

SOURCE PATHWAY RECEPTOR ANALYSIS – RUTONGO MINE

TRINITY METALS

FINAL





GroundTruth

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EXECUTIVE SUMMARY

GroundTruth was commissioned by Trinity Metals to perform a Source-Pathway-Receptor (SPR) analysis for three mining concession areas in Rwanda: Musha/Ntungwa, Rutongo, and Nyakabingo. This study for the Rutongo concession area 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, utilising a Tier II Generic Quantitative Risk Assessment. 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). Risk was classified based on the likelihood of exposure and the severity of consequences, ranging from "Very Low" to "Very High".

The Rutongo concession area is characterised by extensive legacy issues across the six mine sites and significant interference from unauthorised (informal) mining and aggregate mining. Nyamyumba and Gasambya mines present the highest risk for metal leaching (arsenic, lead, and manganese) and exhibit the most acidic pH levels. The following High and Very High environmental risks were identified and require urgent intervention, while moderate risks should be addressed in the medium to long term:

- **Gisanze Mine:**
 - **Very High Risk:** Identified for **livestock watering** and the **aquatic ecosystem and sediments** of the Rusine River due to direct discharge of groundwater (mine water) from adits and contaminated surface runoff containing elevated metals (lead, manganese, iron) and non-conductive pH levels.
 - **High Risk:** Assigned to **communities** and **livestock** due to ad hoc use of river water and discharge containing aluminium, arsenic, iron, lead and manganese.
- **Nyamyumba Mine:**
 - **Very High Risk:** Assigned to **community springs** (e.g., Kabuga spring) due to arsenic exceedances and to the **Sanzari River aquatic ecosystem** and **river sediments** due to high concentrations of lead, manganese and iron, suspended solids, and acidic pH, and extreme arsenic enrichment, respectively.
 - **High Risk:** Identified for **air quality** (PM₁₀ and PM_{2.5}) impacting surrounding **communities** and for **communities** and **livestock** from use of the Sanzari River that contains aluminium, arsenic, iron, lead and manganese exceedances and acidic pH.
- **Gasambya Mine:**
 - **Very High Risk:** Found for **community springs** (lead and manganese exceedances), **aquatic ecosystems**, and **river sediments** (arsenic enrichment)

because the site is not a closed system and discharges mine water direct to the Kivomo River.

- **High Risk:** Noted for **communities** and **livestock** utilising surface water impacted by arsenic, lead, and manganese.
- **Karambo Mine:**
 - **Very High Risk:** Assigned to the **aquatic ecosystem** and **river sediments** of the Nyirabukungore River due to the discharge of collective mine water bearing high metal concentrations and TSS, and metal enrichment of the sediments.
 - **High Risk:** Identified for **air quality** (PM_{2.5}), **communities** (aluminium and manganese exceedances and acidic pH in tunnel water, and ad hoc use of Nyirabukungore River), and **livestock watering** at the river.
- **Mahaza Mine:**
 - **High Risk:** Primarily associated with **communities** and **livestock** utilising the Rusine River, where surface water runoff contains arsenic, lead, and manganese exceedances and acidic pH.
 - **Note:** While the site operates as a closed circuit, overtopping of dams during high rainfall remains a concern. The lower Rusine River is expected to be less sensitive to environmental disturbance (i.e. more resilient).
- **Masoro Mine:**
 - **Very High Risk:** Identified for **community springs** due to groundwater seepage containing exceedances of aluminium, iron, lead and manganese.
 - **High Risk:** Found for **livestock watering** (groundwater input), and **river sediments** and **aquatic ecosystem of the Gatiti/Umurinidi Rivers** due to potential overtopping of the storage dam, and evidence of high metal and suspended solid concentrations.

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 mine materials and excess mine water in underground workings.

While Trinity Metals' operations at Rutongo Mine contribute to environmental degradation, impacts are compounded by externalities, including natural geological background levels, intensive agriculture, and authorised/unauthorised aggregate mining.

Remediation will likely be required in both the short- and long-term, focussing on various aspects at each site. High-level remediation recommendations, which require detailed investigation for site-specific suitability and efficacy, broadly include source control, pathway interruption and receptor protection, as well as institutional collaboration and alignment. The mines were prioritised according to their overall risk and where remediation is thus urgently required (in order of highest to lowest priority): Nyamuyumba, Gasambya, Karambo, Gisanze, Masoro and Mahaza.

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 in the Rutongo mining concession area.

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LIST OF ACRONYMS

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

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 the provided 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 at its three mining concession areas namely, Musha/Ntunga Mine, Rutongo Mine and Nyakabingo Mine located in Rwanda (**Figure 1-1**). All three mines possess an extensive history of manual (artisanal) extraction. As a result, the surrounding riverine systems have been significantly altered in terms of hydrological and geomorphological functioning and water quality. This Report is for the Rutongo Mine, forming part of Phase 1 of the 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 at each mine site. The individual reports have also been prepared for the Musha/Ntunga and Nyakabingo Mines, respectively.

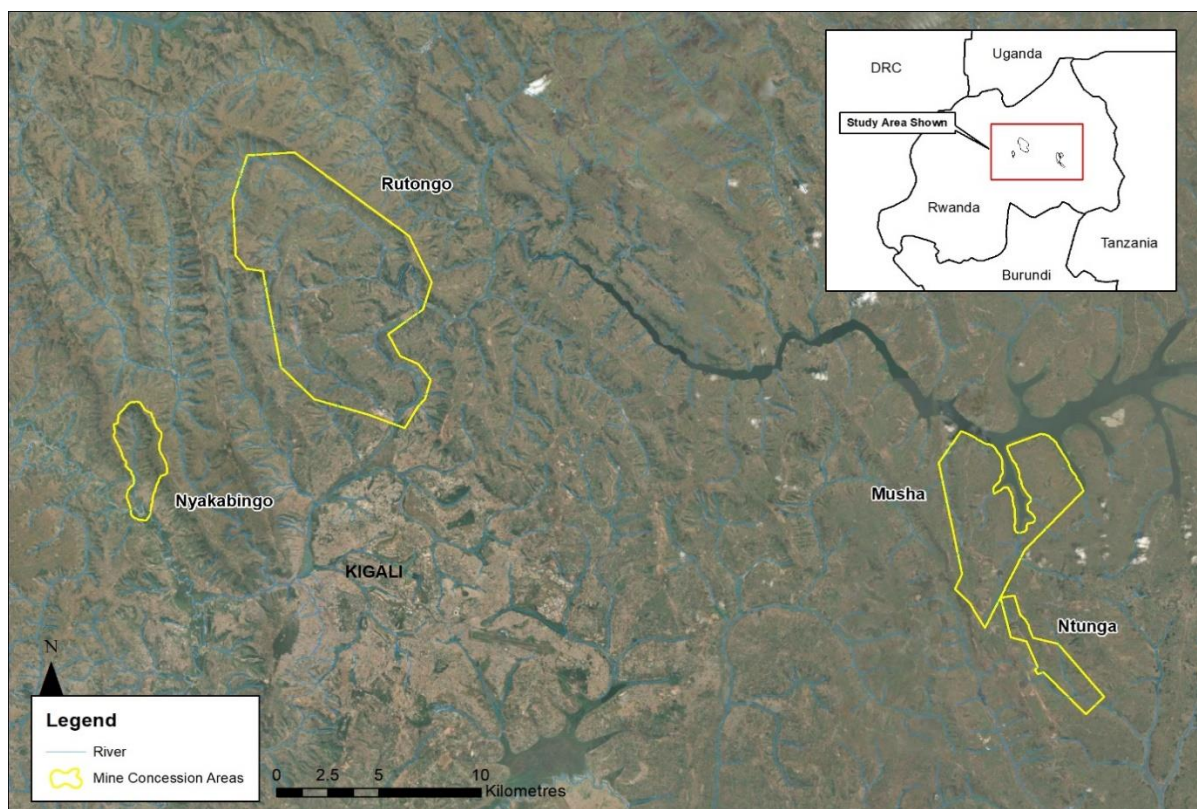


Figure 1-1 Map of the regional locations of the Trinity Metals mining concession areas

1.2 Key Objectives

The key objectives of this SPR analysis were to:

- i) Review the baseline assessments undertaken as part of the 2024 Environmental and Social Impact Assessment (ESIA), and more recent reports (e.g. 2025 Hydrocensus, 2026 Geochemistry assessment of legacy tailings, soils and sediments), 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 of the six mine sites.
- v) Develop a Conceptual Site Model for each mine 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 and 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

The structure of this report is as follows:

- Section 2 describes the approach adopted for this assessment.
- Section 3 contains a description of the landscape setting of the mines.
- The Conceptual Site Models (CSM) that identify the potential sources of contamination, pathways and receptors at each mine site are provided in Section 4.
- Section 5 provides the quantitative risk assessments that evaluate the likelihood of contamination based on available information and data.
- Considerations related to the impacts of climate change are described in Section 6.
- The report concludes with Section 7, which describes the critical areas at each site 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.
- 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.
- River systems are inherently sensitive ecosystems. Heavily degraded rivers have low resilience, and even small additional disturbances have the potential to cause disproportionate negative impacts. Thus, degraded rivers can be considered more sensitive than intact, diverse systems. Smaller systems are also more sensitive to disturbance in comparison to larger systems.
- 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.

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, authorised and unauthorised 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).
- The level of detail within the specialist reports varied from desktop assessments, data collected through once-off field sampling, data derived from monitoring conducted over several months, and detailed modelling exercises. Apart from surface water monitoring, data availability was of low confidence and thus SPR analysis was conservative and should be interpreted with caution.
- The uncertainties and limitations noted in the various specialist reports have reference.
- Specialist assessments did not compare the geochemical results and water quality results against the Rwanda Standards for ambient water (RS 564: 2024) and the East African Standard for wastewater discharged on land and into water bodies (RS EAS 1172: 2024), which provide protection of receiving environment water quality. This was added by the author of this report for surface water and groundwater quality.
- The Air quality specialist study only considered the impact of gases and particulate matter on human receptors. The impact of these contaminants on wildlife and aquatic ecosystems was therefore not established.
- 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.
- As per the Aquatic Specialist Report, the impacts of contamination on aquatic biota were assessed collectively for Rutongo mine sites, and not on a site-by-site basis. In this SPR analysis the lower Rusine River was assessed as moderately sensitive in comparison to the other rivers which were assessed as highly sensitive. This was integrated into the risk assessment.
- No toxicology studies or bioassays were undertaken on surrounding village 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

The approach adopted for this 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**. A Tier II Risk Assessment was deemed appropriate for the current analysis (see further detail below).

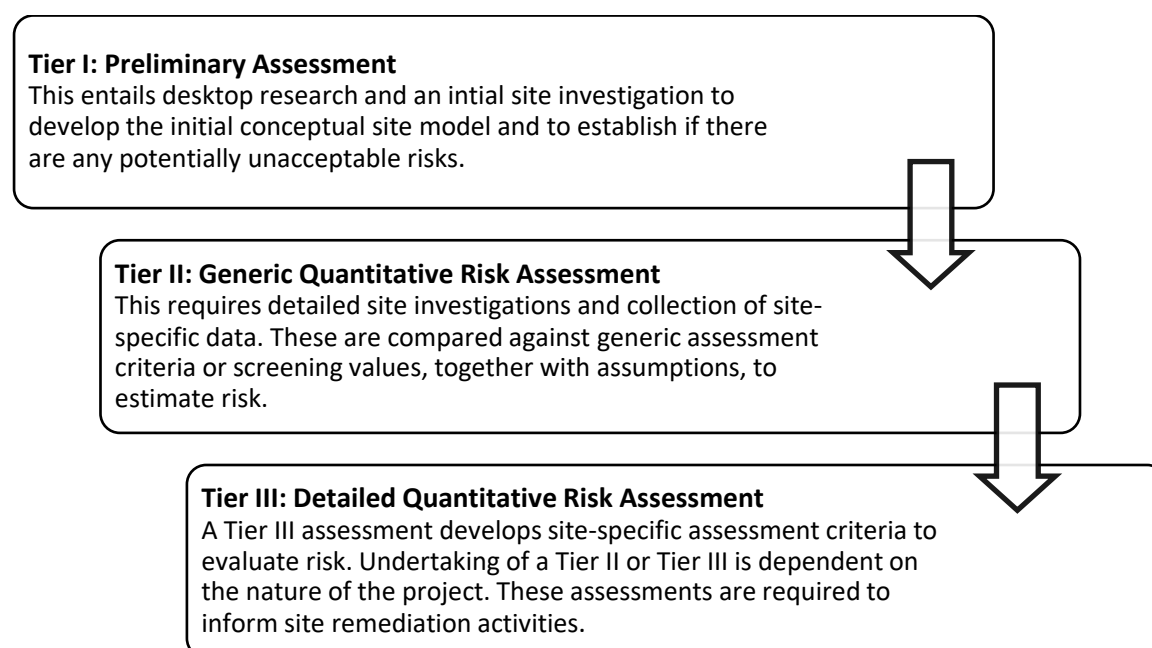


Figure 2-1 General phases of assessment and management of risk related to contaminated land or groundwater (Adapted from DEA, 2010)

2.1 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 mining concession area. 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 this SPR analysis. 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; and
- 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 were:

- Hydrocensus (2025);
- Geochemistry Assessment of Legacy Tailings and Soil/Sediment (2026); and
- 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) (see Section 2.4). This will in turn inform remediation design and implementation of the Legacy Tailings Management and River Rehabilitation/Mitigation Programme.

