SOURCE PATHWAY RECEPTOR ANALYSIS

TRINTY METALS

DRAFT V.02

GroundTruth

FEBRUARY 2026

GT1377/022026/02

GroundTruth
PO Box 916
9 Quarry Road, Hilton
KwaZulu-Natal, South Africa
+27 33 343 2229
admin@groundtruth.co.za

www.groundtruth.co.za

Title	SOURCE PATHWAY RECEPTOR ANALYSIS TRINTY METALS
Report Issue	DRAFT V.02
Consultant Ref Number	GT1377/022026/02
Prepared by	GroundTruth environment & engineering
Author(s)	Catherine Meyer (Pr. Sci. Nat.)
Contributors	Gary de Winnaar (Pr. Sci. Nat.)
	Fiona Eggers (Pr. Sci. Nat.)
	Steven Ellery (Pr. Sci. Nat.)
Document Reviewer	Gary de Winnaar
Prepared For	TRINITY METALS

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EXECUTIVE SUMMARY

GroundTruth was commissioned by Trinity Metals to perform a Source-Pathway-Receptor (SPR) assessment for three mining concession areas in Rwanda: Musha/Ntunga, Rutongo, and Nyakabingo. This study serves as a critical component of Phase 1 for the Legacy Tailings Management and River Rehabilitation Programme, intended to guide priority management and restoration actions. The primary objectives included identifying contamination sources, developing Conceptual Site Models (CSM), integrating environmental data to establish pollution linkages, and evaluating risks to human and environmental receptors based on safe limits.

The assessment followed international best practices for contaminated land management. The SPR model categorised environmental data into: Sources – the origin of contamination (e.g., fugitive emissions, legacy tailings, process water); Pathways – release and transport mechanisms (e.g., wind dispersal, surface water runoff, groundwater infiltration); and Receptors – targets adversely affected (e.g., local communities, aquatic ecosystems, livestock, and crops). Through a Tier II Generic Quantitative Risk Assessment, risk was classified as a function of the likelihood of exposure and the severity of consequences, ranging from "Very Low" to "Very High".

For the Musha/Ntunga Mine, the assessment identified significant environmental degradation due to historical artisanal mining and current operations.

- **Very High Risks:** Identified for air quality due to PM2.5 exceedances affecting workers and communities. Additionally, a Very High Risk is assigned to soils and crops at Musha due to extreme salinity (sodium and chloride) and acidification, which pose severe threats to crop yields.
- **High Risks:** At Musha, High Risk exists for community water supplies due to groundwater metal exceedances and for livestock watering from the Bisinia Dam and Nyirabigaji River. High risks are also noted for river sediments showing extreme arsenic enrichment. At Ntunga, High Risk is specifically noted for the impact of contaminated water on soils and crops downstream.

The Rutungo concession area is characterised by extensive legacy issues across the six mine sites and significant interference from unauthorised (informal) mining. Nyamyumba and Gasambya mines present the highest risk for metal leaching (arsenic, lead, and manganese) and exhibit the most acidic pH levels.

- **Very High Risks:** At Nyamyumba and Karambo, air emissions (PM2.5) are a Very High Risk. At Nyamyumba, groundwater seepage poses a Very High Risk to community springs (e.g., Kabuga spring), which already exceed WHO arsenic limits. At Gisanze, groundwater discharge into the Rusine River creates a Very High Risk for livestock watering. At Masoro, groundwater seepage into community springs is rated as Very High Risk due to elevated lead, manganese, and iron.
- **High Risks:** High Risks for livestock watering are prevalent across the Gisanze, Nyamyumba, Gasambya, and Karambo sites due to surface water runoff containing elevated metal concentrations and acidic pH. At Masoro, groundwater seepage also presents a High Risk for livestock.

Nyakabingo Mine faces the most significant challenges related to acid rock drainage.

- **Very High Risks:** Very High Risk is assigned to air quality ($PM_{2.5}$) impacting the surrounding village areas. Furthermore, groundwater seepage poses a Very High Risk to community springs, notably the Mwagiro-Bugarura spring, which exhibits arsenic and aluminium exceedances.
- **High Risks:** High Risk is identified for mine materials (slurry and waste rock), which have the highest metal leaching potential and contribute to the collective effluent's extreme acidity (pH 2.9).

The climate change projections for the region were briefly considered. Projected increases in mean annual temperature (up to 11.8% by 2059) and maximum daily rainfall (up to 16.4%) pose additional risks. Increased rainfall is expected to accelerate surface runoff, leading to a higher probability of overtopping of control dams and enhanced leaching of contaminants from legacy tailings.

While Trinity Metals' operations contribute to environmental degradation, impacts are compounded by externalities, including natural geological background levels, intensive agriculture, and formal/ informal aggregate mining. Recommended remediation opportunities, which require detailed investigation for site-specific suitability and efficacy, broadly include source control, pathway interruption and receptor protection. The SPR analysis confirms that without intervention, current pollution linkages will continue to impose long-term adverse effects on the surrounding human populations and ecosystems.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

AQG - Air Quality Guidelines	RBSS - Rutongo Business of Sand and Stone
CSM - Conceptual Site Model	REDEMI - Régie d'Exploitation et de Développement des Mines
DEA - Department of Environment Affairs, South Africa	RMB - Rwanda Mines, Petroleum and Gas Board
DRC - Democratic Republic of Congo	RMM - Rwanda Minerals and Mining
EAS - East African Standards	RS - Rwanda Standards
ED - Eastern Domain	SCC - Species of Conservation Concern
FAO - Food and Agriculture Organization of the United Nations	SLR - SLR Consulting (Africa) (Pty) Ltd
GAI - Geochemical Abundance Index	SOMIRWA - Société Minière du Rwanda
HDPE - High-Density Polyethylene	SOMUKI - Société des Mines de Muhinga et Kigali
IFC - International Finance Corporation	SPLP - Synthetic Precipitation Leaching Procedure
IR-EPA - Environmental Protection Agency of Ireland	SPR - Source Pathway Receptor
ECD - Early Childhood Development	SSP - Shared Socio-economic Pathways
KAB - Karagwe-Ankole Belt	SSV1 - Soil Screening Value Level I
KIB - Kibara Belt	TDS - Total Dissolved Solids
KL-WN - Borough Council of King's Lynn & West Norfolk	TSF - Tailings Storage Facility
LOM - Life of Mine	TSS - Total suspended solids
MAP - Mean Annual Precipitation	TVET - Technical and Vocational Education and Training
MINIRENA - Ministry of Natural Resources, Rwanda	USEPA - United States Environmental Protection Agency
NICOLA - Network for Industrially Contaminated Land in Africa	UK-EA - UK Environmental Agency
PM - Particulate Matter	WD - Western Domain
PPR - Personal Protection Equipment	WHO - World Health Organisation

USE OF VERBATIM EXTRACTS AND SOURCE ACKNOWLEDGEMENT

In preparing this document, it is important to note that substantial portions have been presented verbatim from existing specialist reports. These extracts have been included to consolidate and present relevant information in a clear and comprehensive manner, rather than to claim authorship of the original material. While the source reports have been referenced to acknowledge their contribution, the citations provided do not indicate the precise location of each extract. This approach ensures transparency and integrity in the use of external material while maintaining the focus on synthesising and contextualising the information for the purposes of this report.

SLR Consulting and their team of specialists are duly acknowledged as the primary source(s) of baseline information. Where applicable this information has been updated or corroborated by insights, additional studies and information provided by GroundTruth.

1. INTRODUCTION

1.1 Background

GroundTruth was appointed by Trinity Metals to undertake a Source-Pathway-Receptor (SPR) Analysis of potential contaminants to understand the environmental risks associated with past and current mining operations, including informal mining operations, at its three mining concession areas namely, Musha/Ntunga, Rutongo Mine and Nyakabingo Mine in Rwanda. All three mines possess an extensive history of artisanal-scale extraction. As a result, the surrounding riverine systems have been significantly altered in terms of hydrological and geomorphological functioning and water quality. This study forms part of Phase 1 of Trinity Metals' Legacy Tailings Management and River Rehabilitation Programme and will be used to inform and guide priority management actions towards rehabilitation and ecosystems restoration.

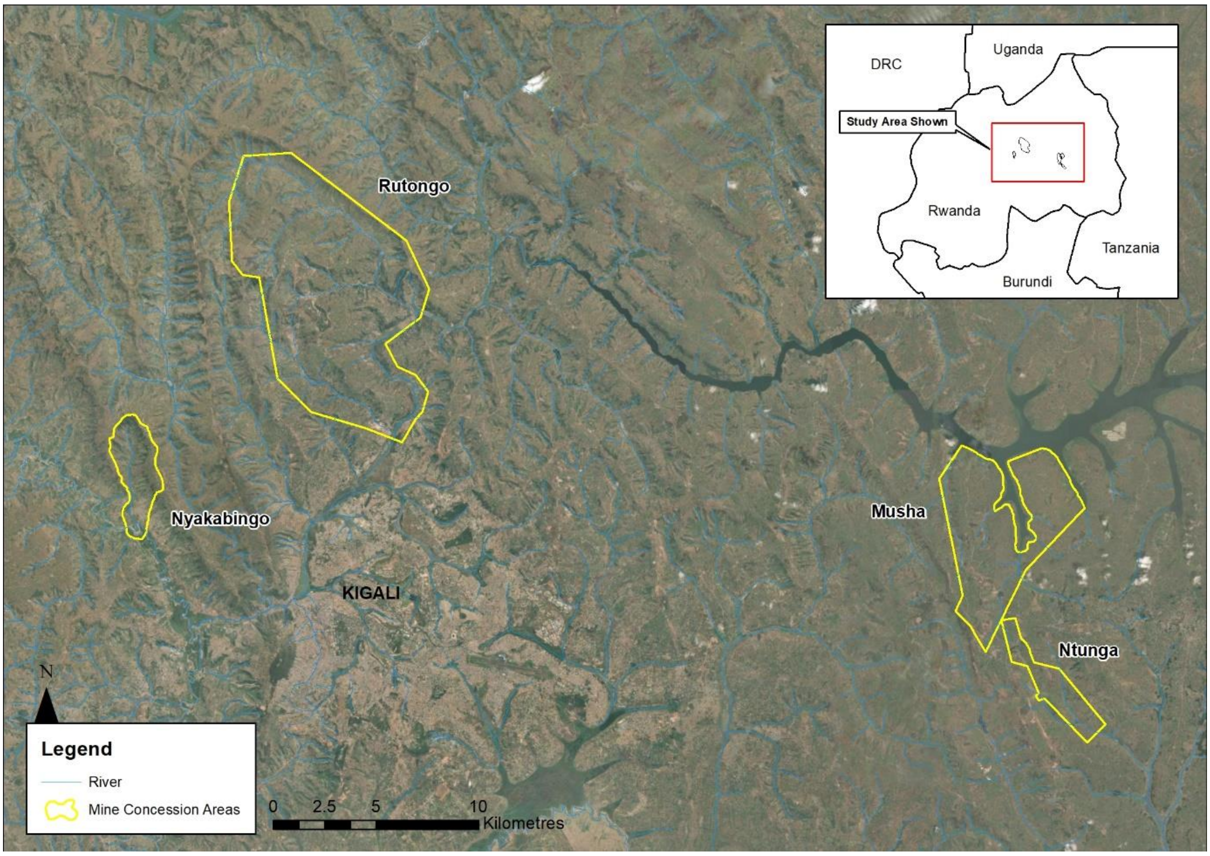

Figure 1-1 Map of the regional locations of the Trinity Metals mine concession areas

1.2 Key Objectives

The key objectives of this SPR analysis were to:

i) Review the baseline assessments undertaken as part of the Environmental and Social Impact Assessment (ESIA) and gather existing data and information.
ii) Analyse spatial and temporal distribution of existing data.

iii) Identify key information gaps to be addressed with additional desktop assessment, field studies, and data collection if necessary.
iv) Identify and map sources of contamination in relation to existing receptors within the landscape context of each site.
v) Develop a Conceptual Site Model for each site.
vi) Integrate existing surface water and groundwater hydrological modelling to establish pollution linkages.
vii) Establish contamination risks using available limits considered safe and/or acceptable for human ecosystem wellbeing.
viii) Identify important and/or sensitive receptors to inform interventions to be incorporated into the Legacy Tailings Management and River Rehabilitation Programme.

1.3 Structure of Report

This report considers the three Trinity Metals concession areas, namely, Musha/Ntunga, Rutongo and Nyakabingo, which have been assessed in separate sections. Each major section contains a description of the landscape setting of the concession area; a Conceptual Site Model (CSM) that identifies the potential sources of contamination, pathways and receptors at the site; and a quantitative risk assessment that evaluates the likelihood of contamination based on available information and data. The report concludes with critical areas that should become key focus areas for mitigation interventions and rehabilitation.

1.4 Assumptions and Limitations

This section highlights the assumptions, limitations and knowledge gaps associated with this study that may influence the type of information collected and the accuracy of the data.

1.4.1 *Assumptions*

Source-Pathway-Receptor analyses rely on various assumptions. For this study, these were as follows:

- The SPR study is based solely on information collected and presented in numerous specialist reports. It is assumed that all data, graphical representations and written work presented in the specialists' reports are accurate and correct at the time of reporting.
- Substantial information and data are presented in the specialists' reports, and these were deemed sufficient to fulfil a Tier II Assessment as part of the SPR analysis process.
- Generic assessment criteria were used in determining potential risk/s. That is, exceedances of specific soil, water, and effluent quality guideline limits, as determined by geochemical analyses, were assumed to infer significant risks to human and environmental receptors.
- Communities living within, downstream or in close proximity to the mining areas will be impacted by mining activities and contaminants arising from such activities.
- The risk assessment is semi-quantitative and based on probabilities, and not absolute data.
- Natural environmental processes of transportation and dispersion are assumed, such that the contaminants will move down gradient/ downslope and will dissipate/ attenuate/

dilute with increasing distance from the source. Where available, modelled data is used to confirm this.
- Heavily degraded riverine ecosystems were deemed to have low sensitivity to mining activities and contaminants arising from such activities.
- Hydrocarbons are stored and distributed from the camps and central workshops, not at the active mining areas.
- Water pump stations on the river(s) are electric and not diesel operated (e.g. Nyamyumba Mine, Rutongo concession area.
- Vehicles are key sources of hydrocarbons, particularly aggregate mining vehicles owned Rutongo Business of Sand and Stone, [RBSS], which drive and park within the riverbeds.
- According to the Aquatic specialist assessment for the Musha/Ntunga mine, assessments at Ntunga were reportedly undertaken on the Kabacuzi River, however, based on location of the site and background information provided, this was corrected to be the Gashahi River.

1.4.2 *Limitations*

The following limitations apply to this current SPR study:

- This study is limited to the impacts of mining activities by Trinity Metals only, as presented by the specialist studies. External pollution sources and their potential impacts on sensitive receptors were noted where observed but not investigated or assessed. This includes, for example, informal and formal mining activities (ore and sand/aggregate mining) affecting landscape characteristics, and soil and river water quality (e.g. turbidity, fuel spillages within the riverbed from RBSS aggregate mining vehicles). These factors were acknowledged but not assessed in conjunction with the impacts of mining.
- The uncertainties and limitations noted in the various specialists' reports have reference.
- Information related to the storage and handling of hydrocarbons (fuels, greases, etc.) and other hazardous materials (OHM) is limited to anecdotal reports and (few) site observations. Current water and soil quality monitoring does not include hydrocarbons or OHM and thus these aspects could not be included in this assessment.
- Within the Rutongo Concession area, air quality sampling was undertaken at two of the six mines only, namely Nyamyumba and Karambo. Air quality data is therefore lacking for the remaining sites.
- No toxicology studies or bioassays were undertaken of surrounding villages and communities, livestock/wildlife, or aquatic biota. The end-point condition of these receptors relative to the impacts of mining activities was therefore not established.

The reported results, comments, conclusions and recommendations, are based on the available information and the authors' professional knowledge. This study is based on assessment techniques and investigations that were limited by time and budgetary constraints applicable to the type and level of survey undertaken. This study, however, includes recent assessments of selected rivers, streams and wetlands associated with the relevant concession areas, and should be used to inform Trinity Metals' decision-making.

2. APPROACH

2.1 Introduction

The approach adopted for this Source-Pathway-Receptor (SPR) Analysis is based on international best practice for the assessment and management of risk relating to contaminated land or groundwater (e.g. guideline documents produced by DEA, 2010; IR-EPA, 2013; UK-EA, 2025; US-EPA, 1998).

In general, the assessment process encompasses three tiers of assessment, as summarised in **Figure 2-1** below.

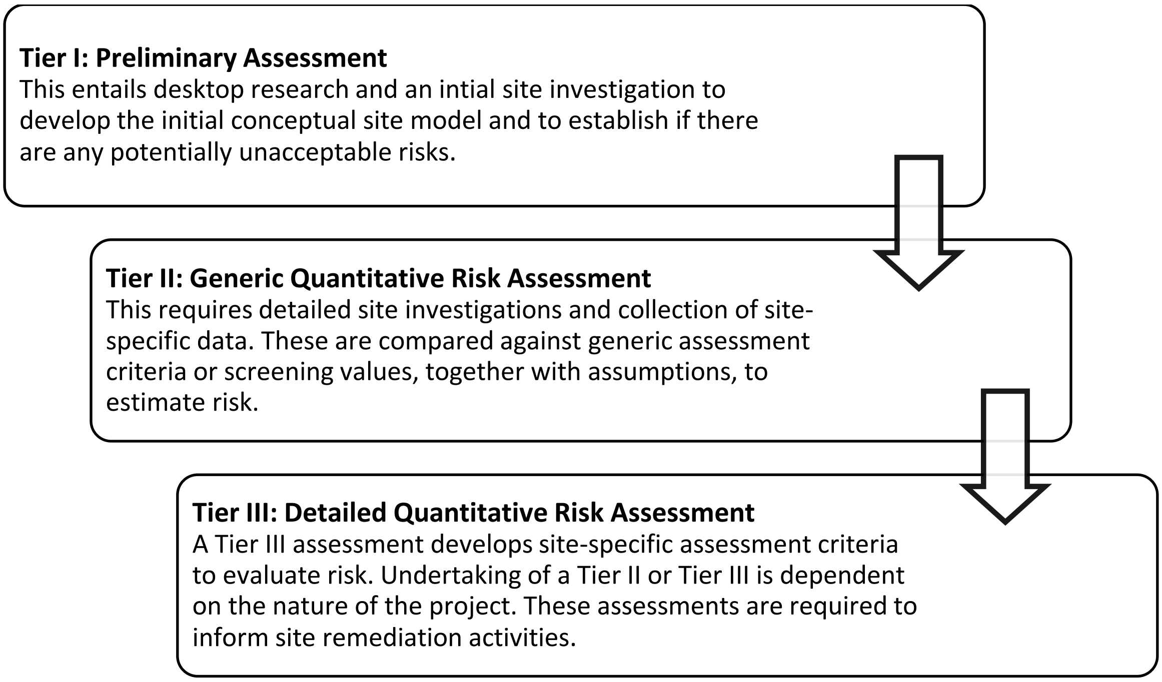

Figure 2-1 General phases of assessment and management of risk related to contaminated land or groundwater (Adapted from DEA, 2010)

2.2 Review of existing documentation

As part of the Trinity Metals ESIA process, a number of specialist assessments were conducted and incorporated into the final report for each mine site. The level of detail within these specialist reports varies from desktop assessments, data collected through once-off field sampling, data derived from monitoring conducted over several months, and detailed modelling exercises. These reports were considered relevant and directly formed the basis of the SPR analysis for each site. Information was extracted directly to present relevant information in a clear and comprehensive manner, rather than to claim authorship of the original material. The source reports are duly referenced throughout, specifically the following fields of expertise:

- Air Quality
- Terrestrial Biodiversity
- Aquatic Biodiversity

- Hydrology
- Geohydrology
- Geochemistry
- Social Risk
- Climate Change Risk

More recently, further investigations and studies were undertaken by various specialists. These works sought to update and/or fill identified information gaps. Specialist reports, data and/or in-field observations that were also included:

- Hydrocensus for each concession area (2025)
- Legacy Tailings and Soil/Sediment Geochemistry for each concession area (2026)
- Freshwater Ecosystems Health and Drivers (GroundTruth, 2026 – *in progress*)

Based on the review of the above-mentioned specialist reports and information, the detailed intrusive field investigations and data generated were considered adequate to fulfil a Tier II Risk Assessment (this report). This will in turn inform remediation design and implementation of the Legacy Tailings Management and River Rehabilitation/Mitigation Programme.

2.3 Source-Pathway-Receptor Model

The SPR model is a commonly used concept in contaminated land management to systematically assess how contamination moves through the landscape from its origin to the point of impact. The SPR model integrates a risk-based approach to establish the level of risk of contamination or harm (Novakowski et al., 2023).

There are three main elements that make up the SPR model that are investigated in both qualitative and quantitative assessments of contamination risk (DEA, 2010; Novakowski et al., 2023; Sustainability Directory, 2025; UK-EA, 2025):

Source	The origin of the contamination that has potential to cause an impact to human health or the environment and can include point and diffuse sources.
Pathway	The route or mechanism through which the contaminants (s) are released, transported or migrate from the source. Transportation can occur through different mechanisms including *inter alia* air, surface water, groundwater, soil, biological food chains.
Receptor	The entity or target that can be adversely affected by exposure to the contaminant(s). Receptors can include living organisms (e.g. human communities, wildlife) and ecosystems (e.g. rivers, lakes), as well as property and infrastructure (e.g. buildings, bridges). The receptor can be exposed to the contaminant(s) through different methods (e.g. ingestion, inhalation, dermal contact).

These are displayed diagrammatically below (**Figure 2-2**).

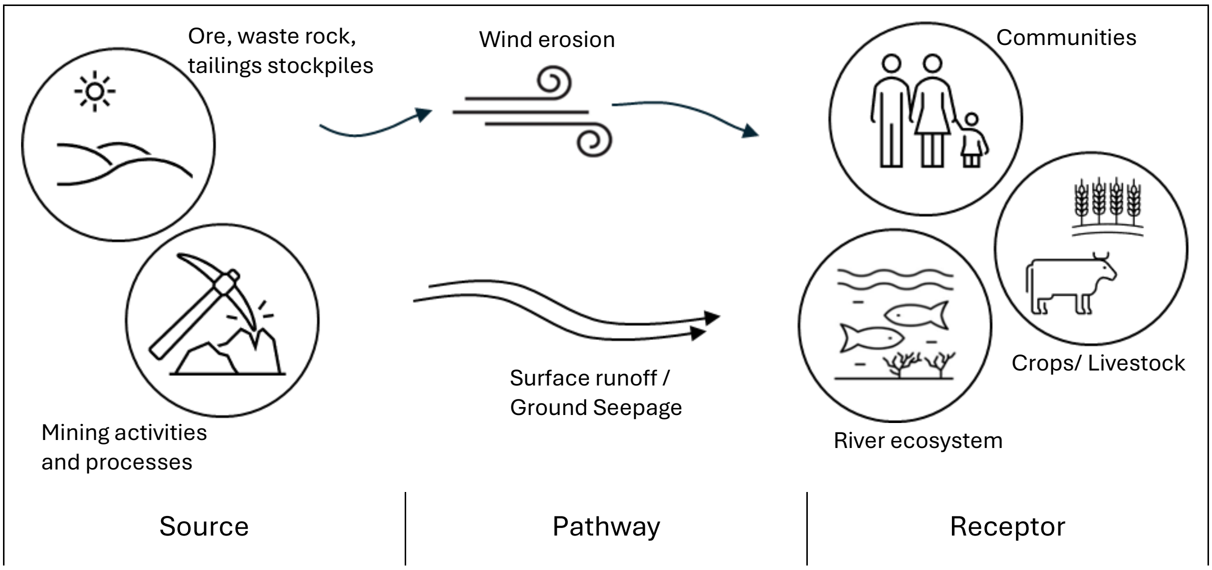

Figure 2-2 The Source-Pathway-Receptor Preliminary Conceptual Site Model in the context of Trinity Metals mining operations (Adapted from Novakowski et al., 2023)

Each of these elements can exist independently, however, the risk is only realised when they are linked together ('pollution linkages') and the receptors are exposed to the contaminants (DEA, 2010). It is therefore important to have a robust understanding of the characteristics of each of these elements to better assess potential negative impacts and effectively address the problem, which may be possible at one or more stages in the effects linkage. Overall, the SPR model enables a holistic view of the contamination risk for a particular site towards proactive environmental management (Novakowski et al., 2023).

Taking these potential pollution linkages into account, a CSM was then developed for each concession area, which summarises the potential sources, pathways of exposure, and risk to human health and the environment.

2.4 Generic Quantitative Risk Assessment

Using the potential SPR linkages identified through the CSM, a risk assessment was undertaken to estimate the risk of harm to the identified receptor(s). Under a Tier I assessment, this assessment is typically qualitative. Once information gaps and uncertainties are identified, detailed/intrusive field investigations are then undertaken to enable an evidence-based quantitative assessment of risk (Tier II), as informed by the abovementioned specialist reports (DEA, 2010; UK-EA, 2025).

The purpose of the risk assessment was to establish whether there is unacceptable risk, and this was established based on specific evaluation criteria, e.g. soil screening values, water quality guidelines limits, etc. The relevant water quality and effluent standards utilised in the specialists' report is provided in APPENDIX 1: STANDARDS.

This assessment incorporated an evaluation of the **likelihood** (or probability), nature and extent of adverse effects and the potential **severity** of consequence should exposure occur. Key influencing factors that were also considered include, but were not limited to (NICOLA, n.d.):

Source	Volume of source material, location/proximity to sensitive receptors, chemical signature, contaminant concentrations, and other (geology, minerology, etc.), background/natural levels.
Pathway	Influence of environmental factors on pathway behaviour, rate of transport, transformation and/or degradation along the pathway.
Receptor	Mediums/means of exposure, duration and frequency of exposure, effects of exposure, sensitivity of the receptor, acceptable levels of exposure, seasonality of biological communities.

In taking the above into account, the severity and probability of exposure to the contaminant and overall risk was then assessed. The severity of the contaminant was classified as follows (adapted from IR-EPA, 2025; KL-WN Borough Council, 2025):

- **High:** Short term (acute) risk to human health likely to result in significant harm. Short term risk of pollution of sensitive water resources. Catastrophic damage to buildings or property. Short term risk to an ecosystem or organism forming part of that ecosystem.
- **Medium:** Chronic damage to human health, pollution of sensitive water resources, significant change in an ecosystem or organisms forming part of that ecosystem.
- **Low:** Pollution of non-sensitive water resources. Significant damage to crops, buildings, structures and services. Damage to sensitive buildings, structures or the environment.
- **Minor:** Harm, though not necessarily significant harm, which may result in financial loss, to expenditure to resolve. Non-permanent human health effects (easily prevented by use of personal protective equipment). Easily repairable effects of damage to buildings, structure and services.

The probability was classified as follows (adapted from IR-EPA, 2025; KL-WN Borough Council, 2025):

- **Highly likely:** The exposure appears very likely in the short term and almost inevitable over the long term, or there is evidence at the receptor of harm or pollution.
- **Likely:** It is probable that exposure will occur, or circumstances are such that the exposure is not inevitable, but possible in the short term and likely over the long term.
- **Low likelihood:** Circumstances are possible under which exposure could occur, but it is not certain even in the long term that exposure would occur and it is less likely in the short term.
- **Unlikely/Improbable:** Circumstances are such that it is improbable that exposure would occur even in the long term.

A risk category was then assigned based on the Risk Assessment Matrix below **(Table 2-1)**, with risk being a function of likelihood and severity. This is accompanied by interpretation of the perceived risk.

Table 2-1 Risk Assessment Matrix used to classify risk at Trinity Metal mines and risk interpretation (Adapted from IR-EPA, 2025; KL-WN Borough Council, 2025)

Risk Assessment Matrix			Severity of Consequence			
			High	Medium	Low	Minor
			4	3	2	1
Likelihood	Highly Likely	4	Very High	High	Moderate	Mod/Low
	Likely	3	High	Moderate	Mod/Low	Low
	Low likelihood	2	Moderate	Mod/Low	Low	Very Low
	Unlikely	1	Mod/Low	Low	Very Low	Very Low

Rating	Description
Very High Risk	There is a high probability that severe harm could arise to a designated receptor from an identified contaminant, OR there is evidence that severe harm to a designated receptor is currently happening. This risk, if realised, is likely to result in a substantial liability. Urgent investigation (if not undertaken already) and remediation are likely to be required.
High Risk	Harm is likely to arise to a designated receptor from an identified contaminant. Realisation of the risk is likely to present a substantial liability. Urgent investigation (if not undertaken already) if required to clarify the risk and to determine the potential liability. Some remedial work may be required in the longer term.
Moderate Risk	It's possible that harm could arise to a designated receptor from an identified contaminant. However, it is relatively unlikely that any such harm would be severe, or if any harm were to occur it is more likely that harm would be relatively mild.
Moderate/Low Risk	It is possible that harm could arise to a designated receptor from an identified contaminant. However, if any harm were to occur it is more likely that harm would be relatively mild.
Low Risk	It is possible that harm could arise to a designated receptor from an identified contaminant, but it is likely that this harm, if realised, would at worst normally be mild.
Very Low Risk	There is a low possibility that harm could arise to a receptor. In the event of such harm being realised it is unlikely to be severe.

3. MUSHA/NTUNGA MINE

This section on the Musha/Ntunga Mine contains information extracted from the various baseline specialist assessments as part of the 2024 ESIA (see Section 1.3 and Section 2.2). Further insights and infield observations have been added by GroundTruth specialists where relevant.

3.1 Setting

3.1.1 Location

The Trinity Musha Mine currently consists of one primary site, the Musha Mine, and one satellite site, Ntunga Mine (collectively known as the Trinity Musha Mine). The Trinity Musha Mine is situated in the tin-rich area of Rwamagana District in Rwanda, approximately 45 km east of the capital city of Kigali in the Eastern Province. While the operation encompasses sub-mines, the majority of the production is derived from Musha (SLR, 2024a). Both Musha and Ntunga Mine sites produce tin, with smaller amounts of tantalum and a lithium potential.

The topography of the broader area is characterised by undulating, mountainous terrain with the surface elevation of the Musha concession area ranging from 1 461 m to 1 651 m above sea level and the Ntunga Mine concession area ranging from 1 486 m to 1 519 m (SLR, 2024b).

3.1.2 Brief History

The Musha Mine in Rwanda has a long operational history, beginning in 1928 under Société Minière de la Télé. In 1939, the Ntunga deposit was added to the Musha Mining License area. Minétain succeeded the original operator until 1973, after which Société des Mines du Rwanda managed the mine until 1985. In 2000, Régie des Mines du Rwanda initiated small-scale tantalite mining in Duha. In 2008, the Musha and Ntunga concession areas were separated. Rwanda Minerals and Mining (RMM) managed Musha from 2008 to 2011, while artisanal miners operated in Ntunga (SLR, 2024b).

Following the end of RMM’s lease, the Musha Concession was offered for tender in 2011. However, in 2012, the Ministry of Natural Resources decided to reconsolidate the Musha and Ntunga areas into a single concession, which was then made available for tender. In September 2013, Pella Rwanda Resources Ltd signed a 25-year Mining and Exploitation License Agreement, effective from 2014. This agreement included two Exploration Licenses and granted exclusive rights to prospect, explore, exploit, and process tin (cassiterite), tantalite, tungsten (wolframite), and lithium within the Musha and Ntunga concessions (SLR, 2024b).

