Addendum to the 2015 Approved ESIA for MNG Gold Liberia

Development of Underground Mining Operations

MNG Gold, Kokoya, Bong County

May 2020

Reviewed and Compiled by Petra Resources, Inc.

Prepared by:

Petra Resources Inc.
Ocean Ambassador Compound, Capitol Hill
Monrovia, Liberia
www.petraliberia.com

May 2020

Contents

PART 1

1. INTRODUCTION

This document presents the Addendum to the Environmental and Social Impact Assessment (**ESIA**) for MNG Gold (Kokoya, Bong County). The document has been prepared for MNG Gold, owner and operator of the Mineral Development Agreement (**MDA**) and holders of the mining license for its Kokoya Gold mine, located about 180 km North of Monrovia into the District of Kokoya, Bong County. Figure 1.0.

Figure 1: Map of Liberia showing the project area

The Addendum ESIA is based on the KGM *Concept Study* conducted by AMC Consultants in February 2017; and its 2015 Approved ESIA; along with multiple experts' studies as outlined in Part 6 of this document. However, it should be noted that MNG mine planning team is still working on the improve the efficiency of project and it will end up with some minor changes. This Addendum ESIA is comprised of the main document, issues reconciliation table; several specific project studies; baseline conditions including the potential environmental and socio-economic impacts of the project.

The ESIA Addendum also identifies mitigation measures that will avoid, reduce, compensate for, PR reverse impacts, and assesses the residual impacts after mitigation. The ESIA addendum includes an Environmental and Social Management Plan (**EMP**).

The KGM currently consists of two open – pit mines both commencing in 2016 averaging a total of 42,000tons / month; it is expected that average production of underground gold operations is projected at 36,000tons / month until 2023. The current infrastructure on the site includes a retention pond; a tailings storage facility; a waste rock dump, and a few site facilities including offices, ablution blocks, residents, etc.

It is expected that the current processing plant and associated apparatuses will be used to process the ore from the underground operations.

1.1 Scope of Work

MNG Gold has retained the services of Petra Resources, Inc. (**PRI**) to complete the Addendum ESIA for the KGM mining operations that meets all national standards. This report presents the Addendum ESIA which is consistent with all national environmental statutes and regulations.

The ESIA Addendum scope of works in includes:

a) National regulatory framework review.
b) Detailed project description.
c) Baseline studies on the environmental, social and economic environment.
d) Environmental and social economic impacts.
e) Impact mitigation and assessment; and
f) Environmental and social action plan

1.2 Report Organization

This ESIA Addendum addresses the environmental and social impact associated with operating underground mine at its gold mining operations in Kokoya, Bong County. To ensure that the context and scope of the report is maintained; the report is presented in 10 parts; a summary of each part is presented below:

PART 1: Summarizes the size, scale, and scope of the Addendum report including the summaries and conclusions derived from the studies. This section also presents a table to catalogue all responses from regulatory authorities during the review process – to ensure that all questions, concerns are properly captured and reported so that feedbacks and reconciliations are adequately aligned.

PART 2: List and summarizes all national statues and regulatory requirements that are aligned to this addendum document, it also identifies which requirement is appliable to the addendum or not

PART 3: Project Description - this part describes the various activities included in the Project historical and ongoing activities. A description of each activity is provided, including the construction, operation, and closure phases. The project description serves to identify the activities interacting with the environmental and needing to be addressed in the impact assessment.

PART 4: Assessment Alternatives – this part describes the alternatives considered as well as most importantly describes the potential changes in key physical features of the project. Finally summarizing the preferred options of the project.

PART 5: Describes the existing environment, physical, biological and socio-economic conditions are described in this part of the report, the description serves to establish the baseline conditions against which likely effects of the Project will be assessed.

PART 6: Describes the environmental – impact assessment methodology approach is presented within this section of the report.

PART 7: Describes the socio – impact assessment methodology approach is presented within this section of the report.

PART 8: Environmental Impact Assessment. The environmental impacts of the project activities described in PART 3; the project description is assessed using the assessment framework described in PART 5

PART 9: Environmental and Social Action Plan. The Part identifies the mitigation and management measures to be implemented to ensure that adverse impacts on the environment are minimized and that potential benefits are maximized. In addition, the monitoring programs that will be used to confirm the impact assessment, confirm the effectiveness of mitigation measure and, if necessary, modify the environmental management plans are described.

PART 10: Project Risk Assessment. The Part examines the project risks including environmental, social, and reputational risks. The section also looked at issues of prices, force majeure, and political unrests are potential sources of impacts to the project.

1.3 Studies Summary and Conclusion

The KGM Project is being undertaken with due consideration of the environmental, health, social and economic factors as well as all relevant national statues, regulations, and guidelines. The KGM Project will have a range of positive and negative impacts on the environment (physical and social components). Some of the positive impacts for this project is the potential benefit for the country in revenue and most of all the key skills in mining that will be obtained by locals and nationals on the project. Some of the direct benefits includes the improving of social conditions in local towns and villages; direct local employment; local procurement and the development of local infrastructure.

The greatest negative impact is on the physical environment most notably with discharge into the St. John’s River. However, it should be noted that there is a current robust program in place to manage this risk and historical water monitoring shows fully compliance with the limit; it is imperative that this does not lead to any short- or long-term negative impact on the quality of the St. John’s River water quality and damage the aquatic life of the river.

With the construction and commencement of new tailing storage facility (TSF II); and additionally and additional infrastructure (retention pond) put in place MNG, ensures that effluent discharges to the St. John’s are far below the required limits.

The population in the project area will increase the demand for goods and services. Increases in income-earning opportunities will also increase spending potential, providing opportunities for supply of such services, indirectly increasing the overall wealth of the area. The project may provide opportunities for continued improvements in basic infrastructure and community development, especially in the support or provision of education, health care and basic services, and in providing opportunities for skills development.

Such development will need to take into consideration the project’s impact on access to services from all villages, planning development to benefit the entire community with the traditional area of jurisdiction.

Evaluating the impacts on the environment (physical and social), without mitigation measures, results in the potential for some impacts to occur, however when mitigation measures are implemented, as contained in the ESMP of this report. These impacts can be reduced significantly, as demonstrated in Part 8, which contains the impact assessment section of this report. The same can be said regarding the positive impacts of the project. There are several positive impacts the project will have; these include extended mine life, the development of skills and training, employment opportunities, development of local businesses and improved access to services.

The interpretations and conclusions reached in this Report are based on current scientific understanding and the best evidence available to the authors at the time of writing. It is the nature of all scientific conclusions that they are founded on an assessment of probabilities and, however high these probabilities might be, they make no claim for absolute certainty.

These factors include, but are not limited to, site-specific mining and geological conditions, management and personnel capabilities, availability of funding to properly operate and capitalize the operation, variations in cost elements and market conditions, developing and operating the mine in an efficient manner, unforeseen changes in legislation and new industry developments. Any of these factors may substantially alter the performance of any mining operation.

1.4 EPA Comments and Reconciliation

Part / Focal Area	EPA Comment	KGM Comments	Resolution

PART 2

2. NATIONAL REGULATORY REQUIREMENTS

The environmental review and approval procedure in Liberia is highly regulated and constantly evolving. This procedure is referred to as Revised Environmental and Social Impact Assessment Guidelines (2017). The ESIA process for the KGM underground mining operation is conducted as an addition to the 2015 Approved ESIA for the open – pit mining operations; this Addendum is only limited to the proposed underground operations and within the mining area of influence (AoI).

This Addendum is based entirely on national statues and legislations, which although might seem fragmented are equally aligned to international standards and principles such as the International Finance Corporation (IFC) Performance Standards (PS) 1 – 8.

2.1 The Constitution of The Republic of Liberia

The Constitution of Liberia provides for the protection and management of the environment and natural resources of Liberia, this is the highest decision-making instrument in the nation. It is from this instrument that the powers and authority is handed to the EPA through the National Environmental Policy (NEP) – which provides a broad framework for the implementation of national objectives and plans.

The constitutional basis for environmental law is provided in Article 7 of the Constitution (1986). The Article:

- Provides for environmental protection as a fundamental rule;
- Provides for public participation of all citizens in the protection and management of the environment and natural resources; and,
- Binds state organizations to adopt and activate environmental policy and formulate national development plans that are environmentally sustainable.

2.2 The Environmental Protection and Management Law of Liberia

The Environment Protection and Management Law (**EPML**) contain rules, regulations, and procedures for environmental impact assessment, auditing and monitoring. It establishes regulations for environmental quality standards; pollution control and licensing; guidelines and standards for the management of the environment and natural resources. It also addresses the protection of biodiversity and national heritage. Other areas covered include environmental restoration orders; inspections; international obligations; and information access, education and public awareness.

- Resource efficiency management including:
    - Green House Gases emission

  - Water consumption
- Pollution prevention
  - Waste
  - Hazardous materials management
  - Pesticide use and management

2.3 Decent Work Law of Liberia

The Decent Work Act of Liberia (2017) ensures labor and working conditions are aligned to the Constitution of Liberia and does not violate the human rights of employees. The Act ensures amongst other things that employees working conditions and management of workers relationship are not in contravention of human rights and dignity. Among other things the DWA (2017) provides that the following are provided for and protected:

- Human resources policies and procedures.
- Working conditions and terms of employment.
- Non-discrimination and equal employment opportunity.
- Employees retirement and retrenchment.
- Grievance mechanism.
- Protection against child labor or forced labor

2.4 National Forestry Reform Law of Liberia

The National Forestry Reform Law (2006) of Liberia ensures that the management and conservation of the forest resource of Liberia are properly managed. It also defines ownership rights and regulated commercial and other use of forest resources and provides for the protection and conservation of the environment.

The Forestry Reform Law addresses amongst other things:

- Protection and conservation of biodiversity including:
  - Modify habitat
  - Natural habitat
  - Critical habitat
  - Legally protected and internationally recognized areas
- Management of ecosystem services.
- Sustainable management of living natural resources;

2.5 Minerals and Mining Law of Liberia

The Minerals and Mining Law (2000) states that minerals on the surface of the ground or in the soil or subsoil, rivers, streams, watercourses, territorial waters and continental shelf are the property of Liberia. Section 3.4 allows for the establishment of a Minerals Technical Committee consisting of: Minister of Mines and Energy, Ministry of Justice, Ministry of Finance, Ministry of Planning and Economic Affairs, National Investment Commission, Ministry of Labor, Council of Economic Advisors, and Central Bank of Liberia. This committee has the power to negotiate agreements for Class A Mining Licenses. The Law, which is administered by the Ministry of Mines and Energy, has clearly defined exploration and licensing system. It is worth noting that at the time of preparation of this report, the law is undergoing review and may require reconsideration of the relevant section once a new law is passed.

2.6 Public Health Law of Liberia

The New National Public Health Law of Liberia (2019) ensures that authorization, operations, and systems are always designed to protect individual and community health and safety without compromise. The law guides that regulation of accountability of the health and safety of the nation, building program structures and establishes roadmaps that guides the protection of the individual and community health and safety.

The law amongst other things, addresses:

- Community health and safety infrastructure including.
    - Hazardous materials management and safety
    - Ecosystem services.
    - Community exposure to diseases
    - Emergency response and preparedness

2.7 Land Right Act

The Land Right Act of Liberia (LRA) 2018 ensures that land classification and ownership is properly defined. The act also clearly establishes process of sale and transfer of land rights; most of all the LRA outlines the protection of vulnerable groups including local communities, women, children, and elders.

The LRA ensures that acquisition and involuntary resettlement is properly managed so that adverse impacts are mitigated. To ensure proper management and mitigation measures, the LRA provides provisions on:

- Compensation and benefits for displaced persons
    - Community engagement
    - Resettlement and livelihood restoration planning and implementation
    - Grievance mechanism
- Displacement
    - Physical displacement
    - Economic displacement
- Private sector responsibility under government managed resettlement

2.8 Water Sanitation and Hygiene Policy of Liberia

The provision of safe and improved drinking water, sanitation and hygiene (WASH) services in Liberia is managed by the Water Sanitation and Hygiene Act (2017). The act ensures that development project recognizes that services are fundamental human rights, and that results of mining activities and other human induced activities including logging, and unhealthy farming practices do not undermine the provision and access to WASH facilities and services. This policy helps to ensure that sustainable natural resource management can therefore be a key to the success of WASH activities in Liberia.

2.9 Summary of Applicable Regulations to Project

Table 1.0 summarizes the applicability of national statues and regulations to each specific area of this Addendum. The applicability denotes that appropriate mitigation measures are defined and applied; while non – applicable denotes that such criteria is not applicable to the project and does not require a design set of mitigation measures – however; the potential is recognized and acknowledged.

Part Number	Description	National Regulation / Statue	Applicability
	Executive summary and project background	Revised ESIA[1] Guidelines 2017	☒ Applicable / Non – Applicable ☐
	Project setting and description	Revised ESIA Guidelines 2017	☒ Applicable / Non – Applicable ☐
	Project alternatives and preferred options	Revised ESIA Guidelines 2017	☒ Applicable / Non – Applicable ☐
	Specialists Studies	Specific Requirement from EPA[2] Technical Team	☒ Applicable / Non – Applicable ☐
	Biological studies including critical habitats; modified habitats; legally protected; and internationally protected species	EPML[3] § 83; United Nations Convention on Biological Diversity (ratified 2002)[4]; EPML § 85; EPML § 84; EPML § 80 (1)	☐ Applicable / Non – Applicable ☒
	Social economic assessment; including WASH infrastructures and services	National WASH[5] Policy;	☒ Applicable / Non – Applicable ☐
	Project risk assessment including cumulative impacts	EPML (Part III) pg. 18; NFRL § 5.6 d (v); LMML Chapter 8 EPML § 11(1)(c); Part IV § 37 EPA Act; LMML § 8.4 EPML § 50 EPML §§ 24, 25; Part IV § 39 EPA Act; LMML § 8.6	☒ Applicable / Non – Applicable ☐
	Assessment of environmental and social risks	EPML §§ 8(1), 9 (1), 11(3), 14; NFRL § 5.6 d (iv) EPML § 15; LMML § 8.5 EPML: N/A; NFRL § 5.6 d (iv) EPML §§ 11(1) (2) (3), 17, 33; NFRL Chapter 10; LMML § 11.5 EPML §§ 30, 67 Part IV § 32 (2) EPA Act; LMML § 11.5 EPML: N/A; NFRL §§ 18.13, 18.15	☒ Applicable / Non – Applicable ☐
	Labor and working conditions	DWA, CoL DWA § 13.1(e,f,g,i,j) DWA Part IV: Chapter 15 DWA § 2.6, Chapter 37 DWA §§ DWA § 2.4, 2.5, 2.7; LMML § 20.6 DWA §14.5 DWA § 14.4(b) (Internal Procedure)	☒ Applicable / Non – Applicable ☐

---

[1] ESIA = Environmental and Social Impact Assessment
[2] EPA = Environmental Protection Agency of Liberia
[3] EPML = Environmental Protection and Management Law
[4] This Convention focuses exclusively on the Country's or Agency's role in promoting national biodiversity.
[5] WASH = Water Sanitation and Hygiene

		§§ 2.13, 2.15(a,b), 14.5(l,m), 14.9, 34.5, Chapters 9 & 10, 40: DWA §§ 2.10, 2.11, 2.12 DWA § 2.3; LMML § 16.10 DWA § 2.2 DWA Chapter 24; LMML Chapter 16	
	Resource efficiency and pollution prevention	EPML Part II, § 4(2)(a-e), Part IV §§ 74-82; NFRL § 8.1 d EPML Part IV § 89 EPML Part V; Part IV § 40 EPA Act EPML Part V §§ 55; PHL §21.1 (f,g); NFRL § 12.4 EPML Part V §§ 55, 56; LMML[6] § 16.11 EPML Part V §§ 52, 53	☒ Applicable / Non – Applicable ☐
	Community health and safety management	EPML Part III §§ 13, 14, 15 EPML Part V §§ 50, 55, 56; EPML §§ 84, 85; CRL §§ 2.2(g), 6.6 PHL[7] §21.1 (g) EPML § 50 NFRL § 18.16	☐ Applicable / Non – Applicable ☐
	Land acquisition and involuntary resettlement	NFRL § 11.3, NFRL § 11.3, LRA Article 54, CoL Article 24 EPML §§ 11(1) (2) (3), 17, 33; NFRL Chapter 10 CoL Article 24; LRA Article 54; EPML § 67; CRL Chapter 8; NFRL §§ 11.4, 20.10; LMML Chapter 19 CoL Article 24; CRL § 2.2 (c); LRA Article 50 (2), Article 54	☐ Applicable / Non – Applicable ☒
	Biodiversity conservation and natural resources management	EPML § 85 EPML § 84 EPML § 80 (1) NFRL §§ 8.2 (c, d), 9.10, EPML § 75; LRA Article 42 (3)(5) EPML §§ 75 (2) (c,d), 82 (7)(d), 84(1)(e), EPML §§ 35 (1)(iv), 84 (1) (b,c), 85(1)(c) NFRL §§ 5.6 d (iv), 8.1(d) 8.2, 9.12, 18.10; EPML § 77 (5)	☒ Applicable / Non – Applicable ☐
	Hinterland people's management	CoL Article 24; CRL § 2.2 (c); LRA[8] Article 50 (2), Article 54 EPML §§ 83 (1) (e), 88 EPML § 50	☒ Applicable / Non – Applicable ☐

---

[6] LMML = Lands Mines Mineral Law
[7] PHL = Public Health Law
[8] LRA = Land Right Act

	Cultural and traditional heritage management	EPML §§ 83 (1) (e), 88; LRA Article 41, 42 (3) EPML § 11(1)(c); Part IV § 37 EPA Act CRL[9] § 2.2 (c); NFRL[10] § 19.2; LRA 48 (2) NFRL § 7.1 LMML § 11.3 LMML § 11.3 EPML §§ 83 (1) (e), 88 LRA Article 42 (5)	☐ Applicable / Non – Applicable ☒

Table 1: Applicable national statues and regulations

PART 3

3. PROJECT DESCRIPTION

3.1 Project Location

The Kokoya Gold Mining Project (Project) is owned by Avesoro Holdings and currently managed through its local subsidiary MNG Gold Liberia. The Project was purchased from Amlib Holdings in April 2014 at Pre-Feasibility Study (PFS) stage and continued to be governed by the Mineral Development Agreement (**MDA**) on March 14, 2002, for the mining of gold ore, valid until March 13th, 2027. The Government of Liberia through the Ministry of Lands, Mines and Energy in January of 2015 issued a Class A Mining License for MNG to exploit the gold bearing ore under the terms of the MDA. The mine was designed and built by Avesoro Holdings, with construction commencing in June 2015 and operation start up in June 2016.

Kokoya is an open pit mining operation and the processing plant has an industry standard two stage crushing and milling, gravity and Carbon in Leach (**CIL**) plant flowsheet.

The KGM is located approximately 50km north of the Capital Monrovia to the town of Gbarnga, Bong County, from there to the mine site is approximately 21km of laterite road via the Kokoya village that can take up to 2hrs in driving through small villages and towns that are mostly occupied by small scale farmers and some artisanal miners.

---

[9] CRL = Constitution Republic of Liberia

[10] National Forestry Reform Law

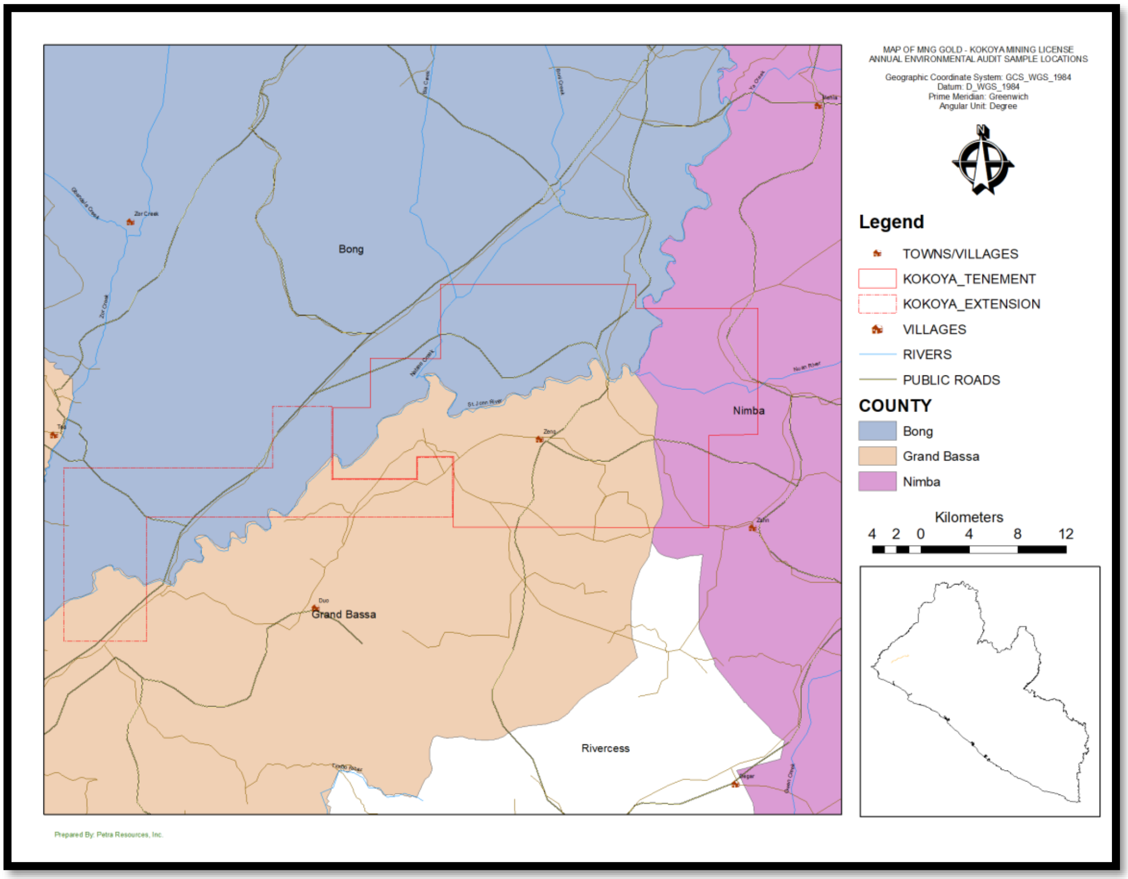


Figure 2: Map of Project area

3.2 Project Background and Setting

The project is in Kokoya, Bong County (Kokoya District); the site is approximately 759.51km^2 in area. The site was originally 539.31km^2; however, in 2017 a request was made for additional area and an extension of 220.20km^2 was annexed to the project site.

The project area is located approximately 50 km SE of Gbarnga city in Bong County, Liberia, West Africa (Figure-1). The Kokoya License covers an area of 539.95 km^2, however a Kokoya MDA extension license area was obtained from the MME, adding an area of 227.1 km^2 to the South West boundaries of the original Kokoya MDA license (Figure-2).

The Kokoya project area lies within the Archean aged Liberian metamorphic province and is dominated by northeast-southwest trending, strongly deformed amphibolite and gneissic units with a probable volcanic origin (felsic rhyolite and dacite, and mafic basalt respectively). Certain areas have undergone varying degrees of partial melting resulting in migmatite and pegmatite being observed.

The deposit area is primarily composed of gneiss and amphibolite. General strike of the dominant structures such as veins are NE and common dip direction is NW with dominant dip angles varying between 40^o-60^o. Amphibolite has been found to occur as lenses in gneissic rock mass which has mostly reached partial melting forming migmatite and pegmatite. There are series of continuous/discontinuous shear zones, composed by schist-like foliated rock with biotite-muscovite-sericite and actinolite. In many cases the zones control gneiss-amphibolite contacts, pegmatite and quartz veins and metasomatic alteration. Shear zones are the host for quartz veining or intersected by veins.

There are two main directions of the quartz veins strike. The first is 35 – 55degree veins of that direction tracing several faults/shear zones. Veins of that direction are forming Arhavi (Rock Crusher) trend. The second principal direction varies between 70 and 90 degrees succeeding the shear zones described above. Istanbul (Caterpillar) trend belongs to this type.

A swarm of northwest trending dolerite dykes of Jurassic age intrude the gneisses and amphibolite. A major east-northeast trending zone of intense shearing, the St John Shear Zone, runs through the Project area.

The Resource Area is covered by a thick, up to 20m, blanket of Saprolite. The project consists of the development and operations of underground mine. As part of the project, the existing above ground developments (2 open pits, waste rock dumps, tailing storage facility) will be incorporated into the operations of the underground mining operations. New Portals will be developed for the purpose of the underground mine near the existing pits.

Following extensive and ongoing geotechnical studies to support the future underground mining operations, the locations for the construction of the surface support infrastructures were carefully sited to avoid any negative impact to the proposed underground mining operations.

The underground mine will be developed through advancement of ramps and drifts from the portals. Access to the mine is through two portal areas: a north portal (Decline Entrance II) and a west portal (Decline Entrance I).A crusher and concrete plant will be constructed to the NW of the portal area with the sedimentation pond between the portals and the crusher / concrete plant.

All the current facilities that are involved in the open pit mining operations will be included for use in the underground mining operations; and the current closure plan will be amended to include the closure and rehabilitation of the underground portion of the mining operations.

3.3 Project History

MNG developed and currently operates an open pit mining operation within its 759.51 km^2 mining license area. The project consists of a gold processing plant, Tailings Storage Facility (TSF), a Waste Rock Dump (WRD), a retention pond, accommodation facilities, administrative offices and haul roads. The current Life of Mine (LoM) is calculated to be 4 years with an ore production and treatment rate of approximately 0.3 Mt/y. Based on ongoing geological exploration works, the LoM is to be extended due to the discovery of additional mineralization within the current license area and underground of the current open pit at KGM. Golder Associates (Ghana) Ltd (Golder) undertook an Environmental and Social Impact Assessment (ESIA) which was approved by the EPA in 2015. In 2017 AMC Consultants also conducted a Concept Study for the development and operations of underground mining activities at the KGM. A feasibility study is currently being undertaken by Hacettepe University in Turkey and expected to be submitted to Ministry of Mine and Energy in the May 2020.

The purpose of the approved 2015 ESIA was to investigate the local environmental and social situation existing prior to the development of the Project and to determine the likely positive and negative impacts of the Project. In addition to this, the ESIA identified the necessary management measures required to mitigate the identified impacts which formed the basis of the Environmental Management Plan (EMP). Once the ESIA was completed, a Crop Compensation Plan (CCP) and Alternative Livelihood Plan (ALP) was developed by Earth Environmental Consultants, Inc in July 2015, which was submitted to the Environmental Protection Agency (EPA). The focus of this Addendum ESIA is to address potential risks and make improvements from design, operational and environmental perspectives for the underground operation. The work undertaken aims to improve the Approved 2015 ESIA for MNG through an addendum for underground mining.

- Prior to 2000 artisanal mining in the area;
- 2002 AmLib United Minerals Incorporated started mineral exploration in the license area;
- 2013 AmLib United Minerals Incorporated granted Mineral Development Agreement (MDA);
- 2014 MNG bought the mining rights of AmLib United Minerals Incorporated for KGM;
- 2015 ESIA completed by Golder Associates for KGM and approved by EPA;
- 2017 Underground mining concept studies completed by AMC Consultants, Inc;
- 2019 Formal application to EPA and MME for permit / license for underground construction activities;

3.3.1 Construction Phase

During the construction phase, equipment and material will be transported to the site during the dry season, as rain season poses to many challenges on the road. Clearing, grubbing, and site levelling will be undertaken where infrastructure is to be placed. Site drainage will be constructed in line with existing drainages. Drainage are diverted to ensure that runoff does not cause erosion, flooding, or contamination in downstream areas. In the initial stage, existing access roads where upgraded and new access roads, where required, constructed. During the construction activities, erosion protection will be constructed to limit sediment transport to adjacent watercourses where erosion has been identified as an issue. The area is classified as high rainfall area and as a result erosion and sedimentation is a concern in many areas.

The Project is located at higher elevations in rocky terrain and as a result soils are generally lacking in the Project area. Where soils exist, the soils removed during opening of these areas where stockpiled for future use in rehabilitation. Since there is limited vegetation on site, and since most of the upland areas are comprised of rock, removal of soils and vegetation is limited to those areas where there is vegetation. These typically occur only in the river valleys at lower elevations. Any removed fertile soils (if identified) stockpiled and protected against erosion for future use in rehabilitation.

Baseline studies have confirmed that there is a lack of fertile soils in most of the area around the Project. Stockpile and laydown areas is prepared for equipment and supplies that are brought to site. These are temporary use areas that will be rehabilitated upon completion of construction. Accommodation for construction workers and offices for the construction camp will be in the existing camp area that has enough capacity to accommodate additional workers. The existing offices will continue to be used during the construction phase, while new accommodations and office facilities are constructed where and when needed.

The site infrastructure, including the construction of a water supply pipeline, storage and maintenance areas, permanent accommodations and support facilities such as a paramedic station and offices constructed for the open pit operations will remain in place to support the underground mining operations. Facilities where potentially hazardous materials are stored or used, such as fuels and lubricants include mitigation measures, such as impermeable surfaces and spills containment and clean-up equipment, in order to minimize potential environmental impacts will be upgraded and management plans also updated.

Fuel storage areas constructed and include berming to contain any spills. A pad to prevent seepage of spilled materials into the underlying soil/rock is in place. Spills containment and cleanup materials are maintained on-site. Vehicle and machinery maintenance facilities (located both at the portal and the surface maintenance facility) will have drainage systems constructed that direct water (e.g., wash water) to the treatment facilities.

Waste management systems, including a sewage treatment system for domestic sewage, and a solid waste disposal are constructed on site. The sewage treatment system will continue to use the existing facilities to support the underground operations. Existing pits and the tailings facility from previous mining operations will be rehabilitated in line with the proposed closure plan. The existing tailings facility will be used to support the underground mining operations; and if need be additional studies will be completed to ensure the current facility is enough to support the additional ore processing from the underground operations.

Access road upgrade will continue throughout the LoM. Where required road upgrade will require beaming to protect water courses and slumping of the road. Borrow areas identified and reclaimed upon completion; while some borrow areas will need to be kept open to provide materials for on-going maintenance of the road.

3.3.2 Operations Phase

During the operations phase, the process of removing the ore through underground mining begins. The project is proposing the operations of underground mining activities with the total 1.7 Mt of ore production in 4 years of mine life.

The operation phase is expected to start in the 3rd quarter of 2020. Based on calculations made by the MNG mine planning team, total calculated production will be approximately 150,000 ounces. This involves the mining of one inventory that was selected for the preparation of simple schedules with the average grade of 2.71 g/ton.

Mine planning studies are ongoing to clarify the expected mine production rates by the MNG planning team. The expected project life of mine is 4 years. During operations, ore will be brought to the surface and placed in stockpiles for transport to the processing plant. Waste rock that is not used immediately as backfill will be brought to the surface and stored in the WRD. Some of the waste rock will be used for further processing into cement rock backfill with the remainder used as rock fill.

3.3.3 Closure Phase

The closure phase includes a list of activities that are designed to ensure that the project site is closed in a manner that reduces the potential impacts on the social and natural environment. In the closure phase, the mining activities are terminated and dismantling, and closure of the site begins. Closure involves the progressive decommissioning of the site through the removal of infrastructure that will not be needed in the post-closure phase, and the closing of waste management areas in an environmentally acceptable manner. Closure activities typically require up to 2 years to complete. Details on closure activities shall be included in the site management plans, and will be approved by the EPA – as some of the closure activities will need to be discussed and agreed on by both the regulators, the community and MNG; such activities may include access roads; air strips; building infrastructures, etc.

During the closure phase, the storage, warehousing and maintenance areas are dismantled, any potentially hazardous materials such as fuels, oils, lubricants, chemicals and reagents are removed from the site by licensed contractors, and any contaminated soils are remediated. The infrastructure is demolished, and all inert demolition debris will be disposed of appropriately.

Equipment in the underground workings will be removed, where salvage of equipment is practicable. Equipment that cannot be salvaged will be left in place and will be drained of all fluids. Equipment components that could retain residual fluids will be removed, as will vehicle tires. Contaminated soils will be remediated.

Waste disposal areas, such as the landfill and sewage treatment system will be decommissioned. All closed areas that will not be used in the post-closure phase will be rehabilitated. If there are soils available in the stockpiles created during the construction phase, they will be used as a source of cover material. The closure and rehabilitation costs are estimated at $ 7,162,920.

3.4 Project Components

The mine development plan as described in the Pre – Feasibility Phase describes the project components as:

- Dual ramp access via surface portals (North and South Portals);
- Ore from the underground mine will be brought to surface via truck.
- Waste rock to be used for cemented and non-cemented rock fill for backfilling in the underground mine.
- Transport of ore by truck via an all-season road to the existing processing plant; and
- The current processing plant and tailings storage facilities are adequate to process the underground ore.

Supporting infrastructure for the Project includes:

- Portal building that also houses the workshop, store and offices.
- An accommodation camps.
- Fuel storage and supply.
- Power generation and supply.
- Water supply and treatment.
- Administrative facilities, including gatehouse and security.

- Chemical storage facility; and

The operations phase will be similar to the construction phase in that development of the underground mine will involve on-going transport of equipment and supplies to the site, followed by installation underground. Underground mining activities are supported by facilities that are currently in use for the surface mining activities. It is envisaged that once the underground development is completed – all surface mining operations will be brought to a halt – except for surface rehabilitation where applicable.

The Project components are discussed separately in the following sub-sections.

3.4.1 Open Pit Mining

The conventional open pit method is currently employed for the project. Prior to mining, the site was demarcated and cleared of all vegetation and topsoil. The ore was accessed through a mix of free ripping and conventional drill and blasting methods. A ramp entry and exit system was used for accessing the pit at depth. Ore and waste were hauled by articulated dump trucks (ADTs) via the access ramp.

The open pits are designed to have a bench height of 20 m and a berm width of 5 m. Overall pit slope angles of 35° in the weather zone (i.e. saprolite and saprock) and 45° for the fresh rock. The overall slope angle for the final pit wall is 50°

3.4.2 Underground Mining

The underground mine will be developed through advancement of ramps and drifts from the portals. Access to the mine is through two portal areas: a north portal (Decline Entrance II) and a west portal (Decline Entrance I).

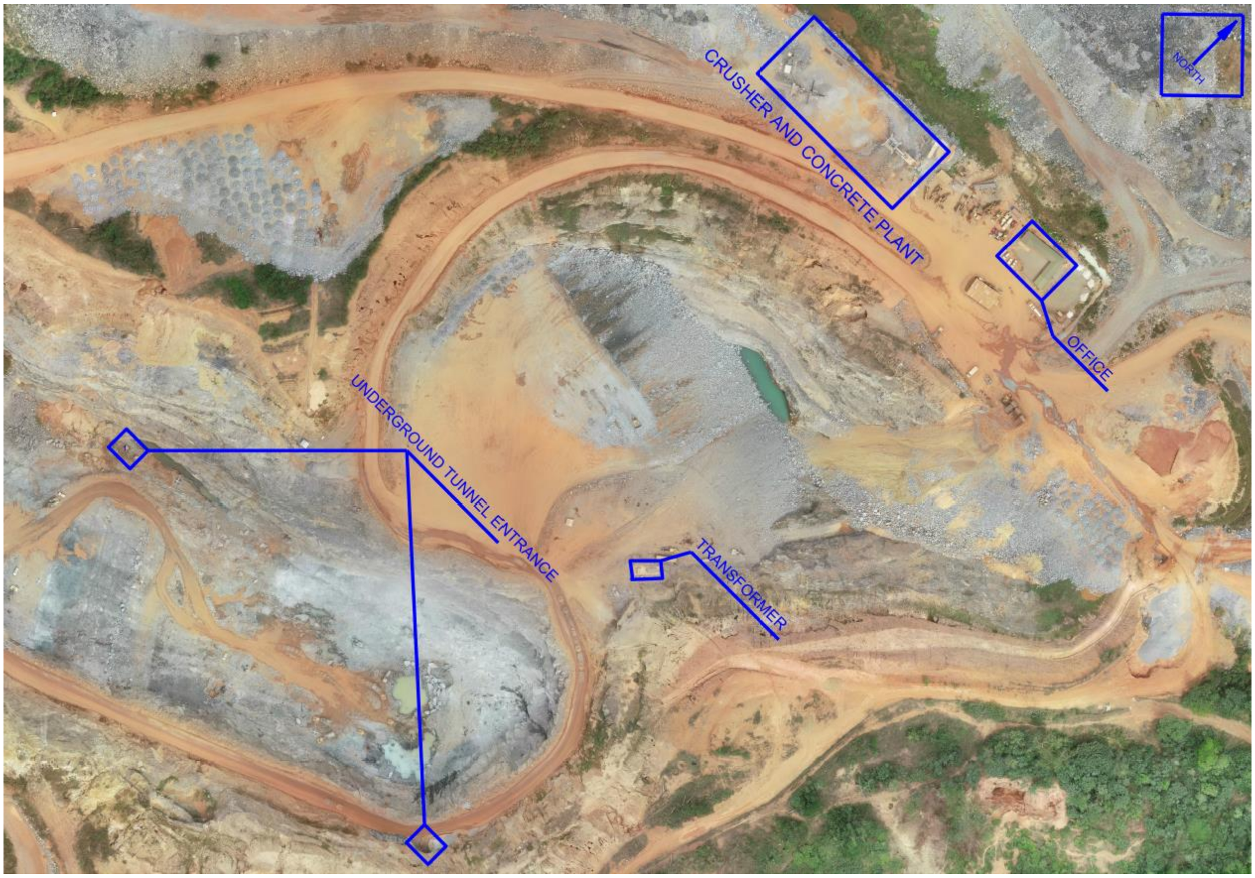


Figure 3: Mine entrances and other infrastructures

The portal area includes the two portals, surface ventilation fans, fueling areas, ore stockpiles, cemented rock fill plant and associated facilities. Groundwater infiltration into the mine is maybe expected, as such pumping stations are designed into the construction.

Further underground mine development will proceed through development of drifts and ramps that will require underground blasting. Explosives will be transported underground to the development headings in a dedicated explosives transport truck. During full production, blast times are predicted to occur 3 times daily: during lunch break and at end of shift on the day and night shifts. Blast times may vary due to meal breaks and shift ends.

Mined ore will be brought to surface uncrushed via truck haulage and stockpiled at the ROM for shipment by conveyor belt to the processing plant. Mine vehicles will be equipped with low emissions engines, will operate on low sulphur fuels and will be equipped with diesel particulate filters to control emissions. Vehicles will undergo regular maintenance to ensure emissions control measures are operating properly.

The ore stockpiles will be protected with berms to control runoff. Runoff and seepage will be directed to the stormwater management system for treatment prior to discharge or re-use. Waste rock brought to surface will be temporarily placed in the WRD before being moved to the cemented rock fill (CRF) plant for processing into cemented rock backfill that will be used in the underground mine. The CRF plant consists of two parts: an aggregate preparation and a cement preparation and truck loading. The rockfill waste stockpile will also be equipped with ditching to collect seepage and runoff.

During operations, the Pit will be drained for mine safety reasons before mining of the ore body under the pit commences. Water quality coming to the pit indicates that the pit water can be pumped directly to the St. John's River. The St. John's River currently flows NE – SW of the mine area (southernly of the TSF), and a diversion channel is constructed to divert spring runoff around the pit. The diversions will be lined (due to presence of fractures in the rock) and bermed. Watercourses will flow through previously disturbed areas and may receive runoff and seepage from waste rock and ore stockpiles and working areas around the portals. Sediment traps will be included in the diversion plans with additional treatment included as required.

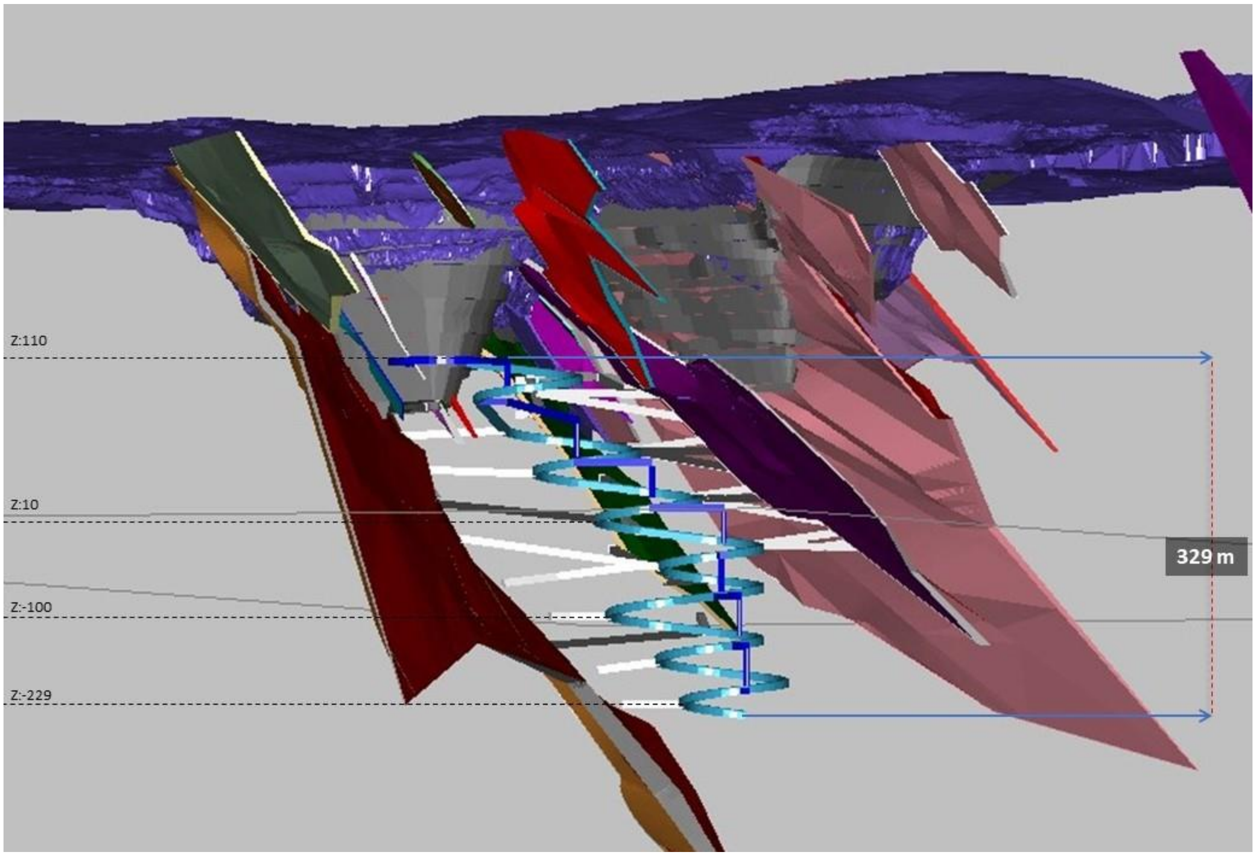


Figure 4: ore body occurrence in the underground mine

3.4.3 Processing Plant

A well compacted laterite haul road (all weather) is constructed from the open pit mine to the existing processing plant. Ore from the underground operations will be transported to the processing plant using dump truck and trailer combinations with a 20-t payload capacity. A fleet of 10 trucks will be required to support the proposed mine production rate of 1500t/d. Ore delivered to the plant will be stockpiled at the ROM which is currently in operations for the surface mining. Stockpiles will have seepage/runoff collection ditching that will connect with the existing storm water management system at KGM.

Modifications may not be necessary to the processing equipment at to accommodate the increased throughput from addition of the underground ore; as it is expected that surface mining production would've seized. Metallurgical testing on the underground ore indicate that processing of this material will result in less consumption of reagents, and therefore, will require less cyanide use than the existing open pit ore.

No structural changes to the existing tailings facility are expected, and relocation of the seepage collection ditches as the dams are raised is not warranted. Currently, non-acid generating (NAG) waste rock from the open pit mining has been used to construct the tailings dams. The tailings storage facility is currently equipped with a retention collection system, and a reclaim pump to transfer seepage back into the tailings pond.

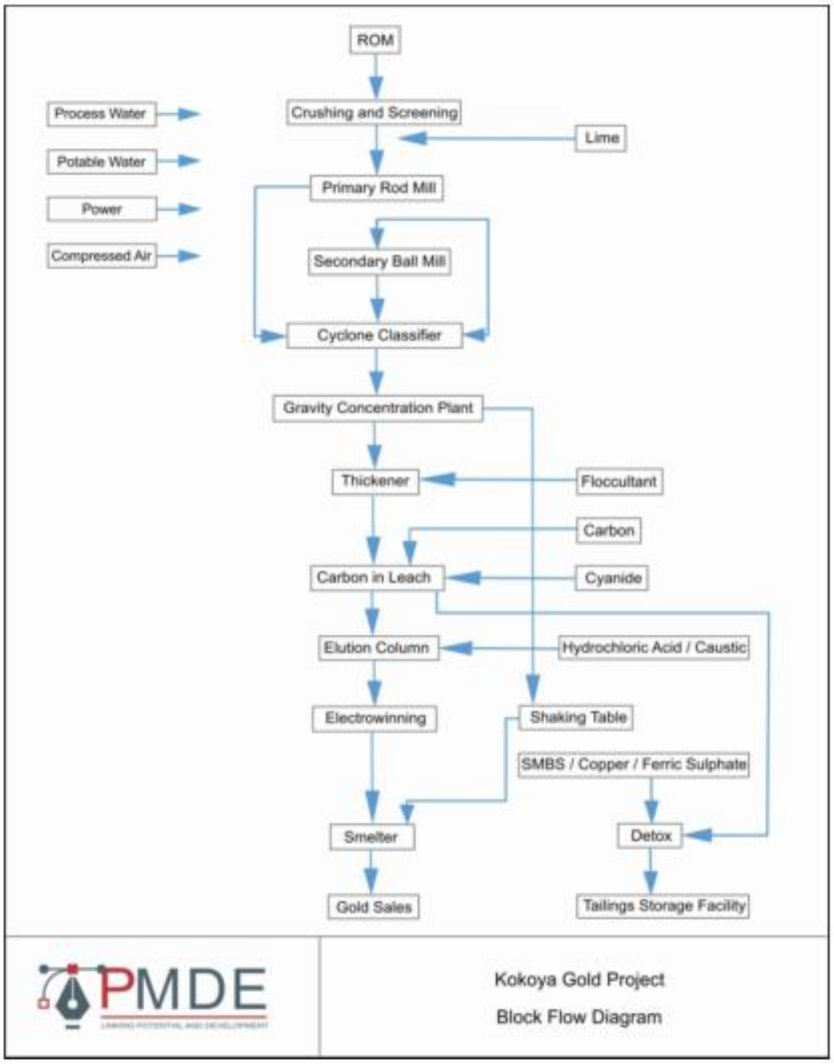


Figure 5: Mine process flow chart

The process plant is currently equipped to capture all emissions from the plant. The system includes a wet scrubber in the crusher building, baghouse dust collector in the refinery, a scrubber and fan to remove cyanide vapor, and dust collectors and scrubbers in the assay laboratories.

3.4.4 Explosives Management

The explosives management facility will be located onsite and away for the from the accommodations complex. The facility will be protected by fencing and barbed wire and all explosives will be stored in the containers in which they were shipped to site. This location is advantageous because of the natural physiography that provides a natural barrier between the explosives store and the mine site.

The explosives store will be equipped with safe explosive preparation equipment. The mine planning notes that explosives will be stored onsite – as there are logical challenges in the ordering and supplying to the site in a timely manner. The explosives facility has been designed to hold 1000 t of explosives. Estimated daily explosive usage is 1.2 ton/day. The facility includes the explosives store, distribution building, preparation plant and laboratory.

The accommodations and office complex are located outside of the blast radius of the storage facility.

3.4.5 Power Supply

All electrical power will be provided by on-site generators. There is no off-site electrical power source. The main electrical powerhouse is near the process plant.

As noted earlier, during construction, diesel generators will be available on-site. Generators will remain on site during operations as backup supply at the mine to provide emergency power for the ventilation units. The generators will be housed in a separate generator building – both the accommodation camp and the mine generator will be separate. The primary and only power source envisaged for the LOM is independent diesel power generators.

During operations, the main power will be supplied by 4 diesel generators with the total capacity of 1,500 KVA diesel generators. Under normal operations, two units will be used to supply power, one unit will be on standby, and one unit will be undergoing maintenance. An on-site power distribution network with substations (transformer) will be constructed. Figure 3.0

Backup power to supply the accommodations and office complex will be provided by diesel generators. Power will be supplied from the main powerhouse via a power cable. The transmission line will follow the site access road to the mine portal area.

3.4.6 Water Supply

Water is required for process use, domestic use and firefighting. Estimated daily demand is 30 m^3/day for domestic water and 15 m^3/day for underground mining equipment.

The Project is in an area of continuous fractures, and as a result, sources of freshwater are unlimited. The streams in the Project area are continuously flowing for most of the year, especially during the raining season. Due to the fault zone through which the St. John's River flows groundwater contribution to stream flow is unlimited all year round.

A suitable supply of domestic water has been identified from groundwater for mostly domestic purposes. Testing has indicated heavy metals in the levels in the water are elevated and therefore the water supply system includes reverse osmosis treatment to reduce metals levels in the water. Water will be pumped from the wells to the storage tanks from where it is pumped directly into accommodation units, including mining operations and emergency management.

The water supply facility is located west of the accommodation dorms. The facility contains 80 m^3 storage tanks for domestic water use including emergency management. Potable water for human consumption is delivered to the site by local vendors and stored in site storage facilities.

Process and fire water for the mine and portal will be distributed by tanker truck from the main water supply or will be supplied from the existing groundwater wells. The water distribution system includes supply of water to the underground mine for use on drills and emergency response management. Water will be supplied to the underground mine from a main tank at the surface from which it is distributed via pipeline to end points. Daily water consumption in the underground mine is estimated as 15 m^3/d.

Tables 2 - 6 below documents the water balance within the mining operations.

Month	Rainfall	Evaporation
Jan	23.40	100.00
Feb	28.60	89.00
Mar	52.00	107.00
Apr	91.00	97.00
May	234.00	84.00
Jun	345.80	74.00
Jul	392.60	66.00
Aug	483.60	65.00
Sep	478.40	65.00
Oct	301.60	76.00
Nov	137.80	82.00
Dec	31.20	95.00
Total	2600.00	1000.00

Table 2: Monthly rainfall and evaporation averages

Max. Impoundment Area (at crest level)	245,000	m^2
Average Annual Rainfall	2,600	mm
Estimated Evapotranspiration	1,000	mm
Rainfall on Impoundment Area (at crest level)	637,000	m^3
Estimated Evapotranspiration from TSF-1	245,000	m^3
Accumulated Water on TSF-1	392,000	m^3

Table 3: Annual rainfall and impoundment area (TSF 1) statistics

Max. Impoundment Area (at crest level)	275,437	m^2
Average Annual Rainfall	2,600	mm
Estimated Evapotranspiration	1,000	mm
Rainfall on Impoundment Area (at crest level)	716,136	m^3
Estimated Evapotranspiration from TSF-2	275,437	m^3
Accumulated Water on TSF-2	440,699	m^3
Daily Discharge Requirement	2,281	m^3
Open Pit Area	290,000	m^2
Average Annual Rainfall	2,600	mm
Estimated Evapotranspiration	1,000	mm
Rainfall on Impoundment Area (at crest level)	754,000	m^3
Estimated Evapotranspiration from TSF-2	290,000	m^3
Accumulated Water on Open Pit	464,000	m^3
Daily Discharge Requirement	1,277	m^3

Table 4: Annual rainfall and impoundment area (TSF – 2) statistics

Tailings Storage Facility Water Balance (Rainy and Dry Seasons)

Rainy Season (May – October)

Average Annual Rainfall	2,236	mm
Estimated Annual Evapotranspiration	430	mm
Max. Impoundment Area (at crest level) TSF-1	245,000	m^2
Max. Impoundment Area (at crest level) TSF-2	275,437	m^2
Accumulated Water on Open TSF-1	442,470	m^3
Accumulated Water on Open TSF-2	497,439	m^3
Average Daily Discharge Requirement from TSF-1 & TSF-2	2,575	m^3

Table 5: Average rainfall data (Rainy season)

Dry Season (November – April)

Average Annual Rainfall	364	mm
Estimated Annual Evapotranspiration	570	mm
Max. Impoundment Area (at crest level) TSF-1	245,000	m^2
Max. Impoundment Area (at crest level) TSF-2	275,437	m^2
Accumulated Water on Open TSF-1	-50,470	m^3
Accumulated Water on Open TSF-2	-56,740	m^3

Table 6: Average rainfall data (Dry season)

3.4.7 Fuel Supply

Liquid fuel will be required for the electrical generators and mobile mine equipment. Fuel will be transported to site via trucks by an independent vendor; to ensure continual supply – a fuel storage facility is already constructed on site. Fuel storage requirements include 200 tons of diesel fuel in storage tanks. Fuel storage areas are lined, bermed and provided with spill cleanup materials. The lined and bermed area has enough capacity to contain more than 1.5 times the storage capacity of fuel. The fuel storage area includes fuel unloading and loading systems.

The vehicle fueling system is done on constructed concrete pads and will continue to use this means of fueling; graded to drain spills to a sump for collection and disposal. The fuel storage and distribution system have built-in fire protection systems with automatic shutoff valves, and flame and explosion proof valves on all storage tanks.

Diesel fuel will be supplied to the main electrical powerhouse via dedicated fuel tankers into above ground storage tanks. Tanks will be seamless welded steel, and leak proof, with a minimum ground clearance of 1m.

Additional fuel and lubricant storage areas will be provided at the mine portal area to service underground equipment. Equipment travelling to surface will be serviced at dispensing stations in the portal areas. Underground equipment will be serviced by underground fuel transfer trucks.

3.4.8 Storm Water Management

Storm water is mostly rainfall runoff is diverted around facilities to avoid contamination of the storm water. Non-contact storm water is discharged directly to local watercourses. Stormwater runoff from areas not connected to the stormwater collection system will be directed to pits from which the water can settle and then slowly discharged to water courses or evaporated. The waste rock and the ore stockpiles are protected with berms to control runoff. The site is designed so that storm water has minimum contact with site operations – this is to prevent any sort of contamination – as storm water is discharged directly into surface water bodies. (St. John's River) after settled in the settlement ponds.

3.5 Waste Management

A waste storage facility is constructed onsite for disposal of organic and solid wastes. The site is designed to accommodate domestic and industrial solid wastes that meet the national waste classifications categories of hazardous and non – hazardous wastes.

The hazardous wastes categories are defined as:

- used lubricants, sludge resulting from oil residue removal from tanks, automobile exhaust
- oily cleaning materials, and sand, car tires, construction debris, welding slag,
- medial waste, mechanical and biological water purification sludges, cesspool sludge

The non – hazardous wastes categories are defined as:

- plastic wastes.
- domestic garbage
- wood wastes
- scrap paper and cardboard

- waste rock, drilling mud, and ferrous scrap
- non – ferrous scrap; and
- other domestic wastes

The wastes are staged separately at the site. A certified and licensed vendor is hired to remove all the hazardous wastes from the site and disposed of them at a licensed and approved hazardous wastes facility. Ensuring that the vendor is licensed and certified by the EPA is a critical control that KGM ensures.

Waste minimization includes:

- Use of used oils for heating; and
- Use of waste tires as barrier materials.

Where possible materials will be re-used and recycled to minimize the amount of waste that needs to be disposed of at the site storage facility.

3.5.1 Waste Rock Dump

Mine waste rock will be used as backfill in the mine. Cemented and non-cemented rock fill will be used as backfill as needed. Some areas will not require cemented rock fill, and in these areas, waste rock from the development headings will be moved directly to stopes that do not require cemented rock fill.

Waste rock destined for use as cemented rock fill will be transported to surface and will be stored in the waste stockpile, or on constructed pads, until it is needed as backfill. A cemented rock fill (CRF) plant will be constructed on site. The CRF plant will be supplied with rock fill from the aggregate plant. The existing waste rock at surface from previous mining operations will be used to supplement waste rock generated during underground mining. The existing waste rock will be used as backfill in the final years of mining. The mine planning predicts that all waste rock generated by underground mining will be used as backfill. Remaining waste rock sites from the backfill will be rehabilitated.

3.5.2 Tailings Storage Facility

Ore will be transported by truck from the underground operations to the processing plant facilities. Therefore, tailings generated will be disposed of in the existing tailings storage facility. Mine planning have shown that the existing tailings facility has enough capacity to handle the underground mine wastes. The TSF consists of a retention pond before discharge to the St. John’s River. A closure plan will be developed for the mine including the existing tailings facility and will be upgraded to include tailings from the underground mining operations. The activities will be undertaken will be summarized in the mine closure plan.

3.6 Mine Infrastructures

3.6.1 Access Roads

Access to site is via a laterite road that runs through Dean's town which is approximately 20km east of Gbarnga. The mine site a accessed via a network of access tracks connecting the open – pits; the accommodation facilities; the processing plant; and other storage areas; these access tracks are constructed on compacted laterite and allows access all year round; no additional access road will be constructed for the underground operation.

Access tracks within the actual mining license area will be maintained all year round to ensure that access to and from the mines and supporting surface infrastructures are un-restricted.

3.6.2 Accommodations and Offices

The accommodation and office complex is located south of the open pits. The offices include administrative offices, a paramedic station, assay laboratory, mine rescue, and warehousing facilities. The accommodation facilities are designed to accommodate 500 persons. Accommodations are provided by modular units transported to site. The complex includes mess and dining facilities, medical facilities with on- site doctor, laundry facilities, gymnasium/exercise facilities, recreation facilities in addition to accommodations.

Predicted daily water needs for domestic (potable) water as 30 m^3/day. The estimated available reserve potable water is 50 m^3/day, and therefore enough water to meet domestic requirements. Water for mining operations is sufficient due to the closeness of the St. John's River. Domestic sewage treatment is expected to be similar during underground operations at approximately 100 m^3/day.

3.6.3 Maintenance Facilities

Workshops for maintaining trucks, heavy machines and emergency vehicles for medical emergencies are constructed near the process plant and close the accommodations and office complexes. The facility has garages for emergency vehicles, vehicle wash bay and maintenance bays and associated facilities.

3.6.4 Air Strip

The existing airstrip will continue to be used for gold transportation to support the underground mining operations. The air strip is constructed of compacted fill. Fueling of the plane will not take place at the site. The air strip also serves as emergency access and exist from the site.

PART 4

4 Assessment of Alternative

In developing the Feasibility Study, several alternatives to constructing and operating the mine have been considered. These are described in the following subsections.

In addition, the “do nothing” or zero alternative (not constructing the project) is assessed this Addendum ESIA.

4.1 Environmental Footprint Reduction

It is expected that the environmental footprint of the mine will reduce in terms of land use and expansion. The current strike length of the ore body is 1.4km; there is no further expansion of the surface area (open – pit); therefore the development of underground operations is expected to limit the mine environmental footprint (land disturbance) to only 1.4km.

4.2 Description of Changes in Major Project Components

4.2.1 Mining Methods

Sublevel caving, Shrinkage stoping, Sublevel Long hole, Room and pillar, Block Caving, open stoping and cut and fill are different mining methods which were first considered. The selection of the most suitable mining method for Kokoya underground mining operation was done based on the following factors:

- continuity, size, and shape of the orebody
- local orebody ground conditions (ground support requirements)
- dip angle of the orebody
- achievable production rate based on mucking requirements
- value of in situ ore, mining dilution and recovery.

Sublevel Caving

The sublevel caving could have been a cost effective and appropriate choice for the mine. However, it was found that many mining infrastructures (offices, waste dumps and access roads) are located in the hanging wall o of the orebody which make it risky to apply the sublevel caving in the Kokoya mine site. It can be added rain and surface waters accumulating in the open pits during rainy seasons can pose some threats to underground operation. Finally, the low angle dip of the orebody in many areas (35 to 50 degrees) could lead to extreme dilution. These reasons made the sublevel caving not qualified for operation.

Shrinkage Stoping

The shrinkage stoping method is similar to cut and fill, but instead of removing the ore after blasting and backfilling, the initial broken ore is left in the void to create a working platform for the next level (and to support the wall stability of the stope).

After all the planned levels have been blasted, then all the ore is removed for processing.

This method is very selective and keeps dilution low, but requires many active stopes because ore is not removed from each mining area until completion – meaning longer lead times for ore to get to the process plant compared to cut and fill operations.

Sublevel Longhole

This bulk underground mining method involves mining large amounts of material from a single stope – similar to cut and fill, this method starts at the bottom of a level and moves upward. Ore is removed from the bottom, and then more ore is blasted from a higher level that falls to the same level to be removed, with the process repeating up the orebody.

The supporting walls need to be very strong in order to support the large underground openings that will be created by this process.

Room and Pillar

Room-and-pillar mining is typically chosen for flat-lying (or at slightly dipping) ore bodies. Commonly used for base metal or uranium metal deposits, or bedded seams of coal/potash/salt, mining is done by creating openings (rooms) on a single level, leaving pillars of rock at regular intervals to support the weight of the material above (the roof).

In hard-rock deposits (i.e. copper, lead-zinc), drilling and blasting is required in order to break up the ore before being able to remove it.

After mining out levels, the pillars may be removed (to recover the remaining ore or material) and the roof is allowed to safely collapse and fill in the mined-out area.

Block Caving

Block caving is essentially the underground version of open-pit mining. It’s the only underground mining method that can reach similar production rates to surface mining operations, up to over 100,000 tonnes per day.

The method involves undermining an ore body, then allowing it to collapse under its own weight. The orebody is drilled and blasted, and the collapsed ore is removed through a haulage access, and as more material is removed the orebody caves in.

This mining method is useful because it allows for huge volumes of material to be mined at relatively low costs, which makes lower grade deposits economical to turn into mines or new pits. Many large-scale open-pit operations have plans to progress into block caving operations over time.

This mining method is typically used in situations where the orebody is both large and steeply dipping, and because of the depth below surface is not suitable for surface mining methods.

Therefore, open stoping with waste rock fill utilizing mining block heights of 20 m floor to floor was seen as the best alternative in the Kokoya Mine context.

Nonetheless as mentioned above there are some areas of the orebody where dips are very low such as the zone below the current Arhavi pit where some dip angles are around 36 degree. In such an area material flow would be impossible if open stope were to be applied. Therefore, for this specific area of the orebody the Cut&Fill with mining block heights of 5 m was found as the most appropriate operating technique.

To sum up as it can be seen on the figure below open stoping and Cut &Fill methods are the two mining techniques that were found as most suitable for ore extraction in Kokoya Gold mine.

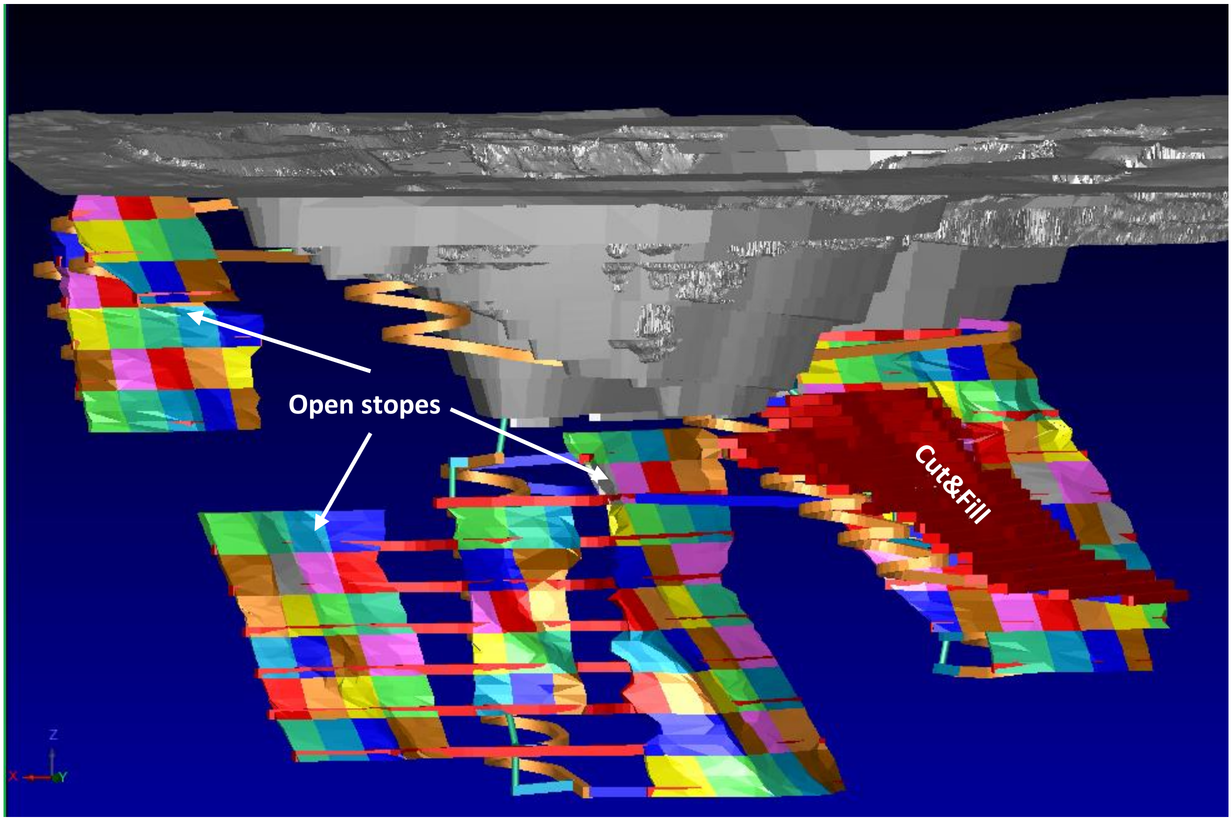


Figure 6: Underground mining structure with open stopes including areas of cut and fill

Cut and Fill:

This method uses artificial support to the full extent. As shown in the figure, it starts from the bottom of the stope and advances upwards by taking horizontal slices of ore from the roof. The broken ore is loaded into the ore pass and the stope face is therefore cleaned completely.

In this system, selectivity is even higher. Drills can be adjusted to leave the unwanted ore in place and also to dig into the walls for the extraction of high-grade ore.

Open Stopes:

Open Stopes also provides high productivity from a small number of work areas. Long hole stopes will be along the strike of the orebody using a drilling sublevel on top of the stope, followed by an extraction level at the bottom. Open Stopes will be used for stoping widths between 8 m and 15 m.

The block height will be 20 m floor to floor. Average lengths of individual stopes will be determined by geotechnical analysis during the detailed engineering stage. The stope development sequence will commence with a slot between the drilling level and extraction level at the end of the stope. Stope development will be in ore. The slot raise will be developed by long hole drilling, and stage blasted from the bottom up. Vertical rings of drill holes will be blasted as required into the slot during production.

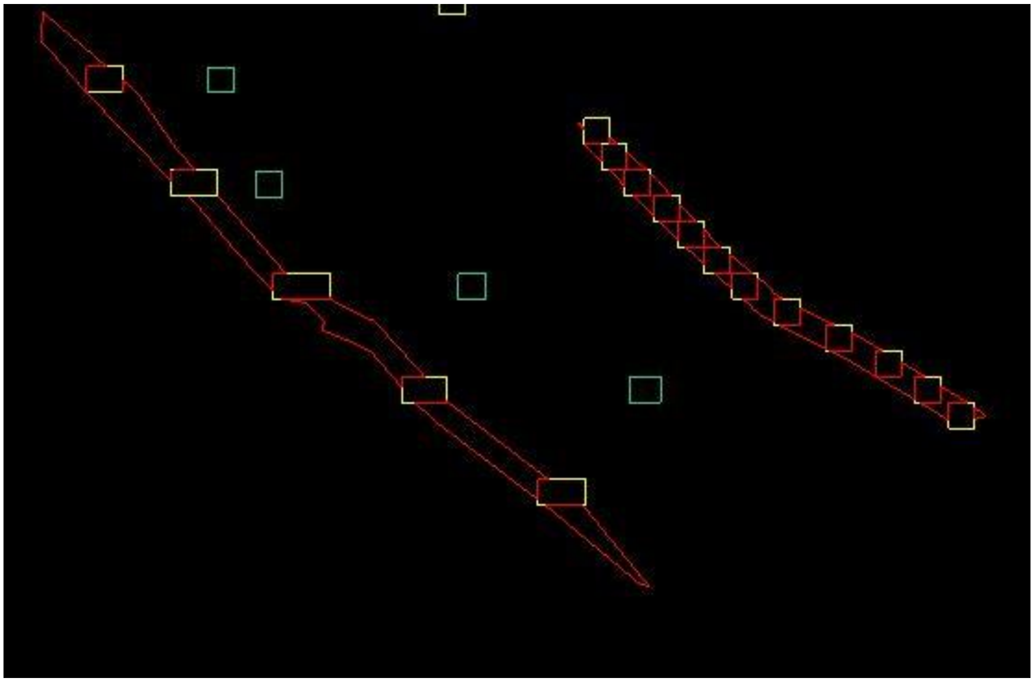


Figure 7: Preferred mining method

4.2.2 Mine Design

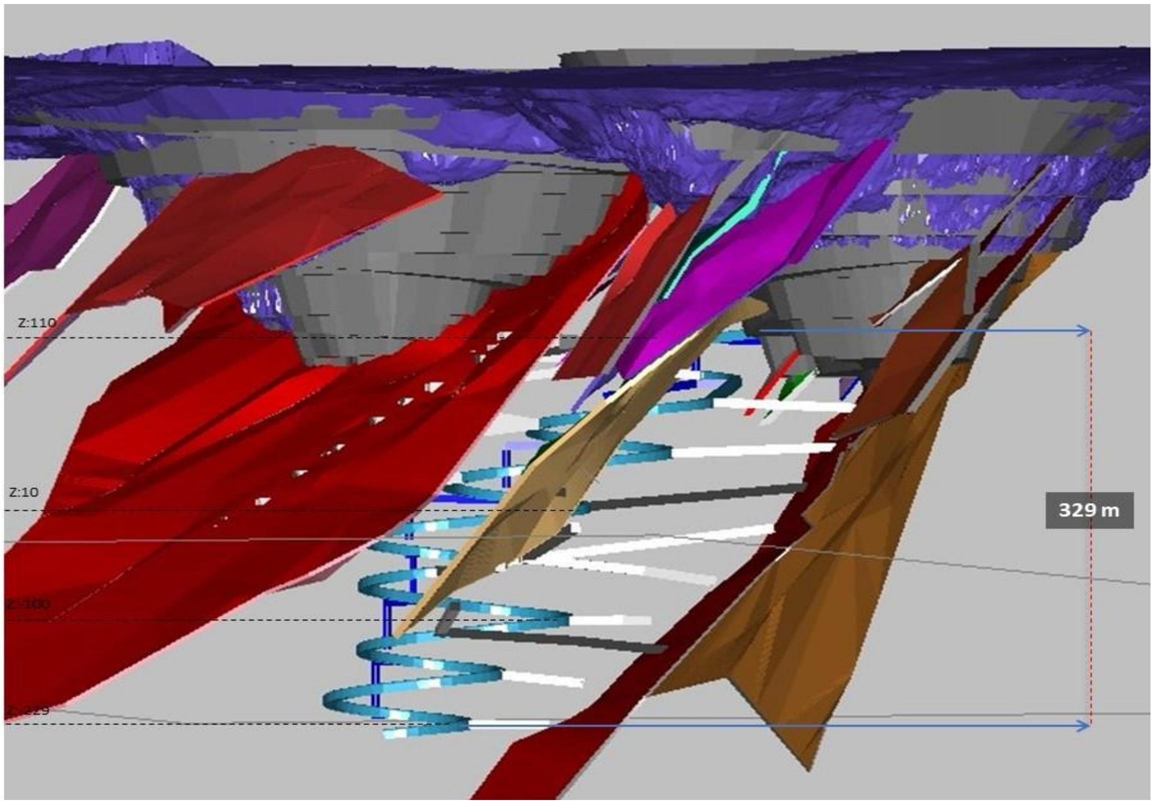


Figure 8: Preferred mine design

The mining method for the proposed underground mining operations was informed by the geology and ore orientation, which resulted in the following mine design.

In total 3 portal will be opened, two of which will be used as main portal (1 & 2). Portal 1 will be opened at 185 elevation at Arhavi.). Portal 2 will be opened at 125 elevation at Adana and will be used as the Ventilation Gallery. Portal 3 will be opened to get the ore in the north-east of Arhavi. Portal elevation is 205.

4.3 Project Summary of Preferred Option

The alternative to pursue an underground mining operation at the KGM is based on 2 key issues:

- Limited surface expansion capacity; and
- Economic recovery and associated costs.

Based on the inventories resulting from MNG mine planning team estimated potential production rates and operating costs.

The inventory was selected for the preparation of simple schedules, the inventories are based on 2.71g/t COGs. Key economic factors applied to determine preferred options are:

- $1,500/oz
- 94% metallurgical recovery.
- 4% royalties.
- Administration $6/t of ore.
- Processing cost $15.1/t and
- A 5% discount rate has been applied

PART 5

5 Existing Environment

Before determining impacts, the existing conditions in the Project area are assessed to provide the baseline conditions against which changes associated with the Project are considered. Since mining activities have been undertaken at the site, the assessment of existing conditions includes an assessment of the potential impacts these activities may have had on the local environment.

The assessment of existing conditions is based upon information from a variety of sources that include:

5.1 Open Pit

The site current consists of 2 open – pits measuring approximately 1.4km in strike length. The open pits are designed to have a bench height of 20 m and a berm width of 5 m. Overall pit slope angles of 35° in the weather zone (i.e. saprolite and saprock) and 45° for the fresh rock. The overall slope angle for the final pit wall is 50°

5.2 Phasing Between Open Pit and Underground Development

Considering the diminishing incremental value beyond Ankara pit, it is economical, environmentally, and socially viable to transition to underground mining versus the current open pit mining which continues to expand, thus increasing the mining environmental footprint. This alternative was considered by looking at the pit increments between Istanbul and Ankara pits; considering the Price Factor with an assumed processing cost of US 15.1/t, it can be shown that it is more economic to transition to underground mining versus expanding the Ankara which has reached its limit of expansion.

5.3 Physiography

5.3.1 Mine License Area

The MNG concession is approximately 100 km north-east of Buchanan City, and approximately 75 km south- west of Sanniquellie City (Figure 1.0). The concession area stretches over three counties: Nimba, Grand Bassa, and Bong counties. In Bong County, the concession covers Kokoya and Jorquelleh Districts, in Grand Bassa County, it is in District # 3 and in the Nimba County, it is found in Yarwein-Mehn Sohnneh

The mine site is located within a disturbed forest area – where most of the vegetation has been removed for agricultural purposes; the area has also had a long history of artisanal and small-scale mining in the area. The area is characterized by low mountains which reach heights of 200 – 300m; and a highly fault zone which host the St. John's River. A number of factors to be considered in the mining area, affecting local physiography, soils, vegetation, hydrology and consequently, biological communities as well includes:

- Highland terrain dissected by dendritic drainage system.
- Widespread distribution of bare rock and loose soils / sediments.

These processes have led to the evolution of a landscape dominated by erosional processes that, in turn, have resulted in the formation of shallow valleys with flat, rocky sides, filled with, gravitational (erosion) and fluvial deposits. The slopes of the gently undulating lands contribute clastic sediments due to weathering of parent rock. Sediments range in size from rock to clay-sized fractions. The gently undulating slopes are characterized by erosional gullies, rocky outcrops and alluvial fans.

The first 50 cm layer of topsoil covering the surface of the footprints of the open pits, run-of-mine stockpile and waste rock dump are stripped and stockpiled in designated areas for capping and rehabilitation during mine closure. The topsoil stockpiles have a maximum height of 2 m and is graded to slopes of less than 1V:2.5H. The stockpile areas are be bunded.

5.3.2 Weather and Climate

The climate in Liberia is hot and humid, and there are two distinct dry and wet seasons. The dry season is between November and March and the wet season from April to November. Temperatures vary from 27°C to 32°C during the day and 21°C to 24°C during the night. Recent rainfall during the wet season has been recorded to vary from 4,000 mm at the coast to 1,300 mm inland (PMDE, 2014).

The project site receives an estimated 2,600 mm of rainfall on average per year. Rainfall is at its highest during the month of June with volumes of up to 530 mm being recorded, while the least rainfall occurs in February, with an average of 58 mm being experienced in this month.

Relative humidity is generally high throughout the country. Along the coastal belt it does not drop below 80 per cent and on average is above 90 per cent. A relative air humidity of 90-100 per cent is common during the rainy season

(UNDP, 2006). Dominant wind directions in West Africa are the NE and SW Monsoons as well as the Harmattan, which is a dust laden wind from the Sahara Desert. Total wind speed is greatest in the rainy season and lowest in the dry season. Along the coast, the average annual wind speed was 30 km/h. The greatest wind speed is between July and September and the lowest is in December and July. The highest wind speed recorded in Liberia is 72 km/hr recorded in Buchanan (on the coast) in April and May 1988 (UNDP, 2006).

5.3.3 Air Quality and Noise

Air quality for the project area was conducted before the open pit operation starts as a baseline. Monitoring of the stack gasses (NO_2, CO, SO_2, CO_2) in the mine site is ongoing and compared with the baseline where possible.

5.3.4 Geology

The regional geology of the Kokoya area was mapped as part of a project between the Liberia Geological Survey and the United States Geological Survey between 1965 and 1972. From the geological map the rocks of the Kokoya concession of MNG are Precambrian of the Liberian Age Province. Rocks of this age range are dates between 2.5 to 2.7 billion years. The rocks of the lowland are mainly leucrocratic gneiss which is typically well foliated medium grained biotite gneiss, with numerous small bodies of amphibolite. A composite rock unit which is predominantly magic schist, associated with quartzite and the iron formation itabrite is also found. This unit forms part of a fault system through which the St. John's River flows.

5.3.4.1 Geochemistry

Golder conducted a geochemical characterization program and evaluated the acid rock drainage/metal leaching (ARD/ML) potential of ore and waste rock in the Kokoya Gold Deposit, based upon a static testing program. The sample set of 45 ore and waste rock samples reasonably represents the compositional range of the various lithologies and the spatial coverage of the deposit. The complete geochemistry report can be found in Appendix A. The test program included the following components:

- Major oxide analysis (all samples)
- Trace metal analysis (all samples)
- Acid base accounting (ABA) (all samples)
- Single addition net acid generation (NAG) testing (all samples)
- Short term leach testing (on selected 15 samples)
- NAG leach testing (on selected 3 samples)

Based on the ABA and NAG results, there is only one potentially acid generating (PAG) sample (a quartz vein sample). Two schist samples have uncertain ARD potential and the remaining samples are all classified as non-potentially acid generating (NON-PAG) since they either have a high neutralization potential or contain less than 0.2 % sulphide sulphur are NON-PAG.

Drainage qualities from short-term leach testing indicate that near neutral or alkaline drainage is expected, with low dissolved base metal concentrations. Leachate was found to be within IFC standards for less than half of the fifteen samples due to elevated (alkali) pH or low (acidic) pH and an elevated nickel content in one sample. The pH values also place six of the fifteen samples as outside the Liberian water quality standards for any use, and fourteen of the fifteen are unsuitable for domestic drinking water. Six samples exceed WHO drinking water guidelines on iron or manganese. Recommendations are made on the design and operation of the waste rock dump and the ore stockpile, to ensure that low quality mine drainage is not discharged to the environment.

5.3.4.2 Hydrogeology

As stated in Golder (2015a) the rivers in Liberia are predominantly rain fed and not aquifer fed. Rural domestic water supplies are generally drawn from opened sources such as rivers or stream and from groundwater. The water table is on average between 7m – 13m below the surface.
The hydro startigraphic units in the mine area comprises from top to bottom of:

- Saprolite zone (~20m thick)
- Saprock zone (~10m thick) and
- Basement rock (fresh bedrock) zone

Hydraulic conductivity of these units decreases from the surface toward the depths of bedrock. Hydraulic conductivity (K) values of saprolite, saprock and basement rock units are in the order 10−6 m/s, 10−7 m/s and 10−8 m/s, respectively and, probably decreases 10−9 m/s or lower at the greater depths of the bedrock hosting the gold- rich quartz veins. The Saprolite layer is a shallow hydrogeological unit of less significance formed by the weathering of the underlying rock. The saprolite generally shows a high degree of heterogeneity between its clay and sandy constituents and as such, layers of variable permeability are often present. The highest hydraulic conductivity in the saprolite is often associated with the saprock at its base as it is fractured and less weathered and therefore contains less clay than the overlying laterite. Deep lateritic zones can, however, provide significant storage to the underlying saprock aquifer unit.

The hydraulic conductivity of the bedrock is more dependent on the rock competency than its mineralogy. The flow of groundwater in this zone is structurally controlled with water movement occurring through fractured and weathered zones. Water storage is low due to the majority of the rock mass being impermeable, but the ability to transmit water can be high through the fracture systems which can control the groundwater flow. (PMDE, 2014). Significant water storage from the overlying laterite, depending on its thickness, can however be drawn into the basement rock through vertical leakage.

The hydrogeological assessment report is included as Appendix B.

5.3.4.3 Ground Water Quality

Many hand – dug wells, boreholes, springs and creeks were identified by the survey team for the hydrogeological assessment (Golder 2015a) during the hydro census undertaken in and around Sayeweh Town; Dean Town; the Rock

Crusher; Bahn Town; Dahnway Town; Gbon Town; and Quah Town. The spatial locations of these points were geo-referenced and site codes assigned to each point. The locations of hand dug wells and existing groundwater wells identified during the hydro-census are presented in Figure 9.0. The static water levels were measured as well as total depth of the wells.

At some locations, measurements could not be taken either because the hand pumps or borehole were sealed up or had been blocked with rocks that were put into them.

Within the scope of Kokoya Project, 11 groundwater wells and one water supply well were drilled to provide data for Golder (2015a) Report. Later on, some of these wells were abandoned due to project activities during the Construction and Operation Phases. However, new wells were drilled in order to sustain the monitoring activities. Before the Operation Phase, four of the groundwater wells (KDW01, KDW02, KDW03 and KDW04) were drilled at the proposed open pit areas. KDW01 and KDW02 were drilled at the Rockcrusher Pit, KDW03 was drilled at the Adana Pit and KDW04 was drilled at the Istanbul Pit. KDWs are diamond drilled boreholes which were converted in standpipe piezometers for water level measurements.

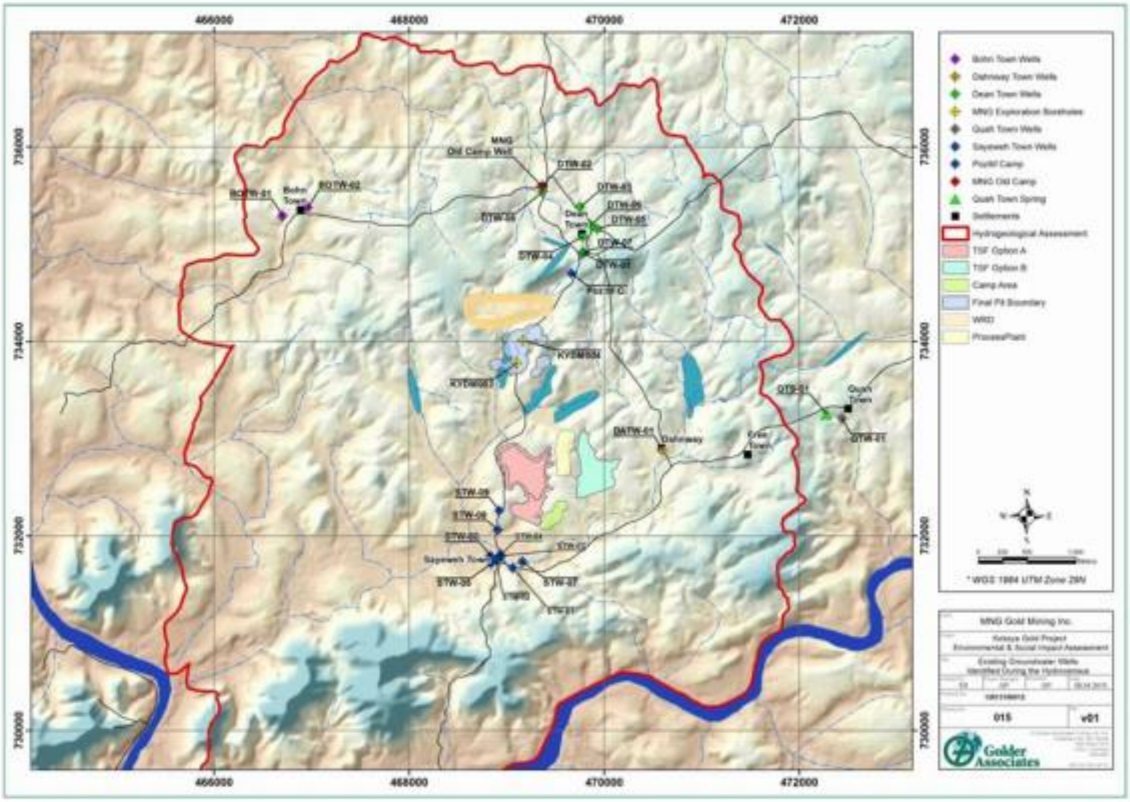


Figure 9: Map of the mine area showing hand dug well locations

KDW01: KDW-01 was drilled at the Rockcrusher Pit area. The well drilled down to 80 m bgl (below ground level) or 144 m asl, which is below the proposed final pit-floor elevation. The borehole was drilled with a 96 mm diamond drill bit and completed with 63 mm UPVC casing. The static groundwater level (SWL) was measured at 5.27 m bgl. The main lithology encountered during the drilling of this borehole has been described as metamorphic rock with quartz veins. The first 17m or so were logged as laterite and saprolite.

KDW02: KDW-02 was also drilled at the Rock crusher Pit area. The well drilled down to 60 m bgl or 168 m asl, which is also lower than the proposed final pit-floor elevation of the pit. The borehole was drilled with a 96 mm diamond drill bit and completed with 63 mm UPVC casing. Groundwater was measured at 9.77 m bgl. The main lithology encountered during the drilling of this borehole was metamorphic rock with quartz veining. The first 15m or so were logged as laterite.

KDW03: KDW-03 was drilled at the Adana Pit area and drilled down to 40 m bgl. The borehole reached 195 m asl, which is below the proposed final pit-floor. The borehole was drilled with a 96 mm diamond drill bit and completed with 63 mm UPVC casing. Groundwater was measured at 7.85 m bgl. The main lithology encountered during the drilling of this borehole was metamorphic rocks, with quartz vein Laterite extends to a depth of 25 m bgl is laterite.

KDW04: KDW-04 was drilled at the İstanbul Pit area. The borehole was drilled down to 60 m bgl reaching 157 m asl, which is also below the proposed final pit-floor elevation. The borehole was drilled with a 96 mm diamond drill bit and completed with 63 mm UPVC casing. Groundwater was measured at 3.21 m bgl. The main lithology encountered in this borehole during drilling was metamorphic rock with minor quartz veining. The first 30 m or so below surface were logged as laterite and saprolite.

In addition to the core drilled KDW boreholes, seven groundwater monitoring wells (KMW01, KMW02, KMW03, KMW04, KMW05, KMW06 and KMW07) and one water supply well (KWS) were drilled for the purpose of monitoring the water levels and supplying water. All eight wells were drilled by the RC (reverse circulation) drilling system. The following boreholes with the exception of boreholes KMW06, KMW07 and KMS were drilled with a 6-inch (152.4 mm) hammer constructed with 125 mm PVC (polyvinyl chloride) casing.

KMW01: Borehole KMW-01 was drilled between the Arhavi Pit and the waste dump. The borehole was drilled to a depth of 50 m bgl. The SWL (static groundwater level) was measured at 9.82 m bgl.

KMW02: Borehole KMW-02 was drilled in the downstream of Adana Pit. The borehole was drilled to a depth of 40 m bgl. The SWL was measured at 4.61 m bgl.

KMW03: Borehole KMW-03 was drilled in the vicinity of İstanbul Pit. The borehole was drilled down to 60 m bgl. The SWL was measured at 11.58 m bgl.

KMW04: Borehole KMW-04 was drilled in the upstream of the waste dump. The borehole was drilled down to 46 m bgl. The SWL was measured at 4.77 m bgl.

KMW05: Borehole KMW-05 was drilled between the Arhavi Pit and the waste dump. The borehole was drilled to 40 m bgl. The SWL was measured at 1.56 m bgl.

KMW06: Borehole KMW-06 was drilled in the downstream of the proposed tailings. The borehole was drilled with an 8 inch (203.2 mm) hammer and constructed with 125 mm PVC casing down to 40 m bgl. The SWL was measured at 3.83 m bgl.

KMW07: Borehole KMW-07 was drilled in the upstream of the proposed tailings. The borehole was drilled with an 8 inch (203.2 mm) hammer and constructed with 125 mm PVC casing down to 40 m bgl. The SWL was measured at 8.05 m bgl.

KWS: Borehole KWS was drilled at the Camp Area. The borehole was drilled down to 50 m bgl. The SWL was measured at 7.70 m bgl.

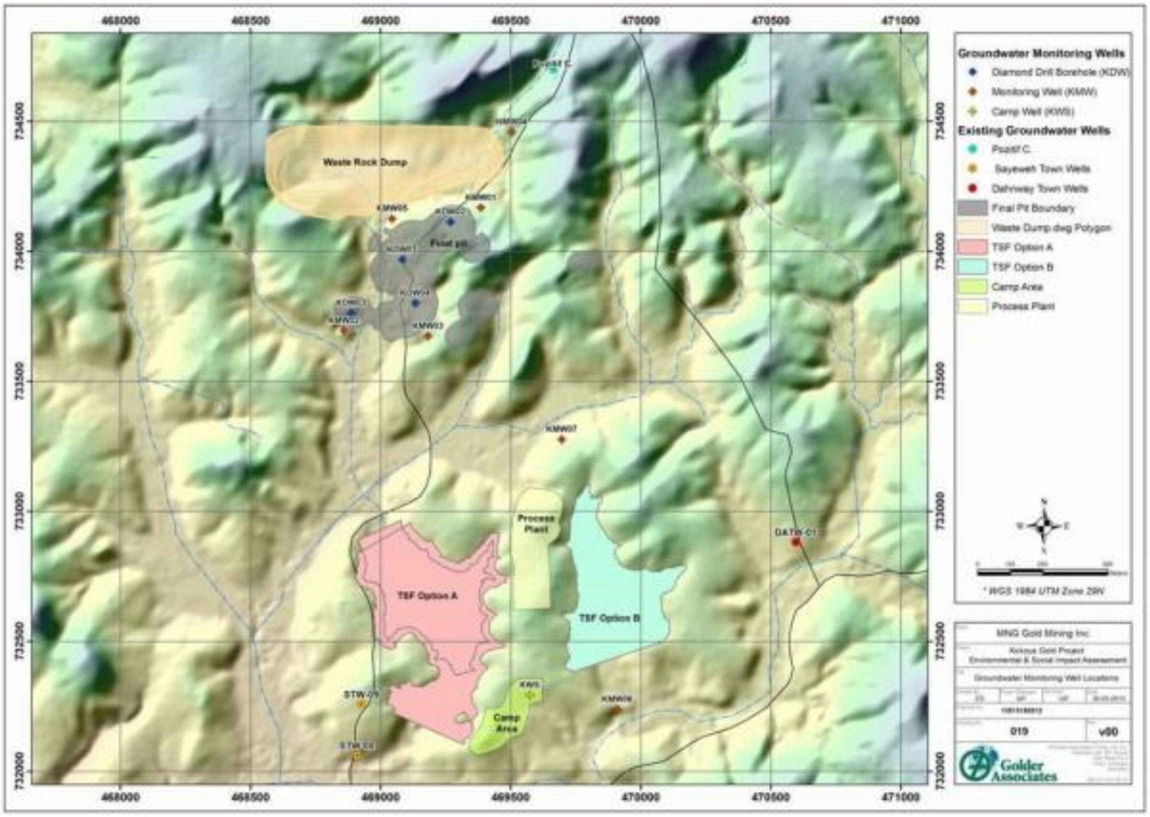


Figure 10: Map of ground water monitoring wells in the study area – Courtesy of Golder Associates (2015)

Additional information on groundwater is available in the hydrogeological assessment report included as Appendix B.

5.4 Biological Environment

The project area falls within the forest biome, which extends throughout the majority of the northern region of the country (Figure 1.0). It is characterized by tall trees making up a multi-layered and continuous canopy, with lower layers consisting of a variety of flora species. Though most of the natural habitat in the region has been left unaltered, areas close to the proposed project area are utilised for farming, artisanal mining and for residential purposes, and have been cleared of vegetation. The forest biome vegetation which characterizes the study area is made up of a various layer of grasses, ground cover, woody plants and tall trees.

Soil Type and Land Use

Liberia has four major soil types. They are the latosols, lithosols, regosols and alluvial. Latosols occupy about 75% of the total area of the country, Lithosols about 16.7% and Regosols about 5%. Highly fertile alluvial soils represent only approximately 3% of the land area of Liberia (FAO, 2012).

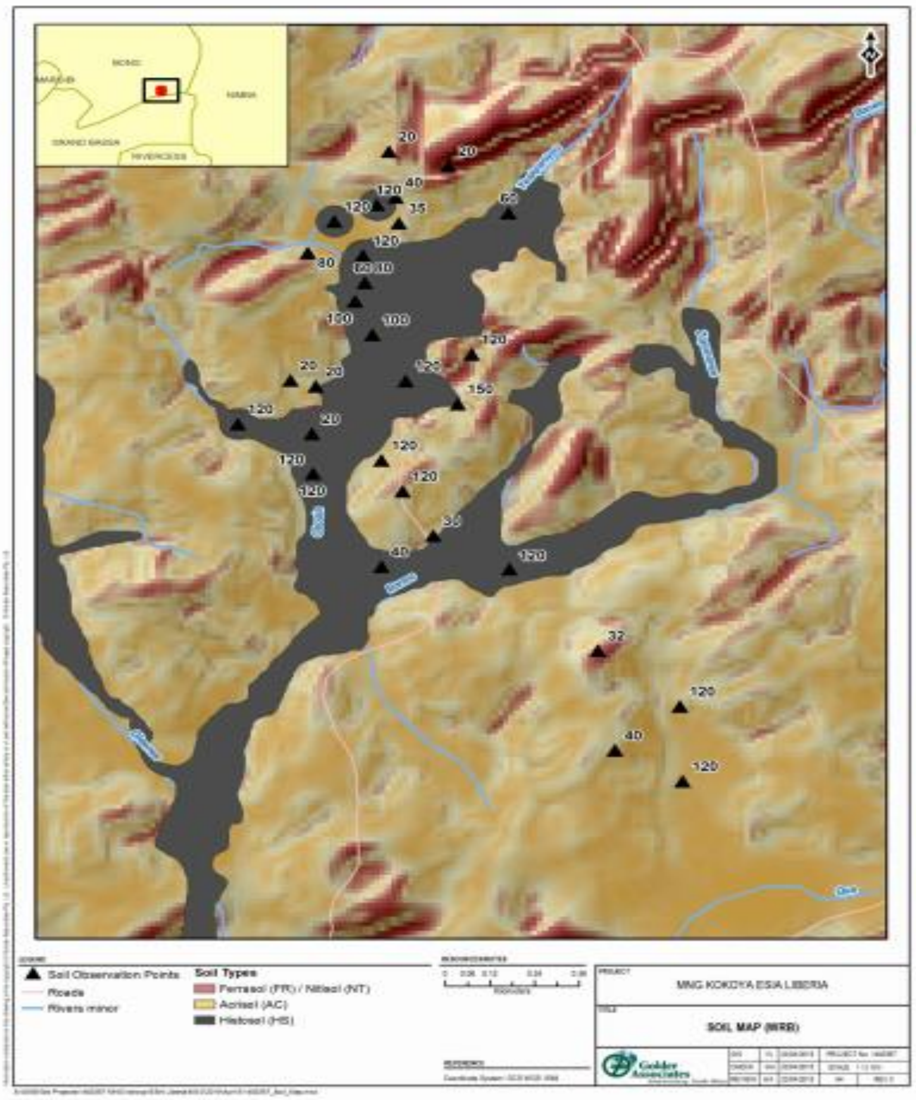


Figure 11: Soil map of the project area

These soils are grouped into seven (7) associations as shown in Figure 212.0: The Kakata, Salala, Suakoko, Gbarnga, Ganta, Zorzor and Voinjama Associations. The project area is mostly in the Suakoko Association, with a small area in the Lithosol region. In the Suakoko Association, the soils are yellowish brown in color and consist of sandy loam soils developed on quartzite and light-colored schists. They occur along the upper parts of the escarpment areas on gently rolling to rolling topography. The Suakoko soils have low moisture holding capacity and low drought resistance. They are loose, friable soils with free internal drainage. These soils are intensely leached by the heavy tropical rainfall and are of only medium to low fertility.

Soil Group	Brief Description
Feralsol (FR)	Deeply weathered, red or yello soils. Good physical properties such as depth, good permeability and microstructure stability. The chemical fertility of Ferralsols is generally poor.
Acrisol (AC)	Red, brown or yellow colored soil. Storngly weathered acid soils with low base saturation
Nitisol (NT)	Well - drained, red tropical soils predominantly found on level to hilly land under tropical rainforest or savannah vegetation. Considered most productive soils of the humid tropics
Histosol (HS)	Found at all altitudes, but predominantly occurs in lowlands consisting of incompletely decomposed plant remains, with or without combinations of sand, silt or clay
Fluvisol (FL)	Predominantly recent, fluvial, lacustrine and marine deposits. Fluvisols have a good natural fertility and are often used for paddy rice cultivation
Vertisol (VR)	Heavy clay soils with a high proportion of welling clays typically found in depressions and level to undulating with moderately good chemical fertility

Table 7: Soil group types

5.4.1 Mine Area Context

Much of the proposed project in and around the Gbosia and Yeakpaniyou streams has been transformed by existing artisanal mining activities, while the remaining areas, both within the project site and in the surrounding landscape, are disturbed by various other anthropogenic activities, most notably agriculture.

Within the villages (David Deans) to the northeast of the project area, and Sayewheh, Duo Village and Dahnway Village along the Qua River to the south ecosystem disturbances caused by various anthropogenic activities associated with daily livelihood, such as agriculture, are evident in the highly fragmented, patch-work condition of remaining forest habitat.

The St John River lies approximately 1.7 km to the south of the study area and flows in a south-west direction. The river is an important ecological feature in the landscape, with many of smaller rivers streams draining into it in the vicinity of the mine infrastructure.

5.5 Biodiversity

Biodiversity in the project area is non – related as the area is currently disturbed, and there are no flora or fauna associated with underground mining activities.

5.5.1 Protected Areas and Areas of National Significance

Protected areas and areas of national significance in the project area is non – related as the area is currently disturbed, and there are no protected areas and areas of national significance associated with the proposed underground mine.

5.6 Socio – Economic Environment

5.6.1 Socio – Economic Baseline

The socio-economic baseline data captured in Section 6 of the Approved Kokoya ESIA (2015) continues to remain valid and has served as a guide for MNG's understanding and engagement of its host communities. Over the course of its open-pit mining operations thus far, the company has continued to make the required MDA social development payments. MNG Liberia also implements a diversified social investment program in close consultation with host communities to identify priority activities and implement them. This has ranged from emergency, humanitarian intervention and provision to road rehabilitation and construction, and scholarships. These activities further support the ongoing direct and indirect employment offered by the operations and associated job and skills training in respective roles, with prioritization of host community residents for available positions.

5.6.2 National Overview

The territorial land space of Liberia is approximately 37,420 square miles. And according to the National Population and Housing Census Report (NPHC) of 2008, there are 1,739,945 males and 1,736,663 females in Liberia with a sex ratio of 100.2 as compared to a sex ratio of 102.0, in 1984. In other words, the sex ratio of 2008 was lower than the sex ratio of 1984; which means that in 2008, there were relatively more women than men in Liberia. In 2008, Liberia's national household size was 5.1 with a population density of 93 persons per square mile.

Bong County's population, in 2008, was recorded at about 333,481 people, with a growth rate of 1%. Said figure represents an increment of 77,668 people in the last 24 years from 1984. The county covers approximately 3,380 square miles, with a population density of 99 persons. There were approximately 3,702 people that lived in Kokoyah District, in 2008, with a male population of 1,829 and female population of 1,873. The average household size of Bong County was put at 4.7, which is less than 1% of Liberia's national household size of 5.1.

The 2008 NPHC labeled Bong County as a moderate populated county by relative comparison with other counties in Liberia. The moderate population density of Bong County, as compared to other counties in Liberia, is predominantly attributed to the advantages of local alluvial gold and diamond mining, being hosts to former mining and agricultural companies, fertile arable lands for farming, moderate transport and communication facilities, and local trade that attracts and holds populations in the county. The county population is mainly concentrated in rural areas rather than urban areas. However, it is imperative to state that the demography characteristics of the project area have changed as a result of in-migration and the possibility of exploring opportunities around artisanal mining and gaining employment with MNG Gold Liberia.

Liberia is ranked as one of the most under-developed countries in the world and lacks basic infrastructure. According to the UNDP's Human Development Index (HDI), Liberia scores an HDI of 0.338 out of 1.000; it has low indicators for infant survival, life expectancy and educational attainment. The country was plunged into several years of civil bloodshed and anarchy which evolved in the 1980s and ended in 2003 from a Peace Accord signed in Accra, Ghana. The signing of the accord gave birth to a transitional government that led the country for two (2) years, followed by the holding of three (3) consecutive democratic elections in 2005, 2011 and 2017. Madam Ellen Johnson Sirleaf of the Unity Party won in the two previous elections by the National Elections Commission of Liberia, while Mr. George M. Weah was the leader elected in the 2017 elections. The UN Mission in Liberia (UNMIL) had been in control of Liberia's security with major withdrawal of troops and finally concluded its mandate of the peacekeeping operations in March 2018.

Efforts remain ongoing to train and restructure the security apparatus of the country while the process of rebuilding the social and economic structure of Liberia continues. In 2008, the Government of Liberia published the Poverty Reduction Strategy (PRS) which defines the development program of the Government in a process towards long-term development of the country. The document makes the observation that Liberia is not a poor country, but a rich country that has been poorly managed, and the main thrust of the PRS was to build on the country's potential. Because the PRS was a short-term strategy that lasted for approximately 4 years, it was recently succeeded, in 2012, by a new economic development platform called Agenda for Transformation (AfT) or Vision 2030. The AfT is a new development initiative that succeeds the Government of Liberia Poverty Reduction Strategy (PRS). It is a long-range strategic document that is bent on promoting national peace, national identity and reconciliation, as well as making Liberia a middle-income economy in the year 2030. With the ushering in of a new administration in 2017, the Government of Liberia has now published its medium-term development plan – the Pro-Poor Agenda for Prosperity and Development (PAPD 2018 – 2023).

Liberia ranks 176th out of 189 countries on the 2018 Human Development Index, highlighting the immense poverty and social development needs of the country. The PAPD sets out the government's plans to reduce poverty, from increased spending on rural education to establishing a more comprehensive social safety net. The document sets out a more comprehensive study of groups lacking basic services, access to necessary foodstuffs or healthcare, and those earning low incomes or in vulnerable employment. The government plans to assist a number of these groups by improving road connections, which will improve access to markets and to services, and by creating jobs. The PAPD plans to increase secure employment by supporting micro-, small- and medium sized enterprises (MSMEs) through better access to electricity and infrastructure, as well as by developing community forestry and small-scale mining.

5.6.3 Local Governance and Structure

Liberia has a democratic republican form of government, with a constitution approved in 1986. The country has a dual system of statutory law based on Anglo-American common law for the modern sector, and customary law based on unwritten tribal practices. Both systems are operative in the project area and will form the basis for grievance procedures and monitoring, throughout the project.

The MNG Gold Liberia project is situated in the Central Region of Liberia, in Kokoyah District of Bong County. The Superintendent of Bong County, like all superintendents of the subdivisions of the country, is appointed by the President and he/she is the administrative head of the county. The superintendent is closely assisted by a Development Superintendent who is also appointed by the President. Kokoyah District, where the project area is located, is one of several districts of Bong County. It is headed by a statutory superintendent, who is assisted by a statutory development superintendent and followed by commissioners, all of whom are also appointed by the President. The tribal authority in the project area, which represents the local traditional structures, is headed by a paramount chief. Next to the paramount chief, in descending order, are the clan chief, a general town chief, and town chief. The paramount chief controls the chiefdom. The clan chief controls a given clan in the chiefdom. The general town chief controls several towns in a given clan. And the town chief controls a single town.

5.6.4 Demographics and People

Residents of project area communities indicate that there has been some level of influx in their towns during the last two years. The smaller towns indicated the presence of migrant laborers settling in the towns for short periods, but their population has remained stable. The larger towns increased in population because of employment opportunities and artisanal mining activities in the project area. A number of people leave the towns in the project area to other towns for secondary and tertiary education. Others also move to seek employment and better living conditions elsewhere. Estimates of local populations as captured in the 2015 ESIA are indicated below.

Towns	**Estimated Population**
Sayewheh	1000
Free Town (Finita)	10
David Deans	4000
Dahnway	75
Qua-Garyeazon	150
Total Estimated Population	**5,235**

Table 8: Population of nearby towns

5.6.4.1 Health

The health service delivery system of Liberia is confronted with a plethora of challenges to render efficient service to sick patients. This deficiency, particularly in rural areas such as the project location, was further exacerbated in 2014 when the deadly Ebola Virus Disease struck Liberia. This remains a concern in view of the current COVID-19 global pandemic which may potentially spread across the country, jeopardizing the fragile and under-resourced health systems.

Major causes of illness and mortality in Liberia, according to UNEP 2004, include communicable diseases, malaria, acute respiratory infections, measles, and diarrhea emanating from poor sanitation and limited access to safe drinking water. It is believed that less than 10 percent of Liberians have access to healthcare. There are clinics in Gbarta and Botota, approximately 30-50km from the camp site of MNG Gold Liberia, there are no health facility in very close proximity to the project area. Serious medical cases are referred to Gbarnga City or Monrovia, where there are hospital facilities.

According to field observations and community consultations, water and public latrines construction to meet the demands of the sanitation needs of the growing population are amongst the main problems facing people in the project area.

5.6.4.2 Education

There are two (2) formal primary public schools noticeable in the immediate project area. They are the David Deans Town Elementary Public School and Sayewheh Town Elementary Public School. In addition to these two aforesaid schools, an informal elementary public school was said to be present in Dolo Town.

Tertiary education is non-existent in the project area and only accessible in Gbarnga City, the provincial capital of Bong County. Most tertiary institutions are publicly owned, and they received some level of funding and support from the national government. However, these institutions are believed to be confronted with capacity and funding challenges which strangulate them from being very much aggressive in providing quality education to the growing population in the region. Skills training are not accessible in the project area.

The unavailability of skills training and its corresponding ability to contribute to national development, coupled with the dysfunctional state of recreational facilities, is reportedly giving birth to the low social output and productivity in the project area.

5.6.4.3 Land Tenure and Use

The project area follows a customary right ownership or communal land ownership system where the land is owned by the community and managed through the Council of Elders and Town Chief for each town or village. In order to acquire land in the area, a request is submitted to the relevant Town's Chief or Council of Elders. However, despite customary land tenure in the project area, commercial projects such as mines are often granted rights to large parcels of land at the government level. These processes are now subject to the recently passed Land Rights Act (2017).

The current land use in the project area is residential, subsistence agriculture and artisanal mining. Acquisition of land in the towns in the project area is managed through the Council of Elders and Town Chiefs. Land within the town is categorized as land for construction purposes (town lots) and land for farming purposes. There are different processes to follow for people who already reside within the town and for outsiders who wish to acquire land in the town. A resident who wishes to acquire land for construction would first go to the town elders. If the Council of Elders is satisfied with the request, they would refer the resident to the town's development chairman. She/he will further refer the resident to the Town Chief and the Town Chief will then refer the person to the Quarter Chief who may be in direct control of the land required. After all these processes are completed, the resident would be asked to pay a negotiable token to the Council of Elders for the land. This token is a symbol of appreciation to live in peace and harmony with the people of the town. Failure to live in peace with the people could mean forfeiting ownership of the land.

A resident who wishes to acquire farmland would submit the request through the relevant quarter's chief. If the request is reasonable to the quarter's chief, she/he will give a portion of his quarter's land for the resident's farming purposes. However, no one has permanent ownership status over farmland given to him/her by the community.

On the other hand, if an outsider is interested in acquiring land for construction purposes, they would be required to find a host or "stranger father" who resides in the town. The request for land must be channelled through the "stranger father". The "stranger father" will then forward the request to the quarter chief, where he (stranger father) resides. The quarter chief will forward the said request to the town chief and the town chief will forward it to the council of elders. If the request is convincing and reasonable to all of the above authorities, the stranger would be asked to pay a negotiable token to the council of elders for the land. However, if a stranger is interested in subsistence farmland, they would be required to follow all of the above channels and the farm land may be given to them free of charge, based on the discretion of the town's authorities. No one has permanent ownership status over farmlands given to him/her by the community.

Communities reported that they initially had sufficient land to farm and conduct artisanal mining activities but since the presence of the Kokoya operations and migrant artisanal miners' activities, they are experiencing restricted access to land. All the towns in the project area indicated that they are concerned about the loss of farmlands and artisanal mining sites due to the mine's acquisition of land in the area. They perceive the consequences to their livelihoods from not having enough available land to meet their household needs or need of their children and future offspring which has economic implications.

5.7 Cultural and Traditional Heritage

Traditional West African cultural practices may survive in the region typically focused on gendered bush societies, whose practices and related spaces may be kept secret from the non-initiated. The official 2008 census recorded the population of Liberia as comprising 85.6% Christian, 12.2% Muslim and 0.6% 'traditional' (https://www.cia.gov/library/publications/the-world-factbook/geos/li.html). Other estimates vary wildly suggesting up to 30% of the population are Muslim and 20% Christian with the remaining 50% practicing indigenous religion, centred on membership to secret societies (http://www.everyculture.com). As documented by Golder Associates during the 2015 ESIA, the Liberian civil war (1989-1997) led to massive population movements and sacred cultural areas were often desecrated. It was also impossible for people on the move to regularly practice their culture, commonly, the initiation of young boys and girls into the Poro and Sande societies, respectively.

Within the NLGM Project concession however, the ESIA community consultation phase identified a number of cultural site types in participation with the village elders. The major site types identified included: Poro (male) and Sande (female) bushes; cultural prayer sites; burial grounds; shrines; community centres (town halls); and churches and mosques. There is a high probability that similar site types, and related intangible heritage practices, are prevalent throughout the Kokoya study area, warranting research, identification and management. Sensitivities may surround local cultural sites which may require further investigation to ensure that taboos are noted and respected by contractors during site survey and subsequent development phases. Typically, this could include gender specific spaces (bushes, rivers, areas of forest) and areas out of bounds for the non-initiated.

PART 6

6 Environmental Impact Methodology

The KGM project is a complex and extensive undertaking that will occur in phases that differ in their potential interactions with the natural and socio – economic environments and in the occurrence of residual impacts. In order to focus the impact assessment, the project activities were divided into three main categories or phases:

1. Construction Phase: During which all the activities associated with preparing the site and supporting infrastructure for operation of the mine will be carried out. During this phase – no decommissioning of existing mine facilities will be required; as the mine planning envisioned the use of all facilities and infrastructures used during the open pit mining activities.
2. Operations phase: During which all of the activities associated with underground mining, ore processing and extraction of the gold will be carried out for the LoM. This including stockpiling; WRD management; and TSF management.
3. Closure and Post – Closure Phases: During which all of the activities required to close and stabilize the mine and associated facilities are carried out; the activities required to monitor the effectiveness of the closure are carried out, and during which the potential for long-term effects are considered.

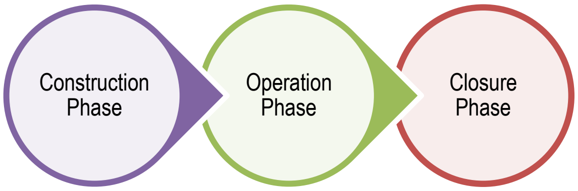


Figure 12: Project process flow chart

The impact assessment methodology for this Addendum ESIA is described in this section. The assessment is restricted to the underground mining operations and addresses the physical components of the environment, mainly:

- Geology and geochemistry (leaching and ARD)
- Geotechnical (mine stability and safety)
- Hydrogeology (groundwater quality)
- Hydrology (Surface water quality and sediment quality)
- Air quality (Health and safety)
- Noise and Vibration (Health and safety);
- Community and livelihood (Social impact and security)

The impact did not include predictions of changes to biological components mostly because – impact to these are not material enough for underground mining operations. Impacts documented in the 2015 Approved ESIA for biological components are referenced in this document.

Additionally, the impact assessment also addresses the social dynamics of the project – which has changed since the start of mining operations in 2016.

6.1 Approach

The methodology for the environmental impact analysis involved the following steps:

- Identification of project and environmental interactions that could result in measurable impacts (undertaken in Part 3);
- Identification of the suitable social components that could be affected by project activities (undertaken in Parts 7 & 8); and
- Assessment of environmental issues and potential impacts (undertaken in Part 9).

The identification of potential environmental impacts has been undertaken on the basis of the identified project activities and the likely interactions of these with the natural environment, including issues that have been identified in consultation with local communities, regulators and other stakeholders. The process recognizes that only where there is a potential interaction could there be a potential impact.

6.2 Identification of Project and Environmental Interactions

The assessment of environmental effects was performed using the following procedure:

- All project activities were identified (from Part 3, Project Description).
- An initial screening was undertaken to identify those project activities that could have an effect on, or interact with, the natural environment.

The project activities identified in the screening were assessed against existing or baseline attributes of the natural and social environment, including the physical, biological and socio-economic parameters that have been identified in the ESIA study areas.

Particular attention was given to mine safety, surface and groundwater resources, and social and community issues. Project activities that will not interact with the environment were not considered further.

6.3 Selection of Biological Components for Assessment

The effects on biological communities are typically addressed through consideration of changes that occurred at the surface mining level. These effects are typically manifested either through changes in habitat that render certain components of the habitat unavailable or unusable, or through potential direct effects on the organisms, such as increased lethality or reduced fecundity. Impact assessments strive to consider the effects on all of the components of the natural ecosystem.

Given that no species (fauna or flora) occurs within the project area habitats, it is neither possible, nor particularly useful, to attempt to measure effects on all possible receptors; as the project is only focused on underground mining operations.

6.4 Environmental Study Areas

Three areas are identified for the purpose of the environmental impact assessment: Site Study Area, MDA Study Area, and Regional Study Area. The study areas are generally defined as described below. While the Site Study Area is common to all study components, the extent and shape of the Local and Regional Study Areas will differ slightly for each study component. Where the study areas differ from the generic description provided below, these are described for each study component.

Site Study Area (actual mining license area): is the area located within the Project footprint that will be directly affected by the Project. It includes:

- At KGM mine site, the footprint of the deposit, the mine infrastructure, and the associated servicing and maintenance areas and local roads.
- **MDA Study Area** – the area outside the Project footprint that could be physically affected by the Project (e.g., noise and dust along the roads). The Local Study Area includes:
    - At the mine site, the Site Study Area (as defined above) plus areas within a radius of 2 km around the Project site, and up to 5 km downstream for hydrological, water quality and aquatic biology study components; at least the first 1km distance from the outfalls;

Regional Study Area For environmental technical disciplines, the Regional Study Area is defined to extend beyond the Local Area generally Bong County and Liberia. However, for most environmental components, impacts are not expected to extend beyond the Site Study Area.

6.5 Assessment of Environmental Issues and Potential Impacts

A systematic and consistent approach was employed in the assessment of environmental issues and potential impacts. Proposed mitigation measures were considered in order to determine residual impacts and their net significance. The assessment of potential impacts was assessed in consideration of different categories of effect. The categories were:

- ***Direction:*** The direction of an impact may be positive, neutral or negative with respect to a given issue (e.g., enhancement of a wildlife movement corridor would be classed as a positive direction.
- ***Extent:*** The spatial area affected by the project. For the purposes of this assessment *Extent* was classified as: within the project footprint (i.e., the Mine Study Area), within the MDA Study Area, or within the Regional Study Area.
- ***Magnitude:*** The amount of change in a measurable parameter or the predicted/actual level of change relative to an existing or specified condition. *Magnitude* was defined according to the specific nature of the impact. For the purpose of this assessment, magnitudes were classified as: low, moderate and high. The definition of magnitude differs for each study component and is defined separately for each in this Section.
- ***Duration:*** This refers to the length of time over which an environmental impact occurs. For the purpose of this assessment, duration was classified as: short term (i.e., lasting only during the construction period), medium-term (i.e., lasting the entire operational period) and long-term (i.e., extending beyond the closure of the project, sometimes in perpetuity).
- ***Reversibility:*** This is an indicator of the potential for recovery of a given receptor from the impact. For the purpose of this assessment, reversibility was classified as Low for impacts that reverse to the pre-impact condition after the source of the impact is removed, Moderate for impacts that reverse to achieve 50% or

greater of the pre-impact condition, and High for impacts in which a greater than 50% change occurs such that the pre-impact condition cannot be substantially achieved.

Magnitude for physical disciplines, such as hydrology, water quality and air quality are often assessed relative to existing criteria, such as national statues or regulatory guidelines. As a result, physical components, such as air quality, surface water and groundwater quality, and soils and sediment quality are assessed with respect to the environmental standards presented in Part 2.

Determination of the significance of an impact is based on an integration of the assessment measures. For example, an impact that has high magnitude, but is confined to the Mine Study Area, is of short duration, and is reversible, would be considered to have low significance. In addition, significance is often modified by mitigation measures that serve to lessen the impacts, and for many of the components, these are inherent in the engineering design.

Exceedance of a national statue or regulatory criterion is not necessarily a significant effect in itself, and it does not automatically provide a measure of significance to environmental receptors. Each environmental change must be interpreted according to the degree of risk of impact to the environmental communities based on specific attributes of pathway, exposure and receptor characteristics, as well as the likelihood of measurable effects on populations or communities. This approach recognizes that effects at the community or population level can have much longer lasting impacts than effects on individuals. Therefore, the significance of an impact is usually assessed relative to an environmental endpoint, such as effects on communities or human health.

The determination of significance is based on the potential impacts on environmental receptors. Since the effects on physical components, such as water quality, are determined with respect to their potential biological effects (e.g., water quality guidelines have been developed with the purpose of protecting water resources), the assessment of significance is considered within this context.

The assessment is based on the current project description and includes all mitigation measures currently incorporated into the design. Where potentially significant impacts to the environment were identified, additional mitigation measures have been incorporated, where feasible, to minimize the residual impacts, which were then re-evaluated to determine the final significance of the likely impact.

The assessment was conducted with the use of tables that organized and summarized the process described above into comparable and intuitive presentations for each of the construction, operations, and closure and post-closure phases. Assessment methods specific to each environmental component are briefly described in the following sections. Assessment measures for extent, duration, frequency and reversibility are common to each study component. (Table 9 below)

Assessment Measure	Levels for Measures		
	Low	**Moderate**	**High**
Extent	Impacts are restricted to the Mine Site.	Impacts are confined to the local study area.	Impacts extend to the regional study area.
Duration	Impacts are short-term, limited to the construction phase.	Impacts are medium-term, limited to the operations phase.	Impacts are long-term, extending many years and possibly into perpetuity.

Frequency	Impacts occur occasionally (once or a limited number of times).	Impacts occur regularly.	Impacts occur on a continuous or near continuous basis.
Reversibility	The receptor has the ability to return to an equal or improved condition; the effects of the impact are fully reversible.	The receptor has the ability to return to a state that somewhat reflects the original pre disturbance condition; 50% or more of the original value can be regained.	The receptor has <50% ability to return to an equal or improved baseline condition; the effects of the disturbance are irreversible.

