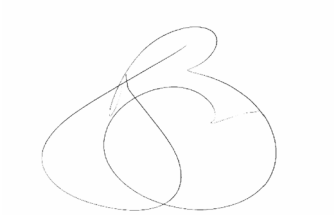
MOLO FEASIBILITY STUDY

National Instrument 43-101 Technical Report

On the Molo Graphite Project located near the village of Fotadrevo
in the Province of Toliara,
Madagascar

Prepared by



Erudite Strategies (Pty) Ltd

J.K. de Bruin Pr.Eng

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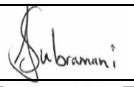
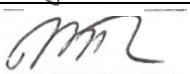
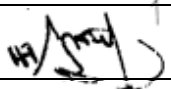
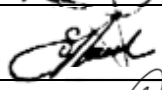
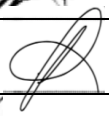
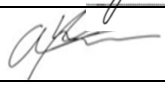
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Abbreviations, Symbols, Acronyms and Units of Measure

Agence de Promotion du Secteur Minier	APSM
Ariary Madagascan Currency	MGA
Betsimisaraka Suture	BS
Bureau de Recherches Géologiques et Minières (France)	BRGM
Bureau du Cadastre Minier de Madagascar	BCMM
Caracle Creek International Consulting Coal's	CCIC
Carbon	C
Centimetres	cm
Closed side setting (crusher)	CSS
Cubic metres	m^3
Cubic metres per hour	m^3/h
Cubic metres per minute	m^3/min
Degrees	°
Degrees Celsius	°C
Diamond Drill Hole	DDH
Dry metric tonnes	dmt
Dry metric tonnes per hour	dmt/h
Environmental Commitment Permit	RIM
Feet	' or ft
Free air delivery	FAD
Greater than	>
Greater than or equal to	≥
Grams	g
Grams per tonne	g/t
Hectares	ha
High density polyethylene	HDPE

Hours	h
Inductively coupled plasma (assay)	ICP
Intermediate bulk container	IBC
Internal diameter	ID
Kilobar	kbar
Kilograms	kg
Kilograms per tonne	kg/t
Kilometres	km
Kilovolt-amps	kVa
Less than	<
Less than or equal to	≤
Life of Mine	LOM
Madagascar Minerals & Resources SARL	MMR
Mesh size (of screen or sieve)	mesh
Metres	m
Metres above mean sea level	mamsl
Metric tonnes	t
Micrometres	µm
Millilitres	ml
Millimetres	mm
Million tonnes	Mt
Million tonnes per annum	Mtpa
Million Watts	MW
National Environmental Action Plan	NEAP
National Instrument 43-101	NI-43-101
Original equipment manufacturer	OEM
Particle size distribution where 80% of particles in a stream are larger than the size indicated	P_{80}

Parts per million	PPM
PEG Mining Consultants Inc.	PEG
Percent	%
Percent graphitic carbon	% C(g)
Percent total carbon	% C(t)
Projet de Gouvernances des Ressources Minérales	PGRM program
Projet de Reforme du Secteur Minier	PRSM program
Qualified Persons	QPs
Quality Assurance / Quality Control	QA/QC
Rock Quality Description	RQD
Run of Mine	ROM
Special Advisory Committee	SAC
Square metres	m^2
Stirred media detritor	SMD
Taiga Consultants Ltd.	TAIGA
Tailings storage facility	TSF
Thousand Pascals	kPa
Thousand tonnes per annum	ktpa
Thousand tonnes per month	ktpm
Thousand Watts	kW
Three dimensional	3D
Tonnes (1000kg)	t
Tonnes per cubic metre	t/m^3
Universal Transverse Mercator	UTM
Uranium Star Minerals SARL	USM
Whole Rock Analysis	WRA
X-Ray Fluorescence	XRF

1 SUMMARY

1.1 Introduction

Next Source Materials Incorporated (formerly Energizer and Uranium Star) is a mineral exploration and development Company based in Toronto, Canada, which is currently focused on the exploration and development of its 100% owned, flagship Molo Project.

The Molo deposit is situated 160 km southeast of the city of Toliara, in the Tulear region of south-western Madagascar. The deposit occurs in a sparsely populated, dry savannah grassland region, which has easy access via a network of seasonal secondary roads radiating outward from the village of Fotadrevo. Fotadrevo in turn has an all-weather airstrip and access to a road system that leads to the regional capital (and port city) of Toliara and the Port of Ehoala at Fort Dauphin via the RN10, or RN13.

Geologically Molo is situated in the Bekikiy block (Tolagnaro-Ampanihy high grade metamorphic province) of southern Madagascar. The Molo deposit is underlain predominantly by moderately to highly metamorphosed and sheared graphitic (biotite, chlorite and garnet-rich) quartzo-feldspathic schists and gneisses, which are variably mineralised. Near surface rocks are oxidised, and saprolitic to a depth, usually of less than 5m.

Molo is one of several surficial graphite trends discovered by Energizer (now NEXT) in late 2011 and announced in early January 2012. The deposit was originally drill tested in 2012, with an initial seven holes being completed. Resource delineation, drilling and trenching on Molo took place between May and November of 2012, and allowed for a maiden Indicated and Inferred Resource to be stated in early December of the same year. This maiden mineral resource estimate formed the basis for a Preliminary Economic Assessment (the “PEA”), which was undertaken by DRA Mineral Projects in 2013. The positive outcome of this assessment lead Energizer to undertake another phase of exploratory drilling and sampling in 2014, which was done under the supervision of Caracle Creek International Consulting (Proprietary) Limited. This phase of exploration was aimed at improving the geological confidence of the deposit and it’s contained mineral resources, and included an additional 32 diamond drill holes (totalling 2,063 metres) and 9 trenches (totalling 1,876 metres). Caracle Creek were subsequently engaged to update the geological model and resource estimate. The entire database on which this new model and resource estimate is based contains 80 drill holes (totalling 11,660 metres) and 35 trenches (totalling 8,492 metres). This new resource forms the basis for the Molo 2015 FS which targeted 860ktpa of ore processing capacity.

The Molo 240ktpa 2017 FS utilises the knowledge base of the Molo 2015 FS on a smaller scale low capital cost 240ktpa process capacity option.

1.2 Project Location

The Molo deposit is located some 160 km southeast of Madagascar's administrative capital (and port city) of Toliara, in the Tulear region and about 220 km NW of Fort Dauphin. It is approximately 13 km NE of the local village of Fotadrevo. See Figure 1 below.



Figure 1: Project Location

1.3 Project Description

The proposed development of the Molo graphite project includes the construction of a green fields open pit mine, a processing plant with a capacity of 240,000 tonnes of ore per annum and all supporting infrastructure including water, fuel, power, tailings, buildings and permanent accommodation.

See Figure 2 below for the proposed layout of the site.