2.2 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). These include:

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.
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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 <i>inter alia</i> 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**).

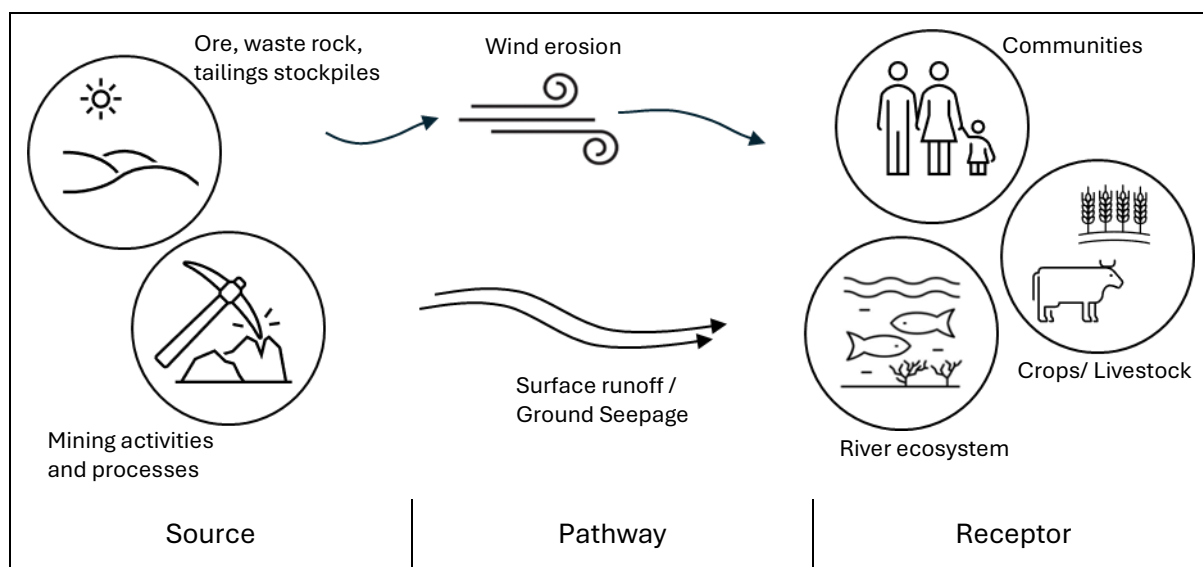


Figure 2-2 The Source-Pathway-Receptor Preliminary Conceptual Site Model in the context of Trinity Metals mining operations (Adapted from Novakowski et al., 2023)

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.

2.3 Generic Quantitative (Tier II) 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 specialist reports are provided in **Appendix 1**.

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

Sources	Volume of source material, location/proximity to sensitive receptors, chemical signature, contaminant concentrations, and other (geology, minerology, etc.), background/natural levels.
Pathways	Influence of environmental factors on pathway behaviour, rate of transport, transformation and/or degradation along the pathway. Multiple pathway interactions could increase the severity of risk to receptors.
Receptors	Mediums/means of exposure, duration and frequency of exposure, effects of exposure, sensitivity of the receptors, acceptable levels of exposure, seasonality of biological communities. The presence of multiple receptors increases risk.

In taking the above into account, the severity and likelihood/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 likelihood/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/probability and severity. This is accompanied by interpretation of the perceived risk. This is risk *without* mitigation.

Table 2-1 Risk Assessment Matrix used to classify risk at Trinity Metal mines and risk interpretation without mitigation (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) is 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. 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 2.1) and more recent reports (GroundTruth, 2025; SLR, 2026). Further insights and infield observations have been added by GroundTruth specialists where relevant.

3.1 Setting

3.1.1 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, 2024a).

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, 2024b).

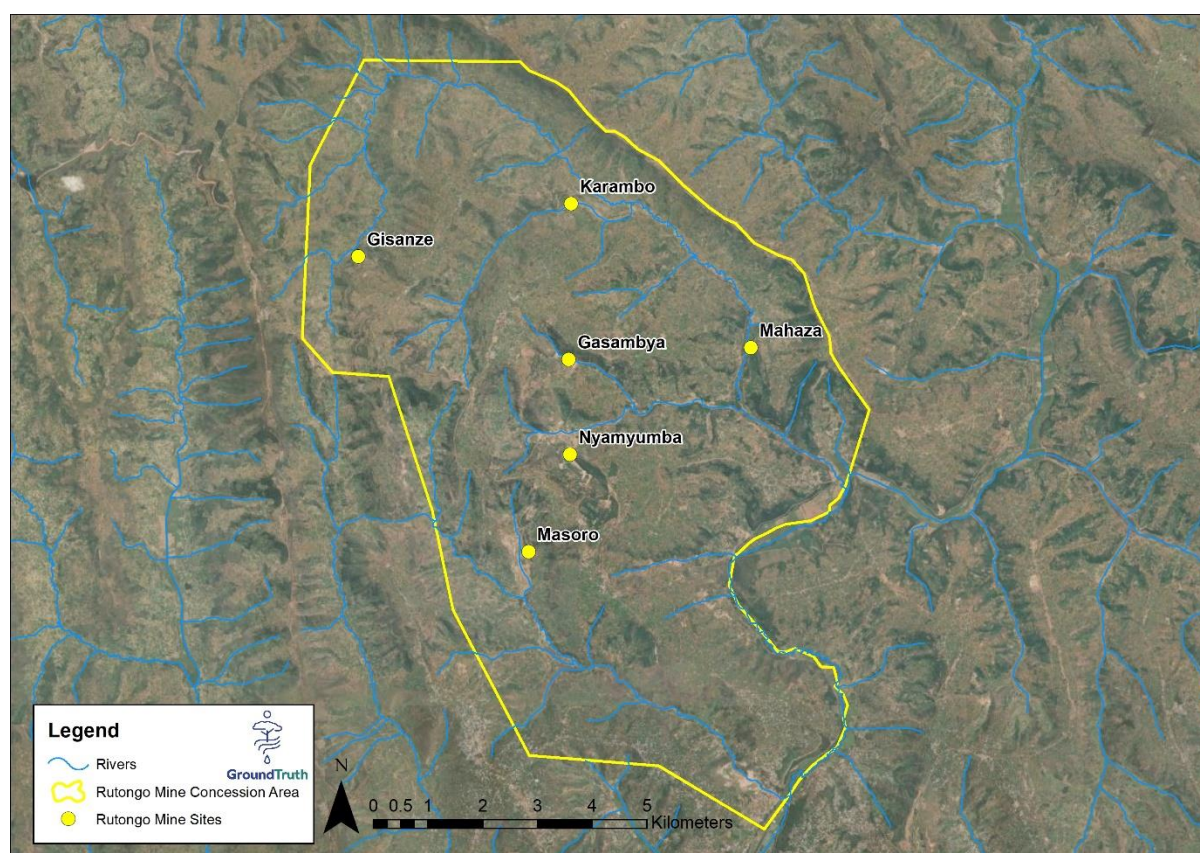


Figure 3-1 Six mine sites that comprise the Trinity Rutongo Mine

3.1.2 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, 2024c).

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, 2024c).

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, 2024c).

3.1.3 Land-use

Land-use within the Rutongo Mine concession areas includes authorised and unauthorised mining, and a range of other activities that include *inter alia* mining of sand and aggregate¹, unauthorised 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. (Blue Gum tree), which are also part of forestry woodlots (GroundTruth, 2026; Nepid Consultants, 2024; SLR, 2024d).

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, 2024c).

¹ 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.

3.2 Site Layout and Operations

3.2.1 Layout

The layouts of the primary Nyamyumba site and five satellite sites are provided in **Figure 3-2** to **Figure 3-7** below.

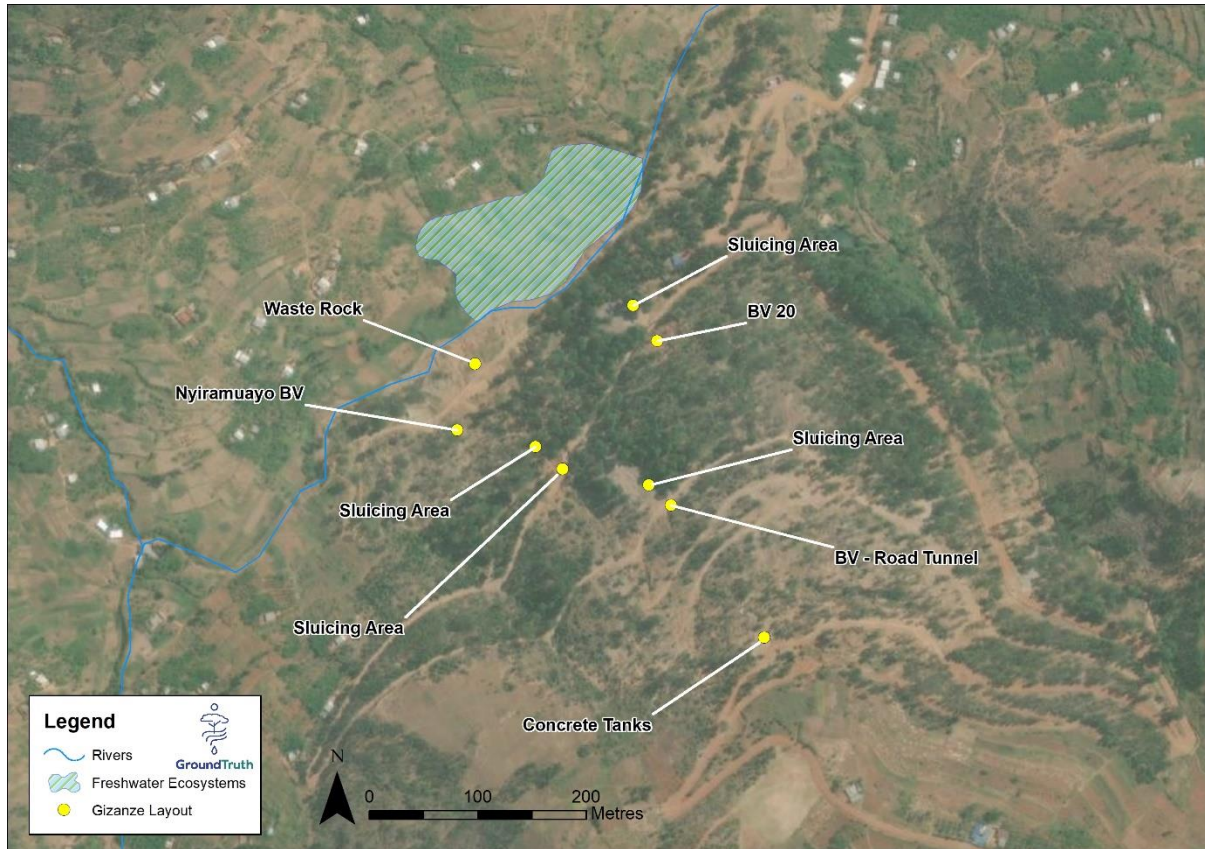


Figure 3-2 Layout of Gisanze Mine (satellite site)

