

# NYAKABINGO CONCESSION AREA FRESHWATER ECOSYSTEM ASSESSMENTS

Trinity Metals

DRAFT





## GroundTruth

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

[www.groundtruth.co.za](http://www.groundtruth.co.za)

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| Prepared by           |   |
| Author(s)             | Fiona Eggers (Pr.Sci.Nat – Ecology)   |
|                       | Gary de Winnaar (Pr.Sci.Nat – Ecology)  |
|                       | Esi Bossman (Cand.Sci.Nat – Aquatic Science)  |
| Document Reviewer     | Craig Cowden (Pr.Sci.Nat – Ecology)   |
| Prepared For          |  |

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## ***INDEMNITY***

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## **EXECUTIVE SUMMARY**

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GroundTruth was commissioned by Trinity Metals to perform a baseline assessment of the freshwater ecosystems in the Nyakabingo Mine Concession Area to support Phase 1 of the Legacy Tailings Management and River Rehabilitation Programme. The study's primary objective was to establish the Present Ecological State (PES) and evaluate ecosystem. Utilising desktop mapping and field surveys conducted in 2025, the wetland and riverine integrity was evaluated through frameworks such as WET-Health and riverine assessment tools. Findings indicate that the high-relief, mountainous landscape has been heavily modified by intensive anthropogenic activities, including both formal and unauthorised mining and widespread subsistence agriculture. These pressures have caused severe degradation, with the Nyakabingo River classified as "seriously modified" due to impacts associated with the mine, extensive sedimentation, and the loss of natural riparian vegetation.

Similarly, assessed wetlands like the Lower Nyakabingo Seep are in a "Seriously modified" state (Category E), primarily because they have been extensively drained for cultivation. While the demand for regulating ecosystem services - such as sediment trapping and water purification - is high, the supply of these services is currently very low due to the altered state of the habitats. To mitigate these impacts in Phase 2, the report recommends focusing on source control for pollution, implementing "grey-green" hybrid infrastructure like biofiltration systems and vegetated swales, and creating constructed wetlands to buffer downstream environments. Additionally, the study suggests launching pilot projects for sustainable land-use practices, such as contour farming, and emphasizes the need for a robust monitoring and adaptive management framework combined with active community engagement to ensure the long-term success of rehabilitation efforts.

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## LIST OF ACRONYMS

| Acronym | Explanation                                 |
|---------|---|
| ASPT    | Average Score Per Taxon                     |
| BAP     | Biodiversity Action Plan                    |
| CHA     | Critical Habitat Assessment                 |
| DDS     | Development Strategy                        |
| DRC     | Democratic Republic of the Congo            |
| DWS     | Department of Water and Sanitation          |
| EGS     | Ecosystem goods and services                |
| EIA     | Environmental Impact Assessment             |
| ESA     | European Space Agency                       |
| ESIA    | Environmental and Social Impact Assessment  |
| ESMP    | Environmental and Social Management Plan    |
| FIP     | Forest Investment Program                   |
| GIS     | Geographic Information System               |
| HGM     | Hydrogeomorphic                             |
| IFC     | International Finance Corporation           |
| IHI     | Index of Habitat Integrity                  |
| IWRM    | Integrated Water Resources Management       |
| KAB     | Karagwe-Ankole Belt                         |
| KIB     | Kibara Belt                                 |
| MAP     | Mean Annual Precipitation                   |
| MoE     | Ministry of Environment                     |
| NbS     | Nature-based Solutions                      |
| NST1    | National Strategy for Transformation 1      |
| NST2    | Second National Strategy for Transformation |
| NW      | Northwest                                   |
| PES     | Present Ecological State                    |
| RFA     | Rwanda Forestry Authority                   |
| PFM     | Public Financial Management                 |
| PS6     | Performance Standard 6                      |
| REMA    | Rwanda Environment Management Authority     |
| RWB     | Rwanda Water Resources Board                |

| Acronym | Explanation                              |
|---------|--|
| SASS5   | South African Scoring System (version 5) |
| SDGs    | Sustainable Development Goals            |
| SE      | Southeast                                |
| UN      | United Nations                           |
| WRI     | World Resources Institute                |
| WSE     | Water Surface Elevations                 |

## 1. INTRODUCTION

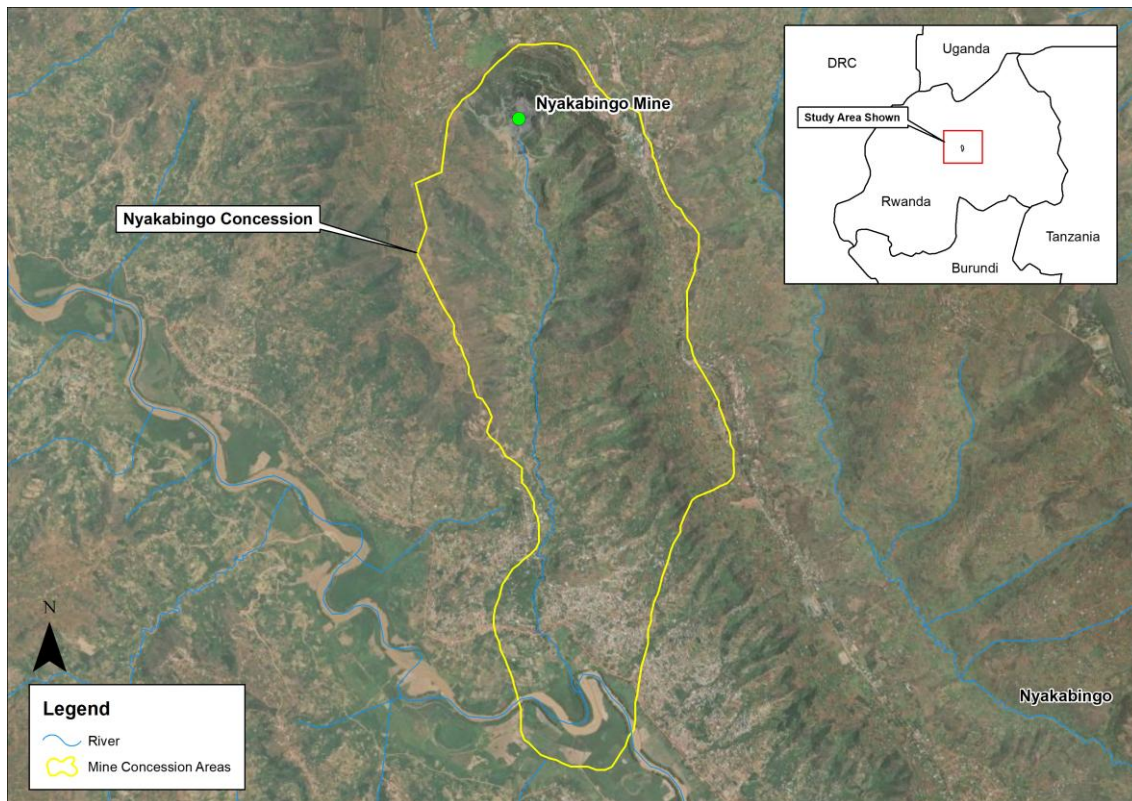
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GroundTruth were appointed by Trinity Metals to undertake a broad range of ecological, social and engineering studies across their mining concession areas in Rwanda, to contribute towards Phase 1 of Trinity Metal's Legacy Tailings Management and River Rehabilitation Programme.

Freshwater ecosystems, including rivers and wetlands, and associated biota, are crucial features within the landscape, which not only contribute towards biodiversity but provide a suite of ecosystem services that support the livelihoods of people. These systems support provisioning services such as freshwater supply, regulating services including flow regulation and water purification, cultural services linked to heritage and recreation, and processes that maintain ecological integrity and productivity. The importance of these systems has been globally assessed, and the systems have been recognised by international agreements (e.g. Convention on Biological Diversity) that guide how organisations like the IFC (International Finance Corporation) protect nature and the benefits people get from them.

This study has been initiated to assess the freshwater ecosystems within the various mining concession areas, particularly focussing on developing an understanding of the extent, ecological condition and functioning, the overall operating rules, and drivers and pressures of the freshwater ecosystems within the current landscape setting. To align with international requirements, this baseline study of the freshwater ecosystems is required, in order to ascertain whether the concession areas incorporate areas with critical habitat but are also recommended for high-risk projects potentially impacting on natural areas (IFC, 2012). The freshwater ecosystem baseline study will form the basis from which future action and mitigation strategies can be developed to achieve a net gain (or no net loss), where feasible, within the modified landscape, so as to align with the IFC requirements.

The focus of this freshwater ecosystem report is the Nyakabingo Mine Concession Area. The Nyakabingo Mine is located in Northern Rwanda, in Rulindo District, Northern Province, about 19 km northwest of Kigali. The mine is primarily known for producing cassiterite, which is the main ore of tin. It is one of Rwanda's largest underground tin mines and has historically been a major contributor to the country's tin exports. In addition to tin, small quantities of tantalum and tungsten may also be recovered as by-products, though cassiterite remains the dominant mineral extracted. **Figure 1-1** provides an overview of the study area.



**Figure 1-1 Overview of the mine site in the Nyakabingo Mine Concession area**

## 1.1 Key Objectives

The purpose of this report is to provide a comprehensive baseline of the freshwater ecosystems within the Nyakabingo concession area. The objective of the site visit was to verify and evaluate the freshwater ecosystems, distinguishing between riverine and wetland ecosystems, and recognising their landscape linkages. Baseline information was collected to enable the assessment of ecosystem functioning and integrity, as well as to develop an understanding of the overall importance and sensitivity of these freshwater habitats. This information, together with the results of the floodline and sediment modelling, will inform impact mitigation measures and guide resilient rehabilitation planning during Phase 2 of the project.

The key objectives of the freshwater ecosystem study were to:

- Undertaking desktop studies and field-based surveys of associated ecosystems within the area of influence for each site;
- Characterise patterns and processes of freshwater systems in terms of biota (i.e. fauna and flora), vegetation, hydrology, geomorphology, etc.;
- Establish baseline ecological conditions/Present Ecological State (PES), as well as the provision of ecological benefits and services.
- Highlighting any species of conservation concern (i.e. rare, endemic, Red Data species), in particular species that trigger Criterion 1 to 3 IFC PS6 that will need to be considered in the Critical Habitat Assessment (CHA); and
- Identifying and assessing key indicators suitable for monitoring (e.g. biomonitoring) and determining additional in-situ water quality indicators for assessment and longer-term monitoring.

## 2. REGULATORY AND INSTITUTIONAL FRAMEWORK

### 2.1 National Strategy for Transformation

Following several decades of progress since the 1994 Genocide against the Tutsi, Rwanda continues its journey toward self-reliance and economic modernisation through the implementation of Vision 2050. This long-term roadmap was preceded by Vision 2020 and is being realised through a series of medium-term national development strategies. The National Strategy for Transformation 1 (NST1) served as the initial bridge for this transition between 2017 and 2024. Rwanda is now commencing the next phase through the Second National Strategy for Transformation (NST2), which spans from 2024 to 2029. This strategy continues to integrate global and regional agendas, including the UN Sustainable Development Goals (SDGs), the African Union Agenda 2063, and the East African Community Vision 2050 (Republic of Rwanda, 2024; Republic of Rwanda, 2020).

NST2 maintains the three core pillars of transformation: Economic Transformation, Social Transformation, and Transformational Governance (Republic of Rwanda, 2024).

The Economic Transformation Pillar in NST2 prioritises building resilience to climate change and the sustainable management of natural resources to ensure long-term prosperity. A critical objective within this pillar is achieving universal access to water supply for both productive use and households, with a target to scale access to all villages countrywide by 2029. The strategy aims to more than double daily water production capacity and reduce non-revenue water to enhance efficiency. These efforts are supported by integrated water resource management (IWRM) that focuses on restoring catchment areas and improving watershed management to mitigate disasters like flooding (Republic of Rwanda, 2024).

The Social Transformation Pillar focuses on enhancing human capital and the quality of life for all Rwandans. Key interventions include increasing access to quality education, reducing stunting among children under five from 33% to 15%, and scaling up access to sanitation and hygiene (WASH) services. Major infrastructure projects, such as the Kigali Centralised Sewerage System, are planned to support the sustainability of densified urban areas. Furthermore, this pillar seeks to empower households to graduate from poverty through social safety nets and the provision of technical and financial skills (Republic of Rwanda, 2024).

The Transformational Governance Pillar serves as the foundation for these gains by strengthening the rule of law and ensuring an accountable and capable state. This pillar targets a service delivery satisfaction level above 90% and emphasises citizen-centered governance through enhanced participation platforms. While not directly managing water, this pillar supports resource management by fostering international cooperation, strengthening Public Financial Management (PFM) for "green public procurement," and building institutional capacity at all levels (Republic of Rwanda, 2024).

The Government of Rwanda implements these national priorities through specialised sectors and cross-sectoral collaboration platforms, such as Sector Working Groups (SWGs). The implementation arrangement for NST2 is cascaded down to local levels through District Development Strategies (DDS), which ensure that national objectives are aligned with local

economic potential and community needs. This allows all districts to prioritise interventions that contribute to the overarching national goals (Republic of Rwanda, 2024).

Ultimately, NST2 acts as the critical vehicle toward Vision 2050, which aspires for Rwanda to reach upper-middle-income status by 2035 (with a GDP per capita of over \$4,036) and high-income status by 2050 (with a GDP per capita of over \$12,476). The vision emphasises an inclusive model of development, recognising the collective commitment required from the government, private sector, civil society, development partners, and all Rwandan citizens to modernise the nation and ensure a high quality of life for future generations (Republic of Rwanda, 2024; Republic of Rwanda, 2020).

## 2.2 Applicable Rwandan regulations/legislation

Rwanda’s environmental legislation is anchored in its Constitution<sup>1</sup>, which guarantees every citizen the right to live in a healthy and balanced environment and places a duty on the state to protect natural resources while promoting sustainable development.

Rwanda’s constitutional commitment to environmental protection was first translated into the 2005 Organic Law on Environmental Protection and Management, which established principles for conservation and introduced mandatory Environmental Impact Assessments (EIAs) for projects likely to affect the environment. Building on this foundation, Law No. 48/2018 on Environment strengthened the framework by expanding provisions on pollution control, waste management, biodiversity conservation, and environmental governance, while also imposing stricter penalties for violations and emphasising community participation.

The legislation’s major focus areas include pollution control, waste reduction and recycling, biodiversity protection, climate change adaptation, and citizen engagement in conservation efforts. Implementation is overseen by the Ministry of Environment, enforced by the Rwanda Environment Management Authority (REMA), and supported by local governments at the grassroots level.

### 2.2.1 Environmental and Freshwater Ecosystem Legislation in Rwanda

Rwanda’s environmental and freshwater ecosystem legislation is shaped by the 2018 Law on Environment, which provides a comprehensive framework for conservation, sustainable resource use, and environmental governance.

Freshwater ecosystems are safeguarded through the oversight of the Rwanda Water Resources Board (RWB), which plays a central role in managing rivers, lakes, and wetlands under the principle of Integrated Water Resources Management (IWRM). This approach ensures that water resources are allocated equitably among competing needs - such as domestic supply, agriculture, industry, and energy - while maintaining ecological integrity. Implementation is overseen by the Ministry of Environment, enforced by REMA, managed by the RWB, and supported by local governments at the grassroots level. Together, these measures ensure that Rwanda’s rivers, lakes, wetlands, and broader ecosystems are protected from pollution,

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<sup>1</sup> Article 22 of the Constitution of the Republic of Rwanda of 2003, revised in 2015.

overuse, and unsustainable development, while balancing biodiversity conservation, human needs, and climate resilience.

Wetlands are legally protected, with any conversion for agriculture, construction, or other development strictly requiring environmental assessment and government approval. Lakes and rivers are managed to balance biodiversity conservation with human needs, supporting livelihoods through regulated fishing, irrigation for food security, and hydropower generation. Rwanda’s environmental legislation provides clear protections and regulated uses for its freshwater ecosystems, ensuring that conservation and sustainable utilisation are balanced. Error! Reference source not found. summarises how each ecosystem type is managed under this legislation:

**Table 2-1 Freshwater Ecosystem Legislation, Protection & Use**

| Ecosystem Type | Legal Protection  | Permitted Uses   | Restrictions  |
|----------------|---|--|---|
| Wetlands       | Legally protected under Law No. 48/2018; conversion requires government approval; managed by Rwanda Environment Management Authority (REMA) | Sustainable agriculture, eco-tourism, research, regulated fishing.   | No unauthorized drainage, construction, or industrial waste discharge.                            |
| Lakes          | Protected as biodiversity hotspots; water quality monitored; pollution control enforced.  | Fishing, irrigation, hydropower, transport, recreation are regulated through a water use permit managed by Rwanda Water Resources Board (RWB). | Ban on untreated waste disposal; restrictions on overfishing; shoreline development requires EIA. |
| Rivers         | Managed under Integrated Water Resources Management (IWRM); protected against pollution and overuse.  | Irrigation, hydropower, and domestic water supply are regulated through a water use permit managed by Rwanda Water Resources Board (RWB).      | No industrial effluent discharge without treatment; sand mining and damming require permits.      |
| Groundwater    | Protected under national water policy; extraction monitored and regulated by RWB.   | Domestic use, agriculture, industry (with permits).  | Over-extraction prohibited; pollution from chemicals strictly controlled.                         |

In addition, the RWB enforces strict pollution control measures, prohibiting the discharge of untreated industrial or domestic waste into water bodies and mandating continuous monitoring of water quality. These safeguards are complemented by restoration projects aimed at rehabilitating degraded wetlands and catchments, as well as community-based initiatives that involve local populations in conservation and sustainable water use. Importantly, wetlands and river systems also serve as natural buffers against climate change impacts, reducing flood risks, mitigating drought effects, and enhancing resilience to extreme weather events.

The legislation is guided by key principles, including the right to a healthy environment, precautionary measures for activities that may harm ecosystems, sustainable use of resources for future generations, and active community participation in conservation efforts.

