringue Village

Source: Interim report, LASA, April 2024

Table 4-19 Locations of bus bays and stop signs km 84-168 Gorongosa to Caia

Serial	From (Km)	To (Km)	Description/Name
1	88+975	89+080	Mussicadzi-2 Market Place
2	126+310	126+690	Nhampaza Settlement
3	126+690	127+020	**Tc Nhampaza**
4	127+020	127+620	Nhampaza Settlement
5	135+800	135+850	Matombo Market Place
6	135+850	136+040	Matombo Village
7	155+620	155+810	Fudza village
8	162+650	163+340	EPC-1 De Maio Caia

Serial	Busbay	
	Chainage	Side
1	126+560	LHS
2	127+360	RHS

Source: Interim report, LASA, April 2024

Table 4-20 Locations of informative signs (church/school) km 84-168 Gorongosa-Caia

Serial	Chainage	Side	Remarks
1	88+970	RHS	Church
2	92+840	RHS	School
3	105+730	RHS	School
4	113+870	RHS	School
5	117+280	LHS	School
6	122+680	LHS	School
7	128+960	LHS	School
8	135+850	LHS	School
9	143+090	LHS	School
10	149+880	LHS	School
11	163+245	LHS	School

Source: Interim report, LASA, April 2024

Table 4-21 Locations of directional signs km 84-168 Gorongosa-Caia

Serial	Chainage	Side	Remarks
1	111+310	RHS	Connecting to Gorongosa
2	119+680	LHS	Going to EPC de Nhago
3	125+210	RHS	Going to EPC Juchengi
4	126+80	LHS	Going to Maringue Palame Senga Senga
5	126+860	RHS	Going to Nnaminga
6	127+530	LHS	Zona Neighbourhood
7	134+970	LHS	Going to EP de Maguide (5km from road)
8	155+660	LHS	Maringue Village

Source: Interim report, LASA, April 2024

Table 4-22 Location of place identification signs km 84-168 Gorongosa - Caia

Serial	From (Km)	To (Km)	Description/Name
1	88+975	89+080	Mussicadzi-2 Market Place
2	126+310	126+690	Nhampaza Settlement
3	126+690	127+020	**Tc Nhampaza**
4	127+020	127+620	Nhampaza Settlement
5	135+800	135+850	Matombo Market Place
6	135+850	136+040	Matombo Village
7	155+620	155+810	Fudza village
8	162+650	163+340	EPC-1 De Maio Caia

Source: Interim report, LASA, April 2024

Table 4-23 Location of edge beams km 84-168 Gorongosa-Caia

Serial	Chainage	Side	Width	Remarks
1	111+310	RHS	6m	Connecting to Gorongosa
2	119+680	LHS	5.5m	Going to EPC de Nhago
3	125+210	RHS	5m	Going to EPC Juchengi
6	127+530	LHS	7m	Zona Neighbourhood
7	134+970	LHS	6m	Going to EP de Maguide (5km from road)
8	155+660	LHS	6m	Maringue Village

Source: Interim report, LASA, April 2024

Table 4-24 Warning sign - cattle crossing locations km 84-168 Gorongosa to Caia

WARNING SIGN BOARD (CATTLE CROSSING)				
Serial	Location	Side	Type	Description
1	116+740	LHS	W310	Cattle Crossing
2	116+940	RHS	W310	Cattle Crossing
3	126+310	LHS	W310	Cattle Crossing
4	126+210	RHS	W310	Cattle Crossing

Source: Interim report, LASA, April 2024

Safety Barriers

To enhance safety at high embankment stretches, metal beam crash barriers are proposed. To have the guardrails fixed properly, shoulders are proposed to be widened as per the provision given in the design manual.

96 guard rails are proposed at various locations along the stretch of road, on both left- and right-hand sides of the road, of varying lengths of 20, 50, 60, 85, 90, 93,100,200, 240, 250,270, 350, 420 and 1,500m.

Concept Design Audit

The concept design consultant, LASA, undertook an audit of the aforementioned road safety proposals following the 'Road Safety Audit Manual' to verify the design suggestions (Pg 9-19 to 9-22, Interim report, LASA, April 2024).

4.4 Operation Phase

This Phase commences on completion and handing over of the project. At the end of the maintenance period the Contractor will be responsible for removing all temporary facilities provided for the works and for cleaning up the site, including camps and facilities sites. ANE IP will then take over responsibility for the monitoring and maintenance of the road and its facilities. This will include all routine and periodic maintenance requirements which will include but not be limited to:

- Regular maintenance inspections;
- Clearing of vegetation;
- Road cleaning;
- Patching and sealing of cracks;
- Resurfacing when required;
- Replacement of traffic signs and markings when required;
- Cleaning of ditches and culverts; and
- Repair of bridges including movement joints, protection works, guardrail and railings.

4.5 Project facilities and Associated facilities and Inputs

The project, including its permanent facilities and components, will require inclusion in the various maintenance management systems of ANE IP.

It is anticipated that the facilities and inputs described in the sections below will be required during the implementation of the Project:

4.5.1 Temporary Workshops and Offices per Project Site

Infrastructure will be required for the administration of the project as well as repair and maintenance of construction equipment and machinery. It is anticipated that the following infrastructure may be required:

- Administration office;
- Mechanical, engineering and electrical workshop;
- Wash bays and refueling site, and
- Materials storeroom.

The offices to be constructed or erected at each Project site will help the Contractor and some workers to coordinate, manage and supervise the workers, including the implementation of the Project activities.

4.5.2 Roads

It is anticipated that goods and construction materials (e.g., aggregate, stones, river sand, gravel, water, asphalt, cement, plant and machinery, equipment, energy/electricity/generators, office containers, etc.) that will be required for the construction works for rehabilitation, improvement and maintenance of the targeted sections of the N1 corridor will be transported from various sources within or outside the province in which the projects are located. These goods and services will be transported by road to each project site by both gravel and tarmac roads. In this respect, the existing gravel roads through which goods and services will be transported to the Project sites may need to be upgraded to accommodate the increase in traffic flow.

4.5.3 Campsites

Housing options for non-local workers at project site will be analyzed as part of the ESIA/ESMP process. It is anticipated that there will be some form of campsite constructed near the targeted project to accommodate some project workers such as skilled migrant national or international workers. Guidance from the IFC/EBRD Workers' Accommodation Processes and Standards, 2009 will be referred to and used during implementation[1]. Additional accommodation may be required in host communities depending on the amount of housing required during the construction period. As far as practicable, all local workers will be residing at their respective homes.

Since the location of the campsites at each project site is not yet known, it is important that the Client and the Contractor must ensure that the infrastructure required is not constructed or erected in or near sensitive receptors (e.g., protected areas, communities, water courses, areas for recharge of aquifers) and identified areas must be 50m away from water lines. Alternative prefabricated or container options could be considered to reduce the environmental impact of construction of the temporary campsite.

4.5.4 Water Supply

Implementation of Components involving construction and rehabilitation will require abstraction of water from nearby rivers and streams for use in various activities such as, soil compaction, suppression of dust emissions, cooling engines of equipment/machinery, plant, and equipment, as well as for domestic use by workers to be living in the camp site(s). In addition, groundwater can be abstracted to be used for construction and domestic use as well. Wastewater from the construction sites will be discharged into the environment. However, this wastewater must be treated in accordance with the WBG Environmental, Health and Safety Guidelines and with national laws, prevailing whichever is more stringent.

All water abstraction (surface or ground), as well as wastewater effluent discharge permits must be obtained prior to any civil works from the Regional Water Administration[2] (ARA), including a description of the proposed use, economic justification, and technical description.

[1] https://www.ebrd.com/downloads/about/sustainability/Workers_accomodation.pdf

[2] *Administração Regional de Água* (*ARA*) in Portuguese. There are 5 ARAs that serve the different regions of the country: ARA-Sul is responsible for the river basins in southern Mozambique; ARA-Centro, for the

In order to minimize surface water, use in each selected site for road rehabilitation, rainwater harvesting in the form of tanks, or earth dams must be constructed to capture rainwater for reuse in the Project. These water harvesting tanks may help minimize water abstraction from natural rivers and streams for construction and domestic use, particularly in areas where water sources are scarce.

Consideration should also be given to local communities and other water users in the area to avoid conflict in harvesting water for subproject purposes.

4.5.5 Quarries and borrow pits

Road maintenance requires use of large quantities of suitable soil and gravel/stone. To reduce the risks and impacts associated with stone and soil extraction on sensitive receptors, these materials should only be obtained from existing licensed sources located within or outside the targeted project sites. If new quarries or borrow pits are to be opened to supply construction materials to the project, the Client and the Contractor must ensure that such areas cumulatively comply with the following locational criteria:

- Be located as near as possible to the construction site to minimize the transportation distance and potential associated impacts (air and noise emissions, road traffic accidents, among others);
- Be located as far as possible from sensitive receptors (at least 500 m);
- Not be in areas relevant for communities' livelihoods;
- Be at least 100-200 m away from watercourses and water lines, areas subject to flooding, and/or any areas relevant for the recharge of aquifers;
- Not interfere with areas with relevant biodiversity values, namely classified areas for conservation;
- Not be in areas geotechnically sensitive;
- Not be located in areas visually sensitive (subject to relevant landscape impacts);
- Not interfere with cultural heritage sites (including tangible and intangible heritage).

Development of borrow pits and quarry areas will be done in accordance with the WBG Environmental, Health and Safety Guidelines on Construction Materials Extraction. Extraction site reclamation and closure activities should be considered as early in the planning and design stages as possible.

The anticipated risks and impacts on receptors generated by these construction supporting infrastructures are identified and assessed in Section 5. Any future materials extraction areas must undergo the initial ES Screening process to identify risks and impacts and if required, additional

central region; ARA-Norte is responsible for the northern region; ARA-Centro Norte for the central and northern regions of the country; and ARA- Zambeze focuses on activities around the Zambeze Hydrographic basin.

ESIA to be prepared prior to the commencement of any civil works. Contractors are required to follow land acquisition process outlined in the RPF instrument for the opening of a new quarry and/or a borrow pit.

Before the quarry or a borrow pit is opened, local authority or authorities, traditional leaders and Project Affected Persons (PAPs) must be adequately consulted throughout the whole process, and affected assets must be correctly inventoried, identified and valued for compensation. All agreements made must be signed, so that payments can be done to PAPs. The developer must then apply to the Ministry of Minerals Resources and Energy (MIREME) so that they can obtain the required license to enable them to proceed to open a new quarry or borrow pit after submitting a comprehensive Quarry/Borrow pit management and rehabilitation plan to the relevant authorities. The mining license is issued by the Ministry of Minerals Resources and Energy. In addition, before opening any quarry or borrow pit, an Environmental License must be issued for that particular activity too, to be issued by Province Services of Environment (SPA).

4.5.6 Waste Disposal Areas

Solid and liquid waste will be generated during the construction, demobilization/decommission, and operation and maintenance phases. Prior to disposal of waste, waste segregation, reuse and recycling efforts will be made. General waste should be disposed of correctly in designated landfill areas following an approval by local authorities. Hazardous wastes should be identified and assessed separately and must be stored in sealed containers before they are disposed of correctly at a designated, fenced site approved by the Municipal Authority in the Province. General criteria used for selecting waste disposal sites are as follows:

- General waste dumpsite site must be located at least 50 m away from sensitive receptors such as water courses, recharge of aquifers, flooding susceptibility, human settlements, cultural and protected sites, threatened habitat and biodiversity; and
- The selected site must be fully assessed to identify any risks and impacts that dumping of waste at that particular site may have on the environment, cultural heritage and biological resources so that appropriate measures can be developed to mitigate the identified risks and impacts, The analysis of risks and impacts associated with the proposed waste dumpsite area shall be identified in an ES screening report and if required, detailed in an ESIA to be prepared prior to any civil works for a site-specific project.

4.5.7 Project Workers

Project workers will be required at all levels (i.e., Central, provincial and local levels) to ensure effective, efficient and successful implementation of the Project. The Labor Management Procedures (LMP) developed provide additional guidance to be followed during implementation.

Skilled workers may be hired from within Mozambique and may be national migrant workers. International skilled migrant workers may be required where local skilled workers are not available. Unskilled workers may be hired locally where the sub projects will be implemented. The Contractor must ensure that at least 25% of workers to be hired are females to promote gender equality and women's empowerment.

5 PROJECT ALTERNATIVES

A range of project options were evaluated in relation to the road alignment and bridgeworks in order to determine the best solution according to technical (engineering), economic (cost-benefit) and sustainability (environmental and social impact) criteria. In each case a “do nothing” scenario was considered.

Within the scope of this project, two alternatives can be considered: one in which there is no rehabilitation, maintaining the current conditions of the road, and another in which the rehabilitation is carried out according to the execution project and the conditions of the road are improved.

The “**Without the Project**” alternative would maintain the current impacts, characterized by difficult conditions for the movement of people and goods between the Center and North of the country, which would entail enormous costs for motorists and consequently an increase in the cost of living.

The “**With the Project**” alternative will bring improvements in the quality of the road, which presupposes an increase in traffic speed and safety, which could contribute to better integration between consumption and production areas. However, environmental and social impacts are anticipated during the construction phase. These must be mitigated during the construction of the project with the implementation of an environmental management plan.

However, the recommended options regarding road alignment and bridges are:

- In the road alignment: Substantially maintain the existing alignment with only minor changes where mandatory.
- On bridges: Various solutions depending on width, cost and heritage conservation considerations on a case-by-case basis, including: rehabilitation through widening and improving cross sections.

Therefore, this document assumes the alternative “With the Project” and maintaining the current road alignment, being prepared in accordance with the applicable legislation and the classification carried out by the Ministry of Land and Environment (MTA).

It should be noted that the design consultants did not consider any alternative road alignment in the concept design reports. Some alternatives, for example, those related to pavement design were considered but not accepted by the Employer.

6 DESCRIPTION OF THE ENVIRONMENTAL AND SOCIAL BASELINE OF THE PROJECT AREA

6.1 Overview

The Central provinces are more prone to floods, tropical cyclones and epidemics. According to the National Institute for Disasters Risk Management and Reduction (INGD), the climate will be more extreme with drought spells being hotter and longer and rains being more unpredictable, increasing risks of crop failure and droughts, floods, and uncontrolled fires. The Central zone is likely to be the hardest hit in terms of climate change, particularly those regions at lower altitude, which are already experiencing hot temperatures. Of particular relevance to this ESIA is the phenomenon of flooding in certain areas as it is becoming increasingly severe and more frequent, affecting especially the poorest and vulnerable populations. This was noted recently in 2019 when Cyclone Idai affected more than 1.5 million people, injured over 1,600 people and 602 people died, and over 100,000 homes were damaged or destroyed. The floods have also affected infrastructure, particularly roads and bridges, that sometimes have not been able to withstand the floods and have also been damaged or destroyed.

6.2 Area of Influence

The spatial scope of the study area for the assessment has been determined for each of the environmental and social aspect on a case-by-case basis. A distinction between two different spatial areas is taken into consideration. Firstly, the area within the Project Footprint or boundaries of the Project site and, secondly, the Area of Influence (AoI). Any impacts anticipated within the former spatial scope will necessarily denote direct impacts while impacts within the latter may be direct or indirect according to the impact and receptors in question.
The potential area of influence of the project is defined as the radius in which significant effects are expected from the Project whilst also accounting for other relevant Projects being implemented in the vicinity.

The sizes of the study area for each environmental and socio-economic aspect have been examined separately to ensure that its size appropriately captures the impacts of the Project on the environment. The table below shows the area of influence and justification for choice.

Table 6-1 Delineation of Area of Influence for Different Impacts

Impact/ Aspect	Area of Influence	Justification
Noise Emissions	600m	The propagation of noise and vibration tends to diminish as one moves further from the sources. Unlike atmospheric pollutants, the influence of noise and vibration remains unaffected by meteorological conditions, behaving as an immediate form of energy disturbance. These disturbances are conveyed through the physical surroundings, lessening in intensity over distances. Given the nature of major infrastructure Projects like ours, some noise and vibrations are expected. The dynamics of noise and vibration can be categorized into three segments: the origin, the transmission route, and the endpoint or receiver. Based on recorded data from construction equipment used in similar contexts, noise levels peak at approximately 100 dB at a distance of 15m from the source. Utilizing the standard diminution rate of 6 dB for every doubling of distance from the primary construction noise source and adhering to the Project's Performance Standards framework the noise levels should not surpass 70 dB, which roughly translates to a distance of about 600m from the noise origin. Consequently, a buffer zone has been established to encapsulate and protect sensitive receptors, predominantly residential areas, from excessive noise levels.
Gaseous Air Emissions	500m	Emissions such as dust and other particulate matter are generally noticed within a range of 100-200m from the construction or operation sites. To comprehensively assess the direct impact on air quality, a study area has been delineated with a buffer zone extending at least 500m around the core Project area and around associated facilities as a precautionary approach to ensure complete coverage. This boundary is designed to account for all potential emission sources, encompassing vehicular movements on access roads and other associated activities. The buffer's breadth ensures the inclusion of sensitive receptors, with a primary focus on residential properties.
Waste Impacts	5km	The delineation of the Area of Influence (AoI) for waste-related impacts has been conservatively set at 5km from the core Project areas. This expansive boundary has been established to account for potential factors like wind and water transport, which can disseminate improperly managed waste materials over considerable distances. Additionally, the wider AoI considers the possibility of accidental spills during the transportation of waste materials, ensuring a comprehensive assessment of potential impacts and safeguarding surrounding environments and communities.
Terrestrial Biodiversity	1km	An Area of Influence (AoI) spanning a radius of 1km around the Project location has been determined as adequate to evaluate potential impacts on terrestrial biodiversity. This boundary encompasses potential effects that construction activities and subsequent operation and maintenance (O&M) procedures might have on local habitats, flora, and fauna. This delineation ensures a thorough assessment of the Project's

Impact/ Aspect	Area of Influence	Justification
		influence on the surrounding ecosystem during its entire lifecycle.
Cultural Heritage	500m	The study area for the cultural heritage and archaeological aspects extends approximately 500m around the Project site. This distance is considered sufficient for adequately defining and studying the cultural and archaeological setting of the Project area.
Topography	1km	For topographical impacts, an Area of Influence (AoI) encompassing a 1km strip of land surrounding the project site has been delineated. By setting this perimeter, the aim is to holistically assess and manage the alterations to the natural landscape brought about by the Project's developments (although the results of such topographical changes are likely to provide the positive influence which safeguards the city against floods and extreme weather events).
Geology and soils	5km	For impacts related to soil and land, while many such effects are typically confined to the immediate Project footprint, the Area of Influence (AoI) for the project has been set with a radius of 5km around the Project site. This expanded boundary was defined to consider indirect impacts that might arise, predominantly from the movement of vehicles and heavy machinery, as well as activities at associated Project locations. This ensures a comprehensive evaluation of potential disruptions to the land and soil environment in the vicinity of the Project.
Hydrogeology	2km	For the hydrogeological impacts, given the specific site characteristics and groundwater depths associated with the project, a focused Area of Influence (AoI) is essential. Hydrogeological systems, by their very nature, can be intricately linked yet can demonstrate localized behavior based on geological formations, porosity, and other subsurface conditions. Considering these factors, as well as the potential for dispersed effects, an AoI of 2km radius around the Project site is proposed. This conservative boundary ensures that any potential changes to groundwater flows, quality, or recharge rates, even if they manifest in a dispersed manner, are effectively captured and addressed.
Land Use	Local	The delineation of the Area of Influence (AoI) with respect to land use is primarily localized. This AoI specifically encompasses areas targeted for land acquisition. As the Project progresses, it's vital to ensure that any changes to the existing land use patterns remain within this predefined boundary to maintain harmony with the local context and to minimize unintended disruptions.
Socio-Economic Conditions	5km	The Area of Influence (AoI) for socio-economic consultations has been delineated as a 5 km radius around the Project site. This boundary has been established to capture indirect impacts associated with the Project. This will ensure proper assessment of the community's perceptions of potential effects tied to the Project, which may range from employment opportunities and livelihood disruptions to increased vehicular activities. The aim is to ensure that both the positive

Impact/ Aspect	Area of Influence	Justification
		opportunities and potential challenges presented by the Project are holistically addressed.
Community Health and Safety/Occupational Health and safety	1km	For the project understanding its proximity to residential zones and markets, a designated Area of Influence (AoI) of a 1 km radius around the Project site has been demarcated. This boundary consideration is crucial, especially when construction activities are taking place near populated areas, with heightened risks linked to health and safety, including risks related to SEA/SH from interactions between workers and community members. By doing so, the Project considers potential concerns related to general construction hazards, potential disease transmission, and the possible emergence of waterborne diseases. This AoI ensures a comprehensive assessment of these health risks and provides a framework for mitigation strategies during both the planning and execution phases of the Project.

The baseline has been developed to follow the Area of Influence.

6.3 Physical baseline

6.3.1 Topography

The topography of Sofala province in the central-eastern Mozambique covers an area of approximately 68,018 square kilometers. The province is bordered to the north by Tete province, to the north-east by Zambézia province, to the south by Inhambane province and to the west by Manica province. The altitude of the province ranges between 14 and over 109.6 meters above the see level. The city of Beira, the province capital is located below sea level, with coastal flood plain areas and undulated relief, interrupted from time to time by the rock formations of “Inselbergs” (FAO, 1998; https://en.wikipedia.org/wiki/Sofala_Province).

6.3.1.1 Geological Formations

Sofala's geological landscape primarily comprises sedimentary formations, including sandstones, shales, and limestone, deposited in diverse environments such as river systems. Intrusive igneous rocks, such as granites, punctuate the landscape alongside volcanic formations like basalts and rhyolites. Alluvial deposits are prevalent along riverbanks, while coastal sediments and river terraces contribute to the region's geological diversity.

6.3.1.2 Soils

Figure 14 presents the soil map of Sofala province. The soils of this province stem from two primary geological formations: quaternary sediments, forming the bedrock of alluvial deposits, and sandy coastal dune sediments. The province features various soil compositions including alluvium, sediment soil, basaltic soil, colluvium, marine sandy soil, mananga formation, shallow soil, brown soil, and litic soil. According to FAO (1998), the province boasts a variety of soil types, as noted in the map below:

- **Peat/organic soils**: predominantly found along the coastal areas of the Indian Ocean. These soils are conducive to agriculture.
- **Hydromorphic sandy soils**: typically located in coastal plain areas and lagoons.
- **Dark alfisols**: occurring in lowland arable land regions.
- **Red alfisols**: prevalent in highland areas, susceptible to erosion.

All these soil types are well-drained, with peat soils being particularly suitable for agriculture.

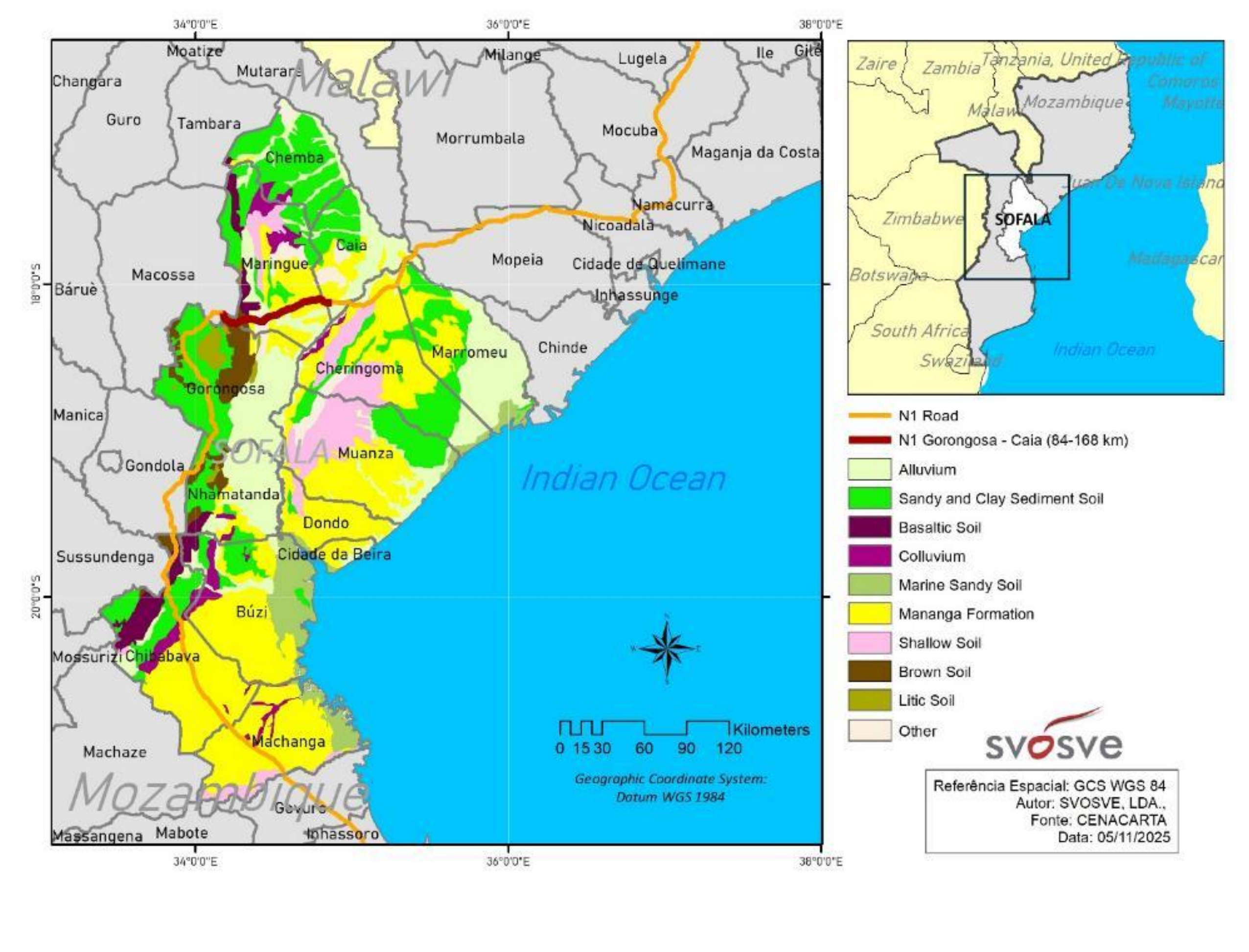


Figure 14 Soil map of Sofala province

6.3.1.3 Hydrology

Sofala Province has a diverse hydrological system shaped by three major rivers: the Búzi, the Púnguè, and the Zambezi. Among these, the Púnguè directly traverses the project area, complemented by a network of smaller streams and tributaries. From south to north, the Búzi River rises in Zimbabwe, crosses Manica and Sofala, and plays a key role in agriculture and local livelihoods. The Púnguè River, also originating in Zimbabwe, flows through Sofala into the Indian Ocean and is vital for irrigation, drinking water, and sustaining ecosystems along its course. Further north, the Zambezi River – one of Africa's largest – crosses Sofala, providing significant water resources for agriculture, fisheries, and hydropower. Within the project's targeted section, the main rivers encountered are the Nhamapaza, Mombezi, and Nhanzazo (Km 84–168). The floodplains of the Zambezi and other rivers are vital for agriculture, especially rice cultivation, also serving as important habitats for wildlife. Wetlands, such as those along the Pungue and Buzi rivers, play a crucial role in maintaining biodiversity, supporting fisheries, and acting as natural water filters. The province's coastline along the Indian Ocean includes estuaries and mangrove forests, which are important for coastal protection, fisheries, and supporting marine biodiversity.

Sofala experiences a tropical climate with distinct wet and dry seasons. The wet season, from November to April, brings heavy rains that replenish rivers and groundwater but also pose risks of flooding. Major rivers, especially the Zambezi, are prone to flooding, which can cause displacement and damage to infrastructure and crops. In contrast, the dry season, from May to October, sees reduced rainfall, leading to lower river flows and potential water scarcity in some areas/communities. Groundwater is an important source of water for rural communities and agriculture. The province has various aquifers, with recharge rates depending on rainfall and geological formations.

The maps below show some of the main river basins through which the N1 passes for each of the Packages in the project.

The map below shows the hydrology of the area through which the N1 passes for the section Gorongosa-Caia (km 84-168).

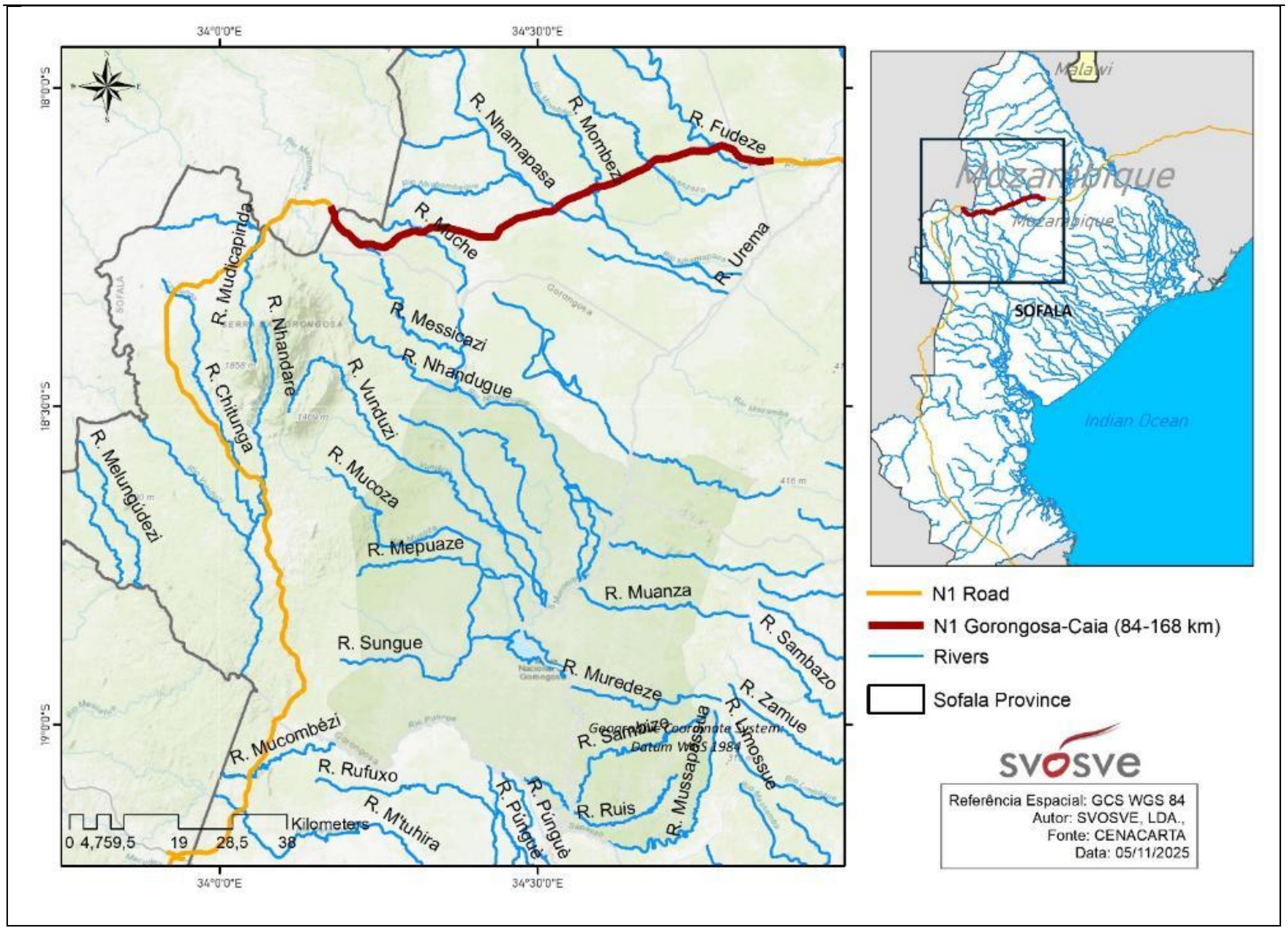


Figure 15 Hydrology for km84-168 (Gorongosa to Caia)

The following main rivers and bridges crossing the N1 are considered for rehabilitation for Km84-168 (Gorongosa to Caia) with estimated chainage location:

- S-20 (Nhapherua River) (Km 101+260)
- S-21 (Nhampaza River) (Km 126+260)
- S-22 (Mombeze) (Km 133+260)
- S-23 (Nhanzaza River) (Km 143+680)
- S-24 (Fudza River) (Km 143+680)

6.3.1.4 Climate and Temperature

The climate and temperature of Sofala province is a Tropical Continental Climate characterized by wet and dry seasons. The average maximum daily temperature is 25-30 °C which occurs mainly in the rainy season that is between December and March while the average lowest daily temperature is 12-15 °C in the dry season, especially during the months of June to August (Government of Mozambique, Ministry of Transport and Communication, 2020).

The precipitation rate in the province ranges from 110 mm to 900 mm per year. The lowest rainfall is experienced during the dry season which occurs between May to October. Sofala is at high risk of flooding during the rainy season with increases risks when tropical storms and cyclones occur. The central provinces are particularly prone to floods, tropical cyclones, and epidemics. According to the INGD, climate conditions will become more extreme, with hotter and longer drought spells and more unpredictable rainfall, increasing the risks of crop failure, droughts, floods, and uncontrolled fires. For example, in 2022, the southern part of the province (Machanga, Chibabava, and Buzi) recorded rainfall exceeding 110%, while the central and northern parts (Maringue, Gorongosa, and Nhamatanda) recorded negative anomalies of 60%. The central region is expected to be hit the hardest by climate change, especially the lower-altitude areas already experiencing high temperatures.

Flooding events, a critical concern highlighted in this ESIA, are becoming increasingly severe and frequent, disproportionately affecting the poorest and most vulnerable populations. In March and April 2019, Sofala was hit by cyclones Idai and Kenneth, respectively. Cyclone Idai affected more than 1,5 million people, causing 602 deaths. Over 100,000 houses were partially or totally destroyed. The damage caused by both cyclones amounted to over $3,2 billion. Cyclones Eloise and Freddy also impacted the province; Freddy hit in January 2021 with strong winds and heavy rains, while Freddy formed in February 2023. As a direct result, the floods have severely affected infrastructure, particularly roads and bridges, many of which have been damaged or destroyed as they could not withstand the water pressure.

6.3.1.5 Air Quality

Air quality baseline measurements were conducted along the Project corridor during daylight hours between 07:00 and 18:00. At each selected sensitive receptor location, ambient air quality was measured for approximately one minute to characterize existing environmental conditions.
The identification of sensitive receptors was undertaken during the 2022 baseline field survey based on site reconnaissance, settlement distribution, and field verification. Sensitive receptors were defined as locations with potential human exposure, such as schools, health facilities, and places of worship located in proximity to the project road.

For the specific section of the corridor under assessment, only one sensitive receptor was identified and confirmed during field investigations at the time of the survey (as noted in Table 6 – 2). This reflected the low density and dispersed nature of settlements within this section, as well as accessibility constraints during fieldwork (Figure 16). Consequently, this receptor was selected as the representative monitoring location for baseline air quality assessment for that section.

Table 6-2 Air quality measurements in project area in Sofala

Item	Measuring point (Schools, health facilities, mission)	Type of receptor	PM 2.5	PM 10
10	EPC Alberto Joaquim Chissano (Nhamapaza)	School	28	1

Source: SWMoz, 2023

As part of the revision ESIA to reflect only Lot 2, km84-168 Gorongosa to Caia, a supplementary desktop analysis was undertaken using updated satellite imagery available through Google Earth. This review identified approximately 18 additional potential sensitive receptors along the same section of the corridor (Figure 16). These comprise built-up areas and infrastructural features that may correspond to new residential or community land uses. However, these locations are classified as potential receptors, as their exact function and occupancy status could not be fully confirmed without field verification.

This updated information is presented to complement the original baseline assessment and to improve the completeness of receptor identification for impact assessment purposes (Table 6 – 3).

As a site visit for confirmation of the new potential sites could not be undertaken at the time of revision, the main sources of air emissions are therefore still associated with local anthropogenic activities, including:

- exploitation of forest resources, particularly charcoal production activities, which generate smoke and particulate matter through the carbonization and combustion of biomass;
- use of charcoal and firewood for cooking and household energy needs, contributing to localized emissions of particulate matter and combustion-related pollutants;
- subsistence agriculture practices, notably slash-and-burn land preparation and vegetation clearing, which result in periodic emissions of smoke, suspended particulates, and other combustion by-products into the atmosphere involving biomass burning for land clearing.

Table 6-3 Potential sensitive receptors identified using Google satellite maps

Receptor	Latitude	Longitude	Altitude	Identification reference and distance from road	Chainage (km)
1	18°14'53.06"	34°14'45.76"	217 m	R1 (10m)	10.900
2	18°13'36.61"	34°19'15.28"	128 m	R2 (50m)	19.400
3	18°13'26.68"	34°19'31.31"	544 m	R3 - 40m	20.300
4	18°13'23.04"	34°19'40.16"	527 m	R4 (more than 70m)	21.100
5	18°13'10.25"	34°19'22.10"	333 m	Outside of road area	21.700
6	18°13'10.41"	34°20'2.90"	441 m	R5 (40m)	21.800
7	18°13'12.22"	34°21'20.47"	336 m	R6 (60m	24.090
8	18°13'9.93"	34°21'32.49"	321 m	R7 (60m)	24.900
9	18°13'24.02"	34°21'59.67"	210 m	R8 (Outside of road area - More than 100m)	25.500
10	18°14'3.95"	34°25'47.24"	297 m	R9 (40m)	31.500

Receptor	Latitude	Longitude	Altitude	Identification reference and distance from road	Chainage (km)
11	18°12'55.21"	34°26'54.81"	262m	R10 (67m)	35.500
12	18°12'8.23"	34°28'22.34"	347 m	R11 (more than 100m)	38.400
13	18°11'0.17"	34°32'9.70"	832 m	R12 (10m)	45.500
14	18°10'23.04"	34°33'5.28"	332 m	R13 (80m)	47.700
15	18° 9'20.81"	34°35'40.65"	205 m	R14A (70m)	52.600
16	18° 9'15.88"	34°35'37.50"	205 m	R14B (80m)	52.600
17	18° 9'7.67"	34°36'41.74"	202 m	R15 - Escola de Nhamapaza (40m)	54.500
18	18° 9'3.76"	34°36'41.74"	165 m	Same as R15	54.500

Receptor 1 (R1)

Receptor 2 (R2)

Receptor 3 (R3)

Receptor 4 (R4)

Receptor 5 (R5)

Receptor 6 (R6)

Receptor 7 (R7)

Receptor 8 (R8)

Receptor 9 (R9)

Receptor 10 (R10)

Receptor 11 (R11)

Receptor 12 (R12)

Receptor 13 (R13)

Receptor 14a (R14s)

	
Receptor 14b (R14b)	Receptor 15 (R15) Escola de Nhamapaza

Figure 16 Potential sensitive receptors identified using Google satellite maps

According to the quantitative data obtained, air quality in the study area is generally considered to be within acceptable limits when compared with the national 24-hour limit for PM_{10} (150 µg/m³) and the more stringent World Bank (WB) guideline of 50 µg/m³, noting that interim targets range from 75–150 µg/m³. For $PM_{2.5}$ the WB 24-hour guideline is 25 µg/m³, with interim targets ranging between 37.5–75 µg/m³.

Possible localized exceedances of the WB guideline values and interim targets for $PM_{2.5}$ may be associated with anthropogenic activities commonly observed within the Project area, including vegetation burning for agricultural land clearing and charcoal production, both of which are prevalent in the rural areas where monitoring was undertaken. In addition, the degraded condition of certain sections of the N1 is likely to contribute to increased dust generation from vehicle movement, particularly from heavy-duty traffic operating on unpaved or deteriorated road surfaces.

The baseline data will be further refined during the detailed design phase through additional verification and monitoring activities, where required. Sensitive receptors identified along the corridor through satellite imagery in Table 6-3 should be verified and considered in the planning and implementation of construction activities and be subject to continued environmental monitoring throughout Project implementation.

6.3.1.6 Noise

As noted in the previous section, the project area is predominantly rural, with the main source of noise being road traffic along the N1. Much of this traffic consists of heavily loaded trucks and inter-city buses, many of which are not well maintained. The degraded condition of the road, with irregular potholes, further amplifies noise levels.

Applicable Standards

According to the **World Bank EHS Guidelines (2007)** and **WHO community noise guidelines**, the following limit values are generally applied:

- **55 dBA**: daytime guideline value for residential, institutional, and educational receptors.
- **45 dBA**: nighttime guideline value for residential, institutional, and educational receptors.
- For **schools and hospitals**, more stringent levels are recommended, typically not exceeding **35-40 dBA indoors** to avoid disturbance.

The table below presents the noise levels measured at the sensitive receptor identified in this section of the N1 in 2022 during the baseline data capture survey.

Table 6-4 Noise levels measured in project area at sensitive receptor identified in km84-168 Gorongosa to Caia

Sample point	Name of receptor	Type of receptor	Geographic coordinates		Estimated Chainage (Gorongosa to Caia)	Level of noise measured (dBA)	
			Latitude	Longitude		Without traffic	With traffic
1	EPC Alberto Joaquim Chissano (Nhamapaza)	School	18.1516001	34.611841	Km 139+230	51.9	79.9

Source: SWMoz, 2023

The results show that background noise levels without traffic are generally within or close to the WB/WHO guideline values. However, with traffic, measured levels are significantly above guideline limits at all receptors, particularly in areas with frequent passage of heavy vehicles.

From the results presented in the table above, it is observed that:

- In villages, going from a moderate and calm environment without vehicle traffic to a moderate environment with road traffic, the sound goes from 51.9 dBA to 79.9 dBA, with the passage of heavy vehicles.

Overall, while noise levels in the absence of traffic are relatively low, in some sections, the traffic-related noise significantly exceeds WB/WHO guideline values. This indicates a potential adverse impact that will need to be carefully managed during the construction and operation phases.

Additional potential sensitive receptors were identified in the previous section in Table 6-3 which would need verification on the ground. As noted previously, the baseline data would need to be updated during the design phase by the contractor and monitored closely during the construction phase.

6.3.1.7 Vibration

As noted in the previous section on noise, the baseline results from the data capture survey undertaken in 2022 at the sensitive receptor located near the roadside identified in this section of the N1 indicate that vibration levels tend to increase to high values whenever the receivers are exposed to heavy vehicles and noise, although generally in the absence of traffic, these levels are low.

Table 6-5 Vibration levels measured in project area at sensitive receptor identified in km84-168 Gorongosa to Caia

Item	Name of receptor	Type of receptor	Vibrations in decibels (D)
1	EPC Alberto Joaquim Chissano (Nhamapaza)	School	129

Source: SWMoz, 2023

The outliers observed in the noise levels (vibrations) were produced by high traffic of buses and trucks at the time of data collection.

Additional potential sensitive receptors were identified in the previous section in Table 6-3 which would need verification on the ground. As noted previously, the baseline data would need to be updated during the design phase by the contractor and monitored closely during the construction phase as vibration levels are expected to increase when activities commence.

6.3.1.8 Existing borrow pits in Sofala currently in use

14 borrow pits were noted in the Inchope to Caia section. 4 are within the buffer zone of Gorongosa National Park, 2 noted by the park authorities which local communities use are at two points of Mbulawa (S -18.89895 E034.12264) and Mbulawa (S -18.91348 E034.12496). Some of these are shown in Figure 16 Sample points of potential borrow pits, sand sources, water source sample site and camp sites in concept design reports. It was not possible to verify if mining and environmental licenses were available for these locations.

Table 6-6 Borrow pits located in Sofala province in use

Name	Location	Altitude (meters above sea level)	Image	Comments
Bendecal	Latitude: 19.110S Longitude: 33.5153E	127 m		Active and gravel is being used for rehabilitation works in the Inchope area. The surrounding environment is characterized by traces of fires, dominated by grasses, *Acacias* and young *Combretum sp* trees.
Mitochira-Hernoque	Lat: 33.5153S Long: 34.01140E			100m from EN1 Close to EPC Mitochira-Hernoque, and a small market at the truck entrance
Mitochira-Hernoque 2	Lat: 19.08627S, Long: 34.01513E	133m		Dominated by shrubs of *Combretum sp.*

Name	Location	Altitude (meters above sea level)	Image	Comments
Tchiro Bondu	Lat: 19.01221 Lat: 34.04413	191m		Gorongosa National Park buffer zone Potential for exploration. Mixed vegetation, some trees from the *Fabacea* family, *canhueiros*, *Combretum sp* trees
Massinha	Lat: 18.56956S Long: 34.07476E	101m		Gorongosa National Park buffer zone Tree species *Combretum sp*. mostly shrubs and grasses
Tchiro	Lat: 19.01311S Long: 34.04792E			Gorongosa National Park buffer zone 145m from EN1

Name	Location	Altitude (meters above sea level)	Image	Comments
Mutondo	Lat:18.19076S Long:33.55843E	301m		Large timber forest trees with a mixture of shrubs of a variety of species
Nhandue	Lat:18.11624S, Long:34.06177E	404m		Native vegetation of *Panga-panga* species, *Albizia sp*, *Canhueiros,*
Nhapombue	Lat: 18.11451S Long:34.10524E	404m		Native mixed vegetation of large trees and shrubs

Name	Location	Altitude (meters above sea level)	Image	Comments
Nhampherua-Movitel Antenna	Lat: 18.21958S Long:34.33461E	304m		Manica-Sofala boundary zone Vegetation dominated by *Acacia sp*, adjacent to the residential area of the communities.
Sand yard	Lat:18.15001S Long:34.15719E			Sand extraction, native plants around, large trees, slightly dark soils mixed with limestone
Nhauzaza	Lat:18.1376149S Long:34.644853E	105m		Located in Nhamapaza, Sofala, far from the community Extraction of Red sand, Native plants around the site, alternated by grasses and shrubs.

Name	Location	Altitude (meters above sea level)	Image	Comments
Paveca	To be verified			
Maringue area	Lat: 18.2348103S Long:34.4151953E		No photo	Located near Nhamapaza
Fudza	Lat: 18.09855 S Long: 34.80785E	71m	No photo	Extraction of typically dark sand, mixed vegetation, alternated by grasses
Nhatengua-Josina Machel	Lat: 18.12095S Long: 35.08199E	91m	No photo	Mixed and dense vegetation with large trees

6.4 Biological Baseline

6.4.1 Natural habitats/Ecosystems and biodiversity

As shown in the figure below, the initial 10km or so of the 84 km section of the road from Gorongosa to Caia (Km84 to Km168) passes through the buffer zone of the Gorongosa National Park and continues for a further 74 km towards Caia.

This section traverses the Gorongosa ecosystem, one of the most important areas for biodiversity conservation in Mozambique and globally, widely recognized as one of the richest and most diverse ecosystems in Africa. The ecosystem encompasses a wide range of habitats, including floodplains, savannas, and mountainous tropical forests, forming a complex ecological mosaic that supports a remarkable diversity of fauna and flora. In this context, the Gorongosa ecosystem plays a critical role in biodiversity conservation in Southern Africa, contributing significantly to regional ecological connectivity by enabling species migration and maintaining genetically viable wildlife populations.

Within this area, the ecologically important biodiversity areas include the Gorongosa National Park (GNP) and its Gorongosa Mountain Rift Valley Complex, which rises to 1,863m above the sea level in the southern-most sector of the African Rift Valley in Mozambique, as well as hunting areas, forest reserves and several river floodplains. Gorongosa National Park is home to African elephants (*Loxodonta africana*), lions (*Panthera leo*), wild dogs (*Lycaon pictus*), hippos (*Hippopotamus amphibius*) and many other other fauna and flora species.

A variety of wetland habitats occur within this ecosystem including rivers, lakes, temporary pans, reed swamps, floodplain grassland and palm savanna. The diversity of habitats in this area makes it one of the finest wildlife grazing ecosystems in Africa as reflected by the spectacular wildlife that inhabited the valley prior to the armed conflict.

The road segments are also near to the Gorongosa-Marromeu Key Biodiversity Area (GMKBA) of international significance. This proposed site is ecologically unique, with high species diversity and environmental features found nowhere else in sub-Saharan Africa (Parque Nacional da Gorongosa, 2010). The N1 road borders, to a great extent, the limits of the GMKBA, starting from the bridge of the Púngué river through around 9km after the boundary between the districts of Cheringoma and Caia. In addition, the area is also close to the Marromeu Complex Ramsar Site (MCRS), recognized as an Important Bird Area (IBA). Additionally, the Government of Mozambique designated the Marromeu Complex as the country's first Wetland of International Importance (WII) (Beilfuss *et al.*, 2010; Beilfuss, 2015) thus highlighting this complex as being among the most important wetlands in Africa (Beilfuss, 2015).

Although the figure below shows Mount Gorongosa located within the buffer zone, the mountain itself was formally incorporated into the formal protection area within the boundaries of Gorongosa National Park in 2010 (Müller, T*., et al*. (2012), and hence has the same legend color as the GNP.

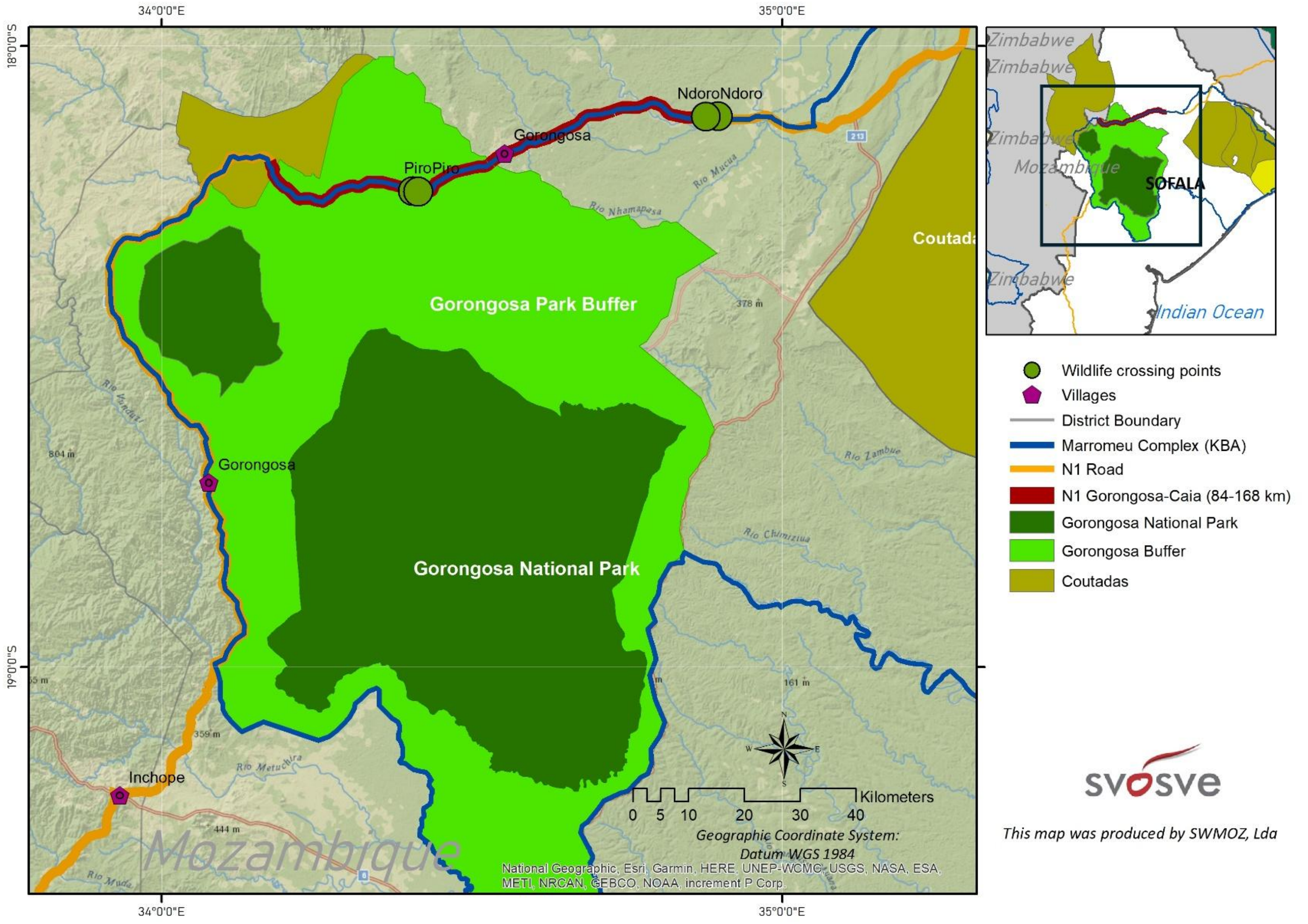


Figure 17 Gorongosa ecosystem (GNP and GNP buffer zone) Marromeu complex and official coutadas with wildlife crossing points for Lot 2 km 84-168, Gorongosa to Caia

6.4.2 Critical habitats

As per ESS6, critical habitat is defined as areas with high biodiversity importance or value, including:

(a) habitat of significant importance to Critically Endangered or Endangered species, as listed in the IUCN Red List of threatened species or equivalent national approaches;

(b) habitat of significant importance to endemic or restricted-range species;

(c) habitat supporting globally or nationally significant concentrations of migratory or congregatory species;

(d) highly threatened or unique ecosystems;

(e) ecological functions or characteristics that are needed to maintain the viability of the biodiversity values described above in (a) to (d).

The GNP and the Marromeu Complex are recognized as critical habitats under the ESS6, particularly due to their classification as a unique ecosystems (d), and for supporting globally threatened species listed by the IUCN (b). The broader Gorongosa ecosystem, in particular, qualifies due to its ecological distinctiveness, biodiversity richness, and the presence of species with high conservation value and ecological sensitivity — such as the lion (*Panthera leo*), African elephant (*Loxodonta africana*), leopard (*Panthera pardus*), ground pangolin (*Smutsia temminckii*), and the Gaboon viper (*Bitis gabonica*).

However, it is important to clarify that the project area itself does not intersect with any designated critical habitats. The section of the N1 closest to the GNP runs along the border of its buffer zone, with the nearest point located approximately 10 km from the park's boundary. Although part of the N1 passes through the buffer zone, most of the road remains at a considerable distance from the main sensitive areas of the park. As such, while the GNP and its buffer zone are of high conservation significance, the area of direct influence of the road is limited, and no permanent ecological features defined as critical habitat (e.g., breeding grounds, corridors, or feeding sites) have been identified within the immediate vicinity of the road alignment.

Nevertheless, the road traverses a functionally connected ecosystem, and species with wide-ranging behavior may cross the road corridor, particularly during seasonal movements or dispersal events.

It is also noted that the remaining sections of the N1 passing through the official *coutadas* are not defined as critical habitat, and do not support ecosystems or species that would meet the ESS6 thresholds for such classification.

6.4.3 Fauna

Mammals

This ecosystem supports a diverse range of wildlife, including elephants, lions, buffaloes, hippos, and antelopes. Additional data on mammals were gathered from community testimonies, which confirmed the presence of wildlife corridors in the buffer zone, particularly used by elephants (*Laxodonta africana*), wild pigs (*Potamochoerus porcus*), black-faced monkeys (*Cercopithecus aethiops*), samango monkeys (*Chlorocebus pygerythrus*), lion (*Panthera leo*), and wild dog (*Lycaon pictus*) were observed.

As noted in the wildlife permeability study in section 6.4.7 below, the table below identifies mammal species in the Project area.

Table 6-7 Mammal species identified in the project area in Sofala

Scientific name	Common Name	Conservation Status IUCN 3.1, Red list 2013	Probability of Occurrence
Alcephalus buselaphus	Hartebeest	Least Concern	Recorded
Aepyceros melampus	Impala	Least Concern	Recorded
Crocuta crocuta	Spotted hyena	Least Concern	Recorded
Cephalophus natalensis	Red forest duiker	Least Concern	Recorded
Connochaetes taurinus	Blue wildebeest	Least Concern	Recorded
Equus quagga	Plains zebra	Least Concern	Recorded
Hippotragus niger	Sable antelope	Least Concern	Recorded
Kobus ellipsiprymnus	Waterbuck	Least Concern	Recorded
Loxodonta africana	African savannah elephant	Endangered	Recorded
Lycaon pictus	African wild dog	Endangered	Recorded
Smutsia temminckii	Ground pangolin	Vulnerable	Recorded
Ourebia ourebi	Oribi	Least Concern	Recorded
Phacochoerus africanus	Common warthog	Least Concern	Recorded
Redunca arundinum	Southern reedbuck	Least Concern	Recorded
Papio cynocephalus	Yellow baboon	Least Concern	Recorded
Panthera leo	Lion	Endangered	Recorded
Syncerus caffer	African buffalo	Least Concern	Recorded
Sylvicapra grimmia	Common duiker	Least Concern	Recorded
Tragelaphus angasii	Nyala	Least Concern	Recorded
Taurotragus oryx	Common eland	Least Concern	Recorded
Tragelaphus strepsiceros	Greater kudu	Least Concern	Recorded

Animal movements across the N1 and occasional sightings of leopard, lion, elephant, buffalo, kudu, and smaller species have also been recorded in specific locations such as Piro and Ndoro as per the corresponding coordinates provided below by ANAC and the GNP authorities. It should be noted that the chainage has been estimated from Google earth and is not accurate and requires verification on the ground when monitoring during Project implementation:

Locations identified

- 18.233835°, 34.404710°- Piro (approximate chainage km115 + 400)
- 18.234497°, 34.413110° - Piro (approximate chainage km116 + 500)
- 18.113897°, 34.877284°- Ndoro (approximate chainage km166 + 400)
- 18.113600°, 34.896571°- Ndoro (approximate chainage km168 + 900)

With respect to the risk of labor influx and poaching of wild animals, the park authorities mentioned the risk of poaching of species of elephant, buffalo, kudu and small antelope such as suni occurring in the buffer zone of the GNP as noted in the area of Ndoro.

According to the Gorongosa Park Science Director (late Dr Marc Stalmans), occasional dispersal of individual animals across the EN1 may occur; however, significant or sustained movements are not expected. This is largely due to the relatively high human population density along the EN1 – particularly between Inchope and the area north of Vila Gorongosa – combined with the low density, or in some areas, absence of wildlife on both sides of the road.

The maps presented in the figures below show those areas where the GNP authorities mapped a density of people in excess of 100 per km^2. Those kinds of human densities coupled with extensive cultivation will make for low wildlife densities and little movement.

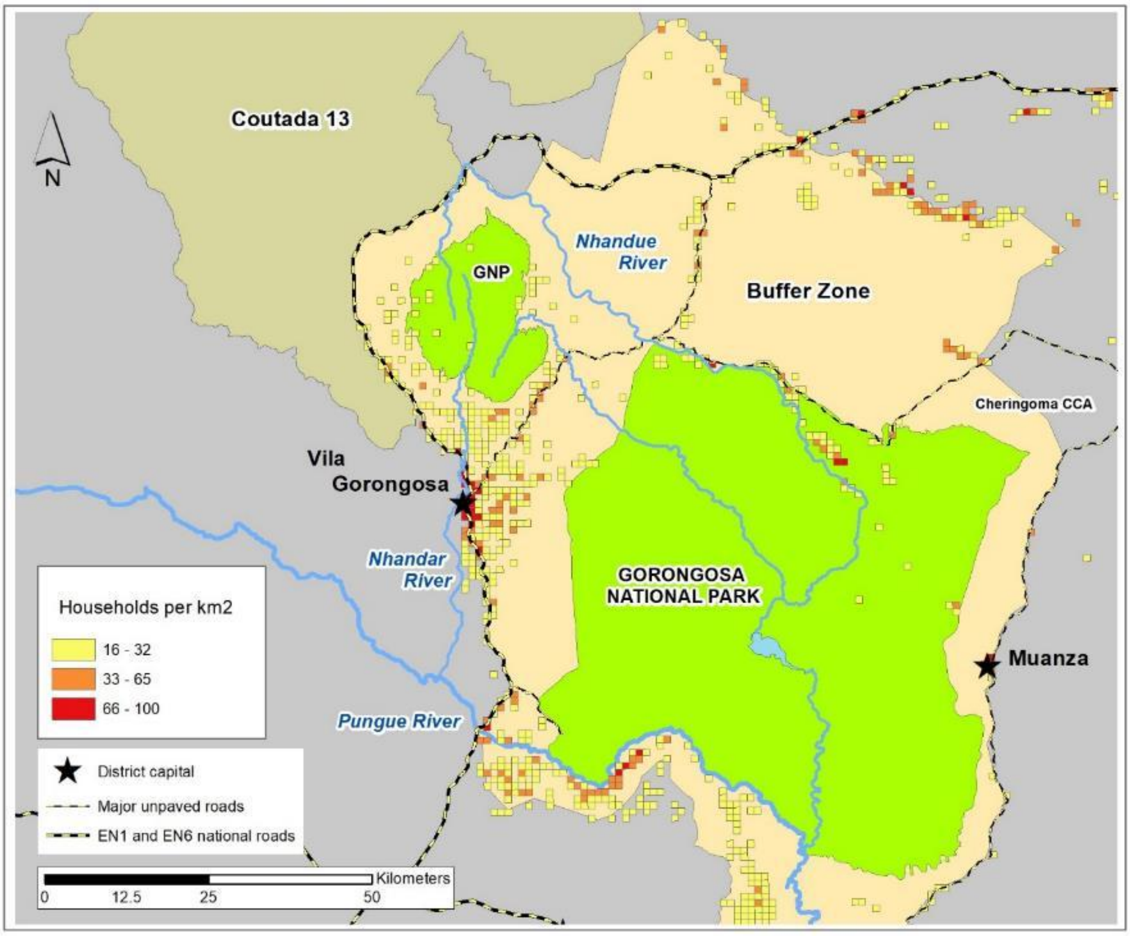


Figure 18 Maps showing population density from Gorongosa to Caia
Source: Gorongosa Park Science Director (late Dr Marc Stalmans), email, July 2024

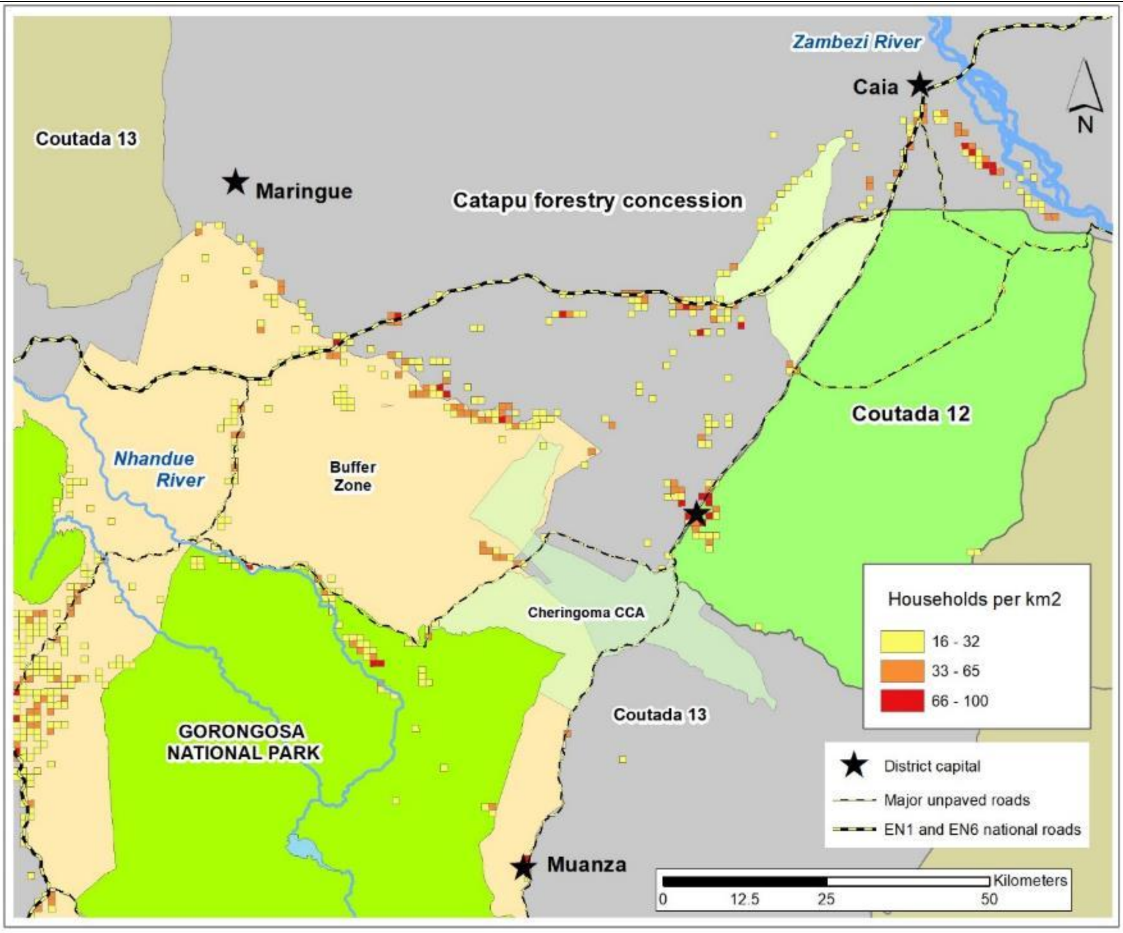


Figure 19 Map showing population density from Gorongosa to Caia
Source: Gorongosa Park Science Director (late Dr Marc Stalmans), email, July 2024 possible to edit and indicate Lot 2

The park authorities believe there is no need for "aqueducts" to allow the movement of animals, and fencing would not be recommended. However, appropriate signage should be provided for the movement of wildlife, as well as speed humps/rumble strips and maximum speed limits should be defined in order to reduce possible incidents of being run over and the consequent deaths of wild animals and/or material damage or human injury/death.

The conceptual design consultants have taken this information into account and included road safety measures such as a reduced speed limit (from 100 km/h to 60 km/h) over the affected section of road, and signs for wildlife in the area (as noted previously).

Cattle crossing signs have been considered for the section Gorongosa-Caia (km 84-168) by the design consultant and noted previously in Table 4-24.

Birds

There have been approximately 350 bird species recorded within the greater area of the site of which seven are of conservation concern (CR: White-headed vulture – *Trigonoceps occipitalis*;

Hooded vulture – *Necrosyrtes monoclaus*; White-headed vulture – *Gyps africanus*; EN: Secretary bird – *Sagittarius serpentarius*; Lapped-faced vulture – *Torgos tracheliotos*; Grey crowned crane – *Balearica regulorum*; Martial eagle – *Polemaetus bellicosus*; VU: Wattled crane – *Bugeranus carunculatus*; Southern Ground hornbill – *Bucorous leadbeateri*; Swynnerton's robin – *Swynnertonia swynnertoni*; Tawny eagle – *Aquila rapax*; Chirinda apalis – *Apalis chirindensis*). The remaining species noted are Least concern on the 2024 update of the Red List.

Four bird species are protected by Mozambican legislation, law No. 10/99, of July 7, were identified, namely: *Haliaeetus vocifer* (African fish eagle), *Egretta garzetta* (Little egret), *Grus carunculatus* (Wattled Crane), and *Tockus erythrorhynchus* (Red billed horn bill).

Table 6-8 Bird species identified in the project area in Sofala

Scientific name	Common Name	Conservation Status IUCN 3.1, red list 2013	Probability of Occurrence
Passer domesticus (Linnaeus, 1758)	House sparrows	Least Concern	Recorded
Scopus umbretta	Hamerkop	Least Concern	Recorded
Actophilornis africana	African jacana	Least Concern	Recorded
Haliaeetus vocifer	African fishing eagle	Least Concern	Recorded
Phalacrocorax africanus	Reeds Cormorant	Least Concern	Recorded
Streptopelia semitorquata	Red eyed dove	Least Concern	Recorded
Ploceus sp	Yellow weaver	Vulnerable (Vu)	Recorded
Corvus albus	Pied crow	Least Concern	Recorded
Egretta garzetta	Little egret	Least Concern	Recorded
Dicrurus adsimilis Bechstein, 1794	Fork tailed drongo	Least Concern	Recorded
Agelastes niger	Guinea fowl	Least Concern	Recorded
Tockus erythrorhynchus	Red billed horn bill	Not yet classified	Probable
Scolopacidae Rafinesque, 1815	Sand piper	Least Concern	Probable
Tauraco persa (Linnaeus, 1758)	Turaco	Least Concern	Recorded
Coraciidae; species *Coracias* or *Eurystomus* Rafinesque, 1815	Roller	Least Concern	Recorded
Grus carunculatus	Wattled crane	Vulnerable	Recorded
Uraeginthus angolensis	Blue wax	Least Concern	Recorded
Pycnonotus jocosus (Linnaeus, 1758)	Crested bul bul	Least Concern	Recorded
Ardea cinerea	Gray heron	Least Concern	Recorded
Streptopelia capicola (Sundevall, 1857)	Ring necked dove	Least Concern	Recorded
Alcedo cristata Pallas, 1764	Malachite king fisher	Least Concern	Recorded
Pternistis afer (Müller, 1766)	Red necked francolin	Least Concern	Recorded
(Trigonoceps occipitalis)	White-headed Vulture	Critically Endangered	Probable
(Necrosyrtes monachus)	Hooded Vulture	Critically Endangered	Recorded
(Gyps africanus)	White-backed Vulture	Critically Endangered	Probable

(Polemaetus bellicosus)	Martial Eagle	Vulnerable	Recorded
(Stephanoaetus coronatus)	Crowned Eagle	Vulnerable	Recorded

Herpetofauna

According to data obtained from local communities along the project road, they confirmed the existence of many reptiles, crocodiles – *crocodilus sp*, freshwater turtles, snakes - *Python sehae*, Mozambique spitting cobra, black mamba, boa constrictor, puff adder - *Bitis arietans* (Merrem, 1820) and chameleons. Most of these reptiles are common crossing the N1 road. Out of the reptile species listed and mentioned by the communities, boa constrictor and puff adder, are protected by Law no. 10/99, of 7 July.

