Sierra Rutile Project Area 1 – Environmental, Social and Health Impact Assessment: Geochemistry Characterisation of Selected Residues

Report Prepared for

Sierra Rutile Limited

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Report Number: 515234/ Final Geochem

Report Prepared by

srk consulting

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Sierra Rutile Project Area 1 – Environmental, Social and Health Impact Assessment: Geochemistry Characterisation of Selected Residues

Sierra Rutile Limited

SRK Consulting (South Africa) (Pty) Ltd
265 Oxford Rd
Illovo 2196
Johannesburg
South Africa

e-mail: johannesburg@srk.co.za
website: www.srk.co.za

Tel: +27 (0) 11 441 1111
Fax: +27 (0) 11 880 8086

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Compiled by:	**Reviewed by:**
Levi Ochieng, Pr Sci Nat Senior Geochemist	James Lake, Pr Sci, Nat Principal Scientist/Partner
Email: lochieng@srk.co.za	

Authors:

Levi Ochieng; James Lake

Executive Summary

Sierra Rutile Limited (SRL) is an existing mining operation located in the Bonthe and Moyamba Districts of the Southern Province of Sierra Leone. The mine has been in operation for over 50 years and produces rutile, ilmenite and zircon concentrates. The SRL operation has an existing Environmental Licence (reference number EPA-SL030) and has previously undertaken two Environmental and Social Impact Assessment (ESIA) studies for their operations, in 2001 and an update in 2012. When these studies where undertaken, the primary mining process was dredge mining. SRL started open cast dry mining as an auxiliary method of ore extraction in conjunction with dredge mining in 2013. SRL commissioned a second dry mining operation in 2016 and anticipates that, over time, dredge mining will cease and dry mining will be the primary mining method employed.

SRL appointed SRK Consulting (South Africa) (Pty) Ltd (SRK) to undertake an Environmental, Social and Health Impact Assessment (ESHIA) to include the new dry mining processes and update the existing ESIA and the associated Environmental, Social and Health Management Plans (ESHMPs). This geochemistry study is part of the ESHIA study.

The objective of the geochemistry study is to characterise the tailings generated from Lanti (dredge and dry mining) and Gangama (dry mining) operations in Area 1 with respect to their Acid Sulfate Soils (ASS) and Metal Leaching (ML) potential in accordance with the Sierra Leone's Environmental Protection (Mines and Minerals) Regulations, 2013 (SLEP (M&M) Regs 2013) and Good International Industry Practice (GIIP).

To address the above objectives, the scope of the study included sampling of tailings, laboratory analysis of the samples, analysis and interpretation of the laboratory data and reporting.

SRK undertook the sampling of the tailings in June 2017 during the wet season (May – October). Sampling focussed on Area 1 (Gangama and Lanti) tailings that include primary process tailings and secondary process tailings. Ten (10) primary process tailings samples were collected; 3 from Gangama dry mining; 4 from Lanti dry mining and 3 from Lanti dredge mining. Sixteen (16) secondary process tailings were collected from the deposits located next to the Mineral Separation Plant (MSP).

Four (4) process water samples were collected from the MSP; 2 overflow samples from the green tank that stores water from Mogbwemo Dredge Pond and 2 water samples from Lake Gray. Lake Gray water is used as the process water and contributes to the supernatant quality or leachate quality of the secondary process tailings. Mogbwemo Dredge Pond receives effluent water from the secondary process tailings ponds.

Laboratory analysis of the samples was undertaken by M&L Laboratory Services (Pty) Ltd in Johannesburg, South Africa. Initial analysis of the all tailings samples involved total element chemistry, Acid Base Accounting (ABA) and sulfur speciation. Sub-sets of the samples were composited for mineralogy and leaching tests. Contact leaching tests were conducted only on the solid samples. The leachates and supernatants from slurry samples were analysed for metals, metalloids and anions.

The key findings of the geochemical study are as follows:

Mineralogy

The mineralogy of the primary process tailings consist predominantly of inert or resistant quartz that does not contribute to either acidity or alkalinity.

The reactive minerals in primary tailings include kaolinite [$Al_4(OH)_8(Si_4O_{10})$] and gibbsite ($Al(OH)_3$). Kaolinite occurs in all the analysed primary process tailings samples. Kaolinite is an aluminosilicate mineral that dissolves to some extent in ASS, and therefore acts as a neutralising agent in the tailings.

Gangama dry mining and Lanti dry mining tailings contain gibbsite ($Al(OH)_3$), a low solubility secondary mineral, which can also contribute to Neutralisation Potential (NP).

Gibbsite does not occur in the Lanti dredge mine tailings in detectable quantities but occurs in detectable quantities in the Lanti dry mining tailings. The precipitation of gibbsite in the tailings was confirmed by running a PHREEQC check using 25% water extract data at a paste pH of 5.6.

The reactive minerals in secondary process tailings include marcasite and pyrite in Sulfide Flotation Tailings (SFT), goethite in Total Tailings (TT) and Coarse Electrostatic Tailings (CET) and almandine in CET, TT, Ilmenite Tailings (IT) and Fine Electrostatic Tailings (FET). Marcasite and pyrite are likely to contribute to acidity in SFT when exposed to oxidising conditions. Goethite, a pseudomorph of marcasite and pyrite may contribute to NP in TT and CET at pH range of 3.0 – 3.7. Almandine, a fast weathering aluminosilicate mineral, may contribute to the NP in CET, TT, IT and FET. In addition, monazite, a radioactive phosphate mineral, occurs in CET, FET, IT and TT.

Elemental composition

Total metal analysis of the tailings was undertaken to identify elements that are present at concentrations that may be of environmental concern with respect to water quality.

The appropriate media to compare the concentrations of the elements in the tailings is the total elemental concentration of the ore material from which the tailings are generated to determine enrichment relative to the ore given that there is no physical or chemical alteration of the materials. However, elemental concentration data of the ore material was unavailable and the elemental concentrations of the tailings have been compared to the average crustal abundance (Forstescue, 1992). Although the average crustal abundance data do not necessarily account for mineralisation present in the ore body, in the absence of ore data, the use of crustal abunbace data is an industry accepted approach of identifying enrichment and is commonly applied in ESIA studies.

Elements that are significantly enriched (i.e. GAI ≥3) in the primary process tailings include silver (<0.40 – 0.81 mg/kg), boron (240 – 590 mg/kg), cadmium (0.78 – 1.4 mg/kg) and selenium (22 – 41 mg/kg).

Elements that are significantly enriched (i.e. GAI ≥3) in the secondary process tailings include silver (<0.40 – 28 mg/kg), boron (370 – 1 290 mg/kg), cadmium (<0.10 – 1.4 mg/kg), cobalt (16 – 443 mg/kg), lead (<0.10 – 194 mg/kg), selenium (<3.0 – 91 mg/kg), titanium (0.29 – 33%) and zirconium (114 – 4 000 mg/kg).

However, significant enrichment does not necessarily imply that the element represents an environmental risk although the enriched element in the tailings may leach into surface water and groundwater depending on site conditions. The risk that these enriched elements present is a function of the environmental mobility of the element, assessed by leach tests.

Acid generating characteristics

The primary process tailings are Non-Acid Forming (NAF). This is consistent with the mineralogy results that showed that there are no detectable sulfide minerals that could potentially generate acidity in the primary process tailings.

SFT are Acid Generating (AG) and have the potential to stay acidic in the long term if exposed to oxidizing conditions. This is consistent with the mineralogy results that indicated the presence of acid generating sulfide minerals, marcasite and pyrite. TT and IT also contain sulfides and are Potentially Acid Generating (PAG). FET and CET are NAF.

Leachate quality

The leachate and supernatant qualities are assessed against:

- Sierra Leone's Environmental Protection (Mines and Minerals) Regulations 2013 (SLEP(M&M) Regs 2013) "limit at any moment" effluent quality for mining and metallurgic operations; and
- Background surface water quality (average concentrations for July, August and October 2017) from surface water monitoring point SW6, located a distance away from the mining activities and representing the least affected surface water monitoring point within Area 1.

The background surface water quality is within the World Health Organisation (WHO) limits and the SLEP (M&M) Regs 2013 are more stringent than the WHO limits except mercury limit [SLEP (M&M) Regs 2013, 0.002 mg/l and WHO, 0.0005 mg/l).

The leachates from primary process tailings are acidic (pH <6.0) and characterised by low salinity (EC < 3.3 mS/m). All the measured parameters in the leachate are within the SLEP(M&M) Regs 2013 "limit at any moment" except pH. The parameters that exceed the background surface water levels in the leachate of the primary process tailings include the following:

- pH (<6.0), conductivity (>0.98 mS/m), aluminium (>0.02 mg/l), copper (>0.007 mg/l), manganese (>0.015 mg/l) and nickel (>0.002 mg/l) and sulfate (>2.3 mg/l); and
- Aluminium (>0.06 mg/l), chloride (>1.7 mg/l) and calcium (>2.0 mg/l), nitrate as N (>0.31 mg/l in Lanti tailings.

The leachates from secondary process tailings are acidic (pH <5.7) and characterised by low salinity (EC < 7.8 mS/m). All the measured parameters in the leachate are within the SLEP(M&M) Regs 2013 "limit at any moment" except pH.

The parameters that exceed the background surface water levels in the leachate from the secondary process tailings include pH (<6.0), Al (>0.06 mg/l), Ca (>2.0 mg/l), Cu (>0.007 mg/l), Mn (>0.015 mg/l), Ni (>0.002 mg/l), SO_4 (>2.3 mg/l) and TDS (>35 mg/l).

The implication of the findings of the geochemistry study are as follows:

- As the primary process tailings are currently slightly acidic to their slsightly acidic soil environment, but inherently NAF and non-saline, the bulk of this material is considered to be geochemically unreactive. Due to the low ASS/ML risk, no special ASS/ML management requirements are recommended except continuation with operational monitoring and testing to detect any unexpected changes that may occur during mining.
- Due to the elevated concentrations of Al, Ca, Cu, Mn, Ni, NO_3 as N and SO_4 in the leachate from the primary process tailings relative to background surface water levels it is recommended that these constituents be included in the site monitoring program.
- The secondary process tailings, specifically SFT, TT and IT, are PAG, acidic and non-saline and are likely to present a risk of increased acidity when exposed to oxidising conditions. These materials should continue to be deposited sub-aqueously as is currently done to limit exposure to oxygen. It is recommended that sufficient depth of water cover over the PAG tailings be ensured to prevent resuspension of tailings by wind or wave action to minimise exposure to potential oxidising conditions.
- The low pH of the tailings supernatant and seepage is likely to present a risk to the already slightly acidic environment and add to the overall acidity of the surface and groundwater system.

- Due to the elevated concentrations of Al, Ca, Cu, Mn, Ni and SO_4 in the leachate from the secondary process tailings relative to background surface water levels it is recommended that these constituents be included in the site monitoring program.

Table of Contents

List of Tables

List of Figures

Disclaimer

The opinions expressed in this Report have been based on the information supplied to SRK Consulting (South Africa) (Pty) Ltd (SRK) by Sierra Rutile Limited (SRL). The opinions in this Report are provided in response to a specific request from SRL to do so. SRK has exercised all due care in reviewing the supplied information. Whilst SRK has compared key supplied data with expected values, the accuracy of the results and conclusions from the review are entirely reliant on the accuracy and completeness of the supplied data. SRK does not accept responsibility for any errors or omissions in the supplied information and does not accept any consequential liability arising from commercial decisions or actions resulting from them. Opinions presented in this report apply to the site conditions and features as they existed at the time of SRK's investigations, and those reasonably foreseeable. These opinions do not necessarily apply to conditions and features that may arise after the date of this Report, about which SRK had no prior knowledge nor had the opportunity to evaluate.

List of Abbreviations

ABA	Acid Base Accounting
AG	Acid Generating
ARD/ML	Acid Rock Drainage and Metal Leaching
ASTM	American Society for Testing and Materials
CET	Coarse Electrostatic Tailings
EC	Electrical Conductivity
EEC	European Economic Commission
EMPs	Environmental Management Plans
EPA-SL	Environmental Protection Agency – Sierra Rutile Licence
ESHIA	Environmental, Social and Health Impact Assessment
ESHMP	Environmental, Social and Health Management Plan
ESHMPs	Environmental, Social and Health Management Plans
ESIA	Environmental and Social Impact Assessment
FET	Fine Electrostatic Tailings
G/T	Green Tank
GAI	Geochemical Abundance Indices
GARD	Global Acid Rock Drainage
GIIP	Good International Industry Practice
HCM	Heavy Mineral Concentrate
IB	Ion Balance
ICP	Inductively Coupled Plasma
IT	Ilmenite Tailings
LOD	Limit of Detection
MSP	Mineral Separation Plant
NAF	Non Acid Forming
NAG	Net Acid Generation
NAG	Net Acid Generation
NNP	Net Neutralisation Potential
NP	Neutralisation Potential
NPR	Neutralisation Potential Ratio
PAG	Potentially Acid Generating
QA/QC	Quality Assurance and Quality Control
RPD	Relative Percent Difference
RPD	Relative Percent Difference
SFT	Sulfide Flotation Tailings
SLEP (M&M) Regs 2013	Sierra Leone's Environmental Protection (Mines and Minerals) Regulations 2013
SRK	SRK Consulting (South Africa) (Pty) Limited
SRL	Sierra Rutile Limited
TT	Total Tailings
WCP	Wet Concentrator Plant
WHO	World Health Organization
XRD	X-Ray Diffraction
XRF	X-ray Fluorescence

1 Introduction

Sierra Rutile Limited (SRL) is an existing mining operation located in the Bonthe and Moyamba Districts of the Southern Province of Sierra Leone. The mine has been in operation for over 50 years and produces rutile, ilmenite and zircon concentrates. The SRL operation has an existing Environmental Licence (reference number EPA-SL030) and has previously undertaken two Environmental and Social Impact Assessment (ESIA) studies for their operations, in 2001 and an update in 2012. When these studies where undertaken, the primary mining process was dredge mining. During 2013, SRL started open cast dry mining operation of the Lanti and Gbeni deposits as an auxiliary method of ore extraction in conjunction with dredge mining. In 2016, SRL commissioned a second dry mining operation at Gangama. SRL anticipates that, over time, dredge mining will cease and dry mining will be the primary mining method employed.

SRL appointed SRK Consulting (South Africa) (Pty) Ltd (SRK) to undertake an Environmental, Social and Health Impact Assessment (ESHIA) for their current and proposed dry and wet mining activities within SRL's current operations in Sierra Rutile Area 1 (SR Area 1). This geochemistry study is part of the ESHIA to include the new dry mining processes and to update the existing ESIA and the associated Environmental Management Plans (EMPs).

The specific objective of the geochemistry assessment is to characterise the tailings generated from Lanti (dredge and dry mining), Gbeni and Gangama dry mining operations (within Area 1) with respect to their Acid Sulfate Soil and Metal Leaching (ASS/ML) potential in accordance with the Sierra Leone's Environmental Protection (Mines and Minerals) Regulations, 2013 (SLEP (M&M) Regs 2013) and Good International Industry Practice (GIIP).

2 Background

2.1 Location

The SRL operation is located in the Moyamba and Bonthe District in the Southern Province of Sierra Leone. The operation is located 30 km inland from the Atlantic Ocean and 135 km southeast of Freetown, Figure 2-1.

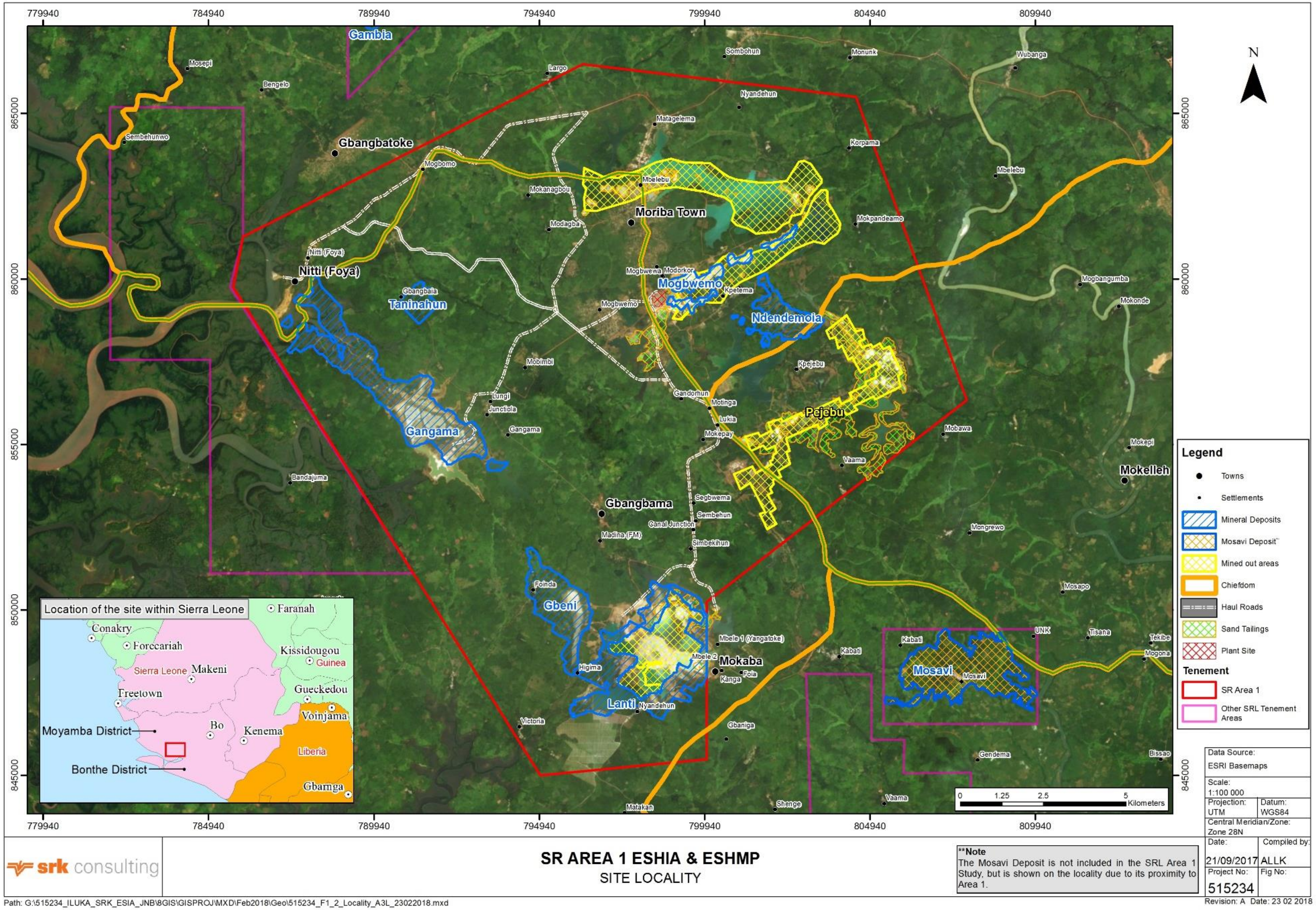


Figure 2-1: Sierra Rutile Area 1 locality map

2.2 Geology

2.2.1 Regional geology

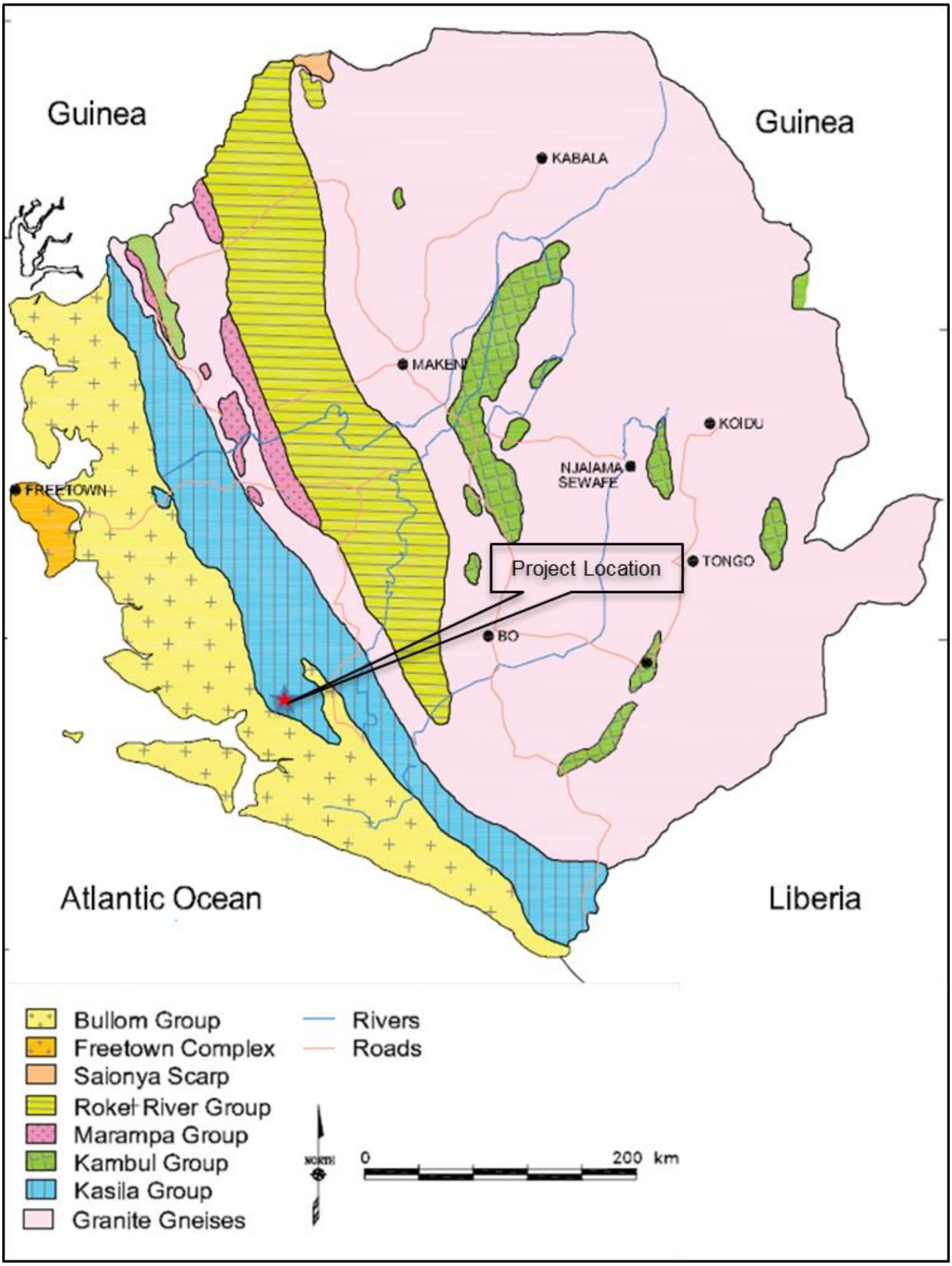
Sierra Leone is located within the central portion of an Archean craton, which was disrupted by the opening of the Atlantic Ocean and is within the eastern tectonostratigraphic units that are part of the Precambrian West African Craton consisting of high-grade metamorphic rocks and granitic gneisses.

The SRL deposits occur in sediments in the Archean Kasila Group (refer to Figure 2-2). Fine to medium-grained basic granulites with minor horizons of quartz magnetite, quartz diopside, and sillimanitic rocks dominate the Kasila Group lithology. Deformed gabbros, anorthosites, and ultramafics intrude the granulites (Warnsloh, 2011).

SRL holds mining leases covering a land area of 559 km^2, with a total of 16 mineral deposits identified. The tailings under investigation in this report are from the mining and processing of Lanti, Gbeni and Gangama deposits (Figure 2-1).

The mineral deposits consist of large alluvial ore bodies formed by the deposition of rutile bearing unconsolidated sediments in valleys. The bulk of the deposits occur in two clusters; the Area 1 deposits (ML011/72), and the Sembehun deposits (ML15/72). The deposits are proximal alluvial placers in origin, infilling north-easterly (and north-westerly) trending channels incised during the imposition of the secondary drainage system.

The Gbangbama group consists of at least six major deposits as does the Sembehun group. The deposits consist of lithologic zones of topsoil, laterite, sand and clay with silty clay sand being the dominant lithology.



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SR AREA 1 ESHIA & ESHMP
REGIONAL GEOLOGICAL MAP

Project No.
515234

Figure 2-2: Regional geology of Sierra Leone (Warnsloh, 2011)

2.2.2 Ore mineralisation

Mechanical and chemical weathering of metamorphic rocks (gneisses and charnockites) resulted in the formation of rutile deposits formed near the Gbangbama and Moyamba Hills, formed by the Kasila Gneiss. The relatively low levels of sorting and the wide grain size distribution of the minerals reflects the short distance of transport from the source to the current location of the deposits.

Surface geology of the study area consists of laterite derived from weathered bedrock exposed in the Gbangbama and Moyamba Hills. The local bedrock is a Precambrian high-grade quartzo-feldspathic-garnet gneiss (charnockite) with accessory rutile, ilmenite, zircon and monazite. Concentrations of these heavy accessory minerals in the laterites and associated clay soils surrounding the hills, constitute the ore bodies exploited by SRL.

The heavy mineral deposits are contained in shallow clayey soils with hard lateritic inclusions, spread over an area of about 150 km^2 in a series of discrete ore bodies of variable thickness and grade. The heavy mineral assemblage comprises of mainly the following minerals:

- Rutile (TiO_2);
- Ilmenite ($FeTiO_3$); and
- Zircon ($ZrSiO_4$).

The minor minerals include the following:

- Monazite (Ce,La,Nd,Th,PO_4);
- Kyanite (Al_2SiO_5);
- Corundum (Al_2O_3); and
- Garnet ($X_3Y_2(SiO_4)_3$). The X site is usually occupied by divalent cations $(Ca, Mg, Fe, Mn)^{2+}$ and the Y site by trivalent cations $(Al, Fe, Cr)^{3+}$.

In addition, conditions in the alluvium have resulted in the localised formation of sulfide minerals, pyrite and marcasite (FeS_2), with the level of sulfur generally increasing with depth.

2.3 Mining

Figure 2-3 presents a simplified depiction of the current SRL mining operations. Rutile occurs in the surface material right down to the bedrock. Two types of mining methods are currently being utilised, namely dredge mining at Lanti and dry mining at Lanti and Gangama.