## **2.3 Rwanda’s Environmental Governance Institutions**

### **2.3.1 Ministry of Environment**

The Rwandan Ministry of Environment (MoE) is the central government body responsible for environmental protection, climate change policy, and the sustainable management of land, water, and forestry resources. Its mandate includes developing and enforcing national environmental policies and legal frameworks, coordinating climate change adaptation and mitigation programs in line with international commitments such as the Paris Agreement, overseeing sustainable land use and forest conservation, protecting biodiversity and wetlands, and integrating environmental concerns into Rwanda’s broader development agenda.

The Ministry operates through specialised directorates, including the Directorate General of Environment and Climate Change, which implements climate policies and monitors emissions, and the Directorate General of Land, Water, and Forestry, which manages land use planning, water resources, and forest ecosystems. It works closely with affiliated agencies such as the Rwanda Environment Management Authority (REMA), which enforces environmental law and conducts EIAs, and the Rwanda Forestry Authority, which manages forest conservation and reforestation programs. The Ministry and its affiliated agencies work closely with the Rwanda Water Resources Board (RWB), which oversees freshwater ecosystems and Integrated Water Resources Management (IWRM) and affiliated to the Office of the Prime Minister.

As of July 2025, the Ministry is led by Bernadette Arakwiye, an expert in land restoration and environmental research with prior experience at the World Resources Institute (WRI). Under her leadership, recent initiatives include the Legacy Tree Project to preserve Rwanda’s oldest native trees, international cooperation with Singapore under Article 6 of the Paris Agreement to strengthen climate action, and ongoing wetland restoration projects to rehabilitate degraded ecosystems. Central to Rwanda’s sustainability agenda, the Ministry combines policy-making, enforcement, and international collaboration to protect the environment while supporting economic growth, with current priorities focused on climate resilience, biodiversity conservation, and land restoration.

### **2.3.2 Rwanda Environment Management Authority**

The Rwanda Environment Management Authority (REMA), established in 2006, serves as the national authority responsible for implementing environmental policies and laws, with a mission to protect, conserve, and promote Rwanda’s environment while ensuring sustainable development. Its core responsibilities include enforcing compliance with environmental legislation such as Law No. 48/2018 on Environment, reviewing and approving EIAs, monitoring pollution levels, waste management practices, and biodiversity conservation, and promoting environmental education and public awareness.

REMA also works with the Ministry of Environment to translate policies into action and coordinates Rwanda’s participation in international environmental agreements. Its focus areas span pollution control, waste management, biodiversity conservation, climate change

adaptation and mitigation, and community engagement in environmental decision-making. Operating under the Ministry of Environment, REMA collaborates with agencies such as the Rwanda Water Resources Board (RWB) and the Rwanda Forestry Authority, while also working closely with local governments to implement grassroots initiatives. As the enforcement arm of Rwanda’s environmental governance system, REMA ensures that development projects meet environmental standards, safeguards ecosystems, and promotes sustainable resource use, playing a central role in Rwanda’s vision of becoming a green, climate-resilient nation.

### **2.3.3 *Rwandan Water Resources Board***

The Rwanda Water Resources Board (RWB), established in 2020 by Law No. 71/2019 of 29 January 2020, is tasked with ensuring the sustainable management of the country’s water resources. Its mission is to coordinate, regulate, and promote Integrated Water Resources Management (IWRM) to deliver social, economic, and environmental benefits. The Board develops national strategies for water use, allocation, and conservation, oversees water quality and pollution control, and ensures compliance with environmental laws. It manages wetlands, rivers, and lakes to balance biodiversity conservation with human needs, implements measures to strengthen climate resilience against droughts and floods, and conducts hydrological research while maintaining national water resource databases.

RWB also engages communities and local governments to promote sustainable water use. Its focus areas include pollution prevention, water supply security, hydropower development, wetland restoration, and transboundary cooperation on shared basins such as the Nile. Operating under the Office of the Prime Minister, RWB works closely with REMA on compliance, partners with the Rwanda Forestry Authority for watershed protection, and coordinates grassroots initiatives with local governments. As the guardian of Rwanda’s freshwater ecosystems, RWB integrates water management across agriculture, energy, domestic use, and biodiversity conservation, ensuring that rivers, lakes, wetlands, and groundwater are protected for both present and future generations.

### **2.3.4 *Rwanda Forestry Authority***

The Rwanda Forestry Authority (RFA), formally established by Law No. 72/2019 of 29 January 2020, is the national agency responsible for managing, protecting, and expanding Rwanda’s forest resources to ensure sustainable development. Its mandate includes promoting forest growth and conservation, conducting forestry research and innovation, implementing national forestry policies, engaging communities in tree planting and agroforestry, and supporting climate change mitigation through reforestation and forest preservation. The Authority oversees natural forests, plantations, and agroforestry systems, regulates the sustainable harvesting of non-timber forest products such as honey, medicinal plants, and bamboo, coordinates national reforestation campaigns including Umuganda (monthly community service), enforces forestry laws to prevent illegal logging, and develops guidelines for urban forestry. Organised into specialised divisions - Forest Research, Forest Management, and Administration and Finance - the RFA combines scientific research with practical management and policy enforcement. Recent initiatives include the Forest Investment Program (FIP), which promotes agroforestry and sustainable land use in districts like Gakenke, the 2025 Urban Tree Guidelines that set standards for planting in residential and public spaces, and community mobilisation efforts encouraging citizen participation in reforestation and erosion control. As a central institution in Rwanda’s

environmental governance, the RFA plays a vital role in forest conservation, reforestation, and sustainable resource use, advancing the country’s vision of becoming a green, climate-resilient nation.

## 2.4 International Finance Corporation Performance Standards

The International Finance Corporation (IFC) Performance Standards provide an internationally recognised framework for managing environmental and social risks associated with development projects and they are widely adopted by financial institutions, development banks, and private sector lenders. Through its Environmental and Social Sustainability Policy and accompanying Performance Standards (updated in 2012), the IFC requires projects with potentially significant environmental and social impacts to align with these standards as a condition of financing. In the context of freshwater ecosystems, including rivers (and associated riparian systems), wetlands, lakes, and floodplains, the IFC framework plays an important role in integrating biodiversity conservation, ecosystem services, and sustainable water resource management into project planning and decision-making.

Freshwater ecosystems are addressed primarily through IFC Performance Standard 6 (PS6): *Biodiversity Conservation and Sustainable Management of Living Natural Resources*. PS6 explicitly recognises that conserving biodiversity, maintaining ecosystem services, and sustainably managing living natural resources are fundamental to sustainable development. Under PS6, clients are required to identify and prioritise ecosystem services through a systematic assessment process. Priority ecosystem services are defined as, 1) services on which project activities are likely to have significant impacts, particularly those affecting the well-being and livelihoods of affected communities, and 2) services on which project operations directly depend. For freshwater systems, this may include water supply, water purification, flood attenuation, fisheries, sediment regulation, groundwater recharge, and cultural or livelihood-related services associated with rivers and wetlands.

PS6 places strong emphasis on the application of the mitigation hierarchy, requiring projects to first avoid impacts, then minimise and restore impacts where feasible, and finally offset significant residual impacts where necessary. The overall objective is to achieve “no net loss” of biodiversity and ecosystem services, and where “critical habitat” is affected, a measurable “net gain” may be required. The standard also recognises the importance of maintaining ecological integrity and connectivity within freshwater systems, including the protection of environmental flows, aquatic habitats, and wetland functioning. In practice, this requires robust baseline assessments, biodiversity and aquatic ecology studies, water quality and hydrological investigations, and ongoing monitoring throughout the project lifecycle.

Under IFC PS6 and associated Guidance Note 6, habitats are classified into modified, natural, and critical habitats, with all terrestrial and freshwater ecosystems considered within this framework. Critical habitats include areas supporting threatened species, endemic or restricted-range species, highly threatened ecosystems, or globally significant biodiversity concentrations. Consequently, freshwater ecosystems such as intact wetlands, ecologically important river systems, Ramsar wetlands, or habitats supporting threatened aquatic species may qualify as critical habitat and trigger additional requirements, including Biodiversity Action Plans (BAPs), enhanced mitigation measures, and potentially biodiversity offsets.

While PS6 is the primary biodiversity standard, several other IFC Performance Standards are also relevant to freshwater ecosystems. **Performance Standard 1** (*Assessment and Management of Environmental and Social Risks and Impacts*) establishes the overarching framework for environmental and social assessment, stakeholder engagement, cumulative impact assessment, and adaptive management. **Performance Standard 3** (*Resource Efficiency and Pollution Prevention*) addresses sustainable water use, wastewater management, pollution prevention, erosion and sediment control, and efficient resource utilisation. **Performance Standard 4** (*Community Health, Safety and Security*) is relevant where changes in water quality, flooding, dam safety, or ecosystem services may affect downstream communities. Collectively, these standards reinforce the requirement for integrated and sustainable management of freshwater resources at both site and catchment scales.

The IFC Performance Standards are also closely aligned with broader international sustainability frameworks, including the Equator Principles, and therefore form a key benchmark for projects seeking international financing. As a result, freshwater ecosystem protection is increasingly considered a core component of environmental and social due diligence, requiring projects to demonstrate that development activities will not result in unacceptable degradation of rivers and wetlands, or the ecosystem services on which communities and biodiversity depend.

### 3. KNOWLEDGE GAPS

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.

#### 3.1 Assumptions

- The mapping of freshwater ecosystems within the Nyakabingo Mine Concession area was initially undertaken at a desktop-level utilising available topographical maps, current and historical aerial imagery, existing coverages, contour data, and available Geographical Information System (GIS) coverages. The desktop-level mapping was performed in a GIS at a scale of 1:5'000 to create an initial draft spatial coverage of the freshwater ecosystems within the study area. The extent of the freshwater ecosystems was later updated following the site visit in November 2025, during which stage the HGM unit type was also verified.
- Most rivers and wetlands have been significantly altered from their benchmark conditions to the extent that their original operating rules and functional processes are no longer representative. In such cases, systems are assessed against their new operating rules and reclassified into more appropriate Hydrogeomorphic (HGM) unit types, since they are unlikely to ever be reinstated to their benchmark conditions. This redefinition ensures that management reflects current functional processes rather than historic classifications.
- The catchment landcover/uses coverage was mapped at a scale of 1:20'000 using Google Earth imagery due to the extent of the Nyakabingo concession area.
- The assessment of Present Ecological State for each system was based on a rapid visual assessment of modifications to the biophysical drivers and was principally based on a brief site review of localised portions of the system, which were used to verify desktop derived information and inform the assessment of the greater system.
- Given the extensive size of the concession area and the limited time available on site, the specific locations visited were considered representative of the broader site context. Accordingly, the conditions observed during the site visit were assumed to be representative of the general condition of the systems across the wider area.
- The small seepage wetland along the Nyaborongo River, located upstream of the Nyakabingo River decant, was excluded from further assessment because it is hydrologically isolated from mining-related impacts, and is driven by impacts from the upstream Nyaborongo River catchment area.

#### 3.2 Limitations

The following limitations apply to the studies undertaken for this report:

- The assessments of the freshwater ecosystems and identified wetland/riverine habitats were based two brief site visits conducted in July/August and November 2025. As such, they represent a 'snapshot in time' due to budgetary and time constraints. This approach did not allow for extensive assessment across multiple seasons, meaning that some

species may have been missed and temporal trends not captured. Furthermore, changes in features and characteristics within the wetlands, rivers, and their catchments (potentially influenced by seasonality and land use) may not be fully reflected. Given the long history of transformation and degradation at the site, it was not expected to support unique or highly sensitive biodiversity features.

- All assessments undertaken were based on the impacts that were noted during the time of the site visit. Should conditions onsite change, including catchment conditions, the assessments may not necessarily reflect such changes. Any subsequent changes in a systems catchment may have adverse effects on the overall system's integrity.
- The wetland/riparian assessment techniques are considered to be the most appropriate at the time of the compilation of the report, as these techniques have been compiled based on international best practice, undergoing a peer-review process during their development. However, in some instances where systems have been highly modified/transformed, these techniques may have shortfalls.
- The technique adopted for the assessment of wetland condition (i.e. WET-Health) did not account for all land use types within the Nyakabingo concession, and as such, modifications to wetland land cover categories were adopted, particularly to reflect the impacts of extensively drained subsistence croplands.
- As the assessment techniques have a predominant South African focus and rely on quaternary catchment information specific to South Africa, the catchment data for the Nyakabingo concession was updated using client-provided rainfall records (MAP), while runoff and evaporation values were derived from the ERA5 repository.
- WET-EcoServices (Kotze *et al.*, 2020) assists in identifying the importance and sensitivity of specific wetlands/rivers but is recognised as having limitations in terms of quantifying specific impacts linked to development or changes within the landscape; and accounting for the size of the wetland and ecosystem services strongly associated with the size of the systems.
- The instream and riparian site assessments reflect the state of a particular river segment and not the state of the full length of each river, however, the knowledge and information gained from the field verification was then extrapolated for the entire river reach being assessed.
- The riparian assessments are subject to seasonal constraints as certain characteristics of the rivers are only evident at certain times of the year.

The project deliverables, including the reported results, comments, recommendations and conclusions, are based on the authors' professional knowledge as well as available information. This study is based on assessment techniques and investigations that are limited by time and budgetary constraints applicable to the type and level of survey undertaken.

## 4. METHODS

### 4.1 Site visit

The field survey was conducted from 18<sup>th</sup> – 19<sup>th</sup> November 2025 to assess the freshwater ecosystems within the Trinity Nyakabingo concession, with additional observations from the July/August 2025 site visit also incorporated into the assessment.

#### 4.1.1 Wetland assessments

**Table 4-1** below shows the field survey programme that was followed for the wetland habitat assessment component of the study.

**Table 4-1 Field Survey Programme for wetland habitat assessment.**

| Day       | Date       | Site  |
|-----------|------------|---|
| Wednesday | 19/11/2025 | Nyakabingo Mine and downstream catchment area |

The wetland assessment included on-site verification of habitat extent by examining landscape position, soil characteristics, and vegetation indicators to confirm the boundaries of wetland areas. The functional assessment evaluated how well the wetlands perform key ecosystem roles and the extent to which they provide important goods and services to the surrounding landscape and communities. In addition, an integrity assessment was undertaken to compare current conditions against natural reference states by examining four key drivers namely hydrology, water quality, geomorphology, and vegetation; thereby identifying how human activities have altered the condition and functioning of the wetlands.

#### 4.1.2 Riverine assessments

**Table 4-2** below shows the field survey programme that was followed for the riverine assessments.

**Table 4-2 Field survey programme for the riverine assessments.**

| Day     | Date       | Site  |
|---------|------------|---|
| Tuesday | 18/11/2025 | Five sites along the Nyakabingo River with two observational sites on the Nyabugogo |

Sampling and assessments took place at a total of five sites covering the Nyakabingo River and selected community springs draining the concession. Water clarity was measured at four sites using a clarity tube to provide a relative indication of turbidity and suspended sediment levels. Benthic diatom samples, which serve as sensitive indicators of water quality effects on aquatic life, were collected at five sites following standard protocols. Aquatic macroinvertebrates were assessed at two sites with suitable habitat using the ISO-accredited SASS5 method to determine river health based on community composition and scoring metrics. In addition, the Index of Habitat Integrity (IHI) was applied at three sites to evaluate the Present Ecological State of both riparian and instream habitats.

## 4.2 Freshwater ecosystem classification

The freshwater ecosystem classification utilised for the study is based on the classification systems developed in South Africa, as these classification systems form the basis against which the freshwater ecosystems were assessed.

### 4.2.1 Wetland classification

Wetlands were classified into Hydrogeomorphic (HGM) units to facilitate assessment of the systems across the site. The classification approach distinguished wetland systems according to their functional characteristics and hydrological setting (Error! Reference source not found.).

**Table 4-3 A description of the various HGM unit types**

(Ollis *et al.* 2013)

| Landscape unit            | HGM unit                   | Description of HGM Units<br>(Ollis <i>et al.</i> 2013)   |
|---------------------------|----------------------------|--|
| Plain <sup>2</sup>        | Floodplain                 | A wetland area on the mostly flat or gently-sloping land adjacent to and formed by an alluvial river channel, under its present climate and sediment load, which is subject to periodic inundation by over-topping of the channel bank.  |
| Valley Floor <sup>3</sup> | Channelled valley-bottom   | Valley-bottom areas with a clearly defined stream channel but lacking characteristic floodplain features. May be gently sloped and characterised by the net accumulation of alluvial deposits or may have steeper slopes and be characterised by the net loss of sediment. Water inputs from main channel (when channel banks overspill) and from adjacent slopes. |
|                           | Unchannelled valley-bottom | A valley-bottom area with no clearly defined stream channel, usually gently sloped and characterised by alluvial sediment deposition, generally leading to a net accumulation of sediment. Water inputs mainly from channel entering the wetland and also from adjacent slopes.  |
| Slope <sup>4</sup>        | Hillslope seep             | A wetland area located on gently to steeply sloping land and dominated by colluvial (i.e., gravity-driven), unidirectional movement of water and material downslope. Seeps are often located on the side slopes of a valley, but they do not typically extend onto the valley floor.   |
| Bench <sup>5</sup>        | Depression                 | A wetland or aquatic ecosystem with closed (or near-closed) elevation contours, which increases in depth from the perimeter to a central area of greatest depth and within which water typically accumulates.  |

<sup>2</sup> Plain – an extensive area of low relief. These areas are generally characterized by relatively level, gently undulating or uniformly sloping land with a very gentle gradient that is not located within a valley. Gradient is typically less than 0.01 or 1:100.

<sup>3</sup> Valley-floor - the base of a valley, situated between two distinct valley- side-slopes, where alluvial or fluvial processes typically dominate.

<sup>4</sup> Slope – an inclined stretch of ground typically located on the side of a mountain, hill or valley, not forming part of a valley floor. Includes scarp slopes, mid-slopes and foot-slopes.

<sup>5</sup> Bench – a relatively discrete area of mostly level or nearly level high ground (relative to the broad surroundings), including hilltops, saddles and shelves. Benches are significantly less extensive than plains, typically being less than 50ha in area.

| Landscape unit | HGM unit | Description of HGM Units<br>(Ollis <i>et al.</i> 2013)  |
|----------------|----------|---|
| Plain/bench    | Flat     | A level or near-level wetland area that is not fed by water from a river channel, and which is typically situated on a plain or a bench. Closed elevation contours are not evident around the edge of a wetland flat. |

The HGM unit identified within the Trinity Nyakabingo Mine area have been classified as a seep.