Amphibians found in the GNP are listed in the table below:

Table 6-9 Amphibians found in the GNP

n	Scientific name	Common name	IUCN status	Population trend
1	*Ptychadena mascareniensis*	Mascarene grass frog	LC	Unknown
2	*Xenopus laevis*	African clawed frog	LC	Increasing
3	*Afrixalus fornasini*	Fornasini's spiny reed frog	LC	Unknown
4	*Hyperolius tuberilinguis*	Tinker reed frog	LC	Unknown
5	*Hylambates maculatus*	Red-legged kassina	LC	Unknown
6	*Kassina senegalensis*	Senegal land frog	LC	Unknown
7	*Phrynobatrachus acridoides*	East African puddle frog	LC	Unknown
8	*Afrixalus crotalus*	Zimbabwe banana frog	LC	Unknown
9	*Phrynomantis bifasciatus*	Banded rubber frog	LC	Unknown
10	*Tomopterna marmorata*	Marbled sand frog	LC	Unknown
11	*Chiromantis xerampelina*		LC	Unknown
12	*Amietia delalandi*	Dekakande's river frog	LC	Stable
13	*Ptychadena schillukorum*		LC	Unknown
14	*Hyperolius mitchelli*		LC	Unknown
15	*Ptychadena guibei*		LC	Unknown
16	*Ptychadena mossambica*		LC	Unknown
17	*Arthroleptis stenodactylus*	Dune squeaker	LC	Stable
18	*Hemisus guineensis*	Guinea snout-burrower	LC	Unknown
19	*Hemisus marmoratus*	Marbled snout-burrower	LC	Unknown
20	*Ptychadena oxyrhinchus*	Sharp-nosed frog	LC	Stable
21	*Pyxicephalus angusticeps*	Parry's bullfrog	LC	Unknown
22	*Schismaderma carens*		LC	Unknown
23	*Afrixalus delicatus*	Pickersgill's banana frog	LC	Unknown
24	*Hyperolius argus*	Argus reed frog	LC	Unknown
25	*Hyperolius pusillus*	Water lily reed frog	LC	Unknown
26	*Ptychadena anchietae*	Plain grass frog	LC	Unknown
27	*Hildebrandtia ornata*	African ornate frog	LC	Unknown
28	*Sclerophrys pusilla*	Merten's striped toad	LC	Stable
29	*Arthroleptis xenodactyloides*		LC	Stable
30	*Hylarana galamensis*	Marble-legged frog	LC	Unknown
31	*Xenopus muelleri*	Müller's clawed toad	LC	Stable
32	*Sclerophrys gutturalis*		LC	Increasing
33	*Phrynobatrachus natalensis*		LC	Stable
34	*Hyperolius mormaratus*	Painted reed frog	LC	Increasing
35	*Leptopelis mossambicus*	Mozambique tree frog	LC	Unknown
36	*Breviceps mossambicus*		LC	Unknown

n	Scientific name	Common name	IUCN status	Population trend
37	*Phrynobatrachus mababiensis*	Mababe puddle frog	LC	Unknown
38	*Pyxicephalus edulis*	Lesser bull-frog	LC	Decreasing
39	*Leptopelis flavomaculatus*	Brown-backed tree frog	LC	Unknown
40	*Tomoptera cryptotis*	Catequero bullfrog	LC	Stable
41	*Hylarana darlingi*	Golden-backed frog	LC	Unknown
42	*Hyperolius benguellensis*	Benguella long reed frog	LC	Unknown

Reptiles in the Gorongosa ecosystem exhibit diverse movement patterns that are closely tied to their ecological roles, environmental conditions, and behavioral strategies. Because some of the reptiles are ectothermic, and considering the environmental conditions of the area, it is plausible to assume that species move around for basking or due to seasonal movement patterns, as well as foraging. Due to the overall flatness of the study area, these species might cross the road, using either the road platform or the bridges as underpasses. In the case that the species use the road, there is a probability that they might be overrun by vehicles, especially snakes, but these incidents are still anecdotal at the study area. Regular monitoring schemes might provide better knowledge of this situation.

In addition to reptiles, the project area is home to a rich diversity of amphibians, particularly frogs and toads, which play vital ecological roles as insect predators and indicators of environmental health. Species such as *Ptychadena mascareniensis*, *Xenopus laevis*, and *Hyperolius marmoratus* are commonly found in wetlands, temporary ponds, and moist vegetation along the road corridor. Amphibians, being highly sensitive to changes in humidity, temperature, and water availability, may exhibit seasonal movement patterns, especially during the rainy season when breeding activity increases.

Ichthyofauna

As part of the baseline survey, communities interviewed in the project area identified the presence of the following species: *Tilapia sp*, *Anguilla spp., Barbus lineomaculatus, Brycinus imberi, Chiloglanis neumannii, Clarias gariepinus*.

6.4.4 Riverine habitats and wetlands

The following summarizes riverine habitats, wetlands, and associated riparian vegetation within the area of influence (1–2 km from the road and bridges) for the project section described. Information is based on field surveys and existing data.

- Nhapherua River - Km 101+260
- Nhampaza River - Km 126+260
- Mombeze - Km 133+260
- Nhanzaza River - Km 143+680
- Fudza River - Km 143+680

These seasonal rivers may be used by animals as passages when accessibility is possible, as drainage structures have already been built as noted in Tables 4-5 and 4-6.

Based on field observations and remote verification (Google Earth imagery), these watercourses are predominantly seasonal and were dry at the time of survey, consistent with their ephemeral hydrological character. They are not considered primary regional fauna corridors when compared to major river systems in Sofala Province such as the Pungue River. However, at a local scale, they may function as opportunistic movement pathways for small mammals, reptiles, amphibians, and other fauna, particularly during wet-season periods when water availability and vegetation cover increase habitat continuity.

Field observations and available mapping indicate the following infrastructure types at these crossings:

- **Nhapherua, Nhampaza, Mombezi and Fudza River:** crossed by big bridge structures (span bigger than 50 m), which provide open spans beneath the road and generally allow greater landscape permeability and continuity of riparian vegetation, thereby supporting higher potential for fauna passage;

- **Nhanzaza River:** crossed by a medium bridge structure (between 15 to 50 m), which provides more constrained under-road passage and therefore offers limited permeability, primarily suitable for smaller fauna species depending on hydrological conditions and accessibility.

The surrounding riverine plains support riparian and freshwater vegetation, including floating plants such as *Nymphaea* spp. and aquatic grasses such as *Phragmites australis*. These habitats provide ecological functions such as soil stabilization, runoff filtration, and habitat provision, and contribute to maintaining local biodiversity despite moderate levels of agricultural disturbance observed in some locations.

Overall, while these seasonal watercourses do not represent major regional ecological corridors, they retain localized ecological functionality and may contribute to small-scale fauna movement within the broader landscape matrix. These features should therefore be considered in the design and implementation of mitigation measures, particularly in relation to maintaining permeability at existing crossing structures.

The design consultants have also noted 14 existing box culverts in Table 4-1, of varying spans (single, double, triple and 4 span) with a minimum dimension of 1.5m x 1.5m and maximum of 4.0m x 4.0m and 124 pipe culverts of varying spans (single, double and triple) with a minimum dimension of 1.0m x 0.6m and maximum of 3m x 0.85m in Table 4-2 which will also assist to maintain permeability.

6.4.5 Flora

Flora species noted in the footprint of the road are found in the checklist below. No protected flora species were identified during the baseline survey.

Table 6-10 Checklist of species of common flora (main tree species found in the area of influence of the project) in the Zambezia region (Palgrave. 1984 and Pooley,1993).

Family	Species	Common name	Conservation status IUCN 3.1, red list 2013
Caesalpinoideae	*Burkea africana*		Least Concern
	Gulbourtia conjugata		Least Concern
	Brachystegia spiciformes	*Massassa*	Least Concern
	Tamarindus indica	*Tamarindus*	Least Concern
	Julbernadia globiflora	*Muimbe*	Least Concern
	Bauhinia galpinii		Least Concern
Papilinoidae	*Pterocarpus angolensis*	*Umbila*	Least Concern
	Cordyla africana		Least Concern
	Millettia stuhlmannii		Least Concern
	Dalbergia melanoxylon		Least Concern
Combretaceae			Least Concern
	Combretum apiculatum	*Mondzo*	Least Concern
	Combretum imberbe	*Mondzo*	Least Concern

Family	Species	Common name	Conservation status IUCN 3.1, red list 2013
Ebenaceae			Least Concern
	Diospyros sp		Least Concern
Loganiaceae			Least Concern
	Strychnos spinosa		Least Concern
Apolynaceae			Least Concern
	Voacanga schweinfurthii		Least Concern
Moraceae			Least Concern
	Ficus zambesiaca	*Figueira*	Least Concern
Mimosaceae	*Acacia Xanthophloea*	*Fever Tree*	Least Concern
			Least Concern
	Acacia nilotica		Least Concern
	Acacia nigrescens	*Micaia*	Least Concern
	Albizia brevifolia		Least Concern
	Dichrostachys cinerea		Least Concern
Anacardiaceae	*Rhus sp*		Least Concern
			Least Concern
	Mangifera indica	*Mango*	Least Concern
	Sclerocarya birrea	*Morula/Canhueiro*	Least Concern

<u>Existing invasive alien species</u>

No areas with large numbers of invasive alien species were noted in any of the project areas. However, there is a great chance that *Lantana camara* and *Mimosa pigra* might be species of concern in the areas, as they have already been reported as a problem within the GNP (Pringle and Gonçalves, 2020; Guyton *et al*., 2020).

Figure 20 Mimosa pigra

6.4.6 Ecosystem Services

These are the benefits people obtain from the earth's many life-support systems. The Millennium Ecosystem Assessment (MEA) defines four categories of ecosystem services: provisioning, regulating, cultural, and supporting services.

As the sections of the N1 to be rehabilitated in this project area largely pass through rural areas of Mozambique, the majority of ecosystem services noted are provisioning, i.e., the ability of humans to obtain products from ecosystems, such as food, water and resources, including wood, oil and genetic resources and medicines. People living all along the project area of the N1 will be using the natural resources available to them, e.g. timber and other forestry products, soils/gravel/stone, water, use of rivers etc. for fishing for food, and use of medicinal plants for traditional medicine. No specific areas were noted which were heavily used by the population.

6.4.7 Landscape permeability assessment for wildlife crossings

The primary goal of this landscape permeability assessment was to evaluate how infrastructure developments, such as road construction and rehabilitation, influence wildlife movement, habitat connectivity, and the natural flow of ecosystems, with the understanding that the Project is the rehabilitation of an existing road which fauna have adapted their movements to. By examining key factors such as land use changes, habitat fragmentation, and the presence of natural corridors, this assessment aims to provide a comprehensive understanding of landscape permeability in Sofala province, for the sections of the N1 road to be rehabilitated. The study focuses on identifying critical barriers, determining areas where wildlife and ecosystems are most at risk, and proposing solutions to enhance connectivity and mitigate negative impacts.

Landscape permeability refers to the levels or degrees to which a landscape allows for the movement of organisms, species, and ecological processes across it. These scales are often used in environmental and conservation studies to assess how well different species can move through a landscape that has been affected by human development, infrastructure, or other changes.

This landscape permeability assessment was undertaken for the Gorongosa–Caia road corridor within the Greater Gorongosa Ecosystem to identify areas with higher potential for wildlife movement and ecological connectivity. The assessment combined species occurrence records from the Global Biodiversity Information Facility (GBIF), Gorongosa National Park field data, and environmental variables including land cover, elevation, slope, population density, habitat suitability, and human footprint. The species used are mammals noted in Table 6-7. Species Distribution Models (SDMs) were developed in MaxEnt v4.3.3 for selected mammal species, and a resistance surface was prepared in ArcGIS to represent the relative difficulty of movement across the landscape. Connectivity and movement corridors were subsequently analyzed using Circuitscape v4.0.5 based on circuit theory principles. The results were used to identify potential wildlife movement areas, permeability constraints, and priority locations for mitigation measures along the N1 corridor. A detailed description of the methodology, datasets, modelling assumptions, and analytical procedures is presented in Annex 1.

<u>Results</u>

Landscape permeability refers to the levels or degrees to which a landscape allows for the movement of organisms, species, and ecological processes across it. These scales are often used in environmental and conservation studies to assess how well different species can move through a landscape that has been affected by human development, infrastructure, or other changes.

Landscape permeability in the study region was generally low, with most species exhibiting permeability values below 0.5 on a scale from 0 (completely impermeable) to 1 (fully permeable). Across all species and the entire landscape, permeability values ranged from 0.0625 to 0.3120, indicating that large portions of the region present limited permeability for animal movement.

When permeability was examined at the species level, substantial variation among species was observed. The highest permeability values were recorded for *S. temminckii* (pangolin), with values ranging from 0.5333 to 0.9380, indicating that this species experiences comparatively high landscape permeability and encounters fewer spatial constraints to movement. In contrast, most other species showed more restricted permeability patterns and reached considerably lower maximum values. Specifically, the maximum permeability values for the remaining species were 0.516 for *Crocuta Crocuta* (spotted hyena), 0.7342 for *Hippotragus niger* (Sable antelope), 0.5928 for *Kobus ellipsyprimnus* (waterbuck), 0.5291 for *Loxodonta Africana* (elephant), 0.5566 for *Ourebia* oureb (oribi), 0.6650 for both *Papio cynocephalus* (yellow baboon) and *Syncerus caffer* (buffalo), and 0.6129 for *Redunca arundinum* (Southern reedbuck). Although some species locally reached moderate to high permeability values, these were spatially limited and did not represent the dominant condition across the landscape.

Overall, the results indicate that permeability is spatially heterogeneous and species-specific, with only a small number of taxa experiencing high permeability over substantial areas. For most species, movement across the landscape appears to be constrained, resulting in generally low permeability values across much of the region. This pattern is consistent with the predominantly hilly and topographically complex nature of the Gorongosa ecosystem, which is characterized by pronounced elevational gradients, rugged terrain, and a mosaic of land cover types that may restrict or channel animal movement. Taken together, these results suggest that the study area does not function as a uniformly permeable landscape for large mammals, but rather as a patchwork of areas with varying degrees of permeability, where only certain species (notably *S. temminckii* - pangolin) are able to move relatively freely across a broader portion of the region.

The generally low and spatially heterogeneous landscape permeability observed in the study area indicates that the region already imposes significant constraints on animal movement. This suggests that the rehabilitation of the N1 road is likely to have a disproportionate impact on ecological connectivity and wildlife movement, particularly for species with low permeability and limited movement alternatives. As a result, road impacts are expected to be spatially concentrated at specific corridors and pinch points, rather than uniformly distributed. These findings underscore the need for targeted, species-appropriate mitigation measures, including strategically placed wildlife crossing structures and carefully designed fencing, to reduce collision risk and maintain functional connectivity. The permeability maps developed in this study therefore provide a critical evidence base for identifying priority locations for mitigation and for guiding adaptive management throughout the project lifecycle.

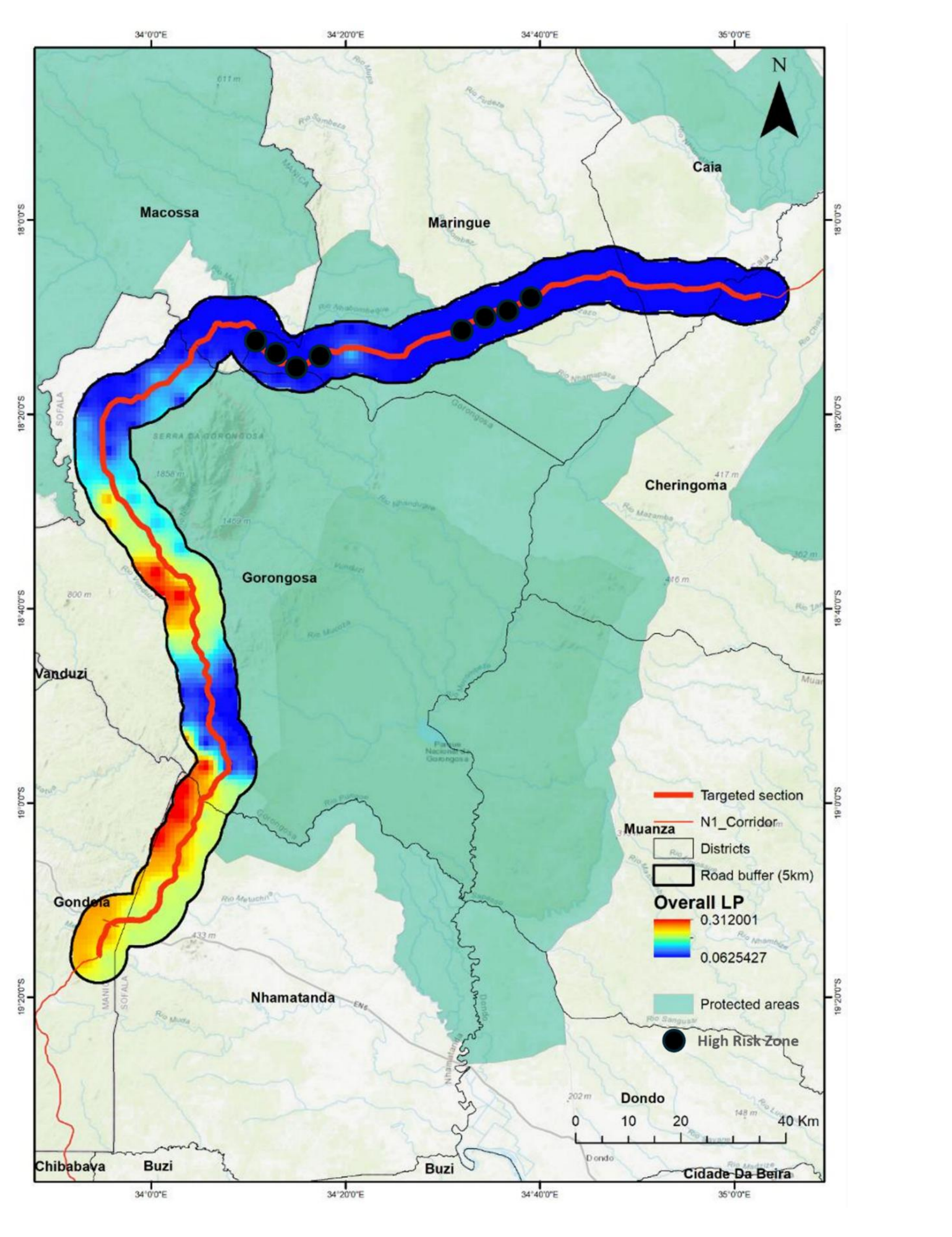


Figure 21 Landscape permeability (considering all species) across the Inchope-Caia road rehabilitation project. The scale should be considered between 0 and 1. A 5km buffer was considered. Model images for separate species can be found in the original report in Annex 1.

The km 84-168 (Gorongosa to Caia) section of the road requires particular attention, as it largely coincides with the GNP buffer zone and therefore intersects areas of high ecological importance and wildlife use. Within this section, the first 10 km (km84-km94) represent a priority zone where enhanced protection and mitigation measures are necessary to reduce the risk of wildlife–vehicle collisions. Moreover, even after the N1 corridor exits the buffer zone, elevated risk persists for approximately the subsequent 10 km (approximate chainage km 128-km138), indicating that additional precautionary measures remain warranted beyond the formal boundary of the protected area to ensure continued safety for both wildlife and road users.

The spatially differentiated risk patterns identified along the N1 indicate that the ecological impacts of the road rehabilitation will not be uniform, but concentrated in specific segments, particularly where the road intersects the Gorongosa National Park buffer zone and adjacent high-permeability areas. These segments coincide with some active wildlife movement and involve species of high ecological and conservation importance, implying a non-negligible risk of increased wildlife mortality, disruption of movement, and functional fragmentation. Consequently, mitigation measures must be spatially targeted and species-appropriate, rather than uniformly applied along the corridor. The results support the prioritisation of precautionary measures and monitoring. Overall, the findings indicate that the road rehabilitation does not constitute an ecologically sensitive intervention that necessitates hard engineering but rather proactive, targeted, and adaptive mitigation to ensure that impacts on wildlife movement and survival are effectively minimised.

Conservation and rehabilitation implications are noted in section 7 below.

6.5 Socioeconomic Baseline

6.5.1 Administrative Location and Division

Sofala Province, located in central-eastern Mozambique, covers an area of 68,018 Km². The province is bordered to the north by Tete Province, to the northeast by Zambezia Province, to the south by Inhambane Province, and to the west by Manica Province. Rivers flowing through the province include the Chiveve River, the Buzi River, the Save River, which flows along the Inhambane provincial border, and the Púnguè River, which flows into the sea at Beira, with Beira as its capital city. The province is divided into 13 Districts (Buzi, Chemba, Cheringoma, Chibabava, Dondo, Gorongosa, Machanga, Maringue, Muanza, Nhamatanda and Marromeu) and 5 Municipalities (Beira, Dondo, Marromeu, Gorongosa, Nhamatanda and Caia).

At the grassroot (District), the community's structural hierarchy can be divided into four main tiers: Administrative Post, Neighborhood, Unit blocks, and Quarter areas. Leadership within these domains ranges from the Administrative Post's top leader, cascading down through the Neighborhood Secretary, the Unit block leader, and culminating with the Quarter area leader. Additionally, certain influential figures within these communities earn respect and legitimacy due to their significant socio-cultural, economic, and religious contributions, particularly concerning traditional ceremonies, rites, and conflict resolution. Community leaders assist with understanding both the community's needs and its intrinsic resources, emphasizing the talents and capacities inherent within its members. Their goal is not just to spotlight issues but to also harness existing community strengths, fostering self-worth among members while galvanizing them towards collective problem-solving. These leaders play a pivotal role, acting as both catalysts and mediators. Their duties extend beyond community bounds, bridging the gap between local interests and a myriad of external entities, including the State, the marketplace, media houses, academic institutions, NGOs, religious groups, and other factions within civil society.

The socioeconomic characteristics of the project area are based on information from socioeconomic surveys well as secondary sources.

6.5.2 Population

The 2022 Statistical Yearbook from INE indicates that Sofala province has a population of 2,600,754 inhabitants (1,266,427 males and 1,33,327 females), spread across 13 Districts. Starting from a base population of 2.255.439 inhabitants in 2017, the Projected population by 2025 is 2.827.922 inhabitants.

The analysis of data from 2022 Statistical Yearbook indicates that in the Province of Sofala, Beira City is the most populous (719,805 inhabitants) and has the highest population density (1,137 inhabitants/km^2). The districts with the lowest population density are the District of Cheringoma (68.108 inhabitants) and District of Muanza (44.349 inhabitants) with 8 inhabitants/km^2 each. Some areas have sections of high population density, mainly associated with migration to these areas and the establishment of settlements along the main road (N1) and in coastal areas.

6.5.3 Gender of Household Head

In the project area there are 392 households who are expected to be impacted by the project directly, on which about 87.8% are headed by males, while 12.2% are female-headed households (SWMoz survey, 2023). These are the people who are decision makers on key issues of the family and on the capability and willingness to join project activities in the locality.

6.5.4 Household Size and Marital Status

On average each household is composed of 4 persons (4.7) and the household head has an average age of 37 years (SWMoz survey, 2023). The majority of household heads (49%) are married or live in marital union, while an average 38.5% are single. The household size indicates the availability of family labor to participate in income generation activities.

6.5.5 Education

According to UNICEF (2022), in Sofala more than 3 out of 10 people are literate (36.8%), compared to the national average of 39%, where almost 4 in 10 people are illiterate. Women are twice as likely as men to be illiterate.

Sofala province has 1,909 public educational institutions (INE, 2022), of which 12% of all public educational establishments are in the Nhamatanda district. Out of 1,909 establishments, 922 are schools (47%), which provide primary education categorized as EPI and 1.7% provide general secondary education categorized as ESG (33).

Table 6-11 Public Educational Institutions network in Sofala

District	EP1	EP2	ESG1	ESG2
Beira City	57	56	10	8
Buzi	103	103	3	3
Caia	63	62	2	2
Chemba	66	64	3	1
Cheringoma	47	46	1	1
Chibabava	91	88	3	2
Dondo	53	52	6	4
Gorongosa	84	82	2	2
Machanga	44	44	1	1
Maringue	72	72	4	1
Marromeu	70	70	3	3
Muanza	56	55	1	1
Nhamatanda	116	114	7	4
TOTAL	**922**	**908**	**46**	**33**

Source: INE, 2022

Statistics further show that the admission rate at age 6 in Primary Education (EP1+EP2) is 66.3% for girls; Gross Enrolment Rate in Primary Education (EP1+EP2) was 105.8%[3] for girls and the net rate of schooling in Primary Education (EP1+EP2) was 92.0% for girls. In 2022 the proportion of girls enrolled in primary education was 47.5% (EP1) and 45.5% (EP2) and in secondary education 46.6% (ESG1) and 45.5% (ESG2).

In terms of early marriage, 53% of girls in Mozambique are married before they turn 18, and 17% are married before the age of 15. 10% of boys in Mozambique are married before the age of 18.

[3] Gross Enrolment Rate: the value can reach more than 100% because the model does not take into account the grade specific age in the denominator.

48% of women in Mozambique aged 20–24 was first married or in a union before the age of 18, and 14% before the age of 15 (DHS, 2011).

The province has nine (9) universities, of which 3 are publicly funded and 6 are private. Additionally, Beira has two state-run public Technical and Vocational schools specializing in commerce and industry, namely *Escola Industrial e Comercial 25 de Junho* e *Instituto Industrial e Comercial da Beira* (INE, 2022).

6.5.6 Ethno-linguistic Groups

In the project area many ethno-linguistic groups were identified that are based on language used for communication at household level. The majority of potential PAP´s belong to the Cisena ethnicity (45%), while Cindau (23.6%). Although these groups have a smaller representation, they do not face discrimination or disadvantage as per the national constitution (2018) in article nº 9. In addition, despite this diversity of ethnicity groups in Mozambique community members who participated on FGD´s stated that at community level all groups live in harmony and share the existing natural resources. This means that there are no discriminated, marginalized or minority ethnic groups that will need special action during project design and implementation.

6.5.7 Religion, Faith and Spirituality

Mozambique boasts a great diversity in religious groups or affiliations. According to the 2021 Report on International Religious Freedom: Mozambique published by the United States Department of State, the dominant religious group nationally is the Catholics, comprising 27% of the total population. Muslims make up 19%, Evangelical or Pentecostal Christians 17%, Zionist Christians 16%, Anglicans 2%, while the Jewish, Hindu, and Baha'i faiths each represent less than 5%. Notably, 14% of the national population does not identify with any religious denomination.

In Sofala, the Catholics make up a more significant portion, with 32% of the city's inhabitants, followed by Evangelicals, representing 23%, Zionist Christians at 8.8% and Muslims at 6.4%. About 1% of Sofala's population identifies as Anglican. The remainder either follow other faiths (4%) or do not adhere to any religious beliefs (24%).

6.5.8 Employment

Sofala Province is responsible for 10.2% of Mozambique's Gross Domestic Product (GDP) and 49.56% of the population of the province is living below poverty line. In 2022, World Bank data revealed that Mozambique's total labor force numbered 14.614.366 [4], of which 51.63% are female[5]. This demonstrates that they formed a majority of the country's labor force. The general

[4] World Bank, World Development Indicators. 2022. *Labor force, total – Mozambique* [Data File]. Retrieved from https://databank.worldbank.org/source/world-development-indicators.

[5] World Bank, World Development Indicators. 2022. *Labor force, female (% of total labour force) – Mozambique* [Data File]. Retrieved from https://databank.worldbank.org/source/world-development-indicators.

unemployment rate in Mozambique stood at 18%[6]. Breaking this down further, 18.1% of the female labor force[7], and 18.7% of the male labor force were unemployed.[8]

The Economically Active Population (EAP) comprises individuals of working age from both genders who contribute to the nation's production capacity. This demographic includes both the employed and those actively seeking employment, including first-time job seekers.

The unemployment rate in Sofala province is higher than the national average at 21.7%, comparatively, Beira City's working-age population equates to 56.3% of its total populace. In Beira, the Port of Beira and the Industrial Zone offer most men, whether on temporary or permanent terms, their main source of employment.

The 2020 Annual Report (INEP) also noted the creation of 1,771 jobs in Sofala province during that year, mainly seasonal roles in agriculture. However, only 197 of these jobs were based in Beira. These data suggests that unemployment is critical in the project area, mainly among vulnerable groups, as current situation adversely affects the disposable income of families, erodes purchasing power, diminishes employee morale, and reduces an economy's output of the project area.

6.5.9 Economic and Livelihood Activities

a) Agriculture and Livestock

The economy is dominated by subsistence-based agriculture; the most productive crops are maize, sorghum, millet, peanuts, cassava, orange-pulped sweet potatoes, and beans. According to the Sofala Provincial Directorate of Agriculture and Fishery (DPAP, 2022), the most widely harvested crop in Sofala by area was maize with 269,795 ha with a total of 520 050 tons.

In terms of the cash crops, sugar cane (91,682 tons) was the most produced in the province in 2022.

Table 6-12 Production of cash crops in Sofala (2018-2022)

Crops	Production of Cash Crops (t), 2018-2022				
	2018	2019	2020	2021	2022
Cotton	4725	1998	13	388	-
Cashew Nuts	1623	4257	108	5433	3357
Sugar Cane	-	13015	30	36348	91682
Banana	-	-	-	24944	-
Sunflower	-	13	-	-	52

Source: DPAP, 2022

[6] IOF (2022)
[7] World Bank, World Development Indicators. 2022. *Unemployment, female (% of female labour force) – Mozambique* [Data File]. Retrieved from https://databank.worldbank.org/source/world-development-indicators.
[8] World Bank, World Development Indicators. 2022. *Unemployment, male (% of male labour force) – Mozambique* [Data File]. Retrieved from https://databank.worldbank.org/source/world-development-indicators.

Livestock production is also an important subsector in the socioeconomic life of the population for employment, income generation and food security, as shown in the table below.

Table 6-13 Livestock production in Sofala Province (2018-2022)

Description	Unit	Livestock Production, 2018-2022				
		2018	2019	2020	2021	2022
Bovine	T	819.30	841.70	863.20	943.70	32103
Pig	T	272.90	300,30	369.50	411.80	575
Chicken	T	478.80	459.20	621.80	906.10	988.70
Milk	L	691.173	691.173	649.80	1367810	630315
Eggs	Dozen	0	242095	226257	719867	414931

Source: DPAP, 2022

Data from the Household Budget Survey 2022 shows that in Sofala, 69.6% of women above 15 years are employed, while 72.8% of men are employed, indicating that women are taking less advantage on employment opportunities available in the project area.

According to data from IAI 2020, in Sofala province about 33% of households engaged in the agriculture sector are headed by women.

b) Fishing

Sofala province is a place where fishing is an important activity, mainly in the city of Beira where there are industrial and artisanal fishermen. The artisanal fishermen use smaller boats and traditional methods, industrial fishing is conducted further out at sea with larger vessels. The fish caught varies, with the Púngué Estuary region having a range of species, many of which are exported. The Pungué river is the largest river crossing the project area, in the N1 section of Inchope-Gorongosa (70 Km). Smaller rivers cross the N1 in other sections, as shown previously. However, in the project area, fishing is not a common livelihood activity due to the seasonality of the rivers, i.e., water flow is very dependent on the rainy season. The tilapia fish (*Oreochromis niloticus* L.) is the main fish species that can be found in the project area regularly sold by fishermen along the N1 road, whenever there is a catch of fish from the river. The small-scale fishermen's catch (including some of the project area) in Mozambique is projected to reach 508,000 tons (PESOE, 2024).

In the section, Gorongosa – Caia (84-168km), the N1 crosses the Urema River system and adjacent floodplain channels. This area presents a somewhat higher potential for fishing due to the presence of more permanent or semi-permanent aquatic habitats. However, there is no evidence of consistent fishing activity along the N1 adjacent rivers. Commonly caught species include tilapia, catfish, small cyprinids (e.g., *Enteromius* spp.), and occasionally lungfish (*Protopterus* spp.).

6.5.10 Household Income and Wealth

a) Income sources

The household's living condition depends on the stability of the main breadwinner in the family. They usually rely on more than one job. A household head can work on agricultural production, and other members could belong to the state-salaried groups (including civil servants and the retired) who have relatively stable income and life. As for the poor and medium households, they often have unstable and temporary jobs.

According to INE, 2022, in terms of income source farming in households took the highest proportion (71%); followed by those in business and finance (8%) and those in other income activities accounted in 6%. These data suggest that the main source of income is mainly from agricultural activities, which influence stability and living standards of the households.

Table 6-14 Source of income for households in Sofala province

Income source	Sofala
Agriculture, Silviculture and Fishing	71.3
Mining	0.2
Industry	2.8
Energy	0.0
Construction	1.3
Transport and Communication	1.9
Business and Finance	11.6
Administrative Services	1.5
Others	9.3

Source: INE (2021), IOF (2020), INE (2017), IAI (2020)

b) Income and Expenditure

The highest incomes are earned in Sofala (1,508 MZN). Meanwhile, in the project area the monthly average expenditure is 1,782 MZN per capita.

Table 6-15 Monthly Household Income and Expenditure per Capita in the Project Area (in MZN)

Province	Monthly HH Budgeting (per capita)	
	Income	Expenditure
Sofala	1.813,00	1.782,00

Source: IOF (2020)

6.5.11 Industry, Commerce and Tourism

Most industry is concentrated in Beira City with very limited amounts of industrial development in the project area.

Current notable industrial operations near the project road include a coffee-processing factory in Gorongosa village.

There are a number of roadside markets along the project road, typically located near the Administrative Posts or the Village-Sede. Most are informal with simple stalls constructed from materials such as zinc steel and wood. There are formal markets – in Inchope, Gorongosa, Maringue and Caia. Markets sell local farm produce, fruits, soap, batteries, salt, oil, and other basic items.

In the project area the tourism has high potential in Gorongosa National Park.

6.5.12 Financial Institutions

Sofala province has 62 branches of financial institutions, of which 44 are in the capital Beira city. The main financial institutions are Millennium BIM, BCI, Standard Bank and ABSA.

Table 6-16 Financial institutions in Sofala Province

Districts	No. of Branches	Means of payments	
		ATM	PO's
Beira	44	97	2339
Buzi	1	2	98
Caia	2	3	36
Chemba	1	2	21
Cheringoma	1	2	14
Chibavava	2	4	11
Dondo	5	13	165
Gorongosa	1	2	37
Machanga	1	1	9
Maringuè	1	1	16
Marromeu	1	3	48
Muanza	1	1	4
Nhamatanda	1	4	33

Source, INE, 2022

6.5.13 Public Services and Utilities

a) Electricity

Access to public services such as electricity and water are crucial for community's development as allows people to use electricity for lighting, heating, cooling, and refrigeration and for operating appliances, computers, electronics and machinery.

According to INE (IIAES, 2023), in Sofala province, 43% of households have access to electricity from the national network, 10.0% through other sources out of the electricity network. This means that 47% of households are not connected to the network or other electricity solutions. Additionally, in rural Sofala, other sources of energy that are significantly used by the local communities include firewood, car batteries and kerosene. It is important to note that the rural population is still heavily reliant on biomass to fulfill their vital domestic needs of lightning and cooking.

In Mozambique, about 72% of households collect firewood to use as main source of fuel for cooking. In Sofala, about 61% of households collect firewood for cooking and the majority of them are headed by women.

In all provinces crossed by N1 corridor people access the national power grid, 23% of households use electricity and the majority of these people are in Sofala (36%).

b) Water Supply, Sanitation and Waste

The Sofala Province Strategic Development Plan (PEDPS) has been designed as a long-term management plan (2010-2020) and its objective in water, sanitation and hygiene (WASH) is aligned with national strategies and the need of the target group is to provide water supply and sanitation services to the population of Sofala Province. Only 51% of the population, or 1,252,538 out of the 2,048,676 people living in the province, have access to water by dispersed sources. Only 27.9% of the population in rural areas has access to safe sanitation.

According to Austrian Development Agency (ADA, 2021), another challenge is the costing of the maintenance for sustainability of investments and services which has not yet been measured at the provincial level. Public-private initiatives in the rural water sector, where innovations largely depend on coordinated work between local government, the private sector and communities, have shown improvement in the sustainability of the rural water services through the availability of spare parts, trained artisans, professional management of service areas, post-construction technical support, alternative approaches to encourage the collection and productive use of fees and better data collection.

The average growth rate required to cover the public drinking water supply (water sources and public systems) of Sofala province is 3.4% as of 2021. For rural sanitation the coverage rate for Sofala in 2015 was 24% and a rate of 56% is expected to be achieved by 2021 (with an annual average growth rate of 8.1% till 2021) or the number of people with access to safe sanitation is expected to grow from 387,037 people to 777,695 people.

In terms of licensed wastewater treatment plants, only Beira city has a municipality wastewater treatment plant.

c) Waste facilities and waste recycling

In Mozambique, solid waste management is currently the responsibility of municipalities. Establishing landfills nearby the municipality boundary is a way to reduce costs of waste transportation. In the project area, only one municipality area was identified and is located in

Gorongosa. However, there is no solid waste facility in the Gorongosa municipality, or along Gorongosa-Caia (Km 84-168). Waste recycling or reuse in the project area was unavailable either from private or government institutions contacted during the data collection process (e.g. Municipality of Gorongosa). The closest licensed waste processing facilities, with recycling options, are located in the city of Beira. Hazardous waste materials are currently only processed in the Mavoco landfill site in Matola, Maputo.

d) Health Facilities

Sofala province has 184 health facilities, of which 152 are health centers in different regions. The Central and Provincial hospital is located in Beira City.

Table 6-17 Type of Health Facility in Sofala Province

Districts	Total Hospitals	Central/Provincial Hospitals	District/Rural Hospitals	Health Centers	Health Posts
Beira	16	2	0	12	2
Buzi	17	0	1	12	4
Caia	15	0	1	14	0
Chemba	12	0	0	10	2
Cheringoma	10	0	0	9	1
Chibavava	16	0	1	13	2
Dondo	18	0	0	14	4
Gorongosa	18	0	0	14	4
Machanga	10	0	0	10	0
Maringuè	11	0	0	11	0
Marromeu	11	0	1	7	3
Muanza	8	0	0	7	1
Nhamatanda	22	0	1	19	2

Source: INE (2022)

According to the National Malaria Control Program (PNCM, 2021), access to healthcare in Mozambique is very low and it is estimated that 50% of the population lives more than 20 kilometers from the nearest health unit, a situation that effectively implies no access to health services for a most of the population. In Sofala province, malaria is also the biggest problem affecting pregnant women in rural areas. Approximately 20% of pregnant women are infected by the parasite, with primigravidae being the most affected with a rate of prevalence of 31%. The prevalence estimates in the age group 2 to 9 years of age ranges from 40 to 80%, with 90% of children under 5 years of age infected by malaria parasites in some areas.

According to UNAIDS, 2021, Mozambique has the eighth highest HIV prevalence in the world, with 12.6 % of adults living with HIV, and one of the highest HIV mortality rates. The country has improved in testing people for HIV and providing treatment. INSIDA, 2023 has reported that

HIV prevalence in Sofala is 13.2% in adults aged over 15 years.

Data from Province Directorate of Health in Sofala indicates that in 2023 a total of 1,745 cases of GBV were registered in the province.

In 2020, 11 deaths per 1,000 people were registered in Sofala province (Antonio *et. al*, 2022). The birth rate for Mozambique in 2022 was 36,257 births per 1,000 people and in Sofala province 39.000 births per 1,000 people were projected in 2023 (INE, 2023)

The Demographic and Health Survey (HS 2022) indicates that in Sofala about 28.5% of women used contraception methods.

e) Transportation - Roads

In general, roads in high density neighborhoods to the households in the project areas are not uniform and do not meet the local needs of development in the current conditions. Asphalt roads are focused only on main roads, national roads, roads in urban centers, inter-district roads and inter-commune roads. In the project area stone/gravel roads are the majority with an extension of 1,919 Km, while there are 584Km of paved roads (asphalt/concrete). This suggests people have access to paved roads however the majority are not in good condition.

Table 6-18 Paved and unpaved road extension in the project area

Province	Road surface (Km)			
	Concrete/Asphalt	Stone/Brick/Gravel	Earth	All
Sofala	584	1919	0	2503

Source: INE (2020) and INE (2019)

With respect to road traffic, it has been noted that the N1 highway road section Gorongosa-Caia (Km 84-168) benefitted from some improvements due to emergency works funded by GoM. This contributed to increased traffic flow as many vehicles use these project sections of N1 road for cargo transportation, mainly heavy trucks. According to the Road Fund report in 2022, the annual average daily traffic (AADT) in the road section between Inchope-Caia was 550 vehicles. From December 2023 the traffic speed increased from 20-40 Km/h (before improvements) to 60-80 Km due to the emergency works. Road insecurity also increased, suggesting that speed control is required to reduce the risks of accidents. The emergency works also improved the road safety through setting up the vertical and horizontal road signage in the main villages crossed by N1 road.

f) Communications

Movitel and Vodacom's telecommunications coverage reaches most of the road. TMcel is also present in the Districts Headquarters. Their fiber optic cable follows the road alignment particularly close to the road in some parts.

g) Historical, Archeological and Sacred Sites

No historical, archeological or sacred sites were identified in the corridor of impact of the project from Km 84-168 Gorongosa to Caia.

h) Security

Sofala Province is one of the strongholds of RENAMO. In late 1978 RENAMO guerrillas were "launching attacks along the Beira–Chimoio road and rail line, the Dondo–Inhaminga corridor". Some of the more scarcely populated areas of the province are affected by landmines; defensive rings around villages were still common in some rural areas according to mid-1990s reports.

An agreement was reached between RENAMO and FRELIMO in August 2019, resulting in the virtual end of the insurgency. A RENAMO splinter group known as the RENAMO Military Junta (RMJ) was quickly formed from party dissidents opposed to the peace process; the RMJ continued to carry out minor guerrilla operations until December 2021, when the last of its members surrendered to Mozambican security forces. The peace accord led to the disarmament of RENAMO, the integration of some of its fighters into the Mozambican army, and its transformation into a regular political party.

7 ENVIRONMENTAL AND SOCIAL IMPACTS AND MITIGATION MEASURES

The planning and design, rehabilitation, demobilization/decommissioning and operation phases of the road rehabilitation and improvement works of the SRSEI between Inchope-Gorongosa-Caia in Sofala Province are likely to induce and generate a wide range of risks and impacts on the physical, biological and social environments. The main purpose of this chapter, therefore, is to identify the potential environmental, social-economic and cultural risks and impacts associated with the proposed project, assess their significance to the environmental and social setting and propose feasible and appropriate measures for mitigating negative risks and impacts and enhancing the positive environmental and social risk and impacts.

The Management Measures required are organized into an Environmental and Social Management Plan (ESMP) in a separately bound as ***Volume 2E.***

7.1 Methodology

This Chapter outlines methods used by the consultant to identify, analyze and evaluate the risks and impacts of the proposed road construction project on biophysical, socio-economic and cultural environment. Subsequent sections described in detail how the project risks and impacts were identified, analyzed and evaluated in order to provide an insight on how each identified risk and impact could be appropriately avoided, mitigated and/or reduced to an acceptable level. This will ensure environmental and social sustainability as far as the implementation of the proposed project is concerned.

7.1.1 Environmental and Social risks and impacts identification methods

The impacts were identified by analyzing activities during all the project phases and how these would affect biophysical and social-economic environments. Specifically, the following approach was used to determine the possible impacts:

a) Assessment of baseline conditions

The purpose of assessing baseline conditions was to understand the existing situation as this will act as benchmark against which change would be evaluated.

b) Assessment of project activities that will be undertaken

Project activities were examined to identify the impacts that the activities would have on the project.

c) Assessment of project outputs associated with the proposed project

Project outputs associated with the project were examined to determine the potential changes and impacts that would be created by the project.

d) Determination of environmental and social-economic impacts

Based on the above steps, the environmental and social-economic impacts of the project were identified.

e) Techniques used in the identification of risks and impacts included the use of tools such as Leopold matrix to aid in impact identification, consultative approaches and professional judgment.

To facilitate identification of the potential significant risks and impacts, a matrix given in the table below was developed, relating to the project activities to the environmental and social components. The "x" against the respective activities in the matrix denotes a potential positive or negative impact.

A simple risk or impact identification matrix was used to identify both positive and negative risks and impacts of this proposed project. Potential risks and impacts of this proposed project and their potential sources have been assessed and evaluated using a simple matrix (Table 7-1) which correlates the interaction between the project activity and the environmental and/or social parameters. Where the interaction results in positive impact a "+" sign is indicated; whereas the interaction results in negative impact an "x" sign is indicated; and where there is no interaction a "-"sign is used. The results of the interaction of the project activities and the environmental and social receptors that may occur during the pre-construction, construction, demobilization/decommissioning, operation and maintenance phases.

Table 7-1 Risk and impact assessment and identification matrix for the proposed N1 rehabilitation sections in Sofala province

PROJECT ACTIVITIES/ ENVIRONMENTAL AND SOCIAL RECEPTORS	Environmental Components												Social Components				
	Terrestrial flora	Terrestrial fauna	Aquatic flora	Aquatic fauna		Natural habitat		Ecosystem services	Air	Water	Soil	Geology	Cultural heritage	Human health	Social services	Utility services	Security
Studies (Design studies, traffic studies, ESIA/ESMP studies)	-	-	-	-		-		-	-	-	-	-	-	+	+	-	-
Mobilization of machinery, equipment and workers and construction materials (i.e. gravel, aggregate stones)	x	x	-	-		-		-	x	-	-	-	-	-	-	-	x
Project footprint site pegging	-	-	-	-		-		-	-	-	x	-	-	x	x	-	-
Road reserve clearing & earth excavating	x	x	x	x		x		x	x	x	x	x	x	x	x	x	-
Construction of temporary materials storage facilities	x	x	x	x		x		x	x	x	x	x	x	x	x	x	x
Transportation of construction materials	x	x	x	x		x		x	x	x	x	x	x	x	x	x	x
Removal of topsoil & broken old bituminous materials	x	x	x	x		x		x	x	x	x	x	x	x	x	x	x
Construction of and/or expand access roads	x	x	x	x		x		x	x	x	x	x	x	x	x	x	x
Construction of administration block and associated internal and external structures	x	x	x	x		x		x	x	x	x	x	x	x	x	x	x
Installation of batching plant	x	x	x	x		x		x	x	x	x	x	x	x	-	-	-
Water abstraction	x	x	x	x		x		x	x	x	x	-	x	-	-	-	x

PROJECT ACTIVITIES/ ENVIRONMENTAL AND SOCIAL RECEPTORS	Environmental Components												Social Components				
	Terrestrial flora	Terrestrial fauna	Aquatic flora	Aquatic fauna		Natural habitat		Ecosystem services	Air	Water	Soil	Geology	Cultural heritage	Human health	Social services	Utility services	Security
Road alignment and grading	-	-	-	-		-		-	-	-	-	-	-	-	-	-	-
Waste management	x	x	x	x		x		x	x	x	x	-	x	x	-	-	-
Sub-base filling	x	x	x	x		x		x	x	x	x	-	x	x	x	-	-
Bituminous road surface treatment	x	x	x	x		x		x	x	x	x	-	x	x	x	-	-
Roofing and treating of joinery timber for administration block	-	-	-	-		-		-	x	x	x	x	x	x	-	x	-
Finishing of the administration lock	-	-	-	-		-		-	x	x	x	x	x	x	-	x	-
Installation of the road signs	-	-	-	-		-		-	-	-	-	-	-	-	-	-	-
Constructing road speed calming structures (e.g. rumble surfaces and humps) on busiest and wildlife crossing places	x	x	-	-		-		-	-	-	-	-	x	x	x	x	x
Road markings	x	x	-	-		-		-	-	-	-	-	-	-	-	-	-
Removal of rubble and disposal at licensed/approved dumpsite	-	-	-	-		-		-	x	x	x	-	x	x	x	-	-
Dismantling and removal of some machinery and plants	-	-	-	-		-		-	-	-	-	-	-	-	-	-	-
Plant site-adaptive and site-specific indigenous trees, indigenous shrubs and grass (suitable for	+	+	+	+		+		+	+	+	+	-	+	+	-	-	-

PROJECT ACTIVITIES/ ENVIRONMENTAL AND SOCIAL RECEPTORS	**Environmental Components**												**Social Components**				
	Terrestrial flora	Terrestrial fauna	Aquatic flora	Aquatic fauna		Natural habitat		Ecosystem services	Air	Water	Soil	Geology	Cultural heritage	Human health	Social services	Utility services	Security
local growing conditions) in disturbed sites along the road reserves																	
Rehabilitation and restoration of gravel borrow pits, access roads and plant batching plant sides	+	+	+	+		+		+	+	+	+	-	+	+	-	-	-
Handover of the rehabilitated road to the Client	-	-	-	-		-		-	-	-	-	-	-	+	+	-	-
Conducting routine maintenance and rehabilitation of road	x	x	x	x		-		-	-	-	-	-	-	-	-	-	-
Tree pruning and management of indigenous l plants, including grass along the road reserve	+	+	+	+		+		+	+	+	+	-	+	+	+	+	+
Easy transportation of charcoal and firewood to the urban areas	x	x	x	x		x		x	x	x	-	-	-	-	-	-	-
Loss of forest resources and biodiversity	x	x	x	x		x		x	x	x	x	-	x	x	-	-	-
Legend: x: potential negative impact/risk	+: potential positive impact				-: no impact/risk expected												

7.1.2 Risks and impacts evaluation criteria

The severity of each impact or risk identified in this project was evaluated based on set of criteria presented in the Decree No. 54/2015, of December 31 for Mozambique, while some risks and impacts were evaluated using professional skills. Each of the four factors considered under each criterion is graduated into 5 tier scale and assigned a value ranging from the smallest to the biggest (i.e. 1 to 5). Then each impact is assigned one of the values under each of the four tier factors. These values are then added to make a composite score (impact severity) for each using all the four tier factors. The table 7-2 below illustrates the evaluation criterion. The composite score is a proxy value that provides decision-makers with a basis for comparing the severity of impacts across different biophysical and social components of the environment.

The analysis of the direct, indirect and residual positive and negative risks or impacts and characterization of each risk and impact was carried out to determine its magnitude, spatial extent, reversibility, duration, probability of occurrence and significance to the project receptors. At this stage, each risk or impact was evaluated using 1–5 tier scale. Each of the risk or impact was assigned a value ranging from 1-5. One (1) being the smallest value of the risk or impact which is generally insignificant and 5 being the highest value of the risk or impact which has a high significance on the receptors (tables below). The values can be positive denoted symbol (+) or negative denoted symbol (-) depending on whether the risk or impact is beneficial or detrimental to the biophysical and social environment. For example, if the value of a risk or impact is -5, it means this negative risk or impact is of the highest degree while if the positive impact is +5, it means the impact is of highest beneficial value to the biophysical or social environment. The table below shows the evaluation of the risks and impacts (positive or negative) using the Scoring/Evaluation Matrix Method.

Table 7-2 Criteria for evaluation and ranking of project risks and impacts

Magnitude of impact		**SCORE**
Very Low	Effect confined to a small area within the project site	1
Low	Effect limited to the local area	2
Moderate	Effect limited to the regional area	3
High	Effect limited to the national	4
Very High	Effect extends beyond national boundaries	5
Spatial Extent		
Site	Effect limited to the project site only	1
Local	Effect limited to a local area	2
Regional	Effect limited to regional area	3
National	Effect experienced throughout the country	4
International	Effect felt beyond national boundary/boundaries	5
Reversibility		
Natural Recovery	The environment/social environment recovers itself without applying any mitigation measure(s)	1

Aided Recovery	The environment/social environment recovers after applying minimum mitigation measures	2
Aided Recovery	The environment/social environment recovers after applying moderate mitigation measures	3
Aided Recovery	The environment/social environment recovers after applying substantial mitigation measures	4
Irreversible	The environment/social environment does not recover even after applying mitigation measure	5
Probability of occurrence		
Improbable	The impact will not occur	1
Low probability	The impact may occur but is not probable	2
Medium probability	The impact is likely to occur between 33% and 60% chance of occurrence	3
High probability	The impact is very likely to occur between 60% and 100% chance of occurrence	4
Definite	The impact will occur (unavoidable) at a greater than 100% of occurrence	5
Duration		
Immediate	Effect lasts for a period up to 5 years	1
Short-term	Effect continues at any point for a period of 5-10 years	2
Medium-term	Effect continues at any point for a period of 10-20 years	3
Long-term	Effect continues at any point for a period of 20 -30 years	4
Permanent	Effect continues forever or is irreversible	5

7.1.3 Evaluation and scoring of potential impacts

The project impacts considered to be potential to the biophysical and socio-economic environment for each phase of the project are evaluated and given a score as presented in the table below. The values for magnitude, spatial extent, reversibility, duration and probability of occurrence are added together to make a composite score or a ranked value for the risk or impact, which forms a risk or impact significance. This criteria evaluation of risks and impacts is classified as follows:

- -0 to -5 or +0 to +5 means the impact or risk is Very Low;
- -6 to -9 or +6 to +9 means the risk or impact is Low;
- -10 to 14 or +10 to +14 means the risk or impact is Moderate,
- -15 to -19 or +15 to +19 means the risk or impact is High
- -20 to -25 or +20 to +25 means the risk or impact is Very High (as per table below).

These composite risks and impacts are important because they assist developer, local artisans and decision-makers on how they can avoid High negative risks and impacts of the project as they may be detrimental to the project.

Table 7-3 Evaluation and rating of the potential beneficial and negative risks and impacts of the rehabilitation of the N1 in Sofala Province

Description of potential impact	Impact Scoring (+ or -)							
	Magnitude	Spatial Extent	Reversibility	Duration	Probability	Overall Level of Risk or Impact Significance		
	Very Low (VL=1); Low (L=2); Moderate (M=3); High (H=4) Very High (VH=5)	Site only (S=1); Local (L=2); Regional (R=3); National (N=4); International (I=5)	Natural Recovery (NR=1); Aided Recovery (AR=3); Irreversible (IR=5)	Immediate (L=1); Short-term (ST=2); Medium-term (MT=3); Long-term (LT=4); Permanent (P=5)	Improbable (I-1); Low Probability (LP=2) Moderate Probability (MP=3); High Probability (HP =4); Definite (D=5)	Total Score	Overall Risk or Impact Level (Significance) before applying mitigation/enhancement measures	Overall Risk or Impact Level (Significance) after applying mitigation/enhancement measures
PRE-REHABILITATION (PLANNING AND DESIGN) PHASE								
POSITIVE IMPACTS								
Creation of employment opportunities	+3	+2	+1	+3	+4	+12	Moderate	Moderate
Increased revenue for the Government of Mozambican through taxes	+1	+2	+1	+1	+4	+9	Low	Low
REHABILITATION PHASE								
POSITIVE IMPACTS								
Creation of employment opportunities	+5	+4	+3	+3	+4	+19	Moderate	High
Creation of business/trade opportunities for entrepreneurs	+3	+3	+3	+2	+4	+15	Moderate	High

Description of potential impact	Impact Scoring (+ or -)							
	Magnitude	Spatial Extent	Reversibility	Duration	Probability	Overall Level of Risk or Impact Significance		
	Very Low (VL=1); Low (L=2); Moderate (M=3); High (H=4) Very High (VH=5)	Site only (S=1); Local (L=2); Regional (R=3); National (N=4); International (I=5)	Natural Recovery (NR=1); Aided Recovery (AR=3); Irreversible (IR=5)	Immediate (L=1); Short-term (ST=2); Medium-term (MT=3); Long-term (LT=4); Permanent (P=5)	Improbable (I-1); Low Probability (LP=2) Moderate Probability (MP=3); High Probability (HP =4); Definite (D=5)	Total Score	Overall Risk or Impact Level (Significance) before applying mitigation/enhancement measures	Overall Risk or Impact Level (Significance) after applying mitigation/enhancement measures
Increased skills transfer to the local workers	+3	+2	+3	+3	+4	+15	Moderate	High
Increased revenue for the Government of Mozambican through taxes	+2	+2	+2	+1	+5	+12	Moderate	Moderate
Improved road infrastructure development between Inchope and Caia	+4	+2	+5	+5	+4	+18	Moderate	High
NEGATIVE RISKS AND IMPACTS								
Increased risk of soil erosion	-4	-3	-3	-4	-4	-18	High	Low

Description of potential impact	Impact Scoring (+ or -)							
	Magnitude	Spatial Extent	Reversibility	Duration	Probability	Overall Level of Risk or Impact Significance		
	Very Low (VL=1); Low (L=2); Moderate (M=3); High (H=4) Very High (VH=5)	Site only (S=1); Local (L=2); Regional (R=3); National (N=4); International (I=5)	Natural Recovery (NR=1); Aided Recovery (AR=3); Irreversible (IR=5)	Immediate (L=1); Short-term (ST=2); Medium-term (MT=3); Long-term (LT=4); Permanent (P=5)	Improbable (I-1); Low Probability (LP=2) Moderate Probability (MP=3); High Probability (HP =4); Definite (D=5)	Total Score	Overall Risk or Impact Level (Significance) before applying mitigation/enhancement measures	Overall Risk or Impact Level (Significance) after applying mitigation/enhancement measures
Increased risk of air pollution from dust and gas emissions	4	-2	-1	-4	-5	-17	High	Moderate
Increased risk of water pollution	-4	-3	-3	-4	-4	-18	High	Low
Increased risk of solid waste generation	-5	-1	-3	-2	-5	-16	High	Low
Increased risk of liquid waste generation	-5	-3	-3	-3	-5	-16	High	Low
Loss of fauna and flora species	-3	-1	-3	-4	-4	-15	High	Low
Increased risk of poaching due to labor influx of workers	-3	-1	-3	-4	-4	-15	High	Low

Description of potential impact	Impact Scoring (+ or -)							
	Magnitude	Spatial Extent	Reversibility	Duration	Probability	Overall Level of Risk or Impact Significance		
	Very Low (VL=1); Low (L=2); Moderate (M=3); High (H=4) Very High (VH=5)	Site only (S=1); Local (L=2); Regional (R=3); National (N=4); International (I=5)	Natural Recovery (NR=1); Aided Recovery (AR=3); Irreversible (IR=5)	Immediate (L=1); Short-term (ST=2); Medium-term (MT=3); Long-term (LT=4); Permanent (P=5)	Improbable (I-1); Low Probability (LP=2) Moderate Probability (MP=3); High Probability (HP =4); Definite (D=5)	Total Score	Overall Risk or Impact Level (Significance) before applying mitigation/enhancement measures	Overall Risk or Impact Level (Significance) after applying mitigation/enhancement measures
Increased risk of loss of part of natural forests and wetlands	-4	-1	-3	-5	3	-16	High	Low
Increased risk of noise pollution and vibration	-4	-2	-3	-2	-4	-15	High	Low
Increased risk of the spread of HIV and AIDS and sexually transmitted infections (STIs)	-4	-3	-3	-5	-4	-19	High	Low
Increased risk of Occupational, Safety and Health hazards (accidents, injuries, diseases, death)	-5	-1	-3	-4	-5	-18	High	Low
Increased risk of community health and safety	4	-2	-3	-2	4	-15	High	Low

Description of potential impact	**Impact Scoring (+ or -)**							
	Magnitude	**Spatial Extent**	**Reversibility**	**Duration**	**Probability**	**Overall Level of Risk or Impact Significance**		
	Very Low (VL=1); Low (L=2); Moderate (M=3); High (H=4) Very High (VH=5)	Site only (S=1); Local (L=2); Regional (R=3); National (N=4); International (I=5)	Natural Recovery (NR=1); Aided Recovery (AR=3); Irreversible (IR=5)	Immediate (L=1); Short-term (ST=2); Medium-term (MT=3); Long-term (LT=4); Permanent (P=5)	Improbable (I-1); Low Probability (LP=2) Moderate Probability (MP=3); High Probability (HP =4); Definite (D=5)	Total Score	Overall Risk or Impact Level (Significance) before applying mitigation/enhancement measures	Overall Risk or Impact Level (Significance) after applying mitigation/enhancement measures
Increased risk of the spread of COVID-19 among workers	-3	-2	-3	-2	-3	-13	Moderate	Low
Increased risk of Gender-Based Violence (GBV)/Sexual Exploitation and Abuse (SEA)/Sexual Harassment (SH)	-5	-2	-3	-4	-5	-19	High	Low
Increased risk of child labor and forced labor	-3	-2	-3	-2	-2	-12	Moderate	Low
Increased risk of violence against children (VAC)	-3	-1	-3	-2	-4	-13	Moderate	Low
Increased risk of theft and vandalism of construction materials	-3	-2	-3	-3	-4	-15	High	Low
Increased risk of the spread of cholera and	-4	-2	-3	-3	-4	-16	High	Low

Description of potential impact	Impact Scoring (+ or -)							
	Magnitude	Spatial Extent	Reversibility	Duration	Probability	Overall Level of Risk or Impact Significance		
	Very Low (VL=1); Low (L=2); Moderate (M=3); High (H=4) Very High (VH=5)	Site only (S=1); Local (L=2); Regional (R=3); National (N=4); International (I=5)	Natural Recovery (NR=1); Aided Recovery (AR=3); Irreversible (IR=5)	Immediate (L=1); Short-term (ST=2); Medium-term (MT=3); Long-term (LT=4); Permanent (P=5)	Improbable (I-1); Low Probability (LP=2) Moderate Probability (MP=3); High Probability (HP =4); Definite (D=5)	Total Score	Overall Risk or Impact Level (Significance) before applying mitigation/enhancement measures	Overall Risk or Impact Level (Significance) after applying mitigation/enhancement measures
other communicable diseases								
Increased risk of traffic jam along the road rehabilitation section	-3	-2	-3	-2	-4	-14	Moderate	Low
Increased risk of influx of job seekers	5	-3	-3	-2	5	-18	High	Low
Increased risk of human resettlement due to road rehabilitation	-3	-1	-3	-5	-4	-16	High	Low
Loss of assets and livelihoods for local communities	-2	-1	-3	-4	-4	-15	High	Low
Increased obstruction of road access footpaths	-4	-2	-3	-3	-4	-16	High	Low
DEMOBILIZATION/ DECOMMISSIONING PHASE								
POSITIVE IMPACTS								
Increased revenue for the Government of	+2	+2	+2	+2	+4	+12	Moderate	Moderate

Description of potential impact	Impact Scoring (+ or -)							
	Magnitude	Spatial Extent	Reversibility	Duration	Probability	Overall Level of Risk or Impact Significance		
	Very Low (VL=1); Low (L=2); Moderate (M=3); High (H=4) Very High (VH=5)	Site only (S=1); Local (L=2); Regional (R=3); National (N=4); International (I=5)	Natural Recovery (NR=1); Aided Recovery (AR=3); Irreversible (IR=5)	Immediate (L=1); Short-term (ST=2); Medium-term (MT=3); Long-term (LT=4); Permanent (P=5)	Improbable (I-1); Low Probability (LP=2) Moderate Probability (MP=3); High Probability (HP =4); Definite (D=5)	Total Score	Overall Risk or Impact Level (Significance) before applying mitigation/enhancement measures	Overall Risk or Impact Level (Significance) after applying mitigation/enhancement measures
Mozambique through toll gates taxes								
Improved scenery and beauty along the road section of the corridor	+2	+2	+2	+2	+4	+12	Moderate	Moderate
NEGATIVE RISKS AND IMPACTS								
Increased risk of soil erosion	-4	-3	-3	-2	-4	-16	High	Low
Increased risk of air pollution due to dust and fumes emissions	-3	-2	-3	-2	-4	-14	Moderate	Low
Increased risk of water pollution	-4	-3	-3	-4	-4	-18	High	Low
Increased risk of solid waste generation	-2	-3	-3	-3	-3	-14	Moderate	Low

Description of potential impact	Impact Scoring (+ or -)							
	Magnitude	Spatial Extent	Reversibility	Duration	Probability	Overall Level of Risk or Impact Significance		
	Very Low (VL=1); Low (L=2); Moderate (M=3); High (H=4) Very High (VH=5)	Site only (S=1); Local (L=2); Regional (R=3); National (N=4); International (I=5)	Natural Recovery (NR=1); Aided Recovery (AR=3); Irreversible (IR=5)	Immediate (L=1); Short-term (ST=2); Medium-term (MT=3); Long-term (LT=4); Permanent (P=5)	Improbable (I-1); Low Probability (LP=2) Moderate Probability (MP=3); High Probability (HP =4); Definite (D=5)	Total Score	Overall Risk or Impact Level (Significance) before applying mitigation/enhancement measures	Overall Risk or Impact Level (Significance) after applying mitigation/enhancement measures
Increased risk of poaching due to labor influx of workers	-3	-1	-3	-4	-4	-15	High	Low
Increased risk of noise pollution and vibration	-3	-2	-3	-2	-3	-13	Moderate	Low
Increased risk of the spread of HIV and AIDS and sexually transmitted infections (STIs)	-4	-2	-3	-5	-4	-18	High	Low
Increased risk of Occupational, Safety and Health (accidents, injuries, diseases, death)	-4	-1	-3	-4	-4	-16	High	Low
Increased risk of community health and safety	-3	-2	-3	-2	-3	-13	Moderate	Low

Description of potential impact	Impact Scoring (+ or -)							
	Magnitude	Spatial Extent	Reversibility	Duration	Probability	Overall Level of Risk or Impact Significance		
	Very Low (VL=1); Low (L=2); Moderate (M=3); High (H=4) Very High (VH=5)	Site only (S=1); Local (L=2); Regional (R=3); National (N=4); International (I=5)	Natural Recovery (NR=1); Aided Recovery (AR=3); Irreversible (IR=5)	Immediate (L=1); Short-term (ST=2); Medium-term (MT=3); Long-term (LT=4); Permanent (P=5)	Improbable (I-1); Low Probability (LP=2) Moderate Probability (MP=3); High Probability (HP =4); Definite (D=5)	Total Score	Overall Risk or Impact Level (Significance) before applying mitigation/enhancement measures	Overall Risk or Impact Level (Significance) after applying mitigation/enhancement measures
Increased risk of the spread of COVID-19 among workers	-3	-2	-3	-2	-3	-13	Moderate	Low
Increased risk of Gender-Based Violence (GBV)/Sexual Exploitation and Abuse (SEA)/Sexual Harassment (SH)	-5	-2	-3	-4	-5	-19	High	Low
Increased risk of child and forced labor	-3	-2	-3	-2	-2	-12	Moderate	Low
Increased risk of violence against children (VAC)	-3	-1	-3	-2	-4	-13	Moderate	Low
Increased risk of theft and vandalism of construction materials	-3	-1	-3	-2	-3	-12	Moderate	Low
Increased risk of the spread of cholera and other communicable diseases	-4	-2	-3	-3	-4	-16	High	Low
Disruption of traffic due to demobilization activities	-3	-2	-3	-2	-3	-13	Moderate	Low

Description of potential impact	**Impact Scoring (+ or -)**							
	Magnitude	**Spatial Extent**	**Reversibility**	**Duration**	**Probability**	**Overall Level of Risk or Impact Significance**		
	Very Low (VL=1); Low (L=2); Moderate (M=3); High (H=4) Very High (VH=5)	Site only (S=1); Local (L=2); Regional (R=3); National (N=4); International (I=5)	Natural Recovery (NR=1); Aided Recovery (AR=3); Irreversible (IR=5)	Immediate (L=1); Short-term (ST=2); Medium-term (MT=3); Long-term (LT=4); Permanent (P=5)	Improbable (I-1); Low Probability (LP=2) Moderate Probability (MP=3); High Probability (HP =4); Definite (D=5)	Total Score	Overall Risk or Impact Level (Significance) before applying mitigation/enhancement measures	Overall Risk or Impact Level (Significance) after applying mitigation/enhancement measures
OPERATION AND MAINTENANCE PHASE								
POSITIVE IMPACTS								
Improved connectivity and access to potential markets within the corridor and beyond	+2	+2	+3	+3	+4	+14	Moderate	High
Reduced travel time and transportation costs for people and goods	+4	+3	+3	+4	+4	+18	High	Very High
Reduced fatal accidents and injuries due to road rehabilitation and improvement works	+4	+3	+3	+4	+4	+18	High	Very High
NEGATIVE RISKS AND IMPACTS								
Increased risk of deforestation along the corridor due to easy transportation of goods and services	-4	-2	-3	-3	-4	-16	High	Low

Description of potential impact	**Impact Scoring (+ or -)**							
	Magnitude	**Spatial Extent**	**Reversibility**	**Duration**	**Probability**	**Overall Level of Risk or Impact Significance**		
	Very Low (VL=1); Low (L=2); Moderate (M=3); High (H=4) Very High (VH=5)	Site only (S=1); Local (L=2); Regional (R=3); National (N=4); International (I=5)	Natural Recovery (NR=1); Aided Recovery (AR=3); Irreversible (IR=5)	Immediate (L=1); Short-term (ST=2); Medium-term (MT=3); Long-term (LT=4); Permanent (P=5)	Improbable (I-1); Low Probability (LP=2) Moderate Probability (MP=3); High Probability (HP =4); Definite (D=5)	Total Score	Overall Risk or Impact Level (Significance) before applying mitigation/enhancement measures	Overall Risk or Impact Level (Significance) after applying mitigation/enhancement measures
Increased risk of reduction of wildlife population due to poaching, road kills and forestry operations	-3	-2	-3	-3	-3	-14	Moderate	Low
Increased risk of theft and vandalism of road signs and roadside guard rails	-1	-1	-3	-4	-3	-12	Moderate	Low
Increased road safety risks (e.g. accidents, deaths) due to excessive vehicle speeding	-3	-1	-3	-3	-4	-14	Moderate	Low

7.2 Pre-Rehabilitation (Planning and Design) Phase

7.2.1 Positive impacts of Pre-Rehabilitation (Planning and Design) Phase

The main positive impacts during this period include the creation of employment opportunities for those undertaking preliminary project planning requirements (e.g. detailed designs, traffic counts and studies, iRap study, verification of borrow/quarry areas and licensing process, campsite design and authorization).