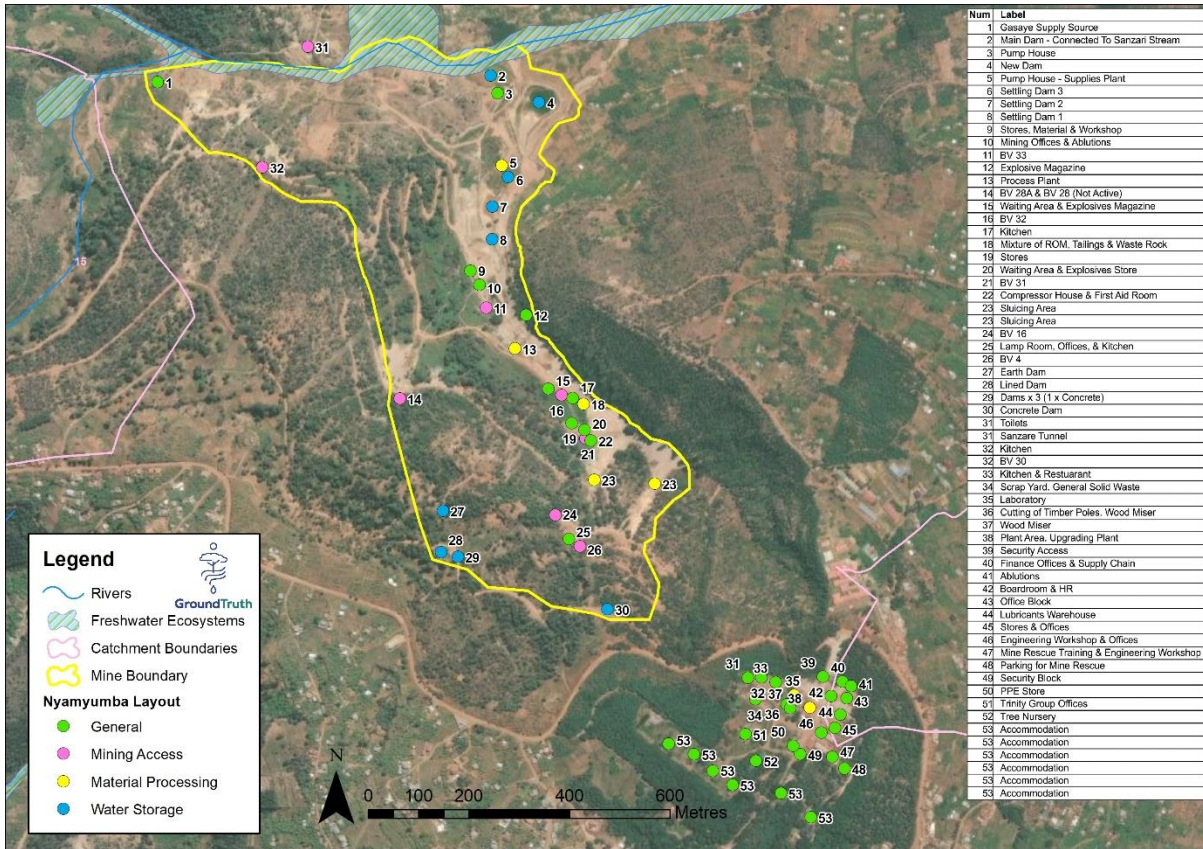


Figure 3-3 Layout of Nyamyumba Mine (primary site)

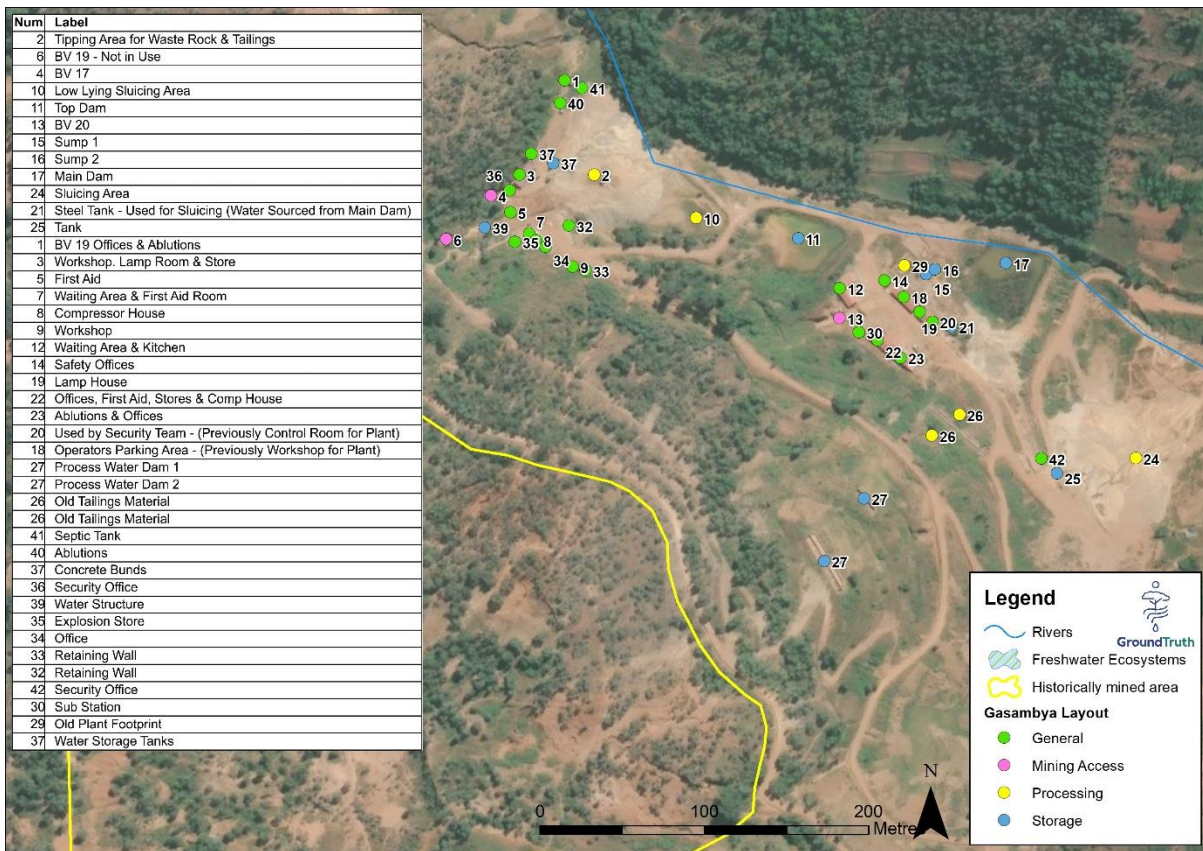


Figure 3-4 Layout of Gasambya Mine (satellite site)

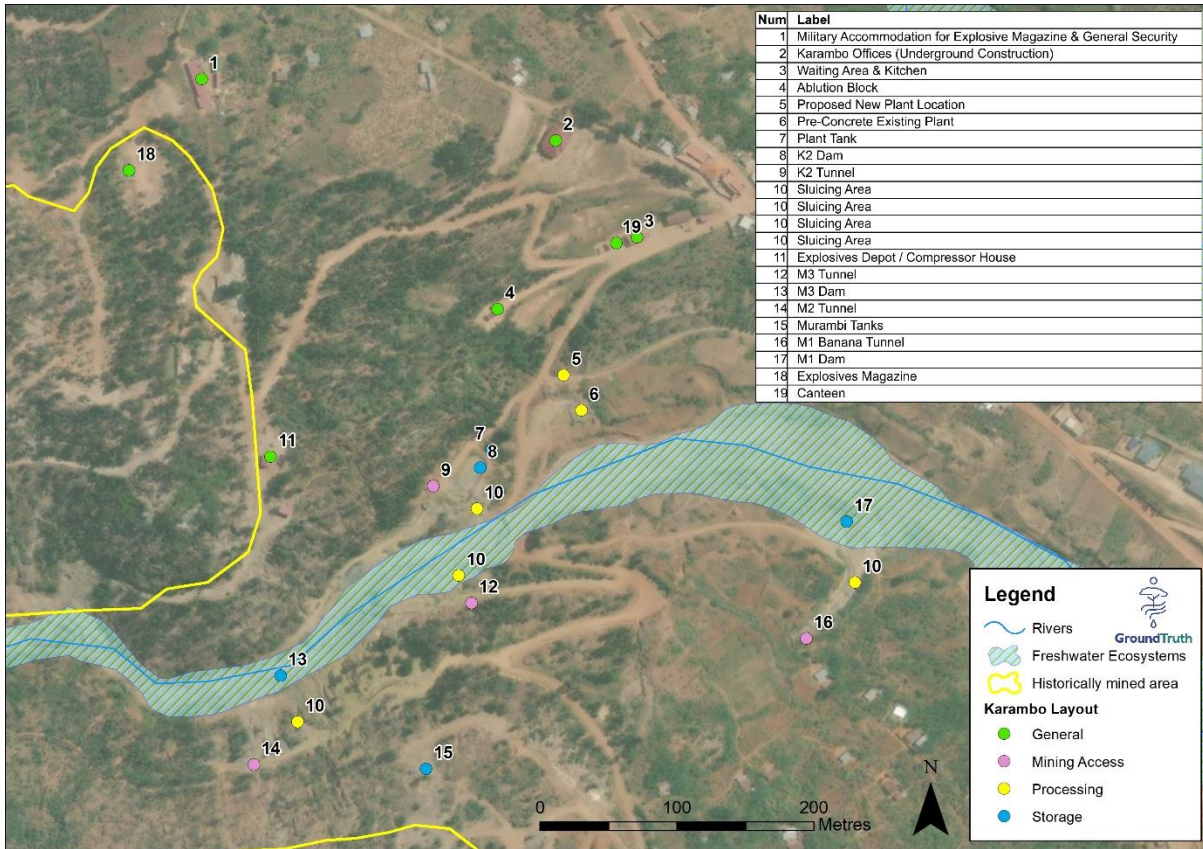


Figure 3-5 Layout of Karambo Mine (satellite site)



Figure 3-6 Layout of Mahaza Mine (satellite site)

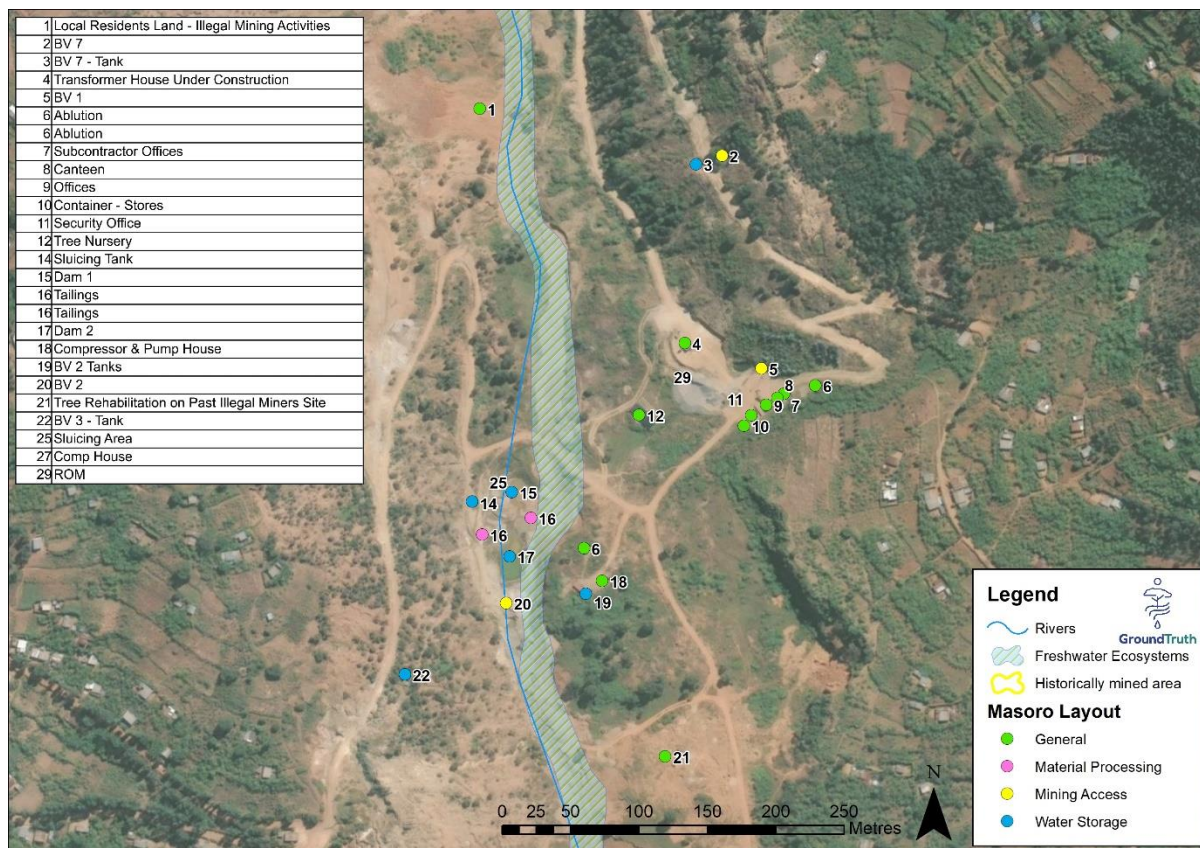


Figure 3-7 Layout of Masoro Mine (satellite site)

3.2.2 Operations

3.2.2.1 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 tonnes/hr gravity separation processing plant, through which most of the mines' off-reef product is processed (SLR, 2024c).