#### 4.2.2 River classification

Rivers are defined as linear landforms with distinct beds and banks that permanently or periodically carry concentrated water flow. Similar to the wetland classification, the South Africa river classification was used for the systems within the Trinity Nyakabigo Concession whereby river reaches were categorised into longitudinal geomorphological zones primarily based on their characteristic gradient and diagnostic channel characteristics, such as substratum type. These classes were used to define the type of riverine systems identified within the concession area and includes mountain headwater streams, mountain streams, transitional rivers, upper foothill rivers, and lower foothill rivers (Rowntree *et al.* 2000), with the following river types generally defining the systems that were assessed in relation to the Nyakabigo Mine:

- *Mountain Headwater Stream*: A very steep (> 10.0%) gradient stream dominated by vertical flow over bedrock with waterfalls and plunge pools. Normally first or second order. Reach types include bedrock fall and cascades.
- *Mountain Stream*: Steep (4.0 – 9.9%) gradient stream dominated by bedrock and boulders, locally cobble or coarse gravels in pools. Reach type include cascades, bedrock fall, step-pool. Approximate equal distribution of vertical' and 'horizontal' flow compartments.

The river types on-site were characterised mainly on gradient rather than substrate largely due to the largely altered nature of instream channel features and habitats. Rivers can be further subdivided into its active channel (i.e. the portion regularly inundated to maintain channel form) and its riparian zone, which consists of the area directly adjacent to the channel influenced by river-induced processes.

### 4.3 Freshwater Ecosystem Assessment

The following sections outlines the approaches adopted in the assessment of the freshwater ecosystems in the mining concession areas.

#### 4.3.1 Assessment of wetland ecological condition

The application of biological assessments to specify the health or integrity of a wetland is common practice internationally, as illustrated by the review of international assessment methods by Ollis and Malan (2014). While these internationally recognised approaches may be applicable to a Rwandan context, Kotze *et al.*, (2009) highlight that the variability of environmental conditions and the range of wetland systems in sub-Saharan Africa, are likely to affect the applicability of international approaches.

To circumvent these challenges, an assessment approach referred to as WET-Health (Macfarlane *et al.*, 2020), has been widely adopted in sub-Saharan Africa to assess ecosystem integrity (Kotze *et al.*, 2009; Walters *et al.*, 2011; Macfarlane *et al.*, 2012). Although other assessment methods exist within South Africa, alongside the Wetland-Index of Habitat Integrity (DWAf 2007), Ollis and Malan (2014) describe WET-Health as the most advanced assessment method to determine wetland integrity. Considering this and the fact that WET-Health includes a comprehensive level of assessment, the method was viewed as an appropriate means of assessing wetlands as the basis for monitoring changes in ecosystem integrity especially in areas that may be affected by mining and/or restoration activities.

The assessment of ecosystem integrity was undertaken using the assessment framework, WET-Health Version 2 (Macfarlane *et al.*, 2020) Level 1B, which was performed for the HGM Units within the mining concession areas. The WET-Health assessment technique gives an indication of the deviation of the systems from the wetlands' natural reference condition for the following biophysical drivers:

- Hydrology – defined as the distribution and movement of water through a wetland its soils.
- Water quality – is defined as the physio-chemical attributes of the water in the wetland.
- Geomorphology – is defined as the physical processes that are currently shaping and modifying wetland evolution as well as the three-dimensional shape (structure) of sediment deposits on which wetland habitat is established.
- Vegetation – is defined as the structural and compositional state of the vegetation within a wetland.

The impacts on the wetland, determined by features of the wetlands and their catchments, were scored based on the extent and intensity of the identified disturbance units. These disturbance units, derived for each of the components, were scored based on a suite of sub-categories using a scale of 0-10, prior to being combined to determine the overall magnitude-of-impact scores. From these scores the overall impact score and Ecological Categories (Error! Reference source not found.) were determined, which reflects the extent to which anthropogenic changes have impacted the wetland from the benchmark/desired state.

**Table 4-4 Description of the Ecological Categories typically used for PES assessments of inland aquatic ecosystems in South Africa, together with the applicable range of Impact Scores and PES Scores for each category (after Kleynhans, 1996; Macfarlane *et al.*, 2008).**

(Macfarlane *et al.*, 2020, p.30)

| Impact Category | Description  | Impact Score Range (0-10) | PES Score | Ecological Category |
|-----------------|--|---------------------------|-----------|---------------------|
| None            | Unmodified, natural.   | 0-0.9                     | 90-100    | <b>A</b>            |
| Small           | Largely natural with few modifications. A slight change in ecosystem processes is discernible and a small loss of natural habitats and biota may have taken place. | 1-1.9                     | 80-89     | <b>B</b>            |
| Moderate        | Moderately modified. A moderate change in ecosystem processes and loss of natural  | 2-3.9                     | 60-79     | <b>C</b>            |

| Impact Category | Description  | Impact Score Range (0-10) | PES Score | Ecological Category |
|-----------------|--|---------------------------|-----------|---------------------|
|                 | habitats has taken place but the natural habitat remains predominantly intact.   |                           |           |                     |
| Large           | Largely modified. A large change in ecosystem processes and loss of natural habitat and biota has occurred.  | 4-5.9                     | 40-59     | D                   |
| Serious         | The change in ecosystem processes and loss of natural habitat and biota is great but some remaining natural habitat features are still recognisable.             | 6-7.9                     | 20-39     | E                   |
| Critical        | Modifications have reached a critical level and the ecosystem processes have been modified completely with an almost complete loss of natural habitat and biota. | 8-10                      | 0-19      | F                   |

The scores for hydrology, geomorphology, water quality and vegetation were simplified into a composite impact score. The combined impact score provided the basis for the calculation of the hectare equivalents (also referred to as a functional area), which can be described as the health of a wetland expressed as an area. The hectare equivalents calculation is a means of deriving a common unit of “currency” to measure the losses and gains, and how the ecosystem integrity has changed in response to anthropogenic impacts, based on the WET-Health results for the biophysical drivers.

#### 4.3.2 Assessment of freshwater ecosystem functioning

A WET-EcoServices Version 2 (Kotze *et al.*, 2020) assessment was performed for the freshwater ecosystems within the mining concession areas to quantify the level of functionality<sup>6</sup> of the systems, and to highlight their relative importance in providing ecosystem benefits and services at a landscape level. The assessment provides a method to measure the ability of a wetland or riparian area to provide sixteen (16) ecosystem services (**Table 4-5**).

The WET-EcoServices assessment technique focuses on assessing the extent to which a benefit is being supplied by each freshwater ecosystem, based on both:

- The supply of the wetland to provide the benefits; and
- The demand of the particular wetland in providing the benefit.

The ecosystem services mentioned above include an assessment of direct and indirect benefits to society and the surrounding landscape, by rating various characteristics of the freshwater ecosystems and their surrounding catchments based on the categories shown in **Table 4-5** as presented within Kotze *et al.* (2021).

**Table 4-5 Ecosystem services supplied by wetlands and rivers.**

(Kotze *et al.*, 2021, p3)

|              |                        |                   |  |
|--------------|------------------------|-------------------|--|
| Servi<br>ces | Regu<br>latin<br>g and | Flood attenuation | The spreading out and slowing down of floodwaters in the wetland/riparian area, thereby reducing the severity of floods downstream |
|--------------|------------------------|-------------------|--|

<sup>6</sup> Functionality refers to the ecological importance and sensitivity of the freshwater ecosystems.

|  |   |  |  |  |
|--|---|--|--|--|
|  |   | Stream flow regulation   | Sustaining streamflow during low flow periods  |  |
|  |   | Water quality enhancement benefits   | Sediment trapping  | The trapping and retention in the wetland/riparian area of sediment carried by runoff waters   |
|  |   |  | Phosphate assimilation   | Removal by the wetland/riparian area of phosphates carried by runoff water, thereby enhancing water quality                                  |
|  |   |  | Nitrate assimilation   | Removal by the wetland/riparian area of nitrates carried by runoff water, thereby enhancing water quality                                    |
|  |   |  | Toxicant assimilation  | Removal by the wetland/riparian area of toxicants (e.g. metals, biocides and salts) carried by runoff water, thereby enhancing water quality |
|  |   |  | Erosion control  | Controlling of erosion at the wetland/riparian area, principally through the protection provided by vegetation                               |
|  |   | Carbon storage   | The trapping of carbon by the wetland/riparian area, principally as soil organic matter  |  |
| Services contributing to direct benefits | <b>Biodiversity maintenance<sup>7</sup></b> |  | Through the provision of habitat and maintenance of natural process by the wetland/riparian area, a contribution is made to maintaining biodiversity |  |
|  | Provisioning services                       | Provision of water for human use   | The provision of water which is taken directly from the wetland/riparian area for domestic, agricultural or other purposes                           |  |
|  |   | Provision of harvestable resources   | The provision of natural resources from the wetland/riparian area - including craft plants, fish, wood etc.  |  |
|  |   | Food for livestock   | The provision of grazing for livestock   |  |
|  |   | Provision of cultivated foods  | The provision of cultivated foods from within the wetland/riparian area  |  |
|  | Cultural (non-material) benefits            | Cultural heritage  | Places of special cultural significance in the wetland/riparian area - e.g. for baptisms or gathering of culturally significant plants               |  |
|  |   | Tourism and recreation   | Sites of value for tourism and recreation in the wetland/riparian area, often associated with scenic beauty and abundant birdlife <sup>8</sup>       |  |
| Education and research                   |   | Sites of value in the wetland/riparian area for education or research (McInnes and Everard 2017) |  |  |

In addition to providing individual scores for each ecosystem service provided by the individual wetland and riparian areas, the WET-EcoServices Version 2 (Kotze *et al.*, 2021) assessment technique also allows for the derivation of a consolidated/integrated overall importance score (Table 4-6), by combining the supply and demand scores for each of the ecosystem services.

<sup>7</sup> It is recognised that biodiversity maintenance is not an ecosystem service in the strict sense and is framed in less anthropocentric terms than all of the other services, but it underpins many other services and is widely acknowledged as having high value to society broadly, even in the absence of any local or downstream beneficiaries.

<sup>8</sup> WET-EcoServices focuses on recreational services which are specifically nature-based, e.g. bird watching. It does not account specifically for recreational services from wetland/riparian areas that have been converted into sports grounds, children's playgrounds, or other built infrastructure.

**Table 4-6 Categories used for reporting the overall importance of ecosystem services**  
(Kotze *et al.*, 2021, p. 27)

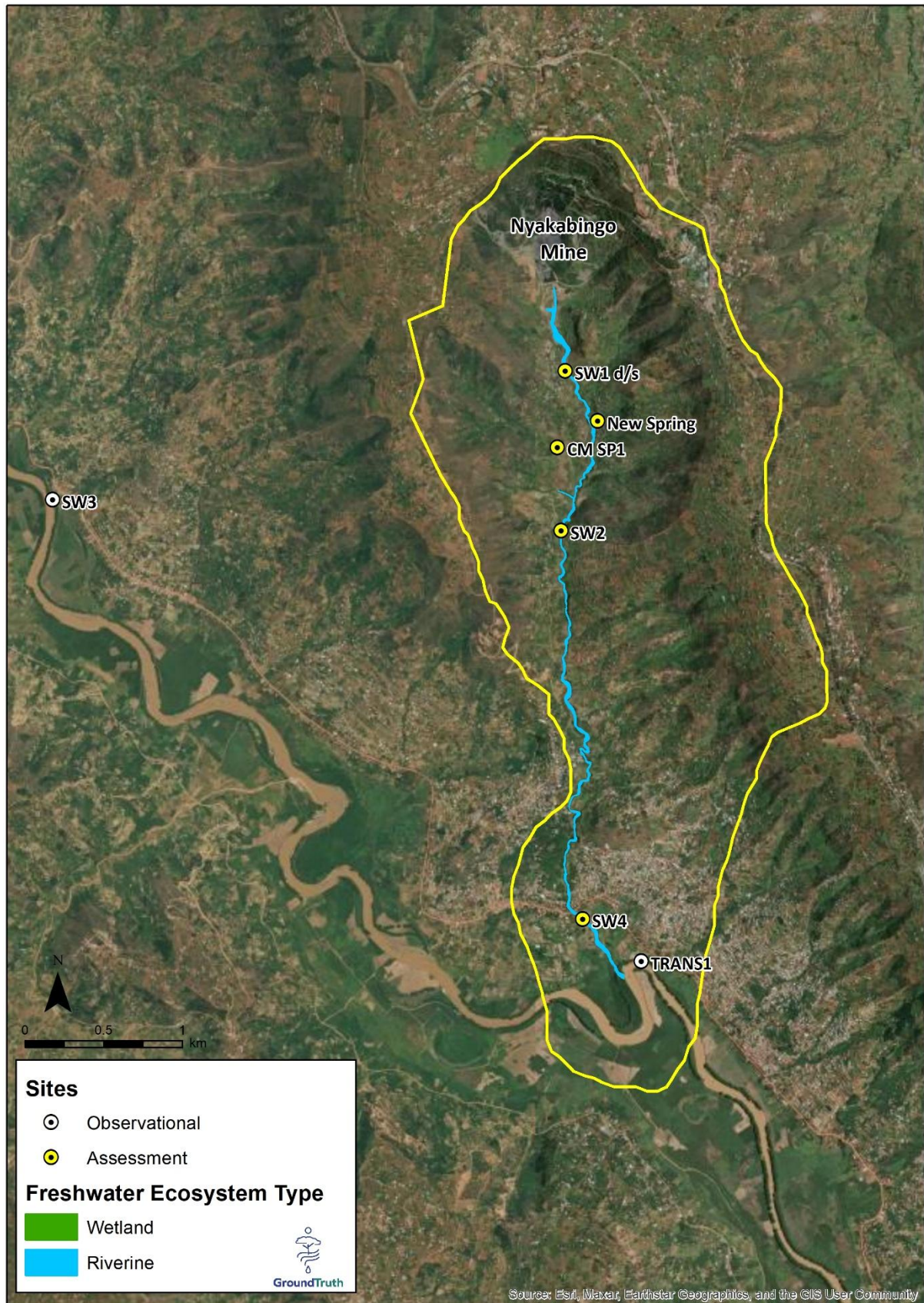
| Importance Category |          | Description   |
|---------------------|----------|---|
| Very Low            | 0-0.79   | The importance of services supplied is very low relative to that supplied by other wetlands.        |
| Low                 | 0.8-1.29 | The importance of services supplied is low relative to that supplied by other wetlands.             |
| Moderately Low      | 1.3-1.69 | The importance of services supplied is moderately low relative to that supplied by other wetlands.  |
| Moderate            | 1.7-2.29 | The importance of services supplied is moderate relative to that supplied by other wetlands.        |
| Moderately High     | 2.3-2.69 | The importance of services supplied is moderately high relative to that supplied by other wetlands. |
| High                | 2.7-3.19 | The importance of services supplied is high relative to that supplied by other wetlands.            |
| Very High           | 3.2-4.0  | The importance of services supplied is very high relative to that supplied by other wetlands.       |

It should be noted that Wet-EcoServices assists in identifying the importance and sensitivity of specific freshwater ecosystems, but is recognised as having limitations in terms of:

- The scores obtained cannot be used to deduce the economic value of the wetland/riparian area.
- Fine-scale differentiation of ecosystem service provisions cannot be made.
- The demand of ecosystem services by users is considered at a coarse scale.
- The level of dependency and level of diversity of dependency does not necessarily correlate to one another, nor does it account for the socio-economic factors contributing to the dependency or differing levels of dependency among users.
- Quantifying specific impacts linked to development or changes within the landscape.
- Accounting for the size of the wetland and ecosystem services strongly associated with the size of the systems.

#### **4.3.3 Riverine habitat assessments**

The applied methodology drew on the latest river assessment tools developed from South Africa and that have been applied throughout sub-Saharan Africa for assessing the Present Ecological State (PES) of aquatic and riparian habitats, with the choice of methods tailored to site-specific habitat characteristics, prevailing flow conditions, and other biophysical constraints. A field survey was undertaken to establish a baseline of river health and catchment condition, providing insights into how ecological integrity is shaped by broader landscape drivers and pressures. Data and assessments from the 2023 aquatic baseline study by Nepid (2024) were collated and used to inform the updated PES.



**Figure 4-1 Overview of river sites visited and assessed within the Nyakabingo Mine Concession area.**

#### 4.3.3.1 Benthic diatoms (as primary producers)

Benthic diatoms are single-celled microalgae that inhabit submerged substrates such as sediment, rocks, and aquatic vegetation, forming a key part of aquatic food webs. Their ecology provides valuable insight into water quality, as they respond directly to chemical parameters, nutrients, salinity, pH, and heavy metals. Unlike larger biotic indicators, diatoms are less dependent on diverse habitats, and their species composition reflects river conditions over several weeks, offering a medium-term view of ecological impacts. Their silica frustules also persist after death, enabling reconstruction of historical water quality.

Sampling followed standard protocols (Taylor *et al.*, 2005). At each site, five small rocks were collected from flowing positions across the river channel. The exposed surfaces were scraped with a toothbrush, dislodging diatoms into <100 ml of river water. The combined subsamples were transferred to a bottle, preserved with ~10% ethanol, and submitted to Diamon Laboratory in South Africa for species-level identification. Results were interpreted using established indices (Harding and Taylor, 2011), including the Specific Pollution Sensitivity Index (SPI), which scores species by tolerance to nutrient enrichment and organic waste, and the Percentage Pollution Tolerant Valves (%PTV), which quantifies the proportion of tolerant taxa. Together, these indices provide a robust assessment of river health and water quality.

Benthic diatoms were sampled during the November 2025 field survey at specific designated sites as presented in **Figure 4-1**. A total of seven diatom samples were collected from Nyakabingo. However, following initial screening of the samples only three were found to contain diatom cells highlighting the severity of sedimentation impacts emanating from formal and unauthorised mining of minerals and aggregate. Results from the three diatom samples were interpreted according to the Specific Pollution sensitivity Index (SPI) to determine river “health status” (CEMAGREF, 1982). Other useful diatom indices used to further infer water quality conditions were the Percentage of pollution Tolerant Valves (% PTV), which was the proportion of diatoms in the sample that are tolerant to pollution, and the percentage of deformed cells, which was the proportion of diatoms in the sample which were deformed as a result of toxicants in the water. River health classes for the sampled sites were determined according to **Table 4-7**, and interpreted using **Table 4-8**.