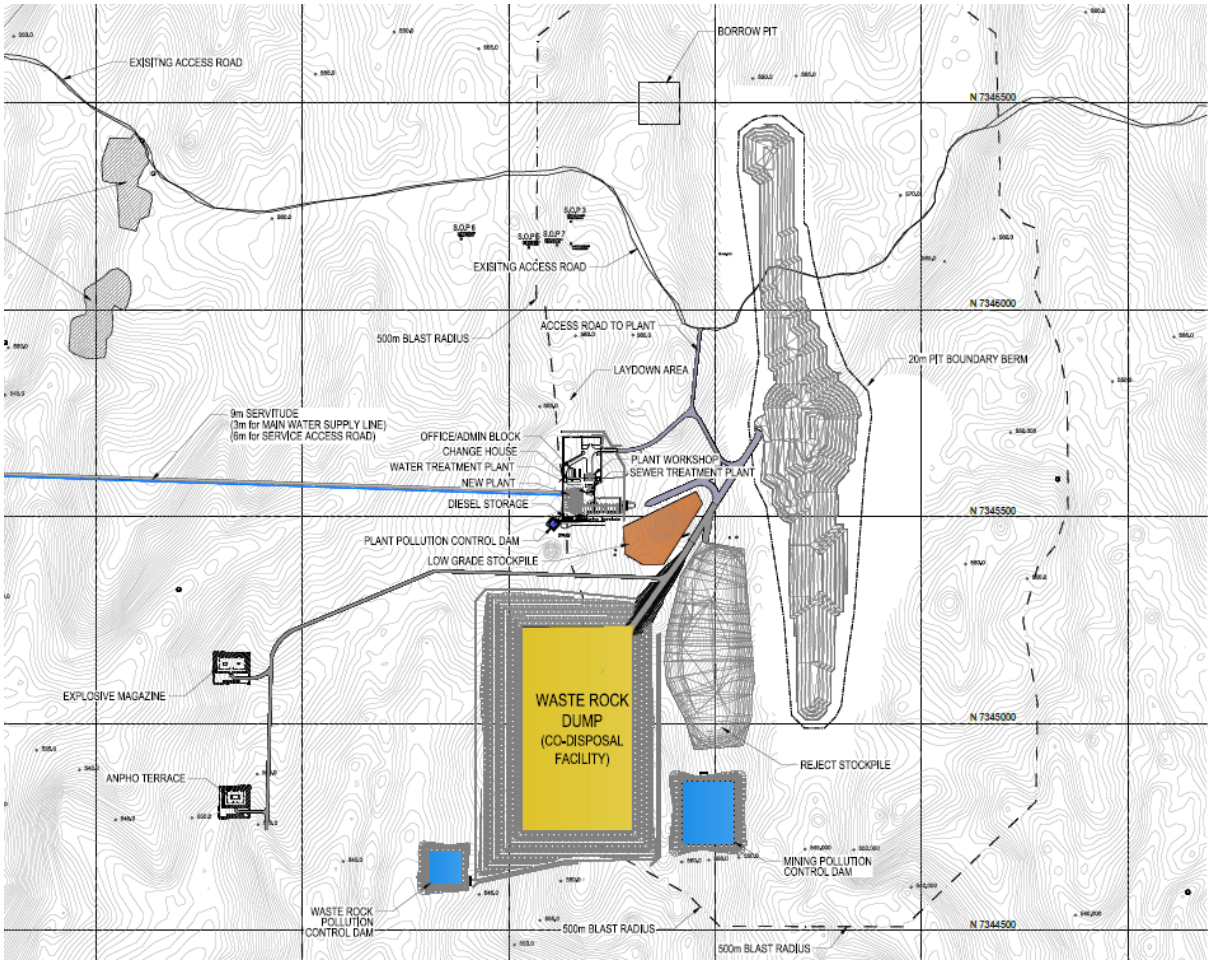


Figure 2: Site layout

1.4 Summary of financial results

Table 1 below summarizes the financial results of the Molo 240ktpa 2107 FS. These are based on a discounted flow analysis of the project using nominal cash flows, which include the effect of inflation.

Table 1: Summary of Financial Results

Description	**Pre-Tax**	**Post-Tax**
Post-tax: NPV (8% Discount Cash Flow)(1)(2)	$34.0m	$25.5m
Post-tax: IRR (1)(2)	25.2%	21.5%
Payback (2)	4.2 years	4.8 years
Capital cost ("CAPEX")	$16,725,869	
Owners Contingency	$1,672,587	
On-site Operating Costs ("OPEX") per tonne of concentrate, (year 3 onward)	Mining $102.81	
On-site Operating Costs ("OPEX") per tonne of concentrate, (year 3 onward)	Processing $265,82	
Transportation per tonne of concentrate (from mine site to Madagascar Port year 3 onward)	$133.01	
Transportation per tonne of concentrate (from Madagascar Port to European Customer Port from year 3 onward)	$122.50	
Average annual production of concentrate	17,000 tonne	
Life of Mine ("LOM")	30 years	
Graphite concentrate sale price (US$/tonne at Start Up - 2017)	$1,014	
Average Head Grade	8.05%	
Average ore mined per annum over Life of Mine	240,000 tonne	
Average stripping ratio	0.53:1	
Average carbon recovery	88.3%	

Notes

- Note 1: Assumes project is financed with 100% equity
- Note 2: Values shown are based on nominal graphite sales pricing
- Table 2 below summarizes key mine and process data.

Table 2: Mine & Process Data

Proven reserves (t)	5,881,243
Probable reserves (t)	1,278,757
Grade (% graphitic carbon)	8.05%
Waste to ore ratio	0.53:1
Processing rate (tpa)	240,000
Mine life (years)	30
Recovery (%)	88.3%
Average annual product tonnes	17,164

1.5 Property Description and Ownership

1.5.1 Property description

The Molo Graphite Project is contained in a portion of Exploration Permit #3432**.** The Project is centred on UTM coordinates 413,390 Easting 7,345,713 Northing (UTM 38S, WGS 84 datum). The Molo Graphite Project is located 11.5 km ENE of the town of Fotadrevo and covers an area of 62.5 hectares (“ha”). The Government of Madagascar designates individual claims by a central LaBorde UTM location point, comprising a square with an area of 6.25 km^2.

1.5.2 Ownership

On December 14, 2011, the Company entered into a Definitive Joint Venture Agreement (""JVA"") with Malagasy Minerals Limited (""Malagasy""), a public company on the Australian Stock Exchange, to acquire a 75% interest to explore and develop a group of industrial minerals, including graphite, vanadium and approximately 25 other minerals. On October 24, 2013, the Company signed a Memorandum of Understanding (""MOU"") with Malagasy to acquire the remaining 25% interest in the land position.

On April 16, 2014, NextSource Materials Inc. (“NEXT”) signed a Sale and Purchase Agreement and a Mineral Rights Agreement with Malagasy to acquire the remaining 25% interest. Malagasy retains a 1.5% net smelter return royalty (""NSR"").

The Molo Graphite Project is located within Exploration Permit #3432 as issued by the Bureau de Cadastre Minier de Madagascar (""BCMM"") pursuant to the Mining Code 1999 (as amended) and its implementing decrees.

CCIC has had sight of and reviewed a copy of the “Contrat d’amodiation” pertaining to this right and are satisfied that the rights to explore this permit have been ceded to Energizer/NEXT or one of its Madagascar subsidiaries.

Energizer/NEXT holds the exclusive right to explore for a defined group of industrial minerals within the permits listed above. These industrial minerals include the following: Vanadium, Lithium, Aggregates, Alunite, Barite, Bentonite, Vermiculite, Carbonatites, Corundum, Dimensional stone (excluding labradorite), Feldspar (excluding labradorite), Fluorspar, Granite, Graphite, Gypsum, Kaolin, Kyanite, Limestone / Dolomite, Marble, Mica, Olivine, Perlite, Phosphate, Potash–Potassium minerals, Pumice Quartz, Staurolite, and Zeolites.

Reporting requirements of exploration activities carried out by the titleholder on an Exploration Permit are minimal. A titleholder must maintain a diary of events and record the names and dates present of persons active on the project. In addition, a site plan with a scale between 1/100 and 1/10,000 showing ""a map of the work completed"" must be presented. Upon establishment of a mineral resource, Exploration Permits may be converted into Exploitation Permits by application. CCIC is of the opinion that Energizer is compliant in terms of its commitments under these reporting requirements.

The Molo Graphite Project has not been legally surveyed; however, since all claim boundaries conform to the predetermined rectilinear LaBorde Projection grid, these can be readily located on the ground by use of Global Positioning System (“GPS”) instruments. Most current GPS units and software packages do not however offer LaBorde among their available options, and therefore defined shifts have to be employed to display LaBorde data in the WGS 84 system. For convenience, all Energizer/NEXT positional data is collected in WGS 84, and if necessary converted back to LaBorde.Royalties.

1.5.3 Royalties

Malagasy retains a 1.5% net smelter return royalty on the Molo Graphite Project

1.5.4 Permits

Exploration Permit PR 3432 is currently held under the name of a subsidiary of NEXT, called ERG Madagascar SARLU. NEXT’s Madagascar domiciled subsidiary have continued to pay all taxes and administrative fees to the Madagascar government and its mining ministry with

respect to all the mining permits held in country. These taxes and administrative fee payments have been acknowledged and accepted by the Madagascar government. In addition, NEXT continues to diligently work with the Madagascar government to obtain the necessary permits in its name as the country clears its backlog of applications and amendments.

The exploration permit will be converted into an exploitation permit in due course. When the permit is transformed from an exploration permit to an exploitation permit, the exploitation permit will be issued in the name of NEXT's local subsidiary, ERG Madagascar SARLU. The exploitation permit is required to advance the Molo Project to the developmental stage.