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 tonnes/hr) is operational at Karambo mining site (SLR, 2024c).

3.2.2.2 Process water and dewatering activities

A summary of the process water and dewatering activities for each mine (SLR, 2024c) is provided in **Table 3-1**.

Table 3-1 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.
Nyamumba Mine (Sanzari River)	Process water is required for drilling activities and 14 sluicing lines and is sourced from the Sanzari River. The gravity separation processing plant (30 tonnes/hr) discharges slurry to the storage/settling dams. There are nine dams used for the storage of source water and effluent water. Only one is reported to be lined, while another is a concrete dam. The remaining dams are unlined, three of these are designated 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 (2.5 tonnes/hour).

	<p>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.</p> <p>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.</p>
<p>Mahaza Mine (Rusine River)</p>	<p>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.</p> <p>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.</p> <p>Currently, no groundwater is actively discharging from any of the tunnel entrances.</p>
<p>Masoro Mine (Gatiti River, tributary of Umurindi River)</p>	<p>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.</p>

3.2.2.3 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, 2024c, 2024a), and potentially seepage into groundwater resources.

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, 2024c).

3.2.3 Unauthorised Mining

A significant amount of unauthorised mining takes place throughout the Rutongo concession area, both upstream and downstream of the mine sites. These unauthorised mining sites can arise at any given time at random locations throughout the Rutongo concession area. The unauthorised mining can take place either within the riverbeds or along the valley slopes, resulting in high turbidity, an increase in sedimentation, bank erosion and modification of in-

channel habitat availability for biota within the rivers. Mine personnel have noted an increase in unauthorised activities, particularly during the wet season, when there is plenty of free water available for unauthorised sluicing (SLR, 2024c).

3.3 Environmental Aspects

3.3.1 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, 2024; SLR, 2024c).

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 loads caused by landscape erosion, deforestation, woodlots/forestry, subsistence cultivation, livestock grazing and settlements (Nepid Consultants, 2024). This is further exacerbated by authorised and unauthorised mining activities, including in-channel aggregate mining.

In terms of hydraulic connectivity, rivers near the Mahaza and Masoro Mines behave as gaining type rivers (whereby there is interaction between surface water and groundwater resources from being hydraulically connected. This results in an increase in surface water baseflows). 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, 2024c). 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, 2025). Spring water is the preferred source of domestic water and serves as the primary supply for the formal water distribution network through community collection points (GroundTruth, 2025). However, rivers are also utilised where access to springs is difficult, or during the dry season when spring flows are insufficient or cease altogether. In such instances communities may also resort to using tunnel water, e.g. M1 Tunnel at Karambo Mine (SLR, 2024c).

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 and Gatiti Rivers requiring 5 m and 2 m buffers, respectively). While the Nyamyumba, Karambo, Mahaza and Masoro mine sites fall within the protection buffer zone, physical mining activities take place outside the buffer zone (SLR, 2024c). 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, 2024c).

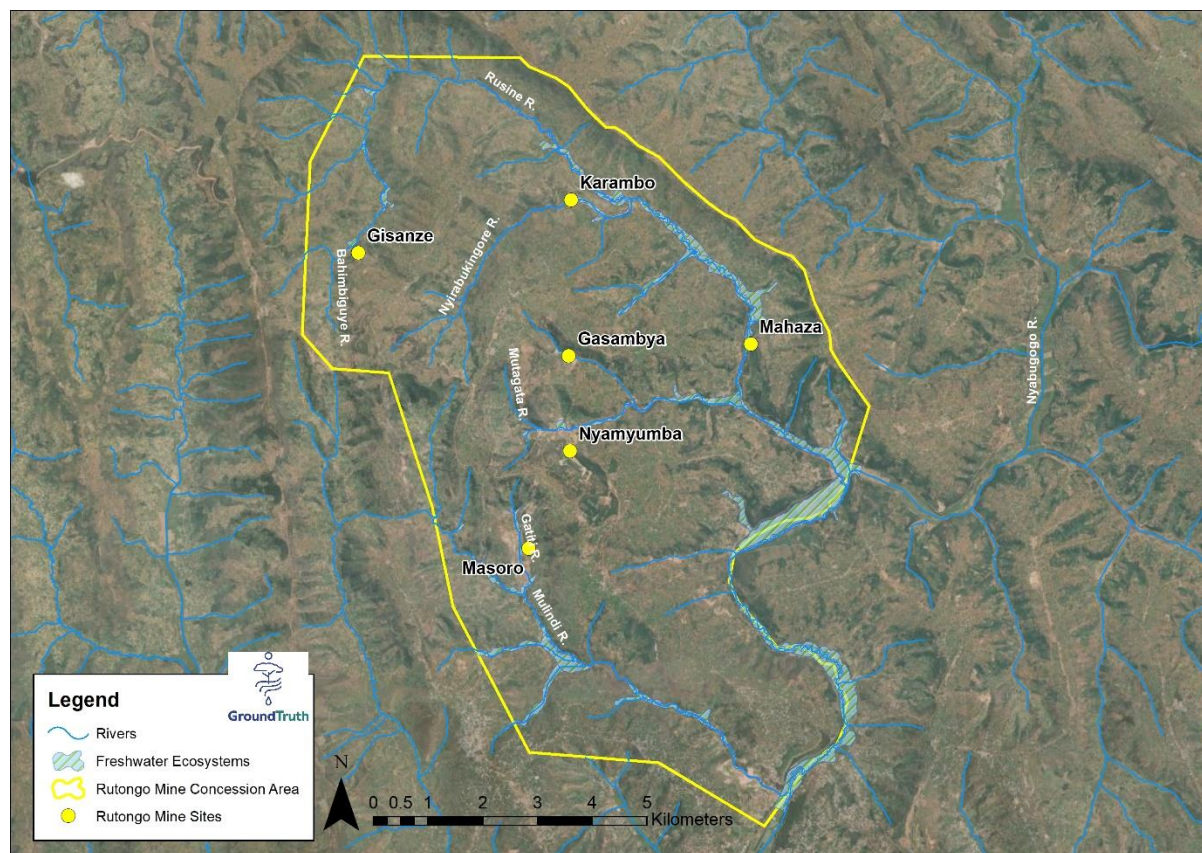


Figure 3-8 Map showing local hydrology of the Rutongo concession area and mine sites

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, 2024b). 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, 2024b, 2024e).

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, 2024e).

3.3.3 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, 2024b):

- **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, 2024b).

3.3.4 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, 2024d). 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, including alien invasive species (e.g. *Eucalyptus* sp). 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, 2024d).

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 within the concession area, namely, *mountain streams* (upper reaches of the Rusine River and most tributaries), *transitional streams* (the Umurindi Stream and middle reaches of the Rusine River), and *upper foothills* (the lower reaches of the Rusine River) (Nepid Consultants, 2024). 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 (Nepid Consultants, 2024). 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 (Nepid Consultants, 2024).. Of the ten sample sites on the various rivers and streams, only two on the upper Rusine River and the Kagombero River², respectively, recorded more than ten macroinvertebrate taxa. These assemblages were dominated by short- to very short-lived taxa indicative of unstable conditions, together with taxa associated with moderately to heavily sedimented stream environments (Nepid Consultants, 2024).. Overall, the biological response appears more consistent with poor water quality and elevated sediment loads as the primary stressors, suggesting that mining activities are likely contributing predominantly through increased sedimentation rather than direct alteration of flow regime or reduction in habitat extent. Nevertheless, excessive sediment deposition can still substantially impair ecological condition by smothering available substrates and instream habitats, thereby favouring disturbance-tolerant communities (Groundtruth 2026). These two systems were subsequently classified as ‘Largely modified’, and the remaining systems ‘Seriously to Critically modified’ (Nepid Consultants, 2024).

No fish were recorded within the main rivers and tributaries during the specialist study, despite the presence of suitable flow conditions. Their absence was attributed to abrasion caused by elevated concentrations of suspended material associated with authorised and unauthorised mining, harvesting of sand and aggregate within the riverbed, and subsistence cultivation (Nepid Consultants, 2024). 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 (harvesting) of woody riparian vegetation. All other sites in the concession, including the site upstream of mining activities, were in much the same condition (Nepid Consultants, 2024). Based on the absence of benthic diatoms and fish, depauperate macroinvertebrate communities comprising disturbance-tolerant taxa (driven by poor water quality conditions and sedimentation), and overall degraded integrity of riverine habitat, most river systems adjacent to the various Rutongo Mines were classified as ‘Highly sensitive’, except for the lower Rusine River at the Mahaza mine, where the system is substantially larger with more diverse habitat, and thus classified as ‘Moderately sensitive’ (GroundTruth, 2026). The overall sensitivity of the rivers system is pertinent given global conservation status of the Lake Victoria Basin Freshwater Ecoregion (classified as ‘Globally Outstanding’) where these systems are located.

² A tributary of the Gatiti River near Masoro Mine (Nepid Consultants, 2024)

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, 2024d).

3.4 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, 2024).

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 3-2**. Sensitive air quality receptors identified in close proximity to the sites (within a 1 km radius) include schools and hospitals/healthcare centres (SLR, 2024a).