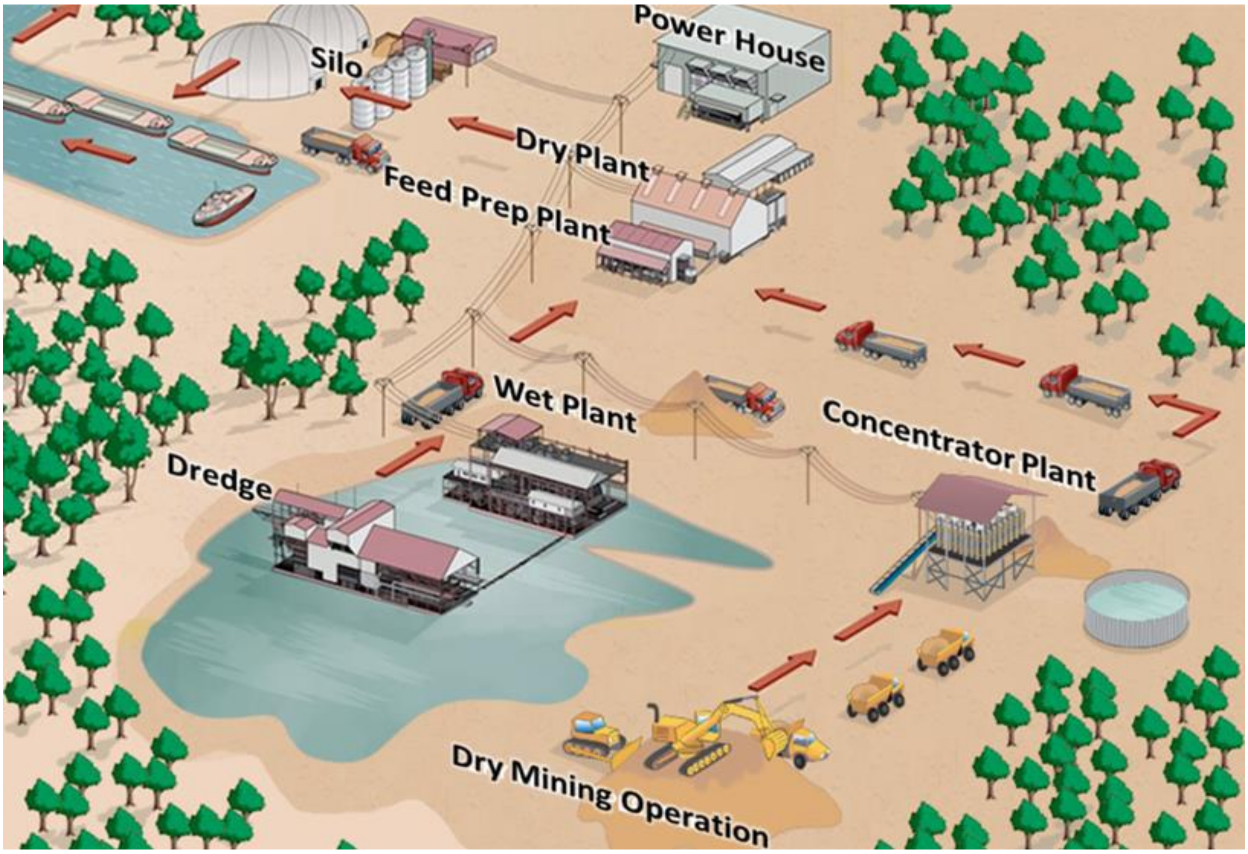

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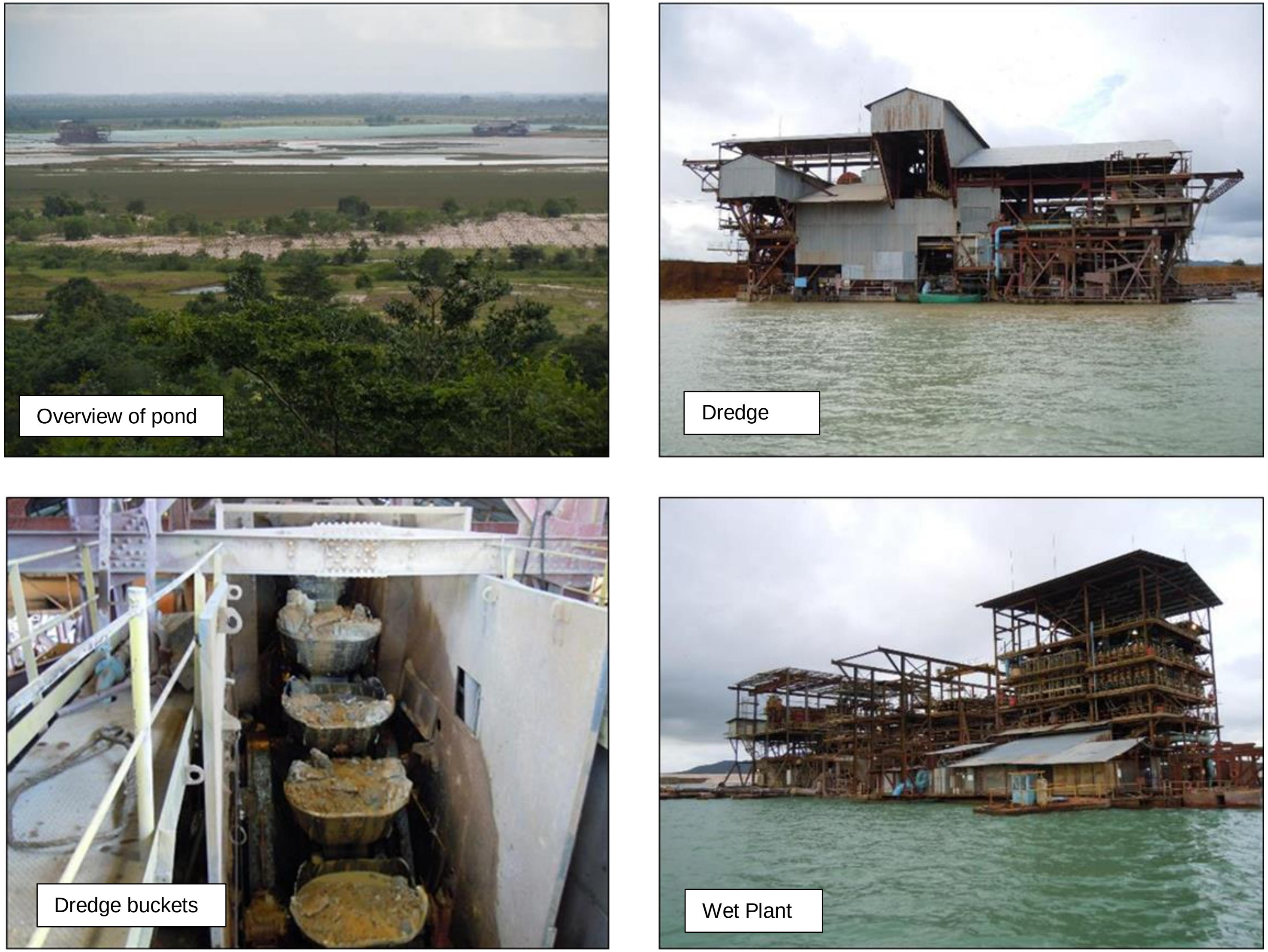
Figure 2-3: Diagram showing current mining operations and processes

2.3.1 Dredge mining – Lanti

Dredge mining involves the removal of vegetation, excavation of the pit and flooding of the open pit with rainwater or water pumped from previous mine sites. The dredge plant excavates using an electric bucket line dredge, which collects and feeds the materials to a floating wet concentrator plant (Figure 2-4).

The dredge scrubs and screens the ore, after which it is pumped to the wet concentrator plant. De-sliming removes clay from the ore. The de-sliming process occurs in two stages. Gravity then separates the heavier minerals from the lighter minerals. The resultant heavy mineral concentrate contains up to 60% recoverable rutile. The concentrate then goes to two separate cyclone towers: one for low sulfur ore and a second one for high sulfur ore.

The slimes (clay materials) is pumped to a containment pond and the sand is pumped to a sand stacking area.


Overview of pond

Dredge

Dredge buckets

Wet Plant

SR AREA 1 ESHIA AND ESHMP
LANTI WET MINING OPERATIONS

Project No.
515234

Figure 2-4: Lanti dredge mining operations

Segregation of sulfide ore

Sulfur mineralization occurs predominantly in the deeper parts of the Lanti deposit. SRL excavates and segregates the sulfide rich ore during concentration. The process involves monitoring of sulfur levels, excavation of the sulfide rich ore under water, separate stockpiling of the ore and prompt delivery of the high sulfide ore to the Mineral Seperation Pant (MSP) for processing. This is for the mining sections of predominantly high sulfur content.

For sections of sporadic high sulfide content, SRL blends the high sulfide content ore with low sulfide content materials.

2.3.2 Dry mining – Lanti, Gbeni and Gangama

A conventional load and haul method delivers ore from Gbeni and Gangama deposits into two beneficiation and Wet Concentrator Plants (WCP), known as the Lanti Plant and the Gangama Plant (Figure 2- 5). Heavy Mineral Concentrate (HMC) is transported to the MSP for further processing.

SR AREA 1 ESHIA AND ESHMP

LANTI AND GANGAMA DRY MINING OPERATIONS

Project No.
515234

Figure 2-5: Lanti (top row) and Gangama (bottom row) dry mining operations

2.4 Processing

Further processing occurs at the MSP. The MSP includes the feed preparation plant (Figure 2-6) and the dry plant.

2.4.1 Feed preparation plant

Trucks transport the HMC from the Lanti dredge, Lanti dry and Gangama plants to the MSP. Here the feed is loaded by front-end loaders onto a conveyor belt from where it is screened, scrubbed, de-slimed and separated using gravity methods.

Hydro-sizers are used to separate coarse and fine materials. The fine fraction is sent to a flotation plant where sulfur is removed by washing and scrubbing with chemicals that include soda ash (sodium bicarbonate - $NaHCO_3$), flotation oil (Almag oil/mineral oil – naphthenic oil and antioxidant), dowfroth 250 (propylene oxide methanol adduct - $C_7H_{16}O_3$) and potassium amyl xanthate ($C_6H_{11}KOS_2$). The resultant rutile rich feed then goes to the dry plant. The sulfur tailings go to the Sulfide Flotation Tailings (SFT) pond.

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SECONDARY PROCESS OPERATIONS | Project No.
515234

Figure 2-6: Mineral separation plant and power plant

2.4.2 Dry plant

The main processes at the dry plant are drying, sizing and electrostatic separation. The electrostatic process deflects non-conductors (zircon and silica) and separates them from conductors (rutile, hematite and ilmenite) in the product stream. The fine and coarse tailings from the electrostatic separation process discharges separately to the Fine Electrostatic Tailings (FET) and Coarse Electrostatic Tailings (CET) ponds (Figure 2-7).

The conductors (rutile, hematite and ilmenite) undergo electromagnetic separation where the non-magnetic rutile separates from the magnetic hematite and ilmenite. Ilmenite Tailings (IT) discharges to the IT pond. The rest of the tailings consisting of a mixture of various streams (slimes, ilmenite etc.), discharge to the Total Tailings (TT) pond (Figure 2-7).

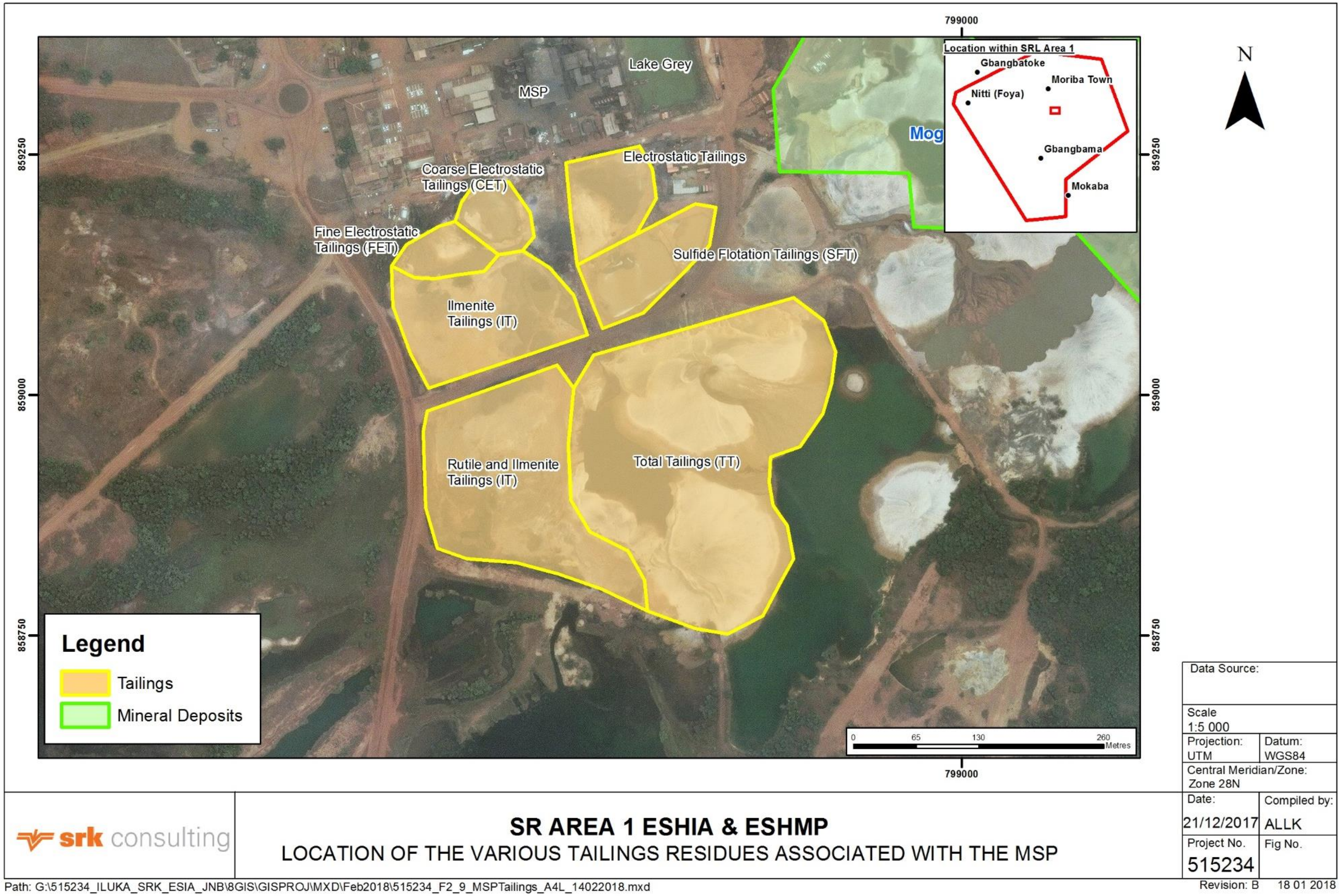

Figure 2-7: Location of the various tailings residues associated with the MSP

2.5 Geochemistry

2.5.1 Sulfur mineralization

The heavy mineral assemblage in the SR Area 1 are chemically resistant to weathering conditions, except the iron-sulfide minerals pyrite and marcasite.

The sulfide minerals are authigenic; they are formed in place, as a result of the interaction of soluble iron made available by organic-rich reducing conditions in the hosting sediments and sulfide produced from sulfate derived from sea water.

The typical geochemical changes in sulfur include the following:

a. Sulfate reducing bacteria reduces soluble sulfates from seawater in the presence of organic matter:

$SO_4 \rightarrow S$……………………………………….… (1)

b. Iron is in a redused form due to the organic-rich reducing conditions in the hosting sediments. With time and available iron and sulfur, iron sulfide recrystallizes to pyrite:

$FeS + S \rightarrow FeS_2$…………………………………… (2)

c. With drainage and aeration, pyrite oxidises and yields sulfuric acid, which causes acidity up to pH 2.0 or even higher:

$FeS_2 + 3.75O_2 + 3.5H_2O \rightarrow Fe(OH)_3 + 2SO_4^{2-} + 4H^+$….(3)

Reactions (a) and (b) occur at neutral to alkaline conditions under a waterlogged reducing environment, while reaction (c) requires oxidising conditions.

These reactions and conditions in the alluvium have resulted in the formation of sulfide minerals, pyrite and marcasite within the sediments, with the level of sulfur in the deposits typically increasing with depth.

2.5.2 Tailings characterization

Knight Piesold previously characterized the tailings (2001 and 2006) (Knight Piesold, March 10, 2008). The key findings of the two studies can be summarised as follows:

- The dredge spoils and dredge tailings are generally unreactive as they are composed primarily of minerals that are chemically resistant to weathering. The minerals are non-acid generating and therefore have a low propensity to leach salts or metals;
- The CET, FET, IT and TT classified as potentially non-acid generating and generally contained low sulfide sulfur and neutralising minerals;
- SFT classified as potentially acid producing and contained marcasite (FeS_2);
- The tailings supernatants were generally acidic (pH 3.3 - 4.9) except for the total tailings supernatant that was circum-neutral (pH 6.5);
- The tailings were characterised by low conductivity (< 10 mS/m) except SFT (60 mS/m);
- Comparison of the leachate or supernatant quality against World Health Organisation (WHO) guidelines indicated that Al, Mn, Ni, Cd and U exceeded the guideline limits.

2.5.3 Radioactivity

Radioactivity of the heavy mineral assemblages is outside the scope of work of this study.

2.5.4 Soils

In general, the soils are characterised as moderately acidic at pH 5.4, a base status ranging from 0.7 me% to 7 me% (dystrophic to mesotrophic), and nutrient levels reflecting generally low levels of all nutrients and moderate levels of organic matter.

The soils are characterised by:

- acidic pH, with a moderately narrow range between 4.9 and 6.3, average of 5.4;
- low reserves of potassium, calcium, magnesium and phosphate;
- moderate to average reserves of sodium;
- elevated iron;
- low clay contents (4% to 12%) associated with the deep sandy loams, and at best moderate clay contents for the in-situ derived materials (8% to 16%); and
- moderate organic carbon (0.7% – 1.5%) (Earth Science Solutions, September 2017).

2.6 Reporting Standards

2.6.1 Quality control

The determination of quality assurance and quality control (QA/QC) parameters in the analytical data comprised, primarily, of the following:

- Precision was assessed by comparing split samples using relative per cent difference (RPD). RPD is the absolute difference between two duplicate measurements divided by the mean, and multiplied by 100. RPD for elements less than the detection limits are excluded. The precision is considered acceptable if the RPD is within ± 15%; and
- Calculation of ion charge balances for solutions. A fundamental property of aqueous solutions is that they are electrically neutral, so the equivalents of cations analysed in the solution should balance the analysed anions. The charge balance error was calculated (considering major anions and cations) using Equation 1.

Equation 1: $$\text{Charge Balance Error} = \frac{(\sum \text{cations} - \sum \text{anions})}{(\sum \text{cations} + \sum \text{anions})} \times 100\%$$

$$\text{where} \sum \text{cations and} \sum \text{anions are expresed in meq/l}$$

The following criteria was applied when deciding whether to accept or disregard analytical data (Wąsik, et.al, 2005):

- RPD is within ± 15%; and
- Charge balance of aqueous samples was to fall within errors of 10%. This is a deviation from standard practice where the error should fall within 5%. The deviation from standard practice is because most of the aqueous samples are acid waters in which H^+ is the major cation but cannot be introduced directly into the charge balance from the pH measurements for two reasons. One is that the activity coefficient for H^+ must be used to convert pH to H^+ equivalents and secondly, sulfate, being the dominant anion, is partially converted to HSO_4^- in acid waters, which diminishes the equivalents of SO_4^{2-}. Hence to achieve a proper charge balance, the analysis would need to be speciated first (Nordstrom, McCleskey, & Ball, 2010).

2.6.2 Elemental enrichment

One measure of enrichment of elements in samples is the Geochemical Abundance Index (GAI). The GAI compares the actual concentration of an element in a sample with the median abundance for that element in the most relevant media (such as crustal abundance, soils, or a particular rock type). The main purpose of the GAI is to provide an indication of any elemental enrichments that may be of environmental importance.

The GAI for an element is calculated as follows:

Equation 2: $\mathbf{GAI} = \mathbf{Log2}\ [\mathbf{Cn}\ /\ (\mathbf{1.5} \times \mathbf{Bn})$

Where Cn is the concentration of the element in the sample and Bn is the median or average content for that element in the reference material (mean world soil, crustal abundance, etc.).

GAI values are truncated to integer increments (0 through to 6, respectively) where a GAI of 0 indicates the element is present at a concentration similar to, or less than, median abundance and a GAI of 6 indicates approximately a 100-fold, or greater, enrichment above median abundance. The actual enrichment ranges for the GAI values are as follows:

- GAI=0 represents <3 times median abundance;
- GAI=1 represents 3 to 6 times median abundance;
- GAI=2 represents 6 to 12 times median abundance;
- GAI=3 represents 12 to 24 times median abundance;
- GAI=4 represents 24 to 48 times median abundance;
- GAI=5 represents 48 to 96 times median abundance; and
- GAI=6 represents more than 96 times median abundance.

As a general guide, a GAI of 3 or above is considered significant and such enrichment may warrant further examination (GARD Guide, 2009).

2.6.3 Acid generating characteristics

SRK's assessment of ASS/ML adopts the following guidelines that have gained regulatory acceptance in various jurisdictions around the world:

- Guidelines and Recommended Methods for the Prediction of Metal Leaching and Acid Rock Drainage at Mine Sites in British Columbia (Price, 1997);
- Prediction Manual for Drainage Chemistry from Sulfidic Geologic Materials (MEND, 2009); and
- Global Acid Rock Drainage (GARD) Guide (INAP, 2009).

SRK adopted the above international guidelines in the absence of ASS/ML guidelines in the SLEP (M&M) Regs 2013.

The international guidelines emphasis is that there is no minimum concentration of sulfide responsible for acid generation. The guidelines base the assessment of ASS/ML on Neutralisation Potential Ratio (NPR) and Net Neutralisation Potential (NNP) criteria as detailed below:

- NPR < 1: Likely acid generating, unless sulfide minerals are non-reactive;
- 1 < NPR < 2: Possibly acid generating if Neutralisation Potential (NP) is insufficiently reactive or is depleted at a rate faster than sulfide;

- NPR > 2: Non Acid Forming (NAF) unless significant preferential exposure of sulfide along fractures planes or extremely reactive sulfide in combination with insufficiently reactive NP;
- NNP less than -20 kg $CaCO_3$/tonne is PAG; and
- A sample is considered PAG if NAG pH is <4.5 and NAF if pH is >4.5.

2.6.4 Effluent quality

The Sierra Leone’s Environmental Protection (Mines and Minerals) Regulations 2013 (SLEP (M&M) Regs 2013) requires that SRL assess the seepage water quality against the background groundwater quality. Where the natural quality of water used in mining activities already exceeds the effluent standards established by the Regulations, the Regulations require SRL to assess the effluent discharges from such operations against the water taken from its natural source. SRK has therefore adopted background surface water quality as a qualitative screening tool to identify constituents of potential concern. The background surface water quality is from surface water monitoring point SW6, located a distance away from the mining activities and representing the least affected surface water monitoring point within Area 1, Figure 2-8.

The Regulations also stipulate effluent quality for mining and metallurgic operations, presented in Table 2-1 that can be applied in the absence of background water quality. The background surface water quality data is supplemented with the stipulated effluent quality for mining and metallurgy.

The discharge quality shall not exceed the value established in the column ‘limit at any moment’. Annual concentration for each parameter shall not exceed the values established in the column ‘annual average limit’.

Table 2-1: Effluent Standards for mining and metallurgic operations, SLEP (M&M) Regs 2013

Parameter	Units	Limit at any Moment	Annual Average Limit
pH	s.u	6 - 9	6 - 9
TSS	mg/l	50	25
Oils and grease	mg/l	20	16
Total cyanide	mg/l	1.0	0.8
Total arsenic	mg/l	0.1	0.08
Hexavalent chrome*	mg/l	0.1	0.08
Total copper	mg/l	0.6	0.4
Iron (dissolved)	mg/l	2.0	1.6
Total lead	mg/l	0.2	0.16
Total mercury	mg/l	0.002	0.0016
Total zinc	mg/l	1.5	1.2

Note: *Unfiltered sample.

2.7 Work program

To address the study objectives (Section 1), the scope of the study included:

- Sampling – collection of tailings samples and associated water samples;
- Laboratory analysis of the tailings and water samples;
- Data analysis and interpretation; and
- Reporting.

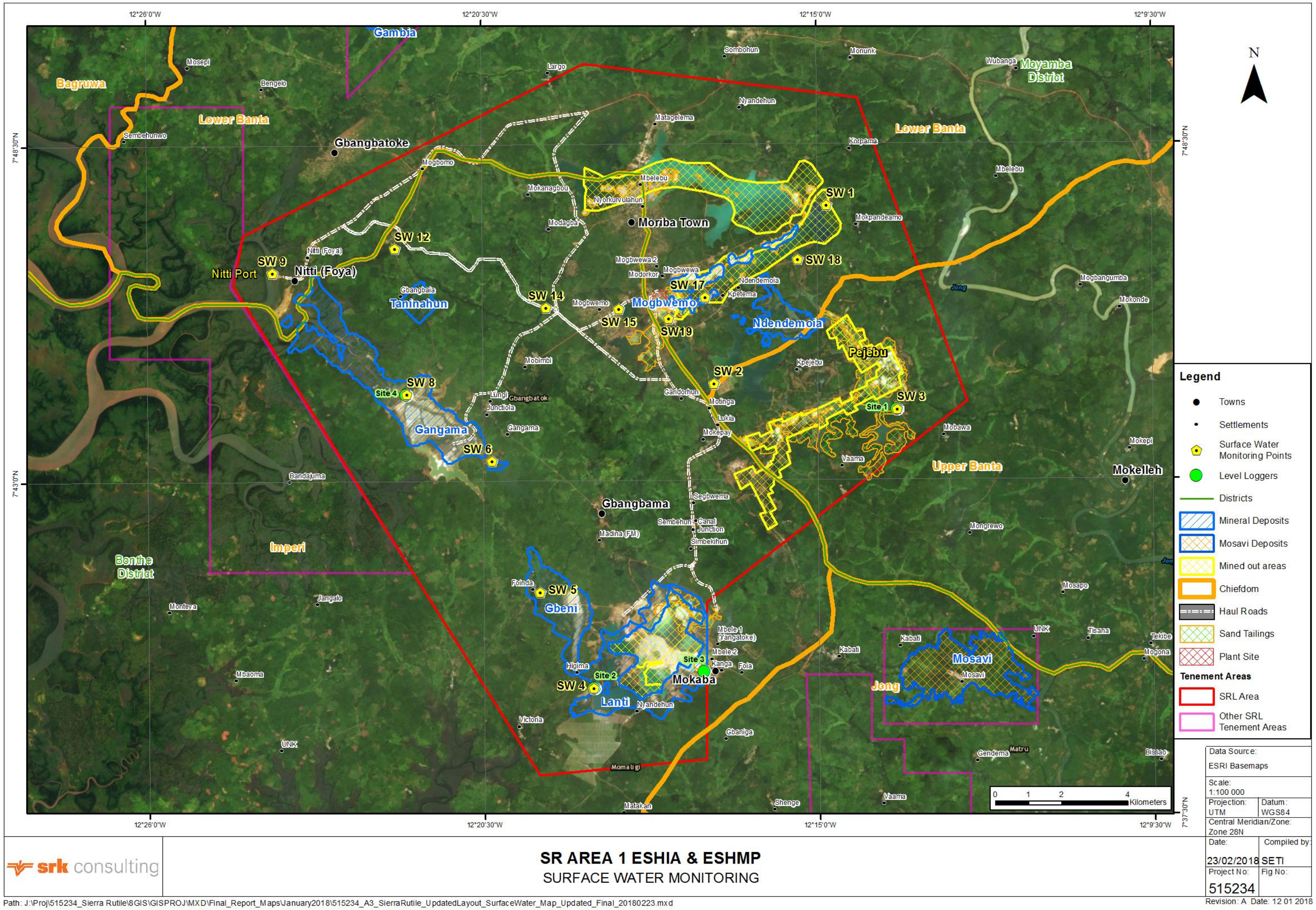

Figure 2-8: Surface water monitoring points

3 Geochemical test work

3.1 Sampling

SRK undertook the sampling of the tailings from 18 June 2017 to 23 June 2017 during the wet season (May – October). The mine site has an average annual rainfall of approximately 2 600 mm and a mean monthly temperature range of 25º to 28º C with a relative humidity of 90%. The average potential evaporation rate at that time of the year (July – August) was 230 mm.

Knight Piesold collected 7 samples from the Chemical Tailings Pond, Lanti North, Mogbwemo Sand Dredge Tailings and Total Tailings in 2001 when the mine was not operational. Knight Piesold further collected 5 samples in 2006, one from each of the current secondary process tailings. SRK has undertaken a more comprehensive and focused sampling for better representability of the various waste streams generated on site now and to clarify the results obtained by Knight Piesold.

SRK's sampling focussed on Area 1 (Gangama and Lanti) tailings that include primary process tailings and secondary process tailings. The primary process tailings are the tailings generated during the primary preparation (feed preparation and concentrator) at the two mining areas before the concentrates go for secondary processing at the MSP. The secondary process tailings are the tailings generated at the MSP following feed preparation and mineral separation.

3.1.1 Primary process tailings

Ten (10) primary process tailings samples were collected; 3 from Gangama dry mining, 4 from Lanti dry mining and 3 from Lanti dredge mining. Table 3-1 details the description of the primary process tailings collected.

The following observations were made during sampling:

- The pH of the tailings supernatant or field shake flask leach are slightly acidic as detailed below:
    - Gangama fine tailings (n=2) – pH 5.0 – 6.2;
    - Gangama coarse tailings (n=1) – pH 5.9;
    - Lanti dry mining coarse tailings (n= 4) – pH 4.9 – 5.6; and
    - Lanti dredge mining tailings (n=1) – pH 5.1.
- Composite samples of Lanti wet (LWPTC) and dry tailings (LDWTC) was obtained from the SRL laboratory. LWPTC is a composite of 12 Lanti dredge-mining tailings collected monthly in 2016. LDMTC is a composite of 12 Lanti dry mining tailings collected monthly in 2016. These tailings represent the general tailings quality of the 2016 tailings composites. SRL collects the samples at distinct sampling points and keeps records of sample dates and times.

Table 3-1: Primary process tailings samples collected from Gangama and Lanti mining operations

Source	Sample Name	Date Sampled	Time Sampled	Description	S:L Ratio	Temp (^{0}C)	pH (s.u)	EC (mS/m)
Gangama Dry Mining	GPTF	19/06/2017	1:32 to 2:15 PM	Gangama Plant Tailings Fines (Wet)	Supernatant	27	5.0	1.7
	GPFT (Dry)			Gangama Plant Fine Tailings (Dry)	1:3	23.9	6.2	0.4
	GCT (Moist)			Gangama Coarse Tailings (Moist)	1:3	24.5	5.9	0.6
Lanti Dry Mining	LCT (DM)		2:35 to 3:15 PM	Lanti Coarse Tailings (Dry Mining)	1:3	23.9	5.6	0.8
	LCT (DM 02)			Lanti Coarse Tailings (Dry Mining 02)	1:3	24	5.4	0.8
	LCT (DM 03)			Lanti Coarse Tailings (Dry Mining 03)	1:2	23.9	5.6	0.7
	LDMTC			Lanti Dry Mine Tailings Composite from the Lab	-	-	-	-
	LFT (DM)		03:15 to 03:20 PM	Lanti Fine Tailings (Dry Mining)	Supernatant	27	4.9	2.0
Lanti Dredge Mining	LWPT	23/06/2017	12:30 PM	Lanti Wet Plant Tailings (from ore of high sulfur content)	-	29	5.1	2.1
	LWPTC			Lanti Wet Plant Tailings Composite from the Lab	-	-	-	-

Note: S:L Ratio – solid to liquid ratio

3.1.2 Secondary process tailings

Sixteen (16) secondary process tailings were collected from the deposits located next to the MSP. Table 3-2 details the description of the samples.

The following observations were made during sampling:

- The slurry samples consist of 20% solids;
- TT are a blend of different streams, e.g. slimes, silica, ilmenite, etc., produced from the spiral process. The content of TT may vary over time in proportion and content, and therefore a composite sample was collected from the residue deposit;
- IT are produced from the electromagnetic separation process.
- SFT are produced from the fine and coarse sulfide flotation circuits. SRL deposits these tailings sub-aqueously to minimise oxidation of sulfides;
- FET and CET are produced during the electrostatic separation process; and
- The pH of the tailings supernatant or field shake flask leachates range from acidic to slightly acidic for the various secondary process tailings streams as detailed below:
    - TT (n=3) from pH 4.3 – 5.2;
    - IT (n=3) from pH 4.6 – 5.3;
    - SFT (n= 3) from pH 2.9 – 5.7;
    - FET (n=3) from pH 4.7- 4.9; and
    - CET (n=4) from pH 4.6 – 6.8.