**Table 4-7 Diatom index scores for relevant health classes (derived from Harding and Taylor, 2011).**

| River Health Class |   | Benthic Diatom Species Specific Pollution Index (SPI) |
|--------------------|---|---|
| Natural            | ≥ | 17.0  |
| Good               | ≥ | 13.0  |
| Fair               | ≥ | 9.0   |
| Poor               | ≥ | 5.0   |
| Seriously Modified | ≤ | 5.0   |

**Table 4-8 River health classes and their attendant ecological and management perspectives (derived from WRC, 2008).**

| Category | river Health Classes | Ecological Perspective   | Management Perspective  |
|----------|----------------------|--|---|
| A        | Natural              | No or negligible modification of in-stream and riparian habitats and biota.  | Protected rivers; relatively untouched by human hands; no discharges or impoundments allowed.   |
| B        | Good                 | Ecosystems essentially in good state; biodiversity largely intact.   | Some human-related disturbance but mostly of low impact potential.  |
| C        | Fair                 | A few sensitive species may be lost; lower abundances of biological populations may occur.   | Zones of competing uses; developmental pressures are dominant feature.  |
| D        | Poor                 | Habitat diversity and availability have declined; mostly only tolerant species present; species present are often diseased; population dynamics have been disrupted (e.g. biota can no longer breed, or alien species have invaded the ecosystem). | Often characterised by high human densities or extensive resource exploitation. Management intervention is needed to improve river health – e.g. to restore flow patterns, river habitats or water quality. |
| E        | Seriously Modified   | Loss of habitat availability and high levels of pollution, result in few families being present due to the loss on most intolerant forms.  | Often characterised by high human densities, pollution or extensive resource exploitation and modification. Management intervention is needed for improvement to occur.                                     |

#### 4.3.3.2 Aquatic macroinvertebrates (as primary consumers)

Aquatic macroinvertebrates include insects in their larval and nymph stages, as well as snails, worms, crustaceans, and clams that spend part of their life in water. They are widely recognised as reliable indicators of river health due to their varying sensitivity to pollution, rapid responsiveness and recovery, and ease of identification. Changes in macroinvertebrate community structure directly reflect shifts in water quality, flow, and habitat, integrating multiple stressors over time. While tolerance can vary geographically, taxa generally exhibit predictable sensitivity levels, making them effective biological indicators for use in river health assessments.

For this project, macroinvertebrates were sampled to inform the assessment of river PES and to understand how macroinvertebrate communities are affected by prevailing land use and mining activities. Sampling followed the accredited South African Scoring System, version 5 (SASS5) (Dickens and Graham, 2002), conducted by a SASS5 accredited practitioners at sites where suitable conditions were available (e.g. flowing water, accessible biotopes, wade-able depth). SASS5 evaluates diversity and abundance at family level, with results recorded on standard datasheets. Key outputs include the SASS score (i.e. the sum of sensitivity values for all taxa) and the Average Score Per Taxon (ASPT), calculated by dividing the SASS score by the number of taxa. Each taxon is assigned a value from 1 (tolerant) to 15 (sensitive). These results are interpreted to determine PES, providing a robust measure of ecological integrity across river sites.

### 4.3.3.3 Index of Habitat Integrity

Riparian vegetation refers to the distinct plant communities that occur along river corridors, particularly perennial rivers, and form a critical component of the broader river ecosystem. These communities shape the interface between terrestrial areas instream/aquatic habitats, exerting direct and indirect influences on physical and chemical processes. Key functions include supplying organic and inorganic material (e.g. leaves, twigs, large woody debris) that underpin aquatic food webs and habitat complexity; regulating water temperature through canopy shading, vital for cold-water species; filtering sediments, nutrients, and pollutants via root and soil systems; and moderating hydrology by slowing runoff and promoting groundwater recharge. Additionally, riparian vegetation provides structural habitat such as overhanging banks and root refuges for fish and aquatic invertebrates.

The composition and structure of riparian vegetation are primarily driven by hydrology and geomorphology, with flooding and other disturbances shaping riverbanks and instream habitats. Disturbances can blur or eliminate vegetation zones, promote encroachment of terrestrial species, alter abundance and growth forms, and facilitate invasive alien plants. These changes cascade into instream impacts (e.g. reduced bank stability and increased erosion, higher nutrient and pollutant load due to diminished filtering, and reduced habitat complexity from fewer woody debris inputs). Collectively, such degradation undermines instream habitat integrity and ecosystem function.

To establish baseline conditions, riparian and instream habitats at sampling sites were assessed using the Index of Habitat Integrity (IHI) method (Kleynhans *et al.*, 2009). This approach evaluates factors such as channel modification, physico-chemical alteration, exotic vegetation, and dumping, providing a comprehensive measure of habitat integrity across defined river reaches. The results inform understanding of how riparian vegetation condition influences aquatic communities and overall river health (**Table 4-9**).

**Table 4-9 Index of Habitat Integrity (IHI) scores for deriving river health classes (derived from Kleynhans, 2009).**

| River Health Class | Index of Habitat Integrity (IHI) |
|--------------------|----------------------------------|
| Natural            | ≥ 90                             |
| Good               | ≥ 80                             |
| Fair               | ≥ 60                             |
| Poor               | ≥ 40                             |
| Seriously Modified | ≤ 40                             |

## 4.4 Expertise of the specialists

Due to the nature of the study, the project team included personnel with experience in mapping, delineation, assessment, rehabilitation, enhancement and creation of freshwater ecosystems (**Table 4-10**).

**Table 4-10 Team members, roles, experience and qualifications**

| Specialist      | Role in the Study  | Experience Level   | Qualifications   |
|-----------------|--|--|--|
| Craig Cowden    | <ul style="list-style-type: none"> <li>Review of the project report.</li> </ul>  | 25+ years' experience with input into various wetland studies: <ul style="list-style-type: none"> <li>Delineation.</li> <li>Assessments.</li> <li>Rehabilitation planning.</li> <li>Mitigation and offset requirements.</li> <li>Monitoring and evaluation of rehabilitation projects</li> </ul>   | M.Sc. (Environmental Science).<br>Pr.Sci.Nat – Ecology.                          |
| Gary de Winnaar | <ul style="list-style-type: none"> <li>Site visit;</li> <li>GIS processing and mapping;</li> <li>Riverine and riparian assessments; and</li> <li>Compilation of the project report.</li> </ul> | 18 years' experience with inputs into various aquatic and terrestrial biodiversity studies, including: <ul style="list-style-type: none"> <li>Terrestrial and aquatic biodiversity surveys;</li> <li>Assessments;</li> <li>Delineation;</li> <li>Monitoring and evaluation of riverine rehabilitation projects; and</li> <li>Mitigation &amp; offset studies.</li> </ul> | M.Sc. (Hydrology)<br>Pr. Sci. Nat - Ecology<br>DWS SASS5 accredited practitioner |
| Fiona Eggers    | <ul style="list-style-type: none"> <li>Site visit;</li> <li>GIS processing and mapping; and</li> <li>Compilation of the project report.</li> </ul>   | 15 years' experience, with input into various wetland studies, including: <ul style="list-style-type: none"> <li>Delineation;</li> <li>Assessments;</li> <li>Rehabilitation planning;</li> <li>Monitoring and evaluation of wetland rehabilitation projects;</li> <li>Mitigation &amp; offset studies; and</li> <li>Wetland creation.</li> </ul>                         | M.Sc. (Botany).<br>Pr.Sci.Nat – Ecology.   |
| Steven Ellery   | <ul style="list-style-type: none"> <li>Site visit.</li> </ul>  | 6 years' experience, with input into various wetland studies, including: <ul style="list-style-type: none"> <li>Delineation;</li> <li>Assessments;</li> <li>Rehabilitation planning;</li> <li>Monitoring and evaluation of wetland rehabilitation projects; and</li> <li>Mitigation &amp; offset studies.</li> </ul>   | M.Sc. (Geography).<br>Pr.Sci.Nat – Ecology.                                      |
| Esi Bossman     | <ul style="list-style-type: none"> <li>Compilation of the project report</li> </ul>  | ~3 years' experience, with input into: <ul style="list-style-type: none"> <li>Macroinvertebrate identification</li> <li>Dragonfly identification</li> <li>Biomonitoring</li> <li>Statistical analysis</li> </ul>   | M.Sc. (Freshwater Ecology).<br>Cand.Sci.Nat – Aquatic Science                    |

## 5. NYAKABINGO CONCESSION AREA BASELINE

The mine concession lies in the southeastern part of the Byumba highlands. Its landscape is predominantly hilly to mountainous, with elevations ranging between roughly 1'800 and 2'100 meters above sea level. The terrain also features flat-bottomed and narrow river valleys, where wetland habitats are largely non-existent (SLR, 2024a, 2024b).

The following section provides an overview of the current condition of the freshwater ecosystems within the Nyakabingo Mine Concession area. **Figure 4-1** provides an overview of the concession area and mine site, along with the various freshwater ecosystems associated with these concession areas.

### 5.1 Study area and site description

The following sections provide an overview of the Trinity Nyakabingo Mine concession area focussing on climate, geomorphology, hydrology, floodlines and land uses. This background information formed the basis for the assessment of the freshwater ecosystems.

#### 5.1.1 Climate

Rwanda's tropical climate is heavily influenced by its diverse topography, which rises along a general elevational gradient from east to west. Based on altitude and geographical position, the country is divided into four primary climatic regions (World Bank, 2021; SLR, 2024a; **Table 5-1**):

**Table 5-1 Climatic conditions of the four climatic regions of Rwanda**

| Climatic Region      | Annual Rainfall (mm) | Avg. Temperature (°C) | Geographic Features                         |
|----------------------|----------------------|-----------------------|---|
| Eastern Plains       | 700 – 1100           | 20 – 22               | Low-lying eastern borderlands.              |
| Central Plateau      | 1100 – 1300          | 18 – 20               | Mid-altitude rolling hills.                 |
| Highlands            | 1300 – 1600          | 10 – 18               | Congo-Nile Ridge & Virunga volcanic chains. |
| Lake Kivu / Bugarama | 1200 – 1500          | 18 – 22               | Western rift valley and Bugarama plains.    |

The Nyakabingo Concession is primarily situated within the transition between the Central Plateau and the Highlands, regions characterised by moderate to high rainfall and temperate thermal regimes.

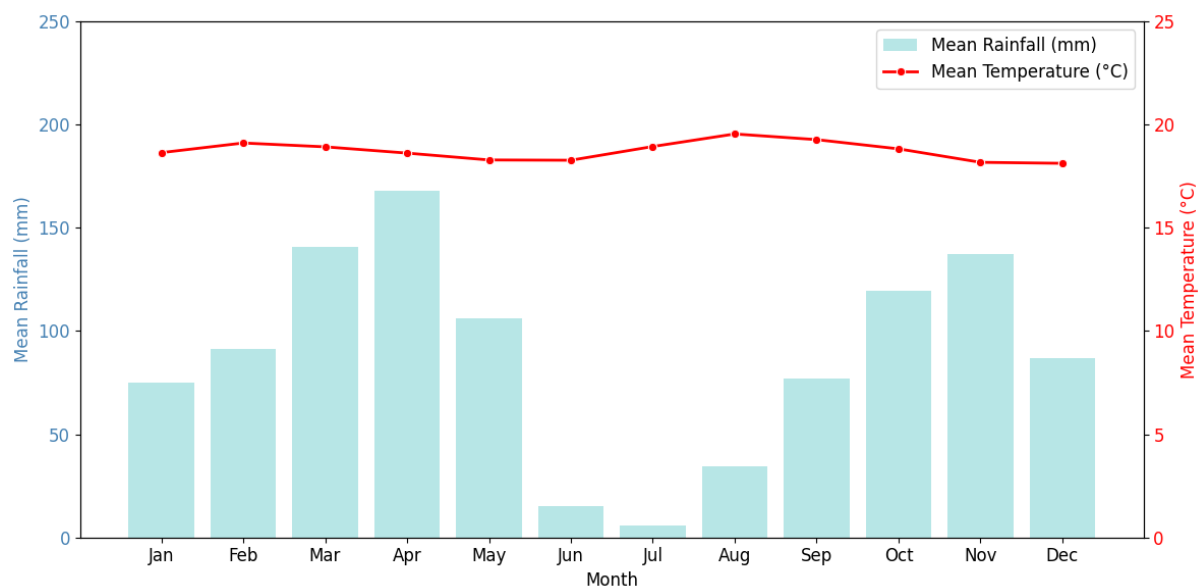
The hydrological cycle in Rwanda is governed by a bimodal rainfall pattern, resulting in four distinct seasons. This seasonality is a critical factor in the sediment transport capacity of the rejuvenated river network, as peak transport events typically coincide with the height of the wet seasons.

- Short dry season (January – February): A transitional period of reduced rainfall.
- Long rainy season (March – May): Historically associated with the highest intensity rainfall events and peak annual discharges.

- Long dry season (June – August): A period of minimal precipitation and baseflow conditions in the freshwater ecosystem.
- Short rainy season (October – December): Characterised by frequent convective storms.

The country maintains a relatively stable thermal regime with a mean annual temperature of 19.1 °C. Monthly variations are narrow, ranging from a minimum average of 18.5 °C in July to a maximum of 19.5 °C in September.

A climatograph was created for the Nyakabingo area (**Figure 5-1**), using 51 years of daily rainfall data (1950 to 2025) obtained from ERA5 to show the long-term monthly rainfall trends. A typical bimodal rainfall distribution is evident, where rainfall peaks in April (mean = 168.03 mm) and November (mean = 137.30 mm), and is generally at its lowest during July (mean = 5.99 mm) and June (mean = 15.22 mm). The overall mean annual precipitation (MAP) for the region is 1057.60 mm over those 51 years, while the mean annual potential evapotranspiration for the area is 2179.16 based on ERA5. Temperatures typically fluctuate between an average of 18.12°C (December) and 19.54°C (August), remaining relatively stable throughout the year.



**Figure 5-1 A climatograph showing average monthly rainfall and typical mean monthly temperatures for the year 1950 to 2025 based on ERA5 data.**

### 5.1.2 Broad geomorphic and fluvial setting

Rwanda is situated on the eastern shoulder of the Kivu–Tanganyika rift, a region defined by active continental rifting driven by the divergence of the Victoria and Nubia plates (Moeyersons, 2003; Depicker *et al.*, 2021). The country’s topography is characterised by a significant elevational gradient, rising from approximately 1000 m above sea level in the east to over 2600 m at the crest of the western rift shoulder (Moeyersons, 2003). This tectonic uplift has initiated a process of landscape rejuvenation, where rivers actively incise the terrain to adapt to new base levels (Depicker *et al.*, 2021). Consequently, this geomorphic setting creates a high-relief environment where energetic rivers and steepened hillslopes lead to a significant potential for erosion (Moeyersons, 2003; Depicker *et al.*, 2021). In contrast, the eastern portion of the country, including the Rwamagana District where the Musha concession is situated, occupies a more geomorphologically stable position on the Eastern Plateau (Karamage, 2016a).

### 5.1.3 Geology

The Karagwe-Ankole Belt (KAB) in East Africa forms part of the Mesoproterozoic Kibara Belt (KIB) of Central Africa, a major metallogenic province rich in granite-related ore deposits, particularly tantalum–tin–tungsten (SLR, 2024d). Extending across Rwanda, Burundi, southwest Uganda, northwest Tanzania, and the Kivu-Muniema region of the Democratic Republic of the Congo (DRC), the KAB is divided into two contrasting domains: the Western Domain, underlain by Proterozoic basement and intensely deformed, and the Eastern Domain, underlain by Archean basement. The Western Domain is especially significant, hosting valuable deposits of tin, tungsten, tantalum, and gold mined throughout the region (SLR, 2024b).

In central Rwanda, the NW–SE-oriented Bugarama–Gifurwe–Nyakabingo zone, known as the “Tungsten Belt,” contains abundant tungsten mineralization (De Clercq *et al.*, 2008). Lithologies along this belt are predominantly siliciclastic, ranging from black shales to quartzites. At the Nyakabingo concession, tungsten ore occurs within metavolcanic and metasedimentary rocks metamorphosed from basaltic and sedimentary precursors. Cassiterite, the primary tin ore, is found in quartz veins, pegmatites, and greisenized granite (SLR, 2024b). The Nyakabingo Mine lithologies are dominated by quartz and muscovite, with minor kaolinite, augite, and microcline, while host rocks such as quartz veins and metasediments occasionally contain pyrite (SLR, 2024b).

### 5.1.4 Soil Types

The following description of the sediment and soil characteristics within the Nyakabingo Mine study area is based on the findings of the specialist geochemical and soil assessment (SLR, 2026d).

Analysis of the river sediments indicates a notable shift in the physical composition of the Nyakabingo River mainstem. The sand fraction downstream of the mine footprint is nearly double that of the side-stream control site, which suggests a significant alteration of the river’s hydrological functioning. This change is attributed to the combined impacts of current mining operations, historic activities, and informal aggregate mining further downstream. From a mineralogical perspective, the presence of hematite, kaolinite, and muscovite provides these sediments with a high capacity to sequester metals and metalloids. Consequently, the riverbed acts as a sink for various elements, showing marked accumulation over time. Whilst side-stream samples exhibit exceedances of arsenic and lead that are likely linked to agricultural runoff, the mainstem samples downstream of the mine show more frequent exceedances of cobalt, copper, manganese, and nickel. These concentrations are further influenced by the acidic pH of the water, which facilitates the mobilisation of these metals. Extreme enrichment and potential contamination were specifically noted for arsenic, tungsten, mercury, and selenium within the mainstem samples.