In 2022, Piran Rwanda, merged with the holding companies of Nyakabingo Mine and Rutongo Mines, consolidating operations under the name Trinity Metals. The mine is now known as Trinity Musha Mines Limited (SLR, 2024b).

3.1.3 *Land-use*

Land-use within the Musha Mine concession area includes formal and informal mining, subsistence cultivation including the harvesting of fodder for livestock e.g. cattle, goats, chickens, *Eucalyptus* sp. timber production/forestry, orchards (avocados, macadamia), bee keeping, peri-urban settlement area including an industrial zone, and the associated road networks. The natural landscape has been substantially transformed with only limited pockets of natural wetland habitat remaining at the confluence of the Nyirabigaji and Kiruhura rivers (GroundTruth, 2026; Nepid Consultants, 2024a; SLR, 2024c).

Subsistence cultivation occurs upstream and downstream of Bisinia Dam and along the Nyirabigaji River in the Musha concession area, as well as in the Gashahi River in the Ntunga concession area. Subsistence cultivation comprises two main practices: hillslope farming, which predominately relies on rainfall for irrigation, and the in-system freshwater ecosystem agriculture, where crop fields are planted alongside the channels which are used for irrigation. In terms of the Gashahi River in the Ntunga concession area, in-system subsistence cultivation only starts approximately 70-100 m downstream from the mine site, given that there is a significant volume of tailings and sediment from the channel banks and alluvial fans within the freshwater ecosystem, which has migrated downstream from the mine site. The headwaters of the Gashahi River are predominantly fed by a series of springs and groundwater discharge points which appear within the channel bed approximately 1 km downstream of the mine site. These in-system springs and those located along the fringes of the freshwater ecosystem are an important source of water for the communities for their crops (GroundTruth, 2026).

Water resources within the Musha and Ntunga concession areas are integral to supporting these land uses (SLR, 2024b).

3.2 Site Layout and Operations

3.2.1 Layout

An overview of the Musha and Ntunga Mines are illustrated in **Figure 3-1** and **Figure 3-2**, respectively. Key infrastructure located at the Musha site includes the following (Nepid Consultants, 2024a):

- Main Office Area:
    - Accommodation, offices, and canteen
    - Storage area
    - Processing and upgrading area (including a crusher, shaking tables and screens)
    - Warehouse and core shed
- Mining Area:
    - Underground entrance - Bouveau tunnel
    - Musha Tunnel Offices, canteen, and engineering shed
    - Platform for the sorting of ore
    - Waste Rock Dump
    - New decline portal and cleared platform
    - Artisanal mining area with artisanal vertical shafts (mined by co-operatives on behalf of Musha Mines)
- Processing Area:
    - Processing area (sluicing)
    - Crushing and screening plant (not in use)
    - Water storage dam (sluicing water)
    - Tailings dam

There are limited activities and infrastructure at the Ntunga site. The key components include the following (Nepid Consultants, 2024a):

- Ntunga tunnel
- Storage shed
- Old settling dams
- Historical tailings
- Historical open pit (no longer in use)

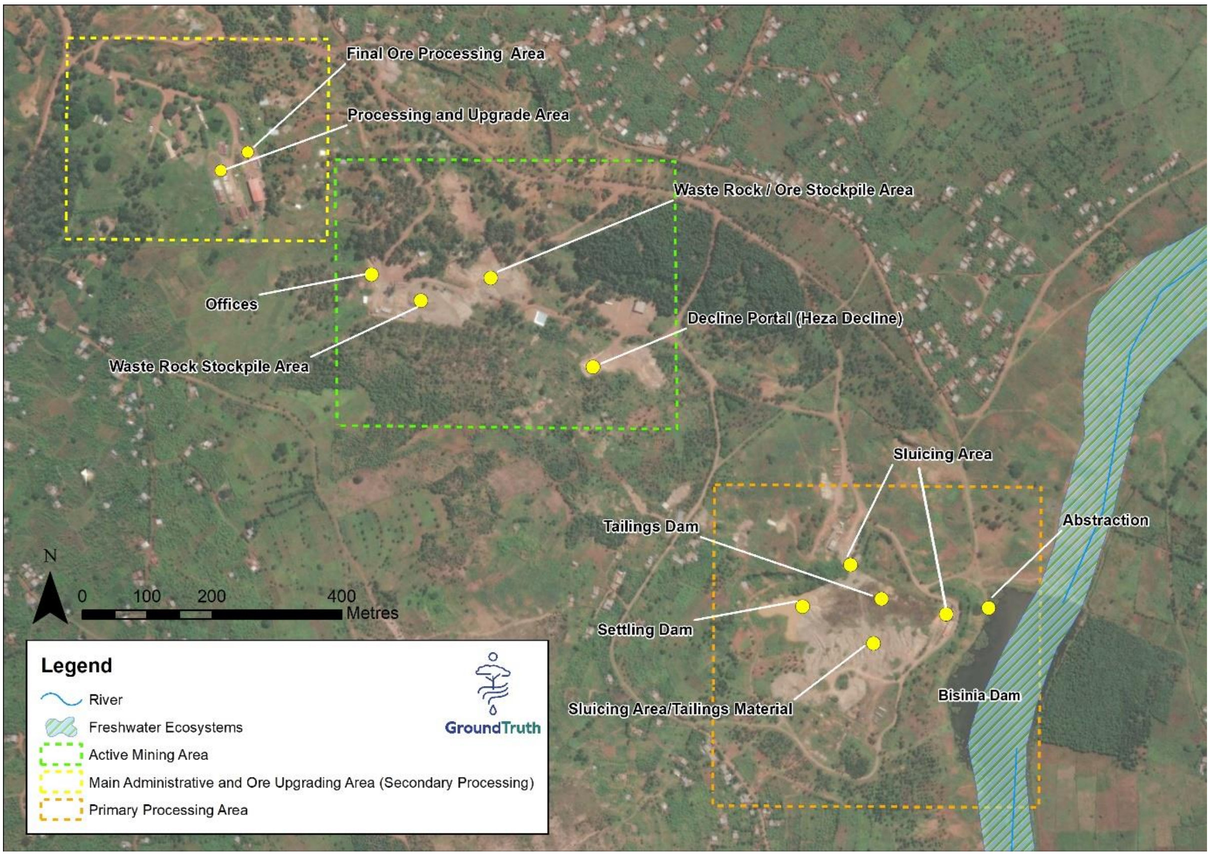

Figure 3-1 Layout of Trinity Musha Mine (primary site)

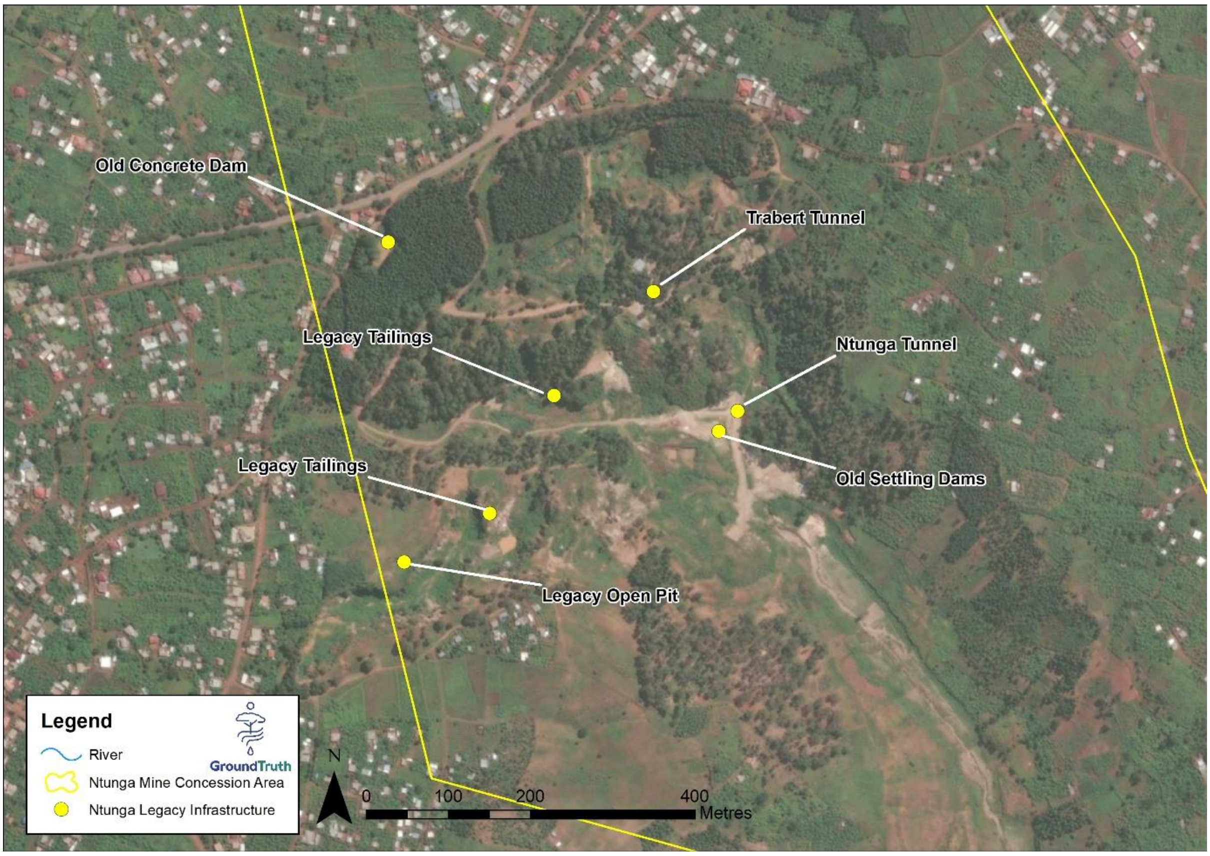

Figure 3-2 Layout of Trinity Ntunga Mine (satellite site)

3.2.2 Operations

3.2.2.1 *Material extraction and processing*

Mining at the Trinity Musha Mine currently consists of one primary site (namely the Musha Mine), with one satellite site (namely the Ntunga Mine). Mining activities at Musha and Ntunga Mines are limited to underground workings and are largely artisanal. Mining currently focuses on extracting tin and tantalum. Ongoing exploration currently aims to assess lithium's scale and extraction possibilities, primarily at the Ntunga Mine (SLR, 2024b).

The Musha mining areas, which extend over five levels, are accessed primarily via the Musha Tunnel. In addition, a number of artisanal-scale vertical shafts provide access to localised underground workings, operated by Musha contractors. Future expansion of the mine is planned via the Heza Decline, which is currently in the development phase (SLR, 2024b).

Jackhammers are used to loosen the underground ore prior to being brought to the surface. Nuggets are extracted by hand (nuggetting) at the mining face and bagged for further processing. The Musha Mine uses artisanal mining methods for the transportation, processing (sluicing) and handling of ore material. Ore is processed using manual sluicing on the banks of a former tailings facility. The product is removed to the Musha Main Camp, where it is crushed and treated at a small upgrade plant before being bagged and tagged for export (SLR, 2024b).

Limited activities occur at the Ntunga Mine, where access to the underground workings is via an adit and limited vertical shafts. Currently no processing of mined materials takes place at the Ntunga Mine. Material is transported to the Musha Mine for processing (SLR, 2024b).

3.2.2.2 *Process water and dewatering activities*

Process water at the Musha Mine site is required for primary processing activities, particularly sluicing, crushing, and panning. Secondary processing activities include upgrading the ore concentrate using shaking tables (SLR, 2024b).

In terms of the primary processing activities, process water is sourced from a storage dam termed the Circular Dam (75 m^3) which is supplied by the Bisinia Dam. The wastewater generated from the sluicing, crushing and panning activities, and tailings dam, is discharged to the Settling Dam, where it is pumped back to the Circular Dam for reuse. The Settling Dam is not engineered and, as such, is unlined. It is possible that this low-lying area was historically one of the historical open pit areas converted into a tailing facility. Along the eastern edge of the mining facility and western shores of Bisinia Dam is a large cutoff drain, which serves to collect seepage and sediments originating from the mining activities, preventing them from entering the dam. However, the cutoff drain itself is unlined and would likely allow slow seepage into Bisinia Dam if any are present in seepage originating from the Settling Dam. Any top-up water required for primary processing activities is sourced from the Bisinia Dam. Approximately 1,800 m^3/d is abstracted with from the Bisinia Dam (SLR, 2024b).

In terms of the secondary processing activities, process water for the shaking tables is stored in the process water tank (75 m^3) at the main Musha Mine site. This water is reused in the upgrading process (closed circuit); however, due to the accumulation of solids and losses through evaporation within the process water tank, this tank requires refreshing (water needs to be replaced with cleaner water and topped up) approximately twice a year. When this is required, the process water tank is cleaned out by removing the water and sludge via a water truck and discharging this into the Settling Dam at the primary processing area. Replacement water from the Bisinia Dam is abstracted and transported via a water truck to the process water tank. No processing activities are taking place at the Ntunga Mine site, thus there are no process water requirements (SLR, 2024b).

Dewatering activities at the Musha Mine site entail the abstraction from underground workings to a surface storage tank where it is used as washdown water or pumped for use at the Heza Decline and Engineering Services area. The volume of water being pumped from underground exceeds the water requirements on site, and as such, excess water from the tank is discharged to the environment via an underground pipe into an unlined trench, which ultimately discharges into the stream downstream of the Bisinia Dam. At the Ntunga Mine site, a small amount of groundwater is periodically abstracted from the underground workings and discharged into the Gashahi River (SLR, 2024b).

3.2.2.3 *Waste areas*

At the Musha Mine site, areas of waste rock stockpiles are located in the active mining area. As detailed above, wastewater generated from panning and sluicing activities is discharged into the Settling Dam in the primary processing area of the Musha Mine site (SLR, 2024b).

At the Ntunga Mine site, there is a significant volume of tailings and waste rock material that has migrated down the upper reaches of Gashahi River (SLR, 2024b).

3.3 Environmental Aspects

3.3.1 Hydrology

The Musha concession area is located on the southern shores of Lake Muhazi and traversed by several streams and rivers which drain into the lake. Lake Muhazi is an artificial impoundment that inundates an area of ~44 km^2, and ~46 km of the Nyabugogo River to the west. Lake Muhazi flows in a westerly direction where it meets with the Nyabugogo River, which is a major tributary of the Nyabarongo River, joining about 6.5 km west of Kigali. The Nyabarongo system flows into Lake Rweru, in the upper reaches of the Kagera River Catchment, of the Nile River Basin (Nepid Consultants, 2024a; SLR, 2024b).

Mining operations at Musha Mine are located adjacent to, and partially drain into, the Bisinia Dam, which is an earth impoundment that inundates ~5.5 ha at full supply (Nepid Consultants April 2024 Aquatic Ecology). The section of the river upstream of the Bisinia Dam is known as the Rwasama River, and the Nyirabigaji River is downstream of the Bisinia Dam. The Bisinia Dam has a pipe outlet that allows water from the dam to discharge to the Nyirabigaji River (SLR, 2024b). The Bisinia Dam serves an impoundment of Nyakagezi Wetland on the Nyirabigaji River, which comprises one of several channelled valley bottom wetlands[1] that drain into Lake Muhazi (Nepid Consultants, 2024a). This wetland does not possess legislative protection, notwithstanding, mining activities occur within 130 m of this unprotected wetland, specifically the adjacent Musha Mine tailings dam (SLR, 2024b).

The Ntunga Mine is in the headwaters of the Gashahi River, which drains south into Lake Mugesera, in the upper reaches of the Kagera River Catchment. The nature of the Gashahi River itself in proximity to the mine is largely that of a valley bottom wetland that has become artificially channelled through agricultural drains. Lake Mugesera eventually flows into the Nyabarongo (GroundTruth, 2026; Nepid Consultants, 2024a; SLR, 2024b)River. The prominent Kamirazovu Cyaruhogo unprotected wetland is located within the Ntunga concession area, approximately 3 km downstream of the nearest mine activities (Nepid Consultants April 2024 Aquatic Ecology; SLR August 2024, Hydrology).

In terms of hydraulic connectivity, the Nyakagezi Wetland located at the Musha Mine, which runs toward Lake Muhazi, as well as the freshwater ecosystem located at the Ntunga Mine site, are assumed to behave as gaining type systems (the stream and groundwater are hydraulically connected and the system receives groundwater as baseflow); however, where channel elevations exceed the elevation of the groundwater, it will behave as a losing type system (groundwater is below the invert level of the channel within the system) (SLR, 2024b). Although there is a diversity of water resources in the concession area for use by local communities (GroundTruth, 2025a), spring water is preferred as a source of drinking and domestic water. However, during the dry season, the springs do not provide adequate water, or sometimes they run dry completely (SLR, 2024b), and the communities must then rely on alternative sources (See Section 3.4 Social Aspects).

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[1] It should be noted that the wetland system/s is currently functioning as a channelled valley-bottom wetland, however, under benchmark conditions it would more likely have been an unchannelled valley-bottom system/s (GroundTruth, 2026).

In respect to prohibited activities near rivers and lakes and protection of river and lake shorelines, mining activities at Musha Mine are located approximately 30 m from the Bisinia Dam and well outside the 10 m regulated buffer zone. For the Ntunga concession area, the Gashahi River must have a 2 m buffer zone; however the Ntunga Mine site falls within the protection buffer zone at the headwaters of the river (SLR, 2024b).

3.3.2 Geology

The Karagwe-Ankole Belt (KAB) located in East Africa is one of two distinct northern and southern segments of the Mesoproterozoic Kibara Belt (KIB) of Central Africa, which hosts a large metallogenic province that contains numerous granite-related ore deposits, with the typical metal association of tantalum–tin-tungsten (SLR, 2024d). The KAB spans across parts of Rwanda and Burundi, SW Uganda, and NW Tanzania, as well as the Kivu-Muniema region of the DRC. It is characterised by two structurally contrasting domains, (1) the Western Domain (WD) with Proterozoic basement and (2) the Eastern Domain (ED) with Archean basement. The WD encompasses the intensely deformed parts of the KAB. The WD is a significant geological region, and it is associated with valuable mineral deposits that include tin, tungsten, tantalum, and gold, which are mined throughout the region (SLR, 2024d).

Trinity Musha Mine is situated within the Karagwe-Ankolean Supergroup, a Neoproterozoic-age geological formation characterised by metavolcanic and metasedimentary rocks. Tungsten mineralisation is associated with quartz veins and greisenized granite. The Musha and Ntunga mine mineralogy is dominated by Quartz, Muscovite and Kaolinite, with minor to trace Dravite, Schorl, Hematite, Goethite, Anatase, and Elbaite. No discernible amounts of carbonates or sulphides were reported for either mine site (SLR, 2024d).

3.3.3 Hydrogeology

The ore deposit is structurally controlled by a series of faults and fractures, and groundwater ingress into the mine workings is most likely also structurally controlled. The aquifers in the Musha and Ntunga concession areas, can be characterised as follows (SLR, 2024d):

- Weathered Aquifer: A shallow, unconfined aquifer formed in the upper 5–30 m of weathered sandstone and schist, with low to moderate water-bearing capacity.
- Primary Alluvial Aquifer: Found along the Rusine and Nyabugogo River and streams, composed of gravel and sand with moderate to high aquifer parameters, recharged by surface water inflow.
- Secondary Fractured Aquifer: A deeper semi-confined aquifer in unweathered shale and quartzite, where groundwater flows through fractures; typically low to moderate yield, but occasionally high aquifer parameters.

The aquifer underlying the site can be regarded as a moderate-yielding aquifer, with reported yields ranging from 0.1-0.5 l/sec. The weathered zone for the area is estimated to be in the order of 10 m thick, followed by a subsequent thicker dry, clay zone (up to 110 m thick). In areas where alluvium occurs, the estimated thickness is of the weathered zone is 30-40 m (SLR, 2024d).

Groundwater is found within fractures and bedrock contacts which are recharged from rainfall through overlying saturated sand, contacts between lithologies or at unconformities and dolerite dyke contacts. As such, where these structures daylight in low laying topographical areas, springs will be produced fed by the groundwater within the contacts. The initial percentages of recharge range from 5 to 1 % of mean annual precipitation (MAP) based on literature, however the calibrated recharge values are however lower. The groundwater table loosely mimics the topography and groundwater flows from high-lying areas (water divides) to low lying areas (SLR, 2024d).

The groundwater quality is generally good and only a few parameters exceeded the guideline limits. However, the slight acidity of the water causes the metal concentrations to be elevated. The variables of concern included aluminium, arsenic, iron and manganese. Apart from iron at one site, the current concentrations are only marginally above the limits and therefore deemed as natural to the environment. pH levels at two borehole sites were below the limit for livestock watering, whilst chloride exceeded the livestock water limit at one site (SLR, 2024d).

3.3.4 Biodiversity

The Musha/Ntunga concession area is located within the Victoria Basin Forest-Savanna Mosaic ecoregion. This ecoregion is centred on Lake Victoria and historically comprised an assortment of tropical forest and savanna woodlands (SLR, 2024c). However, based on site observations, the concession area is not representative of the typical vegetation types of this ecoregion and only contains modified and severely degraded vegetation types. Due to the various human activities (mining, farming and forestry), the concession area has limited biodiversity value and limited potential to support Species of Conservation Concern (SCC). Two bird SCC that are predicted to occur in low numbers are Hooded Vulture (*Necrosyrtes monachus)* and Bateleur (*Terathopius ecaudatus)*. While these species are able to utilise anthropogenic environments for foraging, they are unlikely to breed within the concession areas. It is worth noting that, due to the intensity and extent of habitat degradation from human activities, other expected SCC are unlikely to occur in the area (SLR, 2024c).

In terms of aquatic biodiversity, three aquatic ecosystem types occur with Musha and Ntunga concession areas, namely the Bisinia Dam, which is an *artificial earthen impoundment*; the Nyakagezi Wetland between Bisinia Dam and Lake Muhazi, which is a *channelled valley bottom wetland*; and a *transitional stream*, the Gashahi[2] River, that has its headwaters in the Ntunga concession area (Nepid Consultants, 2024a). As the valley that holds the Gashahi River broadens, small seep wetlands are common along the foot slopes, which provide water and some diversity of habitat in an otherwise modified landscape (GroundTruth, 2026).

Sampling of the Gashahi River approximately 1 km downstream of the mine site, recorded no benthic diatoms. The system was depauperate in aquatic fauna with only five macroinvertebrate taxa and one fish species recorded. These findings were attributed to elevated concentrations of suspended material and limited availability of suitable habitats. Overall, the Gashahi River was classified as 'Critically to Seriously modified' (Nepid Consultants, 2024a), but is not directly linked to the Ntunga Mine via the Gashahi River. The Gashahi River has, however, been critically altered in terms of hydrology and geomorphology, with the valley bottom becoming incised and widened.

[2] Previously reported as the Kabacuzi Stream by Nepid Consultants. This has been corrected to the Gashahi River.

The Musha ecosystems were better in condition. During the wet and dry season, the number of benthic diatom species in the Nyakagezi Wetland was 37 and 34, respectively. The system was assessed as 'Good to Moderately modified'. The community composition revealed elevated nutrient levels and salinity content, and low metal toxicity and organic load. These results were attributed to agriculture and settlements, and the impact of mining activity (Nepid Consultants, 2024a). Regarding macroinvertebrates, a total of 24 and 22 taxa were recorded during the wet and dry season, respectively. There was no measurable difference in the composition or abundance of macroinvertebrates between the two surveys. All taxa recorded prefer standing to slow-flowing water related to the permanent standing waters created by Bisinia Dam and Lake Muhazi, and state of the systems was classified as 'Moderately modified' based on the macroinvertebrate community. Ten species of dragonfly were recorded upstream of the Bisinia Dam. The low index score was indicative of widely distributed species which are typically tolerant of habitat disturbance and pollution(Nepid Consultants, 2024a). Nine and eight species of fish were recorded from the Nyakagezi Wetland and Bisinia Dam respectively, with the most abundant species in both surveys being *Pseudocrenilabrus multicolor ssp. victoriae* (Cichlidae), guppy *Poecilia reticulata*, and an undescribed Cichlid (termed *Haplochromis sp*. "musha"[3]). As with the macroinvertebrates, there was no measurable difference in the composition or abundance of fish between the two surveys, and all species recorded prefer standing to slow-flowing water connecting the two permanent standing waterbodies. Two alien fish species were recorded, the guppy *Poecilia reticulata*, and the Blue-spotted tilapia, *Oreochromis leucostictus* (Nepid Consultants, 2024a).

Based on the state of the Nyakagezi Wetland, the overall habitat integrity of the aquatic ecosystems at the Musha Mine was rated as 'Largely modified' (Nepid Consultants, 2024a), with the key drivers of this condition being associated with the stream channel modifications i.e. diversion of flows through the system, extensive cultivation of crops within the wetland and almost complete modification of the vegetation composition. All other sampling sites in the concession were in much the same condition (Nepid Consultants, 2024a). A small segment of the Nyakagezi Wetland that was historically cultivated is no longer cultivated because the owner of the land decided to allow the wetland to recover (Ninsiima *pers. comms*, 2025[4]). This portion of the wetland has recovered surprisingly well despite still having an extensive drainage network within it. The wetland was dominated by sedges and hydrophilic grasses such as *Cyperus latifolius, Leersia hexandra, Cyperus denudatus* and *Kyllinga melanosperma*. While the species composition of this recovering portion of the wetland is unlikely to represent the benchmark vegetation, it provides important habitat for other aquatic species (GroundTruth, 2026).

There are no protected areas, key biodiversity areas, important bird and biodiversity areas, or Ramsar wetland sites, in close proximity to the Musha Mine sites, which might pose as sensitive ecosystem receptors (SLR, 2024c).

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[3] Additional field survey data suggested that *Haplochromis* sp. "musha" corresponds to the extraneous records of *H. erythromaculatus* recorded in the vicinity of Kigali (Barbour, 2024a).
[4] Remy Ninsiima, Environmental Manager at Musha and Ntunga Mines, 2025.

3.4 Social Aspects

The Musha and Ntunga Mines are located in the Musha, Munyiginya and Mwulire Sectors of the Rwamagana District of the Eastern Province. Combined, these make up 17.7% of the population of the district. Around 65% of district households are rural in nature, and reliant on agricultural activities (crop cultivation 58.9%, livestock 43.5% and horticulture 56.8%) as part of their livelihood strategies (Barbour, 2024a).

There are several communities in close proximity to the Musha Mine and dwellings that are closely integrated with the mine site (Barbour, 2024a). The density of rural homesteads in the area to the north of the current mining areas is relatively high compared to the south and southeast. Agriculture is the dominant land use in the area. Small-scale, labour-intensive crop farming takes place in most areas that can be used. The main crops cultivated include beans, potatoes, sweet potatoes. Livestock kept includes cattle, goats, and chickens. Bee hives are also kept. The Bisinia Dam is used for collecting water, washing clothes, fishing and swimming (Barbour, 2024a). It also serves as the key water source for agricultural use in the two nearby villages of Muhogoto and Cyimbaze (GroundTruth, 2025a). The area downstream of the Bisinia Dam is intensively farmed. Shallow trenches are used downstream of the dam to channel overflow for crop irrigation in surrounding cultivated fields (GroundTruth, 2025a).

There appears to be limited informal mining taking place in the Musha concession area (Barbour, 2024a). Schools, places of worship and recreational areas, some of which are within 1 km of the mine site represent sensitive receptors for the negative impacts of mining, such as poor air quality (SLR, 2024a).

Similarly, dwellings occur within the mine setting of the Ntunga mine site (Barbour, 2024a). Agriculture is the dominant land use with small-scale, labour-intensive crop farming taking place in the area down-stream of the mining area. While there is limited agriculture in the immediate vicinity of the mining area at the top end of the valley due to the steepness of the slopes, the flood plain and valley sides are intensively cultivated. Mining in the head of the valley has resulted in tailings being washed down the valley and has impacted on the river course and a community water collection point (Barbour, 2024a). The Ntunga community and other surrounding communities obtain their water from existing water infrastructure at various collection points within the Ntunga village. There was no evidence of informal mining in the area downstream of the mining area (Barbour, 2024a). The nearest sensitive receptors in terms of air quality concerns include a school, shopping centre and place of worship (SLR, 2024a).

Communities within both the Musha and Ntunga mine concession areas rely on a range of water sources for domestic and agricultural use, including springs, water collection points, dams, Lake Muhazi, and, to a limited extent, rainwater harvesting (GroundTruth, 2025a). The Musha concession area, being relatively flatter than other concessions, has comparatively more reliable and diverse water supply options. However, communities still face difficulties in terms of accessing water resources. There are 45 communities in the Musha concession area; nine of these communities as well as Musha Mine, are supplied by the main water distribution network. The source of the distribution network is the Gahoko spring located 500 m downstream of the Bisinia Dam on the western bank (GroundTruth, 2025a).

3.5 Conceptual Site Model

The following section describes the three main components of the CSM, comprising potential sources, pathways and receptors of possible contamination emanating from the mine areas. These are outlined in **Figure 3-3.**

3.5.1 Sources

Fugitive emissions – Mining operations are known to generate fugitive emissions through mechanical operations[5] and wind erosion of waste rock and tailing stockpiles, which include particulates of varying size fractions, and gaseous emissions from the combustion of fossil fuels in heavy machinery/equipment and vehicles (haulage trucks). Ambient air pollutants of relevance in this context include particulates ($PM_{2.5}$ and PM_{10}), and gases (SLR, 2024a). At the Ntunga site, there is limited infrastructure and activities, however exposed areas have potential for dust generation by wind erosion. Some areas of historical tailings have been revegetated while some remain exposed (SLR, 2024a).

Ore, waste rock, slurry, legacy tailings – Due to the lack of formal stormwater management infrastructure and the proximity of water resources, dirty runoff from the legacy tailings, ore, slurry, and waste rock stockpiles reach downstream water resources on the Ntunga Mine (SLR, 2024b).

Mine impacted / process water / effluent – The Settling Dam at Musha is not engineered and, as such, is unlined. Seepage from the Settling Dam may reach the Bisinia Dam despite the presence of an unlined cutoff drain between the Settling Dam and the Bisinia Dam, whilst water from underground workings and adits at both sites are stored and/or released directly to the downstream water resources (SLR, 2024b).

*There is potential for some hydrocarbon contamination related to the drilling machine operations at the mining face as well as minor spillages from mobile machinery (e.g. Bobcat loaders. However, no monitoring data are available for hydrocarbons, and related substances (Daneel *pers. comm*, 2026[6]).

3.5.2 Pathways

Wind dispersal – Wind facilitates horizontal dispersion of fugitive emissions and dust. Higher wind speeds will move pollutants away from the source more quickly, while low wind speeds can result in air pollution stagnation and high ambient concentrations. Ambient air pollutants of relevance in this context include particulates ($PM_{2.5}$ and PM_{10}), and gases (NO_2 and SO_2) (SLR, 2024a).

Surface water discharge – Due to the lack of formal stormwater management infrastructure and the proximity of water resources, dirty run-off from the legacy tailings, ore, slurry, and waste rock stockpiles, and discharges from the mine adits conveyed via pipeline and trench, reach downstream water resources (SLR, 2024b).

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[5] Sources of fugitive dust emissions from mines result mainly from blasting, handling, processing, or transporting of materials.
[6] Joanne Daneel, ESG Consultant, Trinity Metals, 2026.