Table 3-2: Secondary process tailings samples collected from the tailings ponds adjacent to the MSP

Sampling date	19/06/2017						
Source	**Sample Name**	**Time**	**Description**	**S:L Ratio**	**Temp (^{0}C)**	**pH (s.u)**	**EC (mS/m)**
Total Tailings (TT)							
Point of deposition into the Total Tailings Pond - fresh slurry	TT(F)02	10:15 AM	Total tailings (fresh) slurry	Supernatant	29.8	5.2	3.1
	TT(F)01	10:25 AM		Supernatant	29.9	4.7	4.0
Total Tailings Pond	TT (Moist)	10:30 AM	Total tailings (moist)	Supernatant	24.3	4.3	9.3
Ilmenite Tailings (IT)							
Point of deposition into the Ilmenite Tailings Pond - fresh slurry	IT(F)01	10:00 AM	Ilmenite tailings (fresh) slurry	Supernatant	29.9	5.0	2.9
	IT(F)02	10:05 AM		Supernatant	30.0	4.6	3.7
Ilmenite Tailings Pond	IT (Dry)	10:35 AM	Ilmenite tailings (dry)	1:6	24.6	5.3	1.5
Sulfide Flotation Tailings (SFT)							
Point of deposition into the Sulfide Flotation Tailings Pond - fresh slurry	SFT01	09:45 AM	Sulfide flotation tailings (fresh) slurry	Supernatant	30.7	5.7	5.2
	SFT02	09:50 AM		Supernatant	30.7	5.7	5.7
SulfideFlotation Tailings Pond	SFT (Moist)	10:40 AM	Sulfide flotation tailings (Moist)	1:4	24.1	2.9	115
Fine Electrostatic Tailings (FET)							
Point of deposition into the Fine Electrostatic Tailings Pond - fresh slurry	FET(F)02	09:30 AM	Fine electrostatic tailings (fresh) slurry	Supernatant	31.0	4.8	3.3
	FET(F)01	09:35 AM		Supernatant	31.3	4.7	3.3
Fine Electrostatic Tailings Pond	FET (WET)	10:40 AM	Fine electrostatic tailings (wet)	Supernatant	24.1	4.9	3.3
Coarse Electrostatic Tailings (CET)							
Point of deposition into the Fine Electrostatic Tailings Pond - fresh slurry	CET(F)02	09:10 AM	Coarse electrostatic tailings (fresh) slurry	Supernatant	30.7	4.6	3.4
	CET(F)01	09:15 AM		Supernatant	30.9	4.6	3.4
Coarse Electrostatic Tailings Pond	CET (OLD)	10:50 AM	Coarse electrostatic tailings (Old material)	1:3	24	6.8	0.6
	CET (WET)	11:15 AM	Coarse electrostatic tailings (fresher wet material)	1:6	23.8	5.7	0.8
Total	**16**						

Note: S:L – solid to liquid ratio

3.1.3 Water samples

Table 3-3 presents a summary of the water samples collected from around the MSP. Four (4) water samples were collect; 2 from Lake Grey that supplies water to the MSP process water tank and 2 from the Green Tank (G/T) that stores water from Mogbwemo Dredge pond.

Figure 3-1 shows the locations of the tailings ponds and surface water flow. The MSP is situated on a higher ground relative to the secondary process tailings ponds. Effluent water from the MSP discharges into the secondary process tailings pond. Overflow from the secondary process tailings ponds flow down gradient into Mogbwemo Dredge pond. Mogbwemo Dredge pond overflows into Pejebu Dredge pond and subsequently into Tikote Stream further down gradient of the ponds.

While Lake Gray water represents the water quality before MSP, Mogbweni Dredge pond water represents the water quality after the MSP/tailing ponds area.

Table 3-3: Water samples collected from the MSP

Sampling date	Sample Name	Corresponding Surface Water Monitoring Point (Figure 2-9)	Temp (ºC)	pH (s.u)	EC (mS/m)
16/06/2017	G/T O/F (G/TANK/OF/OW)	SW19	31.1	5.3	2.7
	Lake Grey	-	31.4	4.8	5.6

3.2 Laboratory analysis

Table 3-4 details the laboratory analysis of the samples undertaken by M&L Laboratory Services (Pty) Ltd in Johannesburg, South Africa. The analytical suite included the following test work:

- Total elemental analysis – whole rock major element analysis by X-ray fluorescence (XRF) and multi-element trace analysis by Inductively Coupled Plasma Mass Spectrometry (ICP-MS) after acid digestion;
- Contact leach test (ASTM[1] D3987) and analysis of the leachate for metals, metalloids and anions – 1:4 solid to liquid ratio deionised water contact leach test;
- Water and supernatant analysis for metals, metalloids and anions;
- Acid Base Accounting (ABA) tests including sulfur speciation (total sulfur, sulfate sulfur, organic sulfur and sulfide sulfur) and carbon speciation (total carbon and inorganic carbon);
- Non-Acid Generation (NAG) test with filtration prior to back titration and leachate analysis – where a strong oxidising agent (hydrogen peroxide) is used to assess whether a sample is capable of neutralizing the potential acidity on complete oxidation of sulfides in the sample and analysis of the leachate; and
- Mineralogical analysis – XRD to determine the mineral constituents of the samples.

Initial analysis of the all tailings samples involved total element chemistry, ABA and sulfur speciation. Sub-sets of the samples were composited for mineralogy and leach testing. Contact leachate tests were conducted only on the solid samples. The leachates and supernatants from slurry samples were analysed for metals, metalloids and anions.

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[1] American Society for Testing and Materials.

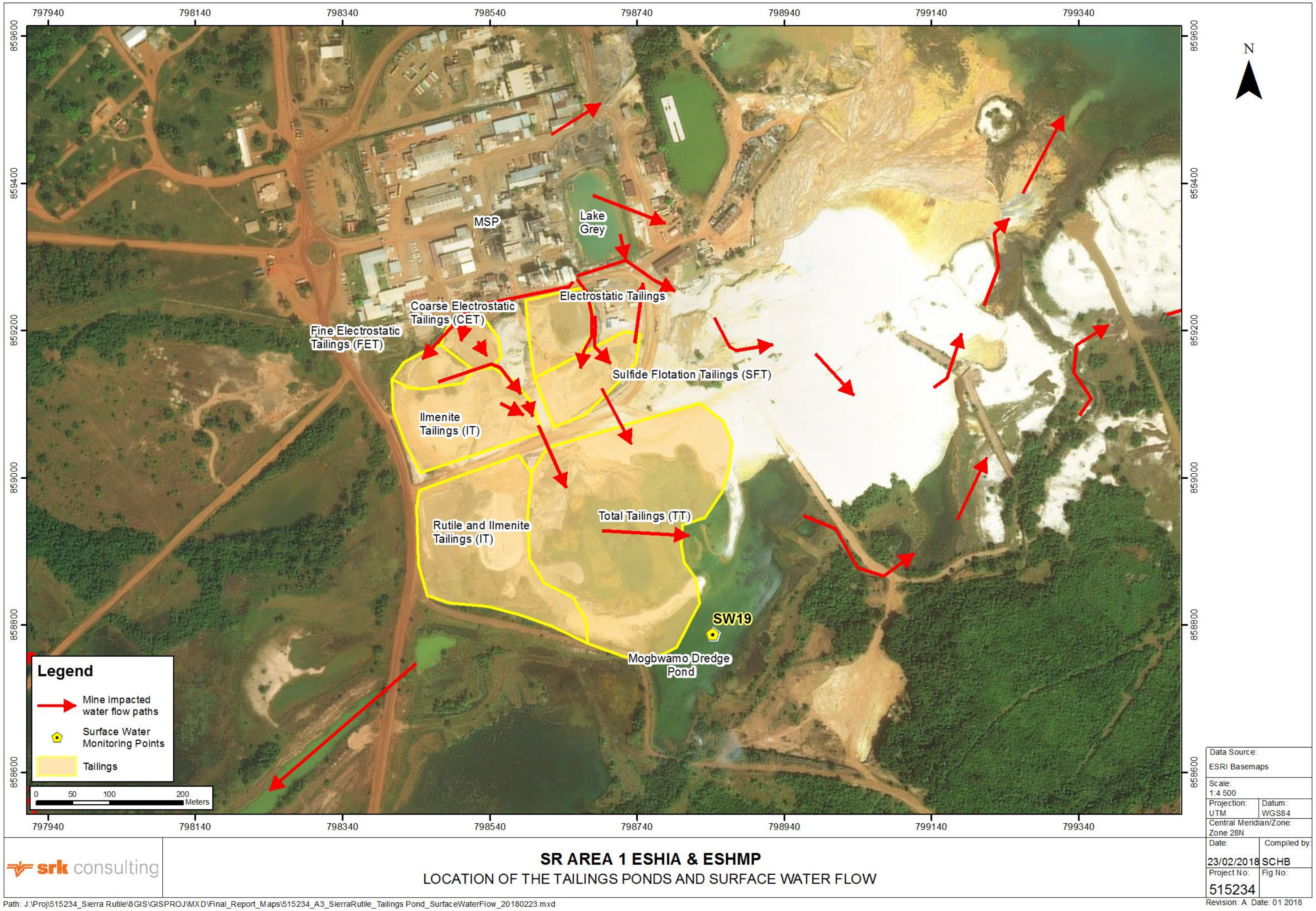


Figure 3-1: Location of the tailings ponds and surface water flow

Table 3-4: Geochemical test work undertaken on the tailings and water samples

Samples	ABA (S- and C-speciation)	Total Metals analysis	XRD	NAG Test	Contact leachate analysis	Water analysis
Solid						
1. CET (OLD)	1	1	1	1	1	
2. CET (WET)	1	1	1	1	1	
3. TT (Moist)	1	1	1	1	1	
4. FET (WET)	1	1				
5. IT (Dry)	1	1	1	1	1	
6. SFT (Moist)	1	1	1	1	1	
7. GCT (Moist)	1	1	1	1	1	
8. GPTF (Dry)	1	1	1	1	1	
9. LWPTC	1	1	1	1	1	
10. LDMTC	1	1	1	1	1	
11. LFT (DM)	1	1	1	1	1	
12. LCT (DM)	1	1	1	1	1	
13. LCT (DM02)	1	1				
14. LCT (DM03)	1	1				
Sub -Total	**14**	**14**	**11**	**11**	**11**	
Slurry						
1. TT(F)02	1	1	1	1		1
2. TT(F)01	1	1				
3. IT(F)01	1	1	1	1		1
4. IT(F)02	1	1				
5. SFT01	1	1	1	1		1
6. SFT02	1	1				
7. FET(F)02	1	1	1	1		1
8. FET(F)01	1	1				
9. CET(F)02	1	1	1	1		1
10. CET(F)01	1	1				
11. GPTF	1	1				
12. LWPT	1	1	1	1		1
Sub -Total	**12**	**12**	**6**	**6**	**0**	**6**
Liquid						
1. G/T O/F						1
2. G/TANK/OF/OW						
3. LAKE GRAY						1
4. LAKE GRAY						
Sub-Total						**2**
Sub -Total	**26**	**26**	**17**	**17**	**11**	**8**
Duplicates (10%)	**2**	**3**			**1**	**1**
Total	**28**	**29**	**17**	**17**	**12**	**9**

4 Data analysis and interpretation

This section presents a summary of the geochemical characterization results, as well as data analysis and interpretation. Appendix A contains detailed laboratory certificates of analyses.

4.1 Quality assessment and quality control

The quality of analytical data from the laboratory was assessed as follows:

4.1.1 Precision

Precision is defined as the agreement between duplicate results, and was assessed by comparing split samples. Three split samples were submitted for total elemental analysis, 2 for water analysis (supernatant and 25% aqueous extract) and 2 for sulfur speciation. RPD was used to assess precision calculated as the absolute difference between two duplicate measurements divided by the mean, and multiplied by 100. RPD for elements less than the detection limits are not calculated. Acceptable precision was defined as 15%. The results of the assessment are presented in Table 4-1, Table 4-2 and Table 4-3. RPD % values exceeding 15% are highlighted yellow.

The precision for total elemental analysis and water analysis are all less than 15% for the duplicates indicating good repeatability of the analysis and therefore acceptable for all the parameters analysed.

The precision for sulfur speciation is acceptable except for total sulfur. The concentration of total sulfur in this case is very close to the detection limit with a 0.01 difference resulting in a RPD value of more than 15%.

4.1.2 Ion balance

Ions balance was calculated for water samples, tailings supernatant and 25% leachate extracts. Aqueous solutions are electrically neutral, so the equivalents of cations analysed in the solution should balance the analysed anions.

The standard practice is that the imbalance should fall within errors of 5%. The 5% was adjusted to 10% for this study. The deviation from standard practice is because most of the aqueous samples analysed in this study are acid waters in which H^+ is the major cation but cannot be introduced directly into the charge balance from the pH measurements for the following reasons:

- The activity coefficient for H^+ must be used to convert pH to H^+ equivalents; and
- Sulfate, being the dominant anion, is partially converted to HSO_4^- in acid waters, which diminishes the equivalents of SO_4^{2-}.

Hence to achieve a proper charge balance, the analysis would need to be speciated first (Nordstrom, McCleskey, & Ball, 2010).

The results of ion imbalance are presented in Appendix A in the laboratory certificate of analysis and in the summary tables presented in Section 4.5 of this report. In summary, the charge imbalances are within the 10% error indicating acceptable data quality for water analysis.

Table 4-1: RPD for laboratory duplicates for total elemental composition

Total Metal/Metalloids Concentrations									
Element	CET(OLD)			LCT(DM02)			LWPT		
	Sample	DUP	RPD (%)	Sample	DUP	RPD (%)	Sample	DUP	RPD (%)
Ag	5.2	4.8	8.0	<0.40	<0.40	-	0.81	0.71	13
Al	41 570	38 980	6.4	0.11	0.095	11	7 953	8 037	1.1
B	783	678	14	591	589	0.34	240	236	1.7
Ba	0.73	0.73	0	35	36	2.8	6.6	6.5	1.5
Ca	6 252	6 594	5.3	267	252	5.8	175	166	5.3
Cd	0.20	0.20	0	0.79	0.80	1.3	1.4	1.4	0
Co	46	46	0	11	11	0.93	3.7	3.8	2.7
Cr	374	382	2.1	273	272	0.37	27	27	0
Cu	<0.20	<0.20	-	1.1	1.0	13	5.4	4.8	12
Fe	17.1%	17.3%	1.2	14.4%	14.3%	0.56	7 284	7 355	1.0
K	78	82	5.0	643	636	1.1	191	207	8.0
Mg	4 096	4 136	1.0	198	208	4.9	68	69	1.5
Mn	1 743	1 568	11	40	41	2.5	26	26	0
Mo	<0.10	<0.10	-	1.4	1.6	13	1.0	0.9	5.2
Na	243	238	2.1	621	611	1.6	390	407	4.3
Ni	9.3	9.4	1.1	22	22	0	9.0	9.0	0
P	3 856	4 411	13	338	333	1.5	53	53	0
Pb	167	145	14	22	23	4.4	22	22	0
Se	<3.0	<3.0	-	41	37	10	26	28	7.4
Sn	5.4	4.8	12	<2.0	<2.0	-	<2.0	<2.0	-
Sr	<0.10	<0.10	-	17	17	0	3.1	3.2	3.2
Ti	2 922	3 055	4.5	3 094	3 101	0.23	827	849	3
V	185	191	3.2	235	235	0	19	19	0
Zn	152	155	2.0	19	19	3.2	4.7	4.2	11
Zr	1 034	1 099	6.1	79	77	2.6	57	59	3.4

Note: DUP - Duplicate

Table 4-2: RPD for laboratory duplicates for water analysis

Parameters (All units in mg/l unless stated otherwise)	Supernatant			25% aqueous extract		
	SFT01 & SFT02			CET (OLD)		
	Sample	DUP	RPD (%)	Sample	DUP	RPD (%)
*pH Value @ 23°C	3.3	3.3	0	6.8	6.8	0
Conductivity mS/m @ 25°C	7.8	7.1	9.4	3.0	3.0	0
Total Dissolved Solids	52	47	10	18	20	11
Calcium, Ca	1.4	1.4	0	0.9	0.9	0
Magnesium, Mg	0.5	0.5	0	0.6	0.6	0
Sodium, Na	8.9	8.4	5.8	2.9	3.0	3.4
Potassium, K	1.5	1.3	14	0.9	0.8	12
Acidity as H^+	0.8	0.8	0	-	-	-
Total Alkalinity as $CaCO_3$	-	-	-	10	9.0	11
Bicarbonate, HCO_3	-	-	-	10	9.0	11
Chloride, Cl	0.7	0.6	15	1.1	1.2	8.7
Sulfate, SO_4	38	34	11	1.1	1.2	8.7
Fluoride, F	0.3	0.3	0	0.1	0.1	0
Aluminium, Al	0.87	0.76	13	-	-	-
Barium, Ba	0.02	0.02	0	-	-	-
Cobalt, Co	0.02	0.018	11	-	-	-
Copper, Cu	0.043	0.038	12	-	-	-
Iron, Fe	0.90	0.78	14	-	-	-
Manganese, Mn	0.22	0.20	9.5	-	-	-
Phosphorus, P	0.07	0.08	13	-	-	-
Strontium, Sr	0.008	0.007	13	-	-	-

Note: * Because the pH is a log-scale, the RPD for pH was calculated using [H] concentration, DUP – Duplicate.

Table 4-3: RPD for laboratory duplicates for paste pH and sulfur speciation

Parameters	FET (WET)			LDMTC		
	Sample	DUP	RPD (%)	Sample	DUP	RPD (%)
*Paste pH @25°C (s.u)	3.34	3.3	1.2	5.56	5.6	0.7
Total Sulfur (%)	0.01	0.01	0	0.03	0.02	40
Sulfide Sulfur (%)	0.01	0.01	0	0.02	0.02	0.0

Note: * Because the pH is a log-scale, the RPD for pH was calculated using [H] concentration, DUP - Duplicate

4.2 Mineralogical composition

The samples were analysed using a PANalytical X'Pert Pro powder diffractometer in θ – θ configuration with an X'Celerator detector and variable divergence and receiving slits with Fe filtered Co-Kα radiation (λ = 1.789À). X'Pert Highscore Plus software was used to identify the mineral phases. Rietveld method (Autoquan Program) estimated the relative phase amounts in percentage weight. Table 4-4 and Table 4-5 presents summaries of the mineralogical composition results for primary and secondary process tailings respectively. The sum of the percentages of the mineral phases in all the samples is 100%.

4.2.1 Primary process tailings

Mineralogical analysis of the primary process tailings indicate that:

- Primary process tailings are dominated by quartz (n=8, 83-99%);
- Kaolinite occur in the tailings (n=8, 1 - 15%);
- Gibbsite occurs in Gangama dry mining tailings (n=2, 1.1-1.5%) and in 1 (LDMTC) of the 3 Lanti dry mining tailings (1%);
- Gibbsite occurs in sample LDMTC but does not occur in the fresh tailings samples from either Lanti dry mining or Lanti wet mining. Sample LDMTC is a composite of 12 Lanti dry mining tailings collected monthly in 2016 obtained from SRL laboratory. This indicates that gibbsite precipitates out as a secondary mineral in the tailings. The precipitation of gibbsite was confirmed by PHREEQC check using 25% water extract data at a paste pH of 5.6; and
- Sample LWPTC contains quartz (99%) and kaolinite (1%) and no detectable quantities of sulfide minerals. This sample is a composite of 12 Lanti dredge mining tailings collected monthly in 2016 obtained from SRL laboratory and therefore accounts to some extent for geological variability in the primary process tailings from high sulfide ore.

In summary, the primary process tailings consists of predominantly inert or resistant quartz that does not contribute to either acidity or alkalinity.

The reactive minerals in primary tailings include kaolinite [$Al_4(OH)_8(Si_4O_{10})$] and gibbsite ($Al(OH)_3$). Kaolinite occurs in all the analysed primary process tailings samples. Kaolinite is an aluminosilicate mineral that dissolves to some extent in ASS, and therefore acts as a neutralising agent in the tailings.

Gangama dry mining and Lanti dry mining tailings contain gibbsite ($Al(OH)_3$), a low solubility secondary mineral, which can also contribute to neutralisation potential.

Gibbsite does not occur in the Lanti dredge mine tailings in detectable quantities but occurs in detectable quantities in the Lanti dry mining tailings composite sample (LDMTC). The precipitation of gibbsite in the tailings was confirmed by running a PHREEQC check using 25% water extract data at a paste pH of 5.6.

4.2.2 Secondary process tailings

Mineralogical analysis of the secondary process tailings indicate that:

- SFT contain acid-generating sulfide minerals pyrite (n=2, 33-58%) and marcasite (n=2, 13-23%). Fresh SFT contain higher concentrations of sulfide minerals (23-58%) than the dry tailings (13 - 33%). SFT also contains quartz (n=2, 12-41%), rutile (n=2, 6-10%) and zircon (n=2, 1-3%);
- Goethite, often formed through the weathering of iron rich minerals, occurs in TT and CET. It commonly forms a pseudomorph (false form) after other minerals, especially marcasite and pyrite and may therefore indicate the occurrence of sulfide minerals. Goethite is acid consuming with a buffering pH range of 3.0 – 3.7;
- Almandine, a fast weathering acid neutralising aluminosilicate mineral, occurs in CET (n=3, 2 - 56%), FET (3%), IT (n=2, 4-5%) and TT (7%). Almandine contributes to the neutralisation potential in these tailings;
- Monazite, a radioactive phosphate mineral containing cerium, occurs in CET (n=2, 4-5%), FET (3%), IT (n=2, 1-2%) and TT (1%);
- TT contain mainly quartz (n=2, 43-90%). Other inert minerals in TT include rutile (n=2, 7-19%), ilmenite (12%), zircon (n=2, 1-6%), hematite (5%) and kyanite (3%);
- IT contain mainly quartz (n=2, 3-57%), rutile (n=2, 17-61%) and ilmenite (n=2, 10-23%);
- FET contain mainly quartz (52%), zircon (30%) and rutile (10%); and
- CET contain mainly almandine (n=3, 22-56%), zircon (n=3, 14-48%), quartz (n=3, 4-39%), Kyanite (n=3, 4-12%) and rutile (n=3, 5-10%).

In summary, the reactive minerals in secondary process tailings include marcasite and pyrite in SFT, goethite in TT and CET and almandine in CET, TT, IT and FET. Marcasite and pyrite are likely to contribute to acidity in SFT when exposed to oxidising conditions. Goethite, a pseudomorph of marcasite and pyrite, may contribute to NP in TT and CET at pH range of 3.0 – 3.7. Almandine, a fast weathering aluminosilicate mineral, may contribute to the NP in CET, TT, IT and FET.

In addition, monazite, a radioactive phosphate mineral containing cerium, occurs in CET, FET, IT and TT.

Table 4-4: Mineralogical composition (% w/w) of primary process tailings

Mineral Group				**Gangama Dry Mining**		**Lanti Dry Mining**			**Lanti Dredge Mining**		**Lanti Ore**
		Mineral	**Formula**	**GPTF (DRY)**	**GCT (MOIST)**	**LCT (DM, DM02 & DM03)**	**LFT (DM)**	**LDMTC**	**LWPT**	**LWPTC**	**LDO1**
Acid neutralising minerals	**Slow weathering**	Gibbsite	$Al(OH)_3$	1	2			1			
		Kaolinite	$Al_4(OH)_8(Si_4O_{10})$	6	15	3	4	4	3	1	7
	Resistant	Quartz	SiO_2	93	83	97	96	95	97	99	93
Total				**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Table 4-5: Mineralogical composition (% w/w) of secondary process tailings

Mineral Group		**Mineral (%)**	**Formula**	**Total Tailings**		**Ilmenite Tailings**		**Sulfide Floatation Tailings**		**Fine Electrostatic Tailings**	**Coarse Electrostatic Tailings**		
				TT (F) 02 & 01	**TT (Moist)**	**IT(F) 02 & 01**	**IT (DRY)**	**SFT (01& 2)**	**SFT (Moist)**	**FET(F)02&01**	**CET(F)02&01**	**CET(OLD)**	**CET(WET)**
Acid forming		Marcasite	FeS_2					23	13				
		Pyrite	FeS_2					58	33				
Acid Neutralizing Minerals	**Fast**	Almandine	$Fe_3Al_2Si_3O_{12}$	7		4	5			3	22	56	23
	Very slow	Goethite	FeOOH	4	2							3	1
	Resistant (inert)	Corundum	Al_2O_3							2	3		5
		Ilmenite	$FeTiO_3$	12		10	23						
		Hematite	Fe_2O_3	5		4						3	
		Monazite	$CePO_4$	1		1	2			3	5	4	
		Kyanite	Al_2SiO_5	3							8	4	12
		Quartz	SiO_2	43	90	57	3	12	41	52	4	12	39
		Rutile	TiO_2	19	7	17	61	6	10	10	10	6	5
		Zircon	$ZrSiO_4$	6	1	5	8	1	3	30	48	13	14
Total				**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

4.3 Elemental composition

Total metal analysis was primarily carried out on tailings samples to identify elements that are present at concentrations that may be of environmental concern with respect to water quality.

The appropriate media to compare the concentrations of the elements in the tailings is the total elemental concentration of the ore material from which the tailings are generated to determine enrichment relative to the ore, given that there is no physical or chemical alteration of the materials. However, elemental concentration data of the ore material is unavailable and the elemental concentrations of the tailings have been compared to the average crustal abundance (Forstescue, 1992). Although the average crustal abundance data do not necessarily account for mineralisation present in an ore body, in the absence of ore data, the use of crustal abundance data is an industry accepted approach of identifying enrichment and is commonly used in ESIA studies.

Table 4-6 and Table 4-7 presents the GAI values obtained for primary process samples and secondary process samples respectively. A GAI value of 0 indicates that the element is present at a concentration similar to or less than the crustal abundance and a GAI of 6 indicates approximately a 100 fold, or greater, enrichment above crustal abundance. As a general guide, a GAI of 3 or above is considered significant and indicates potential environmental concern.

Elements that are significantly enriched (i.e. GAI ≥3) in the primary process tailings include silver (<0.40 – 0.81 mg/kg), boron (240 – 590 mg/kg), cadmium (0.78 – 1.4 mg/kg), and selenium (22 – 41 mg/kg).

Elements that are significantly enriched (i.e. GAI ≥3) in the secondary process tailings include silver (<0.40 – 28 mg/kg), boron (370 – 1 290 mg/kg), cadmium (<0.10 – 1.4 mg/kg), cobalt (16 – 443 mg/kg), lead (<0.10 – 194 mg/kg), selenium (<3.0 – 91 mg/kg), titanium (0.29 – 33%) and zirconium (114 – 4 000 mg/kg).

However, significant enrichment does not necessarily imply that the element represents an environmental risk although the enriched element in the tailings may leach into surface water and groundwater depending on site conditions. The risk that these enriched elements present is a function of the environmental mobility of the element, assessed by leach tests in the later sections of this report.