Table 9: Environmental risk matrix

PART 7

7 Social Impact Assessment and Methodology

Impact assessment methodology for the SIA is described in this section. As with environmental impacts, socioeconomic impacts will also take into consideration construction, operations and closure stages of the project, but these phases will only be highlighted in the impact assessment when it is relevant to changes in the mitigation measures.

7.1 Socio – Economic Impact Areas

Environmental study areas define three areas in relation to the impact assessment: Mine Study Area, MDA Study Area, and Regional Study Area. Socio-economic study areas are based on political and administrative divisions. There are currently no known existing settlements that will have direct site-specific or "local" impacts, such as resettlement, increased population from workers or changes to infrastructure. The direct area of influence (AoI) is assumed to be an unpopulated and remote area of Sayewheh Town, and, Qua-Garyeazon Village, and David Deans Town. No direct impacts are expected on existing settlements and, therefore, there is no expected impact in a "local" area of influence or study area.

The closest settlement is 1.4 km North from the mine site (David Deans Town). However, it is also assumed that some indigenous activities may take place near the access roads. Impacts, such as the potential for economic growth, are possible in the "MDA and regional" area of influence.

The baseline studies have focused on key settlements only as listed above.

Figure 13: Map of mine showing nearby communities

7.2 Methodology

The key steps in developing the socio-economic elements impact assessment are described below:

- **Socio-economic baseline:** The basis of social analysis is the socio-economic baseline, which is complemented by consultation and discussion with those who may be affected by the Project. Information collected during the baseline study and consultation is used to identify factors that may be influencing the human environment prior to Project (underground mining operations).
- **Review of Project activities:** Project activities that may affect the social or economic characteristics of local communities are identified.
- **Key Issue Identification:** Key social and economic issues identified during the 2015 Approved ESIA are revised and considered with the final project activity details. The purpose is to identify the essential issues for the Project within the overall social, political and cultural context described in the baseline.

- **Impact Categories:** The key issues are used to develop a set of impact categories that form the basis of the impact assessment. Each impact category may have a set of sub-category topics that address elements of the national statues or guidelines including the Decent Work Law or Alternative Livelihood Plan or issues raised during consultation.
- **Mitigation:** Actions are developed to avoid or minimize negative impacts and maximize benefits. The interventions to minimize negative impacts and maximize positive impacts make up the social elements of the Environmental and Social Management Plan.
- **Residual Impacts:** Residual impacts, also referred to as social significance, are the impacts predicted to occur after mitigation. The impact assessment is performed on residual impacts.

Determination of socio-economic impact follows a different methodology than the one used for physical and biological impacts. There are, however, some similarities in the definition of attributes. The four attributes applied to the determination of socio-economic impact significance are listed and defined below in Table 10.

- **Direction:** indicates whether the impact is positive, negative or neutral. Some impacts may have both positive and negative dimensions.
- **Magnitude:** indicates the degree of change in a socio-economic parameter and is generally a qualitative assessment.
- **Geographic extent** indicates the geographic and administrative units that will be impacted. Some impacts may affect only individual households, whereas others may affect the Mine Study Area, Regional Study Area, the entire country.
- **Duration:** indicates the length of time over which an impact may occur. Duration is usually related to the Project description.

Unlike environmental impacts, social impacts will not be assessed on reversibility. Socio-economic impacts are part of an ongoing process of interdependent economic and social change. Although there are isolated exceptions, most socio-economic impacts are experienced continuously by people; thus, probability is not often a useful attribute for significance assessment.

Criteria	Definition
Direction	Positive – Impact provides a net benefit to the affected person(s). Negative – Impact results in a net loss to the affected persons(s). Mixed – Impact may be positive or negative but requires an intervention to demonstrate net benefit. Neutral – No net benefit or loss to the affected person(s).
Magnitude	Negligible – No noticeable change anticipated. Low – Result predicted to be different from baseline conditions, but not to impair or change quality of life of the affected person(s). Moderate – Result predicted to impair or benefit quality of life of the affected persons(s). High – Result predicted to seriously impair or substantially improve quality of life.

Geographic extent	Individual – Confined to individuals or individual households. Local – Confined to the MSA. Regional – Confined to the RSA. National – Extends to national level. Trans-boundary – Results impact neighboring countries in the region.
Duration	Short-term – Confined to period before full operations (through 2027). Medium-term – Extends through operations of the mine (until 2022). Long-term – Extends beyond the life of the mine (beyond 2022).

Table 10: Social impact definition table

PART 8

8 Social Impact Assessment

8.1 Key Social Issues Categories

Key issues for the Project are related employment and resourcing skilled workers while trying to maximize local employment and procurement. The Project is located in a remote location with no other industrial facility in the same region, so there are relatively limited new impacts due to the historical development of mining in the regional study area. However, the general area is known to be used by local residents and therefore adds an additional focus to ensure that the industrial development does not negatively impact rural communities and traditional livelihoods. The following are considered to be the high level, key issues for the Project:

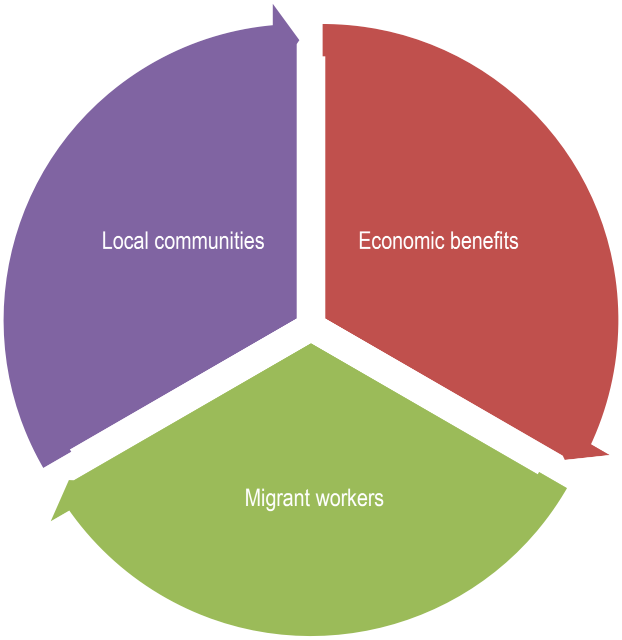


Figure 14: Social impact matrix chart

- **Economic benefits:** The potential for investment additional employment, procurement and tax revenues has created expectations for the success of the Project. However, a general lack of technically skilled people in local settlements will mean that many workers have to come from other regions of the county / country.
- **Indirect impacts of migrant workers:** With in-coming migrant workers, particularly during the construction phase, there is the potential for indirect impacts such as usage of existing local infrastructure and potential health risks such as communicable diseases. The KGM project experience suggests that the impact of migrant workers is low.
- **Impacts on local communities:** Potential changes in the traditional livelihoods of local peoples, including the potential for economic displacement or change in land management. The KGM project experience suggests that these impacts are low.

Other social issues that are contributing factors are described below

8.1.1 Education

The project area has on average a primary school education level. Responses from focus group discussions held during the ESIA studies indicated that there is a lack of opportunity to gain a higher education in the project area. This is because there are no secondary schools or tertiary institutes in any of the towns in the project area. As part of its corporate social responsibility programs MNG Gold is currently constructing a high school in Deans Town which is expected to be completed in 2021. The nearest secondary school, St. Martin's Catholic High School at Gbarnga, is approximately 62 km from the project site. The nearest tertiary institutes, Cuttington University (the oldest private university in Liberia), is in Suakoko approximately 52 km from the project site. People can only receive a higher education if they can afford to travel or live in a town which has a secondary school and return to the area for employment opportunities, but these are few.

Even with the lack of secondary education, students are still dropping out or not attending primary school. Reports suggests (2015 Approved ESIA) that the ability to earn an income for young boys and early pregnancy for girls are the main reasons for leaving school. Children are needed in contributing to the household income either with subsistence farming, artisanal mining or motorbike riding.

8.1.2 Health Impact; Community Safety and Water Sanitation and Hygiene

Health care in the project area is available through local health clinics. The level of health care within these clinics is limited to a few nurses and a doctor. The two main facilities which are frequented by the population within the project area are the Gbahta and Yolota Health clinics which are on average a 2-3 hour walk from the towns in the area. Access to these clinics is generally by foot or by motorbike.

The motorbike rates range between LD$250 per trip and added to the price of treatment, a visit to the hospital becomes expensive. The main diseases prevalent in the towns as indicated project reports are Malaria, Typhoid, Dysentery, colds and coughs, and rheumatism.

The use of traditional medicine is still practiced and provides people with a less expensive, readily available medical option. Herbs and traditional plants are collected from the natural environment and used to treat the symptoms of most of the main diseases mentioned above. Midwives are being certified and registered as decreed by the Ministry of Health, so they mostly practice out of health clinics. There are still many women who give birth at home even if there is a registered midwife residing in the town.

Generally, communities are safe – most crimes are petty theft and land issues; despite the high rate of artisanal mining in the area. While conflicts around mining activities do not occur often, a significant incident did occur in November 2018 when a fatal road accident by a contractor resulted in mass vandalization of the Kokoya mine's camp site, requiring intervention of national security apparatus and Ministry of Internal Affairs to mediate discussions with local communities and residents, as well as arrest and prosecute the perpetrators. There is a full police detachment in the project study area; however, most of the minor cases are settled via the local community leadership.

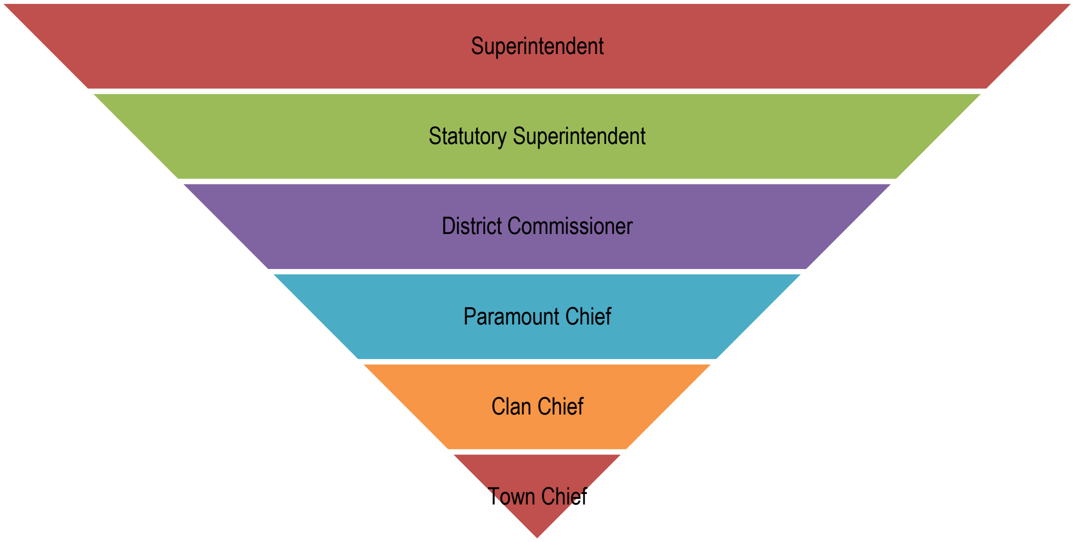


Figure 15: Local Leadership structure of project area

WASH Services

Water, Sanitation and Hygiene services and functions are provided for in the MDA study area mostly by local NGOs and is some interventions of the project. Access to these facilities are via handpumps and pit latrines. While within the mine study area – access to WASH infrastructures are provided directly onsite for all employees, contractors and visitors.

Demographics

Details on population demographics are outlined above in Sections 5.6.2 and 5.6.4, however the total estimated population of the project area as captured in the 2015 Approved ESIA was indicated at 5,235. According to 2008 census figures however, the population of Kokoyah District was captured at 333,481 – with a breakdown of 164,859 males and 168,622 females.

8.1.3 Land Ownership and Land Use

Land is an integral part of societal organization in the project area. Agricultural land is valued highly by the communities as the predominant livelihood for the people is subsistence farming. The mine study area follows a customary right ownership or communal land ownership system where the land is owned by the community and managed through the Council of Elders and Town Chief for each town or village. In order to acquire land in the area, a request is submitted to the relevant Town's Chief or Council of Elders. However, despite customary land tenure in the project area, commercial projects such as mines are often granted rights to large parcels of land at the government level.

The recently passed Land Rights Law defines and delineates the different categories of land ownership and rights recognized in Liberia. It also prescribes the means by which each of the categories of land may be acquired, used, transferred and otherwise managed. The Act further ensures that all communities, families, individuals and legal entities enjoy secure land rights free of fear that their land will be taken from them, except in accordance with due process of law; and confirms, declares and ensures equal access and equal protection with respect to land ownership, use and management, including ensuring that Customary Land and Private Land are given equal legal protection and that land ownership is provided for all Liberians, regardless of identity, custom, ethnicity, tribe, language, gender or otherwise.

8.2 Employment

MNG Gold, are commitment to strict adherence to the national laws and regulations of Liberia, especially when it comes to labor practices – this is in line with its internal employment policies and guidelines. MNG internal employment guidelines ensures health and safety, non-discriminatory practices, forbids child labor, and also presents opportunity for un-retaliatory grievances reporting.

MNG Gold seeks to expand its existing human resources management to support the underground mining operations, especially ensuring that it is in line with the Decent Work Law of Liberia. MNG ensures that its employment practices uphold:

- Freedom of association;
- Elimination of all forms of forced and compulsory labor;
- Effective abolition of child labor; and
- Elimination of discrimination in respect of sex; gender, race, or religion

To ensure that principles and policies are clearly articulated across for all employees; MNG insists on the following protocols that are documented as part of the human resources management system. These protocols include:

- Company regulations.
- Introductory and safety instructions.
- Job descriptions.
- Occupational Health and safety instructions for specific workplace and project wide;
- Salary and payment notification

- Rules of conduct.
- Grievance mechanism.
- Code of business and ethics

PART 9

9 Environmental Impact Assessment

Potential environmental impacts are discussed in this section. The impact assessment includes three project phases:

- Construction (summarized in Table 17)
- Operations (summarized in Table 18), and
- Closure and post-closure (summarized in Table 19).

The impact assessment has relied entirely upon third parties for the project description and baseline characterization.

9.1 Key Environmental Issues

The key environmental issues have been identified based on the existing baseline environmental data and the project description.

The key issues are related to water, air, noise and vibration:

- Water quality, discharges and seepage from the waste rock dump and ore stockpile, and storm water runoff from disturbed areas, effects of re-routing the run-offs around the pits; seepages from the TSF II
- Groundwater quality and flow (quantity) from mining and infrastructure footprint;
- Effects on aquatic life from mining activities, including storm water runoff, seepage from stockpiles,
- Soil erosion, and slope stability; and
- Air quality and noise due to ore processing, dust from vehicles and blasting, vehicle and equipment operation.

While attention has been paid to these, the impact assessment has considered all possible sources of impact, and the assessment is not limited to the issues identified above. A key aspect of environmental impact assessments is consideration of the effects of a project on the mine stability and human safety. Many of the potential impacts of the

Project assessed in this section relate specifically to impacts on stability. Geotechnical impacts that are assessed include:

- Rock strength;
- Mine design;
- ARD;
- Groundwater intrusion and water quality;
- Air quality and lightening (illumination);
- Noise and vibration;
- Toxic effects on aquatic life from chemicals, solvents, fuels, and seepage from waste rock Facilities; TSF discharge into the St. John's;

The intent of the environmental assessment is to consider the overall impacts using the above assessment endpoints, since changes in the environment are due to the interactions of a number of influences.

9.1.1 Geotechnical Studies

As the mine design could not be soundly and reliably performed without taking geotechnical conditions into account, a detailed geotechnical study has been carried out at the site specific to underground operation. This section of the report summarizes the geotechnical data obtained directly from Adana and Arhavi open pits and 9 drill holes opened for this purpose.

The purpose of this section is to reinterpret the drill holes completed for geotechnical purposes and to present the current rock character to support the underground mining operations. There are basically 7 different geological units in the project area. As these geological units present various structural characteristics to a certain extent, it is preferred to determine their geotechnical properties.

Nine (9) of the borings within the scope of the project were drilled and recorded for geotechnical purposes. The data of these nine (9) holes were used to determine the rock quality of the lithological units given in Table 11. The depths of these holes range from 233 m to 470 m where the collar elevation of the drills is averaging 225 m.

Hole ID	X_Coord	Y_Coord	Depth (m)
KYD416	469169	733922	233
KYD826	469228	733889	344
KYD840	469228	733890	338
KYD841	469225	733890	470
KYD856	469229	733890	305
KYD870	469227	733890	362
KYD880	469226	733907	360
KYD892	469227	733889	395
KYD907	469227	733890	359

Table 11: Drill holes to confirm geotechnical studies and depth of hole

9.1.2 Rock Strength

Strength classification of rocks was made by using strength class which is suggested by International Society for Rock Mechanics and Rock Engineering (ISRM). In this context, this classification presented in below in Table 12 was used for all rock materials.

ISRM Strength Classification	ISRM Description	Approximate Range of Uniaxial (Mpa)	Compressive Strength (psi)
RO	Extremely Weak Rock	0.25-1.0	35 -150
R1	Very Weak Rock	1.0 - 5.0	150 - 725
R2	Weak Rock	5.0 - 25	725 - 3500
R3	Medium Strong Rock	25 - 50	3500 - 7500
R4	Strong Rock	50 - 100	7500 - 15000
R5	Very Strong Rock	100 - 250	15000 - 35000
R6	Extremely Strong Rock	>250	>35000

Table 12: Rock strength classification

To fully understand the geotechnical characteristics of the rock types, especially to ensure mine stability; several method of classifications were studied including:

- Rock Mass Rating (RMS) system;
- Geological Strength Index (GSI);
- Rock Quality Designation (RQD)

Overburden requirement has necessitated for switching to underground mining method. There a number of veins dipping beneath the open pit bottom. Portions of these veins had been produced by surface mining method up to certain depth. Although there are a number of veins, having different sizes, only four of them are suitable for underground production.

The mining is going to be performed at two distinct locations in the form of underground mine (large) and small underground mine (small) in terms of location and production capacities as seen in Figure 13.0.

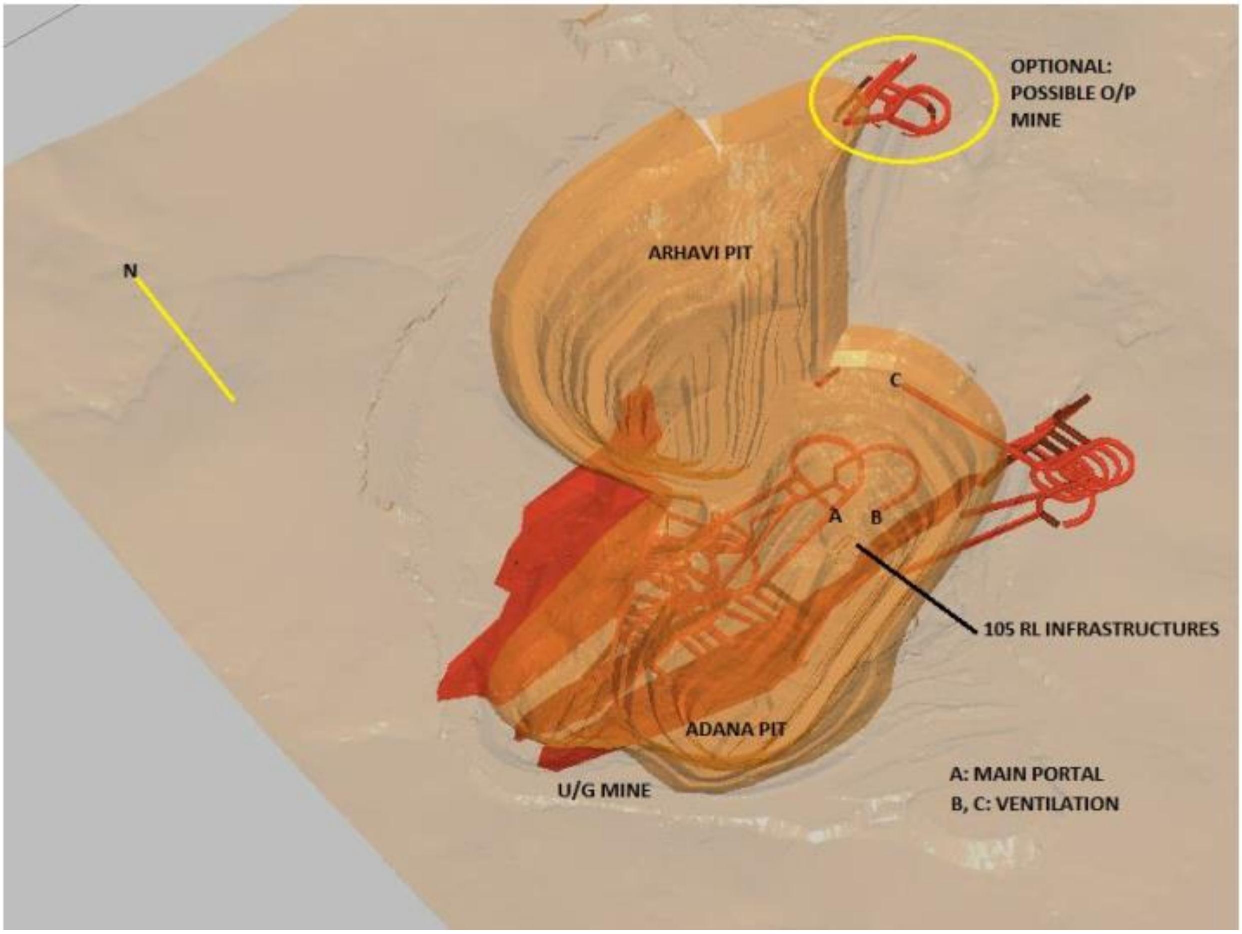


Figure 16: Potential underground mine development

The small one is located at the north-east of Arhavi pit. This mine could be an open pit according to optimization, so it is optional. The main underground mine is located beneath the Adana pit. The main mine has three sectors namely east, middle and west (Figure 15.0). A total amount of 1,119,000 tonnes of ore is planned to be produced from the main mine. Arhavi pit is backfilled up to 185 and 205 mRL to form two platforms for construction of surface facilities.

The main mine has a main entrance and two air return exits which are located at the benches of Adana pit. The main entrance is located at eastern side of Arhavi and Adana pits intersection. A protective barrier pillar of adequate thickness is to be left between the bottom of open pit and the underground mine. As the rock mass is very strong to strong class the thickness of this pillar should not be greater than 15 m in general. Production at underground mine will start from the bottom elevation and will commence upward. Therefore, the thickness of the barrier pillar will be important at the last stage of underground mining. It is suggested that the quality of backfill should be improved at this stage to minimize the effect of roof sagging, hence maximum amount of ore can be produced beneath the open pit bottom. As the surrounding rock behavior would be fully understood up to this stage necessary precautions can be taken to prevent any settlement at the open pit bottom. For this purpose, a few extensometers shall be installed to monitor any settlement at the surface. Water accumulation at the pit bottom should be prevented as the water may seep through cracks to underground mine. Appendix C presents the entire geotechnical studies

9.2 Construction Phase Impact Assessment

The effects of mine activities during the construction phase of the underground mine are considered in this section. The following subsections discuss those aspects of the project that could potentially interact with the environment and provides the rationale for their assessment.

The construction phase is considered to include remediation of previously disturbed areas, in particular the open pits and the existing tailings facility as well as construction of new infrastructure (mine portals, concrete plants, etc). The construction phase does not include development of the underground mine, since this will occur during the operations phase.

9.2.1 Air Quality, Noise, and Vibration

The effects of construction of the mine on ambient air quality for local residents will be limited due to absence of nearby settlements.

Construction (mine portals) will result in increased dust that may have a temporary effect on local vegetation. However, dust effects will quickly be mitigated by rainfall, and the effect of air emissions on vegetation is considered to be of low significance. Effects of dust on terrestrial fauna will likely be low, since terrestrial fauna will avoid the area due to construction noise and activity.

Noise, light and vibration effects will similarly be limited to terrestrial fauna that will naturally avoid the area due to human activity. Since little habitat exists in the Project area, and few individuals have been observed in the area, the effects on wildlife will be confined to the areas directly disturbed. The local wildlife populations are expected to be directly affected and the effects are predicted to be of low significance. Since the Project area is currently subject to human activity, terrestrial fauna, with the exception of scavenger species, will have already avoided the area.

Remediation of existing facilities (tailings disposal facility, open pits) will result in generation of dust, but as noted above, dust impacts are likely to be negligible.

Figure 17: Noise and vibration monitoring in the project area

9.2.2 Groundwater Quality

Remediation of existing pits and tailings areas are expected to improve groundwater quality at down gradient monitoring locations. Closure of the former tailings storage facility (TSF I) has resulted in migration of the groundwater impact, effectively eliminating any infiltration into the local groundwater. This has also eliminated potential migration of tailings water to surface water through this route. As a result, closure of TFS I has improve local groundwater and surface water quality.

Construction activities for infrastructure will take place in rocky areas, where there is no reported shallow groundwater zone. Ditching will be constructed before infrastructure is built, to limit potential migration to local groundwater and therefore the impacts of construction activities on groundwater quality are predicted to be of low magnitude and significance.

Fuel storage and explosives facilities area constructed on impermeable pads to limit infiltration to ground surface that could impact soil or water. Predicted impacts on groundwater are not expected to result in increases in any parameters over baseline conditions, and the significance of this activity is considered to be low.

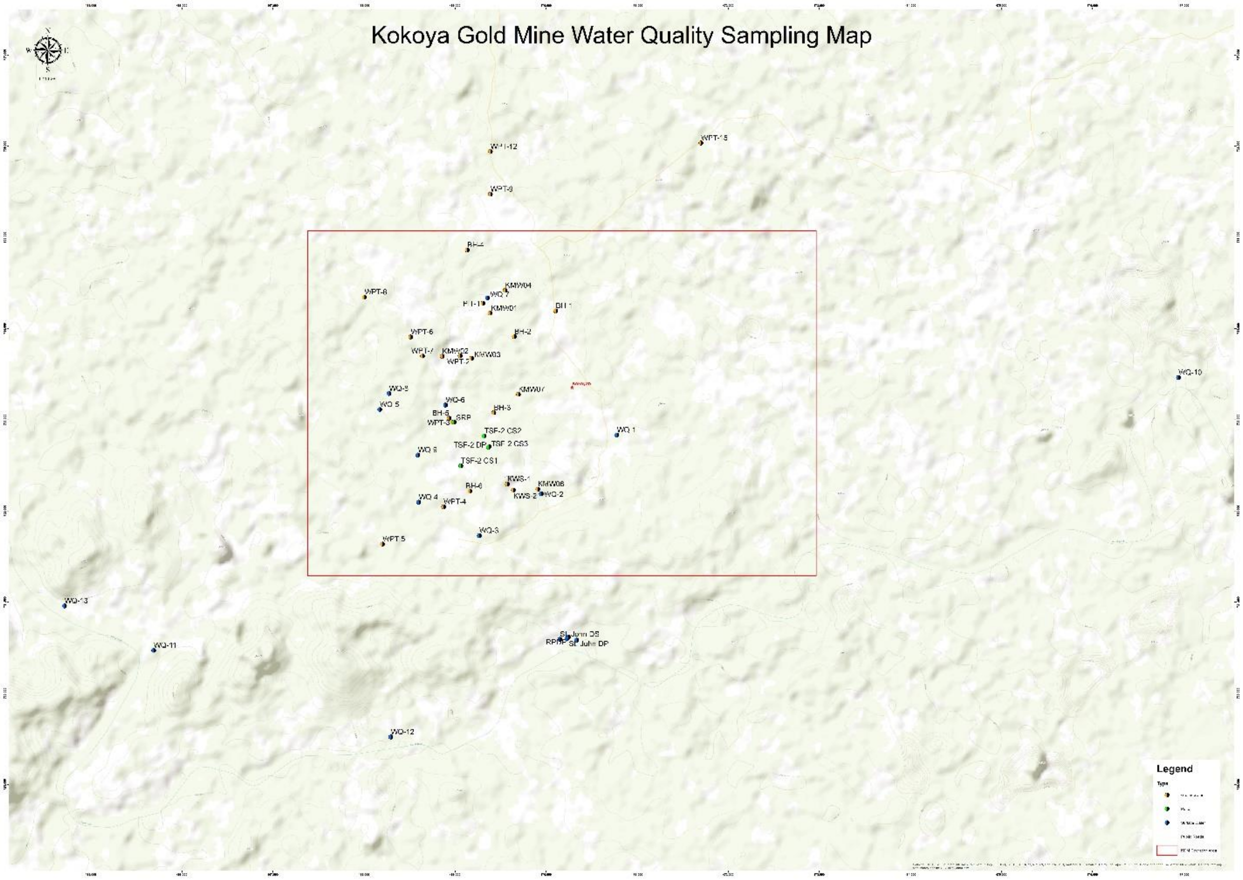


Figure 18: Ground water monitoring locations in the project area

9.2.3 Surface Water Quality

Site preparation and construction activities are not expected to increase the potential for erosion due to surface runoff from exposed areas and, to a lesser extent, by dust generated by construction activities since the site is already and active mining operations.

Ditching was constructed early in the Project to intercept runoff and re-direct the flows to settling ponds prior to release to area watercourses. As a result, minor increases in turbidity are expected during the construction phase. The general relief and sparse ground cover in the area, particularly on the steep slopes around the open pit area, result in local increases in turbidity in local surface water conditions. The effects of localized construction are anticipated to result in only incremental increases in turbidity in the St. John's River, given that the watershed areas upstream of the site that are currently affected by runoff and erosion during heavy rainfall events are a significant source of sediment during these events. Therefore, the magnitude of this impact is considered to be low.

The activity occurs only for a short period until the ditching and settling ponds have been constructed, and the effects are considered immediately reversible upon completion of construction. Therefore, effects of infrastructure construction are of low significance.

Fueling and servicing of vehicles will be in dedicated servicing areas, equipped with impermeable surfaces and spills containment and cleanup to prevent washout of any spilled materials to local watercourses. Construction personnel are trained in their proper use. While fueling will be an on-going activity during construction, this activity will be confined to designated areas with proper spills containment. Therefore, the impacts of fueling activities on surface waters are predicted to be of low magnitude and low significance.

Changes in water quality parameters are not predicted to occur during construction. Therefore, the change from baseline conditions is expected to be negligible, and the impacts on water quality are considered to be of low magnitude and low significance.

Changes in water quantity are not anticipated during the construction phase, since there will be no interference with groundwater flows or interception and retention of surface runoff (i.e., all runoff are currently routed around mining activities or collected in retention pond prior to release to the St. John's River). Therefore, the change from baseline conditions is expected to be negligible, and the impacts on water quantity are considered to be of low magnitude and low significance.

9.2.4 Soils and Sediments

Availability of soils is limited on the site, most of the site consists of exposed rocky areas, with soils confined outside of the mine study and and to the river valleys where little construction activity will take place. Good quality soils, where available, will be stockpiled and protected from erosion. Soils quality will be assessed prior to stockpiling against the background soil quality. Soils will play a critical role in the mine rehabilitation during the closure phase as such – stockpile of soil are managed properly during the LoM.

Impacts to soils and exposed ground during construction phase will be limited to spills of fuels and other substances. Fueling and servicing of equipment will take place in dedicated areas that will be equipped with spills containment and cleanup materials. Any contaminated soils in areas not planned for continued use during operations will need to be cleaned up at the end of the construction phase and placed in the appropriate sections of the current dumpsite. Therefore, effects on soils are considered to be of low magnitude, since there are no activities that could result in widespread degradation of soils, and any contaminated areas will be remediated.

Closure of the existing pits and tailings management area and decommissioning of existing site infrastructure will reduce any potential effects on sediment quality from these areas, improving sediment quality in those reaches immediately downstream of these facilities. Storm water runoff is collected in retention pond or diverted away for contact with mining operations prior to release to local streams, and effects on sediment quality will be minimized.

9.2.5 Biodiversity

Changes in biodiversity reflect the integration of a number of factors, including habitat alteration or loss, disturbance from noise and human activity, the effects of erosion and sedimentation, the spills of materials such as fuels and other chemicals, and seepage from waste rock and ore stockpiles. As such, effects on biodiversity represent the sum of the impacts considered this addendum.

Potential sources of effects on biodiversity include land preparation for construction, vehicle movements, vehicle servicing, erosion and runoff from rainfall events, and spills of fuels and lubricants.

Biodiversity is an interrelated concept. Changes in vegetation communities, for example, can cascade to effects on bird and mammal populations, as well as effects on aquatic communities through increased erosion. The 2015 Approved ESIA and ongoing compliance reporting have shown that with appropriate mitigation measures, the effects on vegetation communities have been minimized, in part due to the location of the mine and infrastructure in terrain that has little native vegetation due historical artisanal mining operations. This, in turn, has minimized the potential impacts on bird and mammal populations that are generally present in the areas outside of areas disturbed by the Project. By avoiding these areas, and by restricting hunting and fishing, these populations are likely to experience minimal impact from the Project. Terrestrial studies have also noted that no rare, threatened or endangered species have been recorded or observed in the Project area.

Biodiversity in local watercourses is naturally low due to the ephemeral nature of these watercourses. These streams naturally experience large fluctuations in flow, with attendant increases in TSS. The small area of the Project relative to the drainage areas of these streams indicates that the effects on the biodiversity of aquatic life are likely to be low.

Therefore, with mitigation measures, such as limiting the areas of disturbance, restricting vehicle speeds and hunting and fishing, minimizing erosion and sedimentation through maintenance of drainage and tailing storage, and containment and cleanup of spills, the effects on biodiversity are expected to be low.

9.2.5.1 Vegetation Communities

Construction of the mine and supporting infrastructure will not result in the removal of vegetation since most of the construction related to the mine are already where vegetation growth is non-existent. As well, much of the Project area has already been disturbed by surface mining activities, which has resulted in bare exposed rocky ground susceptible to erosion.

As noted in the assessment of existing conditions, the vegetation communities in the MDA areas, where these exist, are mainly dominated farmlands and secondary forests. The more diverse vegetation communities that occur at the river valleys and floodplains are outside of the areas where the mine or supporting infrastructure are located. The mine portal and supporting infrastructure will be constructed in an already disturbed area, and there will be minimal vegetation disturbance as a result of the new construction.

Similarly, the concrete plant site will be constructed in a previously disturbed area. Both the portal and concrete plant site are in areas where the natural landscape consists of exposed ground with no vegetation.

Erosion of soils during construction is expected to have little impact on these vegetation communities. As noted in the 2015 Approved ESIA, naturally accumulated alluvial materials that have eroded from higher elevations are deposited in the floodplains. These will continue to accumulate in the flood plains due to runoff and flooding of the rivers during peak flows that will deposit sediments along the floodplain.

The explosives warehouse and other chemical storage areas are located away from the more vegetation communities. Potential runoff from these areas are routed around and moved via conduits so that it is not in direct contact with the facility prior to discharge into water courses.

Disturbance of vegetation communities will be kept to a minimum. Vegetation communities not only stabilize soil conditions, minimizing erosion and sedimentation of streams, they also serve to filtrate surface runoffs. Due to the slow growth characteristics of forest vegetation, disturbed areas can take many years to re-establish vegetative cover.

During construction which will only be limited to mine portals and concrete plant, boundaries for infrastructure will be established, and all clearing and construction activities will be confined to these areas in order to minimize disturbance of adjacent vegetation communities. Boundaries will be clearly marked to minimize incursions of equipment. Existing facilities including the chemical storage; accommodation units; warehousing units will continue to be used for the underground mining operations.

9.2.5.2 Terrestrial Fauna Community

Effects on bird and mammal populations are considered with respect to the loss of habitat that may displace some individuals. Effects of dust from construction activities are expected to be of low significance since these will be confined to the Mine Study Area and there is already some dust creation due to open pit activities. Dust suppression will serve to minimize dust generated by construction equipment. Much of the construction dust will be suppressed via the use of water trucks and sprayers during construction, thus making dust generation very minimal.

Loss of habitat was due to the construction (surface mining) of Project infrastructure. The main areas of new construction will be the mine portal area, the concrete plant; and the underground development the portal and underground development consist mainly of exposed rocky habitat with no vegetation and as a result provide no foraging habitat for wildlife. No critical habitat has been identified in these areas, and the species recorded in the area would at most use the area as part of their larger foraging habitat prior to the construction of the surface mine. These areas have also been disturbed by current mining activities. As a result, there is little available habitat in these areas for wildlife, and the effect on wildlife from development of these areas is expected to be of low magnitude.

As noted, with the exception of potentially nuisance species such as insects, few species of birds or mammals have been observed in the areas, and the observations on wildlife indicate that these areas do not constitute critical habitat for local species.

Additional potential impacts could be through collisions with vehicles operating on site, as well as along transportation routes to the site. Vehicle speed controls may be necessary at certain times or along certain routes. As well, animals may be attracted to the site, where they may become nuisances and will need to be removed or exterminated. These effects can be mitigated by management of domestic solid wastes, and good housekeeping practices.

In particular, bird and small mammal populations are sparsely distributed due to the losses of individuals to predation by hunting prior to the start of mining activities in the area. As part of its, biodiversity management – the project prohibits the hunting of wildlife in the project area for source of protein.

With appropriate mitigation, the effects on bird and mammal populations from construction of the mine and associated infrastructure are expected to be low.

9.2.5.3 Aquatic Community of the St. John’s River

No impact is expected beyond the scale and size of the results of the open – pit mining activities. Current mitigation plans will continue to be enforces through the LoM.

9.3 Operational Phase Impact Assessment

During the operations phase, there is limited new construction, since most of the mine infrastructure necessary to operate the mine are place. Construction will be mainly limited to advancement of the portals, ramps and stopes as underground mining progresses. Supplies will continue to be brought to site throughout the operations phase. Waste rock and ore will be stockpiled and transported to the processing plant while waste rock will be processed for use as backfill in the underground workings.

9.3.1 Air Quality, Noise, and Vibration

Ventilation

The ventilation design for Kokoya Mine gives the intended ventilation method, layout, air quantities and the dimensions of the primary and secondary excavations to cater for the air qualities. Ventilation is the primary means of diluting and removing pollutants such as dust, gases, diesel exhaust emissions and heat.

Criteria used in this study

The ventilation design criteria used conforms to established international best practices to provide a safe and healthy underground working environment.

Ventilation design criteria

Design intake air temperature (wet bulb/dry bulb)	**25.0/30.0°C**
Design relative humidity	67 %
Design reject air temperature (wet bulb/dry bulb)	30.0/35.0°C
“Withdraw from working place” wet bulb temperature	32.0°C
Air to engine rated diesel power ratio at point of use	0.06 $m^3/s/kW$
Overall air leakage factor for the mine	12 %
Declines and intake air tunnels - air velocity	Max. 8 m/s
Return airways - air velocity	Max. 14 m/s
Unequipped air raises and raise bored holes - air velocity	Max. 22 m/s
Return air raises with emergency ladders, pipes & cables - air velocity	Max. 15 m/s
Friction factor – Declines and haulages & crosscuts (average blast)	0.012 $Ns^2/m4$
Friction factor – unequipped raises (rough blast)	0.02 $Ns^2/m4$
Friction factor – Ladder way, pipes & cables equipped raises	0.03 $Ns^2/m4$

Table 13: Ventilation design criteria

Determination of air requirement

The air requirements are based on the active mining fleet in KGM underground sections and other standard mine ventilation criteria:

- Sufficient air to dilute and remove diesel exhaust gases from the active fleet;
- Sufficient air to dilute and remove heat to provide a safe and healthy working environment without requiring refrigeration;
- Sufficient air to ventilate all places where persons work or travel;
- Sufficient air to provide a robust ventilation system to cater for any possible flammable gas occurrences; and
- Allowance for the inevitable leakages that occurs in mines.

An air to diesel power ratio of 0.06 $m^3/s/kW$ of rated power is applied. This ratio is internationally accepted and assumes modern machinery, a good maintenance regime, pollution control measures such as catalytic converters and diesel filters are used combined with low sulphur diesel fuel. The air requirements reflecting sizes of the mining fleet the for Kokoya underground are given in Tables 13 below.

Item	kw	No	kW
Truck	300	10	3000
LHD	200	5	1000
Mixer Trucks	80	4	320
Grader	125	1	125
Long hole rigs	110	1	110
Developments rigs	110	2	220
Utility vehicles	80	1	80
Explosives charges	80	1	80
Total kW diesel power in use			4935
Air requirements			
Diesel power in use x dilution rate in m³/s/kW			
4935	x	0.06	296
Leakage allowance	15	%	34
Allowance for ventilation of workshops etc.			25
Total airflow required m³/s			355

Table 14: Proposed mine equipment

Ventilation simulations

The mine ventilation circuit was modelled program to simulate airflow and temperatures in the mine.

They were modelled for a 'worst case' scenario, daytime mid-summer and mining at the deeper levels. The model also reflected the typical use of diesel-powered equipment. Allowances were made for the wetness of the rock surfaces exposed to air. It was assumed that there was no significant inflow of warm ground water. In the absence of any geothermal data for the mine, default rock settings were used.

Simulation Conclusions

The simulations show the following primary ventilation holings to surface are required:

Intake: The 5.0 m x 5.0 m portal and decline and a second intake holing (9.6 m²) in addition to the portal for fresh air will be required. This will also serve as a second emergency escapeway.

In addition, 9.6 m² intake drop raises covering all levels in parallel with the decline to reduce the air velocity in the decline to an acceptable level, particularly where there are 20 t trucks operating.

The natural air distribution for KGM underground in Figure 16.0

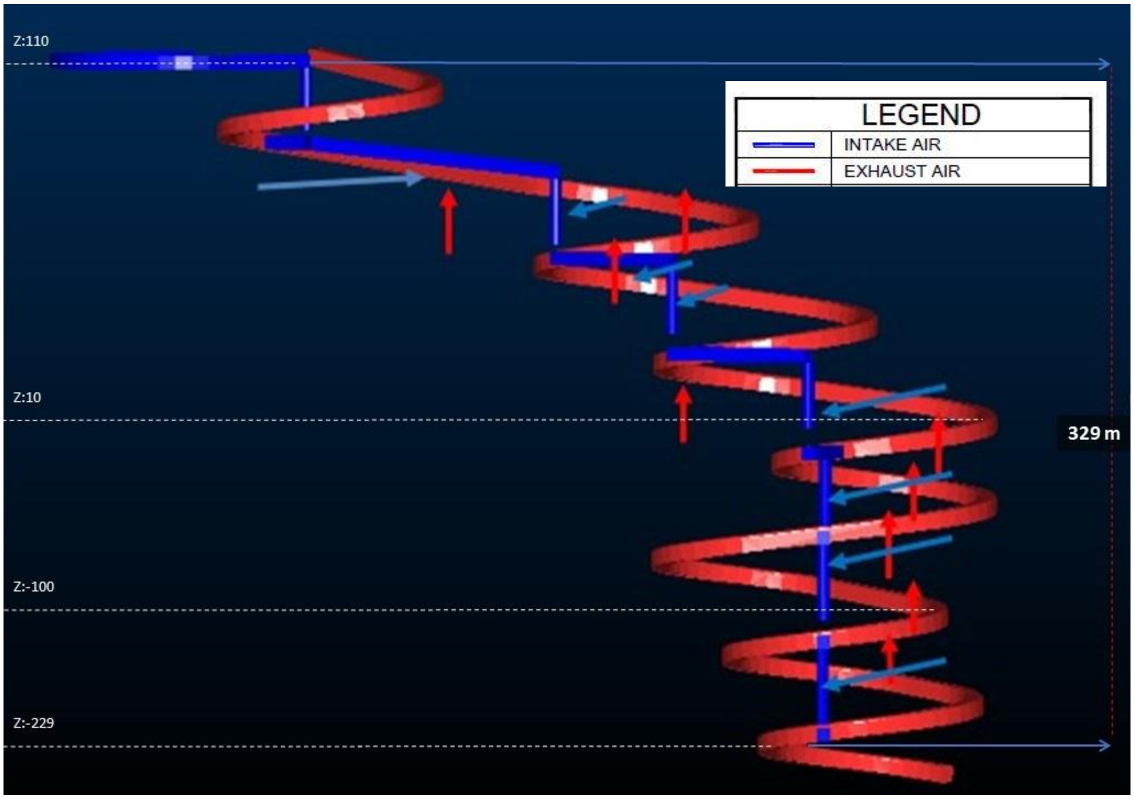


Figure 19: Schematic ventilation diagram

The intake ventilation system at Kokoya will consist of a single 5.0 m x 5.0 m decline from the portal.

Development ventilation

To cater for decline development, a fleet consisting of 1 x 50 t truck, 1 x 14 t LHD and a diesel drill rig/bolter will be used. Employing the convention for vehicles operating in a single major excavation area the formula used is: (Largest vehicle x 1) + (2nd largest x 0.75) + (other vehicles x 0.5).

İtem	Rated kW	Factor	kW
LHD	200 kW	1	200
Drill rig	110 kW	0.75	83
	Total kW	Ratio	283
283 kW × 0.06 m^3/s/kW = Minimum air required m3/s			16.98 m3/s

Table 15: Air requirement table for equipment

Once the decline has reached the particular level's sump position, development will normally stop or be done at a reduced rate. Development towards the ore body can commence and once the appropriate cubby has been mined, work on the drop raise form the level above can commence.

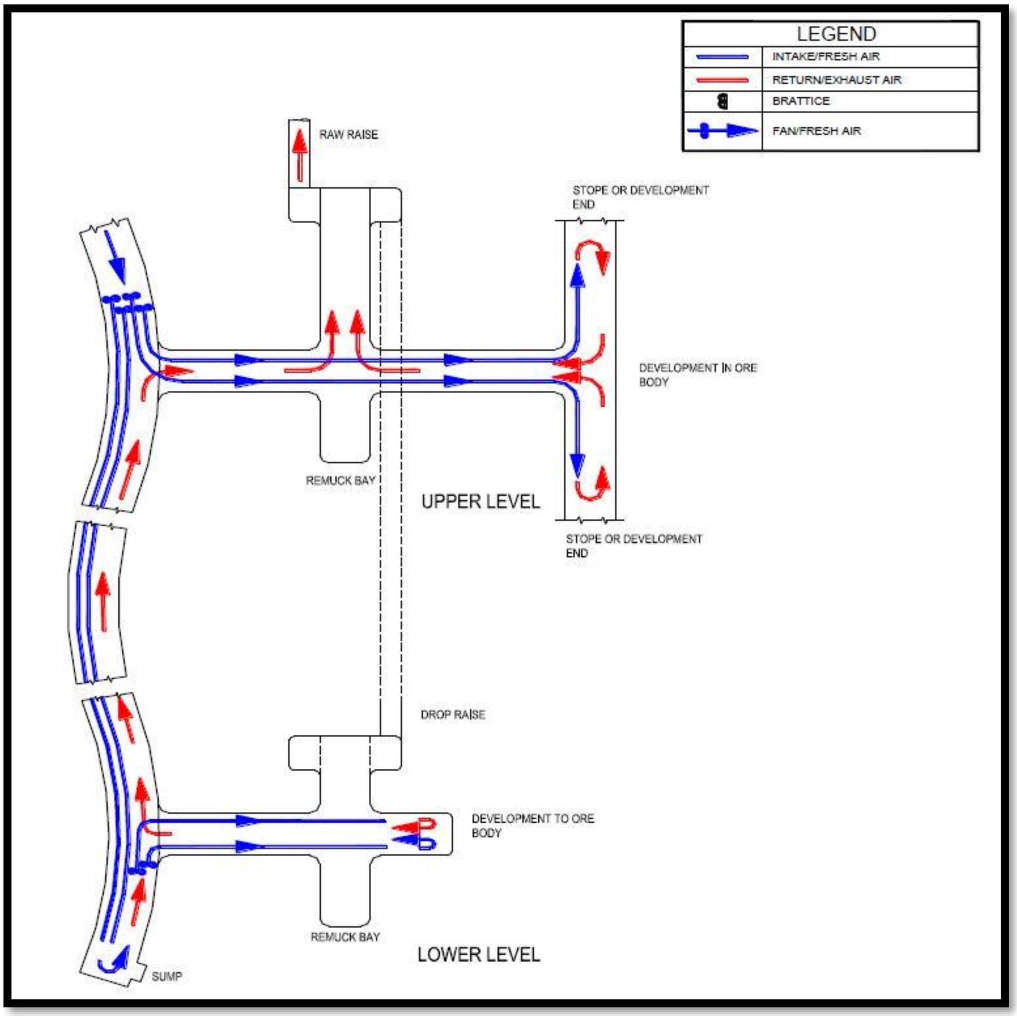


Figure 20: Ventilation layout for development to and in the ore body

The stopes will be ventilated by retaining the development and columns with the return air being extracted up the ventilation exhaust drop raises in the RAW system and out via the main fans. Some air will pass through the worked out stopes above. The amount will vary depending upon the degree of caving, the amount and location of waste fill and the state of the muck pile being extracted. As the mining is carried out on a retreat basis, the column will be gradually shortened until stoping is complete on the particular strike drive.

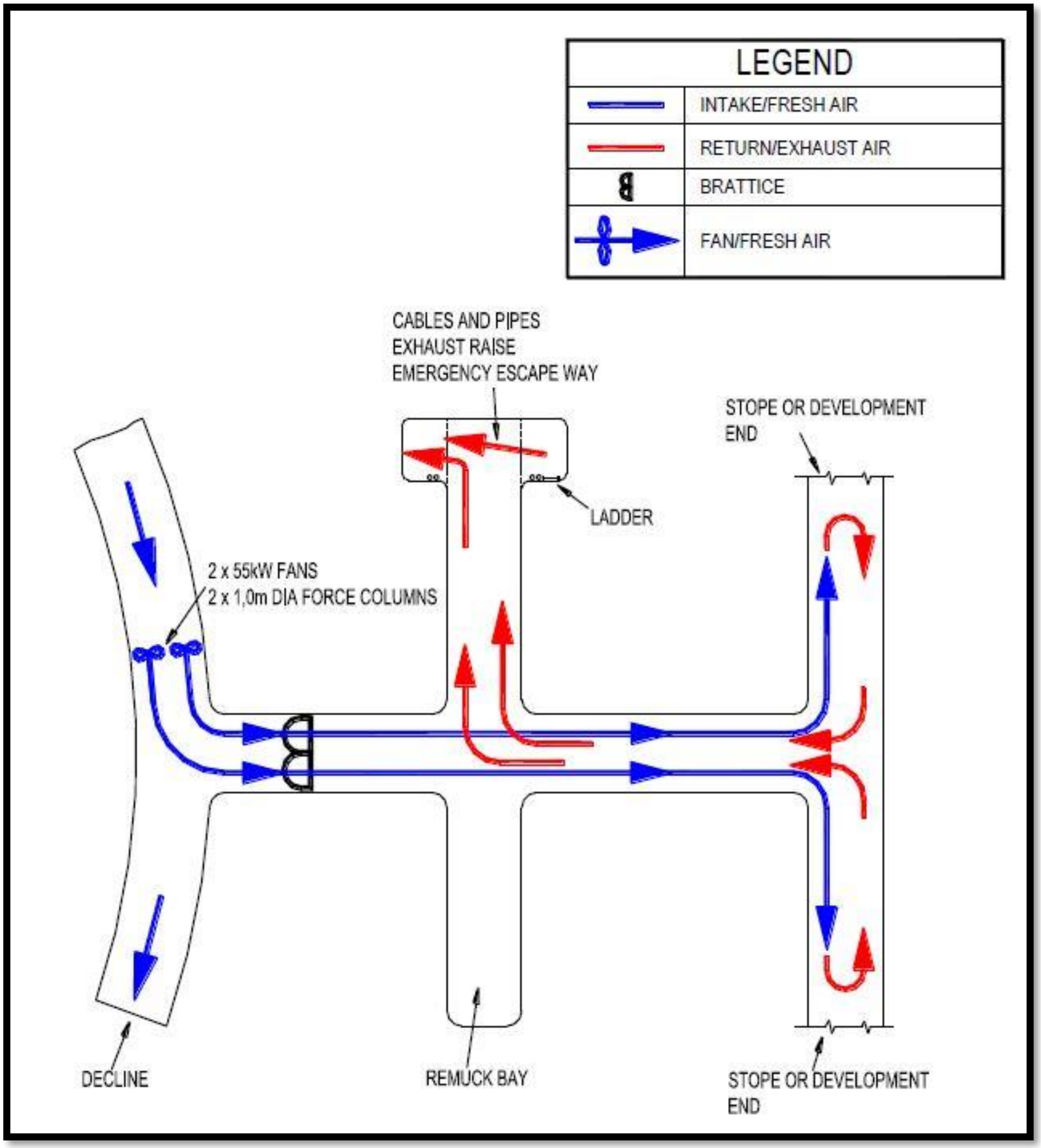


Figure 21: Ventilation layout for stopes

Fans

Due to the fact that varying amounts of air will be required for the 3 ore bodies as the ore bodies build up, achieve steady state production and wind down, it is recommended that Variable Speed Drives by installed as they will optimize air.

requirements and provide considerable power savings over fixed power fans. At KGM underground 1 x fan station with 2 fans operating and 1 fan on the eastern exhaust shaft.

Noise, light and Vibration

Noise, light and vibration are expected to continue at the mine site and will continue to result in terrestrial fauna avoiding the area. As noted earlier noise will be localized around the portal area and the accommodations complex, and will be associated mainly with ore and waste rock stockpiling, ore transfer, operation of the cemented rock backfill plant and operation of the electrical power station. Vibration will be localized to the portal area since all blasting will take place underground. Light will be a disturbance mainly during the night, when few animals will be around, thereby minimizing the impacts of light on local fauna. There are no human settlements nearby (Dean's Town is 1.4km to the north of the mine) that could be disturbed by light, noise or vibrations.

Aquatic habitats would not be affected by noise, light or vibrations.

9.3.2 Groundwater Quality

Advancement of ramps and shafts is not expected to affect shallow groundwater. The ramps and shafts will go much deeper and will avoid perched waters wherever possible since this would necessitate additional pumping of mine water (and treatment). Infiltration of rainfall will be negligible, since rainfall will be diverted around the mine portals.

Any groundwater that may seep into the mine workings will be removed during the mucking process.

Fuel storage areas are constructed on pads, with berming to contain any spills. Any leakage from fuel storage areas will therefore be contained and cleaned up before it can reach shallow groundwater aquifers.

The dumpsite site is constructed with compact laterite that prevents infiltration or seepage to groundwater. Mine portal area infrastructure will be constructed in areas of bedrock exposure which are outside of the areas where shallow groundwater occurs. These areas will have perimeter ditching to prevent off-site migration of any substances to adjacent groundwater aquifers. Therefore, the effects of mine operation on groundwater quality are predicted to be of low significance since there is no predicted change to groundwater quality.

9.3.3 Surface Water Quality

The mine operation will not result in the direct discharge of mine or process water to local surface water courses. All mine water or supernatant are first stored in the TSF II; prior to discharge. To ensure that processed water meet local discharge requirements – the processing plant; and gravity circuit units are designed to ensure that chemical dosing are minimum prior to releasing to the TSF II – which is backed up by a retention pond prior to final discharge into the outfalls – as a results of this process a surface water quality and quantity model has not been developed. The only other discharges from the site are surface runoff, which are routed around (storm water management) from those facilities where runoff could come into contact with contaminating substances, and the domestic wastewater treatment system.

Therefore, the effects on surface water quality and quantity during the operations phase will be primarily from:

- Runoff and seepage from waste rock and ore stockpiles and potential release to area watercourses.

- Runoff from cleared areas of the site; and
- Discharge of domestic water.

Currently, there is no indication that mine water will be generated during underground mining. However, if mine water is generated, water will be tested, and treated as appropriate. It is expected that the small volumes of water generated by use underground for mining will be removed during mucking.

Effluent discharge audits have shown that surface water is not impacted by mining operations since required parameters are within the discharge limits. (2018 – 2019 Effluent discharge audit results).

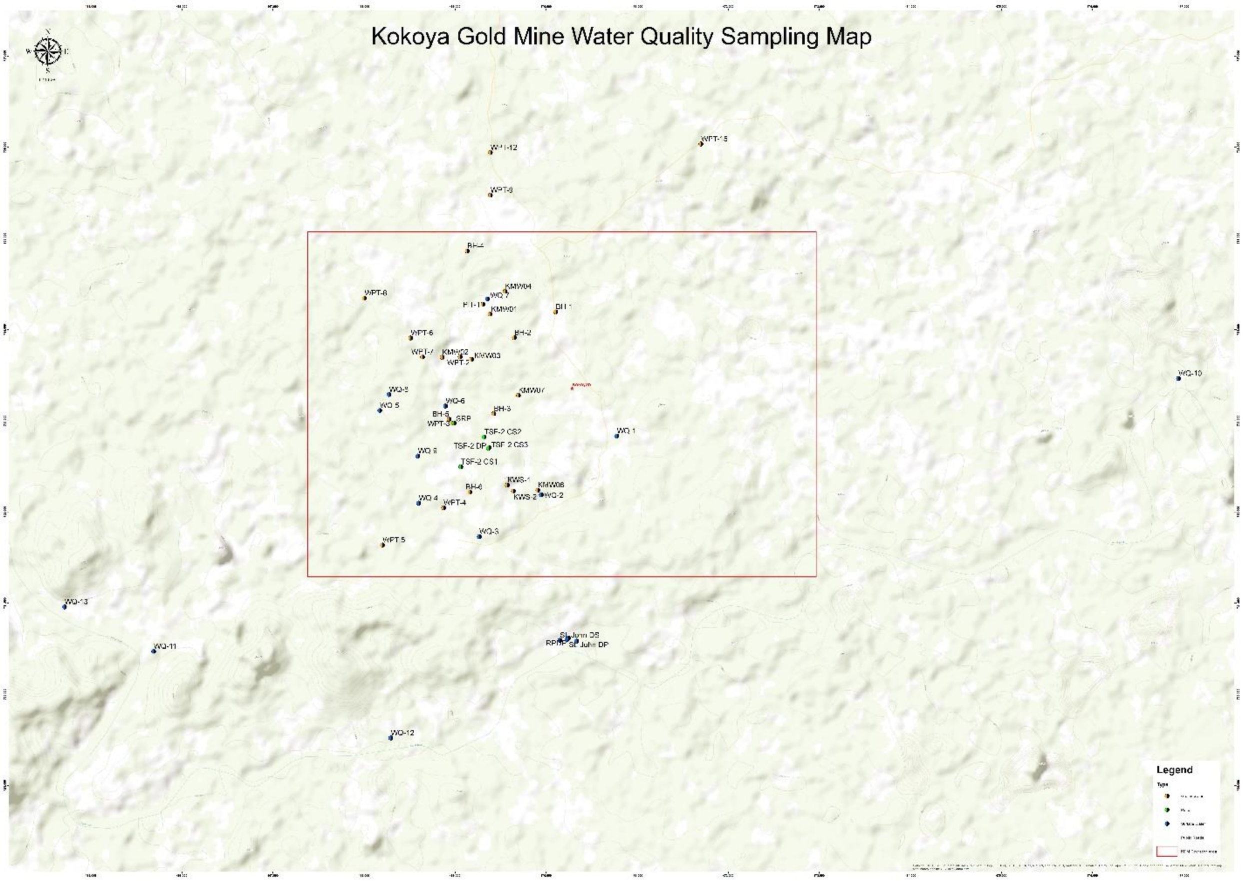


Figure 22: Kokoya water sampling locations

Since geochemical testing has shown that the waste rock to be produced during underground mining would be similar in composition to the existing waste rock, any seepage from the new waste rock pile is not expected to result in changes in water quality.

As noted, waste rock will be processed as cemented rock backfill and will therefore be stored at surface for only short periods of time. Seepage water will be directed to settling ponds prior to release. It is anticipated that water from these sources will not need additional treatment prior to release to surface water courses. However, water quality will be monitored during operations, and if higher concentrations that could result in potential impacts are noted, then additional treatment measures will be implemented as appropriate. Therefore, the effect of runoff from the waste rock and ore stockpiles on water quality is expected to be of low significance.

Water from domestic use will be treated prior to discharge and with appropriate treatment will not result in impacts on receiving waters. Domestic wastewater will be stored in the septic tank and sent to treatment and will be treated prior to discharge.

Surface water quality in streams could be affected by runoff and spills. Sediment controls and spills containment measures implemented during construction will need to be maintained during operations.

9.3.4 Underground Mine, Waste Rock and Stockpile

Surface water is not predicted to be affected by underground mine water since surface mining activities have indicated there is no free water in the rock. Waste rock would be either directly re-used underground as backfill or would be transported to the waste rock pile at surface for processing into cemented backfill. Ore will be transported to surface and deposited at the process plant. Drainage from the surface waste rock and ore stockpiles will be collected by ditches and directed to settling ponds for treatment prior to release. Therefore, effects of any mine water would be mitigated by collection and treatment. Since there is no predicted change in water quality, the significance of seepage from the waste rock and ore stockpiles is low.

Flows in existing water courses will remain unimpeded since there are no impoundments or surface water abstraction facilities. Rainfall runoff will be collected by ditching and treated in settling ponds prior to release to local streams. As a result, there are no predicted changes in stream flows and the significance of this impact is considered to be low.

Radiology

MNG has been conducting soil sampling campaign starting even before the its operation. Although main purpose of the conducting these analyses is get the gold content of the soil of related area, different elements of the soils including Thorium (Th) and Uranium (U) are also analyzed. Figure below represent the soil sample locations and Kokoya Underground Operation.

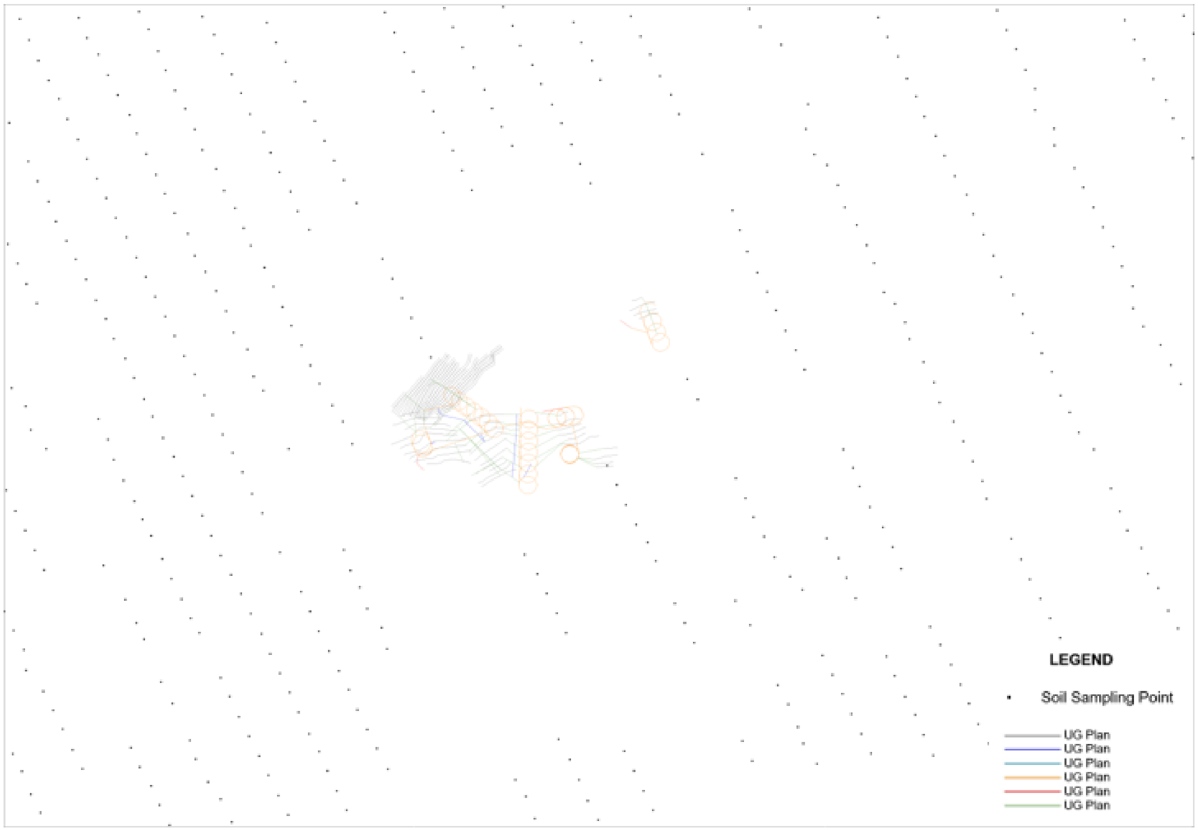


Figure 23: Kokoya Underground Operation Area Soil Sampling Points

According to MNG records and also can be seen in the figure above there are 303 soil samples around the underground operation. Average and maximum mass concentrations of Th and U values can be seen in the table below.

Element	Average (ppm)	Maximum (ppm)
Thorium	12,91	31,6
Uranium	2,64	8,13

Table 16: Radiation associated with underground mining

IFC Environmental, Health and Safety Guidelines for Mining, Section 2.2 Occupational Health and Safety Performance, Table 3 provides ionizing radiation exposure guidelines for mining workers. The limit is 50 mSv/year for single year exposure and 20 mSv/year for five consecutive years exposure. If it is corresponded to Uranium, 20 mSv/year can be found as equilibrium 555 ppm U (https://www.wise-uranium.org/ruxfr.html). This shows that there is no radiation risk for the Kokoya UG ore and waste rock.

(https://www.ifc.org/wps/wcm/connect/595149ed-8bef-4241-8d7c-50e91d8e459d/Final%2B-%2BMining.pdf?MOD=AJPERES&CVID=jqezAit&id=1323153264157)

9.3.5 Maintenance and Fuel Storage

Fueling and servicing of mine vehicles at surface will take place in dedicated areas. These include hard surfaces to reduce infiltration of fuels and lubricants into soils, and spills cleanup materials to contain any spills. The system will discharge to an emergency sump. As a result, there are no anticipated water quality effects from fueling and maintenance areas, and the effects of these operations on surface water quality are judged to be of low significance. Underground equipment will be serviced underground by dedicated fueling vehicles that will be equipped with spills containment and cleanup materials.

Enclosed maintenance areas will have sumps to retain any spilled materials. As a result, there is no expected release of harmful substances to surface waters and the effects on surface water quality are considered to be low.

9.3.6 Chemical Storage Management

A chemical storage facility is designed and managed onsite. The facility maintains a separate permit for the importation, transportation and storage management of cyanide that are used int the processing of the ore. The criteria for the chemical storage management used during the surface mining operations shall remain enforced until altered or redesigned by the EPA.

There's no anticipated change to the use of chemicals during the ore processing as a result, there is no expected release of harmful substances in the project area and the effects from chemical management are considered to be low.

9.3.7 Storm Water

Storm water are routed from site infrastructure through a system of drainage ditches that direct flows around mine activities. Non-contact storm water will be treated in settling ponds prior to release to adjacent surface waters.

Storm water in contact with potential sources of contaminants (e.g., in fueling areas) will initially be pumped to the settling pond to allow for settling of particulates prior to discharge to surface waters. As such, storm water quality is not expected to be altered due to Project activities, and the effects of release of storm water on surface water quality are considered to be low.

Storm water collection systems are not expected to alter flows in the adjacent streams. Runoff will be intercepted by ditches and sumps but released after settling. As a result the stream flow regime may be moderated slightly as the peak discharge will be decreased, but the period over which discharge occurs would be slightly extended as the settling ponds drain (i.e., the storm hydrograph will be slightly flattened and extended).

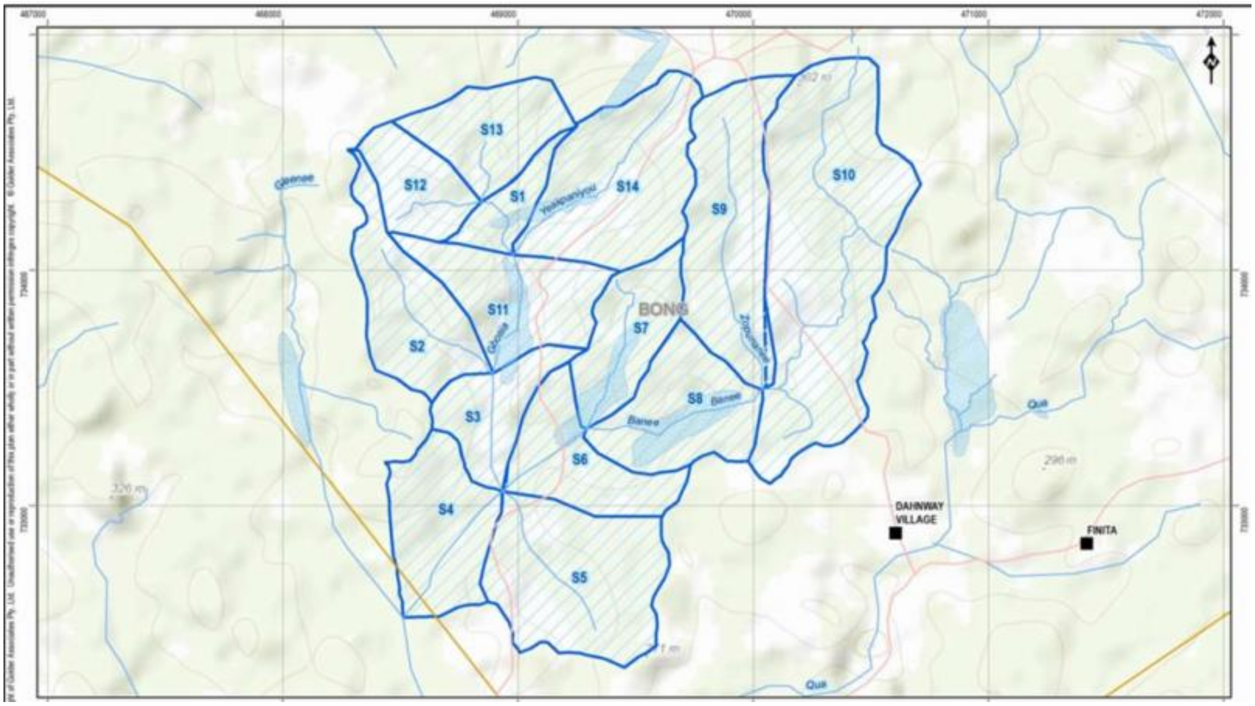


Figure 24: Storm water collection system within the mining area

9.3.8 Biodiversity

Effects on biodiversity during operations are expected to be confined to continued noise disturbance, and the ongoing loss of some habitat. As noted earlier, the Project infrastructure is located primarily in areas of exposed rocky substrates which have been disturbed previously by the surface mining activities and where critical habitat has not been identified and that provide limited foraging habitat for the species recorded in the area. Mitigation measures inherent in the Project design will minimize effects of rainfall runoff (erosion and sedimentation in streams) and the effects of spills and leaks of fuels.

Few biodiversity enhancements are available in these habitats, and the main measures to affect biodiversity are those mitigation measures that minimize the impacts on terrestrial and aquatic ecosystems.

9.4 Closure Phase

During the closure phase, the mining operations cease and infrastructure that will not be required in post-closure is decommissioned. Salvageable equipment is removed; all fuels and reagents removed, and any contaminated soils are remediated.

Site reclamation will be undertaken, and includes re-contouring of the site, construction of post-closure drainage systems, and reclamation of disturbed areas. Soils stockpiled during the construction phase, if any, will be used for site reclamation.

9.4.1 Air Quality, Noise and Vibration

Effects during closure will be similar to those during construction, as the site is decommissioned and include dust from demolition activities, and noise from equipment. In post-closure, the effects on air quality, noise, light and vibration are expected to be eliminated. As a result, species displaced by activity on the site are expected to return, as suitable habitat regenerates.

9.4.2 Water Quality and Quantities

During closure, surface runoff will be directed around any remaining infrastructure. Natural drainage will be restored to the extent possible. Since the mine workings will be compacted, no impact of mine water on surface water is predicted. The existing waste rock will be used as backfill in the mine during operations. Remaining waste rock from the backfill will be rehabilitated. The site will be graded, any contaminated soils (*e.g., potentially contaminated soils around fueling / servicing areas*) will be removed and placed in the landfill, and ditching directed to settling ponds that will drain naturally to surface waters. Once ground conditions are stabilized, there will be no further predicted erosion to surface waters, and TSS levels are expected to revert to pre-development conditions.

Fuels, lubricants and reagents will be removed from the site, and therefore there is no potential for seepage or leakage to surface or groundwater.

Groundwater wells not required for future monitoring will be sealed or handed to local communities for additional water access points. Therefore, conditions during closure and into post-closure are not predicted to result in changes in surface water or groundwater quality or quantity, and the effects are considered to be of low significance.

9.4.3 Soils and Sediments

Soils nutrient levels are generally poor, and addition of nutrients or soil amendments may be necessary to promote regeneration of vegetation cover in those areas where vegetation existed prior to Project development. Soils stockpiled during construction, if any, will be used for site reclamation in those areas where natural soils were disturbed. The barren rocky nature of the site indicates that only very limited areas contained soils and reclamation would be minor.

Soils contaminated during construction and/or operations (e.g., temporary waste rock and ore stockpiles, fueling and servicing areas) will be tested and remediated as required.

Sediments are not expected to be affected during mining. Closure activities that protect surface water quality will also protect sediment quality.

9.4.4 Biodiversity

The closure phase offers opportunities to mitigate some of the habitat destruction that occurred during the construction and operations phases by means of site rehabilitation. However, as noted, most site activities take place in areas of barren, rocky soils with limited or no vegetation.

There is potential for effects on vegetation communities through re-use of contaminated soils stockpiled during the construction phase. Selection of soils for re-vegetation as noted needs to be based on concentrations of metals in soils. Suitability of soils shall be based on site-specific uptake studies using local plant species, or through comparison with published literature thresholds similar in regional context. Since existing soil concentrations exceed guidelines in some areas that indicate potential anthropogenic influences, soil testing and separation may be required prior to re-use. Soils with higher concentrations may be suitable for subsurface applications, beyond the root depths of sensitive plant species.

Any spills of fuels would be remediated before revegetation is undertaken.

9.5 Summary of Impact Assessment

The assessment of potential risks to environmental components has indicated that with proper maintenance of pollution controls, effects on the environment can be minimized and contained within the Mine Study Area. In this case, the potential effects on the environment, which are the ultimate receptors of any changes to the environment, would be limited to physical disturbance of the environment. As such, the effects can be reasonably mitigated upon environmental restoration after closure. The potential environmental impacts are summarized in the Tables below.

Summary of Impacts – Construction Phase

Activity	Environmental Component	Potential Impact	Extent	Duration	Frequency	Reversibility	Magnitude	Significance	Mitigation	Residual
Site preparation and construction of infrastructure	Air quality	Fumes and exhaust from equipment. Dust generation.	Confined to Mine Study Area.	Limited to construction phase.	Continuous during construction.	Immediately reversible upon cessation of construction.	Low: Local exceedance of particulate matter is not expected.	Low: Emissions will be temporary during construction and intermittent. Effects are immediately reversible.	Proper maintenance of equipment will reduce emissions.	None
	Noise	Noise from construction equipment.	Confined to Mine Study Area.	Limited to construction phase.	Nearly continuous during construction.	Immediately reversible upon cessation of construction.	Low: No human settlements in the area.	Low: No human settlements in the area. Animals will avoid the area due to noise and activity.	Worker protection, as per national regulations.	None
	Soils	Soil removal	Confined to parts of the Mine Study Area where infrastructure is sited.	Extends through construction phase.	One-time effect.	Reversible in the medium term, when site restoration occurs during closure.	Low: Small areas will be affected. Limited soils in Project area.	Low: Effects will be confined to local areas within the mine footprint where there are natural soils.	Soil, where available, will be stockpiled and used for site restoration upon Closure.	None
	Water Quality	Runoff of soils to streams. Spills of fuels and lubricants from vehicles and stationary equipment.	Confined to Mine Study Area.	Can occur throughout construction.	Limited to rainfall events during wet season.	Reversible since TSS will be flushed out of the system during peak flows.	Low: Local streams are highly turbid during runoff events.	Low: Effects will be small and localized. Streams are highly turbid during runoff events. Spills will be contained and cleaned up.	Spills containment and designated servicing areas will reduce potential for impacts on water quality.	None

	Groundwater	Site preparation activity effects on groundwater.	Confined to Mine Study Area.	Occur throughout construction	Single occurrence in each area as sites are prepared.	Not reversible	Low: site infrastructure is located in upland areas with no shallow aquifers.	Low: Groundwater occurs in shallow aquifers. Drainage systems will divert runoff upslope areas before flows reach aquifers.	Construct and maintain ditching early in construction phase.	None

Activity	Environmental Component	Potential Impact	Extent	Duration	Frequency	Reversibility	Magnitude	Significance	Mitigation	Residual
Remediation of existing open pits and tailings facility	Terrestrial Biota	. Effects of hunting on local populations. Effects on small mammal and bird populations.	Mine Study Area.	Throughout construction and operations phases.	Confined to one-time removal.	Reversible in most areas upon closure.	Low: small areas (<20%) of habitat affected locally.	Low: limited habitat occurs in areas where Project is located. Animals displaced will find suitable habitat nearby. Restriction on hunting will protect sensitive wildlife populations.	Rehabilitation upon closure will restore most affected habitats. Restrictions on hunting	None
	Aquatic Biota	Effects of runoff on aquatic biota.	Mine Study Area.	Confined to construction phase.	Confined to rainfall events during wet season during construction.	Reversible as TSS will be flushed out during high flows.	Low: small areas contributing runoff. <20% change in benthic community.	Low: erosion is a significant factor in these watersheds. Biota is adapted to periods of high turbidity. Spills will be cleaned up.	Surface drainage and sediment control. Dedicated servicing areas for construction equipment.	None

	Air Quality	Fumes and exhaust from equipment. Dust generation.	Mine Study Area.	Limited to short construction period.	Single occurrence	Immediately reversible upon completion of construction.	Low: dust generated from small area over short period of time.	Low: short duration, and confined extent limit any effects of earth movement. Positive impact on downstream water quality.	None	None

Activity	Environmental Component	Potential Impact						Significance	Mitigation	Residual
			Extent	Duration	Frequency	Reversibility	Magnitude			
	Noise	Noise from construction equipment.	Mine Study Area	Limited to construction phase	Continuous during construction	Immediately reversible upon cessation of construction.	Low: area is already disturbed.	Low: area is already disturbed by mining activities. Local fauna already avoid the area.	None	None
	Soils	Reduction of metals and others compounds.	Mine Study Area	Persist long into post-closure	Confined to one-time remediation.	Not reversible.	Moderate: improved soil quality.	Moderate positive: improved soil quality will protect vegetation, terrestrial and aquatic life from exposure to harmful substances.	Erosion protection during remediation. Monitoring required to verify efficacy of remediation.	None
	Water Quality	Reduction in loading of some metals, suspended solids, nitrates and sulphate	Mine Study Area	Persists long into post-closure	Confined to one-time remediation	Not reversible.	Moderate: loadings expected to be reduced	Moderate positive: improved water quality will benefit aquatic life downstream.	Erosion protection during remediation, Monitoring will be required to verify efficacy of remediation.	None

	Groundwater	Reduction in loading of some metals, suspended solids, nitrates and sulphate.	Mine Study Area	Persists long into post-closure	Confined to one-time remediation	Not reversible.	Moderate: reduced impacts on groundwater	Moderate positive: reduced impacts on local groundwater sources, with potential benefits to surface water.	Monitoring will be required to verify efficacy of remediation.	None
	Vegetation	Restoration of habitats lost during ope pit mining operations	Site Study Area.	Persist into post-closure.	Confined to one-time remediation	Not reversible	Low: small areas of potential habitat affected	Low positive: small areas of habitat returned to natural use. May require extended time period to revegetate.	None required	None

Table 17: Summary of Impacts - Construction Phase

Summary of Impact – Operations Phase

Activity	Environmental Component	Potential Impact	Extent	Duration	Frequency	Reversibility	Magnitude	Significance	Mitigation	Residual
Underground mine							confined areas.	the operations phase.		
	Vegetation	Dust from vehicles and spills of fuels and lubricants.	Confined to local areas in the Mine Study Area.	Impacts extend up until rehabilitation during closure.	Confined to one time.	Reversible upon closure for most areas with remediation of affected areas.	Low: small areas (<20%) will be affected by spills.	Low: small areas of vegetation affected by spills. Any affected areas will be remediated.	Dust control on roads. Spills cleanup.	None
	Terrestrial Biota	Removal of habitat through noise.	Mine Study Area.	Throughout operations phase.	Confined to one time removal.	Reversible in most areas upon closure.	Low: small area (<20%) of habitat affected.	Low: no additional habitat loss during operations.	Limit new incursions into adjacent habitats. Enforce vehicle speeds.	None

	Aquatic Biota	Effects of runoff on aquatic biota.	Mine Study Area.	Confined to construction phase.	Confined to rainfall events during wet seasons.	Not reversible.	Low: effects of sedimentation will be mitigated. <20% of benthic community affected.	Low: erosion and runoff will be controlled.	Regular maintenance of sediment control measures. Immediate spills cleanup	None
	Air quality	Dust from ore stockpile.	Mine Study Area.	Throughout operations phase.	Intermittent.	Reversible upon closure.	Moderate: air quality will be met within 1 km of the mine.	Low: Effects of dust will be confined to the Project area. No human settlements within the area.	None.	None
	Noise	Noise from loading and off-loading	Mine Study Area	Throughout operations	Intermittent	Reversible upon closure	Low: Noise will be low relative to operating plant	Low: wildlife currently avoids the area due to noise and activity. No human settlements in the area.	None	None

Activity	Environmental Component	Potential Impact	Extent	Duration	Frequency	Reversibility	Magnitude	Significance	Mitigation	Residual
	Soils	Dust from loading/offloading. Seepage from stockpile.	Mine Study Area	Throughout operations.	Dust will be continuous. Seepage is intermittent, depending on precipitation.	Reversible upon closure	Low: Ore has low ARD potential.	Low: Seepage from stockpile will be collected and routed to treatment. Ore has low ARD potential.	Stockpile will be a constructed pad to minimize seepage to soils.	None

	Water Quality	Runoff and seepage from stockpiles.	Confined to Mine Study Area	During operations.	Intermittent during open water period in operations	Reversible upon closure	Low: Ore has low ARD potential. No change from baseline water quality	Low: Runoff and seepage will be intercepted by drainage ditches. No effect expected on water courses.	Maintain ditches in good order during operations.	None
	Groundwater	Seepage from stockpiles.	Confined to Mine Study Area	During operations.	Intermittent during operations	Reversible upon closure	Low: No change in groundwater quality.	Low: No groundwater aquifers are known in the area. Ditches will intercept runoff	Maintain ditches in good order during operations.	None
	Terrestrial Biota	Loss of habitat	Confined to Site Study Area	Throughout operations	Continuous during operations.	Reversible upon closure	Low: Lack of vegetation limits habitat for terrestrial biota. <20% of habitat affected.	Low: Exposed rocky habitat is not preferred habitat for most terrestrial species. Small area is affected.	Prevent incursions into adjacent natural areas.	None

Table 18: Summary of Impact - Operations Phase

Impact Summary Closure and Post – Closure

Activity	Environmental Component	Potential Impact	Extent	Duration	Frequency	Reversibility	Magnitude	Significance	Mitigation	Residual
TSF I & 2	Addressed in Addendum ESIA									
	Air quality	There are no sources to the atmosphere during closure and post-closure once mining has ceased								
	Noise	There are no sources of noise during closure and post-closure once mining has ceased.								
	Soils	Restoration of habitat.	Mine Study Area.	Throughout Post Closure.	Continuous	Not applicable.	Low: Habitat in footprints of infrastructure will be restored.	Low: Small areas of habitat lost during construction will remain.	None	None

	Water Quality	Runoff from plant site.	Mine Study Area.	Throughout Post- Closure.	During dry season	Not applicable.	Low: Ditching on site and re-vegetation will reduce erosion.	Low: Sediment control measures will reduce runoff. High background turbidity in local streams from topography.	Regular inspections and maintenance of ditches and sedimentation controls.	None

Activity	Environmental Component	Potential Impact						Significance	Mitigation	Residual
			Extent	Duration	Frequency	Reversibility	Magnitude			
							will be restored.			
	Aquatic Biota	Runoff from plant site.	Mine Study Area.	Throughout Post Closure.	During dry season	Not applicable	Low: No changes in water quality or quantity predicted.	Low: Areas affected will be closed, ditching will be maintained, surface sources such as waste rock and ore stockpiles will be removed.	Inspect and maintain storm water diversion system.	None
Underground Mine	Air quality	There will be no sources to the atmosphere from the underground mine upon closure.								
	Noise	There will be no sources of noise upon closure activities. During closure, noise will be similar to levels during construction.								
	Soils	There are no sources of impact to soils during post-closure. Soils will be re-used during closure for site rehabilitation.								

	Water Quality	Runoff from portal area.	Site Study Area	Throughout Post-Closure	Intermittent	Not reversible	Low: No changes predicted in stream water quality	Low: Ditches will divert runoff around portals. Disturbed areas will be remediated upon closure. No mine water expected from underground working	Maintain ditches in good order.	None
	Groundwater	Mine may affect local groundwater quantity.	Mine Study Area	Throughout Post-Closure	Intermittent	No reversible	Low: No change predicted in groundwater quality	Low: any seepage into mine not express to surface waters	None	None
	Vegetation	No interaction with vegetation communities is anticipated from the underground mine.								
	Terrestrial Biota	Loss of habitat area.	Mine Study Area.	Throughout Post-Closure.	Continuous	Not reversible.	Low: Small area of habitat affected by portal.	Low positive: Small area of habitat lost at portal will be restored.	None	None

Table 19: Summary of Impact - Closure and Post Closure Phase

Summary of Impact – Closure Phase

Activity	Environmental Component	Potential Impact	Extent	Duration	Frequency	Reversibility	Magnitude	Significance	Mitigation	Residual

	Aquatic Biota	Runoff from portal area.	Mine Study Area	Throughout Post-Closure	Intermittent	Not reversible	Low: No changes predicted in stream water quality	Low: Ditches will divert runoff around portals. Disturbed areas will be remediated upon closure. No mine water expected from underground working.	Inspect and maintain storm water diversion system	None
Servicing and Maintenance Facilities	Air quality	There are no sources of atmospheric emissions during closure and post-closure once dismantling is completed. Atmospheric emissions sources during closure are similar to construction as dismantling begins, and areas are remediated and reclaimed.								
	Noise	There are no sources of noise during closure and post-closure after completion of closure operations. Noise sources during closure are similar to construction as dismantling begins, and areas are remediated and reclaimed.								
	Soils	Contaminants from operations.	Mine Study Area.	Throughout Post-Closure.	Continuous	Reversible upon cleanup of contaminated areas.	Low: Contaminated areas will be cleaned up upon closure.	Low: Sources of contamination will be removed.	Remediation and appropriate disposal.	None
	Water Quality	Runoff from site areas.	Mine Study Area.	Throughout Post-Closure.	Continuous	Reversible upon cleanup and revegetation of site.	Low: no change in water quality is predicted.	Low: Revegetation of affected areas and ditching will divert runoff. Cleanup of contaminated areas will remove sources of contamination.	Remediation and appropriate disposal.	None
	Groundwater	Contamination of ground water.	Mine Study Area.	Throughout Post-Closure.	Continuous	Reversible with cleanup of contaminated areas and revegetation.	Low: no change in groundwater quality is predicted.	Low: Effects on groundwater expected to be minimal due to ditching, revegetation and cleanup.	Remediation and appropriate disposal.	None

Activity	Environmental Component	Potential Impact						Significance	Mitigation	Residual
			Extent	Duration	Frequency	Reversibility	Magnitude			
	Vegetation	Contamination from operations.	Mine Study Area.	Throughout Post-Closure.	Continuous	Reversible with cleanup of contaminated areas.	Low: Contaminated areas will be remediated. Re-vegetation will restore habitat.	Low: Vegetation will be restored through cleanup of contaminated areas and rehabilitation.	Restoration and remediation with appropriate disposal.	None
	Terrestrial Biota	Habitat	Mine Study Area.	Throughout Post-Closure.	Continuous	Not applicable.	Low: Small areas of habitat will be restored.	Low: Areas of habitat restored are small relative to local availability of similar habitat.	Site restoration	None
	Aquatic Biota	Runoff	Mine Study Area.	Throughout Post-Closure.	Intermittent	Reversible upon cleanup and revegetation of site.	Low: No changes predicted in stream water quality.	Low: Revegetation of affected areas and ditching will divert runoff. Cleanup of contaminated areas will remove sources of contamination.	Site restoration and remediation with appropriate disposal.	None
Accommodations and Offices	Air quality	There are no sources of atmospheric emissions during closure and post-closure once dismantling is completed. Atmospheric emissions sources during closure are similar to construction as dismantling begins, and areas are capped or remediated.								
	Noise	There are no sources of noise during closure and post-closure after completion of closure operations. Noise sources during closure are similar to construction as dismantling begins, and areas are capped or remediated.								

	Soils	Contaminants from operations	Mine Study Area.	Closure.	Throughout Post-Closure.	Reversible upon cleanup of contaminated areas.	Low: contaminated soils will be contained in the solid waste storage area	Low: Contaminated areas will be cleaned up upon closure.	Sources of contamination will be removed.	None
	Water Quality	Runoff from site areas.	Mine Study Area.	Throughout Post-Closure.	Continuous	Reversible upon cleanup and revegetation of site.	Low: no change predicted in water quality.	Low: Revegetation of affected areas and ditching will divert runoff. Cleanup of contaminated	Regular inspections and maintenance of ditches.	None
Activity	**Environmental Component**	**Potential Impact**						**Significance**	**Mitigation**	**Residual**
			Extent	**Duration**	**Frequency**	**Reversibility**	**Magnitude**			
Underground mine								areas will remove sources of contamination.		
	Groundwater	Groundwater quality and quantity.	Local Study Area.	Throughout Post-Closure.	Continuous	Not applicable	Low: no change in groundwater quality predicted.	Low: Cleanup will reduce potential contamination of ground water. Wells will be shut down, restoring ground water flows.	None	None
	Vegetation	Contamination from operations.	Local Study Area.	Throughout Post-Closure.	Continuous	Reversible with cleanup of contaminated areas.	Low: Contaminated areas will be remediated. Re-vegetation will restore habitat.	Low positive: Vegetation will be restored through cleanup of contaminated areas and rehabilitation.	Site restoration and remediation with appropriate disposal.	None

	Terrestrial Biota	Habitat	Local Study Area.	Throughout Post-Closure.	Continuous	Not applicable.	Low: Small areas of habitat will be restored.	Low positive: Areas of habitat restored are small relative to local availability of similar habitat.	Site restoration and remediation with appropriate disposal.	None
	Aquatic Biota	Runoff	Local Study Area.	Throughout Post-Closure.	Continuous	Reversible upon cleanup and revegetation of site.	Low: No changes predicted in stream water quality.	Low: Revegetation of affected areas and ditching will divert runoff. Cleanup of contaminated areas will remove sources of contamination.	Regular inspections and maintenance of ditches.	None

Table 20: Summary of Impact - Closure Phase

9.5.1 No Project Alternative

Accepted national statues and regulations requires that for such a project, the alternative of not constructing the project must be assessed. The Project adds incrementally to the disturbed area created by surface mining activities at the site and ensures that the existing mine and infrastructure are closed appropriately. Should the Project not proceed, it represents a loss of local income for a variety of workers, both those directly employed by the mine, and for those businesses locally, regionally (e.g., port facilities; and taxes / revenue) and nationally supporting the operations of the mine through provision of equipment, supplies and services. With appropriate mitigation measures, the environmental effects would be managed at levels that would be expected to have low significance.

9.5.2 Cumulative Impacts

Currently the only other project impact is that from the open – pit mining activities; the underground mining activities eliminates the need to have the surface mining operations continuing to expand – laterally thereby taking up more land space – which will certainly result in more forest loss and habitat disruption; by resulting to underground development – the impact is more localized; and therefore reduces the overall impact that would occur had the projects been developed in different areas that would equally require development of self – support infrastructures at each site.

9.5.3 Effects of Climate Change

Climate change predictions typically expect a 2°C increase in the average yearly temperature by 2050. However, it is generally acknowledged that temperature increases in the northern hemisphere would likely be higher. In the recent years – Liberia has experienced higher intensity of rainfall and as such higher surface water flows leading to flooding in lowlands areas.

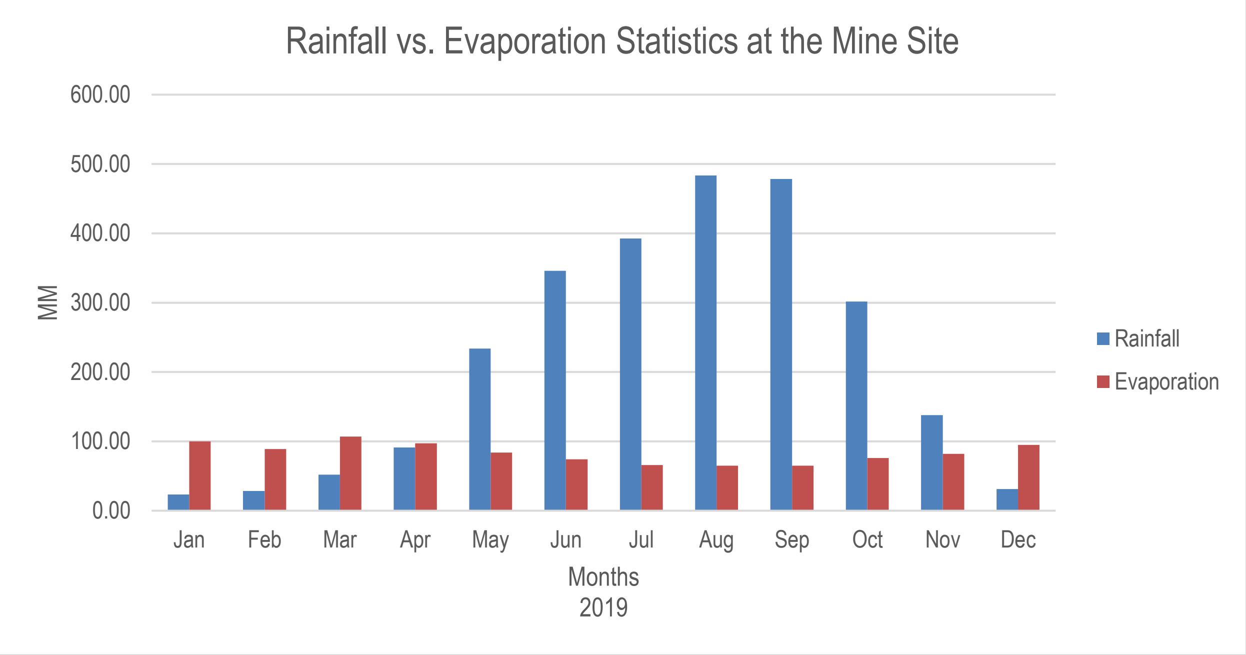


Figure 25: Chart of rainfall vs. evaporation in the project area

According to Liberia's National Climate Change and Adaptation Plan (NAP 2017); the primary impact of climate change in the hinterlands of Liberia will be flooding due to the loss of forest and vegetation coverage. It is very essential that the project maintains the existing vegetation and forest cover around the mine site so as to reduce or mitigate the potential impact of flooding as a result of climate change.

PART 10

10.1 Environmental and Social Action Plan

As part of its environmental and social responsibilities; a detailed Environmental and Social Impact Management Plan (ESMP) has been developed for the existing KGM operations and will be updated to include considerations for underground operations. The plan specifies action, responsible party, deliverables, timeline, and estimated budget to support decisions.

The ESMP defines the management framework, processes, monitoring, and reporting requirements for the project. It should meet all national statues and regulations as well as internal procedures and guidelines. The ESMP covers all project phases from construction to operations including closure and post – closure activities. It is updated regularly to reflect current project status; the plan applies to all project personnel; contractors, and visitors.

The implementation of the ESMP is the responsibility of the Health, Safety, Social and Environment HSSE team and Project Sustainability Managers. The HSSE team will be responsible for the accident prevention, mine safety, environmental awareness, and training programs; while the project sustainability leads will ensure that all KGM policies, systems, and procedures are fully communicated both internally and externally – thereby maintaining KGM social license to operate.

10.2 Management Framework

To ensure the project is delivered in a safe and efficient manner – project management plans will be developed for each component of the project. These plans shall be in the form and nature of standard operating procedures that will be aligned to the overall goals and objectives of this Addendum ESIA. The management framework includes:

- Roles and responsibilities of KGM project stakeholders, and resources required for implementation;
- National statues, requirements, standards, and regulations;
- The goals and objectives of this Addendum ESIA;
- Inspections and auditing;
- Communication and stakeholder consultation management; and
- Grievance management

10.2.1 Education and Training

KGM management team is committed to safety as its highest objective. Safety for its employees, the environment and the community. To ensure this objective is achieved training for all staff and visitors is key to achieving this success. KGM also recognizes the need to develop the local capacities of its national staff and to this a stronger commitment to training in all project aspects are essential.

To this end, KGM shall ensure through continuous training programs that all site employees are trained in their respective roles; and such training records will be maintained by both human resources and the HSSE team.

Capacity to effectively implement the ESMP requires that Project employees and contractors are trained in relevant environmental management procedures. The ESMP training will be implemented by qualified employees and contractors with integration into the Project's operational training programs, where and as applicable.

The ESMP related planning, guidance and training materials will be reviewed annually and where appropriate, modified to changing conditions as these become apparent.

10.2.2 Employment and Grievances

MNG maintains a strict adherence to national employment policies guidelines and regulations. To this MNG highlights the following in its employment practices:

- No to child labor employment.
- No discrimination of employment regardless of gender; tribe; or religion.
- No to harassment.
- No to alcohol and drug abuse.
- No to human and sex trafficking

MNG also maintains a grievance register so that all issues reported are properly documented and investigated; this practice also protects *whistle blowers* from reporting any issue of mal-practice or misconduct.

10.2.3 Compliance Monitoring

MNG is committed to compliance monitoring which goes beyond the conformity to national regulatory requirements; it is aligned to its internal core values and helps to measure KGM performance against documented commitments in the ESIA; which includes:

- Project design and operational readiness;
- Management and monitoring plans;
- Mitigation commitments, and;
- Community development initiatives and obligations

PART 11

11.1 Project Risk Assessment

A detailed project risk assessment has been completed for the project. The risk assessment allows for a risk register (Appendix D) to be developed and managed as a guiding road map against direct and indirect impacts to the project personnel, environment, or reputation. Highlighted in the risk register are key focal areas:

11.1.1 GEOLOGY AND MINERAL RESERVES

Geological risk exists in the offsets between the predicted orebody shape and the actual shape, potentially increasing dilution. This will be mitigated by one or more ofthe following:

- delineation drilling will define the local orebody geometry and reduce mining development rock
- the mechanized cut-and-fill method will allow the convoluted, discontinuous, and narrow areas of the orebody to be selectively mined

- smaller diameter blastholes at closer spacing will reduce overbreak, thus minimizing dilution and increasing fragmentation
- exploration drilling from underground will improve the certainty of some areas of the orebody.

11.1.2 MINING RİSK

Sustainable Mine Production

There is a risk that overproduction from the longhole stoping methods will impact on the ability to achieve long term production targets. The mining methods must be balanced throughout the life of mine. Cut-and-fill is the primary mining method. The narrow orebody requires selective mining. This should be managed as outlined in the mining section of this report.

Selective Mining

There is a risk that mining could become too selective, especially in the epos stope mining areas and production targets may not be met. The grade is irregular throughout the orebody and a broad approach will be required in certain areas. The mining operation will need to trust the delineation and assaying results and not restrict the productivity by being too selective. For both mining and processing grade control is critical, mining must diligently follow the production plan for proper ore blending and maximum recoveries in ore processing.

Ground Water Inflow

Groundwater inflow might be higher than anticipated. The inflows will be reviewed further in detailed engineering. This risk will be mitigated by installing excess pumping capacity, increasing the number of holding tanks and by grouting drain holes to reduce localized inflows.

Mining Contractor Non-Performance

There is a risk that the mining contractor will not meet the schedule, incurring cost over-runs and delaying the start of production. Monitoring and managing the mining contractor's progress closely will minimize this risk. Unavoidable over-runs are covered by the contingency in the capital cost estimate and conservative development productivity targets have been assumed.

Non-Availability of Mining Personnel

There is a risk that personnel required for underground mining, and other key personnel, will not be available when production begins. This will be mitigated by providing overlap between the pre-production contractor work and the start of owner personnel. Expatriate personnel will be used in key roles at the project start-up.

Training of Mining Personnel

Although there is an established mining industry and a pool of experienced mine personnel, some untrained local people will be employed by MNG. There is a risk that productivity may be adversely affected and production targets not met. This will be mitigated by the mining contractor providing specialized training personnel.Training will be undertaken during the pre-production period and the first six months of production. A training department will be on site during life of mine to train MNG employees. Major underground equipment suppliers should provide specialized mechanics to train local personnel on the maintenance and operation of the underground mining equipment.

Non-Availability of Mining Equipment

There is a risk that mining equipment is not available when required due to long lead times. This will be mitigated by retaining the services of the mining contractor, or the mining contractor's equipment, to cover the shortfall.

Backfill

All mining methods will require backfill. The mining cycle is dependent on backfill, especially the cut-and-fill method. The availability of the filtration/backfill plant will be critical. Pump spares and sufficient operational consumables including lining and piping must also be available to repair line failures quickly and efficiently.

There is a risk that the lined backfill boreholes could become unserviceable due to a blockage. This will be mitigated by installing two backfill boreholes between each level.

Oversize Broken Rock

The open stope methods may produce oversize rock as a result of ground water inflows or geological structures in the orebody. This risk may be mitigated by using emulsion in wet holes and increasing the powder factor in areas of the orebody that are considered as harder rock. A mobile rock breaker will be used in the case that large rocks report to the drawpoint. Explosives may also be used at the end of shift.

11.1.3 PROJECT EXECUTİON AND COMPLETİON RİSK

A number of risks may affect the project execution plan including:

- timely completion of permitting
- shortage of key personnel (management, engineering, supervisory, and artisans) will be mitigated by ensuring early placement of contracts, prompt and effective recruiting at start of project, and the expanded use of contractors and consultants as required
- shortage of construction equipment (cranes, modular site buildings, etc.) will be mitigated by ensuring early placement of orders for purchase and contracts for lease of construction equipment and followed by effective expediting
- shortage of contractors (mining, construction, earthworks, and catering) will be mitigated by obtaining early commitment from contractors
- long lead times on capital equipment delivery will be mitigated by ensuring orders are placed early with different vendors and followed by appropriate expediting
- increased excavation time and cost from adverse geotechnical conditions will be mitigated by assessing site conditions and re-evaluating the ground support systems.

11.1.4 POLİTİCAL RİSK

There is a risk that the mine operation may be affected by litigation or other political risks. This may be mitigated by following the permitting process diligently and ensuring that all permitting is completed as soon as possible, in addition to working closely with all levels of government to insure confidence in a responsible execution and operation of the project.

11.1.5 FORCE MAJEURE RİSK

MNG reserves the right to cancel, vary, or suspend the operation of contract of sale if events occur which are in the nature of force majeure including (without prejudice to the generality of the foregoing): fire, floods, storm, plant breakdown, strikes, lock-outs, riots, hostilities, non-availability of materials or supplies, or any other event outside the control of MNG shall not be held liable for any breach of contract resulting from such events.

11.1.6 OVERALL RİSK ASSESSMENT

The risk factors listed for this project are typical for mining projects of this size. the greatest risk will be the definition of the orebody and controlling the mining direction to minimize dilution and maximize the recovery of gold ounces.

Appendices

Appendix A:	Geochemistry Report
Appendix B:	Hydrogeological Assessment Report
Appendix C:	Geotechnical Assessment Report
Appendix D:	Project Risk Register

GEOCHEMICAL CHARACTERIZATION REPORT
ARD&ML POTENTIAL
Kokoya Gold Mine Project, Kokoya, Liberia

April, 2015

Prepared For:

MNG Gold A.Ş.

Address: Ankara Organize Sanayi Bölgesi, 5.Kısım,
Nahçivan Cad. No:11 SİNCAN / ANKARA
TURKEY

Phone: +90 312 955 0664 **/ Fax:** +90 312 267 60 81

Prepared By:

Golder Associates

Address: Hollanda Cad. 691 Sok. Vadi Sit. No:4
06550 YILDIZ - ÇANKAYA / ANKARA
TURKEY

Phone: +90 312 441 0031 **/ Fax:** +90 312 441 0714

Project Number:
14513150012

Distribution:
1 Copy – MNG Gold A.Ş.
1 Copy – Golder Associates Ltd. Co.

Revision:
DRAFT

Report Presentation Record

Client	Submitted to	Revision	Date	Report Format
MNG Gold	Meryem Tekol Pelenk	DRAFT	April 2015	Electronic – .pdf

Executive Summary

MNG Gold Liberia Incorporated (MNG) has acquired the Kokoya Gold Project concession from Amlib United Minerals (Amlib), in April 2014. MNG intends to develop the project from the exploration stage through to the mining stage. The project is a surface mining project and will explore various alternatives for mining and processing. The main mine infrastructure includes open pits, ore stockpiles, a waste rock dump, a processing plant, a tailings storage facility, mine camp, power generation facility, mechanical workshops, administration block and possibly a water storage facility.

Golder Associates (Golder), in partnership with Earth Environmental Consultancy Incorporated (EarthCons) is undertaking the Environmental and Social Impact Assessment (ESIA) for the proposed Project. As part of this effort, Golder conducted a geochemical characterization program and evaluated the acid rock drainage/metal leaching (ARD/ML) potential of ore and waste rock.

Geochemical characterization work was performed to assess the potential for acid rock drainage (ARD) and metal leaching (ML) from the various mine materials. Typically, a geochemical characterization program begins with short-term static testing followed by long-term kinetic testing, if deemed appropriate. Golder selected 45 representative ore and waste rock samples from each key lithology in the Kokoya Gold Deposit for a static testing program. MNG geologists collected the samples and shipped the samples to SGS South Africa Lab for geochemical testing. This report summarizes the geochemical characterization studies, including sample selection, the results of the static tests, ARD/ML potential assessments and recommendations regarding conceptual mitigation measure and future studies.

The average total sulphur content is very low and less than 0.1% in most of the samples. The majority of the total sulphur in the samples occurs as sulphide sulphur and for almost all samples, the neutralization potential (NP) calculated using total carbon is significantly higher than the NP calculated from carbonate. The low NP values suggest that there is practically no neutralising potential, and the NP is not present in the form of readily-available carbonate minerals. Based on the acid base accounting (ABA) and single addition net acid generating (NAG) tests results, there is only one potentially acid generating (PAG) sample from the Quartz Vein (QV) group. Two Schist (SC) samples have and uncertain ARD potential and the remaining samples are all classified as non-potentially acid generating (NON-PAG) since they contain almost no sulphide sulphur. It can be concluded that regardless of rock type, samples with less than 0.2 % sulphide sulphur are NON-PAG and the have relatively low dissolved base metal concentrations. However samples with higher sulphide sulphur content may be PAG and due to the general lack of neutralization potential. Additional, short and long-term testing on samples with high sulphide sulphur content is required and recommended to verify this observation. It may be possible to develop a defensible and reliable sulphur threshold for operational management of PAG vs. NON-PAG waste rock, should this be desired.

Drainage qualities from short-term leach (STL) testing demonstrate that near neutral or alkaline drainage is expected, with low dissolved base metal concentrations.

Comparison of the STL test results with the discharge limits defined in the Environmental, Health and Safety Guidelines prepared by International Finance Corporation (IFC) indicates leachate was within IFC standards for less than half of the fifteen samples due to elevated (alkali) pH or low (acidic) pH and elevated Ni content in one sample.

In terms of the Liberian drinking water classification, leachate from six of the fifteen samples exceed guideline values to elevated (alkali) pH, one sample is Class I (suitable for domestic drinking water), three samples are Class II (fisheries, recreational, industrial or agricultural use) and five samples are Class III (industrial or agricultural use only). Fe and Mn concentrations of six samples also exceed the World Health Organization (WHO) limits.

NAG leach results of the one PAG sample indicate that pH, Cu and Fe concentrations exceed IFC discharge limits. pH, SO_4, Cu, Fe and Mn, Na and Ni parameters exceed Class III limits defined in Liberian drinking water classification. The results indicate that the PAG sample has metal leaching potential over long term.

The static testing results indicate that a total sulphur threshold of 0.2% total sulphur would be used to differentiate PAG and NON-PAG material. It is suggested to continue with static and kinetic tests on additional high sulphur samples.

Most of the materials that will be extracted during the mining operation are expected to have low sulphur content; however especially the ore would include relatively high sulphur content and high sulphur pockets/zones would be encountered during the mining. MNG exploration database only includes Au and Ag results and it is recommended to add total sulphur analyses to the new exploration drilling assays and develop sulphur block models to have a better understanding of the volume and spatial distribution of PAG and NON-PAG material. By using the sulphur block model, facility specific run-off and seepage water quality predictions can be completed. Conducting total sulphur analyses during operation would help MNG to identify PAG material and take necessary precautions during the operation.

Conceptual mitigation measures were provided for each facility to mitigate ARD and ML potential of the Project. Golder used a conservative approach for developing the conceptual ARD mitigation measures and the mitigation measures would be revised in case the volume of PAG material is very low. Having a better understanding of the volume and distribution of low and high sulphur material is required to develop facility-specific water quality predictions which will assist in determining which measure or combination of measures will best address operational and post-closure ARD/ML issues. When the suggested mitigation measures are applied, the project is expected to have low environmental in terms of ARD and ML.

Table of Contents

APPENDICES

List of Figures

List of Tables

Abbreviations

ARD	Acid Rock Drainage
ABA	Acid Base Accounting
AP	Acid Generation Potential
asl	Above Sea Level
ASTM	American Society for Testing and Materials
CVAAS	Cold Vapour Atomic Absorption Spectrometry
GARD Guide	Global Acid Rock Drainage Guide
ICP-MS	Inductive Coupled Plasma - Mass Spectrometry (Test for Trace Metals Identification)
IFC	International Finance Corporation
INAP	The International Network for Acid Prevention
LOI	Loss on Ignition
MEND	Mine Environment Neutral Drainage Program
ML	Metal Leaching
NAG	Net Acid Generation
NNP	Net Neutralization Potential (NP-AP)
NON-PAG	Non- Potentially Acid Generating
NP	Acid Neutralization Potential
NPR	Net Potential Ratio (NP/AP)
PAG	Potentially Acid Generating
SFE	Shake Flask Extraction
STL	Short-Term Leach
TC	Total Carbon
tpm	Ton per Month
WHO	World Health Organization
XRD	X-Ray Diffraction (Test for Mineralogical Identification)
XRF	X-Ray Fluorescence (Test for Major Oxides Identification)

1.0 INTRODUCTION

MNG Gold Liberia Incorporated (MNG) has acquired the Kokoya Gold Project concession form Amlib United Minerals Incorporated, a Liberian registered, subsidiary of Amlib Holdings Plc (Amlib), in April 2014. Amlib had signed a Mineral Development Agreement (MDA) with the Liberian Government on March 14, 2002 for the Kokoya concession. MNG intends to develop the project from the exploration stage through to the mining stage. The project is a surface mining project and will explore various alternatives for mining and processing. The main mine infrastructure includes open pits, ore stockpiles, waste rock dumps, a processing plant, a tailings storage facility, mine camp, power generation facility, mechanical workshops, administration block and possibly a water storage facility.

Golder Associates (Golder), in partnership with Earth Environmental Consultancy Incorporated (EarthCons) is undertaking the Environmental and Social Impact Assessment (ESIA) for the proposed Project. As part of this effort, Golder conducted a geochemical characterization program and evaluated the acid rock drainage/metal leaching (ARD/ML) potential of ore and waste rock. The overall objective of a geochemical characterization program is to evaluate the environmental stability of mine wastes and ore, in particular related to the ARD/ML potential. Typically, a geochemical characterization program begins with short-term static testing followed by long-term kinetic testing, if deemed appropriate.

The static testing program consists of screening-level tests that can be used to describe the bulk chemical characteristics of the material to be mined and to evaluate the potential of the material to generate acid or leach metals. Static tests also provide an indication of the presence of minerals that may generate acid as well as minerals that may act to neutralize any acid formed. If static testing indicates an ARD/ML potential, kinetic testing may be conducted to verify whether the various ARD/ML potentials identified will indeed be realized over time, what the associated reaction rates (sulphide oxidation, depletion of neutralization potential, mineral dissolution) are, and what the composition of long-term mine discharges would be.

Golder selected 45 representative ore and waste rock samples from each key lithology in the Kokoya Gold Deposit for a static testing program. MNG geologists collected the samples and shipped the samples to SGS South Africa Lab for geochemical testing.

The test program included the following components:

- Major oxide analysis (all samples)
- Trace metal analysis (all samples)
- Acid base accounting (ABA) (all samples)
- Single addition net acid generation (NAG) testing (all samples)
- Short term leach testing (on selected 15 samples)
- NAG leach testing (on selected 3 samples)

This report summarizes the geochemical characterization studies, including an overview of the project properties and background, sample selection, the results of the static tests, ARD/ML potential assessments and recommendations regarding conceptual mitigation measure and future studies.

2.0 PROJECT AREA PROPERTIES

2.1 Location

The Kokoya concession is approximately 100 km northeast of Buchanan City, and approximately 75 km southwest of Sanniquellie City. The concession area stretches over three counties: Nimba, Grand Bassa, and Bong counties. In Bong County, the concession covers Kokoya and Jorquelleh Districts, in Grand Bassa County, it is found in District No. 3 and in Nimba County, it is found in Yarwein-Mehn Sohnneh District. The original MDA covered an area of 970 km². However, the production area approved by the Ministry in November 2013 covers an area of 537km². A location map of the project is provided in Figure 1.

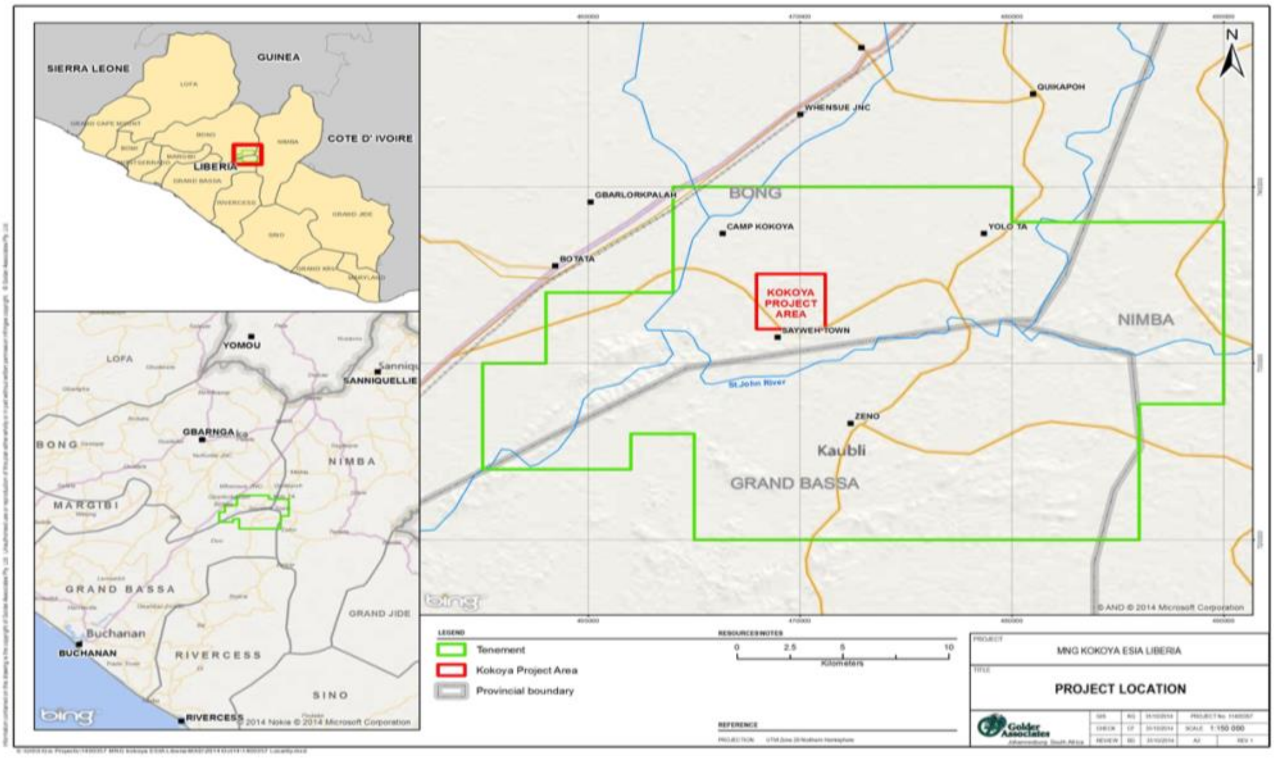


Figure 1 Location Map of the Kokoya Project

2.2 Climatic Condition

The climate in Liberia is hot and humid, and there are two distinct dry and wet seasons. The dry season is between November and March and the wet season from April to October. Temperatures vary from 27°C to 32°C during the day and 21°C to 24°C during the night. Recent rainfall during the wet season has been recorded to vary from 4,000 mm at the coast to 1,300 mm inland. (PMDE, 2014)

2.3 Geology

This section is derived from the Geology, Alteration and Mineralization Study (MNG, 2015) provided by MNG.

2.3.1 Regional Geology

Liberia is underlain by the West African Craton which extends into neighboring Guinea and Sierra Leone, and is composed of Precambrian igneous and metamorphic rocks. The craton is overlain on a local scale by Paleozoic and Cretaceous sandstones, Jurassic dolerite dykes and unconsolidated Quaternary deposits.

The West African Craton comprises two major areas of Archaean to early Proterozoic terrains as the Man Shield and the Birimian.

The Birimian, early Proterozoic terrains, is made up of an alternation of sedimentary belts and volcanic sequences intruded by large granitoid bodies which crop out in north-south to northeast-southwest trending belts extending for tens or hundreds of kilometers. The metamorphic grade within the early Proterozoic rocks is generally low, except along some subsequent trans-current fault zones. The Birimian rocks are present in the eastern third of the country in Liberia.

The basement rocks of Liberia are mainly grouped as three age provinces shown in Figure 2. The oldest is the Liberian age province, which covers the entire western half of the country, with the exception of a thin coastal strip. It was metamorphosed and intruded by plutonic rocks at around 2700Ma. In the Man Shield, the Archaean basement is only exposed in western and central Liberia and Sierra Leone, and characterized by a granite-greenstone association dominated by older granitoid gneisses and migmatite which are in folded with supracrustal schist belts (greenstone belts) and intruded by younger granites. These supracrustal sequences outcrop as synformal relicts elongated parallel to the Liberian foliation of their gneissic basement.

The Eburnean age province covers the eastern third of the country and has an age of around 2150 Ma. The boundary between the two provinces is not well defined due to limited age data from east-central Liberia. The coastal regions of the northern and central parts of the country are covered by supracrustal rocks of the Neoproterozoic to lower Cambrian Pan-African age province, which were metamorphosed and intruded at around 500Ma as part of the Pan-African Orogeny. It is thought that these rocks were originally part of the Liberian province. Rocks in the Pan African age province are reworked and metamorphosed Archaean units similar to those of the Liberian age province, and in some cases can be correlated directly. Minor sedimentary units, largely sandstone and ranging in age from Devonian to Tertiary, occur in the coastal areas to the southeast of Monrovia.

Tropical weathering is also the important factor for the geology of Liberia. Intense rainfall and high temperatures generate severe tropical weathering which decomposes the rock strata causing a reduction in rock strength and inter grain bonding. This weathered matter remains in-situ. The results of all these processes are laterite and saprolite, weakened surface layer of soil matter which can be from tens to hundreds meter thick. These layers support dense vegetation and rain forests (Tysdal and Thorman, 1983).