1.6 Mineral Resource Estimate

The Molo project hosts the following resources:

- Measured mineral resource of 23.62 MT grading 6.32% Carbon ("C")
- Indicated mineral resource of 76.75 MT grading 6.25% C
- Inferred mineral resource of 40.91 MT at 5.78% C
- The effective date of the Mineral Resource tabulation is the 14th August 2014. The Mineral Resources are classified according to the Canadian Institute of Mining, Metallurgy and Petroleum definitions. A cut-off grade of 4% C was used for the "higher grade" zones and 2% C for the "lower grade" zones. It is important to note that while the 'high' grade resource occurs within the 'low' grade resource, each was estimated and reported separately.
- A relative density of 2.36 tonnes per cubic meter was assigned to the mineralized zones for the resource estimation. The resource remains open along strike and to depth. The Mineral Resources above are inclusive of the Mineral Reserves below.
- The current mineral resource estimate for Molo is summarised in Table 3 below. The mineral resources are classified in the Measured, Indicated and Inferred categories as defined by the Canadian Institute of Mining, Metallury and Petroleum definition standards.

Table 3: Mineral Resource Statement for the Molo Graphite Deposit - September 2014

Classification	Material Type	Tonnes	Grade - C%	Graphite - T
Measured	"Low Grade"	13 048 373	4.64	605 082
Measured	"High Grade"	10 573 137	8.4	887 835
Total Measured		23 621 510	6.32	1 492 916
Indicated	"Low Grade"	39 539 403	4.73	1 871 075

Classification	Material Type	Tonnes	Grade - C%	Graphite - T
Indicated	"High Grade"	37 206 550	7.86	2 925 266
Total Indicated		**76 745 953**	**6.25**	**4 796 341**
Measured + Indicated	"Low Grade"	52 587 776	4.71	2 476 157
Measured + Indicated	"High Grade"	47 779 687	7.98	3 813 101
Total Measured + Indicated		**100 367 464**	**6.27**	**6 289 257**
Inferred	"Low Grade"	24 233 267	4.46	1 080 677
Inferred	"High Grade"	16 681 453	7.70	1 285 039
Total Inferred		40 914 721	5.78	2 365 716
Total Measure + Indicated + Inferred	"Low Grade"	76 821 044	4.63	3 556 834
Total Measure + Indicated + Inferred	"High Grade"	64 461 141	7.91	5 098 140
Grand - Total		**141 282 184**	**6.13**	**8 654 974**

C% = carbon percentage; Graphite – T = Tonnes of graphite

Notes:

- Mineral Resources are classified according to the Canadian Institute of Mining definitions.
- “Low Grade” Resources are stated at a cut-off grade of 2% C.
- “High grade” Resources are stated at a cut-off grade of 4% C.
- Eastern and Western high grade assays are capped at 15% C.
- A relative density of 2.36 tonnes per cubic metre (t/m^3) was assigned to the mineralised zones for the resource tonnage estimation.

The total Measured and Indicated Resource is estimated at 100.37 million tonnes, grading at 6.27% carbon. Additionally, an Inferred Resource of 40.91 million tonnes, grading at 5.78% carbon is stated. When compared to the November 2012 resource statement, (Hancox and Subramani, 2013), this shows a 13.7% increase in tonnage, a 3.4% decrease in grade and a 9.8% increase in graphite content. The reason for the increase in tonnage is due to the 2014 drilling on the previously untested north eastern limb of the deposit, which added additional new resources. Additionally 23.62 million tonnes, grading at 6.32% carbon, have been upgraded by infill drilling from the Indicated to Measured Resource category.

1.7 Exploration

No further exploration is currently planned.

1.8 Mineral Reserve Estimate

As a result of the Molo 240ktpa FS 2017, the following maiden proven and probable mineral reserves are declared, see Table 4 below.

Table 4: Mineral Reserves

Category	Tonnage	C Grade (%)
Proven	5 881 243	8.04
Probable	1 278 757	8.07
Proven and Probable	7 160 000	8.05

Proven reserves are reported as the Measured Resources inside the designed open pit and above the grade cut off of 5.5% C. Similarly, the Probable Reserves are reported as the Indicated Resources inside the designed open pit and above the grade cut-off of 5.5% C.

1.9 Metallurgical Test Work

The Molo 240ktpa FS 2017 is based on a full suite of metallurgical test work performed by SGS Canada Metallurgical Services Inc. in Lakefield, Ontario, Canada. These tests included laboratory scale metallurgical work and a 200 tonne bulk sample / pilot plant program. The laboratory scale work included comminution tests, process development and optimization tests, variability flotation, and concentrate upgrading tests.

Comminution test results place the Molo ore into the very soft to soft category with low abrasivity. A simple reagent regime consists of fuel oil number 2 and methyl isobutyl carbinol at dosages of approximately 120 g/t and 195 g/t, respectively. A total of approximately 150 open circuit and locked cycle flotation tests were completed on almost 70 composites as part of the process development, optimization, and variability flotation program. The metallurgical programs culminated in a process flowsheet that is capable of treating the Molo ore using proven mineral processing techniques and its robustness has been successfully demonstrated in the laboratory and pilot plant campaigns.

The metallurgical programs indicated that variability exists with regards to the metallurgical response of the ore across the deposit, which resulted in a range of concentrate grades between 88.8% total carbon and 97.8% total carbon. Optical mineralogy on representative concentrate samples identified interlayered graphite and non-sulphide gangue minerals as the primary source of impurities. The process risk that was created by the ore variability was mitigated with the design of an upgrading circuit, which improved the grade of a concentrate

representing the average mill product of the first five years of operation from 92.1% total carbon to 97.1% total carbon.

The overall graphitic carbon recovery into the final concentrate is 87.8% based on the metallurgical response of composites using samples from all drill holes within the five year pit design of the original feasibility study at the higher concentrate production rate of 53,000 tpa. The average composition of the combined concentrate grade is presented in Table 5. The size fraction analysis results were converted into a grouping reflecting a typical pricing matrix, which is shown in Table 6.

All assays were completed using control quality analysis and cross checks were completed during the mass balancing process to verify that the results were within the estimated measurement uncertainly of up to 1.7% relative for graphite concentrate grades greater than 90% total carbon.

Table 5: Metallurgical Data - Flake Size Distribution and Product Grade

Product Size	% Distribution	Product Grade (%) Carbon
+48 mesh (jumbo flake)	23.6	96.9
+65 mesh (coarse flake)	14.6	97.1
+80 mesh (large flake)	8.2	97.0
+100 mesh (medium flake)	6.9	97.3
+150 mesh (medium flake)	15.5	98.1
+200 mesh (small flake)	10.1	98.1
-200 mesh (fine flake)	21.1	97.5

Table 6: Pricing Matrix - Flake Size Distribution Grouping and Product Grade

Product Size	% Distribution	Product Grade (%) Carbon
>50 mesh	23.6	96.9
-50 to +80 mesh	22.7	97.1
-80 to +100 mesh	6.9	97.2
-100 mesh	46.8	97.6

Vendor testing including solid-liquid separation of tailings and concentrate, screening and dewatering of concentrate, and drying of concentrate was completed successfully.

1.10 Recovery methods

The process design is based on an annual feed plant throughput capacity of 240 kilotonnes at a nominal head grade of 7.04% C(t) producing an estimated average of 15-17 kilotonnes per annum (ktpa) of final concentrate.

The ore processing circuit consists of three stages of crushing which comprises jaw crushing in the primary circuit, followed by secondary cone crushing and tertiary cone crushing; the secondary and tertiary crushers operate in closed circuit with a double deck classification screen. Crushing is followed by primary milling and screening, graphite recovery by froth flotation and concentrate upgrading circuit, and graphite product and tailings effluent handling unit operations. The crusher circuit is designed to operate 365 days per annum for 24 hours per day at ±55% utilization. The crushed product (P80 of approximately 13 mm) passes through a surge bin from where it is fed to the milling circuit.

The milling and flotation circuits are designed to operate 365 days per annum for 24 hours per day at 92% utilization. A single stage primary ball milling circuit is employed, incorporating a closed circuit classifying screen and a scalping screen ahead of the mill. The scalping screen undersize feeds into a flash flotation cell before combining with the mill discharge material. Scalping and classification screen oversize are the fed to the primary mill.