Table 4-6: Total elemental composition and GAI values for primary process tailings

Element	Units	Concentrations (ppm)					Average Crustal Abundance	GAI				
		Gangama Dry Mining		Lanti Dry Mining		Lanti Dredge Mining		Gangama Dry Mining		Lanti Dry Mining		Lanti Dredge Mining
		Fine (n=2)	Coarse (n=1)	Coarse (n=3)	Fine (n=1)	Tailings (n=3)		Fine (n=2)	Coarse (n=1)	Coarse (n=3)	Fine (n=1)	Tailings (n=3)
Ag	mg/kg	<0.40 - 0.62	<0.40	<0.40 - 5.2	<0.40	0.50 - 0.81	**0.08**	2	-	5	-	3
Al	%	1.8 - 7.5	6.8	7.4 - 11	1.2	0.4 - 1.2	**8**	0	0	0	0	0
As	mg/kg	<2.0	<2.0	<2.0	<2.0	<2.0	**1.8**	-	-	-	-	-
B	mg/kg	282 - 302	318	392 - 591	248	240 - 332	**9.0**	4	5	5	4	5
Ba	mg/kg	9.7 - 14.2	22	28 - 38	10.2	5.2 - 9.4	**390**	0	0	0	0	0
Be	mg/kg	<0.20	<0.20	<0.20	<0.20	<2.0	**2.0**	-	-	-	-	-
Bi	mg/kg	<0.50	<0.50	<0.50	<0.50	<0.50	**0.08**	-	-	-	-	-
Ca	mg/kg	195 - 209	171	223 - 457	183	128 - 175	**46 600**	0	0	0	0	0
Cd	mg/kg	1.1 - 1.2	1.1	0.78 - 0.96	1.2	1.2 - 1.4	**0.2**	2	2	2	2	3
Co	mg/kg	6.5 - 10	8.7	8.2 - 12	3.7	3.1 - 5.3	**29**	0	0	0	0	0
Cr	mg/kg	167 - 409	401	200 - 222	34	21 - 88	**122**	1	1	1	0	0
Cu	mg/kg	7.4 - 21	14.6	1.1 - 15	7.4	3.4 - 6.9	**68**	0	0	0	0	0
Fe	%	<0.10	2..5	6.1 - 14	0.68	0.46 - 1.0	**6**	0	0	1	0	0
Hg	mg/kg	<0.10	<0.10	<0.10	<0.10	<0.10	**0.09**	-	-	-	-	-
K	mg/kg	212 - 222	190	470 - 729	262	129 - 196	**18 400**	0	0	0	0	0
Mg	mg/kg	95 - 134	99	138 - 198	104	68 - 92	**27 640**	0	0	0	0	0
Mn	mg/kg	24 - 33	28	32 - 42	21	18 - 26	**1 060**	0	0	0	0	0
Mo	mg/kg	1.2	1.5	1.1 - 1.4	0.97	0.99 - 1.2	**1.2**	0	0	0	0	0
Na	mg/kg	<1.0	443	491 - 621	437	<1.0	**22 700**	0	0	0	0	0
Ni	mg/kg	15 - 37	31	20 - 25	9.8	7.8 - 12.2	**99**	0	0	0	0	0
P	mg/kg	83 - 88	107	263 - 338	51	<2.0	**1 120**	0	0	0	0	0
Pb	mg/kg	18 - 20	20	19 - 22	20	20 - 22	**13**	0	0	0	0	0
Sb	mg/kg	<1.0	<1.0	<01.0	<1.0	<1.0	**0.20**	-	-	-	-	-
Se	mg/kg	23 - 29	22	24 - 41	25	26 - 28	**0.05**	9	8	9	8	9

Element	Units	Concentrations (ppm)					Average Crustal Abundance	GAI				
		Gangama Dry Mining		Lanti Dry Mining		Lanti Dredge Mining		Gangama Dry Mining		Lanti Dry Mining		Lanti Dredge Mining
		Fine (n=2)	Coarse (n=1)	Coarse (n=3)	Fine (n=1)	Tailings (n=3)		Fine (n=2)	Coarse (n=1)	Coarse (n=3)	Fine (n=1)	Tailings (n=3)
Sn	mg/kg	<2.0	<2.0	<2.0	<2.0	<2.0	**2.1**	-	-	-	-	0
Sr	mg/kg	<0.40	16	16 - 17	4.3	2.1 - 4.9	**384**	0	0	0	0	0
Th	mg/kg	<0.20	<0.20	<0.20	<0.20	<0.20	**8.1**	-	-	-	-	-
Ti	%	0.2 - 0.3	0.2	0.2 - 0.3	0.08	0.04 - 0.11	**0.63**	0	0	0	0	0
Tl	mg/kg	<0.90	<0.90	<0.90	<0.90	<0.90	**0.72**	-	-	-	-	-
U	mg/kg	<0.40	<0.40	<0.40	<0.40	<0.40	**2.3**	-	-	-	-	-
V	mg/kg	79 - 135	110	169 - 235	22	14 - 41	**136**	0	0	0	0	0
Zn	mg/kg	6.5 - 8.6	7.9	16 - 20	3.9	3.9 - 5.5	**76**	0	0	0	0	0
Zr	mg/kg	21 - 27	23	60 - 86	25	31 - 57	**162**	0	0	0	0	0

Note: A dash (-) in the table indicates GAI of elements with detection limits greater than their average crustal abundances

Table 4-7: Total elemental composition and GAI values for secondary process tailings

Element	Units	Concentrations (ppm)					Average Crustal Abundance	GAI				
		TT	IT	SFT	FET	CET		TT	IT	SFT	FET	CET
		n=3	n=3	n=3	n=3	n=4		n=3	n=3	n=3	n=3	n=4
Ag	mg/kg	0.58 - 8.9	0.69 - 1.3	<0.40 - 1.9	4.8 - 28	5.8 - 14	**0.08**	6	3	4	8	7
Al	%	0.4 - 0.7	3.5 - 6.2	0.3 - 0.5	0.3 - 0.6	0.8 - 2.0	**8**	0	0	0	0	0
As	mg/kg	<2.0	<2.0	<2.0	<2.0	<2.0	**1.8**	-	-	-	-	-
B	mg/kg	510 - 838	493 - 787	1 054 - 1 293	372 - 415	375 - 783	**9.0**	6	6	7	5	6
Ba	mg/kg	6.3 - 15	41426	12 - 23	<0.10 - 7.9	0.34 - 2.4	**390**	0	0	0	0	0
Be	mg/kg	<0.20	<0.20	<0.20	<0.20	<0.20	**2.0**	-	-	-	-	-
Bi	mg/kg	<0.50	<0.50	<0.50	<0.50	<0.50	**0.08**	-	-	-	-	-
Ca	mg/kg	314 - 1 491	379 - 1 153	214 - 319	327 - 509	1 020 - 2 265	**46 600**	0	0	0	0	0
Cd	mg/kg	<0.10 - 1.0	<0.10 - 0.69	<0.10	0.3 - 1.4	0.15 - 0.59	**0.2**	2	2	0	3	1
Co	mg/kg	64 - 443	83 - 405	127 - 174	16 - 39	26 - 46	**29**	3	3	2	0	0
Cr	mg/kg	249 - 993	376 - 878	165 - 223	64 - 139	160 - 374	**122**	2	2	0	0	1
Cu	mg/kg	15 - 73	48 - 128	208 - 288	7.4 - 97	<0.20 - 3.9	**68**	0	0	1	0	0
Fe	%	4.4 - 25	6.5 - 21	30 - 46	1.0- 1.9	4.7 - 17	**6**	1	1	2	0	1
Hg	mg/kg	<0.10	<0.10	<0.10	<0.10	<0.10	**0.09**	-	-	-	-	-
K	mg/kg	166 - 185	165 - 264	122 - 124	41 - 208	74 - 214	**18 400**	0	0	0	0	0
Mg	mg/kg	181 - 1 508	228 - 1545	402 - 689	237– 2 685	1 029 - 2 252	**27 640**	0	0	0	0	0
Mn	mg/kg	187 - 1 489	176 - 1 306	463 - 534	113 - 230	474 - 1 743	**1 060**	0	0	0	0	0
Mo	mg/kg	<0.10 - 1.7	<1.0 - 1.2	3.9 - 6.2	0.35 - 4.0	<0.10	**1.2**	0	0	2	1	-
Na	mg/kg	433 - 487	412 - 566	150 - 455	178 - 408	119 - 509	**22 700**	0	0	0	0	0
Ni	mg/kg	17 - 49	20 - 46	156 - 294	6.5 - 9.1	4.6 - 9.3	**99**	0	0	1	0	0
P	mg/kg	117 - 2 439	123 - 2 599	122 - 223	219 - 3 830	1 426 - 4 783	**1 120**	0	1	0	1	2
Pb	mg/kg	<0.10 - 10	<0.10 - 14	50 - 85	27 - 134	67 - 194	**13**	0	0	2	3	3
Sb	mg/kg	<1.0	<1.0	<1.0	<1.0	<1.0	**0.20**	-	-	-	-	-
Se	mg/kg	<3.0 - 31	18 - 40	83 - 91	17 - 36	6.4 - 33	**0.05**	9	9	10	9	9

Element	Units	Concentrations (ppm)					Average Crustal Abundance	GAI				
		TT	IT	SFT	FET	CET		TT	IT	SFT	FET	CET
		n=3	n=3	n=3	n=3	n=4		n=3	n=3	n=3	n=3	n=4
Sn	mg/kg	<2.0	<2.0	<2.0	<2.0	<0.20 - 5.4	**2.1**	-	-	-	-	1
Sr	mg/kg	<0.10 - 4.0	<0.10 - 3.6	<0.10 - 0.23	<0.10 - 1.6	<0.10 - 0.46	**384**	0	0	0	0	0
Th	mg/kg	<0.20	<0.20	<0.20	<0.20	<0.20	**8.1**	-	-	-	-	-
Ti	%	2.7 - 33	3.9 - 33	3.3 - 3.8	0.5 - 1.8	0.29 - 0.98	**0.63**	5	5	2	1	0
Tl	mg/kg	<0.90	<0.90	<0.90	<0.90	<0.90	**0.72**	-	-	-	-	-
U	mg/kg	<0.40	<0.40	<0.40	<0.40	<0.40	**2.3**	-	-	-	-	-
V	mg/kg	200 - 1 025	272 - 912	210 - 253	48 - 115	31 - 185	**136**	2	2	0	0	0
Zn	mg/kg	30 - 175	39 - 155	121 - 180	24 - 87	52 - 152	**76**	1	0	1	0	0
Zr	mg/kg	128 - 364	114 - 431	141 - 542	512 - 3 997	1 034 - 2 317	**162**	0	1	1	4	3

Note: A dash (-) in the table indicates GAI of elements with detection limits greater than their average crustal abundances

4.4 Acid generating characteristic

The acid generating potential of a sample is classified on the basis of the ABA and NAG test to evaluate ASS generation potential of the tailings. The tests indicate the relative proportions of Acid Generating (AP) and NP components of a sample.

Table 4-8 and Table 4-9 presents a summary of the results of the ABA test including sulfur speciation and NAG for primary and secondary process tailings samples respectively.

4.4.1 Paste pH

The relative magnitudes of the rates of AP and NP determines the paste pH of a sample. Paste pH is indicative of the pore water pH and the current pH status of the tailings:

- The primary process tailings are slightly acidic (n=10, pH 4.8 - 6.2);
- SFT is acidic to slightly acidic (n=3, pH 2.9-5.7). The acidic paste pH of SFT is consistent with the occurrence of marcasite and pyrite in the tailings; and
- The other secondary process tailings are slightly acidic to neutral (n=13, pH 4.3 - 6.8). The slightly acidic to neutral pH in the CET is consistent with the buffering pH range (5.0 - 6.2) of aluminosilicates mineral, almandine, present in CET.

4.4.2 Sulfur speciation

Sulfur species are the primary source of acid, acidity and potentially deleterious elemental species in the drainage from the tailings. Sulfur speciation indicates that:

- The primary process tailings do not contain significant sulfur with a total sulfur range of 0.01-0.07%;
- The secondary process tailings contain a wide range of sulfur as detailed below:
    - SFT contain significant sulfur (22-46%) with 96-99% as sulfide sulfur. This is consistent with mineralogy results that indicated a sulfide content range of 23-58%;
    - TT contain total sulfur of a range of 0.04-1.5% mainly as sulfates in the fresh tailings and as sulfide in the dry tailings;
    - IT contain total sulfur of a range of 0.06-1.3% mainly as sulfide in the fresh tailings indicating limited oxidation and mainly as sulfate for dry tailings indicating oxidation; and
    - FET and CET are characterised by low sulfur (n=9, <0.03%) content relative to the other secondary process tailings.

Sulfur speciation indicates that SFT contain significant sulfur with 96-99% as sulfide sulfur. This indicates that the tailings are potentially acid generating and will generate acidity when exposed to oxidising conditions.

4.4.3 Carbon content

Carbon species are the primary sources of alkalinity and acid neutralisation in the tailings. Both the primary and secondary process tailings contain low concentrations of total carbon of a range of 0.02-0.16% in primary process tailings and 0.01-0.08% in secondary process tailings. This indicates that the tailings have insignificant carbonate minerals to neutralise acidity.

Table 4-8: Summary of ABA, sulfur speciation and NAG results for primary process tailings samples

	[1]Paste pH	Total Sulfur	Sulfate Sulfur	Sulfide Sulfur	Total Carbon	[2]AP	[3]NP	[4]NPR	[5]NNP	[6]NAG pH	NAG
Units	s.u	% S	% S	%	%	Kg $CaCO_3$/tonne			Kg $CaCO_3$/tonne	s.u	Kg H_2SO_4/tonne
[7]LOD		<0.01	<0.01	<0.01	<0.01		<0.1				<1
Gangama Dry Mining Tailings											
GPTF	5.0	0.05	0.02	0.03	0.09	0.94	0.97	1.0	0.03	-	-
GPTF (DRY)	6.2	0.02	0.02	<0.01	0.04	0.16	1.2	7.8	1.1	5.8	<1
GCT (MOIST)	5.9	0.04	0.02	0.02	0.05	0.63	<0.1	0.08	-0.58	5.8	<1
Lanti Dry Mining Tailings											
LCT (DM)	5.6	0.07	0.06	0.01	0.22	0.31	1.2	3.9	-0.26	5.5	<1
LCT (DM02)	5.4	0.06	0.01	0.05	0.16	1.6	2.9	1.9	-1.5		
LCT (DM03)	5.6	0.04	0.04	<0.01	0.08	<0.31	1.2	7.8	1.1		
LFT (DM)	4.9	0.01	0.01	<0.01	0.03	<0.31	0.48	3.1	0.33	6.0	<1
LDMTC	5.6	0.03	0.01	0.02	0.04	0.63	<0.1	0.08	-0.58	5.9	<1
Lanti Dredge Mining Tailings											
LWPT	5.1	0.04	<0.01	0.04	0.04	1.3	<0.1	0.04	-1.2	5.5	<1
LWPTC	4.8	0.04	0.03	0.01	0.02	0.31	1.2	3.9	1.1	5.1	<1

Notes:

1. Paste pH measured in the field.
2. Acid potential (AP) = acid potential based on sulfide sulfur.
3. The measured NP (Modified Sobek titration).
4. Neutralisation Potential Ratio (NPR) - ratio of NP to AP.
5. Net Neutralisation Potential (NNP) - difference between NP and AP.
6. Net Acid Generation (NAG)
7. Limit of Detection (LOD).

Table 4-9: Summary of ABA, sulfur speciation and NAG results for secondary process tailings samples

	[1]Paste pH	Total Sulfur	Sulfate Sulfur	Sulfide Sulfur	Total Carbon	[2]AP	[3]NP	[4]NPR	[5]NNP	[6]NAG pH	NAG
Units	s.u	% S	% S	%	%	Kg $CaCO_3$/tonne			Kg $CaCO_3$/tonne	s.u	Kg H_2SO_4/tonne
[7]LOD		<0.01	<0.01	<0.01	<0.01		<0.1				<1
TT											
TT (F)02	2.49	1.5	1.5	<0.01	0.05	0.16	0.21	1.34	0.05	2.1	11
TT (F)01	3.28	0.04	0.04	<0.01	0.03	0.16	4.4	28	4.2		
TT (MOIST)	2.11	0.66	0.16	0.50	0.03	16	1.1	0.07	-15	1.8	9.5
IT											
IT (F)01	2.32	1.3	0.07	1.2	0.05	38	<0.1	0.001	-37	2.3	9.2
IT (F)02	3.39	0.06	<0.01	0.06	0.04	1.9	1.2	0.65	-0.7		
IT (DRY)	2.59	0.07	0.05	0.02	0.04	0.63	<0.1	0.08	-0.6	7.0	<1
SFT											
SFT01	1.90	40	0.07	40	0.34	1 238	<0.1	0.00004	-1237	1.7	966
SFT02	2.08	46	0.40	45	0.33	1 416	<0.1	0.00004	-1416		
SFT (Moist)	0.87	22	0.90	21	0.26	644	<0.1	0.0001	-644	1.9	520
FET											
FET (F)01	3.71	0.02	<0.01	0.02	0.02	0.63	1.2	1.9	0.6	6.0	<1
FET (F)02	3.83	0.03	0.03	<0.01	0.02	0.16	1.2	7.7	1.1		
FET (WET)	3.34	0.01	<0.01	0.01	0.02	0.31	<0.1	0.16	-0.26		
CET											
CET (F)02	4.43	0.02	<0.01	0.02	0.01	0.63	1.2	1.9	0.59	5.1	<1
CET (F)01	3.68	0.02	<0.01	0.02	0.01	0.63	1.2	1.9	0.59		
CET (OLD)	5.91	0.02	0.02	<0.01	0.08	0.16	1.0	6.2	0.81	6.6	<1
CET (WET)	2.89	0.02	<0.01	0.02	0.02	0.63	0.73	1.2	0.11	5.9	<1

Notes:

1. Paste pH measured in the field.
2. Acid potential (AP) = acid potential based on sulfide sulfur.
3. The measured NP (Modified Sobek titration).
4. Neutralisation Potential Ratio (NPR) - ratio of NP to AP.
5. Net Neutralisation Potential (NNP) - difference between NP and AP.
6. Nett Acid Generation (NAG)
7. Limit of Detection (LOD).

4.4.4 Acid generation potential

The generation of acidic drainage requires AP to exceed NP. Acidic drainage will only result when the rate of acid generation exceeds the rate of acid neutralisation.

Acid Potential (AP) refers to the total acid (H^+ equivalent) the tailings are capable of producing irrespective of its fate. The primary source of this acidity is the oxidation of sulfide minerals. The sulfide sulfur was used to calculate the acid generation potential of the tailings expressed as kg $CaCO_3$ /tonne as follows:

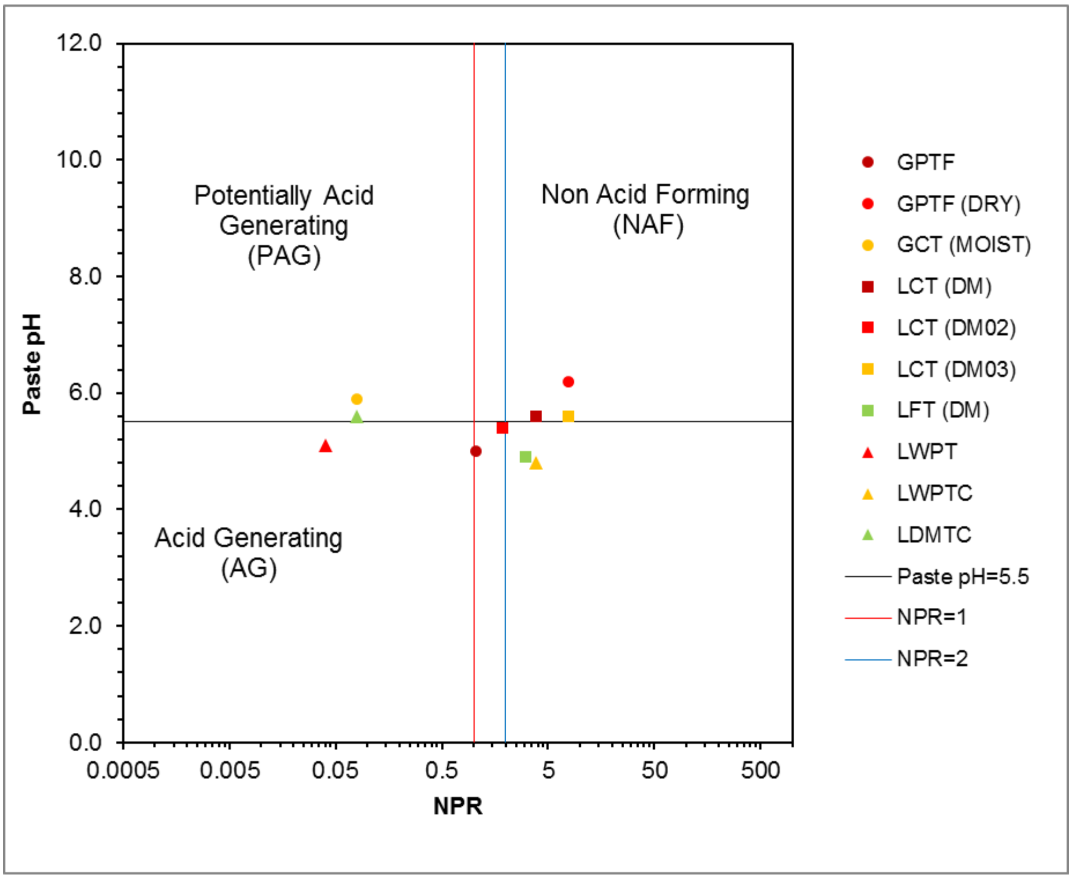
Equation 3: Acid Potential (AP) (kg $CaCO_3$/t) = % sulfide-sulfur x 31.25.

Neutralisation Potential (NP) is a measure of the total neutralisation potential contained in the tailings. The laboratory used the Modified Sobek method to measure NP in the tailings (Lawrence & Wang, July, 1996).

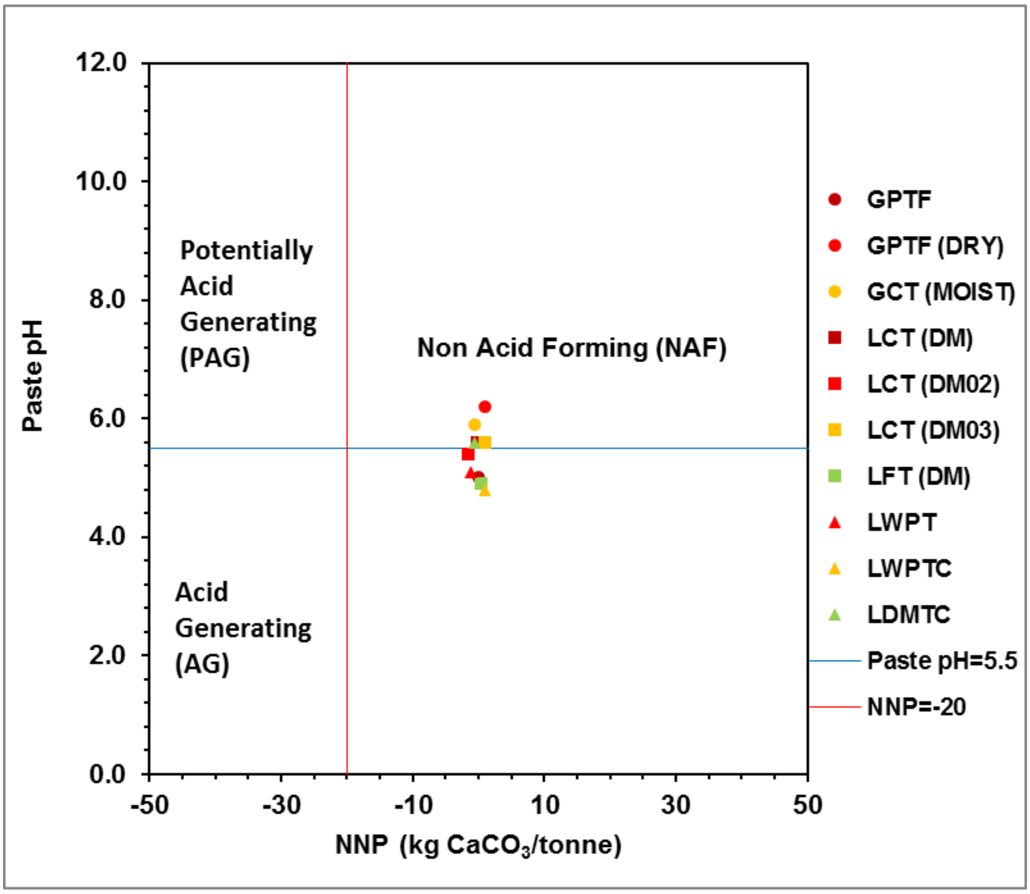
Acidic drainage will only result when the rate of acid generation exceeds the rate of acid neutralisation. The acid generation potential of the tailings samples was evaluated using the criteria indicated in the Prediction Manual for Drainage Chemistry from sulfidic geological materials (MEND Report 1.20.1, 2009). These included NPR, NNP and NAG pH.

Dividing AP by NP (NPR = NP/AP) obtains NPR and subtracting AP from NP (NNP=NP-AP) obtains NNP. NAG pH indicates the resultant pH on complete oxidation of sulfides in the tailings using hydrogen peroxide. A NAG pH < 4.5 indicates acid generation and NAG pH > 4.5 indicates NAF.

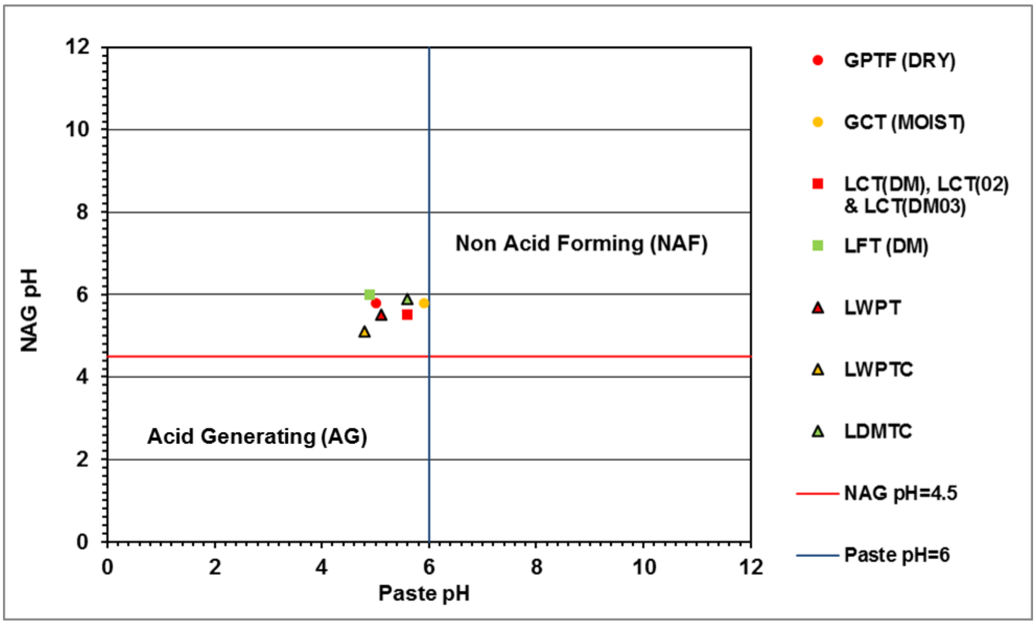
Figure 4-1 and Figure 4-2 present the graphical representation of the acid generation potential of primary and secondary process tailings respectively.