Figure 2 Tectonic Map of Liberia (MNG, 2015)

2.3.2 Project Geology

The Kokoya project area lying within the Archean aged Liberian metamorphic province is dominated by northeast-southwest trending, strongly deformed amphibolite and gneissic units with a probable mafic basalt origin and felsic rhyolite - dacite, respectively. Amphibolite is usually occurred as lenses in gneissic rock mass. Several episodes of deformation are recorded in the metamorphic rocks, including several generations of cross-cutting folding and faulting, metamorphism and locally inferred unconformities. Certain areas have undergone varying degrees of partial melting which has resulted in migmatite and pegmatite occurrences. A swarm of northwest trending dolerite dykes of Jurassic age intrudes the gneisses and amphibolite. A major east-northeast trending zone of intense shearing, the St John Shear Zone, runs through the project area.

Strikes of the dominant structures such as veins are generally NE and the common dip direction is NW with dominant dip angles varying between 40^o - 60^o. There are series of continuous/discontinuous shear zones, composed by schist-like foliated rock with biotite-muscovite-sericite and actinolite.

In many cases, the zones control gneiss-amphibolite contacts, pegmatite and quartz veins and metasomatic alteration. Shear zones are the host for quartz veining or intersected by veins. Two sets of quartz veins, called Rockcrusher and Caterpillar, were identified across the project area. These sets are similar in mineralogy but differ in their strike and morphology. The Rockcrusher veins strike at approximately 35° to 55° and dip to the NW at between 35° and 50°. These veins were formed by strike-slip faults and are displaced by subsequent northwest striking faults. The thickness of these veins ranges from tens of centimeters to seven meters. The Caterpillar veins strike at approximately 70° to 90° and dip to the NW at between 45° and 60°. These veins are controlled by shear zones and in many instances display a lens-like shape. The Caterpillar veins have a smaller thickness and shorter strike length than those of the Rockcrusher.

2.3.2.1 Geologic Units

The rock types observed within the project area include saprolite, amphibolite, schist, granite, quartzite and very high grade metamorphic units including gneiss, migmatite and mylonite. More information regarding the rock units are provided below.

2.3.2.1.1 Saprolite (SAP):

The resource area is covered by a thick, up to 20 m, blanket of Saprolite (SAP), which is the product of deep tropical weathering with generally reddish brown color, ferric compounds and sand to block size bedrock fragments.

2.3.2.1.2 Amphibolite (AM):

There are three principal varieties of Amphibolite: Massive Amphibolite (AM), Feldspar Porphyry Amphibolite (AMP) and Augen Amphibolite (AMA). The most widespread one is Massive Amphibolite. AM units are dark-green to greenish-black colored, fine and equally grained, and massive with traces of lamination. Major minerals include hornblende, quartz, feldspar and biotite. Accessory minerals include actinolite, ilmenite, magnetite, sphene, apatite, epidote, and zircon.

2.3.2.1.3 Schist (SC):

Schist (SC) can be divided into three groups: Biotite Schist (SCB), Actinolite Schist (SCA) and Muscovite Schist (SCM). SC is light-green to dark-brown and greenish-black colored, foliated, laminated-layered, fine to medium grained (0.1 to 3 mm), and resemble lepidoblastic and lepidogranoblastic texture. Major minerals include chlorite, muscovite, biotite, amphiboles (tremolite, actinolite), hornblende, quartz, and feldspar. Accessory minearls include zircon, sphene, apatite, epidote, ilmenite and magnetite.

2.3.2.1.4 Granite:

Three varieties of Granite can be distinguished: Melanocratic Porphyry Granite with a predominance of dark fine grained matrix over the coarse (3 - 5mm) metasomatic porphyroblasts of feldspar (or quartz), Mesocratic Granite (GR) with approximately equal amounts of dark and light minerals, usually equally grained, and Leucocratic Granite (GRL) with a predominance of light minerals, equally grained. Granite is dark grey with white spots to light grey colored, massive, medium grained (2 - 4mm), granoblastic and porphyry textured rock. Major minerals include quartz, feldspar, biotite, hornblende, muscovite. Trace minerals are zircon, sphene and ilmenite.

2.3.2.1.5 Pegmatite and Quartzite (QW):

Pegmatite (PG) consists of vein-like bodies of quartz-feldspar. Quartzite (QW) is the same as Pegmatite but it has a strong prevalence of quartz over the feldspar. The rocks are white - grey, spotted, massive to irregular and coarse grained. They consist of quartz, feldspar, muscovite, biotite minerals and contain sphene as accessory mineral.

2.3.2.1.6 Very High Grade Metamorphic Units (VHM)

Very high grade metamorphic units include: Gneiss, Migmatite and Mylonite. Gneiss is light-grey to dark-grey banded, medium grained (1 – 5mm) and lepidogranoblastic. Major minerals include biotite, hornblende, quartz, feldspar and muscovite. Zircon, sphene, apatite, epidote ilmenite and magnetite are present as accessory minerals. Migmatite is light to dark gray or white and dark-grey or dark-greenish-grey, layered, irregular, folded and fine to medium grained. Migmatite mainly consists of biotite, hornblende, actinolite, quartz, feldspar minerals, and contains zircon, sphene, apatite, epidote, ilmenite and magnetite as accessory minerals. Mylonite are grey to dark greenish colored, layered - laminated, irregular and foliated. They consist of quartz, feldspar, muscovite, chlorite minerals, and contain sphene, apatite, zircon, ilmenite and magnetite as as accessory mineral. Mylonite is ductile deformed rock formed in the large faults. Dynamic recrystallization of the constituent minerals results in a reduction of the grain size of the rock. Numerous porphyroblasts of quartz-feldspar composition (migmatite, pegmatite, granite) can be observed in mylonites which indicate that they are a product of a secondary metamorphic event. Mylonite zones usually trace more ancient shear (schist) zones and can act as structural traps for the ore.

2.3.2.2 Alteration and Mineralization

Three principal types of hydrothermal-metasomatic alteration were recognized by MNG during field work and petrographic investigations.

- Greisen-like sericite-muscovite-quartz (+/- chlorite) alteration more typical for the felsic rocks, such as biotite schist, gneiss, granite. In the full-expressed cases it looks like a breccia with quartz fragments cemented by irregular quartz-muscovite aggregate. Explosive processes probably participated in the formation of this alteration type.
- Biotite-actinolite alteration looks like hydrothermal-explosive breccia. Dark-brown biotite forms strings or cements irregular fragments of the rock.
- Silicification (hydrothermal) is not widespread. It differs from the quartz veins by the absence of sharp contacts and smaller size of the grains; from quartzite and pegmatite by the absence of feldspar, smaller grain size, and a typical association with green micas (chlorite, muscovite, and sericite).

Three types of gold mineralization styles were identified by MNG:

- Quartz veins: Quartz veins are characterized by elevated gold content but do not typically exceed 1 g/t Au, higher grades usually result from quartz veins which have overprinted sulphides.
- Complex quartz-chlorite-sericite-sulphide mineralization forms patches, irregular veinlets and irregular metasomatic dissemination. The sulphides are present as pyrite and chalcopyrite. This type of mineralization on its own tends to produce low grades; however, when this type is overprinted by quartz style mineralization, significant grades are often encountered.
- Galena-sulphosalt mineralization is associated with the highest grades. It is not widespread but is probably responsible for the visible gold occasionally seen. It is postulated that the galena mineralization represents the last stage of the hydrothermal process which started with the quartz vein phase continuing with chlorite-sulphide alteration and ended by galena-sulphosalt mineralization.

3.0 PROJECT BACKGROUND

3.1 Exploration Activities

Kokoya has been subject to five phases of exploration since 2001, all conducted by or on behalf of Amlib. A total of 262 holes for 46,735 m have been drilled and 249 trenches for 7,069 m excavated as of October 14th, 2011. The drilling activities at the project area are given in Table 1. The gold mineralization is thought to be controlled by brittle and ductile deformation zones. MNG recently initiated additional exploration activities at the Project site.

Table 1 Drilling Activities at Kokoya Project (RC-Reverse Circulation, DD-Diamond Drilling)

Year	Drilling	No of Drillings	Total Meters	Drill Hole Nomenclature
2003/04	RC	31	4,514	KYD001
2007/08	RC	158	31,618	KYD032
2010	DD	21	3,141	KYD189
2010/11	DD	52	7,461	KYD212
Total		**262**	**46,734**	

3.2 Drillhole Database

The drillhole database provided by MNG includes the lithological groups presented in Table 2. Lithological information of a total of 13,800 m drilling which is located within the open-pit boundary is summarized below.

VHM - Very High Grade Metamorphic Rock Assemblages is the most abundant unit, comprising 46% of the available lithological drilling information. VHM is followed by AM – Amphibolite (23%) and SC – Schist (12.6%). Each lithological group is composed of several sub-lithological groups and the sampling program will cover all lithologies that will be encountered during the mining operation.

Table 2 Lithological Distribution of the Drilling Database provided by MNG

Lithology Code	Lithology Description	Lithology Group Code	Lithology Group Description	Total Meters	Percentage
AM	Amphibolite massive	**AM**	Amphibolite	3,201	23.2
AMP	Amphibolite feldspar-porphyry				
AMA	Amphibolite augen				
SCA	Schist actinolite	**SC**	Schist	1,737	12.6
SCB	Schist biotite				
SCM	Schist muscovite				
SCAM	Schist amphibolite				
SCS	Schist silicate				
MBS	Magnetite-bearing schist	**VHM**	Very High Grade Metamorphic Rock Assemblages	6,330	45.8
MBM	Magnetite-bearing mylonite				
PR	Peridotite				
MG	Migmatite mesocratic				
MGL	Migmatite leucocratic				
MGM	Migmatite melanocratic				
GN	Gneiss mesocratic				
GNL	Gneiss leucocratic				
GNM	Gneiss melanocratic				
PG	Pegmatite				
QW	Quartzite				
ML	Mylonite				
MLB	Blastomylonite (mylonite with fragments)				
GR	Granite mesocratic	**GR**	Granite	38	0.3
GRL	Granite leucocratic				
GRG	Granite graphic				
QVT	Quartz Veinlets	**QV**	Quartz Vein	274	2.0
QVN	Quartz Vein				
SAP	Saprolite	**SAP**	Saprolite	1,491	10.8
XX	No core	**XX**	No core	747	5.4
PO	Porphyroid	**PO**	Porphyroid	0	0.0
			Total	**13,818**	**100.0**

3.3 Mine Plan

The current mine plan indicates that there will be five open pits (one main and four satellite pits), one waste dump, one tailings facility and two temporary ore stockpiles. The total amount of material planned to be extracted from the open-pit is 10 Mkt. The total RoM ore is approximately 1.4 Mt. The Low grade ore has a grade lower than the economic cut-off grade (0.53 g/t) and will report to the waste dump. Table 3 shows the material planned to be extracted from the open pit. (PMDE, 2014)

Table 3: Material Types in Designed Pit

Description		**Saprolite (kt)**	**Saprock (kt)**	**Fresh Rock (kt)**	**Total (kt)**	**Au (kg)**	**Recovered Au (kg)**
Stockpile	Indicated	141.50	102.23	456.16	699.89	3,856.55	3,536.04
	Inferred	327.47	113.72	248.62	689.81	2,017.06	1,849.43
	Not Classified	0.82	1.30	18.66	20.78	46.54	42.67
	Total	469.78	217.25	723.44	1,410.48	5,920.15	5,428.14
Waste Dump	Low Grade	951.25	295.89	654.29	1,901.44	-	
	Waste	3,036.19	710.55	2,856.98	6,603.72	-	
	Total	3,987.44	1,006.44	3,511.27	8,505.16	-	
Total Rock (kt)		**9,915.63**					
Stripping Ratio		**6.03**					

3.4 Mine Facilities

3.4.1 Topsoil Stockpiles

The first 50 cm layer of topsoil at the project site will be stripped prior to construction and stockpiled for rehabilitation at mine closure (PMDE, 2014). The topsoil from the surface covering the footprints at the open pits, the stockpile and the waste rock dump will be stockpiled in a designated area from where it can be recovered and used for rehabilitation at the end of the LoM.

3.4.2 Ore Stockpiles

Two ore stockpiles are planned to the east and to the west of the processing plant to service the main pit and the satellite pits. They provide capacity for a buffer of one month’s production to accommodate a reduced mining rate during the rainy season.

3.4.3 Open Pits

The conventional open pit method will be employed for the Kokoya Gold Project. The ore will be accessed through a mix of free, ripping and conventional drill and blasting methods. A ramp entry and exit system will be used for accessing the pit at depth. Ore and waste will be hauled by articulated dump trucks (ADTs) via the planned access ramp. A mining fleet consisting of front end loaders, bulldozers, graders, water trucks, and utility vehicles will support the mining operations (PMDE, 2014).

Based on current geotechnical knowledge, the pit is expected to have a bench height of 10 m and a berm width of 3 m. Overall pit slope angles of 35^o in the weathered zone (i.e. Saprolite and Saprock) and 50^o for the fresh rock are proposed. A bench angle of 70^o has also been proposed for fresh rock and 45^o for Saprolite and Saprock. The overall slope angle proposed for the final pit wall is 43^o. However these geometric properties might not represent the optimal pit configuration and could be further enhanced after further geotechnical drilling. Perimeter ditches will be constructed to intercept surface water flows to control erosion and infiltration. Conventional methods will be employed for pit dewatering (PMDE, 2014). It is expected that the production rate of 45 ktpm might not be achievable in the rainy season for safety reasons. The monthly production schedule to deliver an average of 45 ktpm to the plant taking into account an anticipated amount of lost days in each month (non-working days) reduced, (PMDE 2014).

The pump dewatering system for the open pit has been designed to accommodate precipitation of around 50 mm/h for a three-hour period over the entire area of the open pit. The pit dewatering has been designed taking into consideration the rainy season and the management and control of surface run-off. As a result the operation will be able to accommodate high levels of storm-water (PMDE, 2014).

3.4.4 Waste Rock Dump

The waste rock dump is to be located north of the main open pit and will have two entrances (PMDE, 2014). The waste rock dump will have a slope face angle of 35^{o} with 10 m high benches and 10 m bench spacing before starting the next level. The waste will be dozed to ensure that each bench does not exceed 10 m and to ensure that it is flat and well levelled to accept the material for the next bench (PMDE, 2014). A general view of the waste dump, ore stockpiles and open-pit is presented in Figure 3 and the ore bodies within the pits are presented in Figure 4.

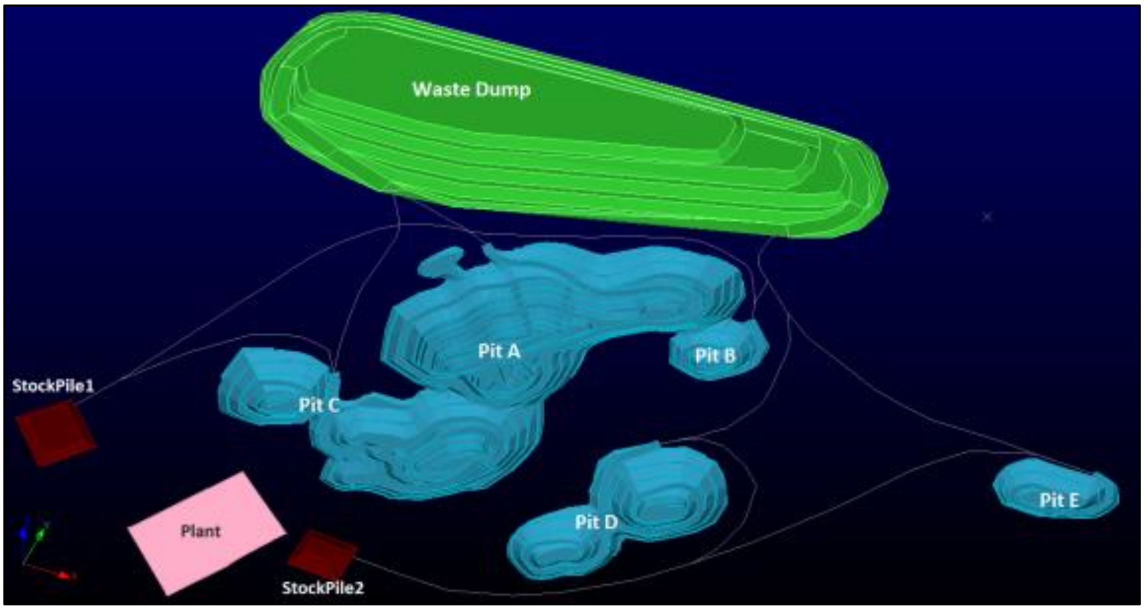


Figure 3 General View of the Mine Facilities

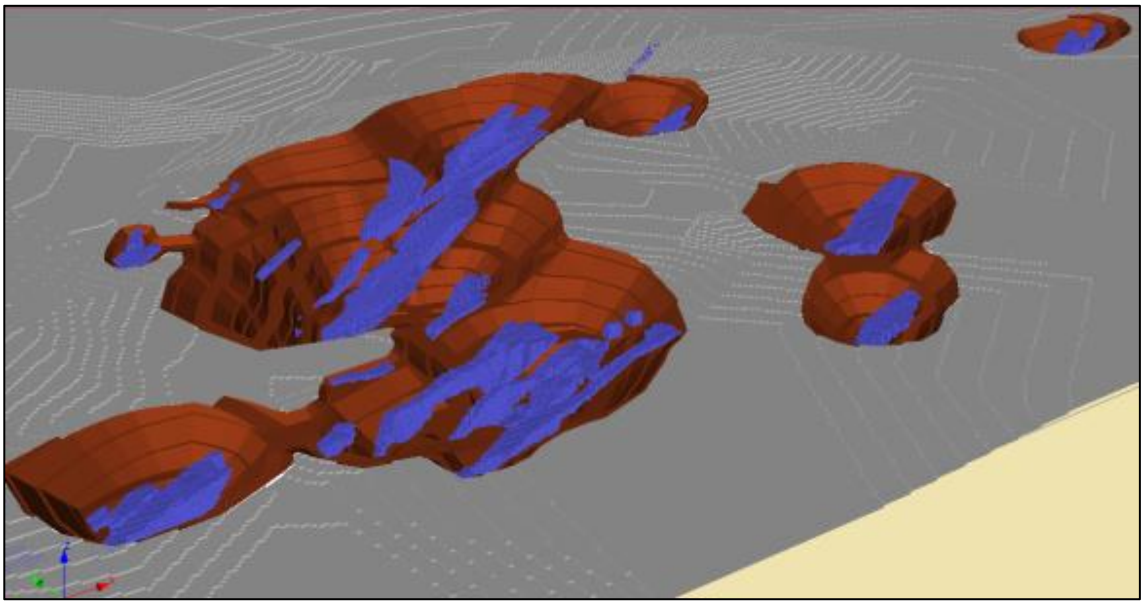


Figure 4 General View of Open Pits and Ore Bodies

3.4.5 Tailings Facility (TSF)

TSF will be located approximately 1,300 m south-east of the main open pit and will cover an area of ~30 ha. The location will be based on proximity to the mining operation and topography among others. Seepage control will be incorporated into the design of the embankment wall in order to maintain wall stability and safety (PMDE, 2014).

The following design criteria were considered for the Tailings Storage Facility (TSF):

- The TSF will be designed to accommodate a production rate of 360 ktpa over a five-year period;
- Particle sizes were assumed to be that of silt, with 80% being less than 75 µm;
- Tailings deposition will make use of the conventional spigot method;
- Construction of the TSF will make use of natural and man-made waste rock containment walls;
- The containment walls will have a minimum crest width of 20 m;
- The floating barge system will be employed to return supernatant water. The access to the barge will be via rock fill jetty and bridge, which will be raised with the pond elevation. This system will be designed to accommodate the 1:100 year storm in 48 hours.
- The site will be preparedby removing the soil, backfilling and compacting waste rock and the establishment of drains within the TSF and perimeter.
- An under-drainage system will be constructed to assist in the consolidation of the tailings solids and the effective use of the available space. Due to the high rainfall, a suitably sized water decant system will be incorporated in order to protect the facility from overtopping. Water that is cleared of solids will be returned to the plant for use in the process.

- The entire area will be impounded and there will be no need for wall rising for the first three years. The tailings delivery system will be fitted with a ring main pipe and spigots that can easily be managed to create a beach, towards the water decant system. The withdrawn water will flow by gravity to a suitable holding dam with pump station for return to the plant.
- A liner will be installed in the basin of the tailings storage paddock in case cyanide is not neutralised for any reason. The basin will be stripped of vegetation and fitted with an elementary drainage system. Surface water runoff from rainfall events will be diverted around the tailings storage area, as this is required from a structural integrity point of view and the fact that the return water system will become overrun with water from the storm event. Suitable diversion trenches and channels will be installed to divert the runoff effectively (PMDE, 2014).

3.5 Water Management

Mine water requirements include, but are not limited to, ore processing, dust suppression, laundering, camp and a vehicle washing bay. The mine intends to use water efficiently and responsibly and thus minimise water abstraction. MNG will achieve this by maximising the recirculation of process water and tailings supernatant water for use within processing facilities. The mine will reuse ‘clean’ runoff stored in sedimentation ponds (PMDE, 2014).

3.5.1 Storm-water Management

Key issues associated with storm water management include the separation of clean and dirty water, minimizing run-off, preventing erosion of exposed surfaces and reducing the siltation of drainage systems. Diversion trenches will be used to divert the majority of clean runoff around disturbed areas to a sedimentation pond designed to contain a 1 in 50 year rainstorm and this water will be used for dust suppression (PMDE, 2014).

3.5.1.1 Raw Water Tank

The raw water tank will contain fresh water abstracted from boreholes as well as “clean” runoff water if required. The size of the raw water tank will be 8.5 m in diameter and 7 m in height to ensure its adequacy in sustaining plant operations during periods of low rainfall. The tank will be located close to the plant and will have a capacity of 385 m^3 (PMDE, 2014).

3.5.1.2 Diversion Channel

Diversion berms and drains will be used to divert ‘clean runoff’ around disturbed areas. Berms will be installed along the pit and waste rock dump (WRD) perimeters to divert surface water around these facilities.

Smaller diversion drains will be used to manage runoff flowing into the processing plant area, workshops, offices, mine camps and the landfill area from their respective local catchments. Discharge from each diversion structure will be so as to minimise downstream erosion (PMDE, 2014).

3.5.1.3 Open Pit

Runoff will be diverted away from the pit by a series of diversion trenches. Rain water within the pit will be collected via a sump and directed to water storage facilities for future use whenever practicable or pumped out to the environment if the quality meets the EPA criteria. All diversion trenches will be lined with waste rock to prevent erosion (PMDE, 2014).

4.0 GEOCHEMICAL CHARACTERIZATION

4.1 Sampling and Analysis Plan (SAP)

The geochemical characterization program was designed for a screening-level evaluation of the ARD/ML potential of waste rock and ore from the Kokoya project. Based on the proposed pit outlines, geologic information, and drilling database, Golder selected 45 rock samples representing the various lithological units (rock types) identified by MNG. The samples were submitted to SGS South Africa Laboratory in Johannesburg, South Africa for a range of static geochemical tests.

4.2 Sample Selection and Preparation

Golder prepared a preliminary list of proposed samples based on available data and shared the data with MNG. MNG geologists collected the samples from the appropriate cores. However, sampling could not be performed for a few intervals due to insufficient core material or damaged core boxes. Golder revised the sample list and replacement samples were collected by MNG staff. After all sampling was completed, the samples were submitted for laboratory analysis. Forty five core samples, representing all rock types, were identified and collected from 24 different drill holes. Three criteria were used to identify the most representative samples from the three proposed pits: spatial distribution, lithological distribution, and geochemical distribution. A description of each of the criteria is presented below.

4.2.1 Spatial distribution

For each pit, a pit outline and borehole locations were provided by MNG. Samples were selected to represent the complete pit volume covered by the proposed pit, with an emphasis on locations that may remain exposed after cessation of mining. Sample locations are shown on Figure 5.

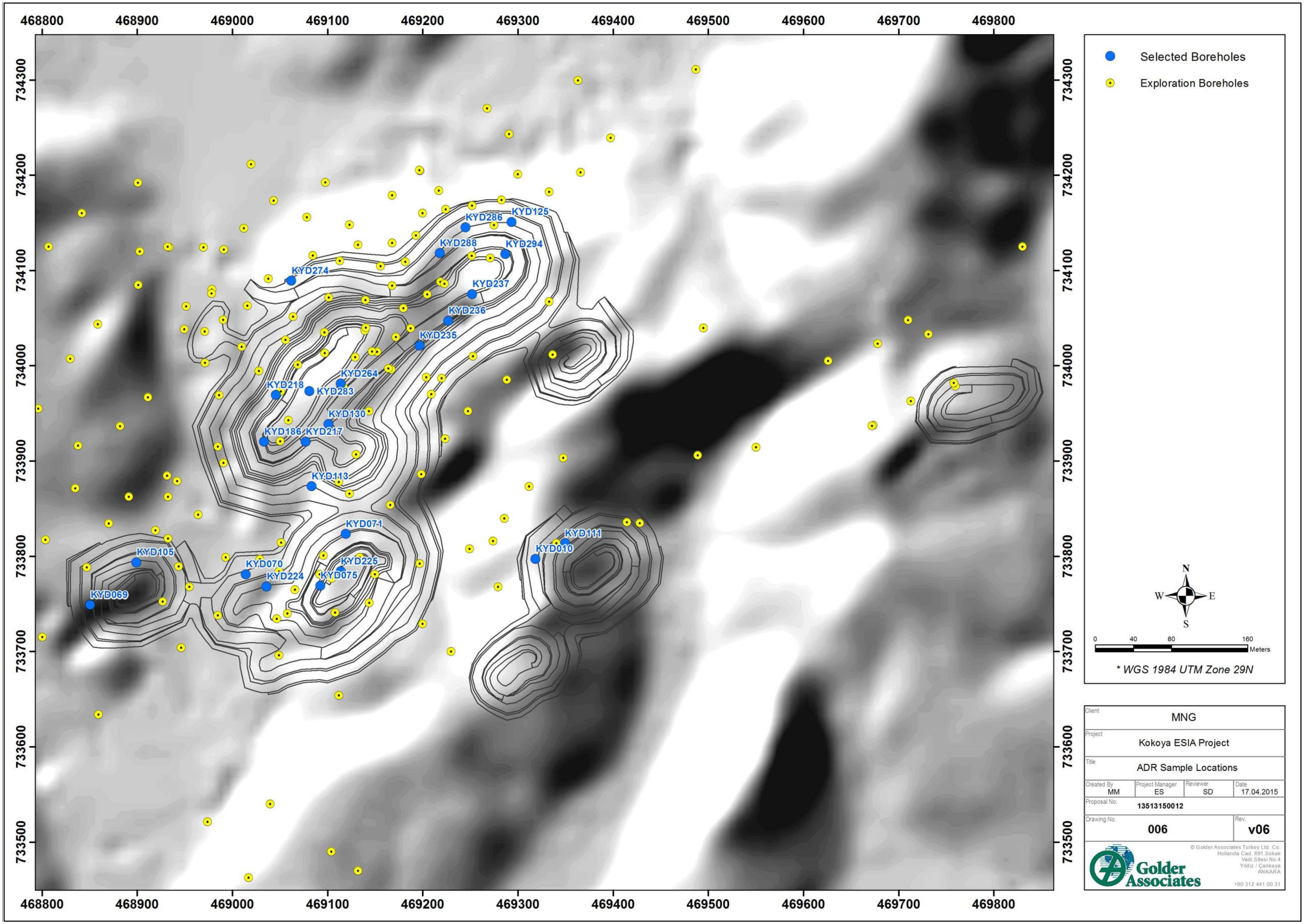


Figure 5 Locations of Boreholes which from the ARD Samples Were Taken

4.2.2 Material Types and Lithological Distribution

MNG defined key lithologies containing similar lithological groupings. During the sample selection, Golder used these key lithologies and evaluated the distribution of those within the pits. The key lithologies developed by MNG are as follows:

- **SAP:** Saprolite
- **QV:** Quartz Vein
- **AM:** Amphibolite
- **SC:** Schist
- **VHM:** Very High Grade Metamorphic Rock Assemblages
- **GR:** Granite

The distribution of these key lithologies is given in Figure 6. Representative rock samples for testing were identified by Golder from each key lithology. GR (Granite) intervals were negligible in the drilling database and samples were, therefore, not collected from the GR unit. The number of samples for each key lithology was determined in approximate proportion to their occurrence in the drilling database.

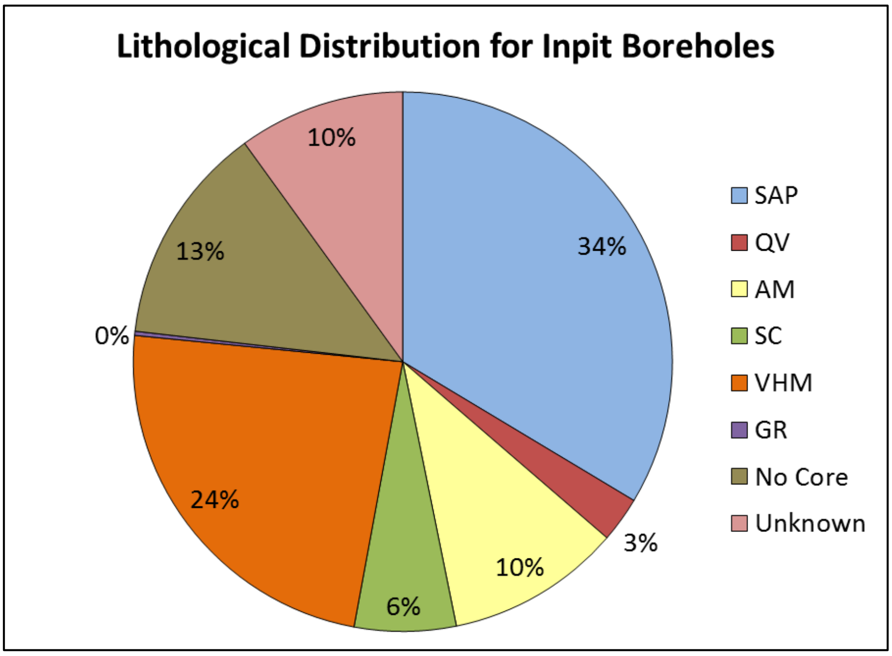


Figure 6 Distribution of the Key Lithologies within the Pits

Representative photographs of key lithologies are given in Table 4. Table 5 presents pertinent information for the samples selected for geochemical analysis, including lithological characteristics as well as the depth.

Table 4 Representative Photographs of Sampled Key Lithologies

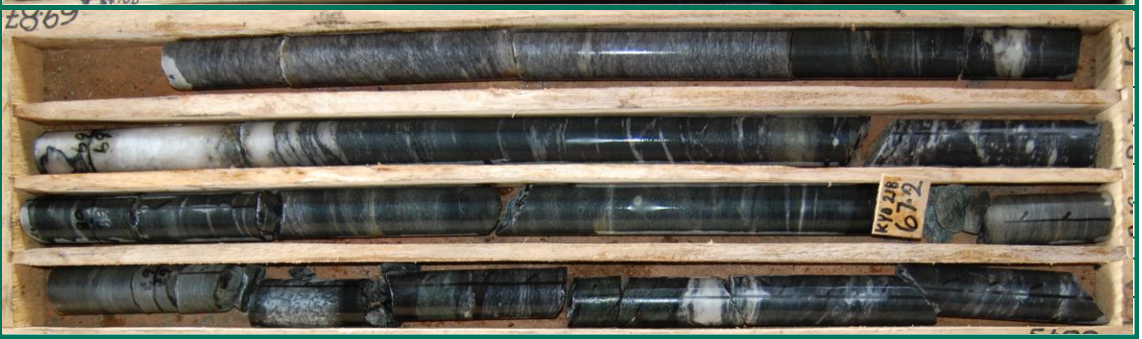
Lithology	Representative Photos of Lithological Units
SAP	
QV	
AM	
SC	
VHM	

Table 5 Selected Samples for Geochemical Characterization (Oxi: A visual oxidation rating system developed by geologists during the core logging, oxidation intensity increase from zero to five)

Sample ID (Golder)	Sample ID (MNG)	Lithology	Drillhole ID	From (m)	To (m)	Interval (m)	Lith1	Oxi	Au (g/t)	Type
KGS001	90246	SAP	KYD069	1.50	20.30	18.80	SAP	3	-0.99	Waste
KGS002	90247	SAP	KYD071	7.50	19.00	11.50	SAP	5	0.02	Waste
KGS003	90248	SAP	KYD075	13.00	25.00	12.00	SAP	5	0.22	Waste
KGS004	90249	SAP	KYD111	0.00	18.60	18.60	-	-	0.01	Waste
KGS005	90272	SAP	KYD113	8.40	17.40	9.00	SAP	3	0.03	Waste
KGS006	90273	SAP	KYD130	16.00	31.00	15.00	SAP	5	0.08	Waste
KGS007	90250	SAP	KYD186	14.00	20.00	6.00	SAP	3	0.02	Waste
KGS008	90251	SAP	KYD217	0.00	6.00	6.00	SAP	5	0.05	Waste
KGS009	90276	SAP	KYD218	1.00 8.00	4.00 14.00	9.00	SAP	5	0.04	Waste
KGS010	90252	SAP	KYD224	4.40	12.00	7.60	SAP	5	0.01	Waste
KGS012	90253	SAP	KYD235	0.00	15.90	15.90	SAP	5	0.55	Ore
KGS013	90255	SAP	KYD236	0.00	7.10	7.10	SAP	5	1.49	Ore
KGS014	90254	SAP	KYD264	0.00	14.80	14.80	SAP	5	-0.99	Waste
KGS031	90290	SAP	KYD288	0.00	11.00	11.00	SAP	-	-	-
KGS016	90256	QV	KYD225	34.80	39.10	4.30	QVN	3	0.02	Waste
KGS017	90288	QV	KYD286	29.95	33.40	3.45	QVN	-	-	-
KGS018	90282	QV	KYD236	20.60	23.60	3.00	QVN	2	12.88	Ore
KGS019	90283	QV	KYD237	17.00	19.10	2.10	QVN	2	0.07	Waste
KGS020	90271	QV	KYD070	35.10	36.90	1.80	QVN	2	0.03	Waste
KGS025	90289	QV	KYD294	9.10	13.10	4.00	QVN	-	-	-
KGS021	90260	AM	KYD071	47.20	50.00	2.80	AM	0	0.07	Waste
KGS022	90257	AM	KYD186	40.40	45.00	4.60	AM	0	0.09	Waste
KGS023	90258	AM	KYD217	31.00	33.00	2.00	AM	1	0.04	Waste
KGS024	90277	AM	KYD218	72.40	76.90	4.50	AM	0	0.08	Waste
KGS026	90259	AM	KYD264	47.00	50.00	3.00	AMP	0	0.04	Waste
KGS027	90261	AM	KYD130	158.00	163.20	5.20	AM	0	0.03	Waste
KGS028	90262	AM	KYD235	61.00	67.00	6.00	AMP	0	0.01	Waste
KGS032	90285	AM	KYD274	78.45	82.25	3.80	AM	-	-	-
KGS011	90287	SC	KYD283	56.00	60.55	4.55	SCB	-	-	-
KGS015	90286	SC	KYD274	25.80 26.80	26.30 28.40	2.10	SCB	-	-	-
KGS029	90263	SC	KYD105	29.40	34.00	4.60	SCB	2	0.06	Waste
KGS030	90264	SC	KYD217	23.00	27.00	4.00	SCB	3	0.96	Ore
KGS033	90265	SC	KYD010	33.75	38.50	4.75	SCB	0	0.02	Waste
KGS034	90275	VHM	KYD125	25.00	31.30	6.30	MGM	0	0.01	Waste
KGS035	90266	VHM	KYD130	44.00	48.00	4.00	MGM	0	0.03	Waste
KGS036	90267	VHM	KYD217	51.00	54.00	3.00	ML	0	0.01	Waste
KGS037	90268	VHM	KYD218	24.00	27.00	3.00	MG	1	0.01	Waste
KGS038	90269	VHM	KYD218	35.00	38.00	3.00	MG	0	0.02	Waste
KGS039	90278	VHM	KYD218	59.70 63.00	62.50 64.90	4.70	MGL	0	0.01	Waste
KGS040	90284	VHM	KYD224	23.90	28.80	4.90	MG	2	0.12	Waste
KGS041	90279	VHM	KYD225	51.20	54.40	3.20	MG	0	0.10	Waste
KGS042	90281	VHM	KYD235	26.40 29.20	28.20 31.50	4.10	MGM	0	0.10	Waste
KGS043	90280	VHM	KYD236	31.20	36.00	4.80	ML	0	0.19	Waste
KGS044	90270	VHM	KYD237	23.00	27.00	4.00	MGM	0	0.01	Waste
KGS045	90274	VHM	KYD130	154.00 163.20	156.25 164.80	3.85	ML	0	0.03	Waste

4.2.3 Geochemical Distribution

The drillhole database provided by MNG did not include assay results, except Au and Ag. Therefore, the sample selection was mainly focused on lithological distribution and a visual oxidation scale provided in the drilling database.

4.3 Test Methods and Results

Static testing is the first phase of geochemical characterization, and is a precursor to kinetic testing. The objective of static testing is to describe the bulk chemical characteristics of a material. These tests are designed to evaluate the potential of a particular rock type to generate acid, neutralize acid, or leach metals. Static tests provide an indication of the presence of minerals that may generate acid as well as minerals that may act to neutralize any acid formed. In some cases, testing may indicate that a surrogate parameter can be used as an indication of ARD potential (e.g., iron as an indicator of the amount of sulphide, calcium or carbon as an indicator of the amount of neutralization potential).

The static testing program consists of screening-level tests that can be used to determine the potential for acid rock drainage (ARD) and metal leaching (ML) of the various rock types, culminating in an initial assessment of potential environmental concerns and identification of mitigative measures, if required. If the static testing program results in uncertainties with regard to expected environmental behavior, or if this behavior is expected to change over time due to transient processes such as sulphide oxidation, kinetic testing is typically recommended.

As no one analytical method or technique is capable of reliably predicting future drainage chemistry, a combination of tests was performed on the samples. The following tests were included in the static testing program:

- Chemical composition (major oxides and trace elements);
- Mineralogy - XRD – Not conducted by Golder
- Acid Base Accounting (ABA)
- Net Acid Generation (NAG)
- Short-term leachates (STL) (24-hour) – Shake Flask Extraction (SFE)
- NAG leach test

The analyses were performed at the Environmental Services Laboratory of SGS South Africa Inc. (“SGS”), in Johannesburg, Republic of South Africa. The results of the geochemical characterization program are presented in the following sections in a combined evaluation of the test results.

4.3.1 Chemical Composition

Total metal and whole rock analyses were conducted to determine the elemental composition of the ore and waste rock material. When combined with mineralogy, ABA and leach tests results, this information can assist in defining a sample's capacity for acid generation, acid neutralization and metal leaching. Whole rock analysis was performed using X-ray fluorescence (XRF) for the major elements; and the trace metal analysis by inductively coupled plasma (ICP-OES and ICP-MS) except for mercury, which was analysed for using atomic absorption spectroscopy (CVAAS). The trace metal content was determined to identify metals of potential environmental concern and for sample selection for short term leach tests with the aim of understanding if the "elevated" trace metal contents mobilize in concentrations that may lead to environmental impacts.

4.3.1.1 Major Oxides

The major oxides assessment table in Appendix A-1 includes the average abundance of these elements in the earth's crust (Smith and Huyck, 1999). The values that exceed the crustal value by a factor of 5 or more are shown in red. Graphical versions of the assessment are presented in in Appendices A-2.

The results from the major oxide analysis of the samples are summarized in Table 6, which shows minimum, maximum and average values for each parameter. The only exceedances observed are MgO and Cr_2O_3 in one AM sample and Cr_2O_3 in one SC sample.

The results from the chemical analysis of the ore and waste rock can be summarized as follows:

- SiO_2 accounts for more than half of the total oxides (48-100%), while Al_2O_3 and Fe_2O_3 account for a further 1 - 23% and 0.66 – 21 %, respectively, of the total oxides across all rock types.
- The highest concentrations of silica (i.e. average > 98%) occur in the Quartz Vein (QV),
- The highest aluminium concentrations are found in the SAP samples. AM, SC and VHM also have relatively high aluminium concentrations. The average concentration in these three rock types is 13.66 – 18.93% Al_2O_3.
- The Fe_2O_3 concentrations are generally highest in AM and SAP samples, with an average of 12.26 and 13.25% respectively.
- The highest CaO and MgO concentrations occur in AM, with an average concentration of 9.93%, likely due to presence of amphibole group minerals.
- K_2O occurs in low concentrations in all the samples (<3%); its lowest concentration was recorded in the Quartz Vein (QV).

Table 6 Summary of Major Oxide Test Results

LITHOLOGY		SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	MnO	Cr_2O_3	V_2O_5	LOI
		%	%	%	%	%	%	%	%	%	%	%	%	%
	ACA*	***57.76***	***15.12***	***7.15***	***3.48***	***4.2***	***3.24***	***3.13***	***0.83***	***0.23***	***0.12***	***0.03***	***0.03***	
SAP	*Min*	44.00	16.00	4.00	0.05	0.04	0.05	0.06	0.40	0.03	0.02	0.01	0.01	6.30
	Max	72.00	23.00	21.00	2.20	3.00	1.30	2.40	1.80	0.35	0.37	0.13	0.07	11.00
	Ave	57.21	18.93	12.26	0.53	0.42	0.23	0.79	1.00	0.11	0.13	0.03	0.04	8.26
QV	*Min*	90.00	0.05	0.66	0.05	0.04	0.05	0.02	0.01	0.01	0.01	0.01	0.01	0.02
	Max	100.00	0.98	3.80	0.37	0.51	0.15	0.23	0.08	0.03	0.06	0.05	0.01	0.96
	Ave	97.50	0.33	1.55	0.17	0.19	0.07	0.06	0.03	0.01	0.02	0.02	0.01	0.49
AM	*Min*	48.00	9.30	11.00	4.10	7.60	0.84	0.24	0.51	0.04	0.17	0.01	0.03	0.57
	Max	55.00	15.00	16.00	**19.00**	11.00	3.70	1.70	1.50	0.17	0.23	**0.24**	0.07	3.70
	Ave	50.50	13.66	13.25	7.88	9.93	2.24	0.62	1.09	0.10	0.20	0.05	0.05	1.06
SC	*Min*	59.00	12.00	1.30	0.08	1.80	1.70	0.65	0.09	0.03	0.01	0.01	0.01	0.30
	Max	75.00	15.00	8.70	10.00	2.70	6.10	3.80	0.42	0.15	0.13	**0.22**	0.02	5.00
	Ave	69.80	13.80	3.72	2.66	2.26	3.90	2.01	0.23	0.06	0.05	0.05	0.01	1.49
VHM	*Min*	58.00	13.00	1.60	0.23	2.10	1.40	1.60	0.12	0.03	0.02	0.01	0.01	0.31
	Max	75.00	17.00	9.10	3.90	7.70	5.20	2.80	0.83	0.19	0.16	0.01	0.04	3.00
	Ave	66.42	14.75	5.04	1.76	4.16	4.03	2.23	0.47	0.13	0.07	0.01	0.02	0.81

NOTES:
*Average Crustal Abundance: Typical crustal abundance for continental rocks taken from Smith and Huyck (1999).
LOI = Loss on Ignition
Detection limits were used in calculations for the parameters whose values are below the detection limit.
Values that are equal or greater than 5 times crustal abundance are highlighted in **Bold Red.**

4.3.1.2 Trace Metals Analysis

The summary of the trace metals results which exceed the crustal value by a factor of 5 (in red) is presented in Table 7. The detailed results are presented in Appendices A-3 and A-4 in tabular and graphical format, respectively. Highlighted boxes were used to show the “exceedances” in the graphs.

Trace metals with “elevated” average values include silver, arsenic, barium, bismuth, chromium, mercury, magnesium and selenium. In general, the other trace metal concentrations are similar to or slightly below the 5x crustal abundance. Trace elements identified here as being of potential environmental concern will be verified through leach testing.

- Arsenic exceeds the consensus crustal abundance in all of the samples,
- Silver exceeds the consensus crustal abundance in most of the lithological groups except VHM,
- Bismuth exceeds the crustal value by a factor of 5 in some samples of SAP, QV and SC,
- Mercury exceeds the abundance value in one SAP and four VHM samples,
- Barium, chromium and magnesium exceed the abundance values in one VHM and one AM sample,
- Selenium exceeds the consensus crustal abundance in three samples, one SAP and two VHM. However, its detection limit exceeds the crustal abundance so this exceedance may be artificial.

Table 7 Summary of Trace Metal Test Results that Exceed Crustal Abundances

Sample ID (Golder)	Sample ID (MNG)	Lithology	Ag	As	Ba	Bi	Cr	Hg	Mg	Se**
			mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Average Crustal Abundance*			0.07	2	430	0.2	200	0.08	21,000	0.09
KGS001	90246	**SAP**	**2.50**	**24.00**	338	**4.90**	269	0.12	1100	**2.00**
KGS002	90247	**SAP**	**0.30**	9.00	553	0.29	134	0.06	2900	**2.00**
KGS003	90248	**SAP**	**2.30**	**12.00**	1161	0.97	749	0.10	5500	**2.00**
KGS004	90249	**SAP**	**2.10**	**12.00**	295	0.34	140	0.09	3200	**2.00**
KGS005	90272	**SAP**	**1.60**	**17.00**	1496	0.11	23	0.05	5000	**2.00**
KGS006	90273	**SAP**	**1.30**	**14.00**	710	**1.90**	110	0.07	3100	**2.00**
KGS007	90250	**SAP**	**1.20**	**12.00**	685	0.23	87	0.05	12000	**2.00**
KGS008	90251	**SAP**	**0.60**	**13.00**	89	0.60	142	0.09	500	**2.00**
KGS009	90276	**SAP**	**1.60**	**20.00**	374	**1.90**	276	0.14	1600	**2.00**
KGS010	90252	**SAP**	**1.10**	**10.00**	1288	0.55	132	0.06	5100	**2.00**
KGS012	90253	**SAP**	**5.30**	**11.00**	157	**2.10**	171	0.18	600	**4.00**
KGS013	90255	**SAP**	**> 10**	**11.00**	145	0.78	49	**0.68**	300	**2.00**
KGS014	90254	**SAP**	**1.40**	**10.00**	295	**1.30**	266	0.09	800	**2.00**
KGS031	90290	**SAP**	**6.00**	**15.00**	102	0.23	72	0.08	400	**2.00**
KGS016	90256	**QV**	**0.30**	**11.00**	13	**0.04**	26	0.05	300	**2.00**
KGS017	90288	**QV**	**0.30**	**14.00**	96	0.35	34	0.09	2100	**2.00**
KGS018	90282	**QV**	**3.40**	**16.00**	23	**4.90**	54	0.13	2100	**2.00**
KGS019	90283	**QV**	**0.40**	**16.00**	16	0.11	23	0.06	200	**2.00**
KGS020	90271	**QV**	0.30	**17.00**	50	**2.40**	29	0.05	800	**2.00**
KGS025	90289	**QV**	**0.30**	**14.00**	6	**0.04**	19	0.03	200	**2.00**
KGS021	90260	**AM**	**0.90**	**14.00**	99	0.29	**1408**	0.03	**110000**	**2.00**
KGS022	90257	**AM**	0.30	**15.00**	74	0.45	256	0.05	44000	**2.00**
KGS023	90258	**AM**	**0.40**	**16.00**	67	0.29	205	0.03	41000	**2.00**
KGS024	90277	**AM**	**0.60**	**16.00**	326	0.24	243	0.07	41000	**2.00**
KGS026	90259	**AM**	**0.40**	**18.00**	418	0.52	73	0.05	23000	**2.00**
KGS027	90261	**AM**	**0.40**	**13.00**	57	0.06	154	0.03	36000	**2.00**
KGS028	90262	**AM**	**0.30**	**14.00**	47	0.05	194	0.03	37000	**2.00**
KGS032	90285	**AM**	**0.30**	**21.00**	145	**0.04**	92	0.07	33000	**2.00**
KGS011	90287	**SC**	**0.60**	**19.00**	539	**1.90**	18	0.05	5300	**2.00**
KGS015	90286	**SC**	**0.80**	**18.00**	1022	**0.04**	9	0.05	2000	**2.00**
KGS029	90263	**SC**	**0.90**	**18.00**	1412	**10.00**	71	0.04	12000	**2.00**
KGS030	90264	**SC**	**0.50**	**18.00**	369	0.42	958	0.03	57000	**2.00**
KGS033	90265	**SC**	**0.30**	**18.00**	454	**0.04**	10	0.07	1100	**2.00**
KGS034	90275	**VHM**	**0.30**	**22.00**	484	0.20	62	0.03	15000	**4.00**
KGS035	90266	**VHM**	**0.30**	**18.00**	1805	**0.04**	15	0.03	6600	**2.00**
KGS036	90267	**VHM**	**0.30**	**17.00**	1591	**0.04**	11	0.03	5400	**2.00**
KGS037	90268	**VHM**	**0.30**	**16.00**	1038	0.05	10	0.03	2600	**2.00**
KGS038	90269	**VHM**	**0.30**	**16.00**	471	0.57	102	0.05	23000	**2.00**
KGS039	90278	**VHM**	**0.30**	**19.00**	1101	0.06	14	0.04	1800	**2.00**
KGS040	90284	**VHM**	**0.30**	**20.00**	**7238**	0.75	100	**2.00**	13000	**2.00**
KGS041	90279	**VHM**	**0.60**	**27.00**	1431	0.76	36	**1.50**	13000	**2.00**
KGS042	90281	**VHM**	**0.30**	**27.00**	1148	0.45	20	**1.20**	7700	**2.00**
KGS043	90280	**VHM**	**0.30**	**23.00**	1534	0.13	16	**0.75**	5800	**2.00**
KGS044	90270	**VHM**	**0.40**	**15.00**	811	0.19	61	0.03	16000	**2.00**
KGS045	90274	**VHM**	**0.30**	**24.00**	1083	0.15	46	0.02	14000	**2.00**

NOTES:

* Typical crustal abundance for continental rocks taken from Smith and Huyck (1999).

Detection limits were used in calculations and highlighted in **Bold Blue** for the parameters whose values are below the detection limit.

** Detection limit of the Selenium (Se) is much greater than the crustal abundance of it.

Values that are equal or greater than 5 times crustal abundance are highlighted in **Bold Red.**

4.4 Mineralogy

Three samples from the Kokoya ore deposit (One Saprolite ROM and two composite samples - Rock Crusher 1 ROM, Rock Crusher 2 ROM) were analysed by SGS for metallurgical testing purposes. The study was conducted before Golder started working on the geochemical characterization program and Golder was not involved with sample selection and testing. The test work included chemical, mineralogical and metallurgical tests.

Mineralogical analysis is important to identify minerals of potential environmental significance, in particular potentially acid generating minerals (i.e. sulphides), acid neutralizing minerals (primarily carbonates and selected silicates), and readily-soluble minerals (e.g., sulphates). The mineralogical compositions of the ROM samples, determined by QEMSCAN Bulk Modal Analysis (BMA), are given Table 8.

The principal findings of the mineralogical analysis were as follows:

- Unspecified carbonate minerals are detected in the Rock Crusher samples.
- Sulphide minerals observed are pyrite, chalcopyrite, galena and bismuthinite, primarily in the Rock Crusher samples.
- The majority of the rock crusher samples consist of quartz (>36%), which is considered inert from an environmental perspective.
- The majority of the saprolite sample consist of clay (kaolinite)
- Plagioclase is abundant in Rock Crusher samples but very limited in Saprolite.
- The majority of the waste samples consist of muscovite (>40%).
- Fe-Oxide/Hydroxide is abundant in Saprolite at concentrations up to approximately 18%. Iron oxyhydroxides can provide significant surface area for adsorption of trace elements such as Cd, Cu, Zn, Pb, etc.
- Epidote and Chlorite is present in Rock Rusher samples in minor concentrations.
- The Rock Crusher samples also contain minor amounts of alunite, which contains stored acidity and metals that can be released upon dissolution.
- Saprolite represents the overlying weathered material, and it can be seem that almost all the sulphide and carbonate minerals have been leached out.
- The two rock crusher samples have been slightly weathered as is shown by the presence of kaolinite an secondary minerals like alunite and jarosite.

Table 8 Mineralogical Composition of the Three Samples (SGS 2014)

Minerals	Approximate Mineral Formula	Abundance %		
		Saprolite	Rock Crusher 1	Rock Crusher 2
Quartz	SiO_2	20.18	36.72	38.56
Plagioclase	$(Na,Ca)(Al,Si)_4O_8$	0.07	23.09	23.57
Kaolinite	$Al_4(Si_4O_{10})(OH)_8$	51.42	5.37	4.82
Epidote	$Ca_2Al_2O.(Al,Fe)OH(Si_2O_7)(SiO_4)$	0.00	2.06	1.43
Chlorite	$(Mg,Fe)_6(Si,Al)_4O_{10}(OH)_8$	0.11	0.79	0.67
Mica/K-feldspar	$KMg_3(Si_3Al)O_{10}(OH)_2/KAlSi_3O_8$	9.17	16.81	15.70
Amphibole/Pyroxene	$Ca_2(Mg,Fe)_5(OH)_2(Si_4O_{11})_2$	0.01	11.16	11.69
Sphene	$CaTiSiO_5$	0.00	0.55	0.54
Other Silicates		0.30	0.06	0.03
Total Silicates		**81.26**	**96.06**	**96.48**
Pyrite	FeS_2	0.19	1.90	1.87
Galena	PbS	0.00	0.02	0.01
Chalcopyrite	$CuFeS_2$	0.00	0.09	0.19
Bismuthinite	Bi_2S_3	0.00	0.01	0.00
Other Sulphides	-	0.00	0.01	0.00
Total Sulphides		**0.19**	**2.04**	**2.08**
Fe-oxide/Hydroxide	Fe_3O_4/α- FeO.OH	18.27	0.54	0.32
Rutile	TiO_2	0.18	0.00	0.00
Other Oxides	-	0.07	0.07	0.03
Total Oxides		**18.51**	**0.61**	**0.35**
Carbonates		0.02	0.38	0.24
Apatite	$Ca(PO_4)_3(OH,F,Cl)$	0.00	0.08	0.11
Gypsum	$CaSO_4.2H_2O$	0.00	0.01	0.00
Alunite	$KAl_3(SO_4)_2(OH)_6$	0.01	0.13	0.11
Jarosite	$KFe^{3+}{}_3(OH)_6(SO_4)_2$	0.00	0.01	0.00
Total Carb/Phos/Sulphates		**0.04**	**0.60**	**0.47**
Silver	Ag	0.00	0.01	0.00
U-phases		0.00	0.09	0.08
Other		0.00	0.03	0.00
Total Other		**0.00**	**0.13**	**0.08**
Total		**100.00**	**100.00**	**100.00**

4.4.1 Acid-Base Accounting and Net Acid Generation Testing

Acid-Base Accounting (ABA) is conducted to predict the ARD potential of a material through assessment of the acid neutralizing potential (NP) and acid generation potential (AP). ABA testing included determination of the following:

- Bulk neutralization potential (NP) by the modified Sobek method
- Total carbon (TC) and carbonate (CO_3)
- Sulphur speciation, including total sulphur, sulphide sulphur, and sulphate sulphur
- Paste pH

The results from the sulphur speciation were used to determine the AP of a sample. For this study, AP was calculated using sulphide sulphur, and assuming that sulphide sulphur was equal to the difference between the measured total sulphur and sulphate sulphur. The bulk NP of a mine waste is determined by treating the sample with a known excess of hydrochloric acid, and back-titrating the amount of unconsumed acid with sodium hydroxide. The principal neutralizing minerals in most geologic materials are calcium and magnesium carbonates. Additional neutralizing minerals accounted for in the determination of bulk NP include basic silicates such as calcic feldspars, olivine, amphiboles, and biotite. However, due to their generally slower dissolution rates, their contribution to the overall NP is generally considered to be small under ambient conditions. Felsic silicates, such as sodic and potassic feldspars, muscovite, most clay minerals, and quartz, do not contribute significantly to the NP. In addition, carbonate minerals that contain iron and/or manganese do not report to the NP measurement, for reasons explained in the paragraph below. The NP is also expressed in kg $CaCO_3$/t, representing the capacity of the solids to neutralize acid, but not necessarily implying that calcite ($CaCO_3$) is present. The TC and carbonate measurements are used to determine the carbon and carbonate neutralization potentials of a sample, respectively. Carbon and carbonate NP are a measure of the neutralization capacity of a sample afforded by carbonate minerals only, assuming all carbonates react like calcite. As noted earlier, calcium and magnesium carbonates generally are the principal neutralizing minerals in most geologic materials. Iron and manganese carbonates (e.g., siderite [$FeCO_3$], ankerite [$CaFe(CO_3)_2$], and rhodochrosite [$MnCO_3$]) do not contribute to buffering capacity since subsequent hydrolysis of the Fe and Mn tends to generate acidity. Therefore, if iron and manganese carbonates are present, carbon and carbonate NP will overestimate the neutralizing capacity of a material.

Paste pH is a qualitative corollary of the NP, and provides additional information on the neutralizing capabilities of a material. The paste pH reflects the balance of readily-soluble acid generating and acid neutralizing components within a sample. A second type of acid-base accounting, developed initially in Australia but now widely applied internationally, is called the net acid generation (NAG) procedure. The NAG procedure uses a strong oxidant (hydrogen peroxide) to rapidly oxidize sulphide minerals in a crushed sample of the entire rock (AMIRA, 2002). The NP of the sample then can be directly challenged by the acidity generated by rapidly oxidizing sulphides. If the sample has sufficient available NP, the alkalinity of the whole rock will not be entirely depleted, and the system is expected to have the capacity to remain circum-neutral. If there is inadequate available NP, then the pH of the test solution will fall below 4.5 and there will be net acidity rather than net alkalinity. In this case, a sample shows potential for acid generation.

4.4.1.1 ABA/NAG Program Results

The principal findings of the ABA/NAG program are discussed below.

Table 9 shows the ABA results, including paste pH, sulphur species, neutralization potential (bulk, carbon and carbonate), NAG pH results and calculated values for NNP and NPR for the samples

The results from the ABA and NAG testing of ore and waste rock are as follows:

- The sulphur contents are typically very low in all samples. There is only one QV sample (KGS017) with a total sulphur content greater than 1.00 % and there are three samples (one AM and two SC) with the total sulphur content between 0.30 % and 0.40 %. Total sulphur contents of the remaining 41 samples are below 0.15 % and many of them are also below the detection limit of 0.01 %, including all SAP samples. Therefore, samples have very low AP values, ranging from 0.31 kg $CaCO_3$/t to 33 kg $CaCO_3$/t.

- The majority of the total sulphur in the samples occurs as sulphide sulphur.

- SAP samples are highly oxidized as expected, and have very low sulphide sulphur content and AP values.

- QV samples have very low AP values except one sample (KGS017) which has the highest sulphide sulphur content of 1.05 % - this sample also has the lowest paste pH and NAG pH of all samples analysed.

- Similar to other lithological groups, the metamorphic units, AM, SC and VHM, have low sulphide sulphur content and AP values. Two SC samples have relatively higher AP values, but they are still less than 10 kg CaCO3/t,

- The various NPs calculated (Bulk NP, Carbonate NP and Carbon NP) are all very low in general. The Bulk NP value ranges from 0 kg $CaCO_3$/t to 39 kg $CaCO_3$/t, and is significantly higher than the CaNP especially in metamorphic rock groups (AM, SC and VHM),

- Paste pH, which represents surficial properties, reflects that the SAP and QV is largely circum neutral, neutral and alkaline (pH range 5.5 to 7.8). The paste pH of metamorphic rocks AM, VHM and SC is alkaline and ranges from 7.60 to 10.20,

- NAG pH is generally circum neutral to neutral except one QV sample with a NAG pH value of 2.8. The NAG pH is more indicative of long-term conditions, and represents complete oxidation of reactive sulphide combined with simultaneous buffering through dissolution of neutralising minerals, if present.

Table 9 ABA and NAG Tests Results

Sample ID (Golder)	Sample ID (MNG)	Lithology	Paste pH	Total-S	Sulphate-S	Sulphide-S	C	CO3	Carbon NP *	Carbonate NP **	AP	Bulk NP	NNP	NPR	NAG pH
			-	%	%	%	%	%	*kg CaCO $_3$/t*	*kg CaCO $_3$/t*	*kg CaCO $_3$/t*	*kg CaCO $_3$/t*	*kg CaCO $_3$/t*	*ratio*	-
KGS001	90246	**SAP**	5.70	0.01	0.03	**0.01**	0.31	**0.05**	*25.84*	*0.83*	0.31	**0.10**	0.00	0.00	6.30
KGS002	90247	**SAP**	6.20	**0.01**	**0.03**	**0.01**	0.04	**0.05**	*3.33*	*0.83*	**0.31**	**0.10**	0.00	0.00	6.30
KGS003	90248	**SAP**	6.70	**0.01**	**0.03**	**0.01**	0.41	**0.05**	*34.17*	*0.83*	**0.31**	0.80	0.50	2.60	6.20
KGS004	90249	**SAP**	6.30	**0.01**	**0.03**	**0.01**	0.21	**0.05**	*17.50*	*0.83*	**0.31**	**0.10**	0.00	0.20	6.40
KGS005	90272	**SAP**	7.50	0.01	**0.03**	**0.01**	0.29	**0.05**	*24.17*	*0.83*	**0.31**	1.30	1.00	4.20	6.40
KGS006	90273	**SAP**	5.60	**0.01**	**0.03**	**0.01**	0.35	**0.05**	*29.17*	*0.83*	**0.31**	1.00	0.70	3.40	6.30
KGS007	90250	**SAP**	6.80	**0.01**	**0.03**	**0.01**	0.09	**0.05**	*7.50*	*0.83*	**0.31**	1.00	0.70	3.40	6.30
KGS008	90251	**SAP**	5.60	0.01	**0.03**	**0.01**	0.33	**0.05**	*27.50*	*0.83*	**0.31**	**0.10**	0.00	0.00	6.50
KGS009	90276	**SAP**	5.90	**0.01**	**0.03**	**0.01**	0.38	**0.05**	*31.67*	*0.83*	**0.31**	0.30	0.00	1.00	6.30
KGS010	90252	**SAP**	6.50	**0.01**	**0.03**	**0.01**	0.04	**0.05**	*3.33*	*0.83*	**0.31**	0.60	0.20	1.80	6.40
KGS012	90253	**SAP**	5.60	**0.01**	**0.03**	**0.01**	0.26	1.20	*21.67*	*20.01*	**0.31**	**0.10**	0.00	0.00	6.50
KGS013	90255	**SAP**	5.80	**0.01**	**0.03**	**0.01**	0.07	**0.05**	*5.83*	*0.83*	**0.31**	0.30	0.00	1.00	6.50
KGS014	90254	**SAP**	5.50	**0.01**	**0.03**	**0.01**	0.22	**0.05**	*18.33*	*0.83*	**0.31**	**0.10**	0.00	0.20	6.40
KGS031	90290	**SAP**	5.70	**0.01**	**0.03**	**0.01**	0.14	0.08	*11.67*	*1.33*	**0.31**	**0.10**	0.00	0.00	6.30
Minimum			*5.50*	*0.01*	*0.03*	*0.01*	*0.04*	*0.05*	*3.33*	*0.83*	*0.31*	*0.10*	*0.00*	*0.00*	*6.20*
Maximum			*7.50*	*0.01*	*0.03*	*0.01*	*0.41*	*1.20*	*34.17*	*20.01*	*0.31*	*1.30*	*1.00*	*4.20*	*6.50*
Average			*6.10*	*0.01*	*0.03*	*0.01*	*0.22*	*0.13*	*18.69*	*2.24*	*0.31*	*0.43*	*0.22*	*1.27*	*6.36*
KGS016	90256	**QV**	6.80	**0.01**	**0.03**	**0.01**	0.01	**0.05**	*0.83*	*0.83*	**0.31**	1.80	1.50	5.80	5.80
KGS017	90288	**QV**	7.30	1.14	0.27	1.05	0.16	0.11	*13.33*	*1.83*	33.00	6.50	-26.50	0.20	2.80
KGS018	90282	**QV**	7.80	0.01	**0.03**	**0.01**	0.01	0.10	*0.83*	*1.67*	**0.31**	2.00	1.70	6.60	6.40
KGS019	90283	**QV**	6.60	**0.01**	**0.03**	**0.01**	**0.01**	**0.05**	*0.83*	*0.83*	**0.31**	1.30	1.00	4.20	6.20
KGS020	90271	**QV**	7.40	**0.01**	**0.03**	**0.01**	0.01	**0.05**	*0.83*	*0.83*	**0.31**	2.00	1.70	6.60	6.10
KGS025	90289	**QV**	5.80	**0.01**	**0.03**	**0.01**	**0.01**	**0.05**	*0.83*	*0.83*	**0.31**	1.80	1.50	5.80	5.90
Minimum			*5.80*	*0.01*	*0.03*	*0.01*	*0.01*	*0.05*	*0.83*	*0.83*	*0.31*	*1.30*	*-26.50*	*0.20*	*2.80*
Maximum			*7.80*	*1.14*	*0.27*	*1.05*	*0.16*	*0.11*	*13.33*	*1.83*	*33.00*	*6.50*	*1.70*	*6.60*	*6.40*
Average			*6.95*	*0.20*	*0.07*	*0.18*	*0.04*	*0.07*	*2.92*	*1.14*	*5.76*	*2.57*	*-3.18*	*4.87*	*5.53*
KGS021	90260	**AM**	9.40	0.06	0.08	0.04	0.12	**0.05**	*10.00*	*0.83*	1.30	39.00	38.00	31.00	7.60
KGS022	90257	**AM**	9.50	0.08	0.19	0.02	0.03	**0.05**	*2.50*	*0.83*	0.63	13.00	13.00	21.00	6.50
KGS023	90258	**AM**	9.30	0.15	0.11	0.11	0.02	**0.05**	*1.67*	*0.83*	3.40	12.00	8.40	3.40	6.40
KGS024	90277	**AM**	9.50	0.12	0.21	0.05	0.11	0.17	*9.17*	*2.84*	1.60	18.00	16.00	11.00	6.70
KGS026	90259	**AM**	10.00	0.09	0.09	0.06	0.13	0.07	*10.83*	*1.17*	1.90	20.00	18.00	10.00	6.90
KGS027	90261	**AM**	9.40	0.30	0.25	0.21	0.08	0.11	*6.67*	*1.83*	6.60	14.00	7.00	2.10	6.50
KGS028	90262	**AM**	9.30	0.11	0.11	0.07	0.07	0.06	*5.83*	*1.00*	2.20	9.30	7.10	4.20	6.90
KGS032	90285	**AM**	9.40	0.13	0.26	0.04	0.04	**0.05**	*3.33*	*0.83*	1.30	14.00	12.00	11.00	6.70
Minimum			*9.30*	*0.06*	*0.08*	*0.02*	*0.02*	*0.05*	*1.67*	*0.83*	*0.63*	*9.30*	*7.00*	*2.10*	*6.40*
Maximum			*10.00*	*0.30*	*0.26*	*0.21*	*0.13*	*0.17*	*10.83*	*2.84*	*6.60*	*39.00*	*38.00*	*31.00*	*7.60*
Average			*9.48*	*0.13*	*0.16*	*0.08*	*0.08*	*0.08*	*6.25*	*1.27*	*2.37*	*17.41*	*14.94*	*11.71*	*6.78*
KGS011	90287	**SC**	9.50	0.32	0.29	0.22	0.06	**0.05**	*5.00*	*0.83*	6.90	5.50	-1.40	0.80	5.50
KGS015	90286	**SC**	10.20	**0.01**	**0.03**	**0.01**	0.03	0.07	*2.50*	*1.17*	**0.31**	6.00	5.70	20.00	6.10
KGS029	90263	**SC**	7.40	0.40	0.44	0.26	0.03	**0.05**	*2.50*	*0.83*	8.10	2.50	-5.60	0.30	5.60
KGS030	90264	**SC**	8.00	**0.01**	**0.03**	**0.01**	0.05	**0.05**	*4.17*	*0.83*	**0.31**	7.50	7.20	24.00	6.60
KGS033	90265	**SC**	9.60	0.01	**0.03**	**0.01**	0.02	**0.05**	*1.67*	*0.83*	**0.31**	4.00	3.70	13.00	6.30
Minimum			*7.40*	*0.01*	*0.03*	*0.01*	*0.02*	*0.05*	*1.67*	*0.83*	*0.31*	*2.50*	*-5.60*	*0.30*	*5.50*
Maximum			*10.20*	*0.40*	*0.44*	*0.26*	*0.06*	*0.07*	*5.00*	*1.17*	*8.10*	*7.50*	*7.20*	*24.00*	*6.60*
Average			*8.94*	*0.15*	*0.16*	*0.10*	*0.04*	*0.05*	*3.17*	*0.90*	*3.19*	*5.10*	*1.92*	*11.62*	*6.02*
KGS034	90275	**VHM**	9.60	0.03	0.05	0.01	0.08	**0.05**	*6.67*	*0.83*	0.31	14.00	13.00	43.00	6.80
KGS035	90266	**VHM**	10.10	**0.01**	**0.03**	**0.01**	0.11	0.06	*9.17*	*1.00*	**0.31**	15.00	14.00	47.00	6.60
KGS036	90267	**VHM**	10.10	0.02	**0.03**	0.01	0.08	**0.05**	*6.67*	*0.83*	0.31	12.00	12.00	39.00	6.70
KGS037	90268	**VHM**	9.60	0.01	**0.03**	0.01	0.02	**0.05**	*1.67*	*0.83*	0.31	4.50	4.20	15.00	6.40
KGS038	90269	**VHM**	9.80	0.07	0.04	0.06	0.12	**0.05**	*10.00*	*0.83*	1.90	19.00	17.00	10.00	6.70
KGS039	90278	**VHM**	9.80	**0.01**	**0.03**	**0.01**	0.02	0.12	*1.67*	*2.00*	**0.31**	6.30	6.00	20.00	6.50
KGS040	90284	**VHM**	7.60	0.03	0.04	0.01	0.08	0.07	*6.67*	*1.17*	0.31	6.70	6.30	21.00	6.50
KGS041	90279	**VHM**	9.90	0.06	**0.03**	0.06	0.03	**0.05**	*2.50*	*0.83*	1.90	12.00	10.00	6.40	6.50
KGS042	90281	**VHM**	10.10	0.01	0.03	**0.01**	0.12	**0.05**	*10.00*	*0.83*	**0.31**	18.00	18.00	59.00	6.90
KGS043	90280	**VHM**	9.90	0.03	0.08	**0.01**	0.08	**0.05**	*6.67*	*0.83*	**0.31**	13.00	13.00	42.00	6.50
KGS044	90270	**VHM**	10.10	0.05	0.15	**0.01**	0.05	**0.05**	*4.17*	*0.83*	**0.31**	14.00	13.00	45.00	6.60
KGS045	90274	**VHM**	10.20	0.02	**0.03**	0.01	0.05	**0.05**	*4.17*	*0.83*	0.31	14.00	14.00	45.00	6.70
Minimum			*7.60*	*0.01*	*0.03*	*0.01*	*0.02*	*0.05*	*1.67*	*0.83*	*0.31*	*4.50*	*4.20*	*6.40*	*6.40*
Maximum			*10.20*	*0.07*	*0.15*	*0.06*	*0.12*	*0.12*	*10.00*	*2.00*	*1.90*	*19.00*	*18.00*	*59.00*	*6.90*
Average			*9.73*	*0.03*	*0.05*	*0.02*	*0.07*	*0.06*	*5.83*	*0.97*	*0.58*	*12.38*	*11.71*	*32.70*	*6.62*

NOTES:

* Carbon NP (kg $CaCO_3$/t) = (%Total C) x (100.09/12.01) x (10)

** Carbonate NP (kg $CaCO_3$/t) = (%Carbonate) x (100.09/60.01) x (10)

AP (Acid Potential) = % Sulphide Sulphur x 31.25

NNP (Net Neutralization Potential) = Bulk NP-AP

NPR (Neutralization Potential Ratio) = Bulk NP/AP

Where Bulk NP<0 kg CaCO3/t, a value of 0 was used for calculation of NNP and NPR.

Detection limits were used in calculations and highlighted in **Bold Blue** for the parameters whose values are below the detection limit.

Figure 7 shows the relationship between total sulphur and sulphide sulphur. Sulphide sulphur represents the majority of the total amount of sulphur presents in the samples. Since this project represents a low-sulphide, gold-quartz vein deposit (greenstone deposit), low sulphide contents are not unexpected.

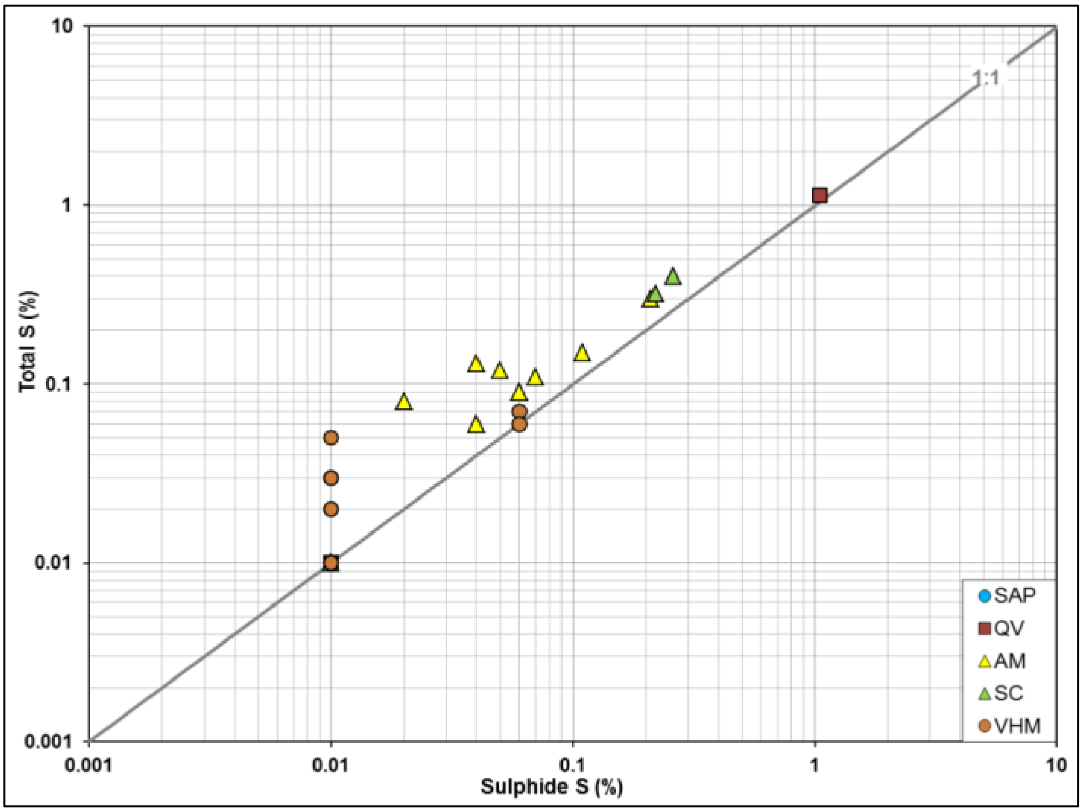


Figure 7 Total Sulphur vs. Sulphide Sulphur

The relationship between bulk NP and carbonate NP (CaNP) is presented in Figure 8. Bulk NP is higher than CaNP in all of the lithological groups except SAP. This situation implies that silicate minerals may be contributing to the bulk NP measurement.

Figure 9 shows the relationship between carbonate NP and carbon NP. As presented in Table 10 for almost all samples, the NP calculated using total carbon is significantly higher than the NP calculated from carbonate. The low NP values suggest that there is practically no neutralising potential, and the NP is not present in the form of readily-available carbonate minerals.

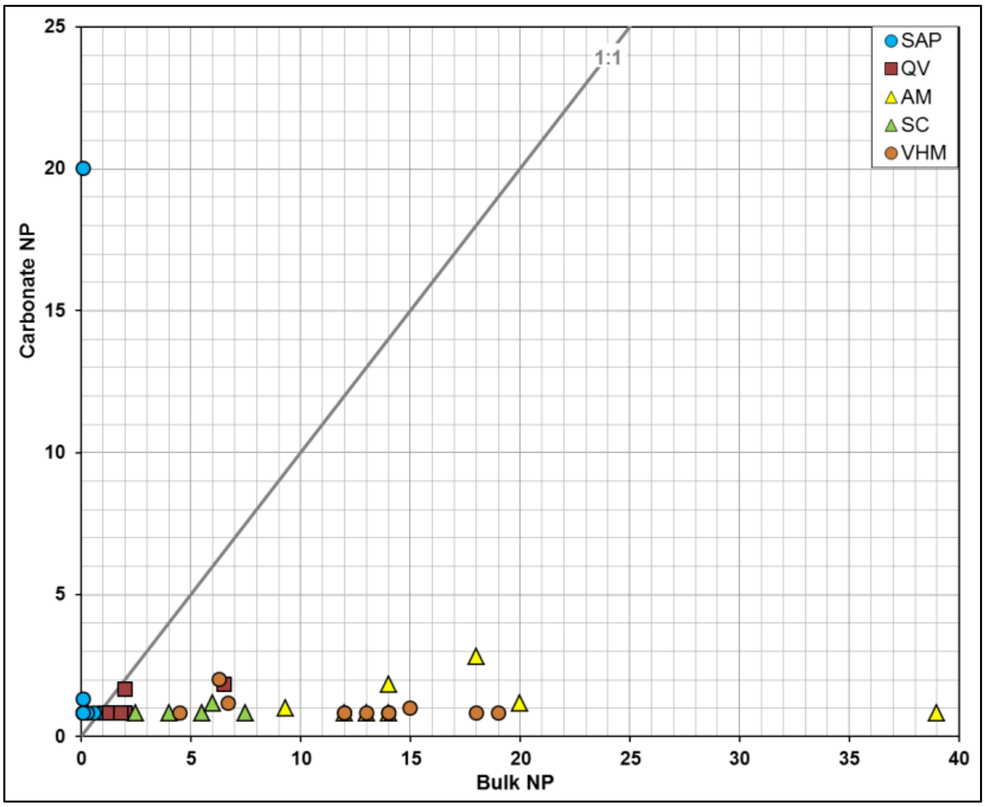


Figure 8 Bulk NP vs Carbonate NP

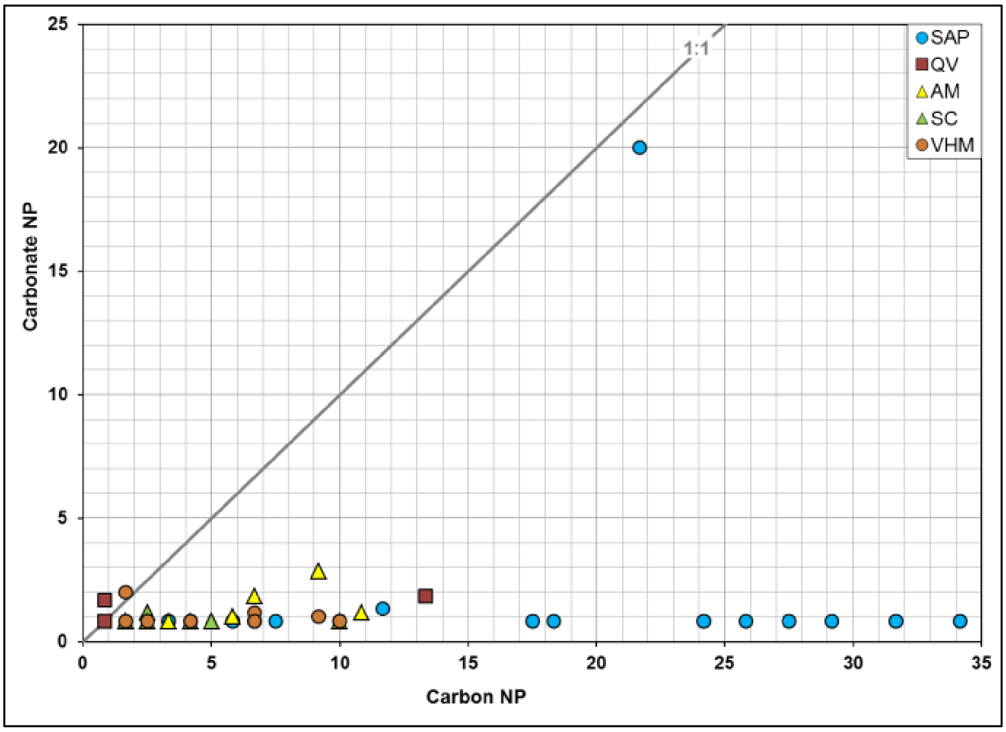


Figure 9 Carbon NP vs Carbonate NP

Paste pH versus sulphide sulphur presented in Figure 10 shows that the samples have circum neutral and alkaline paste pH values. Metamorphic groups, AM, SC and VHM, have alkaline paste pH values greater than 9.00 except three samples with paste pH values between 7.50 and 8.0. SAP and QV samples have near neutral paste pH values ranging from 5.50 to 7.80. No obvious trend between sulphide sulphur and paste pH is observed.

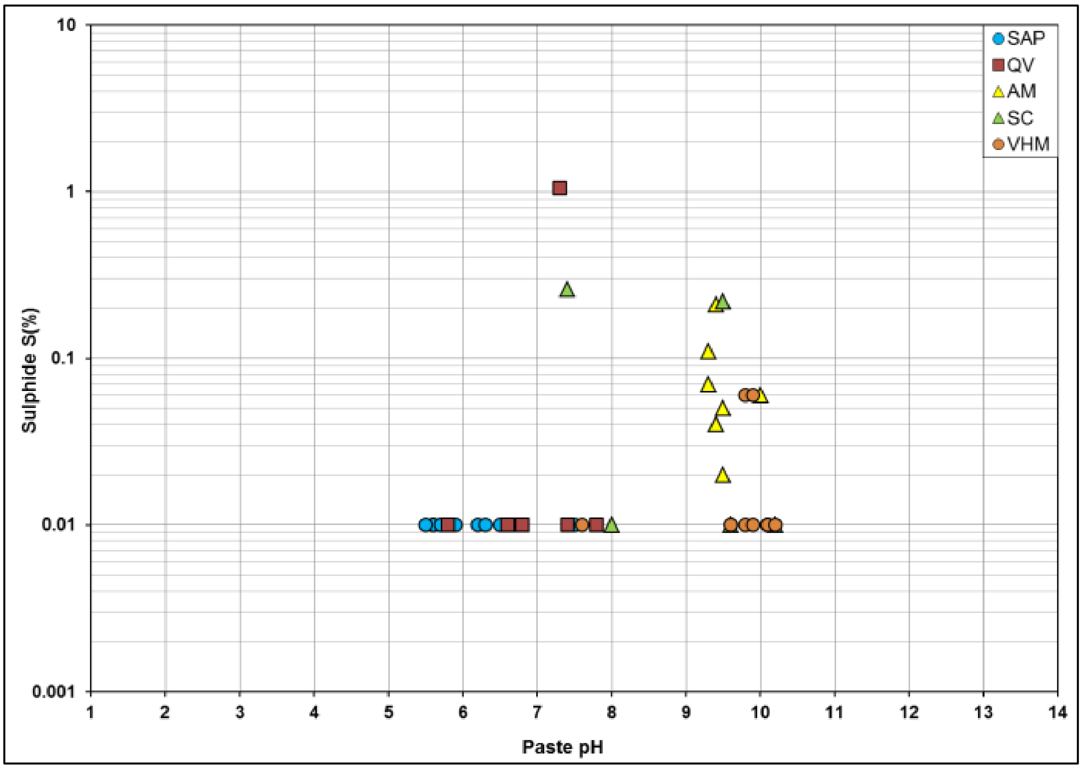


Figure 10 Sulphide Sulphur vs. Paste pH

4.4.1.2 Screening-Level Assessment of ARD Potential

A number of criteria have been proposed to characterize a sample as Potentially Acid Generating (PAG) and Non-Acid Generating Potential (NON-PAG) using ABA and/or NAG results. The most common approach is based on the use of the net potential ratio (NPR = NP/AP). For several reasons, no single ratio has been identified to have universal applicability in terms of predicting acid generation. The actual threshold values for a particular solid are material-specific, and depend on many factors, including the amounts and types of acid generating and neutralizing minerals, their morphology, their grain size, their crystallinity, their chemical composition, their paragenesis, the material's texture, and the site-specific exposure conditions.

Guidelines for evaluation of acid generation potential of mine wastes presented by the Mine Environment Neutral Drainage Program (MEND, 2009) are summarized in Table 10. These guidelines were applied in the evaluation of ABA results.

Table 10 ABA Screening Guidelines for ARD Potential based on NPR (MEND, 2009)

Potential for ARD	Criteria	Comments
Likely	NPR <1	Likely acid generating, unless sulphide minerals are non-reactive.
Possible (uncertain)	1< NPR <2	Possibly acid generating if NP is insufficiently reactive or is depleted at a rate faster than sulphides.
Unlikely or none	NPR >2	Not potentially acid generating unless significant preferential exposure of sulphides along fractures planes, or extremely reactive sulphides in combination with insufficiently reactive NP.

A second set of criteria, summarized in the GARD Guide (INAP, 2009), is based on the net neutralization potential (NNP = NP-AP) (Table 11). The following screening criteria are included in this classification:

Table 11 ABA Screening Guidelines for ARD Potential based on NNP (INAP, 2009)

Potential for ARD	Criteria
Potentially Acid Generating	NNP < -20 kg $CaCO_3$/t
Uncertain Acid Generation Potential	-20 < NNP < 20 kg $CaCO_3$/t
NON-Acid Generating Potential	NNP > 20 kg $CaCO_3$/t

Figure 11 (AP vs. bulk NP) shows that the majority of the samples fall in the NON-PAG field. Further, it should be noted that, although some SAP samples fall into the PAG and uncertain fields, they are actually considered NON-PAG due to the absence of sulphide sulphur and, consequently, very low AP values. The relationship between the NPR and sulphide sulphur is presented in Figure 12, showing the general increase in NPR with decreasing sulphide sulphur content.

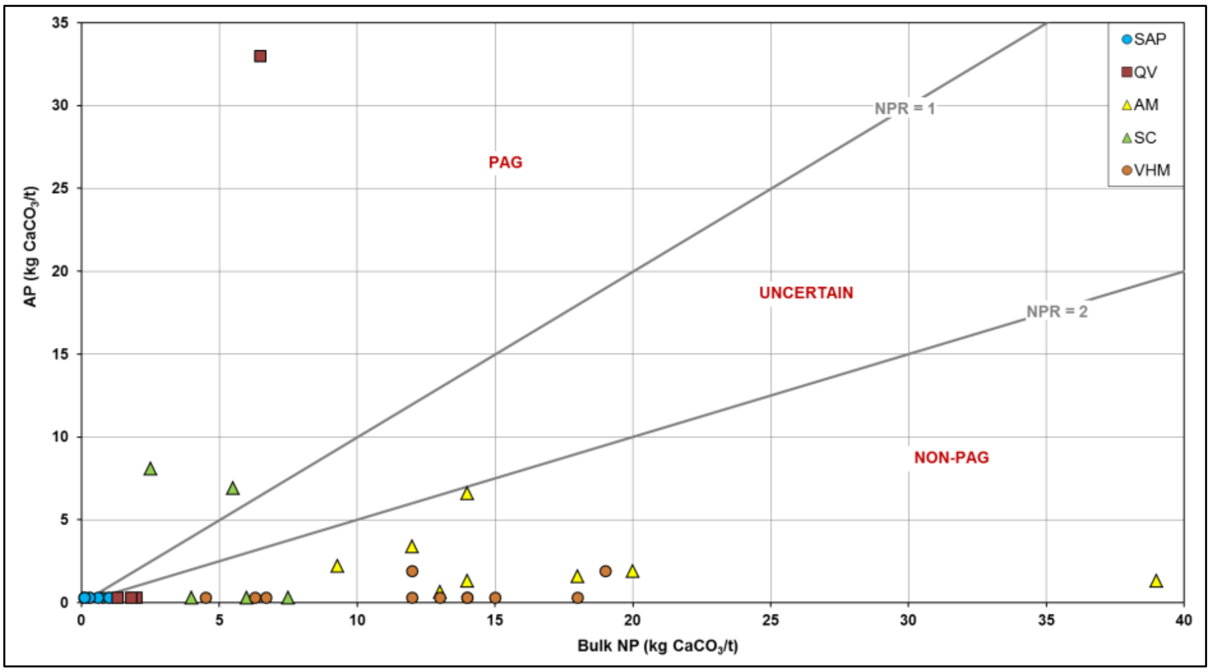


Figure 11 AP vs. Bulk NP

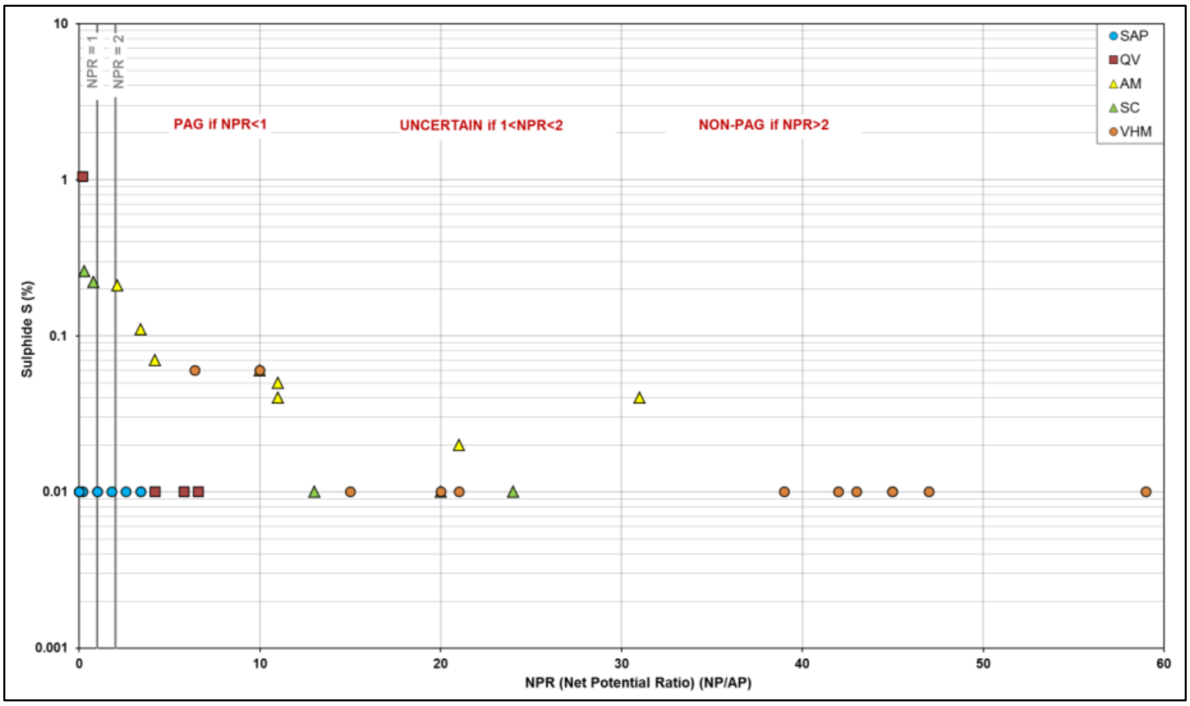


Figure 12 Sulphide Sulphur vs. Net Potential Ratio for Samples

Figure 13 presents sulphide sulphur vs. NNP. A negative NNP value indicates a general potential to generate acid drainage whereas a positive NNP represents a propensity to neutralize any acid generated by the rock. There are three samples (one QV and two SC) that report negative NNP values. Sample KGS017 (QV) is located in the PAG field with an NNP value of -26.50 kg $CaCO_3$/t. KGS011 & KGS029 (SC samples) are UNCERTAIN with values of -1.40 kg $CaCO_3$/t and -5.60 kg $CaCO_3$/t, respectively. KGS021 (AM) which has the highest NNP value (38 kg $CaCO_3$/t) is located in NON-PAG field. The rest of the samples have NNP between 0 and 20 kg $CaCO_3$/t and are considered to have UNCERTAIN acid generating potential based on NNP criteria. However, as mentioned before, most of the samples are NON-PAG due to their very low sulphide sulphur content and inability to generate acid, regardless of the available NP.

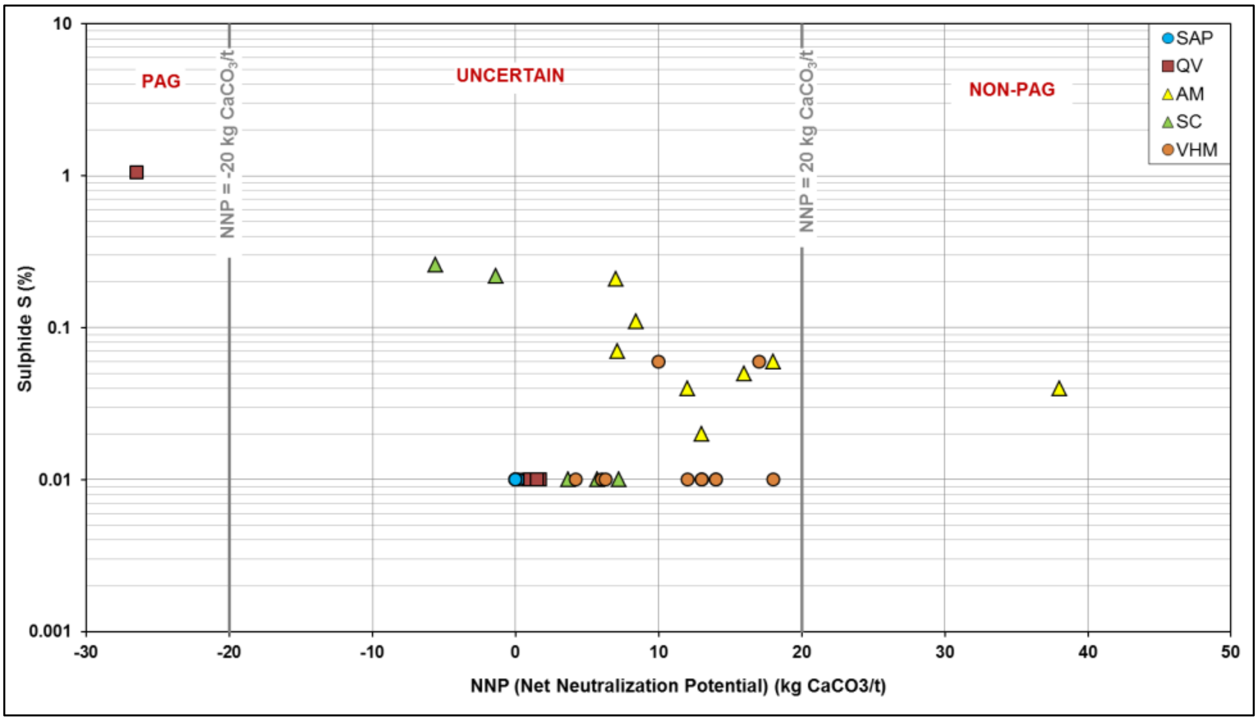


Figure 13 Sulphide Sulphur vs. Net Neutralization Potential

A final set of criteria is based on the NAG test. A NAG pH of 4.5 is generally accepted as the threshold between PAG and NON-PAG material (AMIRA, 2002).

The NAG pH versus sulphide sulphur is presented in Figure 14. This figure shows that KGS017 (QV) is PAG, while all remaining samples, including SC samples KGS011 and KGS029, are NON-PAG.

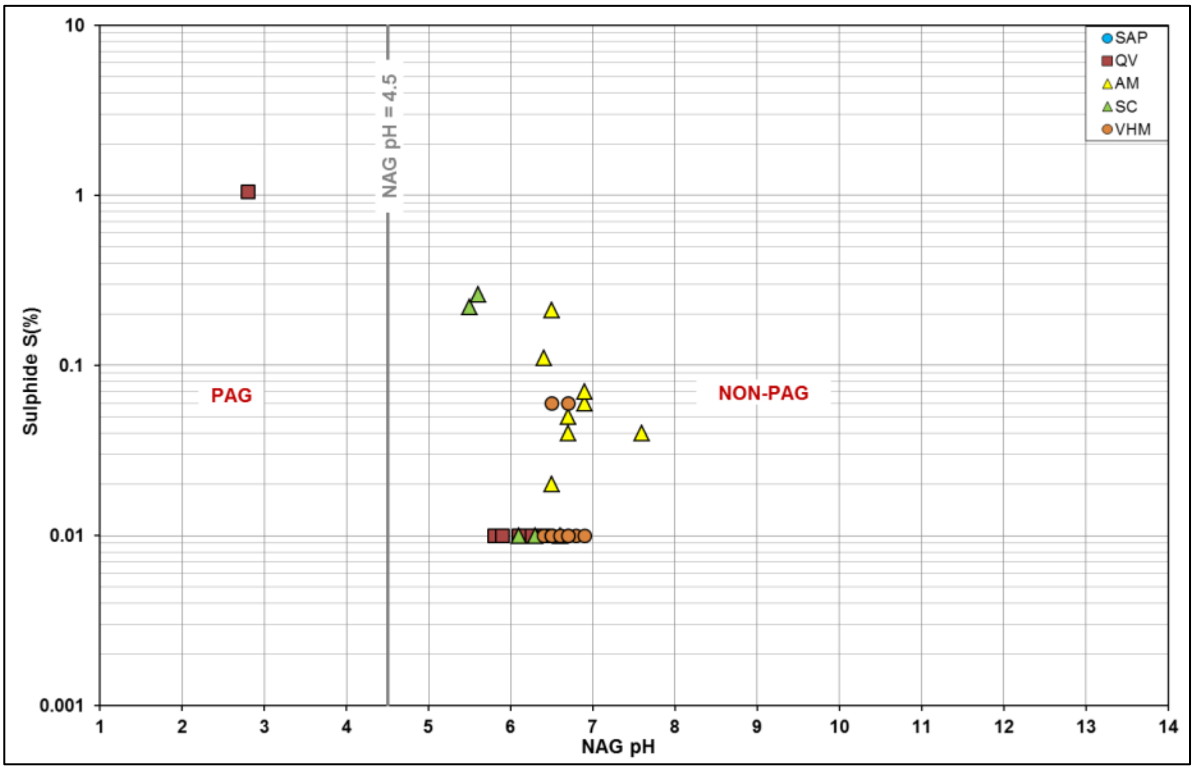


Figure 14 Sulphide Sulphur vs. NAG pH

Figure 15 and Figure 16 are plots of NPR vs. NAG pH and NNP vs. NAG pH, respectively. These graphs identify four quadrants. A majority of the samples have NAG pH values greater than 4.5 and an NPR value greater than 2, and are NON-PAG.

One QV sample (KGS017), with low NAG pH and an NPR value less than 1, falls into the PAG quadrant. Two SC samples and many SAP samples have NAG pH > 4.5 and NPR < 1, and thus these samples fall into uncertain quadrants. However, due to their very low sulphide sulphur content, they are considered NON-PAG. Finally, the two SC samples (KGS011 and KGS029) are UNCERTAIN.

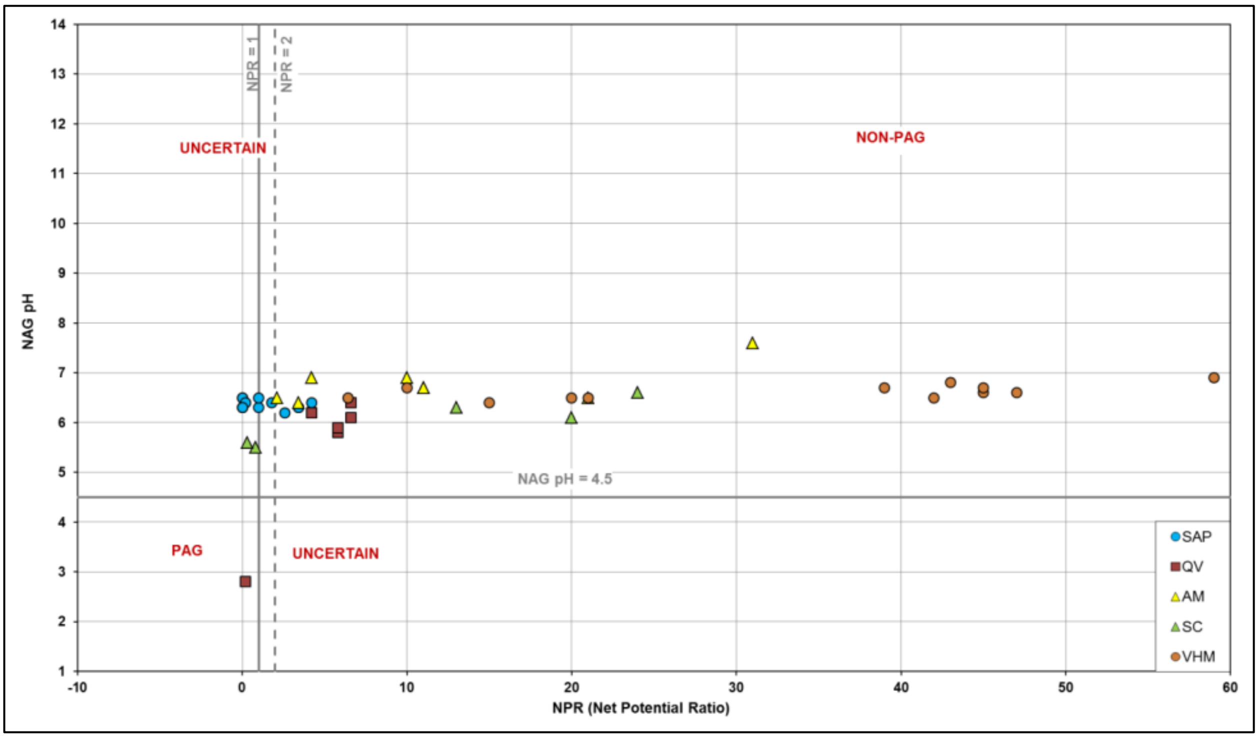


Figure 15 NAG pH vs. NPR for Samples

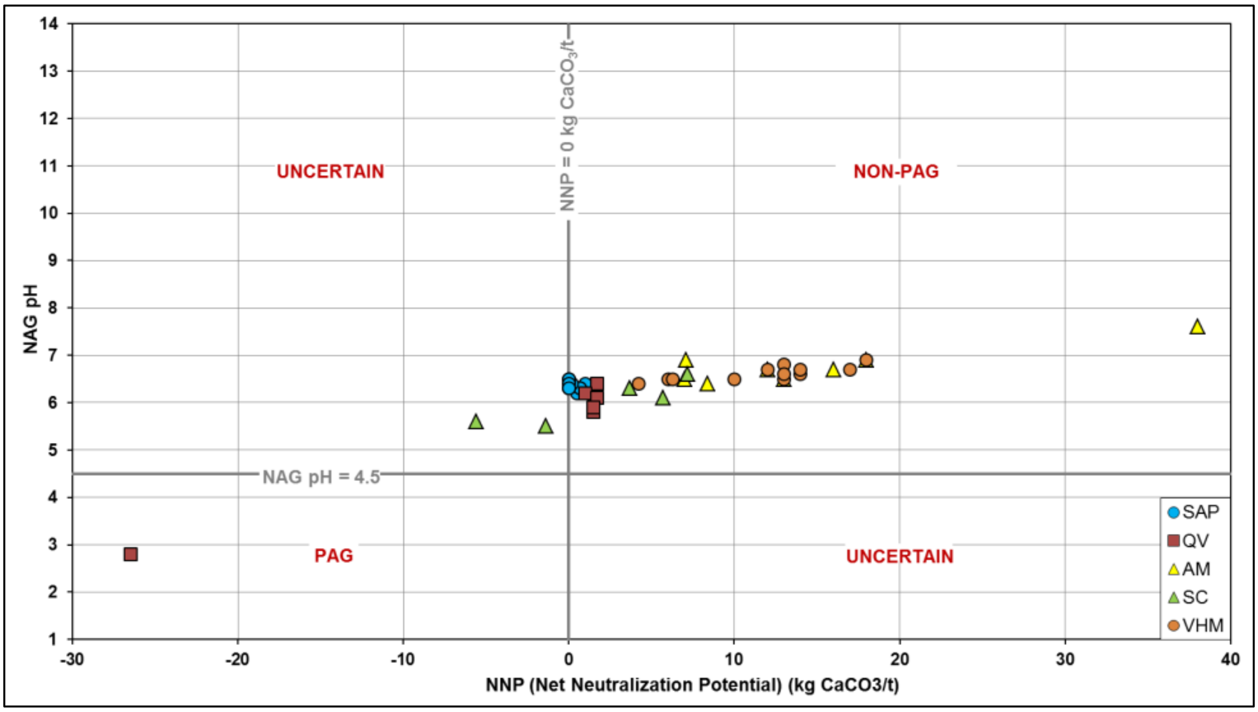


Figure 16 NAG pH vs. NNP

In a general sense, paste pH values represent short-term conditions, whereas NAG pH values would be more indicative of the longer-term conditions. NAG pH versus paste pH is presented in Figure 17. Paste pH values are higher than NAG pH values for all samples except some SAP samples. None of the samples will generate acid conditions over time due to sulphide oxidation (except KGS017), but the SAP samples in particular are capable of maintaining a slightly acidic environment due to their oxide nature.

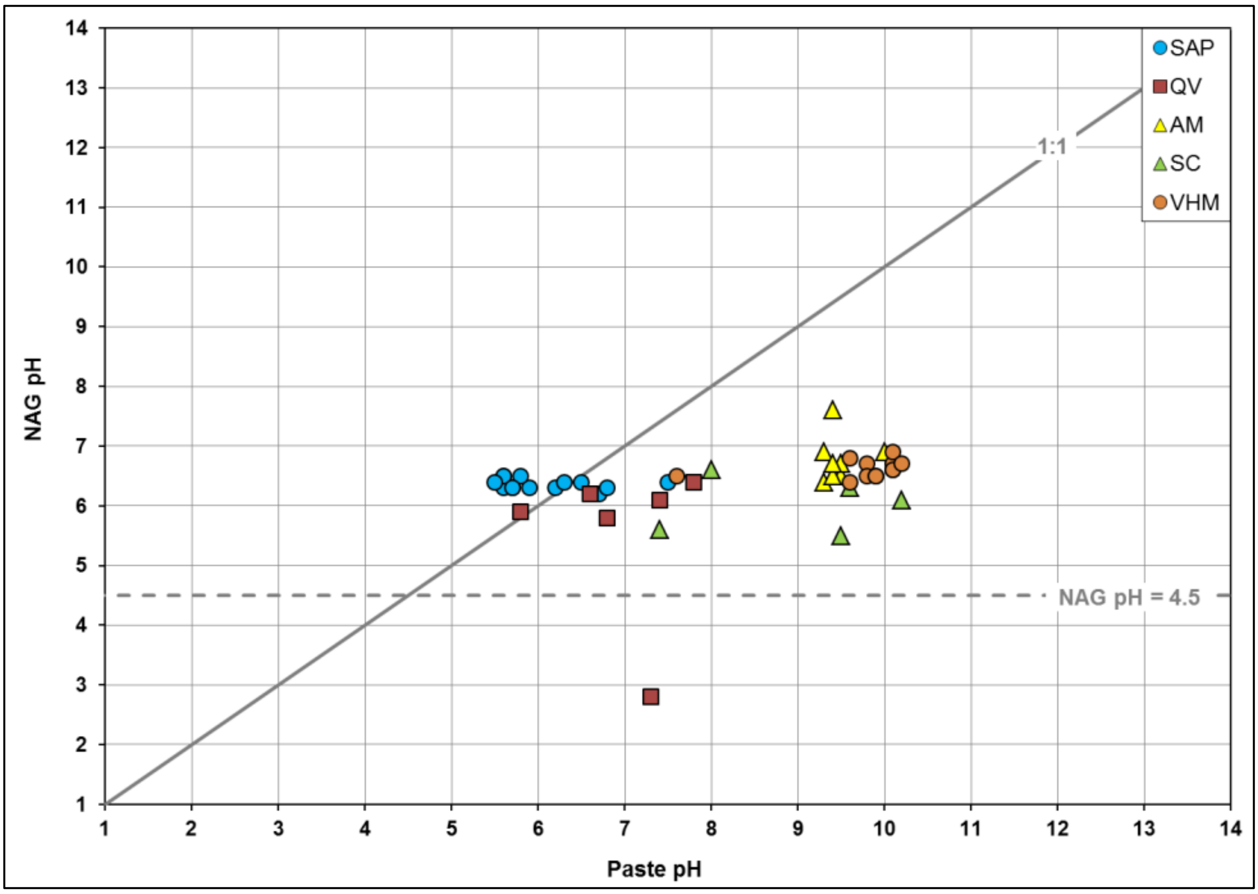


Figure 17 Paste pH vs. NAG pH

4.4.2 Summary of Screening Assessment of Acid Rock Drainage Potential

A summary of the results from the screening evaluation for ARD potential is provided in Table 12. An individual assessment of the acid generation potential for each sample has been identified based on the defined criteria for the three approaches discussed previously (NPR, NNP and NAG pH), followed by an overall assessment based on all available information and best professional judgment. The results can be summarized as follows:

- **SAP:** All 14 samples are NON-PAG
- **QV**: 5 samples are NON-PAG and 1 sample (KGS017) is PAG
- **AM:** All 8 samples are NON-PAG
- **SC:** 3 samples are NON-PAG and 2 samples are uncertain (KGS011, KGS029)
- **VHM:** All 12 samples are NON-PAG

In summary, regardless of rock type, samples with less than 0.2 % sulphide sulphur are NON-PAG; however samples with higher sulphide sulphur content may be PAG due to the general lack of neutralization potential. Additional, short and long-term testing on samples with high sulphide sulphur content is required and recommended to verify this observation. It may be possible to develop a defensible and reliable sulphur threshold for operational management of PAG vs. NON-PAG waste rock, should this be desired.

Table 12 Summary of Screening Assessment Results for ARD Potential

Sample ID (Golder)	Sample ID (MNG)	Lithology	NNP	NPR	NAG pH	STATIC TESTS OVERALL ASSESSMENT
KGS001	90246	**SAP**	**UNCERTAIN**	**PAG**	NON-PAG	**NON-PAG**
KGS002	90247	**SAP**	**UNCERTAIN**	**PAG**	NON-PAG	**NON-PAG**
KGS003	90248	**SAP**	**UNCERTAIN**	NON-PAG	NON-PAG	**NON-PAG**
KGS004	90249	**SAP**	**UNCERTAIN**	**PAG**	NON-PAG	**NON-PAG**
KGS005	90272	**SAP**	**UNCERTAIN**	NON-PAG	NON-PAG	**NON-PAG**
KGS006	90273	**SAP**	**UNCERTAIN**	NON-PAG	NON-PAG	**NON-PAG**
KGS007	90250	**SAP**	**UNCERTAIN**	NON-PAG	NON-PAG	**NON-PAG**
KGS008	90251	**SAP**	**UNCERTAIN**	**PAG**	NON-PAG	**NON-PAG**
KGS009	90276	**SAP**	**UNCERTAIN**	**UNCERTAIN**	NON-PAG	**NON-PAG**
KGS010	90252	**SAP**	**UNCERTAIN**	**UNCERTAIN**	NON-PAG	**NON-PAG**
KGS012	90253	**SAP**	**UNCERTAIN**	**PAG**	NON-PAG	**NON-PAG**
KGS013	90255	**SAP**	**UNCERTAIN**	**UNCERTAIN**	NON-PAG	**NON-PAG**
KGS014	90254	**SAP**	**UNCERTAIN**	**PAG**	NON-PAG	**NON-PAG**
KGS031	90290	**SAP**	**UNCERTAIN**	**PAG**	NON-PAG	**NON-PAG**
KGS016	90256	**QV**	**UNCERTAIN**	NON-PAG	NON-PAG	**NON-PAG**
KGS017	90288	**QV**	**PAG**	**PAG**	**PAG**	**PAG**
KGS018	90282	**QV**	**UNCERTAIN**	NON-PAG	NON-PAG	**NON-PAG**
KGS019	90283	**QV**	**UNCERTAIN**	**NON-PAG**	NON-PAG	**NON-PAG**
KGS020	90271	**QV**	**UNCERTAIN**	**NON-PAG**	NON-PAG	**NON-PAG**
KGS025	90289	**QV**	**UNCERTAIN**	**NON-PAG**	NON-PAG	**NON-PAG**
KGS021	90260	**AM**	NON-PAG	NON-PAG	NON-PAG	**NON-PAG**
KGS022	90257	**AM**	**UNCERTAIN**	NON-PAG	NON-PAG	**NON-PAG**
KGS023	90258	**AM**	**UNCERTAIN**	NON-PAG	NON-PAG	**NON-PAG**
KGS024	90277	**AM**	**UNCERTAIN**	NON-PAG	NON-PAG	**NON-PAG**
KGS026	90259	**AM**	**UNCERTAIN**	NON-PAG	NON-PAG	**NON-PAG**
KGS027	90261	**AM**	**UNCERTAIN**	NON-PAG	NON-PAG	**NON-PAG**
KGS028	90262	**AM**	**UNCERTAIN**	NON-PAG	NON-PAG	**NON-PAG**
KGS032	90285	**AM**	**UNCERTAIN**	NON-PAG	NON-PAG	**NON-PAG**
KGS011	90287	**SC**	**UNCERTAIN**	**PAG**	NON-PAG	**UNCERTAIN**
KGS015	90286	**SC**	**UNCERTAIN**	NON-PAG	NON-PAG	**NON-PAG**
KGS029	90263	**SC**	**UNCERTAIN**	**PAG**	NON-PAG	**UNCERTAIN**
KGS030	90264	**SC**	**UNCERTAIN**	NON-PAG	NON-PAG	**NON-PAG**
KGS033	90265	**SC**	**UNCERTAIN**	NON-PAG	NON-PAG	**NON-PAG**
KGS034	90275	**VHM**	**UNCERTAIN**	NON-PAG	NON-PAG	**NON-PAG**
KGS035	90266	**VHM**	**UNCERTAIN**	NON-PAG	NON-PAG	**NON-PAG**
KGS036	90267	**VHM**	**UNCERTAIN**	NON-PAG	NON-PAG	**NON-PAG**
KGS037	90268	**VHM**	**UNCERTAIN**	NON-PAG	NON-PAG	**NON-PAG**
KGS038	90269	**VHM**	**UNCERTAIN**	NON-PAG	NON-PAG	**NON-PAG**
KGS039	90278	**VHM**	**UNCERTAIN**	NON-PAG	NON-PAG	**NON-PAG**
KGS040	90284	**VHM**	**UNCERTAIN**	NON-PAG	NON-PAG	**NON-PAG**
KGS041	90279	**VHM**	**UNCERTAIN**	NON-PAG	NON-PAG	**NON-PAG**
KGS042	90281	**VHM**	**UNCERTAIN**	NON-PAG	NON-PAG	**NON-PAG**
KGS043	90280	**VHM**	**UNCERTAIN**	NON-PAG	NON-PAG	**NON-PAG**
KGS044	90270	**VHM**	**UNCERTAIN**	NON-PAG	NON-PAG	**NON-PAG**
KGS045	90274	**VHM**	**UNCERTAIN**	NON-PAG	NON-PAG	**NON-PAG**

4.4.3 Metal Leaching Potential

Leach testing, in particular short-term testing, provides a snapshot in time of a material's environmental stability. Test results depend entirely on the present disposition of the sample (e.g., unoxidized vs. oxidized; oxidation products present vs. absent, etc.). For reactive materials, the mechanisms that lead to changes in solution chemistry during water-rock interaction often develop over periods of time that are much greater than can be represented in an 24-hour extraction test (e.g., sulphide oxidation). When reactive sulphides are present, the STL test is not capable of simulating the transient conditions resulting from sulphide oxidation. In those cases, NAG leach tests are used.

In order to be able to determine the short-term metal leaching potential short-term leach (STL) testing was carried out on fifteen samples. The selection of the samples was made by considering the ARD potential and chemical contents. The STL tests were performed by Shake Flask Extraction (SFE) method. Unlike the STL test, samples are oxidized with hydrogen peroxide (H_2O_2) during the NAG leach test so as to represent longer-term conditions.

The Kokoya Deposit is an example of a low-sulphide gold-quartz vein deposit. Plumlee et al. (1999) presents a summary of the low-sulphide, gold-quartz vein deposits and their water drainage compositions with some examples around the world. The ore in these deposits typically occurs as native Au in quartz veins in medium-grade greenstone metamorphic rocks (usually metamorphosed basalts, but metamorphosed sediments, ultramafic or felsic volcanic rocks, or granitic intrusive rocks may also host deposits) as with in the Kokoya Deposit. According to Plumlee et al. (1999) low-sulphide gold-quartz vein deposits typically generate mine waters with near-neutral pH values, like other deposit types having abundant carbonate gangue or carbonate alteration. However, quite acidic pH waters can develop in mine tailings or ore stockpiles, presumably due to the physical enrichment of pyrite and other sulphides. Due to the low base metal sulphide contents of the veins, the near-neutral-pH waters typically have relatively low dissolved base metal concentrations, although vein ores with high pyrite contents and sphalerite contents may generate waters with higher dissolved Zn concentrations of several mg/l. Due to the elevated arsenic content, arsenic presents in mine waters, typically in elevated concentrations ranging from several µg/L to 100 µg/L

A Ficklin diagram, which is a scattergram plot, was used to illustrate the metal leaching potential. The FicklIn diagram displays the sum of the base metals zinc (Zn), copper (Cu), lead (Pb), cadmium (Cd), cobalt (Co), and nickel (Ni) against pH. Since these metals have proven the most diagnostic in differentiating between different ore deposit types, these parameters were selected rather than more common metals such as iron (Fe), aluminum (Al), and manganese (Mn). Ficklin diagrams and arsenic plots were prepared based on the both STL results and compared with the Plumlee's plots. Leachate results for arsenic are also compared with the solid-phase arsenic contents.

The Ficklin diagram plot prepared based on STL results is presented in Figure 18. Kokoya samples are mostly consistent with the data provided in Plumlee et al. (1999), except for the VHM leachate samples which have alkaline drainage. All leachate samples are near neutral or alkaline, with low dissolved base metal concentrations.