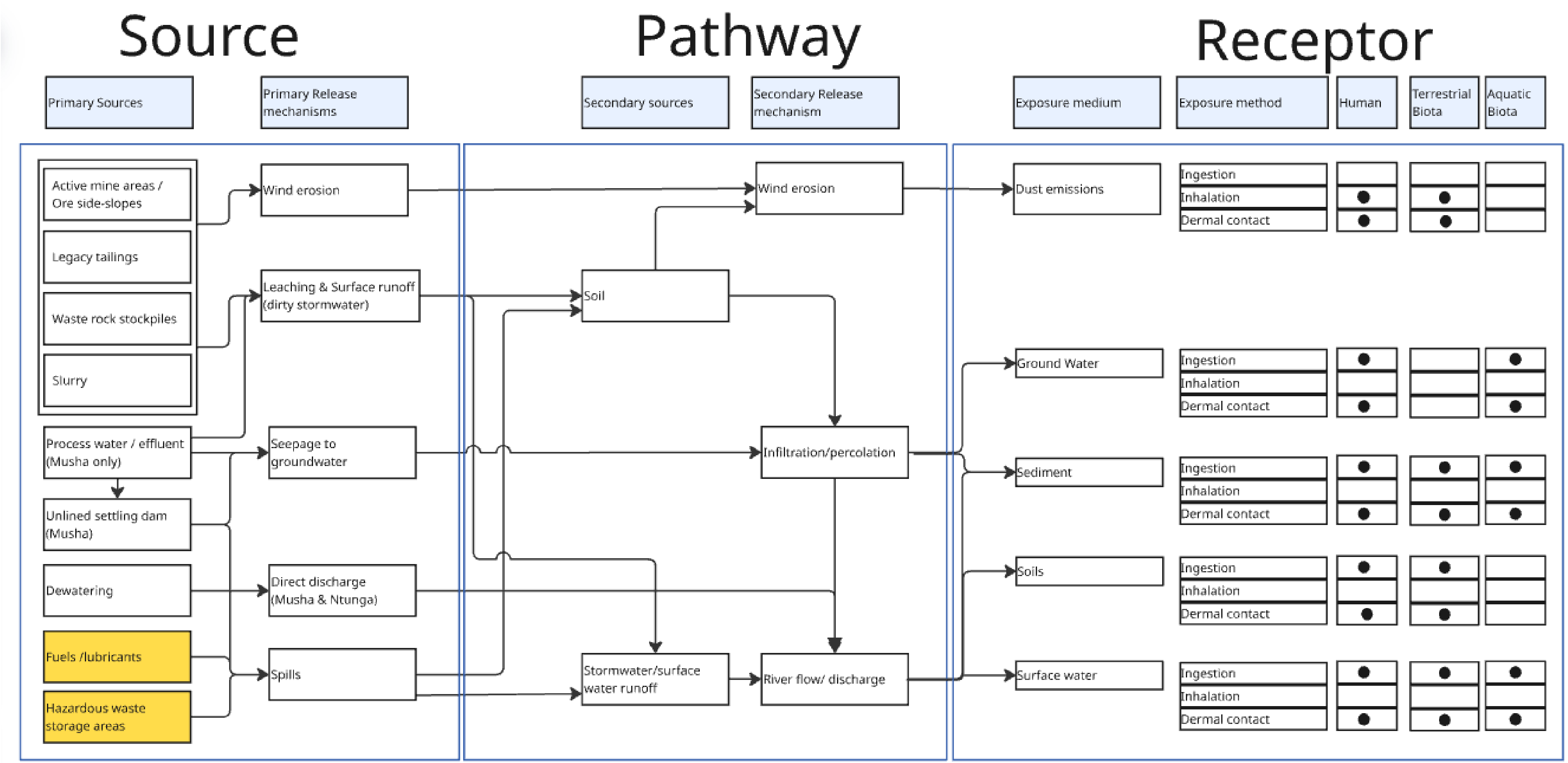

Figure 3-3 **Conceptual Site Model for Trinity Musha/Ntunga Mine showing the predicted migration pathways of contaminants from source to receptors (Yellow = Unconfirmed)**

While no formal stormwater management infrastructure is present at Musha, the Settling Dam receives most of the ore, waste rock and slurry produced at Musha. One stormwater issue was noted at the Bouveau tunnel entrance, where a preferential stormwater path has turned into an erosion gully and is producing sediment and has the potential to carry ore and slurry during rainfall events. It is approximately 500 m upslope of the Nyakagezi Wetland (GroundTruth, 2026). Dilution of contaminants may occur upon reaching river systems or water bodies, or via groundwater recharge. Upstream and surrounding community activities (agriculture, livestock), as well as other instream activities (aggregate mining) can contribute to degraded water quality, in addition to mining activities. Other contaminants, e.g. nitrates, can undergo biochemical transformation (denitrification) and degradation become no longer toxic.

Groundwater infiltration – Host rock minerology contributes to background levels of metals and other potential contaminants. Interaction between groundwater and active mine areas, as well as seepage from the unlined settling dam may lead to contamination of groundwater. This is exacerbated by the absence of formal stormwater management infrastructure. In turn groundwater contamination may lead to contamination of the Bisinia Dam, Nyirabigaji River, and Nyakagezi wetland, as the baseflow of this river system is groundwater-dependent (SLR, 2024b).

3.5.3 Receptors

Human population – This includes mine workers and the surrounding communities in close proximity, in particular communities who utilise water resources within the concession area for drinking, domestic use, agriculture and livestock watering. Spring water is the preferred and primary source of water, however, rivers throughout the concession area are also utilised. At elevated concentrations, contaminants can be harmful to humans primarily through ingestion/drinking. Factors that can influence whether contaminant exposure in drinking water will lead to adverse health effects include the type of contaminant, its concentration, individual susceptibility, the amount of water consumed, and the duration of exposure. Other exposure media include direct dermal contact, inhalation of contaminants, as well as through ingestion of contaminated crops and other food items (e.g. fish). Children and the elderly are the most vulnerable to health complications caused by contaminants, especially in rural communities where health facilities are often undeveloped or located in major centres (Sustainability Directory, 2025).

Aquatic ecosystems – These include rivers, seeps and/or wetlands and related biodiversity within the concession areas, and further downstream, specifically the Bisinia Dam, Nyirabigaji River, the relatively intact portions of the Nyakagezi Wetland, and Lake Muhazi within the Musha concession area, and the Gashahi River in the Ntunga concession area. Factors that can influence whether contaminant exposure will lead to adverse health effects for aquatic biota include the type of contaminant, its concentration (as a factor of river flow), sequestration within river sediments, species-specific sensitivity to pollution, and the duration of exposure (Sustainability Directory, 2025). Bioaccumulation of contaminants in fish tissue can lead to health-related issues in communities through ingestion. Moreover, freshwater ecosystems, especially wetlands, can act as a sink for contaminants, which can then accumulate to toxic levels (GroundTruth, 2026).

Terrestrial ecosystems – These include remaining areas of vegetation and related biodiversity within the concession area or immediately adjacent. Terrestrial organisms (flora and fauna, including domestic livestock), can be exposed to contamination through soil uptake (plants) and ingestion of drinking water, soil and plants, dermal contact or inhalation of contaminants. The same factors influencing contamination exposure also apply to terrestrial organisms.

3.6 Risk Assessment

3.6.1 *Air emissions*

The following findings are extracted from the specialist Air Quality Report (SLR, 2024a):

Musha

- Exceedances of East African Standards (EAS) 2021 and World Health Organisation (WHO) Air Quality Guidelines (AQG) 2021 24-hr average limits were noted for PM_{10} (13.3% and 30.0% of records) and $PM_{2.5}$ (80.0% and 96.7% of records).
- NO_2 and SO_2 concentrations were well within the annual EAS 2021 and WHO AQG 2021 guidelines.

Ntunga

- Exceedances of EAS 2021 and WHO AQG 2021 24-hr average limits were noted for PM_{10} (13.3% and 36.7% of records) and $PM_{2.5}$ (83.3% and 96.7% of records).
- Gas monitoring was not undertaken at Ntunga due to limited activity and lack of mechanisation that would otherwise result in gaseous emissions.

3.6.2 *Mine materials*

The following findings are extracted from the specialist Geochemistry, and Geochemical and Soil/Sediment Assessment reports (SLR, 2026a, 2024e):

The Musha and Ntunga mine materials were classified as having an overall low risk for potential acid rock drainage long term and metal leaching. However, due to the lack of neutralizing minerals in the lithologies present (like sulphides or carbonates), the mine materials have zero buffering capacity and if any localised /in situ acid generating lithologies are encountered or mined, then there could be an immediate risk for acid effluent leaching from the site, which could potentially impact the environment (SLR, 2026a, 2024e).

Musha

- The only notable contaminant of concern was an anomalous exceedance of vanadium in the slurry against the RS irrigation limits, and low pH for legacy tailings.
- Manganese in ore and legacy tailings leachate marginally exceeded the RS livestock watering limits.
- The exceedance of manganese in the legacy tailings in terms of WHO Guidelines for Drinking Water (2022) and RS irrigation limits was confirmed by sampling in July 2025, indicating moderate leaching potential. Manganese is indicated as source term for predicting contamination of surface and groundwater resources.
- The Musha process and effluent water samples reported neutral pH values with none of the metals or ions returning any guideline exceedances.

- These results indicated that the runoff from waste rock, ore, slurry material is not contributing to the water quality deterioration within the Bisinia Dam and the Nyirabigaji River system. However, the legacy tailings are contributing excess manganese.

Ntunga

- The leachate from the legacy tailings exceeded the WHO Guidelines for Drinking Water (2022) for aluminium, iron and manganese. The exceedance of manganese in terms of WHO Guidelines for Drinking Water (2022) and RS irrigation limits was confirmed by sampling in July 2025, indicating a moderate risk for metal leaching.
- Manganese is indicated as a contaminant of concern for surface and groundwater resources.
- No processing activities are undertaken at Ntunga Mine and thus no process water or effluent were assessed.

3.6.3 Groundwater

The following findings are extracted from the specialist Hydrogeology and Hydrology reports (SLR, 2024d, 2024b):

- Two natural springs, one in each concession area downstream of the mining areas and, utilised by village members for drinking water were within the WHO Guidelines for Drinking Water (2022) limits.
- The groundwater quality was generally good and only a few parameters exceeding the WHO Drinking Water Limits (fluoride, aluminium, iron, manganese) and Rwanda livestock watering limits (pH, chloride) at Musha Mine. No exceedances recorded in Ntunga groundwater.
- The presence of aluminium, iron, arsenic and manganese in the groundwater can be attributed to the geological composition of the host rock. Current concentrations are only marginally above the limits and thus considered natural.
- Upstream groundwater water quality at Musha and Ntunga recorded low pH and nitrate levels exceeding effluent, livestock watering and irrigation limits (SLR April 2024, Geochemistry), indicating compromised water quality.
- Mine water discharged from both the Musha Tunnel adit and Ntunga adit does not exceed the WHO Guidelines for Drinking Water (2022) and other guidelines for key parameters.

Potential groundwater contamination

- Modelling of the contamination plume at Musha Mine indicated that the plume follows the hydraulic gradient towards the Bisinia Dam and associated stream. Within three years (2017) the plume reaches the dam progresses steadily until it reaches the stream and the dam. Thereafter a steady-state is reached and there is not further progression.
- At Life of Mine (LOM) (2029), the plume extends approximately 630 m southwest to northeast and approx. 330 m northeast to southwest.
- With expansion of the mining operations to LOM (20 years), the plume continues to migrate northeast (i.e. downstream).
- Due to the river and dam (which act as sinks) being in such close proximities to the tailings storage facility (TSF) (waste area), and with the TSF located at a relatively low elevation

compared to its surroundings, plume migration is not expected to extend to the west of the TSF.

- In terms of mining contamination post-LOM, simulation results show that concentrations and the plume extent appear stable and do not increase or migrate further. This may be attributed to the steep hydraulic gradient that exists towards the Bisinia Dam and Nyirabigaji River.

3.6.4 Surface water

The following findings are extracted from the specialist Hydrology report (SLR, 2024b):

- At the Musha Mine site, upstream water quality and downstream water quality exceeded the WHO Guidelines for Drinking Water (2022) limits for manganese, indicating that water quality is already compromised and that surrounding village activities are contributing to the water quality status of the Nyirabigaji River.
- Geochemical analyses of the Musha mine materials (see above) indicated that the runoff from the legacy tailings specifically, and the other materials to a much lesser degree, is contributing to the water quality deterioration within the Bisinia Dam and the Nyirabigaji River system.
- At Ntunga, aluminium, manganese and iron concentrations from the legacy tailings leachate exceeded the WHO Guidelines for Drinking Water (2022), thereby impacting water quality within the Gashahi River.
- No FAO-recommended livestock limits were exceeded, making the water fit for livestock drinking.
- Sodium and chloride concentrations in the water downstream of the Musha Mine and Ntunga Mine sites pose a severe problem for crop yield.
- The nitrates upstream and downstream of the Musha Mine site and downstream of the Ntunga Mine site, the pH upstream and downstream of the Musha Mine site and the total dissolved solids (TDS) levels downstream of the Ntunga Mine site are classified as increasing problems.

3.6.5 Sediments and Soils

The following findings are extracted from the specialist Geochemical and Soil / Sediment Assessment (SLR, 2026a).

Musha- River sediments

- Due to the presence of Hematite, Schorl, Kaolinite and Muscovite in the sediments, they have capacity to sequester metals and metalloids mobilised by mining activities. The sediments are thus likely to show an enrichment / accumulation of various metals that exceed average crustal abundances or background level values.
- In terms of various water quality and effluent guidelines, the Musha upstream sediment sample exhibited exceedances of iron, manganese and lead, whereas the downstream sediment sample had exceedances of arsenic, iron, and manganese. Exceedances were higher at the upstream site, likely attributed to the higher proportion of Haematite present.

- In terms of potential contamination and comparison against soil screening values (SSV1), both the Musha upstream and downstream sediment samples exhibited exceedances of arsenic, copper, lead and vanadium.
- Significant metal enrichment and potential contamination was noted for arsenic, boron and selenium in the upstream sediment, and boron and tin in the downstream sediment. The latter exhibited extreme enrichment and likely contamination by arsenic.

Musha – Soils

- Soils in the downstream areas of the Musha mine were classified as a Ferralsol, which is formed from intense weathering and has limited capacity to remediate metal leaching and acid rock drainage.
- Organic carbon content was low, and the lack of high activity clay minerals infers limited acid buffering capacity and thus soil that is prone to acidification.
- Soil was acidic (pH<5) thus susceptible to nutrient leaching and with reduced availability of essential nutrients, but increased availability of trace and heavy metals, therefore the potential risk of phytotoxicity. The soil has limited pH buffering capacity.
- In terms of nutrient status, the soil is characterised by relatively low proportions of phosphorous and potassium, and magnesium content was below the range suitable for most crops. No excessive trace metal content was detected, therefore presenting low phytotoxicity risk.
- In terms of potential contamination and comparison against SSV1, the Musha soil exceeded the limit for copper. It is suggested that elevated copper content is derived from the mineralogy of the parent material, and not necessarily due to mining activities impacting the downstream areas.

Ntunga – River Sediments

- At Ntunga Mine, only one sediment sample was obtained at a site downstream of the mine. The predominance of medium and coarse particle size fractions suggests that the hydrological functioning of the river system has been altered as it is anticipated that downstream sediments would consist of a larger proportion of silt and clay.
- Due to its mineralogy, this sediment is also likely to sequester metals and metalloids mobilised by mining activities.
- The Ntunga downstream sediment sample recorded exceedances of iron, manganese and lead relative to water quality and effluent guidelines.
- In terms of potential contamination and comparison against SSV1, the sediment exhibited exceedances of arsenic and lead.
- Significant metal enrichment and potential contamination was noted for arsenic and tin, while extreme enrichment and likely contamination was noted for boron.

Ntunga – Soils

- Soils in the downstream areas of the Ntunga mine were classified as a Nitisol, which has limited capacity to remediate metal leaching and acid rock drainage.
- The soil sample had a sandy loam texture and was also characterized by a high percentage of sand, with silt as the secondary particle size fraction. The drainage of this

soil is likely to decrease with depth due to its increased clay content, which is typical of Nitisols.

- Organic carbon content was low, and the lack of high activity clay minerals infers limited acid buffering capacity and thus soil that is prone to acidification.
- Soil was slightly acidic (pH~6) with slightly reduced availability of essential nutrients, therefore maintaining some productive (fertility) capacity. Soil is prone to leaching and has limited pH buffering capacity.
- In terms of nutrient status, the soil is characterised by relatively low proportions of phosphorous and potassium, and magnesium content was above the range suitable for most crops. No excessive trace metal content was detected, therefore presenting low phytotoxicity risk.
- In terms of potential contamination and comparison against SSV1, the Ntunga soil exceeded the limit for copper. As with Musha soils, elevated copper content is likely derived from the parent material, and not necessarily due to mining activities impacting the downstream areas.

Overall, rivers in the vicinity of the Musha and Ntunga mines have been impacted. Higher metal exceedances in the upstream sediment suggests that mining activities are likely to have had some impact on the rivers, with other anthropogenic activities (like agriculture) occurring in proximity to the rivers contributing to increased metal release and exceedances.

The above findings of the specialist reports are integrated into quantitative risk assessments for the Musha and Ntunga mines (**Table 3-1** and **Table 3-2**).

Table 3-1 Summary of Environmental Risks Associated with Musha Mine

Source	Potential Contaminants*	Pathway	Receptor	Severity**	Likelihood	Risk
Fuel Combustion	NO_2 SO_2	Wind erosion / dispersal	Workers / Communities	MINOR - No exceedances recorded	LIKELY – Workers engaging in mining activities, proximity of access roads	LOW
Ore Stockpile *Waste Rock* *Slurry* *Legacy Tailings*	PM_{10} $PM_{2.5}$		Workers / Communities	HIGH - PM_{10} and **$PM_{2.5}$** exceedances, particularly $PM_{2.5}$, at key points on site and in surrounding communities	HIGHLY LIKELY – Workers engaging in mining activities, proximity of communities and sensitive receptors	VERY HIGH
Slurry *Ore Stockpile* *Legacy Tailings* *Mine impacted / Process Water / Effluent*	Vanadium (anomaly) pH Manganese Nil. No exceedances for discharged tunnel water and process/ effluent	Groundwater seepage	Communities	HIGH – **Al**, **As**, **Fe**, **Mn**, **Fl** exceedances (WHO, 2022) (Spring water compliant with WHO, 2022)	LIKELY – Spring water is the primary source of water, currently unaffected by mining activities. However, groundwater contributes to baseflow, and flows towards Bisinia Dam, which is used by the community (domestic use, fishing and swimming).	HIGH
			Livestock	MEDIUM – pH, Cl exceedances (RS 190)	LIKELY – Mine water not used by community. Spring water is the primary source of water, currently unaffected by groundwater seepage. However, groundwater contributes to baseflow, and thus flows towards Bisinia Dam, which is used for irrigation and livestock watering. Mine water is discharged to Nyirabigaji River.	MOD
			Crops	HIGH – **Fe, Fl, Mn, NO_3, TDS** exceedance (RS188)		HIGH
			Aquatic Ecosystem	MEDIUM – **As**, **Fe**, **Pb**, Fl, NO_3 exceedances (EAS 1772, RS 564). The health of the Bisinia Dam / Nyakagezi Wetland system is 'Largely modified'	LIKELY – Groundwater contributes to baseflow, and flows towards Bisinia Dam. Mine water discharged to Nyirabigaji River. Biota give indication of impacted water quality, particularly increased salinity and nutrients.	MOD

Source	Potential Contaminants*	Pathway	Receptor	Severity**	Likelihood	Risk
				(bearing moderate sensitivity), but supports notable fauna.		
		Surface water runoff /discharge	Communities	MEDIUM - **Mn** exceedances (WHO, 2022) (External factors – upstream water already compromised).	LIKELY –Spring water is the primary source of water for domestic purposes. Rivers used on ad hoc basis. However, Bisinia Dam also utilised for domestic use, swimming and fishing.	MOD
			Livestock	MEDIUM – **Mn**, Fe, exceedances (RS 190). Compliant with FAO limit.	HIGHLY LIKELY – Bisinia Dam and Nyirabigaji River are utilised for livestock watering.	HIGH
			Soils (crops)	HIGH – pH, TDS exceedance (RS 188). **Na**, **Cl** are severe for crop yield. **pH, NO_3** are increasing problems for crop yield. Slight Cu exceedance (SSV1), **acidic pH**. Soil has inherent limited pH buffering capacity, prone to acidification and leaching.	HIGHLY LIKELY – Intensive subsistence floodplain crop cultivation occurs downstream of the mine site. Bisinia Dam and river water are utilised for irrigation purposes. Soils showing acidification.	VERY HIGH
			Sediments	MEDIUM – As, Fe, Mn (WHO 2022, RS 188, RS 190) exceedances. **As**, Cu, **Pb**, V (SSV1) Significant metal enrichment by **B** and **Sn**, extreme enrichment by **As.** The health of the Bisinia Dam / Nyakagezi Wetland system is	HIGHLY LIKELY – Water is released from the Bisinia Dam to the Nyirabigaji River. Bisinia Dam and river water are utilised for irrigation purposes. River sediment showing elevated metal concentrations and enrichment.	HIGH

Source	Potential Contaminants*	Pathway	Receptor	Severity**	Likelihood	Risk
				'Largely modified' (bearing moderate sensitivity.		
			Aquatic Ecosystem	MEDIUM – Fl, Se, TSS, exceedances (RS 564, EAS 1172). The health of the Bisinia Dam / Nyakagezi Wetland system is 'Largely modified' (bearing moderate sensitivity).	LIKELY – Water is released from the Bisinia Dam to the Nyirabigaji River. These systems host notable aquatic biodiversity.	MOD

* Potential contaminants based on geochemical analyses.

** Based on contaminants measured in pathway component (i.e. groundwater or surface water). Elements in **bold** represent very high exceedance that is at least double the limit. WHO (2022) Guidelines for drinking water; RS 109 (2009) Effluent standard; RS 188 (2013) Irrigation use; RS 190 (2013) Livestock watering; IFC (2007) Mining effluent guidelines, RS 564 (2023) Ambient water, RS EAS 1172 (2024) Water discharged into the environment.

Table 3-2 Summary of Environmental Risks Associated with Ntunga Mine

Source	Potential Contaminants*	Pathway	Receptor	Severity**	Likelihood	Risk
Fuel Combustion	NO_2 SO_2	Wind erosion / dispersal	Workers / Communities	MINOR – Due to limited activity and lack of mechanization (*no monitoring data)	HIGHLY LIKELY – Workers engaging in mining activities, proximity of access roads	MOD/ LOW
Ore stockpile *Waste Rock* *Slurry* *Legacy Tailings*	PM_{10} $PM_{2.5}$		Workers / Communities	HIGH - PM_{10} and **$PM_{2.5}$** exceedances, particularly $PM_{2.5}$, at key points on site and in surrounding communities	HIGHLY LIKELY – Workers engaging in mining activities, proximity of communities and sensitive receptors	VERY HIGH
Legacy Tailings *(No exceedances for other mine materials)* *Mine impacted water* (No processing activities at Ntunga Mine)	Aluminium Iron Manganese No exceedances for discharged excess tunnel water	Groundwater seepage	Communities	MINOR – No exceedances of (WHO 2022)	UNLIKELY – Mine water not used by community. Spring water is the primary source of water, currently unaffected by groundwater seepage. Groundwater contributes to baseflow, but concentrations so low and subject to dilution.	VERY LOW
			Livestock	MINOR - No exceedances (RS 190)		VERY LOW
			Crops	MEDIUM - TDS, NO_3 exceedances (RS 188), Cl close to limit.		LOW
			Aquatic Ecosystem	LOW – **Pb, TDS**, NO_3 exceedances (RS 564, EAS 1172). The Gashahi River health is rated as 'Critically - Seriously modified', thus low sensitivity.	LIKELY – Small amounts of excess tunnel water periodically discharged direct to Gashahi River.	MOD/ LOW
		Surface water runoff /discharge	Communities	MEDIUM – Mn exceedance (WHO, 2022)	LOW LIKELIHOOD – River water is secondary source to springs, used on an ad hoc basis.	MOD/ LOW
			Livestock	LOW - pH minor exceedance (RS 190).	LIKELY – Rivers are utilised for livestock watering purposes.	MOD / LOW

Source	Potential Contaminants*	Pathway	Receptor	Severity**	Likelihood	Risk
			Soils (crops)	HIGH – TDS exceedance (RS 188). **Na, Cl,** are severe for crop yield. **NO_3, TDS** are increasing problems for crop yield. Cu (SSV1), elevated Mg, slightly acidic pH. Soil has inherent limited pH buffering capacity, prone to acidification and leaching.	HIGH – Subsistence floodplain crop cultivation occurs downstream of the mine site. River water is utilised for irrigation purposes. Soils showing slight acidification.	HIGH
			Sediments	LOW – Fe, Mn, Pb exceedances (IFC, 2007), **As** and Pb (SSV1). Significant metal enrichment by **As** and **Sn**, extreme enrichment by **B.** Health of the Gashahi is 'Critically - Seriously modified', bearing low sensitivity.	HIGH LIKELY – Stormwater runoff from the mining area drains into Gashahi River. River sediment showing some elevated metal concentrations and enrichment.	MOD
			Aquatic Ecosystem	LOW – Fl, Ni, Hg exceedances (EAS 1172). Health of the Gashahi is 'Critically - Seriously modified', bearing low sensitivity.	HIGHLY LIKELY – Stormwater runoff from the mining area drains into Gashahi River.	MOD

* Potential contaminants based on geochemical analyses.

** Based on contaminants measured in pathway component (i.e. groundwater or surface water). Elements in **bold** represent very high exceedance that is at least double the limit. WHO (2022) Guidelines for drinking water; RS 109 (2009) Effluent standard; RS 188 (2013) Irrigation use; RS 190 (2013) Livestock watering; IFC (2007) Mining effluent guidelines, RS 564 (2023) Ambient water, RS EAS 1172 (2024) Water discharged into the environment.

4. RUTONGO MINE

This section on the Rutongo Mine contains information extracted from the various baseline specialist assessments as part of the 2024 ESIA (see Section 1.3 and Section 2.2). Further insights and infield observations have been added by GroundTruth specialists where relevant.

4.1 Setting

4.1.1 Location

The Rutongo Mine is located in the Northern Province of Rwanda, 26 km north of Rwanda's capital city, Kigali in the Rulindo District. The Rutongo Mine comprises six underground tin mines, namely, Gisanze (currently under care and maintenance), Nyamyumba, Gasambya, Karambo, Mahaza and Masoro. Together they hold one of the largest cassiterite (tin ore) deposits in Africa. The primary mine site is Nyamyumba, with the other five as satellite sites dispersed throughout the concession area (SLR, 2024f).

The Rutongo Mine concession area is located on the south-east of the highlands of Byumba, resulting in a hilly to mountainous topography associated with flat-bottomed river valleys. The mining operations are located on mountainous slopes with elevations ranging from 1 400 – 1 900 m above mean sea level (SLR, 2024g).

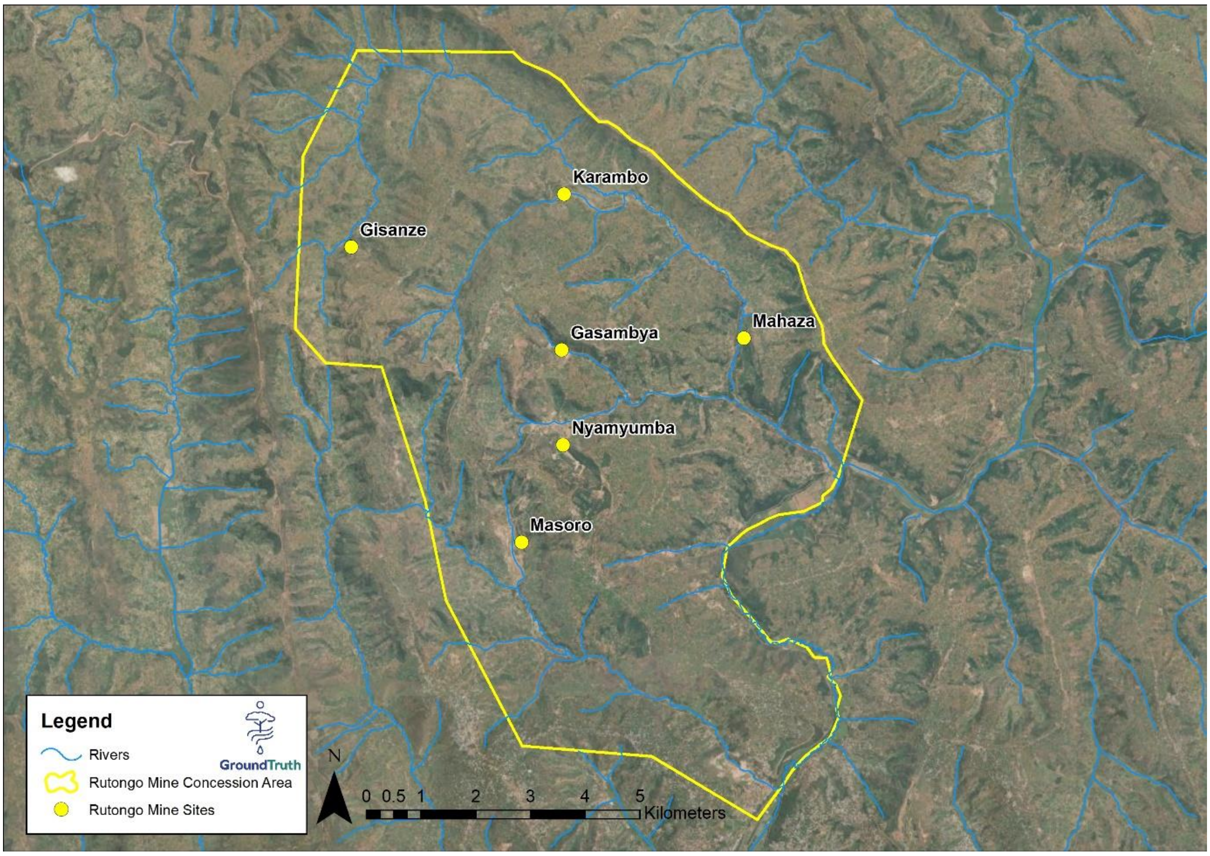

Figure 4-1 Six mine sites that comprise the Trinity Rutongo Mine

4.1.2 Brief History

Tin exploitation at Rutongo began in 1931, and from the 1940s, the mines consistently exported 800 tonnes a year of cassiterite. By the 1950s, SOMUKI, a Belgian mining company, had developed the mine into Rwanda's largest tin concentrate producer. In 1973, the fusion of former colonial mining sites gave rise to SOMIRWA (Société Des Mines Du Rwanda), a joint venture between the Government of Rwanda and GEOMINES. This Belgium-based mining company operated on site until its liquidation in 1986. At this time, the mines were nationalised and operated under REDEMI. The mines closed in 1994 when the genocide occurred. In 1995, they reopened under REDEMI as a miners' cooperative and operated until 2008, when the government re-privatised them (SLR, 2024h).

In September 2014, the Government of Rwanda entered into a 25-year mining agreement with Rutongo Mines Ltd, now a subsidiary of Trinity Metals Group. The Mining Agreement was granted in 2015 and exclusively allows for the prospecting, exploration, exploitation, and processing of tin (cassiterite) minerals within the Rutongo concession area (SLR, 2024h).

The long mining history of Rutongo Mines has resulted in extensive mining legacy issues, including old underground mine workings, tunnel entrances (mostly barred), and waste rock and tailings dumps (SLR, 2024h).