(a) Paste pH versus NPR for primary process tailings

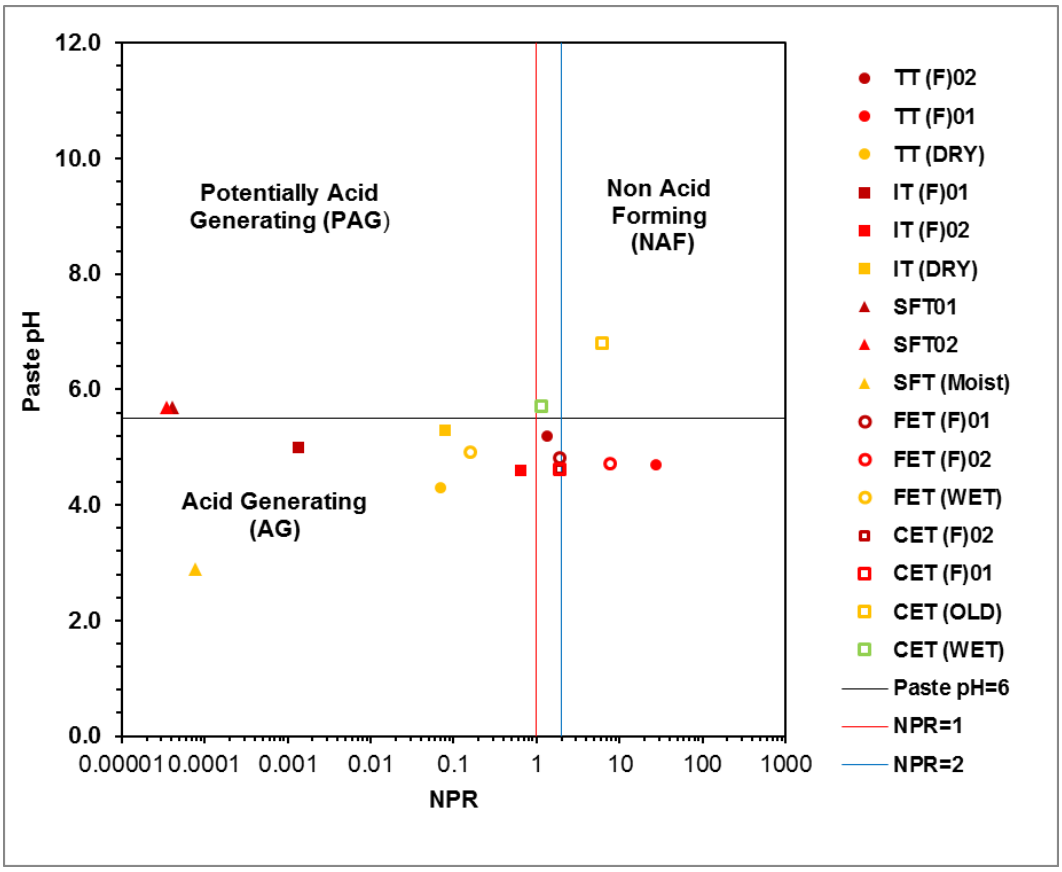


(b) Paste pH versus NNP for primary process tailings

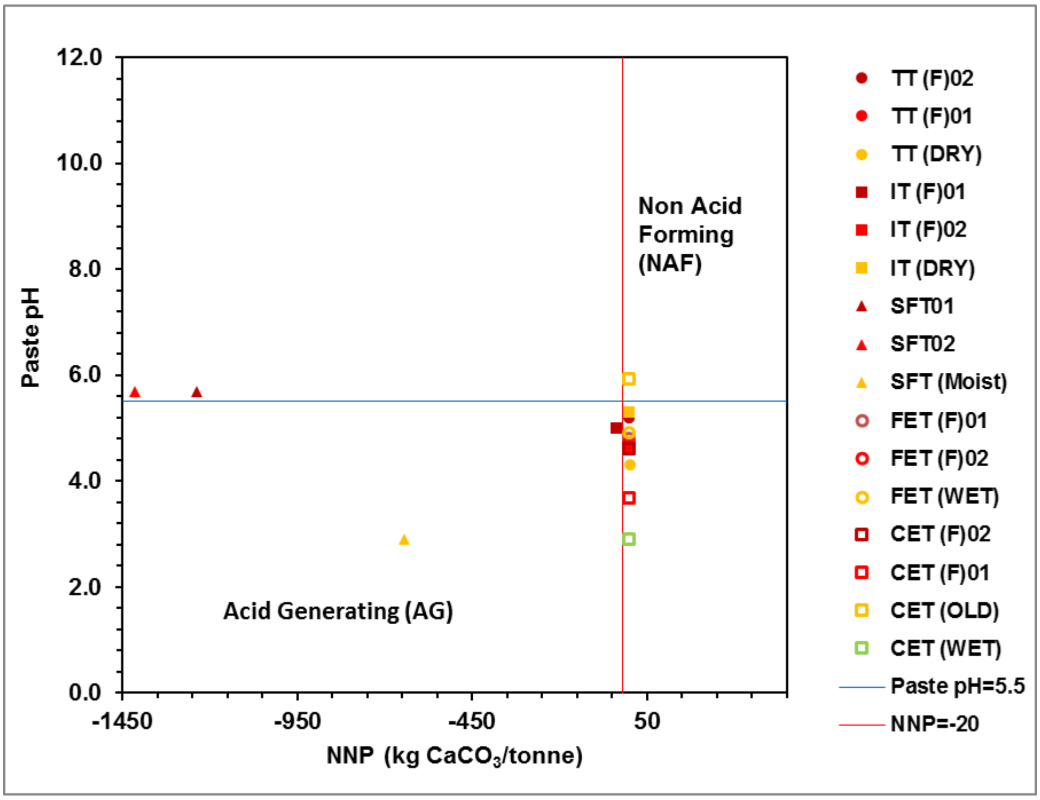


(c) NAG pH versus Paste pH for primary process tailings

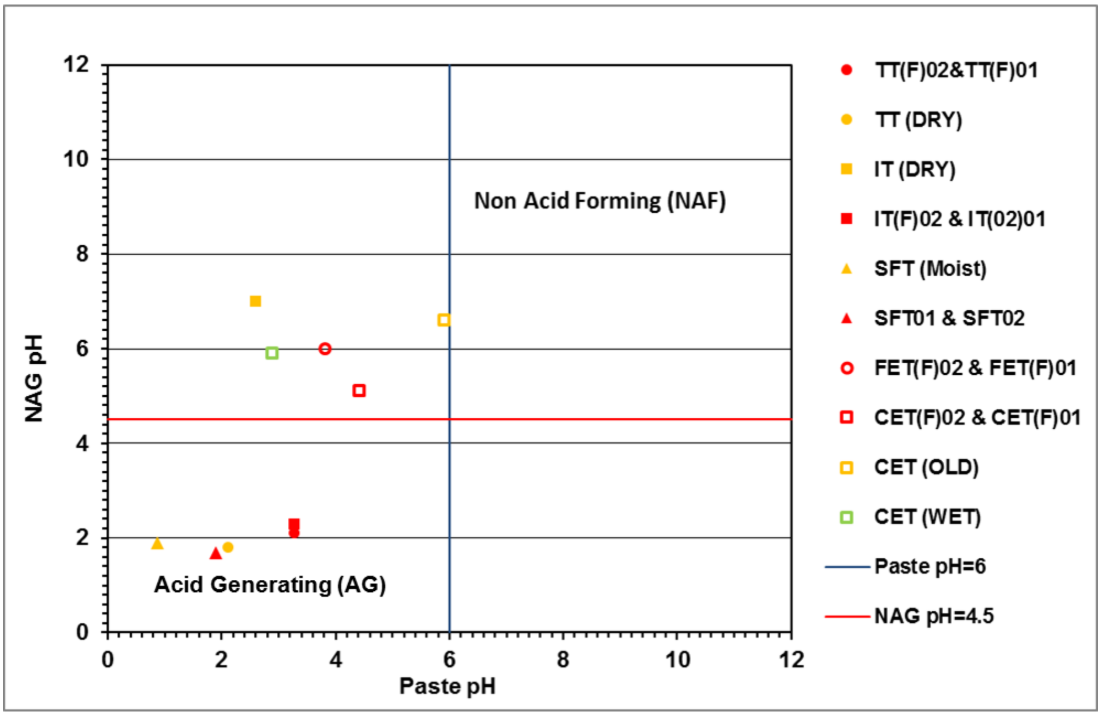
Figure 4-1: Scatter plot of NPR, NNP and NAG pH versus paste pH for primary process tailings



(a) Paste pH versus NPR for secondary process tailings



(b) Paste pH versus NNP for secondary process tailings



(c) NAG pH versus Paste pH for secondary process tailings

Figure 4-2: Scatter plot of NPR, NNP and NAG pH versus paste pH for secondary process tailings

The ABA and NAG test results indicate that:

- The primary process tailings are NAF. Although NPR indicates that 3 samples are PAG, NNP and NAG pH confirms that the 3 samples are NAF. This is consistent with the mineralogy results that showed that there are no detectable sulfide minerals that could potentially generate acidity in the primary process tailings;
- The secondary process tailings are as detailed below:
  - SFT are AG. This is consistent with the mineralogy results that indicated the presence of acid generating sulfide minerals, marcasite and pyrite;
  - TT and IT are PAG. Sulfur speciation results indicated the presence of sulfides in TT and IT; and
  - FET and CET are non-acid generating. This is consistent with the mineralogy and sulfur speciation results that indicated that FET and CET do not contain sulfides but contain substantial NP in the form of almandine (3 – 56%).

In summary, the primary process tailings are NAF. This is consistent with the mineralogy results that showed that there are no detectable sulfide minerals that could potentially generate acidity in the primary process tailings.

SFT are AG and have the potential to stay acidic in the long term if exposed to oxidizing conditions. This is consistent with the mineralogy results that indicated the presence of acid generating sulfide minerals, marcasite and pyrite. TT and IT also contain sulfides and are PAG. FET and CET are NAF.

4.5 Leaching characteristic

To determine the leachable major and trace constituents, short-term leach tests (ASTM D3987) were conducted on the solid samples. The leachates from the solid samples and supernatant from the slurry samples were analysed for major and trace constituents.

Contact leach testing involved the leaching of the sample with deionised water at a solid to liquid ratio of 1:4. The solution was agitated for 18 hours, decanted, pressure filtered and the filtrate analysed for constituents.

The data quality of the leachate and supernatant are assessed using Ion Balance (IB) between reported cation and anion concentrations. An ion imbalance within ± 10% was taken to represent an acceptable level of analytical accuracy as explained in Section 2.6.1 of this report.

The leachate and supernatant qualities are assessed against:

- Sierra Leone’s Environmental Protection (Mines and Minerals) Regulations 2013 (SLEP(M&M) Regs 2013) “limit at any moment” effluent quality for mining and metallurgic operations; and
- Background surface water quality (average concentrations for July, August and October 2017) from surface water monitoring point SW6, located a distance away from the mining activities and representing the least affected surface water monitoring point within Area 1, Figure 2-8.

The background surface water quality is within the WHO limits and the SLEP (M&M) Regs 2013 are more stringent than the WHO limits except mercury limit [SLEP (M&M) Regs 2013, 0.002 mg/l and WHO, 0.0005 mg/l).

Table 4-10 present the leachate quality of primary process tailings. The supernatant quality of the tailings from Lanti dredge and leachate quality of tailings from Lanti dry mining are also compared to the quality of Lanti dredge pond water. Lanti dredge pond water is used as the process water for Lanti dry mining and may contribute to the supernatant quality of the tailings.

The assessment indicates the following:

- The leachates from primary process tailings are acidic (pH < 5.9) and characterised by low salinity (EC < 3.3 mS/m);
- All the measured parameters in the leachate are within the SLEP(M&M) Regs 2013 “limit at any moment” except pH;
- The parameters that exceed the background surface water levels in the leachate of the primary process tailings include the following:
  - pH (<6.0), conductivity (>0.98 mS/m), aluminium (>0.02 mg/l), copper (>0.007 mg/l), manganese (>0.015 mg/l) and nickel (>0.002 mg/l) and sulfate (>2.3 mg/l); and
  - Aluminium (>0.06 mg/l), chloride (>1.7 mg/l) and calcium (>2.0 mg/l), nitrate as N (>0.31 mg/l in Lanti tailings.
- Lanti dredge pond water is acidic (pH 4.24 – 4.34) and elevated in choride, nitrate, sulfate, aluminium, manganese and nickel relative to background surface water concentrations. The dredge pond water is used as process water for Lanti dry mining and contributes to the acidity and salinity of the supernatant and leachate from Lanti dry mining tailings.
- The elements Ag, B, Cd and Se identified as enriched in the primary process tailings are either below, or close to the respective detection-limits in the tailings leachate/supernatant and therefore do not constitute parameters of concern.

Table 4-11 present the supernatant quality of secondary process tailings. The supernatant quality of the tailings are also compared with Lake Gray and Mogbwemo dredge pond water qualities. Lake Gray water is used as the process water for the MSP and Mogbwemo dredge pond receives water from the secondary process tailings ponds. The assessment indicates the following:

- The leachates from secondary process tailings are acidic (pH <5.7) and characterised by low salinity (EC < 7.8 mS/m);
- All the measured parameters in the leachate are within the SLEP(M&M) Regs 2013 “limit at any moment” except pH;
- The parameters that exceed the background surface water levels in the leachate from the secondary process tailings include pH (<6.0), Al (>0.06 mg/l), Ca (>2.0 mg/l), Cu (>0.007 mg/l), Mn (>0.015 mg/l), Ni (>0.002 mg/l), SO_4 (>2.3 mg/l) and TDS (>35 mg/l).
- Process water from Lake Gray is acidic (pH 4.3 – 4.8) and elevated in aluminium, manganese and sulfate relative to background surface water levels. The process water for Lanti dry contributes to the acidity and salinity of the secondary process tailings supernatant.
- Mogbwemo dredge pond water is slightly acidic (pH 5.4) and elevated in manganese and sulfate relative to background surface water levels. Mogbwemo dredge pond water does not seem to be contaminated by the water discharging from the secondary process tailings ponds as its quality is comparable to the quality of Lake Gray water quality before use as process water in the MSP.
- The elements Ag, B, Cd, Co, Pb, Se, Ti and Zr identified as enriched in the secondary process tailings are either below, or close to the respective detection-limits in the tailings leachate/supernatant and therefore do not constitute parameters of concern.

Table 4-10: Leachate quality of primary process tailings relative to background surface water quality and guideline limits

Parameters (All units in mg/l unless stated otherwise)	Gangama Dry Mining		Lanti Dredge Mining			Lanti Dry Mining			[1]SLEP(M&M) Regs 2013	[2]Background (July, Aug & Oct 2017)
	Leachate (25%)		[2]Lanti Dredge Pond	Supernatant	Leachate (25%)	Leachate (25%)				
	Fine [(GCT (Moist)]	Coarse [GPTF (Dry)]	SW4 (July, Aug & Oct 2017, n=3)	LWPT	LWPTC	Coarse (LDMTC)	Fines [LFT(DM)]	Coarse [LCT(DM, DM02 & DM03)]	Limit at any Moment	SW6 (n=3)
pH (@ 23°C (Lab) s.u	4.6	5.9	4.2 - 4.3	3.7	5.9	4.1	5.9	5.9	6 - 9	6.2
pH (Field) s.u	5.9	6.2	-	5.1	-	-	4.9	5.4 - 5.6		
EC mS/m @ 25°C (Lab)	1.5	1.3	3.2 - 4.6	3.2	3.3	1.7	1.4	1.6	-	0.98
EC mS/m (Field)	0.60	0.40	-	2.1	-	-	2.0	0.7 - 0.8		
Cl	1.3	1.3	1.6 - 2.1	0.80	1.9	2.3	1.3	1.5	-	1.7
F	0.10	0.10	<0.3	0.10	0.10	0.20	0.10	<0.1	-	<0.3
NO_2	<0.1	<0.1	-	<0.1	<0.1	<0.1	<0.1	<0.1	-	-
NO_3	0.90	1.0	-	-	1.8	0.70	1.8	1.6	-	-
NO_3 as N	0.20	0.2	0.23 - 0.38	<0.1	0.40	0.20	0.40	0.40	-	0.31
SO_4	3.9	2.0	6.9 - 9.0	25	10	5.1	2.0	2.7	-	2.3
TDS	10	9.0	35	22	22	12	9.0	10	-	35
Total Alkalinity ($CaCO_3$)	0	2.0	-	0	2.0	0	1.0	1.0	-	-
Bicarbonate (HCO_3)	0	2.0	-	0	2.0	0	1.0	1.0	-	-
Acidity as H^+	-	-	-	0.70	-	0.20	-	-	-	-
Ag	<0.004	<0.004	<0.0005	<0.004	<0.004	<0.004	<0.004	<0.004	-	-
Al	0.034	0.02	0.13 - 0.17	0.56	0.67	0.014	0.024	0.023	-	0.06
As	<0.02	<0.02	<0.003	<0.02	<0.02	<0.02	<0.02	<0.02	0.1	<0.003
B	<0.006	<0.006	-	<0.006	<0.006	<0.006	<0.006	<0.006	-	-
Ba	0.001	0.001	-	0.027	0.015	0.005	<0.001	0.002	-	-
Be	<0.002	<0.002	-	<0.002	<0.002	<0.002	<0.002	<0.002	-	-
Bi	<0.005	<0.005	-	<0.005	<0.005	<0.005	<0.005	<0.005	-	-
Ca	0.40	0.20	2.0	2.0	2.1	0.60	0.10	0.30	-	2.0
Cd	0.001	0.001	<0.001	0.001	<0.001	<0.001	0.001	<0.001	-	<0.001
Co	0.003	<0.001	-	0.056	0.042	0.002	<0.001	0.001	-	-

Parameters (All units in mg/l unless stated otherwise)	Gangama Dry Mining		Lanti Dredge Mining			Lanti Dry Mining			[1]SLEP(M&M) Regs 2013	[2]Background (July, Aug & Oct 2017)
	Leachate (25%)		[2]Lanti Dredge Pond	Supernatant	Leachate (25%)	Leachate (25%)				
	Fine [(GCT (Moist)]	Coarse [GPTF (Dry)]	SW4 (July, Aug & Oct 2017, n=3)	LWPT	LWPTC	Coarse (LDMTC)	Fines [LFT(DM)]	Coarse [LCT(DM, DM02 & DM03)]	Limit at any Moment	SW6 (n=3)
Cr_T	<0.003	<0.003	<0.002	<0.003	<0.003	<0.003	<0.003	<0.003	0.1	<0.002
Cu	0.059	0.005	<0.007	0.089	0.024	<0.002	0.004	0.008	0.6	<0.007
Fe	0.25	0.029	0.02 - 0.06	0.36	0.52	0.058	0.011	0.25	2.0	0.55
Hg	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001
K	0.40	0.50		0.70	1.00	0.80	0.60	0.50	-	-
Mg	0.031	0.044	1.00	0.50	0.60	0.20	0.05	0.10	-	1.0
Mn	0.039	0.012	0.03 - 0.04	0.18	0.061	0.009	0.006	0.005	-	0.015
Mo	<0.001	<0.001	-	<0.001	<0.001	<0.001	<0.001	<0.001	-	-
Na	2.6	2.7		1.3	2.5	0.80	2.7	2.8	-	-
Ni	0.005	<0.003	0.01	0.076	0.058	0.004	<0.003	<0.003	-	<0.002
P	<0.04	<0.04	-	<0.04	<0.04	<0.04	<0.04	<0.04	-	
Pb	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.2	0.005
Sb	<0.01	<0.01	<0.002	<0.01	<0.01	<0.01	<0.01	<0.01	-	<0.002
Se	<0.03	<0.03	<0.003	<0.03	<0.03	<0.03	<0.03	<0.03	-	<0.003
Sn	<0.02	<0.02	-	<0.02	<0.02	<0.02	<0.02	<0.02	-	-
Sr	<0.001	<0.001	-	0.015	0.007	0.003	<0.001	<0.001	-	-
Th	<0.002	<0.002	-	<0.002	<0.002	<0.002	<0.002	<0.002	-	-
Ti	0.001	<0.001	-	0.055	<0.001	<0.001	0.001	0.001	-	-
Tl	<0.009	<0.009	-	<0.009	<0.009	<0.009	<0.009	<0.009	-	-
U	0.005	0.006	-	<0.004	<0.004	<0.004	<0.004	<0.004	-	-
V	<0.002	<0.002	-	<0.002	<0.002	<0.002	<0.002	<0.002	-	-
Zn	<0.005	<0.005	<0.003	<0.005	<0.005	<0.005	<0.005	<0.005	1.5	0.003
Zr	<0.001	<0.001	-	<0.001	<0.001	<0.001	<0.001	<0.001	-	-
Ion Imbalanace (%)	7.9	1.0	-	7.3	4.9	4.6	1.4	2.5	-	-

Notes: [1]Sierra Leone's Environmental Protection (Mines and Minerals) Regulations 2013 effluent quality limits for mining and metallurgic operations
[2]Surface water monitoring data, SRK surface water data, July, August and October 2017

Table 4-11: Supernatant quality of secondary process tailings relative to background surface water quality and guideline limits

Parameters (All units in mg/l unless stated otherwise)	Process Water	Secondary Process Tailings Supernatant						[1]SLEP(M&M) Regs 2013	[2]Background (Jul, Aug & Oct 2017)
	Lake Gray	TT	IL	SFT	FET	CET	Mogbweno Dredge Pond	Limit at any Moment	SW6 (n=3)
		TT(F)02 & TT(F)01	IT(F)02& IT(F)01	SFT01 & SFT02	FET(F)02 & FET(F)01	CET(F)02 & CET(F)01			
pH (@ 23°C (Lab) s.u	4.3	3.7	3.6	3.3	4.1	4.2	5.4	6 - 9	6.2
pH (Field) s.u	4.8	4.7 - 5.2	4.6 - 5.0	5.7	4.7 - 4.8	4.6	5.3		
EC mS/m @ 25°C (Lab)	1.7	5.8	5.0	7.8	2.5	2.9	1.3		0.98
EC mS/m (Field)	5.6	3.1 - 4.0	2.9 - 3.7	5.2 - 5.7	3.3	3.4	2.7		
Acidity as H^+	0.04	0.60	0.60	0.80	0.04	0.12			
Cl	0.60	1.2	0.70	0.70	0.60	0.50	0.50		1.7
F	0.10	0.20	0.20	0.30	0.10	0.20	0.10		<0.3
NO_2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1		
NO_3 as N	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1		0.31
SO_4	6.8	28	25	38	11	13	2.9		2.3
TDS	11	38	33	52	17	19	9.0		35
Ag	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004		
Al	0.19	1.8	1.8	0.87	0.66	1.3	0.046		0.06
As	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.1	<0.003
B	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006		
Ba	0.003	0.021	0.016	0.02	0.013	0.01	0.004		
Be	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002		
Bi	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005		
Ca	1.0	2.7	1.9	1.4	1.6	1.5	0.9		2
Cd	0.001	0.001	<0.001	0.001	0.001	<0.001	0.001		<0.001
Co	0.002	0.051	0.037	0.02	0.009	0.031	0.001		
Cr_T	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.1	<0.002
Cu	0.005	0.32	0.029	0.043	0.012	0.055	0.004	0.6	<0.007
Fe	0.46	0.13	0.32	0.90	0.046	0.034	0.059	2.0	0.55
Hg	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001
K	0.60	0.90	0.70	1.5	0.60	0.60	0.40		

Parameters (All units in mg/l unless stated otherwise)	Process Water	Secondary Process Tailings Supernatant						[1]SLEP(M&M) Regs 2013	[2]Background (Jul, Aug & Oct 2017)
	Lake Gray	TT	IL	SFT	FET	CET	Mogbweno Dredge Pond	Limit at any Moment	SW6 (n=3)
		TT(F)02 & TT(F)01	IT(F)02& IT(F)01	SFT01 & SFT02	FET(F)02 & FET(F)01	CET(F)02 & CET(F)01			
Mg	0.4	0.67	0.70	0.50	0.60	0.60	0.60		1
Mn	0.044	0.19	0.13	0.22	0.087	0.084	0.059		0.015
Mo	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001		
Na	1.3	2.0	1.7	8.9	1.5	1.4	1.3		
Ni	<0.003	0.11	0.076	<0.003	0.026	0.10	<0.003		<0.002
P	0.05	0.09	0.04	0.07	<0.04	<0.04	<0.04		
Pb	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.2	<0.005
Sb	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01		<0.002
Se	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03		<0.003
Sn	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02		
Sr	0.005	0.013	0.008	0.008	0.013	0.01	0.005		
Th	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.003		
Ti	0.012	0.002	<0.001	<0.001	0.006	0.002	0.001		
Tl	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009		
U	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004		
V	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002		
Zn	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	1.5	0.003
Zr	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001		
Ion Imbalance (%)	7.4	9.5	9.2	10	6.2	8.8	4.4		

Notes: [1] Sierra Leone’s Environmental Protection (Mines and Minerals) Regulations 2013 effluent quality limits for mining and metallurgic operations

[2] Surface water monitoring data, SRK surface water data, July, August and October 2017

5 Summary and implications

Table 5-1 and Table 5-2 present summaries of the key findings of the geochemical characterisation of the primary and secondary process tailings respectively.

Table 5-1: Summary of key findings, primary process tailings

	Gangama Dry Tailings (n=3)	Lanti Dry Mining Tailings (n=5)	Lanti Dredge Mining Tailings (n=2)
Reactive Minerals (% w/w)	Gibbsite (1 - 2) Kaolinite (6-15)	Kaolinite (3 - 4)	Kaolinite (1 - 3)
Paste pH (s.u)	5.0 - 6.2	Fine (4.9) Coarse (5.4 - 5.6)	4.8 - 5.1
Sulfide Sulfur (% S)	0.02 - 0.03	0.01 - 0.05	0.01 - 0.04
AP (Kg $CaCO_3$/tonne)	0.16 - 0.94	0.31 - 1.6	0.31 - 1.3
NP (Kg $CaCO_3$/tonne)	0.97 - 1.2	0.48 - 2.9	<0.1 - 1.2
NAG pH (s.u)	5.8	5.5 - 6.0	5.1 - 5.5
Classification	NAF	NAF	NAF
	Leachate quality		
pH$_{Field}$ (s.u)	Fine (pH 5.9)	Fines (pH 5.9)	pH 3.7 - 5.9
	Coarse (pH 6.2)	Coarse (pH 5.4 - 5.6)	
EC$_{Lab}$ (mS/m)	1.3 - 1.5	1.4 - 1.7	3.2 - 3.3
Parameters exceeding limits (mg/l unless stated otherwise)	All parameters are within the SLEP (M&M) Regs 2013 limits except pH		
	pH (<6.2), EC (0.98 mS/m), Al (>0.06), Ca (2.0), Cl (>1.7), Cu (>0.007), NO_3 as N (>0.31), Mn (>0.015), Ni (>0.002) and SO_4 (>2.3) exceed the background surface water levels.		

Table 5-2: Summary of key findings, secondary process tailings

	TT (n=3)	IT (n=3)	SFT(n=3)	FET (n=3)	CET (n=4)
Reactive Minerals (% w/w)	Almandine (7)	Almandine (4-5)	Marcasite (13-23)	Almandine (3)	Almandine (22-56)
	Goethite (2-4)		Pyrite (33-58)		Goethite (1-3)
Paste pH (s.u)	2.11 - 3.28	2.32 - 3.39	0.87 - 2.08	3.34 -3.83	2.89 - 5.91
Sulfide Sulfur (% S)	<0.01 - 0.5	0.02 - 1.2	21 - 45	<0.01 - 0.02	<0.01 - 0.02
AP (Kg $CaCO_3$/tonne)	0.16 -16	0.63 - 38	644 - 1416	0.16 - 0.63	0.16 - 0.63
NP (Kg $CaCO_3$/tonne)	0.21 - 4.4	<0.1 - 1.2	<0.1	<0.1 - 1.2	0.73 - 1.2
NAG pH (s.u)	1.8 - 2.1	2.3 - 7.0	1.7 - 1.9	6	5.1 - 6.6
Classification	PAG	PAG	AG	NAF	NAF
	Supernatant quality				
pH$_{Lab}$ (s.u)	3.7	3.6	3.3	4.1	4.2
pH$_{Field}$ (s.u)	4.3-5.2	4.6-5.0	2.9-5.7	4.7-4.9	4.6-6.8
EC$_{Lab}$ (mS/m)	5.8	5	7.8	2.5	2.9
EC$_{Field}$ (mS/m)	3.1-4.0	2.9-3.7	5.2-5.7	3.3	0.6-3.4
Parameters exceeding limits (mg/l unless stated otherwise)	All parameters are within the SLEP (M&M) Regs 2013 limits except pH				
	pH (<6.2), EC (>0.98 mS/m), Al (>0.06), Ca (>2.0), Cu (>0.007), Mn (>0.015), Ni (>0.002) and SO_4 (>2.3) exceed the background surface water levels.				

The key findings of the geochemical study are as follows:

Mineralogy

The mineralogy of the primary process tailings consist of predominantly inert or resistant quartz that does not contribute to either acidity or alkalinity.

The reactive minerals in primary tailings include kaolinite [$Al_4(OH)_8(Si_4O_{10})$] and gibbsite ($Al(OH)_3$). Kaolinite occurs in all the analysed primary process tailings samples. Kaolinite is an aluminosilicate mineral that dissolves to some extent in ASS, and therefore acts as a neutralising agent in the tailings.

Gangama dry mining and Lanti dry mining tailings contain gibbsite ($Al(OH)_3$), a low solubility secondary mineral, which can also contribute to neutralisation potential.

Gibbsite does not occur in the Lanti dredge mine tailings in detectable quantities but occurs in detectable quantities in the Lanti dry mining tailings composite sample (LDMTC). The precipitation of gibbsite in the tailings was confirmed by running a PHREEQC check using 25% water extract data at a paste pH of 5.6.

The reactive minerals in secondary process tailings include marcasite and pyrite in SFT, goethite in TT and CET and almandine in CET, TT, IT and FET. Marcasite and pyrite are likely to contribute to acidity in SFT when exposed to oxidising conditions. Goethite, a pseudomorph of marcasite and pyrite may contribute to NP in TT and CET at pH range of 3.0 – 3.7. Almandine, a fast weathering aluminosilicate mineral, may contribute to the NP in CET, TT, IT and FET.

In addition, monazite, a radioactive phosphate mineral containing cerium, occurs in CET, FET, IT and TT.

Elemental composition

Total metal analysis was primarily carried out on tailings samples to identify any elements that are present at concentrations that may be of environmental concern with respect to water quality.

The appropriate media to compare the concentrations of the elements in the tailings is the total elemental concentration of the ore material from which the tailings are generated to determine enrichment relative to the ore given that there is no physical or chemical alteration of the materials. However, elemental concentration data of the ore material is unavailable and the elemental concentrations of the tailings have been compared to the average crustal abundance (Forstescue, 1992).

Elements that are significantly enriched (i.e. GAI ≥3) in the primary process tailings include silver (<0.40 – 0.81 mg/kg), boron (240 – 590 mg/kg), cadmium (0.78 – 1.4 mg/kg), and selenium (22 – 41 mg/kg).

Elements that are significantly enriched (i.e. GAI ≥3) in the secondary process tailings include silver (<0.40 – 28 mg/kg), boron (370 – 1 290 mg/kg), cadmium (<0.10 – 1.4 mg/kg), cobalt (16 – 443 mg/kg), lead (<0.10 – 194 mg/kg), selenium (<3.0 – 91 mg/kg), titanium (0.29 – 33%) and zirconium (114 – 4 000 mg/kg).

However, significant enrichment does not necessarily imply that the element represents an environmental risk although the enriched element in the tailings may leach into surface water and groundwater depending on site conditions. The risk that these enriched elements present is a function of the environmental mobility of the element, assessed by leach tests in the later sections of this report.

Acid generating characteristics

The primary process tailings are NAF. This is consistent with the mineralogy results that showed that there are no detectable sulfide minerals that could potentially generate acidity in the primary process tailings.

SFT are AG and have the potential to stay acidic in the long term if exposed to oxidizing conditions. This is consistent with the mineralogy results that indicated the presence of acid generating sulfide minerals, marcasite and pyrite. TT and IT also contain sulfides and are PAG. FET and CET are NAF

Leachate quality

The leachate and supernatant qualities are assessed against:

- Sierra Leone's Environmental Protection (Mines and Minerals) Regulations 2013 (SLEP(M&M) Regs 2013) "limit at any moment" effluent quality for mining and metallurgic operations; and
- Background surface water quality (average concentrations for July, August and October 2017) from surface water monitoring point SW6, located a distance away from the mining activities and representing the least affected surface water monitoring point within Area 1.

The leachates from primary process tailings are acidic ($\text{pH} < 5.9$) and characterised by low salinity ($\text{EC} < 3.3$ mS/m). All the measured parameters in the leachate are within the SLEP(M&M) Regs 2013 "limit at any moment" except pH. The parameters that exceed the background surface water levels in the leachate of the primary process tailings include the following:

- pH (<6.0), conductivity (>0.98 mS/m), aluminium (>0.02 mg/l), copper (>0.007 mg/l), manganese (>0.015 mg/l) and nickel (>0.002 mg/l) and sulfate (>2.3 mg/l); and
- Aluminium (>0.06 mg/l), chloride (>1.7 mg/l) and calcium (>2.0 mg/l), nitrate as N (>0.31 mg/l in Lanti tailings.