It is also anticipated that there will be increased revenue for the Government of Mozambican through taxes in process of these activities taking place and mobilization of personnel to the project.

7.2.2 Negative impacts of Pre-Rehabilitation (Planning and Design) Phase

During the process of mobilization by the Contractor negative impacts may arise from mobilization of vehicles, equipment, and the labor influx from non-local national or international workers.

During this phase construction material sources will need to be identified and licensed with adequate management and monitoring requirements in place for the specific areas.

Project footprint areas will be identified and pegged during this phase, e.g. campsite, materials sources, etc.

7.3 Construction/Rehabilitation Phase

7.3.1 Positive Impacts of Construction/Rehabilitation phase

7.3.1.1 Social Impacts

a) Creation of jo opportunities and technical skills transfer

According to the country statistical yearbook the employment rate in Sofala and Manica provinces was about 71% and 76%, respectively (INE, 2023). Based on this data, employment is not a concern in these provinces but in the communities of communities of Nhamapaza, Nhaperua, Cungue, Gumbarassai and Sassajale (km 84-168 Gorongosa to Caia) that are crossed by N1 road there are significant number of unemployed people, mainly in wage employment. The majority of these unemployed people are engaged in formal and informal businesses along the N1 road (project area).

However, during the road rehabilitation phase the project will create several employment skilled and unskilled workers comprising females and males, including vulnerable people such as physically challenged, single mothers and girls who are above the age of 18. In addition, some people will be employed indirectly in the value chain in procurement and supply of construction materials and services.

During stakeholder consultations, it was noted that the local communities around the proposed selected project area have large numbers of young and energetic people that are educated up to the secondary school level but are unemployed due to lack of employment opportunities. As such, the proposed road rehabilitation and improvement works along the N1 target road section will provide employment opportunities to these young people in order to improve their social and economic welfare. However, contractors and subcontractors who may be awarded the construction works, may also bring in their own personnel for works, especially skilled personnel.

Enhancement measures

- Employ at least the largest proportion of workers locally;
- Provide equal employment opportunities to both men and women, including the youth;
- Pair skilled and unskilled workers to promote on-job skills transfer;
- Pay workers' wages and salaries that are above Government minimum wages;
- Engage the Department of Labor during recruitment of process of workers;
- Employ 100% of the unskilled workers from the project area and 25 % of them must be women to increase their living resilience and livelihoods;
- Provide equal opportunities to both male and female and non-discriminatory level of salaries;
- Refrain from employing underage children and local authorities shall facilitate local employment arrangements;
- Adopt a contract system that allows a high number of villages, especially along the route/road to benefit; and
- Train local workers in road rehabilitation and improvement works, maintenance and implementation of ESIA/ESMP and anti-GBV related procedures, and monitoring.

b) Creation of business/trade opportunities

The proposed project will require construction materials such as cement, quarry stones, quarry dust/gravel, river sand, steel bars, iron sheets, timber, plumbing and electrical materials among others during the construction phase. In addition, local suppliers of construction materials and farmers will have an opportunity to sell agricultural food to the workers, including the contractor. Therefore, the local entrepreneurs from the sub-project area, and the surrounding areas will have an opportunity to supply different goods and services to the contractor thereby promoting economic development of the area.

Enhancement measures

- Purchase substantial amount of goods and services from local suppliers;
- Hire trucks and tippers from local transporters; and
- Pay suppliers of goods and services on time.

c) Increased revenue for the Government through taxes

Taxes will be collected from sales of construction materials and services procured during the rehabilitation phase of the project. In addition, people to be employed during the rehabilitation phase will also pay income tax to the government. Further, the contractor will pay corporate tax to the government. The revenue to be realized will assist the Government in the provision of social services to its citizens.

Enhancement measures

- Purchase substantial amount of goods and services from local suppliers;
- Hire trucks and tippers from local transporters; and
- Pay suppliers of goods and services on time.

7.3.2 Negative impacts during Construction Phase

7.3.2.1 Physical Impacts

a) Soil erosion and land degradation

During site office construction, road rehabilitation bridges rehabilitation or substitution and other improvement activities, soil erosion and land degradation could be caused by clearance of vegetation along the road reserves, soil excavation, scraping spalling concrete and replacing damaged concrete damaged structures. These activities may expose loose soil and particles of the scraped bridges concrete to rainwater and wind. As a result, soil and concrete particles may be transported into rivers, streams, and culverts, thereby polluting the water in rivers or streams through siltation and sedimentation, affecting aquatic life and disrupting local ecosystems that aid in transfer of genetic materials between two sub-populations of fauna.

Mitigation measures

- Limit rehabilitation and road improvement works to the PPZ;
- Construct workers' camp sites and site office on flat land and away from water sources;
- Adopt and implement in the technical designs, the International Sector Guidelines such as the Environmental Guidelines for Access Roads and Water Crossings;

- Implement good topsoil management according to International Good Practices and International Sector Guidelines such as the Environmental Guidelines for Access Roads and Water Crossings;
- Rehabilitate all active soil erosion sites at the project site;
- Construct soil and silt pit traps sediment basins around the project site;
- Avoid clearing trees, grass, herbs and shrubs outside the project impact area;
- Stockpile soil materials in an appropriate place and protect them from erosion;
- Firmly compact loose soils to reduce soil erosion;
- Plant indigenous ground cover and drought resistant grass species in all disturbed and active soil erosion sites;
- Reuse unused soils for backfilling;
- Provide adequate and concrete lined storm water drainage at the road rehabilitation and site office construction sites. and
- Construct physical barriers (e.g. silt trap fences, sediment basins, containment booms, etc.) around the bridge going under rehabilitation or replacement.

b) Air pollution due to dust and greenhouse gas (GHG) emissions

Air quality study on Vehicle Emissions based on traffic counts from Concept Design reports

In Mozambique, vehicle emissions are regulated by Decree No. 18/2004, of July 2, which sets limits on pollutants such as CO_2, NOx, CO, and particulate matter (PM10, PM2.5), aligning with international standards (WHO, US-EPA, EU) as per the table below outlining maximum emission limits of permissible air pollutants from motor vehicles.

Table 7-4 Maximum emission limits of air pollutants permissible from mobile sources or motor vehicles (µg/m3)

Vehicle type	Fuel economy (km/liter)	CO_2	NO_x	VNMOC	CO	N_2O	Particles
Passenger cars	5.1	3188	6.05	3.09	6.29	0.08	0.06
Diesel vans	4.3	3188	7.17	4.11	7.96	0.08	0.10
Heavy Diesel Trucks	2.2	3188	42.86	7.63	21.80	0.08	0.26
Motorcycles	12.8	3172	32.30	11.1	40.5	0.08	5.6

VNMOC - Volatile Non-Methyl Organic Compound
Source: Decree No. 18/2004, of June 2

Methodology

The emissions estimation employed a top-down approach (emission and activity factors method) using data from the 2024 traffic counts (vehicle counting and categorization techniques) noted in the Concept Design Reports on the N1 road, factoring in vehicle categories, fuel efficiency, and distance traveled. Emissions were projected for a 25-year period, with intervals of five years. The sampling points were selected by the Concept Design Consultants to capture a representative traffic volume on the N1 road project, Inchope - Caia section, without including local traffic in the town. The traffic volume prediction results are noted in Table 4-13, earlier.

The emissions analysis lacked fuel-specific data; hence, categorization was based on vehicle types – light vehicles (gasoline) and heavy vehicles (diesel). The legal specifications for the density (volume) and sulfur content of fuels considered are indicated in the Ministerial Decree No. 95/2018 (which approves the specifications for marketable petroleum products), are as follows:

Table 7-5 Legal specifications for density and sulfur content of fuels in Mozambique

Type of Fuel	Density at 20°C (Kg/m^3)		Sulphur content (ppm)
	Minimum	Maximum	
Liquefied Petroleum Gas	500	550	200
Gasoline (RON 95)	710	760	50
Gasoline (RON 98)	710	775	30
Diesel 50 ppm	815	847	50
Diesel 10 ppm	801	847	10

Source: Ministerial Diploma No. 95/2018

Due to the lack of local data and information on emission factors, the data used was selected from specific literature, taking into account local conditions and the air quality specialist's recommendations for use of these emission factors. The table below summarizes the emission factors used for each vehicle class.

Table 7-6 Emission factors, in g/kg, adopted for the vehicle emission calculations

Type of vehicle	SO_2	NO	NOx	CO	NM VOC	PM_{10}	$PM_{2.5}$	CH_4	CO_2	N_2O	BC	OC
Light vehicles	2,36	0.11	27	550	63	0.88	0.88	1.7	178.74	0,14	0,07	0,6
Light commercial vehicles	2,36	0.06	29	360	59	0.88	0.88	1,24	302.69	0,14	0,07	0,6
Small bus	0,72	0.47	11	12	3	2.2	2.2	0.13	189.65	0,17	1,7	0,9
Standard bus	0,72	15.22	16	18	4.6	8,4	8,4	0.08	1196.65	0,17	3,5	2
Heavy-duty 2-axle trucks	0,72	0,47	11	12	3	2,2	8,4	0.13	189.65	0,17	1,7	0,9
3/4 axle heavy trucks	0,72	4.11	42	36	8	8,4	8,4	0.25	417.45	0,17	3,5	2
Heavy multi-axle trucks	0,72	4,11	42	36	8	8,4	8,4	0.25	417.45	0,17	3,5	2

Source: IPCC (2006), (Shrestha et al., 2012) e (Keita et al., 2021)

The climatological analysis of the road section under analysis was based on data observed at the Caia and Inchope meteorological stations, which are the two meteorological stations closest to the sections under study, located precisely in the villages of Inchope, at the southern end of the section, and Caia, at the northern end of the section under analysis. The data series from these stations from 2016 to 2024 were provided by the National Institute of Meteorology (INAM). As the local weather data had some gaps, this assessment used global weather data from NCEP/NCAR Re-analysis, (https://psl.noaa.gov/data/reanalysis/). This platform was selected as it has a long series of internationally recognized quality weather data available, from January 1948 to the present.

The pollutant dispersion calculation was undertaken using the Transport Air Pollution Model (TAPM) regulatory model. It is a regulatory model, developed by the Commonwealth Scientific and Industrial Research Organization (CSIRO), the Australian National Science Agency (Hurley et al., 2005). The model is effective due to the availability of long data series, suitability for simulating mesoscale atmospheric circulations (Holmes and Morawska, 2006), and the accessibility of the software.

The TAPM model allows for grid nesting techniques up to a minimum resolution of 300 meters, enabling greater detail in the simulation. It features two main modules: meteorological and atmospheric pollution, allowing visualization of hourly, 8-hour, and 24-hour simulation time sequences, covering key pollutants like PM_{10}, $PM_{2.5}$, NO_2, NOx, O_3, and SO_2. Further details on the model's capabilities are described in detail in Hurley, 2005a.

The figure below shows a smaller grid (pollution area grid) of 80 km x 80 km introduced within a larger grid measuring 200 km x 200 km, with the emitting sources in line and centered at Nhamapaza. The two domains were carefully selected and tested to allow better representation of the necessary boundary conditions, namely atmospheric emissions, meteorological conditions, and topography which are given in the model and improved through insertion of local data.

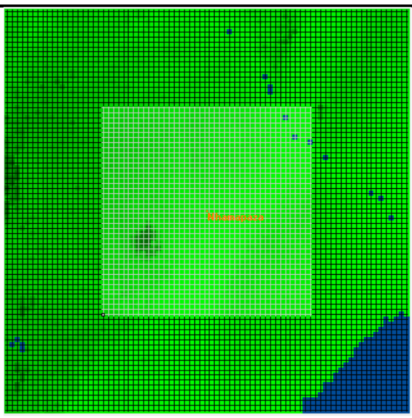


Figure 22 Illustrative aspect of the applied modeling domain configuration

Results

The emission results for km 84-168 Gorongosa to Caia are illustrated in the table and graph below.

The emissions inventory indicates a gradual increase in atmospheric emissions over the assessment period, reflecting the anticipated growth in traffic volume and vehicle activity along the Project corridor (as shown in Table 7-7). Pollutants associated with fuel combustion, including sulphur dioxide (SO_2), nitrogen oxides (NO_x), carbon monoxide (CO), volatile non-methane organic compounds (VNMOC), particulate matter (PM_{10} and $PM_{2.5}$), methane (CH_4), carbon dioxide (CO_2), nitrous oxide (N_2O), black carbon (BC), and organic carbon (OC), are all projected to increase progressively between 2024 and 2049. This trend is consistent with increased operational traffic demand and long-term road utilization.

Among the assessed pollutants, carbon monoxide (CO) and carbon dioxide (CO_2) present the highest projected emission loads, increasing from 0.464 t/year and 0.201 t/year in 2024 to 2.395 t/year and 1.070 t/year in 2049, respectively. Sulphur dioxide (SO_2) and nitrogen oxides (NO_x), which are typically associated with diesel-powered and heavy-duty vehicles, also show increasing trends over time; however, projected emissions remain substantially below the applicable WBG reference values. Similarly, PM_{10} and $PM_{2.5}$ emissions are projected to increase from 0.042 t/year in 2024 to 0.209 t/year in 2049, primarily as a result of vehicle exhaust emissions, dust re-suspension, and traffic movement along degraded or unpaved sections of the corridor.

Table 7-7 Estimation of atmospheric emissions (2024 – 2049)

Pollutant /	Atmospheric emissions (T/Year)

Emissions per year	2024	2029	2034	2039	2044	2049
SO_2	0.171	0.330	0.380	0.522	0.719	0.899
NOx	0.100	0.163	0.213	0.293	0.401	0.514
CO	0.464	0.673	0.932	1.291	1.784	2.395
VNMOC	0.059	0.092	0.121	0.167	0.230	0.389
PM_{10}	0.042	0.071	0.088	0.121	0.163	0.209
$PM_{2.5}$	0.042	0.071	0.088	0.121	0.163	0.209
CH4	0.054	0.079	0.109	0.150	0.205	0.280
CO_2	0.201	0.305	0.422	0.581	0.811	1.070
N_2O	0.008	0.017	0.021	0.029	0.042	0.054
BC	0.025	0.050	0.059	0.084	0.113	0.142
OC	0.013	0.021	0.029	0.042	0.054	0.071

OC – Organic Carbon; BC – Black Carbon; VNMOC –volatile nonmethane organic carbon

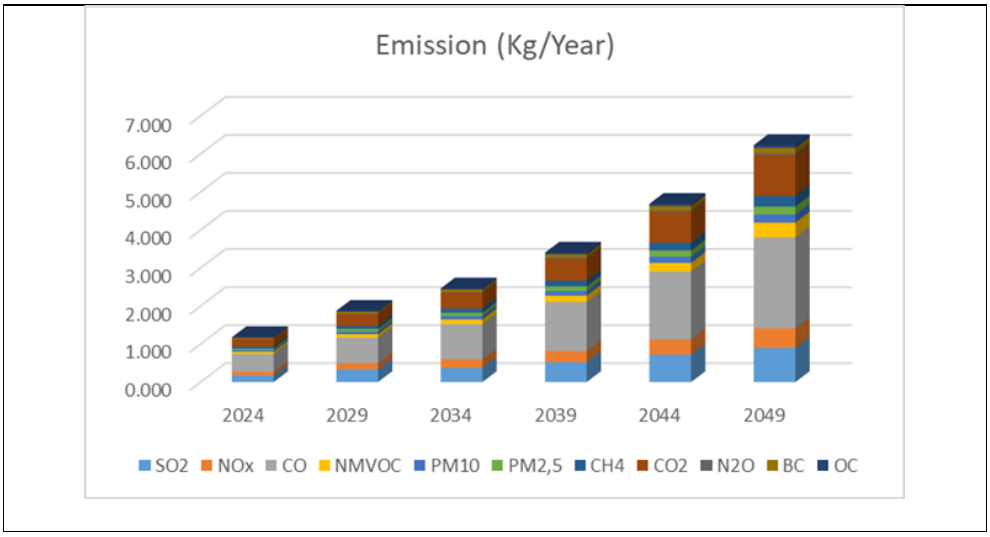


Figure 23 Estimation of atmospheric emissions (2024 – 2049)

Pollutant Dispersion

The following sample maps illustrate the spatial dispersion of the modeled compounds, where it is possible to verify that the concentrations are within the national quality limit standards and/or those applicable to the WBG. The time series, where the maximum daily concentration is analyzed throughout the modeled area, illustrates the expected variation in its values. The complete set of spatial dispersion model maps are in Annex 2.

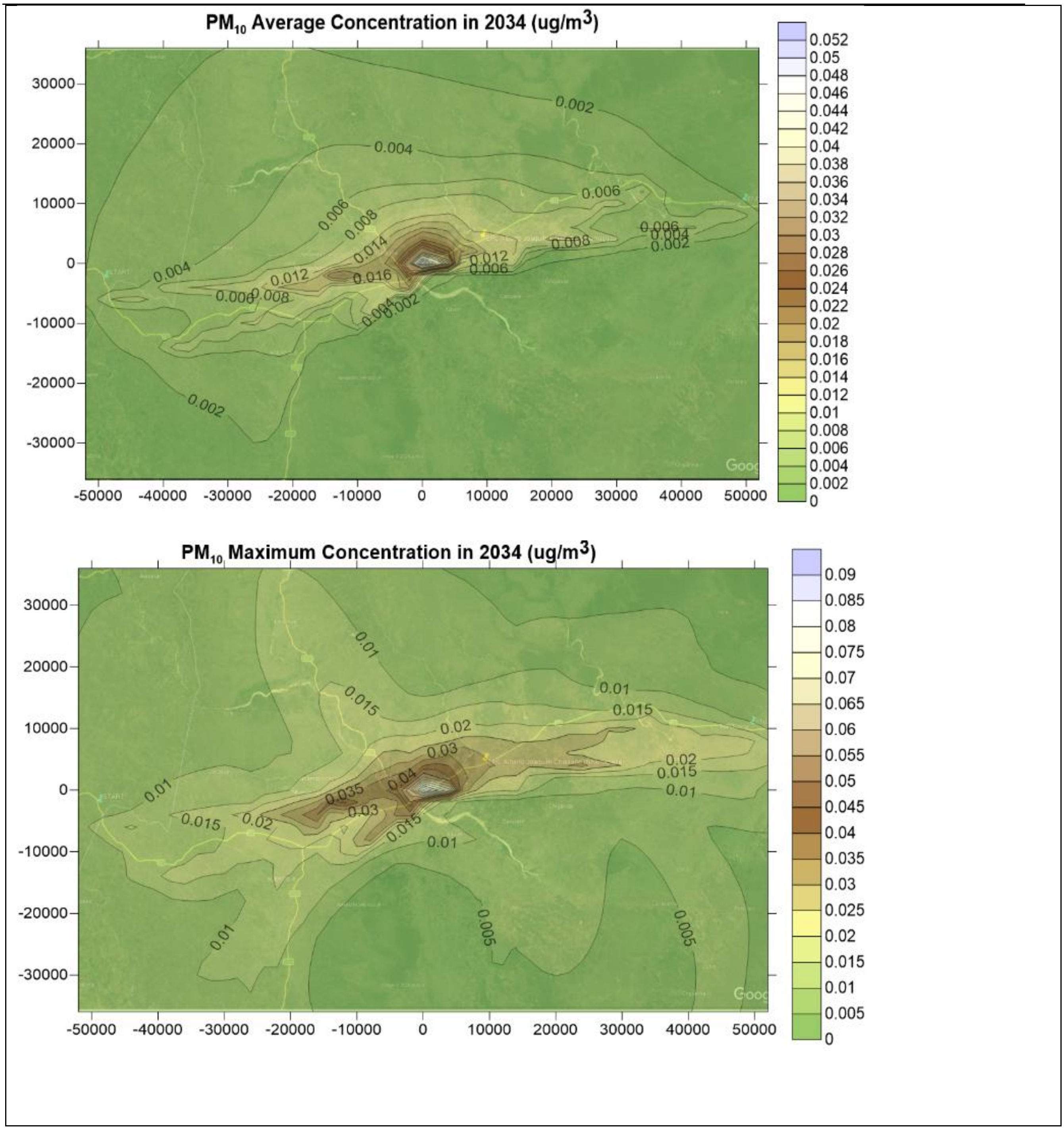
The dispersion modelling results (Figure 26) indicate that PM_{10} concentrations associated with the Project operation are expected to remain low throughout the assessment period. The highest predicted concentrations are localized along the road corridor and decrease rapidly with distance from the source due to atmospheric dispersion processes and prevailing meteorological conditions.

The maximum predicted average PM_{10} concentration was estimated at approximately 0.025 µg/m³ for 2024 and 0.052 µg/m³ under future operational scenarios, while the highest predicted short-term concentration reached approximately 0.065 µg/m³. These values remain substantially below the World Health Organization (WHO) Air Quality Guideline values adopted by the WBG EHS Guidelines, namely 15 µg/m³ for annual average exposure and 45 µg/m³ for 24-hour exposure.

The modelling therefore indicates that the Project's incremental contribution to ambient PM_{10} concentrations is minimal and is not expected to result in significant deterioration of local air quality conditions or adverse impacts on human health. Although a gradual increase in pollutant concentrations and emission loads is projected over time due to increased traffic volumes, the predicted values remain negligible in relation to applicable international standards and guideline thresholds.

It should be noted that the assessment was undertaken in the context of limited locally available emission factor data. Consequently, internationally recognized literature sources and regional meteorological datasets were used to supplement available local information. While this introduces a degree of uncertainty inherent to predictive modelling, the adopted methodology is consistent with international good practice for road infrastructure ESIAs in data-constrained environments. Given that the predicted concentrations remain several orders of magnitude below the applicable guideline thresholds, these uncertainties are not expected to materially affect the overall conclusions of the assessment.

Based on the modelling results, projected emissions profile, and comparison with applicable WBG EHS and WHO guideline values, PM_{10}-related operational impacts associated with the Project are assessed as being of low significance.


PM10 Average Concentration in 2034 (ug/m3)
30000
20000
10000
0
-10000
-20000
-30000
-50000 -40000 -30000 -20000 -10000 0 10000 20000 30000 40000 50000
0.052
0.05
0.048
0.046
0.044
0.042
0.04
0.038
0.036
0.034
0.032
0.03
0.028
0.026
0.024
0.022
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
PM10 Maximum Concentration in 2034 (ug/m3)
30000
20000
10000
0
-10000
-20000
-30000
-50000 -40000 -30000 -20000 -10000 0 10000 20000 30000 40000 50000
0.09
0.085
0.08
0.075
0.07
0.065
0.06
0.055
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0

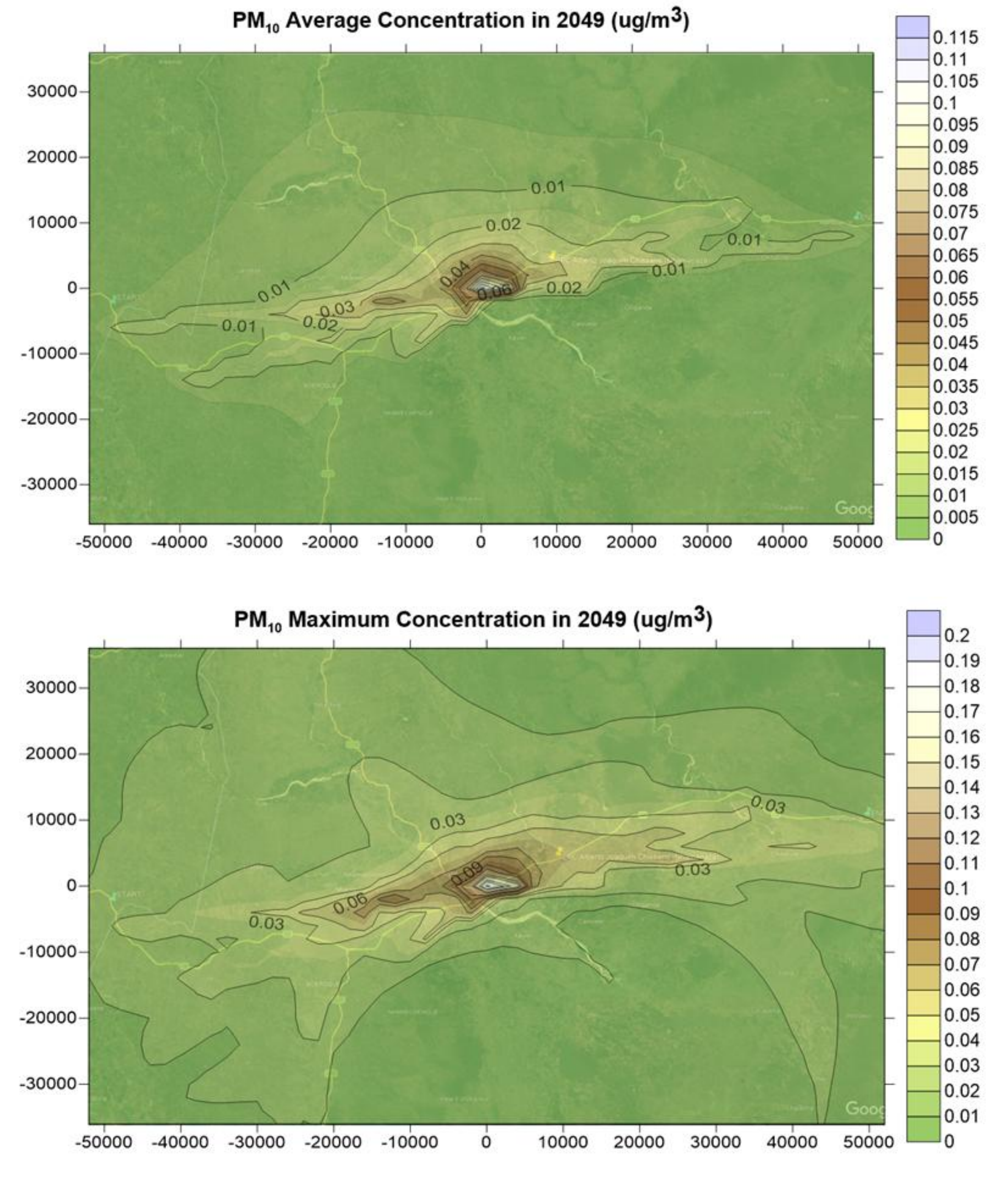
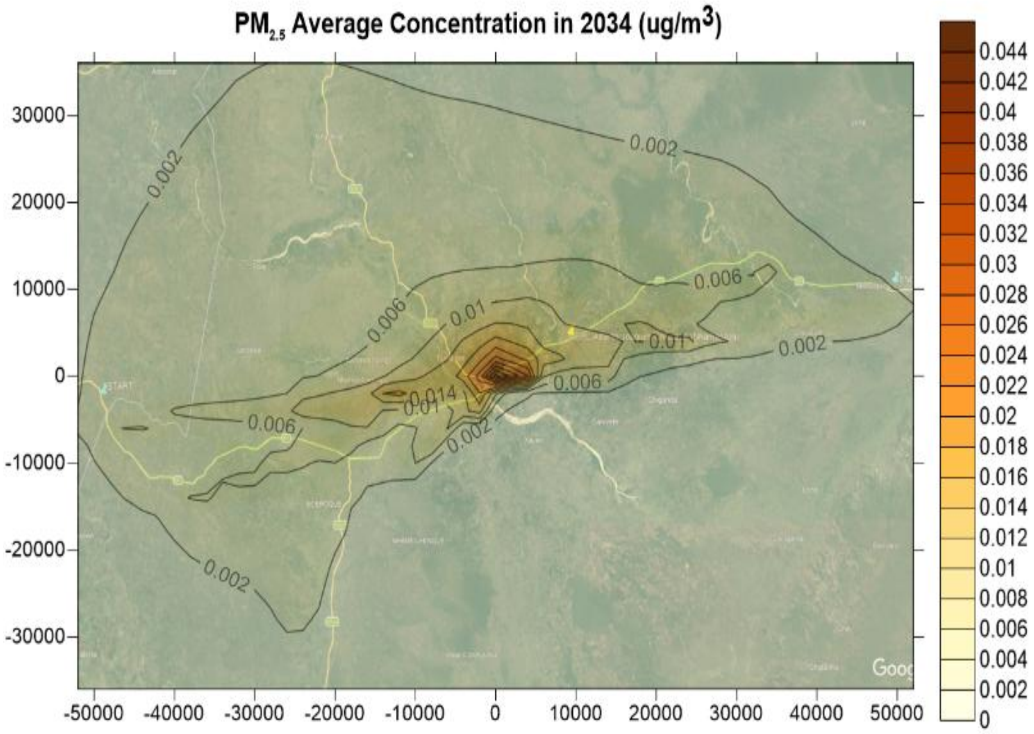
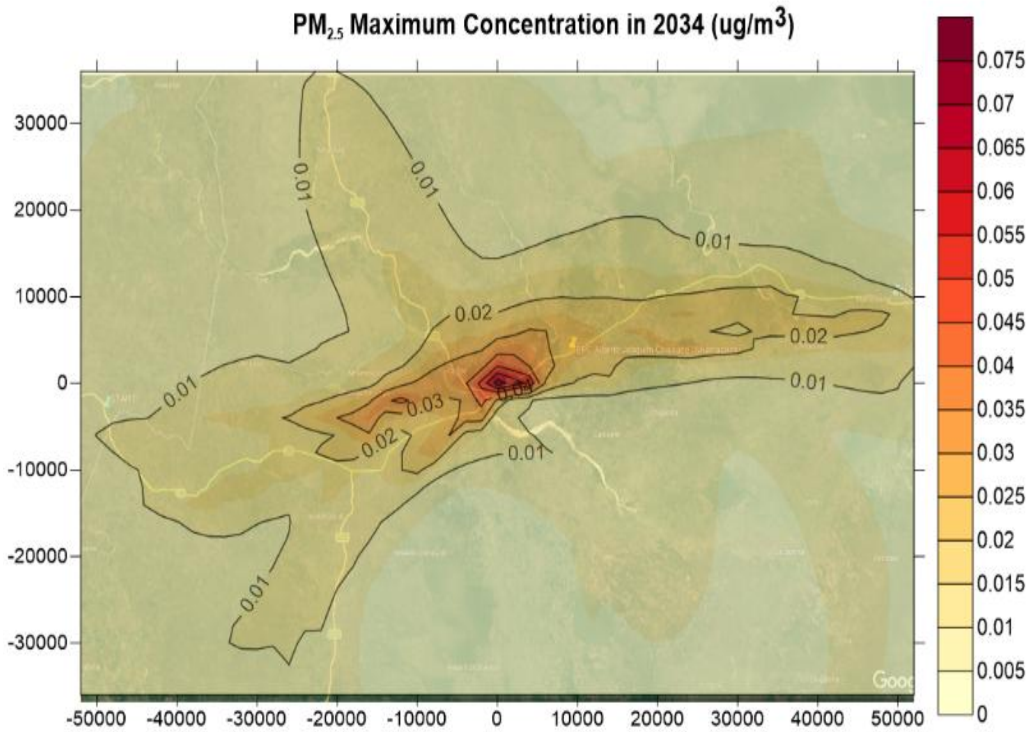


Figure 24 Dispersion map for PM_{10}

Dispersion maps for $PM_{2.5}$





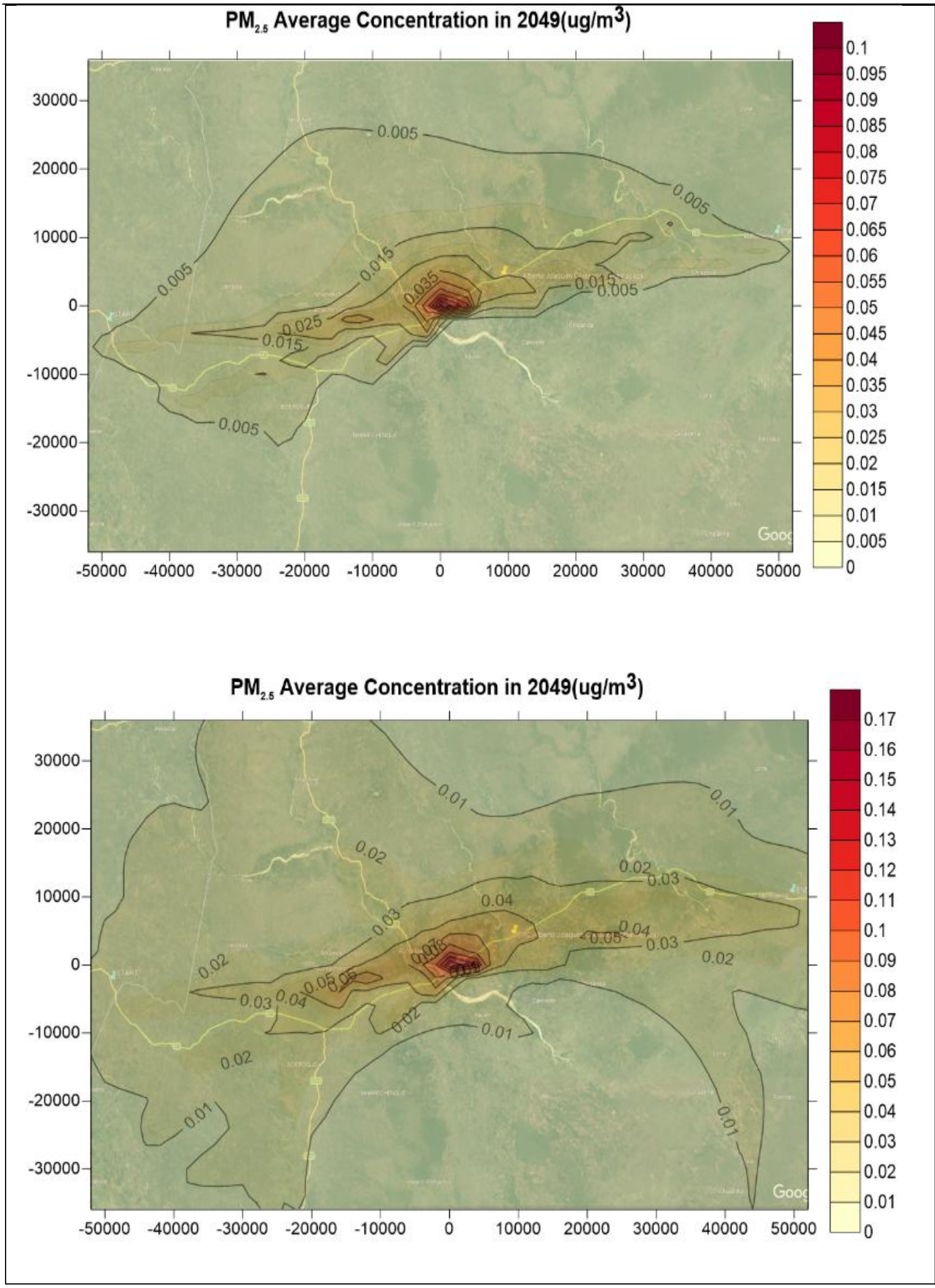
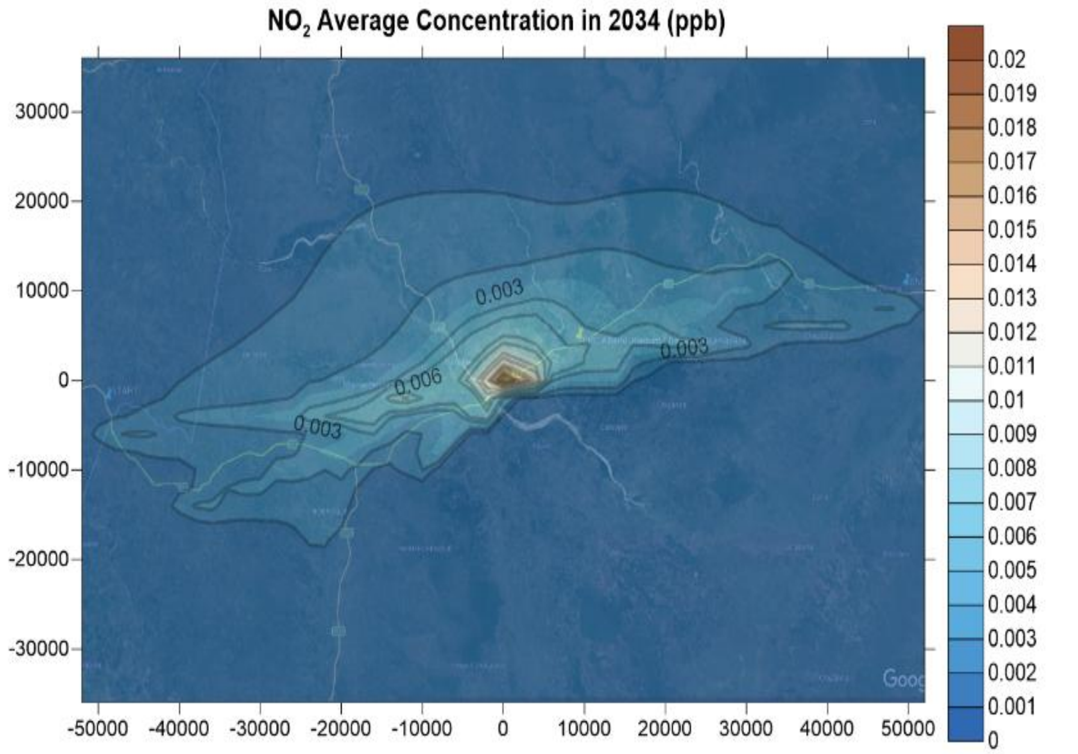
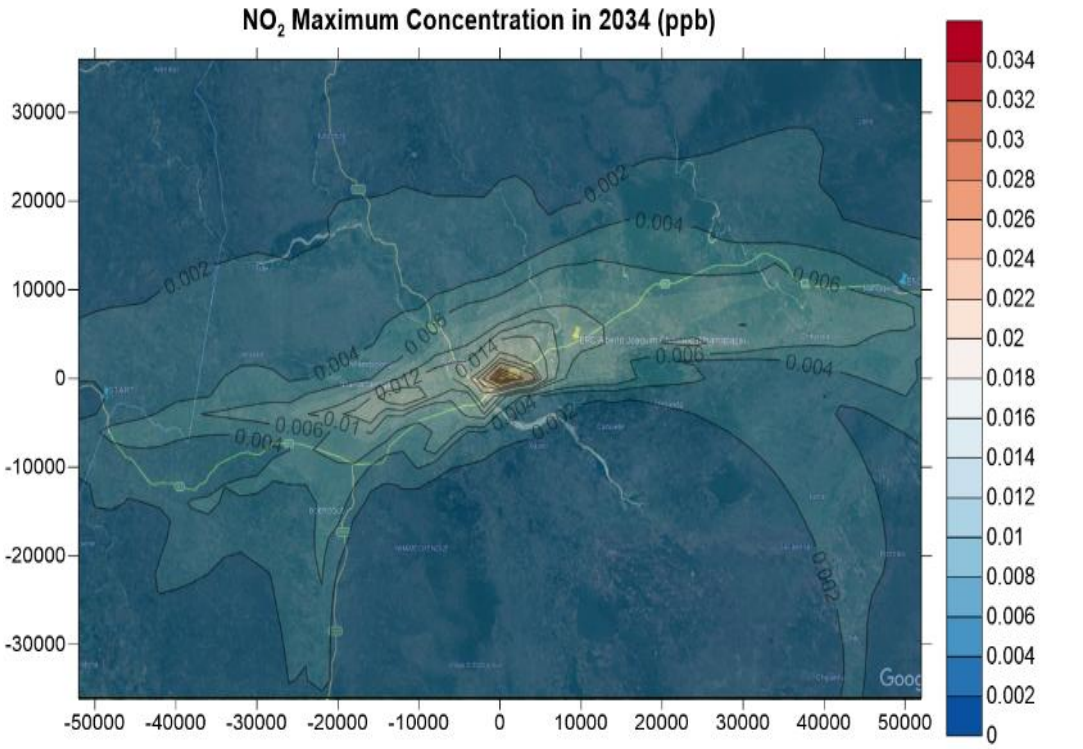


Figure 25 Dispersion map for PM $_{2.5}$

Dispersion maps for NO_2





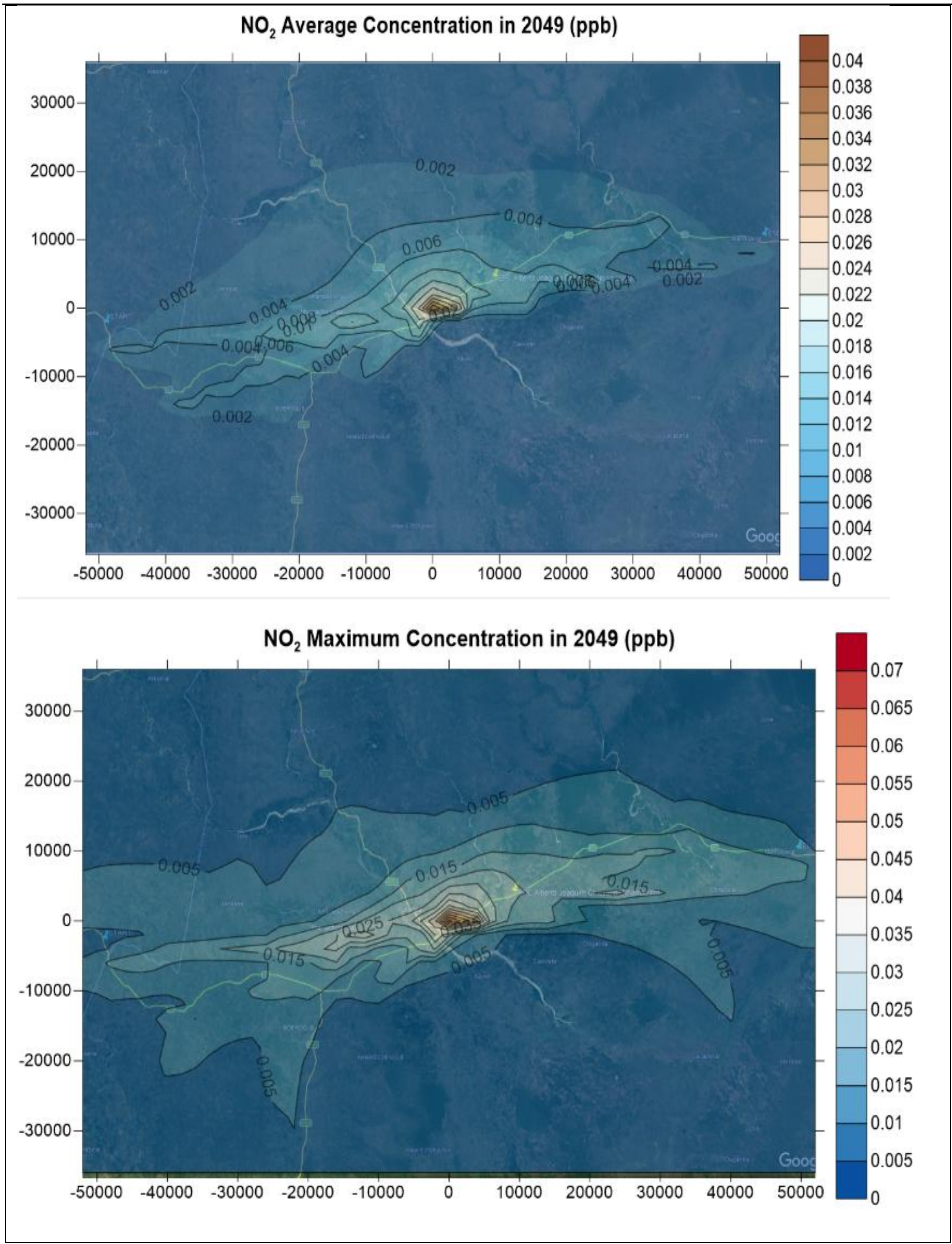
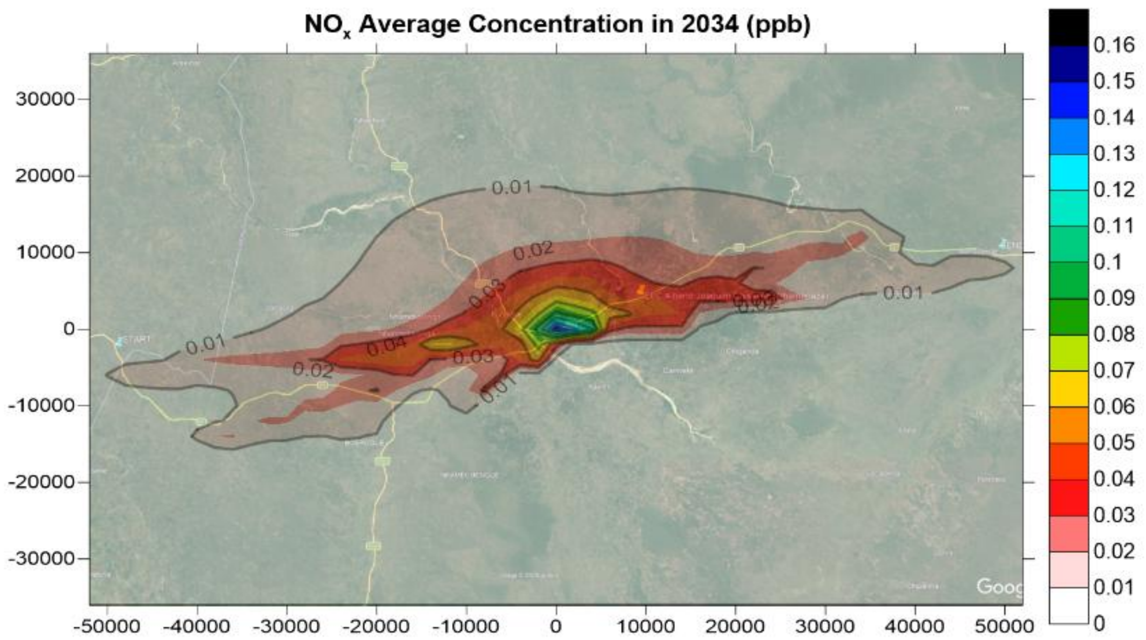
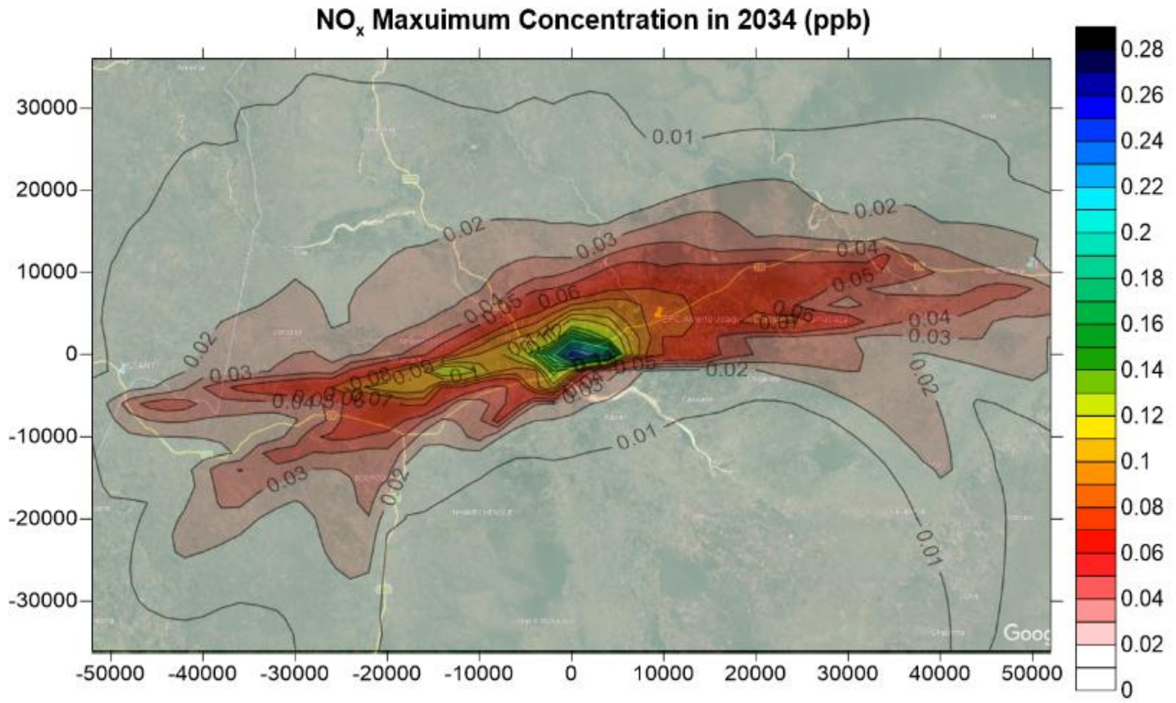


Figure 26 Dispersion Map for NO_2

Dispersion maps for NO_x





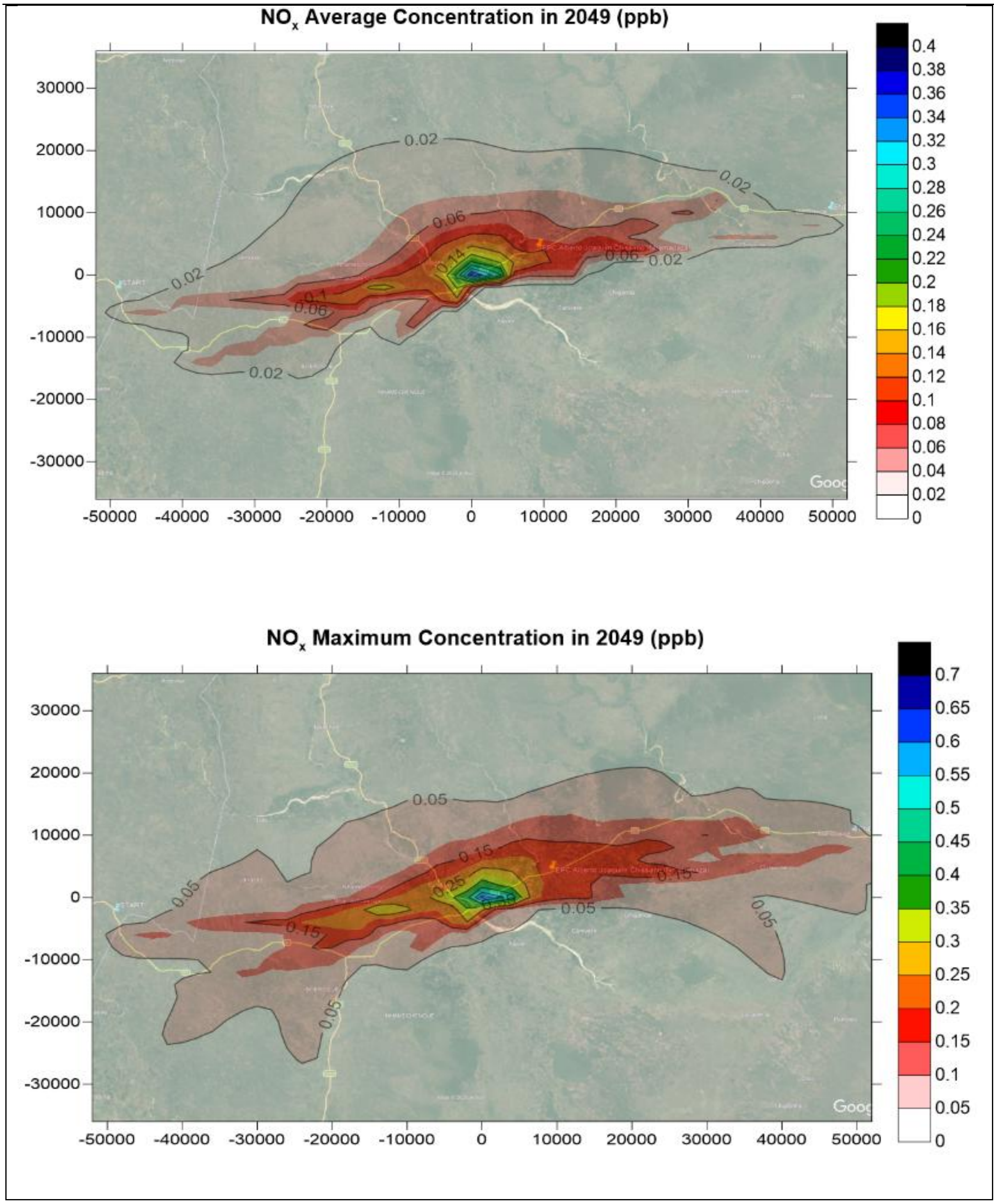
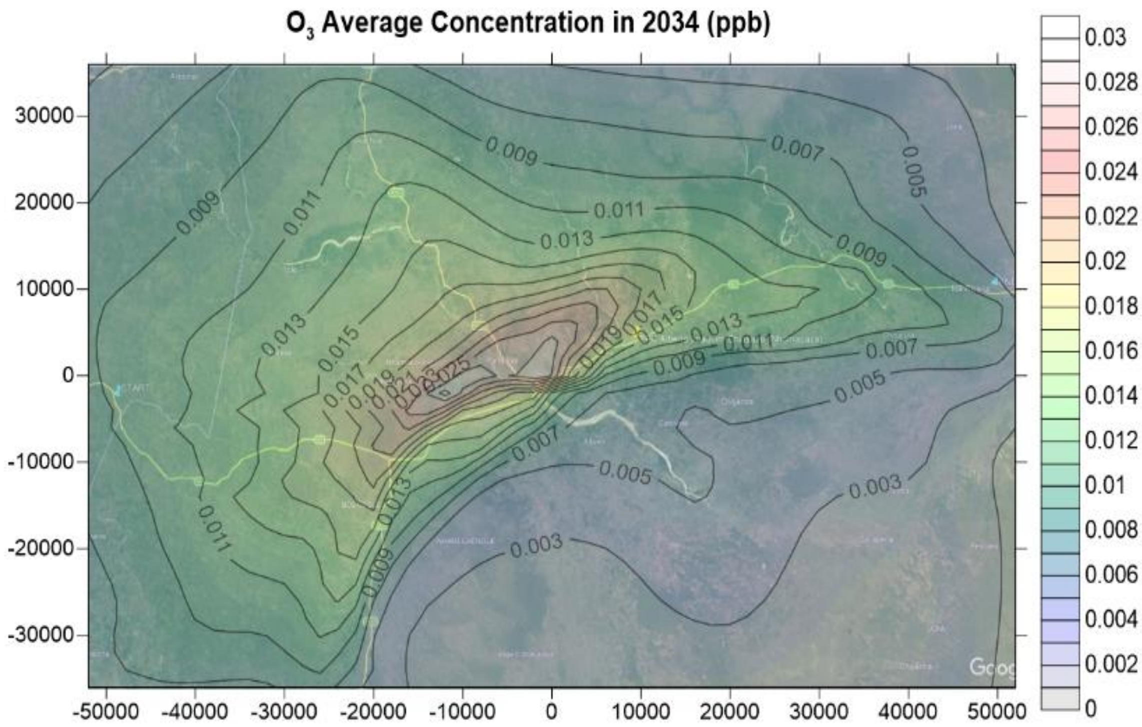
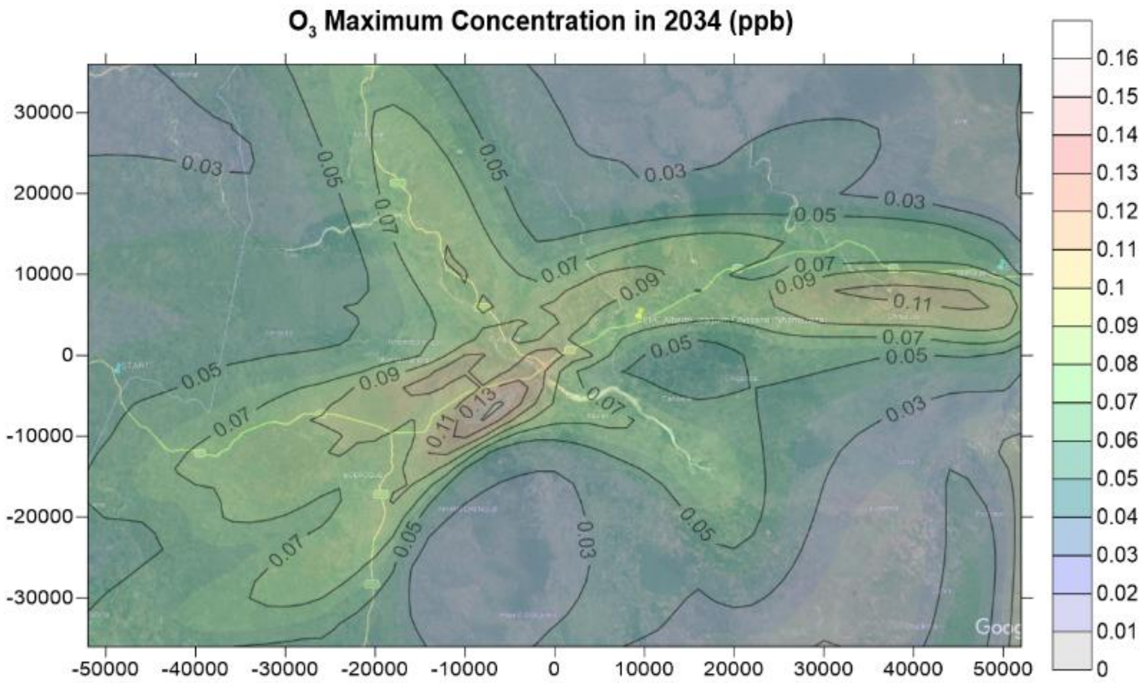


Figure 27 Dispersion map for NOx

Dispersion maps for Ozone





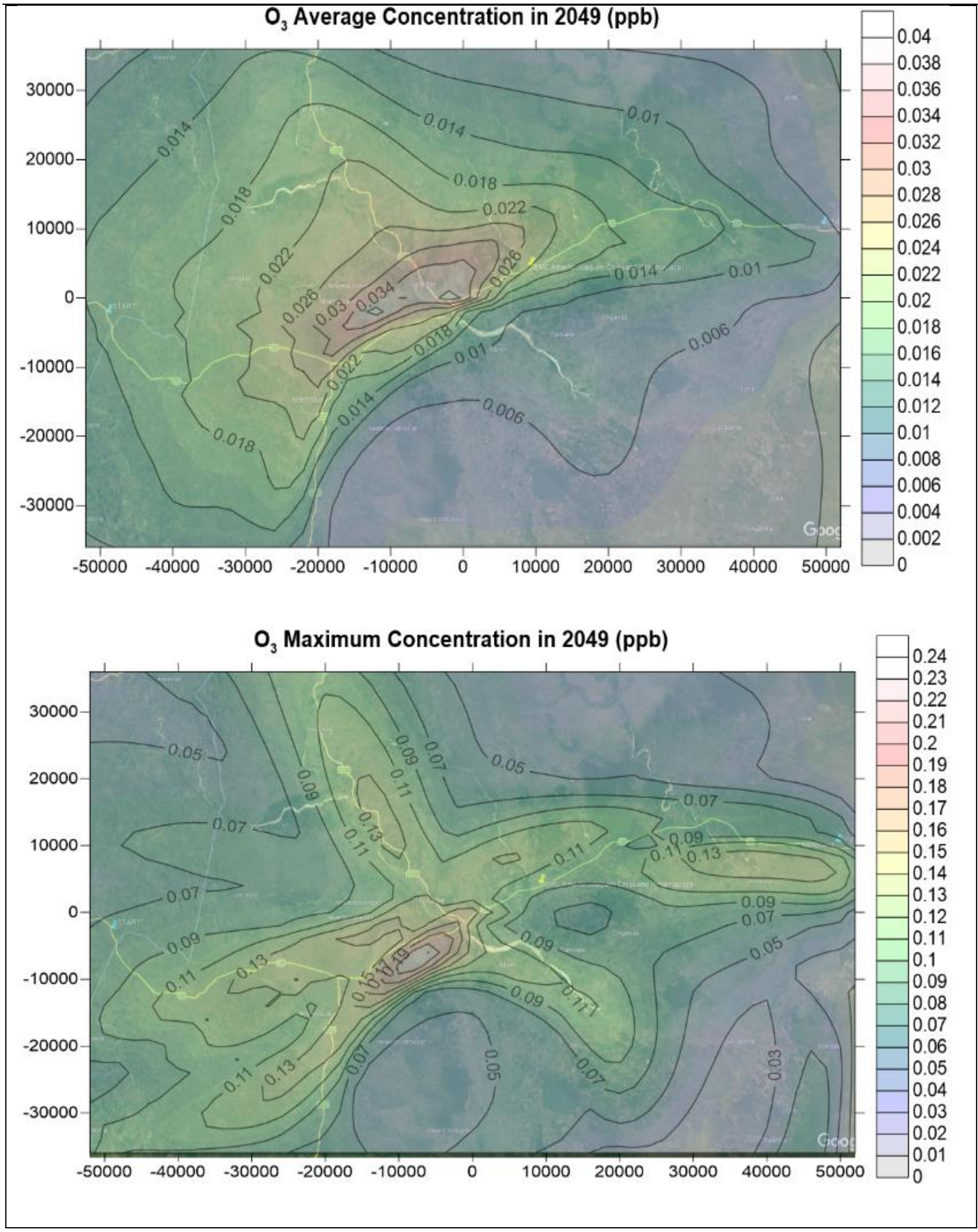
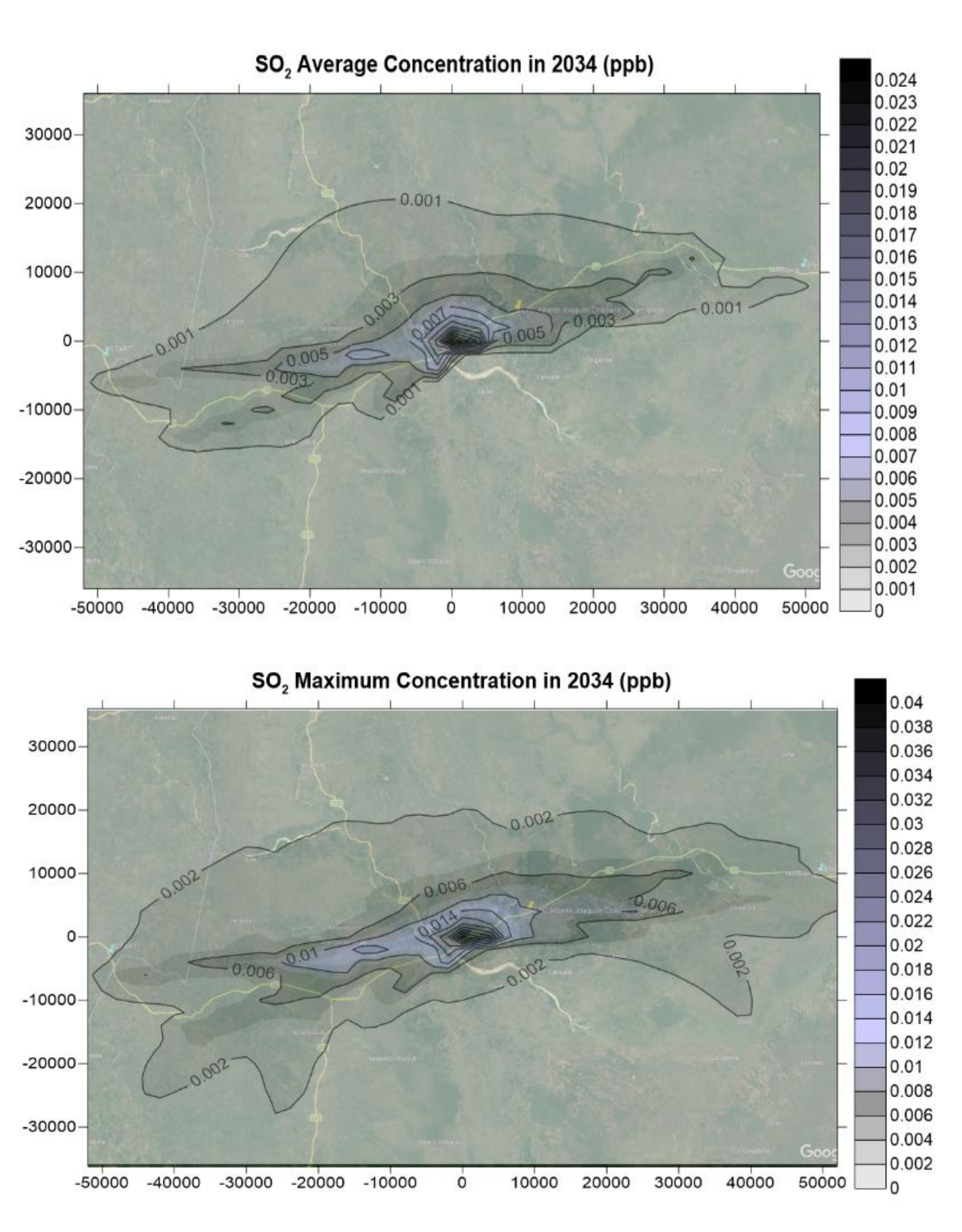


Figure 28 Dispersion map for Ozone

Dispersion maps for SO_2



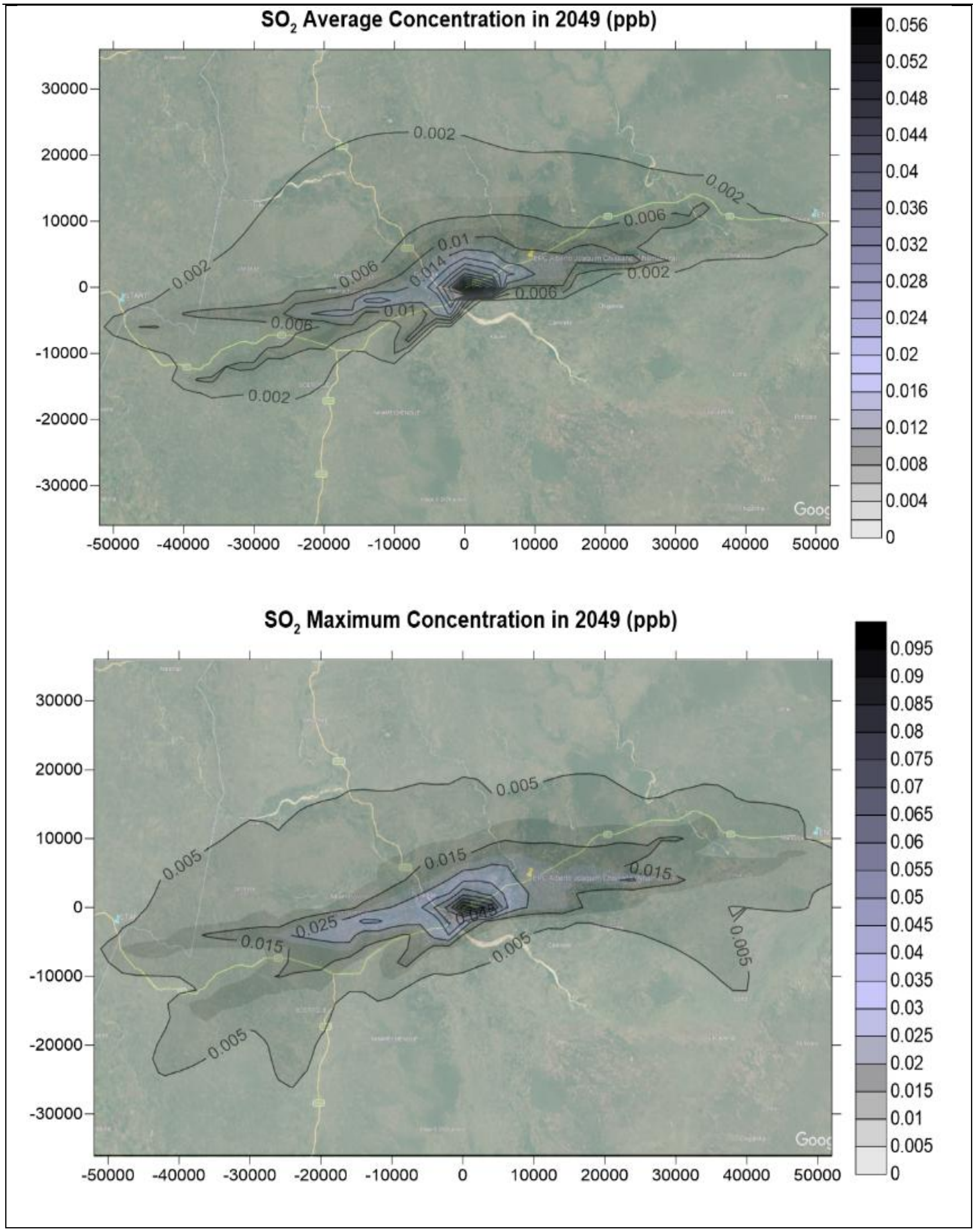


Figure 29 Dispersion map of SO_2

The images below show the modeling of daily levels of each parameter over the years which indicate the levels are well below the national and WBG limits.