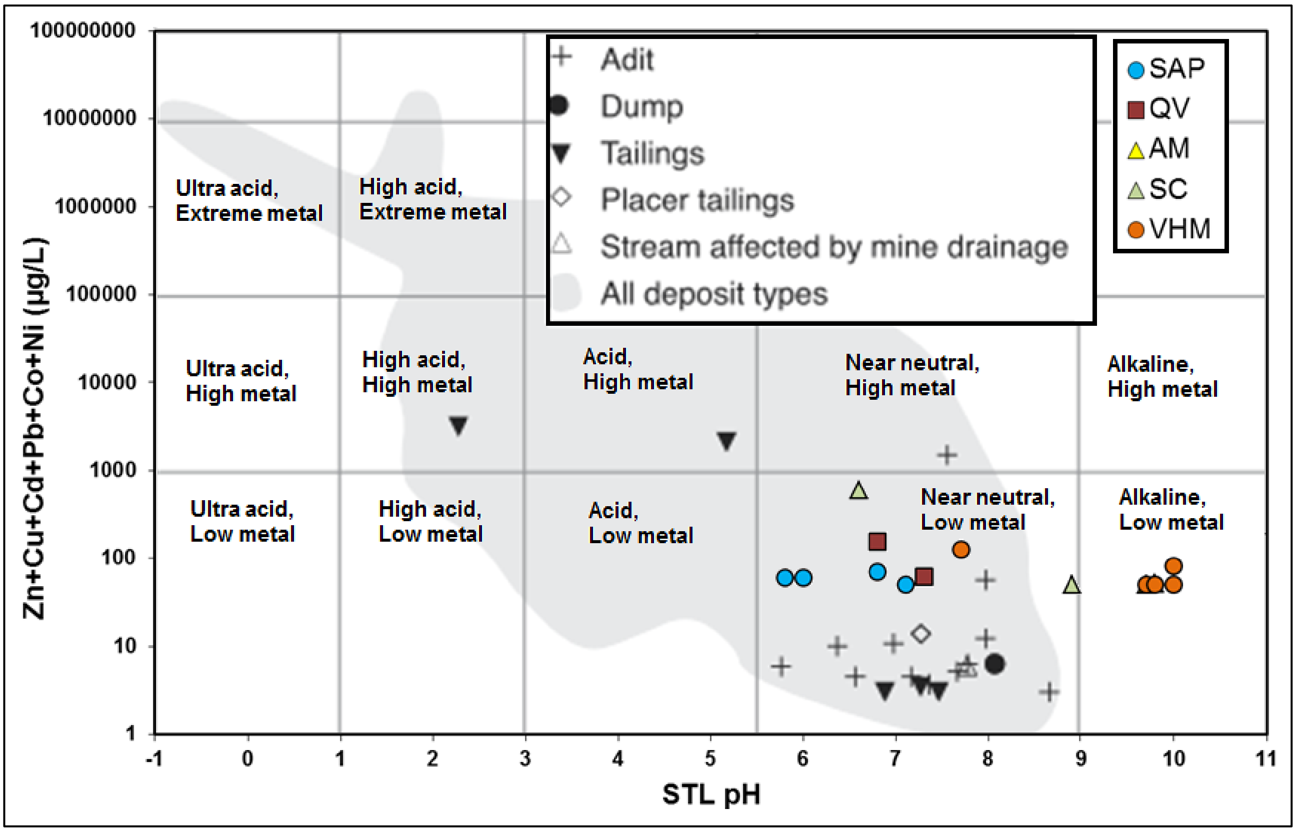


Figure 18 Ficklin Diagram of Mine-Drainage and Stream Compositions for Waters Draining Low-Sulphide, Au Quartz Vein Deposits (Plumlee et al., 1999) with Kokoya STL Results

Figure 19 shows that arsenic concentrations are lower than the values presented by Plumlee et al. (1999), mainly below As detection limit of 10 µg/l. For presentation purposes, 10 µg/l was assigned to samples which are below the detection limit.

Due to the many leachate samples with arsenic below detection limits, the relationship between dissolved arsenic and solid-phase arsenic is not observed, although the highest leachate value (0.02 mg/L) is found for a sample with the highest solid-phase arsenic content. This VHM sample (KGS042) does not have any atypical geochemical characteristics. The IFC Environmental, Health and Safety guidelines for mining suggest a 0.1 mg/l limit for As which is applicable for site runoff and treated effluents reporting to surface waters for general use. All measured leachate arsenic concentrations are less than 0.1 mg/l.

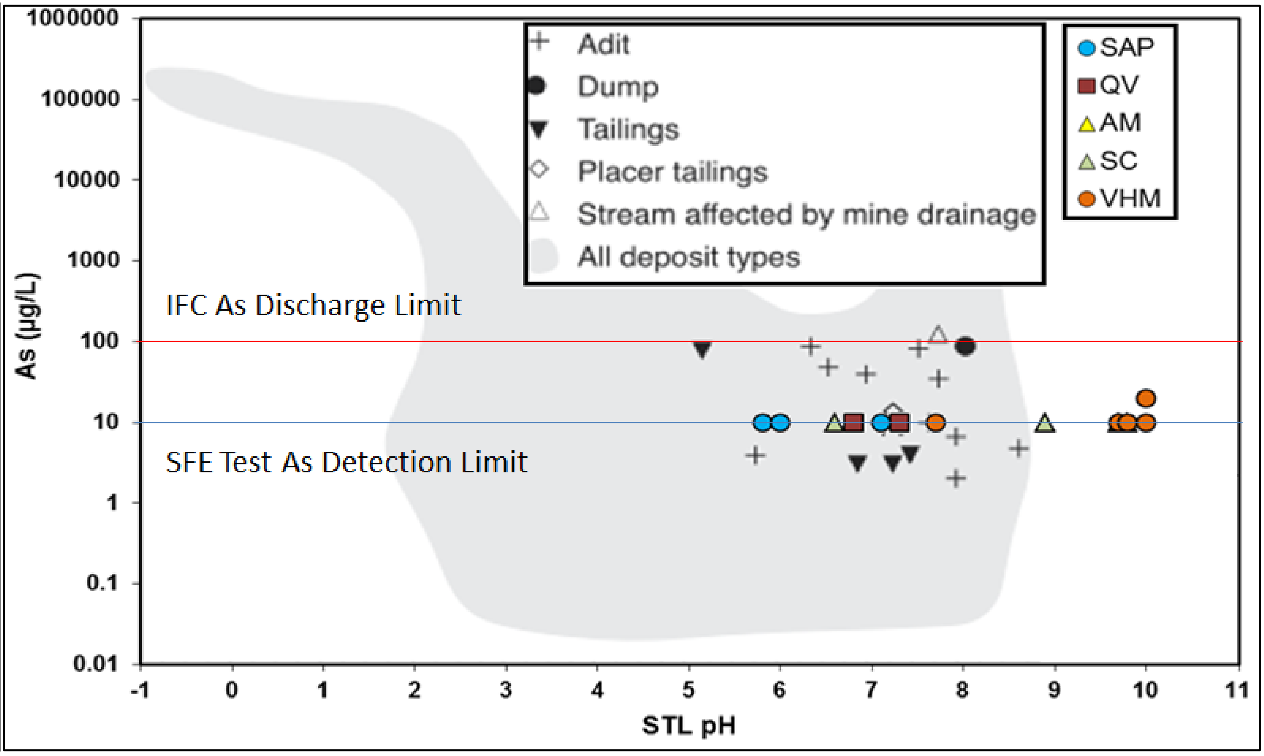


Figure 19 Dissolved Arsenic Plots of Mine-Drainage and Stream Compositions for Waters Draining Low-Sulphide, Au Quartz Vein Deposits (Plumlee et al., 1999) with Kokoya STL Results

NAG leach testing was performed on one PAG (QV) and two UNCERTAIN (SC) samples to have an understanding of the longer-term metal leaching potential. The Ficklin diagram plots prepared based on STL and NAG leachate results is presented in Figure 20. The comparison of NAG vs. STL leachates indicates that, UNCERTAIN samples (SC) have similar leachate compositions which would indicate that the water quality may not change significantly over time. The PAG sample (KGS017) moves from Near Neutral-Low Metal field to High Acid - High Metal field.

The comparison of STL and NAG leach results of PAG sample (KGS017) show that SO_4^{2-}, Al, Cd, Co, Cr, Cu, Fe, Mg, Mn, Na and Ni concentrations are elevated in NAG leach results which indicate that the sample has metal leaching potential in long term. Significant changes have not been observed in UNCERTAIN samples. The comparison of STL and NAG leach results of KGS017, KGS011 and KGS029 are given in Appendix B in graphical format. It should be noted that STL (1:4) and NAG leach test (1:100) has different solid: liquid ratios. Direct comparison of the tests would be misleading. Hg and Ni concentrations are lower in the NAG leach than the STL and this is possibly due to the greater dilution in NAG leach test.

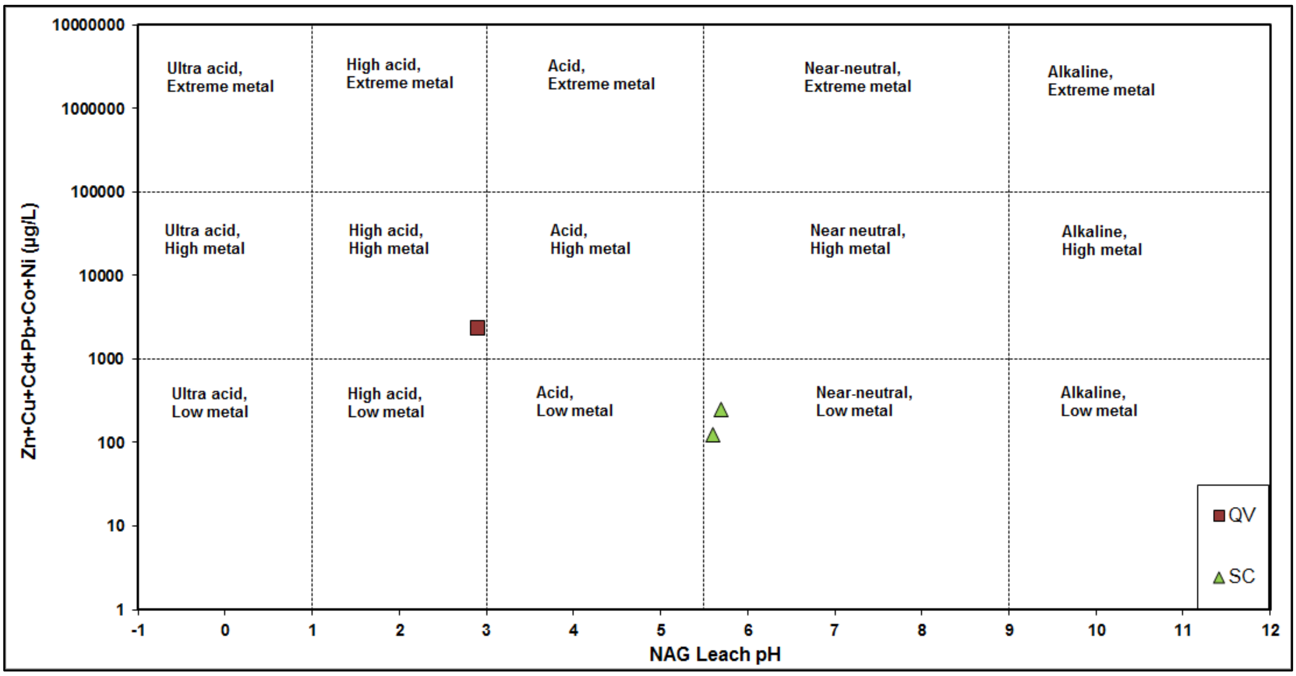


Figure 20 Ficklin Diagrams of NAG Leachate Results

STL test and NAG Leach test results were compared with the discharge limits defined in the Environmental, Health and Safety Guidelines prepared by International Finance Corporation (IFC) and drinking water limits of Liberia and World Health Organization (WHO) for leachate quality.

The comparison of the STL test results with the IFC discharge limits is presented in Table 13. Leachate was found to be within IFC standards for less than half of the fifteen samples: most of the VHM and all of the AM samples had alkaline pH, one SC sample had elevated Ni and one SAP sample acidic pH.

Table 13 Comparison of Short-Term Leach Results with Discharge Limits

Sample ID (Golder)	Sample ID (MNG)	Lithology	pH	As	Cd	Cr	Cu	Fe	Hg	Ni	Pb	Zn
			-	mg/L	mg/L	mg/L	mg/L	mg/L	μg/l	mg/L	mg/L	mg/L
IFC Discharge Limits			6.0-9.0	0.1	0.05	0.1	0.3	2	2	0.5	0.2	0.5
KGS001	90246	**SAP**	**5.8**	<0.01	<0.001	<0.002	<0.02	<0.05	<0.1	<0.005	<0.01	0.02
KGS009	90276	**SAP**	7.1	0.01	<0.001	<0.002	<0.02	<0.05	<0.1	<0.005	<0.01	0.01
KGS012	90253	**SAP**	6.8	<0.01	<0.001	<0.002	<0.02	<0.05	<0.1	<0.005	<0.01	0.03
KGS013	90255	**SAP**	6.0	<0.01	<0.001	<0.002	<0.02	<0.05	<0.1	<0.005	<0.01	0.02
KGS017	90288	**QV**	6.8	<0.01	<0.001	<0.002	<0.02	<0.05	<0.1	0.085	<0.01	0.02
KGS020	90271	**QV**	7.3	0.01	<0.001	<0.002	<0.02	0.06	0.1	0.006	<0.01	0.02
KGS021	90260	**AM**	**9.8**	0.01	<0.001	0.004	<0.02	<0.05	<0.1	0.006	<0.01	<0.01
KGS032	90285	**AM**	**9.7**	0.01	<0.001	<0.002	<0.02	<0.05	<0.1	<0.005	<0.01	<0.01
KGS011	90287	**SC**	8.9	<0.01	<0.001	<0.002	<0.02	<0.05	0.2	<0.005	<0.01	<0.01
KGS029	90263	**SC**	6.6	<0.01	<0.001	<0.002	<0.02	<0.05	<0.1	**0.530**	<0.01	0.02
KGS034	90275	**VHM**	**9.7**	<0.01	<0.001	<0.002	<0.02	<0.05	<0.1	<0.005	<0.01	<0.01
KGS040	90284	**VHM**	7.7	<0.01	<0.001	<0.002	<0.02	0.22	1.5	0.029	<0.01	0.06
KGS041	90279	**VHM**	**9.8**	0.01	<0.001	<0.002	<0.02	0.12	0.5	<0.005	<0.01	<0.01
KGS042	90281	**VHM**	**10.0**	0.02	<0.001	0.003	<0.02	0.12	2.0	<0.005	<0.01	0.04
KGS044	90270	**VHM**	**10.0**	<0.01	<0.001	<0.002	<0.02	0.09	0.1	<0.005	<0.01	<0.01

NOTES:

IFC : International Finance Corporation Finance Corporation - Environmental, Health and Safety Guidelines for Mining

Values exceeding the Mine Industry Waste Water Discharge Standards to Receiver Environment are highlighted in **Bold Red**.

The comparison of the NAG leach test results with the IFC discharge limits is presented in Table 14. All three samples generate leachate pH values that are outside of the regulatory range. Cu and Fe concentrations in KGS017 leachate is also exceed the discharge limits.

Table 14 Comparison of NAG Leach Results with Discharge Limits

Sample ID (Golder)	Sample ID (MNG)	Lithology	pH	As	Cd	Cr	Cu	Fe	Hg	Ni	Pb	Zn
			-	mg/L	mg/L	mg/L	mg/L	mg/L	μg/l	mg/L	mg/L	mg/L
IFC Discharge Limits			6.0-9.0	0.1	0.05	0.1	0.3	2	2	0.5	0.2	0.5
KGS017	90288	**QV**	**2.9**	0.01	0.004	0.052	**1.60**	**26**	<0.1	0.440	<0.01	0.08
KGS011	90287	**SC**	**5.6**	0.01	<0.001	0.006	<0.02	<0.05	<0.1	0.0420	<0.01	0.04
KGS029	90263	**SC**	**5.7**	<0.01	<0.001	0.009	<0.02	<0.05	<0.1	0.110	<0.01	0.09

NOTES:

IFC : International Finance Corporation Finance Corporation - Environmental, Health and Safety Guidelines for Mining

Values exceeding the Mine Industry Waste Water Discharge Standards to Receiver Environment are highlighted in **Bold Red**.

STL results and drinking water limits comparison is given in Table 15. The table shows the Liberian drinking water classification with limit values of each class and drinking limits of WHO. According to the Liberian classification, one sample (SAP) is Class I, three samples (two SAP and one SC) are Class II, and five samples (one SAP, two QV, one SC and one VHM) are Class III. Two AM samples and four VHM samples are highly alkaline and are not suitable for any usage defined in the classification. Iron and manganese values of some samples exceed the WHO limits.

NAG leach and drinking water limits comparison is given in Table 16. According to the Liberian classification, the PAG QV sample (KGS017) is highly acidic and exceeds the limits in pH, SO_4, Fe, Mn and Cu. Two UNCERTAIN SC samples are Class II because of pH and Ni concentration in one sample.

Table 15 Comparison of Short-Term Leach Results with Drinking Water Limits

PARAMETERS	Unit	Liberian Drinking Water Quality Standards			WHO Drinking Water Limits	KGS001	KGS009	KGS012	KGS013	KGS017	KGS020	KGS021	KGS032	KGS011	KGS029	KGS034	KGS040	KGS041	KGS042	KGS044
						90246	90276	90253	90255	90288	90271	90260	90285	90287	90263	90275	90284	90279	90281	90270
		Class I	Class II	Class III		SAP	SAP	SAP	SAP	QV	QV	AM	AM	SC	SC	VHM	VHM	VHM	VHM	VHM
pH	-	6.5 - 8.0	6.0 - 9.0	5.5 - 9.0	-	5.80	7.10	6.80	6.00	6.80	7.30	9.80	9.70	8.90	6.60	9.70	7.70	9.80	10.00	10.00
Sulphate	mg/l	≤ 150.0	≤ 200.0	≤ 250.0	250	5.00	18.00	1.50	0.87	12.00	0.37	7.50	1.50	6.80	201.00	1.90	5.70	1.90	1.20	1.50
Iron Total	mg/l	≤ 0.1	≤ 1.5	≤ 2.0	0.1	<0.05	<0.05	<0.05	<0.05	<0.05	0.06	<0.05	<0.05	<0.05	<0.05	<0.05	**0.22**	**0.12**	**0.12**	0.09
Manganese	mg/l	≤ 0.1	≤ 0.3	≤ 0.8	0.1	0.02	0.09	**0.18**	<0.01	**0.21**	<0.01	<0.01	<0.01	<0.01	**0.52**	<0.01	0.01	<0.01	0.02	<0.01
Zinc Total	mg/l	≤ 1.0	≤ 2.0	≤ 5.0	5	0.02	0.01	0.03	0.02	0.02	0.02	<0.01	<0.01	<0.01	0.02	<0.01	0.06	<0.01	0.04	<0.01
Lead	mg/l	≤ 0.1	≤ 0.1	≤ 0.1	0.1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Mercury	µg/l	n.d.	≤ 5	≤ 10	10	<0.1	<0.1	<0.1	<0.1	<0.1	0.10	<0.1	<0.1	0.20	<0.1	<0.1	1.50	0.53	2.00	0.10
Copper	mg/l	≤ 0.01	≤ 0.01	≤ 0.2	0.05	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Cadmium	mg/l	n.d.	≤ 0.001	≤ 0.01	0.01	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Chromium	mg/l	≤ 0.05	≤ 0.1	≤ 0.1	0.05	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.00	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.00	<0.002
Nickel	mg/l	≤ 1.0	≤ 1.0	≤ 0.1	-	<0.005	<0.005	<0.005	<0.005	0.09	0.01	0.01	<0.005	<0.005	0.53	<0.005	0.03	<0.005	<0.005	<0.005
Silver	mg/l	≤ 0.01	≤ 0.01	≤ 0.01	0.05	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.00	<0.002	<0.002	<0.002	<0.002
Vanadium	mg/l	≤ 1.0	≤ 1.0	≤ 1.0	-	<0.001	<0.001	<0.001	<0.001	<0.001	0.00	0.01	0.03	0.00	<0.001	0.03	0.00	0.01	0.01	0.01
Boron	mg/l	≤ 1.0	≤ 1.0	≤ 1.0	-	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.02	0.04	0.01	0.01	0.02
Arsenic	mg/l	≤ 0.05	≤ 0.05	≤ 0.2	0.05	<0.01	0.01	<0.01	<0.01	<0.01	0.01	0.01	0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.02	<0.01
Water Quality Classification						III	I	II	II	III	III			II	III		III			

NOTES:

WHO : World Health Organization

n.d. : non detectable

Class I : Drinking water for the population, Water Supply for industry requiring drinking water.

Class II : For Fisheries, Cultivated fisheries, Organized public bath, Recreationnal water sports.

Class III : Industry supply except for industry requiring drinking water, irrigation or agricultural land.

Values exceeding the WHO limits are highlighted like **Bold**.

Table 16 Comparison of NAG Leach Results with Drinking Water Limits

PARAMETERS	**Unit**	**Liberian Drinking Water Quality Standards**			**WHO Drinking Water Limits**	KGS017	KGS011	KGS029
						90288	90287	90263
		Class I	**Class II**	**Class III**		**QV**	**SC**	**SC**
pH	**-**	6.5 - 8.0	6.0 - 9.0	5.5 - 9.0	**-**	2.90	5.60	5.70
Sulphate	**mg/l**	≤ 150.0	≤ 200.0	≤ 250.0	**250**	**327**	78	85
Iron Total	**mg/l**	≤ 0.1	≤ 1.5	≤ 2.0	**0.1**	**26.0**	<0.05	<0.05
Manganese	**mg/l**	≤ 0.1	≤ 0.3	≤ 0.8	**0.1**	**1.30**	0.09	0.08
Zinc Total	**mg/l**	≤ 1.0	≤ 2.0	≤ 5.0	**5**	0.08	0.04	0.09
Lead	**mg/l**	≤ 0.1	≤ 0.1	≤ 0.1	**0.1**	<0.01	<0.01	<0.01
Mercury	**µg/l**	n.d.	≤ 5	≤ 10	**10**	<0.1	<0.1	<0.1
Copper	**mg/l**	≤ 0.01	≤ 0.01	≤ 0.2	**0.05**	**1.60**	<0.02	<0.02
Cadmium	**mg/l**	n.d.	≤ 0.001	≤ 0.01	**0.01**	0.004	<0.001	<0.001
Chromium	**mg/l**	≤ 0.05	≤ 0.1	≤ 0.1	**0.05**	**0.05**	0.01	0.01
Nickel	**mg/l**	≤ 1.0	≤ 1.0	≤ 0.1	**-**	0.44	0.04	0.11
Silver	**mg/l**	≤ 0.01	≤ 0.01	≤ 0.01	**0.05**	<0.002	<0.002	<0.002
Vanadium	**mg/l**	≤ 1.0	≤ 1.0	≤ 1.0	**-**	0.02	0.01	0.03
Boron	**mg/l**	≤ 1.0	≤ 1.0	≤ 1.0	**-**	<0.005	0.01	<0.005
Arsenic	**mg/l**	≤ 0.05	≤ 0.05	≤ 0.2	**0.05**	0.01	0.01	<0.01
Water Quality Classification							**III**	**III**

NOTES:

WHO : World Health Organization

n.d. : non detectable

Class I : Drinking water for the population, Water Supply for industry requiring drinking water.

Class II : For Fisheries, Cultivated fisheries, Organized public bath, Recreationnal water sports.

Class III : Industry supply except for industry requiring drinking water, irrigation or agricultural land.

Values exceeding the WHO limits are highlighted like **Bold**.

5.0 CONCEPTUAL MITIGATION MEASURES

Regardless of rock type, samples with less than 0.2 % sulphide sulphur are NON-PAG; however, waste and ore samples with higher sulphide sulphur content may be PAG due to the general lack of neutralization potential. Conducting additional static tests on high sulphur samples, performing kinetic tests and having a better understanding of the volume and distribution of low – high sulphur material is required to develop facility-specific water quality predictions which will assist in determining which measure or combination of measures will best address operational and post-closure ARD/ML issues. Golder developed a conservative approach and the mitigation measures should be revisited once the volume of PAG material is estimated.

5.1 Construction Phase Mitigation Measures

5.1.1 Top Soil Stockpile

Test results indicate that low sulphide material is NON-PAG and the surficial material within the Project Area is highly oxidized and leached. In that respect the runoff and seepage from the topsoil stockpile are expected to meet the discharge limits.

Suspended solids may be increased relative to ambient water quality. Therefore, the following recommendations for mine planning are proposed:

- Minimise erosion of the topsoil stockpile by keeping the stockpile height to a minimum and profiling the stockpile
- Place berms upslope of the stockpile to divert runoff around the stockpile.
- Construct a silt trap to capture stockpile runoff and allow the suspended solids to settle before discharge to the downstream environment.

5.2 Operational Phase Mitigation Measures

5.2.1 Waste Rock Dump

- Run-of-mine ore will be transported to the ore stockpile and to the Process Facility; however, several different rock units and low grade ore (grade less than cut-off) will be stored in the waste rock dumps. The waste rock dump surface will be exposed to air and water, resulting in weathering, including mineral dissolution, oxidation of sulphide sulphur, and the formation of secondary minerals. The potential mitigation approaches for waste rock dump(s) based on the initial characterisation results are listed below.
- The static testing results indicate that a total sulphur threshold of 0.2% total sulphur would be used to differentiate PAG and NON-PAG material. MNG exploration database only includes Au and Ag results and it is recommended to add total sulphur analyses to the new exploration drilling assays and once more data had been collected total sulphur should be included to the block models to have a better

understanding of the volume and spatial distribution of PAG and NON-PAG material. During the operation phase MNG will conduct analyses to differentiate ore and waste rock and adding total sulphur to such analyses would help MNG to identify PAG material and take necessary precautions during the operation.

- Non-PAG units have very low NP values. If the PAG material has a significant volume, blending PAG with Non-PAG units may not help to minimize acid rock drainage. In such a case; selectively mining and segregating the PAG and NON-PAG material during waste rock dumping should be considered.
- Management of the waste rock should be directed at minimising infiltration so as to reduce the volume of waste rock drainage. This can be achieved by:
  - Minimising the waste rock dump footprint;
  - Placing NON-PAG material on the top of the waste rock dump
  - Compacting and profiling the top surface of the waste rock dumps so as to encourage runoff and decrease seepage and to prevent ingress of oxygen and water and generation of acidic runoff.
  - Placing berms and diversion channels upslope of the waste rock dumps to prevent upstream discharge from flowing into the waste rock and divert upstream runoff (non-contact water) to downstream of the dump to prevent contact between the water and the waste rock pile. Constructing a pond/retention facility at the downstream of the waste rock dumps to capture run-off and seepage
  - Establishing an underdrain system at the bottom of the dump area for the management of the seepage water from waste rock. Underdrain systems can be used to direct the drainage from the dump to the collection pond at the toe of the dump. Underdrain systems should be established during the construction period.
- A network of collection channels should be designed around the waste rock dumps to collect contact water from the waste rock dumps and convey it to the contact water ponds.
- The drainage quality should be monitored to establish whether it is suitable for discharge, or whether treatment is required to achieve discharge standards. A monitoring program should be developed and at a minimum include analysis of parameters included in the Liberian and IFC water quality guidelines.

5.2.2 Ore Stockpile

Water movement from the ore stockpile is similar to that in the waste rock facility and will occur as runoff and seepage. The static test results indicate that rock with less than 0. 2% Total S is NON-PAG. According to Plumlee et al. (1999) low-sulphide gold-quartz vein deposits typically generate mine waters with near-neutral pH values, however, acidic pH waters can develop in mine tailings or ore stockpiles, presumably due to the physical enrichment of pyrite and other sulphides.

It should be noted that the volume of the high sulphur ore and waste rock is not known and the available data is not enough to develop a conclusion regarding the ARD and ML potential of the overall project. However the mitigation measures are developed by using a conservative approach.

The mitigation measures will be similar to waste rock dump.

- A network of collection channels should be designed around the ore stockpiles to collect contact water and convey it to the contact water ponds.
- Ore should not be stored for a long time at the stockpiles before it is transported to the Process Plant. Kinetic tests should be conducted to have a better understanding of the reaction rates and define the duration of the temporary ore storage.
- Seepage and run-off water should be captured. Water captured from ore stockpile should be stored in the retention pond and analysed before any discharge. If the water is not suitable for discharge it would be pumped or trucked back to the process facility or to the TSF.

5.2.3 Open-Pit

MNG will continuously dewater the pit during the operation so the pit is expected to be dry during mining and dumping activities. However the groundwater levels will gradually increase and reach steady state conditions after the mining operation ceases and pumping stops.

- Diversion channels should be constructed around the pit to prevent surface water from flowing into the pit.
- Surface run-off from the pit walls would be collected by collection channels and sumps would be excavated at the bottom of the pit.
- The contact water collected at the sump should be pumped or trucked to the ponds and should be analysed before any discharge.

5.2.4 Tailings Facility (TSF)

Tailings will be stored in the dedicated tailings facility which will include impermeable bottom liner system. The facility will work on a closed system principle and water from the TSF will not be discharged to the environment. The facility will also include diversion channels. In that respect no additional mitigation measures are required for the TSF. Upstream and downstream monitoring wells would be required to monitor groundwater quality.

5.3 Decommissioning Phase Mitigation Measures

5.3.1 Waste Rock Dump

The closure mitigation measures will depend on the operation practices/mitigation measures and the volume of PAG material stored at the waste rock dump. The run-off and seepage water quality of the waste rock dump should be monitored during the operation stage. On closure of the mining operation, the waste rock dumps should be covered with a cover system and topsoil to a depth sufficient to reduce rainfall infiltration to the waste rock. The required depth of topsoil and or the type of the cover system should be selected depending on the site specific climatic conditions, waste dump and soil parameters in order to minimise the infiltration into the dump. Monitoring of waste rock drainage quality as described above should continue after closure until long-term steady state drainage quality has been established.

5.3.2 Open-Pit

A pit lake will develop after the cessation of the dewatering and mining activities. The pit lake development will take around five years and flooding will minimize the ARD and ML potential in long term. The ore will be mined and most of the exposed pit walls are expected to be low sulphide NON-PAG. A pit lake water quality prediction cannot be done without knowing the surface area of PAG and NON-PAG material that will be exposed at the pit walls. Placement of PAG waste rock below the final, rebounded groundwater table would prevent further sulphide oxidation by effectively preventing further interaction between oxygen and reactive sulphides.

5.3.3 Tailings Facility

On closure of the mining operation, the TSF should be covered with a cover system sufficient to reduce rainfall infiltration to the ADF. The required cover system should be selected depending on the site-specific climatic conditions, tailings and soil parameters, and expected performance criteria. Monitoring of groundwater wells around the TSF drainage quality should continue after closure until long-term steady state drainage quality has been established.

5.4 Impact Assessment

The aim of this section is to identify the potential ARD and ML impacts that are likely to arise as a result of the proposed project. The following project facilities were rated and ranked in terms of their likely impacts on ground and surface water quality for the different phases of the Project:

- The Open Pit Mines,
- The Ore Stockpiles,
- The Tailings Storage Facility (TSF),

- Waste Rock Dump (WRD),

The ARD risk associated with the project facilities relates to the oxidation of the sulphide-bearing material and consequent generation of low quality seepage and runoff. Based on the geochemical test results presented in the preceding sections, the ARD risk associated with these mine facilities has been assessed. Due to the uncertainly mainly because of the unknown volume of PAG and NON-PAG material, a conservative approach is applied in the recommendation of mitigation measures. The Impact Assessment presented below assumes that the mitigation measures presented in the report will be applied during the operation and closure stage of the project.

5.4.1 Impact Assessment Methodology

The impact was assessed according to the Magnitude, Duration, Extent and Probability of Occurrence of Impact.

Magnitude is a measure of the degree of change in a measurement or analysis (e.g., the area of pasture, or the concentration of a metal in water compared to the water quality guideline value for the metal), and is classified as none/negligible, low, medium or high. The categorization of the impact magnitude may be based on a set of criteria (e.g. health risk levels, ecological concepts and/or professional judgment) pertinent to each of the discipline areas and key questions analysed. The specialist study must attempt to quantify the magnitude and outline the rationale used. Appropriate, widely-recognised standards are used as a measure of the level of impact.

Duration refers to the length of time over which an environmental impact may occur: i.e. transient (less than 1 year), short-term (0 to 5 years), medium term (5 to 15 years), long-term (greater than 15 years) or permanent.

Scale/Geographic extent refers to the area that could be affected by the impact and is classified as site, local, regional, national, or international.

Probability of occurrence is a description of the probability of the impact actually occurring as improbable (less than 5% chance), low probability (5% to 40% chance), medium probability (40 % to 60 % chance), highly probable (most likely, 60% to 90% chance) or definite (impact will definitely occur).

For the purposes of this impact assessment, the Project timeframe has been subdivided into three phases, as follows:

- Construction Phase;
- Operational/Mining Phase; and
- Decommissioning and Closure Phase.

Impact significance will be rated by the specialists using the scoring system shown in Table 17.

Table 17 Scoring System for Evaluating Impacts for Proposed Development

Magnitude	Duration	Scale	Probability
10 Very high/ don't know	5 Permanent	5 International	5 Definite/don't know
8 High	4 Long-term *(impact ceases after closure of activity)*	4 National	4 Highly probable
6 Moderate	3 Medium-term (5 to 15 years)	3 Regional	3 Medium probability
4 Low	2 Short-term (0 to 5 years)	2 Local	2 Low probability
2 Minor	1 Transient	1 Site only	1 Improbable
1 None			0 None

Maximum SP is 100 points

SP>75	High environmental significance
SP 30 to 75	Moderate environmental significance
SP<30	Low environmental significance

- After ranking these factors for each impact, the significance of the two aspects, occurrence and severity, will be assessed using the following formula:
- SP (significance points) = (magnitude + duration + extent) x probability
- The maximum value is 100 significance points (SP). The potential environmental impacts were then rated as of **High** (SP >75), **Moderate** (SP 30 – 75) or **Low** (SP <30) significance, both with and without mitigation measures on the following basis:

SP >75	🟥 Indicates **high** environmental significance	Where it would influence the decision regardless of any possible mitigation. An impact which could influence the decision about whether or not to proceed with the project.
SP 30 - 75	🟨 Indicates **moderate** environmental significance	Where it could have an influence on the decision unless it is mitigated. An impact or benefit which is sufficiently important to require management. Of moderate significance - could influence the decisions about the project if left unmanaged.
SP <30	🟩 Indicates **low** environmental significance	Where it will not have an influence on the decision. Impacts with little real effect and which should not have an influence on or require modification of the project design or alternative mitigation.
+	🟦 **Positive impact**	An impact that is likely to result in positive consequences / effects.

Accordingly, impact assessments for operation stage and closure stage of the project are given in Table 18 and Table 19, respectively.

Table 18 Environmental and Social Impacts Rating for Operation Stage

Aspect	Impact	Rating – Pre mitigation				Total Rating	SP	Rating – Post mitigation				Total Rating	SP
		Magnitude	Duration	Extent	*Probability*			Magnitude	Duration	Extent	*Probability*		
Waste Rock Dump	Development of ARD & ML & Ground Water Contamination	10	5	2	3	51	MODERATE	6	5	2	2	26	LOW
Open Pit	Development of ARD & ML & Ground Water Contamination	10	5	2	3	51	MODERATE	6	5	2	2	26	LOW
Tailings Facility	Development of ARD & ML & Ground Water Contamination	10	5	2	4	68	MODERATE	6	5	2	2	26	LOW
Ore Stockpile	Development of ARD & ML & Ground Water Contamination	10	3	2	4	60	MODERATE	8	3	2	3	39	MODERATE

Table 19 Environmental and Social Impacts Rating for Closure Stage

Aspect	Impact	Rating – Pre mitigation				Total Rating	SP	Rating – Post mitigation				Total Rating	SP
		Magnitude	Duration	Extent	*Probability*			Magnitude	Duration	Extent	*Probability*		
Waste Rock Dump	Development of ARD & ML & Ground Water Contamination	8	5	2	2	30	MODERATE	6	5	2	2	26	LOW
Open Pit	Development of ARD & ML & Ground Water Contamination	8	5	2	2	30	MODERATE	6	5	2	2	26	LOW
Tailings Facility	Development of ARD & ML & Ground Water Contamination	10	5	2	2	34	MODERATE	6	5	2	2	26	LOW
Ore Stockpile	Development of ARD & ML & Ground Water Contamination	8	3	2	3	39	MODERATE	6	1	2	1	9	LOW

6.0 CONCLUSION & RECOMMENDATIONS

Golder selected 45 representative rock samples from each key lithology in the Kokoya Gold Deposit for static testing program. The sample set represents the compositional range of the various lithologies and the spatial coverage of the deposit.

The test program included the following components:

- Major oxide analysis (all samples)
- Trace metal analysis (all samples)
- Mineralogy-XRD (3 samples – Not selected and tested by Golder)
- Acid base accounting (ABA) (all samples)
- Single addition net acid generation (NAG) testing (all samples)
- Short term leach testing (on selected 15 samples)
- NAG leach testing (on selected 3 samples)

The elemental analysis has identified that trace metals with “elevated” average values relative to crustal abundances include silver, arsenic, barium, bismuth, chromium, mercury, magnesium and possibly selenium. Arsenic exceeds the consensus crustal abundance in all of the samples. Although the results from solid-phase chemical analysis can be used to make an inference regarding elements of potential environmental concern, it should be understood that a high concentration of a particular element does not necessarily imply that this element will indeed be mobilized in concentrations that may lead to environmental impacts. Short-term leach tests are being conducted to investigate the relationship between the presence and mobility of the trace metals.

The average total sulphur content is very low and less than 0.1% in most of the samples. The majority of the total sulphur in the samples occurs as sulphide sulphur.

For almost all samples, the NP calculated using total carbon is significantly higher than the NP calculated from carbonate. The low NP values suggest that there is practically no neutralising potential, and the NP is not present in the form of readily-available carbonate minerals.

Based on the ABA and NAG results, there is only one potentially acid generating (PAG) sample from the QV group. Two SC samples have and uncertain ARD potential and the remaining samples are all classified as non-potentially acid generating (NON-PAG) since they contain almost no sulphide sulphur.

Short-term leach test results agree well with data for worldwide low-sulphide gold-quartz vein deposits presented in Plumlee et al. (1999); however, the short term leach test arsenic concentrations are lower than Plumlee’s observations. All STL leachate results are near neutral or alkaline, with low dissolved base metal concentrations. Arsenic concentrations in the leachates are lower than those typically observed for low-sulphide gold-quartz vein deposits and below IFC mine discharge limits.

Comparison of the STL test results with the discharge limits defined in the Environmental, Health and Safety Guidelines prepared by International Finance Corporation (IFC) indicates leachate was within IFC standards for less than half of the fifteen samples due to elevated (alkali) pH or low (acidic) pH and elevated nickel content in one sample.

In terms of the Liberian drinking water classification, leachate from six of the fifteen samples exceed guideline values to elevated (alkali) pH, one sample is Class I (suitable for domestic drinking water), three samples are Class II (fisheries, recreational, industrial or agricultural use) and five samples are Class III (industrial or agricultural use only). Fe and Mn concentrations of six samples also exceed the World Health Organization (WHO) limits.

The comparison of STL and NAG leach results of the PAG samples (KGS017) indicate that SO_4, Al, Cd, Co, Cr, Cu, Fe, Mg, Mn, Na and Ni concentrations are significantly higher in NAG leach results. pH, Cu and Fe concentrations exceed IFC discharge limits. pH, SO_4, Cu, Fe and Mn, Na and Ni parameters exceed Class III limits defined in Liberian drinking water classification. The results indicate that the PAG sample has metal leaching potential over long term. Significant changes have not been observed in UNCERTAIN sample leachate results; however, this may be due to the greater dilution in NAG leach test.

Geochemical characterization study indicates that most units are NON-PAG due to their low sulphide sulphur content. Regardless of rock type, samples with less than 0.2 % sulphide sulphur is NON-PAG and the have relatively low dissolved base metal concentrations. However samples with higher sulphide sulphur content may be PAG and due to the general lack of neutralization potential. Additional, short and long-term testing on samples with high sulphide sulphur content is required and recommended to verify this observation. It may be possible to develop a defensible and reliable sulphur threshold for operational management of PAG vs. NON-PAG waste rock, should this be desired.

It is recommended to continue with mineralogical determination on select samples, additional collection and characterization of samples with high sulphur contents, and kinetic tests on PAG and uncertain samples. It should be also performed static tests on pilot tailings and kinetic tests if tailings are PAG.

Most of the materials that will be extracted during the mining operation are expected to have low sulphur content; however the ore would include relatively high sulphur content and high sulphur pockets/zones would be encountered during the mining. Having a better understanding of the volume and distribution of low and high sulphur material is required to develop facility-specific water quality predictions which will assist in determining which measure or combination of measures will best address operational and post-closure ARD/ML issues. It is recommended to add S% analyses to the exploration drilling assay suite and develop a block model presenting the sulphur distribution within the open-pit mine. Once the volume of the PAG and NON-PAG material are estimated, Golder will conduct geochemical modelling to predict the drainage water qualities from the project facilities. Golder used a conservative approach for developing the conceptual ARD mitigation measures and the mitigation measures would be revised in case the volume of PAG material is very low.

7.0 CLOSURE

We trust the information contained in this report meets your requirements at this time. Should you have any questions regarding the information contained herein, please do not hesitate to contact the undersigned.

GOLDER ASSOCIATES (TURKEY) LTD. ŞTI

Serhat Demirel, M.Sc., **Senior Geological Engineer**	**M. Yusuf Celen** **Geological Engineer**
Rens Verburg, Ph.D., P.Geo., L.G. **Principal Geochemist. Senior Reviewer**	**David Lowe, Ph.D** **Geochemistry & Group Leader, Senior Reviewer**

\\ank1-s-main02\projects\2014\mng\13513150012_kokoya_esia_project\06_reports\06_02_draft_report\ard\version_final draft\gat_14513150012_mng_kokoya_ard&ml_28042015.docx

REFERENCES

AMIRA International Ltd., 2002, ARD Test Handbook – Prediction and Kinetic Control of Acid Mine Drainage. Environmental Geochemistry International Pty. Ltd. and Ian Wark Institute, University of South Australia.

International Network for Acid Prevention (INAP), 2009, Global Acid Rock Drainage Guide (GARD Guide). http://www.gardguide.com/

Mine Environment Neutral Drainage (MEND), 2009, Prediction Manual for Drainage Chemistry from Sulphidic Geologic Materials, Report No 1.20.1, CANMET – Mining and Mineral Sciences Laboratories, Smithers, British Columbia, Canada, December 2009.

Ministry of Environmental and Forestry 31.12.2004, Water Pollution Control Regulation - Waste Water Discharge Standards to Receiver Environment - Mining Industry

MNG Gold (MNG), 2015, Geology, Alteration and Mineralization of Kokoya Gold Mine Project

Plumlee G.S., Smith K.S., Montour M.R., Ficklin W.H., and Mosier E.L., 1999, Geologic Controls on the Composition of Natural Waters and Mine Waters Draining Diverse Mineral-Deposit Types, Published by the Society of Economic Geologist

Project Managers and Design Engineers (Pty) Ltd (PDME), 2014, Definitive Feasibility Study Report for Kokoya Gold

SGS, 2014, Metalurgical and Mineralogical Analyses of Four Samples from the MNG Gold Mining Project, Liberia. Metmin Report NOÇ 13/568 Rev 1

Smith K. S. and Huyck H. L. O., 1999, An Overview of the Abundance, Relative Mobility, Bioavailability, and Human Toxicity of Metals, Published by the Society of Economic Geologist

Weiner, E. R., 2007, Applications of Environmental Aquatic Chemistry.

APPENDICES

APPENDIX A

Chemical Composition Assessments

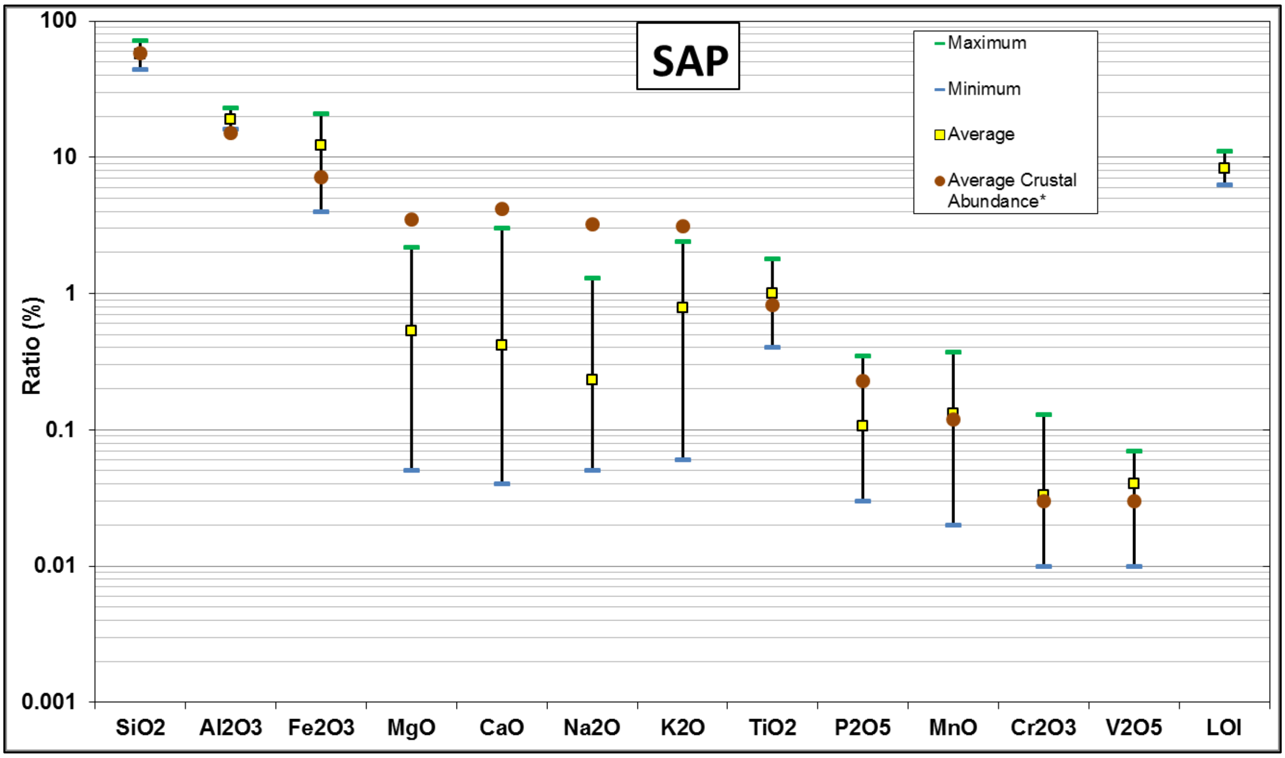
Appendix A-1: Major Oxides Test Results Assessment Table

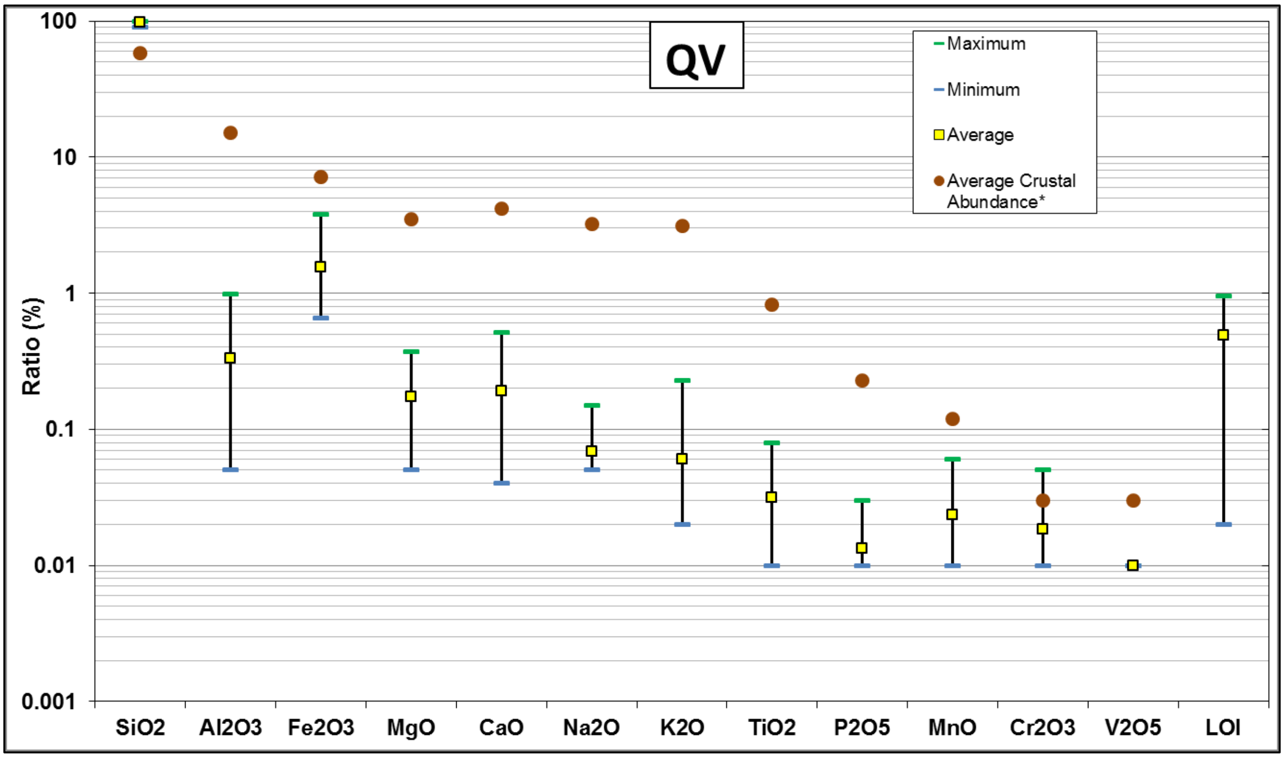
Sample ID (Golder)	Sample ID (MNG)	Lithology	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	MnO	Cr_2O_3	V_2O_5	LOI
			%	%	%	%	%	%	%	%	%	%	%	%	%
Average Crustal Abundance*			57.76	15.12	7.15	3.48	4.2	3.24	3.13	0.83	0.23	0.12	0.03	0.03	
KGS001	90246	**SAP**	69.00	16.00	7.60	0.19	0.04	**0.05**	1.10	0.47	0.05	0.09	0.05	0.03	6.30
KGS002	90247	**SAP**	44.00	20.00	21.00	0.51	0.81	0.05	0.09	1.70	0.11	0.28	0.02	0.05	11.00
KGS003	90248	**SAP**	54.00	18.00	15.00	0.98	0.45	0.73	1.10	0.83	0.08	0.37	0.13	0.04	8.10
KGS004	90249	**SAP**	61.00	17.00	11.00	0.58	0.72	0.63	0.88	0.75	0.04	0.05	0.02	0.04	7.00
KGS005	90272	**SAP**	68.00	18.00	4.00	0.85	0.07	0.07	2.40	0.40	0.05	0.04	**0.01**	**0.01**	6.30
KGS006	90273	**SAP**	49.00	21.00	15.00	0.53	0.10	**0.05**	1.20	1.50	0.24	0.26	0.02	0.05	10.00
KGS007	90250	**SAP**	50.00	18.00	15.00	2.20	3.00	1.30	1.10	1.80	0.35	0.19	0.02	0.04	6.50
KGS008	90251	**SAP**	45.00	23.00	19.00	0.05	0.04	**0.05**	0.06	1.50	0.12	0.08	0.02	0.06	11.00
KGS009	90276	**SAP**	50.00	19.00	17.00	0.27	0.21	**0.05**	0.25	1.30	0.19	0.19	0.05	0.07	9.70
KGS010	90252	**SAP**	66.00	18.00	5.20	0.89	0.05	0.07	1.80	0.45	0.06	0.04	0.03	0.02	6.60
KGS012	90253	**SAP**	64.00	17.00	11.00	0.09	0.05	**0.05**	0.40	0.82	0.05	0.04	0.03	0.04	7.60
KGS013	90255	**SAP**	72.00	17.00	4.80	**0.05**	0.05	**0.05**	0.18	0.42	0.03	0.02	0.01	0.02	6.50
KGS014	90254	**SAP**	56.00	20.00	13.00	0.13	0.20	**0.05**	0.24	1.00	0.07	0.14	0.04	0.05	9.20
KGS031	90290	**SAP**	53.00	23.00	13.00	0.09	0.05	0.05	0.25	1.10	0.04	0.04	**0.01**	0.04	9.90
Minimum			*44.00*	*16.00*	*4.00*	*0.05*	*0.04*	*0.05*	*0.06*	*0.40*	*0.03*	*0.02*	*0.01*	*0.01*	*6.30*
Maximum			*72.00*	*23.00*	*21.00*	*2.20*	*3.00*	*1.30*	*2.40*	*1.80*	*0.35*	*0.37*	*0.13*	*0.07*	*11.00*
Average			*57.21*	*18.93*	*12.26*	*0.53*	*0.42*	*0.23*	*0.79*	*1.00*	*0.11*	*0.13*	*0.03*	*0.04*	*8.26*
KGS016	90256	**QV**	99.00	**0.05**	1.20	0.07	0.06	**0.05**	0.02	0.02	**0.01**	0.01	**0.01**	**0.01**	-
KGS017	90288	**QV**	90.00	0.98	3.80	0.37	0.51	0.15	0.23	0.08	0.03	0.03	**0.01**	**0.01**	0.96
KGS018	90282	**QV**	98.00	0.22	1.40	0.35	0.32	**0.05**	0.03	0.04	**0.01**	0.06	0.02	**0.01**	0.02
KGS019	90283	**QV**	100.00	0.06	0.66	**0.05**	0.04	**0.05**	0.02	0.01	**0.01**	**0.01**	**0.01**	**0.01**	-
KGS020	90271	**QV**	98.00	0.41	1.30	0.15	0.17	0.06	0.04	0.02	**0.01**	0.02	0.05	**0.01**	-
KGS025	90289	**QV**	100.00	0.28	0.93	**0.05**	0.04	**0.05**	0.02	0.02	**0.01**	0.01	**0.01**	**0.01**	-
Minimum			*90.00*	*0.05*	*0.66*	*0.05*	*0.04*	*0.05*	*0.02*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.02*
Maximum			*100.00*	*0.98*	*3.80*	*0.37*	*0.51*	*0.15*	*0.23*	*0.08*	*0.03*	*0.06*	*0.05*	*0.01*	*0.96*
Average			*97.50*	*0.33*	*1.55*	*0.17*	*0.19*	*0.07*	*0.06*	*0.03*	*0.01*	*0.02*	*0.02*	*0.01*	*0.49*
KGS021	90260	**AM**	48.00	9.30	11.00	**19.00**	8.60	0.84	0.45	0.51	0.04	0.20	**0.24**	0.03	3.70
KGS022	90257	**AM**	50.00	15.00	13.00	7.60	11.00	2.30	0.50	0.96	0.08	0.19	0.04	0.06	0.57
KGS023	90258	**AM**	51.00	14.00	14.00	7.00	11.00	1.80	0.33	1.10	0.10	0.21	0.03	0.05	0.61
KGS024	90277	**AM**	52.00	14.00	12.00	7.00	9.40	2.10	1.00	0.84	0.08	0.18	0.04	0.04	0.96
KGS026	90259	**AM**	55.00	15.00	11.00	4.10	7.60	3.70	1.70	1.10	0.17	0.17	0.01	0.04	0.83
KGS027	90261	**AM**	49.00	14.00	15.00	6.20	11.00	2.40	0.27	1.40	0.11	0.23	0.02	0.07	0.61
KGS028	90262	**AM**	50.00	14.00	14.00	6.40	11.00	2.30	0.24	1.30	0.10	0.22	0.02	0.07	0.64
KGS032	90285	**AM**	49.00	14.00	16.00	5.70	9.80	2.50	0.50	1.50	0.13	0.23	**0.01**	0.07	0.57
Minimum			*48.00*	*9.30*	*11.00*	*4.10*	*7.60*	*0.84*	*0.24*	*0.51*	*0.04*	*0.17*	*0.01*	*0.03*	*0.57*
Maximum			*55.00*	*15.00*	*16.00*	*19.00*	*11.00*	*3.70*	*1.70*	*1.50*	*0.17*	*0.23*	*0.24*	*0.07*	*3.70*
Average			*50.50*	*13.66*	*13.25*	*7.88*	*9.93*	*2.24*	*0.62*	*1.09*	*0.10*	*0.20*	*0.05*	*0.05*	*1.06*
KGS011	90287	**SC**	72.00	14.00	3.20	0.87	2.10	5.20	1.60	0.24	0.05	0.04	**0.01**	0.02	0.61
KGS015	90286	**SC**	73.00	14.00	1.60	0.27	1.80	4.50	3.80	0.14	0.04	0.03	**0.01**	**0.01**	0.30
KGS029	90263	**SC**	70.00	14.00	3.80	2.10	2.70	2.00	3.20	0.42	0.15	0.04	0.02	0.01	1.20
KGS030	90264	**SC**	59.00	12.00	8.70	10.00	2.40	1.70	0.65	0.26	0.04	0.13	**0.22**	0.01	5.00
KGS033	90265	**SC**	75.00	15.00	1.30	0.08	2.30	6.10	0.81	0.09	0.03	0.01	**0.01**	**0.01**	0.32
Minimum			*59.00*	*12.00*	*1.30*	*0.08*	*1.80*	*1.70*	*0.65*	*0.09*	*0.03*	*0.01*	*0.01*	*0.01*	*0.30*
Maximum			*75.00*	*15.00*	*8.70*	*10.00*	*2.70*	*6.10*	*3.80*	*0.42*	*0.15*	*0.13*	*0.22*	*0.02*	*5.00*
Average			*69.80*	*13.80*	*3.72*	*2.66*	*2.26*	*3.90*	*2.01*	*0.23*	*0.06*	*0.05*	*0.05*	*0.01*	*1.49*
KGS034	90275	**VHM**	62.00	14.00	8.10	2.70	6.00	3.70	1.60	0.72	0.12	0.13	**0.01**	0.03	0.65
KGS035	90266	**VHM**	68.00	15.00	3.70	1.10	3.30	4.60	2.70	0.40	0.16	0.05	**0.01**	**0.01**	0.71
KGS036	90267	**VHM**	70.00	15.00	3.40	0.92	3.00	4.70	2.80	0.35	0.13	0.05	**0.01**	0.01	0.67
KGS037	90268	**VHM**	75.00	14.00	2.30	0.36	2.10	4.40	2.70	0.21	0.06	0.03	**0.01**	**0.01**	0.31
KGS038	90269	**VHM**	58.00	15.00	9.10	3.90	7.70	3.40	1.60	0.69	0.10	0.15	0.01	0.04	0.87
KGS039	90278	**VHM**	72.00	15.00	1.60	0.23	2.50	5.20	1.80	0.12	0.03	0.02	**0.01**	**0.01**	0.35
KGS040	90284	**VHM**	61.00	17.00	6.80	2.30	6.00	1.40	1.80	0.44	0.15	0.06	0.01	0.02	3.00
KGS041	90279	**VHM**	68.00	15.00	4.10	2.20	3.80	3.80	2.10	0.57	0.15	0.05	**0.01**	0.01	0.71
KGS042	90281	**VHM**	65.00	15.00	4.30	1.40	3.70	4.90	2.40	0.47	0.19	0.06	**0.01**	0.01	0.80
KGS043	90280	**VHM**	69.00	15.00	3.30	1.00	3.10	4.70	2.40	0.34	0.13	0.04	**0.01**	**0.01**	0.62
KGS044	90270	**VHM**	61.00	13.00	9.10	2.70	5.20	3.40	2.10	0.83	0.18	0.16	**0.01**	0.03	0.44
KGS045	90274	**VHM**	68.00	14.00	4.70	2.30	3.50	4.20	2.70	0.46	0.10	0.08	**0.01**	0.02	0.57
Minimum			*58.00*	*13.00*	*1.60*	*0.23*	*2.10*	*1.40*	*1.60*	*0.12*	*0.03*	*0.02*	*0.01*	*0.01*	*0.31*
Maximum			*75.00*	*17.00*	*9.10*	*3.90*	*7.70*	*5.20*	*2.80*	*0.83*	*0.19*	*0.16*	*0.01*	*0.04*	*3.00*
Average			*66.42*	*14.75*	*5.04*	*1.76*	*4.16*	*4.03*	*2.23*	*0.47*	*0.13*	*0.07*	*0.01*	*0.02*	*0.81*

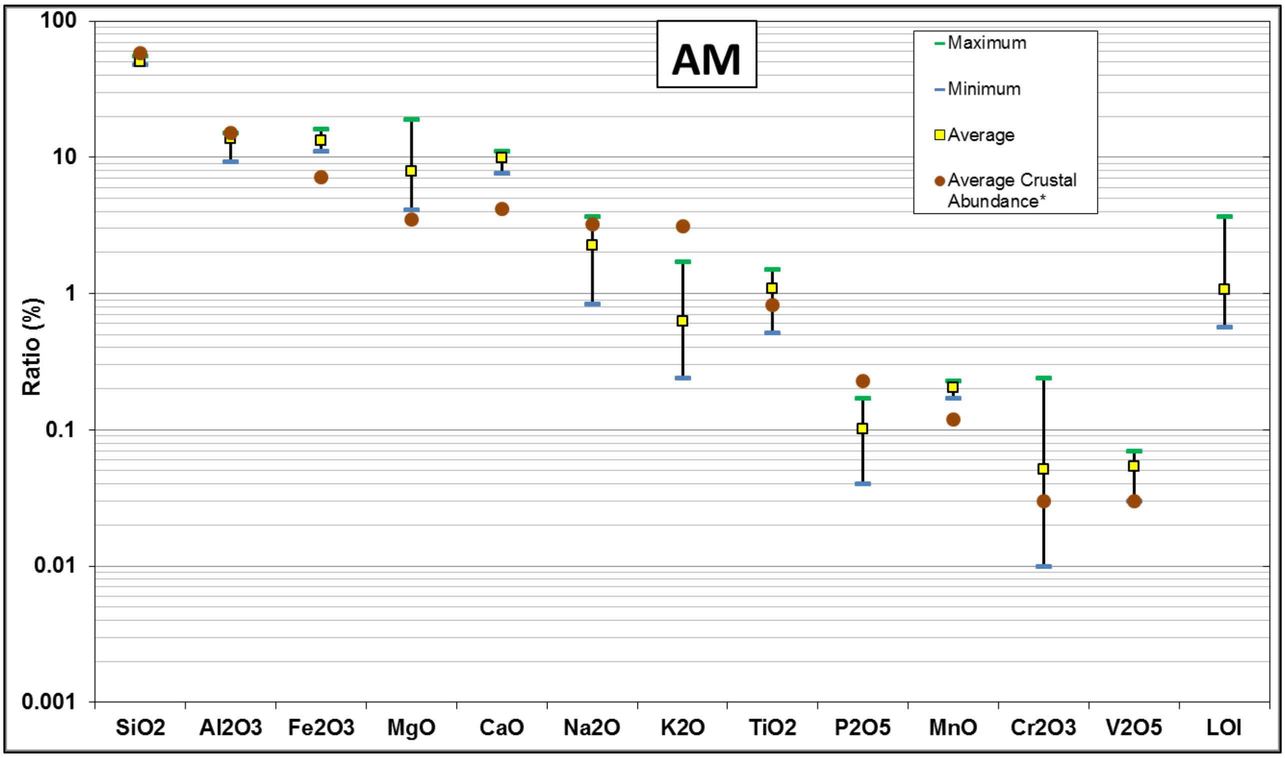
NOTES:

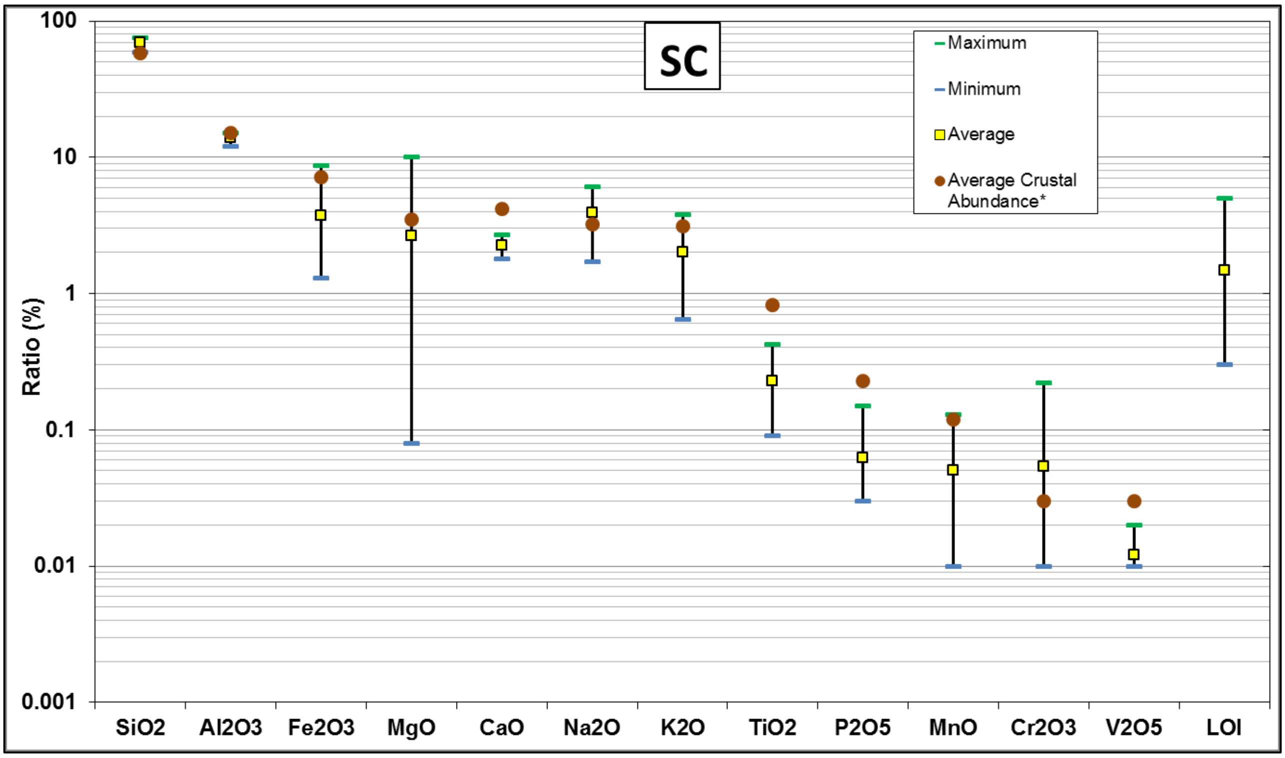
***** Typical crustal abundance for continental rocks taken from Smith and Huyck (1999).
LOI = Loss on Ignition
Detection limits were used in calculations and highlighted in **Bold Blue** for the parameters whose values are below the detection limit.
Values that are equal or greater than 5 times crustal abundance are highlighted in **Bold Red.**

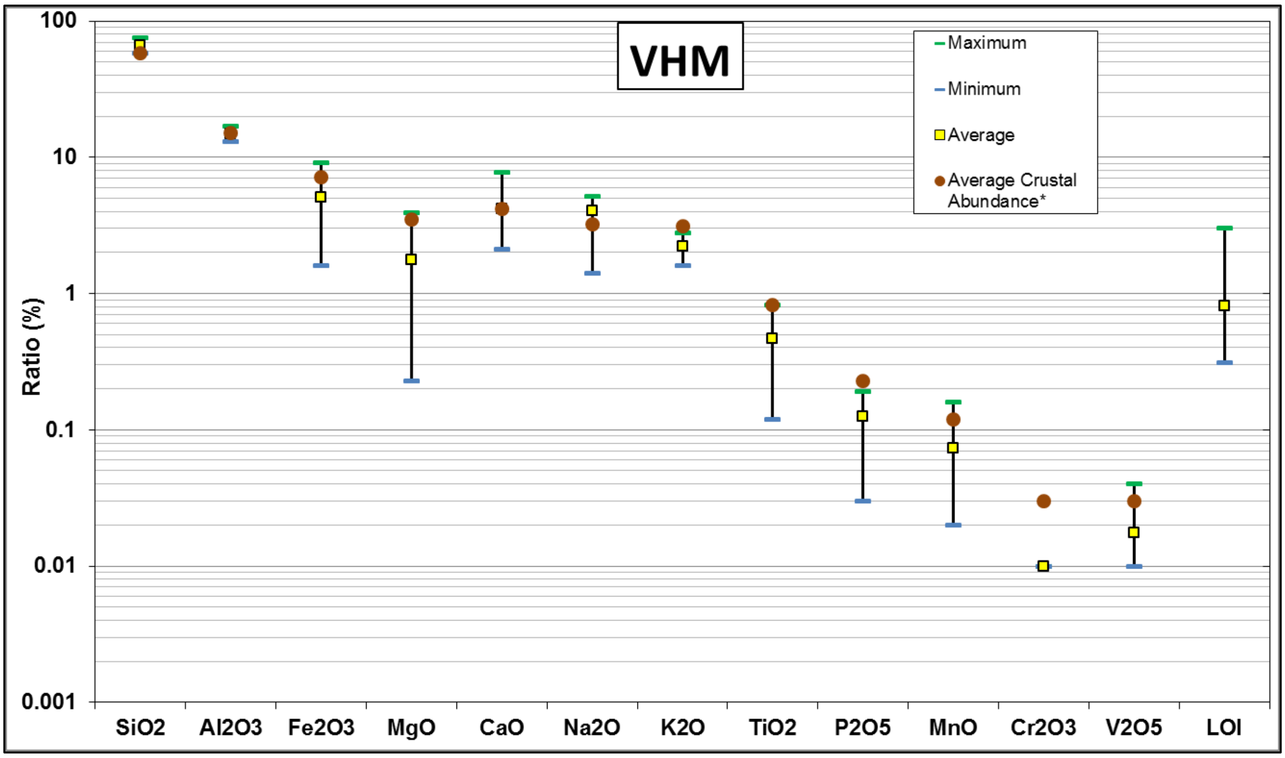
Appendix A-2: Major Oxides Test Results Assessment Graphs






AM
Ratio (%)
100
10
1
0.1
0.01
0.001
SiO2
Al2O3
Fe2O3
MgO
CaO
Na2O
K2O
TiO2
P2O5
MnO
Cr2O3
V2O5
LOI
Maximum
Minimum
Average
Average Crustal Abundance*


SC
Ratio (%)
100
10
1
0.1
0.01
0.001
SiO2
Al2O3
Fe2O3
MgO
CaO
Na2O
K2O
TiO2
P2O5
MnO
Cr2O3
V2O5
LOI
Maximum
Minimum
Average
Average Crustal Abundance*


VHM
Ratio (%)
100
10
1
0.1
0.01
0.001
SiO2
Al2O3
Fe2O3
MgO
CaO
Na2O
K2O
TiO2
P2O5
MnO
Cr2O3
V2O5
LOI
Maximum
Minimum
Average
Average Crustal Abundance*

Appendix A-3: Trace Metals Test Results Assessment Table

Sample ID (Golder)	Sample ID (MNG)	Lithology	Ag	Al	As	Ba	Be	Bi	Ca	Cd	Co	Cr	Cu	Fe	Hg	K	Li	Mg	Mn	Mo	Na	Ni	P	Pb	Sb	Se**	Sr	Ti	Tl	U	V	Y	Zn
			ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Average Crustal Abundance*			0.07	80,000	2	430	3	0.2	30,000	0.18	25	200	60	50,000	0.08	26,000	30	21,000	900	2	24,000	80	1000	16	1	0.09	350	5,000	1	3	150	30	70
KGS001	90246	**SAP**	**2.50**	72000	**24.00**	338	**0.10**	**4.90**	100	0.03	65.00	269	69.00	50000	0.12	8500	9.00	1100	691	1.90	400	113.00	240.00	54.00	0.46	**2.00**	6.4	2400	0.23	3.40	120	5.7	35
KGS002	90247	**SAP**	**0.30**	88000	9.00	553	2.80	0.29	4900	0.07	53.00	134	98.00	130000	0.06	800	6.00	2900	1914	0.70	400	63.00	570.00	8.00	0.19	**2.00**	33.0	8600	0.23	0.49	278	53.0	87
KGS003	90248	**SAP**	**2.30**	76000	**12.00**	1161	1.10	0.97	2800	0.35	104.00	749	186.00	96000	0.10	8300	8.00	5500	2689	2.30	4600	439.00	442.00	69.00	0.27	**2.00**	54.0	4400	0.93	5.30	167	38.0	121
KGS004	90249	**SAP**	**2.10**	74000	**12.00**	295	0.30	0.34	4500	0.03	13.00	140	120.00	73000	0.09	6700	7.00	3200	371	0.93	4000	53.00	223.00	29.00	0.21	**2.00**	32.0	3900	0.37	6.00	171	16.0	60
KGS005	90272	**SAP**	**1.60**	82000	**17.00**	1496	0.40	0.11	300	**0.02**	9.70	23	22.00	27000	0.05	19000	6.00	5000	328	0.80	500	28.00	268.00	23.00	**0.05**	**2.00**	30.0	2100	0.63	2.40	35	16.0	53
KGS006	90273	**SAP**	**1.30**	97000	**14.00**	710	1.70	**1.90**	600	0.07	42.00	110	96.00	93000	0.07	9100	8.00	3100	1904	2.20	500	68.00	1190.00	65.00	0.26	**2.00**	12.0	7700	0.77	4.30	264	46.0	71
KGS007	90250	**SAP**	**1.20**	78000	**12.00**	685	2.70	0.23	19000	0.15	39.00	87	61.00	98000	0.05	7800	14.00	12000	1347	1.80	8100	73.00	1830.00	14.00	0.33	**2.00**	140.0	9500	0.37	3.80	247	44.0	115
KGS008	90251	**SAP**	**0.60**	110000	**13.00**	89	0.40	0.60	200	0.03	9.00	142	103.00	120000	0.09	600	4.00	500	550	3.90	200	43.00	580.00	56.00	0.82	**2.00**	4.5	7600	0.13	6.70	304	8.7	54
KGS009	90276	**SAP**	**1.60**	91000	**20.00**	374	2.50	**1.90**	1400	0.06	49.00	276	108.00	110000	0.14	2100	9.00	1600	1391	5.00	500	68.00	1108.00	25.00	0.68	**2.00**	12.0	6800	0.40	6.60	367	53.0	64
KGS010	90252	**SAP**	**1.10**	84000	**10.00**	1288	0.60	0.55	200	0.03	16.00	132	57.00	35000	0.06	14000	6.00	5100	265	0.49	500	76.00	279.00	42.00	**0.05**	**2.00**	19.0	2400	0.51	4.40	63	53.0	71
KGS012	90253	**SAP**	**5.30**	78000	**11.00**	157	0.20	**2.10**	200	0.06	11.00	171	116.00	69000	0.18	3200	5.00	600	288	4.80	200	46.00	277.00	41.00	0.25	**4.00**	7.7	4200	0.17	4.50	170	11.0	39
KGS013	90255	**SAP**	**> 10**	79000	**11.00**	145	**0.10**	0.78	200	0.07	9.80	49	171.00	33000	**0.68**	1500	4.00	300	131	1.20	300	43.00	180.00	22.00	0.08	**2.00**	8.9	2100	0.06	3.40	75	11.0	29
KGS014	90254	**SAP**	**1.40**	93000	**10.00**	295	0.50	**1.30**	1300	0.06	72.00	266	160.00	85000	0.09	2000	7.00	800	1000	1.80	500	115.00	404.00	31.00	0.25	**2.00**	13.0	5300	0.28	6.60	241	16.0	79
KGS031	90290	**SAP**	**6.00**	110000	**15.00**	102	0.50	0.23	200	0.04	11.00	72	97.00	85000	0.08	2100	4.00	400	251	8.10	300	40.00	232.00	29.00	0.07	**2.00**	5.0	5900	0.10	5.50	248	6.2	40
Minimum			0.30	72000	9.00	89	0.10	0.11	100	0.02	9.00	23	22.00	27000	0.05	600	4.00	300	131	0.49	200	28.00	180.00	8.00	0.05	2.00	4.5	2100	0.06	0.49	35	5.7	29
Maximum			6.00	110000	24.00	1496	2.80	4.90	19000	0.35	104.00	749	186.00	130000	0.68	19000	14.00	12000	2689	8.10	8100	439.00	1830.00	69.00	0.82	4.00	140.0	9500	0.93	6.70	367	53.0	121
Average			**2.10**	86571	**13.57**	549	0.99	**1.16**	2564	0.08	35.96	187	104.57	78857	0.13	6121	6.93	3007	937	2.57	1500	90.57	558.79	36.29	0.28	**2.14**	27.0	5207	0.37	4.53	196	27.0	66
KGS016	90256	**QV**	**0.30**	500	**11.00**	13	**0.10**	**0.04**	200	0.03	2.40	26	6.00	8800	0.05	**100**	**1.00**	300	124	3.60	100	13.00	**50.00**	2.90	**0.05**	**2.00**	1.4	**100**	**0.02**	**0.05**	3	0.1	3
KGS017	90288	**QV**	**0.30**	5600	**14.00**	96	**0.10**	0.35	3400	0.06	23.00	34	187.00	28000	0.09	2000	2.00	2100	265	2.40	1000	47.00	177.00	1.70	0.10	**2.00**	11.0	400	0.06	0.28	15	2.1	7
KGS018	90282	**QV**	**3.40**	1500	**16.00**	23	**0.10**	**4.90**	2000	0.04	74.00	54	77.00	10000	0.13	200	2.00	2100	468	3.70	300	17.00	51.00	17.00	**0.05**	**2.00**	2.3	100	0.04	0.13	6	7.6	11
KGS019	90283	**QV**	**0.40**	600	**16.00**	16	**0.10**	0.11	400	0.08	6.40	23	28.00	5600	0.06	200	**1.00**	200	100	3.60	300	9.00	273.00	7.00	2.30	**2.00**	1.8	**100**	0.03	0.08	2	0.6	15
KGS020	90271	**QV**	0.30	2200	**17.00**	50	**0.10**	**2.40**	1000	0.05	2.70	29	5.30	8500	0.05	300	**1.00**	800	103	3.90	500	17.00	**50.00**	1.20	**0.05**	**2.00**	21.0	**100**	0.02	0.10	3	0.4	4
KGS025	90289	**QV**	**0.30**	1600	**14.00**	6	**0.10**	**0.04**	100	0.02	3.50	19	19.00	7300	0.03	**100**	**1.00**	200	92	2.00	100	20.00	**50.00**	3.30	**0.05**	**2.00**	1.1	**100**	**0.02**	0.07	5	0.2	7
Minimum			0.30	500	11.00	6	0.10	0.04	100	0.02	2.40	19	5.30	5600	0.03	100	1.00	200	92	2.00	100	9.00	50.00	1.20	0.05	2.00	1.1	100	0.02	0.05	2	0.1	3
Maximum			3.40	5600	17.00	96	0.10	4.90	3400	0.08	74.00	54	187.00	28000	0.13	2000	2.00	2100	468	3.90	1000	47.00	273.00	17.00	2.30	2.00	21.0	400	0.06	0.28	15	7.6	15
Average			**0.83**	2000	**14.67**	34	0.10	**1.31**	1183	0.05	18.67	31	53.72	11367	0.07	483	1.33	950	192	3.20	383	20.50	108.50	5.52	0.43	**2.00**	6.4	150	0.03	0.12	6	1.8	8
KGS021	90260	**AM**	**0.90**	46000	**14.00**	99	**0.10**	0.29	55000	0.31	73.00	**1408**	66.00	75000	0.03	3900	4.00	**110000**	1418	0.31	5600	822.00	216.00	7.10	0.06	**2.00**	146.0	2800	0.14	0.14	166	10.0	82
KGS022	90257	**AM**	0.30	75000	**15.00**	74	**0.10**	0.45	69000	0.18	53.00	256	94.00	86000	0.05	4000	8.00	44000	1380	0.49	15000	155.00	449.00	6.60	0.41	**2.00**	170.0	5200	0.09	0.20	271	19.0	72
KGS023	90258	**AM**	**0.40**	74000	**16.00**	67	**0.10**	0.29	70000	0.16	56.00	205	196.00	92000	0.03	2800	9.00	41000	1479	0.47	12000	144.00	594.00	3.40	0.42	**2.00**	109.0	5900	0.06	0.16	266	23.0	79
KGS024	90277	**AM**	**0.60**	69000	**16.00**	326	**0.10**	0.24	60000	0.19	47.00	243	121.00	77000	0.07	8200	12.00	41000	1357	0.58	13000	163.00	463.00	5.30	0.26	**2.00**	119.0	4500	0.24	0.85	228	18.0	69
KGS026	90259	**AM**	**0.40**	73000	**18.00**	418	0.90	0.52	48000	0.22	33.00	73	61.00	70000	0.05	13000	13.00	23000	1227	1.10	24000	61.00	921.00	30.00	0.16	**2.00**	187.0	5700	0.41	2.50	195	25.0	92
KGS027	90261	**AM**	**0.40**	69000	**13.00**	57	**0.10**	0.06	66000	0.16	58.00	154	190.00	100000	0.03	2100	6.00	36000	1660	0.63	15000	105.00	590.00	4.70	**0.05**	**2.00**	103.0	7400	0.04	0.18	316	27.0	114
KGS028	90262	**AM**	**0.30**	70000	**14.00**	47	**0.10**	0.05	69000	0.14	50.00	194	105.00	96000	0.03	2000	8.00	37000	1599	0.46	15000	83.00	565.00	2.20	**0.05**	**2.00**	101.0	7000	0.05	0.19	328	24.0	90
KGS032	90285	**AM**	**0.30**	67000	**21.00**	145	**0.10**	**0.04**	62000	0.12	51.00	92	105.00	100000	0.07	4100	7.00	33000	1691	0.60	16000	70.00	716.00	5.00	0.25	**2.00**	119.0	8200	0.09	0.33	334	29.0	112
Minimum			0.30	46000	13.00	47	0.10	0.04	48000	0.12	33.00	73	61.00	70000	0.03	2000	4.00	23000	1227	0.31	5600	61.00	216.00	2.20	0.05	2.00	101.0	2800	0.04	0.14	166	10.0	69
Maximum			0.90	75000	21.00	418	0.90	0.52	70000	0.31	73.00	1408	196.00	100000	0.07	13000	13.00	110000	1691	1.10	24000	822.00	921.00	30.00	0.42	2.00	187.0	8200	0.41	2.50	334	29.0	114
Average			**0.45**	67875	**15.88**	154	0.20	0.24	62375	0.19	52.63	328	117.25	87000	0.05	5013	8.38	45625	1476	0.58	14450	200.38	564.25	8.04	0.21	**2.00**	131.8	5838	0.14	0.57	263	21.9	89
KGS011	90287	**SC**	**0.60**	64000	**19.00**	539	0.10	**1.90**	13000	0.08	8.70	18	39.00	22000	0.05	12000	10.00	5300	286	0.90	31000	17.00	275.00	45.00	**0.05**	**2.00**	151.0	1200	0.20	2.40	35	6.0	22
KGS015	90286	**SC**	**0.80**	65000	**18.00**	1022	**0.10**	**0.04**	11000	0.05	3.00	9	11.00	11000	0.05	29000	8.00	2000	213	0.75	26000	11.00	243.00	34.00	**0.05**	**2.00**	119.0	700	0.57	8.60	9	10.0	35
KGS029	90263	**SC**	**0.90**	61000	**18.00**	1412	1.00	**10.00**	16000	0.16	17.00	71	49.00	25000	0.04	25000	11.00	12000	292	2.10	12000	78.00	804.00	24.00	**0.05**	**2.00**	157.0	1900	0.35	2.90	50	11.0	33
KGS030	90264	**SC**	**0.50**	56000	**18.00**	369	0.20	0.42	15000	0.14	51.00	958	23.00	57000	0.03	5300	7.00	57000	962	0.57	11000	622.00	226.00	8.90	0.15	**2.00**	45.0	1400	0.23	1.90	77	7.8	88
KGS033	90265	**SC**	**0.30**	73000	**18.00**	454	0.40	**0.04**	15000	0.04	3.20	10	13.00	8900	0.07	6700	5.00	1100	90	1.80	38000	5.30	182.00	21.00	**0.05**	**2.00**	307.0	500	0.10	2.10	7	4.7	7
Minimum			0.30	56000	18.00	369	0.10	0.04	11000	0.04	3.00	9	11.00	8900	0.03	5300	5.00	1100	90	0.57	11000	5.30	182.00	8.90	0.05	2.00	45.0	500	0.10	1.90	7	4.7	7
Maximum			0.90	73000	19.00	1412	1.00	10.00	16000	0.16	51.00	958	49.00	57000	0.07	29000	11.00	57000	962	2.10	38000	622.00	804.00	45.00	0.15	2.00	307.0	1900	0.57	8.60	77	11.0	88
Average			**0.62**	63800	**18.20**	759	0.36	**2.48**	14000	0.09	16.58	213	27.00	24780	0.05	15600	8.20	15480	369	1.22	23600	146.66	346.00	26.58	0.07	**2.00**	155.8	1140	0.29	3.58	36	7.9	37
KGS034	90275	**VHM**	**0.30**	67000	**22.00**	484	1.00	0.20	37000	0.14	26.00	62	61.00	53000	0.03	12000	11.00	15000	925	4.00	23000	54.00	658.00	15.00	0.14	**4.00**	210.0	3800	0.33	4.10	125	25.0	72
KGS035	90266	**VHM**	**0.30**	66000	**18.00**	1805	0.40	**0.04**	22000	0.12	9.60	15	38.00	26000	0.03	22000	13.00	6600	406	0.64	30000	16.00	811.00	16.00	**0.05**	**2.00**	364.0	2300	0.47	1.80	40	11.0	52
KGS036	90267	**VHM**	**0.30**	63000	**17.00**	1591	0.40	**0.04**	18000	0.07	8.80	11	29.00	22000	0.03	22000	11.00	5400	340	1.10	28000	13.00	691.00	20.00	0.10	**2.00**	347.0	1800	0.42	2.70	31	9.7	45
KGS037	90268	**VHM**	**0.30**	65000	**16.00**	1038	**0.10**	0.05	13000	0.08	5.20	10	33.00	15000	0.03	21000	6.00	2600	227	0.80	27000	7.00	298.00	24.00	**0.05**	**2.00**	222.0	1100	0.37	4.60	15	7.8	33
KGS038	90269	**VHM**	**0.30**	73000	**16.00**	471	0.40	0.57	49000	0.13	29.00	102	36.00	60000	0.05	13000	10.00	23000	1144	2.20	22000	68.00	528.00	17.00	**0.05**	**2.00**	191.0	3800	0.33	6.20	171	26.0	81
KGS039	90278	**VHM**	**0.30**	65000	**19.00**	1101	0.60	0.06	15000	0.06	4.00	14	14.00	11000	0.04	14000	6.00	1800	117	2.00	31000	6.80	208.00	28.00	**0.05**	**2.00**	250.0	600	0.20	10.00	17	7.1	10
KGS040	90284	**VHM**	**0.30**	76000	**20.00**	**7238**	0.90	0.75	36000	0.14	24.00	100	15.00	43000	**2.00**	14000	15.00	13000	436	0.93	8400	166.00	811.00	15.00	0.61	**2.00**	399.0	2400	0.41	3.10	62	18.0	36
KGS041	90279	**VHM**	**0.60**	65000	**27.00**	1431	0.70	0.76	24000	0.08	15.00	36	17.00	27000	**1.50**	17000	11.00	13000	361	1.90	24000	47.00	773.00	36.00	**0.05**	**2.00**	359.0	3000	0.33	7.40	47	13.0	49
KGS042	90281	**VHM**	**0.30**	66000	**27.00**	1148	0.90	0.45	23000	0.08	12.00	20	35.00	29000	**1.20**	19000	15.00	7700	437	0.84	30000	21.00	979.00	17.00	**0.05**	**2.00**	362.0	2600	0.56	2.20	49	13.0	58
KGS043	90280	**VHM**	**0.30**	65000	**23.00**	1534	0.30	0.13	21000	0.05	9.10	16	29.00	23000	**0.75**	19000	11.00	5800	313	1.10	30000	17.00	770.00	19.00	**0.05**	**2.00**	361.0	1900	0.42	3.20	35	9.6	41
KGS044	90270	**VHM**	**0.40**	64000	**15.00**	811	0.50	0.19	33000	0.17	26.00	61	61.00	61000	0.03	16000	13.00	16000	1114	2.10	21000	49.00	1017.00	20.00	**0.05**	**2.00**	137.0	4500	0.47	6.20	118	28.0	105
KGS045	90274	**VHM**	**0.30**	63000	**24.00**	1083	0.50	0.15	23000	0.10	17.00	46	42.00	33000	0.02	22000	15.00	14000	582	0.64	27000	97.00	515.00	22.00	**0.05**	**2.00**	217.0	2600	0.75	5.00	53	14.0	68
Minimum			0.30	63000	15.00	471	0.10	0.04	13000	0.05	4.00	10	14.00	11000	0.02	12000	6.00	1800	117	0.64	8400	6.80	208.00	15.00	0.05	2.00	137.0	600	0.20	1.80	15	7.1	10
Maximum			0.60	76000	27.00	7238	1.00	0.76	49000	0.17	29.00	102	61.00	61000	2.00	22000	15.00	23000	1144	4.00	31000	166.00	1017.00	36.00	0.61	4.00	399.0	4500	0.75	10.00	171	28.0	105
Average			0.33	66500	**20.33**	1645	0.56	0.28	26167	0.10	15.48	41	34.17	33583	**0.48**	17583	11.42	10325	534	1.52	25117	46.82	671.58	20.75	0.11	**2.17**	284.9	2533	0.42	4.71	64	15.2	54

NOTES:

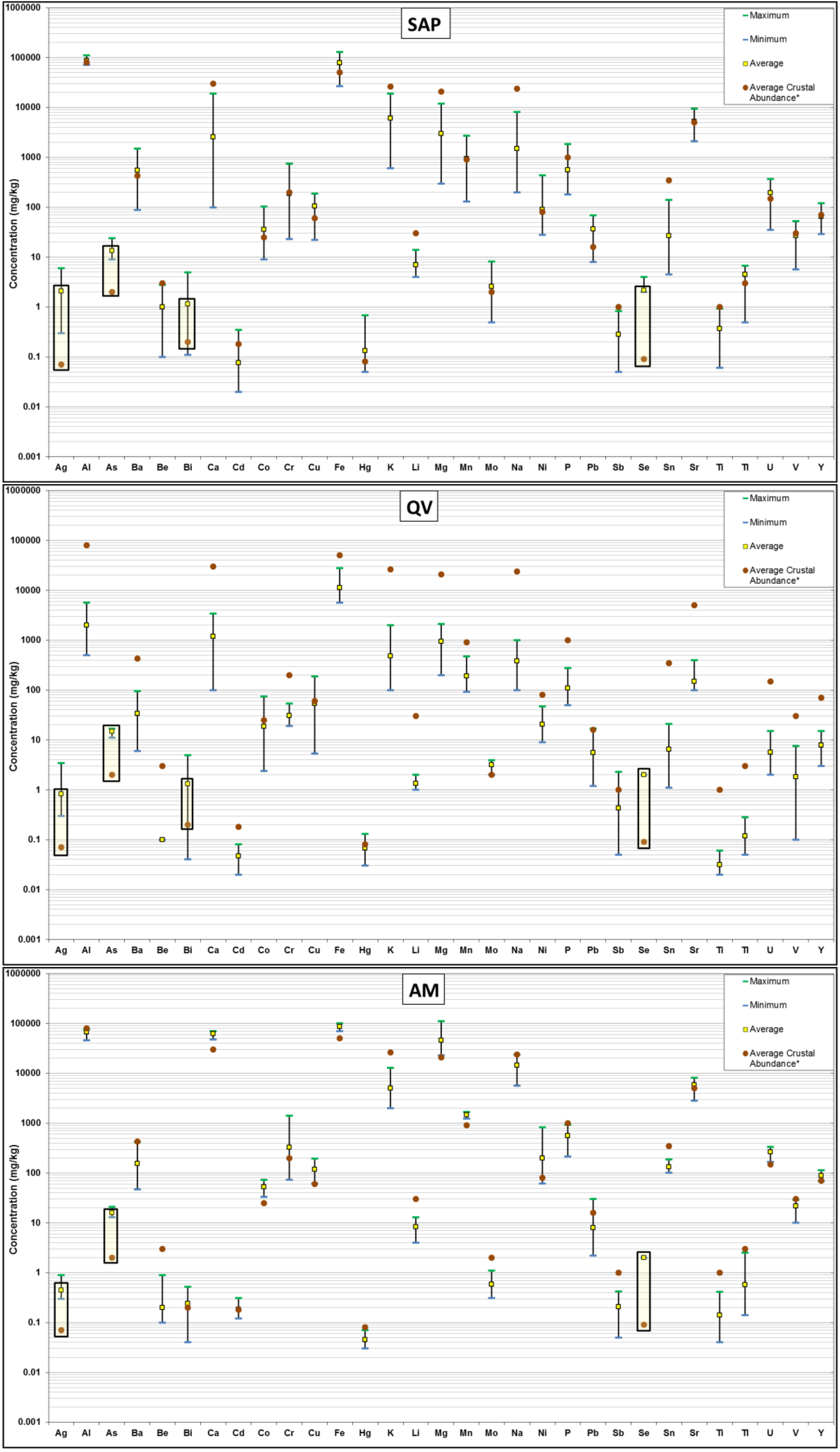
***** Typical crustal abundance for continental rocks taken from Smith and Huyck (1999).

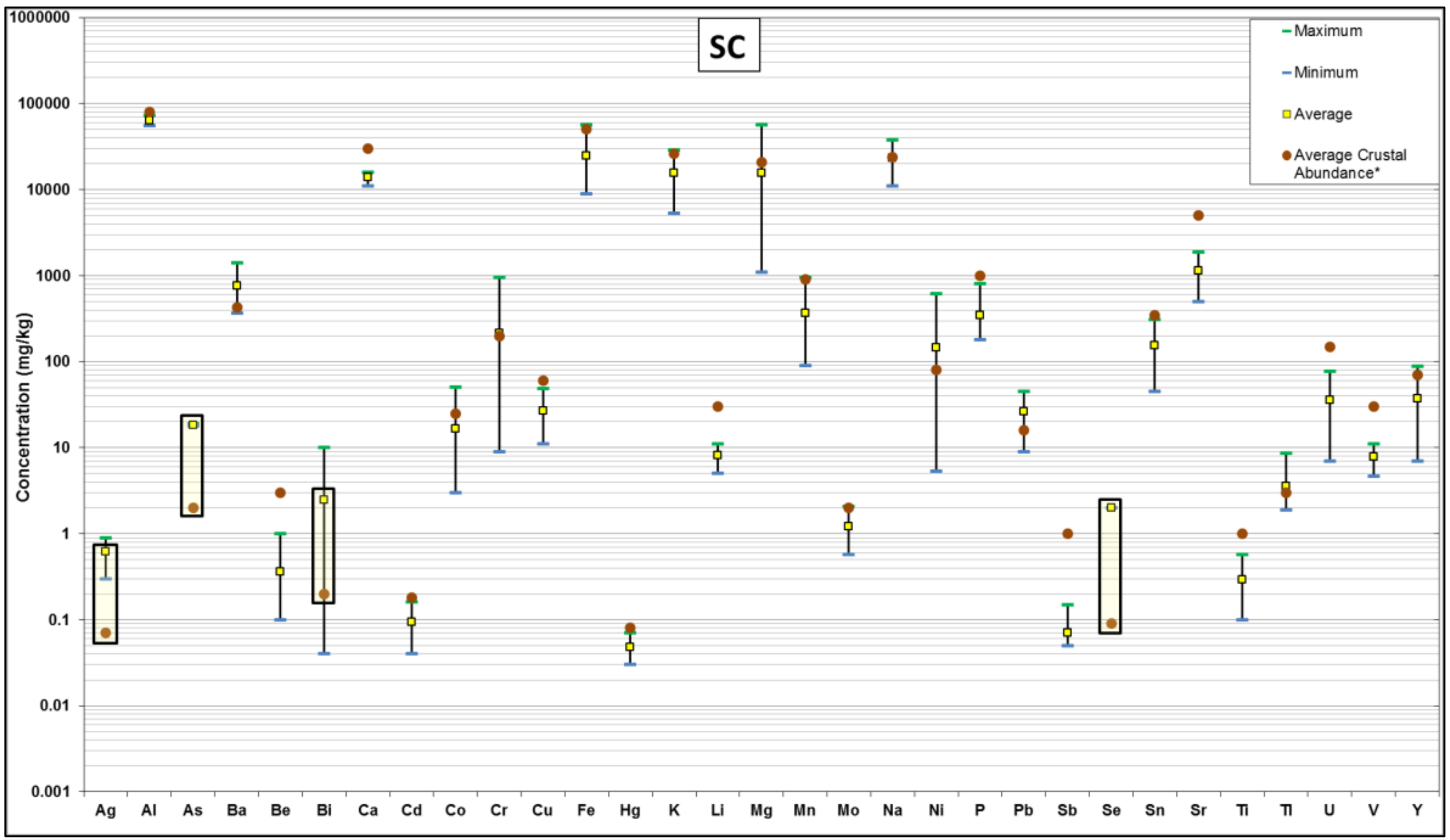
Detection limits were used in calculations and highlighted in **Bold Blue** for the parameters whose values are below the detection limit.

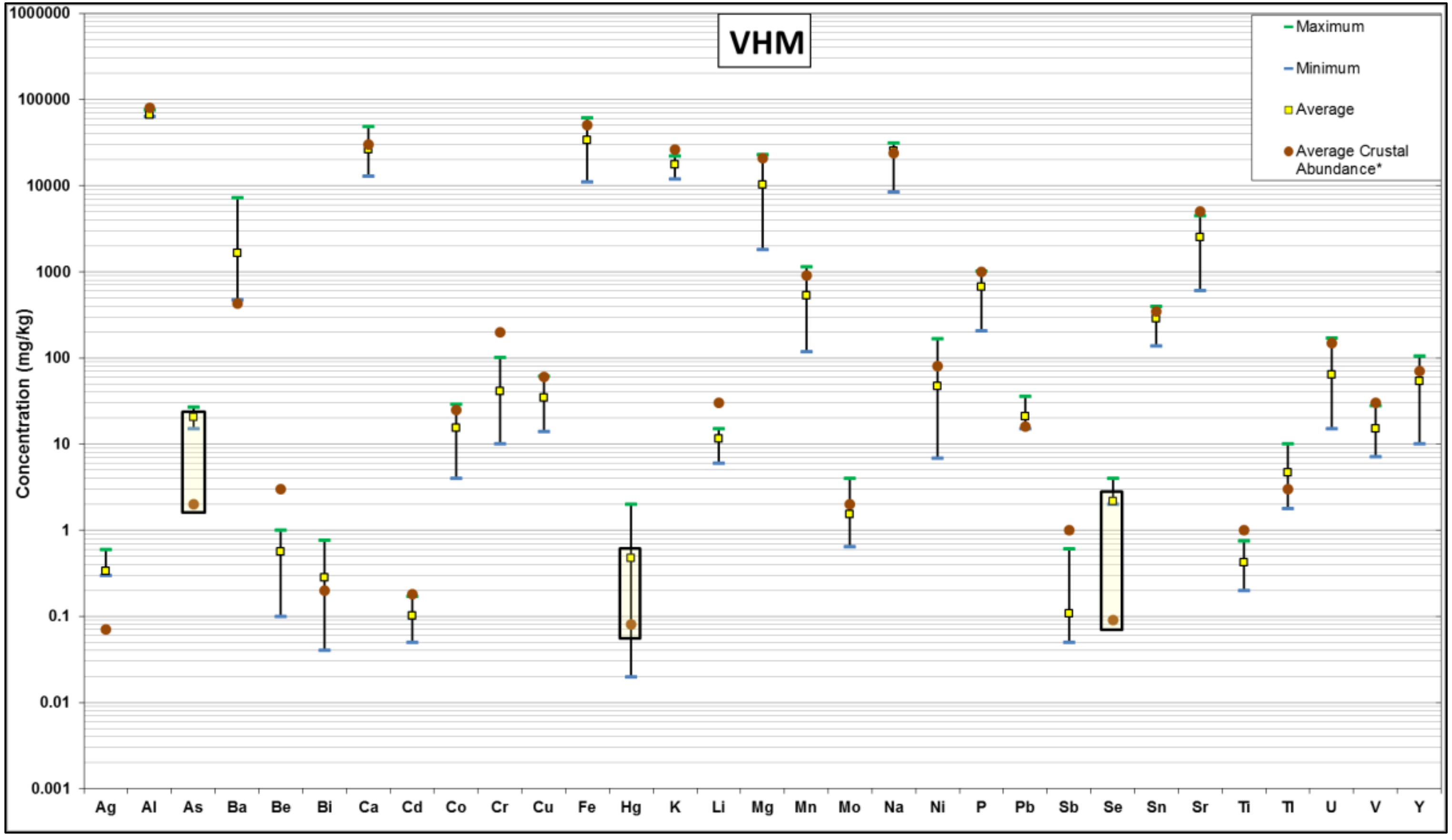
** Detection limit of the Selenium (Se) is much greater than the crustal abundance of it.

Values that are equal or greater than 5 times crustal abundance are highlighted in **Bold Red.**

Appendix A-4: Trace Metals Test Results Assessment Graphs

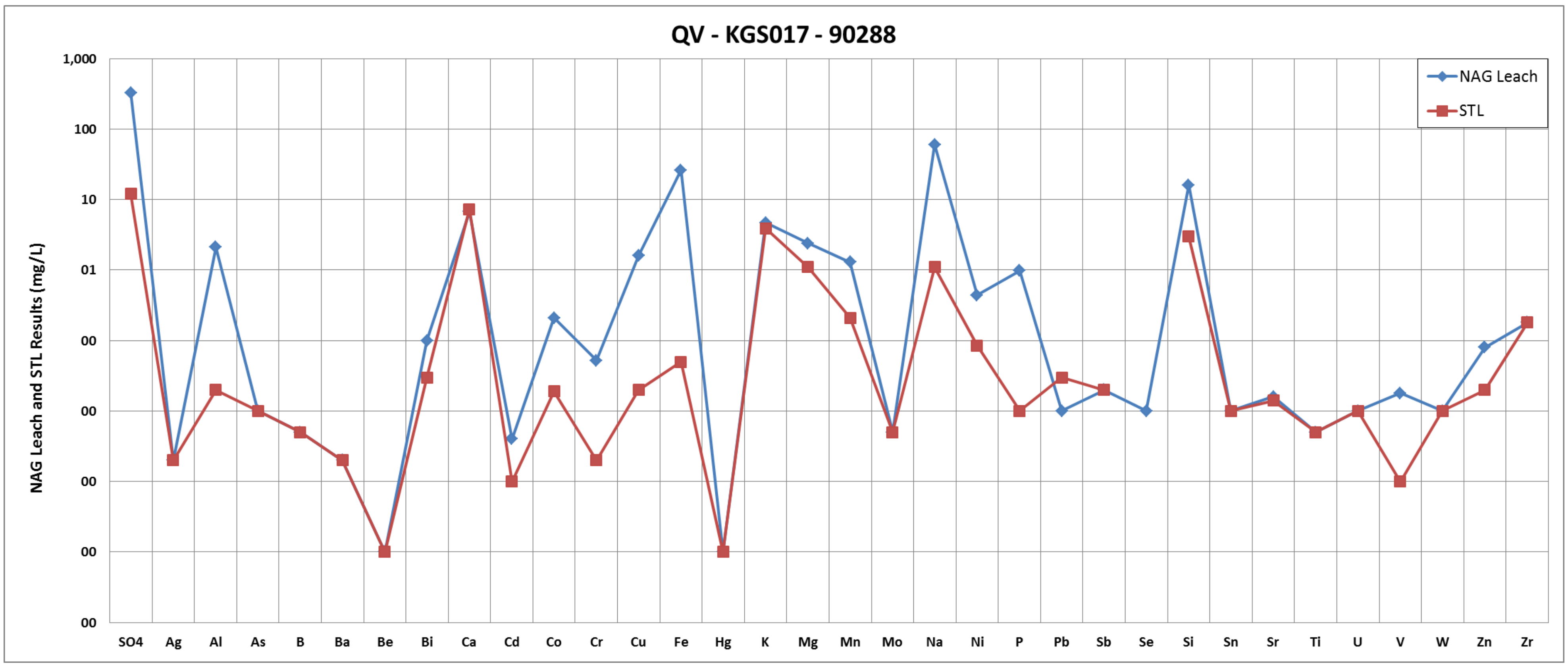


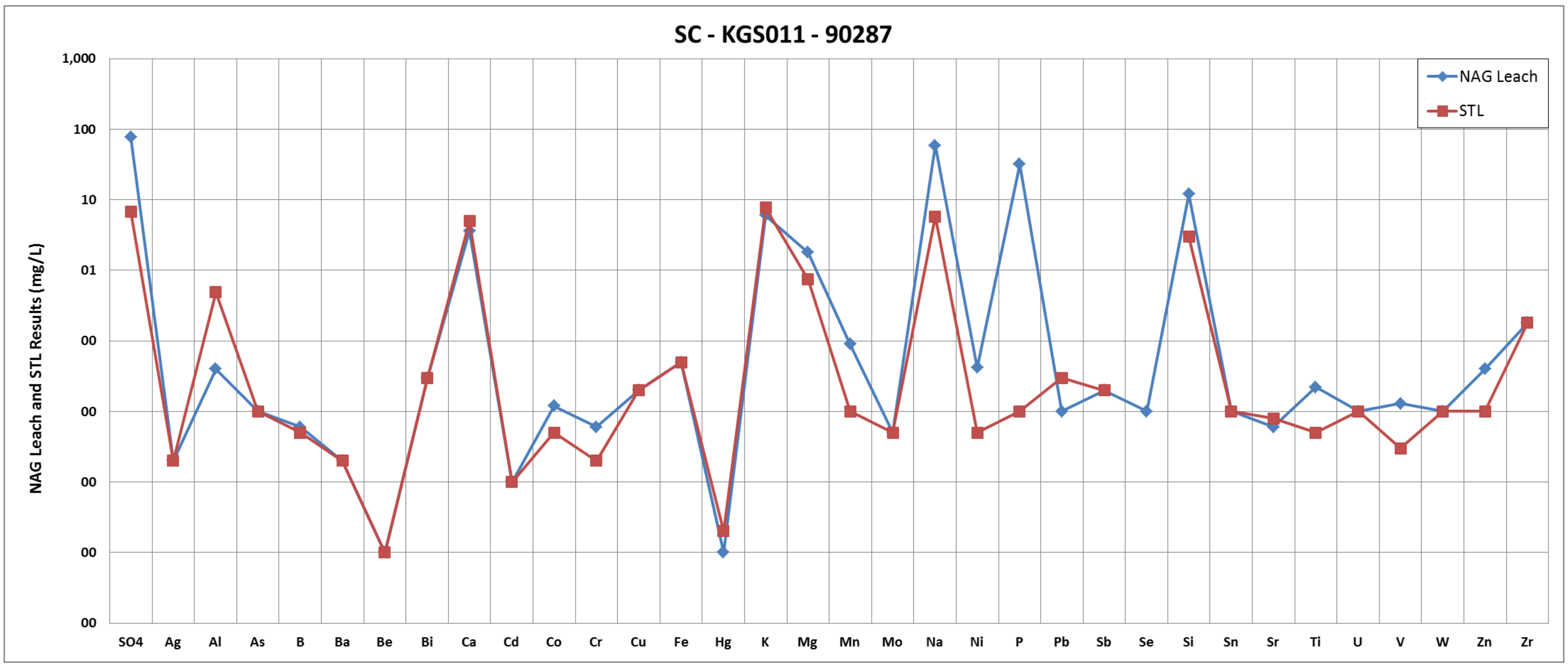

SC
Maximum
Minimum
Average
Average Crustal Abundance*
Concentration (mg/kg)
1000000
100000
10000
1000
100
10
1
0.1
0.01
0.001
Ag Al As Ba Be Bi Ca Cd Co Cr Cu Fe Hg K Li Mg Mn Mo Na Ni P Pb Sb Se Sn Sr Ti Tl U V Y

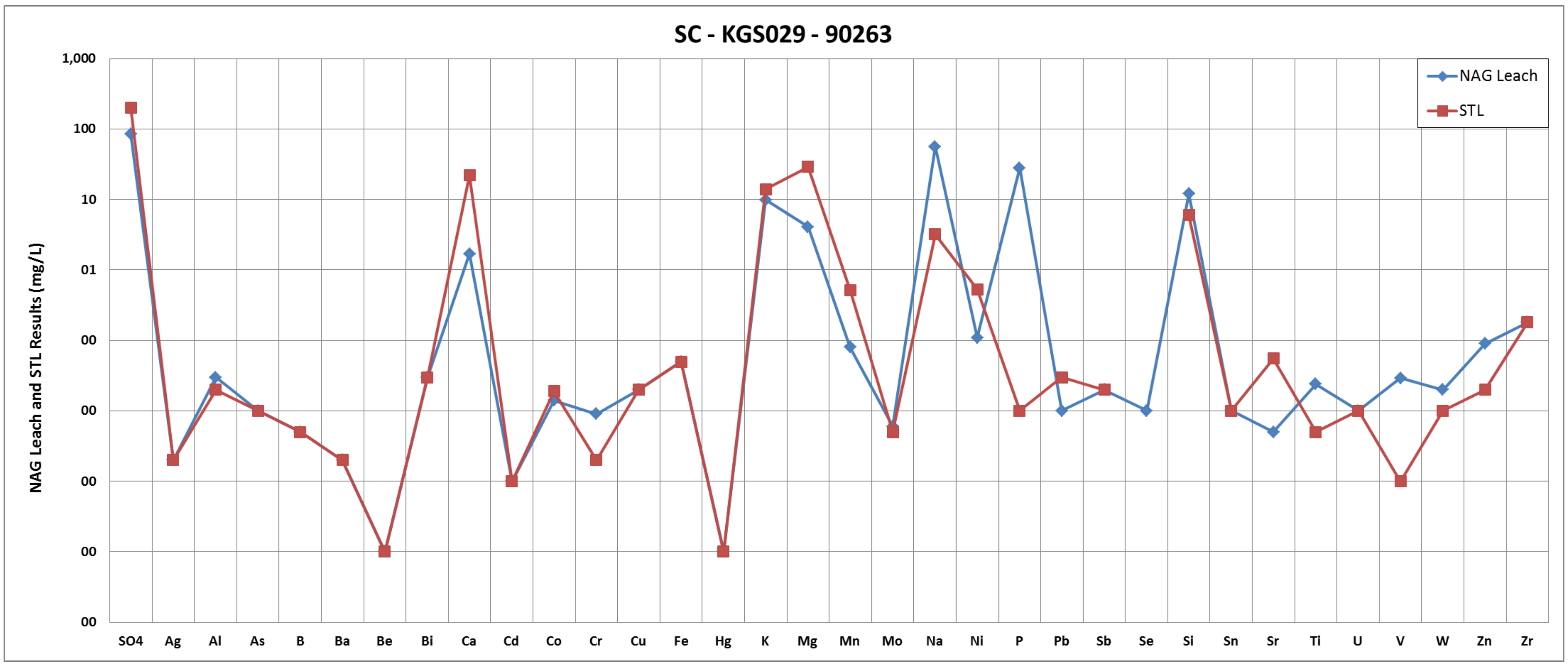

VHM
Maximum
Minimum
Average
Average Crustal Abundance*
Concentration (mg/kg)
1000000
100000
10000
1000
100
10
1
0.1
0.01
0.001
Ag Al As Ba Be Bi Ca Cd Co Cr Cu Fe Hg K Li Mg Mn Mo Na Ni P Pb Sb Se Sn Sr Ti Tl U V Y

APPENDIX B

Comparison Graphs of STL Results and NAG Leachate Results


QV - KGS017 - 90288
NAG Leach and STL Results (mg/L)
1,000
100
10
01
00
00
00
00
00
SO4
Ag
Al
As
B
Ba
Be
Bi
Ca
Cd
Co
Cr
Cu
Fe
Hg
K
Mg
Mn
Mo
Na
Ni
P
Pb
Sb
Se
Si
Sn
Sr
Ti
U
V
W
Zn
Zr
NAG Leach
STL


SC - KGS011 - 90287
NAG Leach and STL Results (mg/L)
1,000
100
10
01
00
00
00
00
00
SO4
Ag
Al
As
B
Ba
Be
Bi
Ca
Cd
Co
Cr
Cu
Fe
Hg
K
Mg
Mn
Mo
Na
Ni
P
Pb
Sb
Se
Si
Sn
Sr
Ti
U
V
W
Zn
Zr
NAG Leach
STL


SC - KGS029 - 90263
NAG Leach and STL Results (mg/L)
1,000
100
10
01
00
00
00
00
00
SO4
Ag
Al
As
B
Ba
Be
Bi
Ca
Cd
Co
Cr
Cu
Fe
Hg
K
Mg
Mn
Mo
Na
Ni
P
Pb
Sb
Se
Si
Sn
Sr
Ti
U
V
W
Zn
Zr
NAG Leach
STL

APPENDIX C

Laboratory Analyses Results

TEST REPORT

CLIENT DETAILS

Contact	Serhat Demirel
Client	Golder Associates (Turkey)
Address	Hollanda Cad.691.Sok Vadi Sit. No.4 Yildiz Cankaya
Telephone	+90-312-441-00-31
Facsimile	+90-312-441-07-14
Email	sdemirel@golder.com
Project	(Not specified)
Order Number	**06550**
Samples	45
Sample matrix	SOIL

LABORATORY DETAILS

Laboratory	SGS South Africa (Pty) Limited
Address	259 Kent Avenue Ferndale, 2194
Telephone	+27 (0)11 781 5689
Laboratory Manager	Martin Olivier
SGS Reference	JB15-06285 R0
Report Number	0000008891
Date Received	2015/03/06 11:24:58AM
Date Reported	2015/03/23 09:27:05AM

COMMENTS

The document is issued in accordance with SANAS's accreditation requirements.
Accredited for compliance with ISO/IEC 17025. SANAS accredited laboratory T0107.

T0107

Analysis of sulphur and carbon species completed by SGS Analytical Services Booysens .

PAG: Potentially acid generating, based on interpretation of ABA data alone.
PAN: Potentially acid neutralising, based on interpretation of ABA data alone.
U: Uncertain with respect to potential acid generation or neutralisation, based on interpretation of ABA data alone.