The soils in the downstream vicinity of the Nyakabingo Mine are classified as Ferralsols, which are formed through intense and prolonged chemical weathering. These soils possess a low organic carbon content and a lack of high-activity clay minerals, resulting in a very limited capacity to buffer against acidification or remediate metal leaching and acid rock drainage. The soil profile is distinctly acidic, with pH levels typically falling below 6, which increases the availability of trace and heavy metals and poses a potential risk of phytotoxicity. Although the

soils are characterised by relatively low proportions of essential nutrients such as phosphorus and potassium, the magnesium levels are generally suitable for vegetation growth. While copper levels were found to exceed standard soil screening values, this is considered a geogenic trait derived from the mineralogy of the local parent material rather than a result of mining-related contamination.

### 5.1.5 Slope and erodibility

In catchments undergoing active tectonic uplift, hydraulic energy and sediment mobility differ significantly from 'graded' systems in dynamic equilibrium. In the Rwandan central highlands, the landscape exists in a state of geomorphological disequilibrium driven by regional uplift (Moeyersons, 2003; Depicker *et al.*, 2021). Rivers are actively incising their channels in response to the tectonic rise of the rift shoulder, resulting in elevated unit stream power and flow velocities within characteristically steep, V-shaped valleys (Moeyersons, 2003; Depicker *et al.*, 2021). However, as the topography transitions eastward from the tectonic rift shoulder toward the Eastern Plateau, where the Musha concession is situated, the landscape becomes more geomorphologically stable (Moeyersons, 2003; Karamage *et al.*, 2016a). Unlike the steep highlands of the west, this region is characterised by rolling hills and a dissected plateau with significantly gentler slope gradients (Verdoodt and Van Ranst, 2006; Karamage *et al.*, 2016a).

This natural vulnerability is significantly influenced by anthropogenic drivers, though the absolute magnitude of soil loss is lower than in the high-relief western catchments. For example, while the estimated mean erosion rate in the steep Nyabarongo River catchment is  $490 \text{ t ha}^{-1} \text{ y}^{-1}$ , which is nearly double the national average of  $250 \text{ t ha}^{-1} \text{ y}^{-1}$ , the Eastern Province is identified as a significantly more stable zone with the country's lowest overall soil erosion risk, with a mean erosion rate of approximately  $20.6 \text{ t ha}^{-1} \text{ yr}$  (Nambajimana and He, 2020). This erodibility is largely a product of land conversion. Across this broader region, croplands occupy the vast majority of the land area and are responsible for the bulk of annual soil loss (Karamage *et al.*, 2016a). The synergy of intensive agricultural land use and a supply of unconsolidated material, primarily deeply weathered tropical soils (specifically Ferralsols and Acrisols) characteristic of the Eastern Plateau, creates a persistent sediment flux environment (Verdoodt and Van Ranst, 2006; Karamage *et al.*, 2016a). Consequently, even on these gentler slopes, the landscape is capable of mobilising and transporting sediment loads during the high-intensity rainfall events characterised by the region's bimodal climate (Karamage *et al.*, 2016b).

### 5.1.6 Hydrology

The Nyakabingo River is the main aquatic system within the Nyakabingo concession, originating in the area as a groundwater-fed gaining stream and flowing south into the Nyabarongo River about 5 km downstream, which ultimately drains into Lake Rweru (SLR, 2024b). Regional rivers, including the Nyabarongo, are heavily impacted by poor agricultural practices, deforestation, and invasive species, resulting in excessive sedimentation (Nepid Consultants, 2024; SLR, 2024c). Historically, the lack of stormwater management at the mine allowed tailings and waste rock to enter the Nyakabingo River, and current mining activities occur within the regulated 10 m buffer zone. Together with subsistence cultivation in the southern concession, these pressures have significantly degraded the river system. Other aquatic ecosystems include seeps, mountain headwaters, and springs, which are vital for local communities for domestic use and livestock watering (Nepid Consultants, 2024; SLR, 2024c).

Three key springs provide water to nearby villages: the Kirikumuryango spring, which supplies the potable water network; the Mwagiro–Gatwa spring, located 200 m downstream of the mine’s settling dam; and the Mwagiro–Bugarura spring, 1.5 km downstream (GroundTruth, 2025a). Small wetlands occur along the Nyakabingo River, with a larger wetland associated with the Nyabarongo floodplain, though none are directly affected by current mining activities (GroundTruth, 2026a).

### **5.1.7 Hydrogeology**

At the Nyakabingo ore deposit, three types of quartz veins are observed: small, folded bedding-parallel veins, thick bedding-parallel veins, and crosscutting veins. Both ore deposition and groundwater ingress into mine workings are structurally controlled. Aquifers in the concession area can be classified as follows (SLR, 2024d):

- **Weathered Aquifer:** Shallow, unconfined, within 5–30 m of weathered sandstone and shale, with low to moderate yield.
- **Primary Alluvial Aquifer:** Along the Nyakabingo River and streams, composed of gravel and sand, with moderate to high parameters, recharged by surface inflow.
- **Secondary Fractured Aquifer:** Deeper, semi-confined, in unweathered shale and quartzite, with groundwater moving through fractures; generally low to moderate, but occasionally high parameters.

Groundwater recharge is estimated at ~3% of mean annual precipitation, with flow following topography toward valleys. Water quality is generally good, though slight acidity promotes leaching of metals, leading to elevated concentrations of aluminium, iron, and manganese (SLR, 2024d).

### **5.1.8 Floodline data**

The hydrological and hydraulic modelling undertaken for the Nyakabingo concession by GroundTruth (2026a) has delineated floodlines for the 2-year, 25-year, and 100-year return periods under both present conditions and projected climate change scenarios.

Under current conditions, flooding is largely confined to the incised river channels and adjacent terraces. The steep valley morphology limits lateral expansion, meaning that increases in flood magnitude are primarily expressed as greater flood depths rather than significant widening of the inundation footprint.

Climate change simulations indicate relatively modest changes in flood extent. Inundation areas decrease by approximately 2% for the 2-year event and 0.3% for the 25-year event, while the 100-year event shows a marginal increase of 1.2%. More pronounced changes are observed in water surface elevations (WSE): for the 100-year event, WSE increases across roughly 75% of the modelled area, whereas for the 2-year event WSE decreases across 86% of the area. These results suggest that climate change is more likely to influence flood depths and hydraulic energy than to substantially alter the spatial footprint of flooding.

Overall, the findings highlight that the Nyakabingo concession’s confined valley setting constrains lateral flood expansion. The principal climate-related risk lies in increased flood depths and velocities within existing flood-prone zones, rather than the emergence of new inundation areas. This has direct implications for rehabilitation and infrastructure planning,

where emphasis should be placed on managing hydraulic forces and ensuring resilience of river rehabilitation measures and mine infrastructure.

### 5.1.9 Land cover and use

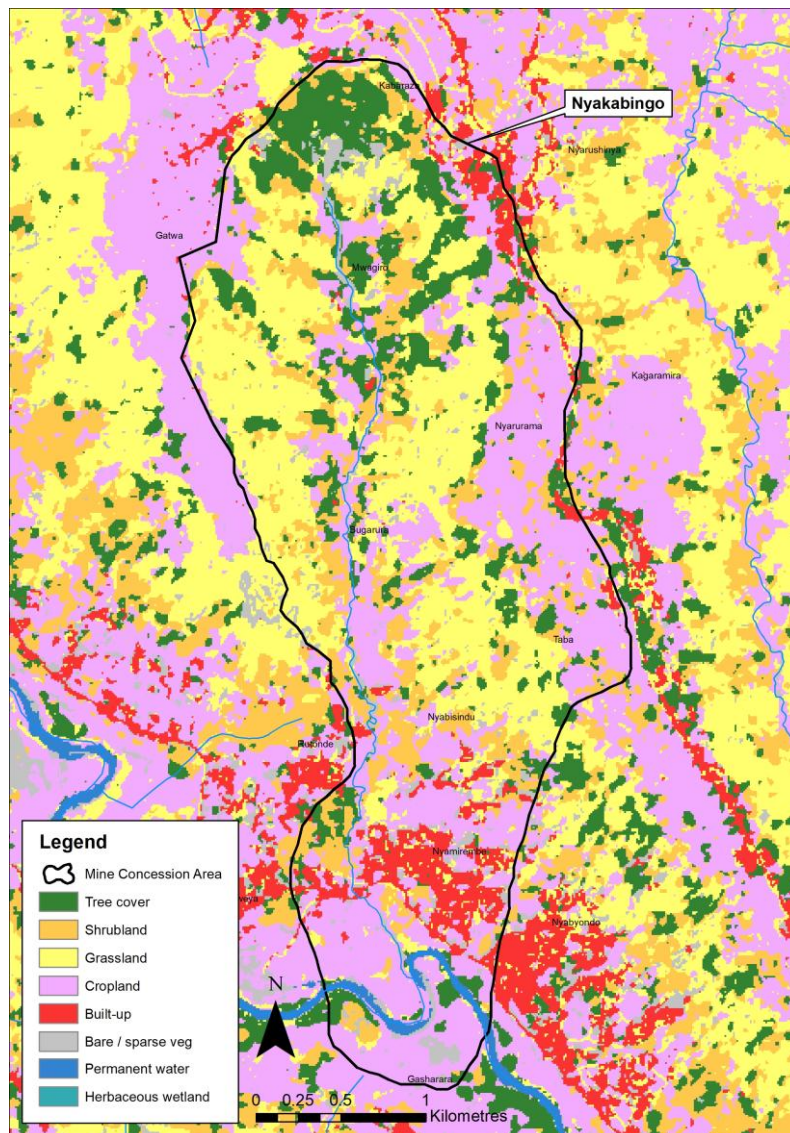
Ecologically, the concession spans the Albertine Montane Forest and Victoria Basin Forest–Savanna Mosaic ecoregions, which historically supported tropical forest and savanna woodlands. Today, vegetation is heavily degraded, biodiversity value is low, and the potential to support Species of Conservation Concern (SCC) is limited (SLR, 2024i).

Land use within the Nyakabingo concession encompasses both formal and unauthorised mining, alongside a variety of other activities such as sand and aggregate extraction, subsistence farming, fodder cultivation and harvesting for livestock, timber production/forestry, the spread of invasive alien plant species, and beekeeping. Homesteads and small-scale farms are situated along both banks of the Nyakabingo River - the primary watercourse in the concession area, apart from a few springs. Natural riparian vegetation is generally absent (onsite observation; Nepid Consultants, 2024).

Given the steep terrain of the Nyakabingo catchment, subsistence agriculture relies primarily on rainfall. Large portions of the catchment are cultivated using terraced fields, though in the lower reaches near Rweya town, terracing is less abundant. The upper and western sections of the catchment remain largely uncultivated due to challenging topography, proximity to water, and mining activities within the headwaters (onsite observation).

The ESA landcover data for Rwanda (**Figure 5-2**) provides a partial indication of the land cover modifications within the concession area. It should be noted that the areas depicted as grasslands/shrublands in the ESA coverage are not a true reflection of the current land use activities and are more likely to be subsistence croplands including banana stands, and not natural vegetation. As a consequence of this significant change in land cover, the impacts on the hydrology of the catchment and associated freshwater ecosystems include the following:

- Reduction in infiltration.
- Reductions in groundwater recharge and therefore of baseflows.
- A reduction in lag times.
- An increase in the magnitudes of peak flows.
- Reductions in water retention.
- An increase in erosion and thus sedimentation.
- A reduction in water quality.
- An increase in topsoil losses.



**Figure 5-2** ESA landcover data for the Trinity Nyakabingo Mine, which highlights the level of transformation within the region.

### 5.1.10 Aquatic Biodiversity

The Nyakabingo Mine Project is situated within the Lake Victoria Basin Freshwater Ecoregion (<https://www.feow.org/ecoregions/details/521>), a region recognised for its exceptional global freshwater biodiversity significance. This ecoregion includes Lakes Victoria, Kivu, Edward, and several associated satellite lakes, and has been classified as “Globally Outstanding” in terms of biological distinctiveness. In addition, the ecoregion is regarded as having a “Critical” conservation status with a “Very High” conservation priority (Oyugi & Chapman, 2008). The region supports more than 600 fish species, approximately 79% of which are endemic, with haplochromine cichlids forming the majority (Sayer *et al.*, 2018). While biodiversity value is concentrated in the major lake systems, smaller rivers and streams in the immediate project area generally support lower diversity assemblages of river-adapted fauna provided that water quality conditions are not severely compromised.

From a regional hydrological perspective, the project area forms part of the greater Nile River Basin (Nepid Consulting, 2024). The Nyakabingo Concession drains into the Nyakabingo River,

which is a tributary of the Nyabarongo River. The Nyabarongo River subsequently flows into Lake Rweru within the upper reaches of the Kagera River Catchment. The Kagera River is recognised as one of the principal tributaries of the Nile River system, highlighting the broader regional connectivity of the project area’s freshwater resources.

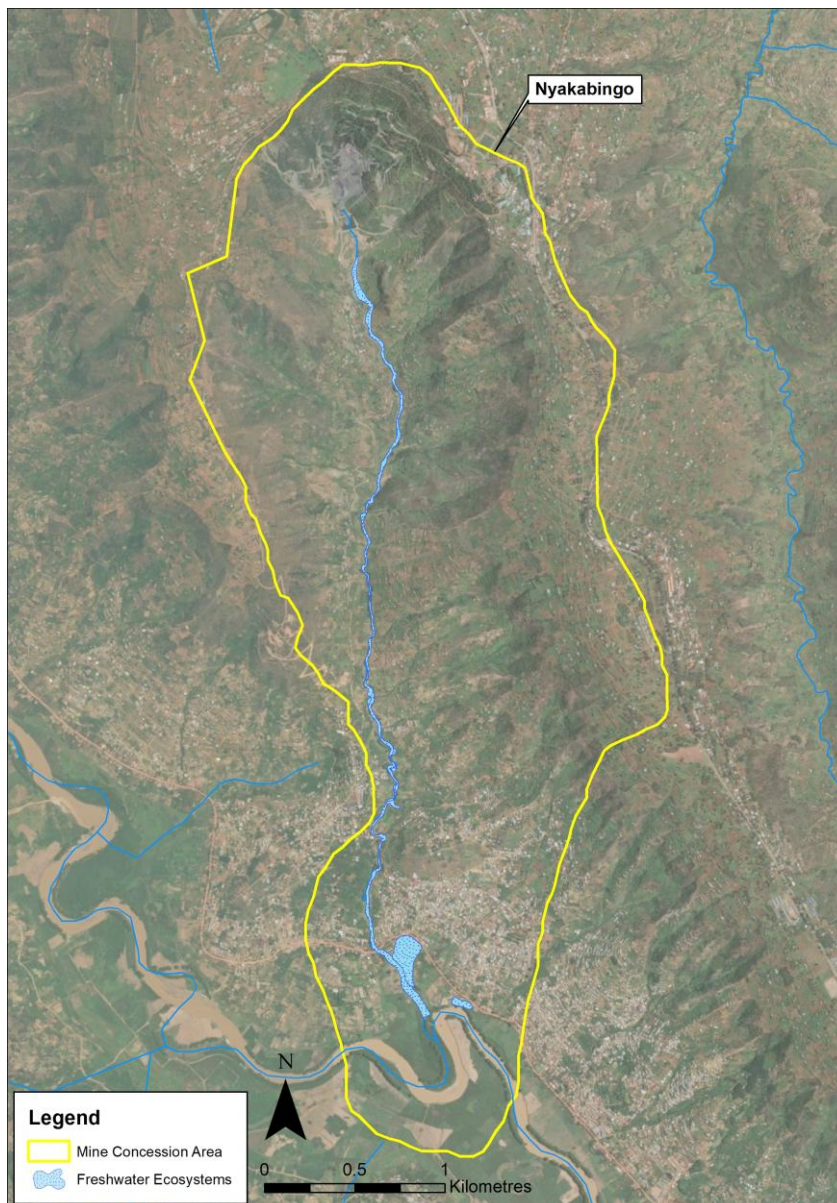
The closest recognised regional biodiversity priority area to the project is the Nyabarongo Key Biodiversity Area (KBA), located approximately 5 km south of the mine. This KBA comprises swamps and marshes associated with the Nyabarongo River, the longest river system in Rwanda, and provides important habitat for several threatened wetland-dependent bird species. Notable species associated with the area include the Vulnerable Papyrus Yellow Warbler (*Calamonastides gracilirostris*) and the Near Threatened Papyrus Gonolek (*Laniarius mufumbiri*) (Birdlife International, 2023). Despite the proximity of the KBA, the Nyakabingo Mine is considered unlikely to have a noticeable impact on the area given the sheer volume of the Nyabarongo River.

Despite the high regional biodiversity significance, the aquatic habitats within the Project Area of Influence are considered to be in a “Modified” ecological state (Nepid Consulting, 2024). Long-term anthropogenic disturbances, including formal and unauthorised mining activities and subsistence agriculture have substantially altered ecological functioning and species composition within the area. Natural riparian vegetation has been extensively removed, resulting in increased bank erosion as well as reduced flood attenuation and carbon storage capacity. Aquatic biodiversity within the Nyakabingo River is severely degraded, with 2023 field sampling recording an absence of fish and extremely low macroinvertebrate diversity (Nepid Consulting, 2024). These conditions are likely attributable to acid mine drainage and elevated sediment transport associated with regional land-use practices and catchment disturbance.

A notable regional biodiversity finding within the broader catchment is the occurrence of the freshwater red alga *Kumanoa rwandensis* (Nepid Consulting, 2024), recorded within an acidic mountain headwater tributary. This species was first described in 2020 from Nyungwe National Park and represents an example of the specialised and locally significant freshwater biodiversity associated with the region.

## 5.2 Freshwater Ecosystem Results

The results of the studies and investigations undertaken for the Trinity Nyakabingo Mine are outlined in the following sections. **Figure 5-3** provides an overview of the freshwater ecosystems within the concession areas.



**Figure 5-3 Overview of the freshwater ecosystems within the Nyakabingo concession area**

### **5.2.1 General catchment characteristics**

The Nyakabingo mine is situated within the headwaters of the Nyakabingo River, with its disturbance footprint extending across much of the hillside and down towards the river’s origin. This section of the catchment is particularly steep, and to access different mining levels, an extensive zig-zagging road network has been constructed along the mountainside. The mining footprint encompasses not only active working areas but also tailings facilities and a series of dams. Vegetated portions of the catchment are dominated by *Eucalyptus* plantations (**Figure 5-4**), which provide less effective soil protection compared to indigenous vegetation.