4.1.3 Land-use

Land-use within the Rutongo Mine concession areas includes formal and informal mining, and a range of other activities that include *inter alia* mining of sand and aggregate[7], informal mining for ore, high-intensity subsistence cultivation including the harvesting of fodder for livestock (cattle, goats and chickens), co-operative/formal crop cultivation, legalised quarry mining, timber production, bee keeping, clay material harvesting for brick making, road networks, and erosion gullies. The natural landscape is considered wholly transformed with no natural habitats remaining. The area is surrounded with alien vegetation with the most common alien invasive species being *Eucalyptus* sp., which are also part of forestry woodlots (Blue Gum tree) (GroundTruth, 2026; Nepid Consultants, 2024b; SLR, 2024i).

Subsistence cultivation is predominantly located within the hillslope areas, ranging from well terraced sections to those with less formal terracing. In addition, cultivation occurs in wetlands and riverine zones that remain largely unaffected by the bi-annual rainfall events, as well as on elevated flood terraces above the rivers. By contrast, the freshwater ecosystems that experience bi-annual flooding are generally excluded from cultivation due to the loss of crops (GroundTruth, 2026).

Villages are strategically located near springs and rivers to ensure easy access to water. Springs are the preferred source of domestic water; however, during the dry season or when springs run dry, villagers resort to using river water or alternative sources. Within the Rutongo concession area, water resources play a critical role in sustaining local livelihoods (SLR, 2024h).

[7] Mining of sand and aggregate by the legal company, Rutongo Business of Sand and Stone (RBSS) takes place at various sites throughout the Rutongo Concession Area.

4.2 Site Layout and Operations

4.2.1 *Layout*

The layouts of the primary Nyamyumba site and five satellite sites are provided in **Figure 4-2** to **Figure 4-7** below.

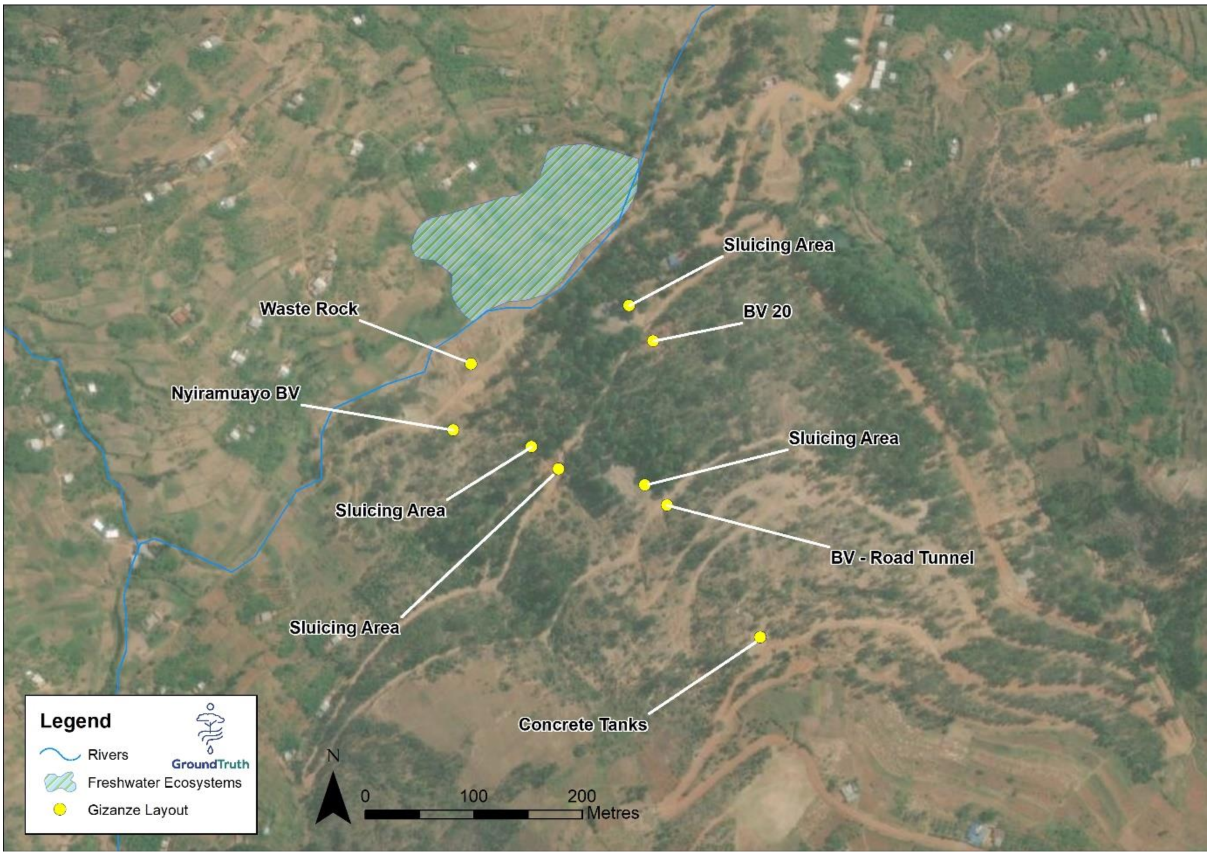

Figure 4-2 Layout of Gisanze Mine (satellite site)

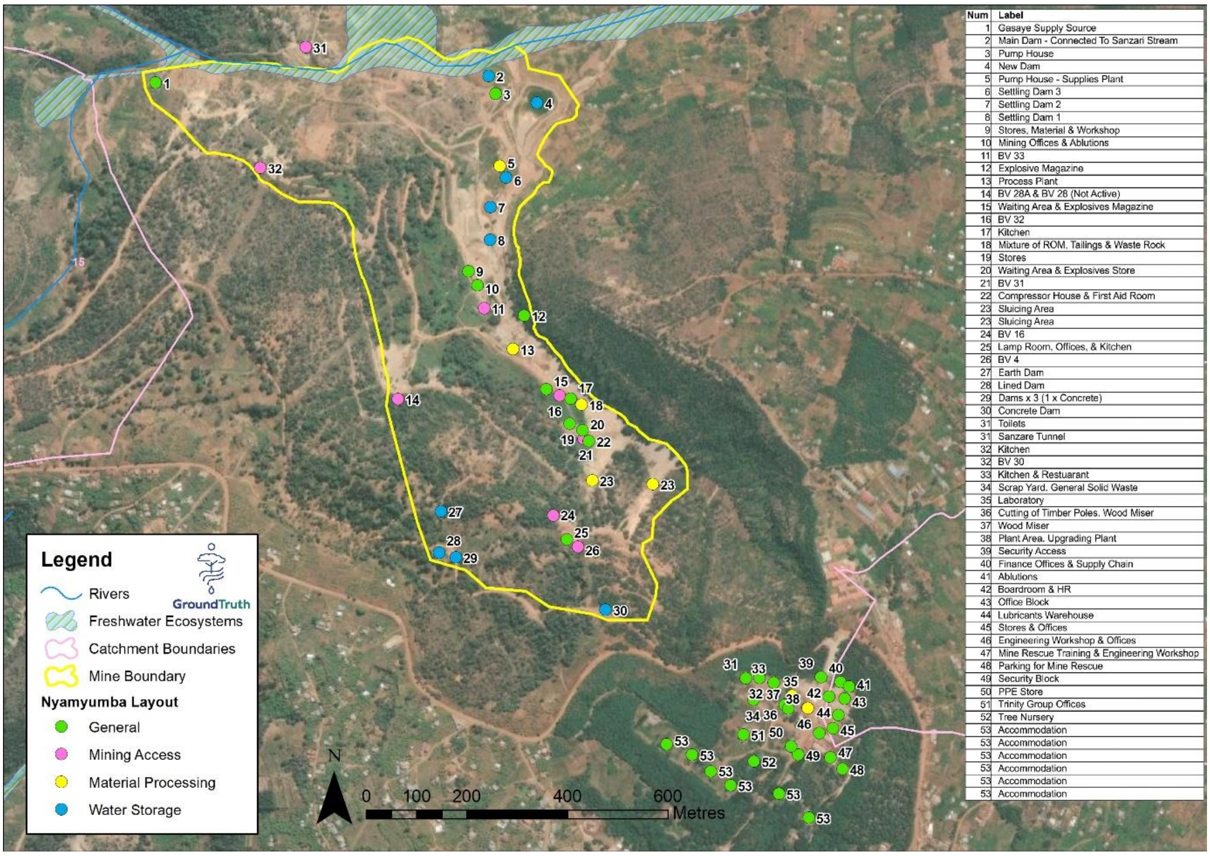

Figure 4-3 Layout of Nyamyumba Mine (primary site)

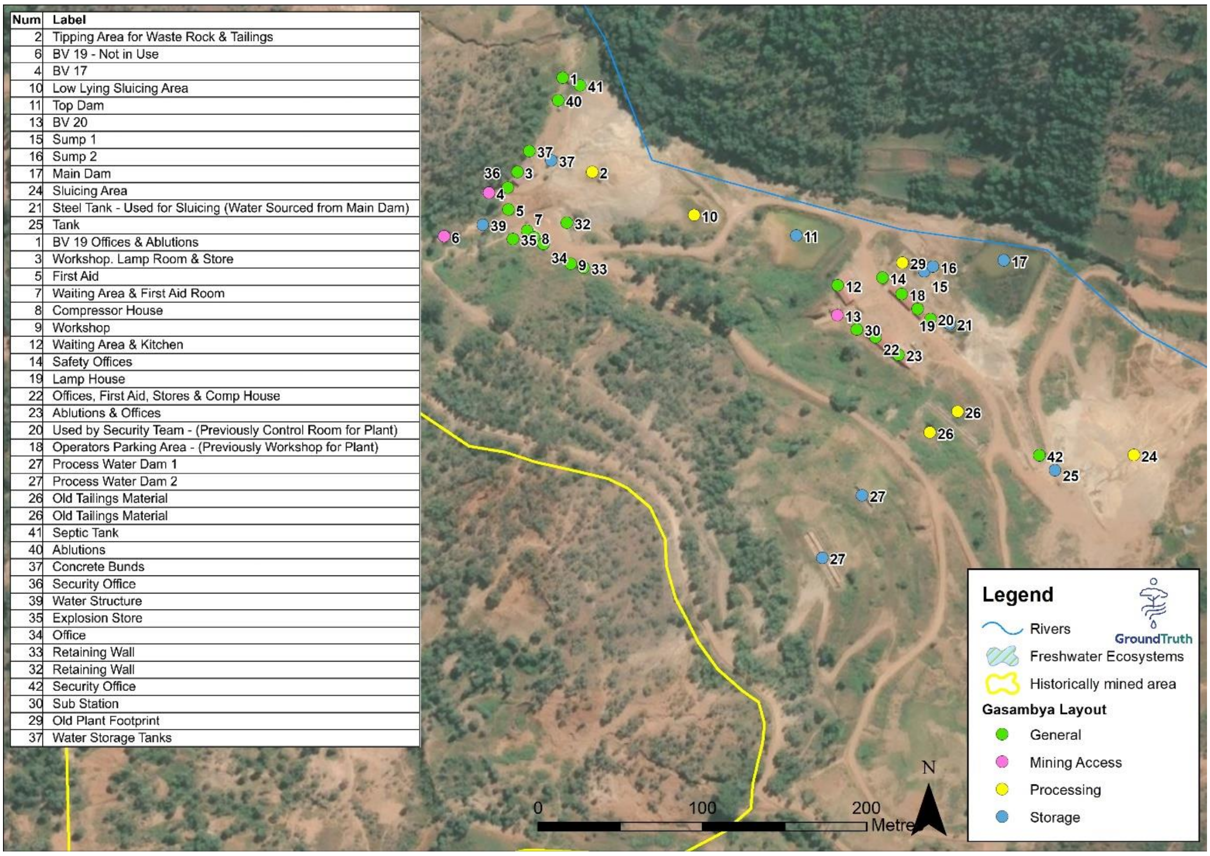

Figure 4-4 Layout of Gasambya Mine (satellite site)

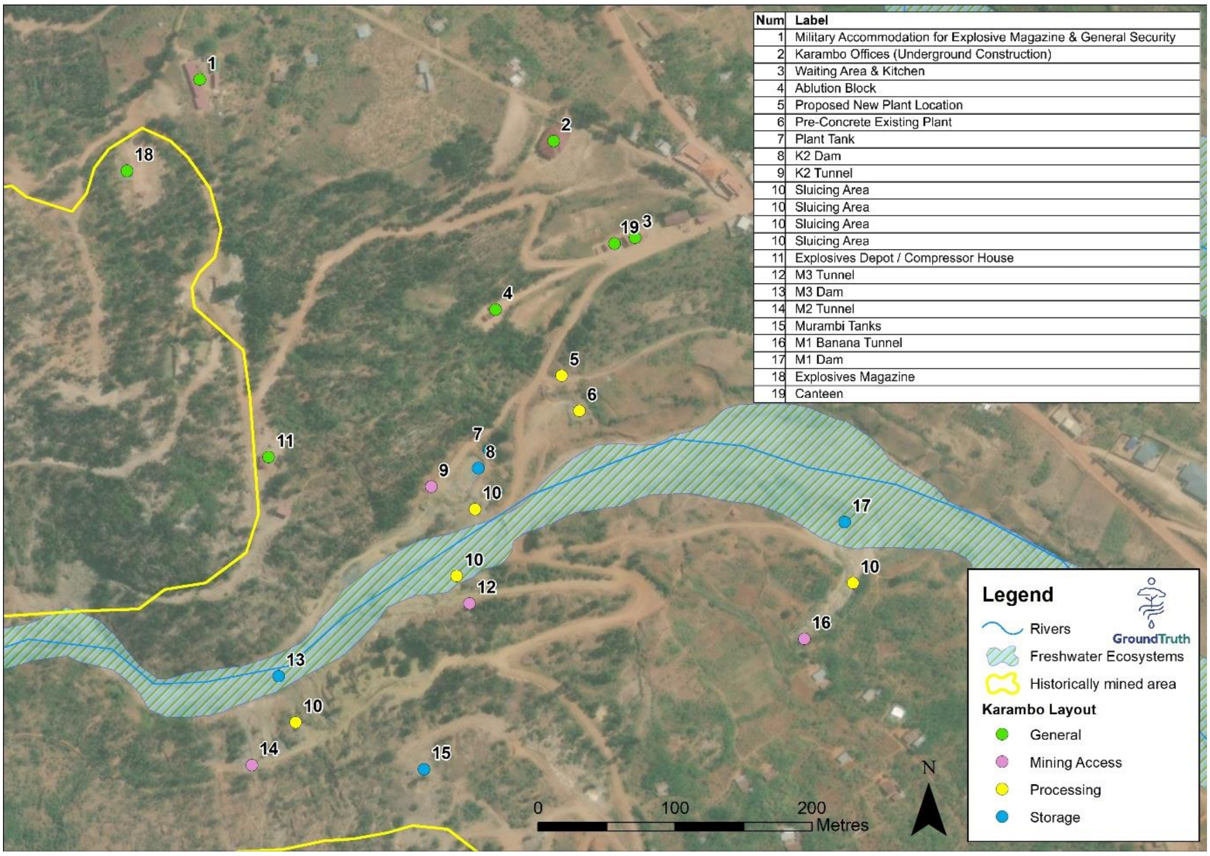

Figure 4-5 Layout of Karambo Mine (satellite site)

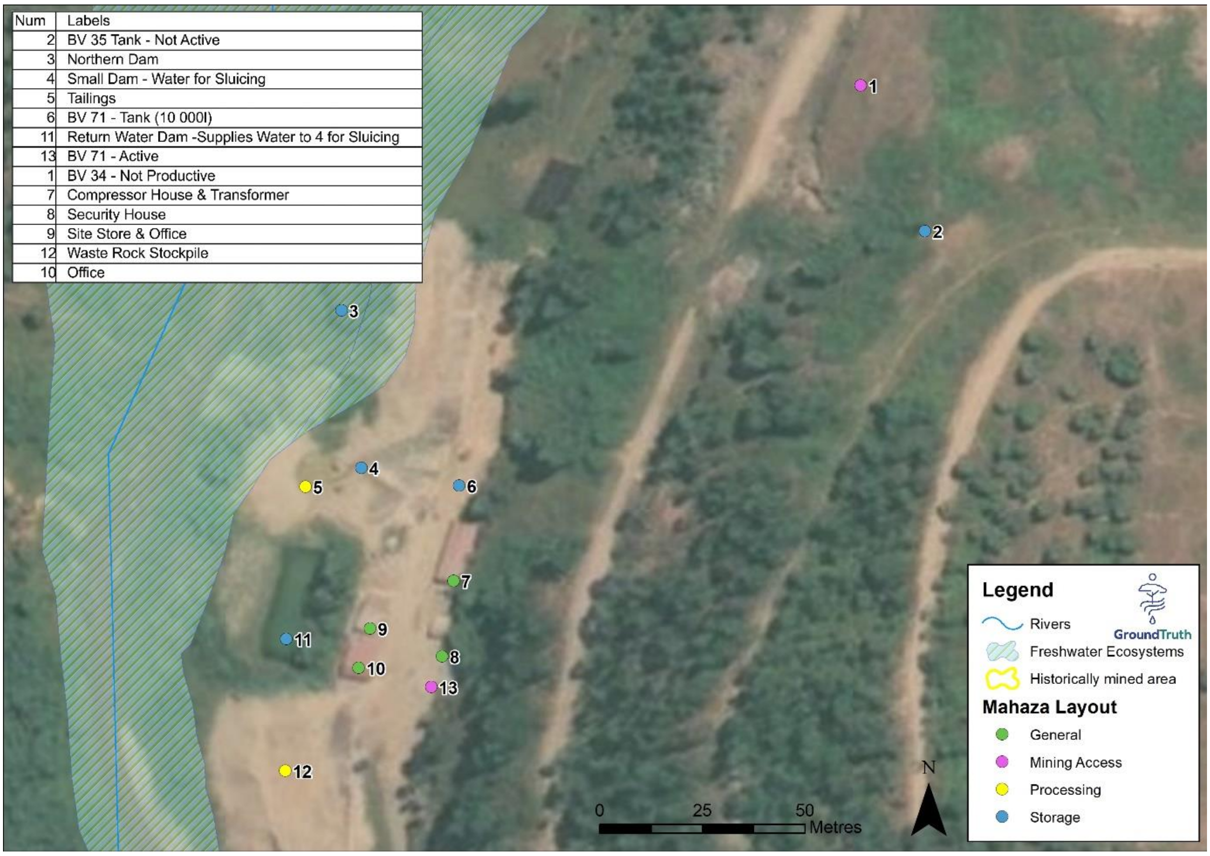

Figure 4-6 Layout of Mahaza (satellite mine site)

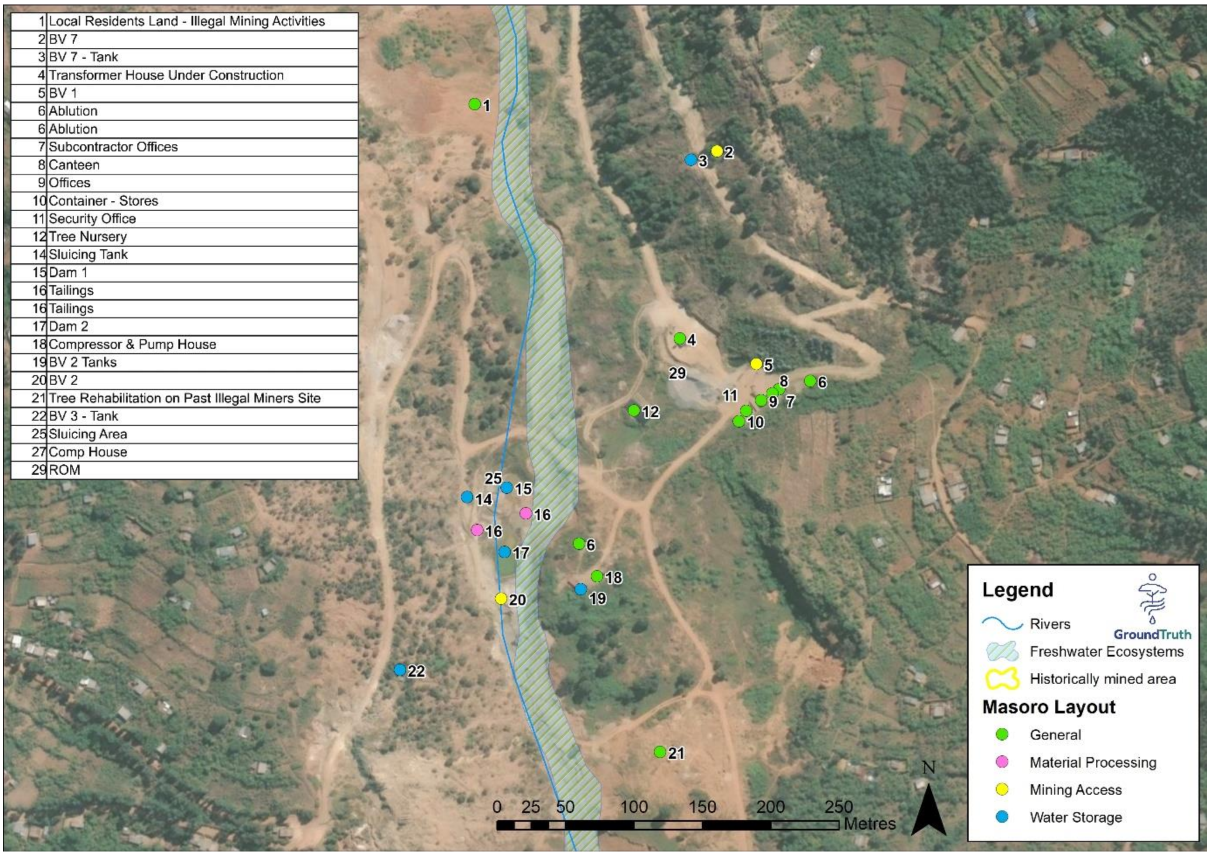

Figure 4-7 Layout of Masoro Mine (satellite site)

4.2.2 Operations

4.2.2.1 *Material extraction and processing*

Cassiterite is mined exclusively from underground with workings accessed via horizontal tunnels (drives or “BVs”) at all mine sites.

At the Nyamyumba Mine, drilling and blasting methods are used to loosen the underground ore prior to being brought to the surface via trams, which then transport the ore to the main processing area. Handpicking (nuggetting) of high-grade ore takes place at the face. The Nyamyumba Mine is host to the main processing plant for the entire mining operation. Low-grade ore is mechanically processed at this site via a 30 ton/hr gravity separation processing plant, through which most of the mines' off-reef product is processed (SLR, 2024h).

At the satellite sites, drilling and blasting also occur at the active faces, with handpicking (nuggetting) of high-grade ore taking place on site. Bagged and low-grade product is trammed out of the tunnels using small electrical locomotives for further processing on the surface. Processing of off-reef (low-grade) material is currently a manual operation at the satellite sites, using open sluicing to gravity separate out the concentrated ore, which is bagged and transported via trucks to the central upgrade plant at the Nyamyumba Mine. In addition to manual sluicing, a small-scale sluicing plant (2.5 ton/hr) is operational at Karambo mining site (SLR, 2024h).

4.2.2.2 *Process water and dewatering activities*

A summary of the process water and dewatering activities for each mine (SLR, 2024h) is provided in **Table 4-1**.

Table 4-1 Process water and dewatering activities at the Rutongo Mines

Mine	Description
Gisanze Mine (Rusine River)	Currently under care and maintenance. No mining is occurring. Groundwater from two adits freely discharges into the Rusine River. Once operational, there are likely to be two drilling operations and one sluicing line at each of the three existing adits. Process water may be sourced from groundwater and a nearby spring. No surface stormwater facilities currently exist to capture and reuse discharged water; run-off/ sluicing effluent will likely be discharged to the Rusine River.
Nyamyumba Mine (Sanzari River)	Process water is required for drilling activities and 14 sluicing lines and is sourced from the Sanzari River. There are nine water dams; some of these are lined and used for the storage of source water and effluent water (3 settling dams). Wastewater from the sluicing activities is pumped to Settling Dam 1, and gravity fed to Settling Dam 2 and Dam 3. Part of the water of Settling Dam 3 is re-used in the processing plant and recycled back to Settling Dam 1. The site does not operate as a closed circuit, with water being discharged to the Sanzari River via Settling Dam 3 when it overflows. Plans are in place for a final storage dam for recycling of water. There is no formal stormwater infrastructure in place and as such, dirty run-off from the site discharges to the Sanzari River. There is currently no excess groundwater discharging from the access tunnels.
Gasambya Mine (Kivomo River)	Process water is required for drilling and four sluicing lines and is sourced from underground ingress. The site does not operate as a closed circuit. Sluicing wastewater is diverted through a gravity-fed line to a storage dam for reuse, and on the eastern side, discharged to the Kivomo River. Overflow groundwater is also pumped to the Main Dam and then discharged into the Kivomo River. No formal stormwater management infrastructure is in place to contain dirty run-off water.
Karambo Mine (Nyirabukingore River)	Process water is required for drilling and sluicing activities and is sourced from the Nyirabukingore River. At the Murambi sub-site, water is fed to the two drilling operations and one sluicing line at each of the two adits. Water for drilling and sluicing operations at the third adit is sourced from underground workings. Wastewater from the sluicing activities from these adits is discharged to the Nyirabukingore River. At the Karambo sub-site, the source water is fed to a single adit with two drilling operation and one sluicing line, and a pre-concentrate plant. The site does not operate as a closed circuit. While sluicing effluent is discharged to a storage dam and reused within the sluicing process, wastewater from the pre-concentrate plant is discharged to the

	Nyirabukingore River. There is no formal stormwater management infrastructure in place to contain dirty water runoff to the downstream Nyirabukingore River. Regarding dewatering activities, excess groundwater from the M1 tunnel is discharged to the Nyirabukingore Stream, and wastewater from the sluicing activities at the same tunnel is discharged to the river.
Mahaza Mine (Rusine River)	Process water is required for seven drilling operations and two sluicing lines and is sourced from the Rusine River. This site is a closed circuit. The wastewater from sluicing activities is diverted through gravity-fed lines to the Sluicing Dam, from where it is diverted through a gravity-fed line to the Northern Dam for re-use. However, water could discharge to the adjacent river during excessive rainy periods if the site dams overtop. Currently, no groundwater is actively discharging from any of the tunnel entrances.
Masoro Mine (Gatiti River, tributary of Umurindi River)	Process water is required for drilling and sluicing activities from underground ingress. This site is a closed circuit. Wastewater from sluicing activities is fed to Dam 1 and gravity fed to Dam 2. Water from Dam 2 is pumped to a sluicing tank for re-use. However, water could discharge to the adjacent rivers (i.e. the Gatiti River) during excessive rainy periods if the site dams overtop. Currently, groundwater is abstracted for process and potable use.

4.2.2.3 *Waste Areas*

There are legacy tailings and waste rock material stockpiles at each of the mine sites. The placement of these storage areas appears to be uncontrolled resulting in downward dispersal of material, thereby contributing to sediment loads entering the downstream river system (SLR, 2024h, 2024f).

At most sites, there is no formal stormwater management infrastructure in place to contain dirty run-off water. Some mine sites, namely Nyamyumba and Masoro, possess settling/storage dams that collect dirty run-off and process water/ effluent. At the former however, effluent is discharged from the settling dam to the Sanzari River. The latter is a closed circuit, and the effluent is reused for sluicing activities. At Karambo, sluicing water is partly captured and re-used in the sluicing process. Such facilities do not exist at the other sites, and process water/ effluent are discharged to the nearby river systems (SLR, 2024h).

4.2.3 Informal Mining

A significant amount of informal mining takes place throughout the Rutongo concession area, both upstream and downstream of the mine sites. These informal mining sites can arise at any given time at random locations throughout the Rutongo concession area. The informal mining can take place either within the riverbeds or along the valley slopes, resulting in high turbidity and an increase in sedimentation within the rivers. Mine personnel have noted an increase in informal activities, particularly during the wet season, when there is plenty of free water available for informal sluicing (SLR, 2024h).

4.3 Environmental Aspects

4.3.1 Hydrology

Most of the Rutongo concession area (including rivers near the Gisanze, Karambo, Mahaza, Gasambya, and Nyamyumba Mine sites) drains into the Rusine River that originates near the north-western boundary and flows for ~16 km through the concession area. The Rusine River is a tributary of the Nyabugogo River downstream of Lake Muhazi. The Nyabugogo River is located on the southeastern edge of the concession area. It is a tributary of the Nyabarongo River, which flows into Lake Rweru, in the upper reaches of the Kagera River Catchment, in the Nile River Basin (Nepid Consultants, 2024b; SLR, 2024h).

The southern portion of the concession area (including rivers near Masoro Mine site) drains into the Umurindi River, a tributary of the Nyabugogo River. The Nyabugogo River is degraded by excessive sedimentation due to inadequate soil conservation practices in agriculture, forestry woodlots and an extensive quarry mine at the confluence of the Umurindi and Nyabugogo River. Other aquatic ecosystems in the concession area comprise the Kagombero, Kazambia, Nyirabukigore, and Sanzari Streams. All these systems are already impacted by elevated sediment caused by deforestation, woodlots/forestry, subsistence cultivation, livestock grazing and settlements (Nepid Consultants, 2024b). This is further exacerbated by formal and informal mining activities, including instream aggregate mining.

In terms of hydraulic connectivity, rivers near the Mahaza and Masoro Mines behave as gaining type rivers (the stream and groundwater are hydraulically connected, and the system receives groundwater as baseflow). The rivers associated with the remaining mine sites are considered to be losing type rivers (groundwater is below the base level of the river) (SLR, 2024h). Communities within the Trinity Rutongo mine concession area rely on a diverse mix of water sources for domestic and agricultural needs, including natural springs, communal water collection points, and, to a lesser extent, rainwater harvesting (GroundTruth, 2025b). Spring water is preferred as a source of domestic water and the primary source of water for the formal water distribution network via community collection points (GroundTruth, 2025b). However, rivers are also utilised where access is difficult or during the dry season, when the springs do not provide adequate water, or run dry. In such instances communities may also resort to using tunnel water, e.g. M1 Tunnel at Karambo Mine (SLR, 2024h).

In respect to prohibited activities near rivers and lakes and protection of river and lake shorelines, all rivers within the Rutongo concession area must have a protection buffer of 10 m (except for the Bahimbiguye River and the Gatiti River). The Nyamyumba, Karambo, Mahaza and Masoro Mine sites falls within the protection buffer zone. There are wetlands located within the Rutongo concession area, along sections of the Rusine and Umurindi Rivers and all are categorised as unprotected swamplands. None of the mines intersect any of the identified unprotected wetlands within the concession area. The Mahaza Mine is the only mine in close proximity (~23 m) to an unprotected swampland (SLR, 2024h).