Analyses of whole rock analysis by XRF and trace metals by ICP were subcontracted

SIGNATORIES

Greg Ondrejkovic
Technical Supervisor/Technical Signatory

Martin Olivier
Operations Manager/Technical Signatory

Parameter	**Units**	**LOR**	**Sample Number** JB15-06285.001 **Sample Name** 90246 **Sample Matrix** Soil	JB15-06285.002 90247 Soil	JB15-06285.003 90248 Soil	JB15-06285.004 90249 Soil	JB15-06285.005 90250 Soil

Paste pH and conductivity and 10% pH in soil Method: ME-AN-024

Paste pH	-	1	5.7	6.2	6.7	6.3	6.8

Neutralising Potential (NP) Method: ME-AN-025

Fizz Rating	-	-	1	1	1	1	1
Sample Weight	g	-	2.00	2.00	2.00	2.00	2.00
Normality of standardised HCl	N	-	0.101	0.101	0.101	0.101	0.101
Volume of HCl added	ml	-	20.0	20.0	20.0	20.0	20.0
Normality of standardised NaOH	N	-	0.100	0.100	0.100	0.100	0.100
Titre of NaOH	ml	-	20.8	21.6	19.9	20.2	19.8
NP as kg CaCO3/T	kg CaCO3/T	0.1	<0.1	<0.1	0.8	<0.1	1.0

SUB_Sulphur and carbon species by LECO Method: SUB

Total sulphur as S^	%	0.01	0.01	<0.01	<0.01	<0.01	<0.01
Sulphide as S^	%	0.01	0.01	<0.01	<0.01	<0.01	<0.01
Sulphate as SO4^	%	0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Total carbon as C^	%	0.01	0.31	0.04	0.41	0.21	0.09
Carbonate as CO3^	%	0.05	<0.05	<0.05	<0.05	<0.05	<0.05

Calculation of acid/base balances Method: ME-AN-025

Acid potential*	kg CaCO3/T	0.31	0.31	<0.31	<0.31	<0.31	<0.31
Net neutralising potential*	kg CaCO3/T	-	<0.0	<0.0	0.5	<0.0	0.7
NP AP ratio*	-	-	<0.0	<0.0	2.6	0.2	3.4
Classification*	-	-	PAG	PAG	U	PAG	U

Net Acid Generation (NAG) Method: MEND 1.20.1

NAG pH*	-	1	6.3	6.3	6.2	6.4	6.3
NAG as kg H2SO4/tonne at pH 4.5*	kg H2SO4/T	0.5	<0.5	<0.5	<0.5	<0.5	<0.5
NAG as kg H2SO4/tonne at pH 7.0*	kg H2SO4/T	0.5	2.0	2.0	1.8	2.0	2.0

SUB_XRF Method: SUB

SiO2^	%	0.05	69	44	54	61	50
Al2O3^	%	0.05	16	20	18	17	18
CaO^	%	0.01	0.040	0.81	0.45	0.72	3.0
MgO^	%	0.05	0.19	0.51	0.98	0.58	2.2
Fe2O3^	%	0.01	7.6	21	15	11	15
K2O^	%	0.01	1.1	0.090	1.1	0.88	1.1
MnO^	%	0.01	0.090	0.28	0.37	0.050	0.19
Na2O^	%	0.05	<0.050	0.050	0.73	0.63	1.3
P2O5^	%	0.01	0.050	0.11	0.080	0.040	0.35
TiO2^	%	0.01	0.47	1.7	0.83	0.75	1.8
Cr2O3^	%	0.01	0.050	0.020	0.13	0.020	0.020
V2O5^	%	0.01	0.030	0.050	0.040	0.040	0.040
Loss on ignition (XRF)^	%	-50	6.3	11	8.1	7.0	6.5

Parameter	Units	LOR	JB15-06285.001	JB15-06285.002	JB15-06285.003	JB15-06285.004	JB15-06285.005
Sample Number			JB15-06285.001	JB15-06285.002	JB15-06285.003	JB15-06285.004	JB15-06285.005
Sample Name			90246	90247	90248	90249	90250
Sample Matrix			Soil	Soil	Soil	Soil	Soil
SUB_SGS Booysens Method: SUB							
Aluminium^	%	0.01	7.2	8.8	7.6	7.4	7.8
Arsenic^	ppm	1	24	9.0	12	12	12
Silver^	ppm	0.3	2.5	<0.30	2.3	2.1	1.2
Barium^	ppm	1	338	553	1161	295	685
Dysprosium^	ppm	0.05	1.5	8.2	8.6	3.3	8.1
Erbium^	ppm	0.05	0.74	5.0	4.7	1.9	4.7
Europium^	ppm	0.05	0.59	2.3	3.1	1.1	2.9
Gadolinium^	ppm	0.05	2.0	8.5	9.4	3.5	9.1
Holmium^	ppm	0.05	0.25	1.6	1.6	0.60	1.5
Neodymium^	ppm	0.1	17	37	54	20	53
Praseodymium^	ppm	0.05	5.5	9.5	15	5.6	14
Samarium^	ppm	0.1	2.6	7.1	9.8	3.7	9.3
Thulium^	ppm	0.05	0.10	0.62	0.61	0.24	0.62
Beryllium^	ppm	0.1	<0.10	2.8	1.1	0.30	2.7
Bismuth^	ppm	0.04	4.9	0.29	0.97	0.34	0.23
Calcium^	%	0.01	0.010	0.49	0.28	0.45	1.9
Cadmium^	ppm	0.02	0.030	0.070	0.35	0.030	0.15
Cerium^	ppb	0.05	70	29	65	47	111
Cobalt^	ppm	0.1	65	53	104	13	39
Cesium^	ppm	0.05	0.59	0.45	7.5	1.8	1.3
Chromium^	ppm	1	269	134	749	140	87
Gallium^	ppm	0.1	20	23	20	21	25
Germanium^	ppm	0.1	1.0	0.50	0.50	0.40	0.30
Copper^	ppm	0.5	69	98	186	120	61
Iron^	%	0.01	5.0	13	9.6	7.3	9.8
Indium^	ppm	0.02	0.050	0.11	0.060	0.050	0.090
Lanthanum^	ppb	0.1	36	55	72	26	57
Lutetium^	ppm	0.01	0.11	0.63	0.58	0.24	0.61
Potassium^	%	0.01	0.85	0.080	0.83	0.67	0.78
Lithium^	ppm	1	9.0	6.0	8.0	7.0	14
Hafnium^	ppm	0.02	1.3	1.0	0.69	0.97	1.4
Magnesium^	%	0.01	0.11	0.29	0.55	0.32	1.2
Mercury^	ppm	0.01	0.12	0.060	0.10	0.090	0.050
Manganese^	ppm	2	691	1914	2689	371	1347
Molybdenum^	ppm	0.05	1.9	0.70	2.3	0.93	1.8
Sodium^	%	0.01	0.040	0.040	0.46	0.40	0.81
Niobium^	ppm	0.1	12	7.8	9.9	11	21
Nickel^	ppm	0.5	113	63	439	53	73
Phosphorus^	ppm	50	240	570	442	223	1830
Lead^	ppm	0.5	54	8.0	69	29	14
Rubidium^	ppm	0.2	26	8.1	50	35	44
Sulphur^	%	0.01	0.050	0.010	0.020	0.030	0.020
Antimony^	ppm	0.05	0.46	0.19	0.27	0.21	0.33
Scandium^	ppm	0.5	14	57	27	19	28
Selenium^	ppm	2	<2.0	<2.0	<2.0	<2.0	<2.0
Tin^	ppm	0.3	2.5	1.3	1.3	1.8	2.1
Strontium^	ppm	0.5	6.4	33	54	32	140
Tantalum^	ppb	0.05	3.2	1.7	1.6	2.0	1.5
Terbium^	ppm	0.05	0.27	1.3	1.4	0.55	1.3
Tellurium^	ppm	0.05	0.16	<0.050	<0.050	0.10	<0.050
Thorium^	ppm	0.2	12	1.2	9.1	9.7	8.5
Titanium^	%	0.01	0.24	0.86	0.44	0.39	0.95
Thallium^	ppm	0.02	0.23	0.23	0.93	0.37	0.37
Uranium^	ppm	0.05	3.4	0.49	5.3	6.0	3.8
Vanadium^	ppm	2	120	278	167	171	247
Ytterbium^	ppm	0.1	0.70	3.9	3.6	2.2	3.9
Yttrium^	ppm	0.1	5.7	53	38	16	44
Tungsten^	ppm	0.1	26	1.8	46	18	1.7
Zinc^	ppm	1	35	87	121	60	115

Parameter	Units	LOR	JB15-06285.001 90246 Soil	JB15-06285.002 90247 Soil	JB15-06285.003 90248 Soil	JB15-06285.004 90249 Soil	JB15-06285.005 90250 Soil
SUB_SGS Booysens Method: SUB (continued)							
Zirconium^	ppm	0.5	29	15	14	24	48

Sample Number			JB15-06285.006	JB15-06285.007	JB15-06285.008	JB15-06285.009	JB15-06285.010
Sample Name			90251	90252	90253	90254	90255
Sample Matrix			Soil	Soil	Soil	Soil	Soil
Parameter	**Units**	**LOR**					

Paste pH and conductivity and 10% pH in soil Method: ME-AN-024

Parameter	Units	LOR	JB15-06285.006	JB15-06285.007	JB15-06285.008	JB15-06285.009	JB15-06285.010
Paste pH	-	1	5.6	6.5	5.6	5.5	5.8

Neutralising Potential (NP) Method: ME-AN-025

Parameter	Units	LOR	JB15-06285.006	JB15-06285.007	JB15-06285.008	JB15-06285.009	JB15-06285.010
Fizz Rating	-	-	1	1	1	1	1
Sample Weight	g	-	2.00	2.00	2.00	2.00	2.00
Normality of standardised HCl	N	-	0.101	0.101	0.101	0.101	0.101
Volume of HCl added	ml	-	20.0	20.0	20.0	20.0	20.0
Normality of standardised NaOH	N	-	0.100	0.100	0.100	0.100	0.100
Titre of NaOH	ml	-	20.7	20.0	25.5	20.2	20.1
NP as kg CaCO3/T	kg CaCO3/T	0.1	<0.1	0.6	<0.1	<0.1	0.3

SUB_Sulphur and carbon species by LECO Method: SUB

Parameter	Units	LOR	JB15-06285.006	JB15-06285.007	JB15-06285.008	JB15-06285.009	JB15-06285.010
Total sulphur as S^	%	0.01	0.01	<0.01	<0.01	<0.01	<0.01
Sulphide as S^	%	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Sulphate as SO4^	%	0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Total carbon as C^	%	0.01	0.33	0.04	0.26	0.22	0.07
Carbonate as CO3^	%	0.05	<0.05	<0.05	1.20	<0.05	<0.05

Calculation of acid/base balances Method: ME-AN-025

Parameter	Units	LOR	JB15-06285.006	JB15-06285.007	JB15-06285.008	JB15-06285.009	JB15-06285.010
Acid potential*	kg CaCO3/T	0.31	<0.31	<0.31	<0.31	<0.31	<0.31
Net neutralising potential*	kg CaCO3/T	-	<0.0	0.2	<0.0	<0.0	<0.0
NP AP ratio*	-	-	<0.0	1.8	<0.0	0.2	1.0
Classification*	-	-	PAG	U	PAG	PAG	PAG

Net Acid Generation (NAG) Method: MEND 1.20.1

Parameter	Units	LOR	JB15-06285.006	JB15-06285.007	JB15-06285.008	JB15-06285.009	JB15-06285.010
NAG pH*	-	1	6.5	6.4	6.5	6.4	6.5
NAG as kg H2SO4/tonne at pH 4.5*	kg H2SO4/T	0.5	<0.5	<0.5	<0.5	<0.5	<0.5
NAG as kg H2SO4/tonne at pH 7.0*	kg H2SO4/T	0.5	1.2	2.0	1.6	1.4	1.8

SUB_XRF Method: SUB

Parameter	Units	LOR	JB15-06285.006	JB15-06285.007	JB15-06285.008	JB15-06285.009	JB15-06285.010
SiO2^	%	0.05	45	66	64	56	72
Al2O3^	%	0.05	23	18	17	20	17
CaO^	%	0.01	0.040	0.050	0.050	0.20	0.050
MgO^	%	0.05	0.050	0.89	0.090	0.13	<0.050
Fe2O3^	%	0.01	19	5.2	11	13	4.8
K2O^	%	0.01	0.060	1.8	0.40	0.24	0.18
MnO^	%	0.01	0.080	0.040	0.040	0.14	0.020
Na2O^	%	0.05	<0.050	0.070	<0.050	<0.050	<0.050
P2O5^	%	0.01	0.12	0.060	0.050	0.070	0.030
TiO2^	%	0.01	1.5	0.45	0.82	1.0	0.42
Cr2O3^	%	0.01	0.020	0.030	0.030	0.040	0.010
V2O5^	%	0.01	0.060	0.020	0.040	0.050	0.020
Loss on ignition (XRF)^	%	-50	11	6.6	7.6	9.2	6.5

		Sample Number	**JB15-06285.006**	**JB15-06285.007**	**JB15-06285.008**	**JB15-06285.009**	**JB15-06285.010**
		Sample Name	**90251**	**90252**	**90253**	**90254**	**90255**
		Sample Matrix	**Soil**	**Soil**	**Soil**	**Soil**	**Soil**
Parameter	**Units**	**LOR**					
SUB_SGS Booysens Method: SUB							
Aluminium^	%	0.01	11	8.4	7.8	9.3	7.9
Arsenic^	ppm	1	13	10	11	10	11
Silver^	ppm	0.3	0.60	1.1	5.3	1.4	> 10
Barium^	ppm	1	89	1288	157	295	145
Dysprosium^	ppm	0.05	2.3	11	3.0	4.4	2.6
Erbium^	ppm	0.05	1.4	6.0	1.6	2.3	1.4
Europium^	ppm	0.05	0.78	4.1	0.97	1.5	0.91
Gadolinium^	ppm	0.05	2.5	14	3.3	4.6	3.1
Holmium^	ppm	0.05	0.42	2.0	0.52	0.75	0.46
Neodymium^	ppm	0.1	15	85	19	30	19
Praseodymium^	ppm	0.05	4.1	24	5.1	8.3	5.8
Samarium^	ppm	0.1	3.0	14	3.7	5.6	3.5
Thulium^	ppm	0.05	0.20	0.77	0.22	0.33	0.19
Beryllium^	ppm	0.1	0.40	0.60	0.20	0.50	<0.10
Bismuth^	ppm	0.04	0.60	0.55	2.1	1.3	0.78
Calcium^	%	0.01	0.020	0.020	0.020	0.13	0.020
Cadmium^	ppm	0.02	0.030	0.030	0.060	0.060	0.070
Cerium^	ppb	0.05	204	121	49	65	31
Cobalt^	ppm	0.1	9.0	16	11	72	9.8
Cesium^	ppm	0.05	0.38	2.8	0.77	0.97	0.32
Chromium^	ppm	1	142	132	171	266	49
Gallium^	ppm	0.1	30	20	21	25	21
Germanium^	ppm	0.1	1.2	0.50	0.90	0.70	0.70
Copper^	ppm	0.5	103	57	116	160	171
Iron^	%	0.01	12	3.5	6.9	8.5	3.3
Indium^	ppm	0.02	0.11	0.030	0.070	0.090	0.030
Lanthanum^	ppb	0.1	15	131	22	39	36
Lutetium^	ppm	0.01	0.22	0.74	0.22	0.32	0.18
Potassium^	%	0.01	0.060	1.4	0.32	0.20	0.15
Lithium^	ppm	1	4.0	6.0	5.0	7.0	4.0
Hafnium^	ppm	0.02	1.5	0.86	1.3	1.2	0.72
Magnesium^	%	0.01	0.050	0.51	0.060	0.080	0.030
Mercury^	ppm	0.01	0.090	0.060	0.18	0.090	0.68
Manganese^	ppm	2	550	265	288	1000	131
Molybdenum^	ppm	0.05	3.9	0.49	4.8	1.8	1.2
Sodium^	%	0.01	0.020	0.050	0.020	0.050	0.030
Niobium^	ppm	0.1	23	13	17	15	9.9
Nickel^	ppm	0.5	43	76	46	115	43
Phosphorus^	ppm	50	580	279	277	404	180
Lead^	ppm	0.5	56	42	41	31	22
Rubidium^	ppm	0.2	3.4	79	14	9.9	6.0
Sulphur^	%	0.01	0.040	0.010	0.030	0.030	0.020
Antimony^	ppm	0.05	0.82	<0.050	0.25	0.25	0.080
Scandium^	ppm	0.5	39	8.6	20	28	10
Selenium^	ppm	2	<2.0	<2.0	4.0	<2.0	<2.0
Tin^	ppm	0.3	4.1	2.7	2.7	3.1	1.6
Strontium^	ppm	0.5	4.5	19	7.7	13	8.9
Tantalum^	ppb	0.05	3.1	2.4	2.4	2.1	2.1
Terbium^	ppm	0.05	0.41	2.0	0.50	0.72	0.46
Tellurium^	ppm	0.05	<0.050	<0.050	0.12	<0.050	0.17
Thorium^	ppm	0.2	13	22	13	12	9.4
Titanium^	%	0.01	0.76	0.24	0.42	0.53	0.21
Thallium^	ppm	0.02	0.13	0.51	0.17	0.28	0.060
Uranium^	ppm	0.05	6.7	4.4	4.5	6.6	3.4
Vanadium^	ppm	2	304	63	170	241	75
Ytterbium^	ppm	0.1	1.5	4.8	1.5	2.2	1.2
Yttrium^	ppm	0.1	8.7	53	11	16	11
Tungsten^	ppm	0.1	25	17	87	21	456
Zinc^	ppm	1	54	71	39	79	29

ANALYTICAL REPORT

JB15-06285 R0

Report number 0000008891
Client reference: **06550**

Parameter	Units	LOR	JB15-06285.006 90251 Soil	JB15-06285.007 90252 Soil	JB15-06285.008 90253 Soil	JB15-06285.009 90254 Soil	JB15-06285.010 90255 Soil
Sample Number / Sample Name / Sample Matrix							
SUB_SGS Booysens Method: SUB (continued)							
Zirconium^	ppm	0.5	50	30	39	38	23

Parameter	Units	LOR	JB15-06285.011	JB15-06285.012	JB15-06285.013	JB15-06285.014	JB15-06285.015
Sample Number			**JB15-06285.011**	**JB15-06285.012**	**JB15-06285.013**	**JB15-06285.014**	**JB15-06285.015**
Sample Name			**90256**	**90257**	**90258**	**90259**	**90260**
Sample Matrix			**Soil**	**Soil**	**Soil**	**Soil**	**Soil**

Paste pH and conductivity and 10% pH in soil   Method: ME-AN-024

Paste pH	-	1	6.8	9.5	9.3	10.0	9.4

Neutralising Potential (NP)   Method: ME-AN-025

Fizz Rating	-	-	2	1	1	2	2
Sample Weight	g	-	2.00	2.00	2.00	2.00	2.00
Normality of standardised HCl	N	-	0.101	0.101	0.101	0.101	0.101
Volume of HCl added	ml	-	20.0	20.0	20.0	30.1	35.2
Normality of standardised NaOH	N	-	0.100	0.100	0.100	0.100	0.100
Titre of NaOH	ml	-	19.5	14.9	15.5	22.6	19.9
NP as kg CaCO3/T	kg CaCO3/T	0.1	1.8	13	12	20	39

SUB_Sulphur and carbon species by LECO   Method: SUB

Total sulphur as S^	%	0.01	<0.01	0.08	0.15	0.09	0.06
Sulphide as S^	%	0.01	<0.01	0.02	0.11	0.06	0.04
Sulphate as SO4^	%	0.03	<0.03	0.19	0.11	0.09	0.08
Total carbon as C^	%	0.01	0.01	0.03	0.02	0.13	0.12
Carbonate as CO3^	%	0.05	<0.05	<0.05	<0.05	0.07	<0.05

Calculation of acid/base balances   Method: ME-AN-025

Acid potential*	kg CaCO3/T	0.31	<0.31	0.63	3.4	1.9	1.3
Net neutralising potential*	kg CaCO3/T	-	1.5	13	8.4	18	38
NP AP ratio*	-	-	5.8	21	3.4	10	31
Classification*	-	-	PAN	PAN	PAN	PAN	PAN

Net Acid Generation (NAG)   Method: MEND 1.20.1

NAG pH*	-	1	5.8	6.5	6.4	6.9	7.6
NAG as kg H2SO4/tonne at pH 4.5*	kg H2SO4/T	0.5	<0.5	<0.5	<0.5	<0.5	<0.5
NAG as kg H2SO4/tonne at pH 7.0*	kg H2SO4/T	0.5	6.1	1.4	1.6	<0.5	<0.5

SUB_XRF   Method: SUB

SiO2^	%	0.05	99	50	51	55	48
Al2O3^	%	0.05	<0.050	15	14	15	9.3
CaO^	%	0.01	0.060	11	11	7.6	8.6
MgO^	%	0.05	0.070	7.6	7.0	4.1	19
Fe2O3^	%	0.01	1.2	13	14	11	11
K2O^	%	0.01	0.020	0.50	0.33	1.7	0.45
MnO^	%	0.01	0.010	0.19	0.21	0.17	0.20
Na2O^	%	0.05	<0.050	2.3	1.8	3.7	0.84
P2O5^	%	0.01	<0.010	0.080	0.10	0.17	0.040
TiO2^	%	0.01	0.020	0.96	1.1	1.1	0.51
Cr2O3^	%	0.01	<0.010	0.040	0.030	0.010	0.24
V2O5^	%	0.01	<0.010	0.060	0.050	0.040	0.030
Loss on ignition (XRF)^	%	-50	******	0.57	0.61	0.83	3.7

		Sample Number	JB15-06285.011	JB15-06285.012	JB15-06285.013	JB15-06285.014	JB15-06285.015
		Sample Name	90256	90257	90258	90259	90260
		Sample Matrix	Soil	Soil	Soil	Soil	Soil
Parameter	**Units**	**LOR**					
SUB_SGS Booysens Method: SUB							
Aluminium^	%	0.01	0.050	7.5	7.4	7.3	4.6
Arsenic^	ppm	1	11	15	16	18	14
Silver^	ppm	0.3	<0.30	0.30	0.40	0.40	0.90
Barium^	ppm	1	13	74	67	418	99
Dysprosium^	ppm	0.05	<0.050	3.6	4.1	4.7	2.0
Erbium^	ppm	0.05	<0.050	2.3	2.7	2.8	1.2
Europium^	ppm	0.05	<0.050	0.92	1.0	1.4	0.55
Gadolinium^	ppm	0.05	<0.050	2.9	3.5	4.7	1.6
Holmium^	ppm	0.05	<0.050	0.71	0.83	0.87	0.38
Neodymium^	ppm	0.1	0.10	7.2	8.5	22	3.7
Praseodymium^	ppm	0.05	<0.050	1.5	1.8	5.9	0.76
Samarium^	ppm	0.1	<0.10	2.1	2.6	4.6	1.1
Thulium^	ppm	0.05	<0.050	0.31	0.35	0.37	0.16
Beryllium^	ppm	0.1	<0.10	<0.10	<0.10	0.90	<0.10
Bismuth^	ppm	0.04	<0.040	0.45	0.29	0.52	0.29
Calcium^	%	0.01	0.020	6.9	7.0	4.8	5.5
Cadmium^	ppm	0.02	0.030	0.18	0.16	0.22	0.31
Cerium^	ppb	0.05	0.32	9.7	12	51	5.0
Cobalt^	ppm	0.1	2.4	53	56	33	73
Cesium^	ppm	0.05	<0.050	0.39	0.15	1.9	1.0
Chromium^	ppm	1	26	256	205	73	1408
Gallium^	ppm	0.1	0.50	16	16	19	10
Germanium^	ppm	0.1	<0.10	0.20	0.40	0.70	<0.10
Copper^	ppm	0.5	6.0	94	196	61	66
Iron^	%	0.01	0.88	8.6	9.2	7.0	7.5
Indium^	ppm	0.02	<0.020	0.060	0.070	0.060	0.040
Lanthanum^	ppb	0.1	<0.10	2.9	4.0	27	1.6
Lutetium^	ppm	0.01	<0.010	0.32	0.37	0.37	0.15
Potassium^	%	0.01	<0.010	0.40	0.28	1.3	0.39
Lithium^	ppm	1	<1.0	8.0	9.0	13	4.0
Hafnium^	ppm	0.02	<0.020	0.59	0.54	1.1	0.32
Magnesium^	%	0.01	0.030	4.4	4.1	2.3	11
Mercury^	ppm	0.01	0.050	0.050	0.030	0.050	0.030
Manganese^	ppm	2	124	1380	1479	1227	1418
Molybdenum^	ppm	0.05	3.6	0.49	0.47	1.1	0.31
Sodium^	%	0.01	0.010	1.5	1.2	2.4	0.56
Niobium^	ppm	0.1	0.80	4.2	4.7	13	2.3
Nickel^	ppm	0.5	13	155	144	61	822
Phosphorus^	ppm	50	<50	449	594	921	216
Lead^	ppm	0.5	2.9	6.6	3.4	30	7.1
Rubidium^	ppm	0.2	0.30	8.3	5.3	54	16
Sulphur^	%	0.01	<0.010	0.15	0.21	0.13	0.11
Antimony^	ppm	0.05	<0.050	0.41	0.42	0.16	0.060
Scandium^	ppm	0.5	<0.50	38	40	25	29
Selenium^	ppm	2	<2.0	<2.0	<2.0	<2.0	<2.0
Tin^	ppm	0.3	<0.30	1.0	0.90	2.0	0.60
Strontium^	ppm	0.5	1.4	170	109	187	146
Tantalum^	ppb	0.05	<0.050	0.71	0.54	1.1	0.19
Terbium^	ppm	0.05	<0.050	0.50	0.57	0.73	0.28
Tellurium^	ppm	0.05	<0.050	<0.050	<0.050	<0.050	<0.050
Thorium^	ppm	0.2	<0.20	0.50	0.70	9.0	0.40
Titanium^	%	0.01	<0.010	0.52	0.59	0.57	0.28
Thallium^	ppm	0.02	<0.020	0.090	0.060	0.41	0.14
Uranium^	ppm	0.05	<0.050	0.20	0.16	2.5	0.14
Vanadium^	ppm	2	3.0	271	266	195	166
Ytterbium^	ppm	0.1	<0.10	2.0	2.3	2.3	1.0
Yttrium^	ppm	0.1	0.10	19	23	25	10
Tungsten^	ppm	0.1	5.1	1.3	1.1	2.2	1.0
Zinc^	ppm	1	3.0	72	79	92	82

Parameter	Units	LOR	JB15-06285.011 90256 Soil	JB15-06285.012 90257 Soil	JB15-06285.013 90258 Soil	JB15-06285.014 90259 Soil	JB15-06285.015 90260 Soil
SUB_SGS Booysens Method: SUB (continued)							
Zirconium^	ppm	0.5	<0.50	13	12	32	7.9

Sample Number			**JB15-06285.016**	**JB15-06285.017**	**JB15-06285.018**	**JB15-06285.019**	**JB15-06285.020**
Sample Name			**90261**	**90262**	**90263**	**90264**	**90265**
Sample Matrix			**Soil**	**Soil**	**Soil**	**Soil**	**Soil**
Parameter	**Units**	**LOR**					

Paste pH and conductivity and 10% pH in soil Method: ME-AN-024

Paste pH	-	1	9.4	9.3	7.4	8.0	9.6

Neutralising Potential (NP) Method: ME-AN-025

Fizz Rating	-	-	2	2	1	1	1
Sample Weight	g	-	2.00	2.00	2.00	2.00	2.00
Normality of standardised HCl	N	-	0.101	0.101	0.101	0.101	0.101
Volume of HCl added	ml	-	20.0	20.0	20.0	20.0	20.0
Normality of standardised NaOH	N	-	0.100	0.100	0.100	0.100	0.100
Titre of NaOH	ml	-	14.8	16.5	19.2	17.2	18.6
NP as kg CaCO3/T	kg CaCO3/T	0.1	14	9.3	2.5	7.5	4.0

SUB_Sulphur and carbon species by LECO Method: SUB

Total sulphur as S^	%	0.01	0.30	0.11	0.40	<0.01	0.01
Sulphide as S^	%	0.01	0.21	0.07	0.26	<0.01	<0.01
Sulphate as SO4^	%	0.03	0.25	0.11	0.44	<0.03	<0.03
Total carbon as C^	%	0.01	0.08	0.07	0.03	0.05	0.02
Carbonate as CO3^	%	0.05	0.11	0.06	<0.05	<0.05	<0.05

Calculation of acid/base balances Method: ME-AN-025

Acid potential*	kg CaCO3/T	0.31	6.6	2.2	8.1	<0.31	<0.31
Net neutralising potential*	kg CaCO3/T	-	7.0	7.1	<0.0	7.2	3.7
NP AP ratio*	-	-	2.1	4.2	0.3	24	13
Classification*	-	-	U	PAN	PAG	PAN	PAN

Net Acid Generation (NAG) Method: MEND 1.20.1

NAG pH*	-	1	6.5	6.9	5.6	6.6	6.3
NAG as kg H2SO4/tonne at pH 4.5*	kg H2SO4/T	0.5	<0.5	<0.5	<0.5	<0.5	<0.5
NAG as kg H2SO4/tonne at pH 7.0*	kg H2SO4/T	0.5	0.8	<0.5	2.7	1.4	3.5

SUB_XRF Method: SUB

SiO2^	%	0.05	49	50	70	59	75
Al2O3^	%	0.05	14	14	14	12	15
CaO^	%	0.01	11	11	2.7	2.4	2.3
MgO^	%	0.05	6.2	6.4	2.1	10	0.080
Fe2O3^	%	0.01	15	14	3.8	8.7	1.3
K2O^	%	0.01	0.27	0.24	3.2	0.65	0.81
MnO^	%	0.01	0.23	0.22	0.040	0.13	0.010
Na2O^	%	0.05	2.4	2.3	2.0	1.7	6.1
P2O5^	%	0.01	0.11	0.10	0.15	0.040	0.030
TiO2^	%	0.01	1.4	1.3	0.42	0.26	0.090
Cr2O3^	%	0.01	0.020	0.020	0.020	0.22	<0.010
V2O5^	%	0.01	0.070	0.070	0.010	0.010	<0.010
Loss on ignition (XRF)^	%	-50	0.61	0.64	1.2	5.0	0.32

	Sample Number	JB15-06285.016	JB15-06285.017	JB15-06285.018	JB15-06285.019	JB15-06285.020
	Sample Name	90261	90262	90263	90264	90265
	Sample Matrix	Soil	Soil	Soil	Soil	Soil

SUB_SGS Booysens **Method: SUB**

Parameter	Units	LOR	JB15-06285.016	JB15-06285.017	JB15-06285.018	JB15-06285.019	JB15-06285.020
Aluminium^	%	0.01	6.9	7.0	6.1	5.6	7.3
Arsenic^	ppm	1	13	14	18	18	18
Silver^	ppm	0.3	0.40	<0.30	0.90	0.50	<0.30
Barium^	ppm	1	57	47	1412	369	454
Dysprosium^	ppm	0.05	5.0	4.5	2.3	1.5	1.0
Erbium^	ppm	0.05	3.1	2.8	1.1	0.86	0.43
Europium^	ppm	0.05	1.2	1.1	1.1	0.54	0.62
Gadolinium^	ppm	0.05	4.2	3.7	3.3	1.6	1.4
Holmium^	ppm	0.05	0.98	0.88	0.37	0.34	0.16
Neodymium^	ppm	0.1	11	9.8	26	9.6	9.0
Praseodymium^	ppm	0.05	2.2	2.0	7.9	3.0	2.6
Samarium^	ppm	0.1	3.3	2.9	4.0	1.7	1.7
Thulium^	ppm	0.05	0.42	0.36	0.13	0.12	0.060
Beryllium^	ppm	0.1	<0.10	<0.10	1.0	0.20	0.40
Bismuth^	ppm	0.04	0.060	0.050	10	0.42	<0.040
Calcium^	%	0.01	6.6	6.9	1.6	1.5	1.5
Cadmium^	ppm	0.02	0.16	0.14	0.16	0.14	0.040
Cerium^	ppb	0.05	14	13	78	27	24
Cobalt^	ppm	0.1	58	50	17	51	3.2
Cesium^	ppm	0.05	0.080	0.12	0.92	1.7	0.25
Chromium^	ppm	1	154	194	71	958	10
Gallium^	ppm	0.1	19	18	18	13	19
Germanium^	ppm	0.1	<0.10	0.20	0.40	<0.10	<0.10
Copper^	ppm	0.5	190	105	49	23	13
Iron^	%	0.01	10	9.6	2.5	5.7	0.89
Indium^	ppm	0.02	0.090	0.070	0.030	0.030	<0.020
Lanthanum^	ppb	0.1	4.8	4.3	46	14	13
Lutetium^	ppm	0.01	0.42	0.38	0.12	0.13	0.050
Potassium^	%	0.01	0.21	0.20	2.5	0.53	0.67
Lithium^	ppm	1	6.0	8.0	11	7.0	5.0
Hafnium^	ppm	0.02	0.70	0.70	0.69	0.80	0.78
Magnesium^	%	0.01	3.6	3.7	1.2	5.7	0.11
Mercury^	ppm	0.01	0.030	0.030	0.040	0.030	0.070
Manganese^	ppm	2	1660	1599	292	962	90
Molybdenum^	ppm	0.05	0.63	0.46	2.1	0.57	1.8
Sodium^	%	0.01	1.5	1.5	1.2	1.1	3.8
Niobium^	ppm	0.1	6.6	5.9	8.6	6.8	5.1
Nickel^	ppm	0.5	105	83	78	622	5.3
Phosphorus^	ppm	50	590	565	804	226	182
Lead^	ppm	0.5	4.7	2.2	24	8.9	21
Rubidium^	ppm	0.2	3.4	4.7	64	31	15
Sulphur^	%	0.01	0.34	0.14	0.46	0.040	0.040
Antimony^	ppm	0.05	<0.050	<0.050	<0.050	0.15	<0.050
Scandium^	ppm	0.5	45	45	6.7	18	1.2
Selenium^	ppm	2	<2.0	<2.0	<2.0	<2.0	<2.0
Tin^	ppm	0.3	1.0	0.90	2.4	0.70	0.70
Strontium^	ppm	0.5	103	101	157	45	307
Tantalum^	ppb	0.05	0.50	0.53	1.3	0.75	0.39
Terbium^	ppm	0.05	0.71	0.63	0.46	0.25	0.19
Tellurium^	ppm	0.05	<0.050	<0.050	0.50	<0.050	<0.050
Thorium^	ppm	0.2	0.70	0.80	20	8.1	6.8
Titanium^	%	0.01	0.74	0.70	0.19	0.14	0.050
Thallium^	ppm	0.02	0.040	0.050	0.35	0.23	0.10
Uranium^	ppm	0.05	0.18	0.19	2.9	1.9	2.1
Vanadium^	ppm	2	316	328	50	77	7.0
Ytterbium^	ppm	0.1	2.7	2.4	0.80	0.80	0.40
Yttrium^	ppm	0.1	27	24	11	7.8	4.7
Tungsten^	ppm	0.1	0.50	0.60	12	2.4	0.60
Zinc^	ppm	1	114	90	33	88	7.0

Parameter	Units	LOR	JB15-06285.016 90261 Soil	JB15-06285.017 90262 Soil	JB15-06285.018 90263 Soil	JB15-06285.019 90264 Soil	JB15-06285.020 90265 Soil
SUB_SGS Booysens Method: SUB (continued)							
Zirconium^	ppm	0.5	14	14	26	22	23

Parameter	Units	LOR	JB15-06285.021 90266 Soil	JB15-06285.022 90267 Soil	JB15-06285.023 90268 Soil	JB15-06285.024 90269 Soil	JB15-06285.025 90270 Soil
Paste pH and conductivity and 10% pH in soil Method: ME-AN-024							
Paste pH	-	1	10.1	10.1	9.6	9.8	10.1
Neutralising Potential (NP) Method: ME-AN-025							
Fizz Rating	-	-	2	2	1	2	1
Sample Weight	g	-	2.00	2.00	2.00	2.00	2.00
Normality of standardised HCl	N	-	0.101	0.101	0.101	0.101	0.101
Volume of HCl added	ml	-	20.0	20.0	20.0	24.5	20.0
Normality of standardised NaOH	N	-	0.100	0.100	0.100	0.100	0.100
Titre of NaOH	ml	-	14.4	15.4	18.4	17.2	14.7
NP as kg CaCO3/T	kg CaCO3/T	0.1	15	12	4.5	19	14
SUB_Sulphur and carbon species by LECO Method: SUB							
Total sulphur as S^	%	0.01	<0.01	0.02	0.01	0.07	0.05
Sulphide as S^	%	0.01	<0.01	0.01	0.01	0.06	<0.01
Sulphate as SO4^	%	0.03	<0.03	<0.03	<0.03	0.04	0.15
Total carbon as C^	%	0.01	0.11	0.08	0.02	0.12	0.05
Carbonate as CO3^	%	0.05	0.06	<0.05	<0.05	<0.05	<0.05
Calculation of acid/base balances Method: ME-AN-025							
Acid potential*	kg CaCO3/T	0.31	<0.31	0.31	0.31	1.9	<0.31
Net neutralising potential*	kg CaCO3/T	-	14	12	4.2	17	13
NP AP ratio*	-	-	47	39	15	10	45
Classification*	-	-	PAN	PAN	PAN	PAN	PAN
Net Acid Generation (NAG) Method: MEND 1.20.1							
NAG pH*	-	1	6.6	6.7	6.4	6.7	6.6
NAG as kg H2SO4/tonne at pH 4.5*	kg H2SO4/T	0.5	<0.5	<0.5	<0.5	<0.5	<0.5
NAG as kg H2SO4/tonne at pH 7.0*	kg H2SO4/T	0.5	2.2	1.2	2.7	1.0	1.6
SUB_XRF Method: SUB							
SiO2^	%	0.05	68	70	75	58	61
Al2O3^	%	0.05	15	15	14	15	13
CaO^	%	0.01	3.3	3.0	2.1	7.7	5.2
MgO^	%	0.05	1.1	0.92	0.36	3.9	2.7
Fe2O3^	%	0.01	3.7	3.4	2.3	9.1	9.1
K2O^	%	0.01	2.7	2.8	2.7	1.6	2.1
MnO^	%	0.01	0.050	0.050	0.030	0.15	0.16
Na2O^	%	0.05	4.6	4.7	4.4	3.4	3.4
P2O5^	%	0.01	0.16	0.13	0.060	0.10	0.18
TiO2^	%	0.01	0.40	0.35	0.21	0.69	0.83
Cr2O3^	%	0.01	<0.010	<0.010	<0.010	0.010	<0.010
V2O5^	%	0.01	<0.010	0.010	<0.010	0.040	0.030
Loss on ignition (XRF)^	%	-50	0.71	0.67	0.31	0.87	0.44

ANALYTICAL REPORT

JB15-06285 R0

Report number 0000008891

Client reference: **06550**

		Sample Number	**JB15-06285.021**	**JB15-06285.022**	**JB15-06285.023**	**JB15-06285.024**	**JB15-06285.025**
		Sample Name	**90266**	**90267**	**90268**	**90269**	**90270**
		Sample Matrix	**Soil**	**Soil**	**Soil**	**Soil**	**Soil**
Parameter	**Units**	**LOR**					
SUB_SGS Booysens Method: SUB							
Aluminium^	%	0.01	6.6	6.3	6.5	7.3	6.4
Arsenic^	ppm	1	18	17	16	16	15
Silver^	ppm	0.3	<0.30	<0.30	<0.30	<0.30	0.40
Barium^	ppm	1	1805	1591	1038	471	811
Dysprosium^	ppm	0.05	2.4	2.2	1.6	4.7	5.3
Erbium^	ppm	0.05	1.2	1.1	0.83	2.9	3.0
Europium^	ppm	0.05	1.4	1.2	0.87	0.97	1.4
Gadolinium^	ppm	0.05	3.6	3.0	1.9	4.0	5.2
Holmium^	ppm	0.05	0.41	0.35	0.27	0.90	0.99
Neodymium^	ppm	0.1	31	24	18	15	20
Praseodymium^	ppm	0.05	9.6	7.0	5.7	3.8	5.2
Samarium^	ppm	0.1	4.3	3.8	2.3	3.3	4.6
Thulium^	ppm	0.05	0.14	0.13	0.11	0.42	0.38
Beryllium^	ppm	0.1	0.40	0.40	<0.10	0.40	0.50
Bismuth^	ppm	0.04	<0.040	<0.040	0.050	0.57	0.19
Calcium^	%	0.01	2.2	1.8	1.3	4.9	3.3
Cadmium^	ppm	0.02	0.12	0.070	0.080	0.13	0.17
Cerium^	ppb	0.05	94	66	59	32	44
Cobalt^	ppm	0.1	9.6	8.8	5.2	29	26
Cesium^	ppm	0.05	1.5	1.2	0.95	1.4	2.3
Chromium^	ppm	1	15	11	10	102	61
Gallium^	ppm	0.1	18	17	16	19	20
Germanium^	ppm	0.1	<0.10	<0.10	<0.10	<0.10	<0.10
Copper^	ppm	0.5	38	29	33	36	61
Iron^	%	0.01	2.6	2.2	1.5	6.0	6.1
Indium^	ppm	0.02	0.030	<0.020	<0.020	0.070	0.070
Lanthanum^	ppb	0.1	58	37	38	17	25
Lutetium^	ppm	0.01	0.13	0.12	0.11	0.43	0.40
Potassium^	%	0.01	2.2	2.2	2.1	1.3	1.6
Lithium^	ppm	1	13	11	6.0	10	13
Hafnium^	ppm	0.02	0.75	0.64	0.69	0.80	1.0
Magnesium^	%	0.01	0.66	0.54	0.26	2.3	1.6
Mercury^	ppm	0.01	0.030	0.030	0.030	0.050	0.030
Manganese^	ppm	2	406	340	227	1144	1114
Molybdenum^	ppm	0.05	0.64	1.1	0.80	2.2	2.1
Sodium^	%	0.01	3.0	2.8	2.7	2.2	2.1
Niobium^	ppm	0.1	12	9.4	6.9	12	15
Nickel^	ppm	0.5	16	13	7.0	68	49
Phosphorus^	ppm	50	811	691	298	528	1017
Lead^	ppm	0.5	16	20	24	17	20
Rubidium^	ppm	0.2	68	63	59	44	72
Sulphur^	%	0.01	0.040	0.050	0.040	0.10	0.090
Antimony^	ppm	0.05	<0.050	0.10	<0.050	<0.050	<0.050
Scandium^	ppm	0.5	4.8	3.3	2.1	24	21
Selenium^	ppm	2	<2.0	<2.0	<2.0	<2.0	2.0
Tin^	ppm	0.3	2.0	1.9	1.1	2.8	2.7
Strontium^	ppm	0.5	364	347	222	191	137
Tantalum^	ppb	0.05	0.79	0.90	0.81	1.2	1.2
Terbium^	ppm	0.05	0.49	0.44	0.29	0.68	0.83
Tellurium^	ppm	0.05	<0.050	<0.050	<0.050	<0.050	<0.050
Thorium^	ppm	0.2	23	17	12	6.7	14
Titanium^	%	0.01	0.23	0.18	0.11	0.38	0.45
Thallium^	ppm	0.02	0.47	0.42	0.37	0.33	0.47
Uranium^	ppm	0.05	1.8	2.7	4.6	6.2	6.2
Vanadium^	ppm	2	40	31	15	171	118
Ytterbium^	ppm	0.1	0.90	0.80	0.70	2.7	2.6
Yttrium^	ppm	0.1	11	9.7	7.8	26	28
Tungsten^	ppm	0.1	0.50	0.30	0.50	2.4	0.60
Zinc^	ppm	1	52	45	33	81	105

Parameter	Units	LOR	Sample Number Sample Name Sample Matrix	JB15-06285.021 90266 Soil	JB15-06285.022 90267 Soil	JB15-06285.023 90268 Soil	JB15-06285.024 90269 Soil	JB15-06285.025 90270 Soil
SUB_SGS Booysens Method: SUB (continued)								
Zirconium^	ppm	0.5		30	22	23	18	27

Sample Number			**JB15-06285.026**	**JB15-06285.027**	**JB15-06285.028**	**JB15-06285.029**	**JB15-06285.030**
Sample Name			**90271**	**90272**	**90273**	**90274**	**90275**
Sample Matrix			**Soil**	**Soil**	**Soil**	**Soil**	**Soil**
Parameter	**Units**	**LOR**					

Paste pH and conductivity and 10% pH in soil Method: ME-AN-024

Paste pH	-	1	7.4	7.5	5.6	10.2	9.6

Neutralising Potential (NP) Method: ME-AN-025

Fizz Rating	-	-	1	1	1	1	1
Sample Weight	g	-	2.00	2.00	2.00	2.00	2.00
Normality of standardised HCl	N	-	0.101	0.101	0.101	0.101	0.101
Volume of HCl added	ml	-	20.0	20.0	20.0	20.0	20.0
Normality of standardised NaOH	N	-	0.100	0.100	0.100	0.100	0.100
Titre of NaOH	ml	-	19.4	19.7	19.8	14.6	14.8
NP as kg CaCO3/T	kg CaCO3/T	0.1	2.0	1.3	1.0	14	14

SUB_Sulphur and carbon species by LECO Method: SUB

Total sulphur as S^	%	0.01	<0.01	0.01	<0.01	0.02	0.03
Sulphide as S^	%	0.01	<0.01	<0.01	<0.01	0.01	0.01
Sulphate as SO4^	%	0.03	<0.03	<0.03	<0.03	<0.03	0.05
Total carbon as C^	%	0.01	0.01	0.29	0.35	0.05	0.08
Carbonate as CO3^	%	0.05	<0.05	<0.05	<0.05	<0.05	<0.05

Calculation of acid/base balances Method: ME-AN-025

Acid potential*	kg CaCO3/T	0.31	<0.31	<0.31	<0.31	0.31	0.31
Net neutralising potential*	kg CaCO3/T	-	1.7	1.0	0.7	14	13
NP AP ratio*	-	-	6.6	4.2	3.4	45	43
Classification*	-	-	PAN	U	U	PAN	PAN

Net Acid Generation (NAG) Method: MEND 1.20.1

NAG pH*	-	1	6.1	6.4	6.3	6.7	6.8
NAG as kg H2SO4/tonne at pH 4.5*	kg H2SO4/T	0.5	<0.5	<0.5	<0.5	<0.5	<0.5
NAG as kg H2SO4/tonne at pH 7.0*	kg H2SO4/T	0.5	3.7	2.2	1.4	1.2	<0.5

SUB_XRF Method: SUB

SiO2^	%	0.05	98	68	49	68	62
Al2O3^	%	0.05	0.41	18	21	14	14
CaO^	%	0.01	0.17	0.070	0.10	3.5	6.0
MgO^	%	0.05	0.15	0.85	0.53	2.3	2.7
Fe2O3^	%	0.01	1.3	4.0	15	4.7	8.1
K2O^	%	0.01	0.040	2.4	1.2	2.7	1.6
MnO^	%	0.01	0.020	0.040	0.26	0.080	0.13
Na2O^	%	0.05	0.060	0.070	<0.050	4.2	3.7
P2O5^	%	0.01	<0.010	0.050	0.24	0.10	0.12
TiO2^	%	0.01	0.020	0.40	1.5	0.46	0.72
Cr2O3^	%	0.01	0.050	<0.010	0.020	<0.010	<0.010
V2O5^	%	0.01	<0.010	<0.010	0.050	0.020	0.030
Loss on ignition (XRF)^	%	-50	******	6.3	10	0.57	0.65

SUB_SGS Booysens **Method: SUB**

		Sample Number	JB15-06285.026	JB15-06285.027	JB15-06285.028	JB15-06285.029	JB15-06285.030
		Sample Name	90271	90272	90273	90274	90275
		Sample Matrix	Soil	Soil	Soil	Soil	Soil
Parameter	**Units**	**LOR**					
Aluminium^	%	0.01	0.22	8.2	9.7	6.3	6.7
Arsenic^	ppm	1	17	17	14	24	22
Silver^	ppm	0.3	0.30	1.6	1.3	<0.30	<0.30
Barium^	ppm	1	50	1496	710	1083	484
Dysprosium^	ppm	0.05	0.090	3.1	9.3	2.6	4.7
Erbium^	ppm	0.05	<0.050	1.5	5.2	1.5	2.7
Europium^	ppm	0.05	<0.050	1.7	3.1	1.1	1.1
Gadolinium^	ppm	0.05	0.090	4.6	10	3.0	4.6
Holmium^	ppm	0.05	<0.050	0.54	1.7	0.46	0.86
Neodymium^	ppm	0.1	0.60	36	54	19	20
Praseodymium^	ppm	0.05	0.18	12	14	5.7	5.3
Samarium^	ppm	0.1	0.10	5.3	10	3.3	4.2
Thulium^	ppm	0.05	<0.050	0.18	0.67	0.19	0.34
Beryllium^	ppm	0.1	<0.10	0.40	1.7	0.50	1.0
Bismuth^	ppm	0.04	2.4	0.11	1.9	0.15	0.20
Calcium^	%	0.01	0.10	0.030	0.060	2.3	3.7
Cadmium^	ppm	0.02	0.050	<0.020	0.070	0.10	0.14
Cerium^	ppb	0.05	1.8	96	80	56	44
Cobalt^	ppm	0.1	2.7	9.7	42	17	26
Cesium^	ppm	0.05	0.050	2.7	2.4	4.9	1.9
Chromium^	ppm	1	29	23	110	46	62
Gallium^	ppm	0.1	0.70	20	25	19	19
Germanium^	ppm	0.1	<0.10	0.20	1.2	0.50	0.50
Copper^	ppm	0.5	5.3	22	96	42	61
Iron^	%	0.01	0.85	2.7	9.3	3.3	5.3
Indium^	ppm	0.02	<0.020	0.030	0.070	0.030	0.060
Lanthanum^	ppb	0.1	<0.10	71	56	33	22
Lutetium^	ppm	0.01	<0.010	0.17	0.69	0.20	0.35
Potassium^	%	0.01	0.030	1.9	0.91	2.2	1.2
Lithium^	ppm	1	<1.0	6.0	8.0	15	11
Hafnium^	ppm	0.02	0.020	0.77	1.1	0.79	0.99
Magnesium^	%	0.01	0.080	0.50	0.31	1.4	1.5
Mercury^	ppm	0.01	0.050	0.050	0.070	0.020	0.030
Manganese^	ppm	2	103	328	1904	582	925
Molybdenum^	ppm	0.05	3.9	0.80	2.2	0.64	4.0
Sodium^	%	0.01	0.050	0.050	0.050	2.7	2.3
Niobium^	ppm	0.1	0.90	12	18	16	16
Nickel^	ppm	0.5	17	28	68	97	54
Phosphorus^	ppm	50	<50	268	1190	515	658
Lead^	ppm	0.5	1.2	23	65	22	15
Rubidium^	ppm	0.2	1.0	88	61	113	47
Sulphur^	%	0.01	0.020	0.030	0.020	0.060	0.060
Antimony^	ppm	0.05	<0.050	<0.050	0.26	<0.050	0.14
Scandium^	ppm	0.5	<0.50	4.4	27	7.7	17
Selenium^	ppm	2	<2.0	<2.0	<2.0	<2.0	4.0
Tin^	ppm	0.3	0.40	1.7	1.9	2.4	2.8
Strontium^	ppm	0.5	21	30	12	217	210
Tantalum^	ppb	0.05	<0.050	0.70	2.1	1.4	1.5
Terbium^	ppm	0.05	<0.050	0.63	1.5	0.44	0.71
Tellurium^	ppm	0.05	0.070	<0.050	<0.050	<0.050	<0.050
Thorium^	ppm	0.2	0.60	24	10	17	11
Titanium^	%	0.01	<0.010	0.21	0.77	0.26	0.38
Thallium^	ppm	0.02	0.020	0.63	0.77	0.75	0.33
Uranium^	ppm	0.05	0.10	2.4	4.3	5.0	4.1
Vanadium^	ppm	2	3.0	35	264	53	125
Ytterbium^	ppm	0.1	<0.10	1.1	4.3	1.4	2.3
Yttrium^	ppm	0.1	0.40	16	46	14	25
Tungsten^	ppm	0.1	1.3	9.1	18	0.90	2.7
Zinc^	ppm	1	4.0	53	71	68	72

Parameter	Units	LOR	JB15-06285.026 90271 Soil	JB15-06285.027 90272 Soil	JB15-06285.028 90273 Soil	JB15-06285.029 90274 Soil	JB15-06285.030 90275 Soil
SUB_SGS Booysens Method: SUB (continued)							
Zirconium^	ppm	0.5	1.3	32	31	25	27

Parameter	Units	LOR	JB15-06285.031 90276 Soil	JB15-06285.032 90277 Soil	JB15-06285.033 90278 Soil	JB15-06285.034 90279 Soil	JB15-06285.035 90280 Soil
Sample Number / Sample Name / Sample Matrix							

Paste pH and conductivity and 10% pH in soil Method: ME-AN-024

Paste pH	-	1	5.9	9.5	9.8	9.9	9.9

Neutralising Potential (NP) Method: ME-AN-025

Fizz Rating	-	-	1	1	1	1	1
Sample Weight	g	-	2.00	2.00	2.00	2.00	2.00
Normality of standardised HCl	N	-	0.101	0.101	0.101	0.101	0.101
Volume of HCl added	ml	-	20.0	23.5	20.0	20.0	20.0
Normality of standardised NaOH	N	-	0.100	0.100	0.100	0.100	0.100
Titre of NaOH	ml	-	20.1	16.6	17.7	15.4	15.0
NP as kg CaCO3/T	kg CaCO3/T	0.1	0.3	18	6.3	12	13

SUB_Sulphur and carbon species by LECO Method: SUB

Total sulphur as S^	%	0.01	<0.01	0.12	<0.01	0.06	0.03
Sulphide as S^	%	0.01	<0.01	0.05	<0.01	0.06	<0.01
Sulphate as SO4^	%	0.03	<0.03	0.21	<0.03	<0.03	0.08
Total carbon as C^	%	0.01	0.38	0.11	0.02	0.03	0.08
Carbonate as CO3^	%	0.05	<0.05	0.17	0.12	<0.05	<0.05

Calculation of acid/base balances Method: ME-AN-025

Acid potential*	kg CaCO3/T	0.31	<0.31	1.6	<0.31	1.9	<0.31
Net neutralising potential*	kg CaCO3/T	-	<0.0	16	6.0	10	13
NP AP ratio*	-	-	1.0	11	20	6.4	42
Classification*	-	-	PAG	PAN	PAN	PAN	PAN

Net Acid Generation (NAG) Method: MEND 1.20.1

NAG pH*	-	1	6.3	6.7	6.5	6.5	6.5
NAG as kg H2SO4/tonne at pH 4.5*	kg H2SO4/T	0.5	<0.5	<0.5	<0.5	<0.5	<0.5
NAG as kg H2SO4/tonne at pH 7.0*	kg H2SO4/T	0.5	1.6	0.8	2.3	2.0	2.2

SUB_XRF Method: SUB

SiO2^	%	0.05	50	52	72	68	69
Al2O3^	%	0.05	19	14	15	15	15
CaO^	%	0.01	0.21	9.4	2.5	3.8	3.1
MgO^	%	0.05	0.27	7.0	0.23	2.2	1.0
Fe2O3^	%	0.01	17	12	1.6	4.1	3.3
K2O^	%	0.01	0.25	1.0	1.8	2.1	2.4
MnO^	%	0.01	0.19	0.18	0.020	0.050	0.040
Na2O^	%	0.05	<0.050	2.1	5.2	3.8	4.7
P2O5^	%	0.01	0.19	0.080	0.030	0.15	0.13
TiO2^	%	0.01	1.3	0.84	0.12	0.57	0.34
Cr2O3^	%	0.01	0.050	0.040	<0.010	<0.010	<0.010
V2O5^	%	0.01	0.070	0.040	<0.010	0.010	<0.010
Loss on ignition (XRF)^	%	-50	9.7	0.96	0.35	0.71	0.62

		Sample Number Sample Name Sample Matrix	JB15-06285.031 90276 Soil	JB15-06285.032 90277 Soil	JB15-06285.033 90278 Soil	JB15-06285.034 90279 Soil	JB15-06285.035 90280 Soil
Parameter	**Units**	**LOR**					
SUB_SGS Booysens	**Method: SUB**						
Aluminium^	%	0.01	9.1	6.9	6.5	6.5	6.5
Arsenic^	ppm	1	20	16	19	27	23
Silver^	ppm	0.3	1.6	0.60	<0.30	0.60	<0.30
Barium^	ppm	1	374	326	1101	1431	1534
Dysprosium^	ppm	0.05	14	3.1	1.3	2.4	2.0
Erbium^	ppm	0.05	7.3	2.0	0.78	1.2	0.91
Europium^	ppm	0.05	4.6	0.85	0.86	1.3	1.2
Gadolinium^	ppm	0.05	16	2.7	1.5	3.1	3.1
Holmium^	ppm	0.05	2.4	0.60	0.24	0.40	0.33
Neodymium^	ppm	0.1	91	9.4	9.7	22	26
Praseodymium^	ppm	0.05	26	2.4	3.0	6.3	7.9
Samarium^	ppm	0.1	17	2.2	1.7	3.5	4.0
Thulium^	ppm	0.05	1.0	0.26	0.090	0.16	0.12
Beryllium^	ppm	0.1	2.5	<0.10	0.60	0.70	0.30
Bismuth^	ppm	0.04	1.9	0.24	0.060	0.76	0.13
Calcium^	%	0.01	0.14	6.0	1.5	2.4	2.1
Cadmium^	ppm	0.02	0.060	0.19	0.060	0.080	0.050
Cerium^	ppb	0.05	46	20	31	60	76
Cobalt^	ppm	0.1	49	47	4.0	15	9.1
Cesium^	ppm	0.05	1.8	2.0	0.53	1.2	1.6
Chromium^	ppm	1	276	243	14	36	16
Gallium^	ppm	0.1	28	17	15	16	18
Germanium^	ppm	0.1	1.4	<0.10	<0.10	0.50	0.10
Copper^	ppm	0.5	108	121	14	17	29
Iron^	%	0.01	11	7.7	1.1	2.7	2.3
Indium^	ppm	0.02	0.10	0.050	<0.020	<0.020	<0.020
Lanthanum^	ppb	0.1	120	10	18	34	45
Lutetium^	ppm	0.01	1.0	0.27	0.10	0.17	0.12
Potassium^	%	0.01	0.21	0.82	1.4	1.7	1.9
Lithium^	ppm	1	9.0	12	6.0	11	11
Hafnium^	ppm	0.02	1.2	0.55	0.58	0.72	0.73
Magnesium^	%	0.01	0.16	4.1	0.18	1.3	0.58
Mercury^	ppm	0.01	0.14	0.070	0.040	1.5	0.75
Manganese^	ppm	2	1391	1357	117	361	313
Molybdenum^	ppm	0.05	5.0	0.58	2.0	1.9	1.1
Sodium^	%	0.01	0.050	1.3	3.1	2.4	3.0
Niobium^	ppm	0.1	17	4.8	7.3	13	11
Nickel^	ppm	0.5	68	163	6.8	47	17
Phosphorus^	ppm	50	1108	463	208	773	770
Lead^	ppm	0.5	25	5.3	28	36	19
Rubidium^	ppm	0.2	18	34	32	54	60
Sulphur^	%	0.01	0.030	0.18	0.050	0.10	0.070
Antimony^	ppm	0.05	0.68	0.26	<0.050	<0.050	<0.050
Scandium^	ppm	0.5	38	33	1.7	6.5	4.4
Selenium^	ppm	2	<2.0	<2.0	<2.0	<2.0	<2.0
Tin^	ppm	0.3	2.6	1.0	0.90	1.5	1.7
Strontium^	ppm	0.5	12	119	250	359	361
Tantalum^	ppb	0.05	2.0	0.46	0.69	1.1	1.1
Terbium^	ppm	0.05	2.4	0.45	0.23	0.43	0.40
Tellurium^	ppm	0.05	0.12	<0.050	<0.050	<0.050	<0.050
Thorium^	ppm	0.2	11	3.4	18	21	21
Titanium^	%	0.01	0.68	0.45	0.060	0.30	0.19
Thallium^	ppm	0.02	0.40	0.24	0.20	0.33	0.42
Uranium^	ppm	0.05	6.6	0.85	10	7.4	3.2
Vanadium^	ppm	2	367	228	17	47	35
Ytterbium^	ppm	0.1	6.8	1.7	0.60	1.1	0.80
Yttrium^	ppm	0.1	53	18	7.1	13	9.6
Tungsten^	ppm	0.1	17	2.9	0.60	141	65
Zinc^	ppm	1	64	69	10	49	41

Parameter	Units	LOR	Sample Number Sample Name Sample Matrix	JB15-06285.031 90276 Soil	JB15-06285.032 90277 Soil	JB15-06285.033 90278 Soil	JB15-06285.034 90279 Soil	JB15-06285.035 90280 Soil
SUB_SGS Booysens Method: SUB (continued)								
Zirconium^	ppm	0.5		31	16	17	24	25

Parameter	Units	LOR	JB15-06285.036	JB15-06285.037	JB15-06285.038	JB15-06285.039	JB15-06285.040
Sample Name			90281	90282	90283	90284	90285
Sample Matrix			Soil	Soil	Soil	Soil	Soil

Paste pH and conductivity and 10% pH in soil Method: ME-AN-024

Parameter	Units	LOR	JB15-06285.036	JB15-06285.037	JB15-06285.038	JB15-06285.039	JB15-06285.040
Paste pH	-	1	10.1	7.8	6.6	7.6	9.4

Neutralising Potential (NP) Method: ME-AN-025

Parameter	Units	LOR	JB15-06285.036	JB15-06285.037	JB15-06285.038	JB15-06285.039	JB15-06285.040
Fizz Rating	-	-	2	1	1	1	1
Sample Weight	g	-	2.00	2.00	2.00	2.00	2.00
Normality of standardised HCl	N	-	0.101	0.101	0.101	0.101	0.101
Volume of HCl added	ml	-	24.5	20.0	20.0	24.0	20.0
Normality of standardised NaOH	N	-	0.100	0.100	0.100	0.100	0.100
Titre of NaOH	ml	-	17.5	19.4	19.7	21.6	14.8
NP as kg CaCO3/T	kg CaCO3/T	0.1	18	2.0	1.3	6.7	14

SUB_Sulphur and carbon species by LECO Method: SUB

Parameter	Units	LOR	JB15-06285.036	JB15-06285.037	JB15-06285.038	JB15-06285.039	JB15-06285.040
Total sulphur as S^	%	0.01	0.01	0.01	<0.01	0.03	0.13
Sulphide as S^	%	0.01	<0.01	<0.01	<0.01	0.01	0.04
Sulphate as SO4^	%	0.03	0.03	<0.03	<0.03	0.04	0.26
Total carbon as C^	%	0.01	0.12	0.01	<0.01	0.08	0.04
Carbonate as CO3^	%	0.05	<0.05	0.10	<0.05	0.07	<0.05

Calculation of acid/base balances Method: ME-AN-025

Parameter	Units	LOR	JB15-06285.036	JB15-06285.037	JB15-06285.038	JB15-06285.039	JB15-06285.040
Acid potential*	kg CaCO3/T	0.31	<0.31	<0.31	<0.31	0.31	1.3
Net neutralising potential*	kg CaCO3/T	-	18	1.7	1.0	6.3	12
NP AP ratio*	-	-	59	6.6	4.2	21	11
Classification*	-	-	PAN	PAN	U	PAN	PAN

Net Acid Generation (NAG) Method: MEND 1.20.1

Parameter	Units	LOR	JB15-06285.036	JB15-06285.037	JB15-06285.038	JB15-06285.039	JB15-06285.040
NAG pH*	-	1	6.9	6.4	6.2	6.5	6.7
NAG as kg H2SO4/tonne at pH 4.5*	kg H2SO4/T	0.5	<0.5	<0.5	<0.5	<0.5	<0.5
NAG as kg H2SO4/tonne at pH 7.0*	kg H2SO4/T	0.5	0.6	2.2	3.1	1.8	0.8

SUB_XRF Method: SUB

Parameter	Units	LOR	JB15-06285.036	JB15-06285.037	JB15-06285.038	JB15-06285.039	JB15-06285.040
SiO2^	%	0.05	65	98	100	61	49
Al2O3^	%	0.05	15	0.22	0.060	17	14
CaO^	%	0.01	3.7	0.32	0.040	6.0	9.8
MgO^	%	0.05	1.4	0.35	<0.050	2.3	5.7
Fe2O3^	%	0.01	4.3	1.4	0.66	6.8	16
K2O^	%	0.01	2.4	0.030	0.020	1.8	0.50
MnO^	%	0.01	0.060	0.060	<0.010	0.060	0.23
Na2O^	%	0.05	4.9	<0.050	<0.050	1.4	2.5
P2O5^	%	0.01	0.19	<0.010	<0.010	0.15	0.13
TiO2^	%	0.01	0.47	0.040	0.010	0.44	1.5
Cr2O3^	%	0.01	<0.010	0.020	<0.010	0.010	<0.010
V2O5^	%	0.01	0.010	<0.010	<0.010	0.020	0.070
Loss on ignition (XRF)^	%	-50	0.80	0.020	******	3.0	0.57

Parameter	Units	LOR	JB15-06285.036 90281 Soil	JB15-06285.037 90282 Soil	JB15-06285.038 90283 Soil	JB15-06285.039 90284 Soil	JB15-06285.040 90285 Soil
SUB_SGS Booysens Method: SUB							
Aluminium^	%	0.01	6.6	0.15	0.060	7.6	6.7
Arsenic^	ppm	1	27	16	16	20	21
Silver^	ppm	0.3	<0.30	3.4	0.40	<0.30	<0.30
Barium^	ppm	1	1148	23	16	7238	145
Dysprosium^	ppm	0.05	2.6	1.7	0.12	3.3	5.3
Erbium^	ppm	0.05	1.2	0.87	0.060	1.9	3.2
Europium^	ppm	0.05	1.4	0.64	<0.050	2.5	1.3
Gadolinium^	ppm	0.05	3.9	2.1	0.14	4.0	4.8
Holmium^	ppm	0.05	0.43	0.31	<0.050	0.59	1.0
Neodymium^	ppm	0.1	33	12	0.90	27	14
Praseodymium^	ppm	0.05	9.5	3.0	0.22	7.6	3.1
Samarium^	ppm	0.1	4.9	2.4	0.20	4.5	3.8
Thulium^	ppm	0.05	0.15	0.11	<0.050	0.25	0.43
Beryllium^	ppm	0.1	0.90	<0.10	<0.10	0.90	<0.10
Bismuth^	ppm	0.04	0.45	4.9	0.11	0.75	<0.040
Calcium^	%	0.01	2.3	0.20	0.040	3.6	6.2
Cadmium^	ppm	0.02	0.080	0.040	0.080	0.14	0.12
Cerium^	ppb	0.05	90	8.2	2.2	71	21
Cobalt^	ppm	0.1	12	74	6.4	24	51
Cesium^	ppm	0.05	2.5	<0.050	<0.050	2.2	0.34
Chromium^	ppm	1	20	54	23	100	92
Gallium^	ppm	0.1	19	0.70	0.40	19	20
Germanium^	ppm	0.1	0.50	<0.10	<0.10	<0.10	<0.10
Copper^	ppm	0.5	35	77	28	15	105
Iron^	%	0.01	2.9	1.0	0.56	4.3	10
Indium^	ppm	0.02	0.030	<0.020	<0.020	0.040	0.090
Lanthanum^	ppb	0.1	53	10	0.30	43	8.5
Lutetium^	ppm	0.01	0.14	0.10	<0.010	0.27	0.45
Potassium^	%	0.01	1.9	0.020	0.020	1.4	0.41
Lithium^	ppm	1	15	2.0	<1.0	15	7.0
Hafnium^	ppm	0.02	0.86	0.030	<0.020	0.74	0.86
Magnesium^	%	0.01	0.77	0.21	0.020	1.3	3.3
Mercury^	ppm	0.01	1.2	0.13	0.060	2.0	0.070
Manganese^	ppm	2	437	468	100	436	1691
Molybdenum^	ppm	0.05	0.84	3.7	3.6	0.93	0.60
Sodium^	%	0.01	3.0	0.030	0.030	0.84	1.6
Niobium^	ppm	0.1	14	0.80	0.50	10	8.4
Nickel^	ppm	0.5	21	17	9.0	166	70
Phosphorus^	ppm	50	979	51	273	811	716
Lead^	ppm	0.5	17	17	7.0	15	5.0
Rubidium^	ppm	0.2	80	0.60	0.60	53	11
Sulphur^	%	0.01	0.050	0.020	0.010	0.050	0.17
Antimony^	ppm	0.05	<0.050	<0.050	2.3	0.61	0.25
Scandium^	ppm	0.5	6.0	<0.50	<0.50	9.1	42
Selenium^	ppm	2	<2.0	<2.0	<2.0	<2.0	<2.0
Tin^	ppm	0.3	2.3	<0.30	0.50	2.8	1.2
Strontium^	ppm	0.5	362	2.3	1.8	399	119
Tantalum^	ppb	0.05	1.1	<0.050	<0.050	0.94	0.63
Terbium^	ppm	0.05	0.53	0.31	<0.050	0.58	0.77
Tellurium^	ppm	0.05	<0.050	0.080	<0.050	<0.050	<0.050
Thorium^	ppm	0.2	24	<0.20	<0.20	20	1.5
Titanium^	%	0.01	0.26	0.010	<0.010	0.24	0.82
Thallium^	ppm	0.02	0.56	0.040	0.030	0.41	0.090
Uranium^	ppm	0.05	2.2	0.13	0.080	3.1	0.33
Vanadium^	ppm	2	49	6.0	2.0	62	334
Ytterbium^	ppm	0.1	1.0	0.70	<0.10	1.7	2.8
Yttrium^	ppm	0.1	13	7.6	0.60	18	29
Tungsten^	ppm	0.1	97	2.9	1.3	433	8.0
Zinc^	ppm	1	58	11	15	36	112

Parameter	Units	LOR	Sample Number: JB15-06285.036 Sample Name: 90281 Sample Matrix: Soil	JB15-06285.037 90282 Soil	JB15-06285.038 90283 Soil	JB15-06285.039 90284 Soil	JB15-06285.040 90285 Soil
SUB_SGS Booysens Method: SUB (continued)							
Zirconium^	ppm	0.5	33	0.90	0.90	31	20

Sample Number			JB15-06285.041	JB15-06285.042	JB15-06285.043	JB15-06285.044	JB15-06285.045
Sample Name			90286	90287	90288	90289	90290
Sample Matrix			Soil	Soil	Soil	Soil	Soil
Parameter	**Units**	**LOR**					

Paste pH and conductivity and 10% pH in soil Method: ME-AN-024

Paste pH	-	1	10.2	9.5	7.3	5.8	5.7

Neutralising Potential (NP) Method: ME-AN-025

Fizz Rating	-	-	1	1	2	1	1
Sample Weight	g	-	2.00	2.00	2.00	2.00	2.00
Normality of standardised HCl	N	-	0.101	0.101	0.101	0.101	0.101
Volume of HCl added	ml	-	20.0	20.0	20.0	20.0	20.0
Normality of standardised NaOH	N	-	0.100	0.100	0.100	0.100	0.100
Titre of NaOH	ml	-	17.8	18.0	17.6	19.5	20.7
NP as kg CaCO3/T	kg CaCO3/T	0.1	6.0	5.5	6.5	1.8	<0.1

SUB_Sulphur and carbon species by LECO Method: SUB

Total sulphur as S^	%	0.01	<0.01	0.32	1.14	<0.01	<0.01
Sulphide as S^	%	0.01	<0.01	0.22	1.05	<0.01	<0.01
Sulphate as SO4^	%	0.03	<0.03	0.29	0.27	<0.03	<0.03
Total carbon as C^	%	0.01	0.03	0.06	0.16	<0.01	0.14
Carbonate as CO3^	%	0.05	0.07	<0.05	0.11	<0.05	0.08

Calculation of acid/base balances Method: ME-AN-025

Acid potential*	kg CaCO3/T	0.31	<0.31	6.9	33	<0.31	<0.31
Net neutralising potential*	kg CaCO3/T	-	5.7	<0.0	<0.0	1.5	<0.0
NP AP ratio*	-	-	20	0.8	0.2	5.8	<0.0
Classification*	-	-	PAN	PAG	PAG	PAN	PAG

Net Acid Generation (NAG) Method: MEND 1.20.1

NAG pH*	-	1	6.1	5.5	2.8	5.9	6.3
NAG as kg H2SO4/tonne at pH 4.5*	kg H2SO4/T	0.5	<0.5	<0.5	11	<0.5	<0.5
NAG as kg H2SO4/tonne at pH 7.0*	kg H2SO4/T	0.5	4.5	3.1	8.2	4.9	1.8

SUB_XRF Method: SUB

SiO2^	%	0.05	73	72	90	100	53
Al2O3^	%	0.05	14	14	0.98	0.28	23
CaO^	%	0.01	1.8	2.1	0.51	0.040	0.050
MgO^	%	0.05	0.27	0.87	0.37	<0.050	0.090
Fe2O3^	%	0.01	1.6	3.2	3.8	0.93	13
K2O^	%	0.01	3.8	1.6	0.23	0.020	0.25
MnO^	%	0.01	0.030	0.040	0.030	0.010	0.040
Na2O^	%	0.05	4.5	5.2	0.15	<0.050	0.050
P2O5^	%	0.01	0.040	0.050	0.030	<0.010	0.040
TiO2^	%	0.01	0.14	0.24	0.080	0.020	1.1
Cr2O3^	%	0.01	<0.010	<0.010	<0.010	<0.010	<0.010
V2O5^	%	0.01	<0.010	0.020	<0.010	<0.010	0.040
Loss on ignition (XRF)^	%	-50	0.30	0.61	0.96	******	9.9

		Sample Number	JB15-06285.041	JB15-06285.042	JB15-06285.043	JB15-06285.044	JB15-06285.045
		Sample Name	**90286**	**90287**	**90288**	**90289**	**90290**
		Sample Matrix	**Soil**	**Soil**	**Soil**	**Soil**	**Soil**
Parameter	**Units**	**LOR**					
SUB_SGS Booysens Method: SUB							
Aluminium^	%	0.01	6.5	6.4	0.56	0.16	11
Arsenic^	ppm	1	18	19	14	14	15
Silver^	ppm	0.3	0.80	0.60	<0.30	<0.30	6.0
Barium^	ppm	1	1022	539	96	6.0	102
Dysprosium^	ppm	0.05	2.0	1.3	0.39	0.060	1.5
Erbium^	ppm	0.05	1.1	0.64	0.23	<0.050	0.86
Europium^	ppm	0.05	0.61	0.55	0.15	<0.050	0.56
Gadolinium^	ppm	0.05	2.1	1.7	0.42	0.050	1.7
Holmium^	ppm	0.05	0.38	0.21	0.070	<0.050	0.26
Neodymium^	ppm	0.1	11	10	1.9	0.20	12
Praseodymium^	ppm	0.05	3.4	2.9	0.49	0.060	3.1
Samarium^	ppm	0.1	2.1	1.9	0.40	<0.10	2.1
Thulium^	ppm	0.05	0.16	0.080	<0.050	<0.050	0.12
Beryllium^	ppm	0.1	<0.10	0.10	<0.10	<0.10	0.50
Bismuth^	ppm	0.04	<0.040	1.9	0.35	<0.040	0.23
Calcium^	%	0.01	1.1	1.3	0.34	0.010	0.020
Cadmium^	ppm	0.02	0.050	0.080	0.060	0.020	0.040
Cerium^	ppb	0.05	35	27	4.2	9.2	60
Cobalt^	ppm	0.1	3.0	8.7	23	3.5	11
Cesium^	ppm	0.05	1.0	0.60	0.25	<0.050	0.35
Chromium^	ppm	1	9.0	18	34	19	72
Gallium^	ppm	0.1	15	17	2.3	0.70	27
Germanium^	ppm	0.1	<0.10	<0.10	<0.10	<0.10	0.30
Copper^	ppm	0.5	11	39	187	19	97
Iron^	%	0.01	1.1	2.2	2.8	0.73	8.5
Indium^	ppm	0.02	<0.020	<0.020	<0.020	<0.020	0.070
Lanthanum^	ppb	0.1	24	14	1.0	<0.10	13
Lutetium^	ppm	0.01	0.13	0.070	0.040	<0.010	0.13
Potassium^	%	0.01	2.9	1.2	0.20	<0.010	0.21
Lithium^	ppm	1	8.0	10	2.0	<1.0	4.0
Hafnium^	ppm	0.02	0.77	0.61	0.090	0.030	1.1
Magnesium^	%	0.01	0.20	0.53	0.21	0.020	0.040
Mercury^	ppm	0.01	0.050	0.050	0.090	0.030	0.080
Manganese^	ppm	2	213	286	265	92	251
Molybdenum^	ppm	0.05	0.75	0.90	2.4	2.0	8.1
Sodium^	%	0.01	2.6	3.1	0.10	0.010	0.030
Niobium^	ppm	0.1	11	6.9	2.1	0.90	11
Nickel^	ppm	0.5	11	17	47	20	40
Phosphorus^	ppm	50	243	275	177	<50	232
Lead^	ppm	0.5	34	45	1.7	3.3	29
Rubidium^	ppm	0.2	93	32	8.2	0.30	6.8
Sulphur^	%	0.01	0.020	0.39	1.2	0.010	0.050
Antimony^	ppm	0.05	<0.050	<0.050	0.10	<0.050	0.070
Scandium^	ppm	0.5	1.9	4.5	1.1	<0.50	27
Selenium^	ppm	2	<2.0	<2.0	<2.0	<2.0	<2.0
Tin^	ppm	0.3	1.2	0.90	0.50	<0.30	2.5
Strontium^	ppm	0.5	119	151	11	1.1	5.0
Tantalum^	ppb	0.05	0.99	0.91	0.070	<0.050	1.7
Terbium^	ppm	0.05	0.32	0.24	0.070	<0.050	0.27
Tellurium^	ppm	0.05	0.070	<0.050	<0.050	<0.050	<0.050
Thorium^	ppm	0.2	17	8.6	0.60	0.20	7.3
Titanium^	%	0.01	0.070	0.12	0.040	<0.010	0.59
Thallium^	ppm	0.02	0.57	0.20	0.060	<0.020	0.10
Uranium^	ppm	0.05	8.6	2.4	0.28	0.070	5.5
Vanadium^	ppm	2	9.0	35	15	5.0	248
Ytterbium^	ppm	0.1	0.80	0.50	0.20	<0.10	0.80
Yttrium^	ppm	0.1	10	6.0	2.1	0.20	6.2
Tungsten^	ppm	0.1	3.4	4.7	4.3	1.0	18
Zinc^	ppm	1	35	22	7.0	7.0	40

Parameter	Units	LOR	Sample Number JB15-06285.041 Sample Name 90286 Sample Matrix Soil	JB15-06285.042 90287 Soil	JB15-06285.043 90288 Soil	JB15-06285.044 90289 Soil	JB15-06285.045 90290 Soil
SUB_SGS Booysens Method: SUB (continued)							
Zirconium^	ppm	0.5	25	21	3.2	0.80	34

METHOD	METHODOLOGY SUMMARY
ME-AN-024	Paste pH/EC is determined by mixing a portion of sample with water at a low liquid to solid ratio and measuring the pH/EC of the resulting paste. Based on MEND 1.20.1. 10% pH/EC is determined by mixing a portion of sample with water at a liquid to solid ratio of 10:1 for a given period of time and measuring the pH/EC of the supernatant.
ME-AN-025	The acid production (AP) is calculated by assuming that all the sulphide sulphur present converts to sulphuric acid (sulphate) at a production of four moles of hydrogen ion per mole of pyrite oxidised. AP = acid potential = sulphide x 31.25. Where sulphide is reported as below the MDL, 0.099 is used for the calculation.
ME-AN-025	The acid/base balances (net NP, NP/AP ratio) are calculated and used to classify the sample as either having a potential to generate acidity, a potential for acid neutralisation or, if the results fall within a certain range, uncertainty with respect to net acid generation potential. Net NP = NP – AP PAG: Potentially acid generating, based on interpretation of ABA data alone. PAN: Potentially acid neutralising, based on interpretation of ABA data alone. U: Uncertain with respect to potential acid generation or neutralisation, based on interpretation of ABA data alone. Based on MEND 1.20.1.
NAG	A portion of the sample is treated overnight with hydrogen peroxide, allowing acid generation and neutralisation reactions to occur simultaneously. The solution is then boiled to remove excess peroxide, pH is measured and the samples titrated with standardised sodium hydroxide. If the pH is > 7, the sample is titrated first to pH 7 and then to pH 4.5. Net acid generation (NAG) values are calculated for each titre. NAG = 49 x (titre x normality / sample mass). Based on MEND 1.20.1

FOOTNOTES

IS	Insufficient sample for analysis.	QFH	QC result is above the upper tolerance
LNR	Sample listed, but not received.	QFL	QC result is below the lower tolerance
*	This analysis is not covered by the scope of accreditation.	-	The sample was not analysed for this analyte
^	Performed by outside laboratory.		
LOR	Limit of Reporting		
↑↓	Raised or Lowered Limit of Reporting		

Samples analysed as received.
Solid samples expressed on a dry weight basis.

Unless otherwise indicated, samples were received in containers fit for purpose.

SGS ***Environmental*** Services ***Randburg*** is accredited by ***SANAS*** and conforms to the requirements of ISO/IEC 17025 for specific test or calibrations as indicated on the scope of accreditation to be found at http://sanas.co.za.

sanas Testing Laboratory

T0107

TEST REPORT

CLIENT DETAILS

Contact	Serhat Demirel
Client	Golder Associates (Turkey)
Address	Hollanda Cad.691.Sok Vadi Sit. No.4 Yildiz Cankaya
Telephone	+90-312-441-00-31
Facsimile	+90-312-441-07-14
Email	sdemirel@golder.com
Project	(Not specified)
Order Number	**06550**
Samples	16
Sample matrix	SOIL

LABORATORY DETAILS

Laboratory	SGS South Africa (Pty) Limited
Address	259 Kent Avenue Ferndale, 2194
Telephone	+27 (0)11 781 5689
Laboratory Manager	Martin Olivier
SGS Reference	JB15-06359 R0
Report Number	0000008997
Date Received	2015/03/25 02:31:29PM
Date Reported	2015/04/09 12:54:17PM

COMMENTS

The document is issued in accordance with SANAS's accreditation requirements.
Accredited for compliance with ISO/IEC 17025. SANAS accredited laboratory T0107.

sanas Testing Laboratory
T0107

Sample(s) leached using deionised water. Results reported on leachate.

SIGNATORIES

Greg Ondrejkovic
Technical Supervisor/Technical Signatory

Martin Olivier
Operations Manager/Technical Signatory

Parameter	**Units**	**LOR**	**Sample Number**	**JB15-06359.001**	**JB15-06359.002**	**JB15-06359.003**	**JB15-06359.004**	**JB15-06359.005**
			Sample Name	**90246**	**90276**	**90253**	**90255**	**90288**

Customised leach Method: IN-HOUSE

Parameter	Units	LOR	JB15-06359.001	JB15-06359.002	JB15-06359.003	JB15-06359.004	JB15-06359.005
Final pH*	-	0.1	5.8	7.1	6.8	6.0	6.8
Leaching Solution*	-	-	DI H2O	DI H2O	DI H2O	DI H2O	DI H2O
Weight Sample*	g	-	250.0	250.0	250.0	250.0	250.0
Vol_ml*	ml	-	1000	1000	1000	1000	1000

Alkalinity on leachates by titration Method: ME-AN-001

Parameter	Units	LOR	JB15-06359.001	JB15-06359.002	JB15-06359.003	JB15-06359.004	JB15-06359.005
Total Alkalinity as CaCO3	mg/l	12	13	19	37	13	45

Conductivity on leachates Method: ME-AN-007

Parameter	Units	LOR	JB15-06359.001	JB15-06359.002	JB15-06359.003	JB15-06359.004	JB15-06359.005
Conductivity in mS/m @ 25ºC	mS/m	2	7	22	14	4	8

Anions on leachates by Ion Chromatography Method: ME-AN-014

Parameter	Units	LOR	JB15-06359.001	JB15-06359.002	JB15-06359.003	JB15-06359.004	JB15-06359.005
Sulphate	mg/l	0.05	5.0	18	1.5	0.87	12

ICP-OES Metals on leachates (Dissolved) Method: ME-AN-027 D

Parameter	Units	LOR	JB15-06359.001	JB15-06359.002	JB15-06359.003	JB15-06359.004	JB15-06359.005
Silver	mg/l	0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Aluminium	mg/l	0.02	<0.02	0.02	<0.02	<0.02	<0.02
Arsenic	mg/l	0.01	<0.01	0.01	<0.01	<0.01	<0.01
Boron	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Barium	mg/l	0.002	<0.002	0.094	<0.002	<0.002	<0.002
Beryllium	mg/l	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Bismuth	mg/l	0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Calcium	mg/l	0.5	<0.5	1.6	0.7	<0.5	7.3
Cadmium	mg/l	0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	0.019
Chromium	mg/l	0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Copper	mg/l	0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Iron	mg/l	0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Potassium	mg/l	0.2	3.0	30	16	0.5	3.9
Magnesium	mg/l	0.01	0.07	1.0	0.37	0.03	1.1
Manganese	mg/l	0.01	0.02	0.09	0.18	<0.01	0.21
Molybdenum	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Sodium	mg/l	0.5	1.8	4.9	2.9	3.3	1.1
Nickel	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	0.085
Lead	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Phosphorus	mg/l	0.03	0.03	0.08	<0.03	<0.03	<0.03
Antimony	mg/l	0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Silicon	mg/l	1	3	7	3	4	3
Tin	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Strontium	mg/l	0.001	<0.001	0.011	0.003	<0.001	0.014
Titanium	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Vanadium	mg/l	0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Tungsten	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	mg/l	0.01	0.02	0.01	0.03	0.02	0.02
Zirconium*	mg/l	0.18	<0.18	<0.18	<0.18	<0.18	<0.18
Uranium	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Parameter	Units	LOR	Sample Number Sample Name	JB15-06359.001 90246	JB15-06359.002 90276	JB15-06359.003 90253	JB15-06359.004 90255	JB15-06359.005 90288
Dissolved Hg on Leachates by ICP-MS Method: ME-AN-026								
Mercury	µg/l	0.1		<0.10	<0.10	<0.10	<0.10	<0.10

Parameter	Units	LOR	JB15-06359.006 90271	JB15-06359.007 90260	JB15-06359.008 90285	JB15-06359.009 90287	JB15-06359.010 90263
Customised leach Method: IN-HOUSE							
Final pH*	-	0.1	7.3	9.8	9.7	8.9	6.6
Leaching Solution*	-	-	DI H2O	DI H2O	DI H2O	DI H2O	DI H2O
Weight Sample*	g	-	250.0	250.0	250.0	250.0	250.0
Vol_ml*	ml	-	1000	1000	1000	1000	1000
Alkalinity on leachates by titration Method: ME-AN-001							
Total Alkalinity as CaCO3	mg/l	12	16	40	29	29	16
Conductivity on leachates Method: ME-AN-007							
Conductivity in mS/m @ 25ºC	mS/m	2	2	11	7	10	48
Anions on leachates by Ion Chromatography Method: ME-AN-014							
Sulphate	mg/l	0.05	0.37	7.5	1.5	6.8	201
ICP-OES Metals on leachates (Dissolved) Method: ME-AN-027 D							
Silver	mg/l	0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Aluminium	mg/l	0.02	0.06	0.02	0.53	0.49	<0.02
Arsenic	mg/l	0.01	0.01	0.01	0.01	<0.01	<0.01
Boron	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Barium	mg/l	0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Beryllium	mg/l	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Bismuth	mg/l	0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Calcium	mg/l	0.5	1.1	5.7	5.9	5.0	22
Cadmium	mg/l	0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	0.019
Chromium	mg/l	0.002	<0.002	0.004	<0.002	<0.002	<0.002
Copper	mg/l	0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Iron	mg/l	0.05	0.06	<0.05	<0.05	<0.05	<0.05
Potassium	mg/l	0.2	1.3	14	6.1	7.7	14
Magnesium	mg/l	0.01	0.55	2.4	0.46	0.74	29
Manganese	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	0.52
Molybdenum	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Sodium	mg/l	0.5	0.9	1.8	3.3	5.8	3.2
Nickel	mg/l	0.005	0.006	0.006	<0.005	<0.005	0.53
Lead	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Phosphorus	mg/l	0.03	<0.03	<0.03	0.04	<0.03	<0.03
Antimony	mg/l	0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Silicon	mg/l	1	7	10	4	3	6
Tin	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Strontium	mg/l	0.001	0.007	0.013	0.006	0.008	0.055
Titanium	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Vanadium	mg/l	0.001	0.001	0.009	0.027	0.003	<0.001
Tungsten	mg/l	0.01	0.02	<0.01	<0.01	<0.01	<0.01
Zinc	mg/l	0.01	0.02	<0.01	<0.01	<0.01	0.02
Zirconium*	mg/l	0.18	<0.18	<0.18	<0.18	<0.18	<0.18
Uranium	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Sample Number Sample Name			JB15-06359.006 90271	JB15-06359.007 90260	JB15-06359.008 90285	JB15-06359.009 90287	JB15-06359.010 90263
Parameter	**Units**	**LOR**					
Dissolved Hg on Leachates by ICP-MS Method: ME-AN-026							
Mercury	µg/l	0.1	0.10	<0.10	<0.10	0.20	<0.10

Sample Number Sample Name			JB15-06359.011 90275	JB15-06359.012 90284	JB15-06359.013 90279	JB15-06359.014 90281	JB15-06359.015 90270
Parameter	**Units**	**LOR**					
Customised leach Method: IN-HOUSE							
Final pH*	-	0.1	9.7	7.7	9.8	10.0	10.0
Leaching Solution*	-	-	DI H2O	DI H2O	DI H2O	DI H2O	DI H2O
Weight Sample*	g	-	250.0	250.0	250.0	250.0	250.0
Vol_ml*	ml	-	1000	1000	1000	1000	1000
Alkalinity on leachates by titration Method: ME-AN-001							
Total Alkalinity as CaCO3	mg/l	12	45	35	50	40	37
Conductivity on leachates Method: ME-AN-007							
Conductivity in mS/m @ 25ºC	mS/m	2	9	10	9	10	8
Anions on leachates by Ion Chromatography Method: ME-AN-014							
Sulphate	mg/l	0.05	1.9	5.7	1.9	1.2	1.5
ICP-OES Metals on leachates (Dissolved) Method: ME-AN-027 D							
Silver	mg/l	0.002	0.003	<0.002	<0.002	<0.002	<0.002
Aluminium	mg/l	0.02	0.20	0.29	0.52	0.65	0.72
Arsenic	mg/l	0.01	<0.01	<0.01	0.01	0.02	<0.01
Boron	mg/l	0.005	0.016	0.039	0.013	0.010	0.017
Barium	mg/l	0.002	0.030	0.32	0.042	0.046	0.035
Beryllium	mg/l	0.0001	0.0001	<0.0001	0.0002	0.0009	0.0002
Bismuth	mg/l	0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Calcium	mg/l	0.5	3.7	4.4	1.6	2.7	2.1
Cadmium	mg/l	0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Chromium	mg/l	0.002	<0.002	<0.002	<0.002	0.003	<0.002
Copper	mg/l	0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Iron	mg/l	0.05	<0.05	0.22	0.12	0.12	0.09
Potassium	mg/l	0.2	11	4.8	13	15	13
Magnesium	mg/l	0.01	0.54	2.9	0.48	0.46	0.31
Manganese	mg/l	0.01	<0.01	0.01	<0.01	0.02	<0.01
Molybdenum	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Sodium	mg/l	0.5	4.6	4.6	5.3	5.7	3.2
Nickel	mg/l	0.005	<0.005	0.029	<0.005	<0.005	<0.005
Lead	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Phosphorus	mg/l	0.03	0.07	0.07	0.12	0.13	0.10
Antimony	mg/l	0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Silicon	mg/l	1	6	10	5	5	4
Tin	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Strontium	mg/l	0.001	0.008	0.037	0.007	0.010	0.004
Titanium	mg/l	0.005	0.007	0.007	0.011	0.007	0.006
Vanadium	mg/l	0.001	0.028	0.004	0.011	0.013	0.013
Tungsten	mg/l	0.01	0.25	0.21	<0.01	0.26	<0.01
Zinc	mg/l	0.01	<0.01	0.06	<0.01	0.04	<0.01
Zirconium*	mg/l	0.18	<0.18	<0.18	<0.18	<0.18	<0.18
Uranium	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Parameter	Units	LOR	Sample Number Sample Name: JB15-06359.011 90275	JB15-06359.012 90284	JB15-06359.013 90279	JB15-06359.014 90281	JB15-06359.015 90270
Dissolved Hg on Leachates by ICP-MS Method: ME-AN-026							
Mercury	µg/l	0.1	<0.10	1.5	0.53	2.0	0.10

Parameter	Units	LOR	Sample Number Sample Name: JB15-06359.016 DI Blank
Customised leach Method: IN-HOUSE			
Final pH*	-	0.1	-
Leaching Solution*	-	-	-
Weight Sample*	g	-	-
Vol_ml*	ml	-	-
Alkalinity on leachates by titration Method: ME-AN-001			
Total Alkalinity as CaCO3	mg/l	12	66
Conductivity on leachates Method: ME-AN-007			
Conductivity in mS/m @ 25ºC	mS/m	2	<2
Anions on leachates by Ion Chromatography Method: ME-AN-014			
Sulphate	mg/l	0.05	<0.05
ICP-OES Metals on leachates (Dissolved) Method: ME-AN-027 D			
Silver	mg/l	0.002	<0.002
Aluminium	mg/l	0.02	<0.02
Arsenic	mg/l	0.01	<0.01
Boron	mg/l	0.005	<0.005
Barium	mg/l	0.002	<0.002
Beryllium	mg/l	0.0001	<0.0001
Bismuth	mg/l	0.03	<0.03
Calcium	mg/l	0.5	<0.5
Cadmium	mg/l	0.001	<0.001
Cobalt	mg/l	0.005	<0.005
Chromium	mg/l	0.002	<0.002
Copper	mg/l	0.02	<0.02
Iron	mg/l	0.05	<0.05
Potassium	mg/l	0.2	<0.2
Magnesium	mg/l	0.01	0.01
Manganese	mg/l	0.01	<0.01
Molybdenum	mg/l	0.005	<0.005
Sodium	mg/l	0.5	<0.5
Nickel	mg/l	0.005	<0.005
Lead	mg/l	0.01	<0.01
Phosphorus	mg/l	0.03	0.12
Antimony	mg/l	0.02	<0.02
Silicon	mg/l	1	<1
Tin	mg/l	0.01	<0.01
Strontium	mg/l	0.001	<0.001
Titanium	mg/l	0.005	<0.005
Vanadium	mg/l	0.001	<0.001
Tungsten	mg/l	0.01	<0.01
Zinc	mg/l	0.01	<0.01
Zirconium*	mg/l	0.18	<0.18
Uranium	mg/l	0.01	<0.01

Parameter	Units	LOR	Sample Number: JB15-06359.016 Sample Name: DI Blank
Dissolved Hg on Leachates by ICP-MS Method: ME-AN-026			
Mercury	µg/l	0.1	<0.10

METHOD SUMMARY

Report number 0000008997
Client reference: **06550**

METHOD	METHODOLOGY SUMMARY
MS_EN_ME-AN-001	An aliquot of aqueous sample is titrated first to pH 8.3 and then to 4.3 using standardised acid. The volumes of acid titrated are used to calculate the alkaline species or total alkalinity. The method is based on EPA 310.2 and APHA 2320 B.
MS_EN_ME-AN-007	The conductivity of an aliquot of aqueous sample is measured electrometrically using a standard cell connected to a calibrated meter with automated temperature correction. This method is based on APHA 2510.
MS_EN_ME-AN-014	Inorganic anions (Br, Cl, F, NO3, NO2, SO4) are determined on aqueous samples by ion chromatography. The method is based on EPA 300.1 and APHA 4110 B. Br, Cl, F and NO2 are not determined on TCLP leachates.
MS_EN_ME-AN-027	Dissolved metals are determined on a filtered and acidified portion of aqueous sample by inductively coupled plasma optical emission spectrometry (ICP-OES). The method is based on EPA 200.7 and APHA 3120.

FOOTNOTES

IS	Insufficient sample for analysis.
LNR	Sample listed, but not received.
*	This analysis is not covered by the scope of accreditation.
^	Performed by outside laboratory.
LOR	Limit of Reporting
QFH	QC result is above the upper tolerance
QFL	QC result is below the lower tolerance
-	The sample was not analysed for this analyte

Samples analysed as received.
Solid samples expressed on a dry weight basis.

Unless otherwise indicated, samples were received in containers fit for purpose

SGS ***Environmental*** Services ***Randburg*** is accredited by ***SANAS*** and conforms to the requirements of ISO/IEC 17025 for specific test or calibrations as indicated on the scope of accreditation to be found at http://sanas.co.za.

TEST REPORT

CLIENT DETAILS

Contact	Serhat Demirel
Client	Golder Associates (Turkey)
Address	Hollanda Cad.691.Sok Vadi Sit. No.4 Yildiz Cankaya
Telephone	+90-312-441-00-31
Facsimile	+90-312-441-07-14
Email	sdemirel@golder.com
Project	(Not specified)
Order Number	**06550**
Samples	4
Sample matrix	SOIL

LABORATORY DETAILS

Laboratory	SGS South Africa (Pty) Limited
Address	259 Kent Avenue Ferndale, 2194
Telephone	+27 (0)11 781 5689
Laboratory Manager	Martin Olivier
SGS Reference	JB15-06358 R0
Report Number	0000009024
Date Received	2015/03/25 02:19:48PM
Date Reported	2015/04/14 04:08:01PM

COMMENTS

The document is issued in accordance with SANAS's accreditation requirements.
Accredited for compliance with ISO/IEC 17025. SANAS accredited laboratory T0107.

sanas Testing Laboratory
T0107

Sample(s) leached using Peroxide Solution. Results reported on leachate.

SIGNATORIES

Greg Ondrejkovic
Technical Supervisor/Technical Signatory

Martin Olivier
Operations Manager/Technical Signatory

		Sample Number Sample Name Sample Matrix	**JB15-06358.001** **90288** **Soil**	**JB15-06358.002** **90287** **Soil**	**JB15-06358.003** **90263** **Soil**	**JB15-06358.004** **Peroxide Blank**
Parameter	**Units**	**LOR**				

Peroxide leach (NAG methodology) Method: MEND 1.20.1

Final pH*	-	0.1	2.9	5.6	5.7	6.7

Dissolved Hg on Leachates by ICP-MS Method: ME-AN-026

Mercury	µg/l	0.1	<0.10	<0.10	<0.10	<0.10

Conductivity on leachates Method: ME-AN-007

Conductivity in mS/m @ 25ºC	mS/m	2	113	46	47	36

Alkalinity on leachates by titration Method: ME-AN-001

Total Alkalinity as CaCO3	mg/l	12	<12	21	19	32

Acidity by Titration on leachates Method: APHA2310

Acidity as CaCO3*	mg/l	10	210	75	60	190
Acidity Hot as CaCO3*	mg/l	5	-	-	-	-
Acidity as CO2*	mg/l	10	-	-	-	-

Anions on leachates by Ion Chromatography Method: ME-AN-014

Sulphate	mg/l	0.05	327	78	85	1.3

ICP-OES Metals on leachates (Dissolved) Method: ME-AN-027 D

Silver	mg/l	0.002	<0.002	<0.002	<0.002	<0.002
Aluminium	mg/l	0.02	2.1	0.04	0.03	<0.02
Arsenic	mg/l	0.01	0.01	0.01	<0.01	<0.01
Boron	mg/l	0.005	<0.005	0.006	<0.005	0.007
Barium	mg/l	0.002	<0.002	<0.002	<0.002	<0.002
Beryllium	mg/l	0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Bismuth	mg/l	0.03	0.10	<0.03	<0.03	<0.03
Calcium	mg/l	0.5	6.7	3.6	1.7	<0.5
Cadmium	mg/l	0.001	0.004	<0.001	<0.001	<0.001
Cobalt	mg/l	0.005	0.21	0.012	0.014	<0.005
Chromium	mg/l	0.002	0.052	0.006	0.009	<0.002
Copper	mg/l	0.02	1.6	<0.02	<0.02	<0.02
Iron	mg/l	0.05	26	<0.05	<0.05	<0.05
Potassium	mg/l	0.2	4.7	6.0	9.9	<0.2
Magnesium	mg/l	0.01	2.4	1.8	4.1	<0.01
Manganese	mg/l	0.01	1.3	0.09	0.08	<0.01
Molybdenum	mg/l	0.005	<0.005	<0.005	0.006	<0.005
Sodium	mg/l	0.5	60	59	56	66
Nickel	mg/l	0.005	0.44	0.042	0.11	<0.005
Phosphorus	mg/l	0.03	0.98	32	28	49
Lead	mg/l	0.01	<0.01	<0.01	<0.01	<0.01
Antimony	mg/l	0.02	<0.02	<0.02	<0.02	<0.02
Selenium	mg/l	0.01	<0.01	<0.01	<0.01	<0.01
Silicon	mg/l	1	16	12	12	<1
Tin	mg/l	0.01	<0.01	<0.01	<0.01	<0.01
Strontium	mg/l	0.001	0.016	0.006	0.005	<0.001
Titanium	mg/l	0.005	<0.005	0.022	0.024	<0.005
Uranium	mg/l	0.01	<0.01	<0.01	<0.01	<0.01
Vanadium	mg/l	0.001	0.018	0.013	0.029	<0.001
Tungsten	mg/l	0.01	<0.01	0.01	0.02	<0.01
Zinc	mg/l	0.01	0.08	0.04	0.09	<0.01
Zirconium*	mg/l	0.18	<0.18	<0.18	<0.18	<0.18

METHOD SUMMARY

Report number 0000009024
Client reference: **06550**

METHOD	METHODOLOGY SUMMARY
MS_EN_APHA2310	An aliquot of aqueous sample is titrated first to pH 3.7 and then to 8.3 using standardised base. The volumes of base titrated are used to calculate the acidity. The method is based on APHA 2310.
MS_EN_ME-AN-001	An aliquot of aqueous sample is titrated first to pH 8.3 and then to 4.3 using standardised acid. The volumes of acid titrated are used to calculate the alkaline species or total alkalinity. The method is based on EPA 310.2 and APHA 2320 B.
MS_EN_ME-AN-007	The conductivity of an aliquot of aqueous sample is measured electrometrically using a standard cell connected to a calibrated meter with automated temperature correction. This method is based on APHA 2510.
MS_EN_ME-AN-014	Inorganic anions (Br, Cl, F, NO3, NO2, SO4) are determined on aqueous samples by ion chromatography. The method is based on EPA 300.1 and APHA 4110 B. Br, Cl, F and NO2 are not determined on TCLP leachates.
MS_EN_ME-AN-027	Dissolved metals are determined on a filtered and acidified portion of aqueous sample by inductively coupled plasma optical emission spectrometry (ICP-OES). The method is based on EPA 200.7 and APHA 3120.
MS_EN_MEND 1.20.1	A portion of sample is treated overnight with hydrogen peroxide. The solution is then boiled to remove all excess peroxide. The concentration of each contaminant of interest is determined in the leachate by appropriate methods after separation from the sample by filtering.

FOOTNOTES

IS	Insufficient sample for analysis.
LNR	Sample listed, but not received.
*	This analysis is not covered by the scope of accreditation.
^	Performed by outside laboratory.
LOR	Limit of Reporting
↑↓	Raised or Lowered Limit of Reporting
QFH	QC result is above the upper tolerance
QFL	QC result is below the lower tolerance
-	The sample was not analysed for this analyte

Samples analysed as received.
Solid samples expressed on a dry weight basis.

Unless otherwise indicated, samples were received in containers fit for purpose.

SGS ***Environmental*** Services ***Randburg*** is accredited by ***SANAS*** and conforms to the requirements of ISO/IEC 17025 for specific test or calibrations as indicated on the scope of accreditation to be found at http://sanas.co.za.

sanas Testing Laboratory
T0107

As a global, employee-owned organisation with over 50 years of experience, Golder Associates is driven by our purpose to engineer earth's development while preserving earth's integrity. We deliver solutions that help our clients achieve their sustainable development goals by providing a wide range of independent consulting, design and construction services in our specialist areas of earth, environment and energy.

For more information, visit golder.com

Africa	+ 27 11 254 4800
Asia	+ 86 21 6258 5522
Australasia	+ 61 3 8862 3500
Europe	+ 356 21 42 30 20
North America	+ 1 800 275 3281
South America	+ 56 2 2616 2000

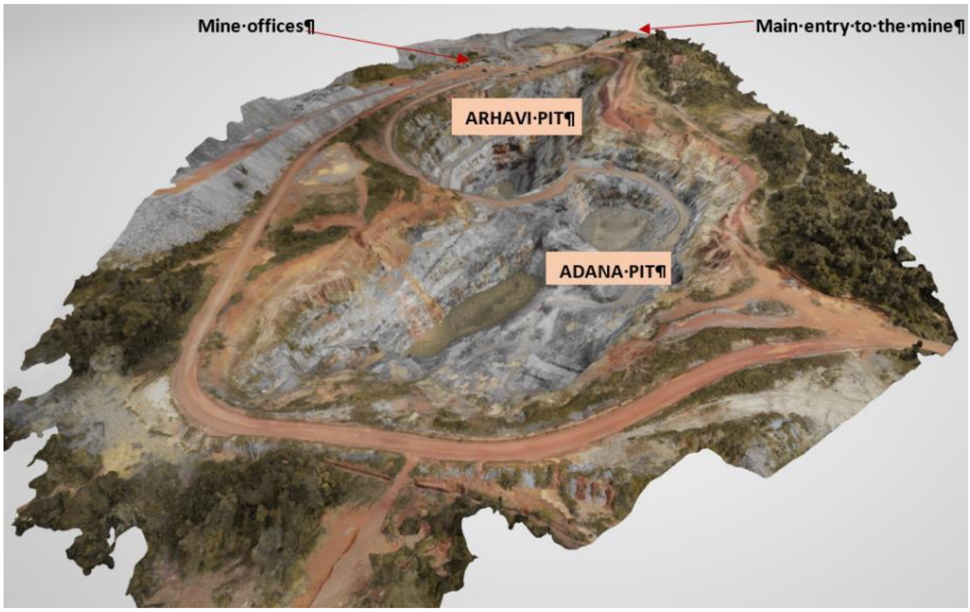
solutions@golder.com
www.golder.com

Golder Associates (Turkey) Ltd. Co.
Hollanda Cad. 691. Sok. Vadi Sit. No:4
Yıldız 06550 Ankara
Turkey
P: +90 312 4410031
F: +90 312 4410714

Golder Associates

KOKOYA GOLD MINE PROJECT
Hydrogeological Assessment Study 2020

MNG Gold A.Ş.



By,

C. Serdar BAYARI, Hydrogeological Engineer, M.Sc., Ph.D. Serdar Bayarı

N. Nur ÖZYURT, Hydrogeological Engineer, M.Sc., Ph.D. nozyurt

Pınar AVCI, Hydrogeological Engineer, M.Sc., Ph.D. PınarAvcı

March 20th, 2020

Table of Contents

ATTACHMENTS

ABBREVIATIONS

Abbreviation	Definition
asl	Above mean sea level
bgl	Below ground level
ARD	Acid Rock Drainage
DW	Drinking Water
K	Hydraulic conductivity
ML	Metal Leaching
NON-PAG	non- potential acid generating
PAG	Potential acid generating
RWW	Raw Water Well
SRP	Seepage Recovery pond
SWL	Static groundwater level
TSF	Tailings Storage Facility
WRD	Waste Rock Dump

INTRODUCTION

MNG Gold Liberia Incorporated (MNG), a Liberian registered, Turkish-owned company, acquired the Kokoya Gold Project from Amlib United Minerals Incorporated (Amlib) (subsidiary of Amlib Holdings PLC) in April 2014. MNG GOLD intends to develop the open pit mining project to a further mining stage with enhancing the present production by means of underground mining in galleries to be developed along a ramp excavated at the bottom of the present open pit mine.

At this stage of the project the aim is to develop underground gold mine using conventional pit and gallery mining methods and extracting gold from the ore through the Carbon-In-Leach (CIL) methodology.

A Hydrogeological Assessment Report (Golder, 2015a) was prepared during the pre-Construction Phase of the open pit mine by Golder Associates (hereinafter Golder). This report is an update to aforementioned study which is enhanced with the evaluation of field data obtained since 2015. Hence, the report presents a hydrogeological assessment of the project as of February 2020.

PROJECT INFORMATION

1.1 Concession Area

The concession area (Kokoya Production Area) approved by the Ministry of Lands, Mines and Energy in November 2013 is 537 km^2. It stretches over Nimba, Grand Bassa, and Bong counties (Figure 1). However, the project area is in the Kokoya District of the Bong County.

1.2 Project Area

The project area is located among Sayeweh, Dahnway, Dean and Bohn Towns. It can be accessed by road from Monrovia through Buchanan to Yekepa and also from Kakata through Totota to Gbanga.

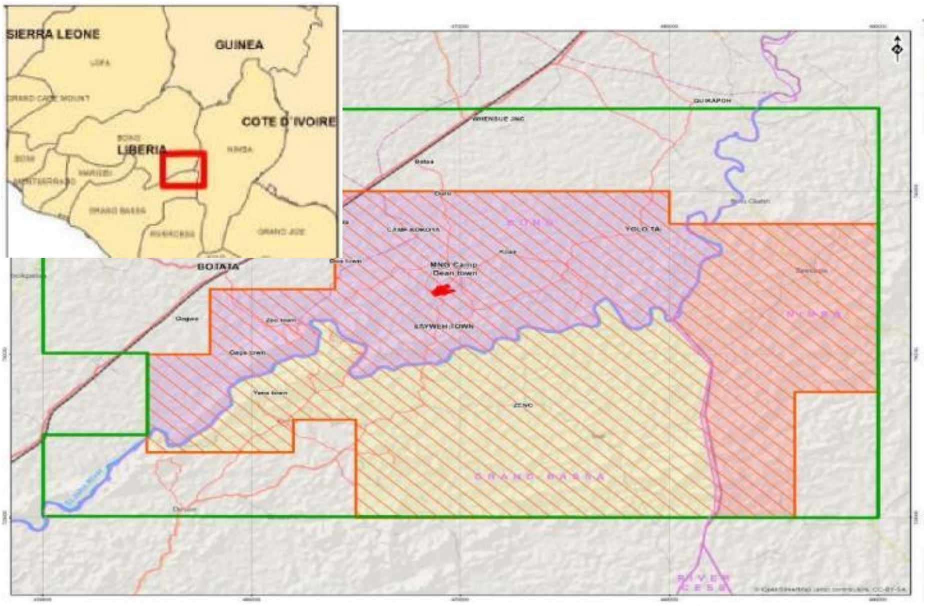


Figure 1 Kokoya Production Area and Mining Resource Area (modified after Golder, 2015b)

1.3 Project Description

The Kokoya Gold Project is proposing to produce approximately 540,000 tons of gold ore for processing in its on-site plant per annum by CIL methodology. The key components of the project are:

- Open Pits;
- Underground galleries and transportation ramps in the Open Pit #1 (i.e. Arhavi Pit and Adana Pit);
- Waste Rock Dump (WRD);
- Tailings Storage Facility (TSF);

- Process Plant;
- Ore Stockpiles;
- Camp Area; and
- Supporting Facilities.

As of March 2020, all of the above components, except the underground galleries and transportation ramps in the Open Pits #1 and #3 (i.e. Arhavi Pit & Adana Pit, respectively) have been operational (Figure 2, Table 1). Currently, the studies regarding the details of underground galleries and access ramps are underway.

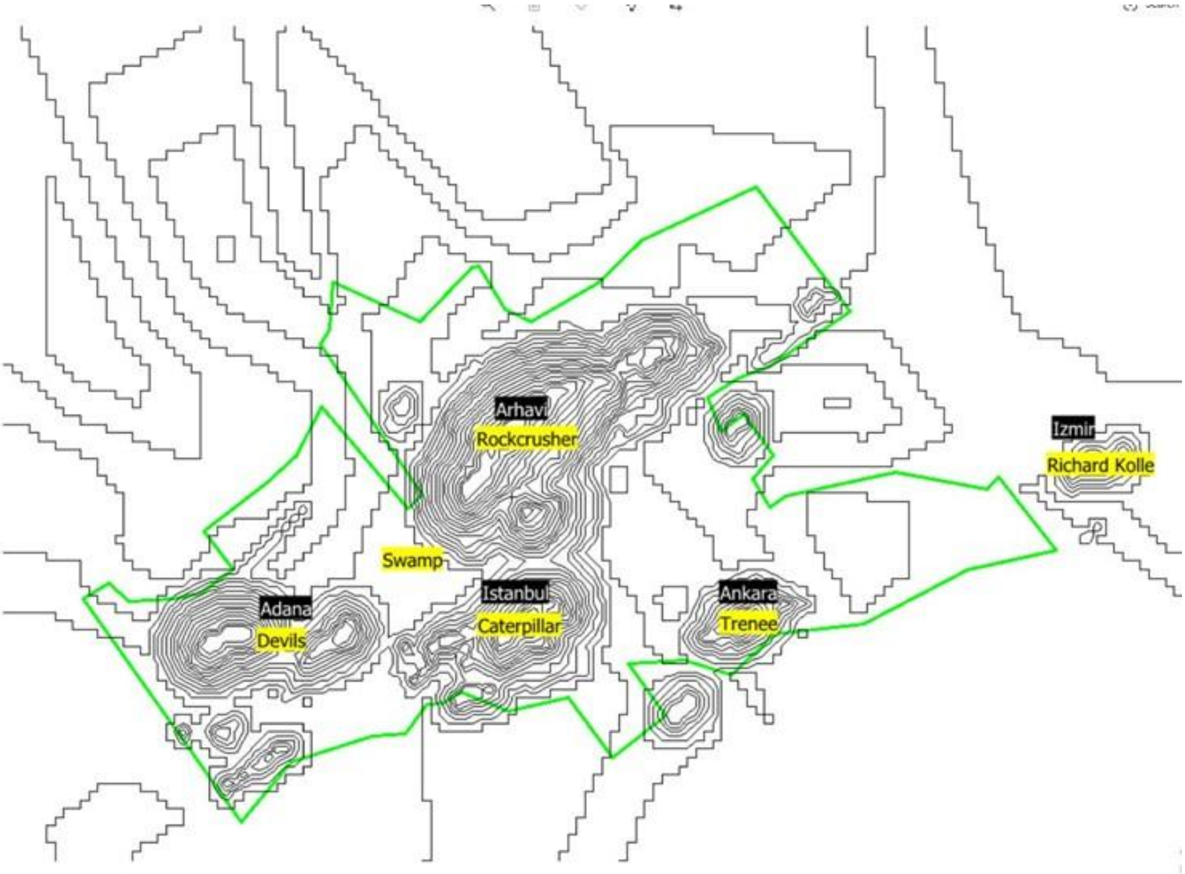
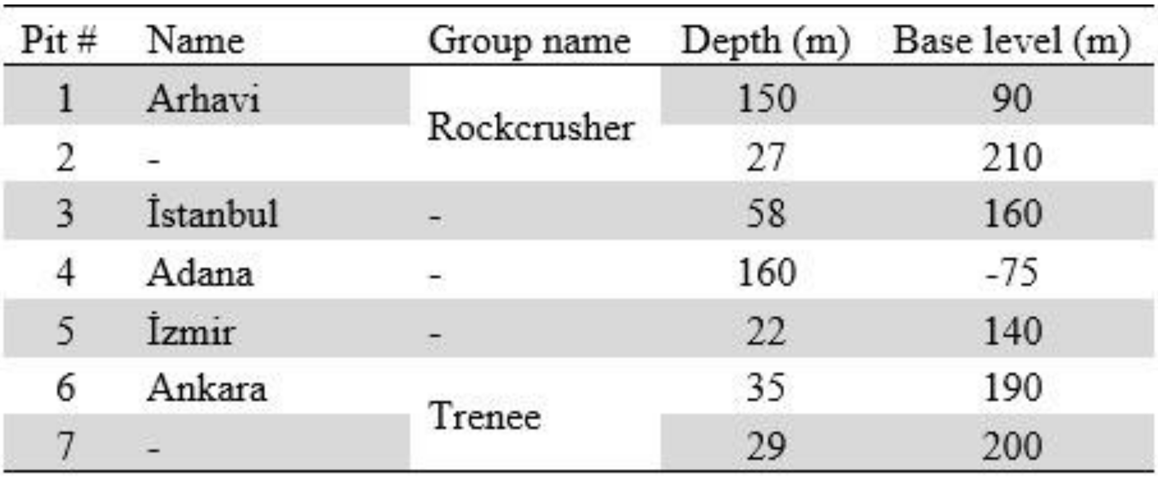


Figure 2: Relative positions of the open pits in the Kokoya Gold Mine

Table 1 Open pits in the Kokoya Gold Mine



Pit #	Name	Group name	Depth (m)	Base level (m)
1	Arhavi	Rockcrusher	150	90
2	-		27	210
3	İstanbul	-	58	160
4	Adana	-	160	-75
5	İzmir	-	22	140
6	Ankara	Trenee	35	190
7	-		29	200

HYDROGEOLOGICAL STUDY

1.4 Objective

Golder (2015a) already conducted a Hydrogeological Assessment Study under the scope of a previous Environmental and Social Impact study (i.e. Golder, 2015b). The objectives of the hydrogeological study of Golder (2015a) included the following:

- Review the existing data and gain an understanding of the baseline conditions;
- Characterize the hydrogeology in the project area through desktop study;
- Determine the preliminary groundwater quality in the study area by comparing the analysis results of the samples to local and international water quality standards.
- Develop a work plan for drilling groundwater monitoring wells and conducting aquifer tests to determine the aquifer parameters;
- Develop conceptual hydrogeological model;
- Conduct pit inflow prediction and pit water balance calculation;
- Identify the potential impacts of the proposed mining activities during the project phases and mitigation measures to minimize the groundwater impacts.

Present hydrogeological assessments (i.e. this report) aims the followings:

- Review of the hydrogeological assessments made in Golder (2015a);
- Evaluate the spatiotemporal groundwater level change around the mine site since March 2015;
- Evaluate the spatiotemporal water chemistry data collected around the mine site since March 2015;
- Establish a basin-wide Numerical Groundwater Flow Model to test the Conceptual Hydrogeological Model.

1.5 Approach and Methodology

The main aim of the Golder (2015a) study was to determine the current occurrence and condition of the groundwater resources at and surrounding proposed Kokoya Gold Mine site. This involved determining the depth of potential aquifer zones, groundwater flow directions and baseline groundwater quality as well as the development of a conceptual groundwater model to describe the essential components of the existing groundwater system that will be affected by the proposed development of the Kokoya Gold Mine.

The approach and methodology that was employed during the hydrogeological assessment is explained in the following.

1.5.1 Data collection

Information from MNG Gold and project consultants such as PDME and EarthCons was used for the assessments by Golder (2015a). This report utilized also from the data available in Golder (2015a and 2015b) as well as the unpublished groundwater level and water chemistry data collected periodically since March 2015.

1.5.2 Desktop review of relevant documentation

Golder (2015a and 2015b) Reports were reviewed at a desktop level in order to obtain secondary data on the groundwater environment, and also to gain an understanding of the scope and context of the proposed project.

1.5.3 Delineation of the study area for the assessment

Golder (2015a) determined the extent of the hydrogeological assessment area boundary by using topographic divides of local sub catchments and local water courses in the vicinity of the project area. It covers an area of approximately 45 km^2. The hydrogeological assessment area defined by Golder (2015a) was modified slightly in this study to better fit a Digital Elevation Model obtained recently from MNG Gold in this study (Figure 3). However, the hydrogeological study area boundaries of Golder (2015a) and of this study are essentially the same.

1.5.4 Field work

Before and during the Golder (2015a and 2015b) studies the following field works conducted:

- A hydrocensus was conducted in January 2015 by EarthCons. During the hydrocensus study:
    - Groundwater points (springs, wells, etc.) in close vicinity of the project area were identified;
    - Discharge measurements from springs and groundwater level measurements form wells were taken.
- Groundwater quality was established by groundwater sample collection in February 2015 from the formerly selected locations. Samples were submitted for analysis by an accredited laboratory (Jones Environmental Laboratory) in the United Kingdom;
- Groundwater well drilling and aquifer testing program was established in March 2015;
- Drilling, testing, and analysis were conducted in April 2015.

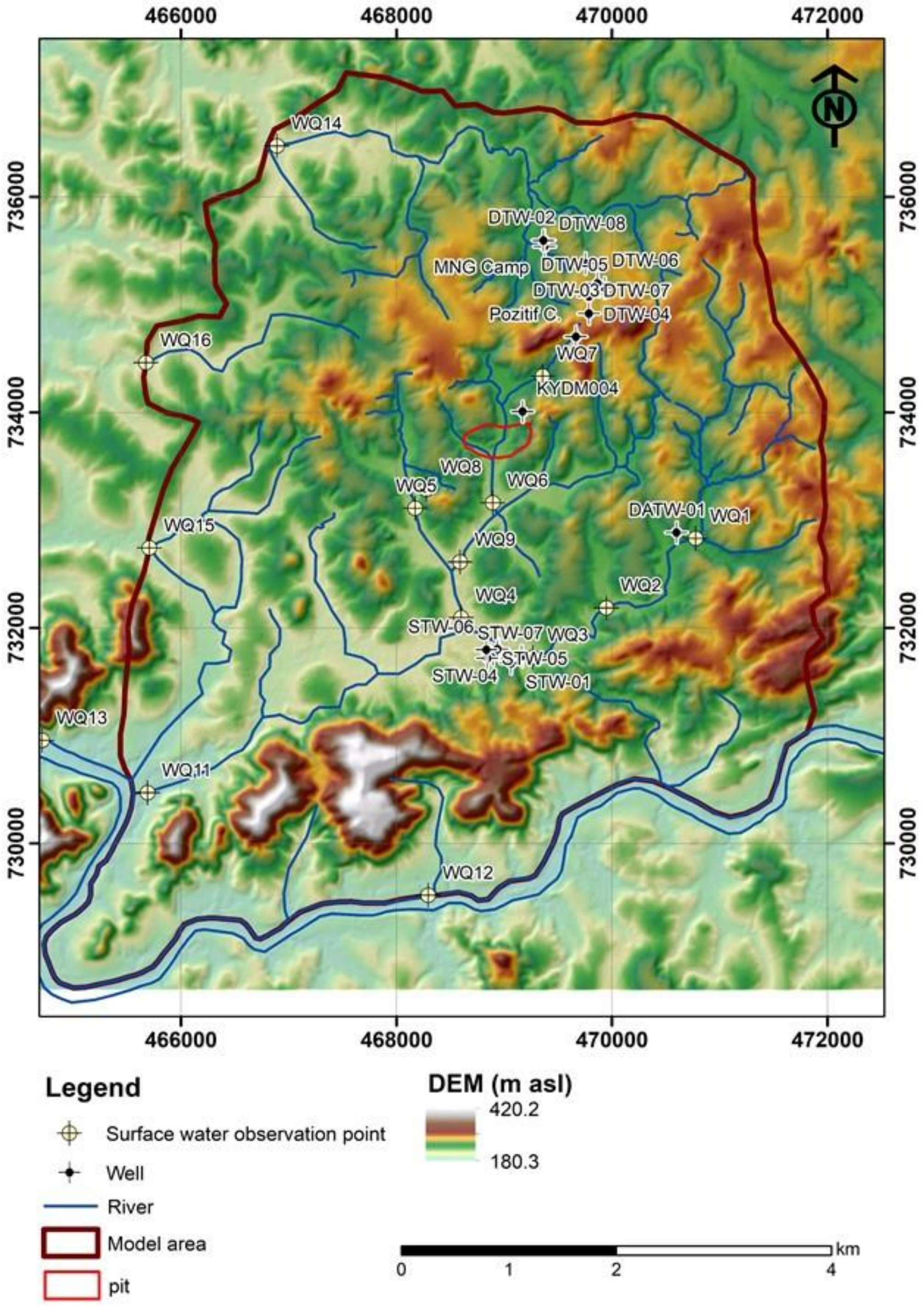


Figure 3: Digital elevation model of the hydrogeological assessment area of the Kokoya Gold Mine as of 2020

During the Construction and Operation phases that follow the Golder (2015a and 2015b) studies, the field works below conducted:

- Groundwater levels in various wells have been monitored since March 2015;
- Water quality has been monitored periodically in surface and groundwater points since March 2015;

- New monitoring wells have been drilled in accordance with the progress of the mining activities.
- Since 2019, data loggers have been put into use in several points to monitor the for the parameters like pH, conductivity, dissolved oxygen, temperature and depth to groundwater level.

1.5.5 Numerical groundwater flow model

A quantitative numerical groundwater flow model, based on data available in Golder (2015a) and those collected from the field afterwards, was used in this report to test the conceptual hydrogeological model and estimate the seepage into the underground mine workings.

BASELINE CONDITIONS

1.6 Climate

The climate in Liberia is hot and humid tropical, and there are two distinct seasons; a low-rainfall (or dry) season between December and April and a high-rainfall (or wet) season from May to November. Mean total rainfall in the dry and wet seasons are 1689 mm and 76 mm, respectively (www.climate.data.org) According to Köppen-Geiger climate classification, the climate in Liberia is in the class of Aw (i.e. Tropical Savanna Climate or Tropical Wet and Dry Climate). Temperatures vary from 27°C to 32°C during the day and 21 °C to 24°C during the night.