Table 3-2 Summary of the social landscapes associated with the six mines site in the Rutongo concession area (after Barbour 2024, with input from GroundTruth, 2025)

Mine	Main Villages	Main activities
Gisanze Mine (Rusine River)	Iraro, Gasizi, Rugaragara,	<p>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.</p> <p>The valley opens below the village and becomes a broad, fertile valley that is a well-established farming area.</p> <p>Unauthorised 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.</p> <p>Agriculture is the dominant land use in the area. Small-scale, labour-intensive crop farming takes place in most areas that can be used.</p> <p>The main crops cultivated include beans, potatoes, sweet potatoes, bananas. Livestock kept includes cattle, goats, and chickens.</p>

Mine	Main Villages	Main activities
Nyamyumba Mine (Sanzari River)	Kabuga, Umutagata, Nyarurembo, Agasharu, Nyakabungo,	<p>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.</p> <p>Agriculture is the dominant land use in the area. Small-scale, labour-intensive crop farming takes place in most areas that can be used.</p> <p>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.</p> <p>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.</p> <p>Unauthorised mining is evident in the upper parts of the valley and within the riverbed and along the banks downstream of the mining area.</p>
Gasambya Mine (Kivomo River)	Nyarurembo, Rebero, Musega, Kanunga	<p>There are no homesteads and limited agriculture upstream of the mining area due to steepness of the valley.</p> <p>Cultivation occurs on the slopes on the northern bank of the river opposite the mining area.</p> <p>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.</p> <p>There is evidence of unauthorised 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.</p> <p>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.</p>
Karambo Mine (Nyarabukingore River)	Kamatongo, Nyakibande,	<p>A newly constructed local hospital and the Karambo Primary School are located downstream of the mining area on the northern bank.</p> <p>Agriculture is the dominant land use in the area. Small-scale, labour-intensive crop farming takes place in most areas that can be used.</p> <p>The main crops cultivated include beans, potatoes, sweet potatoes. Livestock kept includes cattle, goats, and chickens.</p> <p>Waste rock and material from sluicing have been deposited on the steep northern and southern banks and has slipped into the river course.</p>

Mine	Main Villages	Main activities
		<p>The river downstream of the bridge has been heavily impacted by tailings.</p> <p>Unauthorised mining occurs up the valley outside the riverbed.</p> <p>Unauthorised 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.</p>
<p>Mahaza Mine (Rusine River)</p>	<p>Burambi, Gitwa, Gasenga</p>	<p>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.</p> <p>Agriculture is the dominant land use in the area. Small-scale, labour-intensive crop farming takes place in most areas that can be used.</p> <p>The main crops cultivated include beans, potatoes, sweet potatoes. Livestock kept includes cattle, goats, and chickens.</p> <p>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.</p> <p>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.</p> <p>There are no community springs in close proximity to the mine.</p> <p>High sediments levels in the river due to mining and agricultural activities has impacted on the traditional use of rivers in the Rutongo concession area to wash clothes and collect drinking water.</p> <p>The IRIB ECD facility (school) in the Burambi village area is located downstream of the mining area and is engaged in subsistence farming.</p>
<p>Masoro Mine (Gatiti River)</p>	<p>Kigomwa, Gisiza, Akarambi, Rusenyi</p>	<p>Agriculture is the dominant land use in the area. Small-scale, labour-intensive crop farming takes place in most areas that can be used.</p> <p>The main crops cultivated include beans, potatoes, sweet potatoes. Livestock kept includes cattle, goats, and chickens.</p> <p>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.</p> <p>A spring is located at Tunnel 7 of the mine, just over 200 m from the mine office on the eastern slopes and 130 m 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.</p>

Mine	Main Villages	Main activities
		<p>Unauthorised 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.</p> <p>Western and eastern bank of the river have been heavily impacted by unauthorised mining operations, and eroding areas used for banana plantations.</p>

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

- 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); and
- High poverty and unemployment levels.

4. 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 concession area and associated mining activities. These are outlined in **Figure 4-1**.

4.1 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 PM₁₀), and gases (SLR, 2024a).

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 lined dams, formal stormwater infrastructure or ineffective stormwater infrastructure, dirty runoff from the different sites either discharge or potentially seep into the environment (SLR, 2024c). 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, 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). The use of pumps by unauthorised mining activities is also a potential source. However, no monitoring data are available for hydrocarbons, and related substances (Daneel *pers. comm.*, 2026).

4.2 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 (NO₂ and SO₂) (SLR, 2024a).

Surface water discharge – Formal stormwater management infrastructure and/or lining of infrastructure is not in place at any of the mine sites. Where stormwater infrastructure is in place (Nyamyumba, Karambo and Gasambya), these are not always effective and/or maintained and can overflow in high rainfall periods. 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, 2024c). 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, 2024b).

4.3 Receptors

Human population – This includes 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/sensitivity, the amount of water consumed, and the duration of exposure (NICOLA, n.d.). 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, and those with health conditions 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 (SLR, 2024a; Sustainability Directory, 2025).

Aquatic ecosystems – These include rivers, springs and/or wetlands and related aquatic 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.

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 ingestion of drinking water from both surface and groundwater sources, ingestion of plants, dermal contact or inhalation of contaminants. The same factors influencing contamination exposure also apply to terrestrial organisms.

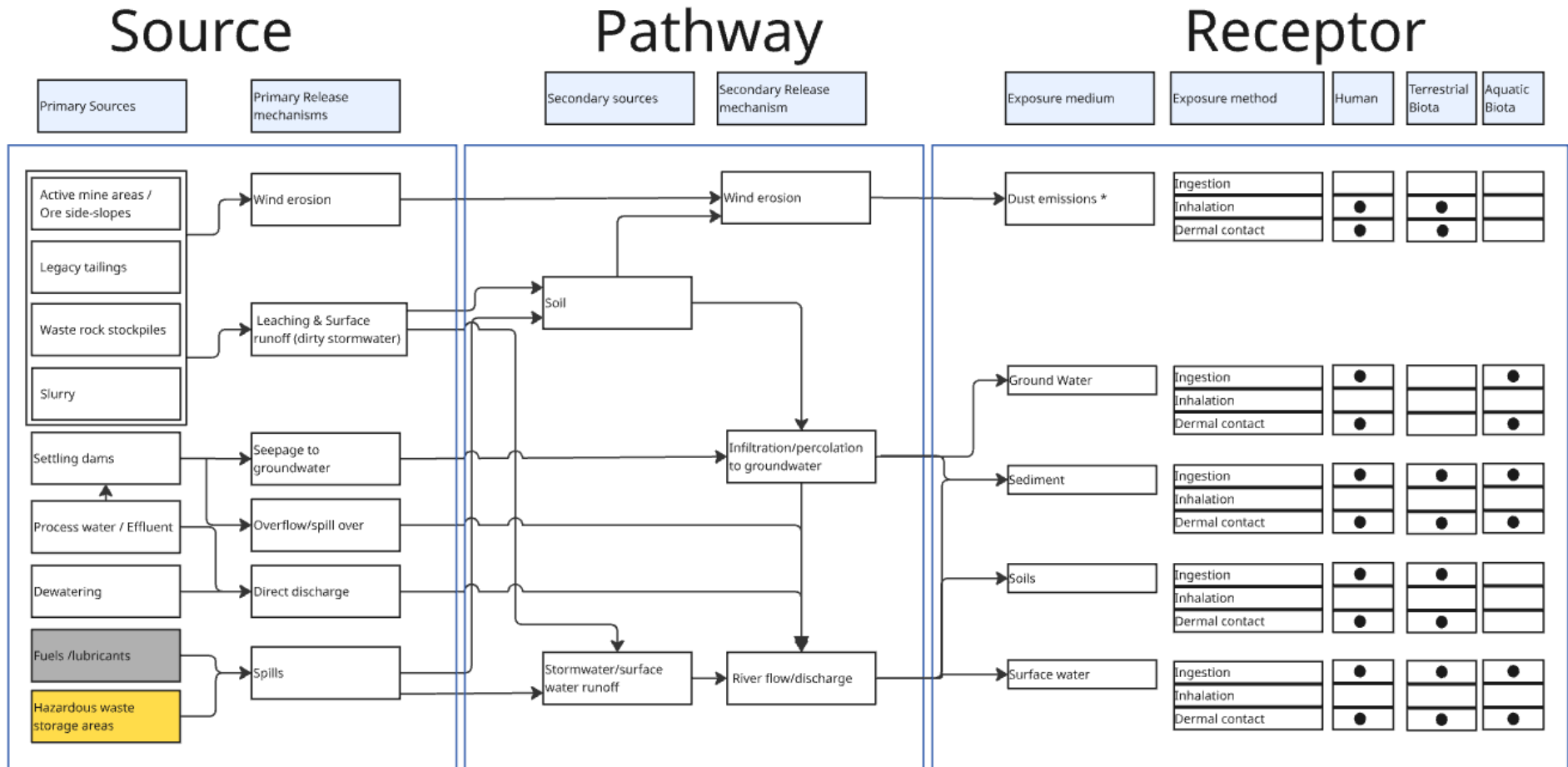


Figure 4-1 Conceptual Site Model for Trinity Rutongo Mine showing the predicted migration pathways of contaminants from source to receptors (*Investigations of dust emissions undertaken at Nyamyumba and Karambo mines only. Grey = Observational; Yellow = Unconfirmed)

5. RISK ASSESSMENT

5.1 Air emissions

The following findings are extracted from the specialist Air Quality Report (SLR, 2024a). To note, air quality monitoring was undertaken at only two of the six mine sites, 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 PM₁₀.
- Exceedances of only the WHO AQG 2021 24-hr average limits were recorded for PM_{2.5} (39.5% of records).
- Survey average NO₂ and SO₂ 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 PM₁₀.
- 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 NO₂ and SO₂ concentrations were well within the annual EAS 2021 and WHO AQG 2021 guidelines for gaseous emissions.

5.2 Mine materials and impacted waters³

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

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, 2024e). 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, 2026).

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, 2026).
- Runoff from waste rock material, slurry, legacy tailings and water discharged from the adits contribute to the contamination of the Rusine River.

³ Impacted waters includes mine water in underground workings, process water and effluent

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, 2026).
- 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, 2026).
- 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, 2026).
- Run-off from waste rock, slurry, and ore and sluice water (dirty run-off) contribute to the contamination of the Nyirabukingore River.

Mahaza

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

Masoro

- Manganese and pH in legacy tailings leachate (SLR, 2026) , and aluminium, lead and manganese in sluice water/effluent exceeded the WHO Guidelines for Drinking Water (2022) limit.
- Parameters that exceeded various other limits included: aluminium, lead, manganese, nitrate and pH.
- 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, 2024e).

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, 2024e).

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, 2024e).

5.3 Groundwater

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

- 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 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), and manganese for 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 and lead 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, manganese and lead exceeded the WHO drinking water (2022) limits.
- Groundwater contributes to river baseflow.

Overall, 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. Tunnel 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 5-1 Source risks to groundwater contamination 100 years after mine closure (After SLR, 2024g)

Mine	Description
Gisanze Mine (Upper 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 ⁴ 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.

⁴ 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, 2024b).

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 the standards and poses very little threat to the environment or the health of the people.
Karambo Mine (Nyarabukingore 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 60 m 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 40 m 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.

5.4 Surface water

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

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 aggregate miners are also operating in the river. There has also been an increase in unauthorised 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). Apart from a spike in lead (downstream) during January 2024, lead remained below the limit during other sample months.
- 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 unauthorised mining activities upstream and downstream of the mine site.

By and large, all the mine sites, except for 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, 2024c).

However, surface water sampling upstream of the Rutongo concession area indicates that river water quality is already compromised before entering the mining area, largely due to surrounding villages, unauthorised mining activities, and authorised aggregate mining (SLR, 2024c). Within and downstream of the concession, elevated concentrations of sodium, chloride, nitrate, and particularly total suspended solids suggest that mining activities may contribute to additional localised water quality deterioration, with potential implications for crop irrigation and aquatic ecosystem health.

However, sampling in the Nyabugogo River approximately 10 km downstream of the concession, prior to its confluence with the Nyabarongo River, recorded all key chemical parameters below WHO drinking water guideline thresholds (WHO, 2022). This more likely reflects downstream attenuation processes such as dilution, sediment deposition, and natural assimilative capacity, rather than confirming an absence of impact. It should also be noted that single-event snapshot sampling may not detect episodic pollution events or short-term fluctuations. Accordingly, while localised downstream impacts may still occur, no significant far-field or transboundary water quality effect was evident at the time of sampling (SLR, 2024c).

5.5 Sediments and soils

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

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, potentially related to flood events and sediment scour.

- 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 concentrations recorded upstream of the Gisanze Mine, and arsenic concentrations recorded downstream at Karambo and Masoro mines (**Table 5-2**). 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 5-2**) suggesting these element 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 unauthorised mining activities.
- Overall, the Rutongo mining concession area is subject to high cumulative impacts arising from multiple activities and operations, as opposed to impacts attributable solely to the mine.

Table 5-2 Summary results of different river sediment analyses : Analyte exceedances (marked with an ‘X’) 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	

* RSA (2014) Soil Screening Value 1(SSV1): all land uses, protective of water resources

**INAP (2014) Geochemical Abundance Index (GAI), GAI>3 indicates significant enrichment, GAI>6 indicates extreme enrichment

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.

5.6 Summary Tables

The above findings of the specialist reports are integrated into the quantitative risk assessment for the six mine sites in the Rutongo concession area. The potential Contaminants of Concern (CoCs) and sources, as determined through air quality sampling and geochemical analyses, are listed in the tables in sections **5.6.1 to 5.6.6**, respectively. These tables must be read in conjunction with the related pathway tables for each mine site: Gisanze (**Table 5-4 to Table 5-5**), Nyamyumba (**Table 5-7 to Table 5-9**), Gasambya (**Table 5-11 to Table 5-12**), Karambo (**Table 5-14 to Table 5-16**), Mahaza (**Table 5-18 to Table 5-19**), and Masoro (**Table 5-21 to Table 5-22**). It is worth noting that some additional contaminants (e.g. parameters for crops health and the ambient water/natural environment) were detected by different specialists that were not necessarily identified in the geochemical analyses (sources). These are documented in the risk tables that follow.