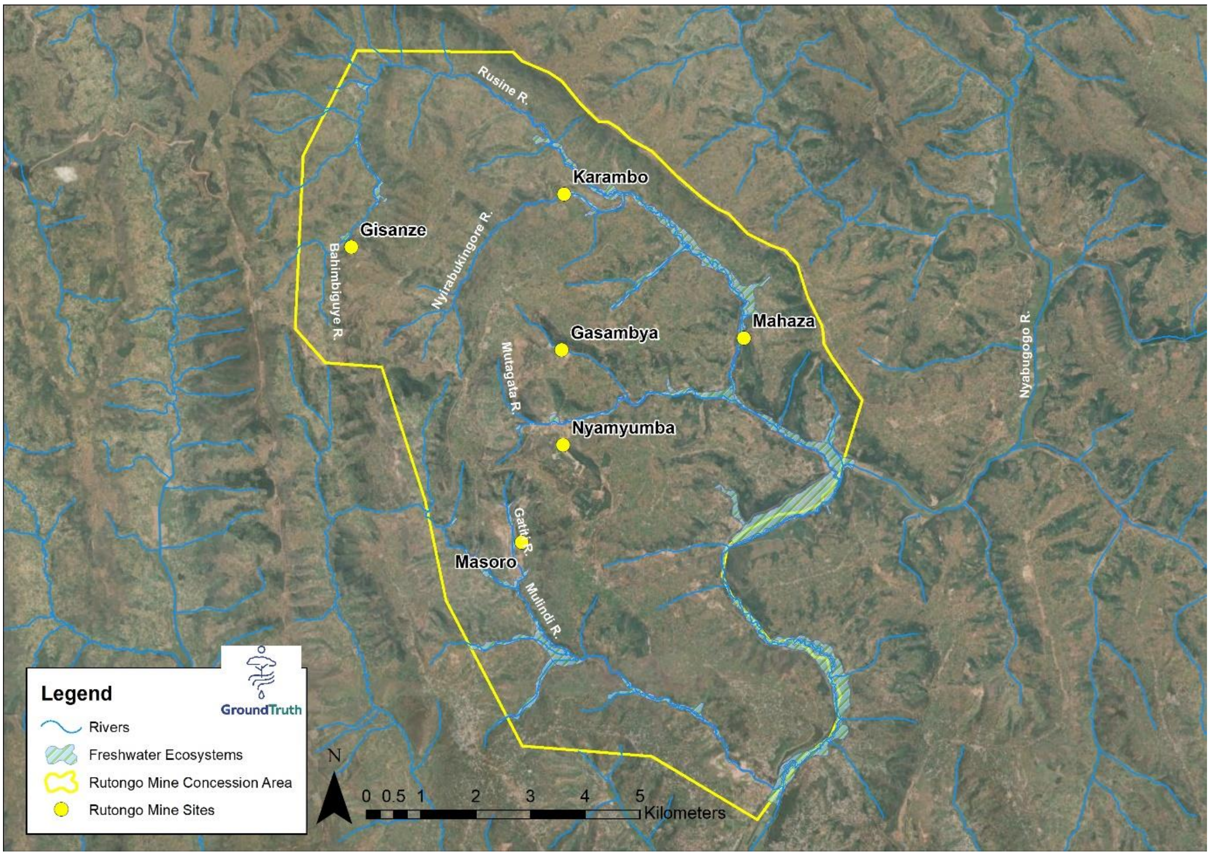

Figure 4-8 Map showing local hydrology of the Rutongo concession area and mine sites

4.3.2 Geology

The Karagwe-Ankole Belt (KAB) located in East Africa is one of two distinct northern and southern segments of the Mesoproterozoic Kibara Belt (KIB) of Central Africa, which hosts a large metallogenic province that contains numerous granite-related ore deposits, with the typical metal association of tantalum–tin-tungsten (SLR, 2024g). The KAB spans across parts of Rwanda and Burundi, SW Uganda, and NW Tanzania, as well as the Kivu-Muniema region of the DRC. It is characterised by two structurally contrasting domains, (1) the Western Domain (WD) with Proterozoic basement and (2) the Eastern Domain (ED) with Archean basement. The WD encompasses the intensely deformed parts of the KAB. The WD is a significant geological region, and it is associated with valuable mineral deposits that include tin, tungsten, tantalum, and gold, which are mined throughout the region (SLR, 2024g, 2024j).

The Rutongo Mine is situated in the KAB, and the basin comprises a sequence of metamorphic rocks including schists, gneisses, and marbles, with associated granitic intrusions. The primary mineral of interest is SnO_2, found within quartz veins, pegmatites, and greisenized granite. The mine lithologies are dominated by Quartz, Muscovite and Kaolinite, with minor to trace Schorl, Hematite, Chlorite, Goethite, Andradite, Microcline, Plagioclase and Dravite. No discernible amounts of carbonates or sulphides. The mineralization at the Rutongo Mine is structurally controlled by a series of faults and fractures, which provided conduits for the circulation of mineral-rich fluids (SLR, 2024j).

4.3.3 Hydrogeology

The ore deposit is structurally controlled, and groundwater ingress into the mine workings is most likely also structurally controlled. The aquifers in the Rutongo concession area, can be characterised as follows (SLR, 2024g):

- Weathered Aquifer: A shallow, unconfined aquifer formed in the upper 5–30 m of weathered sandstone and shale, with low to moderate water-bearing capacity.
- Primary Alluvial Aquifer: Found along the course of the Rusine and Nyabugogo Rivers and other streams, composed of gravel and sand with moderate to high aquifer parameters, recharged by surface water inflow.
- Secondary Fractured Aquifer: A deeper semi-confined aquifer in unweathered shale and quartzite, where groundwater flows through fractures; typically low to moderate but occasionally high aquifer parameters.

Groundwater recharge is estimated at 5-15% of the MAP (1 200 mm/annum). The groundwater flow mimics the topography and is generally towards the valleys. The groundwater and fissure water (mine water) quality is generally good and only a few parameters exceeded the guideline limits. The slight acidity of the water may cause leaching of metals from the parent rock and thus metal concentrations tend to be elevated. The variables of concern included aluminium, arsenic, iron and manganese (SLR, 2024g).

4.3.4 Biodiversity

The Rutongo concession area incorporates two terrestrial ecoregions, namely the Albertine Montane Forest ecoregion to the north and Victoria Basin Forest-Savanna Mosaic ecoregion in the south and historically comprised an assortment of tropical forest and savanna woodlands (SLR, 2024i). However, based on site observations, the concession area is not representative of the typical vegetation types of the terrestrial ecoregions and only contains modified and severely degraded vegetation types. Due to the various human activities (mining, agriculture – subsistence and co-operatives), the concession area has limited biodiversity value and limited potential to support Species of Conservation Concern (SCC). Two bird SCC that are predicted to occur in low numbers are Hooded Vulture (*Necrosyrtes monachus)* and Bateleur (*Terathopius ecaudatus)*. While these species are able to utilise anthropogenic environments for foraging, they are unlikely to breed within the concession area. It is worth noting that, due to the intensity and extent of habitat degradation from human activities, other expected SCC are unlikely to occur in the area (SLR, 2024i).

In terms of aquatic biodiversity, the Rutongo concession area falls within the Lake Victoria Basin Freshwater Ecoregion which is classified as 'Globally Outstanding'; the global conservation status is classified as 'Critical'; and conservation priority is classified as 'Very High'. Three river ecosystem types occur with concession area, namely, *mountain streams* (upper reaches of the Rusine River and most tributaries), *transitional streams* (the Umurindi and middle reaches of the Rusine River), and *upper foothills* (the lower reaches of the Rusine River) (Nepid Consultants, 2024b). A variety of wetland ecosystem types were noted within the Rutongo Concession area, including hillslope seep wetlands, channelled and unchannelled valley-bottom wetlands and a relic floodplain wetland associated with the Nyabugogo River. The Nyabugogo River is a large tributary, approximately 59 km long, that flows southwards into the Nyaborongo River. The active river channel is roughly 15 m wide, and the banks have been become dominated by bamboo, purposely planted to stabilise banks and help provide flood protection. The Nyabugogo River and its associated floodplain wetlands are ecologically important, primarily in terms of supporting aquatic biodiversity patterns and processes within an urban landscape (GroundTruth, 2026).

Specialist studies of the main rivers and tributaries downstream of the six mine sites yielded limited biological data. On the Rusine River, benthic diatoms were absent from the upper reaches and lower reaches before the confluence with the Nyabugogo River. Their absence is attributed to abrasion caused by elevated concentrations of suspended material. Of the ten sample sites on the various rivers and streams, only two on the upper Rusine River and the Kagombero River[8] respectively, recorded more than ten macroinvertebrate taxa. These comprised short- to very short-lived taxa, indicative of unstable conditions, and taxa indicative of moderately to heavily sedimented stream conditions. These two systems were classified as 'Largely modified', and the remaining systems 'Seriously to Critically modified' (Nepid Consultants, 2024b).

No fish were recorded within the main rivers and tributaries during the specialist studies, despite the presence of suitable hydraulic conditions. Their absence was attributed to abrasion caused by elevated concentrations of suspended material associated with informal and formal mining, harvesting of sand and aggregate within the riverbed, and subsistence cultivation (Nepid Consultants, 2024b).

The overall habitat integrity of the Rusine River was rated as 'Seriously modified' with the key drivers of this condition being extensive deposition of sediments and critical removal of riparian vegetation. All other sites in the concession, including the site upstream of mining activities, were in much the same condition (Nepid Consultants, 2024b). The overall ecological condition of the various wetland habitat is 'Largely' to 'Seriously modified', with similar issues such as sedimentation, extensive agriculture, drains and the presence of invasive alien plants being widespread across the wetland habitats. Drawing similarities with the wetland in Musha, a small portion of channelled valley-bottom wetland below Gisanze Mine has recovered from historical agriculture due to a single landowner choosing not to cultivate their land (GroundTruth, 2026).

There are no protected areas, key biodiversity areas, important bird and biodiversity areas, or Ramsar wetland sites, in close proximity to the Rutongo concession area, which might pose as sensitive ecosystem receptors (SLR, 2024i).

4.4 Social Aspects

The Rutongo Mines are located in the Masoro, Ntarabana, Cyinzuzi and Murambi Sectors of the Rulindo District of the Northern Province. Combined, these make up 2.7% of Rwanda's population, and 17.7% of the province. Close to 90% of district households are rural in nature, and heavily reliant on agricultural activities (crop cultivation 79.3%, livestock 66.3% and horticulture 67.4%) as part of their livelihood strategies (Barbour, 2024b).

There are several communities interspersed with mining activities at Rutongo Mine. A summary of the social landscapes associated with each site is provided in **Table 4-2**. Sensitive air quality

[8] The Gatiti River near Masoro Mine

receptors identified in close proximity to the sites (within a 1 km radius) include schools and hospitals/healthcare centres (SLR, 2024f).

Table 4-2 Summary of the social landscapes associated with the six mines site in the Rutongo concession area (after Barbour (2024b) with input from GroundTruth, 2025b)

Mine	Main Villages	Main activities
Gisanze Mine (Rusine River)	Iraro, Gasizi, Rugaragara,	The valley up-stream of the mining area is relatively flat and intensively farmed on both banks, right down to the river course. A small village is located immediately below the mining area on the northeast bank. The valley opens below the village and becomes a broad, fertile valley that is a well-established farming area. Informal mining takes place upstream and downstream of the mining area adjacent to the village, as well as in the riverbed area below some of the adits and a nearby tributary to the Rusine River. This contributes to elevated turbidity and degraded water quality of the affected rivers and streams. Agriculture is the dominant land use in the area. Small-scale, labour-intensive crop farming takes place in most areas that can be used. The main crops cultivated include beans, potatoes, sweet potatoes, bananas. Livestock kept includes cattle, goats, and chickens.
Nyamyumba Mine (Sanzari River)	Kabuga, Umutagata, Nyarurembo, Agasharu, Nyakabungo,	No villages or farming areas are located within the valley where the main mining area is located due to the steep topography at the top of the valley. Agriculture is the dominant land use in the area. Small-scale, labour-intensive crop farming takes place in most areas that can be used. The main crops cultivated include beans, potatoes, sweet potatoes. Livestock kept includes cattle, goats, and chickens. Banana plantations, fields and some houses are located adjacent to the settling dam on the eastern bank of the valley. The Nyabinyana Village spring is located 350 m downstream of the mine water recycle ponds, as is at risk potential contamination from mining activities. The spring is utilised for domestic purposes and for irrigating crops. Shallow trenches are constructed to channel water from the spring to the cultivated fields. Informal mining is evident in the upper parts of the valley and within the riverbed and along the banks downstream of the mining area.
Gasambya Mine (Kivomo River)	Nyarurembo, Rebero, Musega, Kanunga	There are no homesteads and limited agriculture upstream of the mining area due to steepness of the valley. Cultivation occurs on the slopes on the northern bank of the river opposite the mining area.

Mine	Main Villages	Main activities
		There is a Nyarurembo Village spring is located within the active mining area along the Kivomo River. It is at high risk of potential contamination from mining activities, which makes it unsuitable for domestic use. There is evidence of informal mining in the river course downstream of the mining area. Aggregate mining also takes place in the stream bed generating high turbidities and compromising water quality. The river downstream of the mining areas does not appear to be as impacted by tailings compared to the other mining areas in the concession area.
Karambo Mine (Nyirabukingore River)	Kamatongo, Nyakibande,	A newly constructed local hospital and the Karambo Primary School are located downstream of the mining area on the northern bank. Agriculture is the dominant land use in the area. Small-scale, labour-intensive crop farming takes place in most areas that can be used. The main crops cultivated include beans, potatoes, sweet potatoes. Livestock kept includes cattle, goats, and chickens. Waste rock and material from sluicing have been deposited on the steep northern and southern banks and has slipped into the river course. The river downstream of the bridge has been heavily impacted by tailings. Informal mining occurs up the valley outside the riverbed. Informal mining and aggregate mining operations take place downstream of the mining area and the river course, as well as adjacent tributary, has been heavily impacted and exhibit extremely turbid waters.
Mahaza Mine (Rusine River)	Burambi, Gitwa, Gasenga	An area located in mine land on the eastern bank of the river downstream (south) of the mining area has been allocated to the local community farming. Agriculture is the dominant land use in the area. Small-scale, labour-intensive crop farming takes place in most areas that can be used. The main crops cultivated include beans, potatoes, sweet potatoes. Livestock kept includes cattle, goats, and chickens. There is limited agriculture on the eastern bank in the vicinity of the mine due to the steep slope immediately above the site to the east. There are no houses on the eastern bank but there are on the western bank opposite the mining area. The upstream river is used for washing clothes. There are no community springs in close proximity to the mine. High sediments levels in the river due to mining and agricultural activities has impacted on the traditional use of rivers in the

Mine	Main Villages	Main activities
		Rutongo concession area to wash clothes and collect drinking water. The IRIB ECD facility (school) in the Burambi village area is located downstream of the mining area and is engaged subsistence farming.
Masoro Mine (Gatiti River)	Kigomwa, Gisiza, Akarambi, Rusenyi	Agriculture is the dominant land use in the area. Small-scale, labour-intensive crop farming takes place in most areas that can be used. The main crops cultivated include beans, potatoes, sweet potatoes. Livestock kept includes cattle, goats, and chickens. The Rusenyi Village Spring is located 400 m downstream of the mine, on the eastern slopes 140 m away from the Gatiti River. The spring is reportedly adjacent to a historic mine dump and thus at risk of contamination. Two other springs are located at the head of the valley upstream of mining activities that serve the surrounding homesteads, particularly for small scale agriculture. A spring is located at Tunnel 7 of the mine, just over 200 m from the mine office on the eastern slopes and 130m away from the river. It serves as a critical source of potable water for the mine; vandalism of distribution pipeline prevents access by nearby communities to this spring water. Informal mining takes place up stream of the mining area on both sides of the valley, impacting on fields resulting in loss of land and crops. Western and eastern bank of the river have been heavily impacted by unauthorised mining operations, and eroding areas used for banana plantations.

Of the three Trinity Metals mining concession areas in Rwanda, the Rutongo concession area is the most affected by unauthorised mining activities. This linked to several factors including (Barbour, 2024b):

- The size of the concession area,
- The widespread occurrence of and accessibility to mineralisation within the Rutongo concession area,
- The long history of mining in the area (over 100 years),
- High poverty and unemployment levels, and
- Low wages paid to contractor workers employed by cooperatives.

4.5 Conceptual Site Model

The following section describes the three main components of the CSM, comprising potential sources, pathways and receptors of possible contamination emanating from the mine areas. These are outlined in **Figure 4-9**.

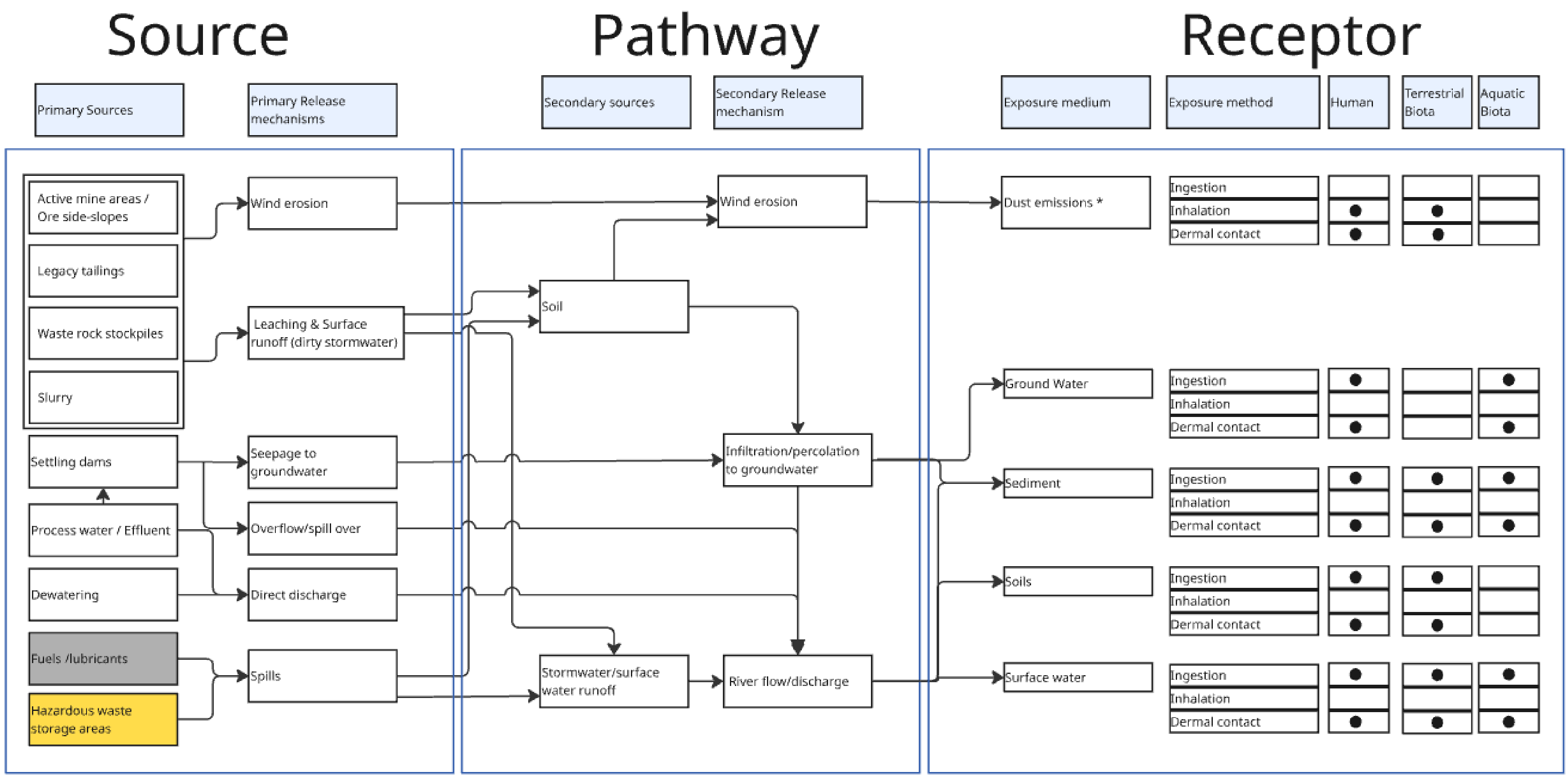

Figure 4-9 **Conceptual Site Model for Trinity Rutongo Mine showing the predicted migration pathways of contaminants from source to receptors (*Investigations of dust emissions undertaken at Nyamyumba and Karambo mines only. Grey = Observational; Yellow = Unconfirmed)**

4.5.1 Sources

Fugitive emissions – Mining operations are known to generate fugitive emissions through mechanical operations and wind erosion of waste rock and tailing stockpiles, which include particulates of varying size fractions, and gaseous emissions from the combustion of fossil fuels in heavy machinery/equipment and vehicles (haulage trucks). Ambient air pollutants of relevance in this context include particulates ($PM_{2.5}$ and PM_{10}), and gases (SLR, 2024f).

Ore, waste rock, slurry, and legacy tailings – Runoff from these sources may contribute to the contamination of the various river systems associated with each mine site. Due to the lack of formal stormwater infrastructure or ineffective stormwater infrastructure, dirty run-off from the different sites is discharged into the environment (SLR, 2024h). In addition, uncontrolled placement of waste rock material and tailings result in downward dispersal. Given the extreme topography of the site, many waste rock dumps begin on the mountainside as a structure resembling a platform, typically adjacent to active tunnels. However, as they grow in size, they often destabilise due to the sheer mass of rock on extremely steep slopes (with slopes often >50%) (GroundTruth, 2026).

Mine impacted / process water / effluent – At the Gisanze Mine site, water freely discharges from two of the adits. At the Karambo Mine, excess groundwater from the M1 tunnel is discharged to the Nyirabukingore Stream. At Gasambya, overflow groundwater is pumped to a storage dam and then discharged into the Kivomo River. For most mines, sluicing water and wastewater from processing plants are discharged to the rivers. Only the Masoro and Mahaza mines are closed circuit, however there is still potential for contamination should storage dams overflow during high rainfall events (SLR, 2024g).

*There is potential for some hydrocarbon contamination related to the drilling machine operations at the mining face as well as minor spillages from mobile machinery (e.g. Bobcat loaders. The use of pumps by informal mining activities is also a potential source. However, no monitoring data are available for hydrocarbons, and related substances (Daneel *pers. comm*, 2026).

4.5.2 Pathways

Wind dispersal – Wind facilitates horizontal dispersion of fugitive emissions and dust. Higher wind speeds will move pollutants away from the source more quickly, while low wind speeds can result in air pollution stagnation and high ambient concentrations (NO_2 and SO_2) (SLR, 2024f).

Surface water discharge – Formal stormwater management infrastructure is not in place at all the mine sites. Where stormwater infrastructure is in place (Nyamyumba, Karambo and Gasambya), these are not always effective and can overflow. In Nyamyumba, a new process water dam was constructed and the old process water dam, which is located within the Sanzari River bed, is no longer formally operational. However, some stormwater inputs are still directed into the old dam, which is unlined and may result in direct discharge into the Sanzari River. Additionally, a stormwater bypass channel exists to the east of the new process water dam, which appears to carry stormflows from the mine site directly into the Sanzari River (GroundTruth, 2026). The Masoro and Mahaza mine sites operate as closed circuits; however, the stormwater infrastructure can overflow during high rainfall events. At the Gisanze Mine site, water freely discharges from two of the adits (SLR, 2024h). Dilution of contaminants may occur upon reaching river systems or water bodies, or via groundwater recharge. Upstream and surrounding community activities (agriculture, livestock), as well as other instream activities (aggregate mining) can contribute to degraded water quality, in addition to mining activities. Other contaminants, e.g. nitrates, can undergo biochemical transformation (denitrification) and degradation become no longer toxic.

Groundwater infiltration – Host rock minerology contributes to background levels of metals and other potential contaminants. Seepage and/or overflow of mine impacted/process water contained in the unlined settling dams may lead to contamination of groundwater. This is exacerbated by the absence of formal stormwater management infrastructure at most sites. In turn groundwater contamination may lead to contamination of the various river systems, particularly at the Mahaza and Masoro Mines where the baseflow is groundwater-dependent, and spring are utilised by communities (SLR, 2024g).

4.5.3 Receptors

Human population – This includes mine workers and the communities within and in close proximity to the mine sites, in particular communities who utilise water resources within the concession area for drinking, domestic use, agriculture and livestock watering. At elevated concentrations, contaminants can be harmful to humans primarily through ingestion/drinking. Factors that can influence whether contaminant exposure in drinking water will lead to adverse health effects include the type of contaminant, its concentration, individual susceptibility, the amount of water consumed, and the duration of exposure. Other exposure media include direct dermal contact, inhalation of contaminants, as well as through ingestion of contaminated crops and other food items (e.g. fish). Children and the elderly are the most vulnerable to health complications caused by contaminants, especially in rural communities where health facilities are often undeveloped or located in major centres (Sustainability Directory, 2025).

Aquatic ecosystems – These include rivers, springs and/or wetlands and related biodiversity within the concession area, and further downstream, specifically the Rusine River and its numerous tributaries. Factors that can influence whether contaminant exposure will lead to adverse health effects for aquatic biota include the type of contaminant, its concentration (as a factor of river flow), sequestration within river sediments, species-specific sensitivity to pollution, and the duration of exposure. Moreover, freshwater ecosystems, especially wetlands, can act as a sink for contaminants, which can then accumulate to toxic levels (GroundTruth, 2026).

Terrestrial ecosystems – These includes forests and bushland/thickets and associated biodiversity within the concession area or immediately adjacent. Terrestrial organisms (flora and fauna, including domestic livestock), can be exposed to contamination through soil uptake (plants) and ingestion of drinking water, soil and plants, dermal contact or inhalation of contaminants. The same factors influencing contamination exposure also apply to terrestrial organisms.

4.6 Risk Assessment

4.6.1 Air emissions

The following findings are extracted from the specialist Air Quality Report (SLR, 2024f). To note, air quality monitoring was only undertaken at two of the six mines, namely Nyamyumba and Karambo.

Nyamyumba

- Twelve exceedances (31.6% of records) of both the EAS 2021 and WHO AQG 2021 24-hr average limits were recorded for PM_{10}.
- Exceedances of only the WHO AQG 2021 24-hr average limits were recorded for $PM_{2.5}$ (39.5% of records).
- Survey average NO_2 and SO_2 concentrations were well within the annual EAS 2021 and WHO AQG 2021 guidelines for gaseous emissions.

Karambo

- No exceedances of EAS 2021 and WHO AQG 2021 24-hr average limits were recorded for PM_{10}.
- Exceedances of EAS 2021 and WHO AQG 2021 24-hr average limits were recorded for $PM_{2.5}$; 8% and 56% of records, respectively.
- Survey average NO_2 and SO_2 concentrations were well within the annual EAS 2021 and WHO AQG 2021 guidelines for gaseous emissions.

4.6.2 Mine materials

The following findings are extracted from the specialist Geochemistry, Hydrology, and Geochemical and Soil/Sediment reports (SLR, 2026b, 2024j, 2024g):

The Rutongo mine materials were classified as having an overall low risk for potential acid generation, however due to the lack of neutralising minerals in the lithologies present, if any sulphide rich zones are encountered/ mined, then there could be an immediate risk for acid effluent leaching from the site (SLR, 2024j). Updated sampling of the legacy tailings in July 2025, confirmed overall low risk of the mine's extractive materials for long term acid generation (SLR, 2026b).

Gisanze

- Aluminium, lead and manganese in leachate and/or effluent exceeded the WHO Guidelines for Drinking Water (2022) limit.
- Parameters that exceeded various other limits included: aluminium, iron, manganese, nitrate and pH.
- Confirmed exceedances of manganese and pH in legacy tailings leachate (SLR, 2026b).
- Runoff from waste rock material, slurry and water discharged from the adits contribute to the contamination of the Rusine River.

Nyamyumba

- Aluminium, arsenic, lead, manganese, and nickel in leachate and/or effluent exceeded the WHO Guidelines for Drinking Water (2022) limit.
- Parameters that exceeded various other limits included: aluminium, arsenic, cobalt manganese, nickel, lead, nitrate, and pH.

- Confirmed exceedances of manganese in legacy tailings leachate (SLR, 2026b).
- Runoff from waste rock, ore, slurry, and legacy tailings stockpiles and overflow from settling dams contribute to the contamination of the Sanzari River.

Gasambya

- Aluminium, arsenic, iron, lead, nickel, and manganese in leachate and/or effluent exceeded the WHO Guidelines for Drinking Water (2022) limit.
- Parameters that exceeded various other limits included: Aluminium, arsenic, cobalt, nickel, iron, manganese, lead, nitrate and pH.
- Confirmed exceedances of arsenic, iron, manganese, and pH in legacy tailings leachate (SLR, 2026b).
- Run-off from waste rock, slurry, ore, legacy tailings, and discharges (overflow from the main dam) contribute to the contamination of the Kivomo River.

Karambo

- Aluminium, arsenic, iron, and manganese in leachate and/or effluent exceeded the WHO Guidelines for Drinking Water (2022) limit.
- Parameters that exceeded various other limits included: Aluminium, arsenic, iron, lead, manganese, nitrate, and pH.
- Confirmed exceedances of arsenic, manganese, and pH in legacy tailings (SLR, 2026b).
- Run-off from waste rock, slurry, and ore and sluice water (dirty run-off) contribute to the contamination of the Nyirabukingore River.

Mahaza

- Aluminium, and manganese in sluice water/effluent (sans leachate) only exceeded the WHO Guidelines for Drinking Water (2022) limit.
- Parameters that exceeded various other limits included: aluminium, manganese, nitrate, and pH.
- Confirmed exceedances of manganese and pH in legacy tailings leachate (SLR, 2026b).
- This mine operates as a closed circuit. No active effluent discharge occurs from this site; however, informal mining activities were noted nearby.

Masoro

- Aluminium, lead and manganese in sluice water/effluent only (sans leachate) exceeded the WHO Guidelines for Drinking Water (2022) limit.
- Parameters that exceeded various other limits included: aluminium, lead, manganese, nitrate and pH.
- Confirmed exceedances of manganese and pH in legacy tailings leachate (SLR, 2026b).
- While the mine operates as a closed circuit, should the site dams overtop during excessive rainy periods, contaminants could reach the Gatiti River.

Nyamyumba and Gasambya mines show the greatest risk in terms of metal leaching potential, most especially from their slurry materials, which infers the mobility of metals like aluminium, arsenic, cobalt, iron, manganese, nickel and lead increases with the processing/ sluicing of the ore and uncontained stockpiling of the waste rock. To a lesser extent, Karambo and Gisanze site waste rock has potential to leach arsenic, manganese, lead and nitrate while the ore and slurry materials may leach manganese, iron and aluminium (SLR, 2024j).

The sluicing effluent water has elevated concentrations of metals when compared to the input water (e.g. at Gasambya Mine) inferring the process of agitating and washing the ore during sluicing mobilises metals, namely aluminium, arsenic, and to lesser extent lead (SLR, 2024j).

Overflow points from settling dams at Nyamyumba and Gasambya sites represents the accumulated site effluent water quality that is being released into the receiving environment. The results show persistent elevated concentrations of aluminium, arsenic, manganese, lead, nitrate and some of the most acidic pH levels reported for the Rutongo Mine sites (SLR, 2024j).

4.6.3 Groundwater

The following findings are extracted from the specialist Geochemistry and Hydrogeology reports (SLR, 2024j, 2024g).

- The groundwater quality and mine (fissure) water are generally good and only a few parameters exceeded the guideline limits.
- The slight acidity of both groundwater and mine water may cause leaching of metals from the parent rock and thus cause metal concentrations to be elevated.
- The presence of these metals namely aluminium, iron, arsenic and manganese in the groundwater may be attributed to the geological composition of the host rock. Current concentrations are only marginally above the limits and thus considered natural.
- The main variables of concern for human consumption in include aluminium, iron, manganese.