Primary milling is followed by rougher flotation which, along with flash flotation, recovers graphite to concentrate from the main stream. Rougher flotation employs six forced-draught trough cells. The primary, fine-flake and attritioning cleaning circuits upgrade the concentrate to the final product grade of above 94% C(t). Concentrate from the main stream feeds into the primary cleaning circuit consisting essentially of a dewatering screen, a polishing ball mill, a column flotation cell and flotation cleaner/cleaner scavenger trough cells.

The primary cleaner column cell concentrate gravitates to a 212 µm classifying screen, from where the large-flake oversize stream is pumped to a high rate thickener located in the concentrate attritioning circuit whilst the undersize is pumped to the fine-flake cleaning circuit.

The fine flake cleaning circuit consists primarily of a dewatering screen, a polishing ball mill, a column flotation cell and flotation cleaner/cleaner scavenger trough cells. The attritioning cleaning circuit employs a high rate thickener, an attritioning stirred media mill, a column flotation cell and flotation cleaner/cleaner scavenger trough cells. Fine flake column concentrate is combined with the +212 µm primary cleaner classifying screen oversize as it feeds the attritioning circuit thickener. Concentrate from the attrition circuit is pumped to the final concentrate thickener.

The combined fine flake cleaner concentrate and the +212 µm may also be processed through the secondary attrition circuit which consists of a dewatering screen, an attrition scrubber, column flotation cell and cleaner/cleaner scavenger trough cells. Concentrate from this circuit is pumped to the final concentrate. The secondary attrition circuit is optimal.

Combined rougher and cleaner flotation final tailings are pumped to the final tailings thickener. Thickened final concentrate is pumped to a filter press for further dewatering before the filter cake is stockpiled prior to load and haul.

The concentrate thickener underflow is pumped to a linear belt filter for further dewatering and fed to a diesel-fired rotary kiln for drying. The dried concentrate is then screened into four size fraction:

- +48 mesh
- -48 + 80 Mesh
- -80 +100 mesh
- -100 mesh

The various product sizes are bagged and readied for shipping.

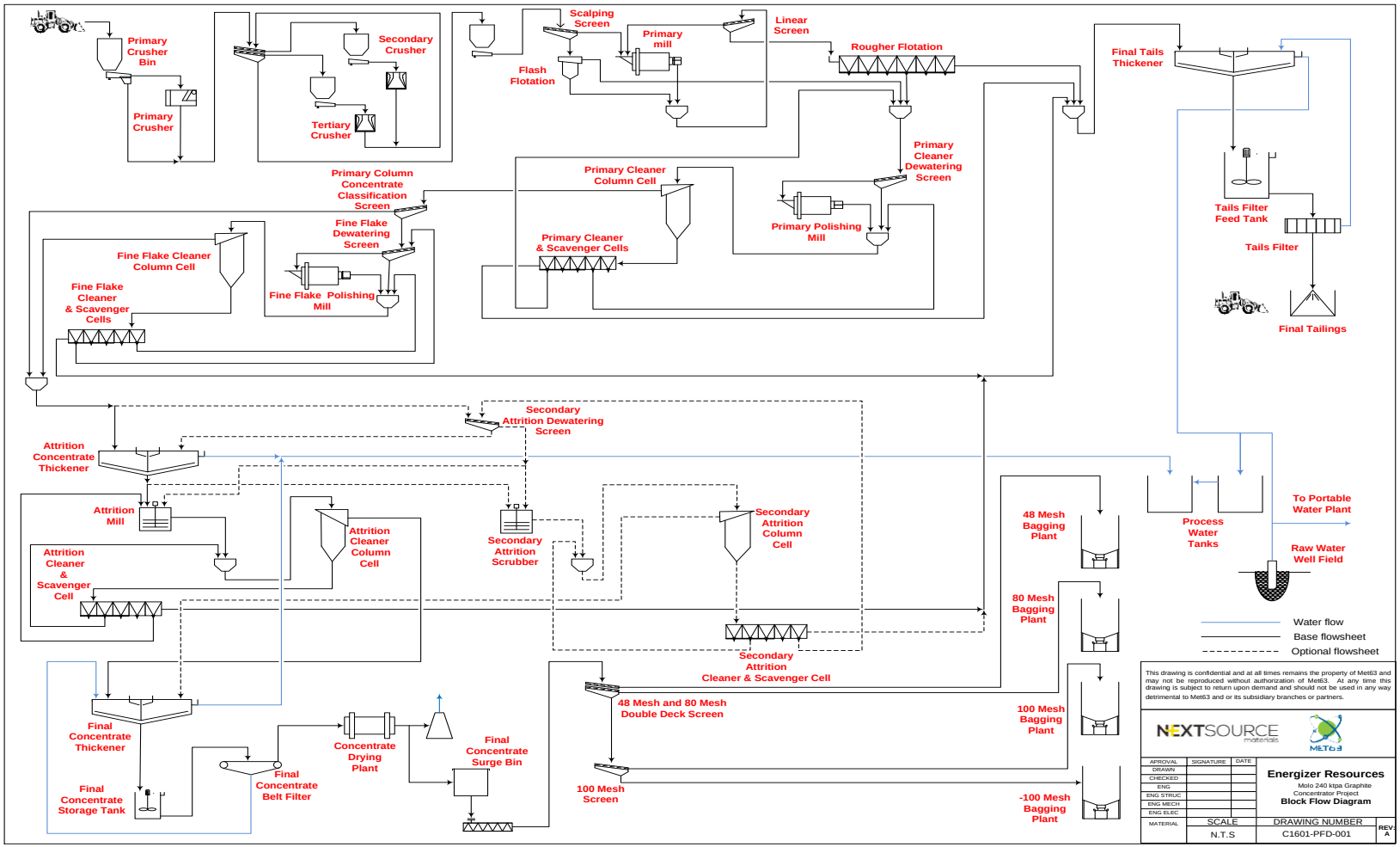
Chemical reagents are used throughout the froth flotation circuits and thickeners. Diesel fuel is used as collector and liquid MIBC (methyl isobutyl carbinol) frother are used within the flotation circuits. Diesel collector is pumped from a diesel storage isotainer, from where it enters a manifold system which supplies multiple variable speed peristaltic pumps which discretely pump the collector at set rates to the various points-of-use within the flotation circuits.

MIBC (methyl isobutyl carbinol) frother is delivered by road to an isotainer. A manifold system on the storage isotainer supplies multiple variable speed peristaltic pumps, which discretely pump the frother at set rates to the various points-of-use within the flotation circuits.

Flocculant powder (Magnafloc 24) is delivered by road to the plant reagent store in 25 kg bags. The bags are collected by forklift as required and delivered to a flocculant mixing and dosing area. Here the flocculant is diluted as required using parallel, duplicate vendor-package automated make-up plants, each one being dedicated to supplying the concentrate and tailings thickeners due to the flocculant types required being different for each application. Variable speed peristaltic pumps discretely pump the flocculant at set rates to the thickeners' points-of-use.

Coagulant powder (Magnafloc 1707) for thickening enhancement is handled similarly to the flocculant as described above, the exception being that a single make-up system is provided to supply both the concentrate and tailings thickeners. Again, variable speed peristaltic pumps discretely pump the coagulant at set rates to the thickeners' points-of-use. Figure 3 below shows a block flow diagram of the Molo Graphite concentrator process plant.

Figure 3: Block flow diagram



1.11 Infrastructure

The project is located in a relatively remote part of South Western Madagascar, approximately 13 km NE of the local village of Fotadrevo. There is currently limited infrastructure on site and project infrastructure will have to be constructed.

The following elements are all part of the project scope:

- Raw water supply (from a network of bore holes extracting ground water)
- Power supply (temporary during construction) and then a permanent diesel power station to supply the plant and permanent camp
- Sanitation for the plant, permanent camp, and temporary during construction
- Storm water control and management
- All permanent buildings (offices, workshops, stores, laboratory)
- All buried services (potable water, sewage, stormwater, electrical reticulation)
- In plant roads
- Haul road
- Waste, high and low grade -Rock dumps.

See Figure 2 in section 1.3 for the site layout.