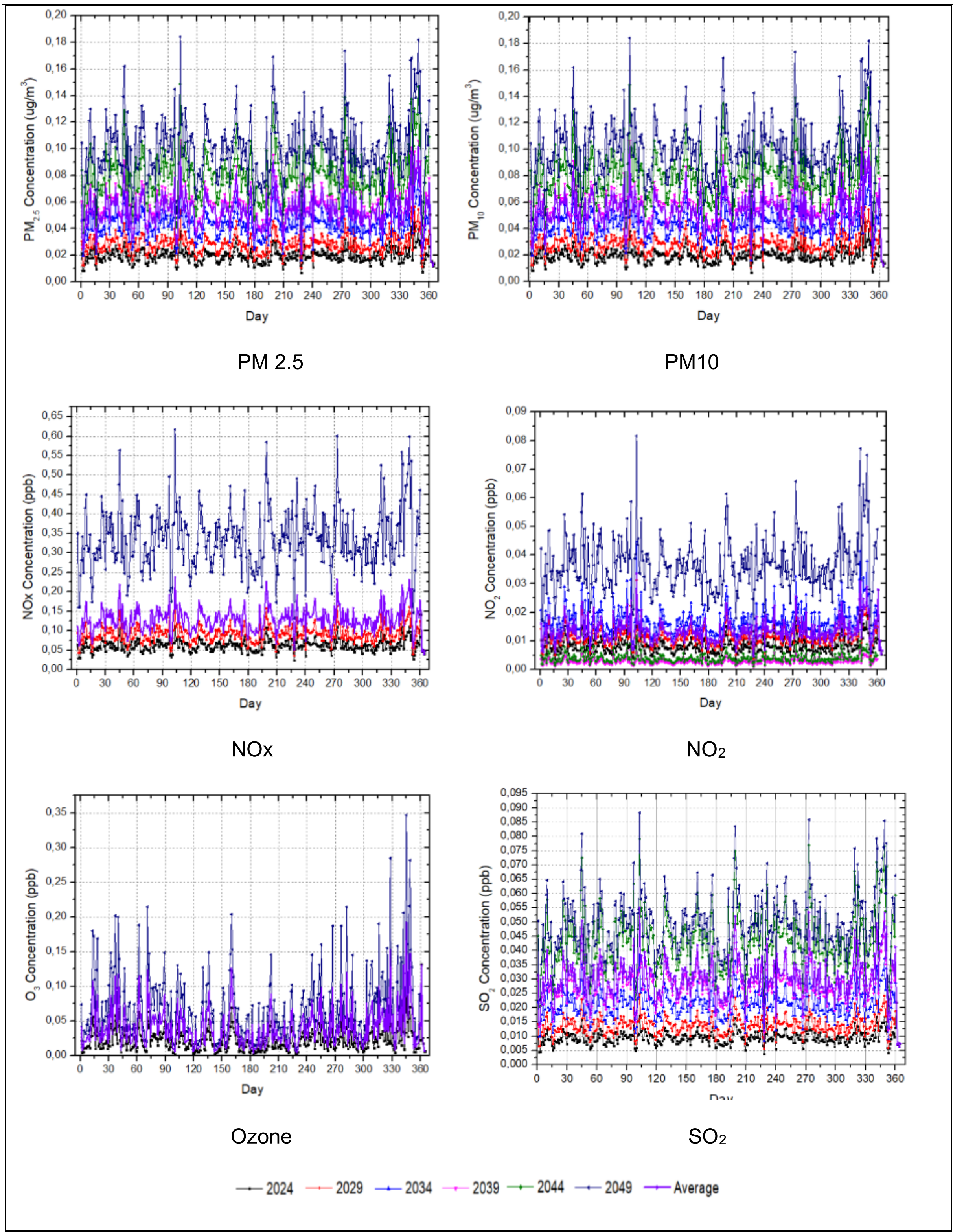


Figure 30 Daily levels of air quality parameters modelled annually

Sensitive receptors

In this section of the N1, km 84-168 one confirmed sensitive receptor was identified during the baseline data capture survey, located on the N1 roadside, as shown in the image below and identified in Table 6-2.

Figure 31 Location of sensitive receptor in Nhamapaza

Table 7-8 Average and maximum annual concentrations of pollutants at the identified sensitive receptor EPC Joaquim J. Chissano in Nhamapaza

Modelled concentrations at the sensitive receptor16 (EPC Alberto J. Chissano - Nhamapaza)									
Yaer	**Average concentration in µg/m³**						**Standards**		
Pollutant	**2024**	**2029**	**2034**	**2039**	**2044**	**2049**	**National**	**WHO**	**WBG**
PM10	0.012	0.013	0.014	0.018	0.022	0.030	40	15	20
PM2.5	0.007	0.003	0.010	0.014	0.017	0.025	25	5	10
NO2	6.732	7.694	9.618	11.618	15.388	17.541	40	10	40
NOx	63.559	47.669	158.898	190.678	222.457	244.491	_	_	150
O3	22.078	24.086	34.121	36.128	44.157	44.157	_	_	_
SO2	6.690	8.029	13.381	17.395	26.762	32.114	50	_	_
Pollutant	**Maximum concentration in µg/m³**						**Standards**		
	2024	**2029**	**2034**	**2039**	**2044**	**2049**	**National**	**WHO**	**WBG**
PM10	0.020	0.022	0.030	0.035	0.050	0.055	40	15	20
PM2.5	0.014	0.040	0.025	0.025	0.045	0.050	25	5	10
NO2	13.465	15.388	23.082	30.776	34.623	40.394	40	10	40
NOx	143.008	222.457	254.237	381.355	508.474	826.270	_	_	150
O3	110.392	130.464	160.571	160.571	180.642	200.713	_	_	_
SO2	13.381	18.733	32.114	37.466	53.524	66.904	50	_	_

The table showing average concentrations shows that annual NOx standards are surpassed from 2034, while the remaining pollutants remain within the established limits. The average of the maximum concentrations also shows that the standards are exceeded for most of the pollutants presented, except for particulate matter. However, it should be noted that vehicular particulate matter here refers to those emitted during the fuel combustion process and does not include those that may be re-emitted due to road and surrounding environmental conditions.

As noted in Table 6-3, additional potential sensitive receptors were identified using Google satellite maps as follows, although unconfirmed through field verification:

Receptor	Latitude	Longitude	Altitude	Identification reference and distance from road	Chainage (km)
1	18°14'53.06"	34°14'45.76"	217 m	R1 (10m)	10.900
2	18°13'36.61"	34°19'15.28"	128 m	R2 (50m)	19.400
3	18°13'26.68"	34°19'31.31"	544 m	R3 - 40m	20.300
4	18°13'23.04"	34°19'40.16"	527 m	R4 (more than 70m)	21.100
5	18°13'10.25"	34°19'22.10"	333 m	Outside of road area	21.700
6	18°13'10.41"	34°20'2.90"	441 m	R5 (40m)	21.800
7	18°13'12.22"	34°21'20.47"	336 m	R6 (60m	24.090
8	18°13'9.93"	34°21'32.49"	321 m	R7 (60m)	24.900
9	18°13'24.02"	34°21'59.67"	210 m	R8 (Outside of road area - More than 100m)	25.500
10	18°14'3.95"	34°25'47.24"	297 m	R9 (40m)	31.500
11	18°12'55.21"	34°26'54.81"	262m	R10 (67m)	35.500
12	18°12'8.23"	34°28'22.34"	347 m	R11 (more than 100m)	38.400
13	18°11'0.17"	34°32'9.70"	832 m	R12 (10m)	45.500
14	18°10'23.04"	34°33'5.28"	332 m	R13 (80m)	47.700
15	18° 9'20.81"	34°35'40.65"	205 m	R14A (70m)	52.600
16	18° 9'15.88"	34°35'37.50"	205 m	R14B (80m)	52.600
17	18° 9'7.67"	34°36'41.74"	202 m	R15 - Escola de Nhamapaza (40m)	54.500
18	18° 9'3.76"	34°36'41.74"	165 m	Same as R15	54.500

Data from two randomly selected additional potential sensitive receptors are presented below:

Table 7-9 Data modelled from two randomly selected additional potential sensitive receptors

Modelled concentrations at the sensitive receptor1									
Yaer	**Average concentration in µg/m³**						**Standards**		
Pollutant	**2024**	**2029**	**2034**	**2039**	**2044**	**2049**	**National**	**WHO**	**WBG**
PM10	0.002	0.003	0.004	0.007	0.008	0.010	40	15	20
PM2.5	0.003	0.003	0.005	0.005	0.006	0.006	25	5	10
NO2	1.924	2.885	3.078	3.655	4.424	7.694	40	10	40
NOx	12.712	19.068	31.780	47.669	73.093	85.805	_	_	150
O3	18.064	20.071	26.093	36.128	40.143	44.157	_	_	_
SO2	1.338	2.275	2.676	4.550	5.352	5.888	50	_	_
Pollutant	**Maximum concentration in µg/m³**						**Standards**		
	2024	**2029**	**2034**	**2039**	**2044**	**2049**	**National**	**WHO**	**WBG**
PM10	0.012	0.015	0.019	0.025	0.042	0.060	40	15	20
PM2.5	0.010	0.014	0.018	0.020	0.027	0.033	25	5	10
NO2	7.309	7.886	8.848	10.964	11.733	19.235	40	10	40
NOx	6.356	9.534	95.339	117.585	174.788	193.856	_	_	150
O3	130.464	142.506	220.785	240.856	270.963	305.084	_	_	_
SO2	5.352	7.493	11.240	14.987	19.001	25.424	50	_	_

Modelled concentrations at the sensitive receptor2									
Yaer	**Average concentration in µg/m³**						**Standards**		
Pollutant	**2024**	**2029**	**2034**	**2039**	**2044**	**2049**	**National**	**WHO**	**WBG**
PM10	0.002	0.002	0.004	0.005	0.006	0.008	40	15	20
PM2.5	0.002	0.002	0.006	0.007	0.008	0.008	25	5	10
NO2	4.232	5.193	5.771	6.925	7.502	8.271	40	10	40
NOx	15.890	18.750	20.021	21.610	22.564	63.559	_	_	150
O3	10.036	16.057	18.064	20.071	28.100	36.128	_	_	_
SO2	1.338	2.676	5.352	6.690	7.761	8.296	50	_	_
Pollutant	**Maximum concentration in µg/m³**						**Standards**		
	2024	**2029**	**2034**	**2039**	**2044**	**2049**	**National**	**WHO**	**WBG**
PM10	0.010	0.016	0.021	0.024	0.030	0.037	40	15	20
PM2.5	0.012	0.018	0.019	0.020	0.027	0.042	25	5	10
NO2	5.963	8.079	9.040	9.618	10.964	13.465	40	10	40
NOx	31.780	57.203	66.737	79.449	92.161	158.898	_	_	150
O3	50.178	90.321	100.357	140.499	150.535	180.642	_	_	_
SO2	2.676	5.352	8.029	14.719	16.325	20.071	50	_	_

Mitigation Measures

Since the emissions are well below or within the recommended national/international limits, immediate risks are low there are no required mitigation efforts at this stage. This may be re-assessed at the end of contract period towards the end of the operations/maintenance phase.

Air pollution due to dust and greenhouse gas (GHG) emissions

Road rehabilitation works and associated site development (e.g., camp construction, detours, borrow pits) will require vegetation clearing, soil excavation, cement mixing, and operation of construction vehicles and heavy machinery. These activities will generate significant dust and contribute to air pollution, especially in areas adjacent to settlements, schools, and ecologically sensitive areas such as the buffer zone of Gorongosa National Park. Air quality deterioration may result from:

- Movement of vehicles and equipment along unpaved areas
- Cutting and removal of concrete (bridge works)
- On-site cement, gravel, and sand mixing
- Earthworks at detours, borrow pits, and spoil areas

In addition, emission of greenhouse gases and particulate matter such as carbon dioxide (CO_2), carbon monoxide (CO), sulphur dioxide (SO_2), nitrogen oxides (NOx), hydrocarbons (HC), volatile organic compounds (VOCs) and particulate matters (PM10+PM2.5) into the atmosphere. These gases and particulate matter may cause air pollution through accumulation of pollutants in the air, which could lead to outbreak of respiratory diseases (e.g. cough, aggravated asthma, irritation of the respiratory airways of people working near the project area and in wildlife that are found near the project area (e.g. in GNP).

Potentially sensitive areas that could be monitored for air quality, noise and vibration impacts are as follows:

Table 7-10 Sensitive areas for monitoring air quality, noise and vibration

Sample point	Name of receptor	Location (District, locality)	Type of receptor	Geographic coordinates		Estimated Chainage Gorongosa to Caia)
				Latitude	Longitude	
1	EPC Alberto Joaquim Chissano (Nhamapaza)	Marromeu, Nhamapaza	School	18.1516001	34.611841	Km 139+230

Additional potentially sensitive receptors are noted in Table 6-3 which require verification on the ground, and should be closely monitored by the contractor, particularly for the construction phase.

Mitigation measures

- Provide all workers with personal protective equipment (PPE);
- Periodically spray water on loose soils and on soil mounds to suppress dust emissions;
- Prepare and implement best management practice for dust emissions;

- Compact firmly loose soils on the rehabilitation and site office construction sites to suppress dust;
- Re-use unused soil removed for backfilling and rehabilitation of borrow pits and abandoned quarries;
- Cover appropriately quarry stones, river sand and gravel when transporting to work front, camp sites and offices construction site
- Minimize the amount of time that loose soil may remain exposed to wind;
- Limit vehicle and machinery speed to 20 km/hr all the time;
- Regularly service vehicles, machinery and equipment as per manufacturer recommendations;
- Reduce idling time for trucks and vehicles at the project site;
- Preserve and/or plant more trees and grass along the PPZ act as carbon sinks.

c) Risks of climate change due to emissions of greenhouse gases

As per the modeling data gathered using data from the traffic counts in the concept designs, noted in Section 6, three types of pollutants were identified: 1) Particulate Matter ($PM_{2.5}$ and PM_{10}) 2) Nitrogen Oxides (NOx) and 3) Sulfur Dioxide (SO_2). All concentrations are well within permissible limits, for both national and WB limits.

Greenhouse gases such as CO_2, CH_4, and N_2O are also projected to rise but remain within acceptable limits. Despite this, the cumulative long-term effects on air quality and health necessitate ongoing monitoring and mitigation.

The dispersion model evaluated the concentration of pollutants at ground level over the 25-year period, factoring in internal combustion engine emissions and atmospheric processes like photochemical ozone production. Key findings are:

- Particulate Matter (PM): Maximum concentrations for PM_{10} ranged from 5% to 29% of allowable national limits.
- Ozone: Modeling indicated weak generation of tropospheric ozone, with no locations exceeding the background concentration of 20 ppb.
- Nitrogen Oxides: NO_2 persists longer in the atmosphere, contributing to the formation of tropospheric ozone and greenhouse gas effects, although concentrations remain below hazardous levels.

Mitigation Measures

Since the emissions are well below or within the recommended national/international limits, immediate risks are low.

d) Climate change: high temperature risks and mitigation measures:

It should be noted that climate change impacts due to extreme temperatures may include deformation of the surface, cracking, accelerated aging of binder, rutting of asphalt and bleeding/flushing of seals. Mitigation measures may include the use of appropriate layer coefficients, drainage coefficients, weather-resistant pavement surfacing materials and asphalt mix designs and revised pavement thicknesses which take into consideration the future temperatures and the use of advanced heat-resistant materials.

The designs are noted to be tailored to available products with requisite drainage and layer coefficients as part and parcel of tried and tested design algorithms and require research to be altered. The pavements employ a DBST which is not susceptible to rutting. An option to prevent bleeding/flushing is to keep binder application as low as possible and to also use harder binders (70/100 instead of 150/200). Using a G1 base compacted to 88% RD (as part of the designs being used) will also reduce embedment of the stone and hence bleeding/flushing.

e) Climate change: flooding risks and mitigation measures

The concept designs have noted that there is no section of the road Gorongosa-Caia which is prone to flooding. The Climate Vulnerability Risk Assessment used by the concept designs to identify climate related hotspots and prioritize adaptation measures is referred to in the project description.

The Scenario by RCP 8.5 [Long Term Period 2081-2100] has been taken into consideration based on baseline 1995-2014.

Due to climate change considerations, there are 6 new box culverts also proposed as improvement works at locations: km 129+965, km 141+590, km 142+099, km 156+981, km 126+275, km 125+890- at approach of major bridge G-21 and river training works both upstream and downstream.

Overall climate change considerations taken into account by the design consultants

As indicated in ANE´s design manuals, the hydraulic capacity of the existing structures was checked using the return periods specified for consideration of climate changes factors. In case of noncompliance, the structure is to be replaced by a new one. The Consultant has allowed for additional relief culverts to make provision for climate change notwithstanding the fact that these are not necessary from a hydrological standpoint. Due to the need to construct a new pavement on top of the existing one, the road platform will be slightly raised providing additional protection against floods.

The existing pavement upper layer will be recycled and integrated in the new pavement, thus decreasing the amount of gravel to be extracted from borrow pits and transported to site, consequently reducing carbon emissions and consumption of diesel. The number of required borrow pits and their final dimensions will also be minimized.

The proposed pavement comprises a wearing course layer of asphalt, which leads to the specification of thinner layers of crushed stone base, thus decreasing the amount of crushed stone to be imported from the quarries to site. This will reduce the number of trips of transport vehicles, again reducing carbon emissions and consumption of diesel.

f) Increased risk of water pollution in the project area

Poor waste management of used oils, fuel spills and wastewater from washing facilities and areas where cement and sand are mixed at the construction site may result in pollution of nearby water resources that are available in rivers, streams, ponds and wetlands that are found in the project area.

Rehabilitation or substitution of bridges along the target sections will generate debris (e.g. sediments and fine concrete particles), which if left unattended may enter into the rivers and streams and pollute the water thereby affecting the aquatic fauna and water end-users downstream. Additional pollution could occur if there was leakage of toxic chemicals and oils into the water especially during the rehabilitation of the section of the road and bridges that have been identified for rehabilitation and/or substitution. Transported and drop-off silts and sediments from the road rehabilitation section and bridges to be rehabilitated may negatively affect spawning grounds for aquatic fauna (e.g. fish and frogs, etc.).

In addition, construction of detours within the PPZ, and unsustainable mining of quarries and borrow pits and use of rivers (Primary suppliers) to obtain construction materials may lead to water pollution due to transportation of soil silts and sediments by rainwater and wind into nearby water bodies. The transportation of loose soils into nearby water bodies may cause high water turbidity and pollution of water if left unchecked, thereby affecting water end-users downstream, aquatic fauna (especially during spawning season) and local ecosystem services found in the project area and beyond.

Potential impacts on groundwater could include infiltration of surface water pollutants or reduction in water table level from increased use of water during the rehabilitation phase.

There could be interruption of natural drainage systems by detours and culverts as well.

The following bridges will be subject to rehabilitation and are potential locations for monitoring water quality:

Main rivers and bridges to be rehabilitated in section Gorongosa-Caia (Km 84-168):

- S-20 (Nhapherua River) (Km 101+260)
- S-21 (Nhampaza River) (Km 126+260)
- S-22 (Mombeze) (Km 133+260)
- S-23 (Nhanzaza River) (Km 143+680)
- S-24 (Fudza River) (Km155+320)

Mitigation measures

- Develop and implement wastewater management plan;
- Obtain water abstraction rights from the relevant authority prior to the commencement of rehabilitation works;
- Consult water authorities to verify which rivers will require monitoring of water quality during construction activities.
- Ensure regular testing of the authorized water sources used for construction water abstraction, upstream and downstream;
- Ensure monthly water quality testing of all potable water sources;
- Mix asphalt, quarry and sand on impervious surfaces and away from areas of potential runoff and water bodies;
- Ensure controlled excavation practices that follow approved management plans to reduce soil erosion;
- Store liquid asphalt, fuel, oil and other chemicals in sealed containers in a bunded area;
- Dispose of used oil at a designated hazardous waste facility approved by local authorities;
- Separate storm water drains from wastewater drains to avoid water pollution;
- Construct septic tanks with soakaway pits designed to accommodate camp population requirements;
- Monitor effluent from septic tanks quarterly for compliance with national standards (e.g., BOD < 30 mg/L);
- Provide male and female workers with appropriate mobile toilet facilities, with adequate handwashing facilities which are cleaned regularly and liquid waste disposed of safely in an appropriate manner;
- Regularly inspect vehicles, plants and machinery for any oil leaks, and immediately repair leaks;
- Clean any accidental fuel spills from the ground immediately and remove any fuel contaminated soil, store securely and dispose of at a designated hazardous waste facility approved by local authorities;
- Conduct periodical monitoring of the quality of wastewater discharged from the kitchen and

washing facilities at the workers camp site;

- Construct soil and silt pit traps sediment basins around the project site;
- Avoid clearing trees, grass, plants and shrubs outside the project impact area; and
- Construct physical barriers (e.g. silt trap fences, sediment basins, containment booms, etc.) around the bridge going under rehabilitation or replacement.
- Construct rainwater harvesting facilities in areas which may be affected by low water levels or if there is a drought to reduce dependence on groundwater harvesting.

f) Increased risk of generation of hazardous waste and non-hazardous waste in the project area

The baseline survey conducted in the project area established that waste management in the project area is poor. It was observed that solid and liquid waste were disposed of carelessly in the project area. Sanitation and hygiene facilities in the project area remain a significant challenge. Many households rely on traditional pit latrines, which can lead to the contamination of surface and groundwater and the surrounding areas. Based on this finding, it is anticipated that during the rehabilitation phase, solid and liquid waste generation will increase. Avoidance of waste production should be considered, together with the reduce, reuse, recycle concept of waste management.

Various types of solid waste will be generated from site clearance (rubble, soil, stone, organic vegetation) camp site preparation (all forms of construction waste), operation of the camp site and work fronts, borrow pits/quarries. Workshops generate hazardous wastes such as used oils. Liquid waste is generated from septic tank toilet facilities, portable toilets, wastewater from washing and bathing facilities, and kitchens etc.

Additional hazardous wastes will be generated from the use of cement, asphalt/bitumen/MC30 and paints, as well as contaminated soil from any fuel/oil/asphalt/concrete spills.

<u>Mitigation measures</u>

- **Develop and implement a robust Waste Management Plan**, covering all stages (procurement, construction, operation), including **annual waste audits** and clear implementation of the **waste hierarchy** (prevention/reduction, reuse, recycling, recovery, treatment, disposal).
- **Enforce a strict prohibition** on burning of waste and on any **illegal disposal of hazardous waste to land**.
- **Always implement proper housekeeping practices on the construction site**.

- **Provide well-labelled dustbins and waste containers** for all workers at the rehabilitation, campsite and site administration office, ensuring segregation of **organic, recyclable, hazardous and biomedical waste** at the source.
- **Ensure waste bins are clearly marked and color-coded**, lined with an impermeable layer, and **protected from wind and rain**. Organic waste containers must be **rodent- and rain-proof**.
- **Store all hazardous materials** in a **dedicated, bunded storage area** with a hard, impermeable (concrete) floor, proper ventilation, and protection from the sun and rain, until safe removal from site by licensed service providers and disposed of in licensed hazardous waste facilities. This area must be accessible only to authorized personnel, flame-proof, and have spill kits nearby.
- **All hazardous waste must be handled by trained and qualified personnel** and transferred using appropriate vehicles to an approved off-site hazardous waste facility at the end of each day.
- **Keep an up-to-date inventory** and **Material Safety Data Sheets (MSDS)** for all hazardous substances on site.
- **Provide separate containers/skips** for construction and demolition waste, which must be adequately covered to prevent scattering.
- **Record and log all waste generated on site**, disaggregated by type, quantity and disposal route.
- **Establish contractual agreements** with the local municipality (or licensed waste contractors) for the collection, transportation and proper disposal of solid, liquid and hazardous waste. Contracts must specify collection frequency, waste types, treatment or disposal facilities, and require **signed consignment notes** for each waste vehicle exiting the site.
- **Agree and sign Memorandums of Understanding (MoUs)** with local communities or other partners for reuse or recycling of contractor waste (where feasible).
- **Investigate and implement arrangements** with companies that recycle **used oil/lubricants**, ensuring proper collection and disposal of used oil at authorized hazardous waste facilities.
- **Prohibit littering** around the rehabilitation site and ensure that any **non-recyclable waste** is disposed of only at designated landfill sites approved by local authorities.
- **Provide separate, well-maintained mobile toilets** for male and female staff, ensuring regular cleaning and safe disposal of waste.
- **Optimize water use** to reduce wastewater generation and ensure **stormwater drains are separated from wastewater drains** to avoid contamination.

- **Locate hazardous waste storage and collection areas inland**, away from residential areas, sensitive receptors and water bodies, to prevent leaching or contamination of soil and water resources.

g) Increased risk of noise pollution and vibration in the project area

Noise modelling

As noise/vibration modelling for the operations and maintenance phase of the Project could not be undertaken during the preparation of this ESIA, it was accepted to provide terms of reference for a potential study which has been included in Annex 3.

Construction/rehabilitation and road improvement activities generally require the use of moderate to heavy machinery that will be moving on rough paved roads in some sections. Construction, rehabilitation, and road improvement activities generally require the use of moderate to heavy machinery, operating along both paved and unpaved sections of the N1 corridor. Noise and vibration in the project area are expected to originate from several main sources, including:

(a) vehicles (engines, transmission, exhaust and suspension);
(b) friction between vehicle tires and the road surface;
(c) operation of machinery and equipment during road construction;
(d) bridge rehabilitation or replacement works;
(e) driver and worker behavior (excessive honking, loud music, shouting, sudden braking or acceleration); and
(f) associated facilities such as concrete batching plants, quarries, and asphalt plants.

The intensity and duration of noise and vibration will vary across the corridor, being intermittent and localized around active work areas. The potential for impact is particularly significant in proximity to sensitive receptors such as schools, health centers, a hospital, and residential areas identified in Tables 7-10 and 6-3. These receptors include, among others, EPC Alberto Joaquim Chissano (Nhamapaza), all of which are located near the road alignment. The cross-reference to this information is essential for identifying locations where stricter control and monitoring of noise and vibration must be implemented, given their direct relevance to community well-being.

Although the N1 road does not traverse densely populated centers, certain sensitive sites are situated close to the road and therefore require reinforced mitigation measures. Noise and vibration effects are expected to be temporary and mostly confined to the rehabilitation phase, diminishing once the works are complete.

Mitigation measures

- Technical design of the subproject must comply with international and national noise standards, particularly at sensitive locations identified in Table 7-10 and 6-3.
- Implement stricter noise and vibration control procedures at receptors closest to the road, such as schools and health centers, by scheduling the noisiest works outside teaching or consultation hours, using well-maintained and silenced equipment, and employing low-vibration construction methods.
- Inform nearby communities in advance of upcoming noisy or vibration-generating activities, specifying timing and duration.
- For works near schools, health centers, and residential areas, ensure off-site daytime noise levels do not exceed 55 dB(A) during a one-hour period, and within worksites classify the activity as "Light Industry", keeping exposure for workers below 50–65 dB(A) over an eight-hour shift.
- Identify and assess project-associated facilities (e.g., quarries, asphalt plants) and implement mitigation measures to control noise and vibration at their source.
- Source construction materials such as gravel and sand from licensed suppliers operating in compliance with environmental and safety standards.
- Fit all heavy equipment and machinery with effective noise control devices (e.g., silencers and mufflers) and ensure proper maintenance at all times.
- Use modern asphalt plants equipped with noise enclosures and damping systems, and construct barriers or partitions to reduce sound propagation to nearby receptors.
- Provide all workers with appropriate personal protective equipment (ear protectors) in areas of high noise exposure.
- Train and orient drivers and machine operators on good practices, including responsible driving, avoidance of unnecessary idling, and switching off engines when not in use.
- Optimize vehicle and machinery movement to minimize cumulative noise generation and vibration exposure.
- Conduct regular medical hearing checks, at least quarterly, for workers exposed to elevated noise levels.
- Maintain a noise and vibration monitoring program, prioritizing the sensitive receptors listed in Table 7-4, to ensure continuous assessment and prompt corrective action if threshold levels are exceeded.

7.3.2.2 Biological Impacts

a) Increased risk of loss of biodiversity (Fauna & Flora) and natural habitats

The project activities will have direct and indirect impact on the biodiversity and natural habitats during road rehabilitation and site office construction phase of the subprojects through clearance of vegetation/habitat(s) for widening of corridors (although restricted to area within the existing PPZ) and for construction of associated facilities (e.g. campsites) as well as for access roads and use of quarry and borrow pits to obtain construction materials for road rehabilitation works.

Animal movements across the N1 of leopard, lion, elephant, buffalo, kudu and other smaller animals have been noted in the Project area below:

Locations identified for Lot 2 km84-168 Gorongosa to Caia:

- 18.233835°, 34.404710°- Piro (approximate chainage km115 + 400)
- 18.234497°, 34.413110° - Piro (approximate chainage km116 + 500)
- 18.113897°, 34.877284°- Ndoro (approximate chainage km166 + 400)
- 18.113600°, 34.896571°- Ndoro (approximate chainage km168 + 900)

The risk of hunting of species of elephant, buffalo, kudu and small antelope such as suni is noted in the area of Ndoro.

Results of the wildlife permeability study are identified in the operation and maintenance phase, but it should be noted that measures should be implemented during construction phase.

The definition of "no-go areas" within the project area remains somewhat unclear due to gaps in Mozambique's legal framework on conservation zones. According to Decree No. 89/2017 of December 29, conservation protection zones are divided into two main categories: a) Total Conservation Areas, which are strictly protected and where any form of resource use is prohibited; and

b) Conservation Areas for Sustainable Use, which include buffer zones, hunting concessions (Coutadas), and forestry concessions, where some controlled activities may be authorized.

Although the decree outlines the rules for creating and managing these areas, it does not clearly specify which activities are permitted within sustainable use areas. Instead, it requires any entity intending to operate there to first obtain authorization from the relevant management authority with the issuance of a permit.

Under this project, borrow pits, quarries, and campsites must not be established within Total Conservation Areas, such as the Gorongosa National Park (GNP) or the Marromeu Complex, as these are considered legal "no-go areas." Additionally, they may only be established inside the Conservation Areas for Sustainable Use, such as inside the GNP Buffer Zone or within Coutadas, located to left and right of the N1 road, respectively with all necessary permits/licenses from relevant authorities in place, including all environmental and mining licenses, prior to use of the resource.

Furthermore, during project implementation, close coordination with GNP will be essential, as the Park leads several key monitoring programs, including the Baseline Biological Exploration of the Greater Gorongosa Ecosystem and aerial wildlife counts. These initiatives mainly focus on wildlife tracking and anti-poaching efforts.

Effective environmental management will also require collaboration with other authorities, such as the Republic of Mozambique Police, Serviços Distritais de Atividades Económicas (SDAE), and ANAC, since monitoring of wildlife-vehicle collisions is outside GNP's current mandate, and these authorities are responsible for the buffer zone and other conservation areas for sustainable use. However, these institutions currently lack detailed, georeferenced wildlife data, limiting the ability to identify potential wildlife movement corridors along the N1. Care should also be taken while recording or using this data so as not to inadvertently increase the risk of wildlife poaching.

Direct, indirect and cumulative risks and impacts from vehicles and workers are expected. The construction trucks will be passing through this section of the road while carrying construction/rehabilitation materials. The movement of vehicles has potential to cause fatalities of wild animals.

In addition, the road rehabilitation and improvement works has great potential to create business opportunities for local communities residing in these targeted sections of the N1 corridor. However, due to no fire policy, workers will not be allowed to use firewood or charcoal in the project area during the road rehabilitation.

Rehabilitation or substitution of bridges along the target sections will generate debris (e.g. sediments and fine concrete particles), which if left unattended may enter into the rivers and streams and pollute the water thereby affecting the aquatic fauna and water end-users downstream. Additional pollution could occur if there was leakage of toxic chemicals and oils into the water especially during the rehabilitation of the section of the road and bridges that have been identified for rehabilitation and/or substitution. Transported and drop-off silts and sediments from the road rehabilitation section and bridges to be rehabilitated may negatively affect spawning grounds for aquatic fauna (e.g. fish and frogs, etc.).

In addition, construction of detours within the PPZ, and unsustainable mining of quarries and borrow pits and use of rivers (Primary suppliers) to obtain construction materials may lead to water pollution due to transportation of soil silts and sediments by rainwater and wind into nearby water bodies. The transportation of loose soils into nearby water bodies may cause high water turbidity and pollution of water if left unchecked, thereby affecting water end-users downstream, aquatic fauna (especially during spawning season) and local ecosystem services found in the project area and beyond.

Mitigation measures

- Avoid extracting resources from the sensitive areas located inside the Coutadas and GNP buffer zone where possible, and if so, only under authorized use with all environmental and mining permits/licenses in place;
- Develop and implement Code of Conduct and Disciplinary/ Penalty measures for workers;
- Develop Concept designs with road safety measures – warning signs and traffic calming measures (e.g. strip rumble surfaces and humps), light deflectors on roadside to reduce wildlife crossings;
- Prohibit wildlife poaching;
- Prohibit workers from using firewood/charcoal;
- Avoid cutting down any trees outside the project impact area;
- Do not cut any trees with bird nests and holes;
- Open canteens where workers can buy meals and/or provide food to workers to avoid cooking (remove demand for firewood and charcoal);
- Plant three site indigenous shrubs/trees for every single shrub/tree to be cut down during land clearing in an agreed area (by Contractor, Supervision and community);
- Prohibit introducing invasive alien plant species in the project sites. Prior to civil works commencing, C-ESMP must identify main invasive alien species of flora existing along the road section to be rehabilitated and remove them before civil works start. Any green waste produced can either be crushed/ground or burnt, to avoid further contamination in disposal areas;
- Develop and enforce No Fire policy in the project area;
- Prohibit workers from buying bush meat from local communities;
- Enhancing speed regulations, and enforcing lower speed limits in areas with frequent wildlife crossings will help reduce collision risk;
- Improvement of animal movement mapping, to better monitor and understand key animal movement corridors across the N1 road, with a focus on migratory routes, breeding areas, and water sources. This will help identify areas where animals, particularly large mammals like elephants and antelopes, are most likely to attempt crossings, but without risk of information being potentially used by poachers to harm wildlife;

- Monitoring of wildlife to include all relevant stakeholders including GNP, ANAC, BIOFUND, Police, etc.;
- Launch campaigns to educate drivers on wildlife risks, including signage, speed reductions in key areas, and information about wildlife crossings. This will eventually help involve local communities and park authorities in monitoring and managing wildlife passages, which can increase ownership and long-term success;
- Avoid excavating in all water crossings;
- Avoid clearing trees, grass, plants, and shrubs outside the project impact area to protect riparian vegetation and reduce soil erosion;
- Construct physical barriers (e.g., silt trap fences, sediment basins, containment booms) around bridges under rehabilitation or replacement to prevent contamination of water bodies with construction debris, particularly concrete waste and other suspended solids, whenever necessary;
- During bridge works, collect and contain all concrete residues and wash water from concrete mixing, curing, or cleaning activities to prevent their discharge into rivers or streams;
- Preserve riparian vegetation around bridge abutments and approaches, replanting where necessary to stabilize banks and maintain water margin integrity;
- Include these measures in ESMP and Bidding Documents Bill of Quantities.

7.3.2.3 Socioeconomic Impacts

a) Increased risk of the spread of HIV, AIDS and STIs

During the construction phase, a number of workers are expected to be employed at the project site to implement different activities. It is anticipated that both skilled and unskilled workers will be employed. These workers will be receiving salaries and wages, which will consequently improve their financial and social status in the society. Since some of the workers will be far away from their spouses, some may engage in sexual relationships with either fellow male/female workers or community members in exchange for money, food and other items. In 2021, the prevalence of HIV/AIDS in Manica and Sofala was about 7.9% and 13.2% respectively, among people aged from 15 years old.

The areas most at risk are in peri-urban areas for the Km84-168 Gorongosa to Caia section is Nhamapaza. This kind of sexual relationship may result in the spread of HIV and AIDS, or STIs among workers and/or between workers and the community, including risks of SEA/SH. In addition, contraction of HIV and STIs will be spread further to their families thereby increasing the spread of the HIV and AIDS and STIs in the country. This impact applies to all project Components 1 to 5.

This is an impact likely to occur in the project area with long term effects affecting people at local and regional level considering its nature in terms of spreading. In addition, this is a high intensity impact that can lead to permanent changes in the natural and social functions and processes in the affected communities. It is an impact with high significance that requires adoption of the mitigation measures below.

Mitigation measures

- Develop and implement HIV and AIDS Workplace Policy;
- Regularly sensitize workers and local communities about HIV and AIDS, and STIs, and links with risks of SEA/SH;
- Distribute HIV and AIDS information and education materials to workers and local communities;
- Mobilize and put condoms in strategic places where workers can easily access them;
- Allow infected workers to access Anti-Retroviral and STIs Treatment (ART) from hospitals and health centers;
- Provide financial literacy sensitization programs to the surrounding local communities;
- Employ people from the surrounding project area to minimize promiscuity; and
- Sensitize workers on putting their income to productive use.

b) Increased Occupational Health and Safety (OHS) Risks and Hazards

During the rehabilitation and construction works, the implementation of the project activities will increase OHS risks and hazards of the workers and visitors. These will result in increased risks and hazards of occupational health and safety such as communicable diseases, accidents and injuries thereby decreasing the quality of health of workers. The contractor will, therefore, implement appropriate mitigation measures to protect workers and visitors from increased risks and hazards of occupational health and safety, such as those listed below.

- Define an Occupational Health and Safety Policy and have an OHS plan for all the construction activities;
- Prepare method statements and risk assessments for prior approval by the Engineer before commencement of activities.
- Orient workers every day on dentification of potential risks and hazards and application of appropriate mitigation strategies;

- Prepare and implement emergency preparedness response, including extreme events (e.g. cyclones, floods, storm rains, etc.). Emergency response extends to production and use of hazardous substances such as hot asphalt;
- Maintain a well-stocked first aid kit at the project area;
- Train some workers on application of First Aid and use of First Aid Kit;
- Develop and implement penalties for recurrent non-compliances of mitigation measures related to the Contractor OHS plan;
- Develop and implement a Code of Conduct, which includes prohibitions against SEA/SH and any sexual contact or activity with minors (persons under 18);
- Implement good house-keeping practices such as sorting and placing loose pieces of construction materials or demolition debris in established areas away from foot paths.
- Train workers in appropriate lifting and material handling techniques;
- Prohibit working against working with defective equipment;
- Implement good housekeeping by regularly cleaning excessive waste debris and wastewater spills from the construction sites;
- Construct temporary shade places at each project site for workers to rest to avoid heat related hazards;
- Ensure sufficient barricading to protect workers and the public from risks of construction activities;
- Ensure workmen’s compensation policy is up to date;
- Ensure all drivers sign a vehicle policy for safe driving behavior and be aware of consequences for infringements of the vehicle policy.
- Ensure all vehicles are licensed and registered with up-to-date insurance policies.
- Ensure all vehicles and machinery are well maintained and records kept up to date. Daily vehicle checks should be performed by all drivers and any anomalies attended by the workshop mechanics timeously, all evidences to be kept on file;
- Prohibit the use of drugs and alcohol;
- Provide for a safe work environment and adequate safety measures, training and protective equipment to all workers including hand, head, eye and ear protection and safety footwear; and
- All workers shall be provided with adequate PPE (Personal Protective Equipment) for the tasks required to be undertaken, including sufficient respiratory equipment for activities generating high dust levels and adequate protection for working with hot asphalt.

Specifically, occupational health and safety issues during the rehabilitation and road improvement include the following:

Physical hazards: Physical hazards represent potential for accident or injury or illness due to repetitive exposure to mechanical action or work activity. Single exposure to physical hazards may result in a wide range of injuries, from minor and medical aid only, to disabling, catastrophic, and/or fatal. Multiple exposures over prolonged periods can result in disabling injuries of comparable significance and consequence.

Mitigation measures

- Design machines to eliminate trap hazards and ensuring that extremities are kept out of harm's way under normal operating conditions.
- Turn off, disconnect, isolate, and de-energize (Lock Out and Tag Out) machinery with exposed or guarded moving parts.
- Design and install equipment, where feasible, to enable routine service, such as lubrication, without removal of the guarding devices or mechanisms.

Chemical hazards: Chemical hazards represent potential for illness or injury due to single acute exposure or chronic repetitive exposure to toxic, corrosive, sensitizing or oxidative substances. They also represent a risk of uncontrolled reaction, including the risk of fire and explosion, if incompatible chemicals are inadvertently mixed.

Mitigation measures

Chemical hazards can most effectively be prevented through a hierarchical approach that includes:

- Replace the hazardous substance with a less hazardous substitute;
- Implement engineering and administrative control measures to avoid or minimize the release of hazardous substances into the work environment keeping the level of exposure below internationally established or recognized limits;
- Stored all hazardous chemicals in a secure area marked with adequate warning signs and provision for emergency response in case of accident;
- Reduce number of employees exposed to chemical hazards to a minimum, ensure adequate training of use of hazardous substances and provide proper protective equipment must be used for substances such as hot asphalt including adequate respiratory equipment and body protection.

Confined spaces: can occur in enclosed or open structures or locations. Serious injury or fatality can result from inadequate preparation to enter a confined space or in attempting a rescue from a confined space.

Mitigation measures

- Implement engineering measures to eliminate, to the degree feasible, the existence of and adverse character of confined spaces;
- Adopt measures to avoid employees working in confined spaces for a long time in area without sufficient ventilation;
- Provide permanent safety measures for venting, monitoring, and rescue operations of a confined space and use the permit to work system to ensure adequate measures are considered.

Working at Heights: Fall prevention and protection measures should be implemented whenever a worker is exposed to the hazard of falling more than two meters; into operating machinery; into hazardous substances; or through an opening in a work surface. Fall prevention / protection measures may also be warranted on a case-specific basis when there are risks of falling from lesser heights.

Mitigation measures

- Conduct detailed risk assessment prior any works starting;
- Provide appropriate training to all workers working at heights (e.g. use of equipment such as scaffolding and ladders), emergency evacuation procedures and proper use of PPE;
- Choose appropriate equipment (e.g. suitable ladders and scaffolding, use of equipment that meets safety standards). Scaffold plans should be approved prior to implementation;
- Install guardrails with mid-rails and toe boards at the edge for any fall hazard area; and
- Develop and implement safe work practices (e.g. avoid working at height wherever possible).
- Use of fall prevention devices, including safety belt and lanyard travel limiting devices to prevent access to fall hazard area, or fall protection devices such as full body harnesses used in conjunction with shock absorbing lanyards or self- retracting inertial fall arrest devices attached to fixed anchor point or horizontal life-line;
- Appropriate training in use, serviceability, and integrity of the necessary PPE; and
- Inclusion of rescue and/or recovery plans, and equipment to respond to workers after an arrested fall.

Risk of fire and explosion: During the rehabilitation and site office construction phase, fires and/or explosions may occur resulting from ignition of flammable materials/chemicals, electrical faults, kitchen camp site facility or gas cylinders. This could lead to loss of property as well as possible injury or fatalities to project workers. This impact may delay the completion of the road rehabilitation works.

Mitigation measures

- Install fire detectors, fire-fighting equipment and fire-alarm systems at the campsites and site office;
- Conduct regular inspections of machinery and equipment service and maintain all electrical equipment as per manufacturer recommendations;
- Eliminate common ignition sources (e.g. smoking, welding, open flames, cutting, etc.) at the campsites and site office;
- Implement good housekeeping practices (e.g. maintain cleanliness by controlling fugitive dust) at the Campsites and site office;
- Train and orient some employees on fire hazards, prevention techniques, emergency procedures, and proper use of firefighting equipment; and
- Prohibit fires for cooking meals by workers.

Health and Sanitation:

Health and safety of workers and other people around the project shall be one of the most important aspects to be considered by the contractor. The project will be implemented within area that is endemic to Malaria and HIV and AIDS. The spread of HIV and AIDS as well as risks related to SEA/SH is likely to increase, especially during road rehabilitation and site office construction, when workers from outside the project area are brought to the project site and live there for long periods of time without their respective spouses. During the project cycle, interaction between workers and local communities, as well as among workers themselves may result in casual sexual relationships, which could lead to the spread of HIV and AIDS and/or STIs and other communicable diseases (e.g. cholera, covid-19) as well as increased risks related to SEA/SH. The contractors shall adopt procedures to help reduce the risks and impacts associated with health and sanitation.

Mitigation measures

- Develop and implement workplace hygiene and sanitation policy;
- Provide workers in campsites, site office and front workers with well-labelled dustbins;
- Implement good housekeeping practices (e.g. maintain cleanliness by controlling fugitive dust) at the campsites, rehabilitation site and at the site office;
- Wash utensils regularly with clean water;
- Wash hands regularly with plenty of water and soap;
- Drink and use safe potable water, i.e. ensure water from wells/boreholes is tested for

potability and treated appropriately if required (use of chemicals or boiling), prior to consumption;
- Boil, cook food well and keep it covered before eating;
- Provide workers with separate mobile toilets for female and male workers;
- Allow workers to access treatment when sick; and
- Provide workers at work fronts with potable water for drinking (e.g. from water dispensers or bottled water).

c) Increased risks to Community Health and Safety

It is not yet known exactly where camp sites will be located, but communities located in the peri-urban areas of Gorongosa, along the N1, or located near borrow pits/quarries which may be employed in the rehabilitation and construction works. In addition, heavy vehicles carrying construction materials will be moving through busy and overcrowded trading centers, villages, schools and health centers to load and off-load materials at the road rehabilitation and construction sites. Increased movements of the heavy vehicles increase community health and safety risks (particularly to children) such as accidents, injuries and even fatalities due to over speeding of vehicles.

Poor traffic management in road construction/rehabilitation and improvements zones presents a potentially deadly hazard to other drivers, cyclists and pedestrians.

Mitigation measures

- Develop and implement a robust traffic management plan, with specific traffic control sketches for complicated traffic management sections, e.g. half-width traffic management;
- Develop community health and safety plan:
- Restrict access to/barricade the rehabilitation/construction site, excavated roadside drains and borrow pit sites and use warning signs;
- Raise sensitization campaigns and awareness on traffic management in community areas and on the project site;
- Limit vehicle speed to 20 km/h or less on roads that are close to populated areas, trading centers, schools and health centers;
- Develop and implement borrow pit management plan; and
- Locate borrow pits and quarry mines (500 m -1.0 km) away from schools, health centers, markets, churches/mosques, play grounds, and ecologically sensitive areas.
- Signs must be kept clean and well maintained if they are to be effective;
- Develop specific measures for pedestrian safety, such as crossing locations taking into consideration the community's preference, as well as pedestrian safety awareness. This

includes considering pedestrian access on any detours that may be required.

- Press and radio releases to warn drivers and pedestrians of what to expect at a site, thus must minimize impatient and dangerous behavior;
- Workers who control traffic must be properly trained; and
- Traffic controllers and general road workers should wear suitable conspicuous clothing to ensure that they can be seen by motorists.

d) Increased risk of disruption of traffic due to road rehabilitation and improvement works

During the road rehabilitation and maintenance works, traffic will be disrupted. This situation will increase volume and congestion of vehicles along the sections of the N1 being rehabilitated. This may lead to changes in travel speeds, travel modes, traffic composition and patterns causing traffic and safety risks which may lead to accidents. including delays in delivering goods and services and reaching passengers' destinations on time.

Mitigation measures

- Develop and implement a robust traffic management plan;
- Ensure all vehicles adhere to maximum speed limits of 30 km/hr in areas where activities are being undertaken;
- Provide temporary detour/diversions for some vehicles to avoid obstruction of traffic, where possible;
- Provide adequate road warning signs to properly guide traffic, control speed and warn road users about the construction works; and
- Deploy flag persons who are well trained in understanding how to undertake good traffic management, particularly half-width traffic management.

e) Increased Risk of spread Covid 19

Data from 2020 to 2022, indicates that Sofala province had 14,245 positive cases of Covid 19. From this figure, in the Km84-168 Gorongosa to Caia section 283 cases. Although Covid 19 is no longer considered a pandemic public health issue during the rehabilitation and works phase, it is anticipated that there will be a lot of workers and job seekers at the proposed project site.

Due to overcrowding and working in confined environment during the rehabilitation and construction phase, it is anticipated that this situation may increase the spread of Covid-19 among workers, job seekers, as well as the surrounding communities.

Proposed mitigation measures to be implemented by the Contractor and project personnel are as follows.

Mitigation measures

- Enforce all workers to wash hands regularly with soap or use hand sanitizer;
- Reduce overcrowding by dividing workers into small groups of 5-10 people;
- Workers must cover their mouth and nose when coughing and sneezing using handkerchiefs or tissue paper or sneeze into a flexed elbow;
- Provide face masks to all workers;
- Workers should keep a social distance of one metre from one another all the time;
- Sensitize workers regularly to refrain from touching their faces, mouths, noses and eyes and to avoid handshakes; and
- Isolate any worker who has symptoms associated with Covid-19 from others.

f) Increased risk of the spread of cholera and communicable diseases

It is anticipated that during the road rehabilitation and office site construction phase, lack of personal hygiene, drinking water from unprotected boreholes and wells, and eating contaminated food may result in waterborne diseases such as cholera and other communicable diseases. This may lead to morbidity and mortality among workers. This situation may delay the completion of the road rehabilitation works and therefore hinder the development of the country.

Mitigation measures

- Wash hands and utensils regularly with clean water;
- Drink and use safe water for cooking (e.g. water drawn from taps, boreholes, and bottled water);
- Treat water from wells boreholes with chlorine to kill germs that causes cholera and other diseases, if water quality testing requires this;
- Boil or filter drinking water drawn from wells and boreholes; and
- Boil, cook food well and keep it covered before eating.

g) Increased Risk of GBV/SEA/SH and Violence Against Children (VAC)

Contractors and workers on site during construction phase may indulge in crimes and illicit behavior such as rape, physical assault, sexual harassment, discrimination and sexual exploitation and abuse, use of provocative and insulting language, other forms of gender-based violence etc.

Although the project will prohibit contractors to hire children for construction works, there are other possibilities of use of child labor by workers or other project personnel for domestic work or other household chores, such as washing clothes, cleaning, cooking, etc. In addition, some parents may see the commencement of the project in their area as an economic opportunity and as such, may send their underage children to sell various food items to the workers. Furthermore, some workers may entice young girls or boys under the age of 18 to have sex with them in exchange for money. All these are forms of GBV as well as violence against children (VAC), which will not be tolerated at the project site. In this respect, the contractor will put in place appropriate mitigation measures to safeguard the rights of underage girls and boys, as well as safeguard all project personnel and surrounding community during the implementation of the project at all times.

Mitigation measures

- Develop and implement GBV/SEA/SH workplace policy;
- Periodically sensitize workers and surrounding local communities on causes and consequences of GBV/SEA/SH
- Develop and implement a clear GBV reporting procedure, including referral pathway for GBV survivor support services
- Implement the Code of Conduct (CoC) for a contractor and workers for GBV/SEA/SH;
- The contractor and all workers shall sign and adhere to Code of Conduct (CoC);
- Institute disciplinary actions (job dismissal, interdiction) against perpetrators of GBV; and
- Take and/or report perpetrators of GBV/SEA/SH to relevant authorities for prosecution.

In addition, the contractor is required to:

- Prepare and implement a C-ESMP that includes a detailed SEA/SH Action Plan, based on a Risk Assessment; identify and map locations of high risk, such as areas with presence of sex workers; identify and map entities that receive GBV survivor complaints; identify and map entities that provide support to GBV survivors and appropriate mitigation actions under the C-ESMP;
- Develop and implement the project’s Code of Conduct (CoC) prohibiting acts of SEA/SH as well as sexual contact and activity with minors (persons under 18);
- Orient all employees on the project’s Code of Conduct, and other standards, such as ESHS and OHS standards;
- Ensure all employees sign the project’s ‘Individual Code of Conduct’ confirming their agreement to comply with ESHS and OHS standards;
- Establish and operationalize GRM that will address issues of GBV/SEA/SH, forced labor and child labor risks;

- Create partnerships with local NGOs to report to the relevant authorities any incidences of GBV/SEA/SH/IPV for appropriate action.
- Implement information and awareness raising campaigns for community members, specifically women and girls including information to host community about the contractor's policies and Worker Code of Conduct (where applicable).

h) Increased Risk of Labor Influx to the project sites

It is anticipated that during the construction phase, the proposed project will attract job seekers as well as migrants from neighboring provinces and districts or other parts of Mozambique. Local residents will be competing for work with national migrants, and this may cause conflict among job seekers. Labor influx and migrants who might want to be residing close to the improved and maintained roads as well as in trading centers to engage themselves in various business opportunities easily will result in increased pressure on the ecosystems functions its carrying capacity. This situation may lead to several environmental and social problems such as erection of temporary huts near the project site, overcrowding, spread of communicable diseases such as Covid-19, HIV and AIDS, and STIs, competition for limited resources such as water and health services, increased cases theft and robbery, and improper disposal of both liquid and solid wastes. These problems may lead to the outbreak of waterborne and communicable diseases, bad odors, and outbreaks of pests that can transmit disease causing organisms.

Labor influx to the project sites may also result in an increased risk of human trafficking, violence against children (VAC), gender-based violence, sexual exploitation and abuse and sexual harassment (GBV/SEA/SH) within local communities or the work sites. There is also the risk of accidents/ incidents related to security and health and safety and increased sex workers.

For the Km84-168 Gorongosa to Caia section, Nhamapaza, Nhaperua, Cungue, Gumbarassai and Sassajale, the main villages along the project area there are people from different ethnic groups or countries (e.g., Somalia, Bangladesh, etc.) living in these areas. The additional labour influx would bring in even more different ethnic groups or countries.

This negative impact definitely will occur as it is expected that people from other communities will move to the project area seeking employment opportunities. In terms of extent this impact is local, as will affect only areas where the project will be implemented and is also considered short-term, only for the duration of construction works in specific sites. The impact intensity is low assuming that at community level the natural, cultural and social functions and processes continue, although with minor changes because of increased competition for job opportunities. The impact significance is low, if the mitigation measures listed below are adopted to minimize this impact.

Mitigation measures

- Develop and implement Contractor's Labor Management Plan in line with Labor Management Procedures (LMP) and World Bank ESS2;
- Employ most of the unskilled workforce from the surrounding project area;
- Inform job seekers regularly about jobs available and where they can apply for available positions;
- Engage local authorities and leaders in each sub project area to assist in recruitment of semi and unskilled workers by the contractor;
- Prohibit child labor (under the age of 18 years) working directly or indirectly at the project site;
- Establish a Grievance Redress Mechanism (GRM) for workers that is sensitive to receipt of SEA/SH-related complaints, including relevant referral pathways for survivor support, and a mediation process shall be adopted in case of conflicts between workers and employer;
- Develop and implement robust guidelines to address issues of human trafficking, GBV/SEA/SH and Violence against Children (VAC) and Forced Labor;
- Train local governance institutions and the police to address issues of human trafficking, GBV/SEA/SH, Violence against Children (VAC) and Forced Labor;
- Conduct GBV/SEA/SH awareness raising and train PIU staff and use third party service providers to assist with implementing mitigation measures on labor influx risk related to SEA/SH risk and impacts.

i) Increased Risks of Losse of Cultural Heritage

During the construction phase, project activities such as earth works (excavation, trenching, digging of foundations for camp sites and offices for workers) may result in the damage and degradation of cultural heritage objects and materials that have been in the soil or on land in previous times. Damage to and loss of archaeological objects and/or materials can lead to loss of natural historical cultural herniate resources (e.g., spiritual sites, artifacts, burial sites, pre-historical sites, caves, cave or wall paintings, sculptures, historical iron weapons, etc.). These cultural herniate resources must be preserved to ensure their availability for the benefits of the current and future generations. This impact applies to Components 1 and 2 that focus on road rehabilitation and maintenance.

No sites of cultural heritage were noted in the project area.

Mitigation measures

To safeguard these sensitive sites, the following measures will be implemented:

- Avoid constructing camp sites and offices in any cultural heritage sites;
- Maintain public access to cultural heritage sites (churches/mosques, cemeteries, etc.) at all times during the works;
- Develop and implement chance finds procedure and Cultural Heritage C-ESMP;
- Stop construction works immediately in case of accidental discovery of new artifacts and archaeological sites and resume the works after the site has been archeological discharged by authorized archeologists;
- Mark and map all previously recorded archaeological sites that along the road section prior to commencement of construction work;
- Repair or restore any damage to any known cultural heritage sites; and
- Train project workers on the recognition of sites with historical or cultural value and the actions to be taken in the event of any sites or finds be encountered.

- Install solid fencing/acoustic barriers on the construction side facing the cemeteries, particularly at the 6 m site.
- Clearly mark cemeteries as sensitive archaeological areas (no storage, parking, or worker access permitted).
- Use quieter equipment (e.g., mufflers, well-maintained machinery) and avoid vibration-intensive methods near cemeteries (e.g., use augers instead of driven piles).
- Conduct continuous noise monitoring at the 6 m site and periodic monitoring at the 13 m site.
- Train workers on respectful behavior (no loitering, eating, or inappropriate conduct near cemeteries).
- Provide advance notice (minimum 48 hours) to local communities before noisy or disruptive works.
- Appoint a focal point/community liaison officer to address cemetery-related concerns.
- If graves, artifacts, or remains are unexpectedly encountered, immediately stop work and notify the relevant authorities.

j) Loss of land and property within PPZ

The implementation of the construction/road rehabilitation activities is expected to have an impact on land acquisition and loss of property (e.g., vending stalls, hawkers, houses, small markets, agricultural field, fruit trees, etc.). Although most of the construction is to take place inside the partial protection zone (PPZ) of a 30m width either side of the road, these areas were noted to be occupied (encroached upon) by local communities with permanent or non-permanent infrastructure. Additional land acquisition may be required for establishment of workers' camp sites, detours, access roads to existing quarries and borrow pits as well as areas for establishing new borrow pits or quarries – if required.

Mitigation measures

- Ensure road rehabilitation and improvement works are implemented within the PPZ, in order to avoid or minimize resettlement;
- Avoid opening of new quarries and borrow pits;
- Obtain quarry and gravel from existing sites of licensed suppliers who have an ESMP in place;
- Carry out sensitization meetings on planned project activities and likely impacts including loss of land/property with local communities directly or indirectly affected, in the case of additional land requirements for detours/access roads/borrow pits/quarries;
- Develop and implement livelihood restoration plans (LRP) for the affected people that are vulnerable.

k) Disruption of utility services

In the project area there are several public utility services such as power lines, telephone poles, fiber optic cables and water pipelines installed within the road reserve area (30 meters) which is the PPZ. In peri-urban areas of Nhamapaza (Km84-168 Gorongosa to Caia) there are power lines, telephone lines and underground water pipelines. It is anticipated that during the road rehabilitation/construction phase these public utility services located within PPZ may need to be relocated to allow the rehabilitation and construction works to take place. As a result, people living in or vicinity of the project will be affected as electricity, water and communication services could be disrupted, and hence require appropriate mitigation measures.

Mitigation measures

- Inform the public utility service providers in advance of planned road rehabilitation works and the need to relocate their utility services;
- Restore utility services as soon as possible;
- Provide information to the users about disruptions and reinstatement of public utility services
- Assist users on identification and recommend use of alternative services providers, whenever possible.

l) Loss of business infrastructure

In the Km84-168 section Gorongosa to Caia there are11 business infrastructures affected in total. 9 stalls for selling food and beverages sales and two shops or warehouses. This is a medium impact occurring locally of short-term duration, but with high intensity because the vendor stalls will be permanently demolished or removed from the project area, changing the natural and social functions and processes in the affected communities. Thus, as losses of business infrastructure will affect the household incomes, the following mitigation measures should be adopted.

Mitigation measures

- Prepare a Compensation Plan and document all the compensation process;
- Provide alternative land for businesses or market establishment outside the Road Reserve Area (PPZ);
- Provide a compensation for demolished business infrastructures (e.g. shops, vending stalls, etc.);
- Develop and Implement a Livelihood Restoration Plan (LRP) for all affected people, including vulnerable groups

m) Loss of incomes and livelihoods

In the project area, formal and informal businesses are the main income source and livelihood for the affected people. A detailed RAP was prepared for all those affected by the project in this section of the N1 to be rehabilitated and submitted separately. Below is a summary of the findings.

In the Km84-168 Gorongosa to Caia section, aside from the 11 business infrastructures affected in total (9 stalls for selling food and beverages sales and two shops or warehouses), there are 4 businesses that will be permanently disrupted in the project area. In addition, an existing market will be transferred outside the PPZ, and losses or a reduction in household incomes and livelihoods are expected.

This local and short-term impact has high intensity considering that vendor stalls will be permanently demolished or removed from the project area and businesses will be relocated to other areas changing the natural and social functions and processes in the affected communities. Therefore, this is an impact with medium significance that can be mitigated following the adoption of the measures below.

Mitigation measures

- Provide compensation to replace the income losses for all affected people in these businesses. The compensation amount can be calculated based on business profits earned by each individual in the business;
- Provide alternative land for businesses and/or establishment of a new market outside the PPZ;
- Hire the affected people or their relatives to work for the project (e.g., construction workers, affiliates in micro-enterprises, GBV activists, etc.);
- Provide training on financial literacy for affected people (e.g., Management of the compensation payment and small business management)
- Support affected people (business owners) and their workers to find other job opportunities.

n) Increase of social conflicts

The primary driver of social conflict is economic inequality, particularly disparities in wealth, income, and access to resources. Informal and formal business is the major livelihood strategy among affected people. As some businesses will be affected in their current locations, the livelihood strategies will be reduced, and social conflicts can occur due to competition by existing job opportunities in the project area or its vicinity. For instance, job opportunities opened by the contractor could be limited to specific skills and unskilled people will be excluded. Furthermore, considering that some business operators will be displaced from the project area, product shortage and price increases are expected to increase, limiting the affordability of food products. Unhappy people could increase the number of labor strikes and contribute to social conflicts.

Social conflicts have a low probability of occurrence and would be local with short-term impact. However, the intensity of social conflicts is high as they can lead to minor changes in the natural and social functions and processes in the affected communities. Then, this is an impact with low significance if the mitigation measures below are implemented.

Mitigation measures

- Disclose any job opportunity related to the project
- Prioritize hiring of local labor for the project (e.g., Construction works, affiliates in micro-enterprises, GBV activist, etc.);
- Provide training on road maintenance for community members, mainly women in order to provide services to the project.
- Support local entities to undertake price inspections in the local markets, whenever possible;
- Support local entities in organization of trade fairs, whenever possible;

o) Increased vulnerability of vulnerable groups

In the project area, there are various groups considered vulnerable due to their inability to cope with and participate in decision making regarding project interventions.

In the Km84-168 Gorongosa to Caia section, only one person was identified as vulnerable due to their being elderly.

Since the project will demolish business infrastructures that are owned by some members of this group, they cannot successfully relocate without adequate support and assistance.

This is an impact with medium significance considering its potential to permanently change the natural and social functions and processes of vulnerable people to cope with the resettlement process due to their financial or other difficulties. This is a medium-term impact that occurs at local level, with medium intensity because changes will affect a small number of people and can be reversible over the medium term. The mitigation measures presented below can reduce this impact.

Mitigation measures

- Ensure that vulnerable group are informed and participate in project-related activities (e.g., public consultation, decision making about resettlement areas, etc.)
- Sensitize and psychologically prepare the group for the entire resettlement process;
- Prioritize this group in all mitigation measures related to them;
- Provide a subsidy for this specific group as way to become self-sufficient and resilient to economic stress;
- Provide assistance in transport during resettlement process.

7.4 Operation and Maintenance Phase

7.4.1 Positive Impacts during Operation and Maintenance Phase

a) Improved connectivity and access to markets within the corridor and beyond

The project will improve the road network between the north and the south by rehabilitating and improving damaged selected road sites within the corridor. This will result in a reduction of costs for transportation of goods and services in the corridor and will improve road safety. In addition, farmers and entrepreneurs will be able to access potential markets for their agricultural crops, goods and services beyond the corridor.

Mitigation measures

- Regular maintenance of the infrastructure;
- Establish/Support/strength community policing committees at strategic places along the corridor to monitor and curb vandalism of road signs along the corridor; and
- Robust Supervision and Monitoring of maintenance of the infrastructure.

b) Improved road safety

Installation of important road safety structures such as road signs, rumble strips, humps and rest stops at appropriate places along the corridor coupled with speed law enforcement by the traffic police will significantly help improve safety and rad accidents and also reduce vandalism of road signage as far as safety of road users are concerned.

Enhancement measures

- Sensitize communities to care for road signs
- Establish/Support/strength community policing committees along the corridor to monitor and curb vandalism of road signs along the corridor;
- Regular maintenance of the road infrastructure;
- Replacement of signage once vandalized.

c) Reduced costs of transportation of goods and services due to less consumption of fuel or gas by vehicles

During the Operation phase of the Project, vehicles travelling along the N1 corridor will be using less fuel or gas per km due to the road rehabilitation, improvement and maintenance of each bumpy and severely potholed sections of the N1 corridor. The rehabilitation, improvement and maintenance of each identified section of the road will result in reduced costs for transportation of goods and services, including lower emissions of GHGs such as carbon dioxide, and methane among others. The reduced GHG emissions will lead to reduced global warming and reduce the effects of climate change.

Enhancement measures

- Regularly inspect and maintain the road surface by sealing any potholes, cracks and other surface issues; and
- Regularly maintain any broken roadside culverts or drainage pipes.

7.4.2 Negative Impacts during Operation and Maintenance Phase

a) Increased deforestation along the rehabilitated road sections

The road rehabilitation and improvement will open the corridor as people and their goods and services will be transported easily from north to south and vice versa to urban centers and cities more quickly than before. With the current rate of deforestation taking place within the corridor intended to get wood for charcoal production to be sold in urban centers and cities, it is expected that the rate of deforestation will continue exponentially, and this may lead to loss and fragmentation of natural forests and habitats for biodiversity found in adjacent areas of N1 corridor. No fencing in these areas of the buffer zone of the GNP or *coutadas*, has been foreseen by the design consultants in the concept designs.

Mitigation measures

- Law enforcement must be implemented by appropriate authorities for those found poaching or cutting down trees without authorization;
- Establish roadblocks at strategic places to curb transportation of fuel wood (charcoal, firewood) to urban centers and cities of the country;
- Police and officers from Departments of Forestry and National Parks/Game Reserves shall conduct regular monitoring and spot check of vehicles, in particular, trucks and lorries;
- Impose heavy fines and/or penalties to any contractor or his worker found breaking the Forestry and Wildlife Decrees and regulations.

b) Wildlife population reduction caused by increased hunting, road kills and forestry operations

During the operation phase, higher volumes of traffic and greater speed may lead to risks of loss of wildlife particularly where the N1 traverses *Coutadas*, forest reserves or national parks, i.e., Gorongosa, or the ecological corridors between the protected areas and *Coutadas*. There may be loss of wildlife in these areas that can be hit by vehicles which may also result in road accidents.