The leachates from secondary process tailings are acidic (pH <5.7) and characterised by low salinity ($\text{EC} < 7.8$ mS/m). All the measured parameters in the leachate are within the SLEP(M&M) Regs 2013 "limit at any moment" except pH. The parameters that exceed the background surface water levels in the leachate from the secondary process tailings include pH (<6.0), Al (>0.06 mg/l), Ca (>2.0 mg/l), Cu (>0.007 mg/l), Mn (>0.015 mg/l), Ni (>0.002 mg/l), SO_4 (>2.3 mg/l) and TDS (>35 mg/l).

Current findings relative to previous studies

The results of this study present a more detailed assessment of the current tailings streams at SR Area 1 than the preliminary investigations undertaken by Knight Piesold in 2001 and 2006 (Knight Piesold, March 10, 2008). While the previous studies used one sample each to conclude that TT and IT are inert, this study shows that TT and IT are PAG.

Consistent with the previous studies, the current study has confirmed that the primary process tailings, FET and CET are NAG, and SFT are AG.

The previous studies assessed tailings leachates quality against the WHO guidelines and indicated that Al, Mn, Ni, Cd and U exceeded the guideline limits. This study has assessed the current tailings leachate quality against SLEP (M&M) Regs 2013 "limit at any moment" effluent quality and background surface water levels. The new findings indicate that all the measured parameters in the leachate from both the primary and secondary process tailings are within the SLEP (M&M) Regs 2013 "limit at any moment" except pH. The parameters that exceed the background surface water levels in the leachate of the primary process tailings include pH, EC, Al, Ca, Cu, Mn, Ni, NO_3 as N and SO_4. The parameters that exceed the background surface water levels in the leachate from the secondary process tailings include pH, EC, Al, Ca, Cu, Mn, Ni and SO_4.

The implication of the findings of the geochemistry study are as follows:

- As the primary process tailings are currently slightly acidic to their slsightly acidic soil environment, but inherently NAF and non-saline, the bulk of this material is considered to be geochemically unreactive. Due to the low ASS/ML risk, no special ASS/ML management requirements are recommended except continuation with operational monitoring and testing to detect any unexpected changes that may occur during mining.
- Due to the elevated concentrations of Al, Ca, Cu, Mn, Ni, NO_3 as N and SO_4 in the leachate from the primary process tailings relative to background surface water levels it is recommended that these constituents be included in the site monitoring program.
- The secondary process tailings, specifically SFT, TT and IT, are PAG, acidic and non-saline and are likely to present a risk of increased acidity when exposed to oxidising conditions. These materials should continue to be deposited sub-aqueously as is currently done to limit exposure to oxygen. It is recommended that sufficient depth of water cover over the PAG tailings be ensured to prevent resuspension of tailings by wind or wave action to minimise exposure to potential oxidising conditions.
- The low pH of the tailings supernatant and seepage is likely to present a risk to the already slightly acidic environment and add to the overall acidity of the surface and groundwater system.
- Due to the elevated concentrations of Al, Ca, Cu, Mn, Ni and SO_4 in the leachate from the secondary process tailings relative to background surface water levels it is recommended that these constituents be included in the site monitoring program.

6 References

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Appendices

Appendix A: Laboratory Certificate of Analysis

Ref.No. :10358005

Issued at : Johannesburg
Date : 29/09/2017

COMPANY NAME :SRK CONSULTING
ADDRESS :P O BOX 55291 NORTHLANDS 2116
SUBJECT :ANALYSIS OF 27 SOLID SAMPLES
MARKED :SIERRA LEONE AND AS BELOW
INSTRUCTED BY :LEVI OCHIENG
ORDER NO. :
RECEIVED ON :23/08/2017
LAB NO(S) :E004561- E004588
DATE ANALYSED :26/08/2017

NET CARBONATE VALUE RESULTS

Analysis on the dry milled of composite samples

SAMPLE MARKS:	LAB NO:	Total Sulfur, S %	Sulfide, Sulfur as S %	AP (CaCO3),ppt	Total Carbon, %	Organic Carbon, %	NP(CaCO3),ppt	NCV (CaCO3),ppt
CET (OLD)	E004561	002	<0.01	<0.31	0.27	0.20	16.7	16.7
CET (WET)	E004562	0.02	0.02	0.62	0.40	0.34	28.3	27.7
TT (MOIST)	E004563	0.66	0.50	15.6	0.07	0.05	4.17	-11.4
VET (WET)	E004564	0.01	0.01	0.31	0.11	0.05	4.17	3.86
FET (WET)DUP	E004564	0.01	0.01	0.31	0.09	0.03	2.50	2.19
IT (DRY)	E004565	0.07	0.02	0.62	0.06	0.06	5.00	4.38
SFT (MOIST)	E004566	21.5	20.6	643	0.27	0.05	4.17	-639
GCT (MOIST)	E004567	0.04	0.02	0.62	0.11	0.09	7.50	6.88
GPTF (DRY)	E004568	0.02	<0.01	<0.31	0.06	0.01	0.83	0.83
LWPTC	E004569	0.04	0.01	0.31	0.05	0.02	1.67	1.36
LDMTC	E004570	0.03	0.02	0.62	0.06	0.03	2.50	1.88
LDMTC(DUP)	E004570	0.02	0.02	0.62	0.07	0.04	3.33	2.71
LFT (DM)	E004571	0.01	0.01	0.31	0.07	0.04	3.33	3.02
LCT (DM)	E004572	0.07	0.07	2.18	0.22	0.03	2.50	0.32

NET CARBONATE VALUE RESULTS

Analysis on the dry milled of composite samples

SAMPLE MARKS:	LAB NO:	Total Sulfur, S %	Sulfide, Sulfur as S %	AP (CaCO3),ppt	Total Carbon, %	Organic Carbon, %	NP(CaCO3),ppt	NCV (CaCO3),ppt
LCT (DM02)	E004573	0.06	0.06	1.87	0.20	0.05	0.83	-1.04
LCT (DM03	E004574	0.04	0.04	1.25	0.13	0.09	7.50	6.25
TT (F)02	E004575	1.47	1.47	45.9	0.16	0.12	10.00	-35.9
TT (F)01	E004576	0.04	0.04	1.25	0.16	0.08	6.66	5.41
IT (F)01	E004577	1.27	1.27	39.6	0.10	0.04	3.33	-36.3
IT (F)02	E004578	0.06	0.06	1.87	0.14	0.08	6.66	4.79
SFT01	E004579	40.3	40.3	1258	0.39	0.11	9.16	-1249
SFT02	E004580	45.7	45.7	1426	0.50	0.23	19.2	-1407
FET (F)02	E004581	0.03	0.03	0.94	0.02	0.02	1.67	0.73
FET (F)01	E004582	0.02	0.02	0.62	0.05	0.05	4.17	3.55
CET (F)02	E004583	0.02	0.02	0.62	0.05	0.02	1.67	1.05
CET (F)01	E004584	0.02	0.02	0.62	0.04	0.04	3.33	2.71
GPTF	E004585	0.05	0.03	0.94	0.14	0.03	2.50	1.56
LDOI	E004586	0.02	0.02	0.62	0.06	0.03	2.50	1.88
LDOI(DUP)	E004586	0.02	0.02	0.62	0.04	0.02	1.67	1.05
LWPT	E004588	0.04	0.04	1.25	0.06	0.06	5.00	3.75

The Sulfate content was determined by a Wet Chemical procedure.

Method Reference: METHOD E1915 – 07 (ASTM 2007)

COMPANY NAME :SRK CONSULTING
ADDRESS :P O BOX 55291 NORTHLANDS 2116
SUBJECT :ANALYSIS OF MINE WASTE SAMPLES
MARKED :SIERRA LEONE AND AS BELOW
INSTRUCTED BY :LEVI OCHIENG
ORDER NO. :
RECEIVED ON :23/07/2017
LAB NO(S) :E004557 + E004559, E004561 - E004588 + E004620 - E4624
DATE ANALYSED :05/09/2017

Analysis of composite samples on as received basis: LIQUID SAMPLES

LAB NO:	E004557	E004559
SAMPLE MARKS	G/T O/F & G/TANK/OF/ON	LAKE GRAY & LAKE GRAY (PROCESS WATER 02)
pH Value @ 23°C	5.4	4.3
Conductivity mS/m @ 25°C	1.91	1.7
Total Dissolved Solids	18	11
Calcium, Ca	0.9	1.0
Magnesium, Mg	0.6	0.4
Sodium, Na	1.3	1.3
Potassium K	0.4	0.6
Acidity as H+	-	0.04
Total Alkalinity as CaCO3	3	-
P Alkalinity as CaCO3	0	-
Bicarbonate,HCO3	4	-
Carbonate, CO3	0	-
Chloride ,Cl	0.5	0.6
Sulfate,SO4	2.9	6.8
Nitrate,NO3	0.6	0.1
Nitrate as N	0.1	<0.1
Fluoride, F	0.1	0.1
Nitrite as NO2	<0.1	<0.1
Hexavalent Chromium, Cr6+	<0.01	<0.01
Free Cyanide,CN	<0.01	<0.01
Total Cyanide, CN	<0.01	<0.01
Sum of Cations meq/ℓ	0.161	0.194
Sum of Anions meq/ℓ	0.149	0.165
% Error	4.376	7.383

The results are expressed in mg/l where applicable.

Analysis on an as received basis: SUPERNATANT LIQUID

LAB NO:	E004588	E004620	E004621	E004622	E004622
SAMPLE MARKS	LWPT	TT(F)02 & TT(F)01	IT(F)02 & IT(F)01	SFT01 & SFT02	SFT01 & SFT02 (DUP)
pH Value @ 23°C	3.7	3.7	3.6	3.3	3.3
Conductivity mS/m @ 25°C	3.2	5.8	5.0	7.8	7.1
Total Dissolved Solids	22	38	33	52	47
Calcium, Ca	2.0	2.7	1.9	1.4	1.4
Magnesium, Mg	0.5	0.67	0.7	0.5	0.5
Sodium, Na	1.3	2.0	1.7	8.9	8.4
Potassium,K	0.7	0.9	0.7	1.5	1.4
Acidity as H+	0.7	0.6	0.6	0.8	0.8
Chloride, Cl	0.8	1.2	0.7	0.7	0.6
Sulfate,SO4	35	28	25	38	34
Nitrate,NO3	<0.1	<0.1	<0.1	<0.1	<0.1
Nitrate as N	<0.1	<0.1	<0.1	<0.1	<0.1
Fluoride, F	0.1	0.2	0.2	0.3	0.3
Nitrite as NO2	<0.1	<0.1	<0.1	<0.1	<0.1
Sum of Cations meq/ℓ	0.297	0.522	0.461	0.675	0.623
Sum of Anions meq/ℓ	0.344	0.631	0.554	0.830	0.744
% Error	7.312	9.464	9.215	9.988	8.913

The results are expressed in mg/l where applicable.

Analysis on an as received basis: SUPERNATANT LIQUID:

LAB NO:	E004623	E004624
SAMPLE MARKS	FET(F)02 & FET(F)01	CET(F)02 & CET(F)01
pH Value @ 23°C	4.1	4.2
Conductivity mS/m @ 25°C	2.5	2.9
Total Dissolved Solids	17	19
Calcium, Ca	1.6	1.5
Magnesium, Mg	0.6	0.6
Sodium, Na	1.5	1.4
Potassium, K	0.6	0.6
Acidity as H+	0.04	0.12
Chloride, Cl	0.6	0.5
Sulfate,SO4	11.0	12.9
Nitrate,NO3	<0.1	<0.1
Nitrate as N	<0.1	<0.1
Fluoride, F	0.1	0.2
Nitrite as NO2	<0.1	<0.1
Sum of Cations meq/ℓ	0.288	0.354
Sum of Anions meq/ℓ	0.255	0.297
% Error	6.213	8.791

The results are expressed in mg/l where applicable.

LAB NO:	E004561	E004561	E004562
SAMPLE MARKS	CET (OLD)	CET (OLD) (DUP)	CET (WET)
pH Value @ 23°C	6.8	6.8	5.3
Conductivity mS/m @ 25°C	3.00	3.00	3.81
Total Dissolved Solids	18	20	20
Calcium, Ca	0.9	0.9	1.4
Magnesium, Mg	0.6	0.6	0.5
Sodium,Na	2.9	3.0	3.0
Potassium, K	0.9	0.8	1.0
Acidity as H+	-	-	-
Total Alkalinity as CaCO3	10	8	2
P Alkalinity as CaCO3	0	0	0
Bicarbonate,HCO3	10	10	2
Carbonate, CO3	0	0	0
Chloride, Cl	1.1	1.2	1.1
Sulfate,SO4	1.1	1.2	7.4
Nitrate,NO3	0.7	<0.1	0.9
Nitrate as N	0.2	<0.1	0.2
Fluoride, F	0.1	0.1	0.1
Nitrite as NO2	<0.1	<0.1	<0.1
Sum of Cations meq/ℓ	0.243	0.243	0.267
Sum of Anions meq/ℓ	0.270	0.235	0.245
% Error	-5.227	1.557	4.343

The results are expressed in mg/l where applicable.

LAB NO:	E004567	E004568	E004569
SAMPLE MARKS	GCT (MOIST)	GPTF (DRY)	LWPTC
pH Value @ 23°C	4.6	5.9	5.9
Conductivity mS/m @ 25°C	1.50	1.3	3.3
Total Dissolved Solids	10	9.0	22
Calcium, Ca	0.4	0.2	2.1
Magnesium, Mg	0.031	0.044	0.6
Sodium, Na	2.6	2.7	2.5
Potassium, K	0.4	0.5	1.0
Acidity as H+	-	-	-
Total Alkalinity as CaCO3	0	2	2
P Alkalinity as CaCO3	0	0	0
Bicarbonate,HCO3	1	2	2
Carbonate, CO3	0	0	0
Chloride, Cl	1.3	1.3	1.9
Sulfate,SO4	3.9	2.0	10
Nitrate,NO3	0.9	1.0	1.8
Nitrate as N	0.2	0.2	0.4
Fluoride, F	0.1	0.1	0.1
Nitrite as NO2	<0.1	<0.1	<0.1
Sum of Cations meq/ℓ	0.160	0.148	0.384
Sum of Anions meq/ℓ	0.137	0.150	0.345
% Error	7.601	1.013	4.901

LAB NO:	E004570	E004571	E004619
SAMPLE MARKS	LDMTC	LFT (DM)	LCT(DM,DM02 &DM03)
pH Value @ 23°C	4.1	5.9	5.6
Conductivity mS/m @ 25°C	1.70	1.41	1.61
Total Dissolved Solids	12	9.0	10
Calcium, Ca	0.6	0.1	0.3
Magnesium, Mg	0.2	0.05	0.1
Sodium, Na	0.8	2.7	2.8
Potassium, K	0.8	0.6	0.5
Acidity as H+	0.2	-	-
Total Alkalinity as CaCO3	0	1.0	1
P Alkalinity as CaCO3	0	0	0
Bicarbonate,HCO3	0	1.0	1
Carbonate, CO3	0	0	0
Chloride, Cl	2.3	1.3	1.5
Sulfate,SO4	5.1	2.0	2.7
Nitrate,NO3	0.7	1.8	<0.1
Nitrate as N	0.2	0.4	<0.1
Fluoride, F	0.2	0.1	0.0
Nitrite as NO2	<0.1	<0.1	<0.1
Sum of Cations meq/ℓ	0.179	0.143	0.156
Sum of Anions meq/ℓ	0.196	0.138	0.164
% Error	4.572	1.387	2.475

The results are expressed in mg/l where applicable.

The Analyses were carried out on 1% NAG Solutions of the dried and milled samples.

LAB NO:	E004561	E004562	E004563	E004565
SAMPLE MARKS	CET (OLD)	CET (WET)	TT (MOIST)	IT (DRY)
pH value @ 23°C(leach Solution)	6.4	6.4	3.1	6.3
Acidity as H+	-	-	8.3	-
Total Alkalinity as CaCO3	49	43	-	39
P Alkalinity as CaCO3	0	0	-	0
Bicarbonate,HCO3	60	52	-	48
Carbonate, CO3	0	0	-	0
Chloride, Cl	7.8	6.6	0	0
Sulfate,SO4	0.5	3.1	93	5.6
Nitrate,NO3	<0.1	<0.1	<0.1	<0.1
Nitrate as N	<0.1	<0.1	<0.1	<0.1
Fluoride, F	0.1	<0.1	0.4	<0.1
Nitrite as NO2	<0.1	<0.1	<0.1	<0.1

The results are expressed in mg/l where applicable.

The Analyses were carried out on 1% NAG Solutions of the dried and milled samples.

LAB NO:	E004566	E004567	E004568	E004569
SAMPLE MARKS	SFT (MOIST)	GCT (MOIST)	GPTF (DRY)	LWPTC
pH value @ 23°C(leach Solution)	2.3	6.4	6.5	2.8
Acidity as H+	117	-	-	12
Total Alkalinity as CaCO3	-	39	45	-
P Alkalinity as CaCO3	-	0	0	-
Bicarbonate,HCO3	-	48	55	-
Carbonate, CO3	-	0	0	-
Chloride, Cl	<1	<0.1	<0.1	<0.1
Sulfate,SO4	475	5.8	<0.2	2.8
Nitrate,NO3	12	<0.1	<0.1	<0.1
Nitrate as N	2.7	<0.1	<0.1	<0.1
Fluoride, F	<0.1	0.1	0.1	0.1
Nitrite as NO2	<0.1	<0.1	<0.1	<0.1

The results are expressed in mg/l where applicable.

The Analyses were carried out on 1% NAG Solutions of the dried and milled samples.

LAB NO:	E004570	E004571	E004586	E004588
SAMPLE MARKS	LDMTC	LFT (DM)	LD01	LWPT
pH value @ 23°C(leach Solution)	6.3	6.3	6.3	6.4
Total Alkalinity as CaCO3	40	50	44	46
P Alkalinity as CaCO3	0	0	0	0
Bicarbonate,HCO3	49	61	54	56
Carbonate, CO3	0	0	0	0
Chloride, Cl	<0.1	17.2	<0.1	5.5
Sulfate,SO4	3.0	2.7	1.5	2.2
Nitrate,NO3	<0.1	<0.1	<0.1	<0.1
Nitrate as N	<0.1	<0.1	<0.1	<0.1
Fluoride, F	<0.1	0.1	<0.1	0.2
Nitrite as NO2	<0.1	<0.1	<0.1	<0.1

The Analysis were carried out on 1% NAG Solutions of the dried and milled samples.

LAB NO:	E004619	E004620	E004621	E004622
SAMPLE MARKS	LCT(DM,DM02 &DM03)	TT(F)02 & TT(F)01	IT(F)02 & IT(F)01	SFT01 & SFT02
pH value @ 23°C(leach Solution)	6.3	3.0	3.1	2.1
Acidity as H+	-	4	7	214
Total Alkalinity as CaCO3	39	-	-	-
P Alkalinity as CaCO3	<1	-	-	-
Bicarbonate,HCO3	48	-	-	-
Carbonate, CO3	0	-	-	-
Chloride,Cl	<0.1	0.5	13.0	3.6
Sulfate,SO4	5.6	131	121	831
Nitrate,NO3	<0.1	10.0	<0.1	0.4
Nitrate as N	<0.1	2.3	<0.1	0.1
Fluoride,F	0.1	0.1	0.3	<0.1
Nitrite as NO2	<0.1	<0.1	<0.1	<0.1

The results are expressed in mg/l where applicable.

The Analyses were carried out on 1% NAG Solutions of the dried and milled samples.

LAB NO:	E004623	E004624
SAMPLE MARKS	FET(F)02 & FET(F)01	CET(F)02 & CET(F)01
pH value @ 23°C(leach Solution)	6.4	6.5
Total Alkalinity as CaCO3	46	46
P Alkalinity as CaCO3	0	0
Bicarbonate,HCO3	56	56
Carbonate, CO3	0	0
Chloride,Cl	4.0	<0.1
Sulfate,SO4	1.2	<0.2
Nitrate,NO3	<0.1	<0.1
Nitrate as N	<0.1	<0.1
Fluoride,F	<0.1	<0.1
Nitrite as NO2	<0.1	<0.1

The results are expressed in mg/l where applicable.

Method reference: A list Appended.

COMPANY NAME : SRK CONSULTING

ADDRESS : P O BOX 55291 NORTHLANDS 2116

SUBJECT : ANALYSIS OF 27 SOLID SAMPLES

MARKED : SIERRA LEONE AND AS BELOW

INSTRUCTED BY : LEVI OCHIENG

ORDER NO. :

RECEIVED ON : 23/08/2017

LAB NO(S) : E004561 – E004588

DATE ANALYSED : 26/08/2017

ACID-BASE ACCOUNTING

SAMPLE MARKS:	LAB NO:	Paste pH @25°C	Total Sulphur, S %	Sulfide, Sulphur as S %	Sulfate Sulphur, S (by calculation) %	Acidity Potential as $CaCO_3$ ppt	NP (CaCO3),ppt	Net Neutralisation Potential as $CaCO_3$ ppt (By Difference)
CET (OLD)	E004561	5.91	0.02	<0.01	0.02	0.62	0.97	0.35
CET (WET)	E004562	2.89	0.02	0.02	<0.01	0.62	0.73	0.11
TT (MOIST)	E004563	2.11	0.66	0.50	0.16	20.6	1.1	-19.5
FET (WET)	E004564	3.34	0.01	0.01	<0.01	0.31	<0.1	-0.31
FET (WET)DUP	E004564	3.30	0.01	0.01	<0.01	0.31	<0.1	-0.31
IT (DRY)	E004565	2.59	0.07	0.02	0.05	2.18	<0.1	-2.18
SFT (MOIST)	E004566	0.87	21.5	20.6	0.90	671	<0.1	-671
GCT (MOIST)	E004567	3.2	0.04	0.02	0.02	1.25	<0.1	-1.25
GPTF (DRY)	E004568	4.3	0.02	<0.01	0.02	0.62	1.21	0.59
LWPTC	E004569	4.75	0.04	0.01	0.03	1.25	1.21	-0.04
LDMTC	E004570	5.56	0.03	0.02	0.01	0.94	<0.1	-0.94

Analysis on the dry milled of composite samples

SAMPLE MARKS: ACID-BASE ACCOUNTING

SAMPLE MARKS:	LAB NO:	Paste pH @25°C	Total Sulphur, S %	Sulfide, Sulphur as S %	Sulfate Sulphur, S (by calculation) %	Acidity Potential as $CaCO_3$ ppt	NP (CaCO3),ppt	Net Neutralisation Potential as $CaCO_3$ ppt (By Difference)
LDMTC(DUP)	E004570	5.60	0.02	0.02	<0.01	0.62	<0.1	-0.62
LFT (DM)	E004571	4.29	0.01	<0.01	0.01	0.31	0.48	0.17
LCT (DM)	E004572	4.7	0.07	0.01	0.06	2.18	1.21	-0.97
LCT (DM02)	E004573	5.12	0.06	0.05	0.01	1.87	2.91	1.04
LCT (DM03	E004574	5.11	0.04	<0.01	0.04	1.25	1.21	-0.04
TT (F)02	E004575	2.49	1.47	<0.01	1.47	45.9	0.21	-45.7
TT (F)01	E004576	3.28	0.04	<0.01	0.04	1.25	4.36	3.11
IT (F)01	E004577	2.32	1.27	1.20	0.07	39.6	<0.1	-39.6
IT (F)02	E004578	3.39	0.06	0.06	<0.01	1.87	1.21	-0.66
SFT01	E004579	1.9	40.3	39.6	0.07	1258	<0.1	-1258
SFT02	E004580	2.08	45.7	45.3	0.40	1426	<0.1	-1426
FET (F)02	E004581	3.83	0.03	<0.01	0.03	0.94	1.21	0.27
FET (F)01	E004582	3.71	0.02	0.02	<0.01	0.62	1.21	0.59
CET (F)02	E004583	4.43	0.02	0.02	<0.01	0.62	1.21	0.59
CET (F)01	E004584	3.68	0.02	0.02	<0.01	0.62	1.21	0.59
GPTF	E004585	3.74	0.05	0.03	0.02	1.56	0.97	-0.59
LDOI	E004586	3.62	0.02	0.02	<0.01	0.62	0.97	0.35
LDOI(DUP)	E004586	3.65	0.02	0.02	<0.01	0.62	1.20	0.58
LWPT	E004588	2.94	0.04	0.04	<0.01	1.25	<0.1	-1.25

Method Reference:

Lawrence, R.W., Polling, G.P. and Marchant, P.B., 1989. Investigation of predictive techniques or acid mine drainage, Report on DSS Contract No. 23440-7-9178/01-SQ,

Energy Mines and Resources, Canada, MEND Report 1.16.1(a).

Sobek, A.A., Schuller, W.A., Freeman, J.R. and Smith, R.M., 1978. 2Field and Laboratory Methods

Applicable to Overburden and Mine soils, EPA 600/2-78-054, 203 pp. The Sulphate content was determined by a Wet Chemical procedure

Analysis on the crushed and milled samples:

SAMPLE MARKS:	LAB NO:	NAG pH @25°C	NET ACID GENERATION AS H_2SO Kg/tonne
CET (OLD)	E004561	6.6	<1
CET (WET)	E004562	5.9	<1
TT (MOIST)	E004563	1.8	9.5
IT (DRY)	E004565	7.0	<1
SFT (MOIST)	E004566	1.9	520
GCT (MOIST)	E004567	5.8	<1
GPTF (DRY)	E004568	5.8	<1
LWPTC	E004569	5.1	<1
LDMTC	E004570	5.9	<1
LFT (DM)	E004571	6.0	<1
LDOI	E004586	5.2	<1
LWPT	E004588	5.5	<1
(LCT(DM), LCT(02) & LCT(DM03)	E004619	5.5	<1
TT(F)02&TT(F)01	E004620	2.1	10.5
IT(F)02 & IT(02)01	E004621	2.3	9.20
SFT01 & SFT02	E004622	1.7	966
FET(F)02 & FET(F)01	E004623	6.0	<1
CET(F)02 & CET(F)01	E004624	5.1	<1

Method Reference:

Miller, S., Robertson, A. and Donohue, T. (1997). Advances in Acid Drainage Prediction using The Net Acid Generation (NAG) Test. Report on Acid Mine Drainage published in Vancouver, BC. Canada

COMPANY NAME : SRK CONSULTING
ADDRESS : P O BOX 55291 NORTHLANDS 2116
SUBJECT : ANALYSIS OF 18 SOLID SAMPLES
MARKED : GOVERNMENT OF SIERRA LEONE AND AS BELOW
INSTRUCTED BY : LEVI OCHIENG
ORDER NO. :
RECEIVED ON :23/08/2017
LAB NO(S) : AS BELOW
DATE ANALYSED : 01/09/2017

ANALYSIS: Qualitative and Quantitative XRD (mineralogy)

The samples were prepared according to the standardized Panalytical backloading system, which provides nearly random distribution of the particles.
The samples were analyzed using a PANalytical X'Pert Pro powder diffractometer in θ–θ configuration with an X'Celerator detector and variable divergence- and fixed receiving slits with Fe filtered Co-Kα radiation (λ=1.789Å). The phases were identified using X'Pert Highscore plus software.
The relative phase amounts (weight%) were estimated using the Rietveld method (Autoquan Program). The quantitative results are listed below.

- Mineral names may not reflect the actual compositions of minerals identified, but rather the mineral group.