The following section describes the methods, assumptions and specifications used in the preliminary design of the civil, structural and infrastructure portions of the proposed new modular graphite plant. As the proposed new plant is a temporary pilot plant for a potentially much larger process plant and mining operation, the brief form the client was to develop a “fit for purpose” and cost-effective design without compromising on safety or quality.

A desktop review was carried out on relevant portions of The Molo Feasibility Study carried out by DRA in 2015. The following sections from this document are listed as reference documents for this study and are treated as relied upon information.

- C8375-RPT-1 - Molo Feasibility Study Section 1 Executive Summary
- C8375-RPT-9 - Molo Feasibility Study Section 9 Infrastructure
- C8375-EDC-PM-001 – Engineering Design Criteria
- Feasibility Geotechnical Investigations Report (SRK Report 479297/Plant Geotech/Final)

The most critical aspects of the design criteria will also be listed hereunder.

1.11.1 Drawings

The drawings in the table below were produced for the civil, structural and infrastructure portions of this phase of the project. Infrastructure areas were laid out to minimize earthworks requirements and footprint requirements.

Drawing Number	Drawing Description
Blockplan Drawings	
17038-BP-0001	Site Layout Plan A
17038-BP-0002	Site Layout Plan B
General Arrangements	
17038-GA-0001	Plant & Infrastructure GA
17038-EW-0001	Terrace Details
17038-SW-0001	Storm Water Drainage Plan
EVHP-17038-GN-0001	General Notes & Specifications
Concrete Drawings	
EVHP-17038-C-0001	Process Plant Concrete Layout GA
EVHP-17038-C-0002	Concrete Base & Plinth Details P1, B1, B2, B3, B4
EVHP-17038-C-0003	Concrete Base & Plinth Details P1, B5, B6, B7
EVHP-17038-C-0004	Concrete Base & Plinth Details P1, P2, P3, B8, B9
EVHP-17038-C-0005	Concrete Base & Plinth Details P2, P4, B10, B11
EVHP-17038-C-0006	Concrete Base & Plinth Details P5, B11
EVHP-17038-C-0007	Concrete Base & Plinth Details P1, B13
EVHP-17038-C-0008	Concrete Base & Plinth Details P6-9, P13-15, B14, B15
EVHP-17038-C-0009	Concrete Base & Plinth Details P1, B16-20
EVHP-17038-C-0010	Concrete Base & Plinth Details P1, P10, B21-27

EVHP-17038-C-0011	Concrete Bund Details 1,2 & 3
EVHP-17038-C-0012	Concrete Bund Details 4 & 5
EVHP-17038-C-0013	Gabion Retaining Wall Details
EVHP-17038-C-0014	Civil Typical Details

1.11.2 Basis of Civil, Structural and Infrastructure Design

The scope of the civil and structural design covers the following facilities and areas:

- Bulk earthworks and terraces for the process plant, administration and workshop areas
- Earthworks for laydown areas
- Bulk earthworks and retaining walls for the Run of Mine (ROM) tip ramp
- Foundations and slabs for:
  - Front end crushing circuit
  - Conveyors, transfer stations and bins
  - Complete modular process plant
  - Workshops, offices, change-house, laboratory and stores
  - Security and access control buildings
  - Modular water treatment plant
  - Modular sewer treatment plant
  - Diesel generators
- In plant roads and access
- Fuel storage and bund area
- Storm water drainage (Concrete lined v-drains) and protection berms
- Plant pollution control dam

As the process plant is supplied in modular units by a vendor, the design of these structures are not included in this section. Critical structural design criteria is however still included.

1.11.3 Standards

The Design shall be based on the technical standards of South Africa (SANS) prevailing at the time when the Works are being executed.

Table 7: Standards to be used in Structural Design

Number	Name
SANS 282	Bending dimensions and scheduling of steel reinforcement for concrete
SANS 10104	Handrailing and balustrading (safety aspects).
SANS 10100-1	The structural use of concrete – Part 1: Design

SANS 10160-1	Basis of structural design and actions for buildings and industrial structures Part 1: Basis of structural design
SANS 10160-2	Part 2: Self-weight and imposed loads
SANS 10160-3	Part 3: Wind actions
SANS 10160-4	Part 4: Seismic actions and general requirements for buildings
SANS 10160-5	Part 5: Basis for geotechnical design and actions
SANS 10160-6	Part 6: Actions induced by cranes and machinery
SANS 10160-7	Part 7: Thermal actions
SANS 10160-8	Part 8: Actions during execution
SANS 10161	The design of foundations for buildings
SANS 10162-1	The structural use of steel – Part 1: Limit-states design of hot-rolled steelwork
SANS 10162-2	The structural use of steel – Part 2: Limit-states design of cold-formed steelwork
SANS 10400	The Application of the National Building Regulations (All Parts)
SANS 10094	The use of high-strength friction-grip bolts.
BS 8007	Design of Concrete Structures for Retaining Aqueous Liquids (British Standard)

The works are to be executed to the following specifications

Table 8 - Construction Specifications

Number	Name
SANS 2001-CC1:2012	Construction Works Part CC1: Concrete Works (Structural)
SANS 2001-CS1:2012	Construction Works Part CS1: Structural Steelwork
SANS 2001-BE1:2008	Construction Works Part BE1: Earthworks (General)
SANS 2001-BS1:2008	Construction Works Part BS1: Site Clearance

1.11.4 Design Loads

The below conditions and loads were considered in the design:

Wind Speed: 40m/s
Temperature Variations: 10 Degrees Celsius Minimum
35 Degrees Celsius Maximum
Terrain Category: Category B – Open terrain with scattered obstructions having heights between 1.5m and 10m.
Class of structure: Class B
Mean Return Period: 50 years
Site altitude: 500m amsl
Steel Grades: S355JR (350W) Hot Rolled Sections

Soil Bearing Capacity	150kPa
Equipment Loading	As per vendor information

The Following floor live loads were considered in the design:

Table 9. Floor Live loads

Location	Design Loading
All plant areas that are to be used for maintenance and major access	5 kN/m^2 or 4.5 kN at any point with maintenance areas
Stairways, landings and walkways in plant	2.5 kN/m^2
Minor platform access only	2.5 kN/m^2
Conveyor walkways (not exceeding 800mm wide)	1.25kN/m^2 full length (global design) or 2.5kN/m^2 over a 4m length (local member design) 1 kN/m^2 for spill trays
Ground floor areas accessible to vehicles	Applicable vehicle wheel load or 10 kN/m^2 whichever is greater
Ground floor areas not accessible to vehicles	7.5 kN/m^2
Floor spillage	1 kN/m^2 not to be used simultaneously with above nominated floor loadings
Handrails	0.33 kN/m or 0.55kN acting vertically, or horizontally outwards on the top rail or edge, but not concurrently

1.12 Bulk Earthworks

1.12.1 Geotechnical

The geotechnical investigation conducted by SRK Consulting in 2014 was used as reference document for the design and planning of this phase of the project. (Report 479297/Plant Geotech/Final)

In summary, transported soils are present across all areas investigated to shallow depths not exceeding a maximum depth of 0.6 m. From the consistencies noted during test pit excavations the transported soils are anticipated to have a maximum allowable bearing capacity of 100 kPa, limiting total consolidation settlement to 25 mm.

Residual soils were noted in the majority of the test pits excavated and comprised dense to very dense silty and/ or clayey sands. The residual soils are expected to have a maximum allowable bearing capacity of 200 kPa, limiting total consolidation settlement to 25 mm (differential settlement expected to be half this value).

As rock is located at a shallow depth at most locations it is recommended that structures generally be founded on rock rather than the overlying thin soils. However, light structures with loads of less than 100 kPa could be founded on the soils if necessary.

1.12.2 Site Clearance

The entire plant area is to be cleared and grubbed. Topsoil shall be stripped nominally 150mm deep after clearing and grubbing and stockpiled in designated areas for possible re-use in accordance with the recommendations of the EIA. Topsoil may also be used for screen and drainage berms.

1.12.3 Terrace Design

Bulk earthworks are required for the process plant and building platforms, plant roads, storm water drainage, access ramps and laydown areas.

Finished surface levels for bulk earthworks at all plant will be 200 mm below the nominated top of concrete of all footings and foundation slabs with grading of the surface surrounding the foundation to ensure runoff is directed away from the foundations.