**Figure 5-4 View of the catchment surrounding the Nyakabingo mine**

Downstream and adjacent to the mining activities subsistence agricultural and housing begin. The majority of the farming activities are concentrated in the lower-lying areas of the catchment, due to the availability of water. Due to the steep topography, many homesteads have adopted terraced farming practices. The upper areas of the catchment are generally dominated by *Eucalyptus* trees, both actively cultivated and areas of invasion (**Figure 5-5**). The majority of the mid to upper areas of the catchment are characteristic of this.



**Figure 5-5 View of the catchment characteristics nearby the Nyakabingo mine**

The lower catchment transitions into peri-urban landscapes, namely the towns of Rutinde and Nyamirembe. Here, subsistence agriculture diminishes and is replaced by dense road networks, housing, schools, and other infrastructure. Notably, this peri-urban zone was identified as one of the most littered areas across all concession sites.

These land-use patterns have led to significant impacts, including soil erosion in areas, sedimentation, declining water quality, and reduced biodiversity. The absence of intact riparian zones diminishes ecosystem services such as water filtration and flood buffering, while invasive species further degrade ecological integrity. Overall, the Nyakabingo catchment reflects a landscape under stress, where mining and agriculture intersect with fragile ecosystems, creating challenges for sustainable management and conservation.

### **5.2.2 Freshwater ecosystem overview**

The freshwater ecosystems (**Figure 5-3**) within the concession area have been significantly modified through the upstream mining activities which has served to deliver aggregate and sediments into the upper reaches of the Nyakabingo River (**Figure 5-6**). The modified nature of the upper reaches of the catchment in combination with the area considered to be highly erosive, the upper portion of the channel has become incised.



**Figure 5-6 View of the sediment and aggregate material that has been deposited within the Nyakabingo River due to the upstream mining activities**

The valley-bottom is narrow and steep, which confines flows within the valley itself. The catchment profile consists of this valley floor, flanked by steep sides that extend upward into the surrounding terrain (**Figure 5-7**). Additionally, access to the valley-bottom is limited, and thus the mining of aggregate and sand occurs along only a limited stretch of the system (). Topographically, the valley-bottom is not conducive for crop cultivation and as such the subsistence agricultural activities are confined to the adjacent slopes.



**Figure 5-7 Examples of the very narrow valley area associated with the majority of the Nyakabingo River**



**Figure 5-8 View of the sand and aggregate mining within the Nyakabingo channel, at one of the few accessible sites**

The valley area becomes especially constrained within the peri-urban zones, where the river channel lies approximately 8–10 meters below the adjacent urban ground level. Below the main access road, the valley-bottom widens however, is still approximately 3-m below the adjacent areas. The freshwater ecosystems within this lower portion have been significantly modified. The channel is incised and receives both sediment and litter from the upstream peri-urban area (**Figure 5-9**). This area has the highest amount of visible litter in comparison to other peri-urban areas in the concession areas.



**Figure 5-9 View of the litter within the lower reaches of the Nyakabingo River**

The eastern terrace adjacent to the Nyakabingo River, is a seepage area, which is dominated by subsistence agricultural activities, and has been heavily drained (**Figure 5-10**). This is the flattest open space alongside the Nyakabingo River, which is sustained by lateral inputs along with runoff from the adjacent peri-urban area.

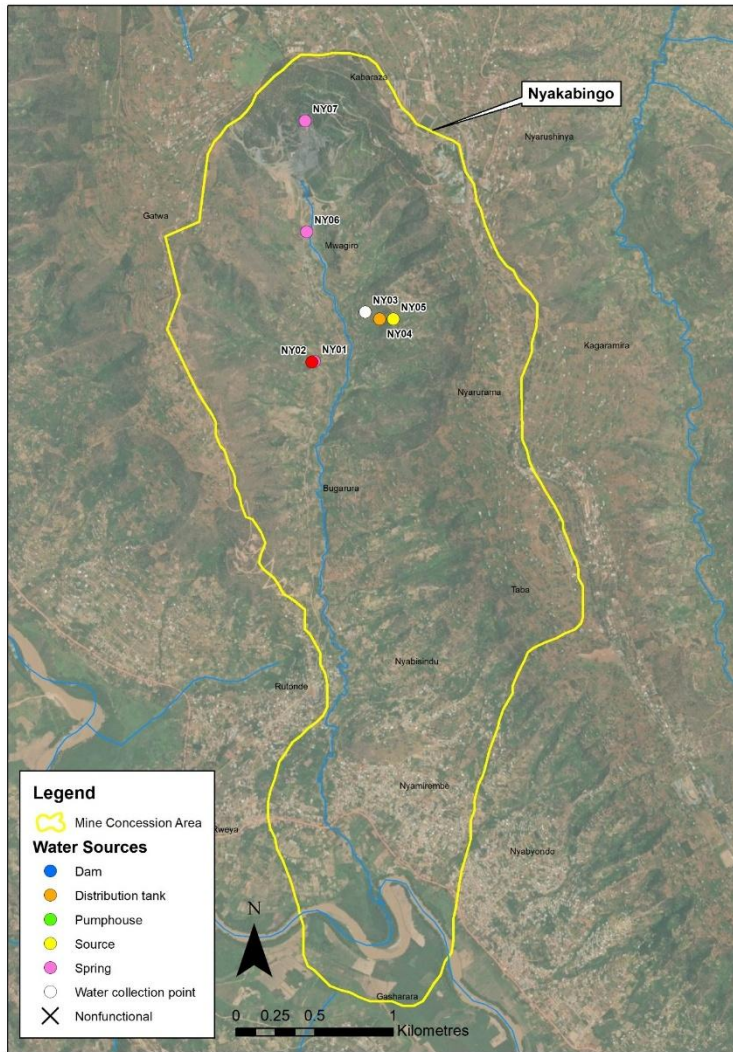


**Figure 5-10 View of the seepage wetland perched on a terrace above the Nyakabingo River**

Where the Nyakabingo River decants into the Nyabarongo River, the channel banks have been stabilised with bamboo. At this point in the Nyabarongo River, which is approximately 60m wide, sediment is being actively harvested from within the channel with a sand pump. The sand is pumped to a bank along the river for further processing. A small seepage area lies adjacent to the Nyabarongo River and is dominated by wetland vegetation. This wetland system was precluded from further assessment due to being hydrologically isolated from the impacts of the mine, as it is located upstream of the Nyakabingo decant point.

### **5.2.3 Functionality and integrity**

**Figure 5-11** provides an overview of the results presented in the rivers tables.



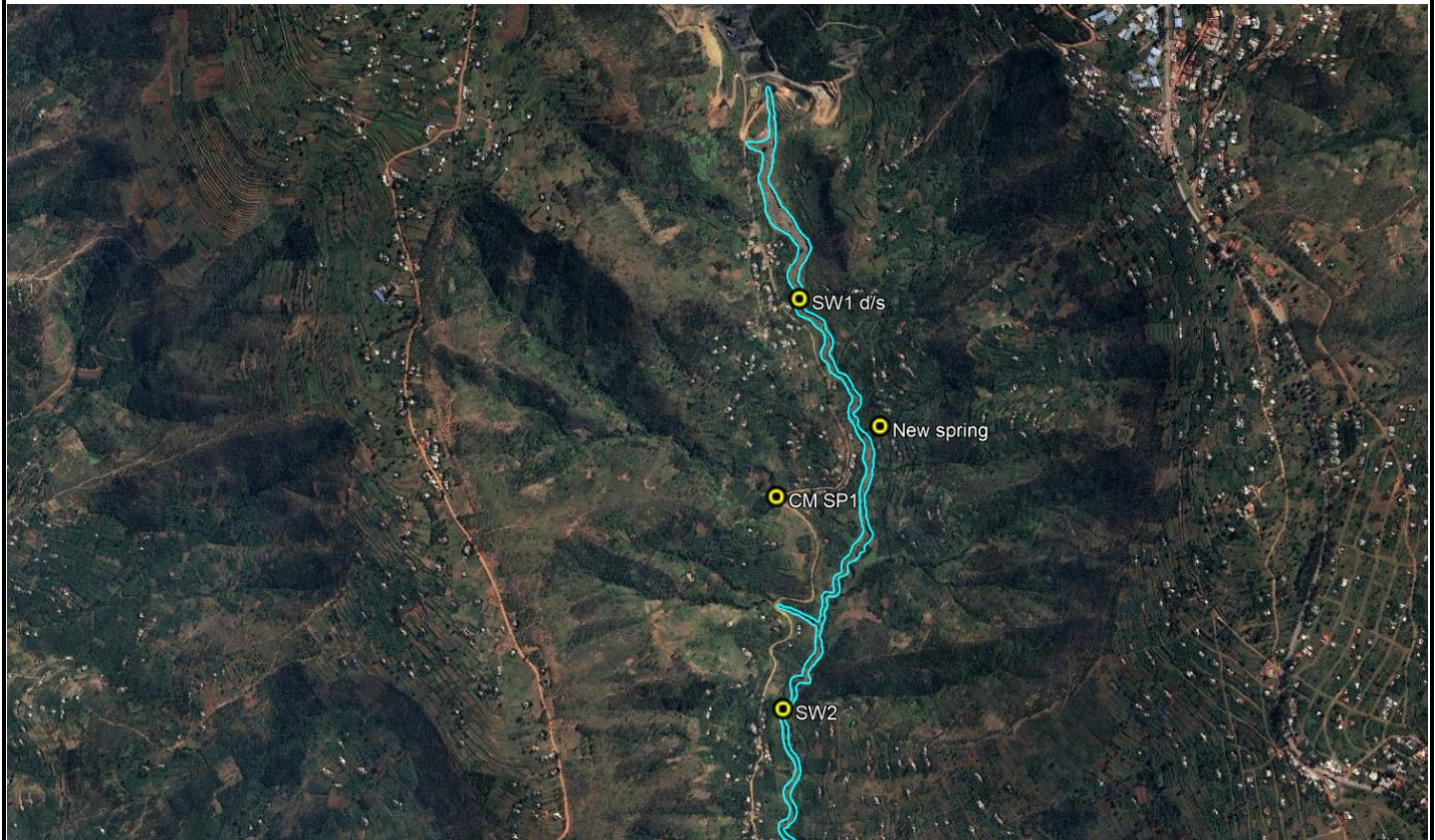
**Figure 5-11 Overview of the samples sites within the Nyakabingo catchment**  
River tables

5.2.3.1 Upper Nyakabingo River

Upper Nyakabingo River downstream of Nyakabingo Mine

|             |            |                       |                 |
|-------------|------------|-----------------------|-----------------|
| Sample Date | 18/11/2026 | Altitude              | 1,576 m.a.s.l.  |
| River       | Nyakabingo | Geomorphological zone | Mountain Stream |
| Latitude    | -1.871593  | Longitude             | 29.972477       |

**River reach overview:** The reach for the upper Nyakabingo River extends 2.5 km from downstream of the Nyakabingo Mine to ~750 m downstream of SW2 and is largely impacted by increased runoff, erosion and sedimentation, and water quality impacts from upstream mining and surrounding land use activities.



SW2 Upstream

SW2 Downstream



Site assessments:

**Water Quality**

During the 2023 survey, the site was characterised as having reddish-coloured, acidic (pH = 4.4) water and the highest turbidity (Nepid Consulting, 2024). During the November 2025 assessment, the pH was highly acidic (pH = 2.6) and water clarity ranged from 45 cm from just downstream of the mine, decreasing to 25 cm at SW2. The increase in turbidity indicates impacts from other activities within the river system causing direct disturbance to the riverbed and channel.

**Water quality based on drinking/potable standards:**

The upper Nyakabingo has a number of drinking water exceedances for aluminium (mean: 15.6 mg/L; limit: 0.20 mg/L), arsenic (mean: 0.126 mg/L; limit: 0.010 mg/L), cadmium (mean: 0.0104mg/L; limit: 0.0030 mg/L), copper (mean: 1.94 mg/L; limit: 1.00 mg/L), iron (mean: 8.78 mg/L; limit: 0.30 mg/L), manganese (mean: 4.58 mg/L; limit: 0.080 mg/L), nickel (mean: 0.39 mg/L; limit: 0.10 mg/L), sulphate (mean: 297.00 mg/L; limit: 250.00 mg/L) and total ammonia (mean: 1.14 mg/L; limit: 0.50 mg/L). Elevated aluminium poses aesthetic and potential neurotoxicological risks; treatment coagulation efficiency may be compromised, increasing coagulant demand and turbidity in treated water (SANS 241:2015). Excess iron causes organoleptic problems (reddish discolouration, metallic taste), staining of fixtures and promotion of iron-oxidising bacteria in water distribution systems (DWAf 1996, Vol. 1). Manganese above 0.08 mg/L causes black deposits in pipes, aesthetic complaints and is associated with neurotoxic effects at high chronic exposures; requires oxidation-filtration treatment (SANS 241:2015; WHO 2022). Arsenic exceedances represent a significant carcinogenic and chronic toxicity risk; prolonged consumption above 0.01 mg/L is linked to skin, bladder and lung cancer (WHO 2022; SANS 241:2015). Ammonia in raw water indicates sewage or organic pollution; while not directly toxic at guideline levels, it reacts with chlorine to form chloramines, reducing disinfection efficacy (DWAf 1996, Vol. 1). Sulphate above 250 mg/L imparts a bitter taste and has laxative effects; high sulphate in mine-impacted catchments may also signal acid mine drainage contributions (DWAf 1996, Vol. 1). Copper at elevated concentrations causes gastrointestinal irritation and, at chronic levels, hepatic damage; it also promotes growth of green/blue staining on fixtures (SANS 241:2015). Nickel exceedances above 0.02 mg/L present chronic health concerns including dermatitis and potential carcinogenicity; often associated with geogenic or industrial sources (SANS 241:2015; WHO 2022). Cadmium is highly toxic to the kidneys and is a Group 1 carcinogen; any exceedance requires urgent investigation and treatment (SANS 241:2015; WHO 2022).

**Water quality based on aquatic ecology standards:**

The upper Nyakabingo also has a number of aquatic life exceedances for arsenic (mean: 0.126 mg/L; limit: 0.010 mg/L), cadmium (mean: 0.0104mg/L; limit: 0.0030 mg/L), copper (mean: 1.94 mg/L; limit: 1.00 mg/L), lead (mean: 0.0053 mg/L; limit: 0.0020 mg/L), manganese (mean: 4.58 mg/L; limit: 1.00 mg/L), and nickel (mean: 0.39 mg/L; limit: 0.10 mg/L) representing one of the most ecotoxicologically complex situations of all of the Mine sites. Manganese at elevated concentrations is toxic to aquatic organisms through enzyme inhibition; co-deposition with iron further degrades benthic habitat quality (DWAf 1996, Vol. 7). Arsenic bioaccumulates in aquatic food webs; sublethal exposures cause reproductive failure, behavioural disruption and histopathological damage in fish and invertebrates (DWAf 1996, Vol. 7). Copper is highly toxic to aquatic organisms even at trace concentrations, disrupting olfaction in salmonids and causing gill damage; it bioaccumulates in invertebrate tissues (DWAf 1996, Vol. 7). Nickel causes chronic toxicity in aquatic invertebrates and fish at concentrations above 0.10 mg/L, impairing reproduction and growth; speciation is strongly influenced by hardness and pH (DWAf 1996, Vol. 7). Lead bioaccumulates in bone and soft tissues of fish; sublethal effects include behavioural changes and reproductive impairment, with cascading effects up the food web (DWAf 1996, Vol. 7). Cadmium is extremely toxic to aquatic life with bioaccumulation in liver and kidney tissues of fish; it inhibits photosynthesis in algae and disrupts calcium metabolism in invertebrates (DWAf 1996, Vol. 7). The combined toxicity of this multi-metal mixture is expected to cause severe reduction in sensitive macroinvertebrates (e.g. Ephemeroptera, Plecoptera, Trichoptera – EPT) richness and presents a serious risk fish assemblages and limiting any potential for recolonisation.

**Diatoms**

|   |  |
|---|--|
| <b>River Health Class:</b><br><b>SERIOUSLY MODIFIED</b> | The diatom sample contained no identifiable cells and consisted entirely of fine sediment highlighting the severity of sedimentation within the river channel. |
|---|--|

**Macroinvertebrates**

|  |                   |                    |             |                            |                    |
|--|-------------------|--------------------|-------------|----------------------------|--------------------|
| <b>River Health Class:</b><br><b>SERIOUSLY MODIFIED</b>  | <b>SASS Score</b> | <b>No. of taxa</b> | <b>ASPT</b> | <b>Ecological Category</b> | <b>Class</b>       |
|  | 5                 | 1                  | 5.0         | E/F                        | Seriously Modified |
| The presence of only one, moderate sensitivity, air-breathing and pollution-tolerant taxon (Gyrinidae) suggests that aquatic macroinvertebrates are unable to survive within the river, and the system is therefore in a seriously modified condition. Although the ASPT value was calculated as 5.0, this value should be interpreted cautiously because it is derived from only one recorded taxon. Under such low-diversity conditions, ASPT is not considered a reliable indicator of ecological condition on its own. |                   |                    |             |                            |                    |

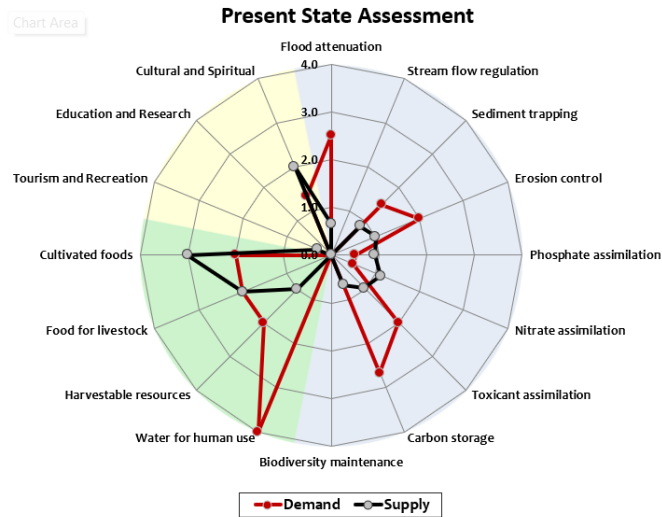
**Instream and Riparian Habitats**

|   |   |
|---|---|
| <b>Instream Habitat Class:</b><br><b>POOR</b> | Instream habitat condition is poor (score 49, Class D) largely due to water quality (extreme impact) from mining activities upstream and unauthorised mining/aggregate extraction activities downstream of the mine, which are causing ongoing bed modification (large impact) and channel modification (moderate impact). In addition, stormwater/runoff impacts from roads and a poor land cover setting, exacerbated by the steep terrain results in a large impact to the rivers natural hydrological regime. |
|---|---|

**Riparian Habitat Class:**  
**POOR**

Riparian habitat is in a poor condition (score 50, Class D) due to bank erosion and riverbank destabilisation (large impact), with some vegetation removal (moderate impact) linked to cultivation, foot paths, channel disturbances, which is also exacerbated by the altered hydrology in the system, notably through increased flow pulses and flooding.