For each mine site, contaminants detected within the three main transport pathways—wind erosion/dispersal, groundwater seepage, and surface water runoff—are presented separately. Contaminants of concern (CoCs) identified in groundwater seepage and surface water runoff

have been colour-coded in the tables to show where the same contaminants recur across pathways or sites.

Where measured concentrations exceed applicable receptor limits or guideline values, this provides an indication of the potential severity of exposure. **Contaminants shown in bold represent very high exceedances, defined as concentrations at least twice the relevant limit.** The tables also include an assessment of the likelihood of exposure and the resulting overall risk rating.

5.6.1 Gisanze Mine

The summary tables of the risk assessment for Gisanza Mine are presented in **Table 5-3** to **Table 5-5**. In summary, the dominant risk profile at this mine site is associated with active operational sources, including mine material stockpiles, slurry material, and process water /effluent (sluice water).

Table 5-3 Sources and Contaminants of Concern identified for Gisanze Mine

MINE MATERIALS				MINE IMPACTED / PROCESS WATER / EFFLUENT	
Ore stockpile	Waste rock	Slurry material	Legacy tailings	BV20 Sluice 1 (GS1)	BV20 Sluice 2(GS2)
Manganese (Mn) Iron (Fe)	Lead (Pb) pH	Aluminium (Al) Iron Manganese pH	Manganese pH	Nitrate (NO ₃) pH	Aluminium Lead Manganese Nitrate pH

Table 5-4 Summary of environmental risks associated groundwater seepage at Gisanze Mine

Receptor	Severity*	Likelihood/probability	Risk
Communities	HIGH – Mn, Fe, exceedance (WHO, 2022 and RS 190) (Spring water compliant with WHO, 2022)	UNLIKELY – Spring water is the primary source of water for domestic purposes. However, 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
Crops	MINOR – Mn at limit. No other exceedances.	UNLIKELY – Subsistence cultivation is predominately reliant on rainfall.	VERY LOW

Receptor	Severity*	Likelihood/probability	Risk
Surface water ecosystem interaction	HIGH – Pb exceedance (RS 564 and EAS 1172) Health of the Rusine River is ‘Serious -Critically modified’, bearing High sensitivity.	HIGHLY LIKELY - Groundwater from two adits freely discharges into the Rusine River.	VERY HIGH

*Contaminants measured through ground water sampling

Table 5-5 Summary of environmental risks associated surface water runoff / discharge at Gisanze Mine

Receptor	Severity*	Likelihood/probability	Risk
Communities	HIGH – Al, Pb, Mn and As exceedances (WHO, 2022)	LIKELY – Proximity of community, however river water is not primary source of water for domestic use. River water used on ad hoc basis.	HIGH
Livestock	HIGH - pH, Al, Fe exceedance (RS 190), FAO compliant.	LIKELY – Livestock utilise rivers for watering.	HIGH
Soils (crops)	HIGH – Mn exceedance (RS 188). Cu, Mn (SSV1) exceedance. Soil has inherent limited pH buffering capacity, prone to acidification and leaching.	UNLIKELY – Subsistence cultivation is predominately reliant on rainfall. Soils show Mn enrichment.	MOD/ LOW
River sediments	HIGH – 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 High sensitivity.	HIGHLY LIKELY – No surface stormwater infrastructure. Sluice water, together with dirty stormwater, will be discharged direct to Rusine River when the mine is operational.	VERY HIGH
Aquatic Ecosystems	HIGH – Al, Pb, pH, Mn, TSS (RS 564, EAS 1172). Health of the Rusine River is ‘Serious -Critically modified’, bearing High sensitivity.	HIGHLY LIKELY – No surface stormwater infrastructure. Sluice water, together with dirty stormwater, will be discharged direct to Rusine River when the mine is operational.	VERY HIGH

*Contaminants measured through surface water monitoring

5.6.2 Nyamyumba Mine

The summary tables of the risk assessment for Nyamyumba Mine are presented in **Table 5-6** to **Table 5-9**. In summary, the Nyamyumba Mine, being the primary mine site, presents a mixed active-operational contamination profile compared to the other satellite mine sites, with regular reoccurrences of aluminium, manganese, low pH, lead and nitrate.

Table 5-6 Sources and Contaminants of Concern identified for Nyamyumba Mine

MINE MATERIALS				MINE IMPACTED/ PROCESS WATER / EFFLUENT	
Ore stockpile	Waste rock	Slurry material	Legacy tailings	BV32 Exit water	Pan water
Manganese	Arsenic Manganese Nitrate	Aluminium Cobalt Lead Manganese Nickel pH	Lead Manganese pH	Aluminium Cobalt Lead Manganese Nickel Nitrate pH	Aluminium Manganese Nitrate pH

Table 5-7 Summary of environmental risks associated with wind erosion/dispersal at Nyamyumba Mine

Receptor	Severity*	Likelihood/probability	Risk
Communities	MINOR – no exceedances of NO ₂ and SO ₂	LIKELY – Proximity of access roads through and between neighbouring communities	LOW
Communities	MEDIUM – PM ₁₀ and PM _{2.5} exceedances at key points on site and in surrounding communities	HIGHLY LIKELY – Proximity of communities and sensitive receptors.	HIGH

*Contaminants measured through air quality sampling

Table 5-8 Summary of environmental risks associated with groundwater seepage at Nyamyumba Mine

Receptor	Severity*	Likelihood/probability	Risk
Communities	HIGH – Al, Mn, pH exceedances (WHO, 2022). Pb, elevated. Communal spring has As exceedance (WHO 2022)	HIGHLY LIKELY – Spring water is primary source of water for domestic purposes.	VERY HIGH

Receptor	Severity*	Likelihood/probability	Risk
Livestock	HIGH – Pb , pH exceedances (RS 190), Mn near limit.	LOW LIKELIHOOD – Livestock utilise rivers for watering, however groundwater does not contribute to baseflow but key metals present	MOD
Crops	MEDIUM – Mn exceedances (RS188)	UNLIKELY – Subsistence cultivation is predominately reliant on rainfall. Groundwater does not contribute to baseflow.	LOW
Surface water ecosystem interaction	HIGH – Pb , pH exceedances (RS 564), Pb , As exceedances (EAS 1172) Health of the Sanzari River is ‘Seriously-Critically modified’, bearing High sensitivity.	LOW LIKELIHOOD – Process water sourced from Sanzari River, not groundwater ingress. Unlined dams are present, however groundwater does not contribute to baseflow.	MOD

*Contaminants measured through ground water sampling

Table 5-9 Summary of environmental risks associated with surface water runoff/ discharge at Nyamyumba Mine

Receptor	Severity*	Likelihood/probability	Risk
Communities	HIGH – Al , As , Fe , Pb , Mn exceedances (WHO, 2022)	LIKELY – Proximity of community, however river water is not primary source of water for domestic use. River water used on ad hoc basis.	HIGH
Livestock	HIGH – Al , As , Mn , Fe , pH exceedances (RS 190)	LIKELY – Livestock utilise rivers for watering.	HIGH
Soils (crops)	HIGH - Al , Fe , Mn , exceedances (RS 188). Na, Cl 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.	MOD/ LOW
River sediments	HIGH – 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 High sensitivity.	HIGHLY LIKELY – Not a closed system. Unlined dams, stormwater management infrastructure limited. Dirty stormwater and sluice effluent discharged to Sanzari River via settling dam. Overflow from dam may occur. Sediment shows metal enrichment.	VERY HIGH

Receptor	Severity*	Likelihood/probability	Risk
Aquatic Ecosystems	HIGH – Pb, Mn, Fe, pH, TSS (EAS 1172, RS 564). Health of the Sanzari River is ‘Serious -Critically modified’, bearing High sensitivity. River flow modification caused by abstraction and discharge.	HIGHLY LIKELY – Not a closed system. Unlined dams, stormwater management infrastructure limited. Dirty stormwater and sluice effluent discharged to Sanzari River via settling dam. Overflow from dam may occur. Aquatic communities are poor.	VERY HIGH

*Contaminants measured through surface water monitoring

5.6.3 Gasambya Mine

The summary tables of the risk assessment for Gasambya Mine are presented in **Table 5-10** to **Table 5-12**. In summary, the Gasambya Mine presents a mixed active-operational contamination profile, with regular reoccurrences of aluminium, arsenic, iron ,manganese, low pH, lead and nitrate. The latter two are generally associated with water-related processing activities (impacted exit water, sluice water and pan water).

Table 5-10 Sources and Contaminants of Concern identified for Gasambya Mine

MINE MATERIALS				MINE IMPACTED / PROCESS WATER / EFFLUENT			
Ore stockpile	Waste rock	Slurry material	Legacy tailings	BV17 Exit water	BV17 Sluice 1	BV17 Sluice 2	Pan Water
Aluminium Arsenic Cobalt Iron Manganese	Manganese	Aluminium Arsenic Cobalt Iron Manganese Lead Nickel pH	Arsenic Iron Manganese pH	Aluminium Lead Manganese Nitrate pH	Aluminium Lead Manganese Nitrate pH	Arsenic Manganese Nitrate pH	Aluminium Arsenic Lead Manganese Nitrate pH

Table 5-11 Summary of environmental risks associated with groundwater seepage at Gasambya Mine

Receptor	Severity*	Likelihood/probability	Risk
Communities	HIGH – As, Pb, Mn, exceedance (WHO, 2022)	HIGHLY LIKELY – Spring water is the primary source of water.	VERY HIGH
Livestock	HIGH - Pb, Mn, pH exceedance (RS 190), Mn marginal, NO ₃ exceedance (RS 188)	LOW LIKELIHOOD – Livestock utilise rivers for watering, however groundwater does not contribute to baseflow.	MOD
Crops		UNLIKELY – Subsistence cultivation is predominately reliant on rainfall.	MOD/LOW
Surface water ecosystem interaction	HIGH – 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 High sensitivity.	HIGHLY LIKELY – Not a closed system. Mine water (acidic) used for processing, discharged to Kivomo River. Groundwater does not contribute to baseflow.	VERY HIGH

*Contaminants measured through ground water sampling

Table 5-12 Summary of environmental risks associated with surface water runoff/ discharge at Gasambya Mine

Receptor	Severity*	Likelihood/probability	Risk
Communities	HIGH – As, Pb, Mn exceedances (WHO, 2022)	LIKELY – Proximity of community, however river water is not primary source of water for domestic use. River water used on ad hoc basis.	HIGH
Livestock	HIGH – As, Mn, pH, Pb, exceedance (RS 190)	LIKELY – Livestock utilise rivers for watering.	HIGH
Soils (crops)	MEDIUM – As, Mn exceedance (RS 188). Na, Cl, NO ₃ are increasing problems for crop yield. As (SSV1). Soil has inherent limited pH buffering capacity, prone to acidification and leaching.	UNLIKELY – Subsistence cultivation is predominately reliant on rainfall.	LOW
River sediments	HIGH - 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-	HIGHLY LIKELY – Not a closed system. Unlined dams, limited stormwater management infrastructure. Mine water (acidic) used for processing, together with dirty stormwater	VERY HIGH

Receptor	Severity*	Likelihood/probability	Risk
	Critically modified', bearing High sensitivity.	discharged to Kivomo River. Sediments showing metal enrichment.	
Aquatic Ecosystems	HIGH – As, Pb, Mn, pH, TSS exceedance (RS 564, RS EAS1172). Health of the Kivomo River is 'Serious -Critically modified', bearing High sensitivity.	HIGHLY LIKELY – Not a closed system. Unlined dams, limited stormwater management infrastructure. Mine water (acidic) used for processing, together with dirty stormwater discharged to Kivomo River.	VERY HIGH

*Contaminants measured through surface water monitoring

5.6.4 Karambo Mine

The summary tables of the risk assessment for Karambo Mine are presented in **Table 5-13** to **Table 5-16**. In summary, the Karambo Mine presents a mixed active-operational contamination profile, with regular reoccurrences of arsenic, manganese, nitrate, low pH and aluminium exceedances. The latter is generally associated with water-related processing activities (sluice water).