<u>Conservation and rehabilitation/construction implications from the wildlife permeability study</u>

The existing N1 road within the Gorongosa ecosystem is currently in poor condition, which limits vehicle speeds and constrains traffic flow between southern and northern Mozambique. This low level of service has the incidental effect of reducing the frequency and severity of wildlife–vehicle collisions, as slower speeds allow drivers more time to react and reduce collision lethality. However, it also restricts economic and social connectivity along the corridor. The proposed rehabilitation aims to improve road surface quality, safety, and reliability, thereby enabling smoother and more efficient transport of people and goods.

As the road already exists, the rehabilitation will not introduce a new linear barrier into the landscape and therefore does not create new fragmentation in a structural sense. Nevertheless, rehabilitation is expected to alter the functional characteristics of the road by increasing average vehicle speeds, improving traffic flow, and potentially attracting higher traffic volumes. These changes may increase the probability of wildlife–vehicle collisions and elevate disturbance levels along the corridor, particularly in ecologically sensitive areas and where wildlife movement overlaps with the road. The primary ecological impact of the project is therefore not the creation of a new barrier, but the potential intensification of its barrier and mortality effects.

The permeability analysis indicates that the surrounding landscape is relatively flat and lacks strongly defined movement corridors that would concentrate animal crossings at specific, narrow locations. Instead, wildlife movement appears to be spatially diffuse, with multiple low-intensity crossing points rather than a small number of dominant corridors. In this context, the construction of large wildlife overpasses or underpasses is unlikely to be ecologically efficient or cost-effective, as such structures are most beneficial where animal movement is naturally channelled through predictable pinch points. Moreover, the installation of continuous fencing along the road could further restrict animal movement, exacerbate functional fragmentation, and interfere with natural ranging behaviour, particularly for wide-ranging species.

These findings suggest that the most appropriate mitigation strategy is not heavy structural intervention, but targeted, proportionate, and adaptive measures aimed at managing incremental risk. Such measures include locally reduced speed limits in high-risk sections, wildlife warning signage, driver awareness campaigns, improved night-time visibility, and the systematic monitoring of wildlife–vehicle collisions. These interventions address the principal mechanism of impact, increased collision risk due to higher vehicle speeds, while maintaining overall landscape permeability and avoiding unnecessary physical barriers.

Taken together, the results indicate that the rehabilitation of the N1 represents an ecologically sensitive modification of an existing infrastructure rather than a fundamentally new disturbance. While the project does not introduce new fragmentation, it may increase functional impacts on wildlife through changes in traffic dynamics. Accordingly, mitigation should focus on managing these incremental effects in a spatially targeted manner, particularly near the Gorongosa National Park buffer zone and other areas of elevated wildlife presence. This approach ensures that the rehabilitation achieves its socio-economic objectives while maintaining ecological safeguards and minimizing unintended impacts on wildlife movement and survival.

The rehabilitation of the N1 road through the Gorongosa ecosystem is expected to modify traffic dynamics, particularly by increasing vehicle speeds and improving traffic flow. While this will enhance transport efficiency, it may also increase the risk of wildlife–vehicle collisions and disturbance to wildlife, especially in ecologically sensitive areas and where wildlife movement intersects the road. To minimise these incremental impacts while maintaining landscape permeability, a set of targeted, non-structural and low-intrusion mitigation measures is proposed that must be embedded in the final design of the road and implemented during the construction phase:

- Speed management and traffic calming - reducing vehicle speed in high-risk sections (km84-94 and km128-138) is one of the most effective measures to decrease both the likelihood and severity of wildlife–vehicle collisions. Locally reduced speed limits should be implemented in areas of elevated ecological sensitivity, particularly where the road intersects the Gorongosa National Park buffer zone and adjacent high-permeability areas. These speed limits should be supported by appropriate road signage, physical speed-calming elements where feasible (e.g. rumble strips or optical speed reduction markings), and enforcement measures to ensure compliance. Lower speeds not only reduce collision probability but also increase driver reaction time and significantly decrease wildlife mortality rates.

- Wildlife warning signage and driver awareness - Targeted wildlife warning signs should be installed in sections identified as having elevated collision risk. These signs should be species-specific where possible (e.g. elephant or antelope silhouettes) and placed strategically in advance of known or predicted crossing zones. In addition, driver awareness campaigns — including informational materials at toll points, service stations, or through transport operators — can further increase driver vigilance, particularly during peak wildlife movement periods such as dawn, dusk, and seasonal migration periods.

- Road design and visibility enhancements - Improving driver visibility reduces collision risk, especially at night and in areas with vegetation close to the road. Vegetation should be managed along the road verge to prevent tall grasses or shrubs from obscuring animals approaching the road. Where feasible, improved road lighting at critical crossing areas can enhance driver detection of animals without creating excessive disturbance to wildlife. Reflective road markings and delineators can also help drivers anticipate potential hazards.

- The mammal identified in the wildlife permeability study with the greatest chance of movement due to its size is the pangolin *(M. temminicki)*. Based on review of the literature, appropriate design consideration for culverts for pangolin and small mammals would be as follows:

  - Size > 1.5 meters
  - Spacing frequency every 0.5 – 1 km in high risk zone for pangolin impact (i.e. if zone is 5 km, then 3 culverts would be needed)
  - Dry ledges or walkways with width > 50 cm
  - Natural substrate flooring > 15 cm over concrete bottom
  - Vegetation for cover appropriate for pangolins should be located at entrances

- Monitoring and adaptive management - a structured wildlife–vehicle collision monitoring programme should be established before and after rehabilitation. This programme should include systematic carcass surveys, incident reporting by road maintenance staff, and collaboration with park authorities and local communities. Monitoring results should be reviewed regularly to assess the effectiveness of mitigation measures and to identify emerging hotspots. If collision rates increase or shift spatially, mitigation measures should be adapted accordingly, for example by extending speed-reduced zones or adding signage in newly identified risk areas.

- Avoidance of extensive fencing and major crossing structures - given the relatively flat terrain in most parts of the area and the absence of strongly concentrated wildlife movement corridors, large wildlife overpasses or underpasses are not considered necessary or cost-effective in this context. Similarly, continuous fencing along the road is not recommended, as it could further restrict animal movement, exacerbate functional fragmentation, and interfere with natural ranging behaviour. The proposed approach therefore prioritises maintaining landscape permeability while managing collision risk through behavioural and operational measures rather than physical barriers.

As mentioned previously, wildlife crossing points were identified:

- 18.233835°, 34.404710°- Piro (approximate chainage km115 + 400),
- 18.234497°, 34.413110° - Piro (approximate chainage km116 + 500)
- 18.113897°, 34.877284°- Ndoro (approximate chainage km166 + 400),
- 18.113600°, 34.896571°- Ndoro (approximate chainage km168 + 900).

Although these may not necessarily be regular crossing areas, and the concept designs contain provisions for additional road safety warning signs, reduced speed limit (from 100 km/h to 60 km/h) over the affected section of road, and traffic calming measures in these areas.

These types of road safety measures to reduce the risks of incidents with wildlife have been implemented along the N1 which passes through the Maputo Reserve. It should be noted that when locating campsites, borrow pits, quarries, access roads, etc.in terms of ‘no go areas’ the only areas are the total conservation areas (in this case GNP and Marromeu Complex), and the PPZ along lakes and rivers as noted in Protection Zones (Decree No. 66/1998, of December 8) which identify the following partial protection zones: 50 m strip of land along lakes and rivers, 250 m strip of land surrounding dams and reservoirs, 100 m strip of land along the seafront and estuaries, a strip of 2 km along the terrestrial border.

Mitigation measures

- Develop and implement Code of Conduct on wildlife poaching and trade;
- Prohibit workers and job seekers against poaching of and/or illegal trade in wildlife animals;
- Institute disciplinary measures on any wildlife poaching and trade; and
- Prosecute appropriately any worker to be found poaching or in possession of wildlife and/or their products.
- Ensure there is adequate maintenance of the mitigation measures equipment to reduce wildlife collisions/crossings, such as a) light defectors on roadside; b) traffic signs and speed calming measures, with particular reference to the sections Gorongosa to Caia (Km84-168) as noted above.
- Ensure that monitoring continues to be undertaken adequately with the consultation and advice of all stakeholders (GNP, ANAC, BIOFUND, Police, etc.) and that any additional measures required over time to enforce road safety are implemented by the Contractor, without risk of publicizing wildlife movement data that may be used for poaching purposes.

c) Road safety risks

During the operation phase, higher volumes of traffic and greater speed may lead to risks of loss of wildlife through road kills particularly around GNP Buffer Zone, Gorongosa - Marromeu Complex Key Biodiversity Area and where the N1 traverses *Coutadas* and forestry concessions as the rehabilitated road sections will not be fenced. Therefore, there is a high probably that wildlife in these areas could be hit and killed by moving vehicles which may also result in road accidents leading to vehicles damage and human injuries in some cases.

Mitigation measures

- Sensitize all road users about the road maintenance works being carried out;
- Install sufficient warning signs in strategic places along the road;
- Barricade all sites under active maintenance with high visibility barricade material, and

regulate movement of vehicles;

- Regularly monitor wildlife road kills in rehabilitated road sections.
- Develop and implement a robust Traffic Management Plan for the Maintenance Phase which should be monitored and updated whenever needed.
- Ensure there is adequate maintenance of the mitigation measures equipment to reduce wildlife collisions/crossings, such as a) light defectors on roadside; b) traffic signs and speed calming measures.
- Ensure that monitoring continues to be undertaken adequately with the consultation and advice of all stakeholders (GNP, ANAC, BIOFUND, Police, etc.) and that any additional measures required over time to enforce road safety are implemented by the Contractor.

d) Urban expansion into agricultural land

During the operation and maintenance phase, the improved conditions of the N1 corridor will influence expansion of urban areas. The construction of new infrastructure may encroach agricultural land found adjacent to the urban areas. This may result in reduced agricultural crop yields and lead to food insecurity for some affected households.

Mitigation measures

- Urban areas must be zoned properly to avoid encroachment of agricultural land;
- Encourage developers in urban areas to build infrastructure vertically as opposed to laterally to reduce demand for new land; and
- Enforce town/urban by-laws on urbanization expansion

7.5 Demobilization and Decommissioning Phase

7.5.1 Positive Impacts during Demobilization and Decommissioning Phase

a) Improved landscape and scenery along the rehabilitated section of the road corridor

During the demobilization and decommissioning phase, all temporary structures such as workers' campsites, domestic waste, workshops, offices, rubble, containers, construction vehicles and equipment, pieces of wood and scrap metals, unused sand and quarry & cement blocks and power back-up generators, including solar panels will be removed and physical structures demolished from the project site. Some materials such as cement blocks, quarry and sand will be used for backfilling of old quarry sites while unused sand and gravel can be used for rehabilitation of borrow pits and other disturbed areas. Containers containing toxic materials such as oil, fuel and solignum will be crushed at an appropriate designated site before being disposed of. Contaminated soil will be cleaned up, removed and disposed of at a licensed hazardous waste facility. This strategy will significantly improve the landscape and scenery of the project site. In addition, associated facilities such as quarries, borrow pits, detours/deviations shall be assessed and mitigation measures shall be put in place to ensure these sites are properly rehabilitated and planted with site specific and adaptive plant flora species such as trees, shrubs, herbs and grass.

Enhancement measures

- Remove all rubble from the project site to the designated dumpsite and must include a written record of final disposal site (to avoid dumping in uncertified sites);
- Remove and use unused soils, concrete slabs and rubbles for backfilling and restoration of old quarries;
- Dispose of all containers where hazardous materials were stored at a designated site approved by MAAP (ex-MTA) and in line with national environmental legislation and guidelines; and
- Rehabilitate and restore by planting indigenous trees, shrubs and grass in collaboration with licensed owners all quarries and borrow pits expected not to be used in future.
- Ensure that contractors implement the rehabilitation plans developed for management of borrow pits and quarries.

7.5.2 Negative Impacts during Demobilization and Decommissioning Phase

a) Air and water pollution from demolition vehicles and earth excavation

During demobilization and decommissioning phase, demolition of associated facilities such as the camp site, concrete or asphalt plants, which involves clearing, earth excavation, demolition of structures and concrete will result in dust emission. This will pollute pollution the quality of air in the project sites, including the surrounding community areas. The pollution of air may cause respiratory diseases such as coughing, aggravated asthma, irritation of the respiratory airways, difficulty breathing, including irregular heartbeat. In addition, excessive dust emissions can lead to occurrence of car accidents due to poor visibility within the project site and along the access roads.

In addition, emission of greenhouse gases and particulate matter from infrastructure demolition machinery, and trucks transporting rubbles to the designated waste disposal site may result in emission of carbon dioxide (CO_2), carbon monoxide (CO), Sulphur Dioxide (SO_2), nitrogen oxides (NOx), hydrocarbons (HC), volatile organic compounds (VOCs) and particulate matters (PM10) into the atmosphere due to combustion of fuel. These gases and particulate matter can cause air pollution, which can lead to outbreak of respiratory diseases, acid rain and global warming, which cause global warming and consequently climate change.

Mitigation measures

- Provide all workers with personal protective equipment (PPE);
- Erect a temporary fence barrier around active construction site to shield spread of dust;
- Periodically spray water on loose soils and on soil mounds to suppress dust emission;
- Prepare and implement best management practice for dust emission;
- Trucks transporting rubble and unused soils to the designed waste dump sites must be adequately covered all the time with tarpaulins or thick plastic sheets;
- Drivers must drive trucks carrying rubble slowly to prevent dust generation over communities and housing;
- Contractor(s) must identify and assess impacts of associated facilities (e.g. Quarries, Borrow pits not only according to ESS3, but also ESS2, ESS4, ESS5 and ESS6 so as to propose mitigation measures to ensure safety of workers;
- Store and handle sand and cement gently to limit dust emission;
- Firmly compact loose soils on the construction site to suppress dust;
- Re-use unused soil removed during excavation for backfilling;
- Minimize the amount of time that loose soil may remain exposed off to wind;
- Adhere to a maximum speed limit of 30 km/h for vehicles and machinery all the time;
- Regularly service vehicles, machinery and equipment as per recommended in manual books;
- Reduce engine idling time; and
- Regularly inspect any oil engine leaks and immediately seal any leakage.

b) Noise pollution and vibrations from demolition vehicles and equipment

During the demobilization and decommissioning phase, sources of noise and vibrations shall include construction machinery, motor vehicles carrying rubble and other organic debris from the project site to the dumping site. Demolition of concrete structures and cement block wall using heavy machinery may cause the vibration of the ground and the surrounding areas. In addition, use of heavy machinery such as bull dozers, caterpillars, and excavators may produce noise which sometimes becomes nuisance to workers and can also lead to the damage of eardrums in human beings and other wildlife. Thus, noise levels at the work site shall not exceed the allowed noise and vibration limits.

Mitigation measures

- Inform in advance communities living around the project sites when noisy and vibration activities will occur;
- Identify and assess Project associated facilities that are likely to produce heavy noise and

vibrations when being demolished so that proper mitigation measures are put in place avoid noise and vibrations from spreading to the adjacent communities;

- Road and Bridge rehabilitation is considered “Light Industry”, so workers shall not be exposed to noise levels over 50-65 dB(A), over an eight hour period.
- For off-site noise levels, such as near the houses, schools, health centers, churches, etc., during daytime, shall be below 55 dB(A), during a one hour period.
- All heavy equipment and machinery shall be fitted with noise pollution control devices (i.e. silencers) that are operating correctly and efficiently.
- Asphalt mixers should be placed on a bituminous ground layer to reduce noise and vibrations of the plants in sensitive areas;
- Provide all workers with PPE (e.g. ear mufflers, helmets, work suits, etc.) in high noise exposure areas.
- Consider erecting noise barriers by constructing temporary fences or planting bushes/hedges around the demolition sites;
- Orient and train drivers on good driving practices (e.g., switching off engine of vehicles and heavy machinery not in use);
- Optimize movement of trucks and vehicles, including heavy machinery at the project site; and
- Minimize engine idling time.

c) Increased Risk of Soil erosion and land degradation

During the demobilization phase, there will be a lot of rubble, organic debris and loose soils that will generated as a result of demolition of facilities and structures, including excavation of concrete. During the course of work, these materials will be exposed to run-off and strong wind, which may lead to loss of loose soils, rubble and organic debris from the demolition site to the surrounding areas. Loss of soils, rubble and organic debris may be drained into nearby water bodies thereby causing water turbidity, siltation and sedimentation in rivers. In addition, these materials may affect the breeding grounds for aquatic life such as fish and frogs, which can eventually reduce their population as well disrupting the food chain.

Mitigation measures

- Spray water to surface of temporary structures to be demolished at the project site;
- Regularly spray water to the ground and unused soil, sand, concrete and quarry to suppress dust;
- Implement good topsoil management according to International Good Practices and International Sector Guidelines;

- Cover all vehicles carrying rubble, unused soil and sand to the designated approved dumpsite by local council with tarpaulins or thick plastic sheets; and
- Rehabilitate all active soil erosion sites at the project site.

d) Increased Risk of Water Pollution

Similarly, during the demobilization and decommission phase, if rubble from demolished earth structures is not properly managed it may be drained into nearby water bodies. This may lead to water pollution and consequently affect the quality of the water in rivers, streams and wells. The deterioration of water quality may lead to outbreak of waterborne diseases such as dysentery and diarrhea as well as affecting aquatic life. In addition, solid and liquid wastes such as used oil, fuel spills and domestic waste from washing and kitchen facilities not properly managed may end up polluting water bodies and the environment that are found in the vicinity of the project sites.

Mitigation measures

- Develop and implement wastewater management plan in line with national regulations;
- Store fuel, oil and used oil in sealed containers;
- Dispose of used oil and other hazardous wastes at a licensed hazardous waste facility. This process will be monitored by MAAP (ex-MTA).
- Refuel machinery and vehicles at least 100 m away from any water course;
- Dispose of used oil at a designated dumpsite approved by the district council;
- Provide male and female workers with appropriate mobile toilet facilities;
- Inspect vehicles and machinery regularly to check any oil leaks, and immediately seal any leaks;
- Clean immediately any accidental oil and fuel spills from the ground; and
- Immediately remove any contaminated soil and dispose of at a designated landfill area approved by the local authorities.

e) Generation of hazardous and non-hazardous waste

During the demobilization and decommissioning phase, solid and liquid wastes such as rubble, unused soil, quarry, pieces of concrete cement, broken pieces of windowpane, scrap metals, food waste, wastewater from washing and kitchen facilities among others are expected to be generated in large quantities. Indiscriminate removal of these wastes from the project sites may lead to the scattering of the waste throughout the project sites and along the road when transported to the designated dumpsites. This may pose occupational health and safety and health hazards of workers and other local communities living around the project sites. This impact applies to Components 1 and 2.

Mitigation measures

- **All hazardous waste must be handled by trained and qualified personnel** and transferred using appropriate vehicles to an approved off-site hazardous waste facility at the end of each day, and final disposal should be at a registered hazardous waste facility (currently only available in Matola, Maputo at the Mavoco landfill site).
- **Keep an up-to-date inventory** and **Material Safety Data Sheets (MSDS)** for all hazardous substances on site.
- **Provide separate containers/skips** for construction and demolition waste, which must be adequately covered to prevent scattering.
- **Record and log all waste generated on site**, disaggregated by type, quantity and disposal route.
- **Establish contractual agreements** with the local municipality (or licensed waste contractors) for the collection, transportation and proper disposal of solid, liquid and hazardous waste. Contracts must specify collection frequency, waste types, treatment or disposal facilities, and require **signed consignment notes** for each waste vehicle exiting the site.
- **Agree and sign Memorandums of Understanding (MoUs)** with local communities or other partners for reuse or recycling of contractor waste (where feasible).
- **Investigate and implement arrangements** with companies that recycle **used oil/lubricants**, ensuring proper collection and disposal of used oil at authorized hazardous waste facilities.
- **Prohibit littering** around the rehabilitation site and ensure that any **non-recyclable waste** is disposed of only at designated landfill sites approved by local authorities.
- **Provide separate, well-maintained mobile toilets** for male and female staff, ensuring regular cleaning and safe disposal of waste.
- **Optimize water use** to reduce wastewater generation and ensure **stormwater drains are separated from wastewater drains** to avoid contamination.
- **Locate hazardous waste storage and collection areas inland**, away from residential areas, sensitive receptors and water bodies, to prevent leaching or contamination of soil and water resources.

f) Risks of Climate change

During the demobilization and decommissioning phase, some natural habitats and trees will be lost due to demolition of associated facilities (temporary offices and campsites, latrines, etc.) and cleaning of rubble. Trucks and equipment to be used in this activity will result in the emission of GHGs such as carbon monoxide, carbon dioxide (CO_2), Sulphur, methane, nitrous oxide and fluorinated gases. These gases are responsible for global warming which may result in climate change that may cause heavy/torrential rains, storm rains, strong wind, cyclones, floods, drought and wildfire. If these gases are not controlled, the effects of climate change can be disastrous to infrastructure, land, crops, and human life as well as to the economy of the country.

Mitigation measures

- Use demolition equipment and machinery that emit low greenhouse gases;
- Periodically service and maintain equipment/machinery in line with manual books;
- Construction materials (e.g., wood/timber, stones, etc.) must be reclaimed for re-use in another project or subproject or donated to elderly people in villages for construction of their houses, minimize greenhouse gas emissions when buried in the ground or used as fuelwood;
- Adopt and implement Climate Resilient Approach in Demobilization/Decommissioning Project of the subprojects; and
- Avoid clearing vegetation outside the demolition area.

g) Increased Risk of spread of Covid-19

During the demobilization phase, it is anticipated that there will be a number of workers at the project sites involved in the demolition of temporary structures and facilities, including loading and offloading the rubbles and organic debris into tippers and other vehicles off to a dumping site. Overcrowding, failure to observe social distance, non-wearing of face masks and working in confined environment may increase the spread of Covid-19 among workers and also between workers and local communities, including job seekers. This may lead to the development of Covid-19 disease in affected human beings and consequently could lead to potential deaths.

Mitigation measures

- Advise workers to regularly wash their hands with plenty of water and soap or use hand sanitizers if water and soap are not available at the project site;
- Divide the workers into small groups and should work in shifts;
- Encourage workers to cover their mouth and nose when coughing using clean

handkerchiefs or tissue paper or flexed elbow;

- Provide face masks to all workers and ensure they wear it at all times;
- Advise workers to keep social distance from each other all the time;
- Regularly sensitize workers to refrain from touching each other, their faces, mouths, noses and eyes and avoid handshakes.

h) Increased Risks of the spread of HIV and AIDS and STIs

During the demobilization phase, a number of workers are expected to be employed at the project sites to implement different activities. It is anticipated that both skilled and unskilled workers will be employed. These workers will be receiving salaries and wages, which will consequently improve their financial and social status in the society. Since some of the workers will be far away from their marital families, some may engage in sexual relationships with either fellow male/female workers or males/females from community members in exchange for money, food and other items. This kind of sexual relationships may result in the spread of HIV and AIDS, including STIs among workers and/or between workers and the community. In addition, contraction of HIV and STIs will be spread further to their families thereby increasing the spread of the HIV and AIDS and STIs in the country.

Mitigation measures

- Implement existing HIV and AIDS Workplace Policy;
- Regularly sensitize workers and local communities about HIV and AIDS, and STIs;
- Distribute HIV and AIDS information and education materials to workers and local communities;
- Mobilize and put condoms in strategic places where workers can easily access them;
- Infected workers must access Anti-Retroviral Treatment (ART) from hospitals and health centers;
- Provide financial literacy sensitization programs to the surrounding local communities;
- Employ people from the surrounding project area to minimize promiscuity; and
- Sensitize workers on putting their income to productive use.

i) Increased Occupational Health and Safety risks

During the demobilization and decommission phase, there will be a number of occupational health and safety issues as described in detail under Sub-section xii of OHS risks in the Construction phase above that require serious attention of workers and communities. Some of the occupational health and safety risks and hazards that require serious attention include scrap metals, toxic chemicals, containers containing toxic liquid materials, falling objects from demolished structures and general rubble.

Mitigation measures

- Before commencing work, the Contractor will be required to identify potential hazards for each work task;
- Provisions for emergency responses are to be included in the Contractor's site safety plan which is to include nomination of a person who will be immediately contacted in case of an accident occur;
- Develop a disciplinary policy, for example, progressively (oral, written warning, suspension and dismissal of the worker);
- Conduct on site trainings to workers on Occupation Health and Safety;
- All the workers must sign the Code of Conduct CoC);
- The Contractor must have/define its Occupational Health and Safety Policy;
- The contractor will be required to keep the site free of drugs and alcohol;
- The contractor 's site safety plan will include provision for a safe work environment and provide safety measures, training and protective equipment to all workers including hand, head, eye and ear protection and safety footwear;
- All workers shall be provided with PPE (Personal Protective Equipment).

j) Increased Risks of GBV/SEA/SH/VAC

Contractors and workers on site during demobilization phase may indulge in crimes and illicit behavior such as rape, physical assault, sexual harassment, gender-based violence, discrimination and sexual exploitation and abuse, use of provocative and insulting language, other forms of gender-based violence etc.

Mitigation measures

- Implement GBV/SEA/SH workplace policy already prepared by the contractor;
- Periodically sensitize workers and surrounding local communities on causes and consequences of GBV/SEA/SH
- Develop and implement a clear GBV reporting procedure, including referral pathway for GBV survivor support services
- Implement the Code of Conduct (CoC) for a contractor and workers for GBV/SEA/SH;
- The contractor and all workers shall sign and adhere to Code of Conduct (CoC);
- Institute disciplinary actions (job dismissal, interdiction) against perpetrators of GBV; and
- Take and/or report perpetrators of GBV/SEA/SH to relevant authorities for prosecution.

In addition, the contractor is required to:

- Prepare and implement a C-ESMP that includes a detailed SEA/SH Action Plan, based on a Risk Assessment;
- Provide support to GBV survivors and appropriate mitigation actions under the C-ESMP;
- Develop and implement the project's Codes of Conduct (CoC) prohibiting acts of SEA/SH as well as sexual contact and activity with minors (persons under the age of 18);
- Orient all employees on Codes of Conduct, that includes other standards (e.g. ESHS and OHS standards);
- Ensure all employees sign the project's 'Individual Code of Conduct' confirming their agreement to comply with GBV related issues (e.g. SEA/SH/VAC), including ESHS and OHS standards;
- Establish and operationalize GRM that will address issues of GBV/SEA/SH/VAC; and
- Create partnership with local NGO to report to the relevant authorities any incidences of GBV/SEA/SH/IPV for appropriate action.

8 PUBLIC PARTICIPATION PROCESS

The need to undertake a Public Participation (PP) process for a Category A project is a legal requirement under the Environmental Impact Assessment Regulation (Decree No. 45/2004 of September 29). The PP process undertaken for this project has been carried out in accordance with the provisions of the aforementioned decree and regulations as well as the General Directive for the Public Participation Process in the Environmental Impact Assessment Process (Ministerial Order No. 130/2006, of July 19).

Apart from the traditional stakeholder engagement process on which several meetings were conducted, in particular, for this ESIA process were undertaken two (2) public meetings held at local level (affected districts). As per the national legislation, the first meeting was conducted during the Environmental Pre-feasibility Report and Scope Definition (EPDA), and the second meeting was conducted after preparation of the ESIA draft report. These meetings were facilitated by technical staff of ESIA consultant and was a forum for providing project information and findings of specialized studies to the project Interested and Affected Persons (I&APs), as well as to collect contributions and concerns related to environmental and social aspects of the project. Furthermore, was conducted consultations with women groups along the project area to discuss women employment and assess project-related SEA/SH risk and safe and confidential reporting channels.

8.1 First Public Consultation

This public consultation meeting was conducted to disclosure preliminary information about environmental and social impacts caused by the project, as well as to present the mitigation measures for each impact. This constituted an opportunity for engagement of I&AP's and disclosure of information that was included on the Environmental Prefeasibility Study and Scope Definition (EPDA) and TORs for preparation of ESIA study. Newspaper advertisement was used to invite the I&APs to attend the first public meeting and the disclosure of the EPDA report and TORs. The advertisement was published on 15th June 2023 edition of the Notícias newspaper which is the greatest printed communication mean in the country.

The advertisement aimed to invite people to register their interest in the project (as an I&AP), inform I&APs of the public meeting dates, times and venues, disclose information on where information documents could be consulted prior to the meetings. Besides the public notice, personalized invitation letters and WhatsApp messages (including the advertise) were sent to the relevant government and non-government institutions such as National Directorate of Environment (DINAB), Province Environmental Services (SPA), District Administrations of Gondola, Nhamatanda, Gorongosa, Maringué, Cheringoma and Caia, Municipality of Gorongosa, Local leaders, OSC´s, NGO´s, etc.

8.1.1 Objectives of 1st public consultation meeting

In specific the first public consultation meeting aimed to:

- Provide updated information about the Project, its components and implementation approach;
- Inform about the need to conduct the Environmental and Social Impact Assessment (ESIA) for the project, including the Resettlement Plan
- Present the preliminary results of the specialized studies, the draft EPDA and ToR: the potential environmental and socio-economic impacts identified and assessed, and mitigation, management and monitoring measures proposed;
- Collect comments, views, concerns and questions from the participants on issues related the EPDA and project implementation.

8.1.2 Summary of 1st public consultation meeting

In the N1 road section between Inchope to Caia five (5) separate sessions were conducted of the 1st public consultation meeting (Inchope, Gorongosa, Nhamapaza, Inhamitanga and Caia) at which 314 IA&Ps attended these meetings (223 males and 91 females), as shown in Table 8-1. Each session was moderated by the district administrators in all districts, with the exception of Inchope where the permanent secretary of Gondola facilitated the meeting (Figure 27). SWMoz-Svosve, the ESIA consultant, was responsible for presenting the content of each document. Portuguese was the main language using during presentation and discussion of the presented topics, but with translation into *Sena, Ndau* and *Chigorongose*, the local languages spoken in the project area. The participants signed an attendance sheet to confirm their participation in these meetings.

Table 8-1 Schedule and Number of participants on the 1st public consultation meeting

Road Section	Date	Time	District: Venue	No. Participants		
				Male	Female	All
Inchope – Caia (322km)	29/06/2023	08:30h	Gondola: Sala de Reuniões da **Pensão Nhandoro Tenesse** (Inchope)	79	22	101
	30/06/2023	08:30h	Gorongosa: **Sala de Secções do Governo Distrital de Gorongosa**	43	16	59
	03/07/2023	08:30h	Maringue: **Sala de Secções do Posto Administrativo de Subue** (Nhamapaza)	07	43	50
	04/07/2023	09:00h	Cheringoma: **Sala de Secções do Posto Administrativo de Inhamitanga**	52	05	57
	05/07/2023	08:30h	Caia: **Sala de Secções do Governo Distrital de Caia**	42	05	47
TOTAL				**223**	**91**	**314**

Figure 32 Images of the 1st public consultation meetings

During each session, the Consultant's team and representatives of project proponent proceeded with a brief presentation in Portuguese, about the project components and objectives, the different stages of project implementation, and a summary of the activities proposed for project implementation. Furthermore, the preliminary proposed environmental and social impacts of the project were presented in the biotic, physical and socio-economic environment, further emphasizing the issue of affecting the assets of the population and infrastructure located in the Project's impact corridor. The Consultant further explained to the participants that the main purpose of the public consultation meeting was to inform the IA&Ps about the existence of the Project and its characteristics, as well as to collect comments, views, concerns and questions from the participants on issues related to the implementation of the Project.

During this public consultation meeting, the participants recognized the project relevance and raised some concerns or questions related to: (i) Increase of GBV/SEA/SH risk due to people’s influx to the communities, (ii) advantage in employment for construction works for local labor (iii) transparency in hiring process and (iii) measures to improve road safety and (iv) approaches for compensation of losses. Details of this consultation process can be found in the report of 1st Public Consultation meeting (Volume 2D – Public Consultation Reports).

8.2 Second Public Consultation

The second public consultation meeting was conducted to disclose information about environmental and social impacts caused by the project, as well as to present the mitigation measures for each impact. This presented an opportunity for engagement of I&AP's and disclosure of information that was included in the draft of the Environmental and Social Impact Assessment Report. A newspaper advertisement was used to invite the I&APs to attend the second public meeting, published on 27th November 2023 edition of the Notícias newspaper which is the greatest printed communication material in the country.

The advertisement was to invite people to register their interest in the project (as an I&AP), inform I&APs of the public meeting dates, times and venues, and disclose information on where information documents could be consulted prior to the meetings. As well as the public notice, personalized invitation letters and WhatsApp messages (including the advertisement) were sent to the relevant government and non-government institutions such as National Directorate of Environment (DINAB), Province Environmental Services (SPA), District Administrations of Gondola, Nhamatanda, Gorongosa, Maringué, Cheringoma and Caia, Municipality of Gorongosa, Local leaders, OSC´s, NGO´s, etc.

8.2.1 Objectives of 2nd public consultation meeting

The second public consultation meeting aimed to:

- Present the results of the specialized studies, the potential environmental and socio-economic impacts identified and assessed, and proposed mitigation, management and monitoring measures;
- Collect comments, views, concerns and questions from the participants on issues related to the environmental and social impacts of the Project, including proposed mitigation measures

8.2.2 Summary of 2nd public consultation meeting

In the N1 road section between Inchope to Caia five (5) separate sessions were conducted of the 2nd public consultation meeting (Inchope, Gorongosa, Nhamapaza, Inhamitanga and Caia) in which 323 IA&Ps attended these meetings (254 males and 69 females), as shown in Table 8-2. Each session was moderated by representatives of the district administrator in Gondola, Caia, Maringué, exception for Gorongosa and Cheringoma where the administrator facilitated the meetings (Figure 28). SWMoz-Svosve, the ESIA consultant, was responsible for presenting the content of each document. Portuguese was the main language using during presentation and discussion of the presented topics, but with translation into Sena, Ndau and Chigorongose, the local languages spoken in the project area. The participants signed an attendance sheet to confirm their participation in these meetings.

Table 8-2 Schedule and Number of participants on the 2nd public consultation meeting

Road Section	Date	Time	District: Venue	No. Participants		
				Male	Female	All
Inchope – Caia (322km)	11/12/2023	08:30h	Gondola: Sala de Reuniões da **Pensão Nhandoro Tenesse** (Inchope)	60	19	79
	12/12/2023	08:30h	Gorongosa: **Sala de Secções do Governo Distrital de Gorongosa**	55	14	69
	13/12/2023	08:30h	Maringue: **Sala de Secções do Posto Administrativo de Subue** (Nhamapaza)	49	10	59
	14/12/2023	09:00h	Cheringoma: **Sala de Secções do Posto Administrativo de Inhamitanga**	54	18	72
	15/12/2023	08:30h	Caia: **Sala de Secções do Governo Distrital de Caia**	36	08	44
TOTAL				**254**	**69**	**323**

Figure 33 Images of the 2nd public consultation meeting

During each session, the Consultant's team and representatives of project proponent proceeded with a brief presentation in Portuguese, where clarification about some concerns raised during the first public consultation by I&APs. Furthermore, the Consultant presented the key findings of preliminary report environmental and social impacts of the project in the biotic, physical and socio-economic environment, further emphasizing the issue of affecting the assets of the population and infrastructure located in the Project's impact corridor. The Consultant further explained to the participants that the main purpose of the public consultation meeting was to inform the IA&Ps about the project impacts, as well as to collect comments, views, concerns, and questions from the participants on issues related to the ESIA report and implementation of the Project.

During this public consultation meeting, participants raised some concerns or questions related to: (i) The extension of road reserve area (ii) the need to create area for resting by truck drivers and markets with associated structures (iii) plan for recovery of borrowed areas (iv) the process of hiring the local labor, including an employment rate for women (v) the need for licensing the borrow pit areas; (vi) Measures to improve road safety and (iv) approaches for compensation of losses. Details of this consultation process can be found in the report of 2nd Public Consultation meeting (Volume 2D – Public Consultation Reports).

9 CONCLUSION

The ESIA identifies that the Project is expected to have significant adverse environmental and social impacts which may include soil erosion, waste generation, risk to loss of natural habitats and biodiversity, resettlement, loss of land and property, risk to climate change, increased spread of HIV and AIDS and STIs, spread of Covid-19, risks to GBV/SEA/SH/VAC, risk to loss of or damage to cultural heritage, loss of livelihoods and risks to OHS hazards among others. The risks and impacts in this project that are classified as Moderate, High and Very High that shall be reduced to tolerable levels through project design, implementation of mitigation measures and Good International Industry Practices (GIIPs), extensive participation of project-affected people in the implementation of subproject activities as well as in the development of resettlement and compensation plans.

In order to effectively mitigate and enhance the potential impacts and risks identified for this road rehabilitation project, the ESMP has been prepared together with the ESMS and must be fully and rigorously implemented by the contractor and ANE, IP in line with relevant national legislations, regulations, standards and guidelines and the World Bank ESF and EHS Guidelines during the rehabilitation, maintenance and demolition/decommissioning phases of the project. The implementation of the ESMP must be on the other hand rigorously monitored by relevant independent institutions or a third party to ensure the contractor and ANE implement the strategies as required and verify their effectiveness.

Notwithstanding the identified negative risks and impacts on the biophysical and socioeconomic and cultural environment, the Project is, however, expected to bring potential positive impacts or benefits, which include improved road safety, improved road connectivity and access to markets, improved trade between regions, reduced road crash accidents and death, creation of employment (for both men and women, the youth and the vulnerable), skills transfer, and increased revenue to the GoM through taxes. Long-term and potential indirect benefits are anticipated, as a result of capacity building programs that will result in transfer of road rehabilitation and building skills to the local workers in the province and these workers would be able to stand on their own and implement similar small to medium scale infrastructure projects in Mozambique in future.

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11 ANNEX 1

Wildlife Permeability study

Road permeability study

From Inchope to Caia

For

Environmental and Social Assessment for the Safer Roads for Socioeconomic Integration in Mozambique – Multiphase Programmatic Approach

January, 2026

List of abbreviations

ENM	Ecological Niche Models
GBiF	Global Biodiversity Information Facility
GIS	Geographic Information Systems
GNP	Gorongosa Pational Park
MPA	Multiphase Programmatic Approach
QGIS	Quantum GIS

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1 Introduction

This report outlines the landscape permeability assessment in Sofala and Manica provinces, conducted as part of the Environmental and Social Impact Assessment for the Safer Roads for Socioeconomic Integration in Mozambique – Multiphase Programmatic Approach.

As Mozambique progresses toward improving its infrastructure to foster economic growth and social development, the integration of environmental sustainability into this process has become paramount. The Landscape Permeability Assessment for Sofala and Manica provinces, conducted as part of the broader Environmental and Social Impact Assessment for the Safer Roads for Socioeconomic Integration in Mozambique – Multiphase Programmatic Approach (MPA), addresses the urgent need to balance development with the conservation of Mozambique's natural landscapes. These provinces, known for their rich biodiversity, vibrant ecosystems, and significant wildlife populations, are also vital corridors for regional connectivity. However, infrastructure development – particularly road networks –poses potential threats to the ecological integrity of these regions. Roads can fragment habitats, isolate wildlife populations, and create barriers that hinder natural movements, thereby affecting biodiversity conservation efforts. This fragmentation may also impact ecosystem services upon which local communities rely, exacerbating existing environmental and socio-economic vulnerabilities.

The primary goal of this landscape permeability assessment is to evaluate how infrastructure developments, such as road construction and rehabilitation, influence wildlife movement, habitat connectivity, and the natural flow of ecosystems. By examining key factors such as land use changes, habitat fragmentation, and the presence of natural corridors, this assessment aims to provide a comprehensive understanding of landscape permeability in Sofala and Manica provinces, for the sections of the N1 road to be rehabilitated. The study focuses on identifying critical barriers, determining areas where wildlife and ecosystems are most at risk, and proposing solutions to enhance connectivity and mitigate negative impacts.

This report outlines the methodology employed to conduct the assessment, which incorporates species habitat suitability, remote sensing data and Geographic Information

Systems (GIS). By integrating these methods, this assessment ensures that both ecological and socio-economic dimensions are considered. The findings offer valuable insights into the current state of landscape permeability in the region, highlighting the intersection of environmental conservation with human development. Furthermore, the report presents recommendations to ensure that future infrastructure projects, particularly those linked to the SRSEIP, do not compromise the ecological connectivity that is crucial for maintaining biodiversity and supporting resilient local communities. The recommendations emphasize the need for strategic planning, ecological corridors, and mitigation measures that facilitate coexistence between development initiatives and environmental sustainability. As Mozambique continues to invest in its road network to drive socioeconomic integration, ensuring that these projects promote ecological resilience will be vital in achieving long-term sustainability.

2 Material and methods

2.1 Overview of the study area

To account for appropriate results, a bounding box (Figure 1) stretching to the limits of the road (all three segments from Inchope to Caia), was created using the bounding box plugin in QGIS v. 3.30.2. This enabled a broader view of the landscape and can more accurately incorporate the movement of the species and the associated constrains within the landscape. The study area is located within the Greater Gorongosa ecosystem, one of Africa's most diverse and ecologically significant environments (E.O. Wilson, person communication). The park spans over 4,000 Km^2 and encompasses a rich mosaic of landscapes, including savannahs, woodlands, grasslands, wetlands, and rainforests.

Within the ecosystem, Mount Gorongosa stands tall, rising to nearly 1.900 meters and encompassing several rare and endemic species. This ecosystem is home to a wide array of wildlife, including elephants, lions, buffaloes, hippos, antelopes, and a variety of bird species, making it a critical conservation area. The park's rivers, particularly the Pungué and Vunduzi and its tributaries, create fertile floodplains that support abundant life, while the seasonal rain patterns sustain wetlands and lakes that are vital for migratory birds and aquatic life (Stalmans et al., 2008).

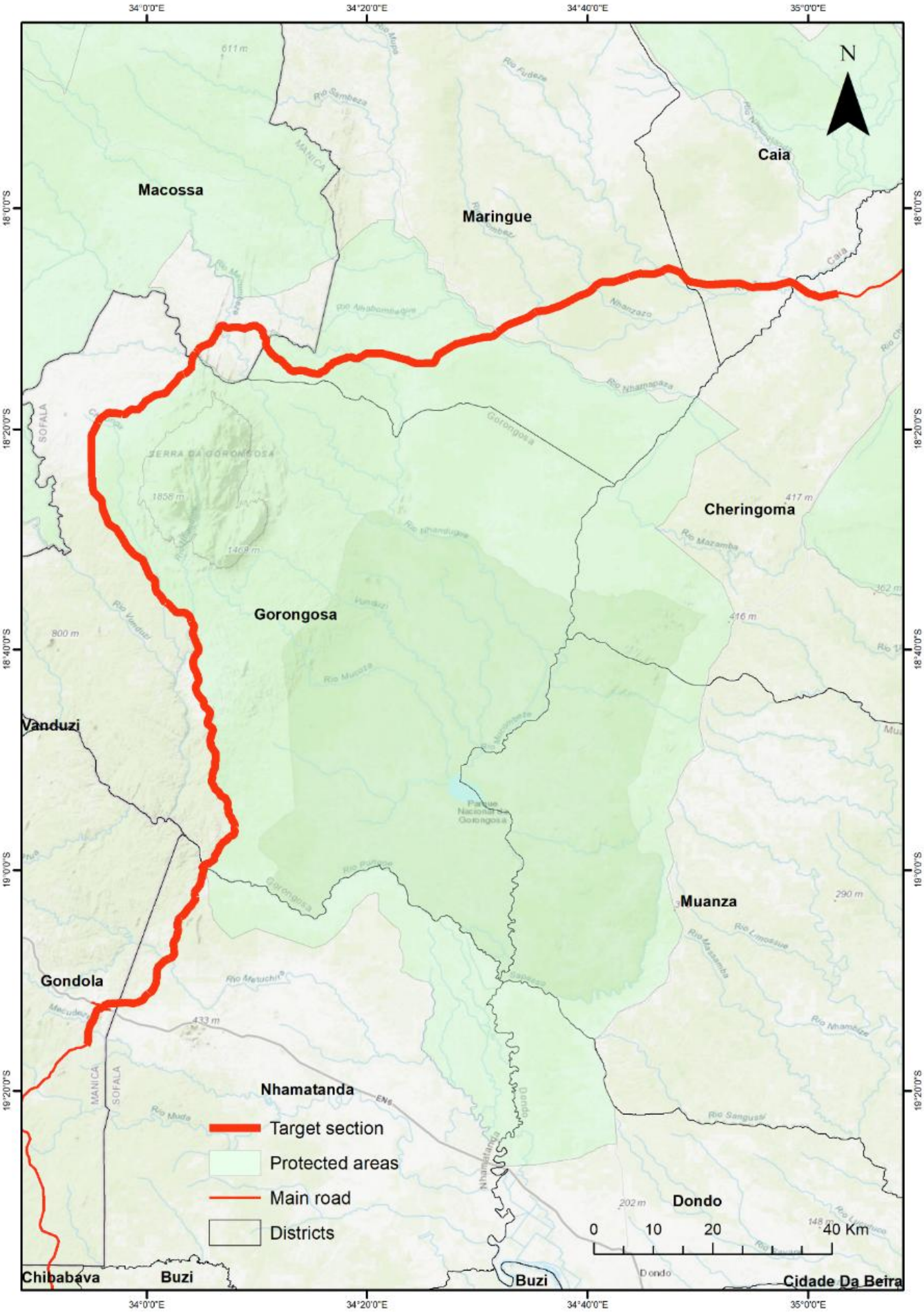

Figure 34: The study area for the landscape permeability assessment.

2.2 Species and occurrence records

Twenty-one species were considered in this study, aiming to provide a balance between large and medium species of mammals and different dispersal capacities (Table 1), with occurrence records retrieved from the Global Biodiversity Information Facility (GBIF), which provides broad-scale, publicly available biodiversity data repository and field records from Gorongosa National Park, which offer high-resolution, locally validated observations. Combining these datasets enhances both the spatial coverage and ecological accuracy of the modelling framework. These species were selected based on the reported presence of the species within the area and crossing the road, but also because some species migrate through the region but have limited speed (pangolins). Among the species, the African savannah elephant was the species with the largest dispersal capacity (nearly 100 km), while the ground pangolin was the species with the lowest dispersal capacity (with 10 km).

Even though only mammals were considered, the results are still useful under the concept of umbrella species and the characteristics of the landscape within the study area. After running the analysis six species were removed from further analysis due to the lower suitability presented within the focal study area: *A. melampus*, *C. natalensis*, *Conochaetus taurinos*, *Equus quagga*, *Taurotragus orix* and *Tragelaphus strepsiceros*.

Table 1-1: List of mammals included in habitat suitability assessment

n	Common name	Scientific name
1	Hartebeest	*Alcephalus buselaphus*
2	Impala	*Aepyceros melampus*
3	Spotted hyena	*Crocuta crocuta*
4	Red forest duiker	*Cephalophus natalensis*
5	Blue wildebeest	*Connochaetes taurinus*
6	Plains zebra	*Equus quagga*
7	Sable antelope	*Hippotragus niger*
8	Waterbuck	*Kobus ellipsiprymnus*
9	African savannah elephant	*Loxodonta africana*
10	African wild dog	*Lycaon pictus*

11	Ground pangolin	*Smutsia temminckii*
12	Oribi	*Ourebia ourebi*
13	Common warthog	*Phacochoerus africanus*
14	Southern reedbuck	*Redunca arundinum*
15	Yellow baboon	*Papio cynocephalus*
16	Lion	*Panthera leo*
17	African buffalo	*Syncerus caffer*
18	Common duiker	*Sylvicapra grimmia*
19	Nyala	*Tragelaphus angasii*
20	Common eland	*Taurotragus oryx*
21	Greater kudu	*Tragelaphus strepsiceros*

Source: Biodiversity specialist elaboration targeting species noted to have crossed the N1 as per information from GNP authorities.

Species distribution models (SDMs) provide a robust framework to assess potential wildlife–road interactions because they predict the probability of species occurrence across a landscape by linking known occurrence records with environmental predictors (Elith & Leathwick, 2009). The central theoretical premise is that the likelihood of encountering a species in each location is structured by ecological gradients and habitat availability, rather than being randomly distributed. This makes SDMs particularly well suited for road ecology, where collision risk is a function of both traffic intensity and the probability of animals being present in or near the road corridor (Clevenger & Nielsen, 2012; van der Ree et al., 2015).

In Mozambique, wildlife monitoring relies heavily on aerial surveys, which face important limitations: they are costly, logistically demanding, and typically restricted to protected areas such as Gorongosa National Park. This means that large areas of adjacent landscapes, including the Gorongosa–Caia N1 corridor, lack systematic survey data. Moreover, aerial surveys are prone to detection biases, especially under dense canopy or for species occurring at low densities (Norton-Griffiths & McConville, 2007).

Under these premises, SDMs offer a defensible way to extend the ecological information embedded in aerial survey data beyond park boundaries, while also providing a framework to correct for sampling bias. Presence-only modelling approaches, such as MaxEnt, explicitly allow the use of bias files or target-group background sampling to ensure that background points are drawn from areas with equivalent survey effort (Phillips et al., 2009). In practice, this means that although the occurrence records originate inside Gorongosa NP, the ecological relationships they capture (e.g., elephants favouring wooded savannas near water, herbivores preferring floodplains and open grasslands) can be transferred across the broader landscape when background sampling and model validation procedures correct for the uneven distribution of effort (Fourcade et al., 2014).

By accounting for sampling bias in this way, the SDMs do not simply replicate the survey footprint of Gorongosa but generalise habitat–occurrence relationships across similar environments in the region. This is particularly valuable where direct monitoring is lacking, as is the case for the N1 corridor. Combining these corrected SDM outputs with traffic volume and speed data allows the identification of high-risk collision "hotspots" with greater confidence, thereby supporting evidence-based mitigation measures such as wildlife crossings, targeted signage, or speed reduction zones.

While raw aerial survey data are spatially limited, the integration of bias-correction methods within an SDM framework enables their ecological signal to be meaningfully extended to areas of conservation concern outside Gorongosa. This strengthens the predictive power of the EIA and aligns with international best practice, where SDMs are routinely applied in data-poor contexts to anticipate and mitigate biodiversity impacts (Franklin, 2010; Guisan & Zimmermann, 2000).

2.3 Environmental variables

Species distribution modelling (SDM) integrates species occurrence records with environmental and ecological predictors to estimate the potential geographic distribution of organisms under current or future conditions. This approach is grounded in ecological niche theory, which posits that species distributions are shaped by climatic and environmental constraints.

For this study, 19 bioclimatic variables (Figure 2) representing near-present climate conditions were retrieved from the WorldClim database (www.worldclim.com), either for near-current (historical) and near-future scenarios (2035). These variables are derived from monthly temperature and precipitation data and are designed to capture biologically meaningful aspects of climate, including:

- Annual trends (e.g., mean annual temperature, annual precipitation).
- Seasonality (e.g., temperature annual range, precipitation seasonality).
- Extreme or limiting factors (e.g., minimum temperature of the coldest month, precipitation of the driest quarter).

Together, these variables provide a comprehensive climatic profile that is widely used in ecological modelling and conservation planning. Prior to modelling, it is critical to address multicollinearity among predictor variables, as strong correlations can inflate model performance metrics and lead to biased estimates of species–environment relationships. To mitigate this, a Principal Components Analysis (PCA) was conducted. PCA reduces dimensionality by transforming correlated variables into a smaller set of uncorrelated components, thereby minimizing autocorrelation and avoiding over- or under-estimation of species distributions. This step ensures that the modelling framework captures the dominant climatic gradients while reducing redundancy in the predictor set.

By combining occurrence data with these processed bioclimatic predictors, SDMs can generate robust estimates of species' potential distributions, which are essential for applications such as landscape permeability analysis, habitat connectivity modelling, and conservation prioritization.

Figure 35: List of variables included for species distribution modelling.

Code	Description
v1	Annual Mean Temperature (°C)
v2	Mean Diurnal Temp Range (Mean of monthly (max temp—min temp)) (°C)
v3	Isothermality (v2/v7) (*100)
v4	Temperature Seasonality (standard deviation *100)
v5	Max Temperature of Warmest Month (°C)
v6	Min Temperature of Coldest Month (°C)
v7	Temperature Annual Range (v5–v6) (°C)
v8	Mean Temperature of Wettest Quarter (°C)
v9	Mean Temperature of Driest Quarter (°C)
v10	Mean Temperature of Warmest Quarter (°C)
v11	Mean Temperature of Coldest Quarter (°C)
v12	Annual Precipitation (mm)
v13	Precipitation of Wettest Month (mm)
v14	Precipitation of Driest Month (mm)
v15	Precipitation Seasonality (Coefficient of Variation)
v16	Precipitation of Wettest Quarter (mm)
v17	Precipitation of Driest Quarter (mm)
v18	Precipitation of Warmest Quarter (mm)
v19	Precipitation of Coldest Quarter (mm)

2.4 Habitat suitability modelling

The potential distribution of the species was predicted using the maximum entropy algorithm in Maxent v4.3.3. (Phillips et al., 2006). Maxent is a machine learning algorithm widely used for species distribution modelling. It operates on the principle of maximum entropy, estimating the probability distribution of a species' presence across a landscape based on environmental variables such as climate, elevation, and land cover. Maxent uses presence-only data, meaning it requires only the locations where the species have been observed, rather than both presence and absence data. The model works by finding the distribution that is closest to uniform (maximum entropy) while still being constrained by the environmental conditions at known species locations. It is particularly effective in handling complex, non-linear relationships between species and their environment, making it a powerful tool for predicting species distributions, assessing habitat suitability, and informing conservation strategies.

Species distribution models (SDMs) provide a robust framework to assess potential wildlife–road interactions because they predict the probability of species occurrence across a landscape by linking known occurrence records with environmental predictors (Elith & Leathwick, 2009). The central theoretical premise is that the likelihood of encountering a species in each location is not random but structured by ecological gradients and habitat availability. This makes SDMs particularly well suited for road ecology, where the risk of vehicle collisions is a function of both traffic intensity and the probability of animals being present in or near the road corridor (Clevenger & Nielsen, 2012; van der Ree et al., 2015).

Direct estimates of collision risk in African contexts face important limitations. Aerial wildlife surveys, which remain the main systematic source of data in Mozambique, are logistically demanding, costly, and spatially constrained. They often cover only protected areas such as Gorongosa National Park, leaving adjacent landscapes, including the Gorongosa–Caia N1 road corridor, poorly surveyed (Craigie et al., 2010). Even when available, aerial counts tend to underdetect species in dense vegetation or at small group sizes, and they provide only coarse spatial resolution, insufficient for road-level risk mapping (Norton-Griffiths & McConville, 2007).

In this context, SDMs offer a scientifically defensible way to extend the ecological signal beyond the boundaries of the aerial survey transects and the park itself. By integrating occurrence data from Gorongosa's aerial surveys with environmental predictors such as land cover, topography, water availability, and vegetation productivity, SDMs can identify suitable habitats across the broader landscape, including the road corridor. The assumption is not that Gorongosa aerial surveys capture all individuals dispersing toward the N1, but rather that the ecological relationships derived from these data (e.g., elephants favouring wooded savannas near water, large herbivores preferring floodplains or open grasslands) remain valid outside the park boundaries (Phillips et al., 2006). This transferability of habitat–occurrence relationships is widely recognized in species distribution modelling and underpins applications in conservation planning, climate adaptation, and impact assessment (Guisan & Zimmermann, 2000; Franklin, 2010).

Using SDMs in this way directly addresses two challenges: (i) the absence of systematic wildlife monitoring along the N1 corridor, and (ii) the need to generate spatially explicit, fine-scale predictions of animal presence where mitigation measures must be prioritized. Rather than relying exclusively on sparse carcass counts or extrapolating raw aerial survey numbers, the modelling framework provides a probabilistic surface of habitat use. When combined with traffic volume and speed data, this enables the identification of high-risk "collision hotspots" along the road, offering decision-makers evidence-based locations for mitigation such as signage, speed regulation, or wildlife crossings.

The use of SDMs in this study is theoretically justified and practically necessary. They allow the ecological information embedded in Gorongosa aerial surveys to inform risk assessments beyond park limits, overcoming the constraints of limited survey coverage and resolution. This approach is consistent with international best practice in environmental impact assessment, where predictive habitat models are increasingly used to anticipate and mitigate biodiversity impacts in data-poor contexts (Clevenger & Huijser, 2011; Mateo Sánchez et al., 2016).

As indicated in section 2.1, data was obtained through public repository and field constrained data. However, raw occurrence data often contain spatial biases due to uneven sampling effort, accessibility of sites, or clustering of records around research stations and roads. Such biases can artificially inflate model performance by over-representing certain environmental conditions while under-representing others. To address this, prior to modelling occurrence points were spatially filtered using the spThin package in R, which applies a thinning algorithm to reduce spatial autocorrelation among records.

Filtering was conducted to ensure that the occurrence data matched the spatial resolution of the climate predictors (bioclimatic variables from WorldClim). Climate data are typically available at resolutions such as 1 km^2 or 5 km^2, meaning that multiple occurrence records within a single grid cell would not provide additional independent information. By thinning records to one per grid cell, the dataset avoids pseudo-replication and ensures that each occurrence contributes unique information to the model. This step is essential for producing robust SDMs because:

- Reduces sampling bias and spatial autocorrelation.

- Aligns the scale of biological data (species occurrences) with the scale of environmental predictors (climate variables).
- Prevents overfitting, which can occur when clustered points exaggerate species–environment relationships.
- Improves the transferability of models to new areas or future climate scenarios, as the relationships are based on independent, representative data.

By harmonizing occurrence records with the resolution of climate variables, the resulting models provide more reliable estimates of species' potential distributions and landscape permeability, supporting conservation planning and ecological inference.

2.5 Preparation of the resistance surface

Prior to assessing landscape permeability, it was necessary to prepare a resistance surface[9], which represents the relative difficulty for species to move across the landscape. To construct this layer, two types of spatial data were initially compiled: vector and raster. All vector datasets were converted into raster format to ensure compatibility, after which all raster layers were reclassified into dimensionless values to allow direct comparison and integration. Resistance values were categorized using a standardized scale: 0 = not suitable; 2 = very low resistance; 4 = low resistance; 6 = medium resistance; 8 = high resistance; 10 = very high resistance.

This classification scheme provides a consistent framework for quantifying landscape features in terms of their permeability to species movement. Except for land cover, all variables were classified into five categories using the Jenks natural breaks method, which optimizes class intervals by minimizing variance within classes and maximizing variance between classes. This approach is widely used in ecological modelling to capture natural groupings in environmental data. The reclassified raster layers were then combined in ArcGIS 16.0.1 through a weighted summation. The following weights were applied, reflecting the relative importance of each variable in shaping resistance: Land cover = 0.20; Habitat suitability = 0.20; Topography = 0.28;

[9] Resistance layers represent the degree to which some landscape feature impedes or facilitates species movement (Adriaensen et al., 2003), typically represented as a cell (pixel) value in a grid (raster) within a Geographic Information System (GIS).

Population density = 0.10; Species richness = 0.07; Human Footprint = 0.15, as indicated in Equation 1. For each species$_i$:

$$Index_i = 0.20Cover + 0.28Topo - 0.10PopDens + 0.07Richness - 0.15HFP + 0.20Species_i$$

These weights were derived from a regression analysis of all variables, following established approaches in landscape ecology (e.g., Zhang et al., 2018; Kott, 2022). The resulting resistance surface integrates multiple ecological and anthropogenic factors, providing a robust basis for evaluating landscape permeability and identifying potential movement corridors. To aid calculations, all variables were normalized to range from 0-1, using the Equation 1:

$$r_{norm} = \frac{r - \min(r)}{\max(r) - \min(r)} \qquad \text{(Eq. 1)}$$

The decision to combine reclassified raster layers through a weighted summation reflects both methodological rigor and practical considerations in landscape ecology. This approach is widely adopted because it allows multiple ecological and anthropogenic variables to be integrated into a single resistance surface while maintaining transparency and interpretability. As such, this method ensures transparency and interpretability, flexibility in incorporating diverse data, avoidance of overfitting and comparability across studies.

Each of the variables represents a distinct ecological or anthropogenic factor influencing movement. The weighting scheme balances biophysical constraints (land cover, topography, slope) with anthropogenic pressures (roads, population density) and ecological relevance (habitat suitability, species richness) to provide a multidimensional resistance surface that realistically captures landscape permeability.

- Land cover is one of the most influential determinants of species movement. Different land cover types (e.g., forest, grassland, cropland, urban areas) vary in permeability: natural habitats typically facilitate movement, while urban or agricultural areas often act as barriers. Assigning a high weight reflects its central role in defining habitat continuity and fragmentation.

- Habitat suitability, derived from species distribution models, indicates how favourable a location is for a species. Areas of low suitability represent higher resistance to movement. Including this variable ensures that the resistance surface reflects species-specific ecological requirements, aligning connectivity modelling with biological realism.

- Topographic features such as elevation and terrain ruggedness influence dispersal. Steep or complex terrain can hinder movement, while flat areas are generally more permeable. This variable captures the physical constraints imposed by the landscape itself. Topography (represented by elevation) was treated as a cost surface, as steeper and higher terrain tends to reduce animal movement and habitat accessibility and was therefore assigned a negative weight.

- Human population density reflects the intensity of human presence and associated pressures (settlements, agriculture, infrastructure). High-density areas typically correspond to reduced permeability due to disturbance, habitat loss, and increased risk of conflict. Including this variable ensures anthropogenic impacts are explicitly represented.

- Areas of high species richness often indicate ecologically valuable and diverse habitats. Incorporating species richness helps prioritize regions that support multiple species simultaneously. Although weighted lower, it adds an important biodiversity dimension, ensuring that connectivity planning benefits broader ecological communities rather than single species alone.

- Human footprint – it was included as a measure of cumulative anthropogenic pressure on the landscape, integrating the effects of infrastructure, settlements, agriculture, and accessibility. Higher values of the Human Footprint indicate greater levels of human disturbance, habitat modification, and fragmentation, which are widely documented to reduce habitat quality, restrict animal movement, and increase mortality and conflict risk for wildlife. Accordingly, the Human Footprint was treated as a cost variable and assigned a negative weight in the composite index, such that increasing anthropogenic pressure reduces the overall suitability or priority value of a given location."

2.6 Connectivity assessment

A connectivity model[10] was developed using Circuitscape v4.0.5 (McRae et al., 2016), a widely applied tool in landscape ecology. Circuitscape is grounded in circuit theory (CT), which conceptualizes population connectivity as analogous to the flow of electrical current across a network (McRae, 2006; McRae et al., 2008). In this framework, landscapes are represented as resistive surfaces, and species movement is modelled as current flow, allowing for the identification of multiple pathways and the quantification of connectivity across heterogeneous environments.

The model employs a graph-theoretical approach to predict movement patterns and evaluate how landscape features influence species dispersal (Cushman et al., 2013). This approach is particularly effective because it accounts for both direct and indirect pathways, thereby capturing the redundancy and complexity of ecological networks that traditional least-cost path methods may overlook.

The resistance surface used in the model was constructed by integrating several ecological and anthropogenic variables. Specifically, the inverse of individual habitat suitability maps (1 – ENM) (Sunny et al., 2022) was combined with species richness maps, as well as environmental and human-related factors including elevation, slope, distance to roads (Euclidean distance), land cover, and population density. The inverse of habitat suitability reflects the relative difficulty of movement within a given location, with lower suitability corresponding to higher resistance (Mateo-Sánchez et al., 2014).

Connectivity calculations were performed using focal points in pairwise modelling mode, which estimates current flow between pairs of habitat patches or species occurrence points. This approach allows for the identification of critical corridors, bottlenecks, and areas of high resistance that may impede movement. By modelling connectivity for each species

[10] Ecological connectivity can be defined as the degree of connection between the various natural environments present within a landscape.

individually, the analysis provides species-specific information into landscape permeability, while also highlighting areas of potential multi-species overlap that are important for conservation planning.

3 Results

Landscape permeability refers to the levels or degrees to which a landscape allows for the movement of organisms, species, and ecological processes across it. These scales are often used in environmental and conservation studies to assess how well different species can move through a landscape that has been affected by human development, infrastructure, or other changes.

Landscape permeability in the study region was generally low, with most species exhibiting permeability values below 0.5 on a scale from 0 (completely impermeable) to 1 (fully permeable). Across all species and the entire landscape, permeability values ranged from 0.0625 to 0.3120, indicating that large portions of the region present limited permeability for animal movement.

When permeability was examined at the species level, substantial variation among species was observed. The highest permeability values were recorded for M. temminckii, with values ranging from 0.5333 to 0.9380, indicating that this species experiences comparatively high landscape permeability and encounters fewer spatial constraints to movement. In contrast, most other species showed more restricted permeability patterns and reached considerably lower maximum values. Specifically, the maximum permeability values for the remaining species were 0.516 for *Crocuta crocuta*, 0.7342 for *Hippotragus niger*, 0.5928 for *Kobus ellipsyprimnus*, 0.5291 for *Loxodonta africana*, 0.5566 for *Ourebia ourebi*, 0.6650 for both *Papio cynocephalus* and *Syncerus caffer*, and 0.6129 for *Redunca arundinum*. Although some species locally reached moderate to high permeability values, these were spatially limited and did not represent the dominant condition across the landscape.

Overall, the results indicate that permeability is spatially heterogeneous and species-specific, with only a small number of taxa experiencing high permeability over substantial areas. For most species, movement across the landscape appears to be constrained, resulting in generally low permeability values across much of the region. This pattern is consistent with the predominantly hilly and topographically complex nature of the Gorongosa ecosystem, which is characterized by pronounced elevational gradients, rugged terrain, and a mosaic of land cover types that may restrict or channel animal movement. Taken together, these results suggest that the study area does not function as a uniformly permeable landscape for large mammals, but rather as a patchwork of areas with varying degrees of permeability, where only certain species (notably *M. temminckii*) are able to move relatively freely across a broader portion of the region.

The generally low and spatially heterogeneous landscape permeability observed in the study area indicates that the region already imposes significant constraints on animal movement. This suggests that the rehabilitation of the N1 road is likely to have a disproportionate impact on ecological connectivity and wildlife movement, particularly for species with low permeability and limited movement alternatives. As a result, road impacts are expected to be spatially concentrated at specific corridors and pinch points, rather than uniformly distributed. These findings underscore the need for targeted, species-appropriate mitigation measures, including strategically placed wildlife crossing structures and carefully designed fencing, to reduce collision risk and maintain functional connectivity. The permeability maps developed in this study therefore provide a critical evidence base for identifying priority locations for mitigation and for guiding adaptive management throughout the project lifecycle.

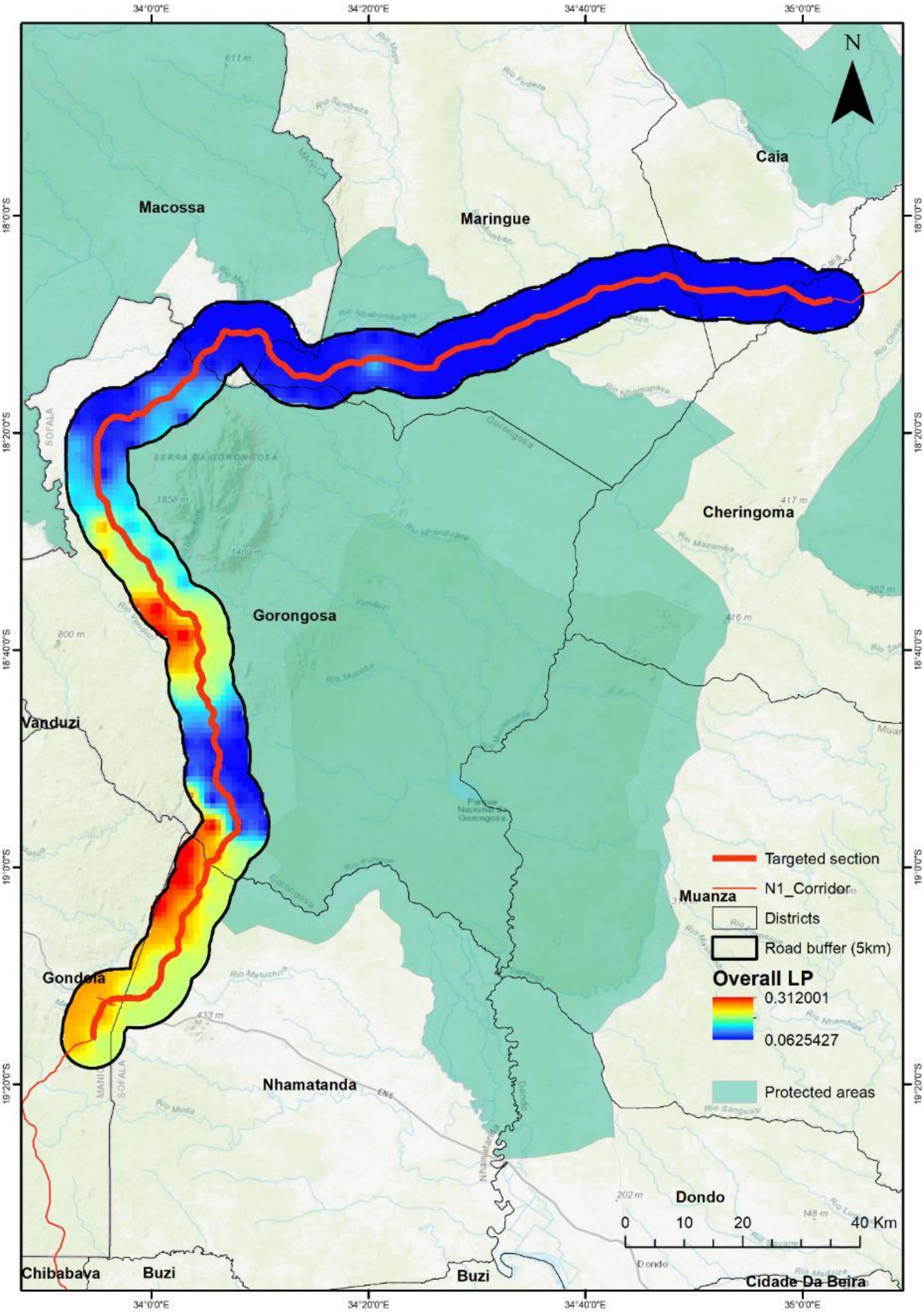

Figure 36: Landscape permeability across the Inchope-Caia road rehabilitation project. The scale should be considered between 0 and 1. A 5km buffer was considered.