**Riverine Ecosystem Services**



**Regulating and Supporting Services:**

Flood attenuation, sediment trapping, and erosion control are in high demand but in limited supply, reflecting the highly modified nature of the river and its catchment. Pollution assimilation is poor, making communities vulnerable in terms of water quality. These services are important for protecting agricultural land, retaining fertile soils, and safeguarding infrastructure such as roads and bridges. The river’s reduced capacity to buffer floods and filter pollutants compromises both livelihoods and resilience to climate variability.

**Provisioning Services:**

Water for human use is the most critical provisioning service, with very high demand and moderate supply. Cultivated food provision and food for livestock follows from water supply, which are closely dependent on fertile soils and sediment trapping. These services are important for sustaining subsistence farming and food security, yet pressures on the river system limit availability and potential for enhanced productivity.

**Cultural Services:**

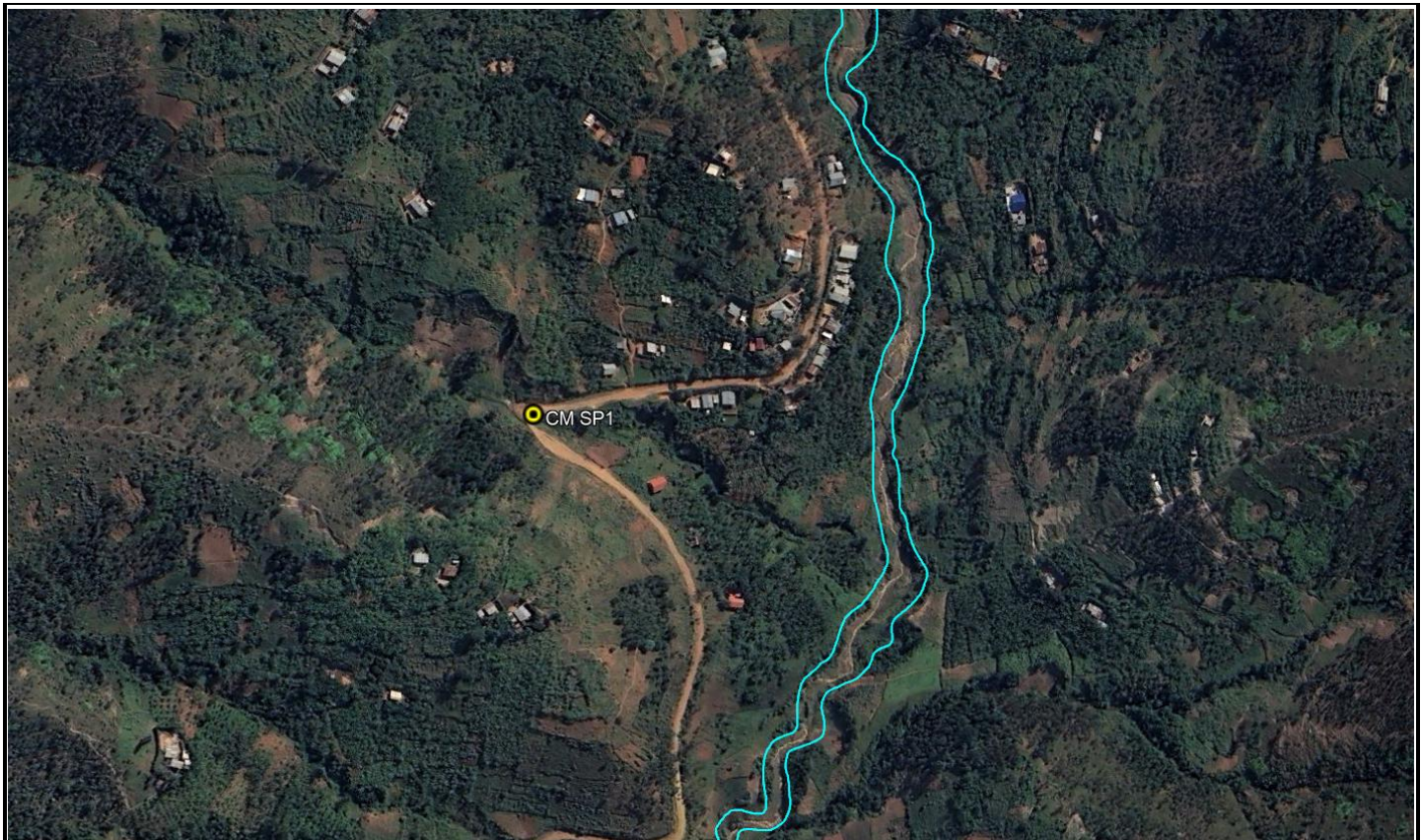
Cultural and spiritual values are of low importance, with moderate supply but limited demand. Tourism, recreation, education, and research are all rated very low, reflecting the diminished ecological integrity of the river ecosystem and its reduced appeal for cultural or learning purposes.

**5.2.3.2 Upper Nyakabingo Springs**

**Nyakabingo Spring at CM SP1**

|                    |                   |                              |                           |
|--------------------|-------------------|------------------------------|---------------------------|
| <b>Sample Date</b> | 18/11/2025        | <b>Altitude</b>              | 1,485 m.a.s.l.            |
| <b>River</b>       | Unnamed tributary | <b>Geomorphological zone</b> | Mountain Headwater Stream |
| <b>Latitude</b>    | -1.880755         | <b>Longitude</b>             | 29.972303                 |

**River reach overview:** Small tributary of the Nyakabingo River which includes a spring (CM SP1) providing water for community members.



Upstream

Downstream



**Site assessments:**

**Water Quality**

In 2023 survey, the site had clear water with low turbidity (Nepid Consulting, 2024). During the November 2025 assessment, the water clarity was 45 cm indicating moderately low turbidity, and pH was moderately acidic (pH = 5.9).

**Water quality based on drinking/potable standards:**

In the 2025 survey the site had drinking water exceedances of Aluminium (mean: 0.23 mg/L; limit: 0.20 mg/L) and Arsenic (mean: 0.014 mg/L; limit: 0.010 mg/L). Arsenic exceedance is a serious carcinogenic risk associated with skin lesions, bladder, and lung cancer with prolonged exposure, even at low doses (WHO, 2011). Aluminium causes aesthetic degradation (taste, colour, staining) but elevated aluminium has been associated with neurotoxicity at chronic doses (DWAf, 1996a).

**Water quality based on aquatic ecology standards:**

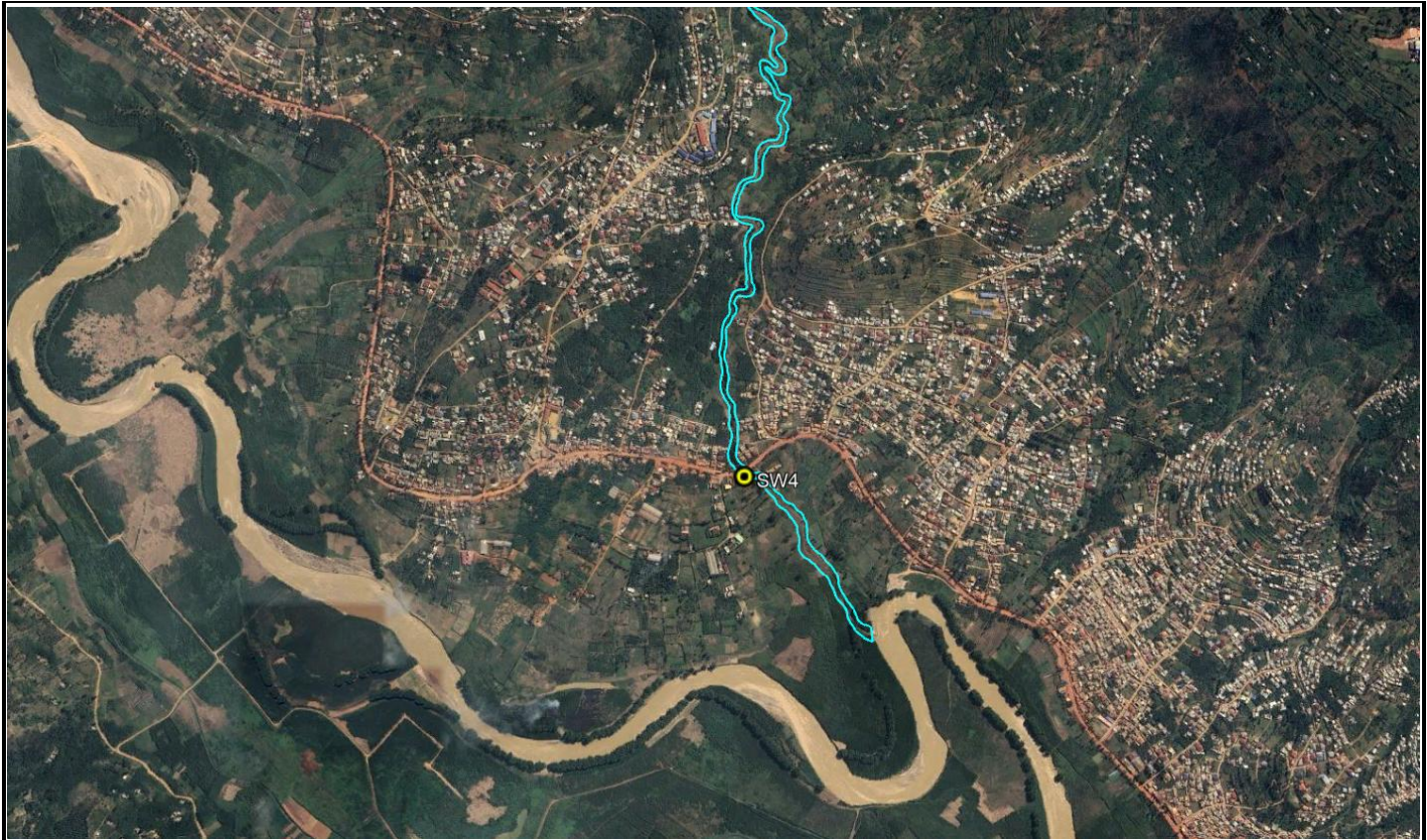
The site had no aquatic life water exceedances.

| Diatoms                                 |   |  |             |                        |
|---|---|--|-------------|------------------------|
| <b>River Health Class:<br/>FAIR</b>     | <b>No. of species</b>   | <b>SPI core</b>  | <b>%PTV</b> | <b>%Deformed cells</b> |
|   | 24  | 11.5   | 56.3        | 0.8                    |
|   | <p>In 2023, no benthic algae were recorded in the Nyakabingo River, due to acidic conditions and elevated concentrations of suspended materials associated with local subsistence farming (Nepid Consulting, 2024). However, <i>Kumanoa rwandensis</i>, a freshwater red alga from the Batrachospermaceae group was recorded at this site. This species is found in acidic streams and has been found in open, sunny and fast flowing streams outside of the forested areas in the Rukarara River which later becomes the Nyabarongo and Akegera rivers, which is one of the main sources to the Blue Nile River (Fischer <i>et al.</i>, 2020<sup>9</sup>).</p> <p>In 2025, diatom community was observed to be in a fair river health class. The dominant diatom species at this site was <i>Gomphonema parvulum</i> making up 49% of the community, followed by <i>Achnanthydium</i> sp. (25%) and <i>Achnanthydium minutissimum</i> (4%). <i>G. parvulum</i>, a species highly tolerant of extremely polluted waters, and it thrives in polluted systems where more sensitive species fail to survive. <i>Achnanthydium</i> sp. is tolerant to moderate to good quality waters, with <i>A. minutissimum</i> found in clean, well-oxygenated waters. The presence of these <i>Achnanthydium</i> species indicates that conditions were not consistently severely polluted, due to factors such as fluctuating water quality, episodic pollution input or localised refugia with patches of suitable habitat for less pollution tolerant taxa.</p> |  |             |                        |
| Macroinvertebrates                      |   |  |             |                        |
| <b>River Health Class:<br/>POOR</b>     | <p>A total of eight taxa were recorded by Nepid Consulting (2024) in August 2023 resulting in a SASS Score of 35 and an ASPT of 4.4. As a result, the Ecological Category was considered to be poor (Class D). The macroinvertebrate community was dominated by leeches (<i>Aiolimnatis cf. obscura</i>), caddisflies (<i>Cheumatopsuche cf. afra</i>) and baetid mayflies (<i>Baetis</i> sp.). There was a low proportion of air-breathing organisms (38%), but the site was dominated by low sensitivity, pollution tolerant taxa so both poor water quality and low habitat availability could be contributing to the low diversity in this system. In terms of feeding ecology, the community was largely made up of predators (50%), collector-gatherers /shredders (50%), which is indicative of slow-flow conditions with some sediment deposition, detritus and decomposing organic material.</p>   |  |             |                        |
|   | Instream and Riparian Habitats  |  |             |                        |
| <b>Instream Habitat Class:<br/>GOOD</b> | <p>Instream habitats are in a relatively good condition (score 84, Class B) with only minor impacts in terms of bed modification (moderately-low impact) and water quality (moderate impact) with localised impacts associated with the road crossing and concentration of people and livestock around the water source point at CM SP1.</p>  |  |             |                        |
|   | <b>Riparian Habitat Class:<br/>GOOD/FAIR</b>  | <p>Riparian habitat is in a good to fair poor condition (score 81, Class B/C) with moderate impacts from vegetation removal, bank erosion and exotic vegetation (<i>Eucalyptus</i>, <i>Lantana camara</i>, <i>Ricinus communis</i>, <i>Senna</i> sp.).</p> |             |                        |

### 5.2.3.3 Lower Nyakabingo River

| Lower Nyakabingo River downstream of Nyakabingo Mine   |            |                              |                 |
|--|------------|------------------------------|-----------------|
| <b>Sample Date</b>   | 18/11/2026 | <b>Altitude</b>              | 1,393 m.a.s.l.  |
| <b>River</b>   | Nyakabingo | <b>Geomorphological zone</b> | Mountain Stream |
| <b>Latitude</b>  | -1.902515  | <b>Longitude</b>             | 29.972865       |
| <p><b>River reach overview:</b> The reach for the lower Nyakabingo River extends 2.5 km from ~750 m downstream of SW2 down to the confluence with the Nyabugogo River. The reach is largely impacted by the continuation of impacts from the upper catchment (i.e. increased runoff, erosion and sedimentation, and water quality impacts from upstream mining/land use activities) as well as from additional land uses (rural settlement and subsistence agriculture) along the riverbanks and within the surrounding catchment areas.</p> |            |                              |                 |

<sup>9</sup> Fischer, E., Gerlach, J., Killmann, D., and Quandt, D. 2020. The freshwater red algae (*Batrachospermales*, Rhodophyta) of Africa and Madagascar I. New species of *Kumanoa*, *Sirodotia* and the new genus *Ahidranoa* (Batrachospermaceae). Plant and Fungal Systematics 65(1): 147–166, 2020.



Upstream

Downstream



**Site assessments:**

**Water Quality**

During the 2023 survey by Nepid Consulting (2024), the site had clear water with low turbidity (Nepid Consulting, 2024). During the November 2025 assessment, the pH was highly acidic (pH = 2.6) towards the upper sections of the lower Nyakabingo River reach, with a slight downstream improvement at SW4 (pH = 2.9). Water clarity measured within the reach was very low, with 6 cm (a significant decrease from 25 cm measured at SW2 upstream) measured in the upper sections of the lower Nyakabingo River reach, decreasing to 3 cm at SW4 highlighting the severity of sedimentation caused by unauthorised mining and aggregate extraction activities within the river channel.

**Water quality based on drinking/potable standards:**

The site has a number of drinking water exceedances for aluminium (mean: 20.70 mg/L; limit: 0.20 mg/L), arsenic (mean: 0.015 mg/L; limit: 0.010 mg/L), copper (mean: 1.80 mg/L; limit: 1.00 mg/L), iron (mean: 5.20 mg/L; limit: 0.30 mg/L), manganese (mean: 5.85 mg/L; limit: 0.080 mg/L), nickel (mean: 0.47 mg/L; limit: 0.10 mg/L), sulphate (mean: 356.00 mg/L; limit: 250.00 mg/L) and total ammonia (mean: 0.95 mg/L; limit: 0.50 mg/L). Elevated aluminium poses aesthetic and potential neurotoxicological risks; treatment coagulation efficiency may be compromised, increasing coagulant demand and turbidity in treated water (SANS 241:2015). Excess iron causes organoleptic problems

(reddish discolouration, metallic taste), staining of fixtures and promotion of iron-oxidising bacteria in distribution systems (DWAF 1996, Vol. 1). Manganese above 0.08 mg/L causes black deposits in pipes, aesthetic complaints and is associated with neurotoxic effects at high chronic exposures; requires oxidation-filtration treatment (SANS 241:2015; WHO 2022). Arsenic exceedances represent a significant carcinogenic and chronic toxicity risk; prolonged consumption above 0.01 mg/L is linked to skin, bladder and lung cancer (WHO 2022; SANS 241:2015). Ammonia in raw water indicates sewage or organic pollution; while not directly toxic at guideline levels, it reacts with chlorine to form chloramines, reducing disinfection efficacy (DWAF 1996, Vol. 1). Sulphate above 250 mg/L imparts a bitter taste and has laxative effects; high sulphate in mine-impacted catchments may also signal acid mine drainage contributions (DWAF 1996, Vol. 1). Copper at elevated concentrations causes gastrointestinal irritation and, at chronic levels, hepatic damage; it also promotes growth of green/blue staining on fixtures (SANS 241:2015). Nickel exceedances above 0.02 mg/L present chronic health concerns including dermatitis and potential carcinogenicity; often associated with geogenic or industrial sources (SANS 241:2015; WHO 2022).