Gisanze

- Groundwater quality was generally very good; only iron exceeded the WHO Guidelines for Drinking Water (2022) limit and livestock watering limit (RS 190).
- Groundwater does not contribute to river baseflow.

Nyamyumba

- Groundwater quality was generally very good; only arsenic and lead exceeded the WHO Guidelines for Drinking Water (2022) limit and lead the livestock watering limit (RS 190).
- Groundwater does not contribute to river baseflow.

Gasambya

- Groundwater quality was generally very good, only lead and manganese exceeded the WHO Guidelines for Drinking Water (2022) limit and livestock watering limit (RS 190).
- Groundwater does not contribute to river baseflow.

Karambo

- Groundwater quality was generally very good; only aluminium exceeded the WHO Guidelines for Drinking Water (2022) limit.
- Groundwater does not contribute to the baseflow of the stream and the elevated aluminium concentration may be due to seepage from the river.

Mahaza

- Groundwater quality was generally very good; only iron exceeded the WHO Guidelines for Drinking Water (2022) limit and livestock watering limit (RS 190).
- Groundwater contributes to river baseflow.

Masoro

- Elevated lead and manganese up-gradient of mine, and the same parameters with the inclusion of iron at down-gradient sample point.
- These mirror the contaminants in surface water, but concentrations are much lower (river has higher contaminant load).
- Concentrations of aluminium, iron, management and lead exceeded the WHO drinking water (2022) limits.
- Groundwater contributes to river baseflow.
- Upstream groundwater water quality at Gasambaya and Gisanze recorded nitrate levels exceeding effluent, livestock watering and irrigation limits indicating external factors influencing nutrient levels.
- Groundwater is likely to contribute to the baseflow of the rivers at the Mahaza and Masoro Mines. However, groundwater quality in these areas suggests that the streams have a bigger impact on the groundwater than vice versa.
- Mine waters at Nyamyumba and Gasambya sites are most impacted by the underground mining with both returning elevated metals and nitrate concentrations. The nitrate levels can be directly linked to the use of ammonium nitrate explosives in the extraction process.

Table 4-3 Source risks to groundwater contamination 100 years after mine closure (After SLR, 2024g)

Mine	Description
Gisanze Mine (Rusine River)	The highest risk in terms of source concentration is the ore stockpile, which will be removed during the mining operations. The nitrate concentrations[9] are well below all the guidelines and poses very little threat to the environment or the health of the people.
Nyamyumba Mine (Sanzari River)	The waste rock dump poses the highest risk, which is very little, to the environment at Nyamyumba Mine. The nitrate concentrations are well below all the guidelines and poses very little threat to the environment or the health of the people.
Gasambya Mine (Kivomo River)	The waste rock dump poses the highest risk, which is very little, to the environment at Gasambya mine. The nitrate concentrations are well below all the and poses very little threat to the environment or the health of the people.

[9] Nitrate was the parameter that was most consistently elevated and was therefore used in the mass transport modelling (i.e. the ‘source term’) to represent the contaminant plume from the potential sources. The “contaminant plume” does not necessarily represent an impact, as the source term concentrations were in all instances below the WHO limits for drinking water, however, irrigation limits were periodically exceeded, and concentrations may therefore pose some threat to the agricultural activities in the region (SLR, 2024g).

Karambo Mine (Nyirabukingore River)	The waste rock dump poses the highest risk to the environment at Karambo Mine. The nitrate concentrations exceed the Rwanda standards for irrigation in the observation borehole, which is approximately 60m below the waste rock dump.
Mahaza Mine (Rusine River)	The waste rock dump poses the highest risk to the environment at Mahaza mine. The nitrate concentrations exceed the Rwanda standards for irrigation in the observation borehole, which is approximately 40m below the waste rock dump.
Masoro Mine (Gatiti River)	The highest risk in terms of source concentration is the waste rock. The nitrate concentrations are well below all the and poses very little threat to the environment or the health of the people.

4.6.4 Surface water

The following findings are extracted from the specialist Geochemistry, Hydrogeology and Hydrology reports (SLR, 2024g, 2024j, 2024h):

Springs

- All the springs (5) that village members use for drinking water are within the WHO Guidelines for Drinking Water (2022) limits, except for the Kabuga village spring (Nyamyumba Mine, on the Sanzari River), which has elevated levels of arsenic.

Gisanze

- Aluminium, lead and manganese upstream of the mine, and the same parameters with the inclusion of arsenic downstream of the mine exceeded the WHO Guidelines for Drinking Water (2022).
- Both upstream and downstream water exhibited very high aluminium and manganese concentrations. Manganese concentration increased at the downstream site.
- High total suspended solids concentrations were recorded at the downstream site, which are suitable for irrigation but problematic for aquatic life.
- pH levels downstream of the mine are not conducive to livestock watering.
- Seasonal fluctuations indicated other external factors also influencing the water quality within the Rusine River.

Nyamyumba

- Aluminium, iron, lead and manganese upstream of the mine, and the same parameters with the inclusion of arsenic downstream of the mine exceeded the WHO Guidelines for Drinking Water (2022).
- The concentration of these parameters increased downstream.
- Excessive total suspended solids concentrations were recorded downstream of the mine, which is problematic for aquatic fauna, while elevated sodium levels indicating an increasing problem for crop yield.
- pH levels were not conducive for livestock watering.

- With limited external factors influencing the quality of the water, the Nyamyumba Mine site contributes to the degradation of the downstream water quality within the Sanzari River.

Gasambya

- Arsenic, lead and manganese upstream of the mine, and the same parameters with marked increases downstream of the mine exceeded the WHO Guidelines for Drinking Water (2022).
- Elevated sodium and nitrate levels were also recorded downstream, indicating an increasing problem for crop yield.
- Excessive total suspended solids concentrations were recorded at the downstream site, which is problematic for aquatic fauna.
- Mining related activities at the Gasambya Mine site are influencing the quality of water in the Kivomo River.
- Wet season increases in the above parameters indicated other external factors influencing the water quality within the Kivomo River.

Karambo

- Lead and manganese upstream of the mine, and the same parameters showed marked increases, and the inclusion of arsenic, downstream of the mine exceeded the WHO Guidelines for Drinking Water (2022).
- pH levels downstream of the mine are not conducive to livestock watering.
- Elevated sodium and nitrate levels were also recorded downstream, indicating an increasing problem for crop yield.
- Excessive total suspended solids concentrations were recorded at the downstream site, which is problematic for aquatic fauna.
- Mine-related activities are contributing to the deterioration of the water quality with the Nyirabukingore River.
- This is not solely attributed to the Karambo mine as legal sandstone miners are also operating in the river. There has also been an increase in informal mining activities upstream of the mine site along the valley slopes, particularly during the wet seasons, and at historical mining areas.
- Seasonal fluctuations indicated other external factors also influencing the water quality within the Nyirabukingore River.

Mahaza

- Lead and manganese upstream of the mine, and the same parameters with the inclusion of arsenic showed marked increases downstream of the mine, which exceeded the WHO Guidelines for Drinking Water (2022).
- pH levels downstream of the mine are not conducive to livestock watering.
- Excessive total suspended solids concentrations were recorded at the downstream site, which is problematic for aquatic fauna.
- Other external factors are therefore contributing to the deterioration of water quality downstream of the Mahaza Mine site.

Masoro

- Arsenic, lead and manganese upstream of the mine, and the same parameters (except arsenic) downstream of the mine exceeded the WHO Guidelines for Drinking Water (2022).
- Sluicing water/effluent, which is contained in an effluent dam, has the potential to cause deterioration of the water quality within the Gatiti River, if the dam overflows.
- pH levels downstream of the mine are not conducive to livestock watering.
- Excessive total suspended solids concentrations were recorded at the downstream site, which is problematic for aquatic fauna.
- Other external factors are contributing to the deterioration of water quality downstream of the Masoro Mine site, namely, a significant increase in informal mining activities upstream and downstream of the mine site.

All the mine sites, except for the Mahaza Mine site and the Masoro Mine site (only when it operates as a closed circuit), are contributing to the deterioration of water quality in the downstream rivers, with the key contaminants including lead, arsenic and manganese (SLR, 2024h).

Surface water sampling upstream of all the Rutongo Mine sites indicated that river water quality is already compromised and that surrounding villages and informal mining activities, as well as legal aggregate mining, contribute to the deterioration of river water quality. Sodium, chloride and nitrate concentrations throughout the Rutongo concession area can influence crop yields and quality should crops come into contact with river water (SLR, 2024h). In additional to the above, excessively high concentrations of total suspended solids is problematic for aquatic life in terms of physiological and habitat impacts, as well as food availability, among others.

Results of a sampling point on the Nyabugogo River, approximately 10 km downstream of the Rutongo concession area, before its confluence with the Nyabarongo River indicated that all key chemical parameters were below the WHO Guidelines for Drinking Water (WHO 2022). This indicates that mining-related activities associated with the Rutongo mines do not have a transboundary effect (SLR, 2024h).

4.6.5 Sediments and Soils

The following findings are extracted from the specialist Geochemical and Soil / Sediment Assessment (SLR, 2026b).

River sediments

- Higher gravel and sand fractions were generally found at the upstream sediment sites than the downstream sites, with the exception of Masoro and Karambo, which reported higher portions of gravel downstream. This implies input of heavier fractions progressing downstream.
- Sand was generally the dominant fraction for most of the sediment samples, except for Gasambya upstream that was dominated by gravel, and Mahaza and Gisanze downstream where silt and clay were recorded in almost equal upstream and downstream proportions. This suggests that the hydrological functioning of the river systems has been altered by anthropogenic activities.

- In terms of mineralogy, Quartz is the dominant mineral, followed by major to minor proportions of Muscovite, minor proportions of Kaolinites and Schorl and minor to trace amounts of Hematite.
- Due to the presence of Hematite, Schorl, Kaolinite and Muscovite in the sediments, they have capacity to sequester metals and metalloids mobilised by historic and current mining activities. The sediments are thus likely to show an enrichment / accumulation of various metals.
- In terms of various water quality and effluent guidelines, there were exceedances of three main analytes across the upstream and downstream sites, namely iron, manganese, and pH, with lead noted at upstream Gisanze, and arsenic at downstream Karambo and Masoro **(Table 4-4)**. The concentrations of metals in the sediment Synthetic Precipitation Leaching Procedure (SPLP) results showed overall trends of increased exceedances in downstream samples, except for iron (Gasambya and Gisanze) and manganese (Nyamyumba and Gisanze).
- The upstream sediments at Nyamyumba, Masoro, and Gasambya reported generally higher arsenic and lead concentrations compared to the downstream sediments; this could be attributed to elevated proportion of Hematite in these sediments.
- There is significant (GAI>3) to extreme (GAI>6) enrichment of arsenic and boron for all sediments **(Table 4-4)** suggesting these elements enrichments are due to inputs from the source materials dominated by the local lithologies present.
- Overall, the rivers in the vicinity of the mines have been impacted by anthropogenic activities, both upstream and downstream from the mine operations. Notably, Gasambya, Nyamyumba, Gisanze, and to a lesser degree Masoro, show impacts upstream from the mine sites likely due to a combination of agricultural, aggregate and informal mining activities.

Table 4-4 River sediment analyte exceedances according to local and international water quality and effluent standards, Level 1 Soil Screening Values (SSV1) and Geochemical Abundance Index (GAI) (After SLR, 2026b)

Mine	Sample Position	Analyte	WHO (2022)	Irrigation (RS 188)	Livestock (RS190)	Effluent (RS 109)	IFC (2007)	SSV1*	GAI **>3	GAI>6
Gisanze	Upstream	Fe Mn Pb	 X X	 X	X X	X	X	As, Pb	As, Sn	B
	Downstream	Fe Mn pH	 X	 X	X X	X	X X	As, Pb	As, Sn	B
Nyamyumba	Upstream	Mn	X	X	X			As, Pb	B, Bi, Se	As
	Downstream	Fe Mn pH	 X		X X		 X	As, Pb	B, Se	As
Gasambya	Upstream	Fe pH			X X		 X	As, Cu, Pb, V	B	As
	Downstream	Mn pH	X		 X		 X	As	B, Se	As
Karambo	Upstream	Fe			X			As, Pb	As	B
	Downstream	As Fe Mn pH	X X		 X X X		 X	As, Cu, Pb,	Ag, Bi, Sn	As, B, Pd
Mahaza	Upstream	Mn pH	X	X	X X		 X	As, Pb	As, B	
	Downstream	Mn pH	X	X	X X		 X	As, Cu, Pb	As, B, W	
Masoro	Upstream	pH			X		X	As, Cu, Pb	B, Se	As
	Downstream	As, Mn Fe pH	X	 X	 X X	 X	 X X	As,	As, B	

Soils

- The soils in the downstream areas of the various Rutongo mines were classified as a Ferralsol or Nitisol. The former is formed from intense weathering and has limited capacity to remediate metal leaching and acid rock drainage. Nitisols are similar to Ferralsol and also strongly weathered but are more fertile. For Gisanze, Nyamyumba Gasambya downstream soils were classified as Nitisol, while downstream soils at Karambo, Mahaza and Masoro mines were Ferralsol.
- All soil samples reported low organic carbon contents, which could be attributed to the rapid decomposition of organic matter due to the climate of the region. Together with the lack of high activity clay minerals infers limited acid buffering capacity and thus soil that is prone to acidification.
- The pH range of the Rutongo soil samples is acidic, which is typical of Ferralsols and Nitisols with Ferralsols being susceptible to nutrient leaching. There is likely a reduced availability of essential nutrients, but increased availability of trace and heavy metals, therefore the potential risk of phytotoxicity. The soil has limited pH buffering capacity.
- In terms of nutrient status, most of the soils are characterised by relatively low proportions of phosphorous and potassium, (except Gisanze soil with an acceptable amount of phosphorus) .
- Half the sites had acceptable magnesium content, whilst Gasambya, Mahaza and Gisanze soils, were below the general range that is suitable for most crops. None of the soils show excessive trace metal contents that could lead to phytotoxicity risks.
- The high iron content is likely related to iron oxides associated with the soil types, while high manganese levels are likely derived from the parent material.
- In terms of potential contamination and comparison against SSV1, only soil downstream of Gisanze Mine exceeded the limits for copper and manganese. It is suggested that elevated copper and manganese content is derived from the mineralogy of the parent material, and not necessarily due to mining activities impacting the downstream areas.

These findings of the specialist reports are integrated into quantitative risk assessments for the Rutongo Mine sites (**Table 4-5 to Table 4-10**).

Table 4-5 Summary of Environmental Risks Associated with Gisanze Mine

Source	Potential Contaminants*	Pathway	Receptor	Severity**	Likelihood	Risk
Fuel Combustion	NO_2 SO_2	Wind erosion / dispersal	Workers / Communities		NOT SAMPLED	
Ore stockpile *Waste Rock* *Slurry* *Legacy Tailings*	PM_{10} $PM_{2.5}$		Workers / Communities		NOT SAMPLED	
Ore stockpile *Waste Rock* *Slurry*	Aluminium Iron Manganese pH	Groundwater seepage	Communities	HIGH – Mn, Fe, exceedance (WHO, 2022 and RS 190) (Spring water compliant with WHO, 2022)	UNLIKELY – While spring water is primary source of water, it is unaffected by groundwater seepage from mine activities.	MOD/ LOW
			Livestock	HIGH - Mn, Fe, pH exceedances (RS 190) (Spring water compliant with WHO, 2022)	HIGHLY LIKELY – Livestock utilise rivers for watering. Groundwater from two adits freely discharges into the Rusine River.	VERY HIGH
Mine impacted / Process Water / Effluent	Aluminium Manganese Iron Lead Nitrate pH		Crops	MINOR – Mn close to limit. No other exceedances	UNLIKELY – Subsistence cultivation is predominately reliant on rainfall	VERY LOW
			Aquatic Ecosystem	LOW – Pb, Mg exceedances (RS 564 and EAS 1172) Health of the Rusine River is 'Serious -Critically modified', bearing low sensitivity.	HIGHLY LIKELY - Groundwater from two adits freely discharges into the Rusine River	MOD
		Surface water runoff /discharge	Communities	HIGH – **Al, Pb, Mn** and As exceedances (WHO, 2022) External factors present	LOW LIKELIHOOD – Proximity of community, however river water is not primary source of water.	MOD

Source	Potential Contaminants*	Pathway	Receptor	Severity**	Likelihood	Risk
			Livestock	HIGH - pH, Al, **Fe** exceedance (RS 190)	LIKELY – Livestock utilise rivers for watering.	HIGH
			Soils (crops)	LOW – **Mn** exceedance (RS 188) External factors present. Cu, **Mn** (SSV1) exceedance. Soil has inherent limited pH buffering capacity, prone to acidification and leaching.	UNLIKELY – Subsistence cultivation is predominately reliant on rainfall.	VERY LOW
			Sediments	LOW – **Mn, Fe,** pH exceedances (WHO 2022, RS 188, RS 190, RS 109). **As**, Pb (SSV1), significant metal enrichment by As and Sn, extreme enrichment by **B.** Health of the Rusine River is 'Seriously-Critically modified', bearing low sensitivity.	HIGHLY LIKELY – Sluice water, together with dirty stormwater, will be discharged direct to Rusine River when the mine is operational.	MOD
			Aquatic Ecosystems	LOW – **Al, Pb** pH, **Mn, TSS** (RS 564, EAS 1172). Health of the Rusine River is 'Serious -Critically modified', bearing low sensitivity.	HIGHLY LIKELY – Sluice water, together with dirty stormwater, will be discharged direct to Rusine River when the mine is operational.	MOD

* Potential contaminants based on geochemical analyses.

** Based on contaminants measured in pathway component (i.e. groundwater or surface water). Elements in **bold** represent very high exceedance that is at least double the limit. WHO (2022) Guidelines for drinking water; RS 109 (2009) Effluent standard; RS 188 (2013) Irrigation use; RS 190 (2013) Livestock watering; IFC (2007) Mining effluent guidelines, RS 564 (2023) Ambient water, RS EAS 1172 (2024) Water discharged into the environment.

Table 4-6 Summary of Environmental Risks Associated with Nyamyumba Mine

Source	Potential Contaminants*	Pathway	Receptor	Severity**	Likelihood	Risk
Fuel Combustion	NO_2 SO_2	Wind erosion / dispersal	Workers / Communities	MINOR – no exceedances	LIKELY – Workers engaging in limited mining activities, proximity of access roads	LOW
Ore stockpile *Waste Rock* *Slurry* *Legacy Tailings*	PM_{10} $PM_{2.5}$		Workers / Communities	HIGH – PM_{10} and $PM_{2.5}$ exceedances at key points on site and in surrounding communities	HIGHLY LIKELY – Workers engaging in mining activities, operation of processing facility, proximity of communities and sensitive receptors.	VERY HIGH
Ore stockpile *Waste Rock* *Slurry* *Legacy Tailings*	Aluminium Arsenic Lead Manganese Nickel Cobalt Nitrate pH	Groundwater seepage	Communities	HIGH – As, **Pb**, Mn, pH exceedances (WHO, 2022) Communal spring has high levels of arsenic exceeding WHO 2022	HIGHLY LIKELY – Spring water is primary source of water for domestic purposes.	VERY HIGH
			Livestock	HIGH – **Pb**, **pH** exceedances (RS 190), Mn near limit.	UNLIKELY – Livestock utilise rivers for watering, however groundwater does not contribute to baseflow. Spring water is the primary source of water for domestic use.	MOD/ LOW
Mine impacted / Process Water / Effluent	Aluminium Lead Manganese Nickel Cobalt Nitrate pH		Crops	MINOR – No exceedances.	UNLIKELY – Subsistence cultivation is predominately reliant on rainfall.	VERY LOW
			Aquatic Ecosystem	LOW – **Pb**, **pH** exceedances (RS 564) **Pb**, As exceedances (EAS 1172) Health of the Sanzari River is 'Seriously-Critically modified', bearing low sensitivity.	UNLIKELY – Process water sourced from Sanzari River, not groundwater ingress. Unlined dams are present, however groundwater does not contribute to baseflow.	VERY LOW

Source	Potential Contaminants*	Pathway	Receptor	Severity**	Likelihood	Risk
			Communities	HIGH – **Al, As, Fe, Pb, Mn** exceedances (WHO, 2022)	LOW LIKELIHOOD – Proximity of community, however river water is not primary source of water for domestic use. River water used on ad hoc basis.	MOD
			Livestock	HIGH – **As, Al, Mn, Fe, pH** exceedances (RS 190)	LIKELY – Livestock utilise rivers for watering. Spring water is the primary source of water for domestic use.	HIGH
		Surface water runoff /discharge	Soils (crops)	HIGH - Al, Fe, **Mn**, exceedances (RS 188). Na is an increasing problem for crop yield. Soil has inherent limited pH buffering capacity, prone to acidification and leaching	UNLIKELY – Subsistence cultivation is predominately reliant on rainfall.	MOD/ LOW
			Sediments	LOW – Mn (WHO, 2022), Fe, pH (RS190, IFC 2007. **As**, Pb (SSV1). Significant enrichment by B and Se, and extreme enrichment by **As**. Health of the Sanzari River is 'Serious -Critically modified', bearing low sensitivity.	HIGHLY LIKELY – Not a closed system. Dirty stormwater and sluice effluent discharged to Sanzari River via settling dam. Livestock utilise rivers for watering. River water used on ad hoc basis by community.	MOD
			Aquatic Ecosystems	LOW – Pb, **Mn**, **Fe**, **pH, TSS** (EAS 1172, RS 564). Health of the Sanzari River is 'Serious -Critically modified', bearing low sensitivity.	HIGHLY LIKELY – Not a closed system. Dirty stormwater and sluice effluent discharged to Sanzari River via settling dam.	MOD

* Potential contaminants based on geochemical analyses.

** Based on contaminants measured in pathway component (i.e. groundwater or surface water). Elements in **bold** represent very high exceedance that is at least double the limit. WHO (2022) Guidelines for drinking water; RS 109 (2009) Effluent standard; RS 188 (2013) Irrigation use; RS 190 (2013) Livestock watering; IFC (2007) Mining effluent guidelines, RS 564 (2023) Ambient water, RS EAS 1172 (2024) Water discharged into the environment.

Table 4-7 Summary of Environmental Risks Associated with Gasambya Mine

Source	Potential Contaminants*	Pathway	Receptor	Severity**	Likelihood	Risk
Fuel Combustion	NO_2 SO_2	Wind erosion / dispersal	Workers / Communities		NOT SAMPLED	
Ore stockpile *Waste Rock* *Slurry* *Legacy Tailings*	PM_{10} $PM_{2.5}$		Workers / Communities		NOT SAMPLED	
Ore stockpile *Waste Rock* *Slurry* *Legacy Tailings*	Aluminium Arsenic Cobalt Iron Lead Nickel Manganese Nitrate pH	Groundwater seepage	Communities	HIGH - **Pb, Mn,** exceedance (WHO, 2022)	LOW LIKELIHOOD – Spring water is primary source of water.	MOD
			Livestock	HIGH - **Pb, Mn, pH** exceedance (RS 190), Mn marginal but NO_3 exceedance (RS 188)	UNLIKELY – Livestock utilise rivers for watering. Groundwater does not contribute to baseflow.	MOD/ LOW
Mine impacted / Process Water / Effluent	Aluminium Arsenic Lead Manganese Nitrate pH		Crops		UNLIKELY – Subsistence cultivation is predominately reliant on rainfall.	MOD/ LOW
			Aquatic Ecosystem	LOW – **Pb** exceedance (RS 564, EAS 1172), Mn close to limits, pH of mine water (RS 564, EAS 1172) Health of the Kivomo River is 'Seriously-Critically modified', bearing low sensitivity.	HIGHLY LIKELY – Not a closed system. Mine water used for processing, discharged to Kivomo River. Groundwater does not contribute to baseflow.	MOD

Source	Potential Contaminants*	Pathway	Receptor	Severity**	Likelihood	Risk
		Surface water runoff /discharge	Communities	HIGH – **As, Pb, Mn** exceedances (WHO, 2022)	LOW LIKELIHOOD – Proximity of community, however river water is not primary source of water.	MOD
			Livestock	HIGH – **Mn, pH**, Pb, exceedance (RS 190)	LIKELY – Livestock utilise rivers for watering.	HIGH
			Soils (crops)	MEDIUM – **As, Mn** exceedance (RS 188). Na, NO_3 are increasing problems for crop yield. Soil has inherent limited pH buffering capacity, prone to acidification and leaching.	UNLIKELY – Subsistence cultivation is predominately reliant on rainfall.	LOW
			Sediments	LOW - Mn (WHO 2022, RS 188, RS190), **pH** (RS 190, IFC 2007). **As** (SSV1). Significant metal enrichment by B and Se, extreme enrichment by **As**. Health of the Kivomo River is 'Seriously-Critically modified', bearing low sensitivity.	HIGHLY LIKELY – Not a closed system. Mine water used for processing, together with dirty stormwater discharged to Kivomo River. Sediments showing metal enrichment.	MOD
			Aquatic Ecosystems	LOW – **As, Pb, Mn, pH, TSS** exceedance (RS 564, RS EAS1172). Health of the Kivomo River is 'Serious -Critically modified', bearing low sensitivity.	HIGHLY LIKELY – Not a closed system. Mine water used for processing, together with dirty stormwater discharged to Kivomo River.	MOD

* Potential contaminants based on geochemical analyses.

** Based on contaminants measured in pathway component (i.e. groundwater or surface water). Elements in **bold** represent very high exceedance that is at least double the limit. WHO (2022) Guidelines for drinking water; RS 109 (2009) Effluent standard; RS 188 (2013) Irrigation use; RS 190 (2013) Livestock watering; IFC (2007) Mining effluent guidelines, RS 564 (2023) Ambient water, RS EAS 1172 (2024) Water discharged into the environment.

Table 4-8 Summary of Environmental Risks Associated with Karambo Mine

Source	Potential Contaminants*	Pathway	Receptor	Severity**	Likelihood	Risk
Fuel Combustion	NO_2 SO_2	Wind erosion / dispersal	Workers / Communities	MINOR – no exceedances	LIKELY – Workers engaging in mining activities, proximity of access roads	LOW
Ore stockpile *Waste Rock* *Slurry* *Legacy Tailings*	PM_{10} $PM_{2.5}$		Workers / Communities	HIGH – $PM_{2.5}$ exceedances at key points on site and in surrounding communities	HIGHLY LIKELY – Workers engaging in mining activities, operation of processing facility, proximity of communities and sensitive receptors	VERY HIGH
Ore stockpile *Waste Rock* *Slurry* ***Legacy Tailings***	Arsenic Manganese Lead Nitrate pH	Groundwater seepage	Communities	MEDIUM – **Al, pH** exceedance (WHO, 2022), Fe close to limit.	LIKELY – Spring water is the primary source of water, unaffected by groundwater seepage. However, M1 tunnel water used by community on ad hoc basis.	MOD
Mine impacted / Process Water / Effluent	Aluminium Arsenic Iron Manganese Lead Nitrate pH		Livestock	MEDIUM – **pH** exceedance (RS 190), Mn close to limit.	LIKELY – Livestock utilise rivers for watering. Spring water is the primary source of water for domestic use.	MOD
			Crops	MEDIUM – **pH** exceedance (RS 188)	UNLIKELY – Subsistence cultivation is predominately reliant on rainfall.	LOW
			Aquatic Ecosystem	LOW – **pH** exceedance (RS EAS 1172, marginal RS 564)	HIGHLY LIKELY – Not a closed system. Excess mine water discharged to river.	MOD

Source	Potential Contaminants*	Pathway	Receptor	Severity**	Likelihood	Risk
				Health of the Nyirabukingore River is 'Serious -Critically modified', bearing low sensitivity.	Groundwater does not contribute to baseflow.	
		Surface water runoff /discharge	Communities	HIGH – **As**, Pb, **Mn, pH** exceedances (WHO, 2022)	LOW LIKELIHOOD – Proximity of community, however river water is not primary source of water.	MOD
			Livestock	HIGH – **Mn**, Pb, **pH** exceedances (RS 190)	LIKELY – Livestock utilise rivers for watering.	HIGH
			Soils (crops)	MEDIUM – **Mn** exceedance (RS 188). **Na, NO_3** are increasing problems for crop yield. Soil has limited pH buffering capacity, prone to acidification and leaching	UNLIKELY – Subsistence cultivation is predominately reliant on rainfall	LOW
			Sediments	LOW – As, Mn (WHO, 2022), Fe, pH (RS 190), pH (IFC 2007). As, Cu, Pb, (SSV1). Significant enrichment by Ag, Bi, Sn, extreme enrichment As, B, Pd. Health of the Nyirabukingore River is 'Serious to critically modified', bearing low sensitivity.	HIGHLY LIKELY – Not a closed system. Dirty stormwater, sluice effluent and excess mine water discharged to river.	MOD
			Aquatic Ecosystems	LOW – **As, Mn, Pb, pH, TSS** exceedances (RS 564, RS EAS 1172)	HIGHLY LIKELY – Not a closed system. Dirty stormwater, sluice effluent and excess mine water discharged to river.	MOD

Source	Potential Contaminants*	Pathway	Receptor	Severity**	Likelihood	Risk
				Health of the Nyirabukingore River is 'Serious -critically modified', bearing low sensitivity.		

* Potential contaminants based on geochemical analyses.
** Based on contaminants measured in pathway component (i.e. groundwater or surface water). Elements in **bold** represent very high exceedance that is at least double the limit. WHO (2022) Guidelines for drinking water; RS 109 (2009) Effluent standard; RS 188 (2013) Irrigation use; RS 190 (2013) Livestock watering; IFC (2007) Mining effluent guidelines, RS 564 (2023) Ambient water, RS EAS 1172 (2024) Water discharged into the environment.

Table 4-9 Summary of Environmental Risks Associated with Mahaza Mine

Source	Potential Contaminants*	Pathway	Receptor	Severity**	Likelihood	Risk
Fuel Combustion	NO_2 SO_2	Wind erosion / dispersal	Workers / Communities		NOT SAMPLED	
Ore stockpile *Waste Rock* *Slurry* *Legacy Tailings*	PM_{10} $PM_{2.5}$		Workers / Communities		NOT SAMPLED	
Ore stockpile *Waste Rock* *Legacy Tailings*	Manganese Nitrate pH	Groundwater seepage	Communities	HIGH - **Fe** exceedance (WHO, 2022) (Spring water compliant with WHO, 2022)	LOW LIKELIHOOD – Spring water is primary source of water, but is unaffected by groundwater seepage from mine site.	MOD
	Aluminium		Livestock	MEDIUM - **Fe** (exceedance RS 190)	LIKELY – Livestock utilise rivers for watering. Groundwater contributes to baseflow.	MOD

Source	Potential Contaminants*	Pathway	Receptor	Severity**	Likelihood	Risk
Mine impacted / Process Water / Effluent	Manganese Nitrate pH		Crops	(Spring water compliant with WHO, 2022)	UNLIKELY – Subsistence cultivation is predominately reliant on rainfall.	MOD/ LOW
			Aquatic Ecosystem	MINOR – No exceedances	LIKELY – Closed system. No water discharging from adits. However, groundwater contributes to baseflow.	LOW
		Surface water runoff /discharge	Communities	HIGH – **Pb**, **Mn** and As exceedance (WHO, 2022) External factors present	LOW LIKELIHOOD – Proximity of community, however river water is not primary source of water for domestic use.	MOD
			Livestock	MEDIUM - pH, Al, **Fe** exceedance (RS 190)	LIKELY – Livestock utilise rivers for watering.	MOD
			Soils (crops)	LOW – **Mn** exceedance (RS 188). **Na** is an increasing problem for crop yield. Soil has inherent limited pH buffering capacity, prone to acidification and leaching.	UNLIKELY – Subsistence cultivation is predominately reliant on rainfall.	VERY LOW
			Sediments	LOW - Mn (WHO 2022, RS 188, RS190), **pH** (RS 190, IFC 2007). **As**, Cu, Pb (SSV1). Significant metal enrichment by As, B, and W. Health of the Rusine River is 'Seriously-Critically modified', bearing low sensitivity.	LOW LIKELIHOOD – Closed system. No water discharged to environment. Overtopping of dam is possible.	LOW

Source	Potential Contaminants*	Pathway	Receptor	Severity**	Likelihood	Risk
			Aquatic Ecosystems	MINOR – Marginal exceedances of pH, As, Pb (RS 564, EAS 1172), **TSS** (RS 564, EAS 1172). Health of the Rusine River is 'Serious -Critically modified', bearing low sensitivity.	LOW LIKELIHOOD – Closed system. No water discharged to environment. Overtopping of dam is possible.	VERY LOW

* Potential contaminants based on geochemical analyses.