The first section of the road (Inchope–Gorongosa, km 0–70) is characterised by the presence of significant human settlements and high traffic volumes, which together increase the risk of wildlife–vehicle collisions across all species. This risk is particularly pronounced where the road intersects the buffer zone of Gorongosa National Park (GNP). In these areas, the overlap between wildlife movement and intense human activity creates conditions conducive to conflict, especially for species such as hartebeest (*Alcelaphus buselaphus*), sable antelope (*Hippotragus niger*), waterbuck (*Kobus ellipsiprymnus*), pangolin (*Smutsia temminckii*), and oribi (*Ourebia ourebi*), which exhibit moderate to high permeability and are therefore more likely to encounter the road.

The second section of the road (Gorongosa–Caia, km 70–84) presents a comparatively lower risk for wildlife–vehicle interactions. This segment traverses a slightly elevated area extending from the Mount Gorongosa plateau, which appears to be less favourable for wildlife movement and crossings, likely due to increased energetic costs associated with traversing steeper or more rugged terrain. As a result, overall crossing probability in this section is reduced. Nevertheless, some risk remains, particularly for wide-ranging and mobile species such as elephants (*Loxodonta africana*), African wild dogs (*Lycaon pictus*), pangolins (*Smutsia temminckii*), oribi (*Ourebia ourebi*), warthogs (*Phacochoerus africanus*), and reedbuck (*Redunca arundinum*), although this risk is limited to a relatively small proportion of the landscape.

The third section of the road (Gorongosa–Caia, km 84–168) requires particular attention, as it largely coincides with the GNP buffer zone and therefore intersects areas of high ecological importance and wildlife use. Within this section, the first 10 km represent a priority zone where enhanced protection and mitigation measures are necessary to reduce the risk of wildlife–vehicle collisions. Moreover, even after the N1 corridor exits the buffer zone, elevated risk persists for approximately the subsequent 10 km, indicating that additional precautionary measures remain warranted beyond the formal boundary of the protected area to ensure continued safety for both wildlife and road users.

The spatially differentiated risk patterns identified along the N1 indicate that the ecological impacts of the road rehabilitation will not be uniform, but concentrated in specific segments, particularly where the road intersects the Gorongosa National Park buffer zone and adjacent high-permeability areas. These segments coincide with some active wildlife movement and involve species of high ecological and conservation importance, implying a non-negligible risk of increased wildlife mortality, disruption of movement, and functional fragmentation. Consequently, mitigation measures must be spatially targeted and species-appropriate, rather than uniformly applied along the corridor. The results support the prioritisation of precautionary measures and monitoring. Overall, the findings indicate that the road rehabilitation does not constitute an ecologically sensitive intervention that necessitates hard engineering but rather proactive, targeted, and adaptive mitigation to ensure that impacts on wildlife movement and survival are effectively minimised.

4 Conservation and construction implications

The existing N1 road within the Gorongosa ecosystem is currently in poor condition, which limits vehicle speeds and constrains traffic flow between southern and northern Mozambique. This low level of service has the incidental effect of reducing the frequency and severity of wildlife–vehicle collisions, as slower speeds allow drivers more time to react and reduce collision lethality. However, it also restricts economic and social connectivity along the corridor. The proposed rehabilitation aims to improve road surface quality, safety, and reliability, thereby enabling smoother and more efficient transport of people and goods.

As the road already exists, the rehabilitation will not introduce a new linear barrier into the landscape and therefore does not create new fragmentation in a structural sense. Nevertheless, rehabilitation is expected to alter the functional characteristics of the road by increasing average vehicle speeds, improving traffic flow, and potentially attracting higher traffic volumes. These changes may increase the probability of wildlife–vehicle collisions and elevate disturbance levels along the corridor, particularly in ecologically sensitive areas and where wildlife movement overlaps with the road. The primary ecological impact of the project is therefore not the creation of a new barrier, but the potential intensification of its barrier and mortality effects.

The permeability analysis indicates that the surrounding landscape is relatively flat and lacks strongly defined movement corridors that would concentrate animal crossings at specific, narrow locations. Instead, wildlife movement appears to be spatially diffuse, with multiple low-intensity crossing points rather than a small number of dominant corridors. In this context, the construction of large wildlife overpasses or underpasses is unlikely to be ecologically efficient or cost-effective, as such structures are most beneficial where animal movement is naturally channelled through predictable pinch points. Moreover, the installation of continuous fencing along the road could further restrict animal movement, exacerbate functional fragmentation, and interfere with natural ranging behaviour, particularly for wide-ranging species.

These findings suggest that the most appropriate mitigation strategy is not heavy structural intervention, but targeted, proportionate, and adaptive measures aimed at managing incremental risk. Such measures include locally reduced speed limits in high-risk sections, wildlife warning signage, driver awareness campaigns, improved night-time visibility, and the systematic monitoring of wildlife–vehicle collisions. These interventions address the principal mechanism of impact, increased collision risk due to higher vehicle speeds, while maintaining overall landscape permeability and avoiding unnecessary physical barriers.

Taken together, the results indicate that the rehabilitation of the N1 represents an ecologically sensitive modification of an existing infrastructure rather than a fundamentally new disturbance. While the project does not introduce new fragmentation, it may increase functional impacts on wildlife through changes in traffic dynamics. Accordingly, mitigation should focus on managing these incremental effects in a spatially targeted manner, particularly near the Gorongosa National Park buffer zone and other areas of elevated wildlife presence. This approach ensures that the rehabilitation achieves its socio-economic objectives while maintaining ecological safeguards and minimizing unintended impacts on wildlife movement and survival.

The rehabilitation of the N1 road through the Gorongosa ecosystem is expected to modify traffic dynamics, particularly by increasing vehicle speeds and improving traffic flow. While this will enhance transport efficiency, it may also increase the risk of wildlife–vehicle collisions and disturbance to wildlife, especially in ecologically sensitive areas and where wildlife movement intersects the road. To minimise these incremental impacts while maintaining landscape permeability, a set of targeted, non-structural and low-intrusion mitigation measures is proposed:

- Speed management and traffic calming - reducing vehicle speed in high-risk sections is one of the most effective measures to decrease both the likelihood and severity of wildlife–vehicle collisions. Locally reduced speed limits should be implemented in areas of elevated ecological sensitivity, particularly where the road intersects the Gorongosa National Park buffer zone and adjacent high-permeability areas. These speed limits should be supported by appropriate road signage, physical speed-calming elements where feasible (e.g. rumble strips or optical speed reduction markings), and enforcement measures to ensure compliance. Lower speeds not only reduce collision probability but also increase driver reaction time and significantly decrease wildlife mortality rates.

- Wildlife warning signage and driver awareness - Targeted wildlife warning signs should be installed in sections identified as having elevated collision risk. These signs should be species-specific where possible (e.g. elephant or antelope silhouettes) and placed strategically in advance of known or predicted crossing zones. In addition, driver awareness campaigns — including informational materials at toll points, service stations, or through transport operators — can further increase driver vigilance, particularly during peak wildlife movement periods such as dawn, dusk, and seasonal migration periods.

- Road design and visibility enhancements - Improving driver visibility reduces collision risk, especially at night and in areas with vegetation close to the road. Vegetation should be managed along the road verge to prevent tall grasses or shrubs from obscuring animals approaching the road. Where feasible, improved road lighting at critical crossing areas can enhance driver detection of animals without creating excessive disturbance to wildlife. Reflective road markings and delineators can also help drivers anticipate potential hazards.

- Monitoring and adaptive management - a structured wildlife–vehicle collision monitoring programme should be established before and after rehabilitation. This programme should include systematic carcass surveys, incident reporting by road maintenance staff, and collaboration with park authorities and local communities. Monitoring results should be reviewed regularly to assess the effectiveness of mitigation measures and to identify emerging hotspots. If collision rates increase or shift spatially, mitigation measures should be adapted accordingly, for example by extending speed-reduced zones or adding signage in newly identified risk areas.

- Avoidance of extensive fencing and major crossing structures - given the relatively flat terrain in most parts of the area and the absence of strongly concentrated wildlife movement corridors, large wildlife overpasses or underpasses are not considered necessary or cost-effective in this context. Similarly, continuous fencing along the road is not recommended, as it could further restrict animal movement, exacerbate functional fragmentation, and interfere with natural ranging behaviour. The proposed approach therefore prioritises maintaining landscape permeability while managing collision risk through behavioural and operational measures rather than physical barriers.

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Appendix 1

Landscape permeability for selected species in the entire targeted section of the road

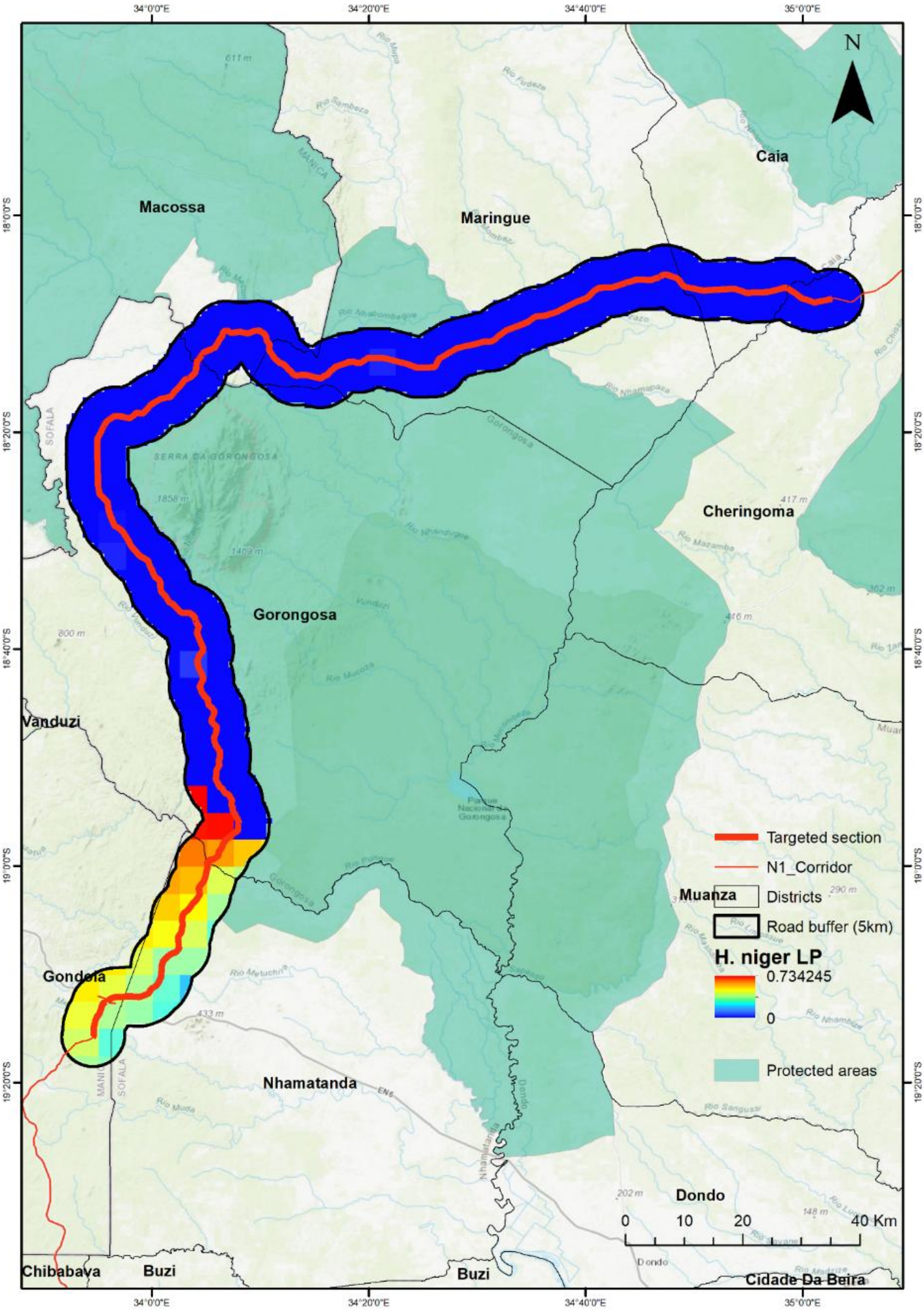


Figure A1: Landscape permeability across the Inchope-Caia road rehabilitation project for the sable antelope. The scale should be considered between 0 and 1.

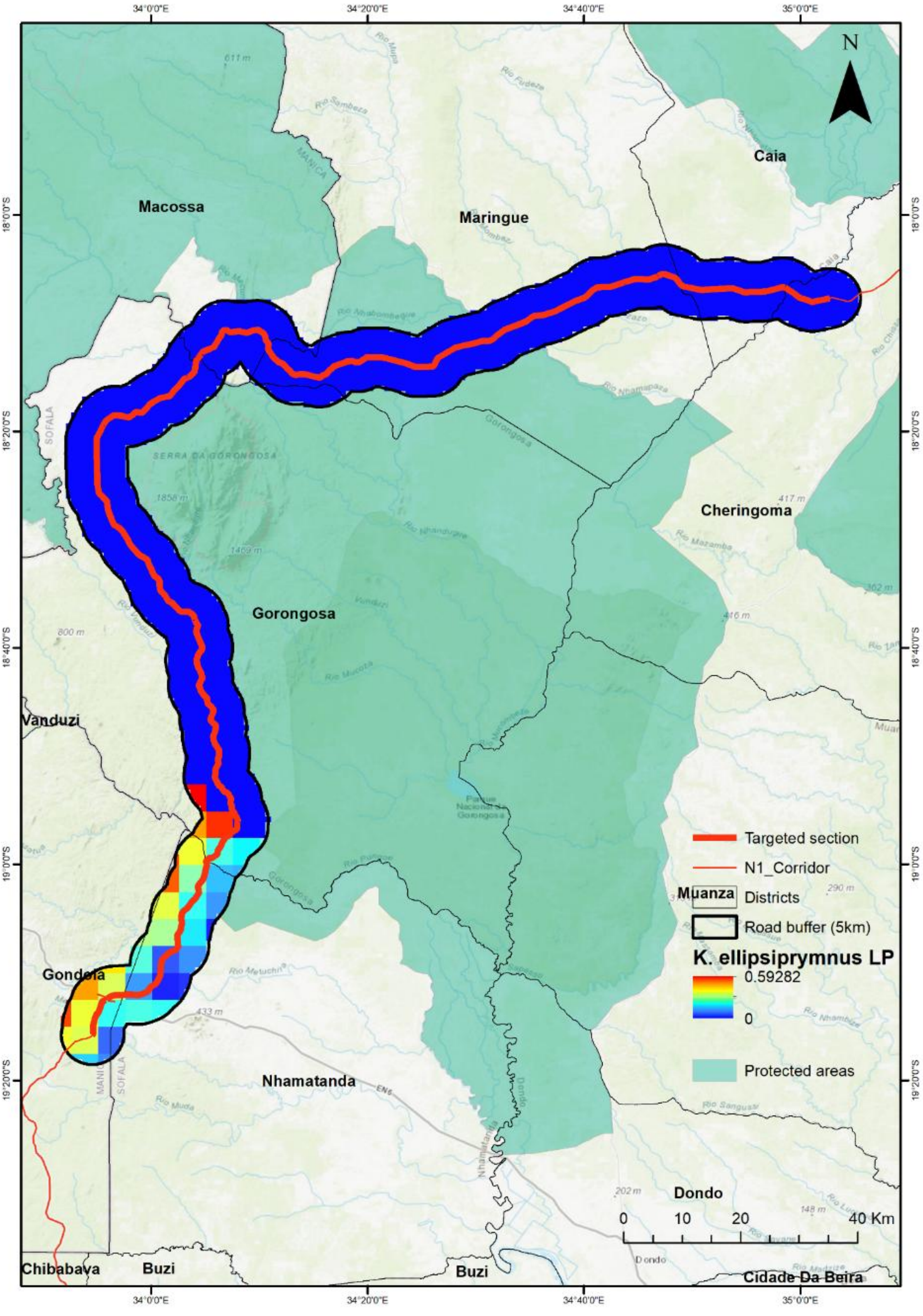


Figure A2: Landscape permeability across the Inchope-Caia road rehabilitation project for the waterbuck. The scale should be considered between 0 and 1.

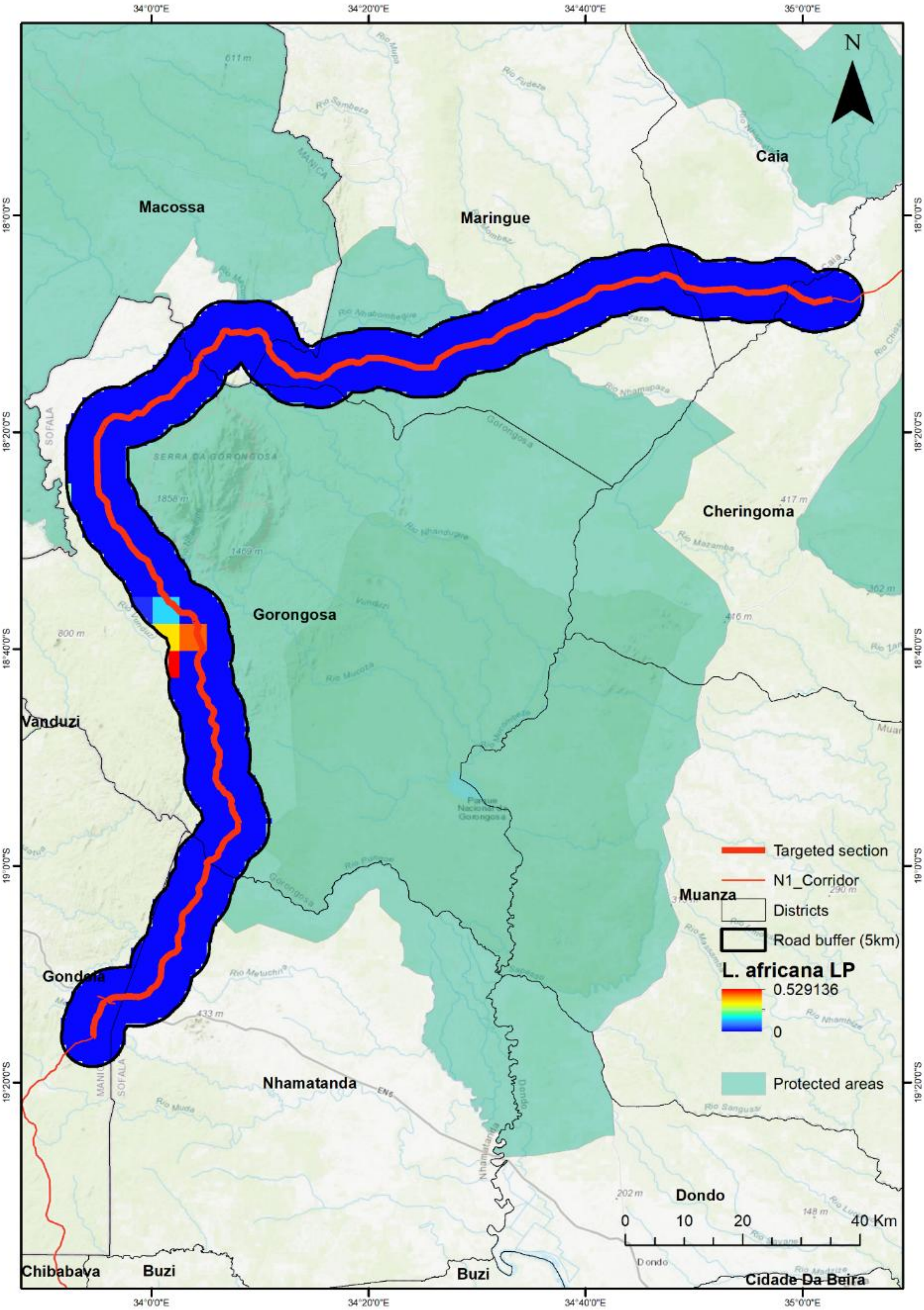


Figure A3: Landscape permeability across the Inchope-Caia road rehabilitation project for the savannah elephant. The scale should be considered between 0 and 1.

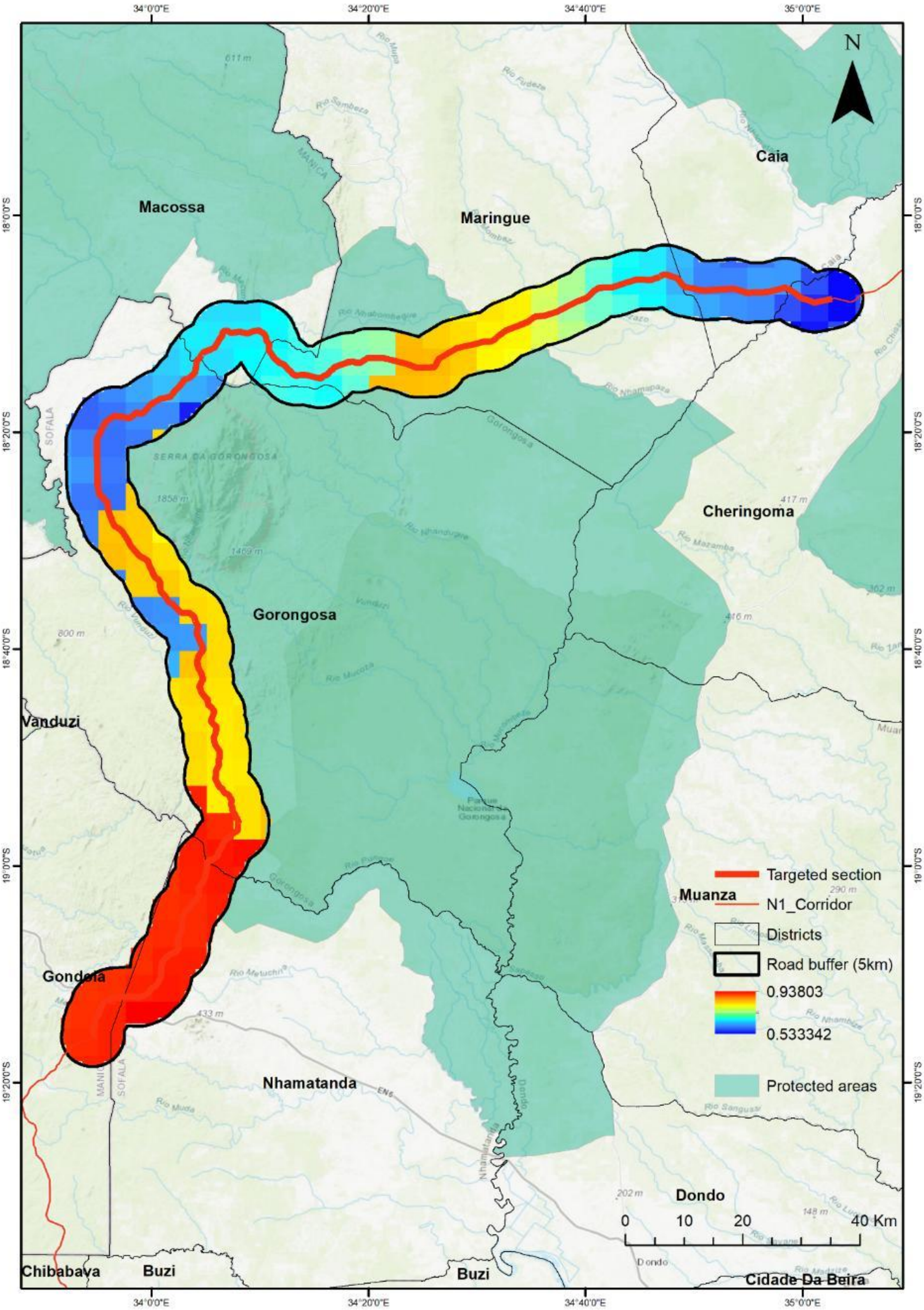


Figure A4: Landscape permeability across the Inchope-Caia road rehabilitation project for the ground pangolin. The scale should be considered between 0 and 1.

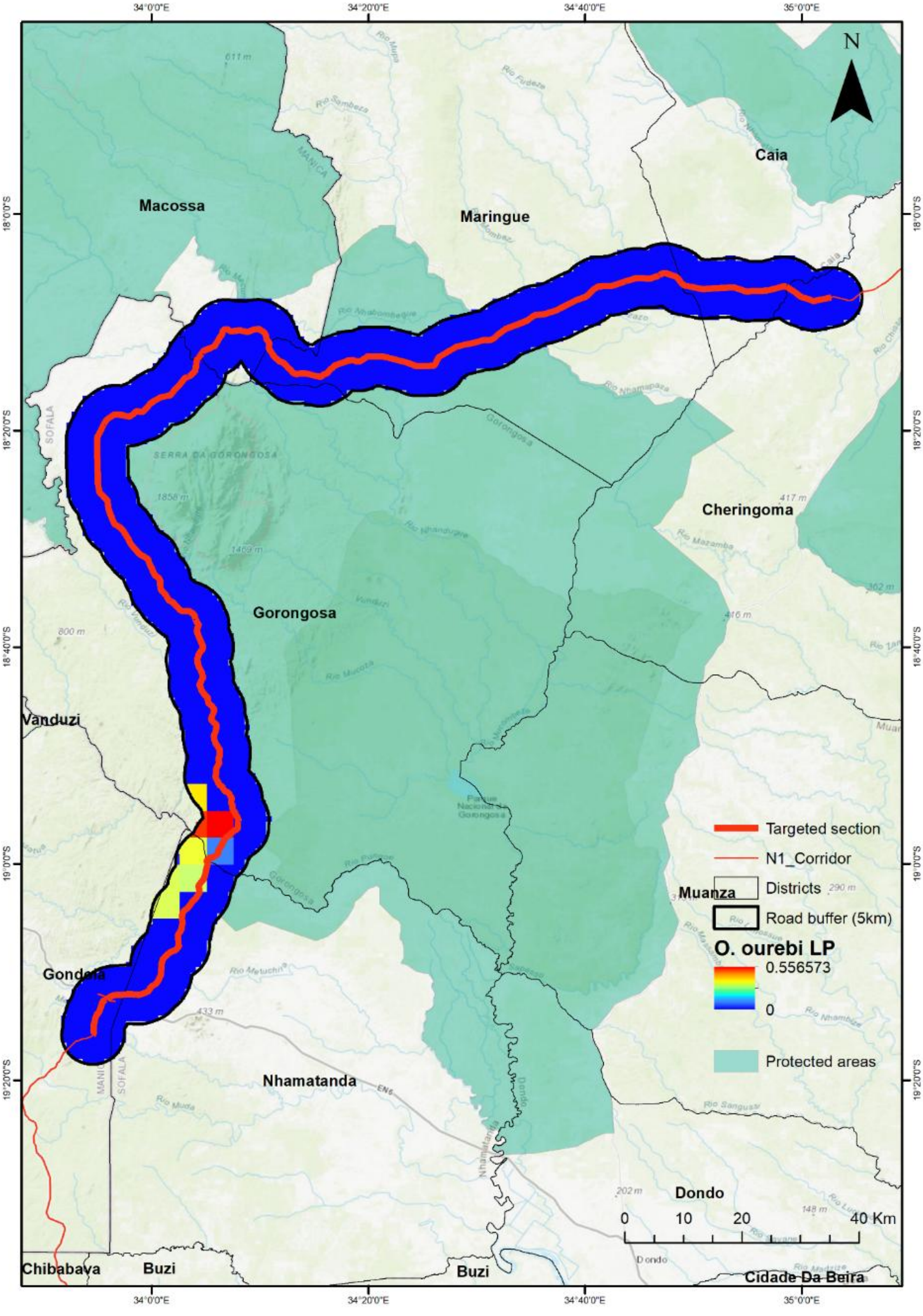


Figure A5: Landscape permeability across the Inchope-Caia road rehabilitation project for the oribi. The scale should be considered between 0 and 1.

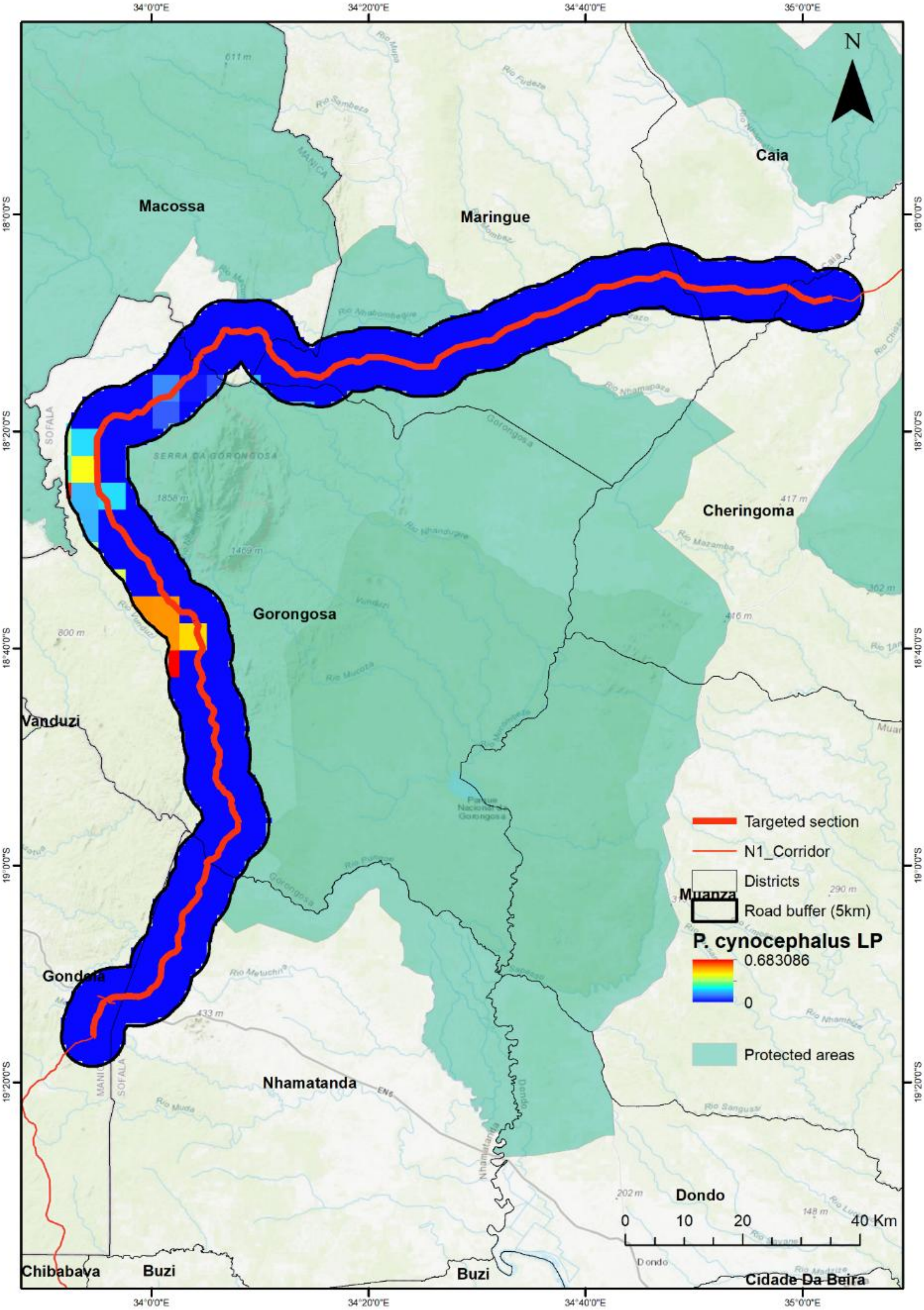


Figure A6: Landscape permeability across the Inchope-Caia road rehabilitation project for the yellow baboon. The scale should be considered between 0 and 1.

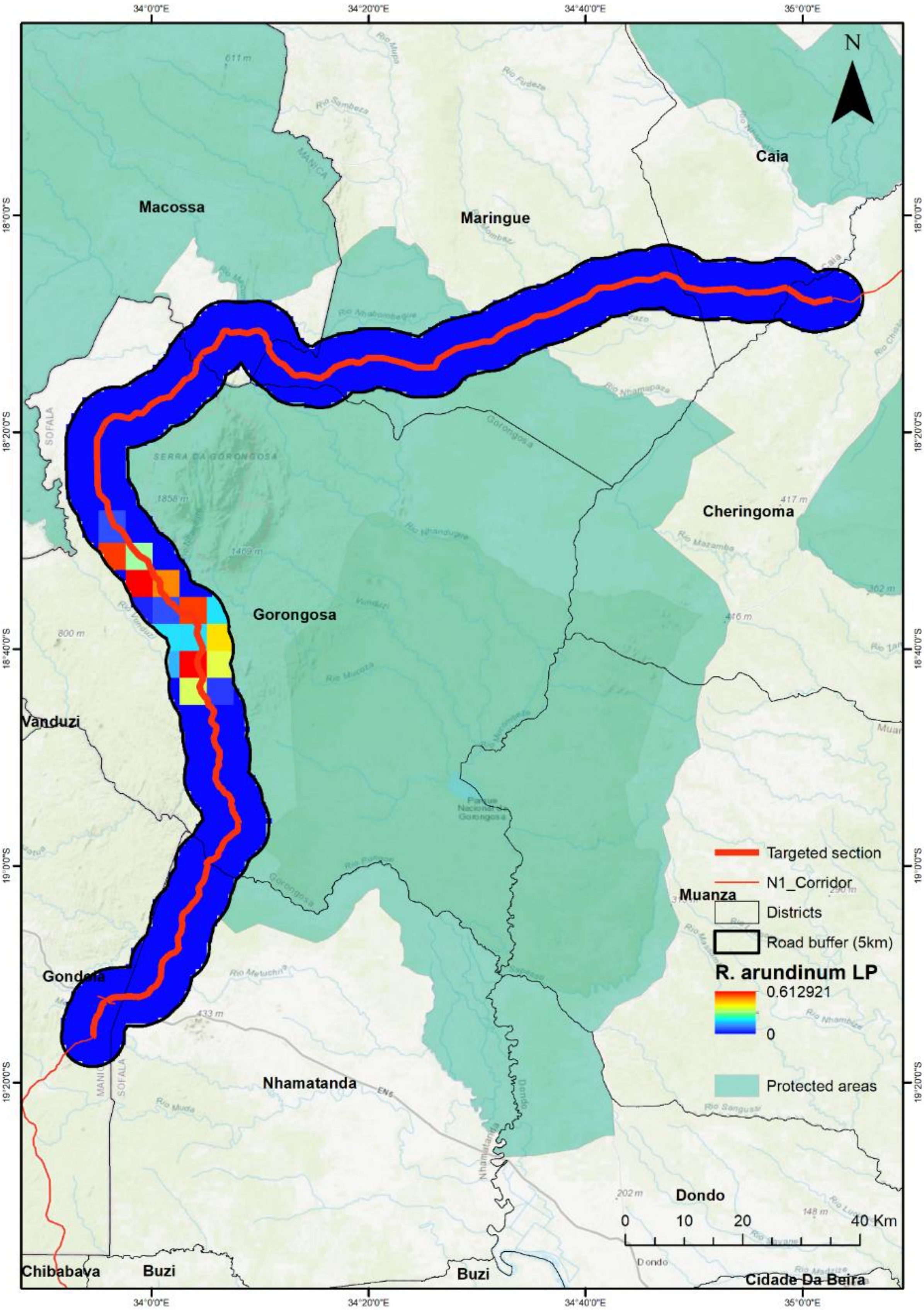


Figure A6: Landscape permeability across the Inchope-Caia road rehabilitation project for the southern reedbuck. The scale should be considered between 0 and 1.

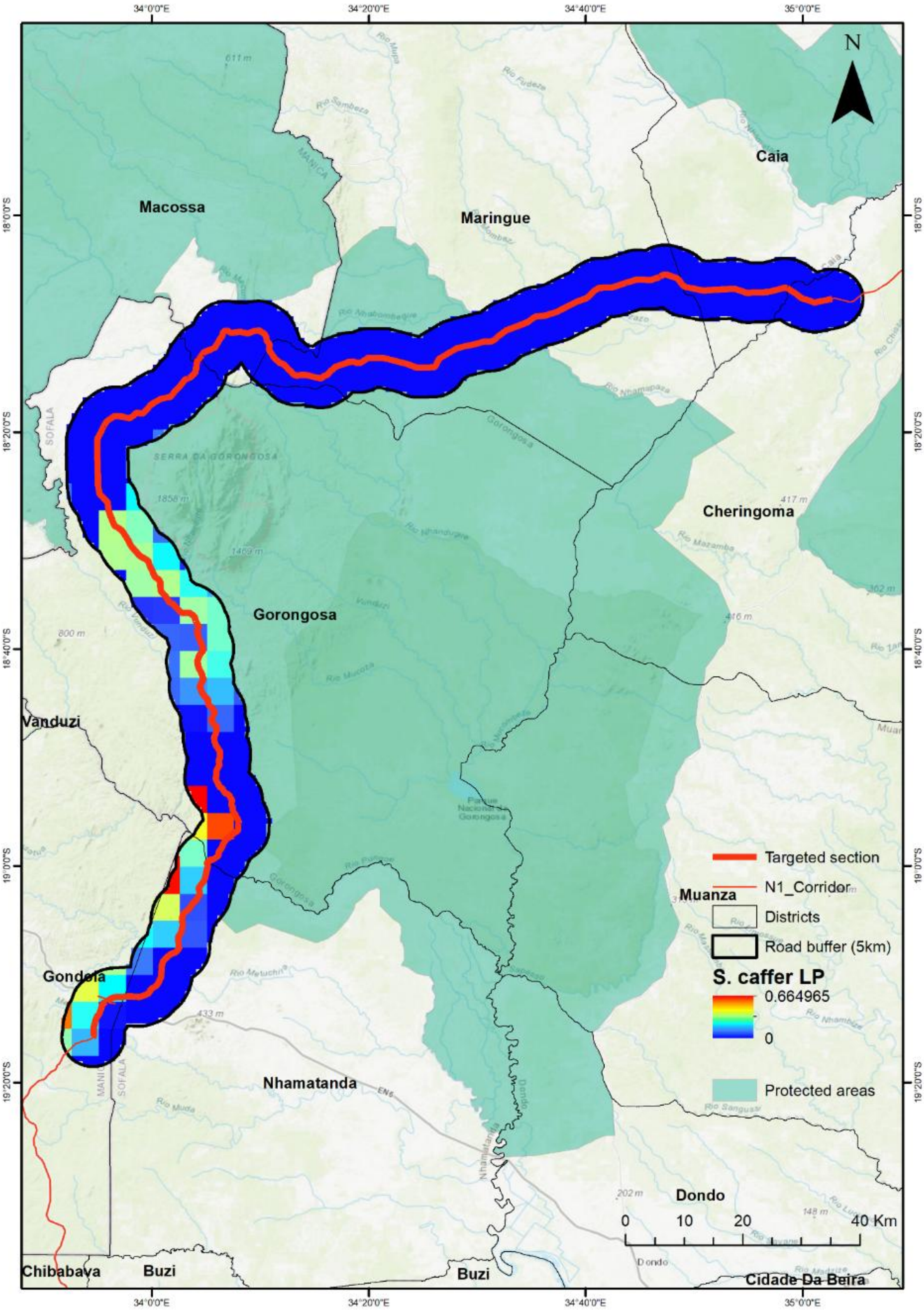


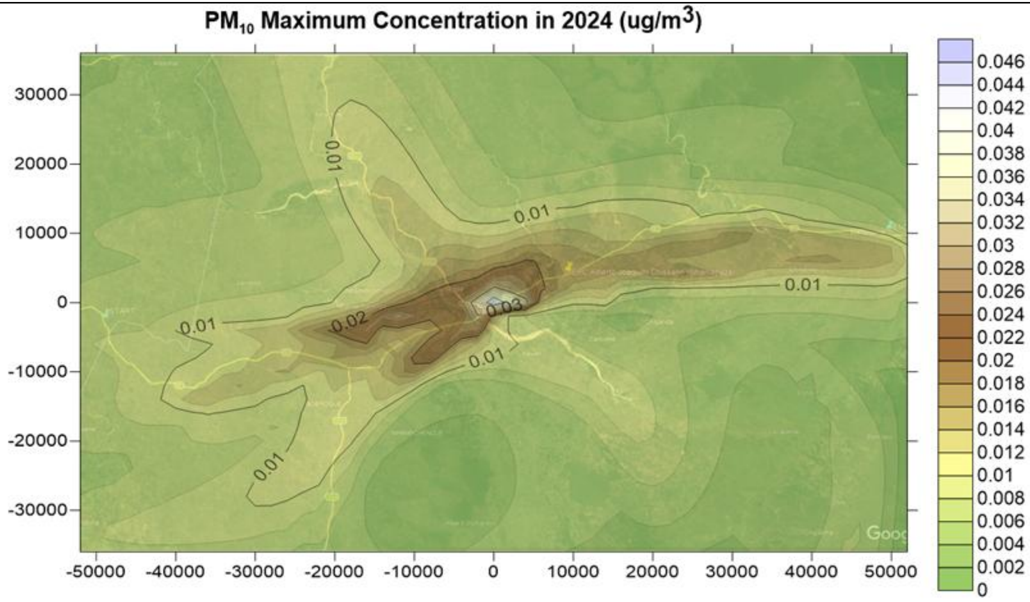
Figure A7: Landscape permeability across the Inchope-Caia road rehabilitation project for the African savannah buffalo. The scale should be considered between 0 and 1.

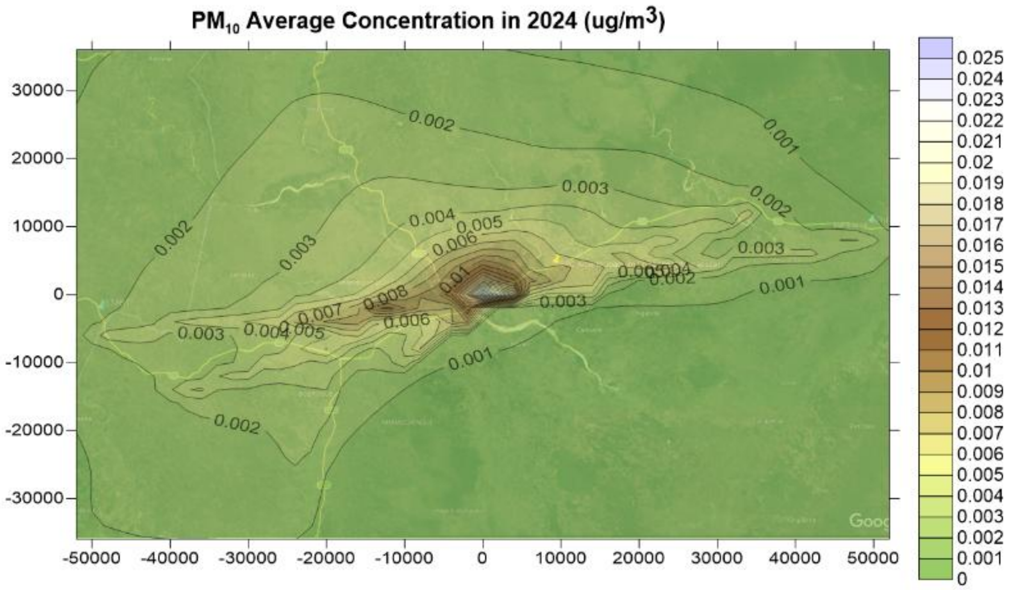
12 ANNEX 2

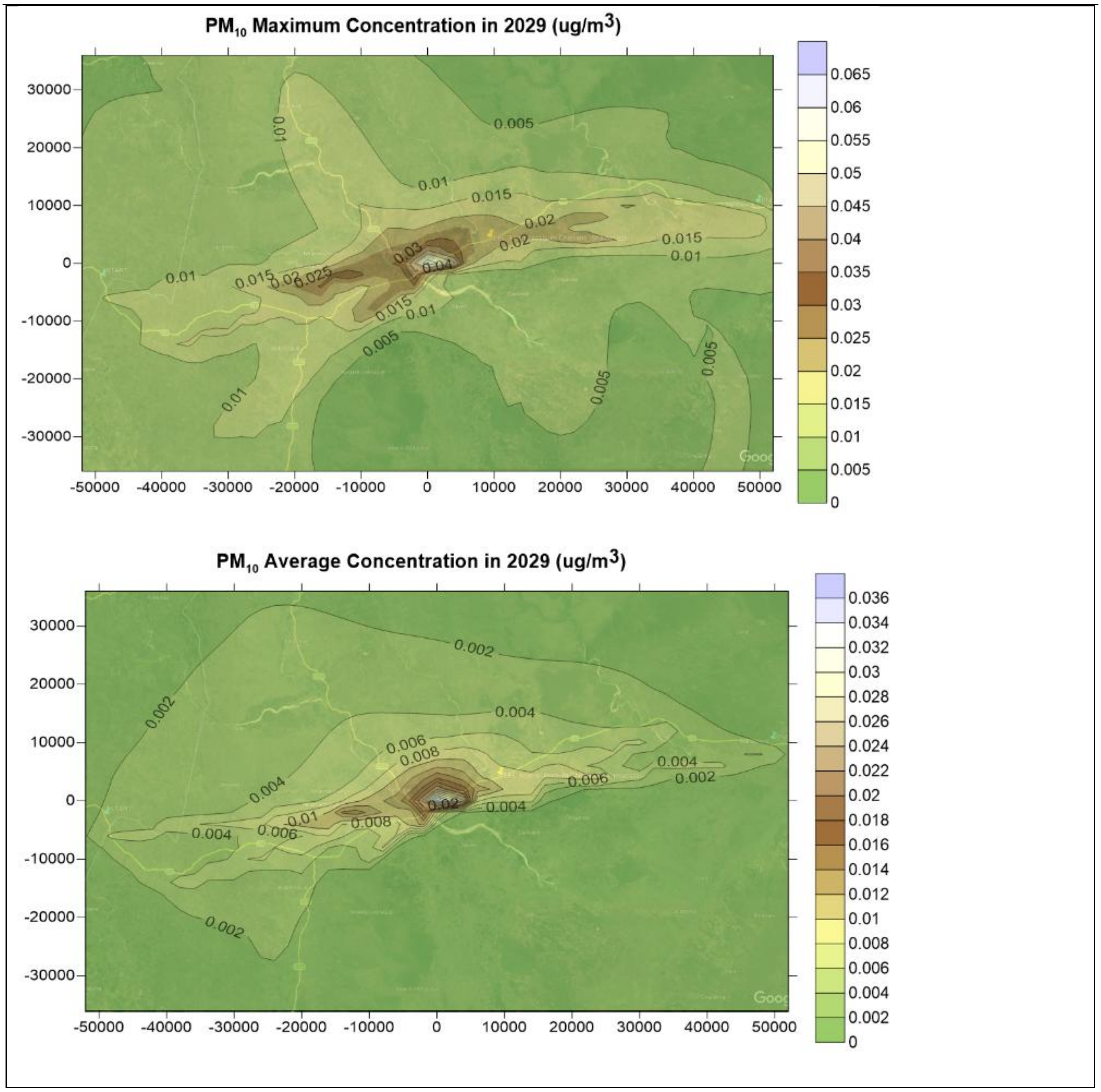
Air quality modeling spatial dispersion maps:

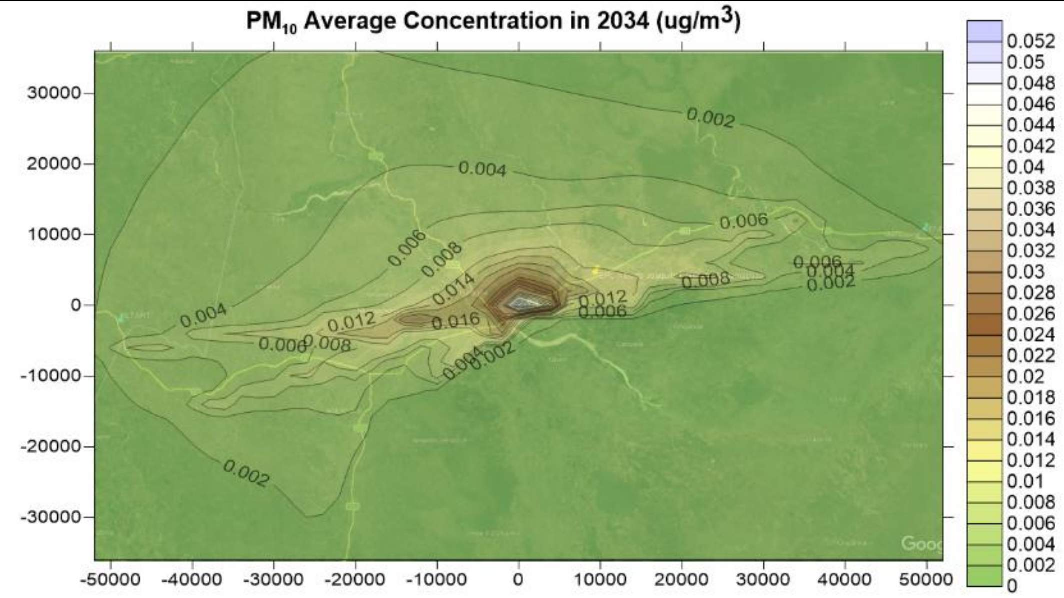
Air quality modeling spatial dispersion maps:

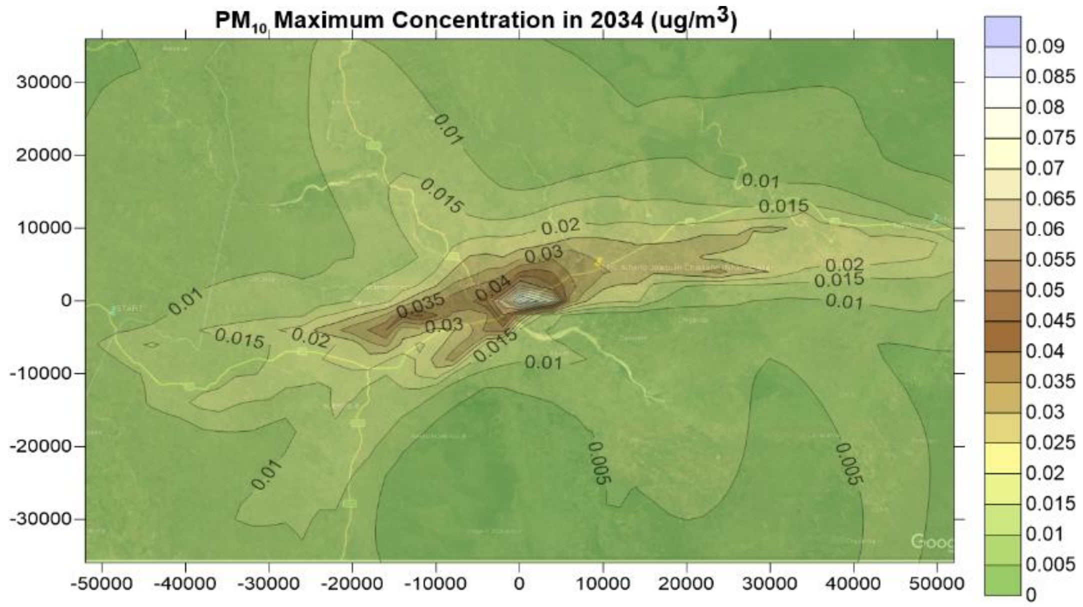
Dispersion maps for PM_{10}

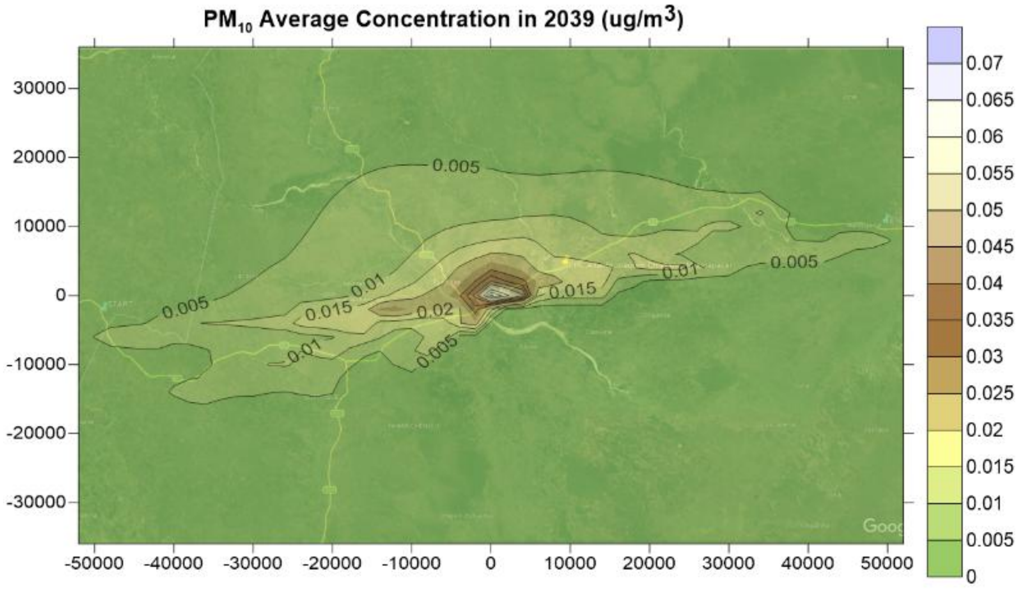


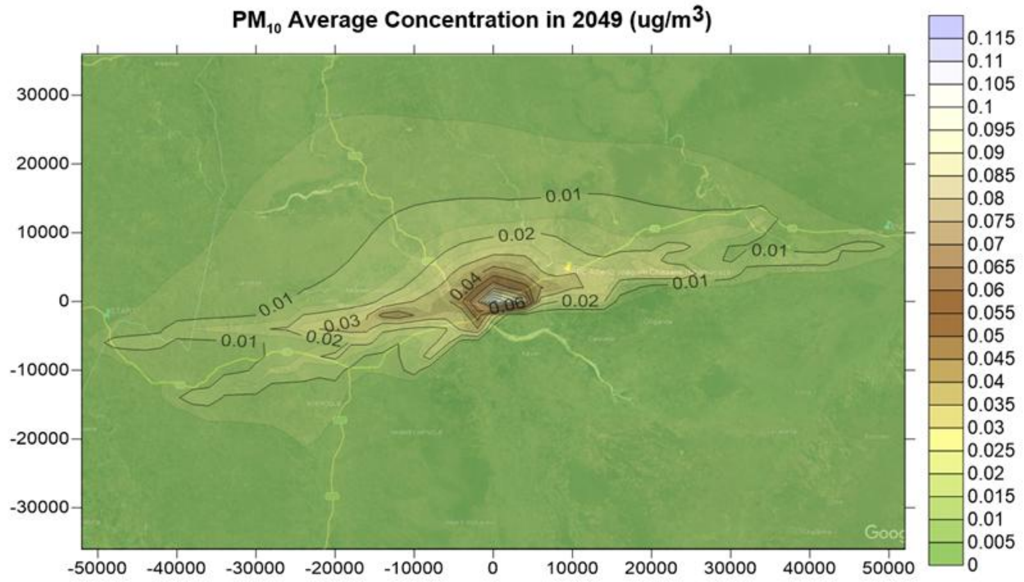


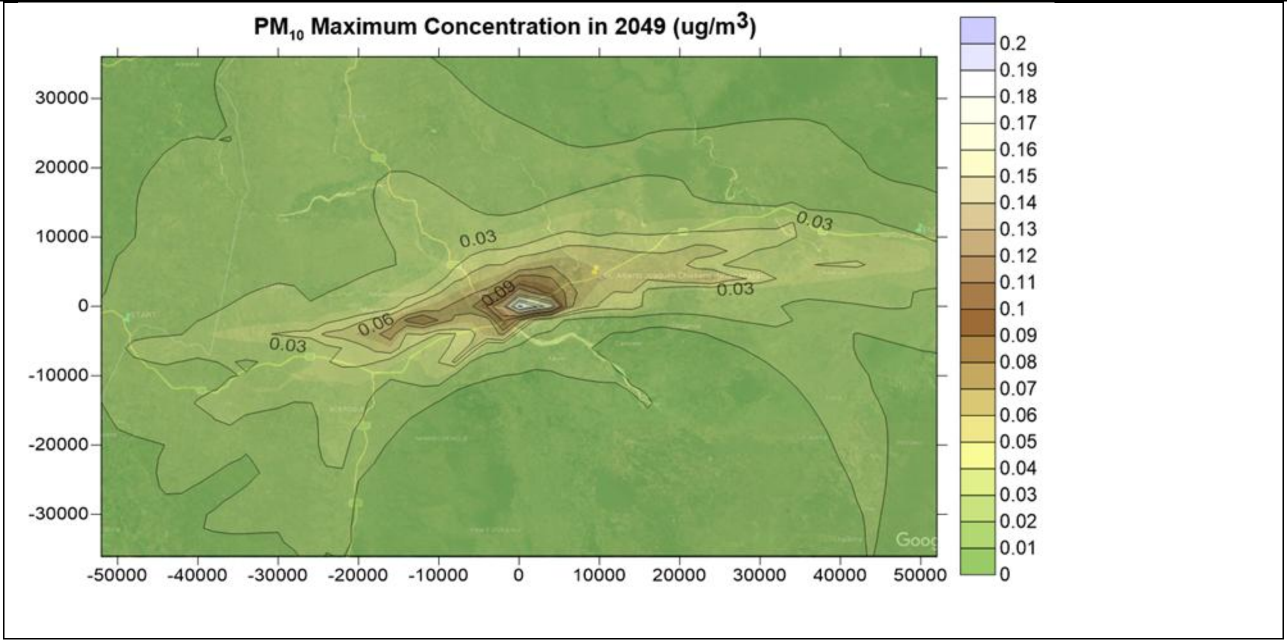

PM10 Maximum Concentration in 2029 (ug/m3)
PM10 Average Concentration in 2029 (ug/m3)


PM_{10} Average Concentration in 2034 (ug/m^3)
30000
20000
10000
0
-10000
-20000
-30000
-50000
-40000
-30000
-20000
-10000
0
10000
20000
30000
40000
50000
0.052
0.05
0.048
0.046
0.044
0.042
0.04
0.038
0.036
0.034
0.032
0.03
0.028
0.026
0.024
0.022
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0

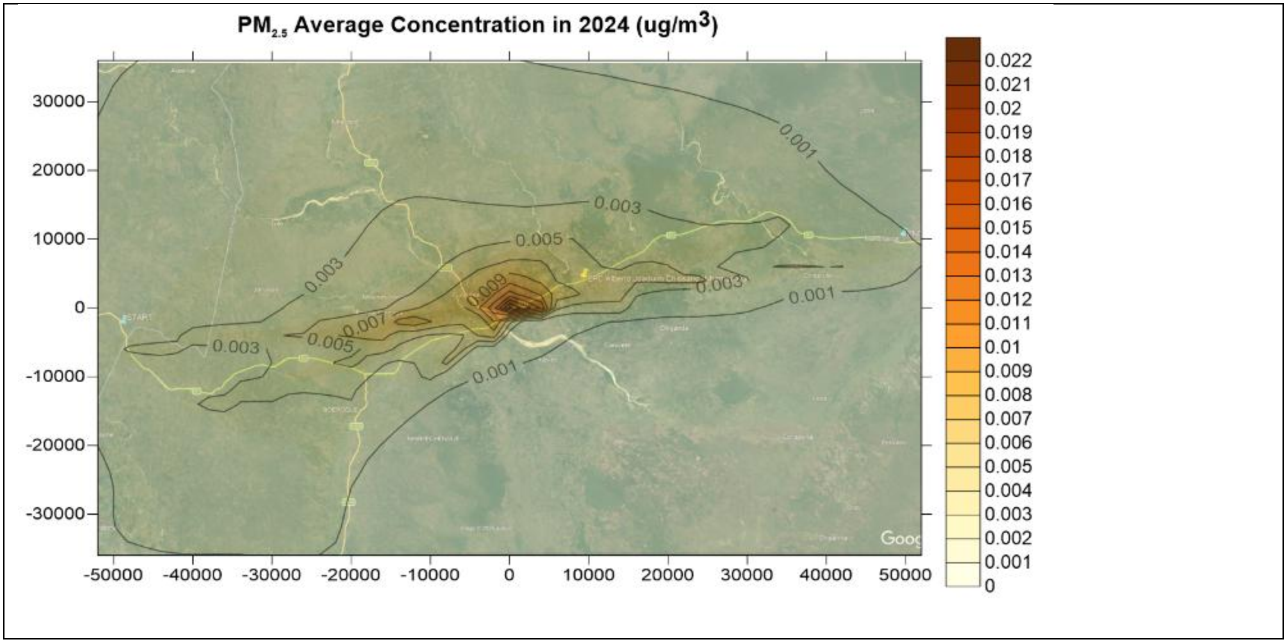

PM_{10} Maximum Concentration in 2034 (ug/m^3)
30000
20000
10000
0
-10000
-20000
-30000
-50000
-40000
-30000
-20000
-10000
0
10000
20000
30000
40000
50000
0.09
0.085
0.08
0.075
0.07
0.065
0.06
0.055
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0

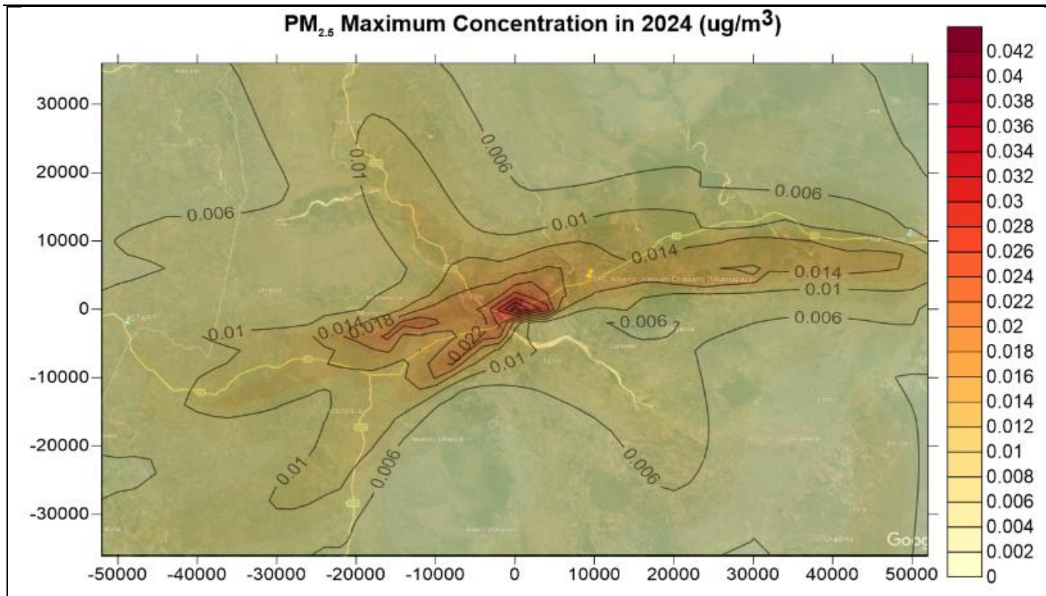

PM10 Average Concentration in 2039 (ug/m3)
30000
20000
10000
0
-10000
-20000
-30000
-50000
-40000
-30000
-20000
-10000
0
10000
20000
30000
40000
50000
0.005
0.01
0.015
0.02
0.07
0.065
0.06
0.055
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0

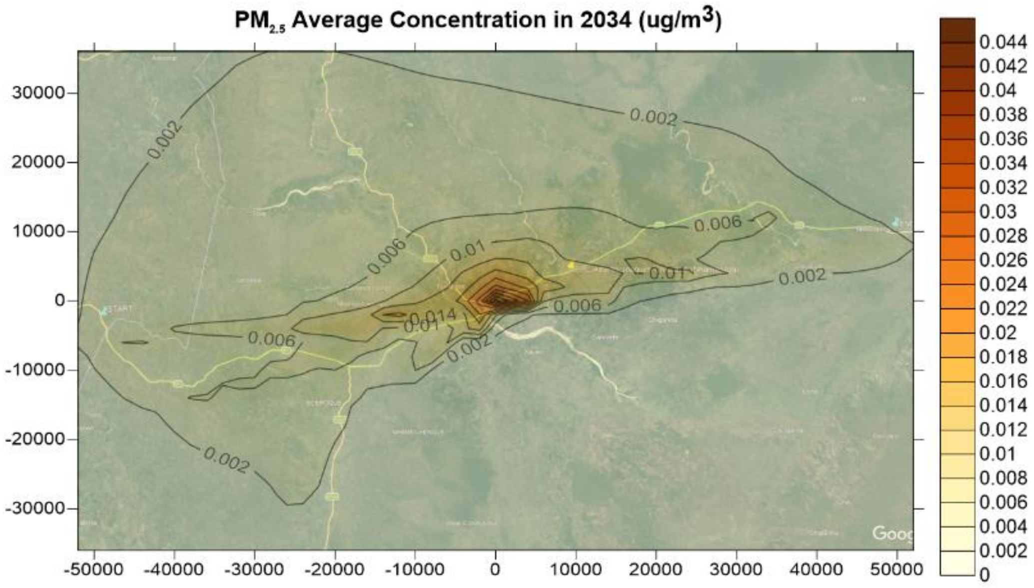

PM10 Average Concentration in 2049 (ug/m3)
30000
20000
10000
0
-10000
-20000
-30000
-50000
-40000
-30000
-20000
-10000
0
10000
20000
30000
40000
50000
0.01
0.02
0.03
0.04
0.115
0.11
0.105
0.1
0.095
0.09
0.085
0.08
0.075
0.07
0.065
0.06
0.055
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0