All fill areas will be compacted to a minimum modified AASHTO density of at least 95%. The terraces will be formed using a cut to fill operation with suitable in-situ material after all unsuitable topsoil has been removed. A borrow pit has been identified for any shortfall fill material.

The terrace design has been done to allow for a minimum load bearing capacity of 150kPa for concrete foundations and structures.

All fill slopes will be between 1:1.5 and 1:3 in accordance with the geotechnical report.

1.12.4 Plant Roads

Site roads will be formed from existing site material and be shaped to assist rainfall runoff. In plant roads will be 6m wide and constructed of in situ material. Borrow pit material is to be used for heavy vehicle haul roads.

1.12.5 Run of Mine (ROM) Ramp

The ROM ramp will be constructed from borrow pit material with a ramp slope of 10 degrees. The ROM ramp retaining walls will be constructed with gabion baskets on a concrete footing.

1.12.6 Soil and Compaction Testing

All tests test work shall be done in accordance with the latest and applicable SANS 1200 specification.

1.13 Concrete

1.13.1 Foundation Design

Concrete foundations were designed according to the specifications and standards listed in section 1.11.3.

All foundations were designed as pad or raft type foundations with load bearing pressures not exceeding 150kPa. Foundations were designed to minimize settlement. A load diagram drawing was supplied by the modular process plant supplier which was used in the design analysis of foundations and slabs.

Heavy equipment to be found on the residual soils with a load bearing capacity 200kPa at approximately 1m below natural ground level as per the geotechnical report, or on engineered fill. Equipment with potentially high dynamic loadings such as the mills, were placed on pad foundations with a weight of 3 times the operating weight of the mill to ensure that the equipment will not vibrate or shake.

Administration buildings will be modular prefabricated buildings with low loading. These building will be placed on lightly reinforced ground slabs or light raft structures.

1.13.2 Concrete Grades

Concrete grades and mix design will be selected taking into consideration durability requirements. Particular attention will be given to wet process plant areas and wash down slabs. The concrete grades specified in Table 10 will be taken as a minimum requirement.

Table 10. Concrete Grades

Element	Concrete Strength
Blinding	10 MPa / 9.5 mm
Footings/Ground Slabs	30 MPa / 19 mm
Suspended Slabs	30 MPa / 19 mm

Element	Concrete Strength
Other Concrete	30 MPa / 19 mm

Where the characteristic strength is denoted by strength followed by maximum aggregate size, e.g. 25 MPa / 19 mm refers to grade 25 mixed with 19 mm aggregate.

1.13.3 Reinforcement Cover

Cover to concrete reinforcing will be specified on the drawings. The concrete covers specified in Table 11 will be taken as a minimum requirement.

Table 11: Concrete Cover Specifications

Location	Cover (mm)
In-situ concrete cast against forms, unless specified otherwise	50
Pre-cast concrete cast in rigid forms with intense vibration, unless specified otherwise	30
Concrete cast against ground	75
Bored piers	75
Pre-cast piles	40
Top cover to footings, walls, pedestals, plinths	50
Bottom cover to slabs, cast against ground	75
Top cover to slabs in wash down and process areas	50

1.13.4 Reinforcing – Bars

Reinforcing shall be high strength deformed steel bar in accordance with SANS 920 with the following properties:

Minimum yield strength, f_y: 450 MPa

Minimum elongation at yield: 14%

Minimum tensile strength, f_u: 1.15 x f_y

1.13.5 Reinforcing – Mesh

Fabric shall be in accordance with SANS 1024 with minimum material properties as listed below:

Characteristic Strength (0.43% elongation proof stress): 485 MPa

Tensile Strength: 510 MPa

1.13.6 Plinths

Plinths will be set nominally at heights given in Table 12.

Plinth heights may be dependent on layout and equipment selection. Plinths inside bund areas shall be at least 50mm higher than the bund wall height to ensure that equipment supports and structural steel does not stand in liquid in the event of a spill.

Table 12: Plinth Heights

Location	Height (mm)
Conveyor trestles	500
Equipment plinths	300
Pump plinths	> 100
Columns inside fully clad workshops and infrastructure	0
External columns to workshops and infrastructure buildings	300

1.13.7 Bund Areas and Slabs

Bund areas containing tanks will contain at least 110% of the volume of the largest tank in the bund area. Concrete floors will be wood float finished with a slope to a sump, containing an automated mechanical pump to pump spills to a pollution control dam.

1.14 Storm Water Layout

1.14.1 Storm Water Runoff

Storm water runoff within the process plant areas are dealt with by a minimum slope on the terrace platform. Runoff is then collected in concrete lined V-drains. All V-drains form the process plant area will be routed to the plant pollution control dam.

Earth berms are proposed on the high sides of the process plant to prevent rainwater runoff from entering the process plant area and possibly becoming contaminated by plant spills or materials.

All runoff not affected by possibly contaminated areas will be routed to local low areas and natural seasonal watercourses.

1.14.2 Plant Pollution Control Dam

A pollution control dam will be constructed on the low side of the plant. All potentially contaminated water runoff from the process plant will be routed to this dam. The dam will be an earth wall dam constructed from in situ materials. If required by the EIA the dam will be li

1.14.3 Raw Water Supply

Water is supplied by a network of boreholes. A detailed water demand and supply analysis was done as part of the feasibility study, and this has shown that the water demands of the plant can be accommodated by boreholes within a radius of 5km from the plant. The daily maximum raw water make up requirement is estimated to be 561m^3 per day, decreasing to 222m^3 per day for latter part of the life of mine.

1.14.4 Power Supply

Due to the remote location of the Molo site, no other power or electrical infrastructure is available on the site, hence the supply to the Molo Graphite plant shall be independent by stand-alone diesel generators and not grid tied.

The total installed generation capacity equals to 2.8MW. Power to the plant and infrastructure shall be supplied by 2 x 1.4 MW, 3-ph, 400Vac diesel generators, interlocked and operating either in parallel or independently. Power to remote areas, such as the water wells shall be supplied via independent stand-alone 15kVA, 3-ph, 400Vac diesel generators.

Subject to the sequential starting of the larger loads for e.g. the Mill, it might be required during an ore loaded start-up, that both generators run in parallel. Once the plant has reached equilibrium the standby generator shall be stepped back. During continuous normal operation of the plant, one generator will suffice. The second unit shall primarily be used during maintenance and operational rotations.

1.15 Product Pricing

Graphite prices are based on current quotes and projected estimates provided by UK-based Roskill Consulting Group Ltd ("Roskill"), recognized as a leader in providing independent and unbiased market research, pricing trends, and demand and supply analysis for the natural flake graphite market.

The weighted average price per tonne of graphite concentrate used for this study is based on the findings of Roskill, a copy of which is attached in “Appendix A” and yielded $1,014/tonne. This is a basket price and reflects the contribution of the different flake sizes and carbon grades to the overall price. The start-up price (in 2018 terms) for a tonne of Molo graphite concentrate is a projection based on Roskill information. The nominal graphite price was used in the financial model, which in essence ‘flat-lines’ the price forecast over the life of mine. The reader is cautioned that these are forecasts and may change subject to market dynamics, and is directed to Appendix A for more detailed information.

1.16 Logistics

The cost to transport one tonne of dry concentrate (0.5% moisture content) from Molo to Rotterdam via Fort Dauphin, Madagascar, in December 2014 terms is 337 USD / tonne. This is based on shipping 26 tonnes of concentrate in 1 m^3 bags placed inside a 40 ft. container.

The route from Molo to Fort Dauphin runs either via the RN 10 or the RN 13. Both these routes are in relatively poor condition and trucks are expected to take between four and five days to make the round trip. A truck was run over the route by a Madagascan trucking contractor to gauge cycle times and they managed to complete the journey in two long days each way. This was in the dry season and in the wet season there may be periods of time when the roads become impassable. No money has been budgeted for roads repairs or upgrades.

The Port of Ehoala at Fort Dauphin is a modern (2009) port developed by Rio Tinto for the QMM project. It has a 15m draft with shipping lines calling on a regular basis. There are however no crane facilities and vessels require their own cranes.

Figure 4 below shows a picture of the Port of Ehoala at Fort Dauphin.



Figure 4: Port of Ehoala at Fort Dauphin

Figure 5 below gives some insight into the road conditions between Molo and Fort Dauphin.