Recent rainfall and temperature observations conducted at the Kokoya Gold Mine are shown in Figure 4 and in Figure 5. Annual total rainfall in the years 2017, 2018 and 2019 is 1956 mm (January data is missing), 1681 mm (January and February data is missing) and 1446 mm (November and December data is missing), respectively. Considering the missing data, the long-term mean annual total rainfall in the Kokoya Gold Mine is thought probably to be around 2000 mm. Highest and lowest mean monthly temperatures during the observation period are 27.9 °C and 23.1 °C, respectively. The mean monthly temperatures in the same period ranged between 25.5 °C and 26.1 °C. Relatively lower monthly temperatures are observed during the high-rainfall season between April to October.

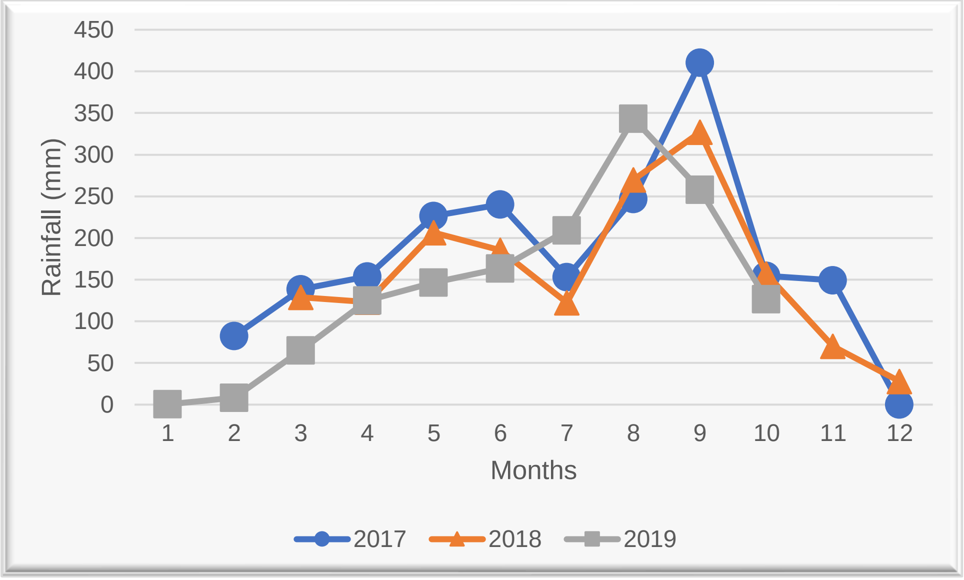


Figure 4: Monthly total rainfall observed in Kokoya Gold Mine

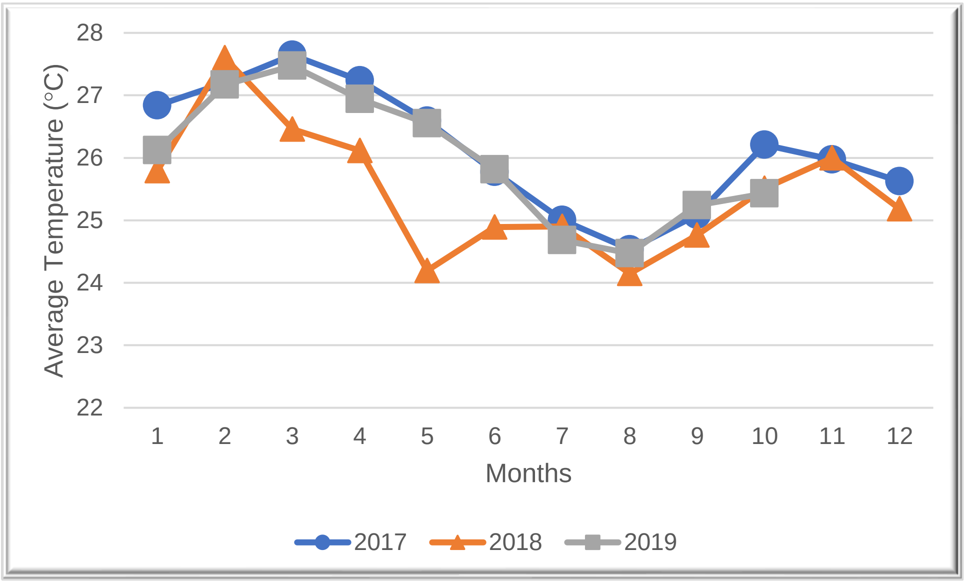


Figure 5: Monthly average temperatures observed in Kokoya Gold Mine

1.7 Topography

The elevation in the hydrogeological study area varies between 360 meter (m) above sea level (asl) to about 180 m asl along the St. John River in the southern part of the study area. Mine site is located at lower elevations, varying between 240 and 210 m asl (see Figure 3). Topography around the mine site is smooth.

GEOLOGY

This section is derived from Golder (2015a) which is based on the Definitive Feasibility Study (PMDE, 2014) and the Geology, Alteration and Mineralization Study (MNG, 2015) reports provided by MNG Gold.

1.8 Regional Geology

Liberia is underlain by the West African Craton which extends into neighboring Guinea and Sierra Leone, and is mostly composed of Precambrian igneous and metamorphic rocks. Other rock types present in much smaller extend on a local scale include Paleozoic and Cretaceous sandstones, as well as Jurassic dolerite dykes and unconsolidated Quaternary deposits.

The West African Craton comprises two major areas of Archaean to early Proterozoic terrains as the Man Shield and the Birimian Shield. In the Man Shield, the Archaean basement is only exposed in western and central Liberia and Sierra Leone, and characterized by a granite-greenstone association dominated by older granitoid gneisses and migmatite which are in folded with supracrustal schist belts (greenstone belts) and intruded by younger granites. These supracrustal sequences outcrop as synformal relicts elongated parallel to the Liberian foliation of their gneissic basement. The Birimian, early Proterozoic terrains, is made up of an alternation of sedimentary belts and volcanic sequences intruded by large granitoid bodies which crop out in north-south to northeast-southwest trending belts extending for tens to hundreds of kilometers. The metamorphic grade within the early Proterozoic rocks is generally low, except along some subsequent trans- current fault zones. The Birimian rocks are present in the eastern third of the country in Liberia.

The basement rocks of Liberia are mainly grouped as three age provinces shown in Figure 6. The oldest is the Liberian age province, which covers the entire western half of the country, with the exception of a thin coastal strip. It was metamorphosed and intruded by plutonic rocks at around 2700 Ma. The Eburnean age province covers the eastern one third of the country and has an age of around 2150 Ma. The boundary between the two provinces is not well defined due to limited age data from east-central Liberia. The coastal regions of the northern and central parts of the country are covered by supracrustal rocks of the Neoproterozoic to lower Cambrian. Pan-African age province, which were metamorphosed and intruded at around 500 Ma as part of the Pan-African Orogeny. It is thought that these rocks were originally part of the Liberian province. Rocks in the Pan African age province are reworked and metamorphosed Archaean units similar to those of the Liberian age province, and in some cases can be correlated directly. In the east of the country, rocks in the Eburnean age province are composed of Proterozoic-age Birimian units, including supracrustal rocks, dominantly meta-sediments, imbricated with remobilized basement and intrusive units. The Toulepleu greenstone belt extends northwards into

Cote d'Ivoire. Minor sedimentary units, largely sandstone and ranging in age from Devonian to Tertiary, occur in the coastal areas to the southeast of Monrovia.

Figure 6 Tectonic map of Liberia (after MNG Gold, 2015)

Tropical weathering is also the important factor for the geology of Liberia. Intense rainfall and high temperatures generate severe tropical weathering which decomposes the rock strata causing a reduction in rock strength and inter grain bonding. This weathered matter remains in-situ. The results of all these processes are laterite and saprolite, weakened surface layer of soil matter which can be over tens of meters thick. These layers support dense vegetation and rain forests.

The predominant strike direction of the major structures such as veins is generally NE and the most common dip direction is to the NW with dip angles varying between 40° - 60°. There are series of continuous/discontinuous shear zones, composed by schist-like foliated rock with biotite-muscovite-sericite and actinolite.

1.9 Geology of Project Area

The Kokoya project area lying within the Archean aged Liberian metamorphic province is dominated by northeast-southwest trending, strongly deformed amphibolite and gneissic units, with a probable felsic rhyolite - dacite and mafic basalt origin, respectively. Amphibolite usually occurs as lenses in gneissic rock mass. Several episodes of deformation are recorded in the metamorphic rocks, including several generations of cross-cutting folding and faulting, metamorphism and locally inferred unconformities. Certain areas have undergone varying degrees of partial melting which has resulted in migmatite and pegmatite occurrences. The surface geology of the project area is presented in Figure 7. A swarm of northwest trending dolerite dykes of Jurassic age intrudes the gneisses and amphibolite. A major east-northeast trending zone of intense shearing, the St John Shear Zone, runs through the project area.

Shear zones are the host for quartz veining or intersected by veins. Two sets of quartz veins, called Rockcrusher and Caterpillar, were identified across the project area. These sets are similar in mineralogy but differ in their strike and morphology. The Rockcrusher veins strike at approximately 35° to 55° and dip to the NW at between 35° and 50°. These veins were formed by strike-slip faults and are displaced by subsequent northwest striking faults. The thickness of these veins ranges from tens of centimeters to seven meters. The Caterpillar veins strike at approximately 70° to 90° and dip to the NW at between 45° and 60°. These veins are controlled by shear zones and in many instances display a lens-like shape. The Caterpillar veins generally have a lesser thickness and shorter strike length than those of the Rockcrusher.

1.10 Lithologies in the Project Area

The typical geological profile of the shallow Kokoya Project subsurface is provided in Figure 8. The NW-SE cross section of the proposed open-pit for the different rock types and the corresponding plan view are also presented in Figure 9 and Figure 10, respectively. The basement rock in the figures refers to the magmatic and metamorphic units.

1.10.1 Saprolite & saprock

Saprolite is the product of deep tropical weathering with generally reddish-brown color, ferric compounds and sand to block size bedrock fragments. Saprolite, containing laterite and saprock, is a massive accumulation of mainly secondary clay minerals with subordinate silty sand and occasional weathered rock fragments.

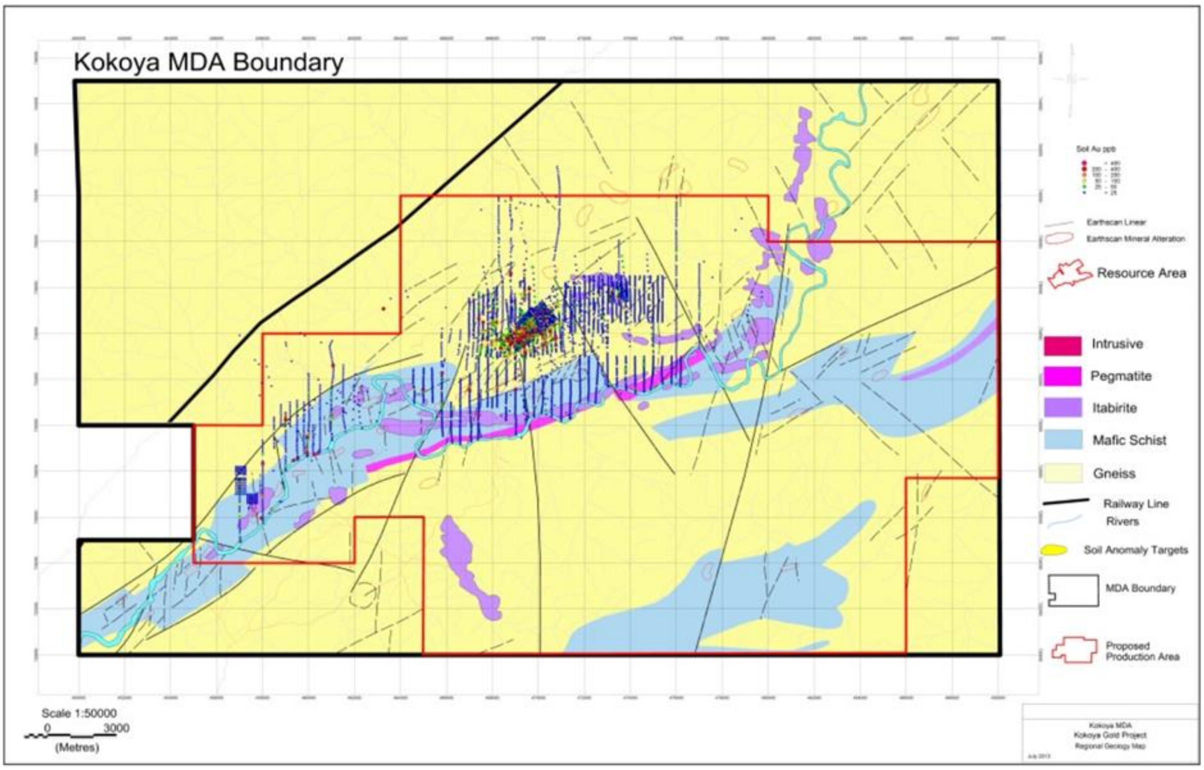


Figure 7 Geological Map of the Kokoya Gold Mine Site (after MNG GOLD, 2015)

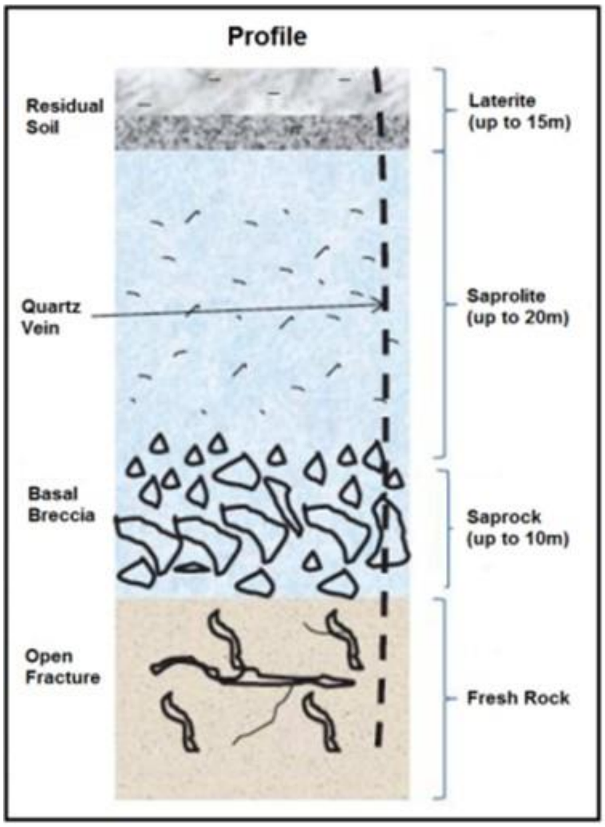


Figure 8 Typical geological profile of Kokoya Project Area (after Golder, 2015a)

The project area is covered by saprolite (including laterite) up to 30m. Under the saprolite unit, a relatively thin layer of saprock (up to 10m), which is also weathered rock with almost the same composition with saprolite but much high proportion of primary minerals and rock fragments (basal breccia), is present.

Moderately weathered basement rocks underlie the saprock. The first meters of the basement rocks are fractured and some fractures are found to be filled by secondary clay. Figure 9 and 10 show the projected view of saprolite, saprock and basement rock extents in the project area. All rock types observed within the project area are described below with their definitions.

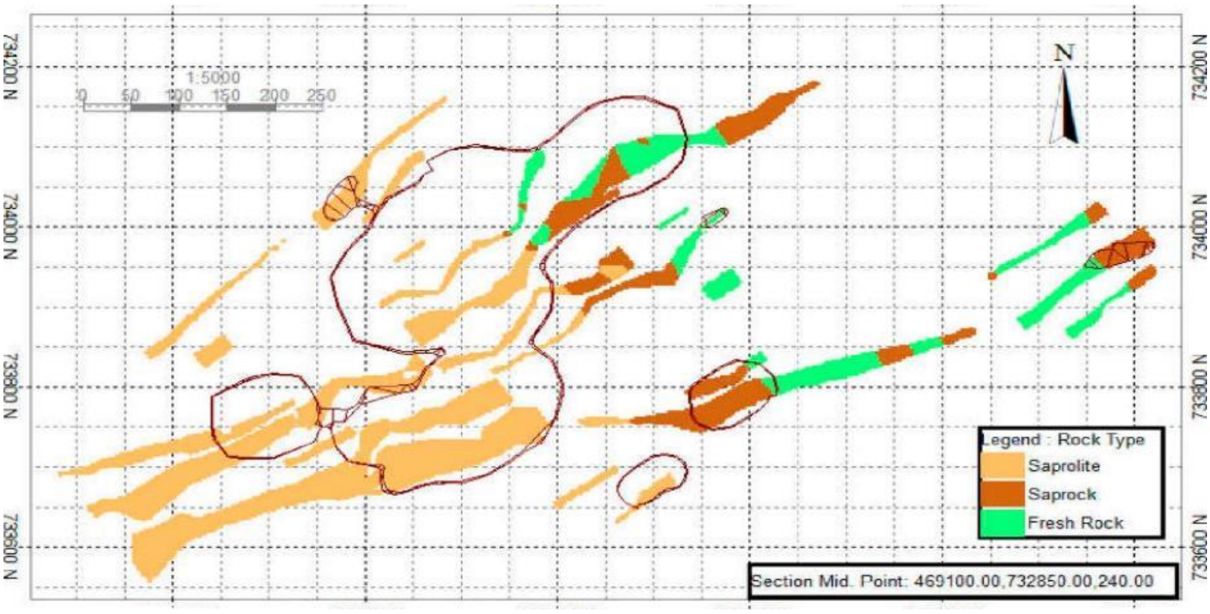


Figure 9 Plan of the pits of the Kokoya Gold Mine (after PMDE, 2014)

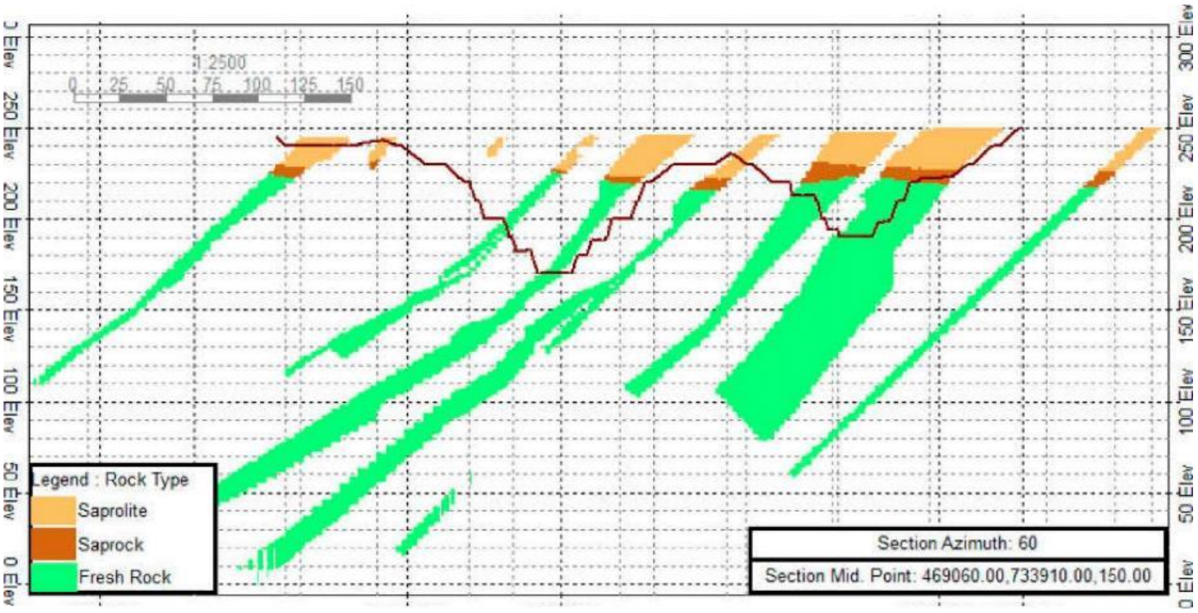


Figure 10 Northwest-southeast cross-section of the pits (after PMDE, 2014)

1.10.2 Basement rock units:

1.10.2.1 Amphibolite

There are three principal varieties of Amphibolite: Massive Amphibolite (AM), Feldspar Porphyry Amphibolite (AMP) and Augen Amphibolite (AMA). The most widespread one is Massive Amphibolite. AM units include hornblende, quartz, feldspar, biotite as major minerals. Trace minerals include actinolite, ilmenite, magnetite, sphene, apatite, epidote, and zircon. They differ from each other by their origin, color, texture and the abundance of accessory minerals. AM whose origin being metamorphosed basalt is relatively competent and forms relatively stable blocks. It is dark-green to greenish-black colored, fine- and equally-grained, and massive with porphyry traces of lamination. Feldspar Porphyry Amphibolite whose origin being metamorphosed porphyry andesite is relatively competent rock. It is dark-green with numerous light-grey or white spots, massive with traces of lamination and textured. Augen Amphibolite whose origin being supposedly metamorphosed basalt with phenocrysts of olivine (or pyroxene) is incompetent rock. It is brown-green with dark-green 'augens', layered and augen textured.

1.10.2.2 Schist

The rock Schist (SC) whose origin being metamorphosed sediments is light-green to dark-brown and greenish- black colored, foliated, laminated-layered, fine to medium grained (0.1 to 3 mm), and lepidoblastic and lepidogranoblastic. It consists of chlorite, muscovite, biotite, amphiboles (tremolite, actinolite), hornblende, quartz, and feldspar minerals and contains zircon, sphene, apatite and epidote as accessory mineral, and ilmenite and magnetite. It is very widespread and can be divided into three groups based on the composition which are Biotite Schist (SCB), Actinolite Schist (SCA) and Muscovite Schist (SCM). Biotite Schist is relatively hard and all with dark brown biotite varieties including biotite-actinolite, biotite, biotite-hornblende, quartz-feldspar-biotite. Actinolite Schist is all green and relatively soft varieties, including tremolite-actinolite, chlorite-actinolite. Muscovite Schist is light-greenish-grey and relatively soft varieties with predominance of muscovite.

1.10.2.3 Granite

Granite is dark grey with white spots to light grey colored, massive, medium grained (2-4 mm), granoblastic and porphyry textured rock. It consists of quartz, feldspar, biotite, hornblende, muscovite minerals, and contains zircon, sphene as accessory mineral and ilmenite. Granite forms concordant, narrow (up to ten meters) lens- or vein-like bodies. Origin of it is anatexis (selective melting) of the metamorphosed sediments with partial shift of the melted leucosoma (enriched in fluids felsic material) the final (and central) member of the chain sediments - schist - migmatite - gneiss. Three varieties of Granite can be distinguished: Melanocratic Porphyry Granite with a predominance of dark fine-grained matrix over the coarse (3-5 mm) metasomatic porphyroblasts of feldspar (or quartz), Mesocratic Granite (GR) with approximately equal amounts of dark and light minerals, is usually equally-grained, and Leucocratic Granite (GRL) with a predominance of light minerals, is also equally-grained.

1.10.2.4 Pegmatite and Quartzite

Pegmatite (PG) consists of vein-like bodies of quartz-feldspar. Quartzite (QW) is the same as Pegmatite but it has a strong prevalence of quartz over the feldspar. The rocks are white-grey spotted, massive to irregular and coarse grained. They consist of quartz, feldspar, muscovite, biotite minerals and contain sphene as accessory mineral. Similar to Granite, the origin of these rocks is anatexis (selective melting) of the metamorphosed sediments with partial shift of the melted leucosoma (enriched in fluids felsic material); along with granite - the final member of the chain sediments - schist - migmatite - granite of pegmatite. Concordant or sub-concordant lens- or vein-like bodies with indistinct contacts are typical. Distinct from quartz veins, they have fuzzy contacts and the presence of 'shadow' structures, while they formed from relicts of dark minerals. In contrast to quartz veins, pegmatite and quartzite usually demonstrate just background gold content.

1.10.2.5 Very High-Grade Metamorphic Units (VHM)

Gneiss:

The rock Gneiss whose origin is metamorphosed sediments or basalts (through schist or amphibolite), product of the migmatite process (with increase in silica potassium), is streaky light-grey to dark-grey colored, medium-grained (1-5 mm) and lepidogranoblastic. It consists of biotite, hornblende, quartz, feldspar and muscovite minerals, and contains zircon, sphene, apatite, epidote ilmenite and magnetite. It is not widespread but it can be distinguished as Melanocratic Gneiss (GNM) with predominance of dark minerals (biotite, hornblende), Mesocratic Gneiss (GN) with approximately equal amounts of dark and light, and Leucocratic Gneiss (GNL) with a predominance of light minerals.

Migmatite:

The rock Migmatite is interchange of light-grey or white and dark-grey or dark-greenish-grey, layered, irregular, folded and fine - to medium grained. It is transformed schist or amphibolite, a product of metamorphism, accompanied by an increase in silica content (as quartz) and potassium (K-feldspar). It is present as numerous quartz-feldspar segregations (nests, veinlets, and porphyroblasts). It consists of biotite, hornblende, actinolite, quartz, feldspar minerals, and contains zircon, sphene, apatite, epidote ilmenite and magnetite as ore minerals. There are three type of Migmatite: Melanocratic Migmatite (MGM) with a predominance of dark matrix, Leucocratic Migmatite (MGL) with a predominance of light segregations, Mesocratic Migmatite (MG) with approximately equal amount of matrix and segregations.

Mylonite and Blastomylonite:

Mylonite (ML) and Blastomylonite (mylonite with fragments) (MLB) are grey to dark greenish to grey-colored, layered-laminated, irregular, porphyry and foliated. They consist of quartz, feldspar, muscovite, chlorite minerals, and contain sphene, apatite, zircon as accessory mineral and ilmenite, magnetite as ore mineral. Mylonite is ductile deformed rock formed in the large faults. Dynamic recrystallization of the constituent minerals results in a reduction of the grain size of the rock. The mineralogical composition depends on the original rocks. It is similar to schist, with the principal difference being that mylonite was formed after the main phase of metamorphism; therefore, there are numerous porphyroblasts of quartz-feldspar composition (migmatite, pegmatite, granite) in the mylonite. Mylonite zones usually trace more ancient shear (schist) zones and can play an important role in the ore localization, acting as the structural traps.

HYDROGEOLOGY

As stated in Golder (2015a) the rivers in Liberia are predominantly rain fed and not aquifer fed. Rural domestic water supplies are generally drawn from open sources such as rivers or streams and from the groundwater. The water table is, on average, between seven meters and thirteen meters below surface.

The hydrostratigraphic units in the study area comprises -from top to bottom- of;

i) Saprolite zone (~20 m thick);

ii) Saprock Zone (~10 m thick); and,

iii) Basement Rock (fresh bedrock) Zone

Hydraulic conductivity of these units decreases from the surface toward the depths of bedrock. Hydraulic conductivity (K) values of saprolite, saprock and basement rock units are in the order 10^{-6} m/s, 10^{-7} m/s and 10^{-8} m/s, respectively and, probably decreases 10^{-9} m/s or lower at the greater depths of the bedrock hosting the gold-rich quartz veins. The Saprolite layer is a shallow hydrogeological unit of less significance formed by the weathering of the underlying rock. The saprolite generally shows a high degree of heterogeneity between its clay and sandy constituents and as such, layers of variable permeability are often present. The highest hydraulic conductivity in the saprolite is often associated with the saprock at its base as it is fractured and less weathered and therefore contains less clay than the overlying laterite. Deep lateritic zones can, however provide significant storage to the underlying saprock aquifer unit

The hydraulic conductivity of the bedrock is more dependent on the rock competency than its mineralogy. The flow of groundwater in this zone is structurally controlled with water movement occurring through fractured and weathered zones. Water storage is low due to the majority of the rock mass being impermeable, but the ability to transmit water can be high through the fracture systems which can control the groundwater flow. (PMDE, 2014). Significant water storage from the overlying laterite, depending on its thickness, can however be drawn into the basement rock through vertical leakage.

1.11 Surface Water Resources

Several smaller ephemeral streams drain the project area and flow into St. John River which is the southern boundary of the study area. St. John River is one of the major rivers in Liberia. It has a catchment area of 17,089 km^2, 14,509 km^2 of which is in Liberia (UN, 1988). Golder (2015a) determined a total of 16 sub-catchments in the study area, based on the surface water monitoring locations and the topography. The surface water monitoring stations, used prior to the Construction Phase and during the Operation Phase are shown in Figure 11a, along with the sub-catchments.

Yeakpaniyou and Gbosia Streams are ephemeral streams draining pits and WRD area from northeast towards south. The streams draining the project facilities are the tributaries of Qua Stream.

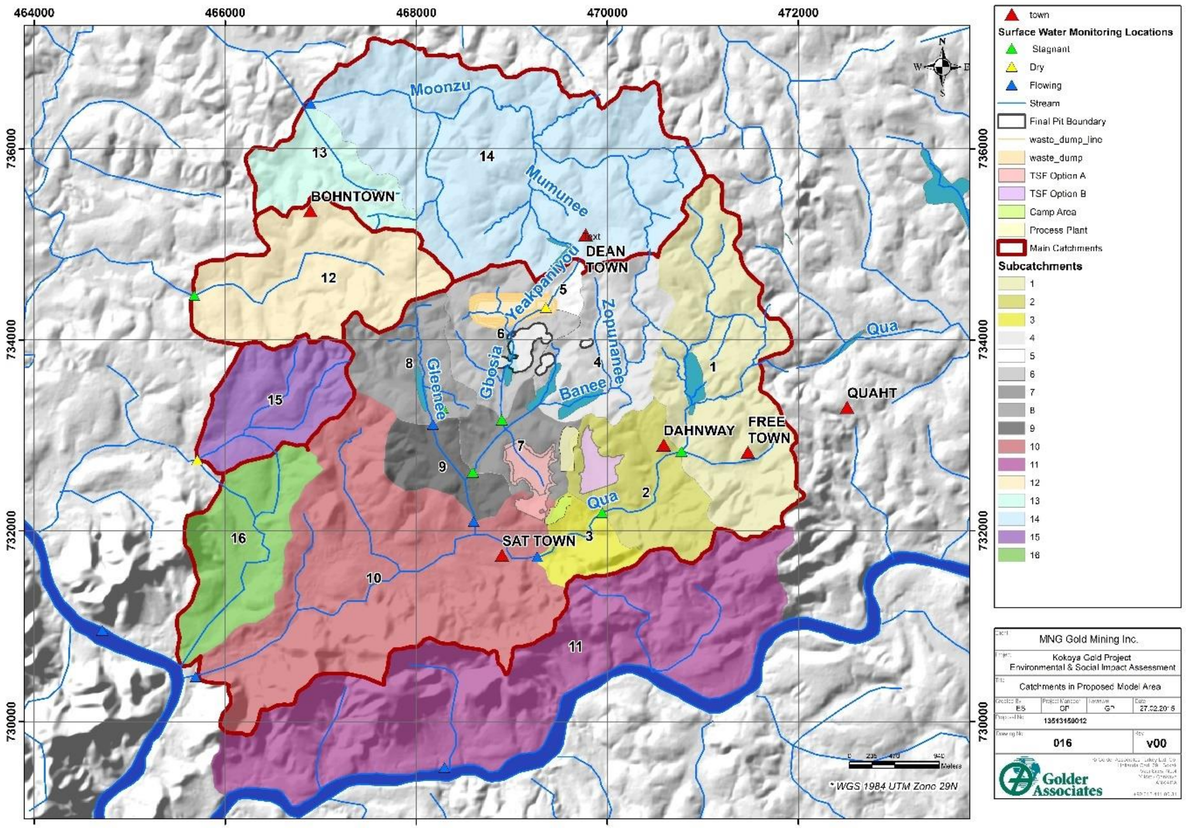


Figure 11a Sub-catchments and the surface water monitoring stations in the hydrogeological basin of the Kokoya Gold Mine (after Golder, 2015a)

1.12 Groundwater Resources

1.12.1 Hand-dug wells & Existing groundwater wells

Many hand-dug wells, boreholes, springs and creeks were identified by the survey team for hydrogeological assessment (Golder 2015a) during the hydrocensus undertaken in and around Sayeweh Town, Dean Town, the Rock Crusher, Bahn Town, Dahnway Town, Gbon Town and Quah Town.

The spatial locations of these points were geo-referenced and site codes assigned to each point. The locations of hand dug wells and existing groundwater wells identified during the hydrocensus are presented in Figure 11b. The static water levels were measured as well as total depth of the wells (Table 2).

At some locations, measurements could not be taken either because the hand pumps or borehole were sealed up or had been blocked with rocks that were put into them.

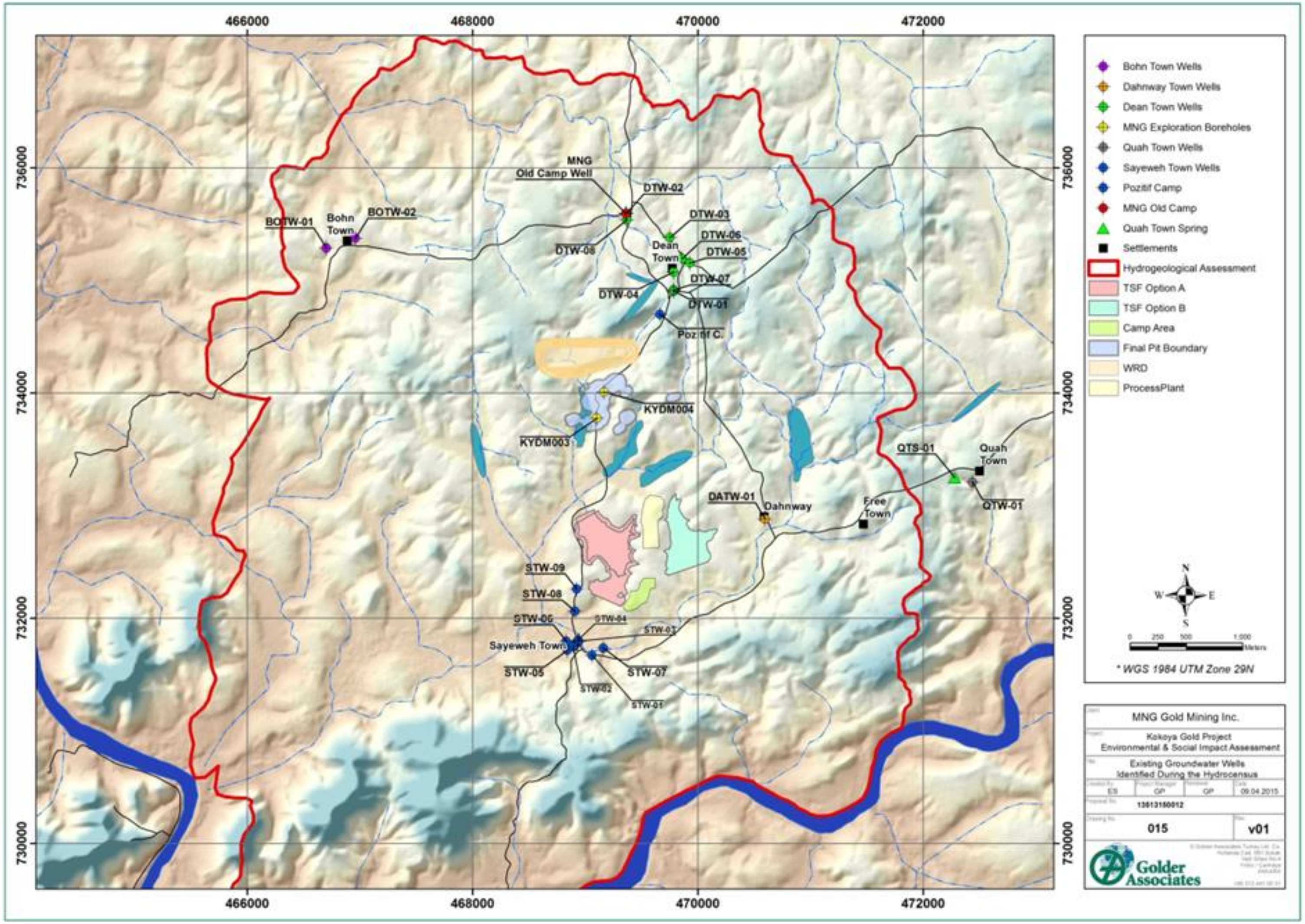
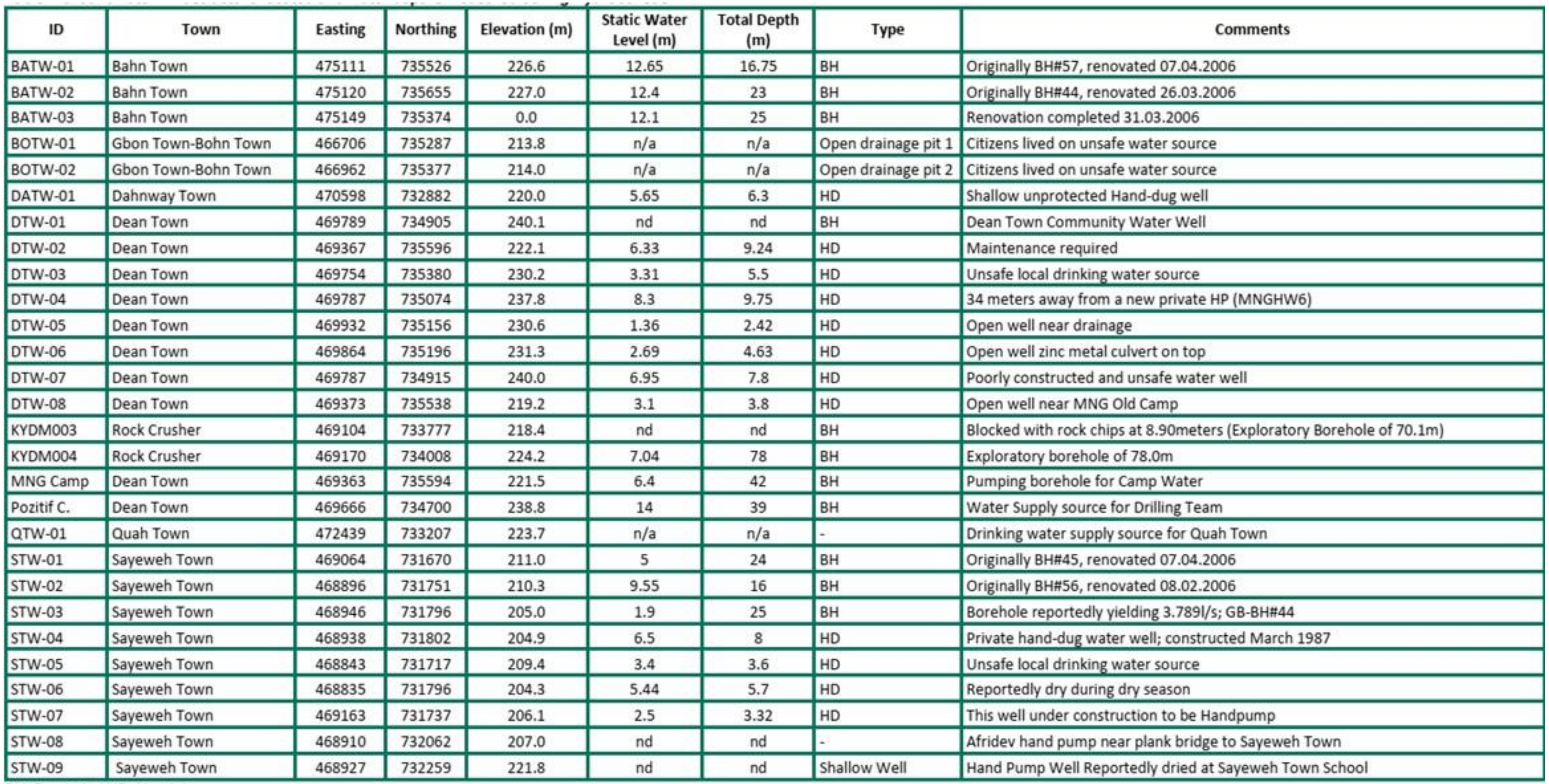


Figure 11b Map showing the locations of hand-dug wells and existing groundwater wells identified during the hydrocensus (after Golder, 2015a)

Table 2 Groundwater infrastructure located and water depths measured during hydrocensus (after Golder, 2015a)



ID	Town	Easting	Northing	Elevation (m)	Static Water Level (m)	Total Depth (m)	Type	Comments
BATW-01	Bahn Town	475111	735526	226.6	12.65	16.75	BH	Originally BH#57, renovated 07.04.2006
BATW-02	Bahn Town	475120	735655	227.0	12.4	23	BH	Originally BH#44, renovated 26.03.2006
BATW-03	Bahn Town	475149	735374	0.0	12.1	25	BH	Renovation completed 31.03.2006
BOTW-01	Gbon Town-Bohn Town	466706	735287	213.8	n/a	n/a	Open drainage pit 1	Citizens lived on unsafe water source
BOTW-02	Gbon Town-Bohn Town	466962	735377	214.0	n/a	n/a	Open drainage pit 2	Citizens lived on unsafe water source
DATW-01	Dahnway Town	470598	732882	220.0	5.65	6.3	HD	Shallow unprotected Hand-dug well
DTW-01	Dean Town	469789	734905	240.1	nd	nd	BH	Dean Town Community Water Well
DTW-02	Dean Town	469367	735596	222.1	6.33	9.24	HD	Maintenance required
DTW-03	Dean Town	469754	735380	230.2	3.31	5.5	HD	Unsafe local drinking water source
DTW-04	Dean Town	469787	735074	237.8	8.3	9.75	HD	34 meters away from a new private HP (MNGHW6)
DTW-05	Dean Town	469932	735156	230.6	1.36	2.42	HD	Open well near drainage
DTW-06	Dean Town	469864	735196	231.3	2.69	4.63	HD	Open well zinc metal culvert on top
DTW-07	Dean Town	469787	734915	240.0	6.95	7.8	HD	Poorly constructed and unsafe water well
DTW-08	Dean Town	469373	735538	219.2	3.1	3.8	HD	Open well near MNG Old Camp
KYDM003	Rock Crusher	469104	733777	218.4	nd	nd	BH	Blocked with rock chips at 8.90meters (Exploratory Borehole of 70.1m)
KYDM004	Rock Crusher	469170	734008	224.2	7.04	78	BH	Exploratory borehole of 78.0m
MNG Camp	Dean Town	469363	735594	221.5	6.4	42	BH	Pumping borehole for Camp Water
Pozitif C.	Dean Town	469666	734700	238.8	14	39	BH	Water Supply source for Drilling Team
QTW-01	Quah Town	472439	733207	223.7	n/a	n/a	-	Drinking water supply source for Quah Town
STW-01	Sayeweh Town	469064	731670	211.0	5	24	BH	Originally BH#45, renovated 07.04.2006
STW-02	Sayeweh Town	468896	731751	210.3	9.55	16	BH	Originally BH#56, renovated 08.02.2006
STW-03	Sayeweh Town	468946	731796	205.0	1.9	25	BH	Borehole reportedly yielding 3.789l/s; GB-BH#44
STW-04	Sayeweh Town	468938	731802	204.9	6.5	8	HD	Private hand-dug water well; constructed March 1987
STW-05	Sayeweh Town	468843	731717	209.4	3.4	3.6	HD	Unsafe local drinking water source
STW-06	Sayeweh Town	468835	731796	204.3	5.44	5.7	HD	Reportedly dry during dry season
STW-07	Sayeweh Town	469163	731737	206.1	2.5	3.32	HD	This well under construction to be Handpump
STW-08	Sayeweh Town	468910	732062	207.0	nd	nd	-	Afridev hand pump near plank bridge to Sayeweh Town
STW-09	Sayeweh Town	468927	732259	221.8	nd	nd	Shallow Well	Hand Pump Well Reportedly dried at Sayeweh Town School

BH: Borehole / HD: Hand dug

1.12.2 Groundwater monitoring wells

Within the scope of Kokoya Project, 11 groundwater wells and one water supply well were drilled to provide data for Golder (2015a) Report. Later on, some of these wells were abandoned due to project activities during the Construction and Operation Phases. However, new wells were drilled in order to sustain the monitoring activities.

Before the Operation Phase, four of the groundwater wells (KDW01, KDW02, KDW03 and KDW04) were drilled at the proposed open pit areas. KDW01 and KDW02 were drilled at the Rockcrusher Pit, KDW03 was drilled at the Adana Pit and KDW04 was drilled at the Istanbul Pit. KDWs are diamond drilled boreholes which were converted in standpipe piezometers for water level measurements.

KDW01: KDW-01 was drilled at the Rockcrusher Pit area. The well drilled down to 80 m bgl (below ground level) or 144 m asl, which is below the proposed final pit-floor elevation. The borehole was drilled with a 96 mm diamond drill bit and completed with 63 mm UPVC casing. The static groundwater level (SWL) was measured at 5.27 m bgl. The main lithology encountered during the drilling of this borehole has been described as metamorphic rock with quartz veins. The first 17m or so were logged as laterite and saprolite.

KDW02: KDW-02 was also drilled at the Rockcrusher Pit area. The well drilled down to 60 m bgl or 168 m asl, which is also lower than the proposed final pit-floor elevation of the pit. The borehole was drilled with a 96 mm diamond drill bit and completed with 63 mm UPVC casing. Groundwater was measured at 9.77 m bgl. The main lithology encountered during the drilling of this borehole was metamorphic rock with quartz veining. The first 15m or so were logged as laterite.

KDW03: KDW-03 was drilled at the Adana Pit area and drilled down to 40 m bgl. The borehole reached 195 m asl, which is below the proposed final pit-floor. The borehole was drilled with a 96 mm diamond drill bit and completed with 63 mm UPVC casing. Groundwater was measured at 7.85 m bgl. The main lithology encountered during the drilling of this borehole was metamorphic rocks, with quartz vein Laterite extends to a depth of 25 m bgl is laterite.

KDW04: KDW-04 was drilled at the İstanbul Pit area. The borehole was drilled down to 60 m bgl reaching 157 m asl, which is also below the proposed final pit-floor elevation. The borehole was drilled with a 96 mm diamond drill bit and completed with 63 mm UPVC casing. Groundwater was measured at 3.21 m bgl. The main lithology encountered in this borehole during drilling was metamorphic rock with minor quartz veining. The first 30 m or so below surface were logged as laterite and saprolite.

Figure 12 Diamond Drilling at KDW03 (after Golder, 2015a)

In addition to the core-drilled KDW boreholes, seven groundwater monitoring wells (KMW01, KMW02, KMW03, KMW04, KMW05, KMW06 and KMW07) and one water supply well (KWS) were drilled for the purpose of monitoring the water levels and supplying water. All eight wells were drilled by the RC (reverse circulation) drilling system. The following boreholes with the exception of boreholes KMW06, KMW07 and KMS were drilled with a 6-inch (152.4 mm) hammer constructed with 125 mm PVC (polyvinyl chloride) casing.

KMW01: Borehole KMW-01 was drilled between the Arhavi Pit and the waste dump. The borehole was drilled to a depth of 50 m bgl. The SWL (static groundwater level) was measured at 9.82 m bgl.

KMW02: Borehole KMW-02 was drilled in the downstream of Adana Pit. The borehole was drilled to a depth of 40 m bgl. The SWL was measured at 4.61 m bgl.

KMW03: Borehole KMW-03 was drilled in the vicinity of İstanbul Pit. The borehole was drilled down to 60 m bgl. The SWL was measured at 11.58 m bgl.

KMW04: Borehole KMW-04 was drilled in the upstream of the waste dump. The borehole was drilled down to 46 m bgl. The SWL was measured at 4.77 m bgl.

KMW05: Borehole KMW-05 was drilled between the Arhavi Pit and the waste dump. The borehole was drilled to 40 m bgl. The SWL was measured at 1.56 m bgl.

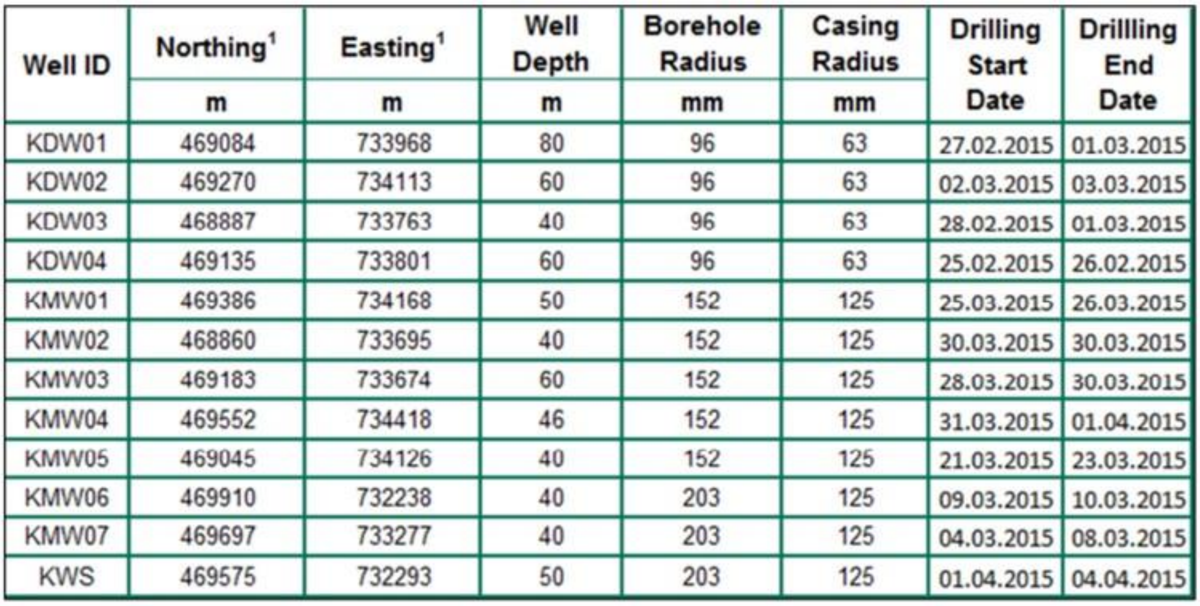
KMW06: Borehole KMW-06 was drilled in the downstream of the proposed tailings. The borehole was drilled with an 8 inch (203.2 mm) hammer and constructed with 125 mm PVC casing down to 40 m bgl. The SWL was measured at 3.83 m bgl.

KMW07: Borehole KMW-07 was drilled in the upstream of the proposed tailings. The borehole was drilled with an 8 inch (203.2 mm) hammer and constructed with 125 mm PVC casing down to 40 m bgl. The SWL was measured at 8.05 m bgl.

KWS: Borehole KWS was drilled at the Camp Area. The borehole was drilled down to 50 m bgl. The SWL was measured at 7.70 m bgl.

Information on groundwater wells are provided in Table 3. Groundwater well locations are shown in Figure 13.

Table 3 Information on groundwater monitoring wells



Well ID	Northing[1]	Easting[1]	Well Depth	Borehole Radius	Casing Radius	Drilling Start Date	Drillling End Date
	m	m	m	mm	mm		
KDW01	469084	733968	80	96	63	27.02.2015	01.03.2015
KDW02	469270	734113	60	96	63	02.03.2015	03.03.2015
KDW03	468887	733763	40	96	63	28.02.2015	01.03.2015
KDW04	469135	733801	60	96	63	25.02.2015	26.02.2015
KMW01	469386	734168	50	152	125	25.03.2015	26.03.2015
KMW02	468860	733695	40	152	125	30.03.2015	30.03.2015
KMW03	469183	733674	60	152	125	28.03.2015	30.03.2015
KMW04	469552	734418	46	152	125	31.03.2015	01.04.2015
KMW05	469045	734126	40	152	125	21.03.2015	23.03.2015
KMW06	469910	732238	40	203	125	09.03.2015	10.03.2015
KMW07	469697	733277	40	203	125	04.03.2015	08.03.2015
KWS	469575	732293	50	203	125	01.04.2015	04.04.2015

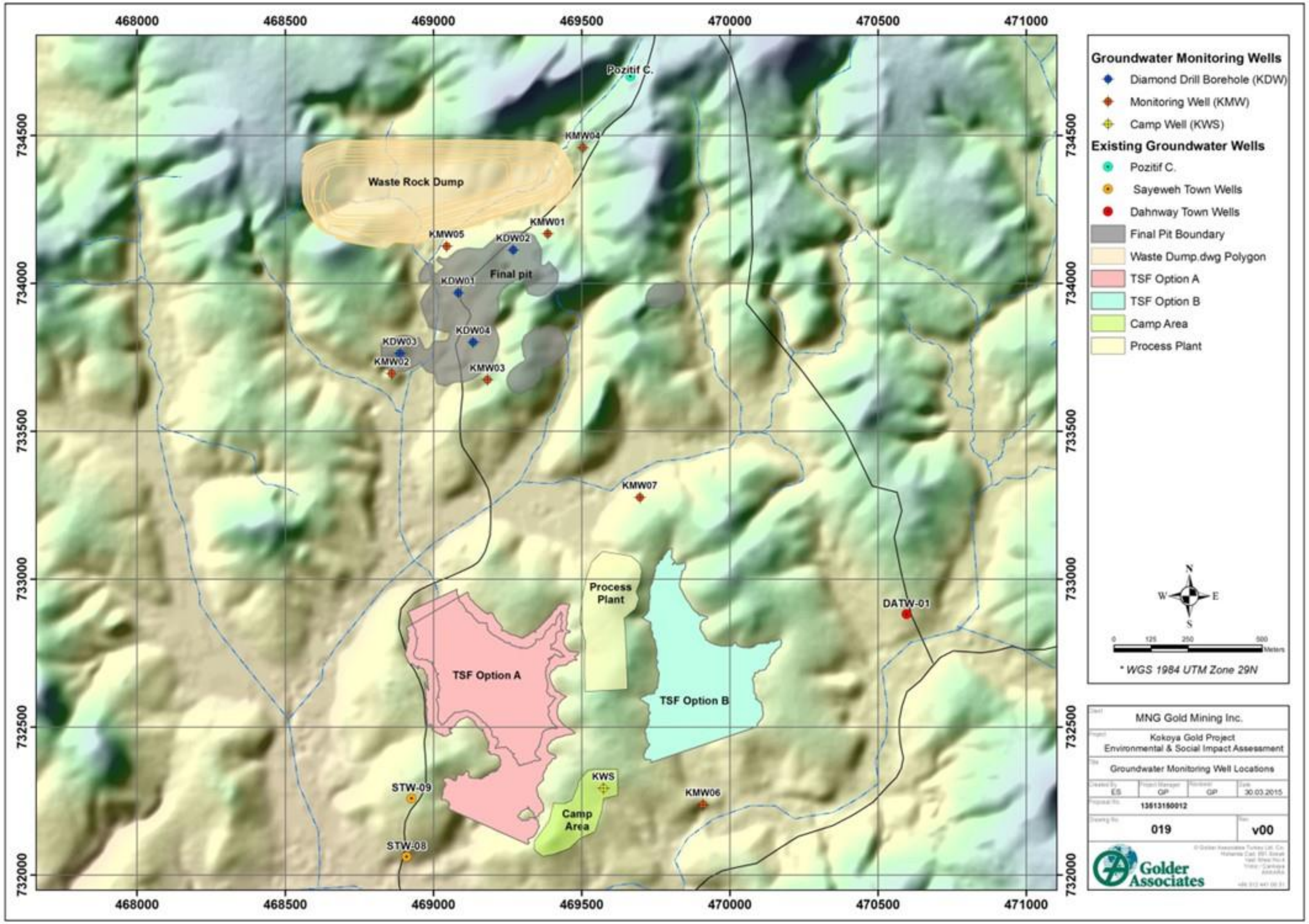


Figure 13 Groundwater monitoring well locations (after Golder, 2015a)

1.13 Groundwater Levels and Flow Directions

A hydrocensus was undertaken in and around the study area in January 2015 by Golder (2015a). Records of the survey indicates that the static water level measurements of the borehole and shallow well range from 0 m bgl to 10 m bgl. Water levels measured from the hand dug wells and some existing groundwater wells were taken into consideration (Table 4). Additionally, water levels measured from the new groundwater monitoring wells (Table 5) were used to interpret the site wide water table elevation map (Figure 14). Sections showing the groundwater levels in the proposed pits are provided in Figure 15.

Figure 16 shows the locations of the temporal groundwater level variation during the Construction and Operational Phases and the location data used in this figure are provided in Table 6.

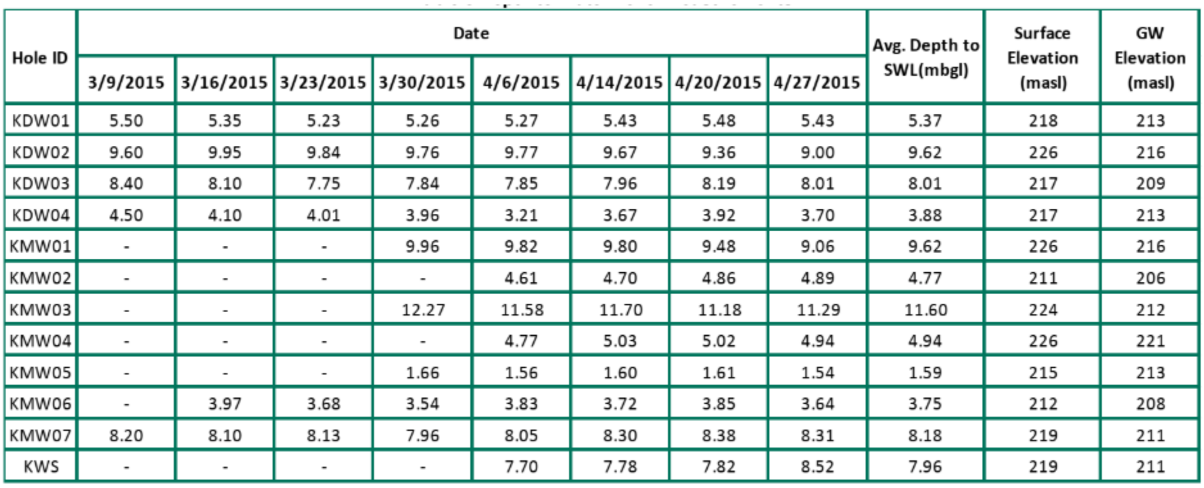
Weekly variation of groundwater level between 9th March 2015 and 21st October, 2019 is presented in Figure 17. As seen from the figure, groundwater level in many of the boreholes is temporally stable and shows minor oscillations that can be attributed to seasonal recharge fluctuations. Groundwater levels in the boreholes KDW03, KMW01, KMW03 and KMW06 located around the open pit declines in time as the pit bottom deepened by excavation. For example, the groundwater level in KMW03 borehole declines from about 12 m bgl in March 2015 to 40 m bgl in October 2019 (38 m in 4 years). This shows that fact the open pit functions as a drain and collects the groundwater around it. However, the groundwater levels in other boreholes, including the domestic use wells, located remotely from the open pit have not been affected by the mining activities. Weekly groundwater level data is presented in Attachment-1.

A recent hydraulic head distribution in the hydrogeological assessment area is shown in Figure 18 along with the water points, data of which have been used in preparation of the map. Groundwater heads declines from about 230 m asl at the northeast of the hydrogeological assessment area to about 185 m asl at the southwest where the St. John River leaves the study area. In general, as one can expect, the overall hydrogeological system seems to drain toward the St. John River.

Table 4 Groundwater level measurements at the existing water points (after Golder, 2015a)

Well ID	Town	Easting	Northing	Surface Elevation (masl)	Depth to SWL (mbgl)	GW Elevation (masl)
BOTW-01	Gbon (Bohn) Town	466706	735287	214	0	214
BOTW-02		466962	735377	214	0	214
DATW-01	Dahnway Town	470598	732882	220	5.65	214
DTW-02	Dean Town	469367	735596	222	6.33	216
DTW-03		469754	735380	230	3.31	227
DTW-04		469787	735074	238	8.3	230
DTW-05		469932	735156	231	1.36	229
DTW-06		469864	735196	231	2.69	229
DTW-07		469787	734915	240	6.95	233
DTW-08		469373	735538	219	3.1	216
KYDM004		469170	734008	224	7.04	217
QTS-01	Quah Town	472283	733249	231	0	231
STW-01	Sayeweh Town	469064	731670	211	5	206
STW-02		468896	731751	210	9.55	201
STW-03		468946	731796	205	1.9	203
STW-04		468938	731802	205	6.5	198
STW-05		468843	731717	209	3.4	206
STW-06		468835	731796	204	5.44	199
STW-07		469163	731737	206	2.5	204

Table 5 Groundwater depth from well head (after Golder, 2015a)



Hole ID	Date								Avg. Depth to SWL(mbgl)	Surface Elevation (masl)	GW Elevation (masl)
	3/9/2015	3/16/2015	3/23/2015	3/30/2015	4/6/2015	4/14/2015	4/20/2015	4/27/2015			
KDW01	5.50	5.35	5.23	5.26	5.27	5.43	5.48	5.43	5.37	218	213
KDW02	9.60	9.95	9.84	9.76	9.77	9.67	9.36	9.00	9.62	226	216
KDW03	8.40	8.10	7.75	7.84	7.85	7.96	8.19	8.01	8.01	217	209
KDW04	4.50	4.10	4.01	3.96	3.21	3.67	3.92	3.70	3.88	217	213
KMW01	-	-	-	9.96	9.82	9.80	9.48	9.06	9.62	226	216
KMW02	-	-	-	-	4.61	4.70	4.86	4.89	4.77	211	206
KMW03	-	-	-	12.27	11.58	11.70	11.18	11.29	11.60	224	212
KMW04	-	-	-	-	4.77	5.03	5.02	4.94	4.94	226	221
KMW05	-	-	-	1.66	1.56	1.60	1.61	1.54	1.59	215	213
KMW06	-	3.97	3.68	3.54	3.83	3.72	3.85	3.64	3.75	212	208
KMW07	8.20	8.10	8.13	7.96	8.05	8.30	8.38	8.31	8.18	219	211
KWS	-	-	-	-	7.70	7.78	7.82	8.52	7.96	219	211

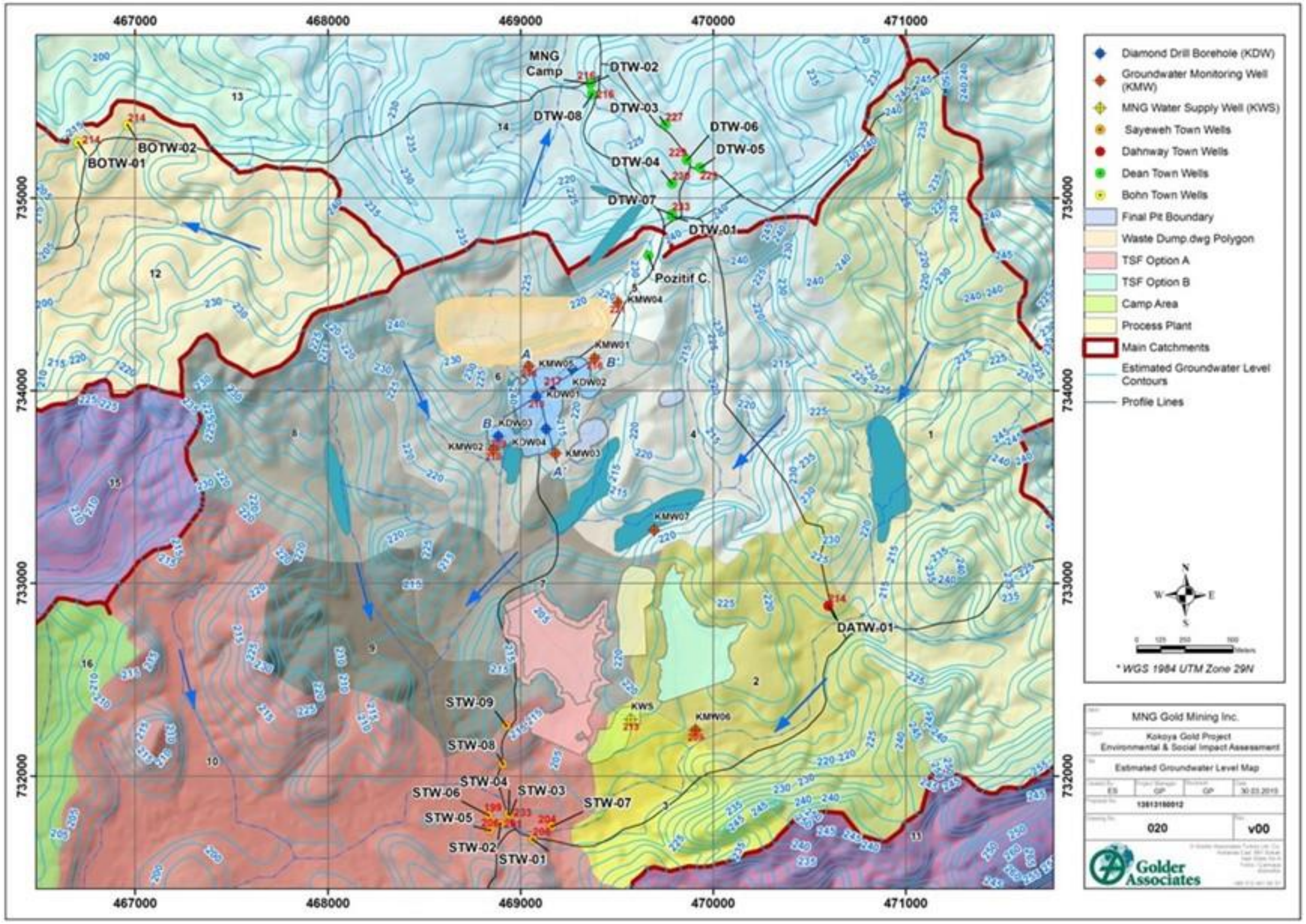


Figure 14 Groundwater level map and flow directions around the open pits in 2015 (After Golder, 2015a)

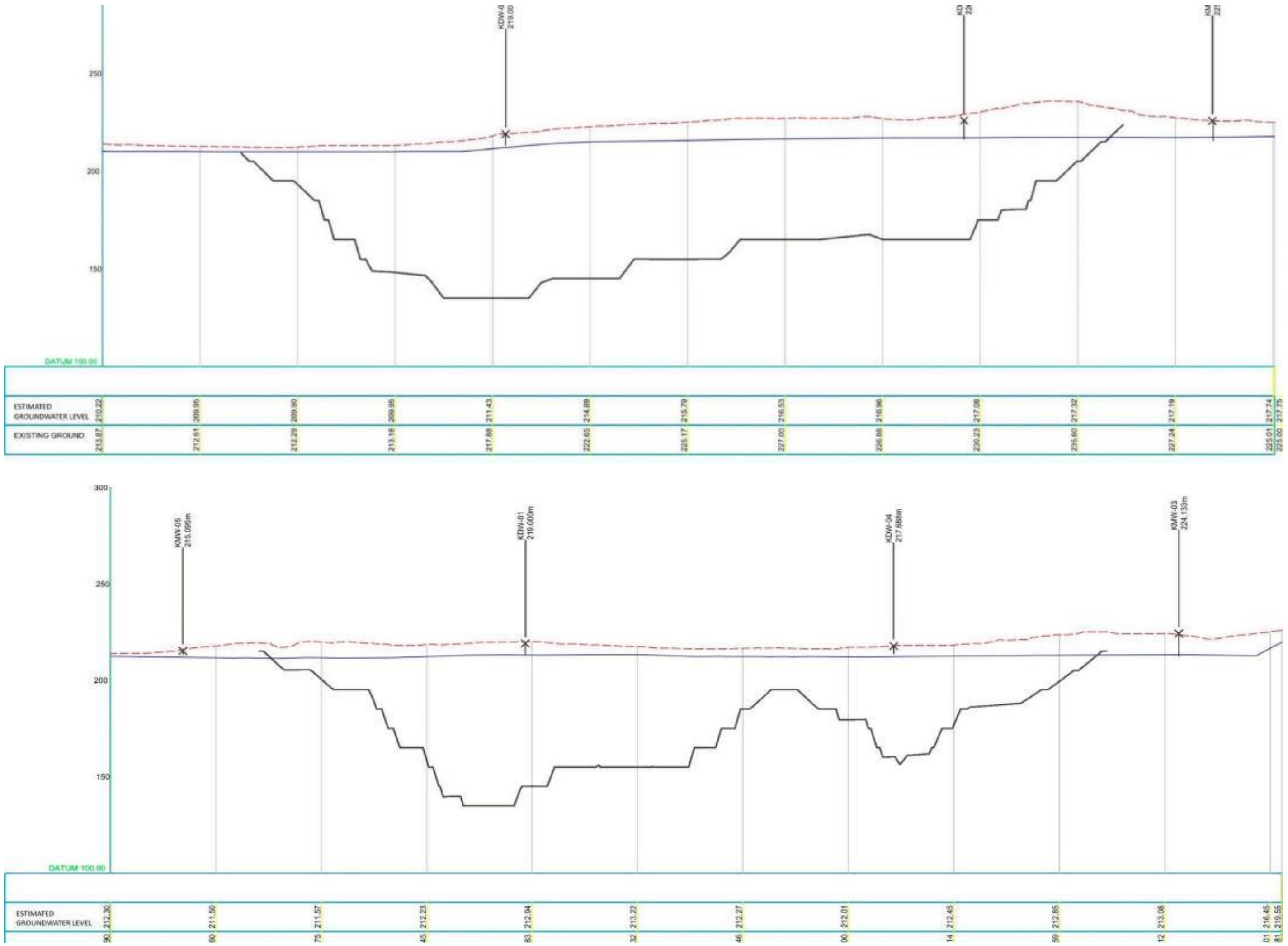


Figure 15 A-A’ (top) and B-B’ cross-sections showing the Rockcrusher final pit geometry and the pristine topographic and groundwater levels (after Golder, 2015a) (Adana and Arhavi pits are located at the left and right, respectively)

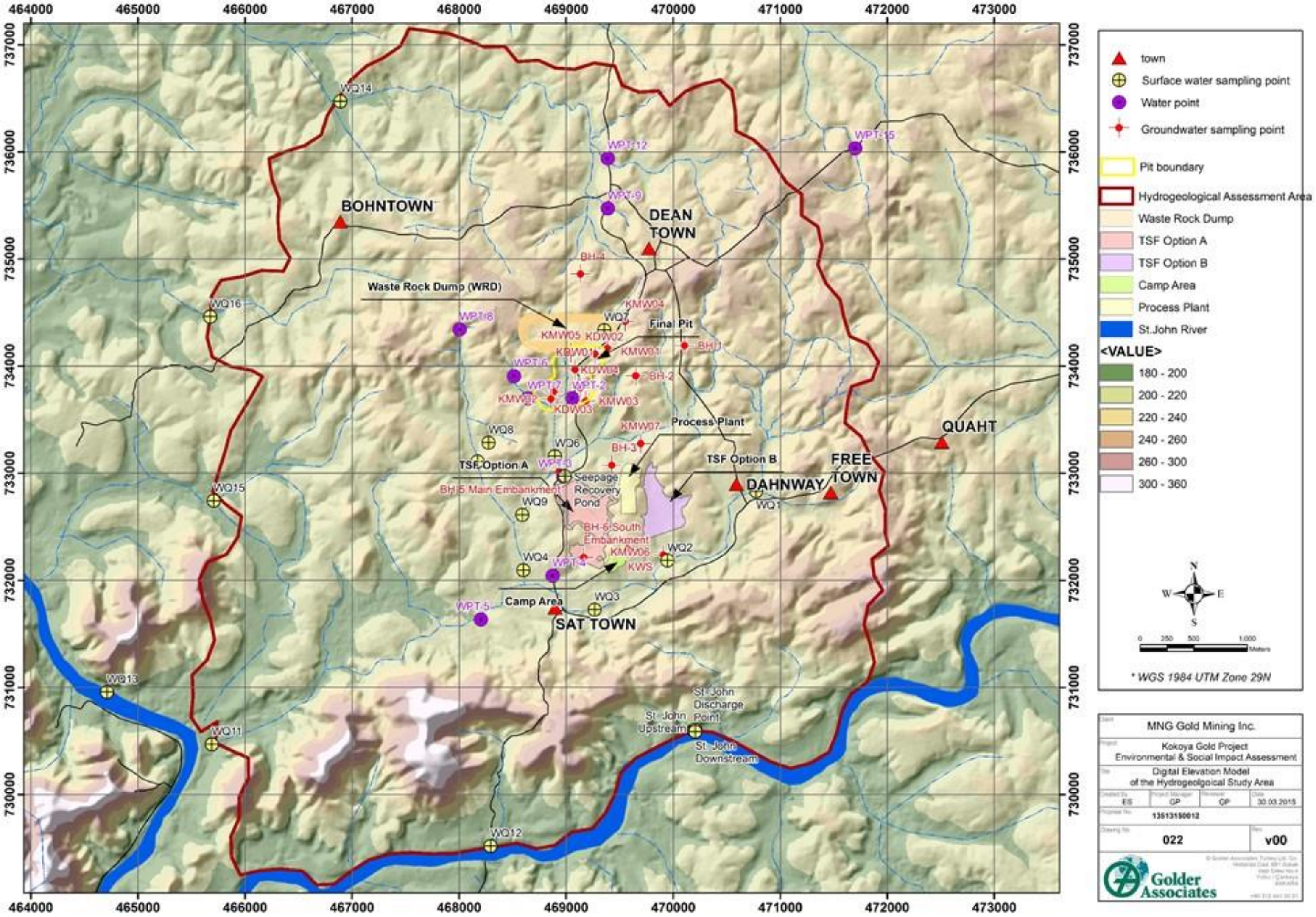


Figure 16 Location of groundwater level monitoring wells used during the Construction and Operational Phases (This study)

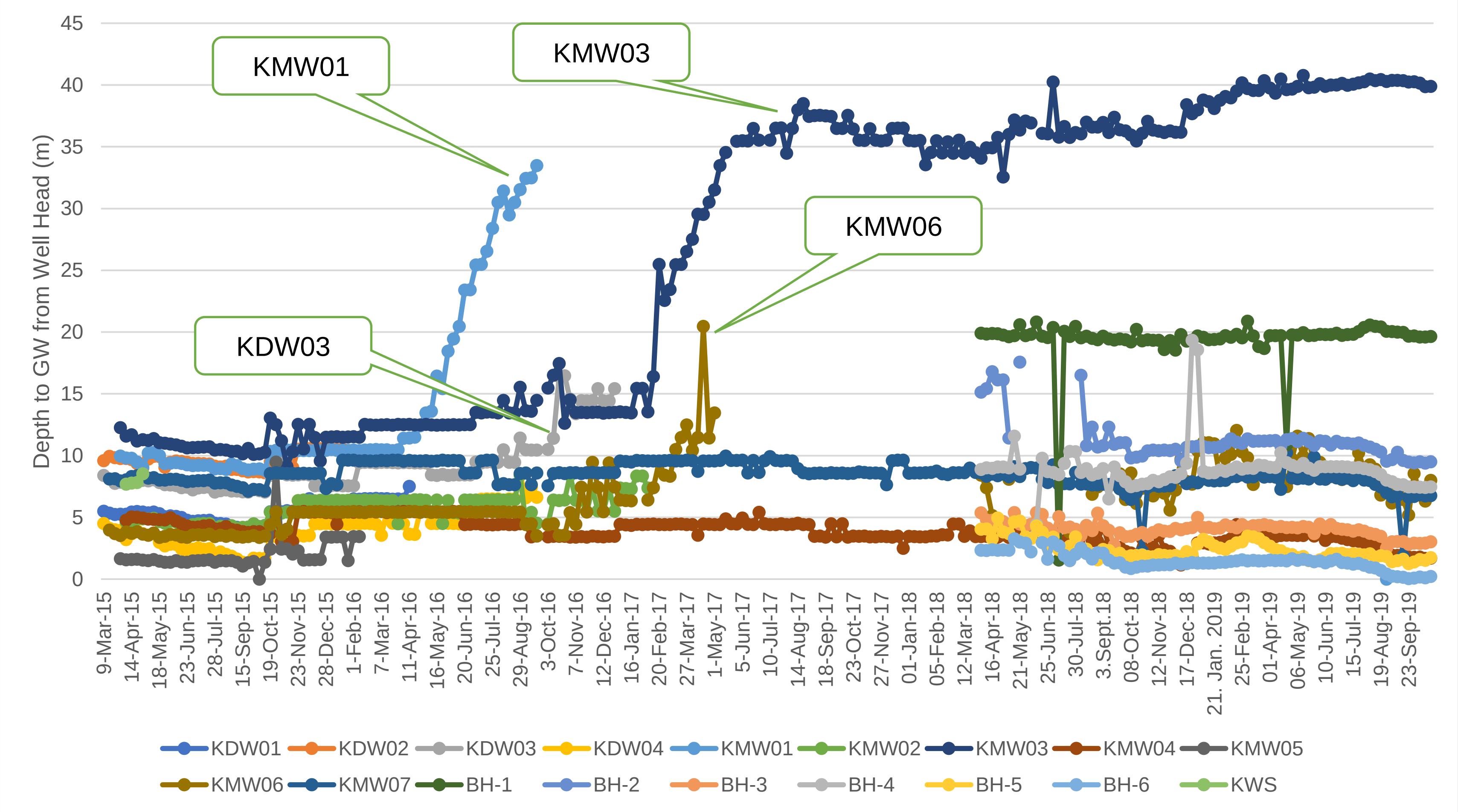


Figure 17 Temporal groundwater level variation during the Construction and Operation phases (This study)

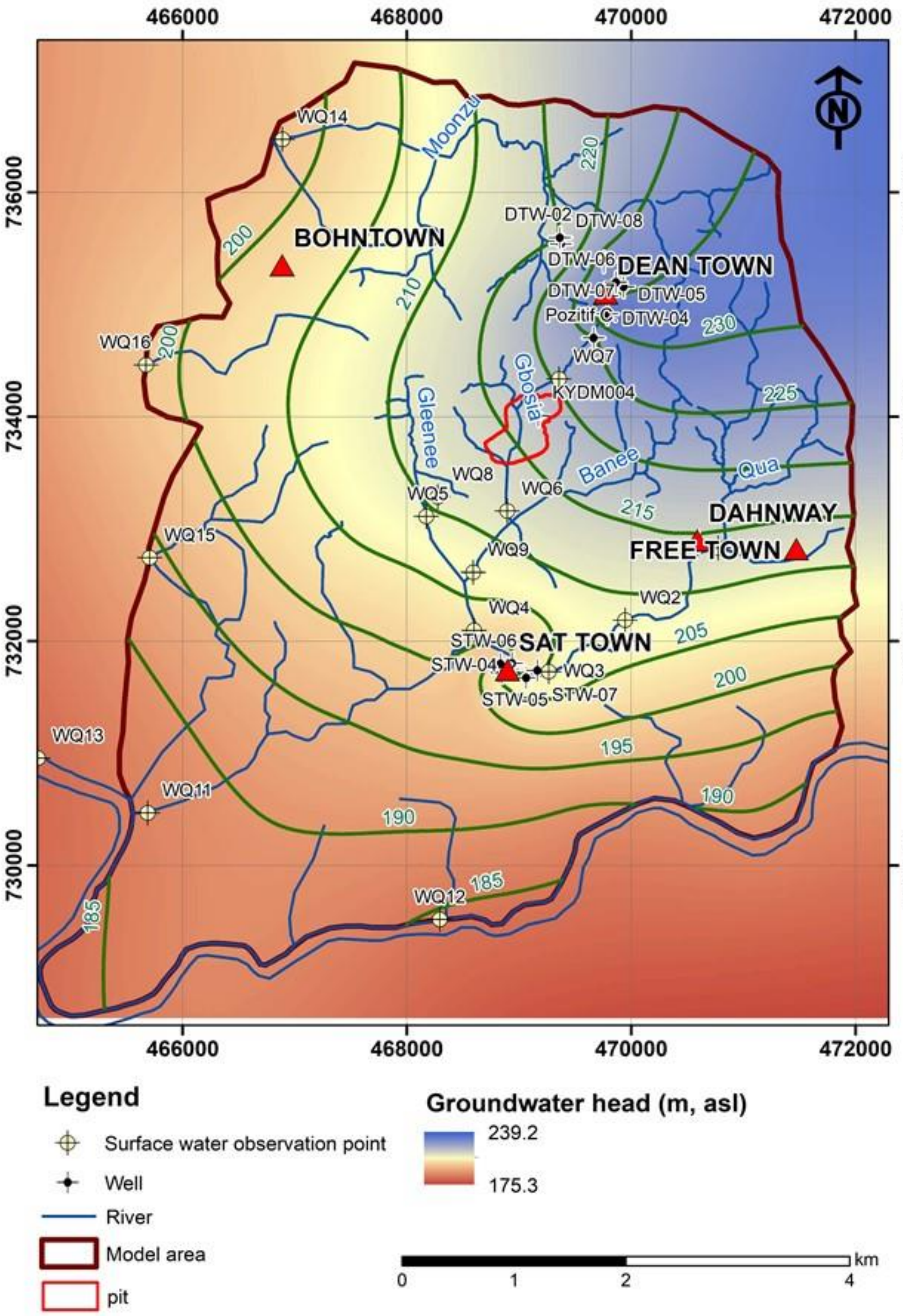


Figure 18 Hydraulic head distribution in the hydrogeological assessment area (This study)

Table 6 Data used to draw the hydraulic head distribution map.

ID	Easting	Northing	Elevation	Groundwater head (m)
BATW-01	475111	735526	226.6	213.95
BATW-02	475120	735655	227	214.6
BATW-03	475149	735374	227	214.9
DATW-01	470598	732882	220	214.35
DTW-02	469367	735596	222.1	215.77
DTW-03	469754	735380	230.2	226.89
DTW-04	469787	735074	237.8	229.5
DTW-05	469932	735156	230.6	229.24
DTW-06	469864	735196	231.3	228.61
DTW-07	469787	734915	240	233.05
DTW-08	469373	735538	219.2	216.1
KYDM004	469170	734008	224.2	217.16
MNG Camp	469363	735594	221.5	215.1
Pozitif C.	469666	734700	238.8	224.8
STW-01	469064	731670	211	206
STW-02	468896	731751	210.3	200.75
STW-03	468946	731796	205	203.1
STW-04	468938	731802	204.9	198.4
STW-05	468843	731717	209.4	206
STW-06	468835	731796	204.3	198.86
STW-07	469163	731737	206.1	203.6
WQ3	469267	731727	206.05	206.05
WQ4	468601	732095	202.09	202.09
WQ5	468175	733111	209.43	209.43
WQ11	465691	730469	186.99	186.99
WQ12	468295	729519	184.43	184.43
WQ13	464712	730957	182.34	182.34
WQ14	466893	736472	197.96	197.96

1.14 Geochemistry - Acid Rock Drainage - Metal Leach

A geochemical characterization study for the Kokoya Project was conducted by Golder (2015a). According to the results; most of the lithologies to be mined were found to be NON-PAG (non-potential acid generating) due to their low sulphide sulphur content. Regardless of rock type, samples with less than 0.2 % sulphide sulphur are NON-PAG and they have relatively low dissolved base metal concentrations. However, samples with higher sulphide sulphur content may be PAG (potential acid generating) particularly in the absence of the general lack of neutralization potential. Despite the following comment of Golder (2015a), “most of the materials that will be extracted during mining are expected to have low sulphur content; however, the ore would include relatively high sulphur content and high sulphur pockets/zones would be encountered during the mining." none of the water quality monitoring samples collected since 2015 revealed any clue of acid rock drainage.

1.15 Water Quality

1.15.1 Water Quality in the Pre-Construction Phase

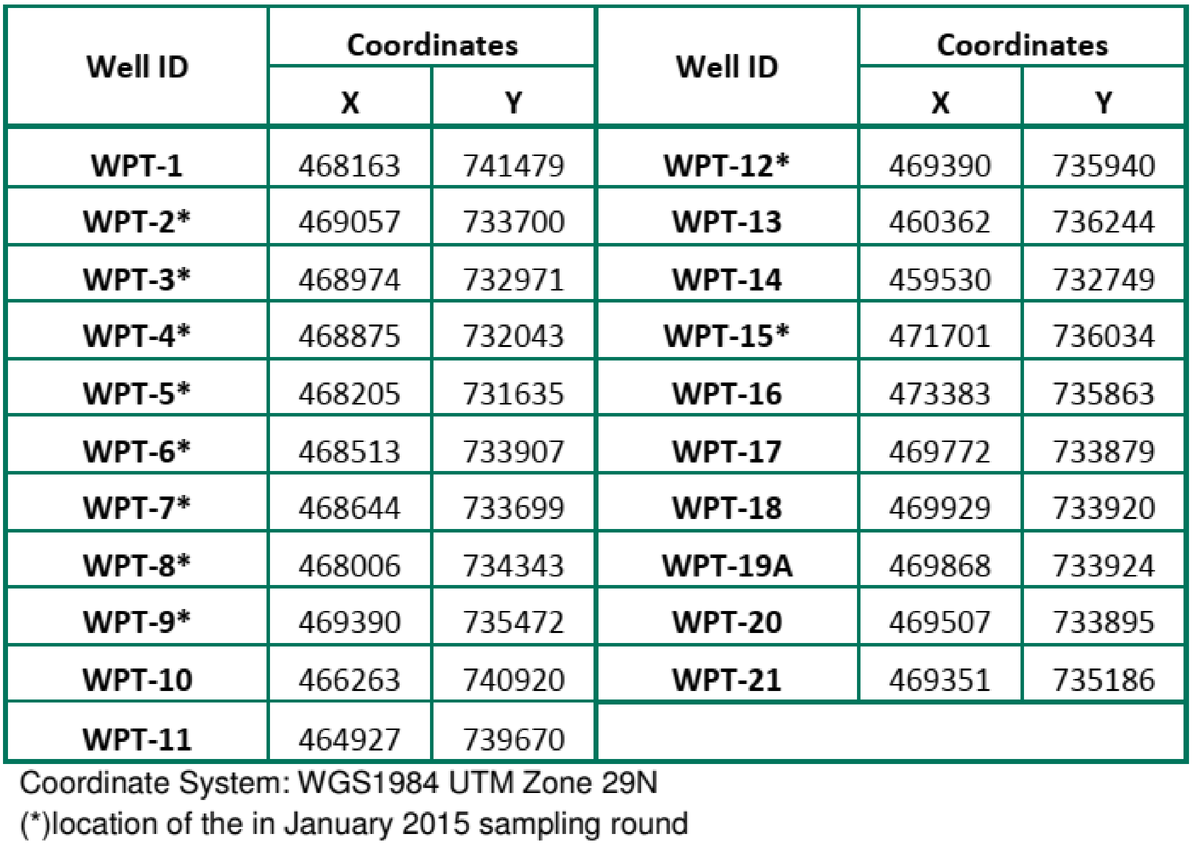
According to Golder (2015a), it is stated in the Environmental Monitoring Reports that several water quality sampling rounds were conducted in 2012 and 2013 before MNG Gold acquired the Kokoya Project. Even though the coordinates of the water points sampled before were known, due to the limited parameters analyzed, results of these sampling are not presented in Golder (2015a). The water points however were used in the water quality sampling session conducted for the purpose of initiating the baseline water quality determination which took place in February 2015.

The previous sessions included twenty-one monitoring and sampling points (WPTs), however Golder (2015a) evaluated the water quality based on ten water samples. Locations of samples were selected considering the proximity of the water points to the project area and the facilities. The coordinates of the Golder (2015a) water points are listed in Table 7 and the sampling locations are presented in Figure 19.

The Golder (2015a) samples were stored in coolers with ice packs and maintained in a cool state until sent to the laboratory within the specified holding times. The samples have been analyzed by Jones Environmental Laboratory (Attachment 1 of Golder, 2015a) according to the parameters listed in Table 8.

The water quality results have been evaluated and compared to the Liberian Drinking Water Quality Standards (Ministry of Health and Social Welfare) and WHO (United Nations, World Health Organization) Standards (Table 9).

Table 7 Coordinates of the water points of Golder (2015a) study.



Well ID	Coordinates		Well ID	Coordinates	
	X	Y		X	Y
WPT-1	468163	741479	WPT-12*	469390	735940
WPT-2*	469057	733700	WPT-13	460362	736244
WPT-3*	468974	732971	WPT-14	459530	732749
WPT-4*	468875	732043	WPT-15*	471701	736034
WPT-5*	468205	731635	WPT-16	473383	735863
WPT-6*	468513	733907	WPT-17	469772	733879
WPT-7*	468644	733699	WPT-18	469929	733920
WPT-8*	468006	734343	WPT-19A	469868	733924
WPT-9*	469390	735472	WPT-20	469507	733895
WPT-10	466263	740920	WPT-21	469351	735186
WPT-11	464927	739670			

Coordinate System: WGS1984 UTM Zone 29N
(*)location of the in January 2015 sampling round

Table 8 Parameters for groundwater quality sampling parameters in Liberian Water Quality Standards

pH	Chloride	Sulfate	Hardness	Iron
Manganese	Zinc	Coliform Bacteria	Bacteria Total	Ammonia
Dissolved Solids	Suspended Solids	Nitrate	Nitrite	Phosphate
Phenols	Detergents	Fluoride	Cyanide	Lead
Mercury	Copper	Cadmium	Nickel	Silver
Chromium Trivalent	Chromium Hexavalent	Vanadium	Boron	Arsenic
Additional Parameters				
Sulfide	Sodium	Calcium	Magnesium	Potassium
Carbonate	Bicarbonate	Aluminium	Conductivity	BOD-COD
Cyanide (free)	Cyanide (WAD)	Oil and Grease	Antimony	Selenium

The results showed that; total iron concentrations were high in almost all samples. Additionally; the manganese concentrations in the samples taken from WPT-2 and WTP-9 were above Class II limits. Total suspended solids were also detected as Class III in samples WTP-4, WTP-5 and WTP-7.

Cadmium, copper, manganese, suspended solid concentrations and pH values in some of the samples were above Class I limits.

Drilling of the groundwater monitoring wells took place after this sampling session and as a result the baseline sampling didn't include any sample from the monitoring wells. However, the recommended groundwater monitoring network also included the samples from the groundwater monitoring wells.

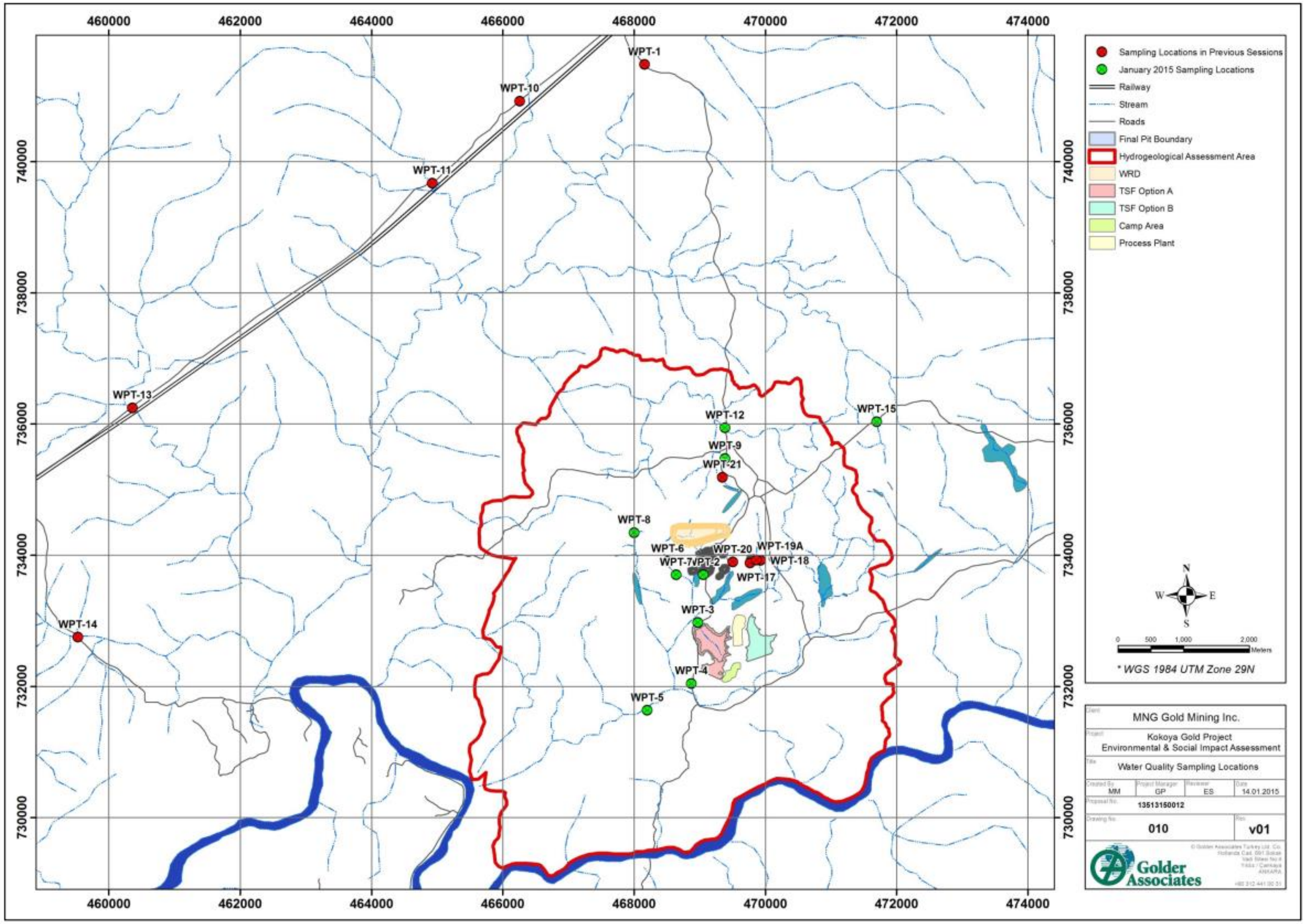


Figure 19 Water points sampled for the Golder (2015a) study.

Table 9 Results of water quality analyses in the January 2015 sampling session

Sample ID	WHO	Liberian DWQ Standarts			Units	Laboratory		WPT-2	WPT-3	WPT-4	WPT-5	WPT-6	WPT- 7	WPT- 8	WPT- 9	WPT- 12	WPT- 15	Method No.
		Class I	Class II	Class III		LOD/LOR	Units											
Total Arsenic	50	≤ 50	≤ 50	≤ 200	µg/l	<2.5	µg/l	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	TM30/PM14
Total Boron	-	≤ 1000	≤ 1000	≤ 1000	µg/l	<12	µg/l	<12	<12	<12	<12	<12	<12	<12	<12	<12	<12	TM30/PM14
Total Cadmium	10	n.d.	≤ 1	≤ 10	µg/l	<0.5	µg/l	<0.5	0.8	2.7	5.4	0.6	2.1	<0.5	0.9	0.6	1.2	TM30/PM14
Total Chromium	-	≤ 500	≤ 500	≤ 800	µg/l	<1.5	µg/l	6.8	2.5	88.1	77.8	40.8	113.4	<1.5	<1.5	3.2	2.2	TM30/PM14
Total Copper	50	≤ 10	≤ 10	≤ 200	µg/l	<7	µg/l	<7	<7	17	33	<7	21	<7	<7	<7	<7	TM30/PM14
Total Iron	100	≤ 100	≤ 1500	≤ 2000	µg/l	<20	µg/l	1262	5992	25320$_{A}$	41120$_{A}$	3602	16450$_{A}$	456	5330	3758	10310	TM30/PM14
Total Lead	100	≤ 100	≤ 100	≤ 100	µg/l	<5	µg/l	<5	<5	10	6	<5	<5	<5	<5	<5	<5	TM30/PM14
Total Manganese	100	≤ 100	≤ 300	≤ 800	µg/l	<2	µg/l	359	44	163	251	24	57	5	638	54	187	TM30/PM14
Total Mercury	10	n.d.	≤ 5	≤ 10	µg/l	<1	µg/l	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	TM30/PM14
Total Nickel	-	≤ 1000	≤ 1000	≤ 100	µg/l	<2	µg/l	4	<2	12	15	8	29	<2	<2	<2	7	TM30/PM14
Total Vanadium	-	≤ 1000	≤ 1000	≤ 1000	µg/l	<1.5	µg/l	<1.5	<1.5	58.5	53.7	5.4	32.6	<1.5	<1.5	<1.5	<1.5	TM30/PM14
Total Zinc	5000	≤ 1000	≤ 2000	≤ 5000	µg/l	<3	µg/l	3	18	23	26	4	11	<3	7	4	4	TM30/PM14
Total Hardness Dissolved (as CaCO3)	100-500	≤ 190.0	≤ 300.0	≤ 600.0	mg/l	<1	mg/l	8	16	36	18	47	46	26	32	11	24	TM30/PM14
Sulphate	250	≤ 150.0	≤ 200.0	≤ 250.0	mg/l	<0.05	mg/l	0.91	0.62	7.78	0.91	0.76	0.79	0.76	0.84	0.65	0.70	TM38/PM0
Chloride	350	≤ 250.0	≤ 350.0	≤ 450.0	mg/l	<0.3	mg/l	2.4	0.8	2.3	1.4	1.2	2.8	1.5	5.5	0.7	0.8	TM38/PM0
Nitrate as NO3	50	≤ 40.0	≤ 60.0	≤ 80.0	mg/l	<0.2	mg/l	0.4	0.4	20.6	0.6	<0.2	0.2	4.7	<0.2	<0.2	0.8	TM38/PM0
Nitrite as NO2	-	≤ 0.1	≤ 0.5	≤ 1.0	mg/l	<0.02	mg/l	0.05	0.05	0.06	0.06	0.06	0.06	0.05	0.06	0.05	0.05	TM38/PM0
Ortho Phosphate as P*	-	≤ 0.01	≤ 0.02	≤ 0.05	mg/l	<0.03	mg/l	<0.03	<0.03	<0.03	0.04	<0.03	<0.03	<0.03	<0.03	<0.03	0.06	TM38/PM0
Total Cyanide	0.05	n.d.	≤ 0.02	≤ 0.05	mg/l	<0.01	mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	TM89/PM0
Hexavalent Chromium	0.05	≤ 0.05	≤ 0.1	≤ 0.1	mg/l	<0.006	mg/l	<0.006	<0.006	<0.006	<0.006	<0.006	0.010	<0.006	<0.006	<0.006	<0.006	TM38/PM0
pH	-	6.5 - 8.0	6.0 - 9.0	5.5 - 9.0	-logH	<0.01	pH units	6.33	6.92	6.64	6.16	7.26	6.48	6.61	7.04	7.04	6.49	TM73/PM0
Total Dissolved Solids	500	≤ 500.0	≤ 1000.0	≤ 1200.0	mg/l	<10	mg/l	24	<10	230	132	44	135	46	<10	<10	<10	TM20/PM0
Total Suspended Solids	-	≤ 10.0	≤ 30.0	≤ 50.0	mg/l	<10	mg/l	18	15	195	74	20	370	<10	28	<10	28	TM37/PM0

<u>Water Classification</u>	<u>Water can be used as</u>
Class I	Drinking water for the population, Water Supply for industry requiring drinking water.
Class II	For Fisheries, Cultivated fisheries, Organized public bath, Recreationnal water sports.
Class III	Industry supply except for industry requiring drinking water, irrigation or agricultural land.

Prepared for the Government of Liberia by UN Department of Technical Cooperation for UNDP New York 1987

"Ortho Phosphate as P" could not be evaluated since its value is below the laboratory detection limits.

1.15.2 Water Quality in the Post-Construction and Operational Phases

1.15.2.1 Monthly observations

Water quality monitoring of the pre-Construction Phase sampling points have been continued during the Construction and Operational Phases as well. In this context, new sampling points have also been monitored. However, some of the previously sampled spots has been abandoned by the expanding mining activities. The water samples have been analyzed by the same laboratory which provided service during the Pre-Construction Phase monitoring study until December 2018 when both the laboratory changed due to analytical quality problems. The list of the parameters being monitored since December 2018 changed as well.

The spots sampled for monthly water quality monitoring during the Post-Construction and Operational Phases are shown in Figure 20 and an enlarged view of the sampling spots in and around the mining facilities are presented in Figure 21. Among all spots, only WQ13 and WPT-15 are located outside the Hydrogeological Assessment Area of this study. Locations of the water quality monitoring points sampled during the Post-Construction and Operational Phases are given in Table 10.The water quality parameters monitored during the period between January 2015 and December 2018 are shown in Table 11 along with the respective World Health Organization Guidelines for Drinking Water Quality (WHO, 2017) and Liberia Water Quality Standard values. The analyses of some of the parameters in this period have been performed by using test kits. In an overall assessment of the collected data until December 2018, the overall analytical uncertainty (i.e. the measurement range) of analyses was found to be unsatisfactory (Table 12) and, as of January 2019, samples started to be sent to another international laboratory (i.e. ALS Prague) which is capable of providing more precise Limit of Reporting (LOR) values (Table 13a). Analytical methods of water quality parameters monitored after January 2019 is given in Table 13b.

The number of the water quality monitoring points have changed several times since January 2015 depending on the field conditions dictated by mining operations. For instance, 10 water points were sampled in January 2015 when the mining activities did not yet start and 20 water samples were collected in June 2019 when the mine is fully operational. A complete list of sampling points versus sampling times is presented in Table 14.

A detailed assessment of the water quality data collected until December 2018 is not made in this report due to the imprecise analytical uncertainty of the results of analyses. In particular, the concentrations reported for some parameters (e.g. cadmium, chromium, cyanide) are found to be unusually high as compared to values reported in literature for similar geological setting. This argument has been supported by the data obtained since January 2019 when more precise analytical methods started to be used by another laboratory.

The pH, Total dissolved solids, total suspended solids and conductivity data measured in the same points in January 2015 and December 2018 are compared in Table 15. These parameters are selected for evaluation because they are easy to measure and are relatively less prone to measurement error. The pH in both periods ranges between 5.2 and 7.4 which are within the range of expected values in a tropical environment where soil biogenic activity is very strong. None of the samples exhibit pH values that can be associated with acid rock drainage. The pH of the recent water sampling points like PIT-1 (i.e. the open pit) and BH-coded boreholes is within the range other water points. The total dissolved solid and conductivity values are well correlated, as expected $(\mathrm{R}^2 = 0.9911)$. In general, both parameters are within the typical range of silicate-dominant metamorphic rocks subject to strong biogenic weathering. The total suspended solid values observed in both periods are not comparable probably because the 2018 samples seem to have filtered in-situ.

The results of monthly water quality monitoring data obtained since January 2019 revealed that none of the parameters mentioned in WHO (2017) Guidelines for Drinking Water Quality have been exceeded in groundwater and Surface water samples including the drinking water samples collected from Sayewheh Town Hand Pump-2, Sayewheh Town Hand Pump-3 and Sayewheh Town Hand Pump-4. The only sample in which WHO (2017) limits are exceeded is the TSF-2 Detox Discharge which is the process outflow and has been treated in Tailing Storage Facility 2 (TSF-2) and Retention Pond before discharging into St. Jown River. The water quality parameter values of the samples of St. John River Discharge Point, St. John River Upstream and St. John River Downstream do not exceed the WHO (2017) limits. An example sheet of the monthly (e.g. January 2019) water quality analyses reports is presented in in Attachment 2.

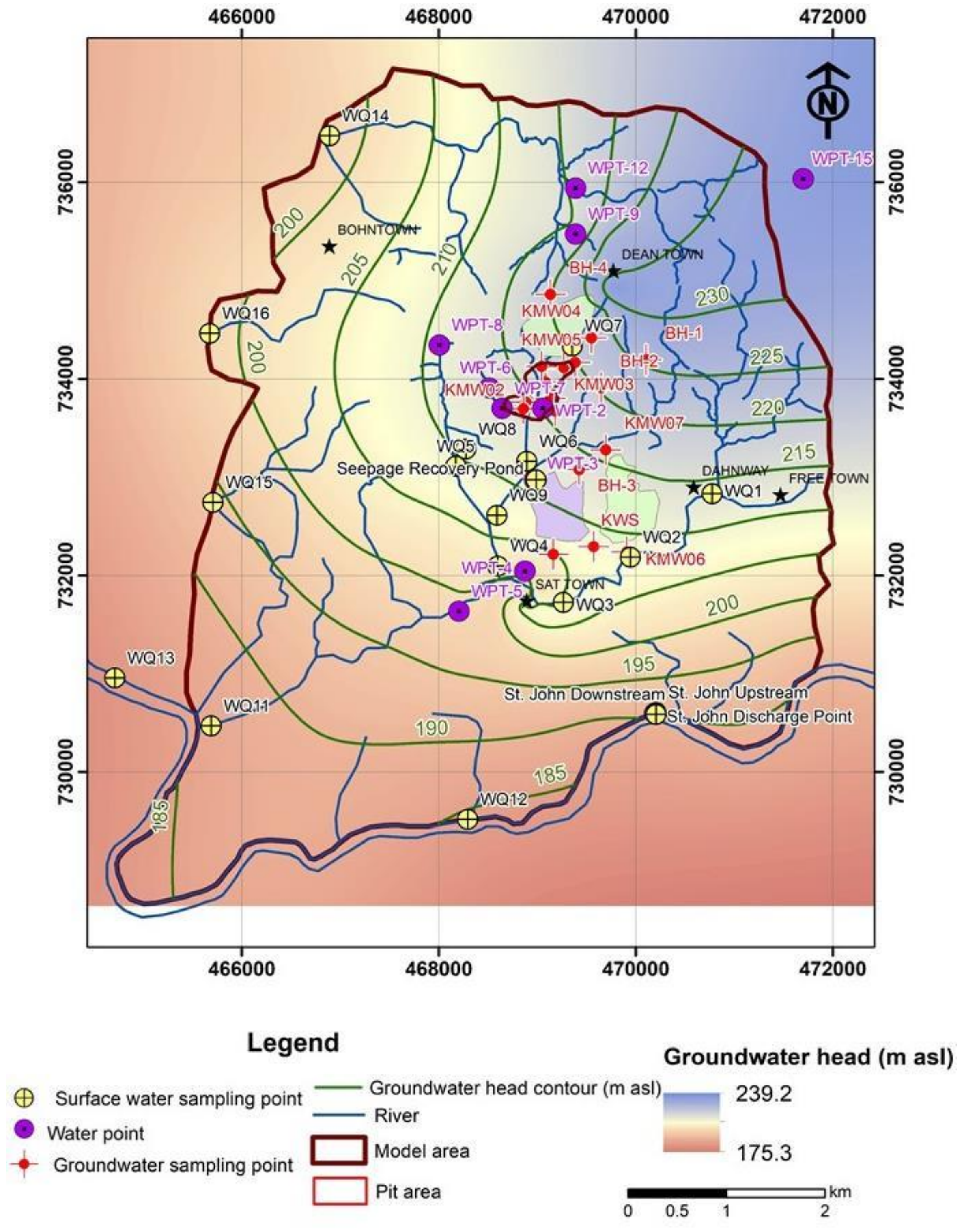


Figure 20 Spots sampled for monthly water quality monitoring during the Post-Construction and Operational Phases (This study)

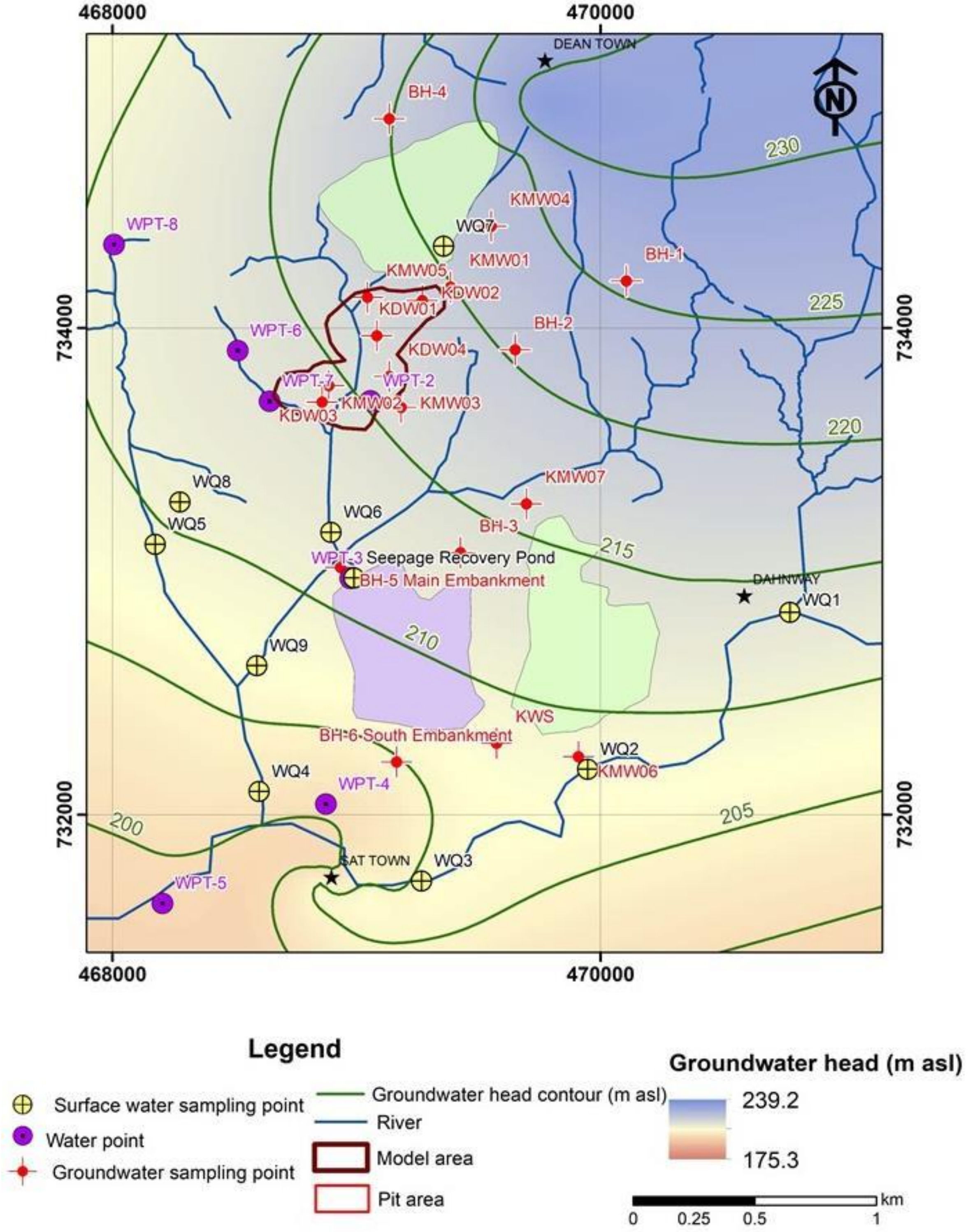


Figure 21 Enlarged view of the spots around the mining facilities, sampled for monthly water quality monitoring during the Post-Construction and Operational Phases (This study)

Table 10 Locations of the water quality monitoring points sampled during the Post-Construction and Operational Phases.

Sampling Points	Coordinates		Decimal Degrees	
	X	Y	Latitude	Longitude
Groundwater Wells (MNG Gold)				
KDW01	469084	733968	6.640062	-9.279697
KDW02	469270	734113	6.641374	-9.278015
KDW03	468887	733763	6.638206	-9.281478
KDW04	469135	733801	6.638551	-9.279235
KMW01	469386	734168	6.641872	-9.276966
KMW02	468860	733695	6.637591	-9.281722
KMW03	469183	733674	6.637403	-9.278800
KMW04	469552	734418	6.644135	-9.275465
KMW05	469045	734126	6.641491	-9.280051
KMW06	469910	732238	6.624416	-9.272216
BH-1	470107	734193	6.642102	-9.270443
BH-2	469651	733910	6.639540	-9.274567
BH-3	469427	733076	6.631994	-9.276589
BH-4	469135	734860	6.648131	-9.279240
BH-5	468935	733016	6.631449	-9.281040
BH-6	469165	732216	6.624213	-9.278955
KMW07	469697	733277	6.633814	-9.274148
KWS	469575	732293	6.624912	-9.275246
Groundwater Wells (Public)				
WPT-2	469057	733700	6.637637	-9.279940
WPT-3	468974	732971	6.631042	-9.280687
WPT-4	468875	732043	6.622647	-9.281578
WPT-5	468205	731635	6.618953	-9.287637
WPT-6	468513	733907	6.639507	-9.284862
WPT-7	468644	733699	6.637626	-9.283676
WPT-8	468006	734343	6.643448	-9.289451
WPT-9	469390	735472		
WPT-12	469390	735940		
WPT-15	471701	736034		
Surface Water				
WQ1	470777	732831		
WQ2	469948	732186		
WQ3	469267	731727		
WQ4	468601	732095		
WQ5	468175	733111		
WQ6	468896	733160		
WQ7	469357	734336		
WQ8	468277	733285		
WQ9	468592	732612		
WQ10	476945	733462		
WQ11	465691	730469		
WQ12	468295	729519		
WQ13	464712	730957		
WQ14	466893	736472		
WQ15	465708	732743		
WQ16	465676	734462		
St. John Discharge Point	470193	730599		
St. John Upstream	470207	730605		
St. John Downstream	470208	730587		

Table 11 Water quality parameters and respective standard values monitored during the period January 2015 thru December 2018.

Element/ Parameter	Units	WHO Guideline (mg/L)	Liberia Water Quality Standard		
			Class I	Class II	Class III
Phenol	mg/l	0.001	0.001	0.02	0.05
Boron	mg/l	2.4	1	1	1
Cadmium	mg/l	0.003	0.001	0.001	0.01
Chromium total	mg/l	0.05	0.5	0.5	0.8
Copper	mg/l	2	0.01	0.01	0.2
Iron	mg/l	***	0.1	1.5	2
Lead	µg/l	10	0.1	0.1	0.1
Manganese	mg/l	***	0.1	0.3	0.8
Nickel	mg/l	0.07	1	1	1
Zinc	mg/l	***	1	2	5
Hardness (as CaCO3)	mg/l	***	190	300	600
Sulphate	mg/l	***	150	200	250
Chloride	mg/l	***	250	350	450
Nitrate (NO3 as N)	mg/l	50	40	60	80
Nitrite (NO2 as N)	mg/l	3	0.1	0.5	1
Ortho Phosphate (as P)	mg/l		0.01	0.02	0.05
Cyanide total	mg/l	**	0.00	0.02	0.05
Chromium Hexavalent	mg/l	0.05*	0.05	0.1	0.1
pH	–log H		6.5 - 8.0	6.0 - 9.0	5.5 - 9.0
Total Dissolved Solids	mg/l	***	500	1000	1200
Total Suspended Solids	mg/l	***	10	30	50
Conductivity	µS/cm				
Coliform	n/ml				
Oil/Grease	mg/l				
Aluminum	mg/l				
Potassium	mg/l				
Magnesium	mg/l				
Calcium	mg/l				
Sodium	mg/l				
Selenium	mg/l				
Ammonia	mg/l	***	1	3	6
COD	mg/l				
BOD	mg/l				
Sulfide	µg/l				
Fluoride	mg/l	1.5	1.5	1.5	2

Note: WHO Guideline values are based on Annex 3 of “Guidelines for drinking-water quality: fourth edition incorporating the first addendum. Geneva: World Health Organization; 2017”.

* Value is for total chromium.

** WHO excludes this parameter stating that “Occurs in drinking-water at concentrations well below those of health concern, except in emergency situations following a spill to a water source”

*** WHO excludes this parameter stating that “Not of health concern at levels found in drinking-water”

Table 12 Analytical methods of water quality parameters monitored during the period January 2015 thru December 2018.