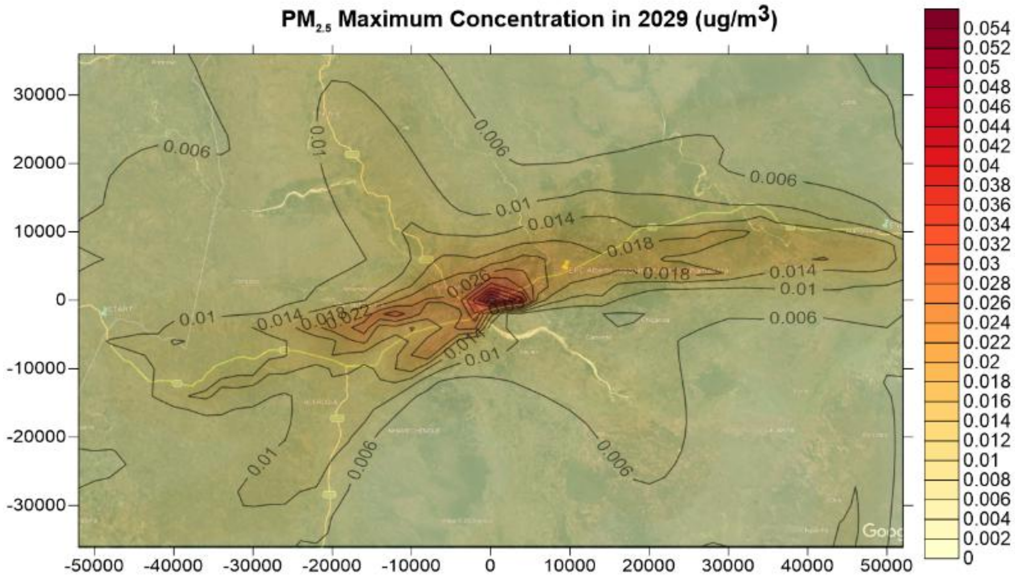


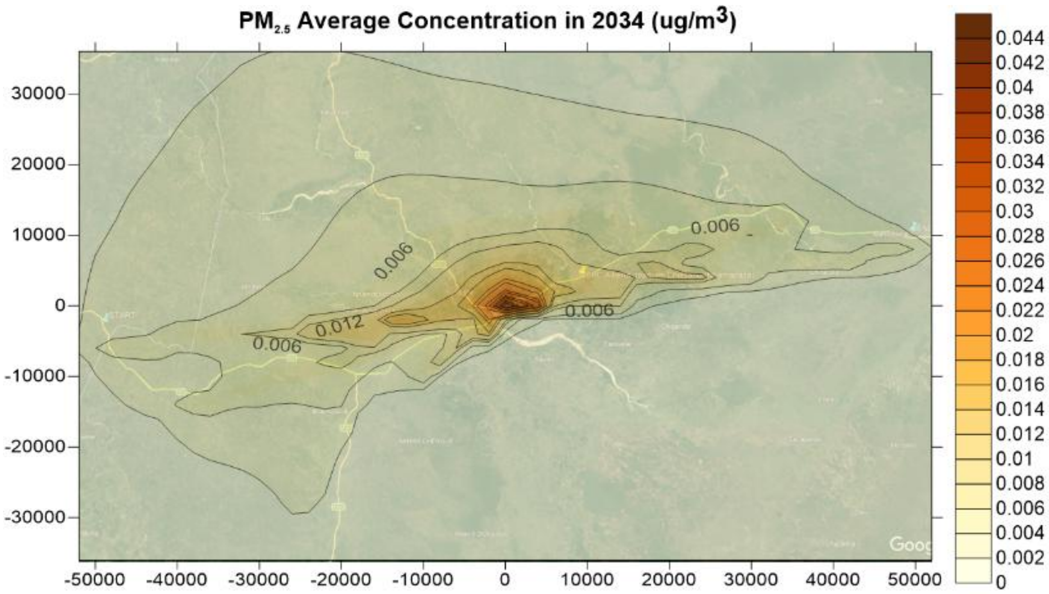
Dispersion maps for $PM_{2.5}$

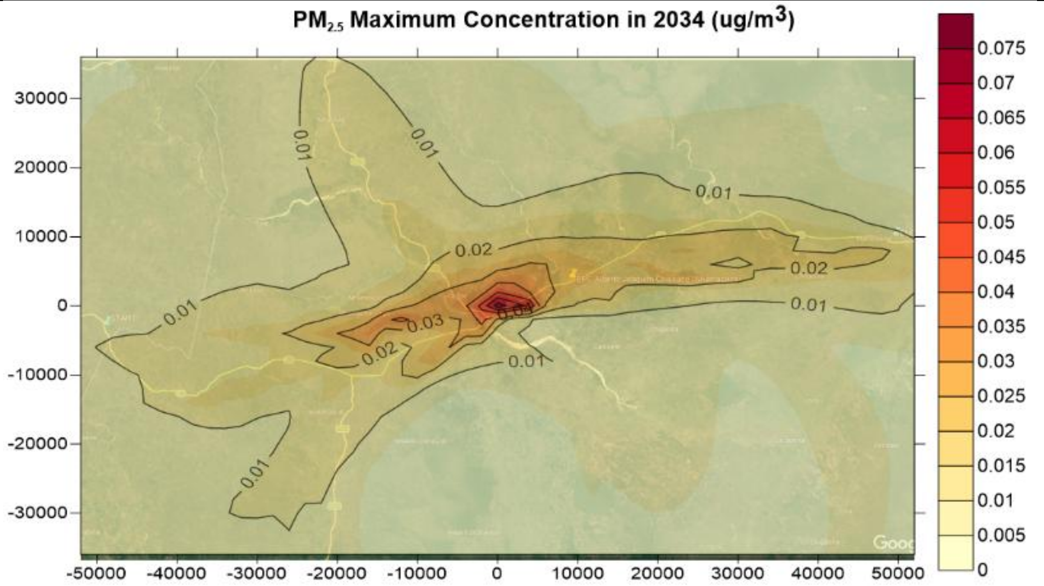


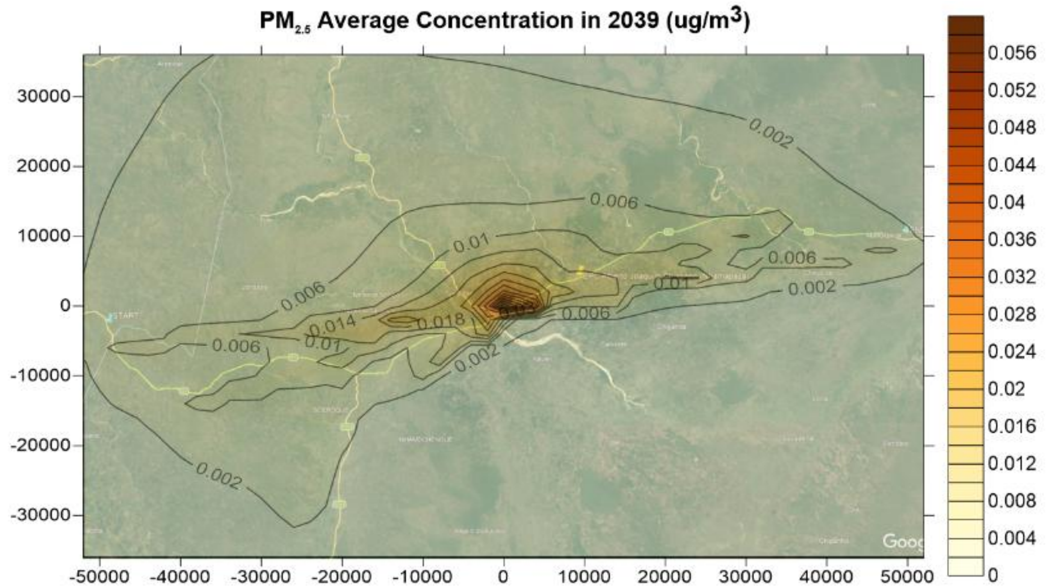

PM2.5 Maximum Concentration in 2024 (ug/m3)
30000
20000
10000
0
-10000
-20000
-30000
-50000 -40000 -30000 -20000 -10000 0 10000 20000 30000 40000 50000
0.006
0.01
0.014
0.018
0.022
0.042
0.04
0.038
0.036
0.034
0.032
0.03
0.028
0.026
0.024
0.022
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0

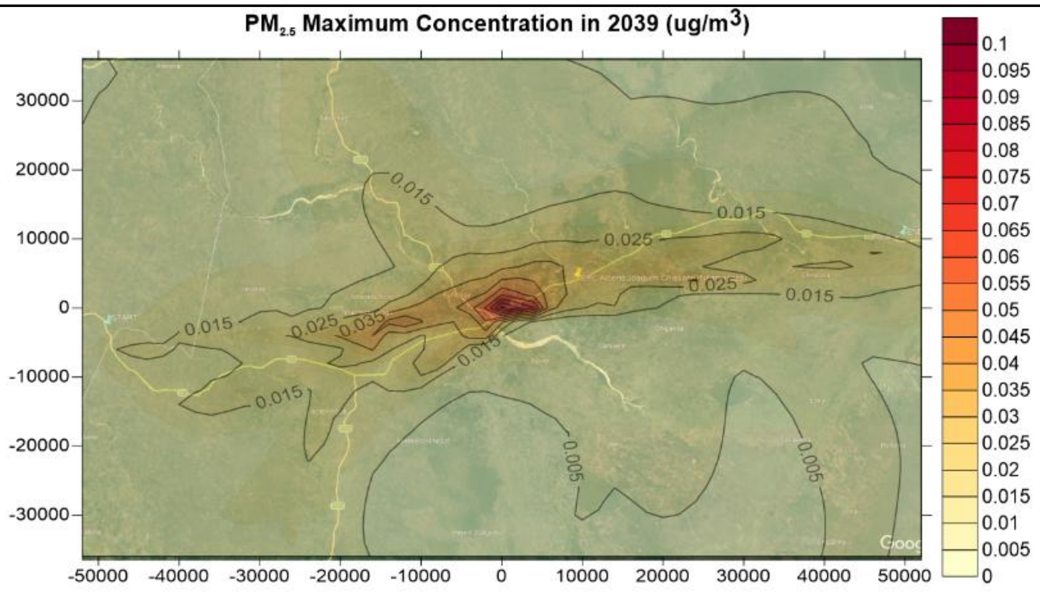

PM2.5 Average Concentration in 2034 (ug/m3)
30000
20000
10000
0
-10000
-20000
-30000
-50000 -40000 -30000 -20000 -10000 0 10000 20000 30000 40000 50000
0.002
0.006
0.01
0.014
0.044
0.042
0.04
0.038
0.036
0.034
0.032
0.03
0.028
0.026
0.024
0.022
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0

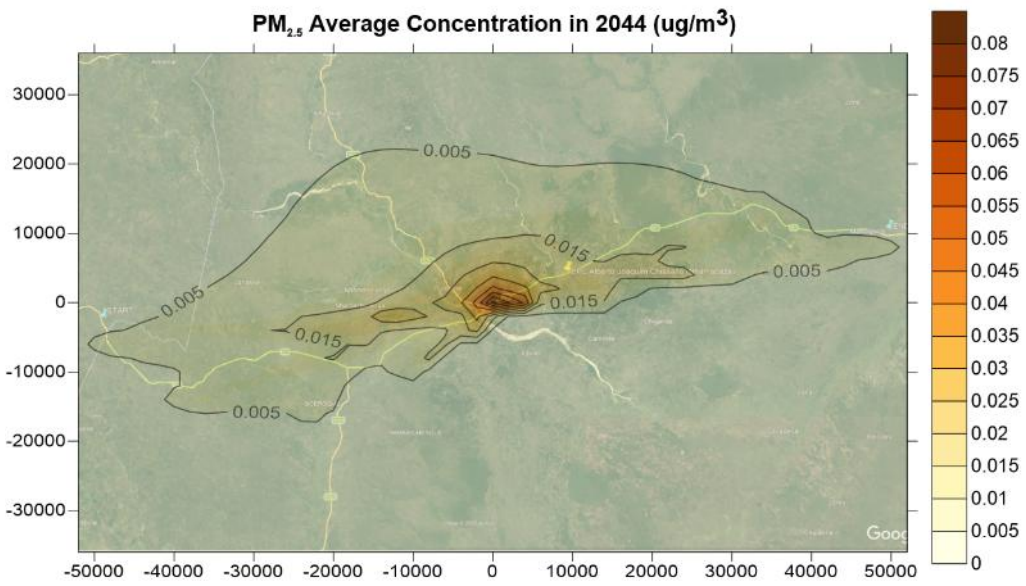

PM2.5 Maximum Concentration in 2029 (ug/m3)
0.054
0.052
0.05
0.048
0.046
0.044
0.042
0.04
0.038
0.036
0.034
0.032
0.03
0.028
0.026
0.024
0.022
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
30000
20000
10000
0
-10000
-20000
-30000
-50000
-40000
-30000
-20000
-10000
0
10000
20000
30000
40000
50000

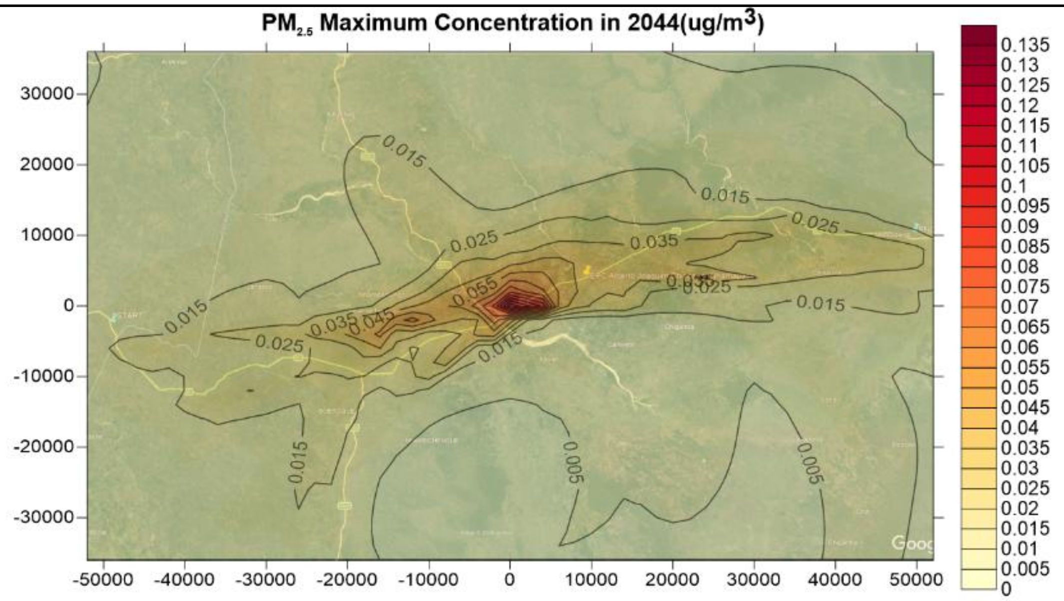

PM2.5 Average Concentration in 2034 (ug/m3)
0.044
0.042
0.04
0.038
0.036
0.034
0.032
0.03
0.028
0.026
0.024
0.022
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
30000
20000
10000
0
-10000
-20000
-30000
-50000
-40000
-30000
-20000
-10000
0
10000
20000
30000
40000
50000

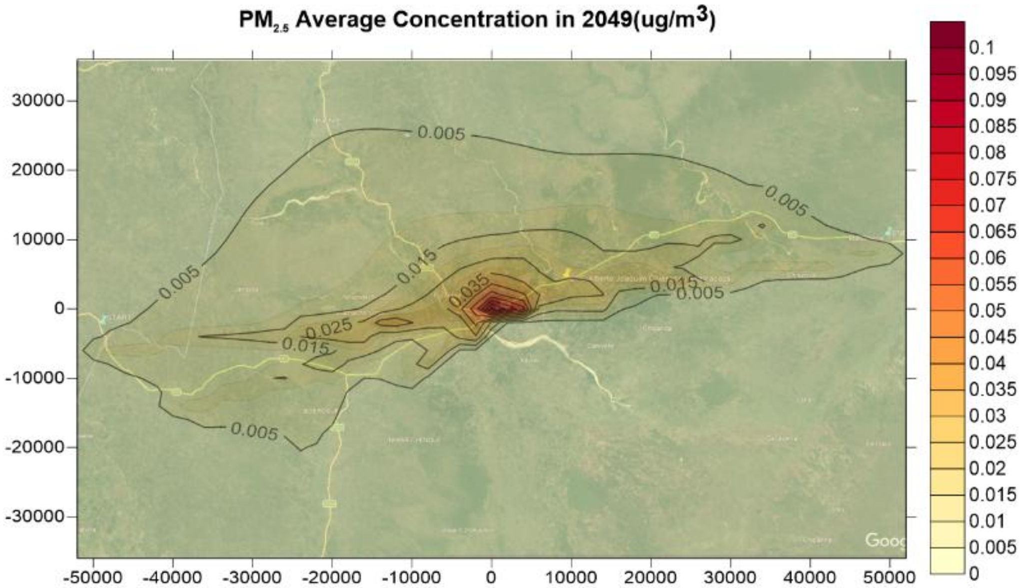

PM2.5 Maximum Concentration in 2034 (ug/m3)
0.075
0.07
0.065
0.06
0.055
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
30000
20000
10000
0
-10000
-20000
-30000
-50000
-40000
-30000
-20000
-10000
0
10000
20000
30000
40000
50000
0.01
0.02
0.03

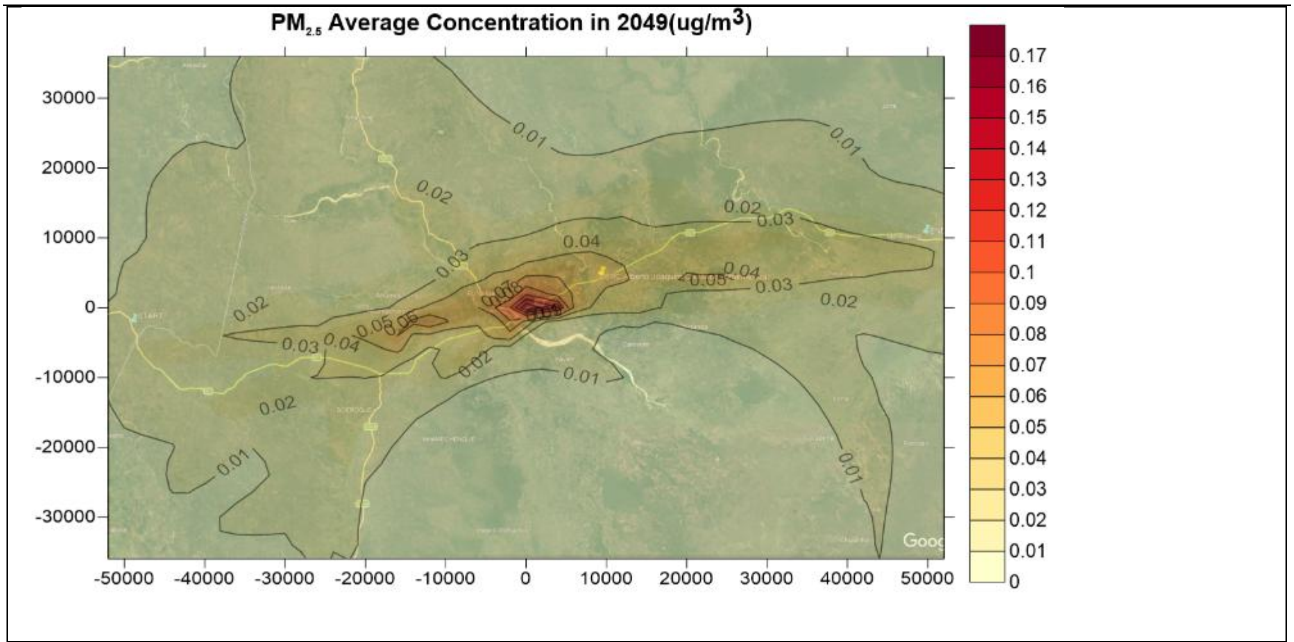

PM2.5 Average Concentration in 2039 (ug/m3)
0.056
0.052
0.048
0.044
0.04
0.036
0.032
0.028
0.024
0.02
0.016
0.012
0.008
0.004
0
30000
20000
10000
0
-10000
-20000
-30000
-50000
-40000
-30000
-20000
-10000
0
10000
20000
30000
40000
50000
0.002
0.006
0.01
0.014
0.018


PM2.5 Maximum Concentration in 2039 (ug/m3)
0.015
0.025
0.035
0.005
0.1
0.095
0.09
0.085
0.08
0.075
0.07
0.065
0.06
0.055
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
30000
20000
10000
0
-10000
-20000
-30000
-50000
-40000
-30000
-20000
-10000
0
10000
20000
30000
40000
50000

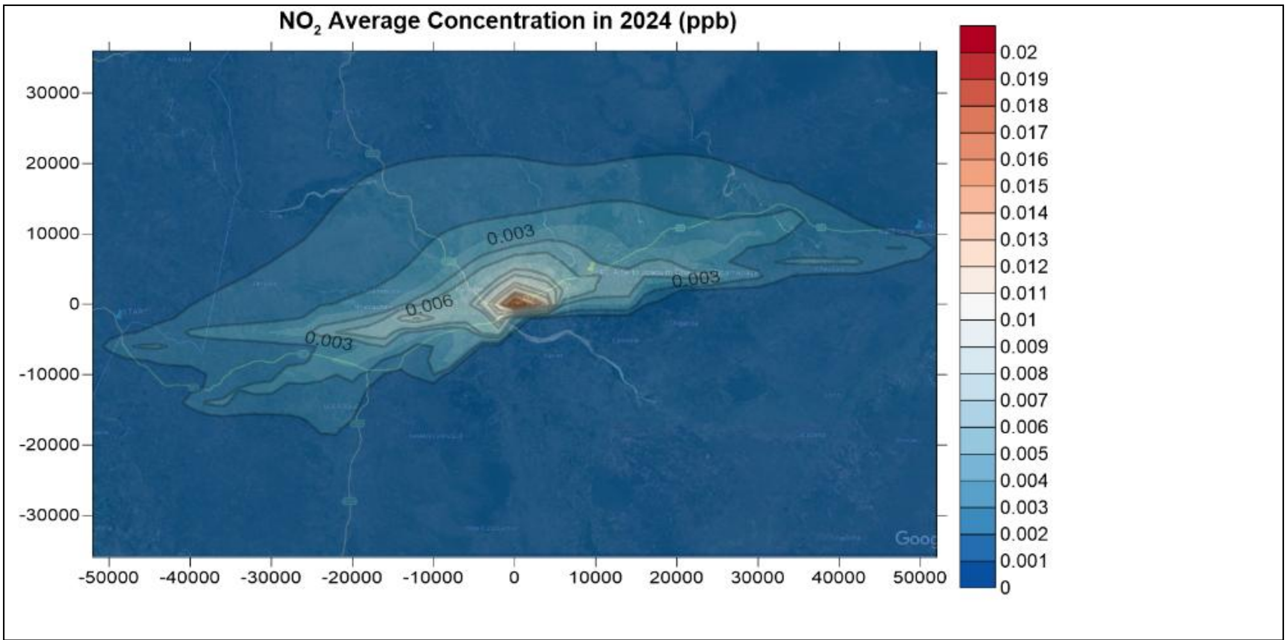

PM2.5 Average Concentration in 2044 (ug/m3)
0.005
0.015
0.08
0.075
0.07
0.065
0.06
0.055
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
30000
20000
10000
0
-10000
-20000
-30000
-50000
-40000
-30000
-20000
-10000
0
10000
20000
30000
40000
50000

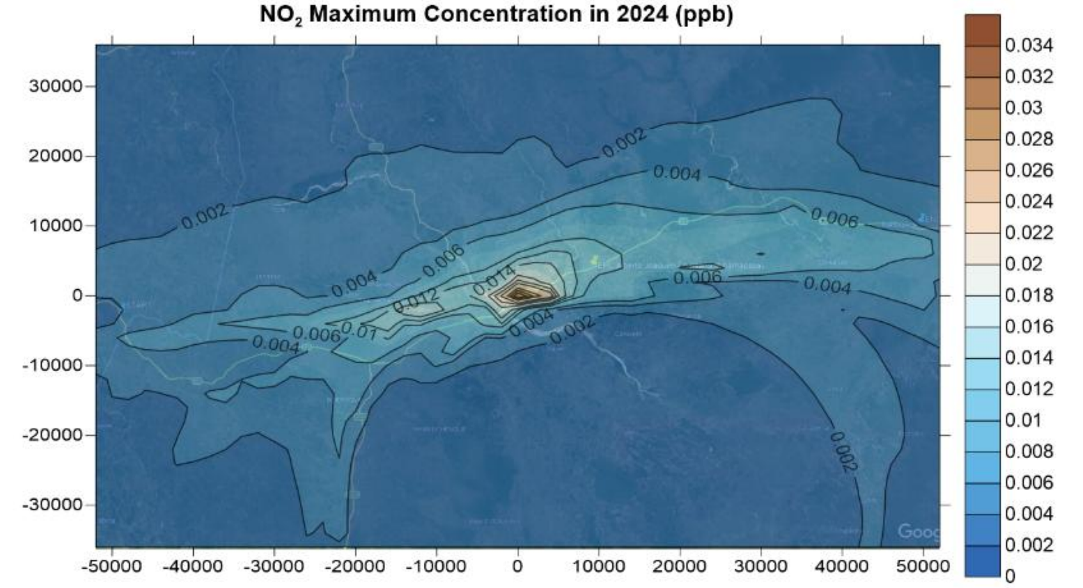

PM2.5 Maximum Concentration in 2044(ug/m3)

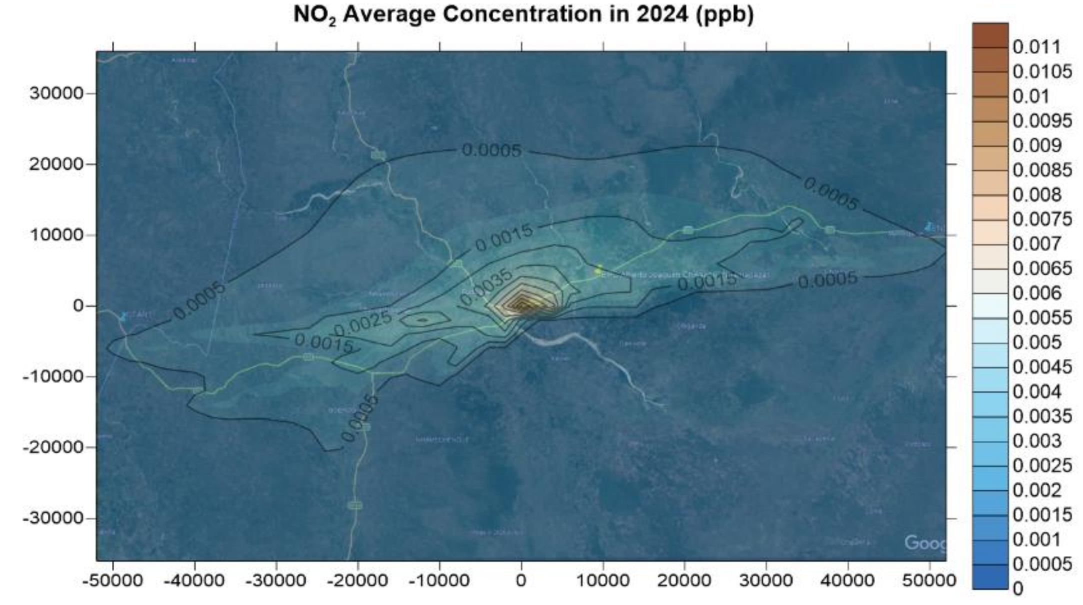

PM2.5 Average Concentration in 2049(ug/m3)

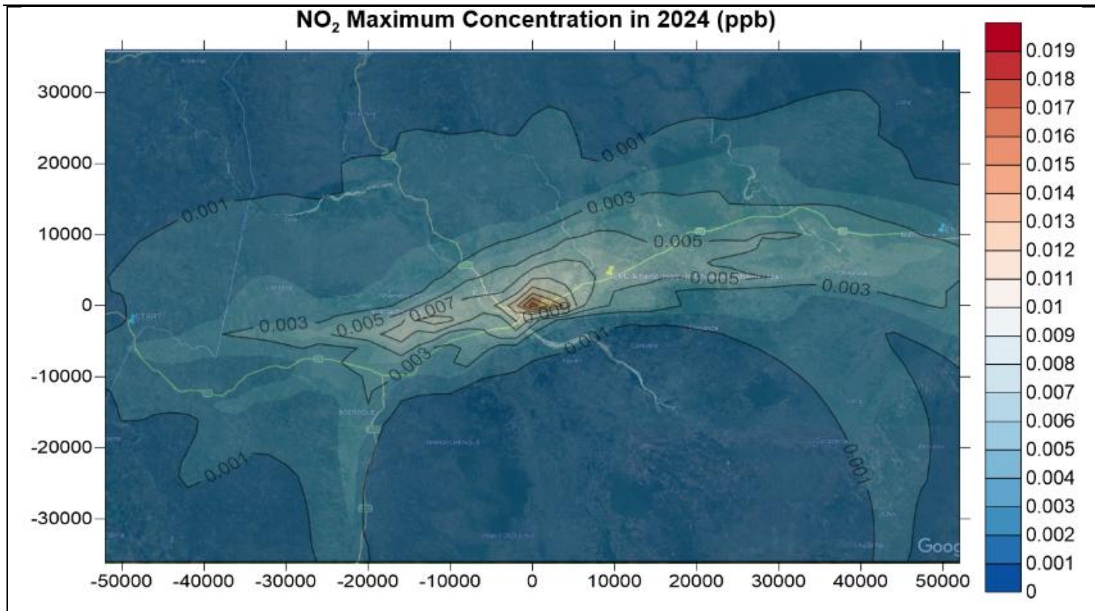


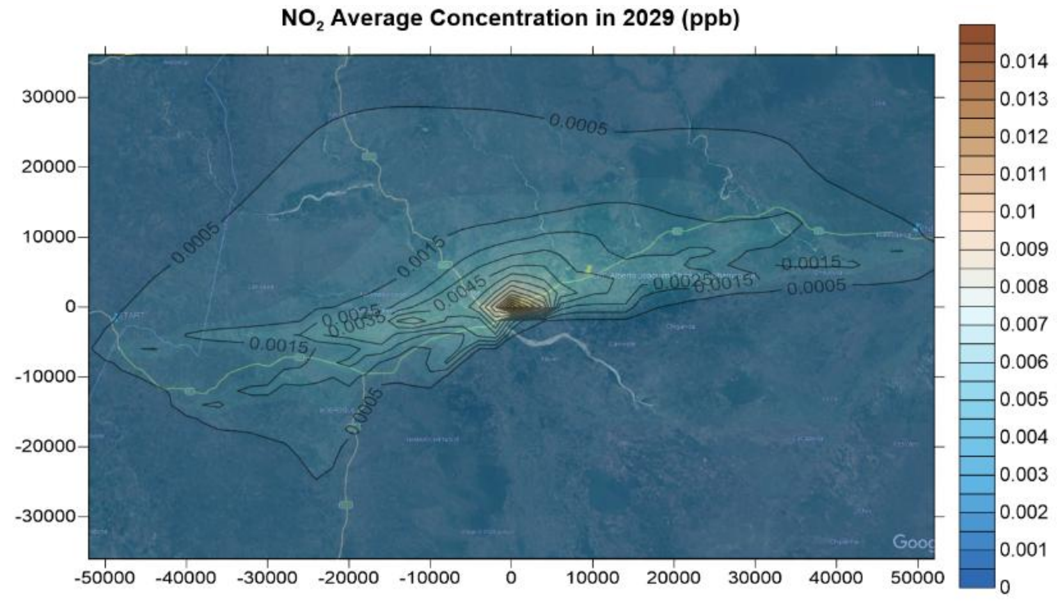
Dispersion maps for NO_2

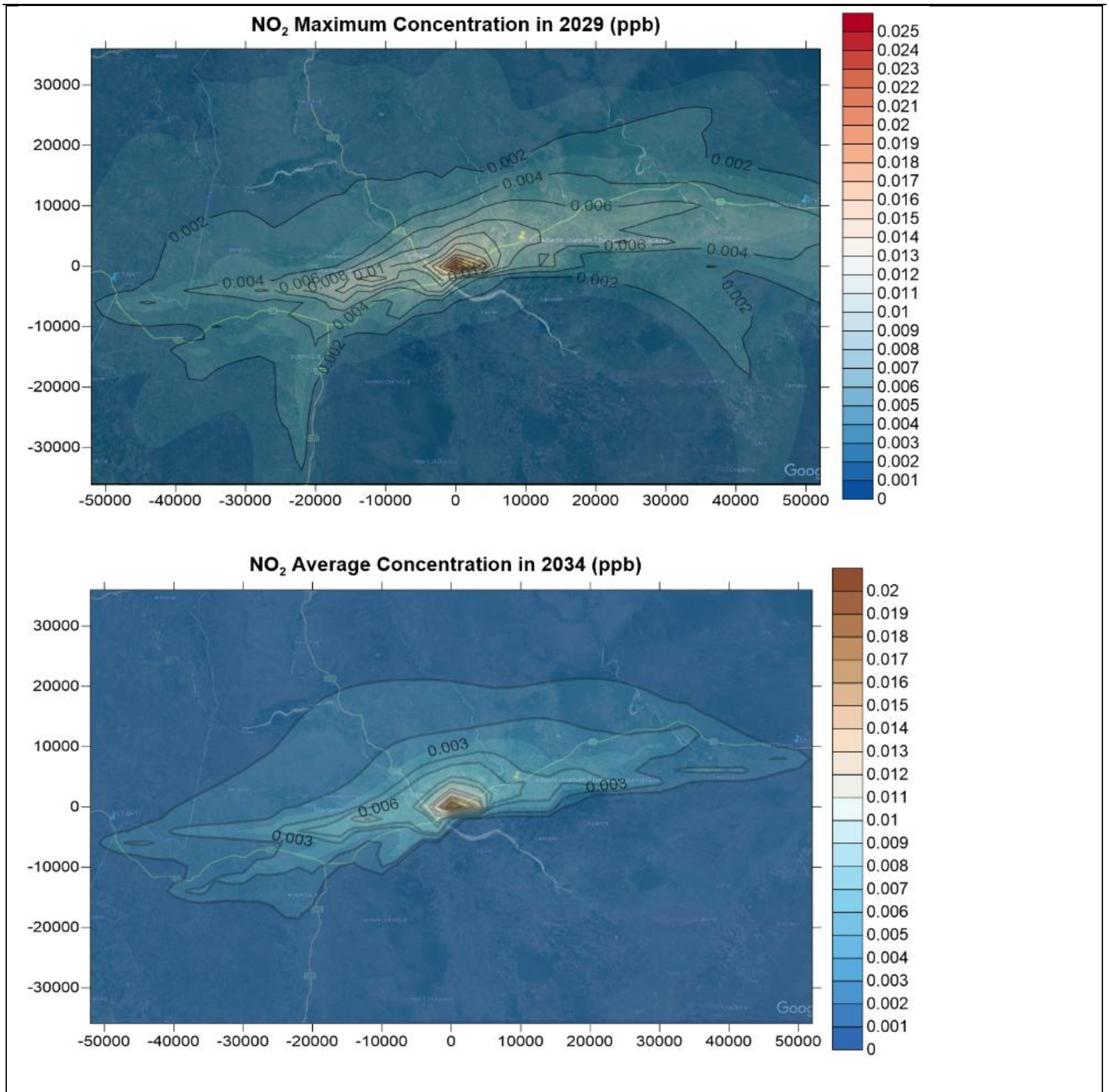



NO$_2$ Maximum Concentration in 2024 (ppb)
30000
20000
10000
0
-10000
-20000
-30000
-50000
-40000
-30000
-20000
-10000
0
10000
20000
30000
40000
50000
0.002
0.004
0.006
0.01
0.012
0.014
0.034
0.032
0.03
0.028
0.026
0.024
0.022
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0

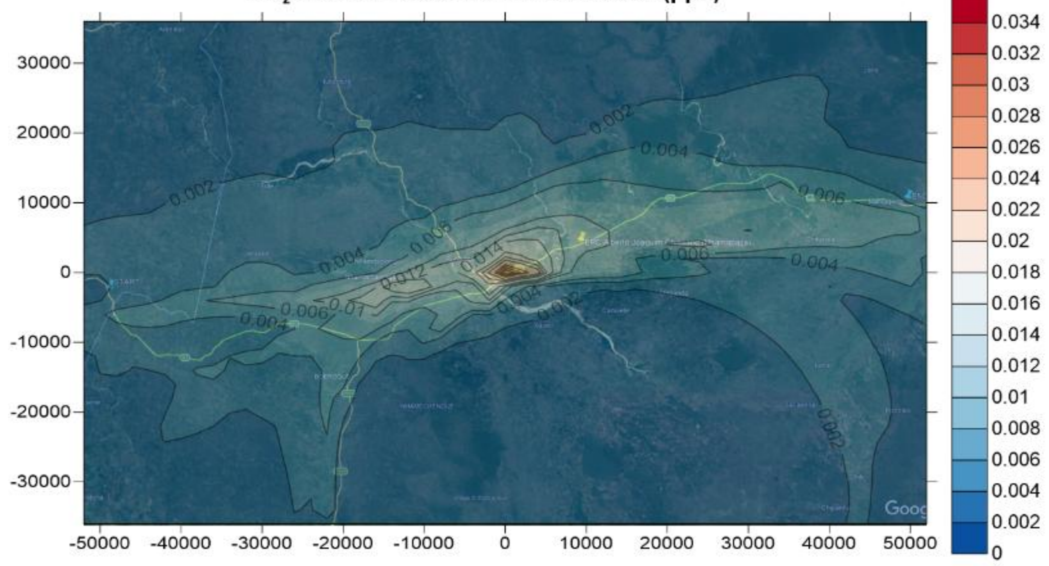

NO$_2$ Average Concentration in 2024 (ppb)
30000
20000
10000
0
-10000
-20000
-30000
-50000
-40000
-30000
-20000
-10000
0
10000
20000
30000
40000
50000
0.0005
0.0015
0.0025
0.0035
0.011
0.0105
0.01
0.0095
0.009
0.0085
0.008
0.0075
0.007
0.0065
0.006
0.0055
0.005
0.0045
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0


NO2 Maximum Concentration in 2024 (ppb)
30000
20000
10000
0
-10000
-20000
-30000
-50000 -40000 -30000 -20000 -10000 0 10000 20000 30000 40000 50000
0.001
0.003
0.005
0.007
0.009
0.011
0.019
0.018
0.017
0.016
0.015
0.014
0.013
0.012
0.011
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0

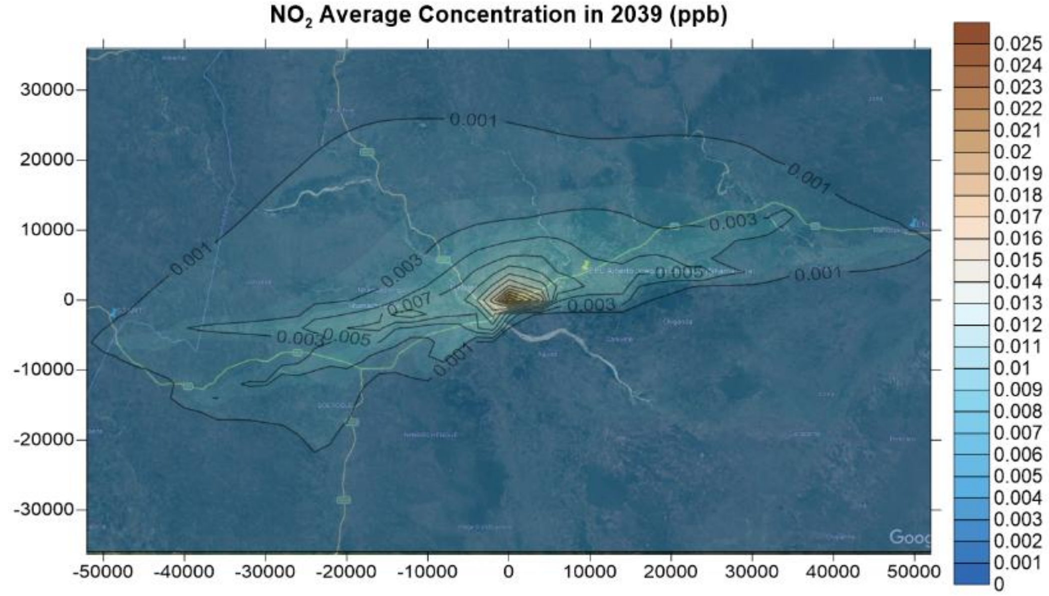

NO2 Average Concentration in 2029 (ppb)
30000
20000
10000
0
-10000
-20000
-30000
-50000 -40000 -30000 -20000 -10000 0 10000 20000 30000 40000 50000
0.0005
0.0015
0.0025
0.0035
0.0045
0.014
0.013
0.012
0.011
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0

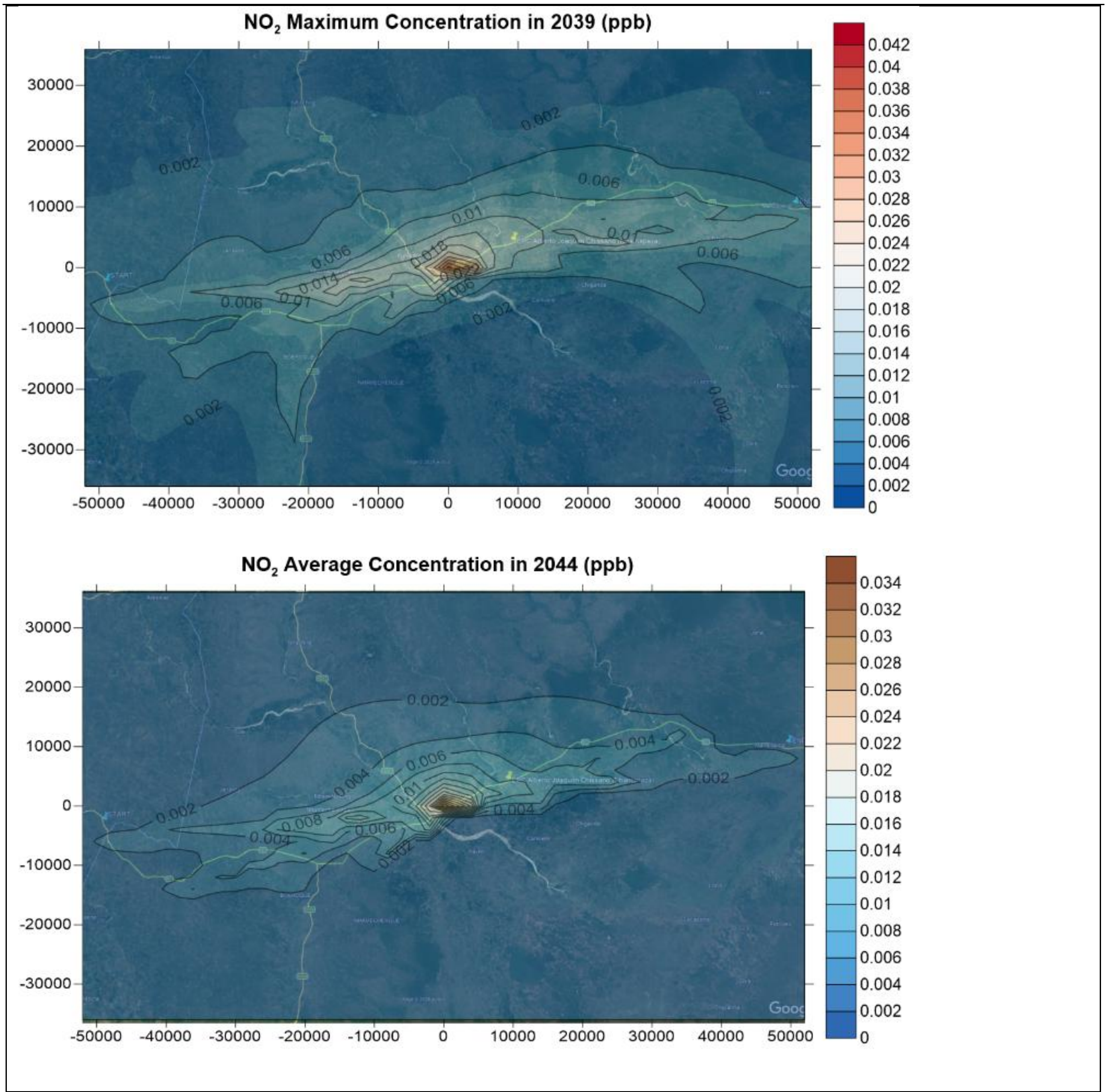

NO2 Maximum Concentration in 2029 (ppb)
30000
20000
10000
0
-10000
-20000
-30000
-50000
-40000
-30000
-20000
-10000
0
10000
20000
30000
40000
50000
0.025
0.024
0.023
0.022
0.021
0.02
0.019
0.018
0.017
0.016
0.015
0.014
0.013
0.012
0.011
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
NO2 Average Concentration in 2034 (ppb)
0.02
0.019
0.018
0.017
0.016
0.015
0.014
0.013
0.012
0.011
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0

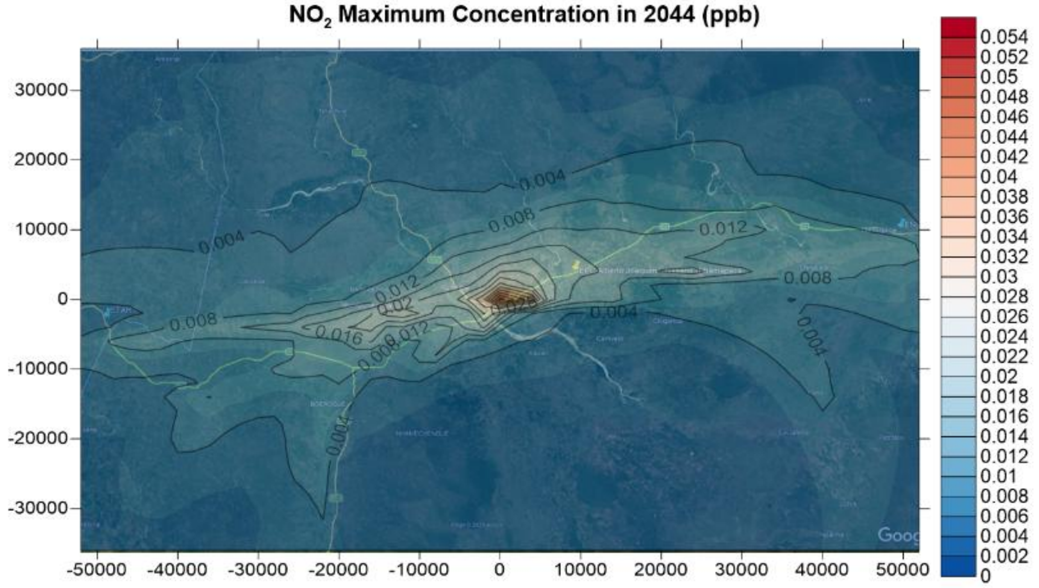
NO_2 Maximum Concentration in 2034 (ppb)

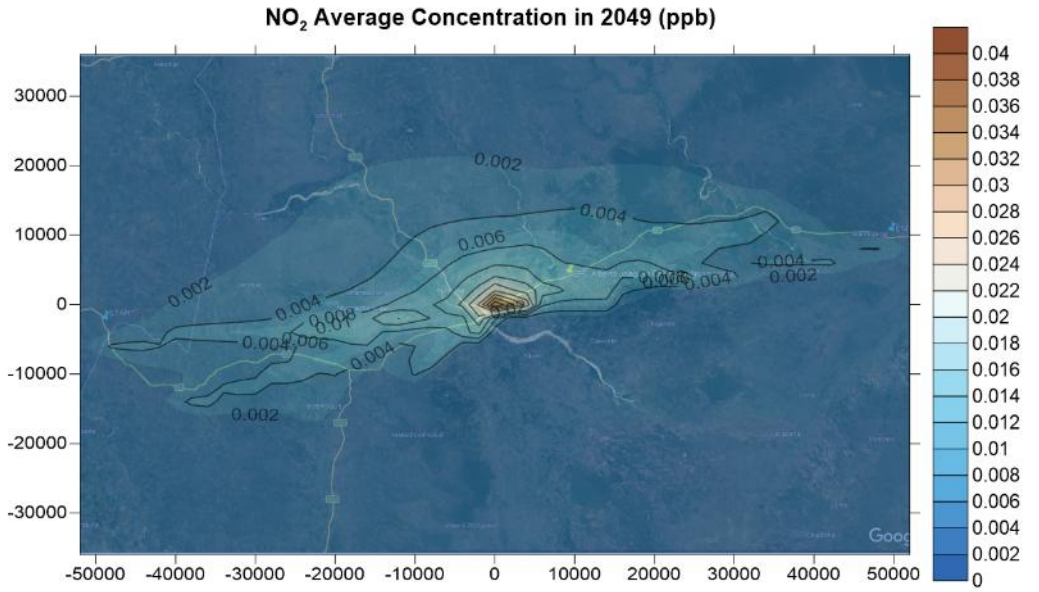


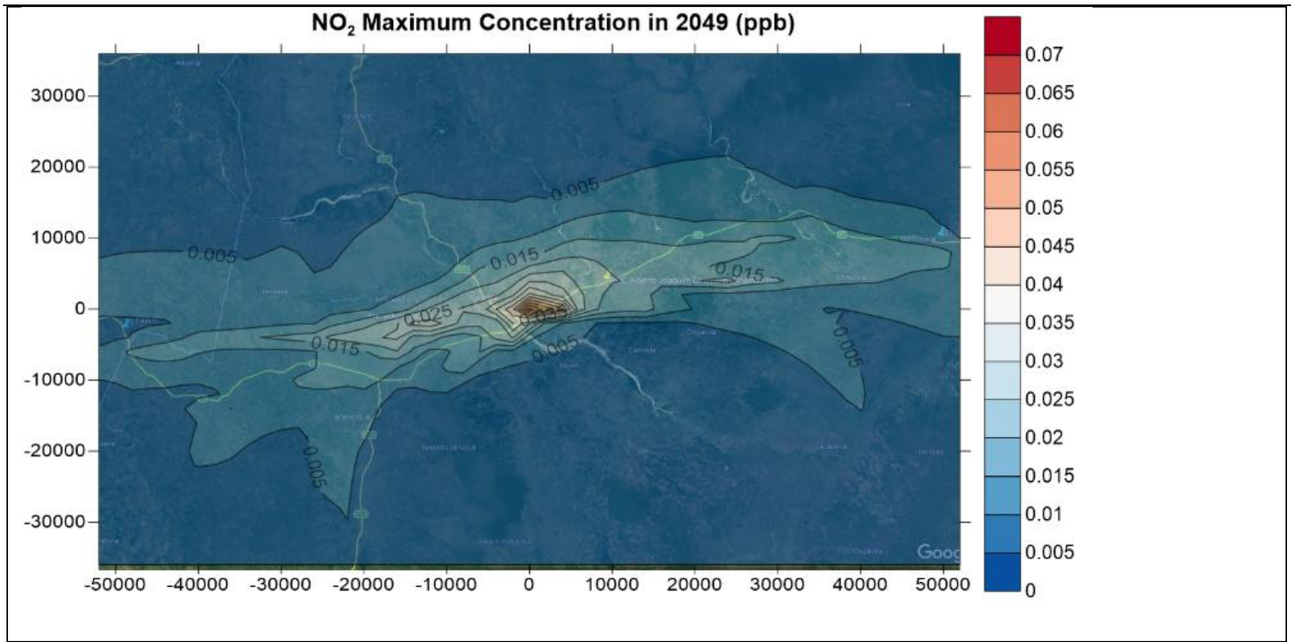
NO_2 Average Concentration in 2039 (ppb)



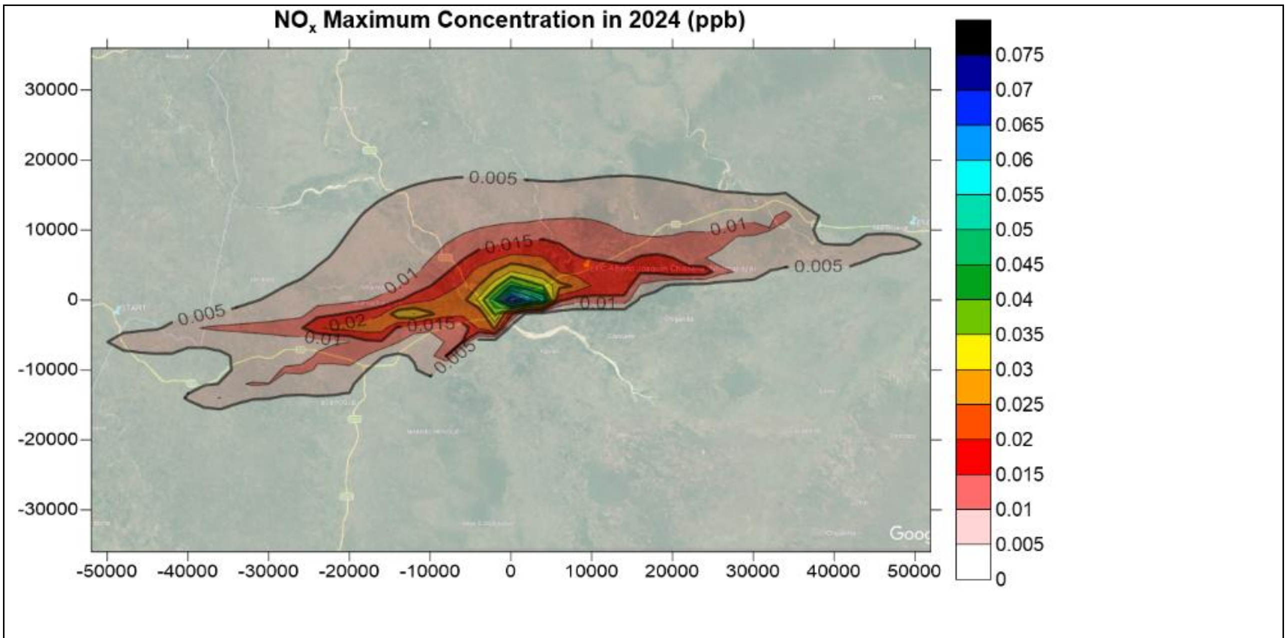

NO2 Maximum Concentration in 2039 (ppb)
0.042
0.04
0.038
0.036
0.034
0.032
0.03
0.028
0.026
0.024
0.022
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
NO2 Average Concentration in 2044 (ppb)
0.034
0.032
0.03
0.028
0.026
0.024
0.022
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0

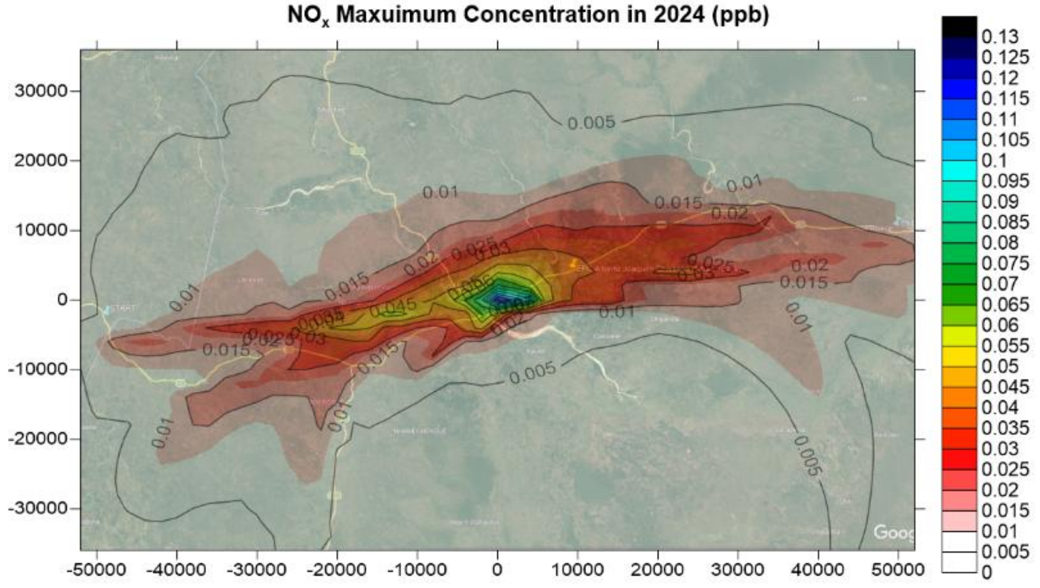

NO_2 Maximum Concentration in 2044 (ppb)
30000
20000
10000
0
-10000
-20000
-30000
-50000
-40000
-30000
-20000
-10000
0
10000
20000
30000
40000
50000
0.004
0.008
0.012
0.016
0.02
0.054
0.052
0.05
0.048
0.046
0.044
0.042
0.04
0.038
0.036
0.034
0.032
0.03
0.028
0.026
0.024
0.022
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0

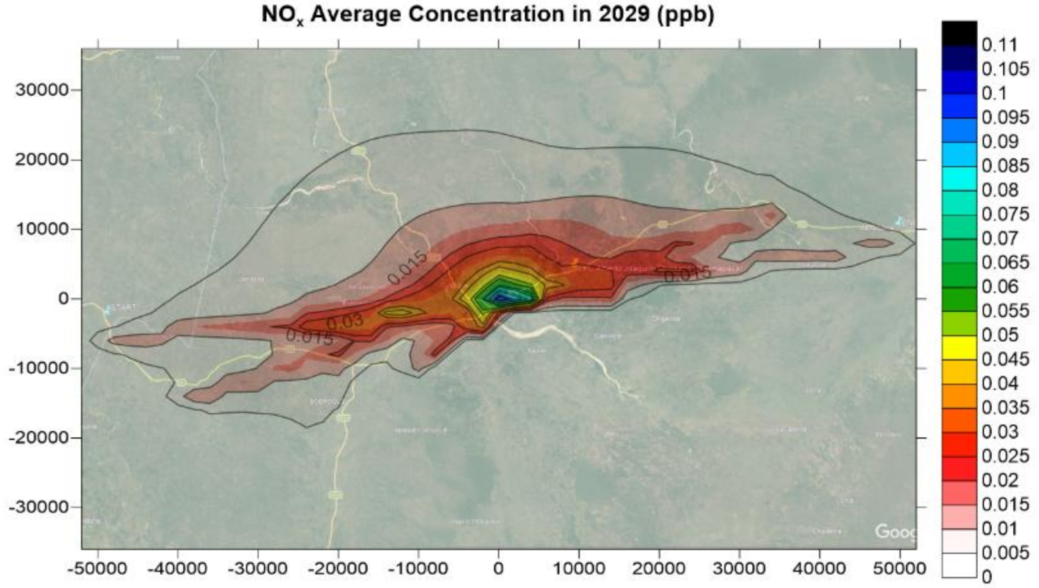

NO_2 Average Concentration in 2049 (ppb)
30000
20000
10000
0
-10000
-20000
-30000
-50000
-40000
-30000
-20000
-10000
0
10000
20000
30000
40000
50000
0.002
0.004
0.006
0.008
0.04
0.038
0.036
0.034
0.032
0.03
0.028
0.026
0.024
0.022
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0

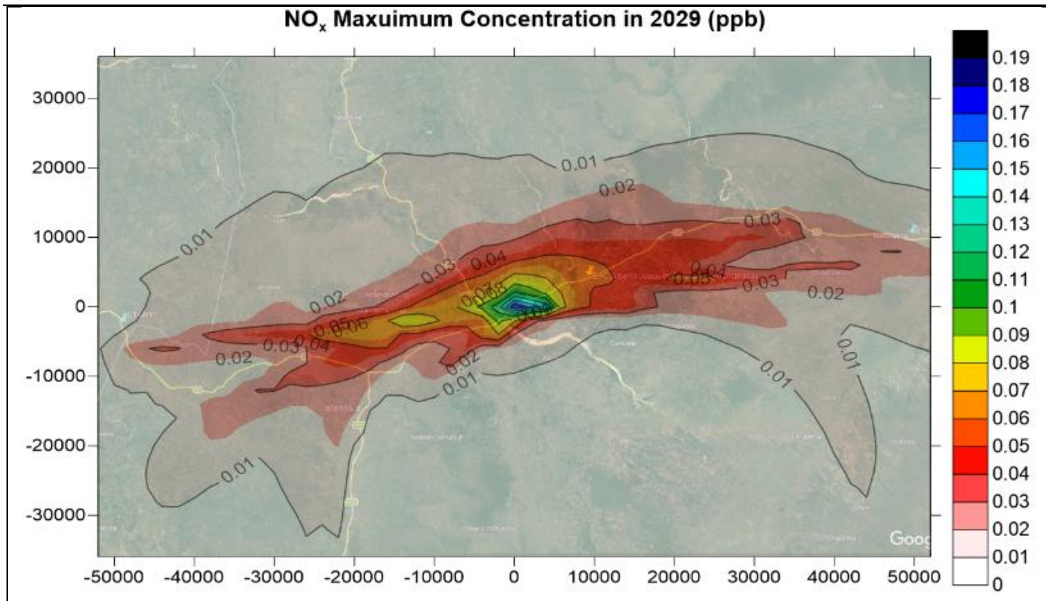


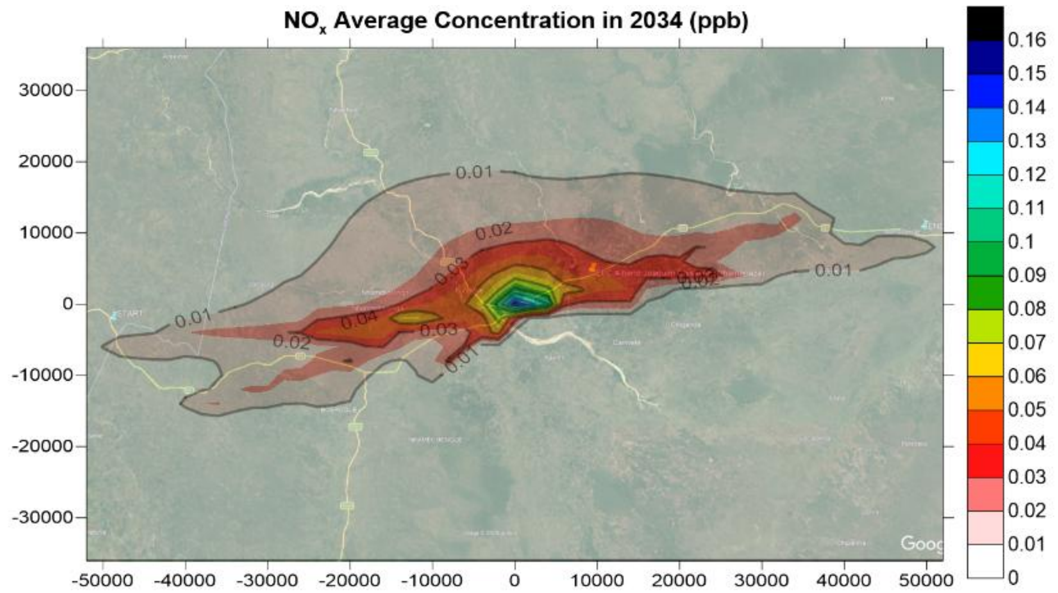
Dispersion maps for NO_x

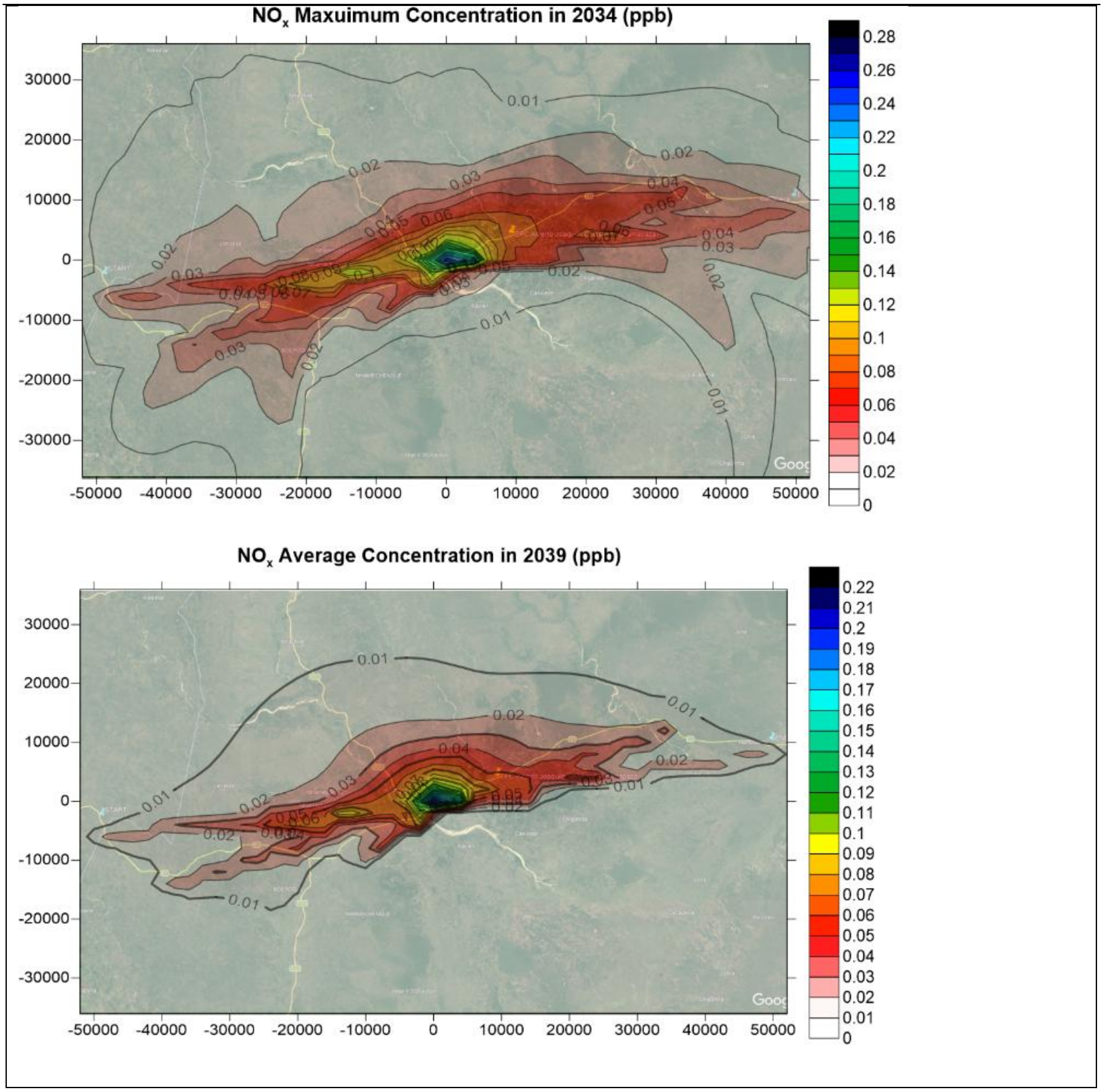



NOx Maxuimum Concentration in 2024 (ppb)
30000
20000
10000
0
-10000
-20000
-30000
-50000 -40000 -30000 -20000 -10000 0 10000 20000 30000 40000 50000
0.13
0.125
0.12
0.115
0.11
0.105
0.1
0.095
0.09
0.085
0.08
0.075
0.07
0.065
0.06
0.055
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0

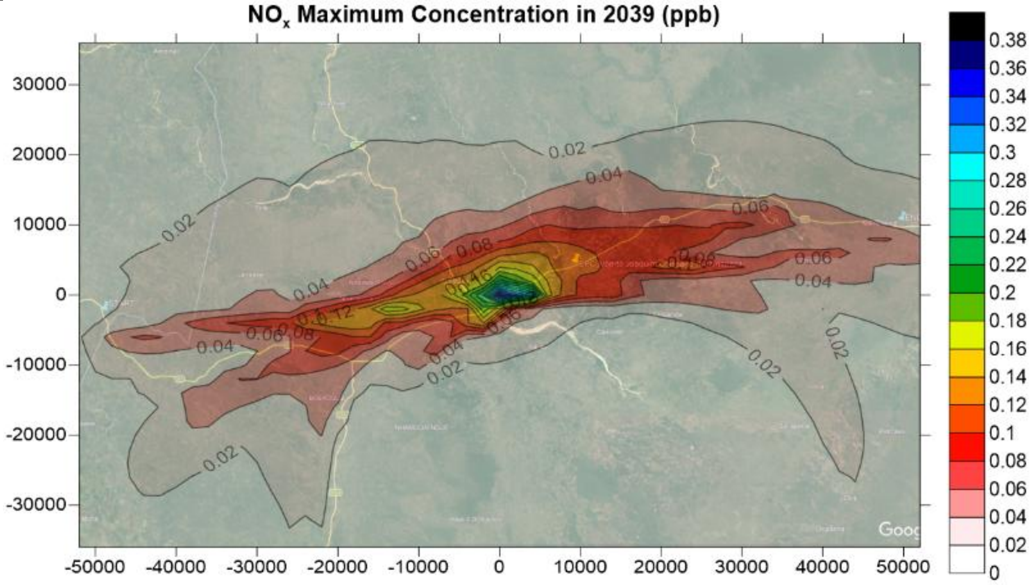

NOx Average Concentration in 2029 (ppb)
30000
20000
10000
0
-10000
-20000
-30000
-50000 -40000 -30000 -20000 -10000 0 10000 20000 30000 40000 50000
0.11
0.105
0.1
0.095
0.09
0.085
0.08
0.075
0.07
0.065
0.06
0.055
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0

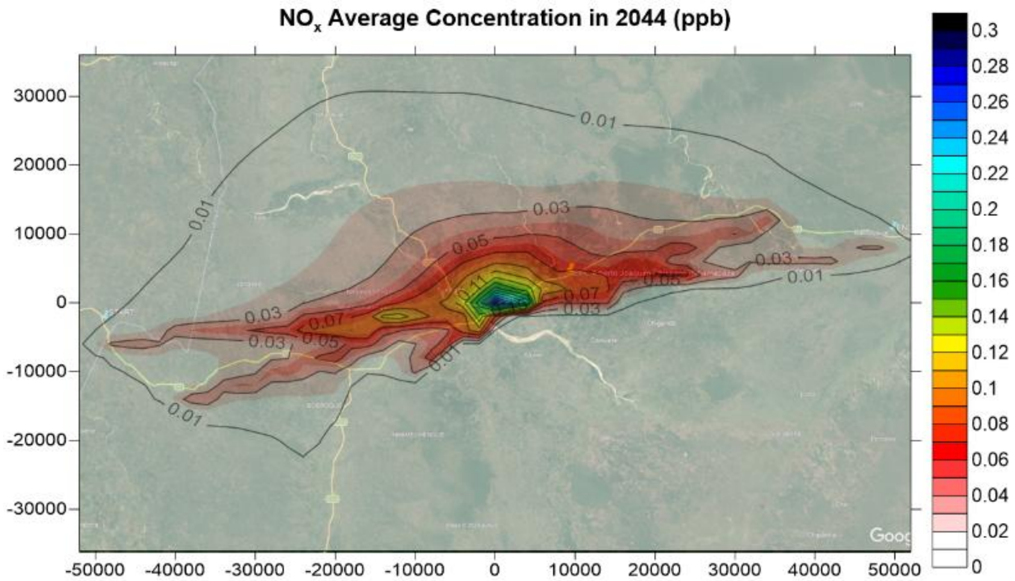

NO_x Maxuimum Concentration in 2029 (ppb)