Figure 5: Typical Road Conditions

1.17 CAPEX and OPEX

The capital cost for the project is estimated to be 18.4 million USD, including a contingency of 1.7 million USD. A firm offer was obtained for the beneficiation facility, and supporting earthworks and civils have been quantified based on detailed designs and firm price offers from contractors established on the island.

The base date for the capital costs is April 2017 and no provision has been made for escalation. The accuracy of capital costs is considered to be with +/- 10%.

Table 13: Construction Capital Costs

Category	**Cost (USD Million)**
Capital Cost	16,669,871
Contingency (10%)	1,669,287
Total	**18,362,158**
*Excludes taxes, tariffs, duties and interest	

Table 14: Initial Capital Cost Summary

Capital Cost Breakdown		
Process Equipment	$	8,072,750
Civil & Infrastructure	$	1,842,450
Mining	$	2,292,885
Buildings	$	322,998
Electrical Infrastructure	$	89,670
Project Services	$	832,041
Construction Services	$	1,050,000
Indirect Costs	$	355,000
Environmental & Permitting costs	$	695,074
Owner's Costs	$	1,140,000
Sub-total	**$**	**16,692,871**
Contingency (10%)	$	1,669,287
TOTAL	**$**	**18,362,158**

Sustaining capital expenditure expected to be incurred has been allowed for in the financial model to cover replacement of the:

- mine fleet,
- replacement of the power plant,
- process plant replacement items,
- administration facilities maintenance
- and for rehabilitation at the end of the project.

Over the life of mine the sustaining capital accounts for 3.3 million USD. Additionally, three months working capital is estimated at 3.1 million USD.

The operating costs per tonne of finished graphite flake concentrate delivered on a CIF basis in Rotterdam are outlined in Table 15.

Table 15: Operating Costs per Tonne of Finished Graphite Concentrate

Category	
Mining (US$/T)	102.81
Processing (US$/T)	265.82
Trucking to local port / Ft. Dauphin (US$/T)	133.01
Shipping to customer port; CIF Rotterdam (US$/T)	122.50
General and Administration (US$/T)	64.29
Total	**$688.43**

The operating costs expressed above are considered to be accurate to +/- 10%, and assume a varying USD inflation rate of 1.6% in 2015 and escalating to 2.0% from 2017 onward. Currency inflation rates were also considered in the financial model and were applied to the South African Rand and Malagasy Ariary portions of the operating costs.

Please note that these operating costs assume that the plant is able to successfully handle the variability in the ore body, as shown by the SGS test work discussed in detail in Section 13. Should the plant not perform as expected this could have a material impact on operating costs as:

- The flake size distribution could be worse than expected
- The product grade could be lower than expected
- The recoveries could be lower than expected or a combination of all of these

1.18 Economic analysis

The Table below summarizes the economic analysis of the project using discounted cash flow methods.

Table 16: Economic Analysis of the Project

Category	**Value**
Average price / tonne of concentrate (at start up, 2018)	$1,014
Internal Rate of Return ("IRR") - Project Equity	25.2%
NPV @ 8% Discounted Cash Flow	$34m
NPV @ 10% Discounted Cash Flow	$24.8m
NPV @ 12% Discounted Cash Flow	$18m
Project Payback Period	4.2
* Assumes that the project is financed through 100% equity.	

Note

All values in the above table do not account for inflation. Also included in the above table are forecasted prices for 2018, which coincides with the year the Molo mine is expected to be in production.

The exchange rates used in the financial model are as follows:

- 11.31 South African Rand (ZAR) to US$1, moving in line with purchasing power parity
- 0.833 Euro to US$1, fixed for the modelled period
- 2,746 Malagasy Ariary (MGA) to US$1, moving in line with purchasing power parity

1.19 Environmental & Permitting

A comprehensive Environmental and Social Impact Assessment ("ESIA"), developed to local Malagasy, Equator Principles, World Bank and International Finance Corporation (IFC) standards, is nearing completion. This process was preceded by an Environmental Legal Review and an Environmental and Social Screening Assessment; both providing crucial information to align the project development and design with international best practice on sustainable project development.

The ESIA submission is subject to approval of the investment amount by Madagascar's Ministry of Mines, which is anticipated in July 2017. The investment application was submitted on the 21st of June 2017. NEXT will receive a Global Environmental Permit upon approval of the ESIA, a process which is expected to take six months from date of submission.

A comprehensive permitting register is in place and additional sectorial permit applications will form part of the early execution phase. Approval of the sectorial applications is expected within the same six month period as the ESIA review.

No material issues were identified in relation to Environmental, Social and Permitting processes and through the stakeholder engagement process the local and regional community has expressed a desire for the project to move forward.

Refer Annexure F (Section 13 – Permitting & Stakeholders Report : Lana Vorster).

1.19.1 Environmental and Social Impact Assessment

A comprehensive Environmental and Social Impact Assessment is nearing completion, and will be submitted to Malagasy government for approval in due course.

Refer Annexure E (Section 12 – Environmental & Social_Rev Final : Ferdi Pieterse).

1.20 Conclusions

1.20.1 Geology

NEXT's 2011 exploration programme delineated a number of new graphitic trends in southern Madagascar. The resource delineation drilling undertaken during 2012-2014 focussed on only one of these, the Molo Deposit, and this has allowed for an Independent, CIM compliant, updated resource statement for the Molo deposit.

The total Measured and Indicated Resource is estimated at 100.37 Mt, grading at 6.27% C. Additionally, an Inferred Resource of 40.91 Mt, grading at 5.78% C is stated. When compared to the November 2012 resource statement (Hancox and Subramani, 2013), this shows a 13.7% increase in tonnage, a 3.4 % decrease in grade, and a 9.8% increase in graphite content. The reason for the increase in tonnage is due to the 2014 drilling on the previously untested north eastern limb of the deposit, which added additional new resources. Additionally 23.62 Mt, grading at 6.32% Carbon, have been upgraded by infill drilling from the Indicated to Measured Resource category.

1.20.2 Mining

Maiden mineral reserves of 7 160 000 tonnes have been declared for the Molo 240ktpa FS 2017 at an average grade of 8.05% and based on the information contained in the feasibility study it is possible to economically mine this deposit.

1.20.3 Tailings

Due to the substantially reduced tonnages for the project as envisaged, tailings will be dried and co-disposed with the waste rock generated as part of the open cast mining. Despite this co-disposal approach, a detailed design has been completed, complete with environmental and social impact assessment and closure to allow for the upgrade to a more conventional, cyclone facility, should the throughput be increased during the life of the mine. This approach has been pursued to ensure that sufficient flexibility is built into the project development strategy to accommodate the anticipated increase in market demand.

1.20.4 Risks

In addition to the qualitative risk assessment completed during the previous BFS, a comprehensive HAZID study was completed as part of this study and the findings summarized in the attached document.

1.20.5 Permitting

Various permits will have to be obtained for the project including an Environmental Permit, a Mining permit, land tenure and land use approvals and finally supplementary sectoral permits. The most urgent permit is for NEXT to obtain the exploitation permit for the right to mine and produce.

1.20.6 Metallurgical Test Work

Comprehensive metallurgical test programs culminated in a process flowsheet that is capable of treating the Molo ore using conventional and established mineral processing techniques.

Process risks associated with the variability with regards to metallurgical performance have been mostly mitigated through the addition of an upgrading circuit. The upgrading circuit treated the combined concentrate after the secondary cleaning circuit. Reduced flake degradation and an improved process flexibility may be obtained by employing separate upgrading circuits for the coarse and fine flakes.

1.21 Recommendations

1.21.1 Geology

No further recommendations.

1.21.2 Mining

The Molo Graphite Project will allow for potential optimisation of drilling and blasting designs during execution that could reduce operating costs slightly.

From a pure mining perspective the Molo Graphite Project is very small and provided reasonable levels of short term planning are applied it should have very few challenges in delivering the required tonnages at the required grade to meet the production targets set out in this study.