**Water quality based on aquatic ecology standards:**

The site has a number of aquatic life exceedances for lead (mean: 0.0083 mg/L; limit: 0.0020 mg/L), and manganese (mean: 1.23 mg/L; limit: 1.00 mg/L). Lead bioaccumulates in bone and soft tissues of fish; sublethal effects include behavioural changes and reproductive impairment, with cascading effects up the food web (DWAF 1996, Vol. 7). Manganese at elevated concentrations is toxic to aquatic organisms through enzyme inhibition; co-deposition with iron further degrades benthic habitat quality (DWAF 1996, Vol. 7).

**Diatoms**

|   |  |
|---|--|
| <b>River Health Class:</b><br><b>SERIOUSLY MODIFIED</b> | The diatom sample contained no identifiable cells and consisted entirely of fine sediment highlighting the severity of sedimentation within the river channel. |
|---|--|

**Macroinvertebrates**

| <b>River Health Class:</b><br><b>SERIOUSLY MODIFIED</b> | SASS Score  | No. of taxa | ASPT | Ecological Category | Class |
|---|---|-------------|------|---------------------|-------|
|   |   | 14          | 4    | 3.5                 | E/F   |
|   | Only a single chironomid larva was recorded by Nepid Consulting (2024) at NYK SW4 during August 2023. The absence of other macroinvertebrates was attributed to a combination of acid mine drainage and abrasion caused by elevated concentrations of suspended material. The overall PES was considered Critically Modified (Category F).  |             |      |                     |       |
|   | During the November 2025 assessment the site was still in a seriously modified condition with low number of pollution-tolerant, low sensitivity taxa recorded. The low ASPT value of 3.5 indicates that the macroinvertebrate community was dominated by relatively tolerant taxa, while sensitive organisms were absent. This reflects the extremity of environmental stressors caused by pollution, excessive sedimentation, nutrient enrichment, habitat degradation, low dissolved oxygen levels, and altered flow conditions. Although slightly more taxa were present compared to a near-absent community, the overall diversity remains very low, indicating limited habitat suitability and reduced ecological functioning. |             |      |                     |       |

**Instream and Riparian Habitats**

|  |  |
|--|--|
| <b>Instream Habitat Class:</b><br><b>POOR</b>                    | Instream habitat condition is poor (score 55, Class D) largely due to water quality (extreme impact) from mining activities upstream, as well as from unauthorised mining/aggregate extraction activities downstream of the mine, which are also causing ongoing bed modification (moderately large impact). In addition, stormwater/runoff impacts from roads and a poor land cover setting, exacerbated by the steep terrain results in a moderately large impact to the rivers natural hydrological regime. |
| <b>Riparian Habitat Class:</b><br><b>POOR/SERIOUSLY MODIFIED</b> | Riparian habitat is in as poor to seriously modified condition (score 40, Class D/E) mainly due to bank erosion and riverbank destabilisation (large impact), channel modification (moderately large impact), with some vegetation removal (moderate impact) linked to cultivation, foot paths, channel disturbances, which is also exacerbated by the altered hydrology in the system, notably through increased flow pulses and flooding.  |

**5.2.3.4 Nyakabingo wetland**

| Lower Nyakabingo Seep        |               |                                  |              |
|------------------------------|---------------|----------------------------------|--------------|
| <b>Date Assessed</b>         | 19/11/2025    | <b>Assessment Level</b>          | Level 1B     |
| <b>HGM Type Modelled</b>     | Seep          | <b>HGM Type Verified Infield</b> | Seep         |
| <b>Latitude</b>              | 9789391,83925 | <b>Longitude</b>                 | 163351,79081 |
| <b>Overview of HGM Unit:</b> |               |                                  |              |



**In-system photos**



**View of the subsistence farming activities within the seep**



View of the seep including some of the drainage network

**Catchment area and dominant landcover (top 5):**

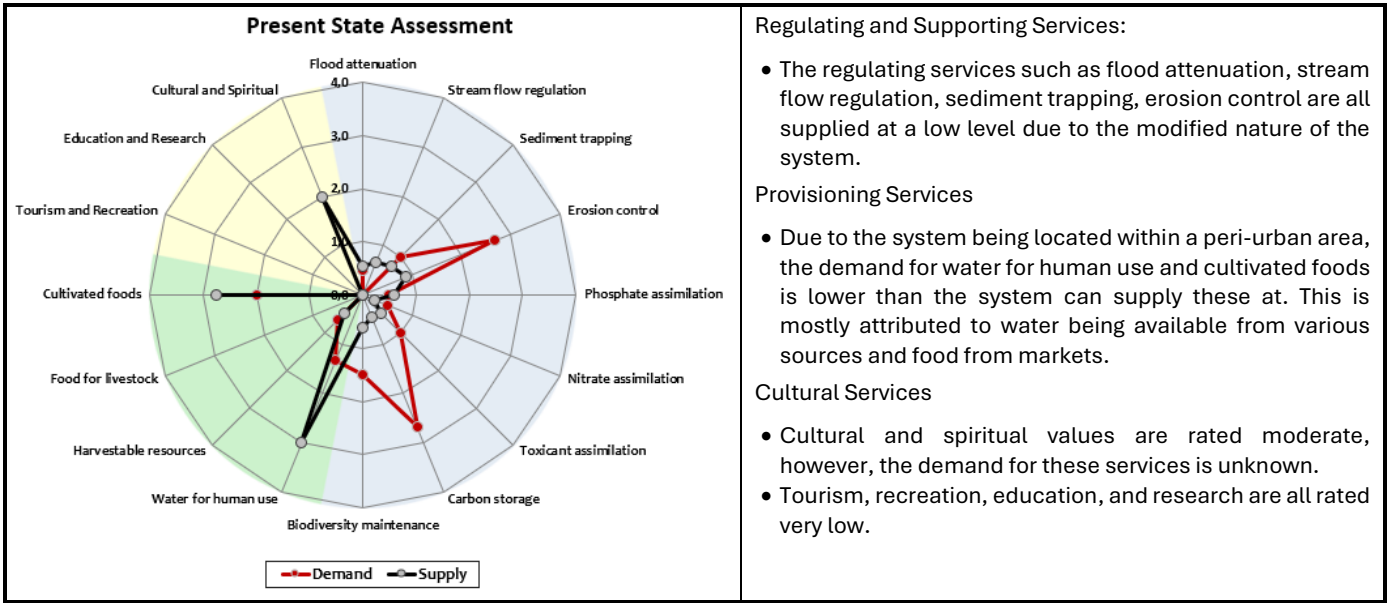
Catchment area = 95.46 ha

| Order | Catchment                                 | Within Wetland                        |
|-------|---|---------------------------------------|
| 1     | Urban Residential – low density (39.96%)  | Subsistence crops (drained) (95.89%%) |
| 2     | Urban Residential – high density (34.22%) | Woodlots/Tree plantations (4.11%)     |
| 3     | Woodlots/Tree plantations (13.06%)        | -                                     |
| 4     | Subsistence crops (12.6%)                 | -                                     |
| 5     | -   | -                                     |

**Site assessment:**

|                    |                                  |     |   |
|--------------------|----------------------------------|-----|---|
| <b>Wetland PES</b> | Score                            | 6.3 | <ul style="list-style-type: none"> <li>• The catchment of the wetland has been significantly modified from its historical conditions, with the majority of the catchment being dominated by varying degrees of urban development.</li> <li>• The wetland is isolated from the mining activities, as it is approximately 3-4m above the Nyakabingo channel, and therefore does not receive any water inputs from the channel but is laterally feed from its upstream catchment.</li> <li>• The majority wetland has been modified through subsistence agricultural activities, which includes the adoption of an extensive drainage network and raised beds for crop cultivation.</li> </ul> |
|                    | Category                         | E   |   |
|                    | Wetland size (ha)                | 2.5 |   |
|                    | Hectare equivalents              | 0.9 |   |
|                    | Anticipated trajectory of change | →   |   |

**EcoServices**



**Regulating and Supporting Services:**

- The regulating services such as flood attenuation, stream flow regulation, sediment trapping, erosion control are all supplied at a low level due to the modified nature of the system.

**Provisioning Services**

- Due to the system being located within a peri-urban area, the demand for water for human use and cultivated foods is lower than the system can supply these at. This is mostly attributed to water being available from various sources and food from markets.

**Cultural Services**

- Cultural and spiritual values are rated moderate, however, the demand for these services is unknown.
- Tourism, recreation, education, and research are all rated very low.

## 6. RECOMMENDATIONS AND CONCLUSION

The following section provides some recommendations that may be considered as part of Phase 2 of the project.

### 6.1 Recommendations

Based on the findings from the Source Pathway Receptor report (GroundTruth 2026b) and sediment report (GroundTruth 2026c), remediation will be required in both the short and long term, with priority actions directed at controlling dust emissions, improving stockpile and waste rock management strengthening stormwater and contaminated water controls, treating effluent to prevent pollution of the Nyakabingo River, and increasing process-water reuse to reduce excess discharges.

In line with international best practice, mitigation should focus on pollution prevention at source before downstream treatment. These findings provide a strong technical foundation for Trinity Metal's future Legacy Tailings Management and River Rehabilitation Programme, with particular emphasis on protecting the Nyakabingo River headwaters and groundwater systems to safeguard downstream water security and ecosystem function (GroundTruth 2026b).

For legacy and abandoned mines, the pollution prevention hierarchy proposed by Novakowski *et al.* (2023), source control, water management, treatment, and finally discharge, provides a clear framework for action. Preliminary remediation opportunities for the Nyakabingo Mine are outlined in **Table 7-1** of the SPR report (GroundTruth 2026) and should be further investigated during Phase 2 of the Legacy Tailings Management and River Rehabilitation Programme to confirm site-specific suitability and efficacy.

To encourage more sustainable operations at the Nyakabingo mine, it is recommended that additional measures of prevention are considered and adopted beyond the mining footprint area i.e., that a more nature-based solution<sup>10</sup> approach is adopted. It should be noted that, depending on the mitigation route adopted, not all of the recommendations listed below may be applicable. The recommendations are presented to highlight the range of mitigation opportunities that could be implemented within the existing mining footprint and immediately downstream thereof. Some considerations that could be adopted includes:

- Grey-green hybrid solutions
  - The adoption of purely nature-based solutions is often not feasible at mine sites due to the large volumes of water and other operational constraints that must be managed. As a result, hybrid approaches that combine engineered and nature-based solutions are often more practical and effective. Some of the grey-green infrastructure solutions that may be considered include:
    - Biofiltration systems could be incorporated into the future design of the mine to assist with further polishing of water discharged from the mine

<sup>10</sup> Nature-based solutions (NbS) are defined as actions that protect, conserve, restore, and sustainably manage natural or modified ecosystems to address social, economic, and environmental challenges, while simultaneously delivering benefits for human well-being, ecosystem services, resilience, and biodiversity (UNEP 2026).

- site. These systems use microorganisms that attach to substrates to remove the contaminants from the water column through biological processes, rather than relying on chemical additions, if applicable.
- Vegetated drainage channels, such as swales and bioswales, can be used in place of concrete-lined channels to manage surface runoff more sustainably. By reducing the velocity of the flows, these systems reduce erosion and peak runoff while allowing sediments and some pollutants to settle out or be taken up by vegetation. In addition to improving water quality, vegetated channels also enhance site stability and integrate more naturally with the surrounding landscape.
  - Treatment trains for the polishing of the water column, may incorporate a series of interventions including an initial dosing area followed by passive reactive barriers prior to being discharged into a constructed wetland for further polishing. A multi-stage approach maximises treatment efficiency and provides greater operational resilience.
- Wetland habitat creation near mining sites
    - Constructed wetland/s may be established adjacent or downstream of the mining operations to manage site-derived contact water, trap sediments, and improve water quality prior to discharge. These wetlands can also support local biodiversity and provide ecological buffering to downstream receiving environments.
    - Constructed wetlands can assist with polishing contaminated water through combining physical, chemical, and biological processes to reduce acidity, remove metals, and improve overall water quality<sup>11</sup>.
    - Design enhancements, including targeted microbial inoculation, phytoremediation using selected macrophyte species, and the incorporation of controlled aerobic and anaerobic treatment zones, may be implemented to optimise treatment performance and further improve the efficacy of the system.
    - A treatment train may be considered and integrated as this approach allows for a modular and scalable design, allowing expansion to occur incrementally as site conditions evolve.
  - Catchment rehabilitation and sustainable land-use practices
    - Launch pilot projects to integrate sustainable subsistence and small-scale agricultural practices, including soil conservation measures (e.g. contour farming, mulching, reduced tillage), agroforestry systems, and water-efficient cropping techniques. These practices aim to reduce soil loss, improve infiltration and soil structure, and limit sediment transport to downstream drainage systems, while maintaining or enhancing local livelihoods and food security.
    - The adoption of buffer areas and/or natural filter strips around freshwater ecosystems should be considered. These features function as important

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<sup>11</sup> It should be noted that constructed wetlands have limitations in their ability to improve water quality, which must be considered during design and application. In addition, the maintenance of the systems is crucial in maintaining their level of efficacy.

ecological infrastructure within the landscape, particularly for freshwater systems, as they assist in reducing sediment inputs, encouraging infiltration, reducing runoff velocities, and increasing soil moisture retention. These functions play a crucial role in reducing peak runoff generation and sediment yields, thereby improving the hydrological resilience of downstream river systems. As a result, the implementation of buffers/filter strips is widely recognised as a key element of nature-based solutions for broader, catchment-scale ecological restoration/rehabilitation.

- Existing tools such as the WET-Sustainable Use guidelines (Kotze, 2010) provide a structured approach for assessing and guiding the ecological sustainability of agricultural activities within wetlands, including cultivation, grazing, and vegetation harvesting. The tool evaluates sustainability based on land use types, the number of people dependent on these activities, and the intensity of use, while recognising the influence of social, economic, political, and environmental drivers. Without the promotion of sustainable use, wetlands are at risk of over-utilisation and degradation, leading to a decline in the goods and services they provide. The WET-Sustainable Use tool supports a holistic understanding of wetland condition and context, enabling site-specific, sustainable management decisions. In addition, the application of the “five-fingers” rule in subsistence agricultural settings offers a practical framework for promoting key soil and water conservation principles.
- Based on the outcomes of the sediment report (GroundTruth, 2026c), there is a need to manage the extractive activities within the river systems (i.e. sediment and aggregate mining). Sustainable extraction requires that riverine sediment and aggregate mining be carefully controlled in space, time, and volume to minimise environmental harm. To achieve this, an understanding of how much material the river can yield without long term degradation is crucial, i.e. extraction should not exceed the annual sediment replenishment rates. Extraction should be confined to areas of natural sediment accumulation. However, in order for this to be achieved a consultative process with the various stakeholders reliant on the material needs to be undertaken, along with site-specific assessments of sediment dynamics being undertaken to ensure long-term channel stability and ecosystem integrity.
- Incorporate Nature-based Solutions (NbS) to stabilise disturbed slopes, restore natural hydrological functioning and increase ecosystem resilience. Such measures may include strategic revegetation with indigenous species, establishment of riparian buffer zones, creation of vegetated infiltration areas, and installation of erosion control features such as live check structures and bio-engineering techniques.
- Community engagement and capacity building
  - Long-term environmental management and resilience of rehabilitated/restored/created systems is underpinned by active and structured community engagement, thereby ensuring that community members are meaningfully involved in any activities beyond the onsite operational activities.

- Incorporating participatory monitoring and citizen science tools not only empowers communities but can further strengthen transparency and accountability while providing valuable supplementary data for adaptive management. By aligning rehabilitation activities with local livelihood needs and socio-economic priorities, this approach fosters community ownership, enhances long-term sustainability of interventions, and reduces the risk of post-closure land-use conflicts, thereby supporting both environmental outcomes and social resilience.
- Monitoring and adaptive management
  - Develop a comprehensive and robust monitoring framework to systematically assess the performance of the adopted mitigation measures within the mine, and mine-influenced areas.
  - Monitoring programmes should be tailored to the specific mitigation measures implemented at each mine site. Monitoring locations, sampling frequencies, and data parameters should be defined in accordance with the objectives and performance requirements of each mitigation activity.
  - However, ongoing monitoring of water quality parameters within key locations of the mine and within the downstream freshwater ecosystems is nonetheless crucial.
  - An adaptive management approach should be applied whereby monitoring data are periodically reviewed and used to evaluate the effectiveness of implemented interventions. Where performance criteria or trigger thresholds are not met, management actions should be refined through adjustment of design elements, operational practices, or maintenance regimes. This iterative process supports continuous improvement, enhances system resilience under changing climatic or operational conditions, and ensures that rehabilitation measures remain effective over the life of mine and into closure and post-closure phases.

## 6.2 Conclusion

The Nyakabingo Mine is located in the headwaters of the Nyakabingo River and is directly impacting the downstream freshwater ecosystems. It is understood that the management of stormwater, process water, and associated storage is currently being addressed through a suite of on-site interventions, which have the potential to reduce impacts on the receiving environment. However, opportunities exist directly downstream of the mine to incorporate a nature-based solutions approach, such as the implementation of constructed wetlands and/or treatment trains. These measures could assist in the trapping of sediments and aggregates as well as assist with the polishing of the water column prior to it being discharge into the Nyakabingo River.

Although the valley-bottom is generally quite narrow, a series of targeted interventions could be considered. The interventions would serve to complement the mitigation measures currently being adopted within the mining area.

The adoption of such measures at, or directly downstream of, mining activities should be considered as it supports compliance with IFC Standard 6 but also reduces the impacts on the

receiving environment and dependent communities. Together, these interventions support more sustainable land and water management within the concession, better aligning human use with long-term environmental integrity.

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