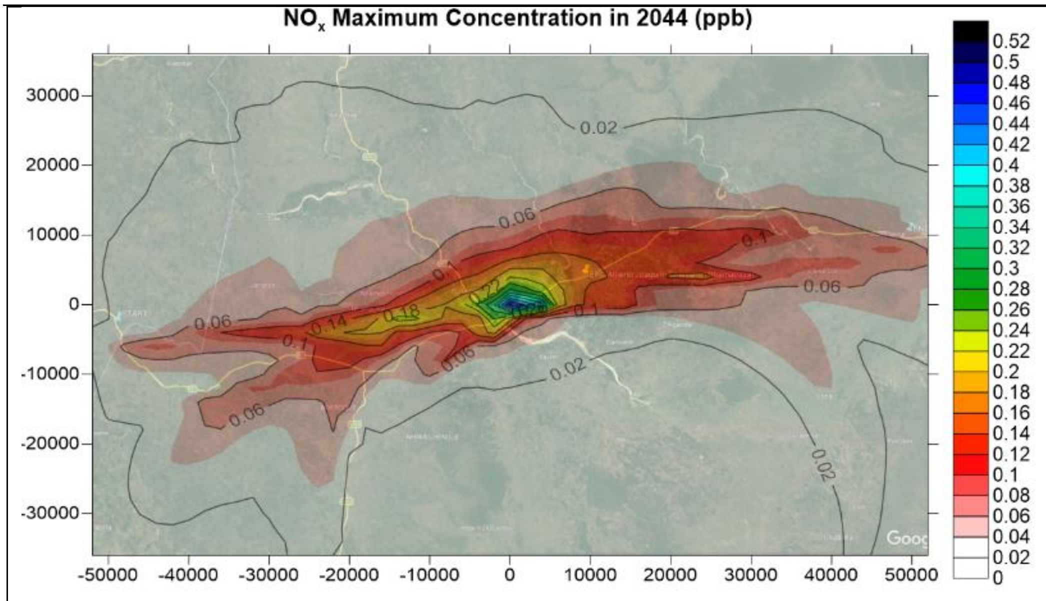

NO_x Average Concentration in 2034 (ppb)

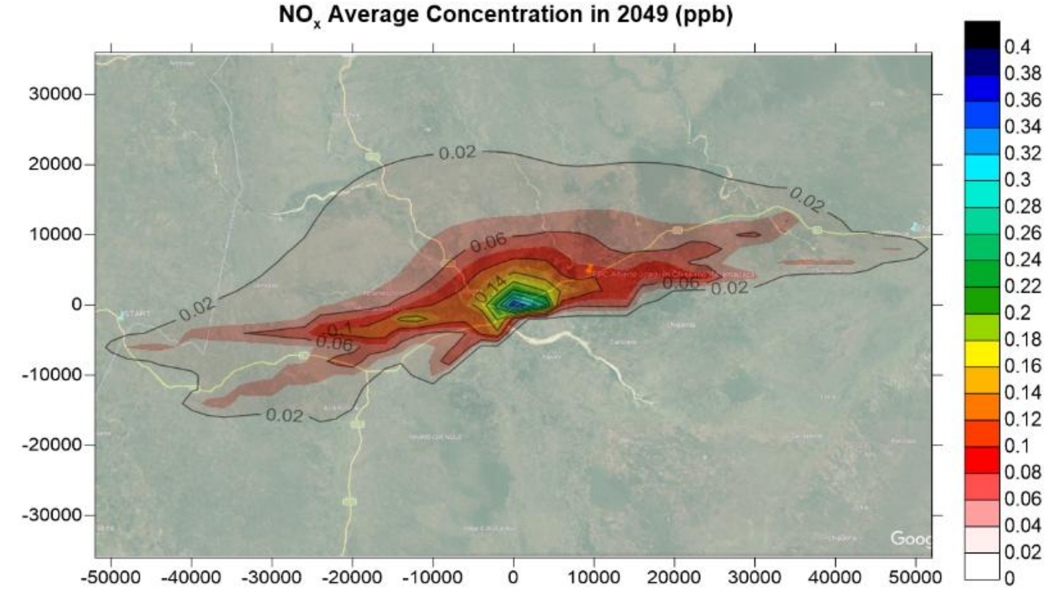

NOx Maxuimum Concentration in 2034 (ppb)
0.28
0.26
0.24
0.22
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
NOx Average Concentration in 2039 (ppb)
0.22
0.21
0.2
0.19
0.18
0.17
0.16
0.15
0.14
0.13
0.12
0.11
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0

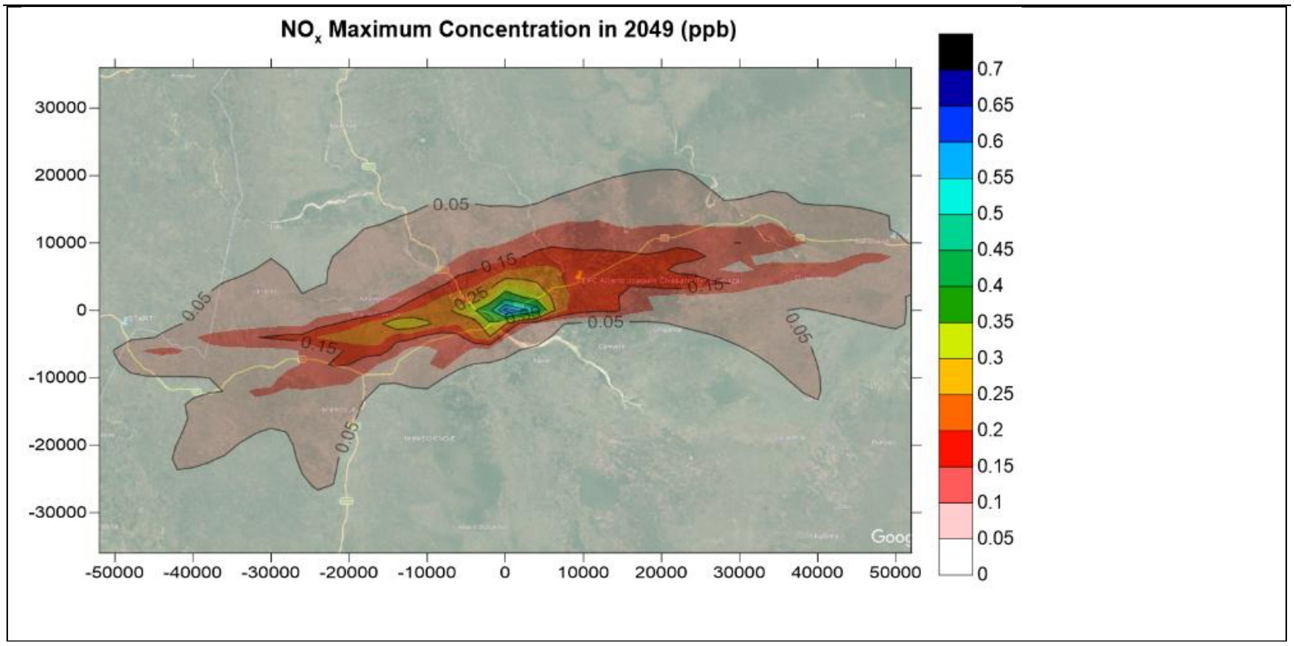
Environmental and Social Impact Assessment: VOLUME 2B - MAIN REPORT



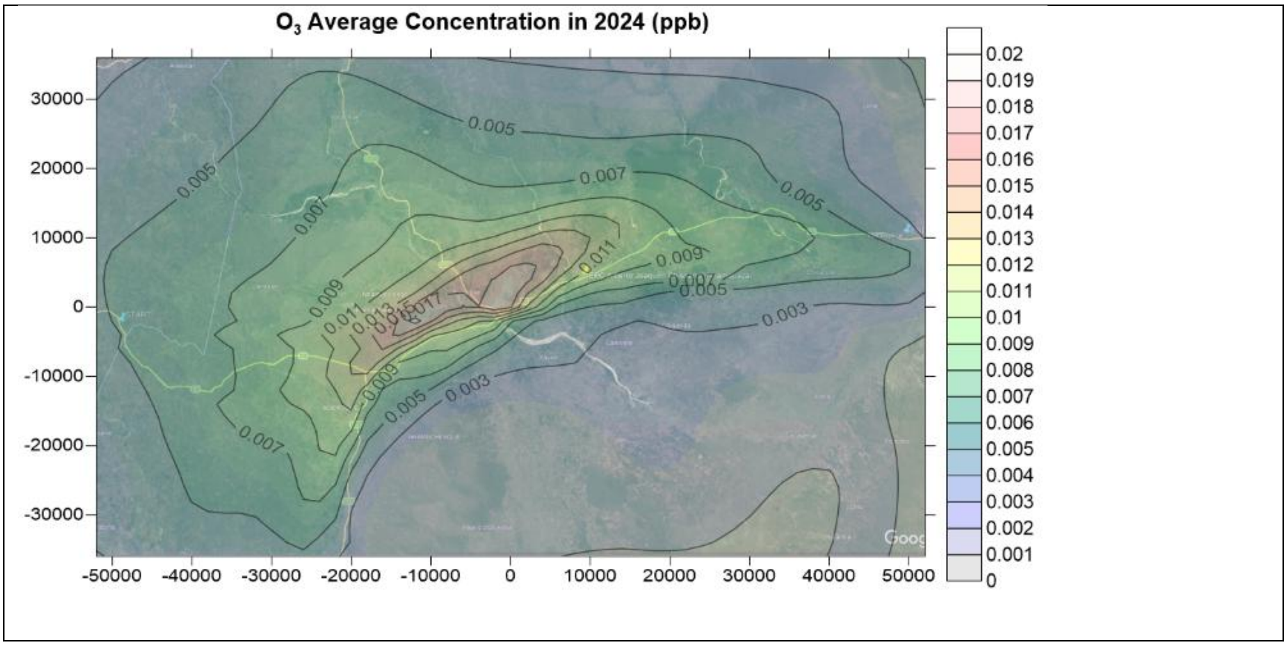


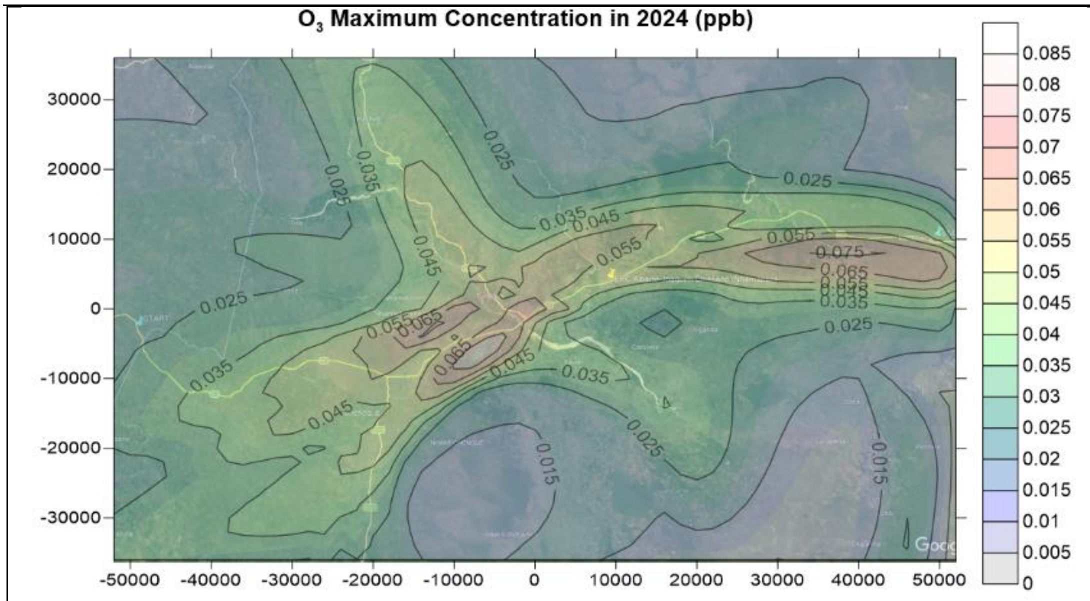

NOx Maximum Concentration in 2044 (ppb)
30000
20000
10000
0
-10000
-20000
-30000
-50000 -40000 -30000 -20000 -10000 0 10000 20000 30000 40000 50000
0.52
0.5
0.48
0.46
0.44
0.42
0.4
0.38
0.36
0.34
0.32
0.3
0.28
0.26
0.24
0.22
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0

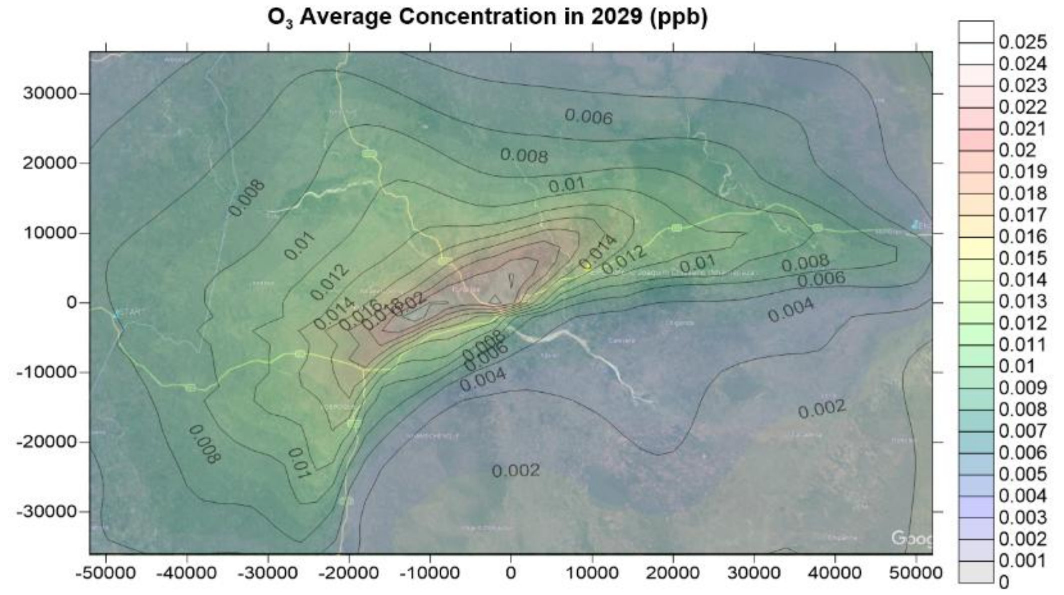

NOx Average Concentration in 2049 (ppb)
30000
20000
10000
0
-10000
-20000
-30000
-50000 -40000 -30000 -20000 -10000 0 10000 20000 30000 40000 50000
0.4
0.38
0.36
0.34
0.32
0.3
0.28
0.26
0.24
0.22
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0

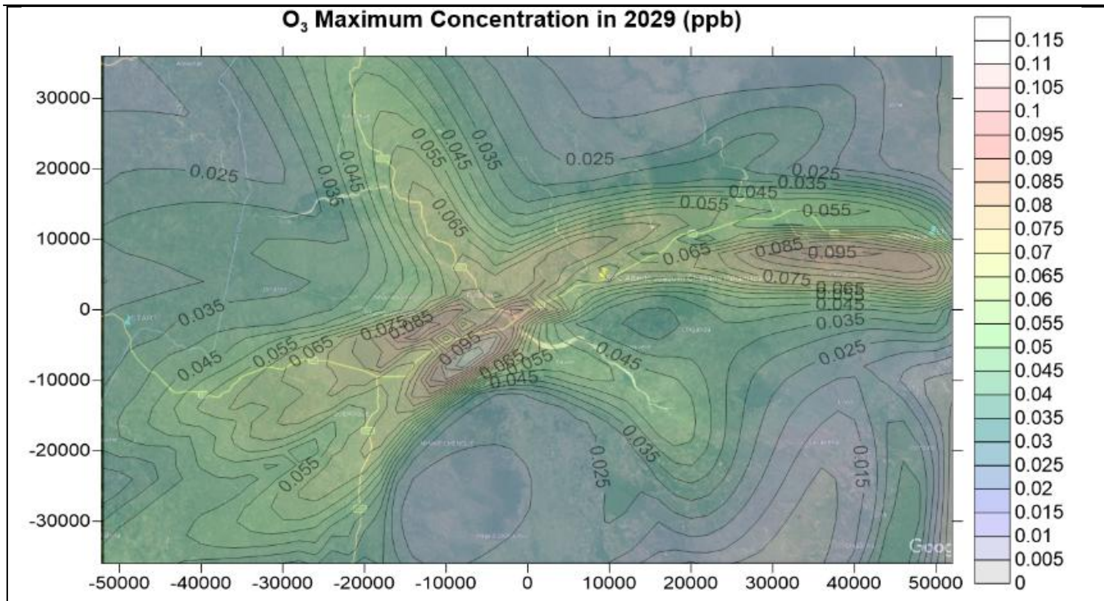


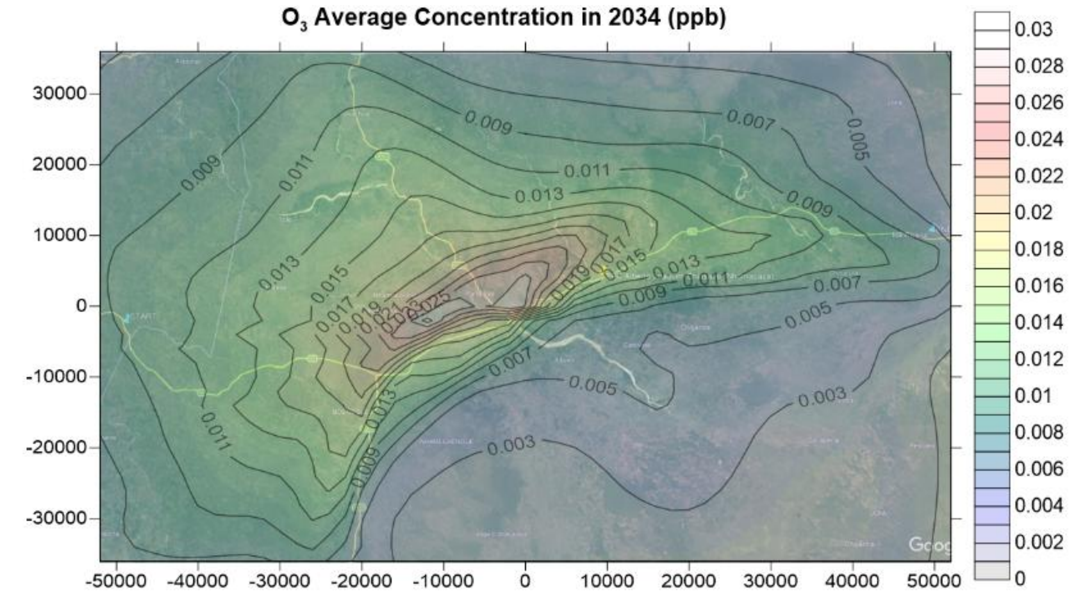
Dispersion maps for Ozone

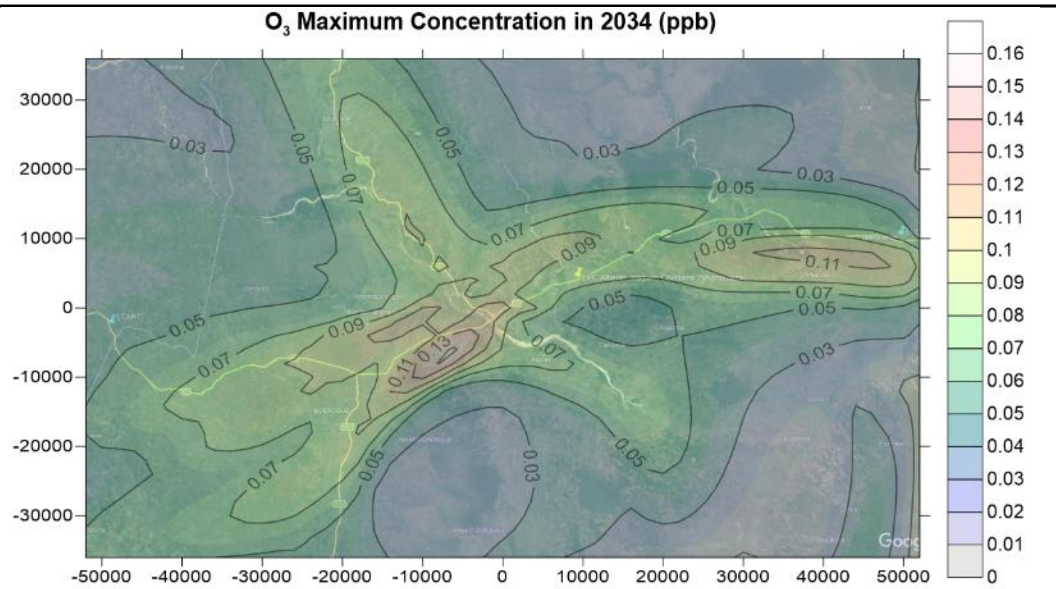


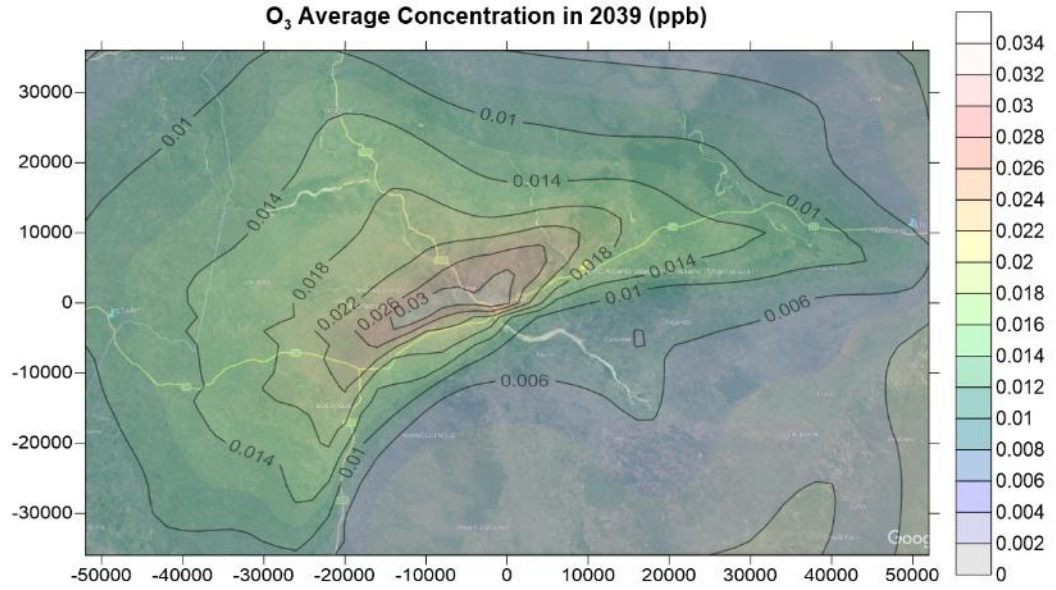

O_3 Maximum Concentration in 2024 (ppb)

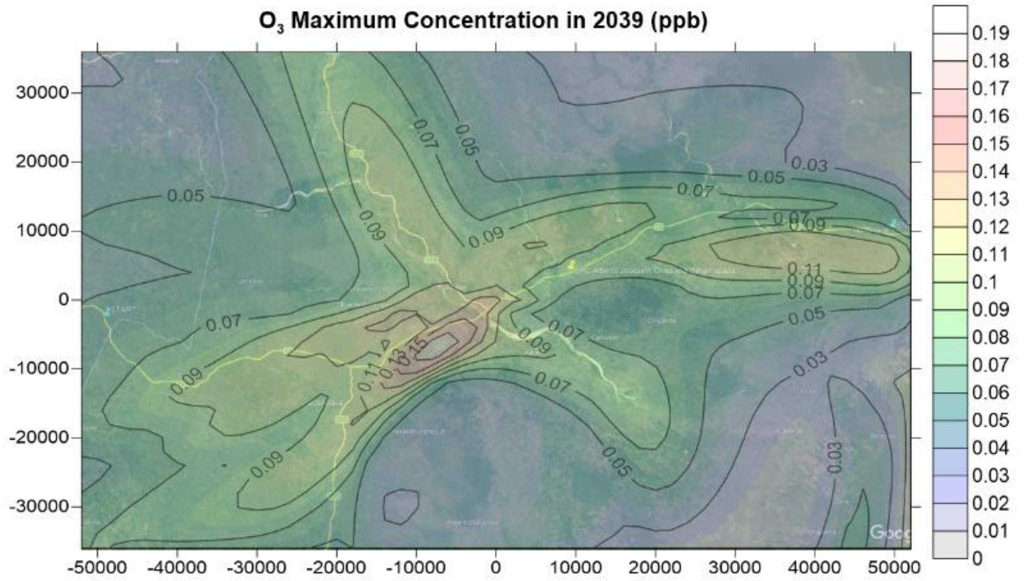

O_3 Average Concentration in 2029 (ppb)

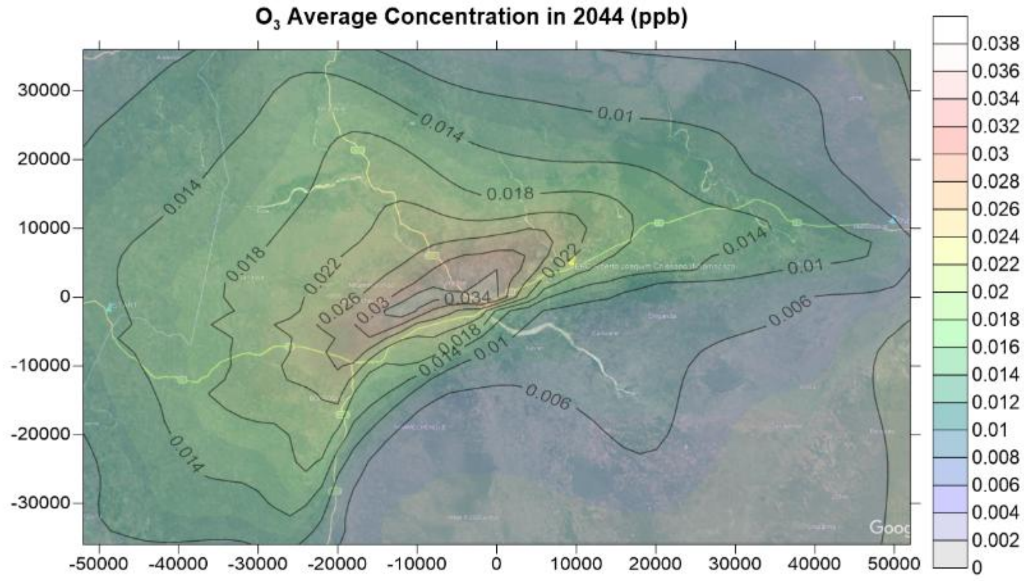

O$_3$ Maximum Concentration in 2029 (ppb)
30000
20000
10000
0
-10000
-20000
-30000
-50000 -40000 -30000 -20000 -10000 0 10000 20000 30000 40000 50000
0.115
0.11
0.105
0.1
0.095
0.09
0.085
0.08
0.075
0.07
0.065
0.06
0.055
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0

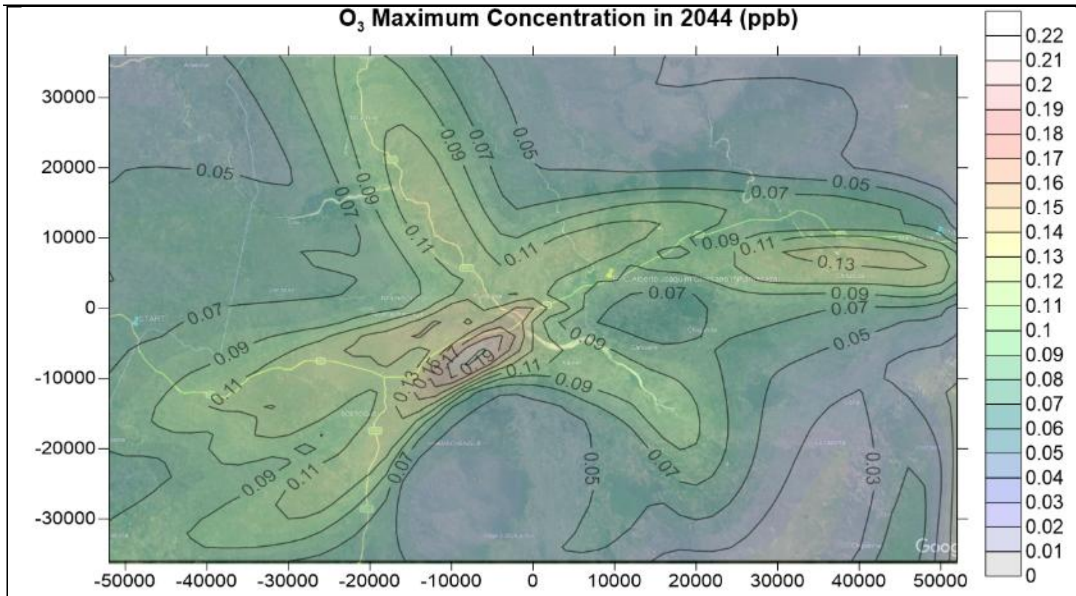

O$_3$ Average Concentration in 2034 (ppb)
30000
20000
10000
0
-10000
-20000
-30000
-50000 -40000 -30000 -20000 -10000 0 10000 20000 30000 40000 50000
0.03
0.028
0.026
0.024
0.022
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0

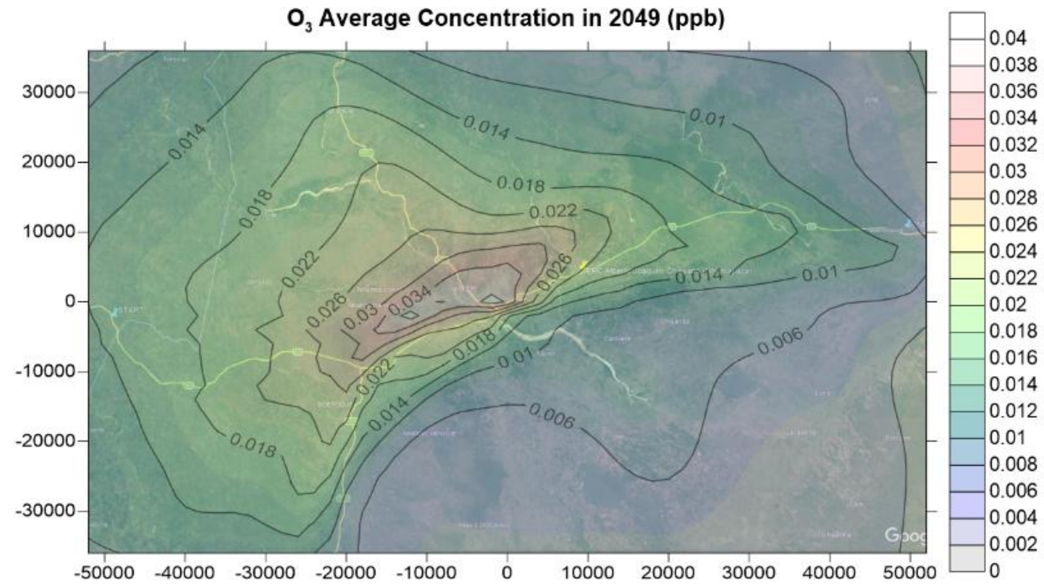

O_3 Maximum Concentration in 2034 (ppb)
30000
20000
10000
0
-10000
-20000
-30000
-50000 -40000 -30000 -20000 -10000 0 10000 20000 30000 40000 50000
0.16
0.15
0.14
0.13
0.12
0.11
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0

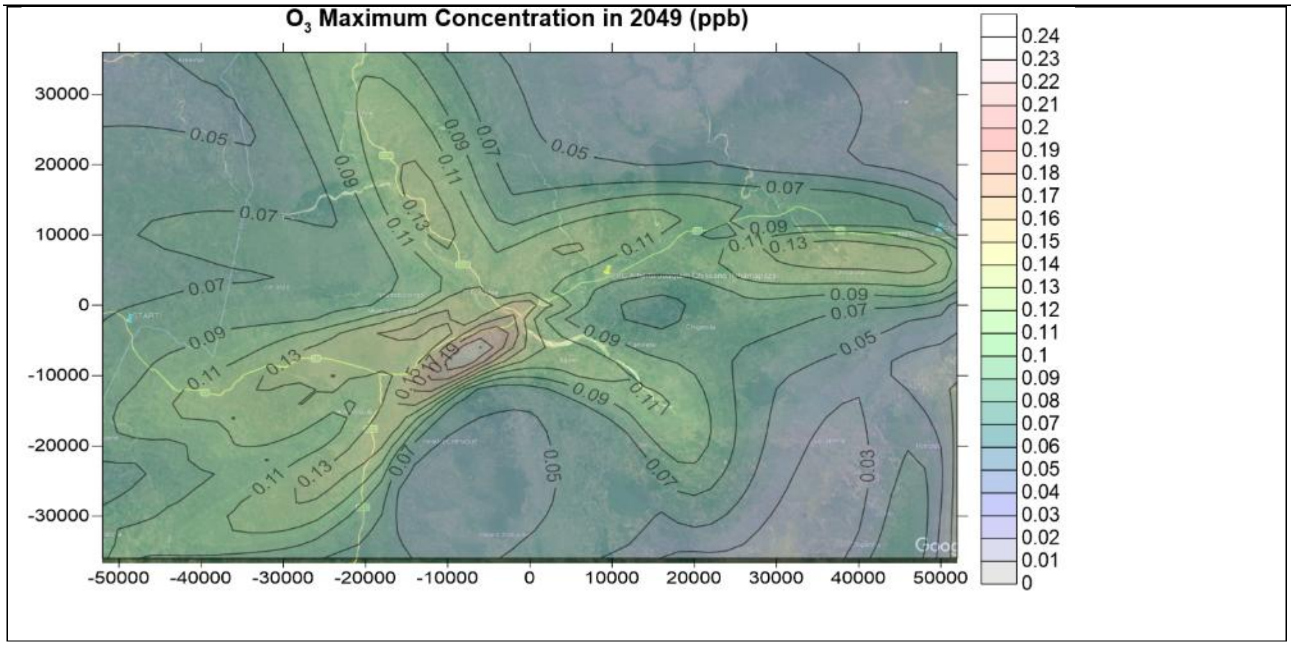

O_3 Average Concentration in 2039 (ppb)
30000
20000
10000
0
-10000
-20000
-30000
-50000 -40000 -30000 -20000 -10000 0 10000 20000 30000 40000 50000
0.034
0.032
0.03
0.028
0.026
0.024
0.022
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0


O3 Maximum Concentration in 2039 (ppb)
30000
20000
10000
0
-10000
-20000
-30000
-50000
-40000
-30000
-20000
-10000
0
10000
20000
30000
40000
50000
0.19
0.18
0.17
0.16
0.15
0.14
0.13
0.12
0.11
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0

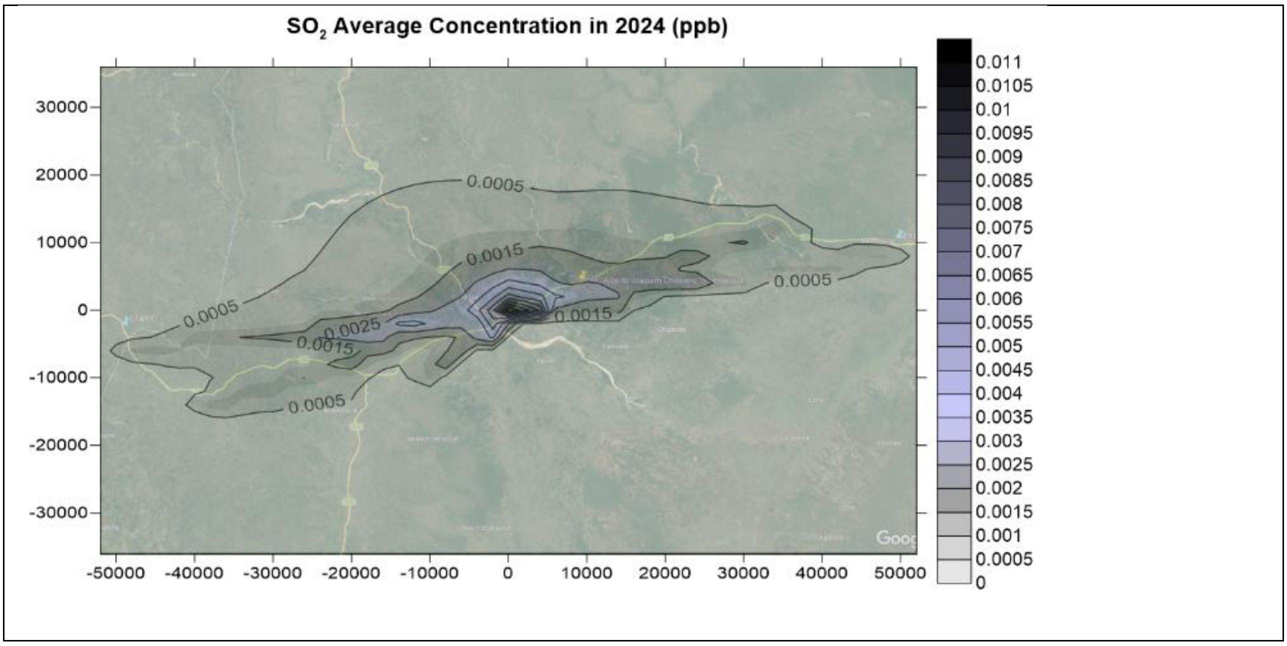

O3 Average Concentration in 2044 (ppb)
30000
20000
10000
0
-10000
-20000
-30000
-50000
-40000
-30000
-20000
-10000
0
10000
20000
30000
40000
50000
0.038
0.036
0.034
0.032
0.03
0.028
0.026
0.024
0.022
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0

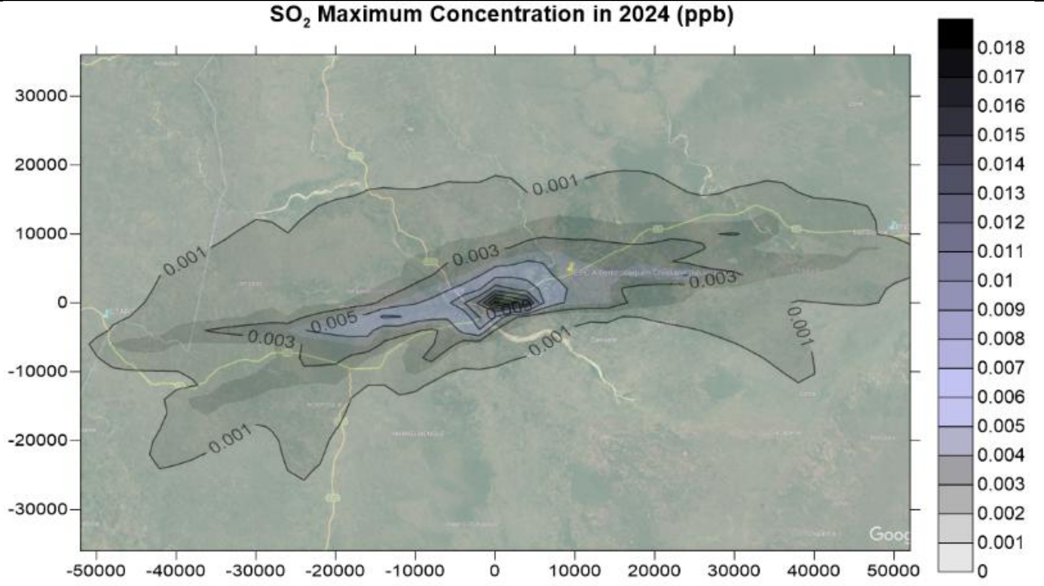

O_3 Maximum Concentration in 2044 (ppb)

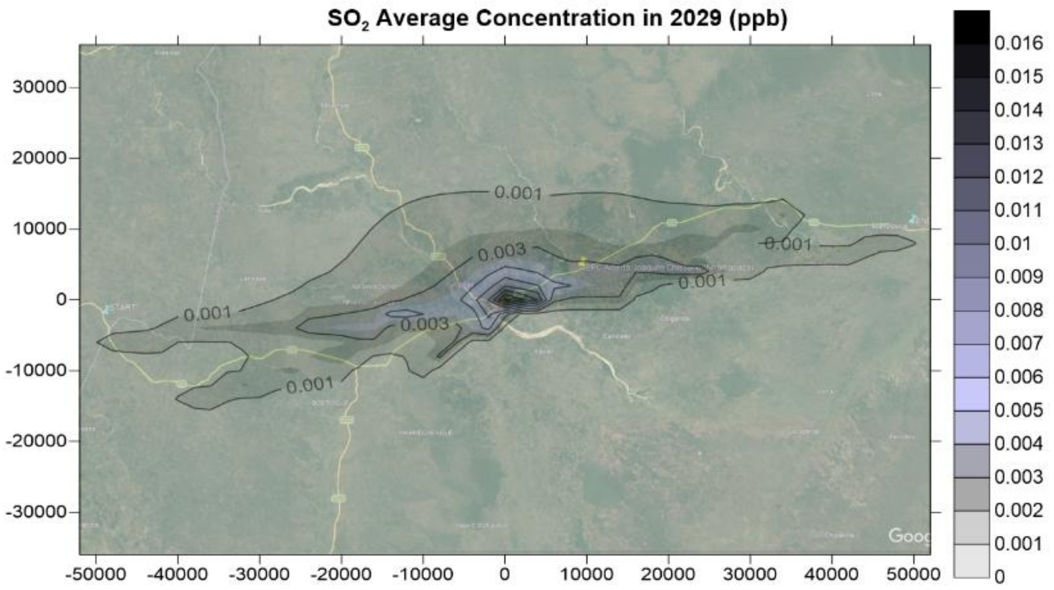

O_3 Average Concentration in 2049 (ppb)

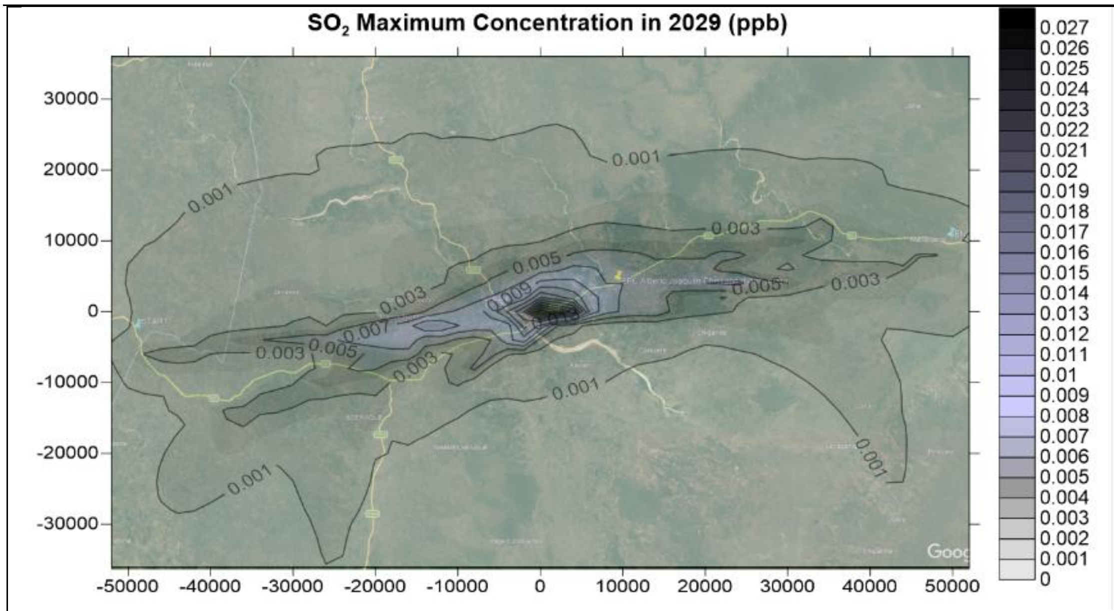


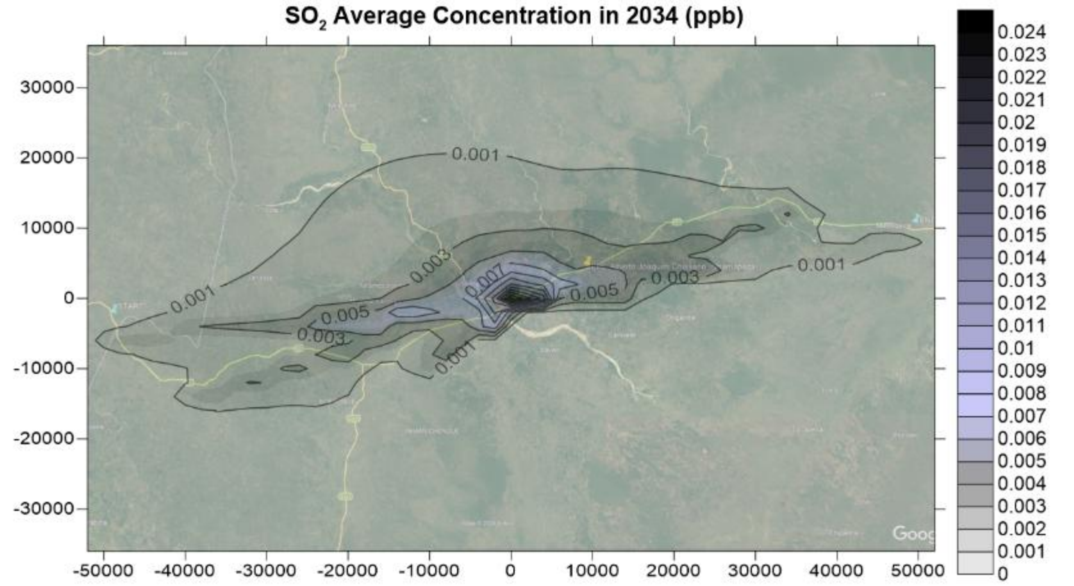
Dispersion maps for SO_2

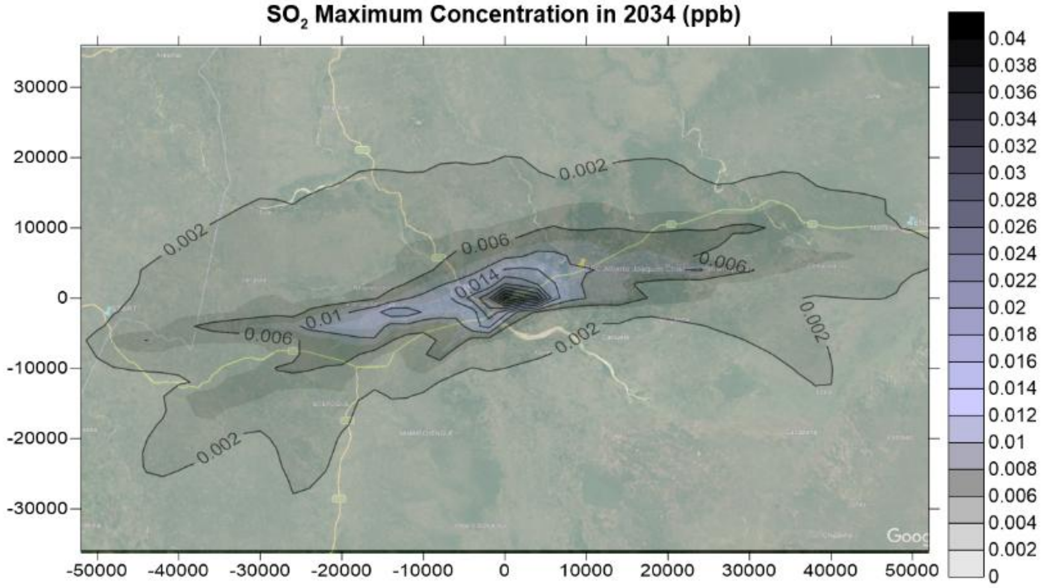


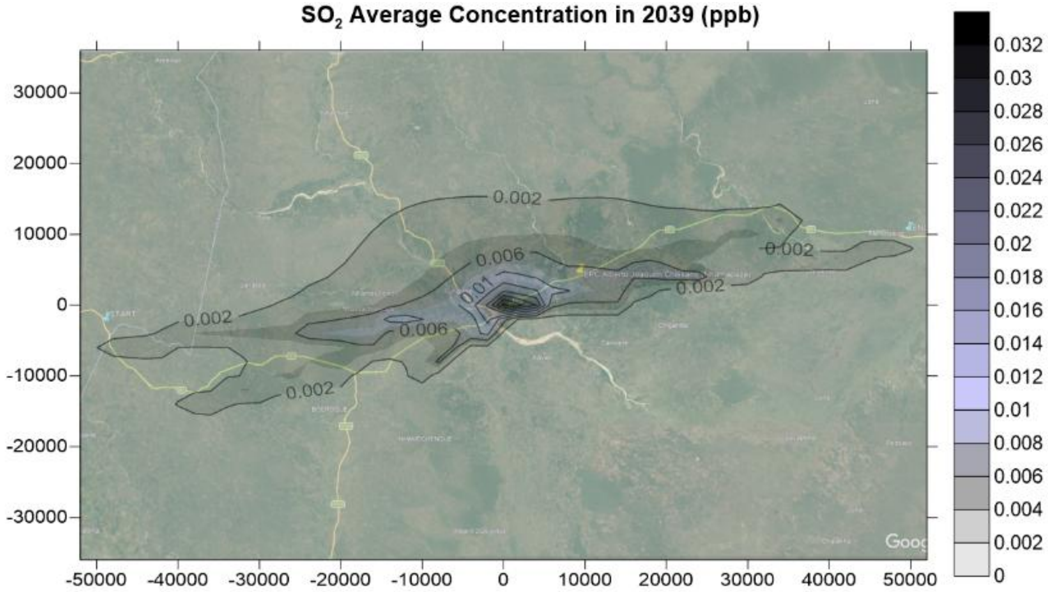

SO2 Maximum Concentration in 2024 (ppb)
30000
20000
10000
0
-10000
-20000
-30000
-50000
-40000
-30000
-20000
-10000
0
10000
20000
30000
40000
50000
0.001
0.003
0.005
0.018
0.017
0.016
0.015
0.014
0.013
0.012
0.011
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0


SO2 Average Concentration in 2029 (ppb)
30000
20000
10000
0
-10000
-20000
-30000
-50000
-40000
-30000
-20000
-10000
0
10000
20000
30000
40000
50000
0.001
0.003
0.016
0.015
0.014
0.013
0.012
0.011
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0


SO2 Maximum Concentration in 2029 (ppb)
0.027
0.026
0.025
0.024
0.023
0.022
0.021
0.02
0.019
0.018
0.017
0.016
0.015
0.014
0.013
0.012
0.011
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0


SO2 Average Concentration in 2034 (ppb)
0.024
0.023
0.022
0.021
0.02
0.019
0.018
0.017
0.016
0.015
0.014
0.013
0.012
0.011
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0


SO_2 Maximum Concentration in 2034 (ppb)
30000
20000
10000
0
-10000
-20000
-30000
-50000 -40000 -30000 -20000 -10000 0 10000 20000 30000 40000 50000
0.002
0.006
0.01
0.014
0.04
0.038
0.036
0.034
0.032
0.03
0.028
0.026
0.024
0.022
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0


SO_2 Average Concentration in 2039 (ppb)
30000
20000
10000
0
-10000
-20000
-30000
-50000 -40000 -30000 -20000 -10000 0 10000 20000 30000 40000 50000
0.002
0.006
0.01
0.032
0.03
0.028
0.026
0.024
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0.02
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0.016
0.014
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0.002
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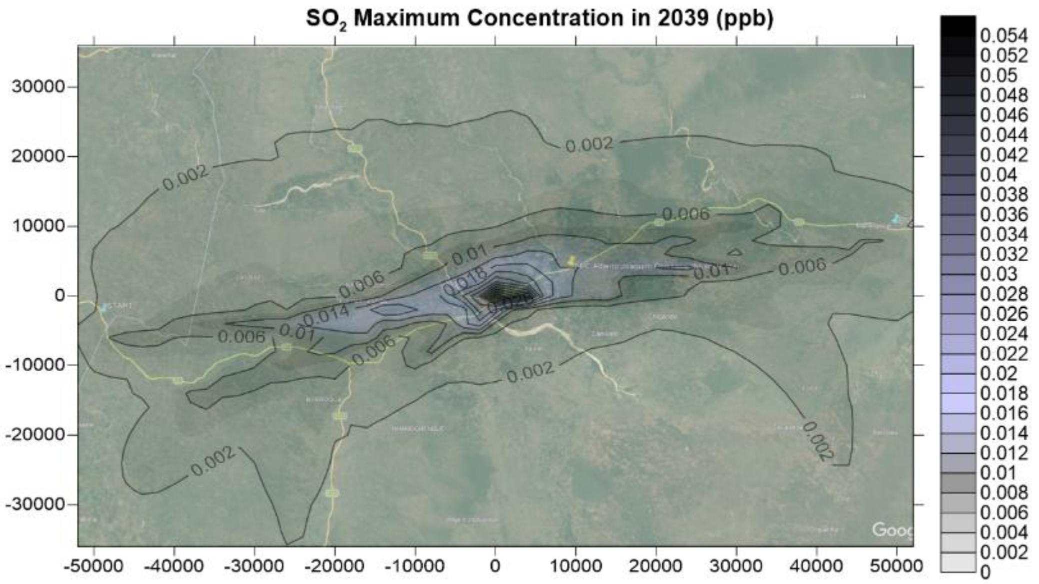
SO_2 Maximum Concentration in 2039 (ppb)
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20000
10000
0
-10000
-20000
-30000
-50000
-40000
-30000
-20000
-10000
0
10000
20000
30000
40000
50000
0.002
0.006
0.01
0.014
0.018
0.054
0.052
0.05
0.048
0.046
0.044
0.042
0.04
0.038
0.036
0.034
0.032
0.03
0.028
0.026
0.024
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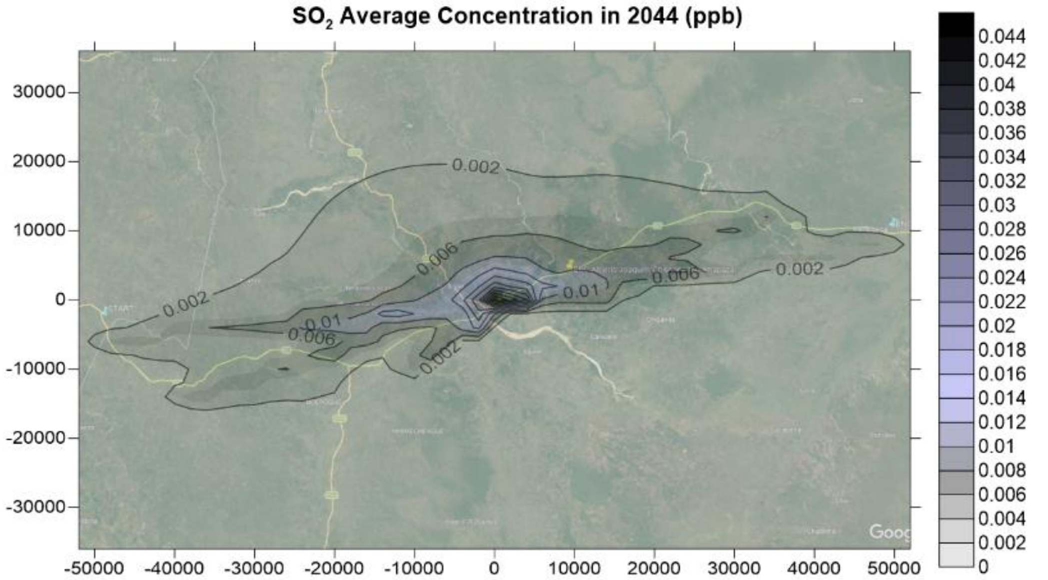
SO_2 Average Concentration in 2044 (ppb)
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-10000
-20000
-30000
-50000
-40000
-30000
-20000
-10000
0
10000
20000
30000
40000
50000
0.002
0.006
0.01
0.044
0.042
0.04
0.038
0.036
0.034
0.032
0.03
0.028
0.026
0.024
0.022
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0.018
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0.008
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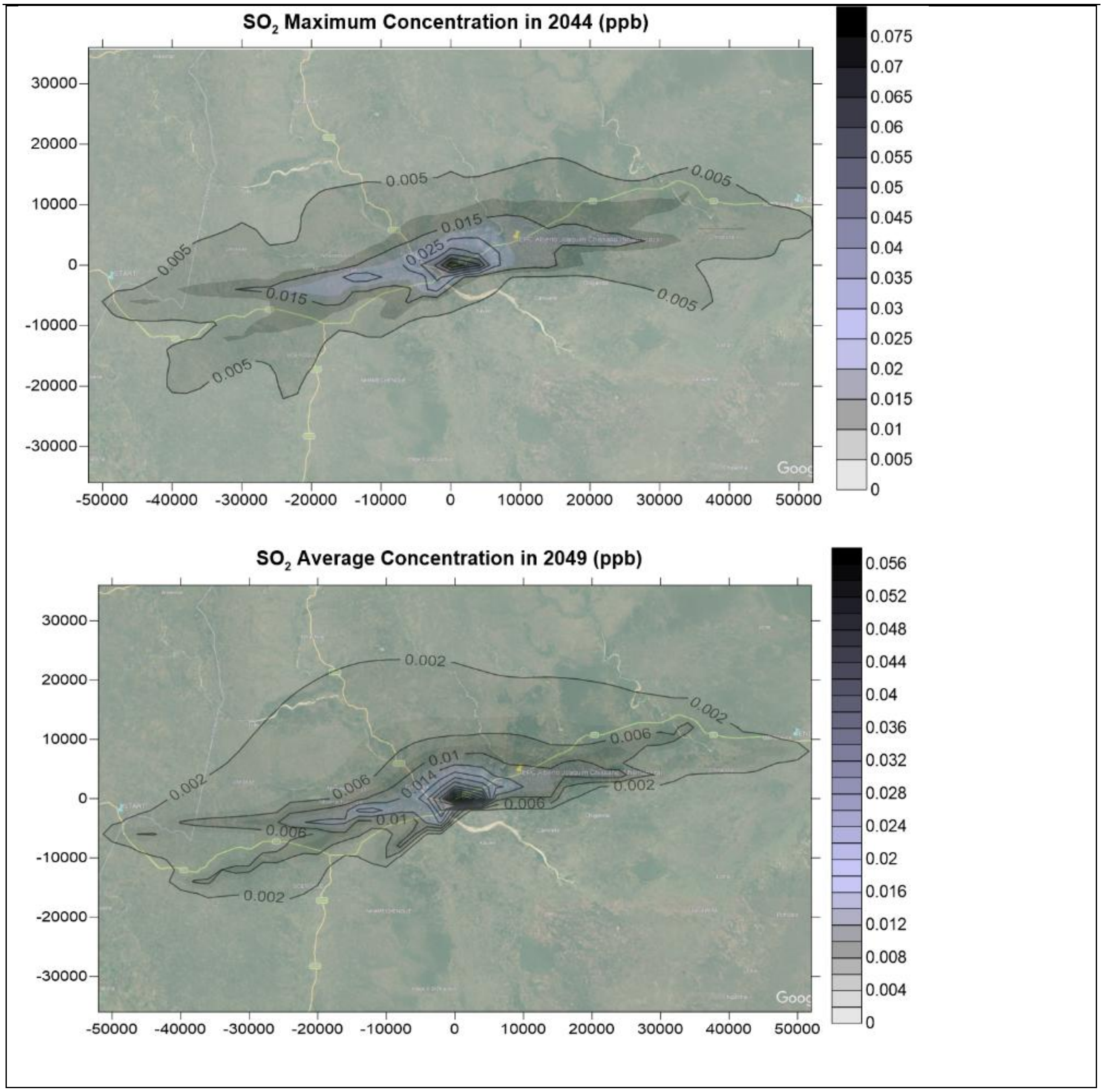
SO2 Maximum Concentration in 2044 (ppb)
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20000
10000
0
-10000
-20000
-30000
-50000
-40000
-30000
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0
10000
20000
30000
40000
50000
0.005
0.015
0.025
0.075
0.07
0.065
0.06
0.055
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
SO2 Average Concentration in 2049 (ppb)
0.002
0.006
0.01
0.014
0.056
0.052
0.048
0.044
0.04
0.036
0.032
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0.024
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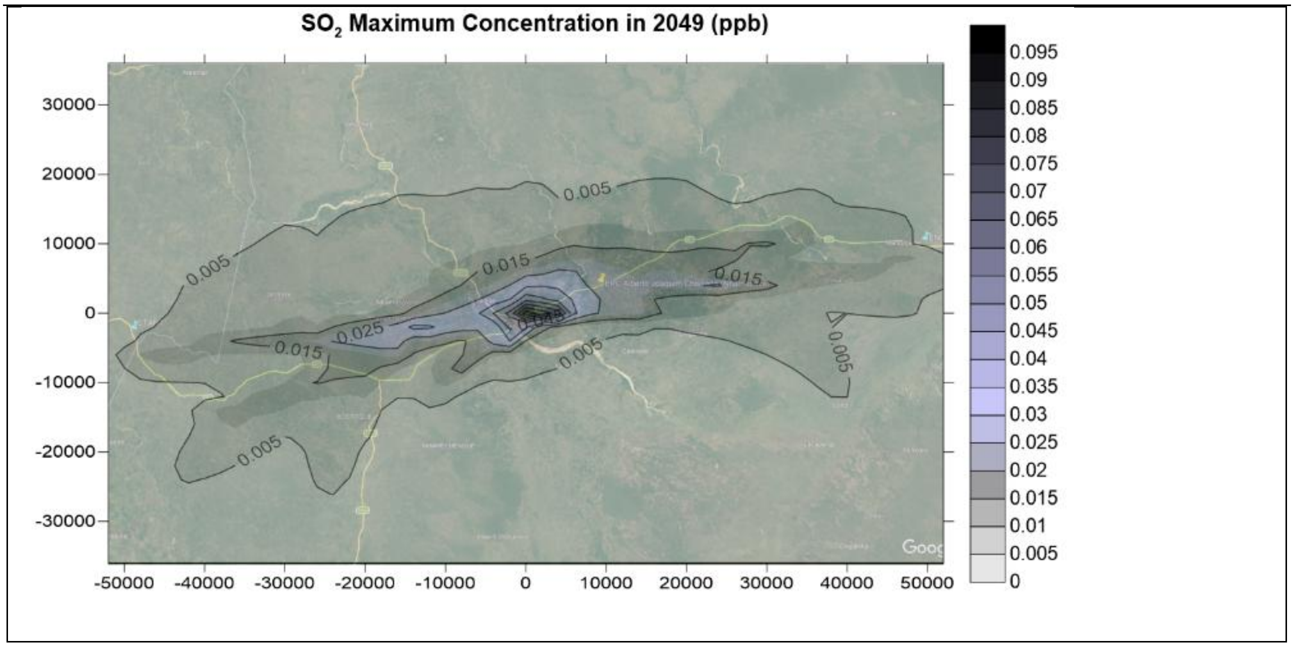
0.016
0.012
0.008
0.004
0


SO2 Maximum Concentration in 2049 (ppb)
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-30000
-50000
-40000
-30000
-20000
-10000
0
10000
20000
30000
40000
50000
0.005
0.015
0.025
0.045
0.095
0.09
0.085
0.08
0.075
0.07
0.065
0.06
0.055
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0

13 Annex 3

TORs for noise modelling

TERMS OF REFERENCE (ToR)

Noise and Vibration Modelling

1. Objective

The objective of this assignment is to assess the current and future noise and vibration impacts associated with the upgrading/rehabilitation of the EN1 corridor, over a 25-year design horizon, in accordance with:

- Applicable Mozambican legislation, and
- The World Bank Group Environmental, Health and Safety (EHS) Guidelines.

The study shall:

- Establish baseline acoustic conditions;
- Predict future noise and vibration levels due to traffic growth;
- Assess compliance at sensitive receptors;
- Support the Environmental and Social Impact Assessment (ESIA) with robust, transparent, and verifiable results.

2. Scope of Work

2.1 Baseline Characterisation

- Compile and review existing noise measurement data;
- Validate representativeness (time period, meteorology, duration);
- Conduct additional measurements if required to ensure:
    - Daytime and night time coverage;
    - Representative conditions.

Parameters shall include:

- LAeq, Lmax, Lmin;
- Statistical indicators (L10, L50, L90);
- Meteorological conditions.

2.2 Identification of Noise and Vibration Sources

- Road traffic (primary source);
- Construction activities (where applicable);
- Local anthropogenic sources.

2.3 Sensitive Receptors

- Identify and map all sensitive receptors, including:
    - Residential areas;
    - Schools;

    - Health facilities;
    - Religious buildings;
- Ensure full spatial representation in GIS, addressing gaps noted in previous studies.

3. Noise Modelling Methodology

3.1 General Approach

The modelling shall:

- Use measured baseline equivalent to safest natural conditions as calibration reference;
- Represent the EN1 as a segmented linear source;
- Predict noise levels for:
    - Baseline scenario
    - Future scenarios (up to 25 years)

3.2 Calculation Method

Two-tier approach is required:

(A) Core Approach (Mandatory)

- Application of ISO 9613-2 principles:
    - Geometrical spreading;
    - Atmospheric absorption;
    - Ground effects.
- Traffic inputs (using traffic count study data from concept designs):
    - AADT/TMDA;
    - Vehicle composition (light/heavy);
    - Speeds.
- Conversion of traffic data into sound power levels, explicitly documented.
- Application of logarithmic relationships for traffic growth:
    - Avoid simplistic +3 dB assumptions unless justified.

(B) Enhanced Approach (Strongly Recommended)

To address World Bank concerns, the Consultant should consider use of dedicated road traffic noise models, such as:

- CadnaA;
- SoundPLAN;
- CNOSSOS-EU or NMPB methodologies.

These allow:

- Vehicle class differentiation;
- Speed-dependent emissions;
- Reflection, barriers, and terrain effects.

Availability of the particular software used will have to be verified by the consultant undertaking the study at that time as licence fees are only valid for certain periods of time.

4. Vibration Assessment

- Measurement and/or estimation of Peak Particle Velocity (PPV);
- Assessment at sensitive structures;
- Projection over the 25-year horizon where applicable.

5. Traffic Growth and Scenarios

- Use traffic projections consistent with air quality modelling;
- Define:
    - Baseline year;
    - Intermediate scenarios (optional but recommended);
    - Design year (25 years).

6. GIS Mapping and Spatial Analysis

6.1 Requirements

- Integration of results into GIS (e.g. ArcGIS or QGIS);
- Production of:
    - Noise contour maps (isophones);
    - Receptor location maps.

6.2 Important Clarification

- Maps are illustrative tools only;
- Compliance assessment shall be based on receptor-specific results, not interpolations.

7. Software and Tools

7.1 Minimum Tools

- Excel-based calculation model (fully transparent and auditable);
- GIS software for mapping.

8. Impact Assessment and Compliance

- Compare results against:
    - Mozambican standards;
    - IFC / WBG EHS noise limits;
- Assess:
    - Daytime and nighttime compliance;
    - Incremental impacts;
    - Significance of change.

9. Deliverables

The Consultant shall produce:

1. **Noise and Vibration Specialist Report**, including:
    - Introduction and objectives;
    - Methodology (fully transparent);
    - Assumptions and limitations;
    - Results and discussion.
2. **Receptor-Based Results Tables**
    - Baseline vs future levels;
    - Compliance assessment.
3. **Noise Maps**
    - Isophones;
    - Receptor overlays.
4. **Data and Tools**
    - Excel calculation sheets;
    - GIS software and files in raster or shapefile format.

10. Key Requirements

To address previous review comments, the study should:

- Explicitly document all assumptions;
- Clearly define metrics (e.g. LAeq, Lden, Lnight);
- Ensure traceability of calculations;
- Include all relevant sensitive receptors;
- Distinguish between:
    - Construction phase;
    - Operation phase.

11. Potential Timeline (to be confirmed by consultant)

- Baseline review and data validation: 4-8 weeks;
- Modelling and analysis: 8-12 weeks;
- Reporting: 4-8 weeks.