Table 5-13 Sources and Contaminants of Concern identified for Karambo Mine

MINE MATERIALS				MINE IMPACTED / PROCESS WATER / EFFLUENT			
Ore stockpile	Waste rock	Slurry material	Legacy tailings	K2 Sluice 1	K2 Sluice 2	M1 Sluice 1	M1 Sluice 2
Manganese pH	Arsenic Manganese Nitrate pH	Manganese pH	Arsenic Manganese pH	Aluminium Iron Lead	Aluminium Arsenic Manganese pH	Manganese pH	Aluminium Manganese Nitrate pH

Table 5-14 Summary of environmental risks associated with wind erosion/dispersal at Karambo Mine

Receptor	Severity*	Likelihood/probability	Risk
Communities	MINOR – no exceedances of NO ₂ and SO ₂	LIKELY – Proximity of access roads through and between neighbouring communities	LOW
Communities	MEDIUM – PM _{2.5} exceedances at key points on site and in surrounding communities	HIGHLY LIKELY – Proximity of communities and sensitive receptors	HIGH

*Contaminants measured through air quality sampling

Table 5-15 Summary of environmental risks associated with groundwater seepage at Karambo Mine

Receptor	Severity*	Likelihood/probability	Risk
Communities	HIGH – Al , pH , Mn exceedances (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.	HIGH
Livestock	HIGH – pH , Mn exceedance (RS 190)	LOW LIKELIHOOD – Livestock utilise rivers for watering. Groundwater does not contribute to baseflow	MOD
Crops	MEDIUM – pH exceedance (RS 188)	UNLIKELY – Subsistence cultivation is predominately reliant on rainfall. River water used on ad hoc basis, but groundwater does not contribute to baseflow	LOW
Surface water ecosystem interaction	HIGH – pH exceedance (RS EAS 1172, marginal RS 564) Health of the Nyirabukingore River is ‘Serious -Critically modified’, bearing High sensitivity.	HIGHLY LIKELY – Not a closed system. Excess acidic mine water discharged to river. Groundwater does not contribute to baseflow.	VERY HIGH

*Contaminants measured through ground water sampling

Table 5-16 Summary of environmental risks associated with surface water runoff/ discharge at Karambo Mine

Receptor	Severity*	Likelihood/probability	Risk
Communities	HIGH – As , Pb , Mn , pH exceedances (WHO, 2022)	LIKELY – Proximity of community, however river water is not primary source of water for domestic use. River water used on ad hoc basis.	HIGH
Livestock	HIGH – Mn , Pb , pH exceedances (RS 190). FAO compliant	LIKELY – Livestock utilise rivers for watering.	HIGH
Soils (crops)	HIGH – Mn exceedance (RS 188). Na , NO₃ 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	MOD/ LOW
River sediments	HIGH – As , Mn (WHO, 2022), Fe , pH (RS 190), pH (IFC 2007). As , Cu , Pb , (SSV1). Significant	HIGHLY LIKELY – Not a closed system. Unlined dams, limited stormwater management infrastructure. Dirty stormwater,	VERY HIGH

Receptor	Severity*	Likelihood/probability	Risk
	enrichment by Ag, Bi, Sn, extreme enrichment As , B, Pd. Health of the Nyirabukungore River is 'Serious to critically modified', bearing High sensitivity.	sluice effluent and excess acidic mine water discharged to river.	
Aquatic Ecosystems	HIGH – As, Mn, Pb, pH, TSS exceedances (RS 564, RS EAS 1172). Health of the Nyirabukungore River is 'Serious - critically modified', bearing High sensitivity. River flow modification caused by abstraction and discharge.	HIGHLY LIKELY – Not a closed system. Unlined dams, limited stormwater management infrastructure. Dirty stormwater, sluice effluent and excess mine water discharged to river. High metal concentrations and TSS detected.	VERY HIGH

*Contaminants measured through surface water monitoring

5.6.5 Mahaza Mine

The summary tables of the risk assessment for Mahaza Mine are presented in **Table 5-17** to **Table 5-19**. In summary, the dominant risk profile at this mine site is associated with active operational sources, particularly process water and effluent, with some influence of ore, waste rock stockpiles and legacy tailings. The principal reoccurring contaminants include manganese, nitrate, and acidic (low) pH.

Table 5-17 Sources and Contaminants of Concern identified for Mahaza Mine

MINE MATERIALS				MINE IMPACTED / PROCESS WATER / EFFLUENT	
Ore stockpile	Waste rock	Slurry material	Legacy tailings	BV71 Sluice 1	BV71 Sluice 2
Manganese pH	Nitrate pH	-	Manganese pH	Manganese Nitrate pH	Aluminium Manganese Nitrate pH

Table 5-18 Summary of environmental risks associated with groundwater seepage at Mahaza Mine

Receptor	Severity*	Likelihood/probability	Risk
Communities	HIGH – Fe, Pb exceedance (WHO, 2022) (Spring water compliant with WHO, 2022)	UNLIKELY – Spring water is the primary source of water, but is unaffected by groundwater seepage from mine site.	MOD / LOW

Receptor	Severity*	Likelihood/probability	Risk
Livestock	HIGH – Fe, Pb (exceedance RS 190).	LOW LIKELIHOOD – Livestock utilise rivers for watering. Groundwater contributes to baseflow.	MOD
Crops	MINOR – No exceedances	UNLIKELY – Subsistence cultivation is predominately reliant on rainfall.	VERY LOW
Surface water ecosystem interaction	MINOR – No exceedances	LIKELY – Closed system. No water discharging from adits. However, groundwater contributes to river baseflow.	LOW

*Contaminants measured through ground water sampling

Table 5-19 Summary of environmental risks associated with surface water runoff/ discharge at Mahaza Mine

Receptor	Severity*	Likelihood/probability	Risk
Communities	HIGH – Pb, Mn and As exceedance (WHO, 2022)	LIKELY – Proximity of community, however river water is not primary source of water for domestic use. River water used on ad hoc basis	HIGH
Livestock	HIGH - pH, Al, Fe exceedance (RS 190). FAO compliant	LIKELY – Livestock utilise rivers for watering.	HIGH
Soils (crops)	HIGH – Mn exceedance (RS 188). Cl is a severe 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
River sediments	MEDIUM - 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 Moderate sensitivity.	LIKELY – Closed system. No water discharged to environment. Overtopping of dam is possible. Sediments show metal enrichment, and low pH	MOD
Aquatic Ecosystems	MEDIUM – 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 Moderate sensitivity.	LIKELY – Closed system. No water discharged to environment. Overtopping of dam is possible. Some metals and high TSS detected	MOD

*Contaminants measured through surface water monitoring

5.6.6 Masoro Mine

The summary tables of the risk assessment for Masoro Mine are presented in **Table 5-20** to **Table 5-22**. In summary, the dominant risk profile at this mine site is associated with active operational sources, particularly process water and effluent, with some influence of ore stockpiles and legacy tailings. The principle recurring contaminants include manganese, low pH, nitrate, and aluminium. The latter two contaminants are generally associated with water-related processing activities (sluice water).

Table 5-20 Sources and Contaminants of Concern identified for Masoro Mine

MINE MATERIAL				MINE IMPACTED / PROCESS WATER / EFFLUENT	
Ore stockpile	Waste rock	Slurry material	Legacy tailings	BV2G Sluice 1	BV2G Sluice 2
Manganese	pH	-	Manganese pH	Aluminium Manganese Nitrate pH	Aluminium Lead Manganese Nitrate pH

Table 5-21 Summary of environmental risks associated with groundwater seepage at Masoro Mine

Receptor	Severity*	Likelihood/probability	Risk
Communities	HIGH - Al, Pb, Mn, Fe, exceedance (WHO, 2022)	HIGHLY LIKELY – Spring water is the primary source of water for domestic use.	VERY HIGH
Livestock	HIGH - Al, Pb, Mn, Fe, exceedance (RS 190)	LIKELY – Livestock utilise rivers for watering. Groundwater does contribute to baseflow.	HIGH
Crops	MEDIUM – Mn exceedance (RS 188)	UNLIKELY – Subsistence cultivation is predominately reliant on rainfall.	LOW
Surface water ecosystem interaction	HIGH – Pb exceedance (RS 564, EAS 1172), Mn close to limits. Health of the Kagombero / Umurindi River is ‘Seriously-Critically modified’, bearing High sensitivity.	LOW LIKELIHOOD – Closed system. No water discharging from adits. However, groundwater does contribute to baseflow.	MOD

*Contaminants measured through ground water sampling

Table 5-22 Summary of environmental risks associated with surface water runoff/ discharge at Masoro Mine

Receptor	Severity	Likelihood/probability	Risk
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 use. River water used on ad hoc basis. Closed system with no discharge to environment. Overtopping of dam is possible.	MOD
Livestock	HIGH - Al, Fe, Mn, Pb exceedance (RS 190). FAO compliant.	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, Cl 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. No water discharged to environment. Overtopping of dam is possible.	MOD / LOW
River sediments	HIGH – 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 Kagombero / Umurindi River is ‘Seriously-Critically modified’, bearing High sensitivity.	LIKELY – Closed system. No water discharged to environment. Overtopping of dam is possible. Sediments show metal enrichment, and low pH	HIGH
Aquatic Ecosystems	HIGH – Al, Fe, Mn, Pb, TSS exceedance (EAS 1172, RS 564). Health of the Kagombero / Umurindi River is ‘Seriously-Critically modified’, bearing High sensitivity.	LIKELY - Closed system. No water discharged to environment, Overtopping of dam is possible. High metal and TSS concentrations detected.	HIGH

*Contaminants measured through surface water monitoring

5.7 Recommended Concession-Wide Prioritisation

Based on Sections 5.6.1 to 5.6.6, the mines were prioritised owing to their overall risk and assessments. It is recommended that the consolidated preliminary remediation opportunities to mitigate environmental risks as listed in **Table 7-2 (see Section 7, pg. 51)** be implemented per priority mine as listed in **Table 5-23** below. Thus, if budget is limited, interventions should be urgently initiated at Nyamuyumba, followed by Gasambya then Karambo. These three sites likely deliver the greatest immediate environmental risk reduction per dollar spent. Gisanze should follow rapidly due to unmanaged legacy seepage despite non-operational status. Alternatively, **Table 7-2** also provides mine prioritisation related to the risk pathway and environmental risk.

Table 5-23 Proposed mine priority order

Rank	Mine	Overall Priority
1	Nyamuyumba Mine	Critical
2	Gasambya Mine	Critical
3	Karambo Mine	Critical
4	Gisanze Mine	High
5	Masoro Mine	Moderate–High
6	Mahaza Mine	Moderate

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 scenarios⁵ (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 Rutongo Mine (SLR, 2024f) are summarised below:

- **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.
- **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 the Rutongo concession area, 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,

⁵ 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, 2024f).

was rated as (negative) Medium, whilst market-related risk from increasing demand for transitional metals was rated (positive) Medium (SLR, 2024f).

Based on the above the assessment, the Rutongo 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

The Source–Pathway–Receptor analysis confirms that both the Rutongo Mines present significant environmental risks linked to historical and current formal mining activities. Gasambya, Nyamyumba and Karambo present string mixed operational contamination profiles, with numerous contaminants of concern prevalent in mine materials, legacy tailing and water related processing activities.

These contaminants are being transported through wind, surface runoff, and in some areas groundwater pathways, resulting in exposure risks to nearby communities, agricultural users, livestock, and downstream aquatic ecosystems. The adjacent river systems are particularly important receptors, with all systems exhibiting negative impacts and water quality degradation related to mining activities. Apart from the lower Rusine River at Mahaza Mine that showed moderate ecological sensitivity due to its larger size and diversity of habitat, the remaining river systems were considered highly vulnerable due to existing habitat degradation, poor water quality, altered hydrology, and low ecological resilience.

The assessment also highlights that not all environmental impacts originate solely from mining. Natural geology, upstream water quality issues, agricultural land disturbance, erosion, commercial activities (namely fluvial sand and aggregate mining, which is particularly prevalent within the Rutongo concession area), and other external community-related activities are compounding contamination pressures across the Rutongo mining concession area. This means that successful rehabilitation will require an integrated catchment-based approach rather than mine-site measures alone.