Element/ Parameter	**Analytical Method/ Concentration Range**
Phenol	Phenol in water test kit (0.1 to 1.0 ppm)
Boron	Camine Method (0.2 to 14.0 mg/L)
Cadmium	Lamotte Test Kit (0.1-1.0 mg/L octa slide)
Chromium total	HACH Test Kit (0-1000 mg/L)
Copper	Bicinchoninate Method (0.04 to 5.0 mg/L)
Iron	Ferromo Method (0.01-1.80.0 mg/L)
Lead	Dithizone method (3 to 300 µg/L) ug/L
Manganese	Periodate Oxidation Methid (0.1-20.0mg/L)
Nickel	1-(2-Pyridylazo)-2-Naphthol PAN Method (0.006 to 1.00 mg/L)
Zinc	Zircon method (0.01 to 3.00 mg/L)
Hardness (CaCO3)	Lamotte Hardness test kit (60 to 120 mg/L)
Sulphate	Lamotte sulfate test kit (50 to 200 mg/L)
Chloride	Mercury thiocyanate method (0.1 to 25 mg/L)
Nitrate (NO3 as N)	Cadmium Reduction Method LR (0.01 - 0.50 mg/L)
Nitrite (NO2 as N)	Diazotization method (0.002 to 0.3 mg/L)
Ortho Phosphate (as P)	HACH Test Kit HR (0-50 mg/L)
Cyanide total	HACH Test Kit (0-0.3 mg/L)
Cromium Hex	Diphenylcarbohydrazide method (0.01 to 0.7 mg/L)
pH	Aquameter
Total Dissolved Solid	Aquameter
Total Suspended Solid	Photometric Method (5-750 mg/L)
Conductivity	Aquameter µS/cm
Coliform	Most Probable Number Procedures MPN/100 ml
Oil/Grease	Imminoassay
Aluminum	Aluminon (0.008 to 0.800 mg/L
Potassium	Tetraphenyl Borate (0.1 to 7.0 mg/L)
Magnesium	Direct Reading Titrator (0 to 200 ppm)
Calcium	Direct Reading Titrator (0 to 200 ppm)
Sodium	Direct Reading Titrator (0 to 200 ppm)
Selenium	Diaminobenzindine (0 01 to 1.00 mg/L)
Ammonia	Salicylate (0.01 to 0.50 mg/L)
COD	TNT 822 HR (20-1500 mg/L)
BOD	Lemotte (Model BOD. Code 7420)
Sulfide	Methylene Blue (5 to 800 ug/L) µg/L
Fluoride	SPADNS (0.0 to 2.00 ppm)

Table 13a Limit of Reporting (LOR) values of the water quality parameters monitored after January 2019

Parameter/Method	**Limit of Reporting, LOR**	**Unit**
Nonmetallic Inorganic Parameters		
Chloride (W-CL-SPC)	5	mg/L
Easily released cyanide (W-CNF-PHO)	0.005	mg/L
Orthophosphate (W-PO4O-SPC)	0.04	mg/L
Sulphate as SO4 2- (W-SO4-SPC)	5	mg/L
Total Cyanide (W-CNT-PHO)	0.005	mg/L
Weak acid dissociable cyanide (W-CNWAD-PHO)	0.005	mg/L
Free Cyanide (W-CNF-PHO)	0.005	mg/L
Orthophosphate as P (W-PO4O-SPC)	0.01	mg/L
Total Metals/Major Cations		
Aluminum (W-METAXFX1)	0.01	mg/L
Antimony (W-METAXFX1)	0.01	mg/L
Arsenic (W-METAXFX1)	0.005	mg/L
Barium (W-METAXFX1)	0.005	mg/L
Beryllium (W-METAXFX1)	0.002	mg/L
Boron (W-METAXFX1)	0.01	mg/L
Cadmium (W-METAXFX1)	0.0004	mg/L
Calcium (W-METAXFX1)	0.005	mg/L
Chromium (W-METAXFX1)	0.001	mg/L
Cobalt (W-METAXFX1)	0.002	mg/L
Copper (W-METAXFX1)	0.001	mg/L
Iron (W-METAXFX1)	0.002	mg/L
Lead (W-METAXFX1)	0.005	mg/L
Lithium (W-METAXFX1)	0.001	mg/L
Magnesium (W-METAXFX1)	0.003	mg/L
Manganese (W-METAXFX1)	0.0005	mg/L
Molybdenum (W-METAXFX1)	0.002	mg/L
Nickel (W-METAXFX1)	0.002	mg/L
Phosphorus (W-METAXFX1)	0.05	mg/L
Potassium (W-METAXFX1)	0.015	mg/L
Selenium (W-METAXFX1)	0.01	mg/L

Silver (W-METAXFX1)	0.001	mg/L
Sodium (W-METAXFX1)	0.03	mg/L
Thallium (W-METAXFX1)	0.01	mg/L
Vanadium (W-METAXFX1)	0.001	mg/L
Zinc (W-METAXFX1)	0.002	mg/L
Dissolved Metals/Major Cations		
Hexavalent Chromium-Soluble (W-CR6-IC)	0.4	µg/L
Parameter/Method	LOR	Unit
Microbiological Parameters		
Coliform Bacteria (W-COLIF)	-	CFU/100mL
Physical Parameters		
pH Value (W-PH-PCT)	1.00	-
Aggregate Parameters		
Total Extractable Compounds (W-TECD-IR)	0.05	mg/L
Nonmetallic Inorganic Parameters		
Biochemical Oxygen Demand (BOD 7) (W-BOD7-OXY)	1.00	mg/L
Chemical Oxygen Demand (COD-Cr) (W-COD-SPC)	5.00	mg/L
Phosphorus (as P2O5) (W-PTOT-SPC)	0.12	mg/L
Total Nitrogen as N (W-NTOT-IR)	0.10	mg/L
Total Phosphorus as P (W-PTOT-SPC)	0.05	mg/L
Total Phosphorus as PO4 3- (W-PTOT-SPC)	0.15	mg/L
Suspended solids dried at 105 °C (W-TSS-GR)	5.00	mg/L

Table 13b Analytical methods of water quality parameters monitored after January 2019

Code	Parameter	Method
W-CPDGMS01	Cresols-Phenol-Dimethylphenols by GCMS	US EPA 8041A, US EPA 3500
W-METAXFX1	Total Metals by ICP-OES A - group 1	US EPA 200.7, CSN EN ISO 11885, CSN EN 16192, US EPA 6010, SM 3120, CSN 75 7358
W-BOD7-CODCR	BOD-7 - COD-CR	based on CSN EN 1899-1, 1899-2; CSN ISO 15705; CSN ISO 6060
W-CR6-IC	Chromium (VI) by IC	CSN EN 16192, EPA 7199, SM 3500-Cr
W-HARD-FX	Hardness - total	US EPA 200.7, CSN EN ISO 11885, CSN EN 16192, US EPA 6010, SM 3120
W-SO4-SPC	Sulphate (SO4) by Aquachem	based on EPA 375.4, SM 4500-SO4(2-)
W-CL-SPC	Chlorides (Cl) by Aquachem	N/A
W-NO3-SPC	Nitrates (NO3) by discrete spectrophotometry by calculation	CSN EN ISO 11732, CSN EN ISO 13395, CSN EN 16192, SM 4500-NO2(-
W-NO2-SPC	Nitrites (NO2) by discrete spectrophotometry	CSN EN ISO 11732, CSN EN ISO 13395, CSN EN 16192, SM 4500-NO2(-
W-PO4O-SPC	Dissolved orthophosphate (PO4) by discrete spectrophotometry	CSN EN ISO 6878 SM 4500-P
W-CNT-PHO	Cyanides (CN) -Total by photometry	CSN 75 7415, CSN EN ISO 14403-2
W-CNF-PHO	Cyanides (CN) easily liberatable (free) by photometry	CSN ISO 6703-2, CSN EN 16192, CSN EN ISO 14403-2, SM 4500 CN
W-PH-PCT	pH at 25 °C by Electrode	based on CSN ISO 10523, US EPA 150.1, CSN EN 16192, SM 4500-H(+)
W-TSSTDS	Total suspended and dissolved solids	based on CSN EN 872, CSN 757350, based on CSN 757346, CSN 757347, CSN EN 16192
W-CON-PCT	Electrical conductivity at 25°C	based on CSN EN 27 888, SM 2520 B, CSN EN 16192
W-COLIF	Coliform Bacteria 4.17	CSN 75 7837
W-TEC-IR	Extractable compounds by FTIR - Low	based on CSN 75 7506, STN 83 0520-27, STN 83 0530-36a, STN 83 0540-4

W-NH4-SPC	Ammonia (NH3) and ammonium ions (NH4) by discrete spectrophotometry	CSN EN ISO 11732, CSN EN ISO 13395, CSN EN 16192, SM 4500-NO2(-
W-H2S-PHO	Hydrogen sulfide (sulfane, H2S) and sulfide (S) by photometry	CSN 83 0520:1978-part 16, CSN 83 0530:1980-part 31, SM 4500-S2- D
W-F-ISE	Fluoride (F) - total inorganic by ISE	ALS internal methodology

Table 14 Sampling dates of water quality monitoring points used since January 2015

Year	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2016	2016	2016	2016	2016	2016	2016	2016	2016	2016	2016	2016
Month	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
KMW01									*	*	*	*	*	*	*	*	*	*	*	*	*			
KMW02									*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
KMW03									*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
KMW04									*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
KMW05									*	*	*													
KMW06									*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
KMW07									*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
KWS-1A											*													
KWS-1									*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
KWS-2										*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
WPT-2	*								*	*		*	*	*	*	*	*	*	*	*	*	*		*
WPT-3	*								*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
WPT-4	*								*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
WPT-5	*								*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
WPT-6	*								*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
WPT-7	*								*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	
WPT-8	*								*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
WPT-9	*								*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
WPT-12	*									*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
WPT-15	*								*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
PIT-1																								
BH-1																								
BH-2																								
BH-3																								

BH-4																								
BH-5																								
BH-6																								
SRP																								
SP-1																								
DRP-1																								
URP-1																								
RWW																								
DW 1																								
DW 2																								
DW 3																								
Sayewheh Town Hand Pump-2																								
Sayewheh Town Hand Pump-3																								
Sayewheh Town Hand Pump-4																								
St. John Upstream																								
St. John Downstream																								
St. John Discharge Point																								

Table 14 Sampling dates of water quality monitoring points used since January 2015 (cont'd).

Year	2017	2017	2017	2017	2017	2017	2017	2017	2017	2017	2017	2017	2018	2018	2018	2018	2018	2018	2018	2018	2018	2018	2018	2018
Month	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
KMW01																								
KMW02																								
KMW03	0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
KMW04	0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
KMW05																								
KMW06	0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
KMW07	0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
KWS-1A																								
KWS-1	0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
KWS-2	0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
WPT-2																								
WPT-3	0	*	*	*	*	*	*	*	*	*	*	*	*	*	*									
WPT-4	0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
WPT-5	0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
WPT-6	0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
WPT-7																								
WPT-8	0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
WPT-9	0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
WPT-12	0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
WPT-15	0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
PIT-1						*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
BH-1																*	*	*	*	*	*	*	*	*
BH-2																*	*	*	*	*	*	*	*	*
BH-3																*	*	*	*	*	*	*	*	*

BH-4																*	*	*	*	*	*	*	*	*
BH-5																*	*	*	*	*	*	*	*	*
BH-6																*	*	*	*	*	*	*	*	*
SRP																								
SP-1																							*	*
DRP-1																						*		
URP-1																						*		
RWW																								
DW 1																								
DW 2																								
DW 3																								
Sayewheh Town Hand Pump-2																								
Sayewheh Town Hand Pump-3																								
Sayewheh Town Hand Pump-4																								
St. John Upstream																								
St. John Downstream																								
St. John Discharge Point																								

Table 14 Sampling dates of water quality monitoring points used since January 2015 (cont'd).

Year	**2019**	**2019**	**2019**	**2019**	**2019**	**2019**	**2019**	**2019**
Month	1	2	3	4	5	6	7	8
KMW01								
KMW02								
KMW03	*	*	*	*	*	*	*	*
KMW04	*	*	*	*	*	*	*	*
KMW05								
KMW06	*	*	*	*	*	*	*	*
KMW07	*	*	*	*	*	*	*	*
KWS-1A								
KWS-1	*	*	*	*	*	*	*	*
KWS-2								
WPT-2								
WPT-3								
WPT-4	*	*	*	*	*	*	*	*
WPT-5	*	*	*	*	*	*	*	*
WPT-6	*	*	*	*	*	*	*	*
WPT-7								
WPT-8	*	*	*	*	*	*	*	*
WPT-9	*	*	*	*	*	*	*	*
WPT-12	*	*	*	*	*	*	*	*
WPT-15	*	*	*	*	*	*	*	*
PIT-1	*	*	*	*	*	*	*	*
BH-1	*	*	*	*	*	*	*	*
BH-2	*	*	*	*	*	*	*	*
BH-3	*	*	*	*	*	*	*	*

BH-4	*	*	*	*	*	*	*	*
BH-5	*	*	*	*	*	*	*	*
BH-6	*	*	*	*	*	*	*	*
SRP	*	*	*	*	*	*	*	*
SP-1								
DRP-1								
URP-1								
RWW		*						
DW 1		*						
DW 2		*						
DW 3		*						
Sayewheh Town Hand Pump-2	*							
Sayewheh Town Hand Pump-3	*							
Sayewheh Town Hand Pump-4	*							
St. John Upstream	*							
St. John Downstream	*							
St. John Discharge Point	*							

Notes: SRP: Seepage Recovery Pond, RWW: Raw Water Well, DW: Drinking Water, 0: Not sampled.

Table 15 Comparison of average pH, TDS, TSS and Conductivity between September 2015 and December 2018

Parameter	**pH**		**Total Dissolved Solid**		**Total Suspended Solid**		**Conductivity**	
Unit >			**(mg/L)**		**(mg/L)**		**(microS/cm)**	
Class I	6.5 - 8.0		500		10			
Class II	6.0 - 9.0		1000		30			
Class III	5.5 - 9.0		1200		50			
Years >>	**2018**	**2015**	**2018**	**2015**	**2018**	**2015**	**2018**	**2015**
KMW03	5.3	6.2	40	187	0	80	78	46
KMW04	5.4	6.6	105	110	0	38	209	100
KMW06	5.3	6.8	20	170	0	43	35	160
KMW07	5.7	7.4	135	100	0	28	269	136
KWS-1	5.4	7.1	70	160	0	36	140	83
KWS-2	7.2	5.8	419	176	109	29	835	149
WPT-4	6	6.7	22	168	0	48	48	80
WPT-5	5.6	6.8	28	179	0	74	29	72
WPT-6	5.3	6.5	183	188	0	8	268	30
WPT-8	5.6	6.1	33	371	0	4	67	112
WPT-9	5.6	6.2	60	236	0	15	125	120
WPT-12	6.5	6.7	17	262	0	22	35	80
WPT-15	5.2	6.9	20	194	0	8	43	96
PIT-1	5.5		276		0		548	
BH-1	6		117		0		238	
BH-2	5.3		28		0		58	
BH-3	5.8		77		0		157	
BH-4	5.5		24		0		47	
BH-5	5.3		110		0		221	
BH-6	5.3		125		0		252	
SP-1	5.5		386		0		770	

1.15.2.2 Weekly TSF-1 upstream and downstream monitoring

Water quality parameters (i.e. conductivity, pH, dissolved oxygen, temperature) and groundwater levels monitored weekly in boreholes KMW06 and KMW07 since 24th December 2018. The boreholes KMW06 and KMW07 are located at the downstream and the upstream of the TSF-1, respectively. The purpose of monitoring is to detect and to assess the effect of any likely seepage from the TSF-1 on the local groundwater system. The data obtained are presented in Table 16. Figures 22, 23, 24, 25 and 26 show temporal trends of conductivity, pH, dissolved oxygen, temperature and depth to groundwater, respectively. Some of the observed data display erratic readings, probably due to sensor malfunctions or personnel error. For instance, conductivty readings drop suddenly at the beginning of April 2019 and the pH readings exhibit a steady increase trend, which do not seem to be associated with likely hydrogeochemical processes. The pH measurements terminated at the end of July 2019 due to sensor breakdown. The temporal trend of dissolved oxygen readings seems plausible. Downstream (KMW06) readings are systematically lower than the upstream (KMW07) readings probably because of the seepage from Qua Stream which flows nearby the boreholw KMW06. Dissolved oxygen content of the streamwater may be depleted by intensive photosynthetic activity of algae. Groundwater temperatures in both boreholes appears to be in agreement with the mean ground temperature which is in equilibrium with the annual temperature. Oscillations observed in temperature readings may associated with the groundwater recharge from rainfall events through preferential fast pathways. Depth to groundwater readings in both boreholes vary May 2019 to November 2019, probably beacuse of the seasonal varation of the recharge from rainfall.

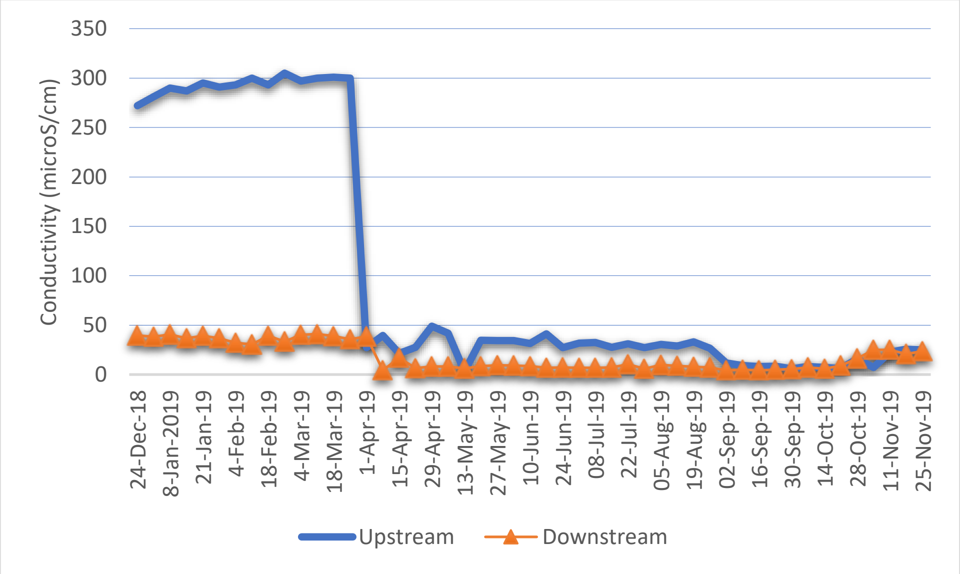


Figure 22 Temporal variation of conductivity in the KMW07 (upstream) and KMW06 (downstream) monitoring boreholes.

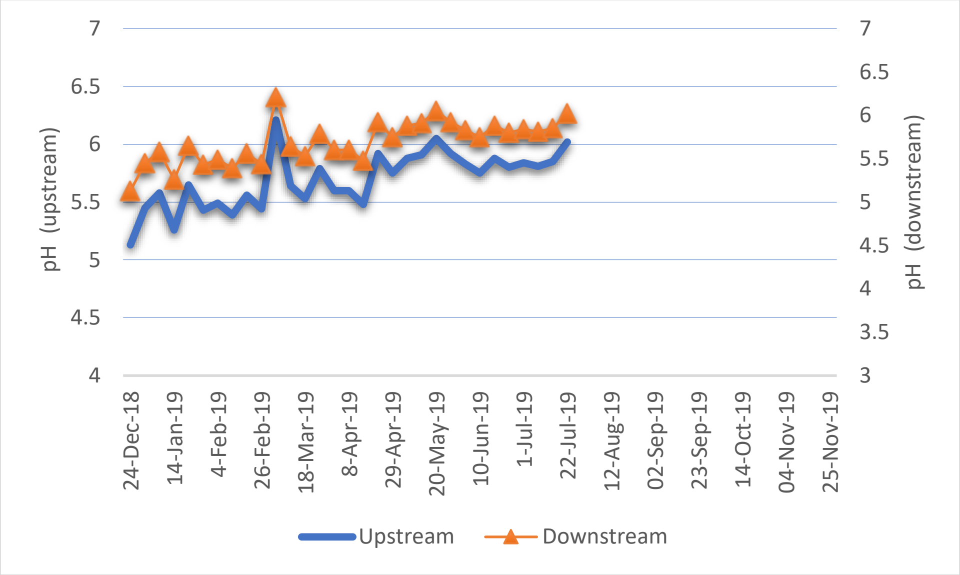


Figure 23 Temporal variation of pH in the KMW07 (upstream) and KMW06 (downstream) monitoring boreholes (Note that different pH scales shifted intentionally to pull apart the overlapping graphs).

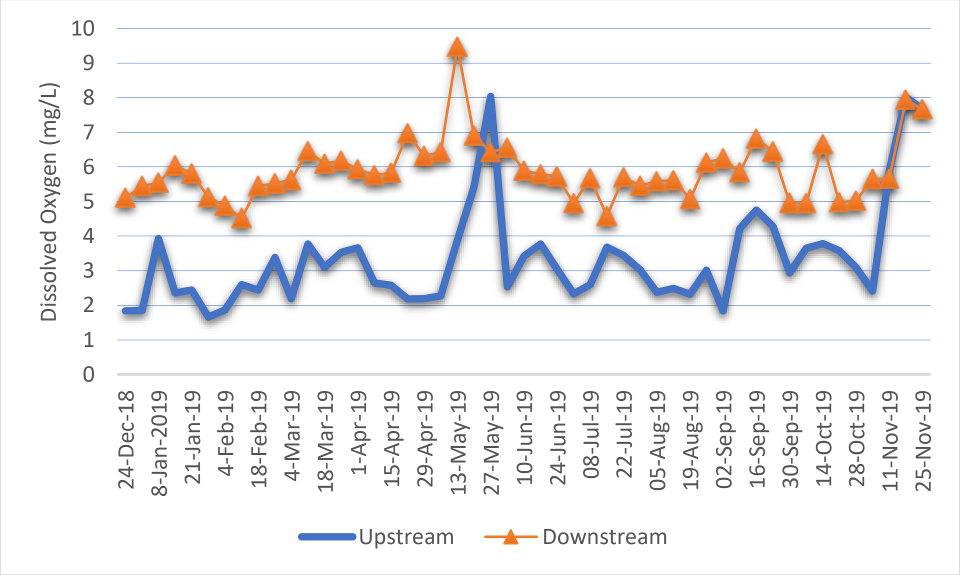


Figure 24 Temporal variation of dissolved oxygen in the KMW07 (upstream) and KMW06 (downstream) monitoring boreholes.

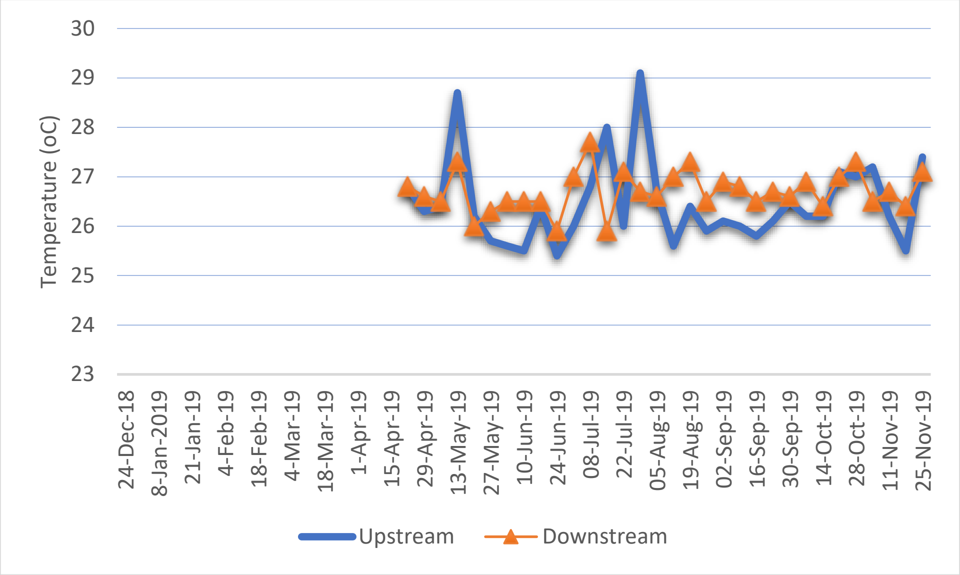


Figure 25 Temporal variation of temperature in the KMW07 (upstream) and KMW06 (downstream) monitoring boreholes.

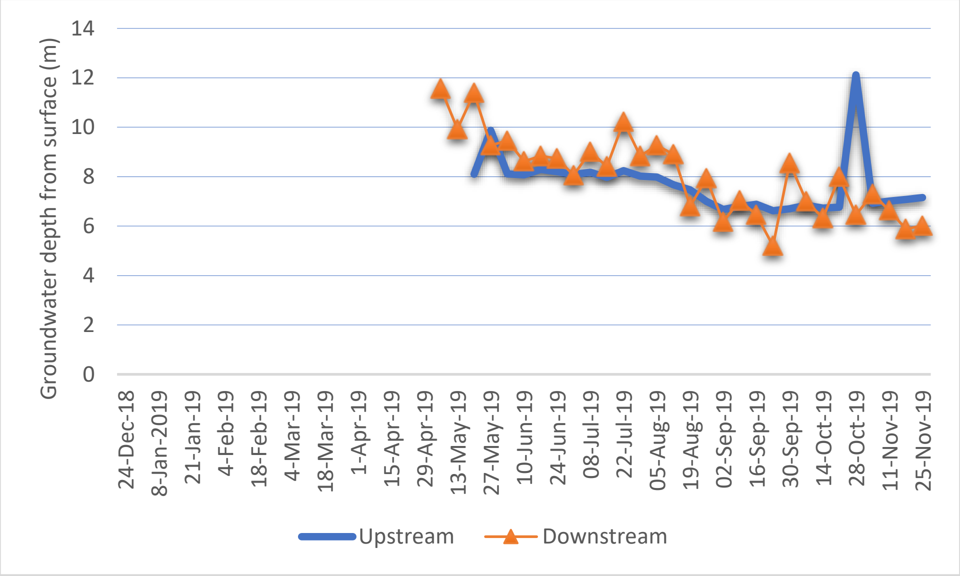


Figure 26 Temporal variation of depth to groundwater depth from surface in the KMW07 (upstream) and KMW06 (downstream) monitoring boreholes.

Table 16 Weekly water quality monitoring data of the KMW07 (upstream)

	Conductivity (µs/cm)	pH	Dissolved Oxygen (mg/L)	Temperature (°C)	Water Level (m)
24-Dec-18	272	6.26	1.84		
2-Jan-19	281	6.45	1.85		
8-Jan-2019	290	6.53	3.93		
14-Jan-19	287	6.49	2.36		
21-Jan-19	295	6.38	2.44		
28-Jan-19	291	6.52	1.66		
4-Feb-19	293	6.57	1.87		
12-Feb-19	300	6.59	2.6		
18-Feb-19	293	6.53	2.44		
26-Feb-19	305	6.52	3.38		
4-Mar-19	297	6.66	2.19		
12-Mar-19	300	6.62	3.77		
18-Mar-19	301	6.75	3.1		
25-Mar-19	300	6.82	3.53		
1-Apr-19	27.3	6.7	3.66		
8-Apr-19	39.7	6.72	2.64		
15-Apr-19	21.3	7.2	2.58		
22-Apr-19	27.7	6.99	2.18	26.8	
29-Apr-19	48.9	7.05	2.19	26.3	
6-May-19	41.8	7.14	2.27	26.4	
13-May-19	3.02	7.24	3.88	28.7	
20-May-19	34.7	7.21	5.43	26.2	8.1
27-May-19	34.3	7.45	8.04	25.7	9.87
3-Jun-19	34.5	6.74	2.53	25.6	8.11
10-Jun-19	31.3	6.95	3.42	25.5	8.08
17-Jun-19	41.1	6.98	3.77	26.4	8.3
24-Jun-19	27.1	6.94	3.05	25.4	8.21
1-Jul-19	31.7	6.49	2.33	26	8.09
08-Jul-19	32.5	6.96	2.6	26.8	8.18
15-Jul-19	27.5	7.14	3.68	28	7.97
22-Jul-19	31	7.02	3.44	26	8.24
29-Jul-19	27.2		3.02	29.1	8.02
05-Aug-19	30.4		2.38	26.7	7.98
12-Aug-19	28.7		2.49	25.6	7.67
19-Aug-19	33.2		2.32	26.4	7.46
26-Aug-19	26.75		3.01	25.9	7
02-Sep-19	11.8		1.84	26.1	6.67
09-Sep-19	9.14		4.22	26	6.79
16-Sep-19	8.26		4.75	25.8	6.88
23-Sep-19	8.46		4.28	26.1	6.62
30-Sep-19	5.77		2.94	26.5	6.7
07-Oct-19	8.04		3.65	26.2	6.84
14-Oct-19	7.13		3.78	26.2	6.73
21-Oct-19	6.1		3.58	27.1	6.76
28-Oct-19	15.95		3.1	27	12.12
04-Nov-19	7.27		2.41	27.2	6.92
11-Nov-19	22.8		5.87	26.2	7.01
18-Nov-19	25.6		8.02	25.5	7.08
25-Nov-19	24.9		7.67	27.4	7.16

Table 16 Weekly water quality monitoring data of the KMW06 (downstream)

	Conductivity (µs/cm)	pH	Dissolved Oxygen (mg/L)	Temperature (°C)	Water Level (m)
24-Dec-18	39.7	5.13	5.11		
2-Jan-19	38.4	5.45	5.45		
8-Jan-2019	40.6	5.58	5.54		
14-Jan-19	36.5	5.26	6.04		
21-Jan-19	39.2	5.65	5.81		
28-Jan-19	36.6	5.43	5.12		
4-Feb-19	32.1	5.49	4.87		
12-Feb-19	30.5	5.39	4.52		
18-Feb-19	39.1	5.56	5.45		
26-Feb-19	33.4	5.44	5.52		
4-Mar-19	40.3	6.21	5.62		
12-Mar-19	41	5.64	6.46		
18-Mar-19	38.8	5.53	6.1		
25-Mar-19	35.7	5.79	6.18		
1-Apr-19	38.7	5.6	5.93		
8-Apr-19	4.32	5.6	5.76		
15-Apr-19	16.89	5.48	5.83		
22-Apr-19	6.4	5.92	6.97	26.8	
29-Apr-19	8.04	5.75	6.32	26.6	
6-May-19	8.05	5.88	6.43	26.5	11.57
13-May-19	6.24	5.91	9.47	27.3	9.93
20-May-19	8.34	6.05	6.9	26	11.39
27-May-19	9.34	5.92	6.43	26.3	9.26
3-Jun-19	9.01	5.83	6.56	26.5	9.46
10-Jun-19	8.35	5.75	5.89	26.5	8.62
17-Jun-19	6.98	5.88	5.79	26.5	8.84
24-Jun-19	7.05	5.8	5.73	25.9	8.73
1-Jul-19	6.79	5.84	4.95	27	8.06
08-Jul-19	6.68	5.81	5.67	27.7	9.01
15-Jul-19	7.11	5.85	4.58	25.9	8.41
22-Jul-19	10.47	6.02	5.7	27.1	10.23
29-Jul-19	5.74		5.46	26.7	8.84
05-Aug-19	9.72		5.59	26.6	9.26
12-Aug-19	8.85		5.61	27	8.9
19-Aug-19	7.74		5.07	27.3	6.81
26-Aug-19	7.32		6.12	26.5	7.93
02-Sep-19	4.19		6.24	26.9	6.17
09-Sep-19	4.98		5.85	26.8	7.04
16-Sep-19	4.39		6.82	26.5	6.45
23-Sep-19	4.83		6.45	26.7	5.2
30-Sep-19	5.67		4.96	26.6	8.55
07-Oct-19	7.04		4.95	26.9	7.01
14-Oct-19	5.91		6.66	26.4	6.32
21-Oct-19	9.24		4.98	27	7.99
28-Oct-19	16.17		5.02	27.3	6.45
04-Nov-19	25.1		5.65	26.5	7.3

11-Nov-19	25.1		5.66	26.7	6.64
18-Nov-19	20.61		7.95	26.4	5.89
25-Nov-19	23.7		7.67	27.1	6.02

1.15.2.3 Daily borehole monitoring

Apart from the weekly observations in the upstream (KMW07) and downstream (KMW06) boreholes of the Tailing Storage Facility, similar observations were conducted also in the boreholes KMW03, KMW04, BH-1, BH-2, BH-4 and BH-6 (from April 2019 to December 2019) and in the boreholes KMW-03, KMW-04, KMW-06, KMW-07, BH-01, BH-02, BH-03, BH-04, BH-05, BH-06 (in January 2020) for the parameters pH, conductivity, dissolved oxygen, temperature and depth to groundwater level. These observation have been conducted regularly and submitted to the Environmental Protection Agency of Liberia (EPAL), as requested by EPAL.

During the observation period, depth to groundwater is almost stable in all boreholes with some oscillations and a few erratic readings which are probably resulted in static voltage spikes (Figure 27). Depth to groundwater was slightly reduced between August and November 2019 due to recharge from precipitation during the high rainfall period.

Figure 28 shows the temporal variation of pH during the first 4 months of the observation period. The pH sensors gave erratic readings and tended to produce temporally increasing values. As a consequence, the pH readings terminated at the end of July 2019.

Figure 29 shows the temporal temperature trend in the boreholes during the observation period. Mean daily temperatures in the Kokoya Gold Mine during the 2017-2019 observation period ranged between24°C and 28 °C (see Figure 5) and the groundwater temperatures tend to be in equilibrium with the mean air temperature whereas shallow groundwater (e.g. less than 5 m deep) is affected by the seasonal air temperature variations. Groundwater temperatures observed in all boreholes agrees with above arguments, for example, groundwater temperature in boreholes with shallow water table (e.g. like BH-6) tends to increase as the air temperature tends to rise in the hotter season (e.g. January thru April).

Figure 30 shows the temporal variation of dissolved oxygen in the groundwater of the monitored boreholes. Dissolved oxygen in groundwater is a difficult-to-measure parameter in the stationary monitoring instruments used boreholes. The sensor of the logger is prone to fouling by suspended sediments and alga and needs frequent cleaning and recalibration. If the positive and negative signal spikes probably originating from static electricity, the dissolved oxygen values exhibit a steady temporal variation in all boreholes, except BH-6 until early November 2019 when high rainfall period terminates. The dissolved oxygen signal in BH-6 tends to increase during the entire observation period. This is probably because of recent rainfall recharge from the surface. Rainfall has a greater dissolved oxygen content compared to the groundwater in which the dissolved oxygen is reduced by organic matter oxidation. Therefore, continuous fresh recharge from the surface (i.e. from rainfall) may rise the dissolved oxygen content of the groundwater. In all boreholes, dissolved oxygen content of groundwater increases about 2 to 5 mg/l after early November 2019.

This increase is attributed to the arrival of the fresh recharge from surface, which has higher dissolved oxygen content that the groundwater.

Temporal variation of the conductivity (Figure 31) agrees with the temporal variations of the temperature and dissolved oxygen. All three data sets exhibit a steady variation until early November 2019 with some static electric spikes and then, observed values start to rise. Increasing conductivity value in all boreholes is attributed to arrival of partly evaporated recharge water at the water table. Hydrologic conditions in the study area allows for about 330 mm/m2_year of net groundwater recharge throughout the year. However, seepage velocity is slower in low rainfall season but is faster in the high rainfall season. As a consequence, low rainfall recharge spends longer time in the seepage zone and evaporates more than the high rainfall which seeps faster and subject to less evaporation. Evaporation increases the dissolved solids content which is linearly proportional to conductivity (or vice versa). Hence, the high rainfall recharge front first pushes the low rainfall seepage (which has high TDS or conductivity) towards the water table. This caused an increasing conductivity trend in the boreholes. However, when the high rainfall recharge (which has a relatively low TDS and conductivity) starts to arrive at the water table, conductivity values start to exhibit a declining trend.

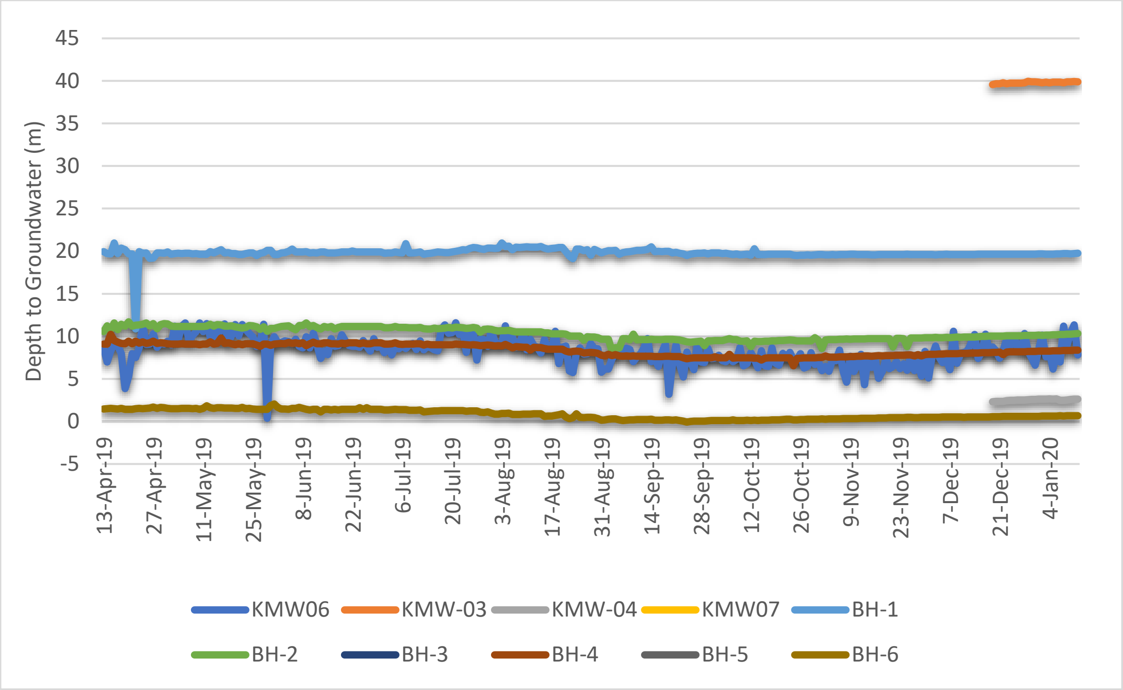


Figure 27 Temporal variation of depth to groundwater in the daily monitoring wells.

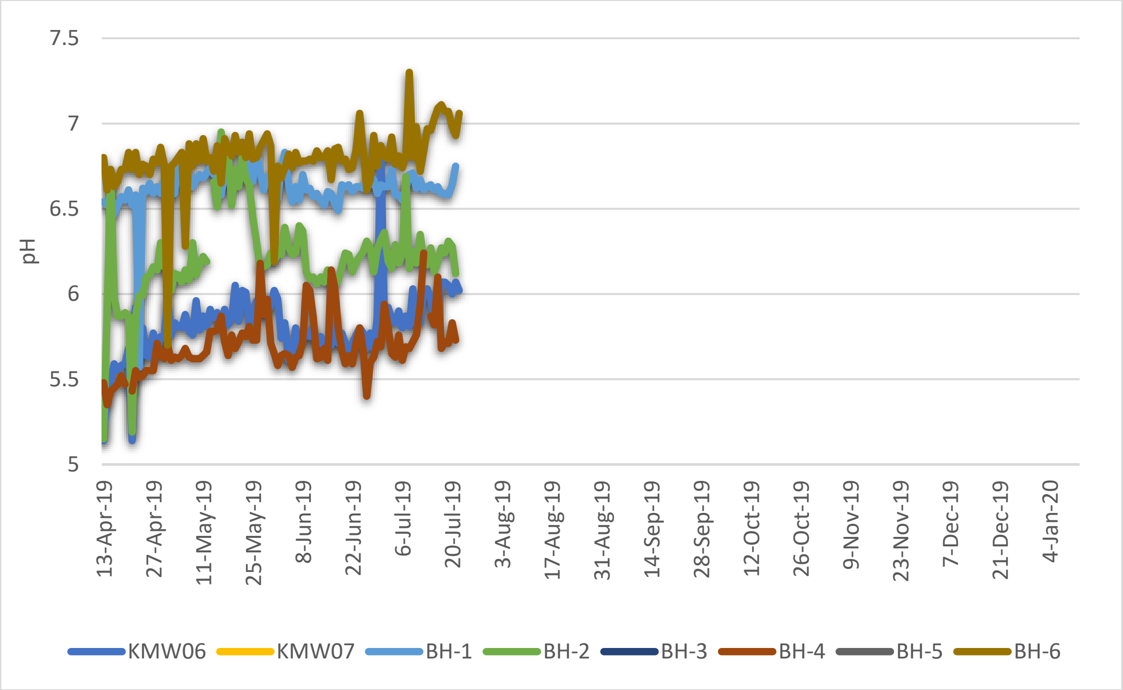


Figure 28 Temporal variation of pH in the daily monitoring wells.

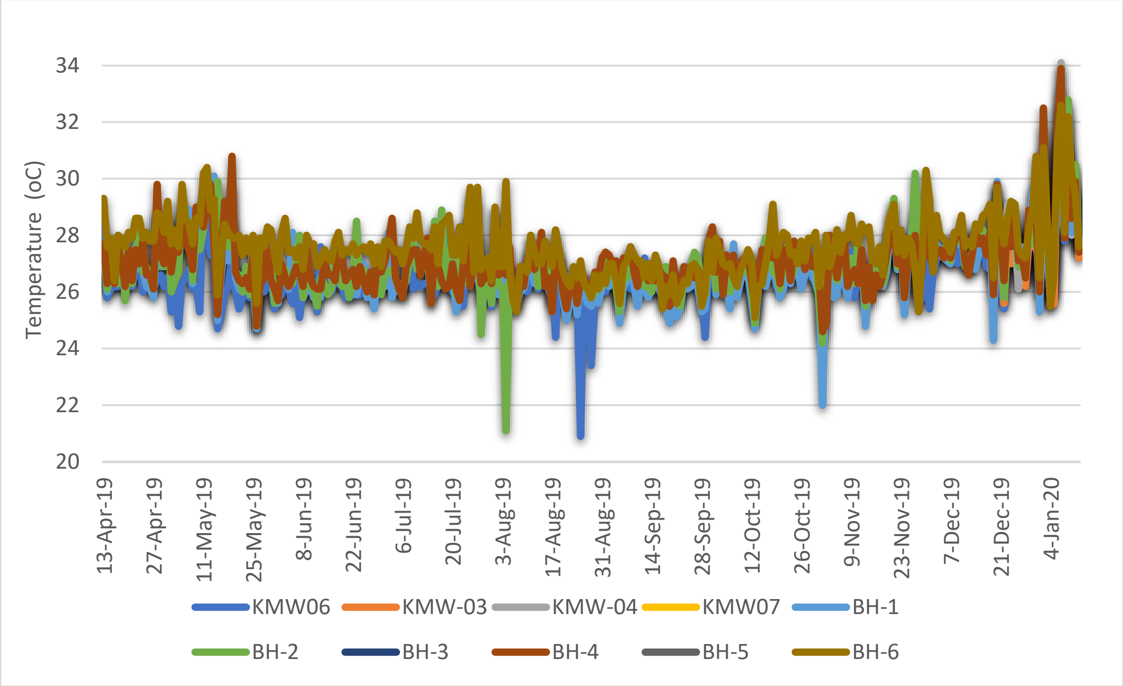


Figure 29 Temporal variation of temperature in the daily monitoring wells.

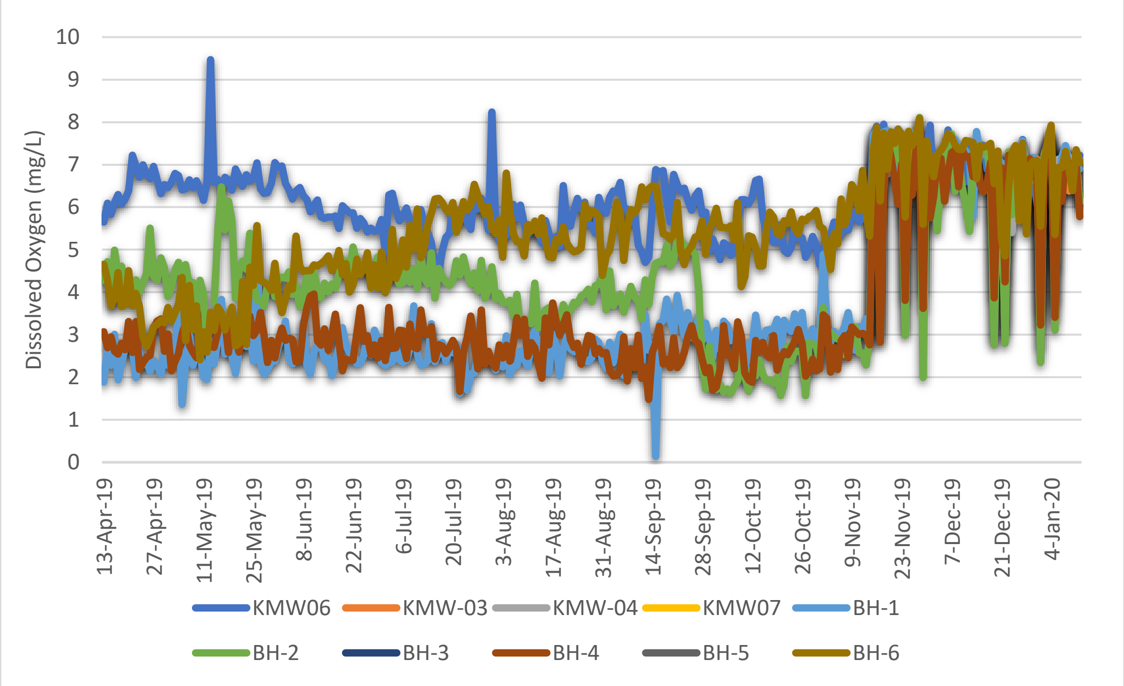


Figure 30 Temporal variation of dissolved oxygen in the daily monitoring wells.

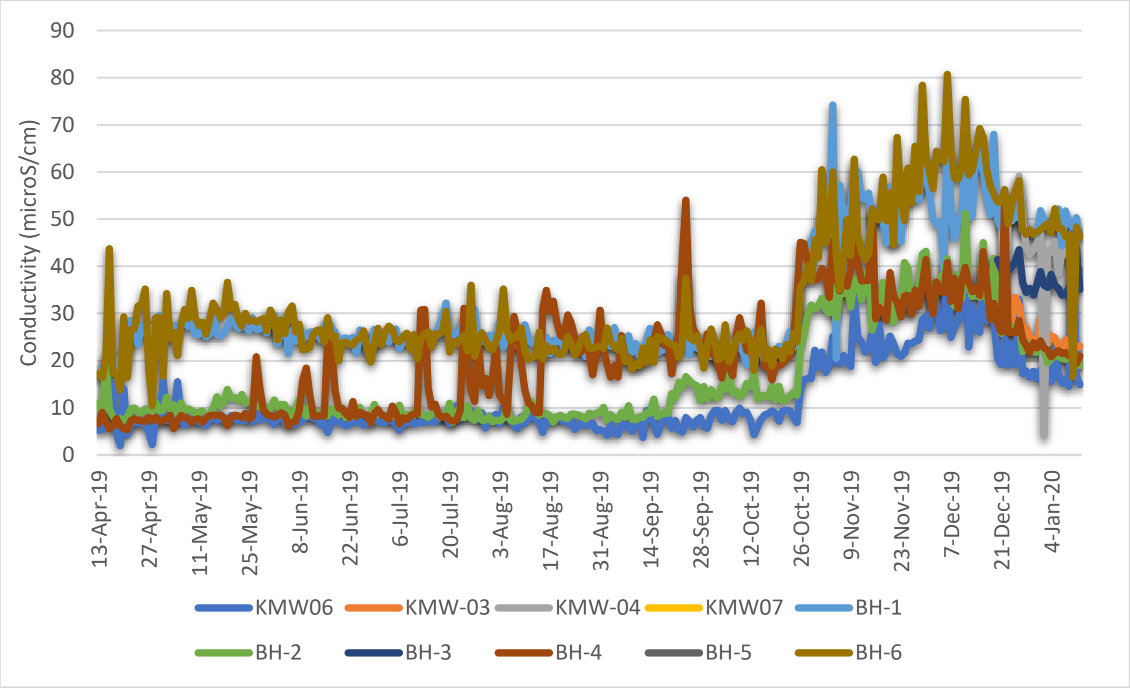


Figure 31 Temporal variation of conductivity in the daily monitoring wells.

1.15.2.4 Evidence for acid rock drainage

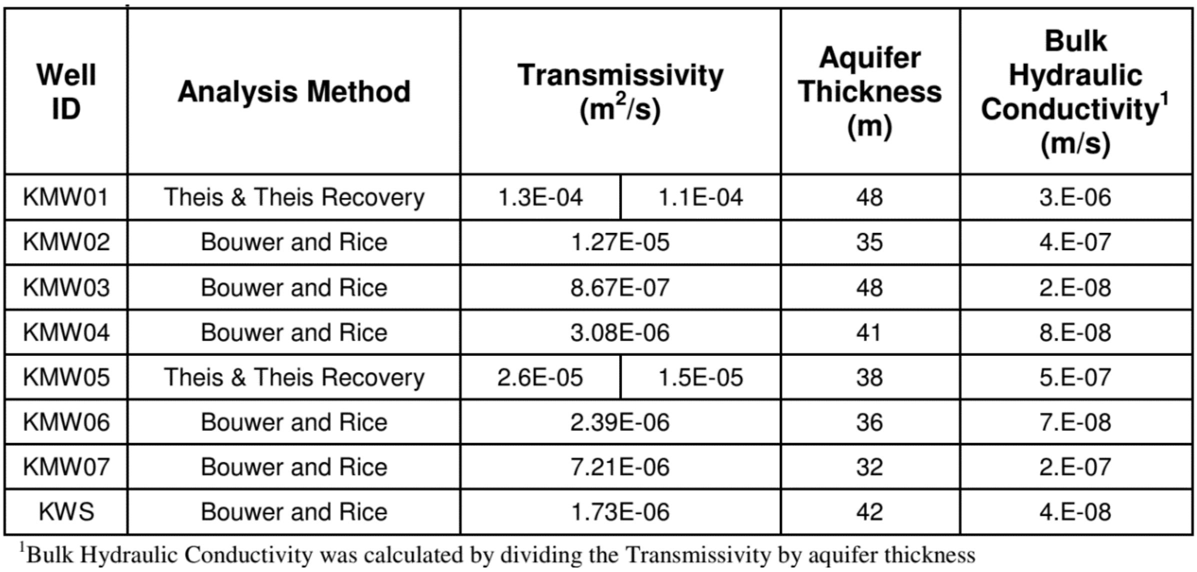
None of the water samples collected since the beginning of the Kokoya Gold Mine Project give any signal of acidic water generation due to acid rock drainage process.

1.16 Aquifer Testing in the Groundwater Monitoring Wells

Before the Construction Phase of the project, groundwater monitoring wells, drilled for the purpose of hydrogeological assessment were tested by using submersible pumps (Golder, 2015a). Short term constant rate pumping test was conducted at each groundwater well for a period of 4 hours. Change in the water level was measured by using the water level meter according to the time intervals provided in the work plan. Pumping discharges were measured manually by a bucket, volume of which was known. After the pumping completed, groundwater level recovery data was also collected for analysis and confirmation of the response of pumping test. Original pumping test data is presented in Golder (2015a).

Analyses of the pumping test data showed that the hydraulic conductivity (K) values are in orders between 10^{-7} m/s and 10^{-8} m/s except, for one well (KMW1) for which the K value is in an order of 10^{-6} m/s (Table 17).

Table 17 Results of aquifer tests (after Golder, 2015a)



Well ID	Analysis Method	Transmissivity (m^2/s)		Aquifer Thickness (m)	Bulk Hydraulic Conductivity[1] (m/s)
KMW01	Theis & Theis Recovery	1.3E-04	1.1E-04	48	3.E-06
KMW02	Bouwer and Rice	1.27E-05		35	4.E-07
KMW03	Bouwer and Rice	8.67E-07		48	2.E-08
KMW04	Bouwer and Rice	3.08E-06		41	8.E-08
KMW05	Theis & Theis Recovery	2.6E-05	1.5E-05	38	5.E-07
KMW06	Bouwer and Rice	2.39E-06		36	7.E-08
KMW07	Bouwer and Rice	7.21E-06		32	2.E-07
KWS	Bouwer and Rice	1.73E-06		42	4.E-08

[1] Bulk Hydraulic Conductivity was calculated by dividing the Transmissivity by aquifer thickness

1.17 Groundwater Inflow Estimation

As a preliminary estimate, Golder (2015a) calculated the temporal steady-state groundwater inflow in to the Pit #1 (i.e. Arhavi Pit and Adana Pit) which the largest and deepest among all. The calculations were based on the analytical solution developed by Marinelli and Niccoli (2000) which is commonly used in open pit mine hydrogeology studies. According to this equation, the flow region is divided into two zones. Zone 1 exists above the base of the pit and represents flow to the pit walls. Zone 2 extends from the bottom of the pit downward and considers flow to the pit bottom. Based on the geological and hydrogeological studies, saprolite, saprock and basement rock were considered. The depth of the main pit is around 80 m. The average depth to groundwater across the pit before mining is assumed to be around 10 m below ground level. The saturated thickness of saprolite and saprock exposed in the pit was assumed to be 20 m and 10 m, respectively. The remainder of the pit was assumed to be basement rock (40 m).

Due to inherent heterogeneity of the subsurface and the uncertainty of the moderately permeable quartz veins which would affect the inflow rates, the weighted average hydraulic conductivity value was used in the calculations. Accordingly, K value in Zone 1 is assumed $5 * 10^{-7}$ m/s (hydraulic conductivity of KMW05). The horizontal conductivity of the bedrock materials below the pit bottom (Zone 2) was assumed to be equal to the horizontal hydraulic conductivity of the basement rock materials in the pit walls. The vertical hydraulic conductivity of Zone 2 was assumed to be 0.5 times the horizontal hydraulic conductivity. The groundwater recharge was estimated to be 330 mm, representing the 15% of the average annual rainfall.

The inflow was calculated for every 10 m of pit elevation from the saturated level of the pit wall to the pit bottom. The results are presented in the Figure 32. As seen from the figure groundwater yield of the hydrogeological system is quite poor. Predicted maximum groundwater inflow is 7 L/s at the pit bottom elevation of 170 m.

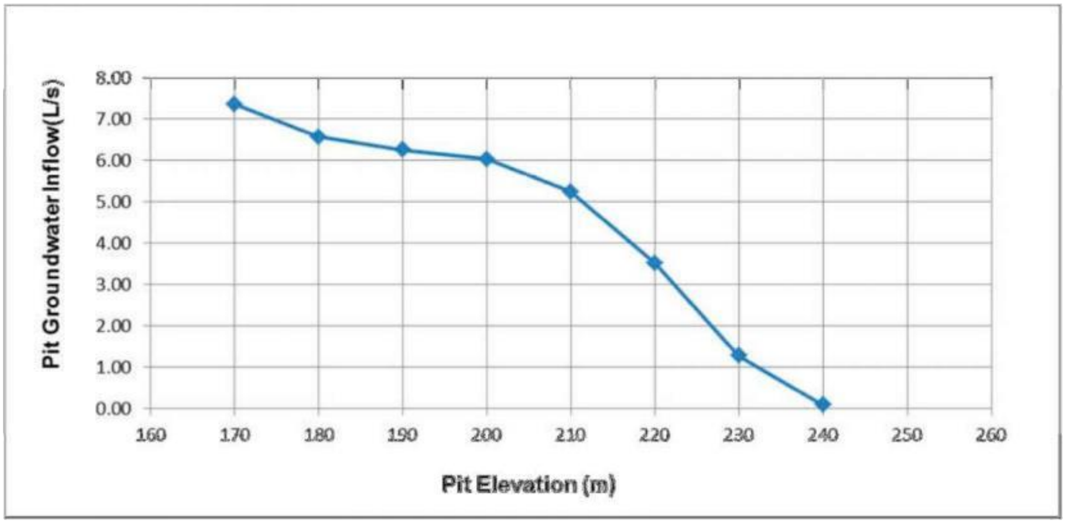


Figure 32 Groundwater inflow prediction to Pit 1# (i.e. Arhavi Pit and Adana Pit) (after Golder, 2015a)

Golder (2015a) notes that “if high-permeability features that were not identified to date by site investigations are encountered during mining in the pit walls at elevations that are below the pre-development water table, they could result in larger inflows that those presented herein”.

It should also be noted that the inflow predictions do not include the effects of direct precipitation and run-off that could enter the pit from the surrounding areas.

1.18 Open Pit water balance

A pit water balance model spreadsheet was developed by Golder (2015a) by using annual values of backfill seepage and net groundwater inflows/outflows. In order to improve the precision of the results, a monthly time step was used as significant water level variations could occur over the course of one year.

The water balance was based on below equation. All units in the equation are expressed in terms of volume.

$$Vt = (Vt-1 + Vdp + GWIt) - (GWOt + Vevp)$$

where:

V_t = Volume of water in the pit at month t

V_t-i = Volume of water in the pit at month t-1, i.e., the previous month

Vdp= Direct Precipitation

GWI_t = Groundwater Inflow

GWO_t= Groundwater Outflow

Vevp= Evaporation from Pit Lake Surface

A depth-surface area and depth-volume relationship for Pit 1 (the Arhavi Pit) was developed based on the pit geometry in drawings provided by MNG Gold as this is where the mining will take place deeper compared to other pits.

Monthly average precipitation data of Cocopa Station was considered in the pit water balance (PMDE, 2014).

The result indicates that the water table will likely reach to 60m above the pit bottom in approximately 6 years. Time to reach the water table to the steady state conditions is 14 years (Figure 33).

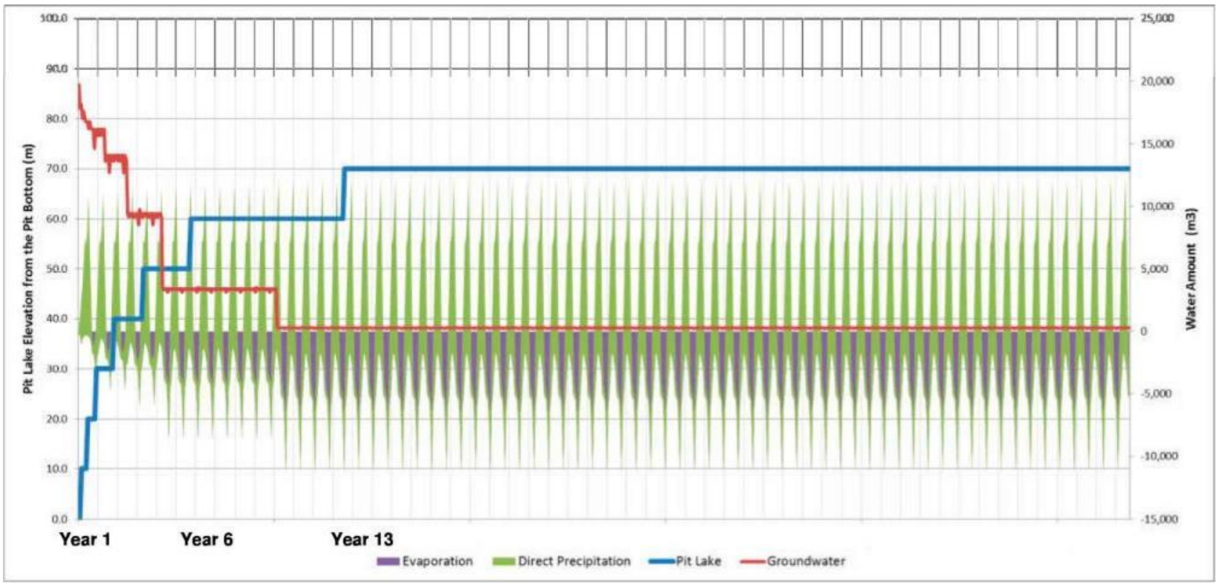


Figure 33 Pit 1 Lake Water Balance

1.19 Conceptual Groundwater Model

A conceptual groundwater model was established by Golder (2015a) based on compilation and review of the available data which included the followings:

- Identification and review of the literature, such as reports on the site or regional geology, hydrogeology, hydrology, water use, etc.
- Municipal/local, provincial database
- Results of previous investigations related to geology, hydrogeology, engineering, etc.
- Baseline data (water levels, hydraulic testing, streamflow, climate, etc.)

Assessments in this study agrees with the conceptual groundwater model of the Golder (2015a) as explained below:

Figure 34 shows the core box photographs of the main hydrogeological units cut in borehole KDW01. Other boreholes present the same view. The uppermost part of the hydrostratigraphic sequence starts with iron-rich reddish soil (i.e. the saprolite) which comprises mainly of clay and silt-sized sediments. The lower part of the saprolite is a transition zone to saprock. Here, the weathering has not reached its final stage of the complete clay formation. Saprock has a greyish color and includes silt, sand and gravel-sized sediments. Below the saprock, basement rock is located as a solid rock unit.

The first hydrogeological unit to consider is the uppermost saprolite layer. This geological unit has been formed by the weathering of the underlying basement rock. Saprolites generally show a high degree of heterogeneity between their clay and sandy constituents and as such layers of high and low permeability are often present.

The permeability of the basement rock is more dependent on the rock competency than its mineralogy. The flow of groundwater in this zone is structurally controlled with water movement occurring through fractures and weather zones. Water storage is low due to the majority of the rock mass being impermeable, but the ability to transmit water can be high through the fracture systems which control groundwater flow.

In general, among all hydrostratigraphic units outlined above, the sand-rich parts of the saprolite and saprock are more promising in view of groundwater abstraction by wells. Groundwater can be easily tapped by shallow hand-dug wells in high rainfall areas. The saprolite/saprock has relatively high groundwater storage compared to the underlying bedrock. Regional groundwater levels in the saprolite are sustained by recharge from surface water and rainfall. Most of the surface run-off occurs during the rainy season when the soil becomes saturated. However, in topographically low parts of the study area, permeable zones of saprolite can recharge local stream zones or ponds.

a) Uppermost section of the saprolite

b) Lower part of the uppermost section of the saprolite

c) View of saprock located between the saprolite and basement rock

d) View of basement rock

Figure 34 Core box photographs of the main hydrogeological units cut in borehole KDW01 (after Golder, 2015a)

The groundwater flow in the hydrostratigraphic sequence is primarily horizontal, moving from northeast to southwest. In the vicinity of study area, regional groundwater is towards St. John River and its tributary which is located at the western boundary of the hydrogeological assessment area.

Eventually, the hydrogeological conceptual model of the study area can be seen as a three-layered unconfined groundwater flow system in which the hydraulic conductivity decreases from about 10^{-6} m/s in saprolite at the top to 10^{-7} m/s in saprock and to 10^{-8} m/s in the basement rock at the bottom. These values suggest a poor aquifer zone at the top of hydrostratigraphic sequence which overlies a very poor aquifer (aquitard) to impervious (aquiclude) zone toward bottom. Groundwater inflow estimate of the Golder (2015a) agrees with the available observations.

Core box photos of the basement rocks indicate in general a solid rock zone. Almost all of the fractures in the cores are fresh-looking and it seems that they have formed during the maneuvering of the wire-line coring system. However, there is always a possibility of encountering crushed zones in the basement rock along which the hydraulic conductivity might have enhanced several orders of magnitude of the primary value. Considering the well log data and the field view of slopes of open pits, average thicknesses of the saprolite and saprock units can be thought as 20 m and 10 m, respectively.

The relation of groundwater to structure and topography is quite important because it may indicate promising hydrogeological conditions; the stream courses, in fact, may be active recharge and discharge zones, often marking fault and shear zones along which groundwater movement occurs. The concept of the groundwater flow particularly in basement rock is therefore related more to the structural aspects of the hard rocks that to their properties as groundwater conductors.

1.20 Numerical Groundwater Flow Model

1.20.1 Field conditions

In the final stage of the Operational Phase of the Kokoya Gold Mine, production will be continued by means of underground mining activities (i.e. Kokoya UG Project) through one main ramp and one auxiliary ramp for possible Ankara ore extraction to be excavated from the existing open pits. Lateral mining galleries will be connected to these ramps. In Kokoya UG Project, the two production methods to be used are Open Stope and Cut & Fill. Both methods involve the backfill of excavated areas as part of production process. As shown in Figures 35 and 36, by the end of the project the whole ore extraction zone will be backfilled leaving very negligible risks for soil compaction.

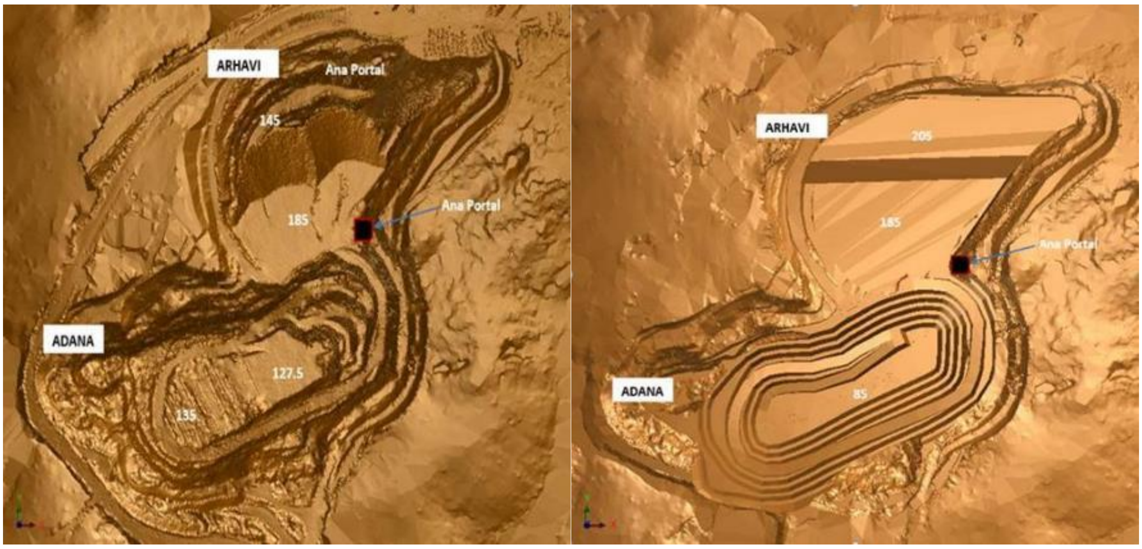


Figure 35 View of the Open pit surface in February 2020 (left) and in June 2020

Figure 36 North-south cross-section of the open pit (at the End of Life of the mine, Arhavi Pit at the left will be backfilled almost completely. and Adana Pit at the right will be backfilled partly)

1.20.2 Properties of model domain

The numerical groundwater flow domain covers the entire basin of the Hydrogeological Assessment Area. The flow domain is bounded by St. John River from the south and by one of its tributaries from the west. Western, northern and eastern boundaries follow the local water divide.

The hydrostratigraphy of the flow domain includes from top to bottom a) the saprolite, b) saprock and c) the bedrock units. According to previous aquifer tests, mean hydraulic conductivity values of saprolite, saprock and bedrock are 10^{-6} m/s, 10^{-7} m/s and 10^{-8} m/s. These values suggest a poor aquifer layer for the saprolite zone whereas the saprock and bedrock can be described as a very poor aquifer (aquitard) layer and impervious (aquiclude) layer, respectively. Therefore, the model domain is described as a three-layer groundwater flow system. The thickness of saprolite and saprock is about 20 m and 10 m, respectively. Saprolite and saprock thicknesses are assumed constant throughout the flow domain. At the beginning, the bottom elevation of the model is assumed 0 m. Since the flow system is not confined from top, unconfined flow condition is assumed for the entire model domain. Porosity (n), specific yield (Sy) and specific retention (Sr) values are taken from the literature as the typical values of the corresponding geologic medium (Table 18).

Table 18 Properties of the model domain

Layer	1	2	3
Unit	Saprolite	Saprock	Bedrock
Top Elevation (m)	SE	Surface - 20 m	Surface - 30 m
Bottom Elevation (m)	Surface - 20 m	Surface - 30 m	0
n (%)	35	25	1
Sy (%)	5	20	0.9
Sr (%)	30	5	0.1
K (m/sec)	1.0E-06	1.0E-07	1.0E-08
K (m/year)	31.5	3.15	0.31

1.20.3 Groundwater flow model of the basin

In the first stage of modeling, entire Hydrogeological Assessment area (i.e. the basin) was taken as the modeling domain to assess the capability of the model in representing the basin-wide hydraulic head distribution.

The finite difference MODFLOW (McDonald and Harbaugh 1988) 2000 is used as the numerical flow groundwater flow model. The model run in transient mode with 12 time steps. The flow domain discretized spatially in to 100 m by 100 m cells. Entire model domain is represented by 4241 cells.

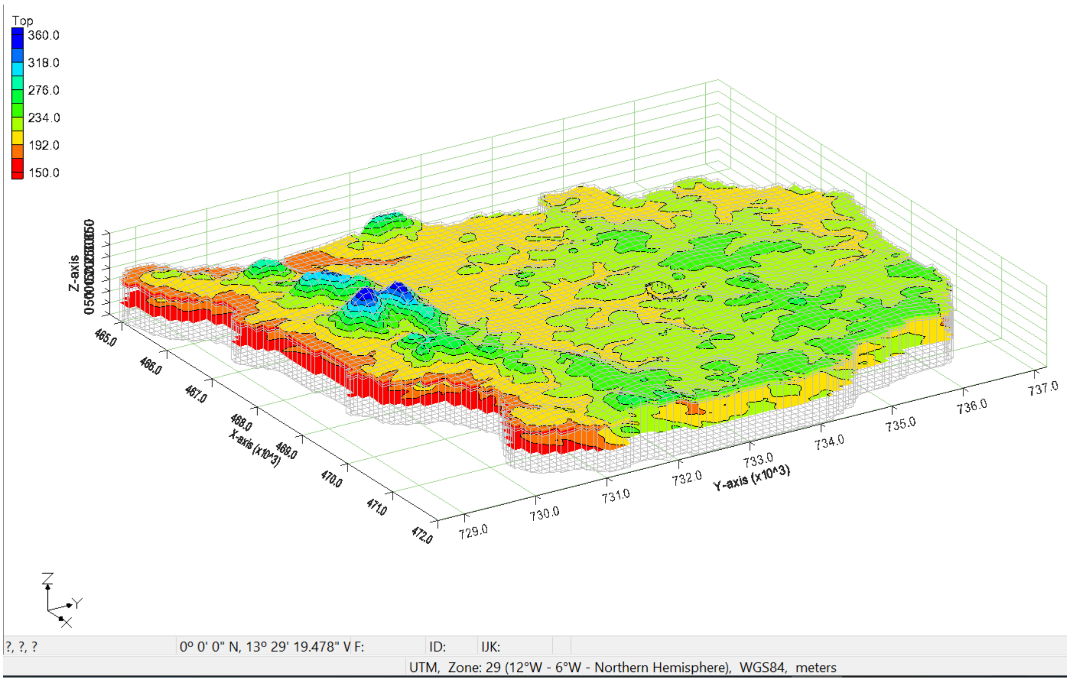
Initial hydraulic head data is derived from the elevations of surface waters like streams, rivers, ponds, swamps and, the groundwater head data is derived from the existing boreholes.

Surface topography of the model domain was obtained from MNG Gold in the form of digital elevation model.

Recharge from rainfall is taken from Golder (2015a) as 330 mm/m2_year.

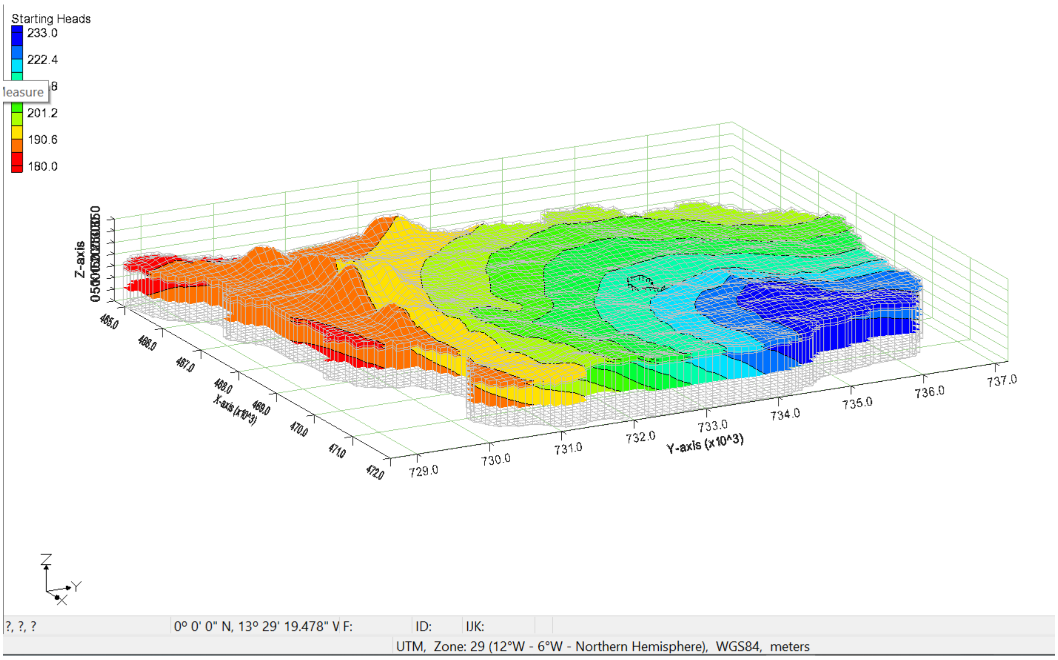
Model boundaries like rivers, perennial streams, ponds and swaps are described as General Head Boundaries (GHB). Model cells defined as GHB can receive groundwater if the groundwater head in the neighboring cells are above the head in the GHB cell. If the head in GHB cell is above the groundwater head in neighboring cells then, the GHB cell recharges the neighboring cells. The flowrate between the GHB and the neighboring cells are determined by the head gradient and the conductance of the cell face through which the flow occurs.

The model run for steady-state flow condition for 12 stress periods which comprises of the entire simulation period of one year. Figure 37 the top elevation of the model domain. Starting groundwater head distribution is shown in Figure 38 and decreases from the northeast towards southwest. The St. John River flows from east to West along the southern boundary of the Hydrogeological Assessment area (i.e. the basin). Numerical model’s performance in representing the groundwater system in the field was checked by the calibration graph presented in Figure 39. The computed and observed groundwater heads in 17 observation boreholes agree reasonably well. Many of the data points scatter along the 1:1 diagonal line. Only a few boreholes deviate slightly from the 1:1 line. These boreholes are located nearby the Say Town and were affected by the potable groundwater use by means of hand pumps. Figure 40 shows the spatial distribution of the boreholes used in model calibration and distribution of the starting groundwater head in the basin. Model-predicted distribution of the groundwater head at the end of the simulation period is shown in Figure 41.



?, ?, ? 0° 0' 0" N, 13° 29' 19.478" V F: ID: IJK:
UTM, Zone: 29 (12°W - 6°W - Northern Hemisphere), WGS84, meters

Figure 37 View of model top elevation (looking to northwest).



?, ?, ? 0° 0' 0" N, 13° 29' 19.478" V F: ID: IJK:
UTM, Zone: 29 (12°W - 6°W - Northern Hemisphere), WGS84, meters

Figure 38 Starting groundwater head distribution in the model domain (looking to northwest).

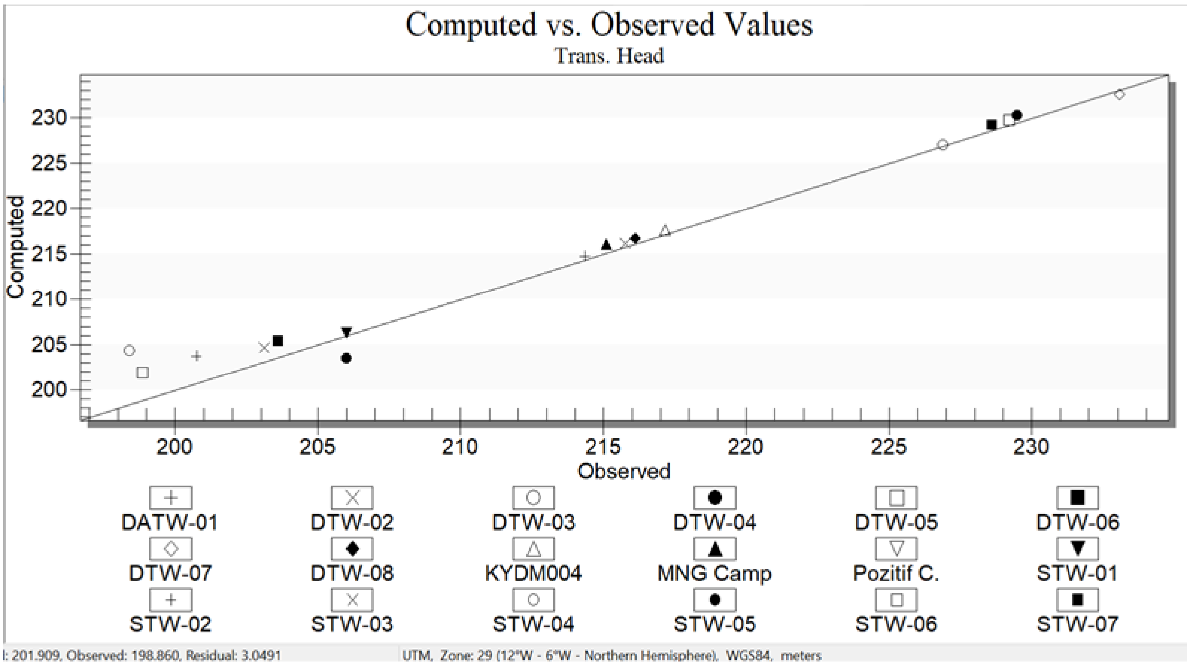


Figure 39 Comparison of the observed and computed groundwater head. Diagonal is the 1:1 line.

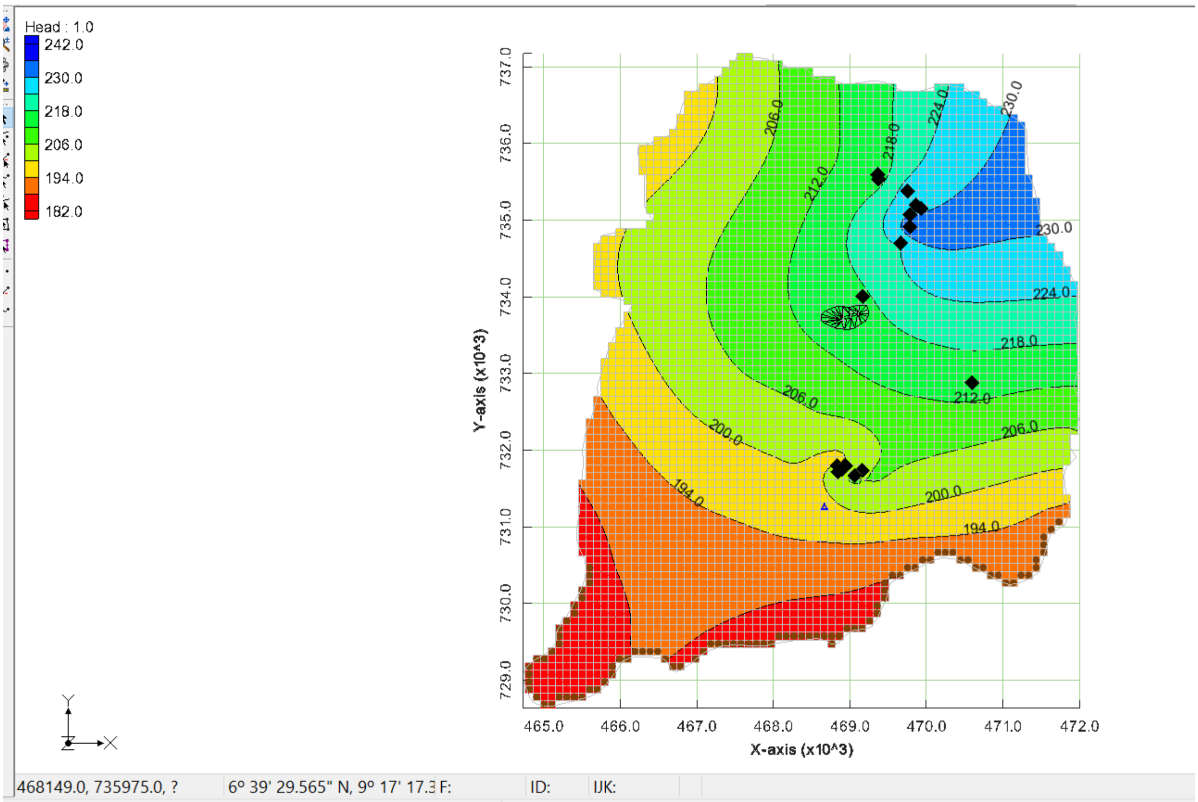


Figure 40 Spatial distribution of the boreholes used in model calibration and distribution of the starting groundwater head.

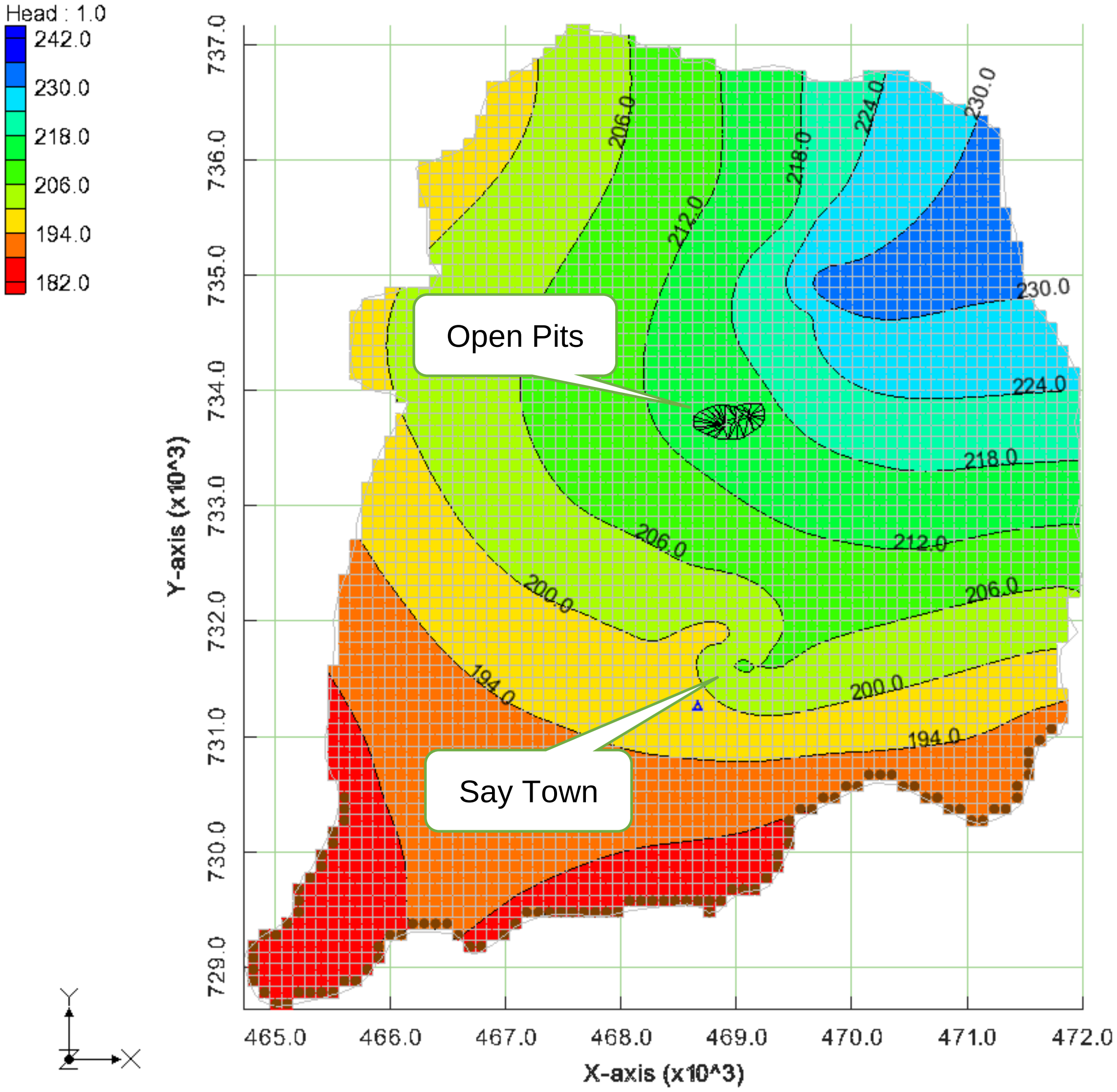


Figure 41 Model-predicted distribution of the groundwater head at the end of the simulation period.

1.20.4 Groundwater flow model of the open pits

In the second stage of the modeling, the aim is to simulate the groundwater flow into the open pits. Only the Arhavi (Rockcrusher) and İstanbul (Caterpillar) pits were considered in the modeling as they represent largest open pit excavations. The detailed geometry of the pits was simplified in agreement with the model cell size dimensions.

The basin-wide flow domain is translated into the model domain as three layers (from top to bottom, saprolite, saprock and bedrock) and sptaially discretized into 25 m by 25 m cells. The entire model domain comprised of 200,123 active cells. Recharge and

GHB (General Head Boundary) packages of the MODFLOW 2000 were used in the model which was run in transient model. Flow into pit was simulated by GHB hydraulic head values which were set to the ground surface elevations of the cells corresponding to the open pit. A very high value of conductance (i.e. 7,000,000 m2/y) was used to ensure groundwater drainage.

Figure 42 shows the GHBs and the starting head distribution of the model domain. Predicted hydraulic head ditribution does not difer much from the initial heads due to the low hydraulic conductivity of the hydrogeological units. In other words, the excavations in the model domain does not disrupt the pristine hydrogeological system because of the low permeability of the surrounding material.

As shown in Fiure 43, the open pits cause a local depression and the hydraulic heads which were around the prisitine ground elevation initially reduced to open pit ground elevations. The depression cone is local and does not extend long distances because of the low permeability of the geological material.

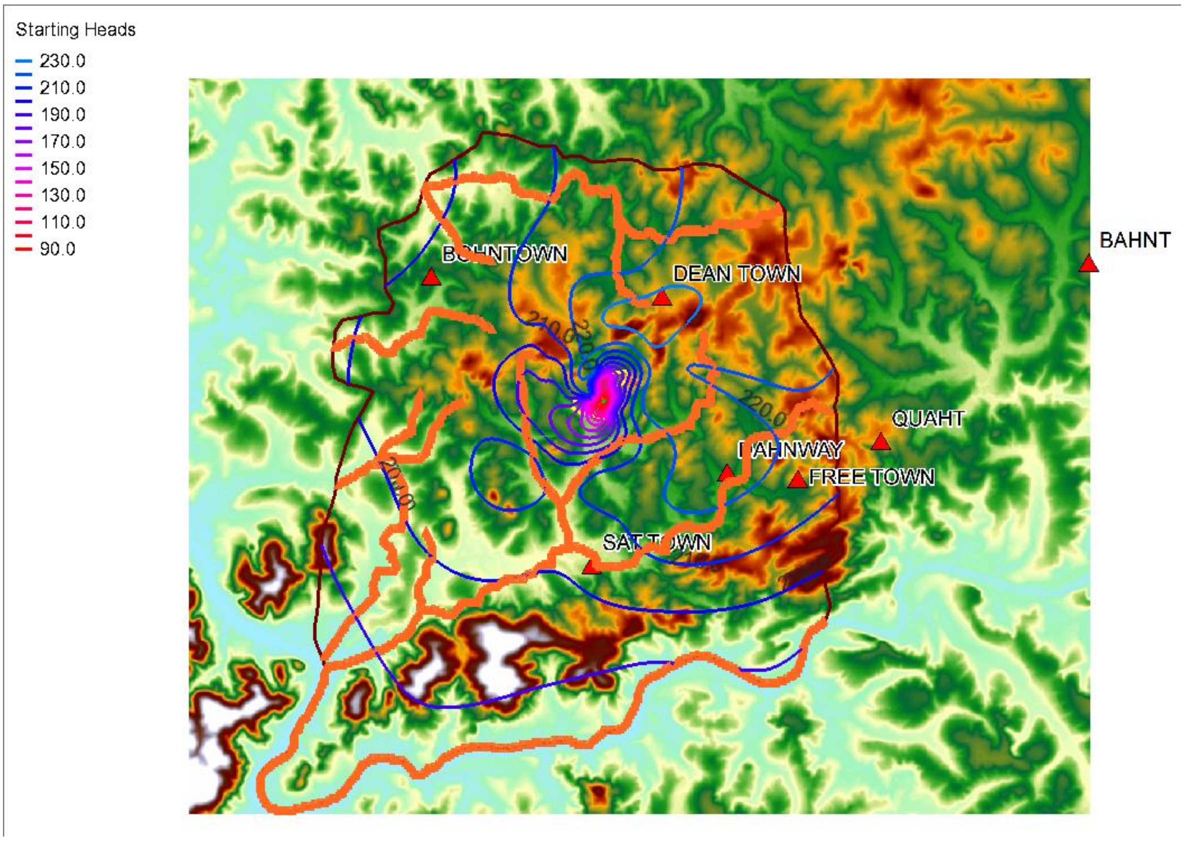


Figure 42 GHBs and the starting head distribution of the model domain.

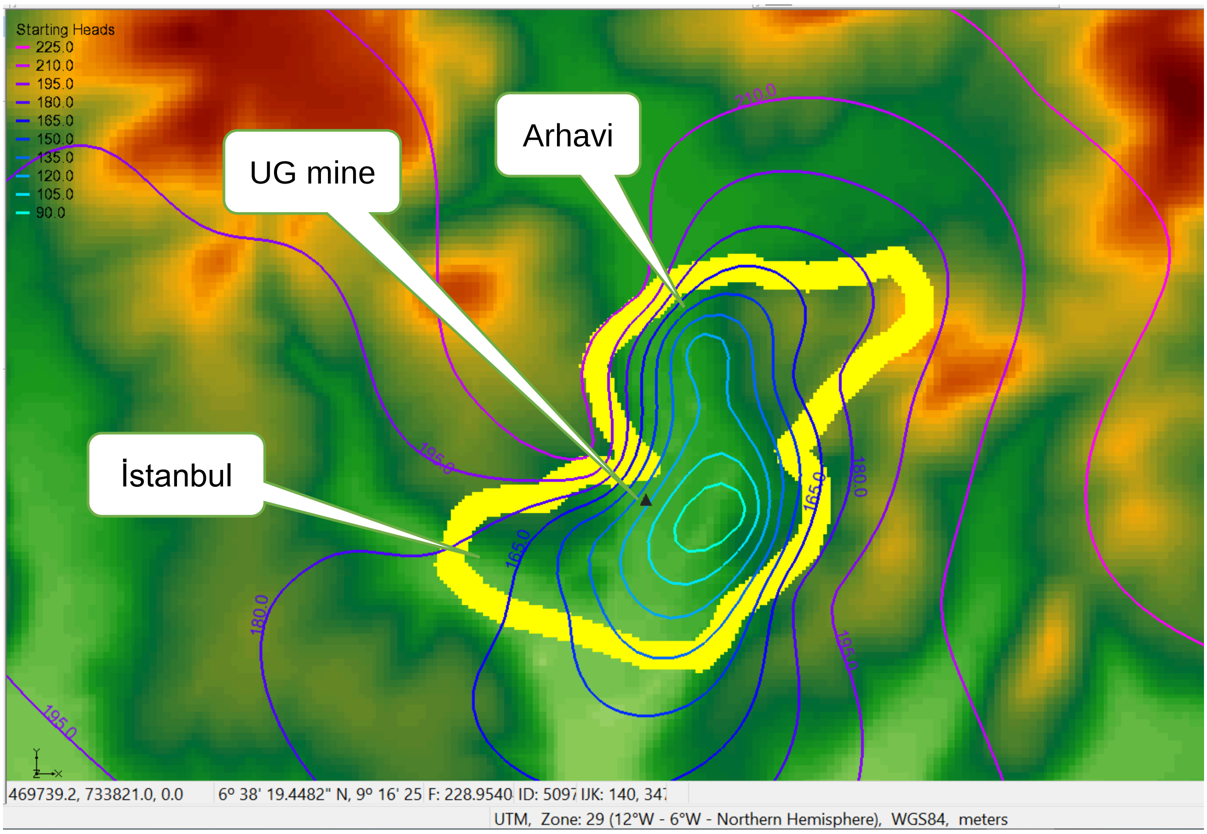


Figure 43 Computed groundwater head distribution around the Arhavi and İstanbul open pits. (Thick yellow line marks the limit of open pits).

1.20.5 Groundwater flow model of the underground excavation

In the third stage of the modeling, the calibrated model is used to estimate the inflow into the UG mine galleries. However, three-dimensionally complex underground structures are difficult to describe to model and even if they can be described in the expense of increased number of model cells, this would increase the computational time tremendously and the the resulting model would suffer from numerical convergence problems. Therefore, the complex mine geometry is converted to equivalent shaft geometry of similar volume. In this context, the UG mining plan of the stope (i.e. geometry) obtained from MNG Gold is converted to equivalent shaft geometry by using the SURPAC software. Table 19 shows to-be excavated void volume (m3) versus depth interval (i.e. Elevation from and Elevation to, in m). Total volume of the material to be excavated and the total height of the zone to be reached in the stope are 99,907 m3 and 190 m. Hence, the to-be excavated area per m depth of the “shaft” is 526 m2 which corresponds to a square that measures 23 m by 23 m. Consequently, a cell size of 25 m by 25 m is selected as the scale of spatial discretization of the secondary model domain which is used to estimate the amount of groundwater inflow into underground excavation. The bottom elevation of the stope (i.e. the shaft) was set to -112 m below sea level.

Figure 44 shows the computed groundwater head distribution around underground excavation in the Arhavi and İstanbul open pits. Figure 45 shows the E-W cross-section of the computed groundwater head distribution around underground excavation in the Arhavi and İstanbul open pits. AS expected from a low hydraulic conductivity medium, there occurs a sharp head decline nearby the underground excavation.

Figure 46 shows the water budget of the model draining the underground excavation in the Arhavi and İstanbul open pits under the so-called “Normal Case” conditions. This case represents the model explained above. However, it is likely that a long shear zone with a hydraulic conductivity higher than that of the bedrock (K= 10^{-8} m/sec) may connect the underground excavation to the St. John River which represents a continuous water supply. To analyze this likely effect, the hydraulic conductivity of saprolite (K= 10^{-6} m/sec) was attributed to a columns of all three layers of the finite difference mesh between the shaft and the river. The width of the column was equal to the model cell size which is 25 m. This “likely” modeling scenario is named as the “Worst Case”

Table 19 Volumetric properties of the UG mine

Elevation from (m)	Elevation to (m)	Volume of excavated void (m3)
80	90	46
70	80	92
60	70	4712
50	60	2420
40	50	9080
30	40	2354
20	30	10293
10	20	2201
0	10	10220
-10	0	2176
-20	-10	10146
-30	-20	2132
-40	-30	10627
-50	-40	2108
-60	-50	10529
-70	-60	2065
-80	-70	9957
-90	-80	2025
-100	-90	6724
-110	-100	10
Total Volume (m3)		99907
Total Height (m)		190
Area (m2)		526
Cell size (m x m)		23

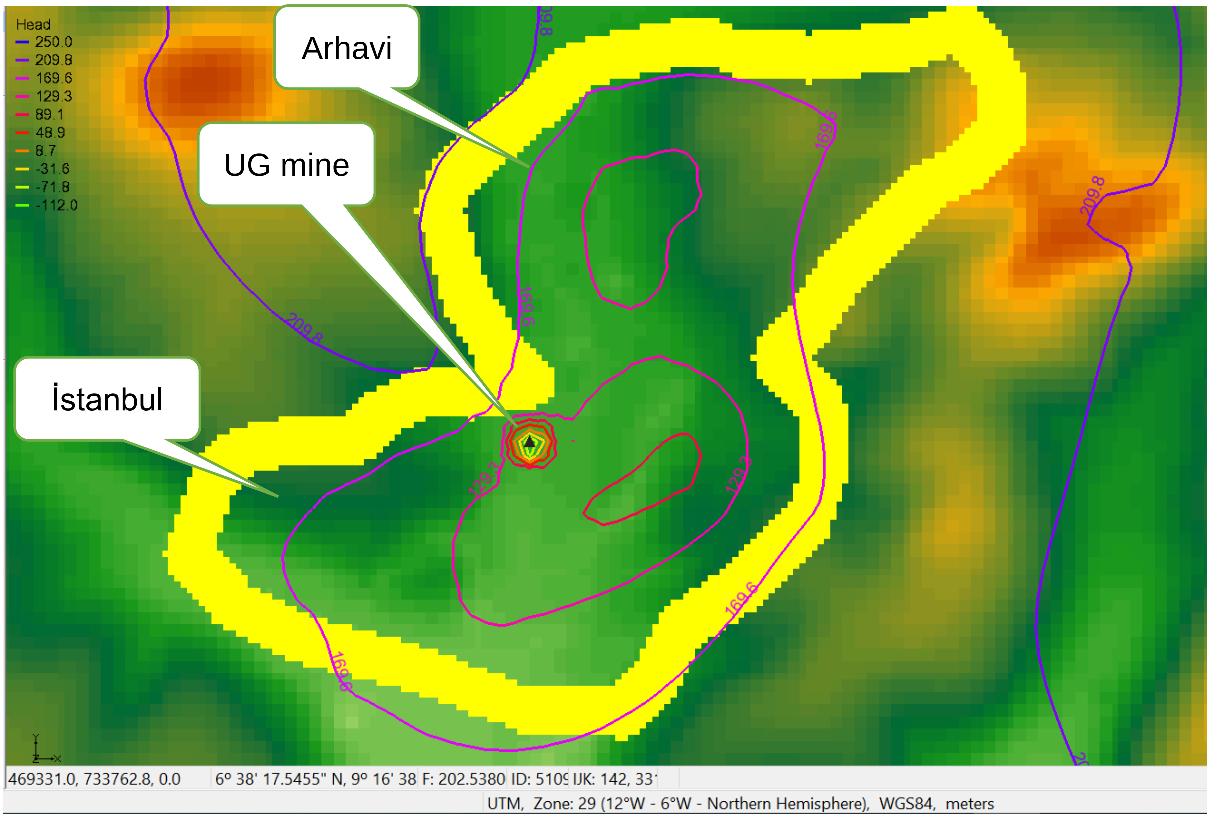


Figure 44 Computed groundwater head distribution around the underground excavation in the Arhavi and İstanbul open pits.

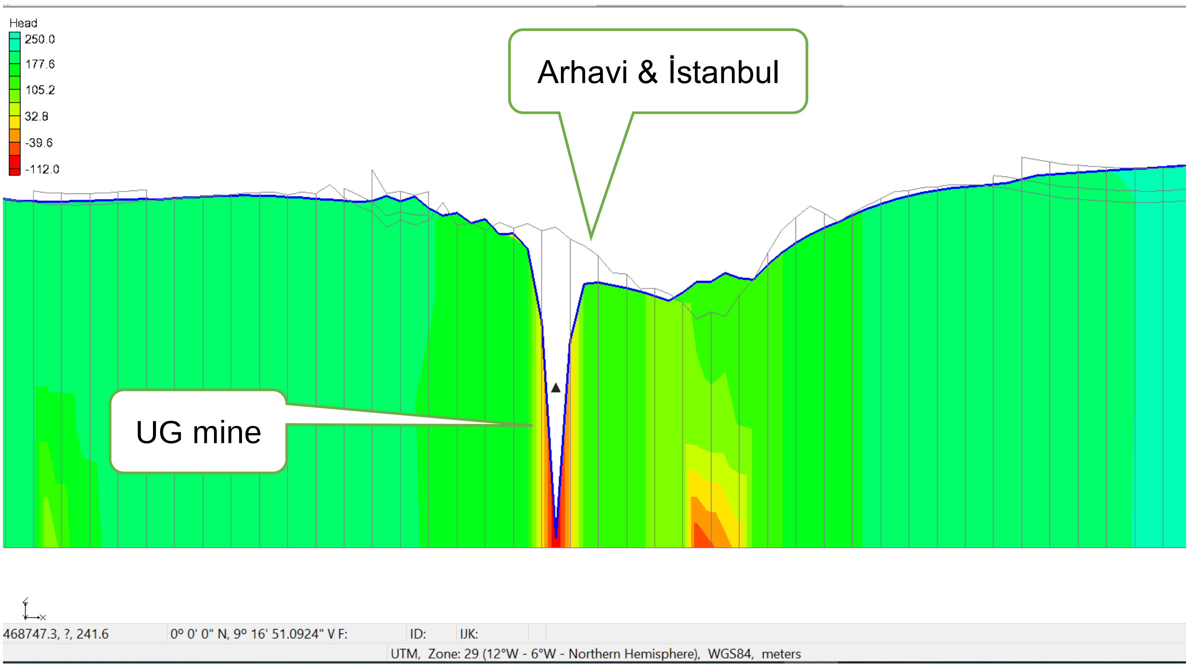
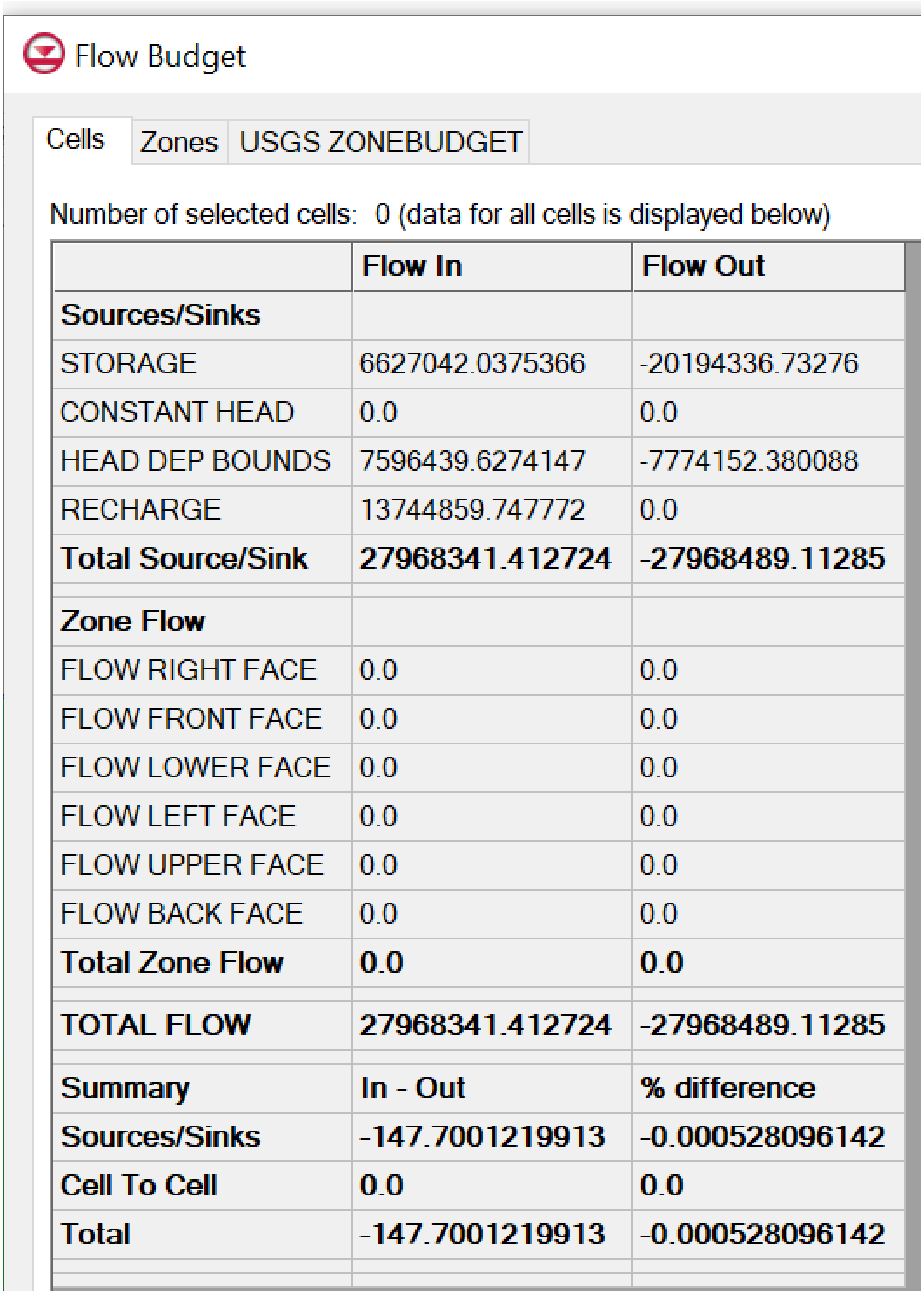


Figure 45 E-W cross-section showing the groundwater head distribution around the underground excavation in the Arhavi and İstanbul open pits.



Number of selected cells: 0 (data for all cells is displayed below)

	Flow In	Flow Out
Sources/Sinks		
STORAGE	6627042.0375366	-20194336.73276
CONSTANT HEAD	0.0	0.0
HEAD DEP BOUNDS	7596439.6274147	-7774152.380088
RECHARGE	13744859.747772	0.0
Total Source/Sink	**27968341.412724**	**-27968489.11285**
Zone Flow		
FLOW RIGHT FACE	0.0	0.0
FLOW FRONT FACE	0.0	0.0
FLOW LOWER FACE	0.0	0.0
FLOW LEFT FACE	0.0	0.0
FLOW UPPER FACE	0.0	0.0
FLOW BACK FACE	0.0	0.0
Total Zone Flow	**0.0**	**0.0**
TOTAL FLOW	**27968341.412724**	**-27968489.11285**
Summary	**In - Out**	**% difference**
Sources/Sinks	**-147.7001219913**	**-0.000528096142**
Cell To Cell	**0.0**	**0.0**
Total	**-147.7001219913**	**-0.000528096142**

Figure 46 Water budget of the model draining the Arhavi and İstanbul open pits and the underground excavation (Normal Case).

Table 20 shows the results of numerical groundwater flow model for the normal and worst cases. Under the normal case, the amount of groundwater to be drained by the underground excavation is 6,132 m^3/year (0.2 L/sec) whereas under the worst case scenario, annual amount of groundwater arriving at the underground excavation is 223,381 m^3/year (7.1 L/sec).

The effect of groundwater drainage towards the UG mine was analyzed also for the local hydraulic head in the towns around the Kokoya Mine. Table 21 shows the comparisons between the initial and computed heads around the towns. In the table, Layer 1, 2 and 3 represent the saprolite, saprock and bedrock units. As seen from the table, UG mining activity is expected to have no measurable effect on the groundwater heads around these towns.

Currently, additional exploratory drilling activities continue in the Arhavi and İstanbul open pits. Hydraulic conductivity of the bedrock will be also determined by Lugeon water pressure tests in these boreholes. The hydraulic conductivity data obtained from these tests should be transferred into the present models to improve the Prediction capability.

Table 20 Predicted groundwater flow into the UG mine

	Groundwater Volume (**m^3**/year)	Drainage Flow Rate (Liters/sec)
Normal Case **(**K= 10^-8 m/sec)	6,132	0.2
Worst Case **(**K= 10^-6 m/sec)	223,381	7.1

Table 21 Initial and calculated groundwater heads in the towns around the UG mine.

Settlement	Initial Head (m)	Computed Head “normal case” (m)			Computed Head “worst case” (m)		
		Layer1	Layer2	Layer3	Layer1	Layer2	Layer3
Bohn town	201.6	203.2	201.9	201.6	203.2	201.9	201.6
Dean town	231	232.2	231.1	230.8	232.2	231.1	230.8
Dahn way	223	223.3	223.2	223.1	223.3	223.2	223.1
Free town	216.2	217.8	217.8	216.2	217.8	217.8	216.2
Say town	202.3	204.4	202.6	202.2	204.5	202.7	202.3

POTENTIAL IMPACTS

1.21 Identified Impacts

Potential impacts of Kokoya Gold Mine Project assessed in detail by Golder (2015a). Observations made so far concerning the groundwater system in the project area did not indicated a problem. However, the evaluations and the recommendations in Golder (2015a) concerning the monitoring of the hydrogeological system are still valid and are summarized below.

The project was subdivided into three phases for the purpose of potential impacts as listed below:

- Construction Phase;
- Operational Phase; and
- Decommissioning and Closure Phases.

Potential groundwater impacts are likely to arise in terms of quantity and quality as a result of the following units in the project for the above-listed phases of the project:

- Open Pits;
- Waste Rock Dump (WRD); and
- Tailings Storage Facility (TSF).

Process plant, camp area, and supporting facilities are not included in the rating and ranking process because of the sizes of these units and assuming that necessary drainage precautions would be in place. Additionally, a waste water treatment plant is proposed for the biological wastes which will treat the water to meet with the local requirements.

Potential groundwater impacts are listed below:

- Groundwater inflows;
- Contact water;
- Groundwater level decline; and
- Seepage and contamination of groundwater.

1.22 Impact Assessment

1.22.1 Construction Phase impact assessment

The Construction Phase has already completed. Yet, the impact assessments concerning this phase are presented below and compared to real situation observed in the field. According to the assessments, the potential impacts for the construction phase were envisaged as follows:

- Groundwater inflows could be minimized by early dewatering which would also reduce the amount of contact water. Although the potential impact of groundwater inflows was assessed to be of **moderate**, it would be reduced to **low** with mitigation as early dewatering would decrease the amount of groundwater inflow and hence makes water management easier. This process has been observed to have a **low** impact in the field.
- Construction of the diversion ditches around the pits would prevent the run-off water from flowing into the construction area and creating additional contact water to be managed. Direct precipitation would be collected in the sumps. The potential impact of contact water was assessed to be of **moderate,** however, with mitigation, it would be reduced to **low** as the amount of water to be managed would be significantly lowered with the mitigations during the construction phase. This process has been observed to have a **low** impact in the field.
- Ground compaction of the WRD and TSF areas would decrease the infiltration rate through the footprints of these areas and hence potential contamination. Although the potential impact of seepage and contamination was assessed to be of **moderate**, it would be reduced to **low** with mitigation as the compaction of the ground would significantly reduce the infiltration. This process has been observed to have a **low** impact in the field.

1.22.2 Operational Phase impact assessment

The Operational Phase has already been continuing. The impact assessments concerning this phase are presented below and compared to real situation observed in the field:

- Groundwater inflows would be decreased by active dewatering during the operation which would also reduce the amount of contact water. The potential impact of groundwater inflows was assessed to be of **moderate**. During the operation phase, even though the inflow amount would be decreased hence the rating, significance would remain as **moderate** as there would still be groundwater inflow to the pits. So far, this process has been observed to have a **low** impact in the field.
- Preliminary groundwater flow modeling assessments indicated a low groundwater inflow in to the underground excavtions due to low permeability of bedrock. Hence, the impact of drainage from underground excavations on surrounding village wells is regarded as **low**.
- Diversion ditches around the pits would keep preventing the run-off water from flowing into the open pits and creating additional contact water to be managed. However, the **moderate** impact rating would still remain as **moderate** as it is not only direct precipitation but also groundwater inflows that goes into the pits and becomes contact water. Contact water in the pits would be collected in the sumps for water quality monitoring. However, the **moderate**

impact for WRD and TSF would be reduced to **low** as the amount of contact water is related with the direct precipitation only due to the diversion channels constructed around these units. So far, this process has been observed to have a **low** impact in the field.

- Groundwater level decline would be **high** especially near the pits. The high rated impact would be reduced to **moderate** by using the dewatering wells for freshwater supply. So far, this process has been observed to have a **low** impact in the field.

  ▪ Ground compaction of the WRD and TSF areas and lining the base of the TSF would decrease the infiltration rate through the footprints of these areas and hence potential contamination. As a result, the **high** rated impact would be reduced to **moderate** with mitigation. So far, this process has been observed to have a **low** impact in the field.
- Underdrain system would be put in place beneath the clay liner of the TSF to allow springs to naturally flow. So far, this process has been observed to have a **low** impact in the field.
- Operational phase groundwater quality monitoring network would be established. The network was established and no adverse effect have been encountered so far.

1.22.3 Closure and post-closure Phase impact assessment

The outlines of impact assessments concerning this phase are presented below:

- Active dewatering will be stopped and groundwater inflow amounts will increase hence the time required for the pit lake formation will be less. However, the **moderate** impact would remain as **moderate** as it would still be short to medium-term to reach the static conditions.
- Run-off ditches would still be in place to safely manage the pit lake formation. Pit lake water quality analysis would be established in support of the groundwater quality monitoring network. As the pit lake forms, groundwater level would increase which would be a positive impact for water levels.
- Seepage at the toe of the WRD and underdrains at the TSF would be analyzed. A conservative approach is used and the **moderate** impact is kept as **moderate** for the seepage and contamination of groundwater, however, with a closure plan that would be developed for the Kokoya project, it may be possible to mitigate the rating to low as well.
- Additional potential impacts identified would be evaluated, monitored, and implemented in the detailed closure plan prepared before the operation ceases.
- Decommissioning, closure, and post-closure phase groundwater quality monitoring network would be established.

CUMULATIVE IMPACTS

There are no other developments that have been identified in the vicinity of the project area which may result in cumulative effects. It has been assumed that any artisanal mining operations currently active in the close vicinity of the project area will not take place at the commencement of the project.

RESIDUAL IMPACTS

The Kokoya deposit is a low-sulphide gold-quartz vein deposit. These deposits typically generate mine waters with near-neutral pH values. However, physical enrichment of pyrite and other sulphides may be observed in the quartz veins. Based on the acid-base accounting results, there is only one potentially acid generating sample (from the quartz vein group) out of 45 samples. The geochemistry study revealed that samples with less than 0.2 % sulphide sulphur are not potentially acid generating. It may be possible to develop a defensible and reliable sulphur threshold for operational management of potentially acid generating/not acid generating rocks. Taking into consideration of the low sulphide sulphur values, no long-term impacts are foreseen.

MITIGATION MEASURES

Throughout the lifetime of the project starting from the construction to the end of the decommissioning, the following mitigation measures would be taken where feasible and applicable:

- Even though the geochemical test results show that the rocks to be mined do not have acid generating potential due to their low sulphide sulphur values, diversion channels and ditches would be constructed around the perimeters of the facilities especially open pit, WRD, and TSF to reduce of the amount of contact water to be managed.
- Contact water would be collected in the sumps and ponds, and analysed to determine whether it is in allowable limits for the discharge or it should be re-used as make-up water / sent to TSF / treated prior to discharge. Sediment basins would be constructed to reduce sediment erosion.
- Monitoring network would be established and re-adjusted throughout the lifetime of the project.
- Groundwater monitoring system would be implemented to measure the quality of the groundwater and the change in the groundwater levels.
- Base of the foundation of waste dump and tailings would be compacted to minimize the infiltration. Lining of the base of the tailings will prevent seepage through the facility if good contact can be achieved between the liner and the underneath. Hence, quality assurance should be applied during the construction.

CONCLUSION & RECOMMENDATIONS

Following the above impact assessment for the MNG GOLD Kokoya Project, below recommendations are applicable:

- Present water quality monitoring studies should be continued. New observation points may be added in the present network if required.
- Dummy, duplicate, SRM analyses are recommended to ensure the analytical quality of the water samples.
- Management plan of the contact water and non-contact water should be made and contact water should be used in the mining activities where it is not a risk to the environment; such as for the make-up requirement.
- Contact water should not be discharged to the environment unless it is compliant with the discharge requirements.
- Geochemical characterization conducted for the lithological units for the Kokoya Project shows that samples with less than 0.2 % sulphide sulphur are not potentially acid generating. Taking into consideration of the low sulphide sulphur values, no long-term impacts are foreseen.
- Numerical groundwater model development is recommended after further investigations to support the analytical solutions and simulations for all phase of the project.

REFERENCES

Golder, 2015a, Kokoya Gold Project, Hydrogeological Assessment Study. Project No: 14513150012, 125 p.

Golder, 2015b, Kokoya Gold Project, Environmental and Social Impact Assessment Final Report, Report No: 1400357, 320 p.

Golder, 2011, New Liberty Gold Mine (NGLM). Project Environmental and Social Impact Assessment (ESIA), Grand Cape Mount County, Liberia – Draft Scoping Report. Report number GHA1044. April 2011.

McDonald, M.G., and A.W. Harbaugh, 1988, A Modular Three-Dimensional Finite-Difference Ground-Water Flow Model, Book 6, Chapter A1, 586. U.S. Geological Survey Techniques of Water-Resources Investigations. Reston, Virginia: USGS.

Marinelli, Fred & Niccoli, Walter, 2000, Simple Analytical Equations for Estimating Ground Water Inflow to a Mine Pit. Ground Water. 38. 311-314.

MNG Gold (MNG), 2015, Geology, Alteration and Mineralization of Kokoya Gold Mine Project.

Ömer Ardıç Mühendislik Müşavirlik (ÖAMM), 2015, Preliminary Geological and Geotechnical Assessment and Compilation.

Project Managers and Design Engineers (Pty) Ltd (PDME), 2014, Definitive Feasibility Study Report for Kokoya Gold Mine.

United Nations (UN), 1988, Groundwater in North and West Africa, Department of Technical Co-operation for Development and Economic Commission for Africa, Natural Resources/Water Series No. 18.