** Based on contaminants measured in pathway component (i.e. groundwater or surface water). Elements in **bold** represent very high exceedance that is at least double the limit. WHO (2022) Guidelines for drinking water; RS 109 (2009) Effluent standard; RS 188 (2013) Irrigation use; RS 190 (2013) Livestock watering; IFC (2007) Mining effluent guidelines, RS 564 (2023) Ambient water, RS EAS 1172 (2024) Water discharged into the environment.

Table 4-10 Summary of Environmental Risks Associated with Masoro Mine

Source	Potential Contaminants	Pathway	Receptor	Severity	Likelihood	Risk
Fuel Combustion	NO_2 SO_2	Wind erosion / dispersal	Workers / Communities		NOT SAMPLED	
Ore stockpile *Waste Rock* *Slurry* *Legacy Tailings*	PM_{10} $PM_{2.5}$		Workers / Communities		NOT SAMPLED	
Ore stockpile *Waste Rock* *Legacy Tailings*	Aluminium Iron Manganese pH	Groundwater seepage	Communities	HIGH - Pb, **Mn, Fe,** Al exceedance (WHO, 2022)	HIGHLY LIKELY – Spring water is the primary source of water for domestic use.	VERY HIGH
			Livestock	HIGH - Pb, **Mn, Fe,** Al exceedance (RS 190)	LIKELY – Livestock utilise rivers for watering. Groundwater contributes to baseflow.	HIGH

Source	Potential Contaminants	Pathway	Receptor	Severity	Likelihood	Risk
Mine impacted / Process Water / Effluent	Aluminium Lead Manganese Nitrate pH		Crops	MEDIUM – **Mn** exceedance (RS 188)	UNLIKELY – Subsistence cultivation is predominately reliant on rainfall.	LOW
			Aquatic Ecosystem	LOW – **Pb** exceedance (RS 564, EAS 1172), Mn close to limits. Health of the Umurindi River is 'Seriously-Critically modified', bearing low sensitivity.	LIKELY – Closed system. No water discharging from adits. However, groundwater contributes to baseflow.	MOD/ LOW
		Surface water runoff /discharge	Communities	HIGH - **Al**, **Fe**, **Mn**, **Pb** exceedance (WHO, 2022)	LOW LIKELIHOOD – Proximity of community, however river water is not primary source of water for domestic purposes. Closed system with no discharge to environment.	MOD
			Livestock	HIGH - **Al**, **Fe**, **Mn**, **Pb** exceedance (RS 190)	LOW LIKELIHOOD – Livestock utilise rivers for watering. However closed system. No water discharged to environment. Overtopping of dam is possible.	MOD
			Soils (Crops)	HIGH - **Al**, **Fe**, **Mn**, **Pb** exceedance (RS 188). **Na** is an increasing problem for crop yield. Soil has inherent limited pH buffering capacity, prone to acidification and leaching.	LOW LIKELIHOOD – Subsistence cultivation is predominately reliant on rainfall. No water discharged to environment. Overtopping of dam is possible.	MOD

Source	Potential Contaminants	Pathway	Receptor	Severity	Likelihood	Risk
			Sediments	LOW – As, Mn (WHO 2022), Fe, pH exceedances (RS 188, RS 190, RS 109). As (SSV1) Significant metal enrichment by As and B. Health of the Umurindi River is 'Seriously-Critically modified', bearing low sensitivity.	LOW LIKELIHOOD – No water discharged to environment. Overtopping of dam is possible.	LOW
			Aquatic Ecosystems	LOW – **Al, Fe, Mn, Pb, TSS** exceedance (EAS 1172, RS 564). Health of the Umurindi River is 'Seriously-Critically modified', bearing low sensitivity.	LOW LIKELIHOOD - Closed system. No water discharged to environment. Overtopping of dam is possible.	LOW

* Potential contaminants based on geochemical analyses;

** Based on contaminants measured in pathway component (i.e. groundwater or surface water). Elements in **bold** represent very high exceedance that is at least double the limit. WHO (2022) Guidelines for drinking water; RS 109 (2009) Effluent standard; RS 188 (2013) Irrigation use; RS 190 (2013) Livestock watering; IFC (2007) Mining effluent guidelines, RS 564 (2023) Ambient water, RS EAS 1172 (2024) Water discharged into the environment.

5. NYAKABINGO MINE

This section on the Nyakabingo Mine contains information extracted from the various baseline specialist assessments as part of the 2024 ESIA (see Section 1.3 and Section 2.2). Further insights and infield observations have been added by GroundTruth specialists where relevant.

5.1 Setting

5.1.1 Location

The Trinity Nyakabingo tungsten ore mine, which consists of a single primary site, is located in the Rulindo District near the village of Shyorongi, 19 km northwest of Kigali in the Northern Province of Rwanda. The mine concession area is located on the south-east of the highlands of Byumba. The topography of the area is characterised by hilly to mountainous terrain with elevations ranging from approximately 1 800 to 2 100 meters above sea level and associated flat-bottomed to narrow river valleys with limited wetland habitat (SLR, 2024k, 2024l).

5.1.2 Brief History

Exploration of the mine's alluvial deposits began in the late 1930s, but only after World War II did systematic open cast mining begin. Underground mining started in the late 1960s with adits, followed by drives along quartz veins situated in bedding planes (known as concordant parallel veins) (SLR, 2024k).

In September 2014, the Government of Rwanda, represented by the former MINIRENA, currently the RMB, entered into a 25-year mining agreement with Eurotrade International Limited, now Nyakabingo Mine (SLR, 2024k).

5.1.3 Land-use

Land-use within the Nyakabingo concession area comprises both formal and informal mining, and a range of other activities including mining of sand and aggregate, subsistence cultivation, cultivation and harvesting of fodder for livestock, timber production/forestry, spread of alien invasive plant species, and bee-keeping. Homesteads and subsistence farming are located along both sides of the Nyakabingo River, which is the primary water course within the concession area, save a few springs. There is no intact natural riparian vegetation (GroundTruth, 2026; Nepid Consultants, 2024c).

Due to the steep topography of the Nyakabingo catchment area, the subsistence cultivation is predominantly reliant on rainfall for its water needs. Large tracts of the catchment are being cultivated through the adoption of terraced lands, whilst within the lower portions of the Nyakabingo system, i.e. near the town of Rweya, this is unnecessary. The upper reaches and western portion of the Nyakabingo catchment remains largely uncultivated due to the topography, proximity to water and within the headwaters due to the mining (GroundTruth, 2026).

5.2 Site Layout and Operations

5.2.1 *Site Layout*

The conceptual layout of the Nyakabingo mine is illustrated in **Figure 5-1**. Key infrastructure located at the mine includes the following (Nepid Consultants, 2024c):

- Administrative Processing Area, including:
    - Main Office
    - Laboratory
    - Secondary Processing and Upgrading Area
    - Geology and Technical Services Offices
    - Stores
    - Ablutions
    - Restaurant
    - Guest House
    - Various other components (nursery, security etc.)
- Active Mining Area, including:
    - Underground entrances (adits)
    - Sluicing area
    - Panning house
    - Engineering workshop
    - Tailings and waste rock material
    - Settlement dam, a storage dam, and a Return Water Dam
    - Ablutions with septic tank
    - Tracks for trams
    - Various other components (pump houses, offices, locomotive charging area, etc.)

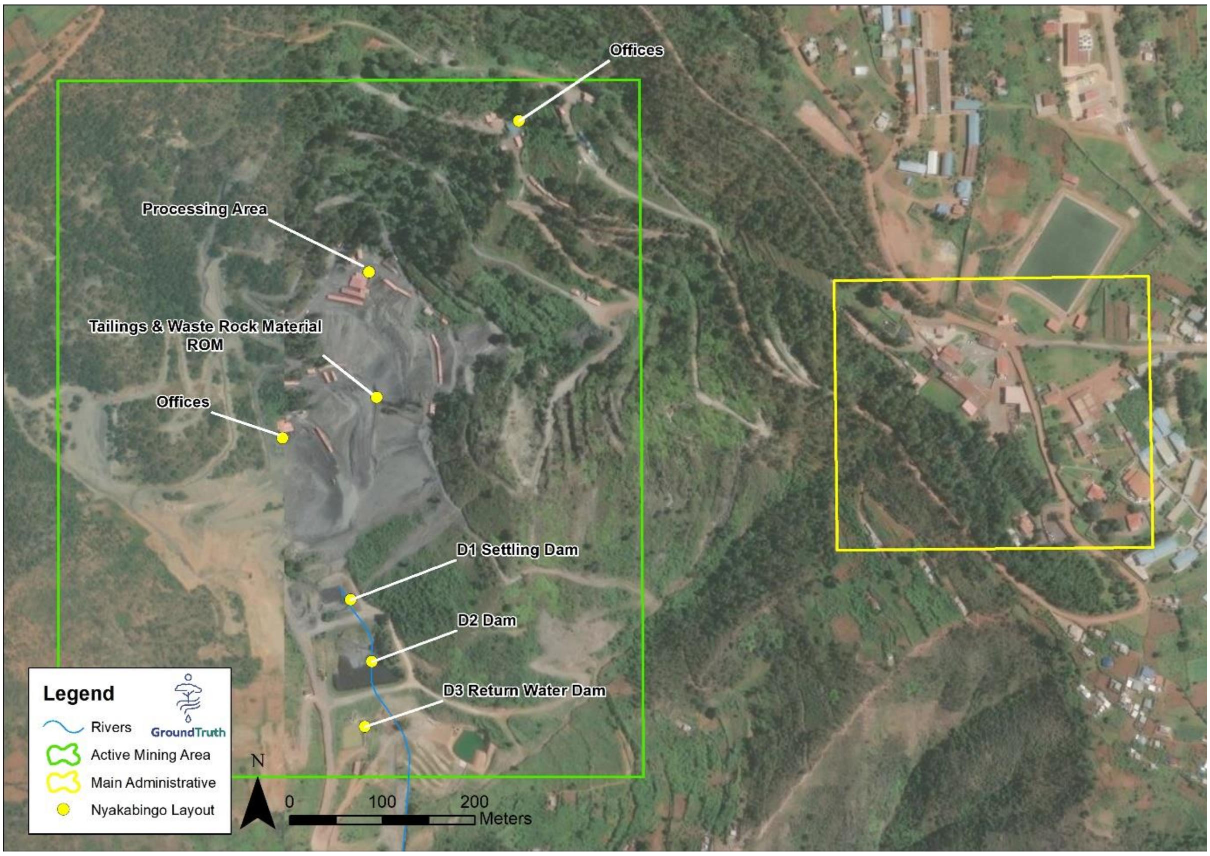

Figure 5-1 Layout of Trinity Nyakabingo Mine

5.2.2 Operations

5.2.2.1 *Material extraction and processing*

The Nyakabingo Mine has a combination of mechanised and artisanal operations. Mining involves the extraction of wolfram (tungsten ore) from underground operations. Reefs are accessed via a number of horizontal tunnels (drives) located at different elevations. Drilling and blasting methods are used to loosen the underground ore prior to being brought to the surface using artisanal methods. Mining is partially mechanised, using pneumatic drills, bobcat loaders, and rail haulage. Handpicking of high-grade ore (nuggetting) takes place at the active mining face where it is bagged and removed separate to the low-grade material and waste. The low-grade ore (and waste) is trammed to surface using small electrical locomotives for further processing on site. Following crushing, the ore is processed on site using manual panning and sluicing, with the product removed to the upgrade plant for further processing (SLR, 2024m).

5.2.2.2 *Process water*

There are approximately 24 drilling machines operational and three sluicing lines. Panning occurs at four active tunnels; sluicing takes place at three areas. Process water, required for drilling, sluicing and panning activities, is sourced from groundwater as well as runoff from the upper slopes of the Nyakabingo River catchment, which is collected in the D1 Settling Dam, via an existing stormwater channel. Excess process water and groundwater are discharged from the adits, and any discarded material flows down to the D1 Settling Dam. Here, a large portion of the solid material is settled out, with overflow discharging to the D2 Settling Dam. Water from the D2

Settling Dam is released to D3 Return Water Dam for re-use, whilst excess water is discharged to the Nyakabingo River (SLR, 2024m).

5.2.2.3 *Waste areas*

The historical tailings and waste rock material are deposited at various stockpiles around the site. The placement of these sites appears to be uncontrolled resulting in downward dispersal of material (SLR, 2024l).

The mine has recently established two settlement dams (D1 and D2) and a Return Water Dam at the base of the mining operations to contain seepage from the waste rock and tailings dumps and to facilitate water recycling to the operations (SLR, 2024k). The D1 and D2 settling dams are unlined earth dams, which have not been engineered. The D3 Return Water Dam is lined with an HDPE earth dam, which has also not been engineered (SLR, 2024m).

5.3 Environmental Aspects

5.3.1 Hydrology

The main aquatic ecosystem in the Nyakabingo concession area is the Nyakabingo River. The river originates within the concession area fed by groundwater baseflow (gaining system), flowing in a southerly direct where it drains into the Nyabarongo River approximately 5 km downstream from the mine (SLR, 2024k), which in turn flows into Lake Rweru. The Nyabarongo River, along with other major river systems in the region, are impacted by poor agricultural practices, deforestation for agriculture, and encroachment by alien invasive species leading to excessive sedimentation (Nepid Consultants April 2024, Aquatic Ecology; SLR August 2024 Hydrology).

Due to the historical lack of formal stormwater management at the mine site (more suitable practices are in the process of being implemented), significant amounts of tailings and waste rock have moved down the Nyakabingo River. Moreover, the current mining activities are located within the 10 m regulated buffer zone. Together with subsistence crop cultivation in the southern sections of the concession area, these human activities have resulted in significant modification and degradation of the river system. Other aquatic ecosystems in the concession area comprise seeps, mountain headwaters, and springs, which are essential for the surrounding communities for domestic purposes, including drinking, washing, and cooking, and livestock watering (Nepid Consultants, 2024c; SLR, 2024m). There are three main springs that serve the local communities, the Kirikumuryango spring source that feeds the potable water network supply villages further afield, the Mwagiro -Gatwa Village spring located 200 m downstream of the mine settling dam, and the Mwagiro -Bugarura Village spring, located 1.5 km downstream of the mine (GroundTruth, 2025c).

A series of very small wetlands are located along the Nyakabingo River and a larger wetland is located along the floodplain associated with the Nyaburongo River. None of the wetlands are in close proximity to the current mining activities (GroundTruth, 2026).

5.3.2 Geology

The Karagwe-Ankole Belt (KAB) located in East Africa is one of two distinct northern and southern segments of the Mesoproterozoic Kibara Belt (KIB) of Central Africa, which hosts a large metallogenic province that contains numerous granite-related ore deposits, with the typical metal association of tantalum–tin-tungsten (SLR, 2024n). The KAB spans across parts of Rwanda and Burundi, south-west Uganda, and north-west Tanzania, as well as the Kivu-Muniema region of the DRC. It is characterized by two structurally contrasting domains, (1) the Western Domain (WD) with Proterozoic basement and (2) the Eastern Domain (ED) with Archean basement. The WD encompasses the intensely deformed parts of the KAB. The WD is a significant geological region, and it is associated with valuable mineral deposits that include tin, tungsten, tantalum, and gold, which are mined throughout the region (SLR, 2024k).

In the central part of Rwanda is located the NW-to-SE-oriented Bugarama-Gifurwe-Nyakabingo zone with abundant tungsten mineralisation and this area is referred to as the 'Tungsten belt' (De Clercq *et al*., 2008). Rocks along the Tungsten belt is predominantly siliciclastic, with compositional ranges from blackshales to quartzophyllades and quartzites. Trinity Nyakabingo tungsten ore mine consists of metavolcanic and metasedimentary rocks, metamorphosed from their original basaltic and sedimentary forms. Cassiterite, the primary ore of tin, is found within quartz veins, pegmatites, and greisenized granite (SLR, 2024k).

The lithologies at Nyakabingo Mine are dominated by Quartz and Muscovite in varying proportions, with minor to trace minerals including Kaolinite, Augite and Microcline. Some of the host and country rocks like the Quartz Vein and Metasediments have been observed to contain minor pyrite (SLR, 2024k).

5.3.3 Hydrogeology

In the Nyakabingo ore deposit, three types of quartz veins have been observed: (1) small-folded bedding-parallel veins; (2) thick bedding-parallel veins and (3) crosscutting veins. The ore deposit is structurally controlled, and groundwater ingress into the mine workings is most likely also structurally controlled. The aquifers in the Nyakabingo concession area, can be characterised as follows (SLR, 2024n):

- Weathered Aquifer: A shallow, unconfined aquifer formed in the upper 5–30 m of weathered sandstone and shale, with low to moderate water-bearing capacity.
- Primary Alluvial Aquifer: Found along the Nyakabingo River and streams, composed of gravel and sand with moderate to high aquifer parameters, recharged by surface water inflow.
- Secondary Fractured Aquifer: A deeper semi-confined aquifer in unweathered shale and quartzite, where groundwater flows through fractures; typically low to moderate, but occasionally, high aquifer parameters.

Groundwater recharge is estimated at 3% of the MAP (1 200 mm/annum). The groundwater flow mimics the topography and is generally towards the valleys. The groundwater quality is generally good and only a few parameters exceeded the guideline limits. However, the slight acidity of the water causes the metal concentrations to be elevated. The variables of concern included aluminium, iron and manganese (SLR, 2024n).

5.3.4 Biodiversity

The Nyakabingo concession area incorporates two terrestrial ecoregions, namely the Victoria Basin Forest-Savanna Mosaic and Albertine Montane Forest ecoregions. However, based on site observations, the concession area is not representative of the typical vegetation types of these ecoregions and only contains modified and severely degraded vegetation types. Due to the various human activities (mining, subsistence farming, encroachment of alien invasive plant), the concession area has limited biodiversity value and limited potential to support SCC. Two bird SCC that are predicted to occur in low numbers are Hooded Vulture (*Necrosyrtes monachus)* and Bateleur (*Terathopius ecaudatus).* While these species are able to utilise anthropogenic environments for foraging, they are unlikely to breed within the concession area. It is worth noting that, due to the intensity and extent of habitat degradation from human activities, other expected SCC are unlikely to occur in the area (SLR, 2024o).

In terms of aquatic biodiversity, Nyakabingo concession area falls within the Lake Victoria Basin Freshwater Ecoregion which is classified as 'Globally Outstanding'; the global conservation status is classified as 'Critical'; and conservation priority is classified as 'Very High'. Four aquatic ecosystem types occur with concession area, namely*, hillslope seeps, mountain headwater* (source of the Nyakabingo River), *mountain stream* (Nyakabingo River) and the *artificial pollution control dams* (Nepid Consultants, 2024c).

Despite the conservation importance of the aquatic resources of the Lake Victoria Basin Freshwater Ecoregion, the ecological conditions of aquatic ecosystems within the concession area are considered degraded (Nepid Consultants, 2024c). No benthic diatoms or algae were recorded in the Nkayabingo River. The river was depauperate in macroinvertebrates with only one fly larvae specimen recorded; moreover, no fish were recorded despite the presence of suitable flow conditions. These findings were attributed to acid mine drainage and elevated concentrations of suspended material associated with subsistence cultivation. Consequently, the system was classified as 'Critically modified'. Conversely, the mountain headwater site recorded eight macroinvertebrate taxa, and one species of acidophytic red algae *Kumanoa rwandensis* (Batrachospermaceae). This site was classified at 'Moderately modified' (Nepid Consultants, 2024c).

The overall habitat integrity of the Nkayabingo River was rated as 'Seriously modified' with the key drivers of this condition being acid mine drainage, critical deposition of sediments, critical removal of riparian vegetation, and serious infestation of alien vegetation (Nepid Consultants, 2024c).

A very limited number of wetlands occur within the concession area, with the majority of the wetlands being small flood benches or hillslope seeps along the Nyakabingo River. The only major wetland is at the southern extreme of the concession area and is associated with the Nyaburongo River floodplain. All wetlands have been cultivated, either currently or historically, and are typically characterised by crops or disturbance tolerant vegetation. One small semi-recovered wetland was noted along the banks of the Nyaburongo River and was dominated by *Cyperus latifolius* (GroundTruth, 2026).

There are no protected areas, key biodiversity areas, important bird and biodiversity areas, or Ramsar wetland sites, in close proximity to the Nyakabingo Mine, which might pose as sensitive ecosystem receptors (SLR, 2024o).

5.4 Social Aspects

The majority of Nyakabingo concession area falls within the Shyorongi Sector, with a small portion located within the Rusiga and Ngoma Sector to the north and the Kanyinya Sector to the east, of the Rulindo District of the Northern Province. Combined, these make up 2.7% of Rwanda's population, and 17.7% of the province. Close to 90% of households are rural in nature, and heavily reliant on agricultural activities (crop cultivation 79.3%, livestock 66.3% and horticulture 67.4%) as part of their livelihood strategies (Barbour, 2024c).

At Nyakabingo Mine, the mining activities are located in the Mwagiro village area, which is located at the head of the Nyakabingo River. Extensive tailings material from historic and current mining fills the head of the valley, and legacy tailings have washed down the valley and impacted on the Nyakabingo River (Barbour, 2024c). Other villages falling within the mine concession area include Nyarurama, Bugarura, Taba, Nyabisindu, and Nyamirembe villages. Communities within the Nyakabingo Mine concession area rely on natural springs and communal water collection points for domestic and agricultural use (GroundTruth, 2025c). The spring at Kirikumuryango is the critical source of safe drinking water feeding the formal water distribution network on the eastern side of the valley, whilst villages immediately downstream of the mine and on the western slopes continue to rely directly on natural springs, some of which are at a risk of contamination due to their proximity to mining activities (GroundTruth, 2025c).

The land uses for the first 3 km downstream of the mining operations, located in the Mwagiro and Bugarura village areas, consist of scattered subsistence agricultural homesteads and associated agricultural plots located on both sides of the river. The primary crops grown include bananas, beans, potatoes, sweet potatoes, and maize (Barbour, 2024c). While most cultivation occurs on hillslopes, agricultural fields in the southern part of the concession area are located within the Nyakabingo floodplain. In the northern river section, cultivation is limited due to significant tailings, waste material, and steep slopes (SLR, 2024m). The village areas of Rutonde, Nyabisindu and Rweya are located at the bottom of the valley. These village areas are more urban than the upstream village areas. The Shyorongi TVET school is located in the Gatwa village area on the western side of the valley (Barbour, 2024c; SLR, 2024l). Sensitive air quality receptors within 1 km of the mine include schools, a place of worship and a health centre (SLR, 2024l).

The Nyakabingo Mining Concession area has been affected by unauthorised mining activities. This is linked to several factors including the long history of mining in the area, which dates to the 1950s. Unauthorised mining is therefore an established activity within areas like Nyakabingo that have a long history of mining and is viewed by many community members as normal and acceptable (Barbour, 2024c). At the time of reporting, there appeared to be limited evidence of informal mining in the area downstream of the mining area. The informal mining is likely to be limited to panning and sluicing tailings material washed down the river (Barbour, 2024c).

5.5 Conceptual Site Model

The following section describes the three main components of the CSM, comprising potential sources, pathways and receptors of possible contamination emanating from the mine areas. These are outlined in **Figure 5-2.**

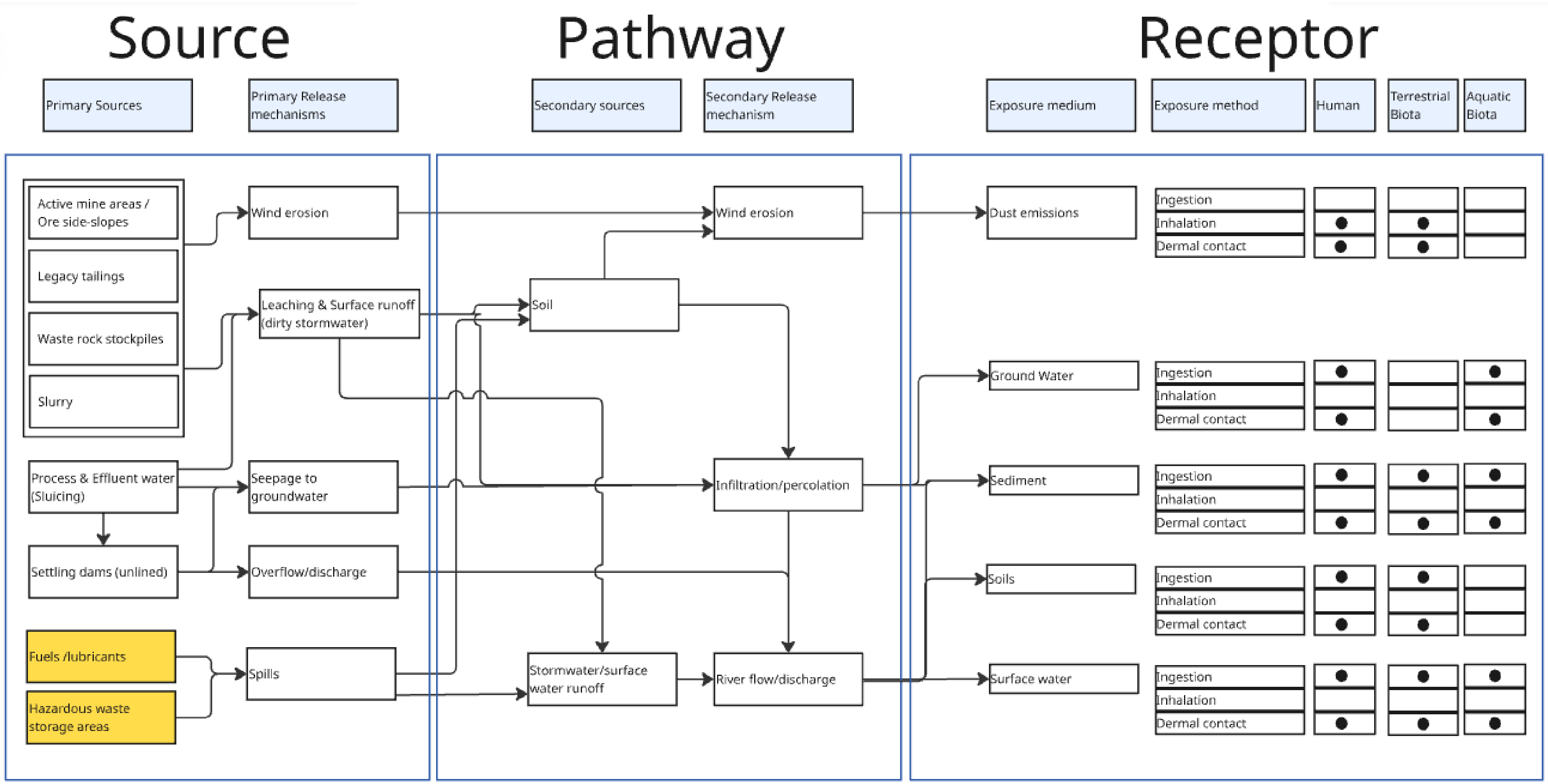

Figure 5-2 **Conceptual Site Model for Trinity Nyakabingo Mine showing the predicted migration pathways of contaminants from source to receptors (Yellow = Unconfirmed)**

5.5.1 Sources

Fugitive emissions – Mining operations are known to generate fugitive emissions through mechanical operations and wind erosion of waste rock and tailing stockpiles, which include particulates of varying size fractions, and gaseous emissions from the combustion of fossil fuels in heavy machinery/equipment and vehicles (haulage trucks). Ambient air pollutants of relevance in this context include particulates ($PM_{2.5}$ and PM_{10}), and gases (SLR, 2024l).

Ore, waste rock, slurry and legacy tailings – Materials discarded from the adits flow down via formal and informal channels to the D1 and into the D2 Settling Dams. Due to the lack of formal stormwater infrastructure, dirty run-off from the site is discharged into the Nyakabingo River from the D2 Settling Dam. In addition, uncontrolled placement of waste rock material and tailings result in downward dispersal of these materials (SLR, 2024l, 2024m)).

Mine impacted / process water / Effluent – Nyakabingo Mine is not a closed circuit[10], with water being discharged to the Nyakabingo River via the D2 Settling Dam and the D3 Return Water Dam when it overflows. Sluicing and panning effluent and other mining process waters flow down to the D1 and D2 settling dams. These dams are unlined storage dams with known [groundwater] seepage losses (SLR, 2024m).

*There is potential for some hydrocarbon contamination related to drilling machine operations at the mining face as well as minor spillages from mobile machinery (e.g. Bobcat loaders). The use of pumps by informal mining activities is also a potential source. However, no monitoring data are available for hydrocarbons, and related substances (Daneel *pers. comm*, 2026).

5.5.2 Pathways

Wind dispersal – Wind facilitates horizontal dispersion of fugitive emissions and dust. Higher wind speeds will move pollutants away from the source more quickly, while low wind speeds can result in air pollution stagnation and high ambient concentrations (SLR, 2024l).

Surface water runoff – While (informal) stormwater management infrastructure is in place, Nyakabingo Mine does not operate as a closed circuit. Surface water runoff from exposed ore, waste stockpiles, and legacy tailings, together with impacted mine and process water, flow down to the D2 Settling Dam, where it is discharged directly to the Nyakabingo River. Water from the D3 Return Water Dam is also discharged to the river when it overflows (SLR, 2024m). Activities in the upper catchment and from the surrounding community (agriculture, livestock), as well as other instream activities (aggregate mining) can contribute to degraded water quality, in addition to mining activities.

Groundwater infiltration – Host rock minerology contributes to background levels of metals and other potential contaminants. Seepage of mine impacted/process water contained in the unlined settling dams may lead to contamination of groundwater. This is exacerbated by the absence of formal stormwater management infrastructure. In turn groundwater contamination may lead to contamination of the Nyakabingo River, as the baseflow of this system is groundwater-dependent (SLR, 2024m, 2024n). Dilution of contaminants may occur upon reaching river systems or water bodies, or via groundwater recharge. Other contaminants, e.g.

[10] Water from flooded underground areas and contained run-off are not reused in mining processes.

nitrates, can undergo biochemical transformation (denitrification) and degradation become no longer toxic.