The outcomes of the risk assessment for each of the Rutongo Mine sites, which identified high to very high environmental risks and consequently deemed areas of concern, 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 / process water /effluent	Groundwater with some high metal concentrations (discharged direct to river) Surface water runoff carrying high metal concentrations	Communities that utilise Rusine river on ad hoc basis Livestock that utilise rivers (Rusine) for watering Rusine River aquatic ecosystem (sediments and biota)
Nyamyumba Mine	All mine materials	Wind dispersal transporting harmful fugitive emissions	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 and TSS concentrations	Communities utilising nearby springs for drinking and domestic purposes Communities that utilise Sanzari River on ad hoc basis Livestock that utilise rivers (Sanzari) for watering Sanzari River aquatic ecosystem (sediments and biota)
Gasambya Mine	All mine materials Mine impacted water/ process water/ effluent	Groundwater seepage with high metal concentrations Surface water runoff carrying high metal and TSS concentrations and acidic pH	Communities reliant on springs Communities that utilise Kivomo River on ad hoc basis Livestock that utilise rivers (Kivomo) for watering Kivomo River aquatic ecosystem (sediments and biota)
Karambo Mine	All mine materials	Wind dispersal transporting harmful fugitive emissions	Communities at risk through inhalation of dust emissions

Mine Site	Sources	Pathways	Receptors
	All mine materials Mine impacted water/ process water/ effluent	Groundwater seepage with high metal concentrations and acidic pH Surface water runoff carrying high metal and TSS concentrations and acidic pH	Communities that utilise tunnel water on ad hoc basis Communities that utilise Nyarabukungore River on ad hoc basis Livestock that utilise rivers (Nyarabukungore) for watering Nyarabukungore River aquatic ecosystem (sediments and biota)
Mahaza Mine	Ore stockpiles, legacy tailings Mine impacted water/ process water/ effluent	Surface water runoff bearing high metal and TSS concentrations	Communities that utilise Rusine River on ad hoc basis Livestock that utilise rivers (Rusine) for watering
Masoro Mine	All mine materials Mine impacted water/ process water/ effluent	Groundwater seepage with high metal concentrations Surface water runoff bearing high metal and TSS concentrations	Communities reliant on springs Livestock that utilise rivers (Gatiti/Umurindi) for watering (fed by groundwater) Gatiti/Umurindi River aquatic ecosystem (sediments and biota)

7.1 Remediation

Remediation will likely be required in both the short- and long-term, focussing on various aspects at each site. Consistent with international best practice, interventions should prioritise pollution prevention at source before treatment or downstream discharge management. The findings therefore provide a strong technical basis for Trinity Metals' future Legacy Tailings Management and River Rehabilitation Programme, enabling focused investment into practical actions that reduce risk, improve water quality, and restore ecosystem function over time.

For legacy and abandoned mines, Novakowski et al. (2023) proposed the following pollution prevention hierarchy, beginning with source control, water management, treatment, and lastly, discharge to the environment. Preliminary remediation opportunities for the Rutongo Mines are provided in **Table 7-2**. These opportunities would require further detailed investigation as part of Phase 2 of the development of the Legacy Tailing Management and River Rehabilitation

Programme in respect to suitability and efficacy for site-specific conditions. This programme may require additional aspects related to catchment recovery, water security measures, Nature-based-Solutions (NbS), mining legacy reduction, agricultural resilience, biodiversity restoration, community wellbeing and involvement through citizen science tools.

Table 7-2 Preliminary remediation opportunities to mitigate environmental risks

SPR Component	Risk Pathway / Issue	Key Source Areas	Primary Environmental Risk	Consolidated Preliminary Remediation / Mitigation Measures	Priority Mine Focus / Recommended Implementation Sequence
Source	Fugitive dust / air emissions	Haul roads, ore stockpiles, waste rock dumps, exposed disturbed areas, processing zones	PM _{2.5} / PM ₁₀ impacts to communities, workers, crops and vegetation	<ul style="list-style-type: none"> • Routine watering of haul roads and active work areas during dry periods • Enforce reduced vehicle speeds on unpaved roads • Progressive rehabilitation and revegetation of inactive disturbed areas • Cover or stabilise fine stockpiles • Dust monitoring at nearby communities and sensitive receptors and monitor monthly 	Immediate at Nyamuyumba and Karambo (confirmed dust hotspots). Thereafter apply at Gasambya, Gisanze and other active haul road areas.
Source / Pathway	Contaminated surface runoff / dirty stormwater	Ore stockpiles, waste rock, slurry areas, tailings, disturbed slopes, process plants	Sediment loading, metal transport, acidic runoff, river turbidity, habitat smothering	<ul style="list-style-type: none"> • Construct clean-water diversion drains upslope of disturbed areas • Separate clean and dirty water systems • Install sediment traps and settlement ponds • Stabilise exposed slopes with drains and vegetation • Inspect and maintain controls before and after heavy rainfall periods • Aim to prevent visible dirty water discharge from site 	Highest priority at Nyamuyumba, Gasambya and Karambo where runoff/discharge pathways are active. Secondary priority at Gisanze. Maintain controls at Mahaza and Masoro.

SPR Component	Risk Pathway / Issue	Key Source Areas	Primary Environmental Risk	Consolidated Preliminary Remediation / Mitigation Measures	Priority Mine Focus / Recommended Implementation Sequence
Source / Pathway	Unlined dams / polluted water storage seepage	Settling dams, process ponds, old dams, slurry dams	Groundwater contamination, seepage to springs and rivers	<ul style="list-style-type: none"> • Line active polluted water dams and ponds • Install seepage interception drains where required • Maintain adequate storage capacity before rainy seasons to prevent overflows particularly in closed circuit mines • Return seepage water to the process circuit where practical • Decommission redundant dams and remove contaminated sludge (if possible) • Monthly routine groundwater monitoring around storage areas 	Urgent at Nyamuyumba (old dam in river zone), Gasambya and Karambo . Review overflow risk at Masoro and Mahaza closed-circuit dams.
Source / Pathway	Mine water / adit discharge	Adits, tunnels, dewatering systems, pumped mine water	Direct river contamination by metals, acidity and suspended solids	<ul style="list-style-type: none"> • Capture mine water before it reaches streams • Use settling ponds/tanks for solids removal • Reuse water in processing where practical • Monitor discharge volumes and water quality routinely and compare to standards following each round 	Critical at Gisanze (free adit discharge), Gasambya (pumped discharge) and Karambo (M1 tunnel discharge).

SPR Component	Risk Pathway / Issue	Key Source Areas	Primary Environmental Risk	Consolidated Preliminary Remediation / Mitigation Measures	Priority Mine Focus / Recommended Implementation Sequence
Source	Legacy tailings / unstable waste rock	Historical tailings, steep waste dumps, abandoned disposal areas	Chronic erosion, slope instability, long-term leaching	<ul style="list-style-type: none"> • Undertake geotechnical risk ranking of legacy facilities • Reshape unstable slopes to safer profiles • Install toe berms and runoff controls • Apply soil cover and revegetate exposed surfaces • Fence unsafe areas and inspect routinely 	Priority at Gisanze, Nyamuyumba and Karambo where steep terrain and legacy material occur. Then review remaining satellite mines.
Pathway / Receptor	Community drinking water exposure	Springs, shallow groundwater, ad hoc river use points	Human exposure to As, Pb, Mn, Fe, acidity	<ul style="list-style-type: none"> • Provide alternative potable water supplies where exceedances occur • Routine testing of community water sources (springs etc) • Communicate water quality results and risks clearly to communities 	Highest human health priority at Nyamuyumba , followed by Gasambya and Masoro . Review Karambo community tunnel water use.
Receptor	Livestock watering exposure	River access points, downstream streams, seepage zones	Chronic livestock exposure to contaminated water	<ul style="list-style-type: none"> • Establish safer controlled livestock watering points • Restrict access to contaminated reaches • Routine water testing at watering locations • Provide alternative trough supply during pollution 	Immediate along rivers below Nyamuyumba, Gasambya, Gisanze and Karambo where active water quality pressures are greatest.

SPR Component	Risk Pathway / Issue	Key Source Areas	Primary Environmental Risk	Consolidated Preliminary Remediation / Mitigation Measures	Priority Mine Focus / Recommended Implementation Sequence
				incidents or increased discharges	
Receptor	Agricultural soils / crop productivity	Floodplain soils, downstream cultivated land	Metal accumulation, acidity, salinity, reduced yields	<ul style="list-style-type: none"> • Undertake a baseline on soil health and follow-up soil sampling in downstream fields • Where required, suggestion to apply lime or soil amendments where acidic • Promote lower-risk crops where contamination is elevated • Encourage use of cleaner irrigation sources • Farmer awareness and extension support (citizen science based tools and collaborate with the mine) 	Priority downstream of Nyamuyumba, Karambo and Gasambya , then Mahaza and Masoro where irrigation exposure may occur.
Pathway / Receptor	Polluted river systems / aquatic habitat degradation	Sanzari, Kivomo, Nyirabukingore, Rusine, Kagombero/Umurindi rivers	Biodiversity loss, poor aquatic communities, sediment toxicity	<ul style="list-style-type: none"> • Eliminate untreated discharges at source • Construct artificial wetlands (Nature-based Solutions) where feasible along buffer zones where discharges take place • Rehabilitate riparian buffer zones • Ensure no further encroachment within the 10m allocated buffer zone along all rivers associated with the mines 	Immediate river restoration focus: Sanzari (Nyamuyumba), Kivomo (Gasambya), Nyirabukingore (Karambo), Rusine (Gisanze) . Secondary focus Masoro/Mahaza reaches.

SPR Component	Risk Pathway / Issue	Key Source Areas	Primary Environmental Risk	Consolidated Preliminary Remediation / Mitigation Measures	Priority Mine Focus / Recommended Implementation Sequence
				<ul style="list-style-type: none"> • Undertake regular biomonitoring to track recovery trends through the assessment of the aquatic macroinvertebrate communities and diatoms on a bi-annual basis. 	
Pathway / Receptor	Flow alteration / abstraction impacts	Water abstraction points for mining/process use	Reduced dilution, altered habitat, compounded water quality stress	<ul style="list-style-type: none"> • Meter abstraction points and maintain a mine water balance • Increase recycling and reuse of process water • Reduce abstraction during low-flow periods • Maintain downstream environmental flows where required for both ecological and basic human needs 	Priority at Nyamuyumba and Karambo , where abstraction plus discharge may be creating combined river stress (flow).
Receptor / Institutional	Care & maintenance liabilities	Inactive / reduced activity mine areas	Pollution continues from non-operational sites	<ul style="list-style-type: none"> • Maintain minimum environmental standards at inactive sites • Monthly inspections of drains, dams and seepage points • Treat ongoing polluted seepage • Periodic compliance audits 	Immediate at Gisanze despite care and maintenance status. Then apply to any future inactive satellite sites.

SPR Component	Risk Pathway / Issue	Key Source Areas	Primary Environmental Risk	Consolidated Preliminary Remediation / Mitigation Measures	Priority Mine Focus / Recommended Implementation Sequence
Receptor / Institutional	Concession-wide cumulative risk management	Entire Rutongo concession	Multiple mines creating combined downstream liabilities	<ul style="list-style-type: none"> • Establish one concession environmental management programme • Shared monitoring dashboard across all mines • Trigger-action plans for exceedances (threshold of potential concerns) • Progressive rehabilitation scheduling • Annual third-party audit and mine closure plan review 	<p>Phase 1: Nyamuyumba, Gasambya, Karambo. Phase 2: Gisanze. Phase 3: Masoro and Mahaza.</p>

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9. APPENDICES

APPENDIX 1: STANDARDS AND GUIDELINES

Air Quality Standards and Guidelines

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

Water Quality and Effluent Standards and Guidelines

- 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 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)
- Rwanda Standard (2013): Livestock watering, specifies the characteristics, requirements to be used for livestock watering (RS 190)

Environmental Standards

- Rwanda Standard (2023): Ambient Water – Specifications [for the protection of human health, welfare and environment] (RS 564)
- Rwanda Standard (2024): Water discharged on land and into water bodies - Specification (RS EAS 1172) (IDT)
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