WHO, 2017, Guidelines for drinking-water quality: fourth edition incorporating the first addendum. Geneva: World Health Organization. Licence: CC BY-NC-SA 3.0 IGO

ATTACHMENTS

ATTACHMENT-1: GROUNDWATER LEVEL MONITORING DATA

ATTACHMENT-2: EXAMPLE OF LABORATORY RESULTS WATER SAMPLES

ATTACHMENT-1: GROUNDWATER LEVEL MONITORING DATA

Borehole ID >>	KDW01	KDW02	KDW03	KDW04	KMW01	KMW02	KMW03	KMW04	KMW05	KMW06	KMW07	BH-1	BH-2	BH-3	BH-4	BH-5	BH-6	KWS
9-Mar-15	5.5	9.6	8.4	4.5														
16-Mar-15	5.35	9.95	8.1	4.1						3.97	8.1							
23-Mar-15	5.23	9.84	7.75	4.01						3.68	8.13							
30-Mar-15	5.26	9.76	7.84	3.96	9.96		12.27		1.66	3.54	7.96							
6-Apr-15	5.27	9.77	7.85	3.21	9.82	4.61	11.58	4.77	1.56	3.83	8.05							7.7
14-Apr-15	5.43	9.67	7.96	3.67	9.8	4.7	11.7	5.03	1.6	3.72	8.3							7.78
20-Apr-15	5.48	9.36	8.19	3.92	9.48	4.86	11.18	5.02	1.61	3.85	8.38							7.82
27-Apr-15	5.43	9	8.01	3.7	9.06	4.89	11.29	4.94	1.54	3.64	8.31							8.52
5-May-15	5.38	9.72	7.95	3.55	10.2	4.88	11.23	4.87	1.51	3.55	8.17							
11-May-15	5.44	9.95	8.04	3.67	10.26	4.92	11.38	4.84	1.6	3.74	8.23							
18-May-15	5.3	9.92	7.82	2.99	10.02	4.66	11.06	4.82	1.45	3.39	8.03							
25-May-15	5.06	9.07	7.64	2.69	9.34	4.52	11	4.79	1.37	3.47	8.02							
1-Jun-15	5.12	9.46	7.63	2.82	9.39	4.69	10.95	4.98	1.38	3.62	8.09							
8-Jun-15	5.09	9.56	7.58	2.8	9.43	4.64	10.88	4.7	1.51	3.58	8.08							
15-Jun-15	4.99	9.53	7.41	2.45	9.37	4.39	10.76	4.48	1.39	3.42	8							
23-Jun-15	4.78	9.47	7.45	2.32	9.25	4.27	10.64	4.3	1.36	3.38	7.9							
2-Jul-15	4.69	9.38	7.22	2.44	9.19	4.42	10.65	4.19	1.48	3.59	7.94							
6-Jul-15	4.74	9.38	7.38	2.55	9.22	4.49	10.68	4.23	1.51	3.61	7.98							
13-Jul-15	4.76	9.34	7.43	2.44	9.21	4.5	10.69	4.32	1.52	3.56	7.98							
20-Jul-15	4.77	9.33	7.44	2.48	9.21	4.51	10.73	4.35	1.56	3.64	8.02							
28-Jul-15	4.53	9.14	7.05	1.82	8.92	4.01	10.45	4.06	1.38	3.45	7.77							
4-Aug-15	4.5	9.08	7.17	2.22	8.94	4.29	10.49	4.09	1.51	3.55	7.8							
12-Aug-15	4.47	9.15	7.23	2.02	8.88	4.15	10.45	4.26	1.47	3.48	7.8							
30-Aug-15	4.32	8.89	7.13	1.85	9.32	4.33	10.35	4.02	1.5	3.57	7.62							
8-Sep-15	4.2	8.88	7.13	1.63	9.19	4.13	10.36	3.96	1.38	3.43	7.52							
15-Sep-15	4.06	8.78	7.07	1.38	8.94	4.21	10.15	3.84	1.06	3.4	7.41							

21-Sep-15	3.94	8.68	7.04	1.34	8.83	4.23	10.59	3.78	1.33	3.44	7.12							
28-Sep-15	3.94	8.7	7.25	1.7	8.91	4.49	10.11	3.85	1.43	3.54	7.28							
6-Oct-15	3.92	8.69	7.16	1.69	8.93	4.27	10.15	3.85		3.38	7.26							
14-Oct-15	3.81	8.62	7.06	1.68	8.82	4.35	10.27	3.66	1.37	3.5	7.14							
19-Oct-15	5.45	9.5	8.4	3.51	10.35	5.44	13.05	3.7	2.42	4.4	8.55							
26-Oct-15	5.47	9.4	8.48	3.45	10.44	4.45	12.5	5.46	9.49	5.44	8.63							
3-Nov-15	5.45	9.02	9.42	3.45	10.43	5.35	11.21	3.05	2.43	3.62	8.57							
9-Nov-15	5.54	9.03	8.45	3.45	10.46	5.44	9.13	4.04	2.45	4.03	8.55							
16-Nov-15	5.51	9.05	8.42	3.5	10.48	5.37	10.33	3.05	2.04	5.45	8.55							
23-Nov-15	5.49	10.53	8.45	3.53	10.4	6.37	12.53	5.42	2.3	5.44	8.55							
1-Dec-15	5.49	10.53	8.48	3.5	10.4	6.41	10.55	5.48	1.55	5.41	8.58							
7-Dec-15	6.51	10.57	8.45	3.53	10.4	6.37	12.53	5.42	1.58	5.44	8.55							
15-Dec-15	5.47	10.54	7.55	4.49	10.4	6.35	11.47	5.43	1.58	5.48	8.55							
21-Dec-15	5.54	10.56	7.58	4.49	10.42	6.38	9.57	5.46	1.59	5.47	8.6							
28-Dec-15	5.52	10.51	7.5	4.5	10.44	6.36	11.5	5.4	3.41	5.43	7.33							
4-Jan-16	5.48	10.56	7.57	4.49	10.49	6.37	11.52	5.4	3.41	5.43	7.73							
11-Jan-16	5.54	10.5	7.57	4.45	10.43	6.42	11.54	4.45	3.42	5.43	7.65							
18-Jan-16	4.59	10.54	7.56	4.51	10.45	6.37	11.49	5.44	3.41	5.42	9.63							
25-Jan-16	4.64		7.55	4.45	10.44	6.38	11.51	5.43	1.5	5.43	9.64							
1-Feb-16	6.49		7.56	4.51	10.45	6.41	11.54	5.41	3.44	5.47	9.63							
8-Feb-16	6.47		9.42	4.48	10.41	6.36	11.49	5.45	3.45	5.41	9.56							
15-Feb-16	6.53		9.47	4.54	10.45	6.4	12.53	5.4		5.4	9.59							
22-Feb-16	6.51		9.45	4.5	10.47	6.36	12.49	5.47		5.48	9.57							
29-Feb-16	6.54		9.41	4.45	10.49	6.4	12.46	5.43		5.46	9.58							
7-Mar-16	6.51		9.45	3.55	10.48	6.35	12.49	5.48		5.47	9.62							
14-Mar-16	6.52		9.47	5.46	10.47	6.35	12.5	5.4		5.43	9.59							
21-Mar-16	6.47		9.44	4.52	10.41	6.37	12.47	5.43		5.42	9.63							
28-Mar-16	6.5		9.41	4.5	10.48	4.49	12.54	5.46		5.42	9.64							
4-Apr-16	6.48		9.44	4.48	11.41	6.35	12.5	5.48		5.4	9.55							

11-Apr-16	7.52		9.44	3.64	11.43	6.35	12.54	5.47		5.45	9.62							
18-Apr-16			9.41	3.63	11.49	6.43	12.49	5.46		5.47	9.57							
25-Apr-16			9.41	5.53	12.43	6.43	12.49	5.42		5.42	9.57							
2-May-16			9.41	5.54	13.45	6.39	12.54	5.48		5.48	9.59							
9-May-16			8.44	4.5	13.59	5.39	12.48	5.44		5.41	9.55							
16-May-16			8.4	4.51	16.45	6.42	12.46	5.44		5.45	9.58							
23-May-16			8.49	4.52	15.43	4.51	12.49	5.43		5.44	9.63							
30-May-16			8.4	4.52	18.45	6.37	12.48	5.42		5.42	9.59							
6-Jun-16			8.44	4.5	19.45	5.4	12.52	5.47		5.43	9.61							
13-Jun-16			8.45	4.48	20.46	5.35	12.48	5.46		5.47	9.59							
20-Jun-16			8.44	4.52	23.41	6.4	12.5	4.43		5.44	8.58							
27-Jun-16			8.45	4.53	23.42	6.41	12.51	4.44		5.45	8.59							
4-Jul-16			9.49	5.47	25.44	6.42	13.5	4.49		5.42	8.6							
11-Jul-16			9.42	6.47	25.49	6.37	13.45	4.44		5.43	9.57							
18-Jul-16			9.48	6.5	26.55	6.4	13.52	4.4		5.47	9.63							
25-Jul-16			9.48	6.49	28.4	6.41	13.52	4.4		5.45	9.63							
1-Aug-16			9.47	6.5	30.49	6.44	13.47	4.42		5.43	7.65							
8-Aug-16			10.47	5.64	31.42	6.4	14.47	4.47		5.46	7.74							
15-Aug-16			9.46	6.5	29.48	6.43	13.46	4.41		5.42	7.65							
22-Aug-16			9.47	6.5	30.49	6.44	13.47	4.42		5.43	7.65							
29-Aug-16			11.42	8.47	31.53	8.41	15.54	4.49		5.44	8.56							
5-Sep-16			10.47	6.58	32.44	4.48	13.63	4.47		4.43	8.59							
12-Sep-16			10.45	7.45	32.49	5.42	13.59	3.43		4.49	7.64							
19-Sep-16			10.46	6.62	33.48	4.54	14.48	3.49		3.51	8.6							
26-Sep-16																		
3-Oct-16			10.49			4.47	15.48	3.42		4.4	7.55							
10-Oct-16			11.4			6.42	16.51	3.47		4.48	8.56							
17-Oct-16			16.42			6.37	17.47	3.46		3.53	8.63							
24-Oct-16			16.47			6.41	12.61	3.48		3.56	8.56							

31-Oct-16			14.59			8.43	14.51	3.41		5.4	8.62							
7-Nov-16			13.4			6.39	13.48	3.41		4.44	8.63							
14-Nov-16			14.46			6.41	13.5	3.44		7.44	8.56							
21-Nov-16			14.43			5.46	13.48	3.41		5.44	8.61							
28-Nov-16			14.45			7.36	13.5	3.49		9.46	8.64							
5-Dec-16			15.43			5.53	13.53	3.45		7.43	8.6							
12-Dec-16			14.44			5.49	13.44	3.42		5.46	8.62							
19-Dec-16			14.43			7.31	13.49	3.46		9.42	8.63							
26-Dec-16			15.42			5.5	13.51	3.48		7.47	8.63							
2-Jan-17						7.39	13.55	4.44		6.42	9.58							
9-Jan-17						7.34	13.5	4.39		6.37	9.53							
16-Jan-17						7.29	13.45	4.35		6.34	9.48							
23-Jan-17						8.36	15.45	4.44			9.62							
30-Jan-17						8.35	15.45	4.42			9.6							
6-Feb-17						7.39	13.55	4.44		6.42	9.58							
13-Feb-17							16.4	4.46		7.41	9.58							
20-Feb-17							25.49	4.43		9.48	9.56							
27-Feb-17							22.56	4.43		8.43	9.59							
6-Mar-17							23.45	4.42		8.34	9.62							
13-Mar-17							25.46	4.46		10.5	9.56							
20-Mar-17							25.48	4.47		11.47	9.58							
27-Mar-17							26.53	4.41		12.49	9.63							
3-Apr-17							27.51	4.42		10.43	9.6							
10-Apr-17							29.54	3.55		11.48	8.72							
17-Apr-17							29.52	4.46		20.46	9.56							
24-Apr-17							30.52	4.44		11.42	9.57							
1-May-17							31.52	4.42		13.47	9.57							
8-May-17							33.48	4.43			9.61							
15-May-17							34.55	4.88			9.96							

22-May-17								4.48			9.61							
29-May-17							35.46	4.47			9.62							
5-Jun-17							35.5	4.95			9.63							
12-Jun-17							35.48	4.44			8.59							
19-Jun-17							36.49	4.43			9.61							
26-Jun-17							35.53	5.42			8.64							
3-Jul-17								4.48			9.6							
10-Jul-17							35.54	4.41			9.92							
17-Jul-17							36.52	4.41			9.62							
24-Jul-17							36.54	4.49			9.56							
31-Jul-17							34.48	4.43			9.62							
7-Aug-17							36.49	4.45			9.58							
14-Aug-17							37.99	4.54			8.96							
21-Aug-17							38.51	4.41			8.62							
28-Aug-17							37.47	4.43			8.54							
04-Sep-17							37.53	3.48			8.58							
11-Sep-17							37.54	3.49			8.59							
18-Sep-17							37.5	3.41			8.55							
25-Sep-17							37.47	4.49			8.63							
02-Oct-17							36.48	3.42			8.58							
09-Oct-17							36.5	4.49			8.59							
16-Oct-17							37.54	3.41			8.55							
23-Oct-17							36.45	3.49			8.58							
30-Oct-17							35.53	3.48			8.69							
06-Nov-17							35.52	3.49			8.64							
13-Nov-17							36.47	3.43			8.6							
20-Nov-17							35.53	3.43			8.59							
27-Nov-17							35.48	3.48			8.57							
04-Dec-17							35.53	3.44			7.65							

11-Dec-17							36.5	3.41			9.6							
18-Dec-17							36.52	3.49			9.64							
25-Dec-17							36.51	2.5			9.64							
01-Jan-18							35.51	3.46			8.58							
08-Jan-18							35.48	3.45			8.6							
15-Jan-18							35.51	3.42			8.6							
22-Jan-18							33.55	3.43			8.63							
29-Jan-18							34.54	3.49			8.64							
05-Feb-18							35.5	3.49			8.76							
12-Feb-18							34.5	3.61			8.53							
19-Feb-18							35.4	3.59			8.47							
26-Feb-18							34.47	4.46			8.62							
05-Mar-18							35.54	4.46			8.63							
12-Mar-18							34.48	3.47			8.63							
19-Mar-18							34.97	3.92			8.99							
26-Mar-18							34.52	3.45			8.64							
02-Apr-18							34.07	3.44		8.42	8.59	19.92	15.13	5.38	8.89	4.05	2.34	
09-Apr-18							34.91	3.46		7.4	8.34	19.85	15.43	4.79	9.02	4.06	2.33	
16-Apr-18							34.93	3.46		5.16	8.5	19.9	16.8	4.77	8.98	3.28	2.39	
23-Apr-18							35.75	3.41			8.37	19.86	16.14	4.68	9.09	4.94	2.35	
30-Apr-18							32.55	3.59			8.51	19.76	16.13	4.66	9.09	3.82	2.37	
07-May-18							36.01	3.39		8.08	8.28	19.62	11.42	4.4	9.02	3.7	2.34	
14-May-18							37.18	4.24			9.1	19.71		5.4	11.59	4.64	3.28	
21-May-18							36.35	3.38			8.3	20.59	17.56	4.47	8.91	4.7	3.01	
28-May-18							37.08	4.18			8.96	19.71		4.34		3.43	2.92	
04-Jun-18							36.94	3.43			9.04	19.82		4.44	3.37	3.3	2.22	
11-Jun-18								4.37			8.99	20.82		5.4	4.44	4.32		
18-Jun-18							36.09	3.34			8.08	19.67		5.24	9.79	3.8	2.96	
25-Jun-18							36.04	4			7.82	19.57		4.14	8.71	2.59	1.62	

02-Jul-18							40.25	3.9			9.25	20.37		3.74	8.64	3.4	3.01	
09-Jul-18							35.78	2.88			7.67	1.55		5.06	8.47	2.38	2.7	
16-Jul-18							36.64	3.12			7.73	20.07		4.18	9.37	2.35	1.92	
23-Jul-18							35.76	2.89		3.8	7.72	19.64		4.22	10.34	2.68	1.5	
30-Jul-18							36.15	2.71			8.65	20.47		4.05	10.33	3.42	2.01	
06-Aug-18							36.05	2.57			7.69	19.53	16.5	3.54	8.64	2.49	2.51	
13-Aug-18							36.99	4.34		7.75	7.71	19.68	10.81	4.35	8.96	2.42	2.08	
20-Aug-18							36.59	3.12		6.88	7.62	19.5	12.31	3.94	8.45	1.94	1.63	
27-Aug-18							36.61	3.07		7.47	7.62	19.39	10.69	5.35	8.58	1.57	2.15	
3.Sept.18							36.97	4.32		7.75	7.7	19.66	10.81	4.34	8.94	2.41	2.09	
10.sept.18							36.15	2.77		7.54	7.66	19.44	12.31	3.96	6.49	2.31	1.55	
17.Sept.18							37.4	2.61		7.72	7.73	19.37	10.92	2.75	9.08	2.02	1.31	
24.Sept.18							36.37	2.56		8.53	7.32	19.44	11.04	3.76	8.37	2.09	1.33	
01-Oct-18							36.29	2.26		6.45	6.85	19.38	11.06	3.45	7.9	1.81	0.98	
08-Oct-18							35.95	2.13		8.6	6.45	19.21	9.81	3.46	7.5	1.9	0.87	
15-Oct-18							35.47	1.97		6.12	7.02	20.22	9.89	3.63	7.59	1.92	0.97	
22-Oct-18							36.1	3.32		7.35	2.28	19.29	9.96	3.78	7.69	1.97	1.06	
29-Oct-18							37.07	2.33		7.46	7.45	19.39	10.39	3.47	7.73	1.84	1.06	
05-Nov-18							36.36	2.58		6.73	7.6	19.33	10.45	3.78	8	1.82	1.16	
12-Nov-18							36.27	3.54		7.12	7.52	19.34	10.41	4.01	7.89	2	1.16	
19-Nov-18							36.15	2.4		6.96	7.53	18.58	10.46	3.88	8.06	1.93	1.18	
26-Nov-18							36.29	2.25		5.6	7.55	19.32	10.41	3.86	8.28	1.87	1.17	
03-Dec-18							36.17	1.56		7.2	8.37	18.55	10.51	4.11	8.24	1.93	1.31	
10-Dec-18							36.17	1.16		9.7	8.18	19.8	9.6	4.01	8.53	1.83	1.21	
17-Dec-18							38.42	1.88		7.92	7.74	19.27	10.68	4.12	9.39	2.23	1.27	
24-Dec-18							37.69	1.82		7.7	7.88	19.37	10.73	4.17	19.34	2.03	1.35	
31-Dec-18							38	2.93		10.4	7.8	19.7	10.76	5	18.57	2.85	1.31	
7. Jan.19							38.78	2.93		11.04	8.12	19.58	10.75	4.17	8.74	3.23	1.31	
14.Jan.19							38.65	2.86		11.05	8	19.38	10.65	4.19	8.59	3.02	1.3	

21. Jan. 2019							38.1	2.93		10.96	7.95	19.41	10.65	4.08	8.61	2.7	1.3	
28. Jan. 2019							38.77	2.99		8.2	7.98	19.45	10.72	4.14	8.84	2.52	1.37	
04-Feb-19							39.08	3.1		9.82	7.99	19.72	10.96	4.39	8.74	2.41	1.36	
11-Feb-19							38.97	3.26		10.1	8.29	19.59	11.35	4.27	8.88	2.67	1.44	
18-Feb-19							39.52	4.43		12.05	8.3	19.82	11.09	4.15	9.08	2.94	1.47	
25-Feb-19							40.19	3.5		10.3	8.44	19.54	10.99	4.41	8.9	3.03	1.56	
04-Mar-19							39.71	3.6		9.84	8.27	20.88	11.37	4.21	9	3.5	1.49	
11-Mar-19							39.56	3.46		7.68	8.29	19.7	11.16	4.33	8.98	3.42	1.52	
18-Mar-19							39.57	3.53		9	8.55	18.82	11.19	4.36	9.24	3.3	1.48	
25-Mar-19							40.35	3.48		8.93	8.27	18.67	11.18	4.41	9.2	2.96	1.47	
01-Apr-19							39.75	3.26		8.44	8.3	19.71	11.21	4.34	9.07	2.68	1.54	
08-Apr-19							39.34	3.45		8.72	8.26	19.72	11.22	4.2	9.04	2.4	1.51	
15-Apr-19							40.49	3.54		8.25	7.27	19.71	10.79	4.26	10.23	2.3	1.53	
22-Apr-19							39.63	3.55		7.5	10.23	10.87	11.29	4.18	9.43	2.05	1.48	
29-Apr-19							39.68	3.55		9.72	8.19	19.79	11.38	4.2	9.22	1.98	1.65	
06-May-19							39.9	3.54		11.57	8.14	19.75	11.14	4.15	9.09	1.74	1.53	
13-May-19							40.78	3.53		9.93	8.17	19.95	11.41	4.26	9.36	1.83	1.61	
20-May-19							39.78	4.11		11.39	8.1	19.71	11.13	4.2	9	1.51	1.53	
27-May-19							39.82	3.5		9.26	9.87	19.74	10.83	3.7	8.81	1.42	1.41	
03-Jun-19							40.12	3.67		9.46	8.11	19.83	11.21	4.46	9.11	1.58	1.47	
10-Jun-19							39.89	3.14		8.26	8.08	19.81	11.16	4.11	9.11	1.74	1.33	
17-Jun-19							40	3.44		8.84	8.3	19.81	10.85	4.41	9.11	2.07	1.48	
24-Jun-19							40	3.44		8.73	8.21	19.92	11.16	4.11	9.11	2.07	1.62	
01-Jul-19							40.14	3.31		8.06	8.09	19.74	11.01	4.04	9.1	2.1	1.35	
08-Jul-19							39.98	3.21		9.01	8.18	19.81	11	4	9.09	2	1.3	
15-Jul-19							40.07	3.11		8.41	7.97	19.82	10.95	3.88	9.02	2.05	1.22	
22-Jul-19							40.19	3.07		10.23	8.24	20.05	11.03	3.99	9.05	2.01	1.29	
29-Jul-19							40.26	2.99		8.84	8.02	20.37	10.84	3.89	8.96	1.96	1.12	
05-Aug-19							40.48	2.95		9.26	7.98	20.58	10.69	3.71	8.86	2.05	0.97	

12-Aug-19							40.36	2.7		8.9	7.67	20.47	10.51	3.63	8.71	1.8	0.9	
19-Aug-19							40.44	2.51		6.81	7.46	20.42	10.29	3.47	8.47	1.9	0.71	
26-Aug-19							40.3	2.14		7.93	7	20.06	9.54	2.52	8.02	1.84	0.43	
02-Sep-19							40.37	1.95		6.17	6.67	20.05	9.67	3.02	7.88	1.41	0.24	
09-Sep-19							40.37	1.92		7.04	6.79	20.01	10.27	3.05	7.68	1.5	0.19	
16-Sep-19							40.35	2.02		6.45	1.87	19.99	9.62	3.06	7.64	1.62	0.16	
23-Sep-19							40.25	1.8		5.2	6.62	19.67	9.48	2.82	7.48	1.27	0.05	
30-Sep-19							40.26	1.76		8.55	6.7	19.7	9.41	2.92	7.47	1.4	0.08	
07-Oct-19							40.16	1.78		7.01	6.82	19.6	9.51	2.9	7.44	1.6	0.17	
14-Oct-19							39.88	1.67		6.32	6.73	19.6	9.39	2.91	7.42	1.53	0.12	
21-Oct-19							39.89	1.71		7.99	6.76	19.65	9.51	3.03	7.48	1.74	0.22	

ATTACHMENT 2: EXAMPLE SHEET OF THE RESULTS OF WATER QUALITY ANALYSES

Analytical Results

Sub-Matrix: GROUNDWATER	*Client Sample ID*		KMW03	KMW04	KMW06	KMW07	KWS-1	WPT-4	WPT-5	WPT-6	WPT-8	WPT-9
	Laboratory Sample ID		PR1912443-001	PR1912443-002	PR1912443-003	PR1912443-004	PR1912443-005	PR1912443-006	PR1912443-007	PR1912443-008	PR1912443-009	PR1912443 010
	Client Sampling Date		13-Jan-19	13-Jan-19	13-Jan-19	13-Jan-19	13-Jan-19	13-Jan-19	13-Jan-19	13-Jan-19	13-Jan-19	13-Jan-19
Parameter/Method	**LOR**	**Unit**	**Result**	**Result**	**Result**	**Result**	**Result**	**Result**	**Result**	**Result**	**Result**	**Result**
Nonmetallic Inorganic Parameters												
Chloride (W-CL-SPC)	5	mg/L	<5.0	<5.0	<5.0	**6.90**	<5.0	<5.0	<5.0	<5.0	<5.0	**7.2**
Easily released cyanide (W-CNF-PHO)	0.005	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.00
Orthophosphate (W-PO4O-SPC)	0.04	mg/L	<0.040	**0.75**	<0.040	**0.33**	<0.040	<0.040	<0.040	<0.040	<0.040	<0.04
Sulphat as SO4 2- (W-SO4-SPC)	5	mg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	**62.60**	<5.0	<5
Total Cyanide (W-CNT-PHO)	0.005	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.00
Weak acid dissocialabe cyanide (W-CNWAD-PHO)	0.005	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.00
Free Cyanide (W-CNF-PHO)	0.005	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.00
Orthophosphate as P (W-PO4O-SPC)	0.01	mg/L	<0.010	**0.25**	<0.010	**0.11**	<0.010	<0.010	<0.010	<0.010	<0.010	<0.01

Total Metals/Major Cations													
Aluminium (W-METAXFX1)	0.01	mg/L	**0.01**	<0.010	<0.010	<0.010	<0.010	**0.66**	**0.22**	**0.02**	**0.03**	<0.010	**0.70**
Antimony (W-METAXFX1)	0.01	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Arsenic (W-METAXFX1)	0.005	mg/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Barium (W-METAXFX1)	0.005	mg/L	**0.14**	**0.09**	**0.06**	**0.11**	**0.06**	**0.04**	**0.02**	**0.07**	**0.04**	**0.00**	**0.03**
Beryllium (W-METAXFX1)	0.002	mg/L	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
Boron (W-METAXFX1)	0.01	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Cadmium (W-METAXFX1)	0.0004	mg/L	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040
Calcium (W-METAXFX1)	0.005	mg/L	**3.81**	**21.20**	**1.87**	**18.00**	**10.90**	**2.88**	**1.32**	**40.10**	**3.64**	**11.20**	**2.18**
Chromium (W-METAXFX1)	0.001	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	**0.00**	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Cobalt (W-METAXFX1)	0.002	mg/L	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
Copper (W-METAXFX1)	0.001	mg/L	<0.0010	**0.00**	<0.0010	**0.00**	<0.0010	**0.00**	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Iron (W-METAXFX1)	0.002	mg/L	**0.01**	**0.01**	**0.03**	**0.21**	**0.01**	**2.36**	**1.51**	**0.34**	**0.08**	**2.55**	**3.34**
Lead (W-METAXFX1)	0.005	mg/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Lithium (W-METAXFX1)	0.001	mg/L	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	<0.0010	**0.00**	**0.01**	**0.00**	**0.00**	**0.00**
Magnesium (W-METAXFX1)	0.003	mg/L	**1.20**	**5.74**	**1.06**	**9.32**	**2.70**	**1.47**	**0.93**	**11.70**	**3.89**	**2.58**	**1.20**
Manganese (W-METAXFX1)	0.0005	mg/L	**0.00**	**0.00**	**0.04**	**1.10**	**0.12**	**0.01**	**0.02**	**0.00**	<0.00050	**0.10**	**0.02**
Molybdenum (W-METAXFX1)	0.002	mg/L	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
Nickel (W-METAXFX1)	0.002	mg/L	<0.010	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
Phosphorus (W-METAXFX1)	0.05	mg/L	<0.0010	**0.21**	<0.050	**0.13**	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Potassium (W-METAXFX1)	0.015	mg/L	**2.79**	**5.71**	**0.91**	**6.41**	**2.43**	**1.17**	**0.55**	**9.63**	**0.84**	**7.25**	**0.47**
Selenium (W-METAXFX1)	0.01	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010

Silver (W-METAXFX1)	0.001	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Sodium (W-METAXFX1)	0.03	mg/L	**8.04**	**5.10**	**2.45**	**11.40**	**5.58**	**5.00**	**2.49**	**8.14**	**4.65**	**6.04**	**2.56**
Thallium (W-METAXFX1)	0.01	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Vanadium(W-METAXFX1)	0.001	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	**0.00**	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Zinc (W-METAXFX1)	0.002	mg/L	<0.0020	**0.00**	<0.0020	**0.01**	**0.02**	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	**0.00**
Dissolved Metals/Major Cations													
Hexavalent Chromium-Soluble (W-CR6-IC)	0.4	µg/L	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40

ATTACHMENT 2: EXAMPLE SHEET OF THE RESULTS OF WATER QUALITY ANALYSES (cont'd)

Analytical Results

Sub-Matrix: GROUNDWATER	***Client Sample ID***		**WPT-15**	**PIT-1**	**BH-1**	**BH-2**	**BH-3**	**BH-4**	**BH-5**	**BH-6**
	Laboratory Sample ID		**PR1912443-012**	**PR1912443-013**	**PR1912443-014**	**PR1912443-015**	**PR1912443-016**	**PR1912443-017**	**PR1912443-018**	**PR1912443-019**
	Client Sampling Date		**13-Jan-19**	**13-Jan-19**	**13-Jan-19**	**13-Jan-19**	**13-Jan-19**	**13-Jan-19**	**13-Jan-19**	**13-Jan-19**
Parameter/Method	**LOR**	**Unit**	**Result**	**Result**	**Result**	**Result**	**Result**	**Result**	**Result**	**Result**
Nonmetallic Inorganic Parameters										
Chloride (W-CL-SPC)	5	mg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Easily released cyanide (W-CNF-PHO)	0.005	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Orthophosphate (W-PO4O-SPC)	0.04	mg/L	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	**0.05**
Sulphat as SO4 2- (W-SO4-SPC)	5	mg/L	<5.0	**35.50**	<0.040	<0.040	<0.040	<0.040	<0.040	<5.0
Total Cyanide (W-CNT-PHO)	0.005	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Weak acid dissocialabe cyanide (W-CNWAD-PHO)	0.005	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Free Cyanide (W-CNF-PHO)	0.005	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Orthophosphate as P (W-PO4O-SPC)	0.01	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	**0.02**

Total Metals/Major Cations										
Aluminium (W-METAXFX1)	0.01	mg/L	**0.10**	**0.02**	**0.02**	**0.25**	<0.010	<0.010	<0.010	<0.010
Antimony (W-METAXFX1)	0.01	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Arsenic (W-METAXFX1)	0.005	mg/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Barium (W-METAXFX1)	0.005	mg/L	**0.04**	**0.09**	**0.11**	**0.09**	**0.04**	**0.06**	**0.10**	**0.12**
Beryllium (W-METAXFX1)	0.002	mg/L	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
Boron (W-METAXFX1)	0.01	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Cadmium (W-METAXFX1)	0.0004	mg/L	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040
Calcium (W-METAXFX1)	0.005	mg/L	**2.13**	**37.70**	**21.10**	**2.98**	**11.40**	**2.91**	**20.20**	**18.20**
Chromium (W-METAXFX1)	0.001	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Cobalt (W-METAXFX1)	0.002	mg/L	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	**0.00**	<0.0020	<0.0020
Copper (W-METAXFX1)	0.001	mg/L	<0.0010	<0.0010	<0.0010	**0.01**	**0.00**	<0.0010	<0.0010	<0.0010
Iron (W-METAXFX1)	0.002	mg/L	**2.99**	**0.09**	**0.38**	**2.98**	**0.88**	**0.47**	**0.00**	**0.05**
Lead (W-METAXFX1)	0.005	mg/L	<0.0050	<0.0050	<0.0050	**0.04**	**0.02**	<0.0050	<0.0050	<0.0050
Lithium (W-METAXFX1)	0.001	mg/L	**0.00**	**0.01**	**0.01**	**0.00**	**0.07**	**0.00**	**0.00**	**0.01**
Magnesium (W-METAXFX1)	0.003	mg/L	**2.16**	**10.10**	**9.12**	**0.93**	**5.45**	**0.67**	**7.05**	**15.40**
Manganese (W-METAXFX1)	0.0005	mg/L	**0.03**	**0.22**	**0.01**	**0.06**	**0.21**	**0.10**	**0.00**	<0.00050
Molybdenum (W-METAXFX1)	0.002	mg/L	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
Nickel (W-METAXFX1)	0.002	mg/L	<0.0020	**0.02**	**0.01**	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
Phosphorus (W-METAXFX1)	0.05	mg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Potassium (W-METAXFX1)	0.015	mg/L	**0.07**	**8.54**	**8.00**	**1.93**	**4.52**	**1.46**	**3.82**	**4.85**
Selenium (W-METAXFX1)	0.01	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010

Silver (W-METAXFX1)	0.001	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Sodium (W-METAXFX1)	0.03	mg/L	**2.31**	**8.00**	**9.65**	**3.19**	**3.91**	**1.71**	**11.00**	**7.56**
Thallium (W-METAXFX1)	0.01	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Vanadium(W-METAXFX1)	0.001	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Zinc (W-METAXFX1)	0.002	mg/L	<0.0020	<0.0020	**0.00**	**0.02**	**0.01**	**0.01**	<0.0020	<0.0020
Dissolved Metals/Major Cations										
Hexavalent Chromium-Soluble (W-CR6-IC)	0.4	µg/L	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40

ATTACHMENT 2: EXAMPLE SHEET OF THE RESULTS OF WATER QUALITY ANALYSES (cont'd)

Analytical Results

Sub-Matrix: GROUNDWATER	***Client Sample ID***		**Seepage Recovery Pond**	**Sayewheh Town Hand Pump-2**	**Sayewheh Town Hand Pump-3**	**TSF-2 Main Embankment**	**St. John Upstream**	**St. John Downstream**	**St. John Discharge Point**	**Sayewheh Town Hand Pump-4**	**TSF-2 Detox Discharge**	**TSF-2 Enba**
	Laboratory Sample ID		**PR1912443-020**	**PR1912443-021**	**PR1912443-022**	**PR1912455-004**	**PR1912455-005**	**PR1912455-006**	**PR1912455-007**	**PR1912455-001**	**PR1912455-002**	**PR191 003**
	Client Sampling Date		**13-Jan-19**	**13-Jan-19**	**13-Jan-19**	**13-Jan-19**	**13-Jan-19**	**13-Jan-19**	**13-Jan-19**	**13-Jan-19**	**13-Jan-19**	**13-J**
Parameter/Method	**LOR**	**Unit**	**Result**	**Result**	**Result**	**Result**	**Result**	**Result**	**Result**	**Result**	**Result**	**Re**
Nonmetallic Inorganic Parameters												
Chloride (W-CL-SPC)	5	mg/L	**15.70**	<5.0	<5.0	**91.00**	<5.0	<5.0	<5.0	<5.0	**68.20**	
Easily released cyanide (W-CNF-PHO)	0.005	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
Orthophosphate (W-PO4O-SPC)	0.04	mg/L	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	
Sulphat as SO4 2- (W-SO4-SPC)	5	mg/L	**108.00**	<5.0	<5.0	**795.00**	<5.0	<5.0	<5.0	<5.0	**408.00**	
Total Cyanide (W-CNT-PHO)	0.005	mg/L	<0.005	<0.005	<0.005	**0.04**	<0.005	<0.005	<0.005	<0.005	**0.20**	
Weak acid dissocialabe cyanide (W-CNWAD-PHO)	0.005	mg/L	<0.005	<0.005	<0.005	**0.01**	<0.005	<0.005	<0.005	<0.005	<0.005	
Free Cyanide (W-CNF-PHO)	0.005	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
Orthophosphate as P (W-PO4O-SPC)	0.01	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	

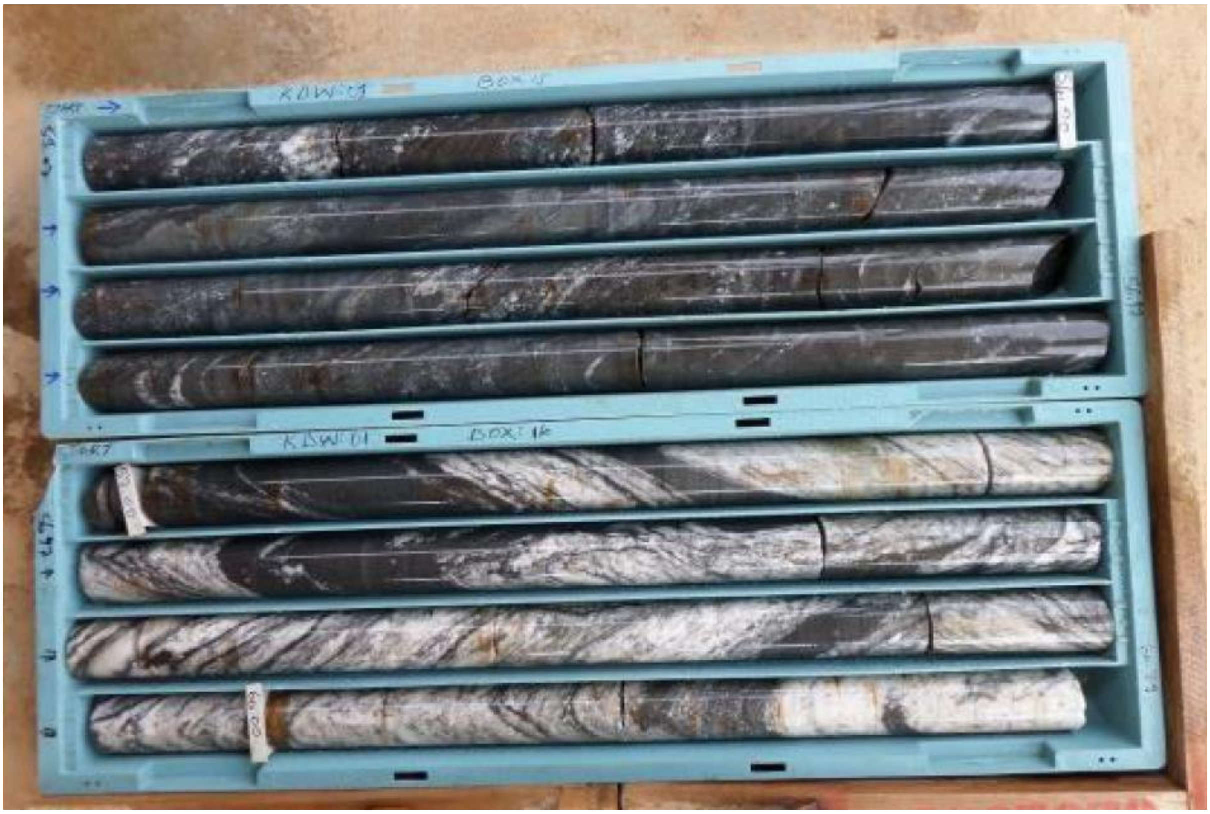
Total Metals/Major Cations											
Aluminium (W-METAXFX1)	0.01	mg/L	**0.01**	<0.010	**0.27**	**0.04**	**0.06**	**0.07**	**0.06**	**0.02**	**103.00**
Antimony (W-METAXFX1)	0.01	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.020
Arsenic (W-METAXFX1)	0.005	mg/L	<0.0050	<0.0050	<0.0050	**0.01**	<0.0050	<0.0050	<0.0050	<0.0050	**0.06**
Barium (W-METAXFX1)	0.005	mg/L	**0.08**	**0.03**	**0.03**	**0.09**	**0.04**	**0.04**	**0.04**	**0.04**	**0.85**
Beryllium (W-METAXFX1)	0.002	mg/L	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	**0.00**
Boron (W-METAXFX1)	0.01	mg/L	<0.010	<0.010	<0.010	**0.01**	<0.010	<0.010	<0.010	<0.010	<0.010
Cadmium (W-METAXFX1)	0.0004	mg/L	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.0020
Calcium (W-METAXFX1)	0.005	mg/L	**57.30**	**28.10**	**33.20**	**82.30**	**2.00**	**2.03**	**2.04**	**3.78**	**166.00**
Chromium (W-METAXFX1)	0.001	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	**1.10**
Cobalt (W-METAXFX1)	0.002	mg/L	**0.01**	<0.0020	<0.0020	**0.25**	<0.0020	<0.0020	<0.0020	<0.0020	**0.23**
Copper (W-METAXFX1)	0.001	mg/L	**0.00**	<0.0010	**0.03**	**0.02**	<0.0010	<0.0010	<0.0010	**0.02**	**1.98**
Iron (W-METAXFX1)	0.002	mg/L	**0.09**	**0.21**	**0.95**	**0.00**	**0.57**	**0.65**	**0.57**	**0.01**	**1.98**
Lead (W-METAXFX1)	0.005	mg/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	**0.11**
Lithium (W-METAXFX1)	0.001	mg/L	**0.00**	**0.01**	**0.00**	**0.01**	**0.00**	**0.00**	**0.00**	**0.00**	**0.11**
Magnesium (W-METAXFX1)	0.003	mg/L	**12.20**	**9.19**	**1.47**	**5.55**	**1.52**	**1.54**	**1.56**	**0.86**	**83.50**
Manganese (W-METAXFX1)	0.0005	mg/L	**0.03**	**0.13**	**0.01**	**0.00**	**0.00**	**0.00**	**0.00**	**0.01**	**3.01**
Molybdenum (W-METAXFX1)	0.002	mg/L	<0.0020	<0.0020	<0.0020	**0.05**	<0.0020	<0.0020	<0.0020	<0.0020	**0.05**
Nickel (W-METAXFX1)	0.002	mg/L	**0.04**	<0.0020	<0.0020	**0.05**	<0.0020	<0.0020	<0.0020	<0.0020	**0.87**
Phosphorus (W-METAXFX1)	0.05	mg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	**2.49**
Potassium (W-METAXFX1)	0.015	mg/L	**15.60**	**2.46**	**1.15**	**61.40**	**1.10**	**1.03**	**1.10**	**0.84**	**77.80**
Selenium (W-METAXFX1)	0.01	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.030

Silver (W-METAXFX1)	0.001	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.030
Sodium (W-METAXFX1)	0.03	mg/L	**28.80**	**12.30**	**1.27**	**305.00**	**2.98**	**2.86**	**2.95**	**3.69**	**208.00**
Thallium (W-METAXFX1)	0.01	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Vanadium(W-METAXFX1)	0.001	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	**0.42**
Zinc (W-METAXFX1)	0.002	mg/L	<0.0020	**0.01**	**0.03**	<0.0020	<0.0020	<0.0020	<0.0020	**0.06**	**0.25**
Dissolved Metals/Major Cations											
Hexavalent Chromium-Soluble (W-CR6-IC)	0.4	µg/L	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40

KOKOYA GOLD PROJECT
Geotechnical Assessment Study 2020

Prepared for

MNG Gold Liberia Inc.



Prepared by

GÜVENLİ VE VERİMLİ
MADEN TEKNOLOJİLERİ

Prof.Dr. Bahtiyar ÜNVER
Prof.Dr. A. Erhan TERCAN
Assoc.Prof.Dr. Mehmet Ali HİNDİSTAN
Assist.Prof.Dr. Fırat ATALAY
Dr. M. Suphi ÜNAL
Dr. S. Yasin KILLIOĞLU
Department of Mining Engineering of Hacettepe University, Ankara, TURKEY

Report Date: February 20, 2020

KOKOYA GOLD PROJECT
Geotechnical Assessment Study 2020

Prepared for

MNG Gold Liberia Inc.

Prepared by

GÜVENLİ VE VERİMLİ
MADEN TEKNOLOJİLERİ

Prof.Dr. Bahtiyar ÜNVER
Prof.Dr. A. Erhan TERCAN
Assoc.Prof.Dr. Mehmet Ali HİNDİSTAN
Assist.Prof.Dr. Fırat ATALAY
Dr. M. Suphi ÜNAL
Dr. S. Yasin KILLIOĞLU

Department of Mining Engineering of Hacettepe University, Ankara, TURKEY

Report Date: February 20, 2020

The signing of this statement confirms this report has been prepared and checked by the following persons of Güvenli ve Verimli Maden Teknolojileri San. ve Tic. Ltd. Şti., GVMT (Safe and Efficient Mining Technologies Limited, SEMT).

Bahtiyar ÜNVER	20 February 2020
A. Erhan TERCAN	20 February 2020
Mehmet Ali HİNDİSTAN	20 February 2020
Fırat ATALAY	20 February 2020
M. Suphi ÜNAL	20 February 2020
S. Yasin KILLIOĞLU	20 February 2020

Important information about this report

Information

SEMT accepts no liability and gives no warranty as to the accuracy or completeness of information provided to it by or on behalf of the client or its representatives and takes no account of matters that existed when the document was transmitted to the client but which were not known to SEMT until subsequently.

Relience

This document may not be relied upon by any person other than the named client, its officiers and employees.

No liability

SEMT accepts no liability for any loss or damage arising as a result of any person other than the named client acting in relience on any information, opinion or advice contained in this document.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 INTRODUCTION

The MNG Gold Liberia (MNG) commissioned Güvenli ve Verimli Maden Teknolojileri San. ve Tic. Ltd. Şti., GVMT (Safe and Efficient Mining Technologies Limited, SEMT) to evaluate the Kokoya Underground Project for the main MNG deposit and to complete the required review works, verification and technical evaluations to facilitate disclosure of a Scoping Study.

MNG Gold Liberia Incorporated (MNG), a Liberian registered Turkish-owned company, acquired the Kokoya Gold mine Project from Amlib United Minerals Incorporated (Amlib) (subsidiary of Amlib Holdings Plc.) in April 2014. MNG inherited a signed Mineral Development Agreement (MDA) (between Amlib and the Liberian Government on the 14 March, 2002) for the concession which will be valid until March 2027.

MNG Gold Liberia Inc. (MNG) exploited the part of the Kokoya gold deposit by open pit methods in 2016 and now plans to produce the resources below the open pit by underground works. The company commissioned Güvenli ve Verimli Maden Teknolojileri San. ve Tic. Ltd. Şti., GVMT (Safe and Efficient Mining Technologies Limited, SEMT) to evaluate the Kokoya Underground Project for the Kokoya gold deposit and to complete the required review works, verification and technical evaluations to facilitate disclosure of a Geotechnical Study.

SEMT is a Turkish based consulting company that has been established since 2018. SEMT has been retained by MNG in the role of independent consultant, neither SEMT nor the authors of this report have any material interest in the companies or mineral assets considered in this report. The relationship with SEMT is purely a professional association between client and independent consultant. This report has been prepared in return for fees based upon agreed commercial rates and payment of these fees is no way contingent on the results of this report.

None of the authors of this report did not visit the Project site.

The current report is based on data, report, map and models provided to SEMT by MNG. The exploration drill-hole database, wireframes for lithologic formations and gold lodes, solid model were provided to SEMT by MNG electronically.

2 PROJECT INFORMATION

2.1 Concession Area

The concession area (Kokoya Production Area) approved by the Ministry of Lands, Mines and Energy in November 2013 is 537 km^2. It stretches over Nimba, Grand Bassa, and Bong counties (Figure 1). However, the project area is in the Kokoya District of the Bong County.

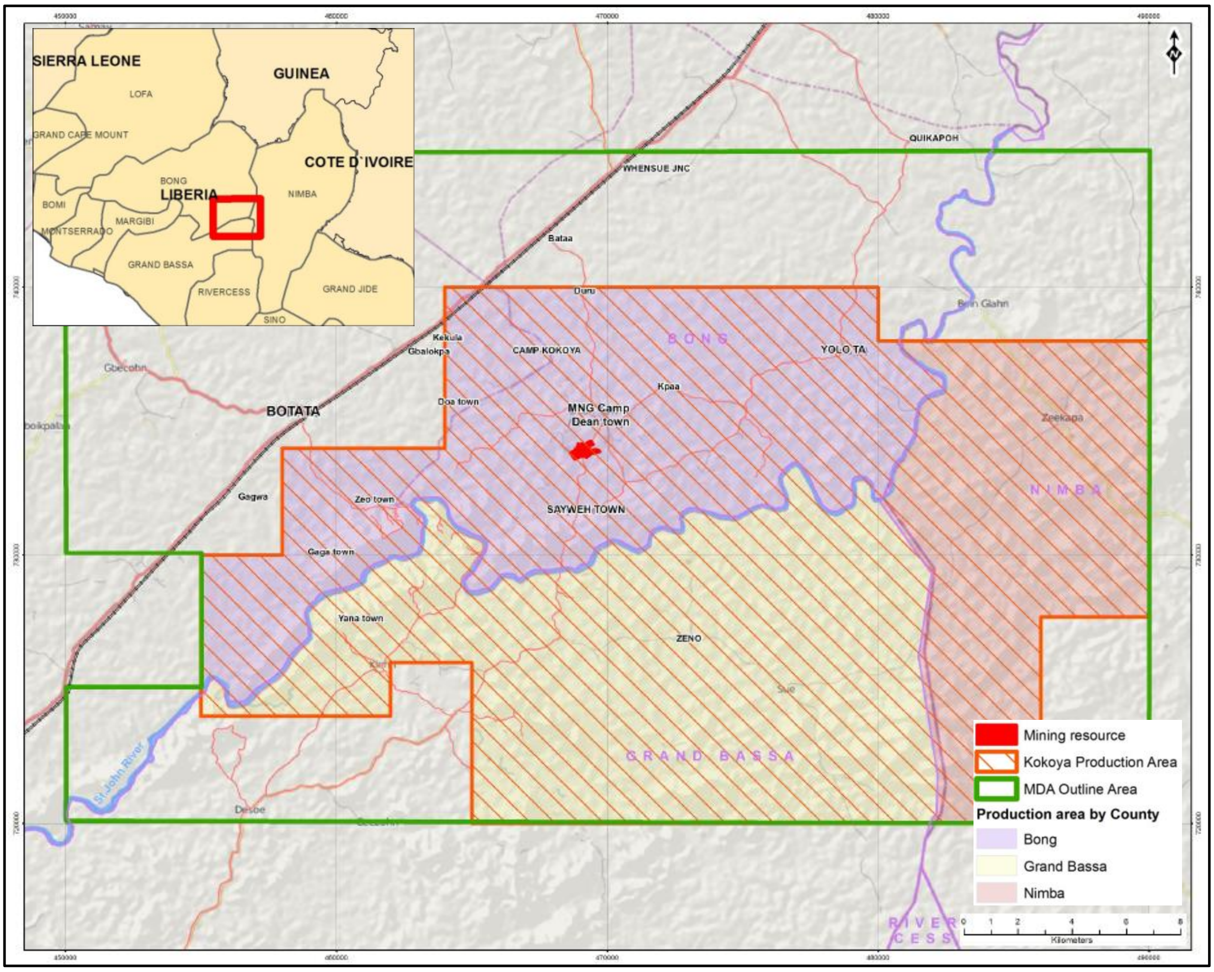


Figure 1. Kokoya production area and mining resource area (modified after Golder, 2015b).

2.2 Project Location

The Kokoya mine is located ~180 km east north-east of the national capital city, Monrovia. It is also 120 km north-east of Buchanan City, and 100 km southwest of Sanniquellie City. The project area is located between Sayeweh, Dahnway, Dean and Bohn towns.

2.3 Project Description

The Kokoya Gold Project is proposing to produce approximately 360,000 tonnes of gold ore for processing in its on-site plant per annum by CIL methodology. The key components of the project will be:

- Open Pits;
- Waste Rock Dump (WRD);
- Tailings Storage Facility (TSF);
- Process Plant;
- Ore Stockpiles;
- Underground galleries,
- Camp Area; and
- Supporting Facilities.

As of February 2020, all of the above components, except the underground galleries and transportation ramps in the Open Pit #1 (i.e. Arhavi Pit), have been operational (Figure 2, Table 1). Currently, the studies regarding the details of underground galleries and access ramps are underway.

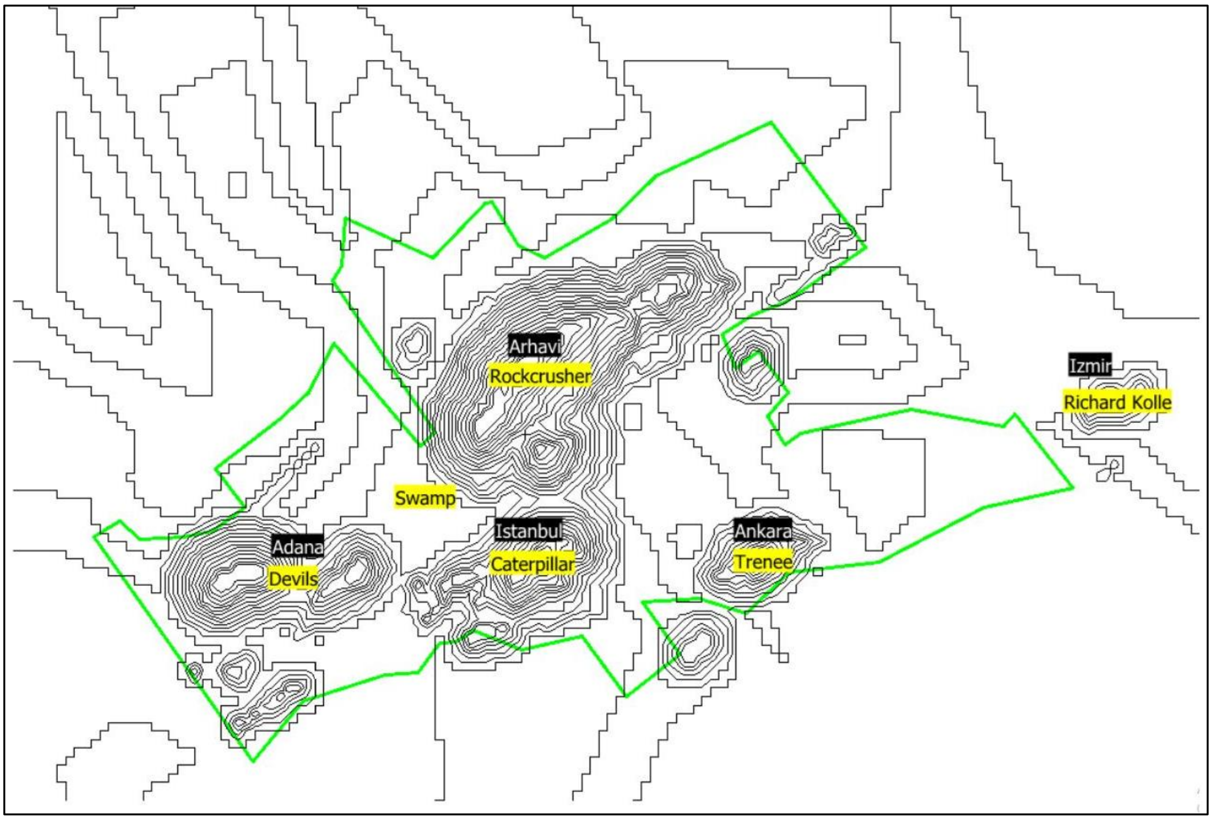


Figure 2. Positions of the open pits in the Kokoya gold mine (after Golder Associates, 2015a).

Table 1. Open pits in the Kokoya gold mine (after Golder Associates, 2015a).

Pit #	Name	Group name	Depth (m)	Base level (m)
1	Arhavi	Rockcrusher	150	90
2	-		27	210
3	İstanbul	-	58	160
4	Adana	-	160	-75
5	İzmir	-	22	140
6	Ankara	Trenee	35	190
7	-		29	200

2.4 Project Phases

The phases of the project, which are used for the impact assessment are as follows:

- Construction Phase;
- Operational Phase; and,
- Decommissioning and Closure Phase.

The construction phase commenced in the third quarter of 2015 and lasted for 10 months. The operational phase initiated immediately after the construction phase and continues until now. The operational phase will be extended by means of underground mining in galleries to be excavated along three access ramps to be developed from the bottom of present open pit (i.e. Arhavi Pit). The decommissioning and closure phase will commence after the completion of the operational phase.

3 ACCESSIBILITY, CLIMATE AND TOPOGRAPHY

3.1 Accessibility

The project area can be accessed by road from Monrovia through Buchanan to Yekepa (approx. 270 km) and also from Kakata through Totota to the closest large town, Gbarnga (approx. 200 km). An existing 4 m wide unsealed road connects the campsite to Gbanga, about 70 km away through Totota. The roads through the concession are few and they are sealed with laterite.

There is an international airport at the capital city, Monrovia. A few international fligths to some neighbour countries and Brussel are scheduled daily.

3.2 Climate

The climate in Liberia is hot and humid, and there are two distinct dry and wet seasons. The dry season is between November and March and the wet season from April to October.

Temperatures vary from 27°C to 32°C during the day and 21°C to 24°C during the night. Recent rainfall during the wet season has been recorded to vary from 4000 mm at the coast to 1300 mm inland (PMDE, 2014). The project site receives an estimated 2600 mm of rainfall on average per year. Rainfall is at its highest during the month of June with volumes of up to 530 mm being recorded, while the least rainfall occurs in February, with an average of 58 mm being experienced.

Relative humidity is generally high throughout the country. Along the coastal belt it does not drop below 80 per cent and on average is above 90 per cent. A relative air humidity of 90-100 per cent is common during the rainy season (UNDP, 2006).

Dominant wind directions in West Africa are the NE and SW Monsoons as well as the Harmattan, which is a dust laden wind from the Sahara Desert. Total wind speed is greatest in the rainy season and lowest in the dry season. Along the coast, the average annual wind speed was 30 km/hr. The greatest wind speed is between July and September and the lowest is in December and July. The highest wind speed recorded in Liberia is 72 km/hr recorded in Buchanan (on the coast) in April and May 1988 (UNDP, 2006).

3.3 Topography

The terrain within the Kokoya project area is gently undulating. The lowlands have an average elevation of 200 mASL, while the average elevation of the Hata Mountain, which is the most dominant elevation in the area is 275 mASL. There are numerous exposures of rocks in the area, especially on the higher elevated terrain. In the lowlands, exposure is less common (EGC, 2015).

The greater project area is found within natural forests, residential towns, land used for farming and areas where artisanal mining takes place. The general topography of the project area is characterized by dense forests and rolling hills, can be seen beyond the cleared site. The southern part of the area is bordered by St John river.

4 GEOLOGY

This section is derived from Golder Associates (2015a) which is based on the Definitive Feasibility Study (PMDE, 2014) and the Geology, Alteration and Mineralization Study (MNG, 2015) reports provided by MNG.

4.1 Regional Geology

Liberia is underlain by the West African Craton which extends into neighboring Guinea and Sierra Leone, and is mostly composed of Precambrian igneous and metamorphic rocks. Other rock types present in much smaller extend on a local scale include Paleozoic and Cretaceous sandstones, as well as Jurassic dolerite dykes and unconsolidated Quaternary deposits.

The West African Craton comprises two major areas of Archaean to early Proterozoic terrains as the Man Shield and the Birimian Shield. In the Man Shield, the Archaean basement is only exposed in western and central Liberia and Sierra Leone, and characterized by a granite-greenstone association dominated by older granitoid gneisses and migmatite which are in folded with supracrustal schist belts (greenstone belts) and intruded by younger granites. These supracrustal sequences outcrop as synformal relicts elongated parallel to the Liberian foliation of their gneissic basement. The Birimian, early Proterozoic terrains, is made up of an alternation of sedimentary belts and volcanic sequences intruded by large granitoid bodies which crop out in north-south to northeast-southwest trending belts extending for tens to hundreds of kilometers. The metamorphic grade within the early Proterozoic rocks is generally low, except along some subsequent trans- current fault zones. The Birimian rocks are present in the eastern third of the country in Liberia.

The basement rocks of Liberia are mainly grouped as three age provinces shown in Figure 3. The oldest is the Liberian age province, which covers the entire western half of the country, with the exception of a thin coastal strip. It was metamorphosed and intruded by plutonic rocks at around 2700 Ma. The Eburnean age province covers the eastern third of the country and has an age of around 2150 Ma. The boundary between the two provinces is not well defined due to limited age data from east-central Liberia. The coastal regions of the northern and central parts of the country are covered by supracrustal rocks of the Neoproterozoic to lower Cambrian Pan-African age province, which were metamorphosed and intruded at around 500 Ma as part of the Pan-African Orogeny. It is thought that these rocks were originally part of the Liberian province. Rocks in the Pan African age province are reworked and metamorphosed Archaean units similar to those of the Liberian age province, and in some cases can be correlated directly. In the east of the country rocks in the Eburnean age province are composed of Proterozoic-age Birimian units, including supracrustal rocks, dominantly meta-sediments, imbricated with remobilized basement and intrusive units. The Toulepleu greenstone belt extends northwards into Cote d'Ivoire. Minor sedimentary units, largely sandstone and ranging in age from Devonian to Tertiary, occur in the coastal areas to the southeast of Monrovia.

Figure 3. Tectonic map of Liberia (after MNG, 2015).

Tropical weathering is also the important factor for the geology of Liberia. Intense rainfall and high temperatures generate severe tropical weathering which decomposes the rock strata causing a reduction in rock strength and inter grain bonding. This weathered matter remains in-situ. The results of all these processes are laterite and saprolite, weakened surface layer of soil matter which can be over tens of meters thick. These layers support dense vegetation and rain forests.

The predominant strike direction of the major structures such as veins is generally NE and the most common dip direction is to the NW with dip angles varying between 40°-60°. There are series of continuous/discontinuous shear zones, composed by schist-like foliated rock with biotite-muscovite-sericite and actinolite.

4.2 Geology of Project Area

The Kokoya project area lying within the Archean aged Liberian metamorphic province is dominated by northeast-southwest trending, strongly deformed amphibolite and gneissic units, with a probable felsic rhyolite - dacite and mafic basalt origin, respectively. Amphibolite usually occurs as lenses in gneissic rock mass. Several episodes of deformation are recorded in the metamorphic rocks, including several generations of cross-cutting folding and faulting, metamorphism and locally inferred unconformities. Certain areas have undergone varying degrees of partial melting which has resulted in migmatite and pegmatite occurrences. The surface geology of the project area is presented in Figure 4. A swarm of northwest trending dolerite dykes of Jurassic age intrudes the gneisses and amphibolite. A major east-northeast trending zone of intense shearing, the St John Shear Zone, runs through the project area.

Shear zones are the host for quartz veining or intersected by veins. Two sets of quartz veins, called Rockcrusher and Caterpillar, were identified across the project area. These sets are similar in mineralogy but differ in their strike and morphology. The Rockcrusher veins strike at approximately 35° to 55° and dip to the NW at between 35° and 50°. These veins were formed by strike-slip faults and are displaced by subsequent northwest striking faults. The thickness of these veins ranges from tens of centimeters to seven (7) meters. The Caterpillar veins strike at approximately 70° to 90° and dip to the NW at between 45° and 60°. These veins are controlled by shear zones and in many instances display a lens-like shape. The Caterpillar veins generally have a lesser thickness and shorter strike length than those of the Rockcrusher.

4.3 Lithologies in the Project Area

The typical geological profile of the shallow Kokoya Project subsurface is provided in Figure 5. The NW-SE cross section of the proposed open-pit for the different rock types and the corresponding plan view are also presented in Figure 6 and Figure 7, respectively. The fresh rock in the figures refers to the magmatic and metamorphic units.

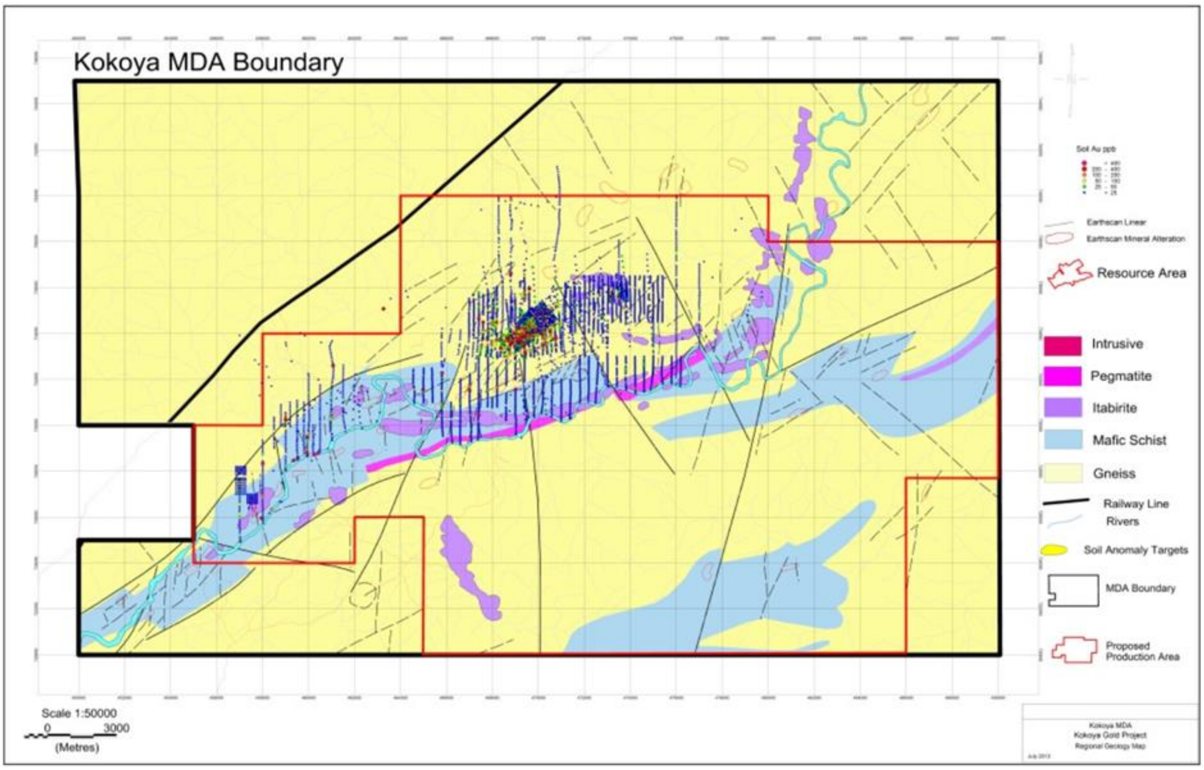


Figure 4. Geological map of the Kokoya gold mine site (after MNG, 2015).

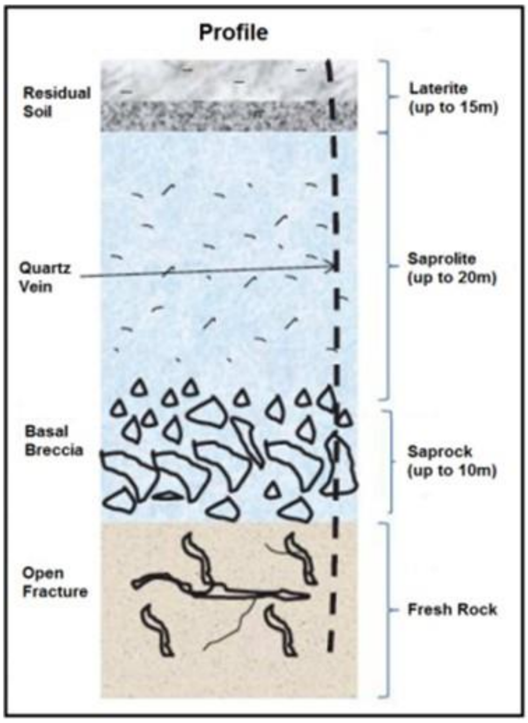


Figure 5. Typical geological profile of Kokoya project area (after Golder Associates, 2015a).

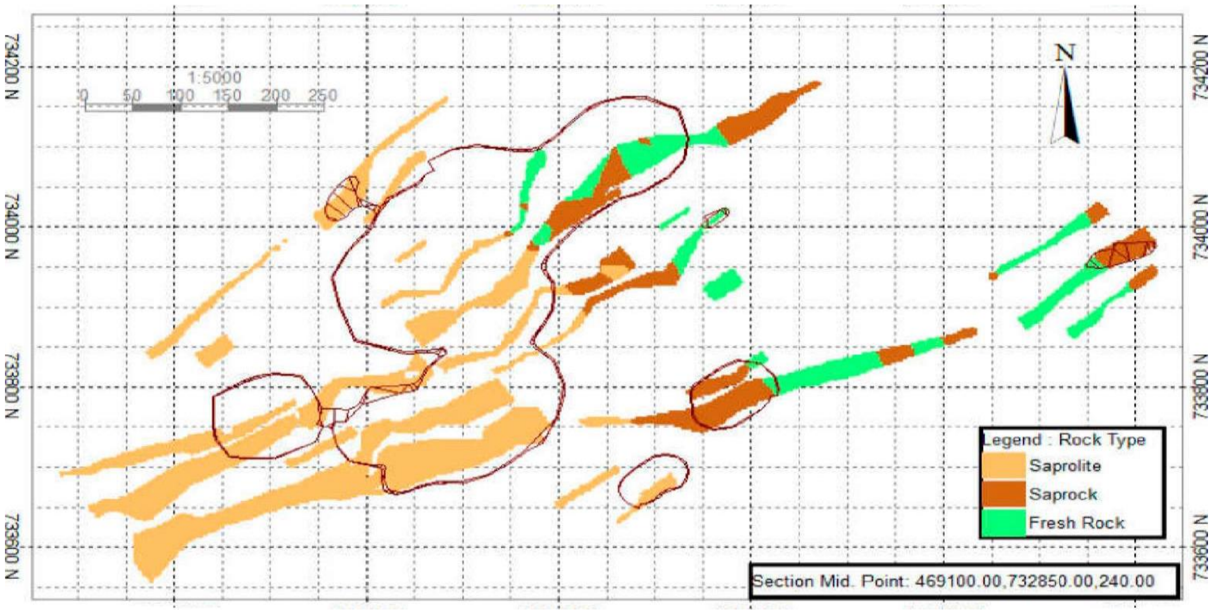


Figure 6. Plan of the pits of the Kokoya gold mine (after PMDE, 2014).

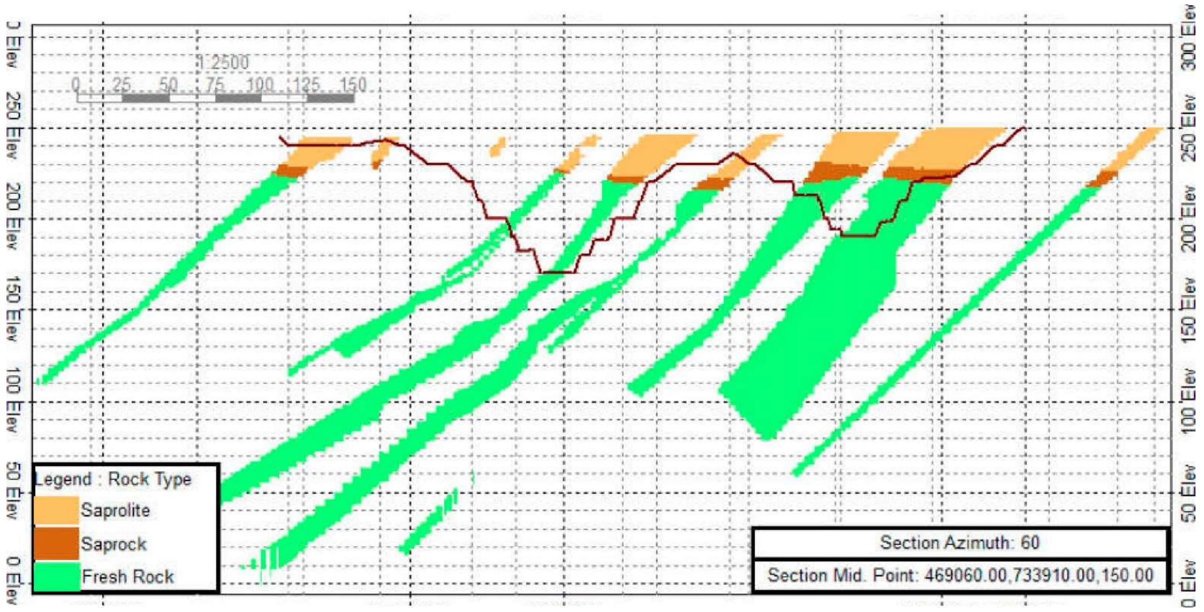


Figure 7. Northwest-southeast cross-section of the pits (after PMDE, 2014).

4.3.1 Saprolite

Saprolite is the product of deep tropical weathering with generally reddish-brown color, ferric compounds and sand to block size bedrock fragments. Saprolite (SAP), containing Laterite and Saprock, is a massive accumulation of mainly secondary clay minerals with subordinate silty sand and occasional weathered rock fragments.

The project area is covered by Saprolite (including Laterite) (up to 30m). Under the Saprolite unit, a relatively thin layer of Saprock (up to 10m), which is also weathered rock with the almost same composition with Saprolite but much high proportion of primary minerals and rock fragments (basal breccia), is present.

Moderately weathered to fresh basement rocks underlie the Saprock. The first meters of the fresh rocks are fractured and some fractures are found to be filled by secondary clay. Figure 9 shows the projected view of saprolite, Saprock and fresh rock extents in the project area. Figure 10 shows the cross-section view of the saprolite, Saprock and fresh rock. All rock types observed within the project area are described below with their definitions.

4.3.2 Fresh rock units

4.3.2.1 Amphibolite

There are three principal varieties of Amphibolite: Massive Amphibolite (AM), Feldspar Porphyry Amphibolite (AMP) and Augen Amphibolite (AMA). The most widespread one is Massive Amphibolite. AM units include hornblende, quartz, feldspar, biotite as major minerals. Trace minerals include actinolite, ilmenite, magnetite, sphene, apatite, epidote, and zircon. They differ from each other by their origin, color, texture and the abundance of accessory minerals. Massive Amphibolite whose origin is metamorphosed basalt is relatively competent and forms relatively stable blocks. It is dark-green to greenish-black colored, fine- and equally-grained, and massive with porphyry traces of lamination. Feldspar Porphyry Amphibolite whose origin is metamorphosed porphyry andesite is relatively competent rock. It is dark-green with numerous light-grey or white spots, massive with traces of lamination and textured. Augen Amphibolite whose origin is (supposedly) metamorphosed basalt with phenocrysts of olivine (or pyroxene) is incompetent rock. It is brown-green with dark-green 'augens', layered and augen textured.

4.3.2.2 Schist

The rock Schist (SC) whose origin is metamorphosed sediments is light-green to dark-brown and greenish- black colored, foliated, laminated-layered, fine to medium grained (0.1 to 3 mm), and lepidoblastic and lepidogranoblastic. It consists of chlorite, muscovite, biotite, amphiboles (tremolite, actinolite), hornblende, quartz, and feldspar minerals and contains zircon, sphene, apatite and epidote as accessory mineral, and ilmenite and magnetite. It is very widespread and can be divided into three groups based on the composition which are Biotite Schist (SCB), Actinolite Schist (SCA) and Muscovite Schist (SCM). Biotite Schist is relatively hard and all with dark brown biotite varieties including biotite-actinolite, biotite, biotite-hornblende, quartz-feldspar-biotite. Actinolite Schist is all green and relatively soft varieties, including tremolite-actinolite, chlorite-actinolite. Muscovite Schist is light-greenish-grey and relatively soft varieties with predominance of muscovite.

4.3.2.3 Granite

Granite is dark grey with white spots to light grey colored, massive, medium grained (2 - 4mm), granoblastic and porphyry textured rock. It consists of quartz, feldspar, biotite, hornblende, muscovite minerals, and contains zircon, sphene as accessory mineral and ilmenite. Granite forms concordant, narrow (up to ten meters) lens- or vein-like bodies. Origin of it is anatexis (selective melting) of the metamorphosed sediments with partial shift of the melted leucosoma (enriched in fluids felsic material) the final (and central) member of the chain sediments - schist - migmatite - gneiss. Three varieties of Granite can be distinguished: Melanocratic Porphyry Granite with a predominance of dark fine-grained matrix over the coarse (3 - 5mm) metasomatic porphyroblasts of feldspar (or quartz), Mesocratic Granite (GR) with approximately equal amounts of dark and light minerals, usually equally grained, and Leucocratic Granite (GRL) with a predominance of light minerals, equally grained.

4.3.2.4 Pegmatite and Quartzite

Pegmatite (PG) consists of vein-like bodies of quartz-feldspar. Quartzite (QW) is the same as Pegmatite but it has a strong prevalence of quartz over the feldspar. The rocks are white - grey, spotted, massive to irregular and coarse grained. They consist of quartz, feldspar, muscovite, biotite minerals and contain sphene as accessory mineral. Similar to Granite, the origin of these rocks is anatexis (selective melting) of the metamorphosed sediments with partial shift of the melted leucosoma (enriched in fluids felsic material); along with granite - the final member of the chain sediments - schist - migmatite - granite of pegmatite. Concordant or sub-concordant lens- or vein-like bodies with indistinct contacts are typical. Distinct from quartz veins, they have fuzzy contacts and the presence of 'shadow' structures, while they formed from relicts of dark minerals. In contrast to quartz veins, pegmatite and quartzite usually demonstrate just background gold content.

4.3.2.5 Very high grade metamorphic units (VHM)

Gneiss: The rock Gneiss whose origin is metamorphosed sediments or basalts (through schist or amphibolite), product of the migmatite process (with increase in silica potassium), is streaky light-grey to dark-grey colored, medium grained (1-5 mm) and lepidogranoblastic. It consists of biotite, hornblende, quartz, feldspar and muscovite minerals, and contains zircon, sphene, apatite, epidote ilmenite and magnetite. It is not widespread but it can be distinguished as Melanocratic Gneiss (GNM) with predominance of dark minerals (biotite, hornblende), Mesocratic Gneiss (GN) with approximately equal amounts of dark and light, and Leucocratic Gneiss (GNL) with a predominance of light minerals.

Migmatite: The rock Migmatite is interchange of light-grey or white and dark-grey or dark-greenish-grey, layered, irregular, folded and fine - to medium grained. It is transformed schist or amphibolite, a product of metamorphism, accompanied by an increase in silica content (as quartz) and potassium (K-feldspar). It is present as numerous quartz-feldspar segregations (nests, veinlets, and porphyroblasts). It consists of biotite, hornblende, actinolite, quartz, feldspar minerals, and contains zircon, sphene, apatite, epidote ilmenite and magnetite as ore mineral. There are three type of Migmatite: Melanocratic Migmatite (MGM) with a predominance of dark matrix, Leucocratic Migmatite (MGL) with a predominance of light segregations, Mesocratic Migmatite (MG) with approximately equal amount of matrix and segregations.

Mylonite and Blastomylonite: Mylonite (ML) and Blastomylonite (mylonite with fragments) (MLB) are grey to dark greenish - grey colored, layered - laminated, irregular, porphyry and foliated. They consist of quartz, feldspar, muscovite, chlorite minerals, and contain sphene, apatite, zircon as accessory mineral and ilmenite, magnetite as ore mineral. Mylonite is ductile deformed rock formed in the large faults. Dynamic recrystallization of the constituent minerals results in a reduction of the grain size of the rock. The mineralogical composition depends on the original rocks. It is similar to schist, with the principal difference being that mylonite was formed after the main phase of metamorphism; therefore, there are numerous porphyroblasts of quartz-feldspar composition (migmatite, pegmatite, granite) in the mylonite. Mylonite zones usually trace more ancient shear (schist) zones and can play an important role in the ore localization, acting as the structural traps.

5 GEOTECHNICAL STUDIES

5.1 Introduction

As the mine design could not be soundly and reliably performed without taking geotechnical conditions into account, a detailed geotechnical study has been carried out at the site. This section of the report summarizes the geotechnical data obtained directly from Adana and Arhavi open pits and 9 drill holes opened for this purpose.

The purpose of this section is to reinterpret the drill holes completed for geotechnical purposes and to present the current rock character in the Kokoya project. There are basically 7 different geological units in the project area. As these geological units present various structural characteristics to a certain extent, it is preferred to determine their geotechnical properties. In this context, 9 holes were reinterpreted and the results of this interpretation are given.

5.2 Geotechnical Investigations

The following subsections describe the geotechnical research studies carried out to ensure the accuracy of the existing rock quality prior to the underground design of the Kokoya Project.

5.2.1 Database

Geotechnical database contains data obtained from drill core logging. It also includes all the structure data measured during logging. For this purpose, the logbook prepared by the exploration team was used and the necessary data was obtained from this logbook.

5.2.2 Logging

The geotechnical logs made by the exploration team were revised again by relogging. Core box photographs of these 9 resource holes were examined in details and especially RMR and GSI values were calculated for geotechnical interpretation.

In particular, we had to accept the previously measured values because there was no chance of relogging the RQD measurements.

The following methodology were followed for relogging the drill holes;

- Copy in the lithology from 9 resource logs;
- Copy in RQD records and drill-run information;
- Correlate run information with geology;

- Use the core photographs to record visible rock mass information on a per run basis - 4 components:
  - ✓ Weathering intensity [Soil (6) to Fresh (1)];
  - ✓ RQD [%RQD code: -Very poor (0-25) to Very good (90-100)]; 3
  - ✓ Defect Intensity [Matrix appearance code: - Soil (0), Rock (1-5.5), Fault /Shear (8)];
  - ✓ Rock Strength – [Estimates with maximum limits from geotechnical tests: -Soil (0) to Very Strong rock (5)];

5.2.3 Geotechnical Geology

The geology derived from logging process is presented in Table 2. As it is seen, seven different rock types were lithologically defined and coded in the project area.

Table 2. Logging codes and rock types in the project area.

Code	Rock type
AM	Amphibolite massive
MG	Migmatite mesocratic
PG	Pegmatite
QVN	Quartz vein
SAP	Saprolite
SC	Schist
SCS	Schist silicate

5.2.4 Boreholes

Nine (9) of the borings within the scope of the Kokoya project were drilled and recorded for geotechnical purposes. The data of these nine (9) holes were used to determine the rock quality of the lithological units given in Table 2.

The coordinates and depths of relogged drill holes are presented in Table 3. The depths of these holes range from 233 m to 470 m where the collar elevation of the drills is averaging 225 m.

5.2.5 Rock Strength

Strength classification of rocks was made by using strength class which is suggested by International Society for Rock Mechanics and Rock Engineering (ISRM). In this context, this classification presented in Table 4 was used for all rock materials.

Table 3. Geotechnical/validation boreholes, Kokoya Project.

Borehole ID	X-Collar	Y-Collar	Z-Collar	Hole depth (m)
KYD416	469169.22	733922.29	223.64	233.00
KYD826	469227.97	733889.76	223.90	344.00
KYD840	469228.46	733890.25	223.82	338.00
KYD841	469224.80	733907.16	227.96	470.00
KYD856	469228.96	733890.54	223.86	305.00
KYD870	469227.27	733889.91	223.96	362.00
KYD880	469226.12	733907.12	228.26	360.70
KYD892	469226.89	733889.67	224.01	395.00
KYD907	469227.39	733890.08	224.23	359.00

Table 4. ISRM suggested rock material strength classifications.

ISRM Strength Classification	ISRM Description	Approximate Range of Uniaxial Compressive Strength	
		(MPa)	(psi)
R0	Extremely weak rock	0.25-1.0	35-150
R1	Very weak rock	1.0-5.0	150-725
R2	Weak rock	5.0-25	725-3500
R3	Medium strong rock	25-50	3500-7500
R4	Strong rock	50-100	7500-15000
R5	Very strong rock	100-250	15000-35000
R6	Extremely strong rock	>250	>35000

When we use the results obtained from the existing drill holes, we see different results, especially RQD, RMR89 and GSI values. For this reason, it is suggested to open new geotechnical drill holes prior to underground analysis which are being drilled in due course. Therefore, there is a need for further study.

5.2.6 Rock Mass Rating (RMR) System

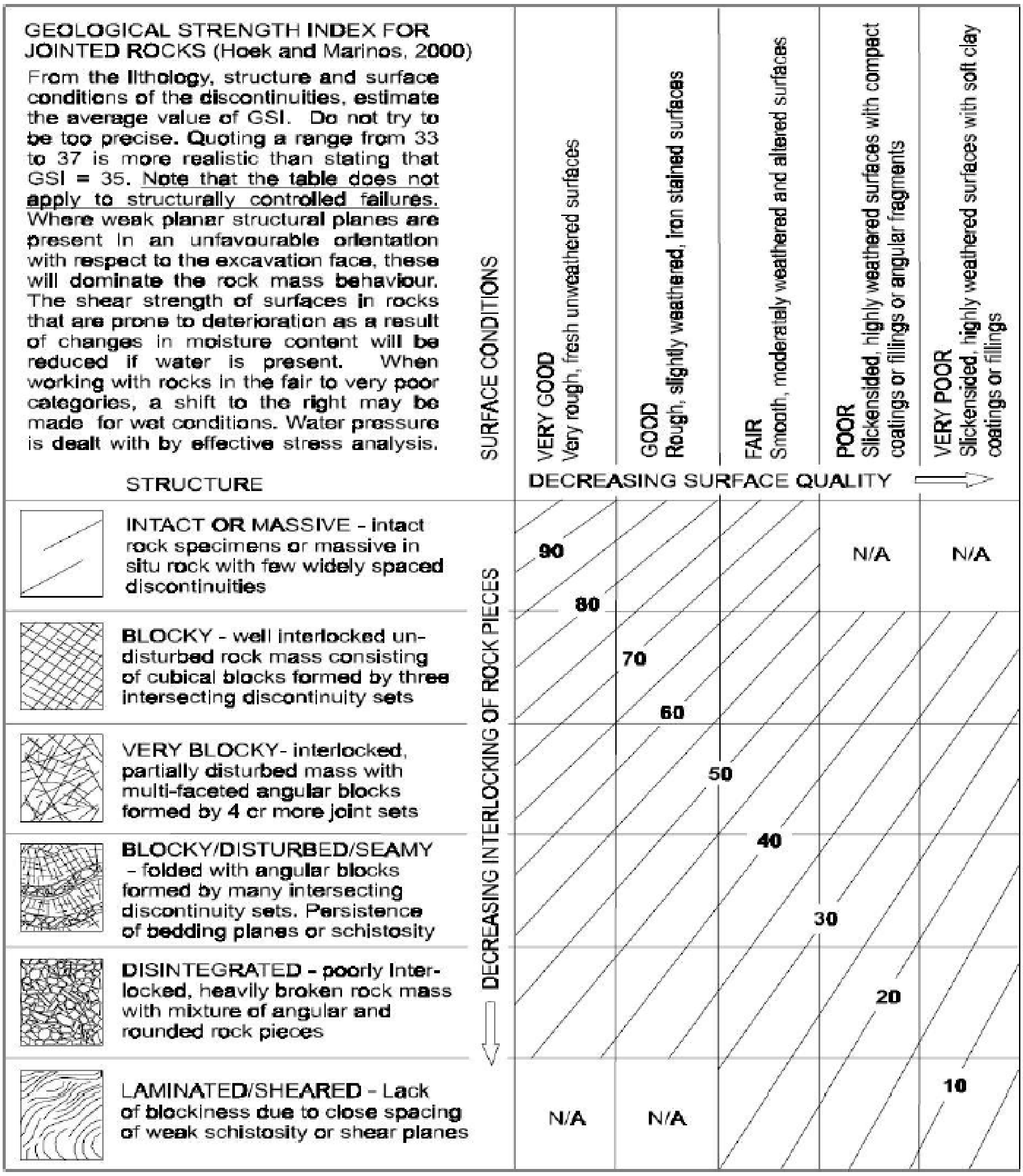
Rock Mass Ratings were calculated on the logging sheets that were provided by exploration for each borehole. The Rock Mass Rating (RMR) system developed by Bieniawski (1973, 1979). The 1989 version of the RMR system was used for the data validation exercise. Hydrogeological conditions are not taken into account due to low permability of the strong rock mass, the following four parameters are used to classify a rock mass using the RMR system as:

- Rock quality designation (RQD)
- Spacing of discontinuities

- Condition of discontinuities
- Orientation of discontinuities

5.2.7 Geological Strength Index (GSI)

The Geological Strength Index (GSI) is a system that can be used for estimating the reduction in rock mass strength for different geological conditions. The GSI is determined by taking into account the surface conditions of the rock mass and the geological structure (Figure 8).



GEOLOGICAL STRENGTH INDEX FOR JOINTED ROCKS (Hoek and Marinos, 2000)

From the lithology, structure and surface conditions of the discontinuities, estimate the average value of GSI. Do not try to be too precise. Quoting a range from 33 to 37 is more realistic than stating that GSI = 35. Note that the table does not apply to structurally controlled failures. Where weak planar structural planes are present in an unfavourable orientation with respect to the excavation face, these will dominate the rock mass behaviour. The shear strength of surfaces in rocks that are prone to deterioration as a result of changes in moisture content will be reduced if water is present. When working with rocks in the fair to very poor categories, a shift to the right may be made for wet conditions. Water pressure is dealt with by effective stress analysis.

INTACT OR MASSIVE - intact rock specimens or massive in situ rock with few widely spaced discontinuities

BLOCKY - well interlocked un-disturbed rock mass consisting of cubical blocks formed by three intersecting discontinuity sets

VERY BLOCKY- interlocked, partially disturbed mass with multi-faceted angular blocks formed by 4 or more joint sets

BLOCKY/DISTURBED/SEAMY - folded with angular blocks formed by many intersecting discontinuity sets. Persistence of bedding planes or schistosity

DISINTEGRATED - poorly inter-locked, heavily broken rock mass with mixture of angular and rounded rock pieces

LAMINATED/SHEARED - Lack of blockiness due to close spacing of weak schistosity or shear planes

Figure 8. Geological strength index for jointed rock masses (Hook, 2007).

This system was introduced by Hoek (1994) and Hoek, Kaiser and Bawden (1995). The information derived from logging contained GSI values calculated with the Russo, Cai et al, and Hoek methods (Table 5). The overall average GSI value was also provided, which was the selected GSI used in the data validation process.

Table 5. GSI classification.

GSI Range	Classification	Description
<20	Very poor quality rock mass	Generally highly to completely weathered, very closely jointed to sheared rocks with poor to very poor quality low strength joint surfaces.
20 - 35	Poor quality rock mass	Generally highly to moderately weathered, close to very closely jointed rock mass with poor quality low to medium strength joint surfaces.
36 - 55	Fair quality rock mass	Generally moderately weathered, closely jointed rock mass with fair quality medium strength joint surfaces.
56 - 75	Good quality rock mass	Generally moderately to slightly weathered, medium to widely jointed rock mass with fair to good quality medium to high strength joints.
>75	Very good quality rock mass	Generally slightly weathered to fresh, wide to very widely jointed, massive rock mass with high quality, high strength joint surfaces.

5.2.8 Rock Quality Designation (RQD)

Rock Quality Designation (RQD) is the sum of all pieces of intact core longer that 10 cm that occur within a specific interval – usually the drill-run (but could be per meter), divided by the interval length and expressed as a percentage.

The RQD is a very useful parameter in describing the extent of fracturing of rock core/core quality.

RQD is widely used in most rock mass classification systems, but despite its use it has some limitations:

- RQD must only be measured between natural defects – beware of including driller / mechanical breaks in measurements.
- RQD measurement is orientation sensitive – a borehole perpendicular to foliation, bedding or structure may produce a very different RQD to an adjacent hole drilled in another direction;
- It is based on a fixed interval and therefore can give large variances for small differences in measurement, for example core that visually looks very similar could have an RQD of

zero or 100, depending on the spacing of core pieces – for example 9.5cm (0% RQD) or 10.5cm (100% RQD).

5.3 Rock Classification

In order to assess the validity of the data from the resource boreholes, it was compared to the data gathered from the new relogging geotechnical boreholes. RMR89, GSI and RQD values with increasing depth for each borehole was carried out. In the calculation of these variables for each lithology, 9 drill hole relogging values were used. The average values of RMR89, GSI and RQD for each rock type are presented in Table 6.

If we look at the RMR89 values calculated for each lithology, a certain impression about the rock quality is provided. On the basis of RMR89 values in the table, MG, PG and SCS rock units are classified as "very good rock" where AM, QVN and SC units as "good rock". For SAP unit, it can only be defined as "poor quality rock".

Quite similar rock quality classes is observed for the GSI and RQD values. It is clear that the saprolite is the lowest strength unit. The other units are in “good” or “very good” class.

As a conclusion, the rock where the underground excavations is to be opened within, can be classified as either very good rock or at least good rock. This implies that, in general it is not expected to have a major stability problem in the mine. When the weak zones are encountered, these zones should be carefully characterized and conditions should be analyzed.

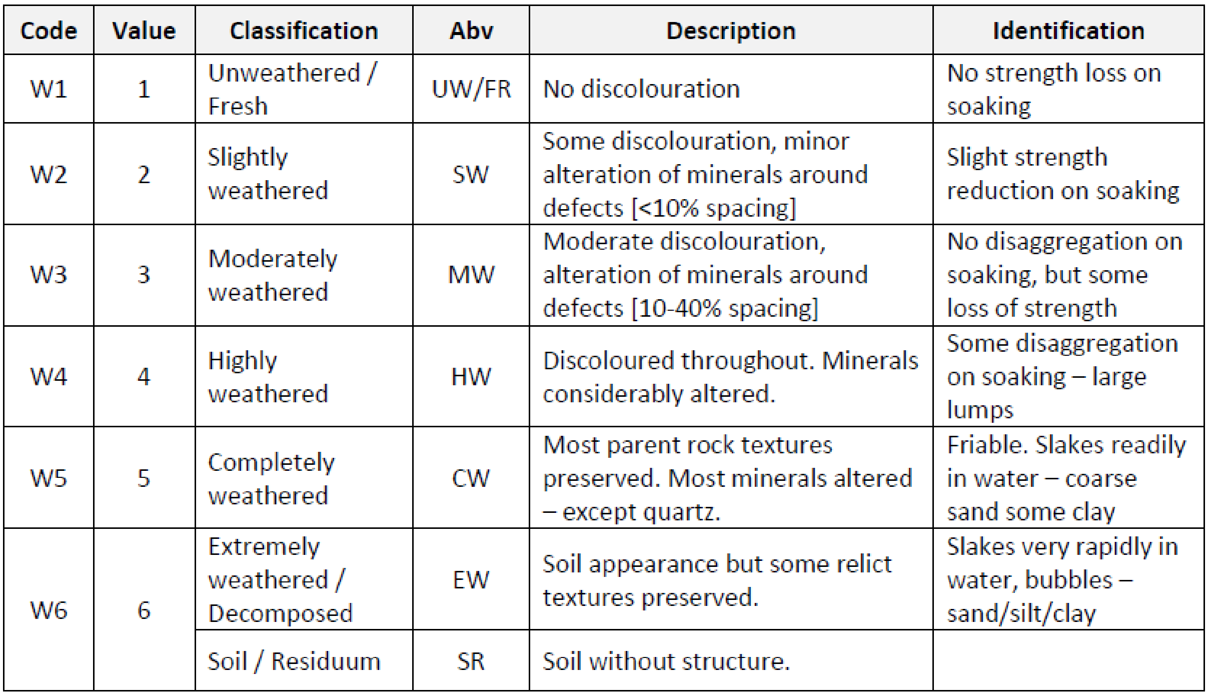
Table 6. Classification of rock types according to different systems.

		RMR89 Classification		GSI Classification		RQD Classification	
Rock type	Code	Score	Class	Score	Class	Score	Class
Amphibolite massive	AM	73	Good	74	Good	78	Good
Migmatite mesocratic	MG	80	Very good	83	Very good	88	Good
Pegmatite	PG	80	Very good	79	Very good	92	Very good
Quartz vein	QVN	77	Good	77	Very good	82	Good
Saprolite	SAP	26	Poor	15	Very poor	1	Very poor
Schist	SC	75	Good	75	Good	76	Good
Schist silicate	SCS	85	Very good	86	Very good	99	Very good

5.4 Weathering and Strength Profile of Lithologies

Weathering is the chemical and physical change in time of intact rock and rock mass material under the influence of the atmosphere and hydrosphere. A detailed description of the weathering classification and strength classification of the lithological units are given in Table 7 and Table 8, respectively.

Table 7. Standard weathering profile and values.



Code	Value	Classification	Abv	Description	Identification
W1	1	Unweathered / Fresh	UW/FR	No discolouration	No strength loss on soaking
W2	2	Slightly weathered	SW	Some discolouration, minor alteration of minerals around defects [<10% spacing]	Slight strength reduction on soaking
W3	3	Moderately weathered	MW	Moderate discolouration, alteration of minerals around defects [10-40% spacing]	No disaggregation on soaking, but some loss of strength
W4	4	Highly weathered	HW	Discoloured throughout. Minerals considerably altered.	Some disaggregation on soaking – large lumps
W5	5	Completely weathered	CW	Most parent rock textures preserved. Most minerals altered – except quartz.	Friable. Slakes readily in water – coarse sand some clay
W6	6	Extremely weathered / Decomposed	EW	Soil appearance but some relict textures preserved.	Slakes very rapidly in water, bubbles – sand/silt/clay
		Soil / Residuum	SR	Soil without structure.	

The type of material in the Kokoya project was classified according to the type of rock, as well as the level of decomposition recorded in the recording data. The weathering coefficients obtained from all drillings were classified according to the above table and mean weathering values were tried to be determined.

The strength value is one of the parameters that gives us the most accurate under which load a rock can remain stable. This value is determined by either performing a Point Load Test (PLT) in place or by performing UCS tests in a rock mechanics laboratory.

Table 9 shows the weathering and strength values of the lithologies and their classification. When we look at the strength values determined for each lithology, it is seen that the solid rock is generally within the "very strong-strong" range of values.

Table 8. Standard rock strength values.

Code	Abv	Strength Description	Hardness-L	Identification	Strength Range (MPa)
R0	EW	Soil/Residuum	-	Residuum / Soil without structure.	<0.5
		Extremely weak	-	Indent with thumbnail, mouldable when wet.	0.5 - 1
R1	VW	Very weak	<300	Crumbles with firm pick blow, knife can cut and pare, can break gravel sized pieces with fingers.	1-5
R2	WR	Weak	300 – 450	Knife can pare and gouge rock surface easily, can snap small core sample.	5 – 25
R3	MS	Medium strong	451 – 600	Dull knock when specimen struck with hammer, Breaks with a single blow, knife can scratch and groove surface, core sample not easily snapped.	25 – 50
R4	SR	Strong	601 – 750	Knock sound when struck with hammer, also hand held specimen broken with single blow.	50 – 100
R5	VS	Very strong	751 – 900	Rock chips when struck with hammer. Several blows to break specimen	100 – 200
R6	ES	Extremely strong	>900	Rock rings when struck with hammer	>200

Table 9. Weathering and strength classification of rock types.

		Weathering Classification		Strength Classification	
Rock type	Code	Value	Class	Value	Class
Amphibolite massive	AM	1	UW	R4	Strong
Migmatite mesocratic	MG	1	UW	R5	Very strong
Pegmatite	PG	1	UW	R5	Very strong
Quartz vein	QVN	1	UW	R5	Very strong
Saprolite	SAP	6	EW	R0	Extremely weak
Schist	SC	1	UW	R5	Very strong
Schist silicate	SCS	1	UW	R5	Very strong

5.5 Results

- 9 resource drill holes completed in the Kokoya project were relogged to determine geotechnical parameters.
- After this study, RMR, GSI and RQD values were tried to be determined.
- RMR, GSI, RQD, weathering and strength parameters were determined for each lithology. As a result;
  - Average RQD value, the rock structure generally corresponds to the "good to very good" range.
  - Average RMR value, the rock structure corresponds to the "good to very good" range.
  - Average GSI value, the rock structure corresponds to the "very good" range.
  - Average strength value, the rock structure corresponds to the "very strong to Strong" range.
  - Average weathering value, the rock structure corresponds to the "UW to EW" range.
- More geotechnical drilling should be performed in order to determine the rock structure better.
- Some strength tests should be applied on rock mechanics samples to be collected from new drill holes. (UCS, TRX, Shear Box, Young's Modulus & Possion's Ratio)

Major stability problems are not foreseen in the mine. Whenever a weak or disturbed zone is faced, the local conditions should be analyzed and necessary supporting strategy should be applied.

6 UNDERGROUND MINE

As the ore zones are in the form of steep veins, open pit could be deepened to a certain level. Overburden requirement has necessitated for switching to underground mining method. There a number of veins dipping beneath the open pit bottom. Portions of these veins had been produced by surface mining method up to certain depth. Although there are a number of veins, as seen in Figure 9, having different sizes, only four of them are suitable for underground production. The mining is going to be performed at two distinct locations in the form of main u/g mine and small u/g mine as seen in Figure 10. The small one is located at the north-east of Arhavi pit. This mine could be an O/P according to optimization so it is optional. The main underground mine is located beneath the Adana pit. The main mine has three sectors namely east, middle and west (Figure 10). A total amount of 1,119,000 tonnes of ore is planned to be produced from the main mine.

Arhavi pit is backfilled up to 185 and 205 mRL to form two platforms for construction of surface facilities. The main mine has a main entrance and two air return exits which are located at the benches of Adana pit. The locational details of these openings to underground are given in Table 10. The main entrance is located at eastern side of Arhavi and Adana pits intersection.

A protective barrier pillar of adequate thickness is to be left between the bottom of open pit and the underground mine. As the rock mass is very strong to strong class the thickness of this pillar should not be greater than 15 m in general. Production at underground mine will start from the bottom elevation and will advance upwards. Therefore, the thickness of the barrier pillar will be important at the last stage (during mining of the level closest to the open pit) of underground mining operation. It is suggested that the quality of backfill should be improved at this stage to minimize the effect of roof sagging, hence maximum amount of ore can be produced beneath the open pit bottom. As the surrounding rock behavior would be fully understood up to this stage necessary precautions can be taken to provent any settlement at the open pit bottom. For this purpose, a couple of extonsemeters should be deviced to monitor any settlement at the surface. Water accumulation at the pit bottom should be prevented as the water may seepage through cracks to underground mine.

Table 10. Coordinates of the underground opening entrances at the surface.

Connection name	Function as	Easting (X)	Northing (X)	R. level (z)
Main entrance (A)	Transportation	469130	733909	105
Air return (B)	Ventilation	469156	733734	156
Air return (C)	Ventilation	468886	733777	105

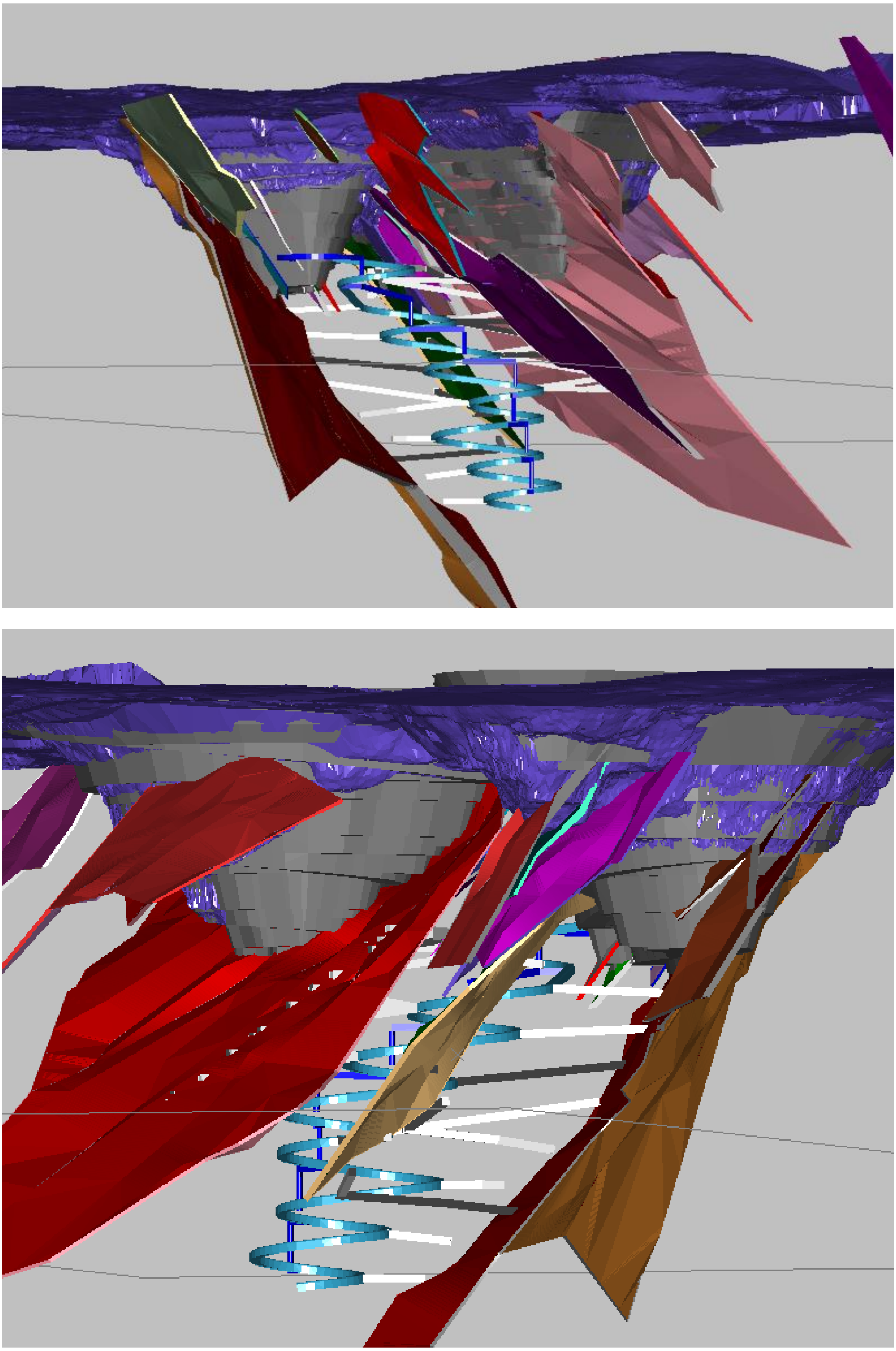


Figure 9. Ore veins and underground mine openings (a) view from SW, (b) view from E.

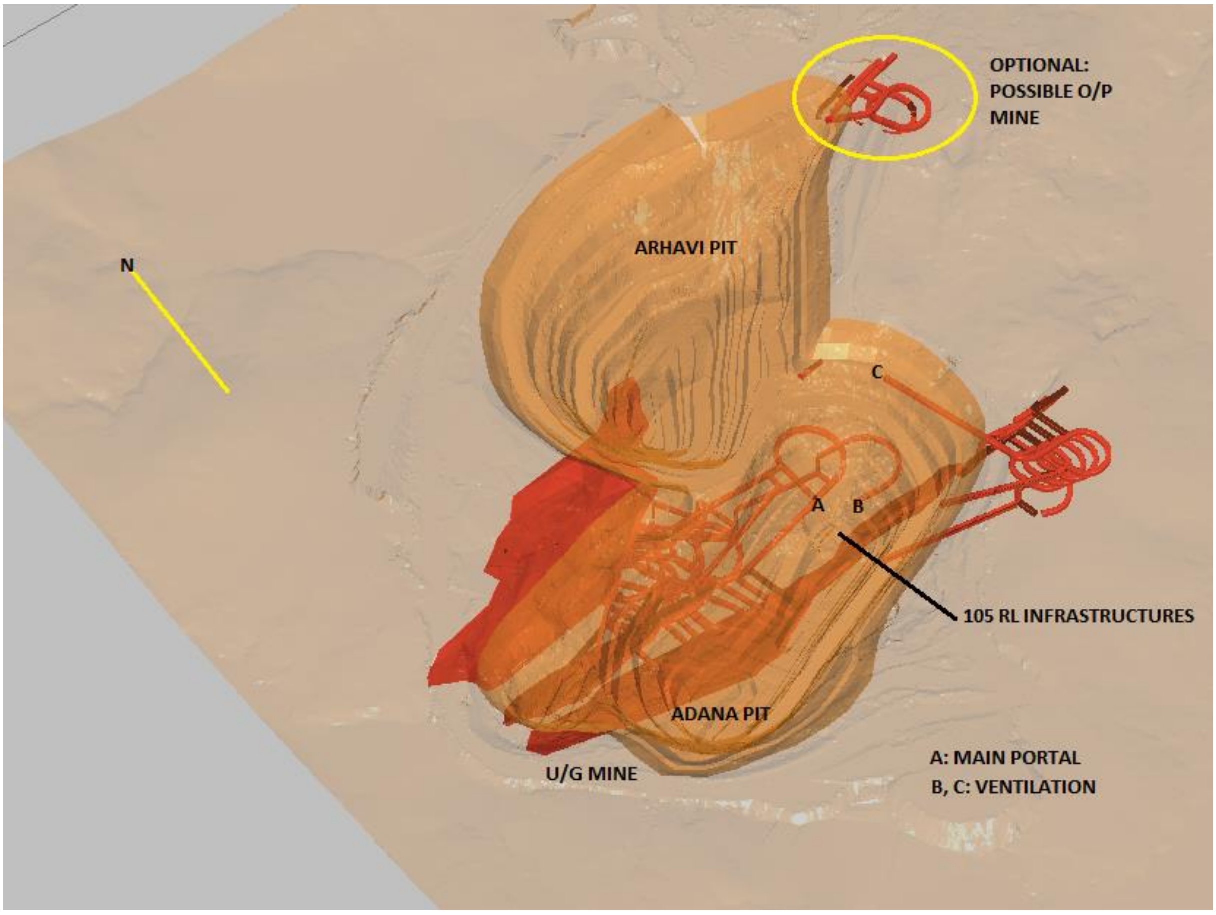


Figure 10. Isometric view of topography and underground mines.

East sector has four levels between +164 and +80 mRL. Middle sector is connected to the Western block with a level gallery opened at +25 mRL and has 9 levels between +60 and -100 mRL (Figure 11). Production is performed at two separate ore veins at west sector. Figure 12 presents the location of ramps and production levels. One of the vein has a slope angle of 37 degrees, it is planned to cut and fill the drift instead of forming a stope between levels because of the fact that a slope of 37 degrees is too low for winning the ore by means of drawing.

The mining method selected for the mine can be named as Sublevel Stoping with backfilling. Production will start from the lowest elevation. At first crosscuts and drifts along the strike are developed leaving an ore stripe having a thickness of 15 m between drifts. The ore between drifts drilled and blasted and the ore is hauled from the lower elevation drift. Upon the production of ore about 20 m along the strike, the stope is filled with rock fill, and occasionally with cemented rock fill. The length of stope can be changed by observing stability, dilution and operational conditions. Upon filling a new stope can be formed and the cycle is repeated. When one level is finished after applying rockfill the upper stope can be ready for production. As the thickness of orebody is around 4 m, a complete stripe of ore at a level can be produced and rock fill is carried out afterwards or waste material from various excavations can be hauled to the open stopes for filling. The length of the opening is to be large in this case and there can be risk of spalling on stope walls. In this case either the length of stope can be shortened, or stope walls may be strengthened by using cable bolts, but length of open stopes will be maximum 20 meters.

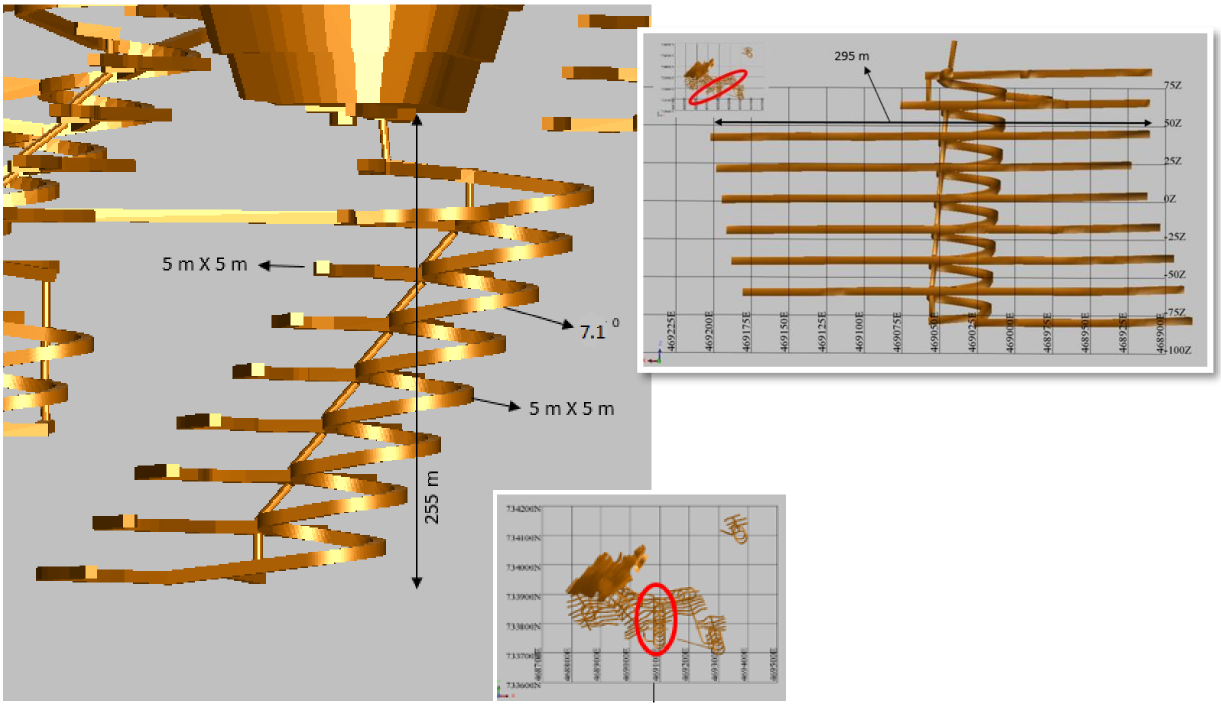


Figure 11. Cross-sectional view of middle sector ramp and production levels.

Apart from saprolite, the surrounding rock and the ore itself is of very strong to strong rock characteristics. Underground mine is not expected to have any openings in the weak saprolite zone. As the surroung rock is very strong to strong rock, it is foreseen to come up with a significant stability problem at underground opening. Systematic bolting may not be necessary at every location. However, occurrence of discontinuities would be crucial for the stability. Intersections of discontinuities may form wedges at the roof or sidewalls which may free fall or slide into the opening. Therefore, it is suggested to systematical record rock mass structure data during the drivage of underground opening. Whenever a weak zone is encountered systematic bolting and shotcreting should be applied. Numerical analysis carried out this study claimed that the stopes at a level can be excavated in a single pass. The selected elevation between levels such as 20 and 25 m is suitable for the mine in general. However, in underground it is always possible to come up with weak zones which may not be determined during design stage. Therefore, a more detailed study should be carried out for better determination of these weakness zones which may not be predicted at this stage.

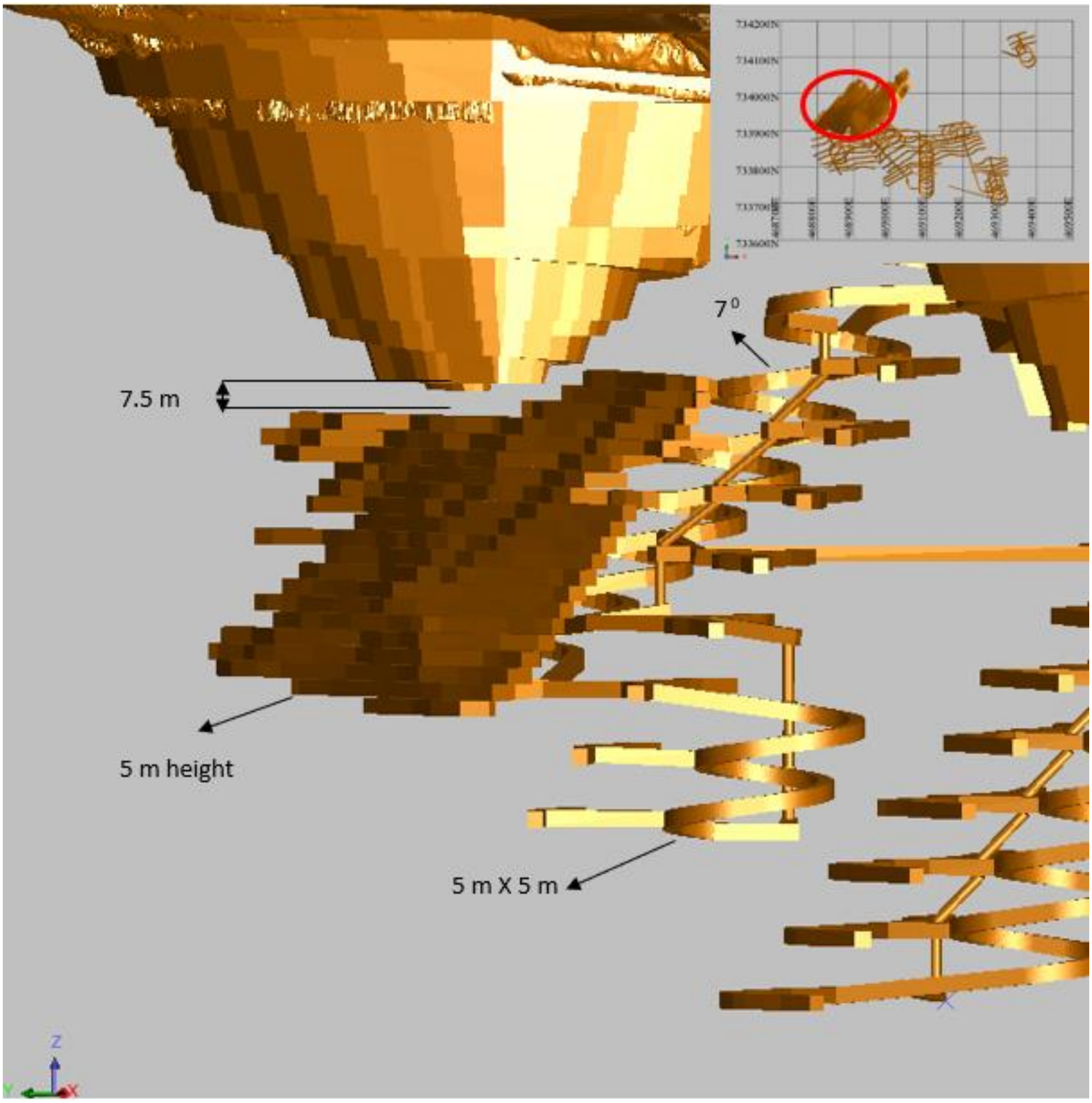


Figure 12. Cross-sectional view of west sector ramps and production levels.

Due to low slope of one of the veins in the west sector, the above explained method could not be used. The production on this vein is to be carried out in the form of driving the drift in the ore along strike and subsequent filling. Production will start fron the lower elevation and the drift is to be backfilled. Next level will be opening just a new drift opened diagonally above the backfilled area and production go on in this manner. A total number of 19 drifts will be opened for ore production and subsequently backfilled one after each other.

A summary of underground mine opening is presented in Table 11. Table 12 includes the size, length and volume of underground development works. Around 14,828 m long underground openings will be driven.

Table 11. Development works and production details of underground mine.

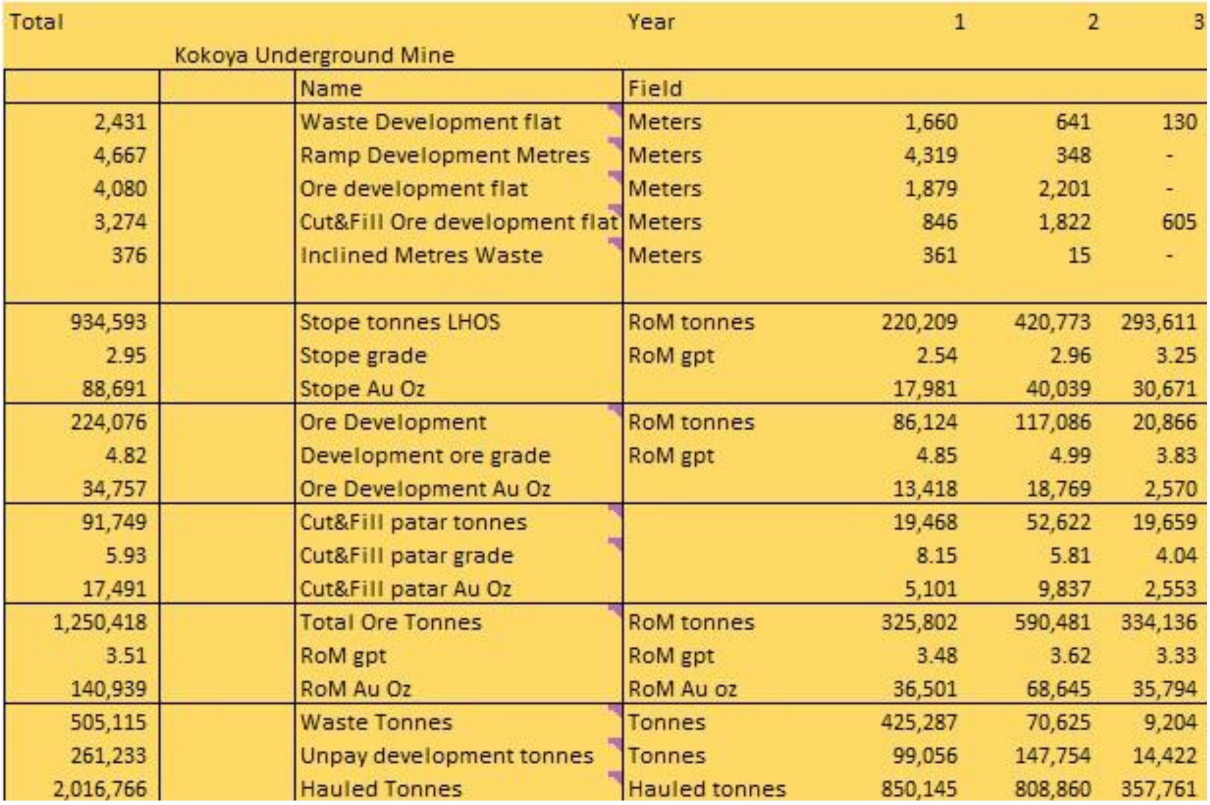
	Unit	Total
Ramp Development	meters	4667
Waste Development	meters	2431
Ventilation Vertical	meters	376
Ore Development Flat	meters	7354
Stope Ore	tonnes	934,593
Stope Ore Au	g/t	2,95
Ore Development tonnes	tonnes	224,076
Development ore Au	g/t	4,82
Cut and Fill tonnes	tonnes	91,749
Cut and Fill ore Au	g/t	5,93
Total Ore Tonnes	tonnes	1,250,418
Total Ore Au	g/t	3,51
Oz		140,939
Waste	m^3	179,460
Waste	tonnes	173,383

Table 12. Dimensions related to development works.

	H (m)	W (m)	Area (m^2)	L (m)	Volume (m^3)
Ramp Development	5.0	5.0	25.00	4667	116,675
Waste Development	5.0	5.0	25.00	2431	60,775
Ventilation Vertical (Circle)		3.5	9.62	376	3,617
Ore Development Flat	5.0	5.0	25.00	4080	102,000
Cut and Fill Development	5.0	4.0	20.00	3274	65,480
Total Drives				**14,828**	**348,547**
Stope Volume					**332,595**
Total Volume					**681,142**

The underground mine life is 3 years. A total amount of 1,375,460 tonnes of ore with 10% dilution is to be produced (Table 13). To reach this production amount, a total of 2,016,233 tonnes of material is to be hauled (ore and waste).

Table 13. Annual production schedule for three years mine life.



Total			Year	1	2	3
	Kokoya Underground Mine					
		Name	Field			
2,431		Waste Development flat	Meters	1,660	641	130
4,667		Ramp Development Metres	Meters	4,319	348	-
4,080		Ore development flat	Meters	1,879	2,201	-
3,274		Cut&Fill Ore development flat	Meters	846	1,822	605
376		Inclined Metres Waste	Meters	361	15	-
934,593		Stope tonnes LHOS	RoM tonnes	220,209	420,773	293,611
2.95		Stope grade	RoM gpt	2.54	2.96	3.25
88,691		Stope Au Oz		17,981	40,039	30,671
224,076		Ore Development	RoM tonnes	86,124	117,086	20,866
4.82		Development ore grade	RoM gpt	4.85	4.99	3.83
34,757		Ore Development Au Oz		13,418	18,769	2,570
91,749		Cut&Fill patar tonnes		19,468	52,622	19,659
5.93		Cut&Fill patar grade		8.15	5.81	4.04
17,491		Cut&Fill patar Au Oz		5,101	9,837	2,553
1,250,418		Total Ore Tonnes	RoM tonnes	325,802	590,481	334,136
3.51		RoM gpt	RoM gpt	3.48	3.62	3.33
140,939		RoM Au Oz	RoM Au oz	36,501	68,645	35,794
505,115		Waste Tonnes	Tonnes	425,287	70,625	9,204
261,233		Unpay development tonnes	Tonnes	99,056	147,754	14,422
2,016,766		Hauled Tonnes	Hauled tonnes	850,145	808,860	357,761

7 CONCLUSIONS

Kokoya gold mine has been operated by MNG by means of surface (open pit) mining. As the stripping ratio increased depending on deepening of open pit mine it was decided to produce deeper gold bearing veins by means of underground mining. Exploration drill-holes revealed that gold bearing veins extend to deeper elevations. Slopes of these veins are steep where one vein has a slope of around 37 degrees. Although trere are numerous veins only five of them are found to be technically and economically suitable for underground production.

The ore body is going to be reached by a ramp opened at an elevation of 185 mRL. There will be two air outlet connections to the surface. Thus, in total, there will be three connections of the mine to the surface. The ramps and connection roadways are to be opened to reach seperate veins.

The surface is covered with saprolite having a thickness around 30 m. The saprolite zone is formed by means of weathering of rocks exhibiting a soft and fractured structure. The effect of weathering is the highest at the surface as it decreases towards deeper elevations. Beneath the saprolite zone, in general fresh, strong rock zones present. All of underground openings are to be located in these strong to very strong rock zones.

The mining method selected for the mine is in comply with the conditions encountered in the mine. Steep veins are to be produced by means of sublevel stoping and subsequent back filling method whereas the vein located at the western end is suitable for production in the form of drifts and back filling method. Therefore it can be concluded that the selected production method on the basis of the geotechnical conditions encountered in the mine is suitable.