5.5.3 Receptors

Human population – This includes mine workers and the surrounding communities in close proximity, in particular communities who utilise water resources within concession area for drinking, domestic use, agriculture and livestock watering. At elevated concentrations, contaminants can be harmful to humans primarily through ingestion/drinking. Factors that can influence whether contaminant exposure in drinking water will lead to adverse health effects include the type of contaminant, its concentration, individual susceptibility, the amount of water consumed, and the duration of exposure. Other exposure media include direct dermal contact, inhalation of contaminants, as well as through ingestion contaminated crops and other food items (e.g. fish). Children and the elderly are the most vulnerable to health complications caused by contaminants, especially in rural communities where health facilities are often undeveloped or located in major centres (Sustainability Directory, 2025).

Aquatic ecosystems – These include rivers, few wetlands and related biodiversity within the concession area, and further downstream, specifically the Nyakabingo River[11]. Factors that can influence whether contaminant exposure will lead to adverse health effects for aquatic biota include the type of contaminant, its concentration (as a factor of river flow), sequestration within river sediments, species-specific sensitivity to pollution, and the duration of exposure. Moreover, freshwater ecosystems, especially wetlands, can act as a sink for contaminants, which can then accumulate to toxic levels (GroundTruth, 2026).

Terrestrial ecosystems – These includes remaining vegetation and associated biodiversity within the concession area or immediately adjacent. Terrestrial organisms (flora and fauna, including domestic livestock), can be exposed to contamination through soil uptake (plants) and ingestion of drinking water, soil and plants, dermal contact or inhalation of contaminants. The same factors influencing contamination exposure also apply to terrestrial organisms.

5.6 Risk Assessment

5.6.1 Air emissions

The following findings are extracted from the specialist Air Quality report (SLR, 2024l) :

- Exceedances of EAS 2021 and WHO AQG 2021 24-hr average limits were noted for PM_{10} (12.5% of records) and $PM_{2.5}$ (62.5% of records). Two readings were anomalously high.
- Survey average NO_2 and SO_2 concentrations were well within the EAS 2021 and WHO AQG 2021 annual limits for gaseous emissions.

[11] Water quality results confirm that there are no transboundary impacts to the Nyabarongo River further downstream (SLR, 2024m).

5.6.2 Mine materials

The following findings are extracted from the specialist Geochemistry and Geochemical Soil/Sediments report (SLR, 2026c, 2024k) :

The Nyakabingo mine materials were classified as having an overall low risk for long term acid rock drainage. However, due to the total lack of neutralising minerals in the local lithologies (like sulphides or carbonates), even small amounts of sulphide minerals present in the (in situ) host rock and extracted materials yield immediate risk of acidic effluent leaching from the site (SLR, 2024k).

- Aluminium, manganese, nickel and sulphate in leachate and/or effluent exceeded the WHO Guidelines for Drinking Water (2022) limit.
- When comparing the metal leaching potential of the four Nyakabingo mine materials, the slurry and waste rock material present the greatest risk, both of which infer the mobility of metals[12] like aluminium, arsenic, cadmium, copper, iron, manganese, nickel, uranium, zinc and sulphates.
- To a lesser extent, the legacy tailings materials have the potential to leach aluminium, arsenic, cobalt, iron, manganese, and nickel, with the ore materials reporting only elevated manganese in the leachate.
- Updated sampling of the legacy tailings in July 2025 (SLR, 2026c), confirmed the exceedance of manganese in terms of WHO Guidelines for Drinking Water (2022) and RS irrigation limits, and pH in terms of IFC and RS Livestock standards indicating a risk for metal leaching under acidic conditions.
- Manganese is indicated as a source term for predicting contamination of surface and groundwater resources.
- For process and effluent water, parameters that exceeded various limits included: aluminium, arsenic, cadmium, cobalt, copper, iron, lead, manganese, nickel, zinc, uranium, total dissolved salts, nitrate, sulphate, and pH.
- The elevated nitrate levels can be directly linked to the use of ammonium nitrate explosives in the extraction process, and will decrease in groundwater via biochemical processes.
- The mine process water becomes more degraded and acidic as the water moves through the operational areas and concentrates in the return water dam.
- At the settling dam, which represents the collective effluent signature of the Trinity Nyakabingo mine site, the water was highly acidic (pH 2.9), composed of low-quality effluent water with several metal and ion exceedances of local and international guidelines.

[12] This is primarily due to the mineralogy composition, where the mining materials are not classified as having long-term acid-generating potential; however, due to some pyritic mineralogy associated with the local host and country rocks, coupled with a lack of neutralising carbonates, the mining materials are directly responsible for the acidification and elevated metal concentrations of the effluent waters found at the site (SLR, 2024k).

5.6.3 Groundwater

The following findings are extracted from the specialist Geochemistry, Hydrogeology and Hydrology reports (SLR, 2024k, 2024m, 2024n):

- The springs that village members use for drinking water exhibited exceedances of the WHO Guidelines for Drinking Water, 2022 limits, namely the Mwagiro - Bugarura village spring (site NYK CM SP1 – 1.5 km downstream and not directly impacted by mining activities), which has elevated levels of arsenic (and aluminium), and the Mwagiro-Gatwa village spring, which has elevated aluminium and manganese (site NYK CM SP2). Sodium exceeded the Rwanda livestock watering limits.
- Overall, the groundwater quality was found to be generally good with only a few parameters exceeded the WHO Drinking Water Limits and the livestock watering limits.
- Slight acidity of the water causes the metal concentrations to be elevated. The variables of concern in terms of fitness for human consumption included aluminium, iron and manganese**.**
- The presence of aluminium, iron, nickel, copper, arsenic and manganese in the groundwater may be attributed to the geological composition of the host rock. Current concentrations are only marginally above the limits and thus considered natural.
- With the exception of water from adit BV21, mine water quality was very good with no parameter exceedances.
- Adit BV21 exhibited poor water quality with several metal exceedances indicating the minerology in this adit is impacting the quality of tunnel water at the site.
- Upgradient groundwater water quality was within acceptable limits for drinking water, effluent, livestock watering and irrigation.

Potential groundwater contamination

- All the potential contaminant sources are close to the Nyakabingo River and seepage from these sources will flow into the river.
- In most instances the slurry material, followed by the tailings, pose the biggest threat to the environment due to the apparent higher leachate potential.
- The seepage concentrations, based on the geochemical assessment, are expected to be above the guideline limits. The impact from the waste bodies is therefore considered to be moderate to high, if left unmanaged.
- Migration of the contaminant plume is restricted to the Nyakabingo River valley and will likely contribute to the river's mass load.
- There is very little difference in the contaminant plume (based on 0.3 mg/L concentration) between the LOM and 50 years after closure (255 m compared to 260 m downstream). This is attributed to the plume's interaction with the river and dilution.

5.6.4 Surface water

The following findings are extracted from the specialist Hydrology report (SLR, 2024m).

- Overall, runoff from waste rock material, ore, legacy tailings, slurry, and process water contribute to the contamination of groundwater and surface water resources in the Nyakabingo concession area.

- Downstream of the mine, reduced pH and increased concentrations of arsenic, lead, manganese, and uranium, are harmful for human consumption.
- The arsenic and copper concentrations downstream of mine are considered toxic for livestock watering.
- The sodium and chloride concentrations downstream of the mine pose a severe problem for crop yield.
- Nitrates and pH pose an increasing problem for crop yield.
- Excessive total suspended solids concentrations were recorded downstream of the mine, which is problematic for aquatic fauna.

The physical and chemical indicators of the water samples from the mine settling dam (which discharges to the Nyakabingo River) show that the Nyakabingo Mine contributes to the degradation of the downstream water quality within the Nyakabingo River (SLR, 2024m).

Results of a sampling point on the Nyakabingo River, approximately 4.7 km downstream of the mine and on the Nyabarongo River indicated exceedances of manganese and lead in terms of the WHO Guidelines for Drinking Water (WHO 2022). There is a notable reduction in manganese moving downstream, thus mining-related activities associated with the Nyakabingo Mine do not have a transboundary effect. In addition, supporting data indicate that there are external factors influencing the water quality (lead) of the Nyabarongo River (SLR, 2024m).

5.6.5 Sediments and Soils

The following findings for Nyakabingo Mine are extracted from the specialist Geochemical and Soil / Sediment Assessment (SLR, 2026c).

River sediments

- The sand fraction in the river sediments of the Nyakabingo River mainstem from two sites downstream of the Nyakabingo Mine, was nearly double than the control site (side stream), indicating alteration of the hydrological functioning of the river system due to activities occurring at Nyakabingo mine, informal mining and aggregate mining activities further downstream.
- Due to the presence of Hematite, Kaolinite and Muscovite in the sediments, they have capacity to sequester metals and metalloids mobilised by historic and current mining activities. The sediments are thus likely to show an enrichment / accumulation of various metals.
- In terms of various water quality and effluent guidelines, the side stream sediment sample exhibited exceedances of arsenic, lead, iron and manganese, whereas the midstream and downstream samples both had exceedances of cobalt, copper, manganese, nickel, and pH; and arsenic in the midstream sample.
- Overall, more exceedances were recorded in the mainstem river samples indicating that the river below the mine footprint has likely been impacted by mining activities. The exceedances are likely attributed to the acidic pH of these samples.
- In terms of potential contamination and comparison against soil screen values (SSV1), all samples exhibited exceedances of arsenic, copper, and lead, with mercury also exceeding the limits in the two mainstem samples.

- Metal exceedances reported for the side stream sample indicates likely impacts from agriculture as opposed to mining activities. Whereas, the mid-stream and downstream sediments the higher metal concentrations and more exceedances can be attributed to historic and current informal mining activities, and runoff from the mine footprint.
- Significant metal enrichment and potential contamination was noted for arsenic and boron in the side stream sediment, and mercury and selenium in the two mainstem sediment samples. The latter exhibited extreme enrichment and likely contamination by arsenic and tungsten.

Soils

- Soil downstream of the Nyakabingo Mine were classified as a Ferralsol, which is formed from intense weathering and has limited capacity to remediate metal leaching and acid rock drainage.
- Organic carbon content was low and the lack of high activity clay minerals infers limited acid buffering capacity and thus soil that is prone to acidification and nutrient leaching.
- Soil was acidic ($pH<6$) with reduced availability of essential nutrients, but increased availability of trace and heavy metals, therefore the potential risk of phytotoxicity. The soil is prone to leaching and has limited pH buffering capacity.
- In terms of nutrient status, the soil is characterised by relatively low proportions of phosphorous and potassium. The magnesium content was suitable and within the range ideal for most crops. No excessive trace metal content was detected, therefore presenting low phytotoxicity risk.
- In terms of potential contamination and comparison against soil screen values (SSV1), the Nyakabingo soil exceeded the limit for copper. It is suggested that elevated copper content is derived from the mineralogy of the parent material, and not necessarily due to mining activities impacting the downstream areas.

The above findings of the specialist reports are integrated into quantitative risk assessment for the Nyakabingo Mine (**Table 5-1**).

Table 5-1 Summary of Environmental Risks Associated with Nyakabingo Mine

Source	Potential Contaminants*	Pathway	Receptor	Severity**	Likelihood	Risk
Fuel Combustion	NO_2 SO_2	Wind erosion / dispersal	Workers / Communities	MINOR - No exceedances recorded	LIKELY – Workers engaging in mining activities, proximity of access roads	LOW
Ore stockpile *Waste Rock* *Slurry* *Legacy Tailings*	PM_{10} $PM_{2.5}$		Workers / Communities	HIGH - PM_{10} and **$PM_{2.5}$** exceedances, particularly $PM_{2.5}$, at key points on site and in surrounding communities	HIGHLY LIKELY – Workers engaging in mining activities, proximity of communities and sensitive receptors	VERY HIGH
Ore stockpile *Waste Rock* *Slurry* *Legacy Tailings*	Aluminium Arsenic Cadmium Cobalt Copper Iron Lead Manganese Nickel Uranium Zinc TDS Sulphates pH	Groundwater seepage	Communities	HIGH - As, **Al**, Mn, **pH** exceedances (WHO, 2022) in <u>spring water</u>	HIGHLY LIKELY - Spring water is the primary source of water for domestic use and livestock watering. *(Mwagiro - Bugarura spring reportedly not directly influenced by mining activities)*	VERY HIGH
				HIGH – **Al, As, Cu, Fe, Mn, Ni, Pb, pH** exceedances (WHO, 2022) in <u>tunnel water</u> (Adit BV21)	UNLIKELY – Tunnel water not used by communities directly. Spring water is the primary source of water for domestic use and livestock watering.	MOD/ LOW
			Livestock	HIGH – **Cu, Fe, Mn, Pb,** NO_3, **pH** exceedances (RS 190) in tunnel water	LOW LIKELIHOOD – Tunnel water not used by communities directly. But discharged to the settling dams, and into Nyakabingo River. River used for livestock watering on ad hoc basis. Livestock is mobile and may not necessarily drink water from the river immediately downstream of the mine continuously. Contaminants are subject to dilution.	MOD

Source	Potential Contaminants*	Pathway	Receptor	Severity**	Likelihood	Risk
Mine Impacted / Process Water / Effluent	Aluminium Arsenic Cadmium Copper Iron Lead Manganese Nickel Uranium Zinc Sulphates Nitrates TDS pH		Crops	HIGH – **As**, Cd, **Co**, **Cu**, **Mn**, Ni exceedances (RS188) in tunnel water (BV21)	UNLIKELY – The Nyakabingo River is utilised for crop irrigation, but crop fields are located approximately 4 km downstream of the mine site. Contaminants are subject to dilution.	MOD/ LOW
			Aquatic Ecosystem	LOW – **pH**, **As, Cd, Cu, Ni, Pb, NO_3** exceedances (RS 564, EAS 1172) in tunnel water (BV21). Health of the Nyakabingo River is 'Seriously-Critically modified', bearing low sensitivity.	HIGHLY LIKELY - Excess mine water from the underground workings is discharged to the settling dams, and into Nyakabingo River at the headwaters. Groundwater also contributes to river baseflow.	MOD
		Surface water runoff /discharge	Communities	HIGH - **As, Pb, Mn, U, pH** exceedances (WHO, 2022).	LOW LIKELIHOOD – Spring water is the primary source of water for domestic use. Dirty stormwater and effluent are discharged to the settling dams, and into Nyakabingo River. River used on an *ad hoc* basis.	MOD
			Livestock	HIGH – **Al, As, Cu, Fe, Mn,** exceedances (RS 190).	LOW LIKELIHOOD – Dirty stormwater and effluent are discharged to the settling dams, and into Nyakabingo River. Livestock utilise rivers for watering. Livestock is mobile and may not necessarily drink water from the river immediately downstream of the mine continuously.	MOD

Source	Potential Contaminants*	Pathway	Receptor	Severity**	Likelihood	Risk
			Crops (soils)	HIGH – **Cu, Mn**, NO_3 **Na**, Cl are severe for crop yield. NO_3, pH are increasing problems for crop yield. Cu (SSV1), acidic pH. Soil has inherent limited pH buffering capacity, prone to acidification and leaching.	LOW LIKELIHOOD – Dirty stormwater and effluent is discharged to the settling dams, and into Nyakabingo River. The Nyakabingo River is utilised for crop irrigation, but crop fields are located approximately 4 km downstream of the mine site. Contaminants are subject to dilution.	MOD
			Sediments	LOW – **As** (WHO 2022), **Co**, **Cu**, **Mn, Ni** (RS 188, RS 190), pH (RS 109) exceedances. **As, Cu, Pb, Hg** (SSV1). Significant metal enrichment by **Hg** and **Se**, extreme enrichment by **As** and **W.** Health of the Nyakabingo River is 'Seriously-Critically modified', bearing low sensitivity.	HIGHLY LIKELY – Dirty stormwater and effluent is discharged to the settling dams, and into Nyakabingo River. River sediment showing high metal concentrations and enrichment.	MOD
			Aquatic Ecosystems	LOW – As, Pb, Mn, pH, NO_3 exceedances (RS 564, EAS1172) Health of the Nyakabingo River is 'Seriously-Critically modified', bearing low sensitivity.	HIGHLY LIKELY – Dirty stormwater and effluent are discharged to the settling dams, and into Nyakabingo River.	MOD

* Potential contaminants based on geochemical analyses.

** Based on contaminants measured in pathway component (i.e. groundwater or surface water). Elements in **bold** represent very high exceedance that is at least double the limit. WHO (2022) Guidelines for drinking water; RS 109 (2009) Effluent standard; RS 188 (2013) Irrigation use; RS 190 (2013) Livestock watering; IFC (2007) Mining effluent guidelines, RS 564 (2023) Ambient water, RS EAS 1172 (2024) Water discharged into the environment.

6. CLIMATE CHANGE CONSIDERATIONS

It is important that climate change predictions are considered in the assessment of risk since changes in different climate variables and associated hazards may affect the different components of the contamination linkages and thus alter potential risk profiles. For each mining concession area, climate change predictions were established for the two climate scenarios[13] (i.e., SSP1 – best case scenario and SSP5 – worst-case scenario) and two periods, namely the near-term (2014-2039) and medium-term (2040-2059). These predictions, as presented by the specialist Climate Change report for the respective concession areas (SLR, 2024p, 2024q, 2024r) are summarised below.

Musha/Ntunga Mine

- **Mean annual temperature -** projected to increase by on average 4.8% to 4.9% in the near term, and 6.8% to 10.0% in the medium-term, relative to average of 20.86°C for the baseline period.
- **Number of very hot days (> 35°C) -** projected to remain unchanged, both in the near term and in the medium-term, relative to maximum for the baseline period.
- **Mean annual rainfall -** projected to increase by on average 1.0% to 2.8% in the near term, and 1.4% to 4.9% in the medium term, relative to the average of 1,083.76 mm for the baseline period.
- **Maximum daily rainfall -** projected to increase by on average 7.0% for the SSP1 scenario and increase by 10.4% for the SSP5 scenario, relative to the average of 16.59 mm for the baseline period. In the medium term, maximum daily rainfall is projected to increase by an average 7.4% for the SSP1 scenario and increase by an average 14.4% for the SSP5 scenario, relative to average for the baseline period.

For the Musha/Ntunga concession area (SLR, 2024q), acute physical risk associated with wildfires was rated as (negative) medium, as well as transitional risk associated with growing global concern over negative impacts associated with transition metals. Acute physical risks associated with flooding and overtopping of control dams, and landslides, and chronic risks related to water scarcity were rated as (negative) low. Market-related risk from increasing demand for transitional metals was rated (positive) medium (SLR, 2024q).

Rutongo Mine and Nyakabingo Mine (SLR, 2024p, 2024r):

- **Mean annual temperature -** to increase by on average 5.6% to 5.8% in the near term, and 8.1% to 11.8% in the medium-term, relative to average of 17.73°C for the baseline period.
- **Number of very hot days (> 35°C) -** projected to remain unchanged, both in the near term and in the medium-term, relative to maximum for the baseline period.

[13] Shared Socio-economic Pathways (SSPs) represent different global policy responses to climate change. SSP1 represents sustainability and SSP5 fossil fuelled development, as per climate model comparisons in the Intergovernmental Panel on Climate Change – Sixth Assessment Report (IPCC, 2021) (SLR, 2024r).

- **Mean annual rainfall -** projected to increase, by on average 1.3% to 3.6%, in the near term and 1.7% to 5.4% in the medium term, relative to the average of 1,962.76 mm for the baseline period.
- **Maximum daily rainfall -** projected to increase by an average 5.7% for the SSP1 scenario and increase by 11.4% for the SSP5 scenario in the near term, relative to the average of 28.94 mm for the baseline period. In the medium term, maximum daily rainfall is projected to increase by an average 6.7% for the SSP1 scenario and increase by an average 16.4% for the SSP5 scenario, relative to average for the baseline period.

For these concession areas, acute physical risks associated with wildfires, flooding and overtopping of control dams, and landslides were rated as (negative) Medium. Transitional risk associated with growing global concern over negative impacts associated with transition metals, was rated as (negative) Medium, whilst market-related risk from increasing demand for transitional metals was rated (positive) Medium (SLR, 2024r, 2024p).

Based on the above the assessments, all three concession areas will experience increases in mean annual temperature, mean annual rainfall and maximum daily rainfall. Increased rainfall will contribute increased surface runoff at the sites. This could lead to increased contamination opportunities arising from leaching from ores, waste rock, and legacy tailings, dirty stormwater from active mining areas and processing areas, and overflow from settling dams. The magnitude and extent of negative environmental impacts may therefore potentially increase but may also be offset to some degree by dilution in the receiving waterbodies or watercourses.

Groundwater recharge and ingress to the underground areas will not be immediate as for surface runoff. However, increases in groundwater will in turn require additional offtake to maintain access to key work areas. This will in turn result in increased discharge to respective settling dams and the natural environment, and subject to some dilution, with potential negative consequences for the receiving waterbodies and watercourses, and ultimately water users.

7. CONCLUSION

Trinity Metals is in the process of developing a Legacy Tailing Management and River Rehabilitation Programme encompassing three mining concessions in Rwanda, namely Musha/Ntunga Mine, Rutongo Mine, and Nyakabingo Mine. As part of Phase 1 of this process, a Source-Pathway- Receptor (SPR) analysis was commissioned to understand the environmental risks linked to historical, current, and informal mining activities across the concessions. The findings of this SPR assessment will serve as an essential guide for prioritising future management actions aimed at effective rehabilitation and the restoration of surrounding ecosystems.

Following a review of the baseline ESIA specialist assessments, a CSM was developed for each concession. The CSMs include several potential pollutant linkages. Using data contained in the specialist reports collected through various sampling surveys, Tier II generic quantitative risk assessments were subsequently conducted.

The outcomes of the risk assessments, which identified high to very high environmental risks and consequently deemed areas of concern, are summarised below.

7.1 Musha/Ntunga Mine

Musha Mine

The critical sources of contamination are:

- stockpiles of ore and waste rock and physical mining activities producing fugitive emissions, and
- ore stockpiles and legacy tailings specifically for manganese-enriched leachate, and the latter including acidic pH.

The critical pathways are:

- wind dispersal that transports harmful fugitive emissions within and beyond the active mining areas,
- groundwater seepage based on the interaction with the Bisinia Dam with metal exceedances detected for drinking water and crop irrigation, and
- surface water runoff carrying high concentrations of manganese, total dissolved salts (particularly sodium and chloride) and nitrates, and acidic pH.
- To note: groundwater and surface water results upstream of the mine site indicated water quality comprised by activities external to the mine.

The critical receptors are:

- workers and communities within close proximity of the mining activities who are at risk through inhalation of dust emissions,
- livestock due to utilisation of this resource for livestock watering,
- the Bisinia Dam due to utilisation of this resource by communities for domestic use, fishing, swimming and crop irrigation. Groundwater modelling demonstrates migration of the contaminant plume down-gradient toward the Bisinia Dam and Nyirabigaji River (contamination is unlikely to migrate as far as Lake Muhazi),
- crops via groundwater inputs to Bisinia Dam and surface/river water use specifically given that intensive agriculture upstream and downstream of the mine is dependent on the Bisinia Dam and its outflow, and susceptibility of soils to acidification, and
- river sediments downstream of the mine serving as a sink for catchment-derived (including mine-related) potential contaminants.
- To note: downstream river sediments indicate metal enrichment. Due to the moderate sensitivity of the aquatic ecosystem, the severity is rated as medium.

Ntunga Mine

The critical sources of contamination are:

- stockpiles of ore and waste rock and physical mining activities producing harmful fugitive emissions, and
- legacy tailings, specifically for manganese-enriched leachate.

The critical pathways are:

- wind dispersal that transports harmful fugitive emissions within and beyond the active mining areas, and

- surface water runoff carrying high concentrations of total dissolved salts (particularly sodium and chloride), and nitrates.
- To note: groundwater results upstream of the mine site indicated water quality compromised by activities external to the mine.

The critical receptors are:

- workers and communities in close proximity to mining activities who are at risk through inhalation of dust emissions, and
- crops downstream of the mine site due to dependency on the Gashahi River by subsistence farmers for irrigation purposes, and susceptibility of soils to acidification.
- To note: downstream river sediments indicate metal enrichment. However, due to the low sensitivity of the aquatic ecosystem, the severity is rated as low.

7.2 Rutongo Mine

The critical sources, pathways and receptors for each of the Rutongo Mine sites are summarised in **Table 7-1** below.

Table 7-1 Summary of identified pollution linkages at Rutongo Mines

Mine Site	Sources	Pathways	Receptors
Gisanze Mine	All mine materials Mine impacted water/ tunnel water and effluent	Groundwater with high metal concentrations for livestock (discharged direct to river) Surface water runoff carrying high metal concentrations	Livestock that utilise rivers (Rusine) for watering
Nyamyumba Mine	All mine materials	Wind erosion	Workers and communities at risk through inhalation of dust emissions
	All mine materials Mine impacted water/ process water/ effluent	Groundwater seepage with acidic pH and high metal concentrations Surface water runoff carrying high metal concentrations	Communities utilising nearby springs for drinking and domestic purposes Livestock that utilise rivers (Sanzari) for watering
Gasambya Mine	All mine materials Mine impacted water/ process water/ effluent	Surface water runoff carrying high metal concentrations and acidic pH	Livestock that utilise rivers (Kivomo) for watering

Mine Site	Sources	Pathways	Receptors
Karambo Mine	All mine materials	Wind erosion	Workers and communities at risk through inhalation of dust emissions
	All mine materials Mine impacted water/ process water/ effluent	Surface water runoff bearing acidic pH and manganese enrichment	Livestock that utilise rivers (Nyirabukingore) for watering
Mahaza Mine	Risks of contamination are rated as moderate or lower		
Masoro Mine	All mine materials Mine impacted water/ process water/ effluent	Groundwater seepage with high metal concentrations Surface water runoff bearing high metal concentrations	Communities utilising nearby springs for drinking and domestic purposes Livestock that utilise rivers (Umurindi) for watering

7.3 Nyakabingo Mine

The critical sources of contamination are:

- stockpiles of ore and waste rock and physical mining activities are producing fugitive emissions, and
- stockpiles of ore and waste rock, slurry and legacy tailings, which are directly responsible for the acidification and elevated metal concentrations of the leachate at the site.

The critical pathways are:

- wind dispersal that transports harmful fugitive emissions within and beyond the active mining areas,
- groundwater interacting with underground workings leading to contaminated tunnel water with metal exceedances detected for several guidelines, and
- surface water runoff carrying high concentrations of metals exceeding guideline limits and acidic pH produced from mining activities.

The critical receptors are:

- workers and communities within close proximity of the mining activities who risk through inhalation of dust emissions,
- communities utilising spring water within close proximity to the mine e.g. the Mwagiro-Bugarura community spring. This spring requires further investigation and monitoring,
- To note: downstream river sediments indicate metal enrichment. However, due to the low sensitivity of the aquatic ecosystem, the severity is rated as low.

It is evident from the intrusive site investigations that groundwater and surface water are contaminated to varying degrees across the concession areas. Contaminants including metals, acidic water and high suspended solids have been transported away from the mine sites into areas where communities, their crops and livestock, as well as aquatic ecosystems, are exposed to levels that are beyond acceptable limits, and therefore likely to impose toxic effects in the long term.

It is important to note, that the severity of mining impacts on aquatic ecosystems in terms of water quality was often rated as low. This is due to the highly degraded state of the rivers, including depauperate aquatic organisms and limited, poor-quality habitat resulting in overall low sensitivity to disturbance and contamination. An overview of natural landscapes within regional protected areas demonstrates the configuration or character of undisturbed riverine corridors, which has been critically modified in the concession areas. In a similar manner, the probability of exposure of communities to contaminated surface runoff or river water was often rated as low likelihood. This is largely due to the fact that communities are highly dependent on spring water because of the poor river water quality. River water is a secondary, or ad hoc resource, particularly during dry periods. Communities would be likely to utilise river water resources more, if the water quality was more suitable.

Notwithstanding the evidence of the impacts of Trinity Mines' operations, there are externalities that are compounding these impacts on the surrounding sensitive receptors. The local geology and parent lithologies are sources of naturally occurring metal-bearing minerals. Natural weathering of these materials results in elevated metal concentrations in groundwater, surface water resources, sediments and soils that are potentially above adopted human health and environmental guideline limits.

Significant agricultural activities are present throughout the mine concession areas, both upstream and downstream of many of the mine sites. Such activities entail land clearing of the protective natural vegetation cover and reworking of the soils rendering the exposed surfaces vulnerable to erosion, and mobilisation of metal-bearing minerals contained therein. This contributes to added enrichment of the river sediments and contamination of important water resources. More severe, however, are the impacts of fluvial sand and aggregate mining, specifically within the Rutongo concession area, which also contribute to metal mobilisation and enrichment. In addition, large-scale physical disturbance of the riverbed and banks results in high sediment loads, excessive turbidity, and elevated concentrations of dissolved substances in the water course compromising water quality, whilst riparian and instream modifications contribute to overall habitat loss of the riverine ecosystem.

In considering potential remedial activities, and in line with environmental best practise, management interventions and potential remedial activities should be considered within a pollution prevention hierarchy, that is, seeking to address contamination at the source and thereby preventing the initial release of contaminants (Novakowski et al., 2023). For legacy and abandoned mines, Novakowski et al. (2023) proposed the following pollution prevention hierarchy: source control, water management, treatment, and lastly, discharge to the environment. Further to this, the Network for Industrially Contaminated Land in Africa (NICOLA) (n.d.) outlines valuable considerations for each component of the SPR model to mitigate environmental risk. Preliminary remediation opportunities for Trinity Metals are provided alongside these considerations in **Table 7-2.** These opportunities would require detailed investigation as part of the development of the Legacy Tailing Management and River Rehabilitation Programme in respect to suitability and efficacy for site-specific conditions.

Table 7-2 Preliminary remediation opportunities to mitigate environmental risks

Component	Considerations	Remediation Opportunities
Source	• Sources can be stopped, isolated, relocated, or removed • Sources can be treated	• Relocation of inappropriately placed stockpiles, especially new material • Control of stockpile dispersion/ migration down-gradient • Coverage (vegetation) of legacy stockpiles • Use of Personal Protective Equipment • Wet-suppression of dust-emitting area • Treatment of process water /effluent • Lining of all storage dams
Pathway	• Pathways can be interrupted • Pathways can be eliminated	• Surface runoff interception (engineered stormwater management system) • Lining of all storage dams • Instalment of ecosystem-based interventions to intercept and polish surface runoff (constructed wetlands) • Enhancement of instream and riparian habitat along downstream reaches
Receptor	• Receptors can be protected and/or enhanced • Institutional controls can be applied • Receptors can be relocated	• Instalment of ecosystem-based interventions to intercept and polish river water (constructed wetlands) • Rehabilitation (revegetation) of riparian buffers

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9. APPENDICES

APPENDIX 1: STANDARDS

Air Quality Standards

- East African Standards (EAS): Air Quality Specification Guideline (2021)
- World Health Organisation (WHO) Air Quality Guidelines (AQG) (2021)

Water Quality and Effluent Standards

- EHS Mining Effluent Guidelines (2007): Applicable for the discharging of sluicing water and dirty stormwater into the downstream environment
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- World Health Organisation (WHO) Guidelines on Recreational use (WHO, 2021)
- World Health Organisation (WHO) Guidelines for drinking-water quality (WHO, 2022)
- Rwanda Standard EAS Potable Water Specifications (2018): For potable water intended for direct human consumption, domestic and industrial use (RS EAS 12: 2018)
- Rwanda Standard (2009): Effluent standard, specifies the limits for the discharge of treated industrial wastewater effluent into the environment (RS 109)
- Rwanda Standard (2013): Irrigation use, specifies the tolerance limits for water intended for irrigation purposes (RS 188)
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Environmental Standards

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- Rwanda Standard (2024): Water discharged on land and into water bodies - Specification (RS EAS 1172) (IDT)