Traces of minor phases may be present

Quantitative Results:

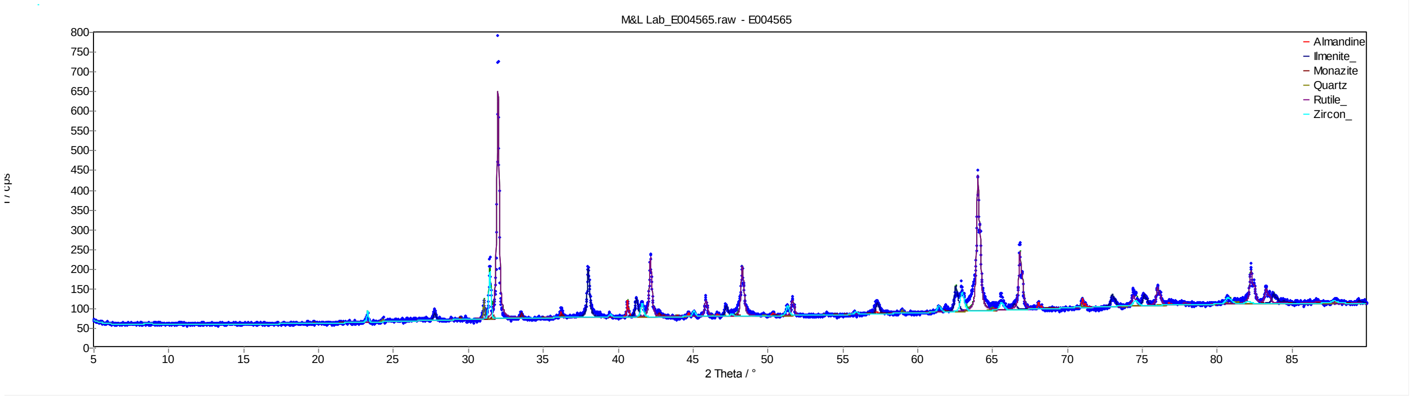
E004561 CET (OLD)		E004562 CET (WET)		E004563 TT (MOIST)		E004565 IT (DRY)	
	weight%		weight%		weight%		weight%
Almandine	56.16	Almandine	22.98	Goethite	2.43	Almandine	4.88
Goethite	2.51	Corundum	4.88	Quartz	89.8	Ilmenite	22.6
Hematite	2.57	Goethite	1.49	Rutile	6.97	Monazite	1.51
Kyanite	3.86	Kyanite	12.13	Zircon	0.81	Quartz	2.88
Monazite	4.48	Quartz	39.03			Rutile	60.54
Quartz	11.96	Rutile	5.44				
Rutile	5.53	Zircon	14.04				
Zircon	12.94						

E004566 SFT (MOIST)		E004567 GCT (MOIST)		E004568 GPTF (DRY)		E004569 LWPTC	
	weight%		weight%		weight%		weight%
Marcasite	13.27	Gibbsite	1.54	Gibbsite	1.09	Kaolinite	1.21
Pyrite	32.91	Kaolinite	15.29	Kaolinite	5.98	Quartz	98.79
Quartz	40.78	Quartz	83.17	Quartz	92.94		
Rutile	10.14						
Zircon	2.91						

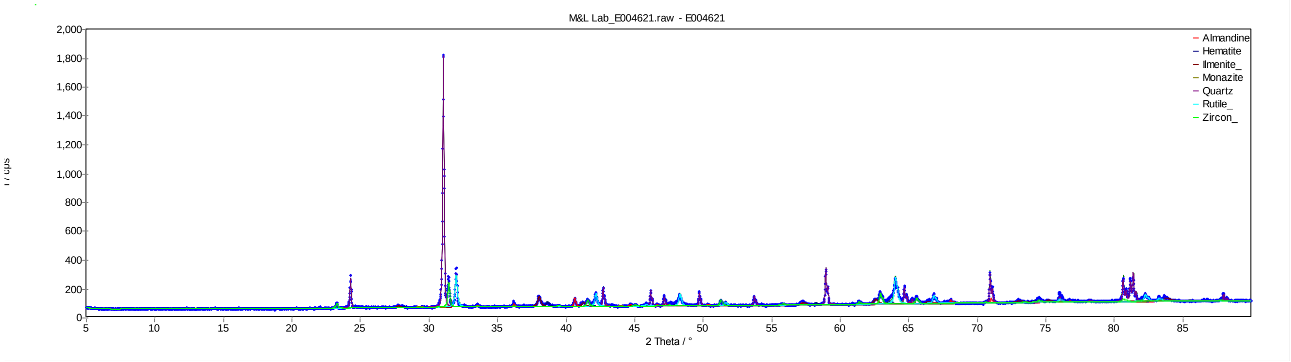
E004570 LDMTC		E004571 LFT (DM)		E004586 LD01		E004588 LWPT	
	weight%		weight%		weight%		weight%
Gibbsite	0.85	Kaolinite	3.53	Kaolinite	7.07	Kaolinite	2.85
Kaolinite	3.97	Quartz	96.47	Quartz	92.93	Quartz	97.15
Quartz	95.18						

E004619 LCT (DM, DM02 & DM03)		E004620 TT (F) 02 &01		E004621 IT (F) 02 & 01		E004622 SFT (01 & 02)	
	weight%		weight%		weight%		weight%
Gibbsite	4.02	Almandine	6.97	Almandine	4.41	Marcasite	22.53
Hematite	5.02	Goethite	3.9	Hematite	4.47	Pyrite	57.75
Kaolinite	25.83	Hematite	5.04	Ilmenite	10.36	Quartz	12.44
Quartz	65.13	Ilmenite	11.99	Monazite	1.01	Rutile	6.34
		Kyanite	2.94	Quartz	57.18	Zircon	0.94
		Monazite	0.89	Rutile	17.34		
		Quartz	43.4	Zircon	5.22		
		Rutile	19.14				
		Zircon	5.73				

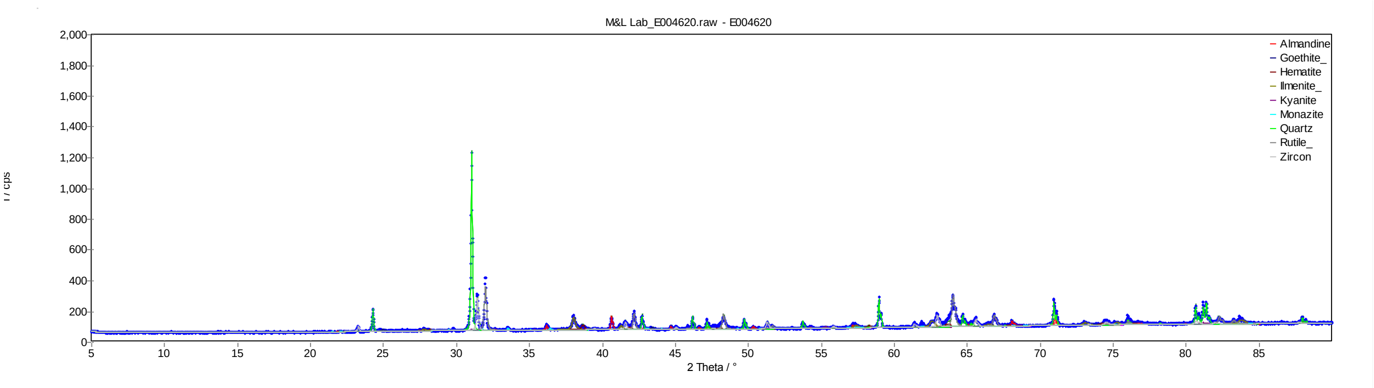
E004623 FET (F) 02 & 01		E004624 CET (F) 02 & 01	
	weight%		weight%
Almandine	3.32	Almandine	21.91
Corundum	2.35	Corundum	3.13
Monazite	2.74	Kyanite	7.77
Quartz	51.73	Monazite	5.3
Rutile	9.64	Quartz	4.2
Zircon	30.21	Rutile	9.58
		Zircon	48.12



Purple high intensity peak = Rutile
Blue smaller intensity peak = ilmenite



Turquoise higher peak = rutile
Brown small peak = ilmenite



Ideal Mineral Composition:

Almandine	Fe3 Al2 Si3 O12	Marcasite	FeS2
Corundum	Al2O3	Monazite	CePO4
Gibbsite	Al(OH)3	Pyrite	FeS2
Goethite	FeOOH	Quartz	SiO2
Hematite	Fe2O3	Rutile	TiO2
Kyanite	Al2SiO5	Zircon	ZrSiO4

Note: The results were supplied by a Sub Contracted Laboratory

COMPANY NAME : SRK CONSULTING
ADDRESS : P.O BOX
SUBJECT : ANALYSIS OF 27 SAMPLES OF SOLID
MARKED : AS BELOW
INSTRUCTED BY : LEVI OCHIENG
ORDER NO. :
DATE RECEIVED : 28.08.2017
DATE ANALYSED : 05.09.2017
LAB NUMBERS : E004561 – E004588

The analysis was carried on an ACID DISSOLUTION of the sample as received:

Lab number	E004561	E004561	E004562	E004563	E004564
Sample marks	CET(OLD)	CET(OLD) DUP	CET(WET)	TT(DRY)	FET(WET)
Silver, Ag	5.2	4.8	11.3	1.3	4.8
Aluminium, Al	41570	38980	12560	4431	3379
Arsenic, As	<2.0	<2.0	<2.0	<2.0	<2.0
Boron, B	783	678	610	510	372
Barium, Ba	0.73	0.73	2.4	14.8	7.9
Beryllium, Be	<0.20	<0.20	<0.20	<0.20	<0.20
Bismuth, Bi	<0.50	<0.50	<0.50	<0.50	<0.50
Cadmium, Cd	0.20	0.10	0.59	1.0	1.4
Cobalt, Co	46	46	37	64	15.7
Total Chromium, Cr	374	382	261	246	64
Copper, Cu	<0.20	<0.20	2.4	15.0	7.4
Iron, Fe	17.10 %	17.3%	7.34 %	4.36 %	10370
Mercury, Hg	<0.10	<0.10	<0.10	<0.10	<0.10
Manganese, Mn	1743	1568	984	187	113
Molybdenum, Mo	<0.10	<0.10	<0.10	1.7	1.6
Nickel, Ni	9.3	9.4	7.9	16.9	9.1
Phosphorus, P	3856	4411	1426	117	219
Lead, Pb	167	145	67	10.1	27
Antimony, Sb	<1.0	<1.0	<1.0	<1.0	<1.0
Selenium, Se	<3.0	<3.0	33	<3.0	36
Tin, Sn	5.4	4.8	<2.0	<2.0	<2.0
Strontium, Sr	<0.10	<0.10	0.46	4.0	1.6
Thorium, Th	<0.20	<0.20	<0.20	<0.20	<0.20
Titanium, Ti	2922	3055	7491	2.69 %	5352
Thallium, Tl	<0.90	<0.90	<0.90	<0.90	<0.90
Uranium, U	<0.40	<0.40	<0.40	<0.40	<0.40
Vanadium, V	185	191	129	200	48
Zinc, Zn	152	155	103	30	24
Zirconium, Zr	1034	1099	1697	202	512
Calcium, Ca	6252	6594	1972	341	451
Potassium, K	78	82	214	166	208
Magnesium, Mg	4096	4136	1029	181	970
Sodium, Na	243	238	509	433	408

- The results are expressed in mg/kg unless stated otherwise.
- Method: Quantitative ICP scan.

The analysis was carried on an ACID DISSOLUTION of the sample as received:

Lab number	E004565	E004566	E004567	E004568
Sample marks	IT(DRY)	SFT(DRY)	GCT(MOIST)	GPTF(DRY)
Silver, Ag	1.1	1.9	<0.40	<0.40
Aluminium, Al	3547	4831	6.81 %	18340
Arsenic, As	<2.0	<2.0	<2.0	<2.0
Boron, B	787	1054	318	302
Barium, Ba	7.0	23	22	9.7
Beryllium, Be	<0.20	<0.20	<0.20	<0.20
Bismuth, Bi	<0.50	<0.50	<0.50	<0.50
Cadmium, Cd	<0.10	<0.10	1.1	1.2
Cobalt, Co	380	174	8.7	10.2
Total Chromium, Cr	853	223	401	167
Copper, Cu	51	288	14.6	7.4
Iron, Fe	16.41 %	30.22 %	24940	18190
Mercury, Hg	<0.10	<0.10	<0.10	<0.10
Manganese, Mn	1174	534	28	33
Molybdenum, Mo	0.16	3.9	1.5	1.2
Nickel, Ni	42	294	31	14.7
Phosphorus, P	1437	223	107	83
Lead, Pb	<1.0	50	19.6	19.6
Antimony, Sb	<1.0	<1.0	<1.0	<1.0
Selenium, Se	40	91	22	29
Tin, Sn	<2.0	<2.0	<2.0	<2.0
Strontium, Sr	<0.10	0.23	15.7	6.0
Thorium, Th	<0.20	<0.20	<0.20	<0.20
Titanium, Ti	21.89 %	3.71 %	2434	3294
Thallium, Tl	<0.90	<0.90	<0.90	<0.90
Uranium, U	<0.40	<0.40	<0.40	<0.40
Vanadium, V	847	253	110	79
Zinc, Zn	149	162	7.9	6.5
Zirconium, Zr	431	542	23	21
Calcium, Ca	658	319	171	209
Potassium, K	165	124	190	212
Magnesium, Mg	734	689	99	134
Sodium, Na	412	344	443	480

- The results are expressed in mg/kg unless stated otherwise.
- Method: Quantitative ICP scan.

The analysis was carried on an ACID DISSOLUTION of the sample as received:

Lab number	E004569	E004570	E004571	E004572
Sample marks	LWPTC	LDMTC	LFT(DM)	LCT(DM)
Silver, Ag	0.52	0.50	<0.40	<0.40
Aluminium, Al	4142	12760	12070	9.60 %
Arsenic, As	<2.0	<2.0	<2.0	<2.0
Boron, B	332	269	248	466
Barium, Ba	5.2	9.4	10.2	38
Beryllium, Be	<0.20	<0.20	<0.20	<0.20
Bismuth, Bi	<0.50	<0.50	<0.50	<0.50
Cadmium, Cd	1.4	1.2	1.2	0.78
Cobalt, Co	3.1	5.3	3.7	11.7
Total Chromium, Cr	21	88	34	222
Copper, Cu	3.4	6.9	7.4	15.2
Iron, Fe	4581	10180	6844	11.19 %
Mercury, Hg	<0.10	<0.10	<0.10	<0.10
Manganese, Mn	17.9	23	21	42
Molybdenum, Mo	1.2	1.0	0.97	1.07
Nickel, Ni	7.8	12.2	9.8	25
Phosphorus, P	42	63	51	338
Lead, Pb	22	19.6	19.8	22
Antimony, Sb	<1.0	<1.0	<1.0	<1.0
Selenium, Se	28	26	25	26
Tin, Sn	<2.0	<2.0	<2.0	<2.0
Strontium, Sr	2.1	4.9	4.3	15.3
Thorium, Th	<0.20	<0.20	<0.20	<0.20
Titanium, Ti	441	1459	794	3421
Thallium, Tl	<0.90	<0.90	<0.90	<0.90
Uranium, U	<0.40	<0.40	<0.40	<0.40
Vanadium, V	13.6	41	22	197
Zinc, Zn	3.9	5.5	3.9	19.9
Zirconium, Zr	31	40	25	86
Calcium, Ca	128	159	183	223
Potassium, K	129	196	262	729
Magnesium, Mg	81	92	104	138
Sodium, Na	355	414	437	578

- The results are expressed in mg/kg unless stated otherwise.
- Method: Quantitative ICP scan.

The analysis was carried on an ACID DISSOLUTION of the sample as received:

Lab number	E004573	E004573	E004574	E004575	E004576
Sample marks	LCT(DM02)	LCT(DM02) DUP	LCT(DM03)	TT(F) 02	TT(F) 01
Silver, Ag	<0.40	<0.40	5.2	8.9	0.58
Aluminium, Al	10.55 %	9.45%	7.40 %	5380	6793
Arsenic, As	<2.0	<2.0	<2.0	<2.0	<2.0
Boron, B	591	589	392	522	838
Barium, Ba	35	36	28	15.4	6.3
Beryllium, Be	<0.20	<0.20	<0.20	<0.20	<0.20
Bismuth, Bi	<0.50	<0.50	<0.50	<0.50	<0.50
Cadmium, Cd	0.79	0.80	0.96	0.50	<0.10
Cobalt, Co	10.7	10.8	8.2	101	443
Total Chromium, Cr	273	272	200	412	993
Copper, Cu	1.1	0.83	4.9	23	73
Iron, Fe	14.38 %	14.3%	6.05 %	7.83 %	25.23 %
Mercury, Hg	<0.10	<0.10	<0.10	<0.10	<0.10
Manganese, Mn	40	41	32	211	1489
Molybdenum, Mo	1.4	1.6	2.0	0.56	<0.10
Nickel, Ni	22	22	20	21	49
Phosphorus, P	338	333	263	131	2439
Lead, Pb	22	23	19.0	<1.0	<1.0
Antimony, Sb	<1.0	<1.0	<1.0	<1.0	<1.0
Selenium, Se	41	37	24	22	31
Tin, Sn	<2.0	<2.0	<2.0	<2.0	<2.0
Strontium, Sr	16.9	16.9	15.2	2.9	<0.10
Thorium, Th	<0.20	<0.20	<0.20	<0.20	<0.20
Titanium, Ti	3094	3101	2467	5.03 %	33.41 %
Thallium, Tl	<0.90	<0.90	<0.90	<0.90	<0.90
Uranium, U	<0.40	<0.40	<0.40	<0.40	<0.40
Vanadium, V	235	235	169	330	1025
Zinc, Zn	19.1	18.5	15.4	49	175
Zirconium, Zr	79	77	60	128	364
Calcium, Ca	267	252	457	314	1491
Potassium, K	643	636	470	177	185
Magnesium, Mg	198	208	192	470	1508
Sodium, Na	621	611	491	486	487

- The results are expressed in mg/kg unless stated otherwise.
- Method: Quantitative ICP scan.

The analysis was carried on an ACID DISSOLUTION of the sample as received:

Lab number	E004577	E004578	E004579	E004580
Sample marks	IT(F) 01	IT(F) 02	SFT01	SFT02
Silver, Ag	1.3	0.69	<0.40	<0.40
Aluminium, Al	5408	6195	3475	3813
Arsenic, As	<2.0	<2.0	<2.0	<2.0
Boron, B	493	752	1262	1293
Barium, Ba	13.4	6.0	12.9	11.9
Beryllium, Be	<0.20	<0.20	<0.20	<0.20
Bismuth, Bi	<0.50	<0.50	<0.50	<0.50
Cadmium, Cd	0.69	<0.10	<0.10	<0.10
Cobalt, Co	83	405	131	127
Total Chromium, Cr	376	878	183	165
Copper, Cu	128	48	208	251
Iron, Fe	6.48 %	21.46 %	45.65 %	46.06 %
Mercury, Hg	<0.10	<0.10	<0.10	<0.10
Manganese, Mn	176	1306	482	463
Molybdenum, Mo	1.2	<0.10	6.2	5.3
Nickel, Ni	19.5	46	156	165
Phosphorus, P	123	2599	127	122
Lead, Pb	<1.0	13.8	74	85
Antimony, Sb	<1.0	<1.0	<1.0	<1.0
Selenium, Se	26	18.4	83	87
Tin, Sn	<2.0	<2.0	<2.0	<2.0
Strontium, Sr	3.6	<0.10	<0.10	<0.10
Thorium, Th	<0.20	<0.20	<0.20	<0.20
Titanium, Ti	3.91 %	33.46 %	3.75 %	3.27 %
Thallium, Tl	<0.90	<0.90	<0.90	<0.90
Uranium, U	<0.40	<0.40	<0.40	<0.40
Vanadium, V	272	912	232	210
Zinc, Zn	39	155	121	180
Zirconium, Zr	114	316	151	141
Calcium, Ca	379	1153	232	214
Potassium, K	193	264	122	122
Magnesium, Mg	228	1545	497	402
Sodium, Na	496	566	150	455

- The results are expressed in mg/kg unless stated otherwise.
- Method: Quantitative ICP scan.

The analysis was carried on an ACID DISSOLUTION of the sample as received:

Lab number	E004581	E004582	E004583	E004584
Sample marks	FET(F)02	FET(F)01	CET(F)02	CET(F)01
Silver, Ag	22	28	9.6	14.01
Aluminium, Al	3165	6243	8305	8473
Arsenic, As	<2.0	<2.0	<2.0	<2.0
Boron, B	402	415	375	489
Barium, Ba	1.1	<0.10	0.42	0.34
Beryllium, Be	<0.20	<0.20	<0.20	<0.20
Bismuth, Bi	<0.50	<0.50	<0.50	<0.50
Cadmium, Cd	0.53	0.30	0.15	0.15
Cobalt, Co	31	39	26	32
Total Chromium, Cr	99	139	160	178
Copper, Cu	97	13.4	3.9	2.9
Iron, Fe	15290	18530	4.69 %	5.08 %
Mercury, Hg	<0.10	<0.10	<0.10	<0.10
Manganese, Mn	197	230	474	499
Molybdenum, Mo	0.35	4.0	<0.10	<0.10
Nickel, Ni	6.5	7.3	4.6	5.1
Phosphorus, P	3298	3830	4655	4783
Lead, Pb	134	132	186	194
Antimony, Sb	<1.0	<1.0	<1.0	<1.0
Selenium, Se	17.0	31	6.4	13.2
Tin, Sn	<2.0	<2.0	<2.0	<2.0
Strontium, Sr	0.35	<0.10	<0.10	<0.10
Thorium, Th	<0.20	<0.20	<0.20	<0.20
Titanium, Ti	1.33 %	17890	6083	9896
Thallium, Tl	<0.90	<0.90	<0.90	<0.90
Uranium, U	<0.40	<0.40	<0.40	<0.40
Vanadium, V	85	115	91	109
Zinc, Zn	65	87	52	62
Zirconium, Zr	3997	3197	1350	2317
Calcium, Ca	509	327	1306	1020
Potassium, K	124	41	149	127
Magnesium, Mg	237	2685	1522	1033
Sodium, Na	333	178	382	310

- The results are expressed in mg/kg unless stated otherwise.
- Method: Quantitative ICP scan.

The analysis was carried on an ACID DISSOLUTION of the sample as received:

Lab number	E004585	E004586	E004588	E004588
Sample marks	GPTF	LDD1	LWPT	LWPT DUP
Silver, Ag	0.62	0.91	0.81	0.71
Aluminium, Al	7.53 %	17560	7953	8037
Arsenic, As	<2.0	<2.0	<2.0	<2.0
Boron, B	282	244	240	236
Barium, Ba	14.2	14.4	6.6	6.5
Beryllium, Be	<0.20	<0.20	<0.20	<0.20
Bismuth, Bi	<0.50	<0.50	<0.50	<0.50
Cadmium, Cd	1.1	1.4	1.4	1.4
Cobalt, Co	6.5	4.6	3.7	3.8
Total Chromium, Cr	409	31	27	27
Copper, Cu	21	5.8	5.4	4.8
Iron, Fe	15370	8831	7284	7355
Mercury, Hg	<0.10	<0.10	<0.10	<0.10
Manganese, Mn	24	32	26	26
Molybdenum, Mo	1.2	1.3	0.99	0.94
Nickel, Ni	37	9.0	9.0	9.0
Phosphorus, P	88	52	53	53
Lead, Pb	17.5	22	22	22
Antimony, Sb	<1.0	<1.0	<1.0	<1.0
Selenium, Se	23	24	26	28
Tin, Sn	<2.0	<2.0	<2.0	<2.0
Strontium, Sr	9.5	5.9	3.1	3.2
Thorium, Th	<0.20	<0.20	<0.20	<0.20
Titanium, Ti	1649	1143	827	849
Thallium, Tl	<0.90	<0.90	<0.90	<0.90
Uranium, U	<0.40	<0.40	<0.40	<0.40
Vanadium, V	135	16.9	18.6	18.6
Zinc, Zn	8.6	5.6	4.7	4.2
Zirconium, Zr	27	72	57	59
Calcium, Ca	195	179	175	166
Potassium, K	222	280	191	207
Magnesium, Mg	95	86	68	69
Sodium, Na	394	381	390	407

- The results are expressed in mg/kg unless stated otherwise.
- Method: Quantitative ICP scan.

COMPANY NAME : SRK CONSULTING
ADDRESS : P.O BOX 55291, NORTHLANDS, 2116
SUBJECT : ANALYSIS OF 18 SAMPLES OF SOLID
MARKED : AS BELOW
INSTRUCTED BY : LEVI OCHIENG
ORDER NO. :
DATE RECEIVED : 28.08.2017
DATE ANALYSED : 05.09.2017
LAB NUMBERS : E004561 – E00

The analysis was carried on an NAG LEACH of the sample as received:

Lab number	E004561	E004562	E004563
Sample marks	CET(OLD)	CET(WET)	TT(DRY)
Silver, Ag	<0.40	<0.40	<0.40
Aluminium, Al	37	43	106
Arsenic, As	<2.0	<2.0	<2.0
Boron, B	16.3	10.7	16.0
Barium, Ba	2.1	1.9	38
Beryllium, Be	<0.20	<0.20	<0.20
Bismuth, Bi	<0.50	<0.50	<0.50
Cadmium, Cd	0.27	0.15	0.19
Cobalt, Co	<0.10	<0.10	0.95
Total Chromium, Cr	1.4	1.9	3.8
Copper, Cu	1.2	1.1	4.4
Iron, Fe	488	81	340
Mercury, Hg	<0.10	<0.10	<0.10
Manganese, Mn	3.2	0.38	3.1
Molybdenum, Mo	2.0	0.76	0.59
Nickel, Ni	<0.30	<0.30	3.5
Phosphorus, P	175	197	4.6
Lead, Pb	1.3	<1.0	<1.0
Antimony, Sb	<1.0	<1.0	<1.0
Selenium, Se	<3.0	<3.0	<3.0
Tin, Sn	<2.0	<2.0	<2.0
Strontium, Sr	<.0.10	0.13	0.48
Thorium, Th	<0.20	<0.20	<0.20
Titanium, Ti	12.8	42	2.2
Thallium, Tl	<0.90	<0.90	<0.90
Uranium, U	<0.40	<0.40	<0.40
Vanadium, V	3.0	2.9	5.3
Zinc, Zn	1.8	0.76	14.1
Zirconium, Zr	5.5	14.3	<0.10
Calcium, Ca	22	35	119
Potassium, K	94	75	111
Magnesium, Mg	14.1	14.1	32
Sodium, Na	3181	3191	3503

- The results are expressed in mg/kg.
- Method: Quantitative ICP scan.

The analysis was carried on an NAG LEACH of the sample as received:

Lab number	E004565	E004566	E004567	E004568
Sample marks	IT(DRY)	SFT(DRY)	GCT(MOIST)	GPTF(DRY)
Silver, Ag	<0.40	<0.40	<0.40	<0.40
Aluminium, Al	41	456	82	104
Arsenic, As	<2.0	<2.0	<2.0	<2.0
Boron, B	9.8	140	8.3	8.3
Barium, Ba	1.5	79	1.3	2.2
Beryllium, Be	<0.20	<0.20	<0.20	<0.20
Bismuth, Bi	<0.50	<0.50	<0.50	<0.50
Cadmium, Cd	0.22	0.87	0.27	0.24
Cobalt, Co	0.71	46	<0.10	<0.10
Total Chromium, Cr	10.2	15.7	7.3	3.4
Copper, Cu	1.2	134	1.6	10.6
Iron, Fe	211	30440	22	65
Mercury, Hg	<0.10	<0.10	<0.10	<0.10
Manganese, Mn	1.5	79	0.10	2.8
Molybdenum, Mo	0.29	3.3	0.22	0.21
Nickel, Ni	<0.30	149	<0.30	<0.30
Phosphorus, P	190	118	137	179
Lead, Pb	<1.0	13.7	<1.0	<1.0
Antimony, Sb	<1.0	<1.0	<1.0	<1.0
Selenium, Se	<3.0	26	<3.0	<3.0
Tin, Sn	<2.0	<2.0	<2.0	<2.0
Strontium, Sr	<0.10	5.4	<0.10	<0.10
Thorium, Th	<0.20	<0.20	<0.20	<0.20
Titanium, Ti	312	41	3.9	4.8
Thallium, Tl	<0.90	<0.90	<0.90	<0.90
Uranium, U	<0.40	<0.40	<0.40	<0.40
Vanadium, V	12.0	27	4.5	3.9
Zinc, Zn	1.6	72	0.99	1.4
Zirconium, Zr	2.0	<0.10	<0.10	<0.10
Calcium, Ca	15.6	927	16.0	14.2
Potassium, K	87	473	89	89
Magnesium, Mg	8.7	203	3.0	3.1
Sodium, Na	3144	22330	3036	3172

- The results are expressed in mg/kg.
- Method: Quantitative ICP scan.

The analysis was carried on an NAG LEACH of the sample as received:

Lab number	E004569	E004570	E004571
Sample marks	LWPTC	LDMTC	LFT(DM)
Silver, Ag	<0.40	<0.40	<0.40
Aluminium, Al	24	108	126
Arsenic, As	<2.0	<2.0	<2.0
Boron, B	8.4	4.4	3.0
Barium, Ba	11.6	1.1	2.5
Beryllium, Be	<0.20	<0.20	<0.20
Bismuth, Bi	<0.50	<0.50	<0.50
Cadmium, Cd	0.42	0.40	0.54
Cobalt, Co	0.30	0.28	0.29
Total Chromium, Cr	1.2	3.1	1.8
Copper, Cu	1.3	2.1	1.3
Iron, Fe	15.5	67	40
Mercury, Hg	<0.10	<0.10	<0.10
Manganese, Mn	0.81	0.47	0.43
Molybdenum, Mo	0.26	0.22	0.19
Nickel, Ni	0.42	<0.30	<0.30
Phosphorus, P	167	178	177
Lead, Pb	<1.0	<1.0	<1.0
Antimony, Sb	<1.0	<1.0	<1.0
Selenium, Se	<3.0	<3.0	<3.0
Tin, Sn	<2.0	<2.0	<2.0
Strontium, Sr	0.24	0.21	0.57
Thorium, Th	<0.20	<0.20	<0.20
Titanium, Ti	12.0	6.6	7.6
Thallium, Tl	<0.90	<0.90	<0.90
Uranium, U	<0.40	<0.40	<0.40
Vanadium, V	2.6	4.2	3.2
Zinc, Zn	5.2	0.84	0.92
Zirconium, Zr	<0.10	0.11	0.33
Calcium, Ca	67	23	54
Potassium, K	85	81	90
Magnesium, Mg	15.6	8.6	14.0
Sodium, Na	3334	3343	3274

- The results are expressed in mg/kg.
- Method: Quantitative ICP scan.

The analysis was carried on an NAG LEACH of the sample as received:

Lab number	E004588	E004619	E004620	E004621
Sample marks	LWPT	LCT(DM,DM02 &DM03)	TT(F)02 & TT(F)01	IT(F)02 & IT(F)01
Silver, Ag	<0.40	<0.40	<0.40	<0.40
Aluminium, Al	97	105	151	207
Arsenic, As	<2.0	<2.0	<2.0	<2.0
Boron, B	3.2	3.5	6.7	2.2
Barium, Ba	3.4	1.3	43	30
Beryllium, Be	<0.20	<0.20	<0.20	<0.20
Bismuth, Bi	<0.50	<0.50	<0.50	<0.50
Cadmium, Cd	0.53	0.60	0.44	0.34
Cobalt, Co	0.27	0.47	1.8	1.7
Total Chromium, Cr	1.6	4.6	10.9	11.6
Copper, Cu	1.4	1.5	66	34
Iron, Fe	53	57	795	497
Mercury, Hg	<0.10	<0.10	<0.10	<0.10
Manganese, Mn	0.51	0.58	28	8.8
Molybdenum, Mo	<0.10	0.25	0.45	0.38
Nickel, Ni	0.38	0.40	4.5	4.5
Phosphorus, P	175	97	7.5	<4.0
Lead, Pb	1.1	<1.0	1.3	1.2
Antimony, Sb	<1.0	<1.0	<1.0	<1.0
Selenium, Se	<3.0	<3.0	<3.0	<3.0
Tin, Sn	<2.0	<2.0	<2.0	<2.0
Strontium, Sr	0.15	0.14	1.1	2.6
Thorium, Th	<0.20	<0.20	<0.20	<0.20
Titanium, Ti	9.9	7.3	4.0	8.5
Thallium, Tl	<0.90	<0.90	<0.90	<0.90
Uranium, U	<0.40	<0.40	<0.40	<0.40
Vanadium, V	3.0	8.4	17.2	16.5
Zinc, Zn	3.1	2.5	28	13.3
Zirconium, Zr	0.40	0.15	<0.10	<0.10
Calcium, Ca	23	9.7	191	313
Potassium, K	96	86	131	114
Magnesium, Mg	4.8	0.86	51	73
Sodium, Na	3261	3081	4145	4030

- The results are expressed in mg/kg.
- Method: Quantitative ICP scan.

The analysis was carried on an NAG LEACH of the sample as received:

Lab number	E004622	E004623	E004624
Sample marks	SFT01 & SFT02	FET(F)02 & FET(F)01	CET(F)02 & CET(F)01
Silver, Ag	<0.40	<0.40	<0.40
Aluminium, Al	1.9	42	49
Arsenic, As	<2.0	<2.0	<2.0
Boron, B	<0.60	2.1	<0.60
Barium, Ba	0.39	2.9	1.7
Beryllium, Be	<0.20	<0.20	<0.20
Bismuth, Bi	<0.50	<0.50	<0.50
Cadmium, Cd	0.56	0.50	0.55
Cobalt, Co	0.34	0.44	0.45
Total Chromium, Cr	<0.30	1.8	2.2
Copper, Cu	0.94	1.4	1.5
Iron, Fe	12.2	52	57
Mercury, Hg	<0.10	<0.10	<0.10
Manganese, Mn	0.53	0.55	0.70
Molybdenum, Mo	0.31	0.16	<0.10
Nickel, Ni	0.32	0.34	0.39
Phosphorus, P	<4.0	219	227
Lead, Pb	<1.0	<1.0	1.1
Antimony, Sb	<1.0	<1.0	<1.0
Selenium, Se	<3.0	<3.0	<3.0
Tin, Sn	<2.0	<2.0	<2.0
Strontium, Sr	0.15	0.10	0.48
Thorium, Th	<0.20	<0.20	<0.20
Titanium, Ti	0.20	58	50
Thallium, Tl	<0.90	<0.90	<0.90
Uranium, U	<0.40	<0.40	<0.40
Vanadium, V	0.36	3.6	3.6
Zinc, Zn	<0.50	2.8	1.8
Zirconium, Zr	<0.10	26	53
Calcium, Ca	8.7	26	55
Potassium, K	81	85	85
Magnesium, Mg	<1.0	10.7	20
Sodium, Na	24	3307	3133

- The results are expressed in mg/kg.
- Method: Quantitative ICP scan.

COMPANY NAME : SRK CONSULTING-JHB
ADDRESS : PO BOX 55291 NORTHLANDS
SUBJECT : ANALYSIS OF 6 SUPERNATANT LIQUID SAMPLES
MARKED : AS BELOW
INSTRUCTED BY : LEVI OCHIENG
ORDER NO. :
DATE RECEIVED : 23-08-2017
DATE ANALYSED : 04-09-2017
LAB NO(S) : E004620 – E004624 & E004588

The analysis on as received basis: SUPERNANTANT PHASE

Lab number	E004620	E004621	E004622	E004622
Sample marks	TT(F)02 & TT(F)01	IT(F)02& IT(F)01	SFT01 & SFT02	SFT01 & SFT02 DUP
Silver, Ag	<0.004	<0.004	<0.004	<0.004
Aluminium, Al	1.8	1.8	0.87	0.76
Arsenic, As	<0.02	<0.02	<0.02	<0.02
Boron, B	<0.006	<0.006	<0.006	<0.006
Barium, Ba	0.021	0.016	0.020	0.020
Beryllium, Be	<0.002	<0.002	<0.002	<0.002
Bismuth, Bi	<0.005	<0.005	<0.005	<0.005
Cadmium, Cd	0.001	<0.001	0.001	< 0.001
Cobalt, Co	0.051	0.037	0.020	0.018
Total Chromium, Cr	<0.003	<0.003	<0.007	<0.007
Copper, Cu	0.32	0.029	0.043	0.038
Iron, Fe	0.13	0.32	0.90	0.78
Mercury, Hg	<0.001	<0.001	<0.001	<0.001
Manganese, Mn	0.19	0.13	0.22	0.20
Molybdenum, Mo	<0.001	<0.001	<0.001	<0.001
Nickel, Ni	0.11	0.076	<0.003	<0.003
Phosphorus, P	0.09	0.04	0.07	0.11
Lead, Pb	<0.01	<0.01	<0.01	<0.01
Antimony, Sb	<0.01	<0.01	<0.01	<0.01
Selenium, Se	<0.03	<0.03	<0.03	<0.03
Tin, Sn	<0.02	<0.02	<0.02	<0.02
Strontium, Sr	0.013	0.008	0.008	0.007
Thorium, Th	<0.002	<0.002	<0.002	<0.002
Titanium, Ti	0.002	<0.001	<0.001	<0.001
Thallium, Tl	<0.009	<0.009	<0.009	<0.009
Uranium, U	<0.004	<0.004	<0.004	<0.004
Vanadium, V	<0.002	<0.002	<0.002	<0.002
Zinc, Zn	<0.005	<0.005	<0.005	<0.005
Zirconium, Zr	<0.001	<0.001	<0.001	<0.001

- The results are expressed in mg/l.
- Method: Quantitative ICP scan (A.P.H.A 3120 B)

The analysis on as received basis: LIQUID PHASE

Lab number	E004623	E004624	E004588
Sample marks	FET(F)02 & FET(F)01	CET(F)02 & CET(F)01	LWPT
Silver, Ag	<0.004	<0.004	<0.40
Aluminium, Al	0.66	1.3	0.56
Arsenic, As	<0.02	<0.02	<0.02
Boron, B	<0.006	<0.006	<0.006
Barium, Ba	0.013	0.010	0.027
Beryllium, Be	<0.002	<0.002	<0.002
Bismuth, Bi	<0.005	<0.005	<0.005
Cadmium, Cd	0.001	<0.001	0.001
Cobalt, Co	0.009	0.031	0.056
Total Chromium, Cr	<0.003	<0.003	0.003
Copper, Cu	0.012	0.055	0.089
Iron, Fe	0.046	0.034	0.357
Mercury, Hg	<0.001	<0.001	<0.001
Manganese, Mn	0.087	0.084	0.18
Molybdenum, Mo	<0.001	<0.001	<0.001
Nickel, Ni	0.026	0.10	0.076
Phosphorus, P	<0.04	<0.04	<0.04
Lead, Pb	<0.01	<0.01	<0.01
Antimony, Sb	<0.01	<0.01	<0.01
Selenium, Se	<0.03	<0.03	<0.03
Tin, Sn	<0.02	<0.02	<0.02
Strontium, Sr	0.013	0.010	0.015
Thorium, Th	<0.002	<0.002	<0.002
Titanium, Ti	0.006	0.002	0.055
Thallium, Tl	<0.009	<0.009	<0.009
Uranium, U	<0.004	<0.004	<0.004
Vanadium, V	<0.002	<0.002	<0.002
Zinc, Zn	<0.005	<0.005	<0.005
Zirconium, Zr	<0.001	<0.001	0.001

- The results are expressed in mg/l.
- Method: Quantitative ICP scan (A.P.H.A 3120 B)

COMPANY NAME : SRK CONSULTING-JHB
ADDRESS : PO BOX 55291 NORTHLANDS
SUBJECT : ANALYSIS OF 2 LIQUID SAMPLES
MARKED : AS BELOW
INSTRUCTED BY : LEVI OCHIENG
ORDER NO. :
DATE RECEIVED : 23-08-2017
DATE ANALYSED : 04-09-2017
LAB NO(S) : E004557 & E004559

The analysis on as received basis:

Lab number	E004557	E004559
Sample marks	G/T O/F	LAKE GRAY
Silver, Ag	<0.004	<0.40
Aluminium, Al	0.046	0.19
Arsenic, As	<0.02	<0.02
Boron, B	<0.006	<0.006
Barium, Ba	0.004	0.003
Beryllium, Be	<0.002	<0.002
Bismuth, Bi	<0.005	<0.005
Cadmium, Cd	0.001	0.001
Cobalt, Co	0.001	0.002
Total Chromium, Cr	<0.003	<0.003
Copper, Cu	0.004	0.005
Iron, Fe	0.059	0.46
Mercury, Hg	<0.001	<0.001
Manganese, Mn	0.059	0.044
Molybdenum, Mo	<0.001	<0.001
Nickel, Ni	<0.003	<0.003
Phosphorus, P	<0.04	0.05
Lead, Pb	<0.01	<0.01
Antimony, Sb	<0.01	<0.01
Selenium, Se	<0.03	<0.03
Tin, Sn	<0.02	<0.02
Strontium, Sr	0.005	0.005
Thorium, Th	<0.002	<0.002
Titanium, Ti	0.001	0.012
Thallium, Tl	<0.009	<0.009
Uranium, U	<0.004	<0.004
Vanadium, V	<0.002	<0.002
Zinc, Zn	<0.005	<0.005
Zirconium, Zr	<0.001	<0.001

- The results are expressed in mg/l.
- Method: Quantitative ICP scan (A.P.H.A 3120 B)

COMPANY NAME : SRK CONSULTING-JHB
ADDRESS : PO BOX 55291 NORTHLANDS
SUBJECT : ANALYSIS OF 10 SAMPLES OF SOLID
MARKED : AS BELOW
INSTRUCTED BY : LEVI OCHIENG
ORDER NO. :
DATE RECEIVED : 23-08-2017
DATE ANALYSED : 04-09-2017
LAB NO(S) : E004561 – E004563, E004565 – E004568, E004571, E004586 & E004619

The analysis was carried out on a 25 % aqueous extract of the sample as received:

Lab number	E004561	E004562
Sample marks	CET (OLD)	CET (WET)
Silver, Ag	<0.004	<0.004
Aluminium, Al	0.015	0.12
Arsenic, As	<0.02	<0.02
Boron, B	<0.006	<0.006
Barium, Ba	0.001	0.003
Beryllium, Be	<0.002	<0.002
Bismuth, Bi	<0.005	<0.005
Cadmium, Cd	<0.001	0.001
Cobalt, Co	<0.001	0.014
Total Chromium, Cr	<0.003	<0.003
Copper, Cu	<0.002	0.23
Iron, Fe	<0.001	0.009
Mercury, Hg	<0.001	<0.001
Manganese, Mn	0.006	0.027
Molybdenum, Mo	<0.001	<0.001
Nickel, Ni	<0.003	0.035
Phosphorus, P	<0.04	<0.04
Lead, Pb	<0.01	<0.01
Antimony, Sb	<0.01	<0.01
Selenium, Se	<0.03	<0.03
Tin, Sn	<0.02	<0.02
Strontium, Sr	0.002	<0.001
Thorium, Th	<0.002	<0.002
Titanium, Ti	<0.001	0.001
Thallium, Tl	<0.009	<0.009
Uranium, U	<0.004	<0.004
Vanadium, V	<0.002	<0.002
Zinc, Zn	<0.005	<0.005
Zirconium, Zr	<0.001	<0.001

- The results are expressed in mg/l.
- Method: Quantitative ICP scan

The analysis was carried out on a 25 % aqueous extract of the sample as received:

Lab number	E004567	E004568	E004569	E004570
Sample marks	GCT (MOIST)	GPTF (DRY)	LWPTC	LDMTC
Silver, Ag	<0.004	<0.004	<0.004	<0.004
Aluminium, Al	0.034	0.02	0.67	0.014
Arsenic, As	<0.02	<0.02	<0.02	<0.02
Boron, B	<0.006	<0.006	<0.006	<0.006
Barium, Ba	0.001	0.001	0.015	0.005
Beryllium, Be	<0.002	<0.002	<0.002	<0.002
Bismuth, Bi	<0.005	<0.005	<0.005	<0.005
Cadmium, Cd	0.001	0.001	<0.001	<0.001
Cobalt, Co	0.003	<0.001	0.042	0.002
Total Chromium, Cr	<0.003	<0.003	<0.003	<0.003
Copper, Cu	0.059	0.005	0.024	<0.002
Iron, Fe	0.25	0.029	0.518	0.058
Mercury, Hg	<0.001	<0.001	<0.001	<0.001
Manganese, Mn	0.039	0.012	0.061	0.009
Molybdenum, Mo	<0.001	<0.001	<0.001	<0.001
Nickel, Ni	0.005	<0.003	0.058	0.004
Phosphorus, P	<0.04	<0.04	<0.04	0.04
Lead, Pb	<0.01	<0.01	<0.01	<0.01
Antimony, Sb	<0.01	<0.01	<0.01	<0.01
Selenium, Se	<0.03	<0.03	<0.03	<0.03
Tin, Sn	<0.02	<0.02	<0.02	<0.02
Strontium, Sr	<0.001	<0.001	0.007	0.003
Thorium, Th	<0.002	<0.002	<0.002	<0.002
Titanium, Ti	0.001	<0.001	<0.001	<0.001
Thallium, Tl	<0.009	<0.009	<0.009	<0.009
Uranium, U	0.005	0.006	<0.004	<0.004
Vanadium, V	<0.002	<0.002	<0.002	<0.002
Zinc, Zn	<0.005	<0.005	<0.005	<0.005
Zirconium, Zr	<0.001	<0.001	<0.001	<0.001

- The results are expressed in mg/l.
- Method: Quantitative ICP scan

The analysis was carried out on a 25 % aqueous extract of the sample as received:

Lab number	E004571	E004619	E004619
Sample marks	LFT (DM)	LCT(DM,DM02 &DM03)	LCT(DM,DM02 &DM03) DUP
Silver, Ag	<0.004	<0.004	<0.004
Aluminium, Al	0.024	0.023	0.025
Arsenic, As	<0.02	<0.02	<0.02
Boron, B	<0.006	<0.006	<0.006
Barium, Ba	<0.001	0.002	0.002
Beryllium, Be	<0.002	<0.002	<0.002
Bismuth, Bi	<0.005	<0.005	<0.005
Cadmium, Cd	0.001	<0.001	<0.001
Cobalt, Co	<0.001	0.001	0.001
Total Chromium, Cr	<0.003	<0.003	<0.003
Copper, Cu	0.004	0.008	0.007
Iron, Fe	0.011	0.25	0.25
Mercury, Hg	<0.001	0.007	0.007
Manganese, Mn	0.006	0.005	0.005
Molybdenum, Mo	<0.001	<0.001	<0.001
Nickel, Ni	<0.003	<0.003	<0.003
Phosphorus, P	<0.04	<0.04	<0.04
Lead, Pb	<0.01	<0.01	<0.01
Antimony, Sb	<0.01	<0.01	<0.01
Selenium, Se	<0.03	<0.03	<0.03
Tin, Sn	<0.02	<0.02	<0.02
Strontium, Sr	<0.001	<0.001	<0.001
Thorium, Th	<0.002	<0.002	<0.002
Titanium, Ti	0.001	0.001	0.001
Thallium, Tl	<0.009	<0.009	<0.009
Uranium, U	<0.004	<0.004	<0.004
Vanadium, V	<0.002	<0.002	<0.002
Zinc, Zn	<0.005	<0.005	<0.005
Zirconium, Zr	<0.001	<0.001	<0.001

- The results are expressed in mg/l.
- Method: Quantitative ICP scan

DETERMINANT	METHOD	METHOD REFERENCE
pH value	Electrometric	W044-27-O
Conductivity	Potentiometric	W044-27-O
Total Dissolved Solids	Gravimetric	W044-03-W
Total Solids and loss on ignition	Gravimetric	A.P.H.A. 2540 BE
Total Alkalinity	Titrimetric	W044-50-O
Calcium	Atomic Absorption Spectrophotometry	W044-28-O
Magnesium	Atomic Absorption Spectrophotometry	W044-28-O
Potassium	Atomic Absorption Spectrophotometry	W044-28-O
Sodium	Atomic Absorption Spectrophotometry	W044-28-O
Colour Hazen unit	Lovibond Comparator	B.D.H Nessleriser method
Turbidity N.T.U	Comparator	W044-37-O
Odour	Physical testing	A.P.H.A. 2150 B
Carbonate Hardness	By calculation	A.P.H.A. 2340 A
Chloride	Colorimetric	W044-50-O
Sulfate	Colorimetric	W044-50-O
Sulfite	Titrimetric	A.P.H.A. 4500-SO_3 B
Settle-able solids	Volumetric Measurement	A.P.H.A. 2540-F
Nitrate	Nitrate electrode (Titrimetric)	A.P.H.A. 4500-NO_3 D
Nitrate	Colorimetric	W044-50-O
Nitrite	Colorimetric	W044-50-O
Fluoride	Colorimetric	W044-50-O
Mercury	ICP Scan	W044-28-O
Hexavalent Chromium	Colorimetric	W044-50-O
Total Cyanide	Colorimetric	W044-50-O
Phenolic Compounds as phenol	Colorimetric	W044-50-O
Biochemical Oxygen Demand	Titrimetric	A.P.H.A. 5210 B
Chemical Oxygen Demand	Colorimetric	A.P.H.A. 5220 C
Total Soluble Solids	Gravimetric	A.P.H.A. 2540 D
Soap, Oil and grease	Gravimetric	S.A.B.S. 1051
Sulfide sulphur	Lead Acetate	S.A.B.S. 1056
Sulfide sulphur	Titrimetric	A.P.H.A. 4500-S^2 F
Free and saline ammonia	Colorimetric	W044-50-O
Kjeldahl Nitrogen	Colorimetric	W044-50-O/ A.P.H.A.4500-Nogr B
Acidity/P-Alkalinity	Titrimetric	A.P.H.A. 2310/2320 B
Dissolved Oxygen	Titrimetric	A.P.H.A. 4500-O-C
Oxygen Absorbed (Permanganate value)	Titrimetric	S.A.B.S. 220
Residual/Free Chlorine	Colorimetric	A.P.H.A. 4500-Cl G
Bromide	Colorimetric	A.P.H.A. 4110 C
Calcium Carbonate saturated pH	Potentiometric	P.C.I. 9.28
Free Carbon Dioxide	Titrimetric	A.P.H.A. 4500-CO_2 C
Arsenic, Selenium, Titanium, Aluminium, Nickel, Manganese, Iron, Vanadium, Zinc, Antimony, Lead, Cobalt, Copper, Total Chromium, Silicon, Tin, Zirconium, Bismuth, Thallium, Beryllium, Cadmium, Boron, Phosphorus as Phosphate, Uranium, Molybdenum, Barium, Silver, Thorium, Lithium, (also Ca, Mg, K, Na).	ICP Quantitative Scan	W044-28-O

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Natural and Agricultural Sciences

Faculty of Natural &
Agricultural Sciences
XRD & XRF Facility
Department of Geology
Pretoria 0002, South Africa

Direct Telephone: (012) 420-2722
Direct Telefax: (012) 362 5219
E-Mail: wiebke.grote@up.ac.za
http://www.up.ac.za/academic/science

CLIENT: M&L Lab

PO Number: 17001521

DATE: 13 October 2017

SAMPLES: 18 Samples

ANALYSIS: Qualitative and Quantitative XRD (mineralogy)

The samples were prepared according to the standardized Panalytical backloading system, which provides nearly random distribution of the particles.

The samples were analyzed using a PANalytical X'Pert Pro powder diffractometer in θ–θ configuration with an X'Celerator detector and variable divergence- and fixed receiving slits with Fe filtered Co-Kα radiation (λ=1.789Å). The phases were identified using X'Pert Highscore plus software.

Comment:

- Samples E004619, E004621, E004565, E004620 and E004563: Using the riffle splitter each sample was splitted and micronized in a McCrone micronizing mill.
- The rutile content stays high, no matter what I do.
- The rutile peaks are of higher intensities than the ilmenite peaks.
- With the micronizing the kyanite and goethite peaks disappeared.
- The peak for rutile in E004620 is relatively high and the weight% is between 23% and 24%.
- Samples E004621 and E004565: The samples do contain more rutile than ilmenite.
- Sample E004619 changed to the initial results.

After splitting with a riffle splitter and micronizing in a McCrone micronizing mill, the samples were prepared for XRD analysis using a back loading preparation method.

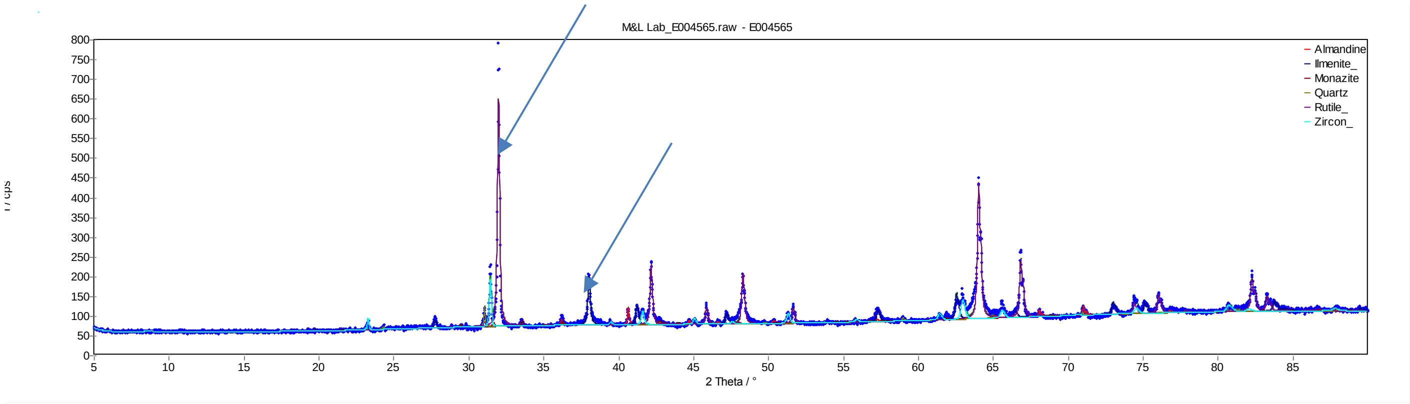
Two different methods of Rietveld refinement were used to quantify the same set of samples.

The relative phase amounts (weight%) were estimated using the Rietveld method (**Autoquan Program software).**

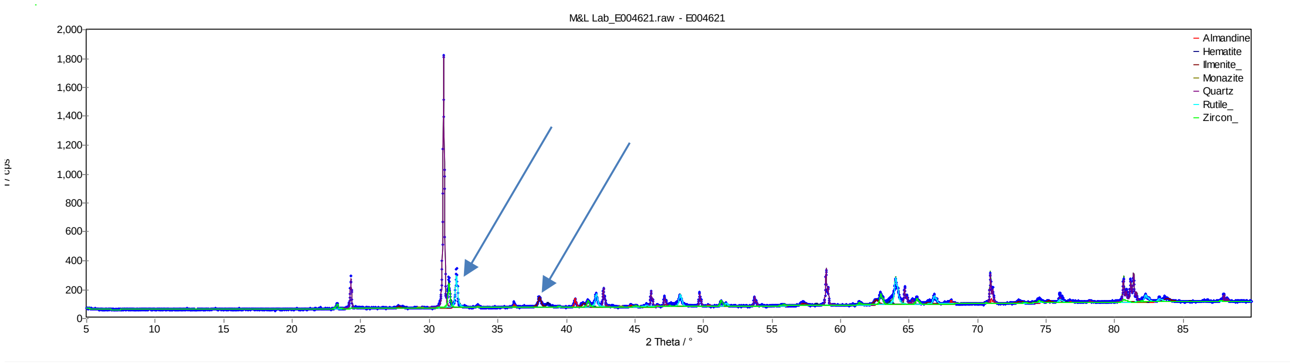
E0054563		**E004565**	
	weight%		weight%
Almandine	1.06	Almandine	5.15
Quartz	90.63	Ilmenite	21.86
Rutile	6.92	Monazite	1.45
Zircon	1.39	Quartz	4.75
		Rutile	59.47
		Zircon	7.31
E004620		**E004621**	
	weight%		weight%
Almandine	8.61	Almandine	6.13
Hematite	2.46	Hematite	3.33
Ilmenite	9.06	Ilmenite	9.72
Monazite	0.78	Monazite	0.75
Quartz	48.97	Quartz	56.75
Rutile	23.99	Rutile	17.68
Zircon	6.13	Zircon	5.64

The relative phase amounts (weight%) were estimated using the Rietveld method (**X'Pert Highscore plus software**).

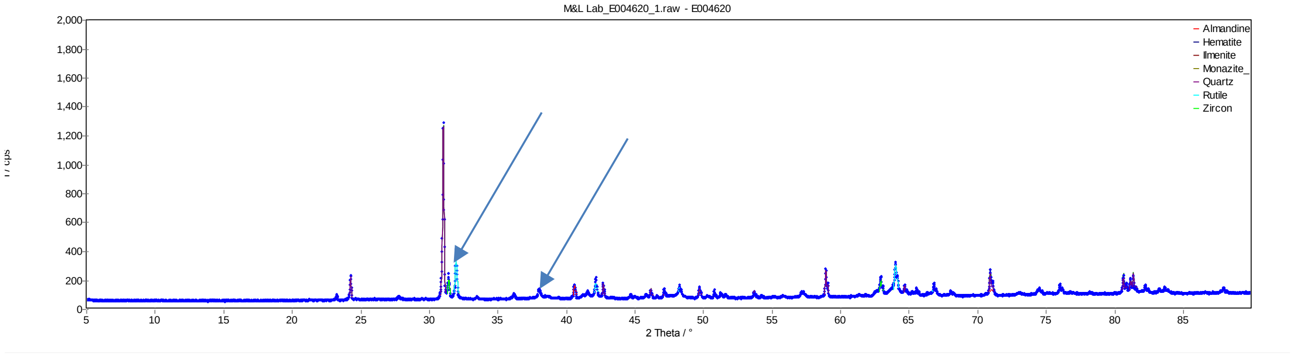
	E004563		**E004565**
Almandine %	1.18	Almandine %	5.99
Quartz %	92.04	Ilmenite %	19.3
Rutile %	6.28	Monazite %	1.01
Zircon %	0.5	Quartz %	5.67
		Rutile %	60.33
		Zircon %	7.69
	E004620		**E004621**
Almandine %	7.85	Almandine %	5.8
Hematite %	1.58	Hematite %	1.59
Ilmenite %	8.27	Ilmenite %	9.25
Monazite %	0.75	Monazite %	0.61
Quartz %	52.19	Quartz %	59.19
Rutile %	23.16	Rutile %	17.34
Zircon %	6.2	Zircon %	6.22



For sample E004565
Purple high intensity peak = Rutile
Blue smaller intensity peak = ilmenite



For sample E004521
Turquoise higher peak = rutile
Brown small peak = ilmenite



Sample E004620

Intensity peak for rutile is higher than the intensity peak of ilmenite

E004561		**E004562**		**E004623**		**E004624**	
	weight%		weight%		weight%		weight%
Almandine	56.16	Almandine	22.98	Almandine	3.32	Almandine	21.91
Goethite	2.51	Corundum	4.88	Corundum	2.35	Corundum	3.13
Hematite	2.57	Goethite	1.49	Monazite	2.74	Kyanite	7.77
Kyanite	3.86	Kyanite	12.13	Quartz	51.73	Monazite	5.3
Monazite	4.48	Quartz	39.03	Rutile	9.64	Quartz	4.2
Quartz	11.96	Rutile	5.44	Zircon	30.21	Rutile	9.58
Rutile	5.53	Zircon	14.04			Zircon	48.12
Zircon	12.94						
E004566		**E004567**		**E004568**		**E004569**	
	weight%		weight%		weight%		weight%
Marcasite	13.27	Gibbsite	1.54	Gibbsite	1.09	Kaolinite	1.21
Pyrite	32.91	Kaolinite	15.29	Kaolinite	5.98	Quartz	98.79
Quartz	40.78	Quartz	83.17	Quartz	92.94		
Rutile	10.14						
Zircon	2.91						
E004570		**E004571**		**E004586**		**E004588**	
	weight%		weight%		weight%		weight%
Gibbsite	0.85	Kaolinite	3.53	Kaolinite	7.07	Kaolinite	2.85
Kaolinite	3.97	Quartz	96.47	Quartz	92.93	Quartz	97.15
Quartz	95.18						
E004619		**E004622**					
	weight%		weight%				
Kaolinite	2.85	Marcasite	22.53				
Quartz	97.15	Pyrite	57.75				
		Quartz	12.44				
		Rutile	6.34				
		Zircon	0.94				

If you have any questions, kindly contact the laboratory.

Analyst:

Wiebke Grote

SRK Report Distribution Record

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