1.21.3 Metallurgical Test Work

The following recommendations are made for the detailed engineering stage:

- Investigate the metallurgical impact of different attrition mill technologies such as stirred media mills or attrition scrubbers;

- Evaluate a range of different grinding media (e.g. different size, shape, material) to determine if flake degradation can be reduced without affecting the concentrate grade;
- Develop a grinding energy versus concentrate grade relationship for the best grinding media. This will allow a more accurate prediction of the required attrition mill grinding energy as a function of the final concentrate grade;
- Conduct attrition mill vendor tests to aid in the sizing of the equipment;
- Carry out vendor testing on graphite tailings using the optimized reagent regime proposed by the reagent supplier.
- Complete a series of flotation tests on samples covering mine life intervals for the 2017 FS pit design.

1.21.4 Recovery Methods

The process plant has been designed to easily optimize the final product grade, this is achieved by having two options in the attrition cleaning step. It is however recommended that additional laboratory testwork be conducted to test the current plant configuration for treatment for highter feed grade material.

1.21.5 Infrastructure

The following are recommended prior to the detailed design stage:

- Additional geotechnical investigations at the proposed new construction and permanent camp site, particularly at the location of the new potable water storage tanks
- A detailed geotechnical investigation will need to be undertaken to identify and confirm suitable sources of concrete aggregate and concrete sand materials at the location of the project site. This testing will need to include for concrete material testing and the production of concrete trial mixes with the material identified
- The geotechnical information will also need to confirm the suitability for construction of all the material to be excavated from the Return Water Dam. It is proposed that all the material excavated from the Return Water Dam is utilised in the works as processed fill material
- Confirmation as to whether the material from the proposed borrow pit near Fotadrevo (which will be used to supply all fill material for the TSF starter wall construction) can be utilised as fill material, or if this material can be stabilized in some manner and used in the works
- A detailed topographical survey will need to be undertaken of the proposed construction site, borrow pit areas and the access road between Fotadrevo and the mine site. This information is required prior to the final detailed design of the plant layout and associated earthworks

1.21.6 Water

The following is recommended during the detailed design phase:

- Water quality and quantity data is required to provide a baseline for comparison once the Molo Mine is commissioned. To provide the necessary baseline data, regular ground and surface water quality monitoring must be carried out leading up to the date when the Molo Mine will be commissioned. Additionally, proposed monitoring boreholes must be installed. This also should include the installation of flow meters on relevant pipelines to verify the dynamic water balance with measured flow rates during operations.
- The installation of a weather station on the Molo Graphite project site should be done as soon as possible.
- Quantitative and predictive water balance, groundwater and geochemical analyses should be undertaken on regular intervals in order to update the water management plan.

1.21.7 Environmental, Social

- The installation of a suitable weather station at or as near as possible to the proposed project site, even before construction commences, is recommended. Accurate, local weather data is almost non-existent in Madagascar. This data will prove invaluable for model calibration, improvement in baseline understanding and for future energy supply options which could utilise wind and or solar power generation.
- Clean and or renewable energy supply should be considered as a medium to long term target.
- Appointment of a community representative and the establishment of a mandate to sensitise the local communities prior to any project activities.
- Monitoring and auditing to commence at project preparation phase.
- Compilation of Standard Operating Procedures for Environmental and Social aspects requiring direct management and intervention.
- It is recommended that actual activity data, (e.g. kilometres travelled, or litres of diesel consumed) for a financial year is used when a GHG Assessment is being calculated. Given that this project involves an estimation of a future GHG assessment for activities yet to begin, a series of assumptions have been made in order to obtain the activity data required to undertake this calculation.
- Community recruitment, skills development and training should begin at project preparation phase.

1.21.8 Permitting

- The receipt of the exploitation permit is a critical step in the larger permitting and licensing regime.
- Security of land tenure is a process and is estimated to take 6-9 months, thus this process should be commissioned as early as possible.
- Application for all other necessary permits (water use, construction, mineral processing, transportation, export, labour and so forth should be undertaken within the ESIA review period (6 months), which is expected to be from September 2017 till February 2018.
- Compilation of a comprehensive legal register.

The permitting and licensing of the proposed Molo Project requires dedicated attention to ensure consistent momentum in application for and delivery of permits and licenses. This is extremely relevant within the Malagasy context.

2 INTRODUCTION

2.1 The Issuer

This Technical Report (the "Report") has been prepared for NextSource Material Incorporated (http://www.NextSourceMaterials.com/) ("NEXT", or "the Company"), a mineral exploration and development company based in Toronto, Canada. Prior to April 24, 2017 the Company was called Energizer Resources Inc. ("Energizer") which was changed from Uranium Star Corporation ("Uranium Star") on December 9, 2009. The Company commenced trading on the Toronto Stock Exchange ("TSX") under the symbol NEXT on April 24, 2017. NEXT is currently focused on the exploration and development of its Molo graphite deposit ("Molo" or "the Project") in south-western Madagascar.

2.2 Technical Team

This Technical Report has been prepared by a combined technical team made up of people from the following organizations:

- Caracle Creek International Consulting (Proprietary) Limited – Geology
- GCS Water and Environment (Pty) Ltd / Agetipa – Water, Environmental, Social, Permitting
- SGS Lakefield – Metallurgical Test work
- Metpro – Metallurgical Test work analysis

- EPOCH – Tailings Storage Facility
- DRA Projects (Pty) Ltd – Mining design & mining capital and operating costs
- EVH Consulting – earthworks, civils and infrastructure
- Met63 – Process design, capital and operating costs
- SDV, Panalpina, Unitrans, Strang – Logistics
- OHMS – Mine Geotech
- RLH – Port Trade Off Study (From BFS 2015)

2.3 Report History

The report history for this project is as follows:

- Maiden resource statement – December 2012
- Molo Graphite Project, Fotadrevo, Province Of Toliara, Madagascar, Preliminary Economic Assessment, Technical Report Update, (NI 43-101), 12 April 2013, DRA Mineral Projects (Pty) Ltd
- Updated resource statement published – 14th August 2014
- Molo Graphite Project, Fotadrevo, Province of Toliara, Madagascar Technical Report NI 43-101 – 25 September 2014 (Hancox and Subramani)

2.4 Terms of Reference and Purpose

The terms of reference for this phase were to build on the earlier resources statement and PEA and complete a full feasibility study on the Molo graphite deposit. The work covered the following key activities:

- Drilling a further 2 063 metres (32 diamond holes) and trenching an additional 1 876 metres (9 trenches) to increase the total Molo resource and upgrade as much as possible into the measured and indicated category to provide a basis for conversion to proven and probable mineral reserves. The entire database on which this new model and resource estimate is based now contains 80 drill holes (totalling 11,660 metres) and 35 trenches (totalling 8,492 metres).
- To generate a mine design and pit schedule and declare maiden proven and probable mineral reserves including understanding the geotechnical conditions and geohydrology of the pit

- To do further process test work (optimization and variability) and finalize a flow sheet to be used for process design and costing
- To engineer the process plant
- To engineer all supporting infrastructure including water, power, buildings, accommodation, etc.
- To complete a full ESIA for submission to the Malagasy government as part of the permitting process
- To understand the permitting regime in Madagascar
- To understand inbound and outbound logistics and logistics costs
- To compile Capex and Operating Cost estimates for the project
- To understand the graphite market
- To build a financial model and perform an economic analysis of the project

2.5 Sources of information

The following sources of information have been used in the feasibility study. See Table 17 below.

Table 17: Sources of Information

Report of Document	**Author / Organization**
Physical Data	
Site Topographical Data	NextSource Materials Inc.
Exploration Permit 3432	Malagasy Government
Civil Geotechnical Reports	EPOCH Consulting
Climate report	GCS Water and Environment
Geochemical analysis	GCS Water and Environment
Geological Block Model	CCIC
Mine Geotech Report	OHMS
Mining and Reserves	
Mine Schedule	DRA
Equipment Tenders	Various

Process Plant and Metallurgy	
Process Design Criteria (PDC)	Modular Supplier
Process Flow Diagrams (PFD)	Modular Supplier
Mechanical Equipment List (MEL)	Modular Supplier
Piping and Instrumentation Diagrams (P&ID)	Modular Supplier
Metallurgical Test Work Reports	SGS
Metallurgical Test Work Analysis	Metpro
Vendor Test Work Reports	Modular Supplier
Hazop Studies (Hazop 1 and Hazop 2 Reports)	NEXT
Plant Layout Drawings	NEXT
Block Plan	NEXT
Rheology Test Work	SGS
Production Schedule	DRA
Tailings Disposal and Storage	
Site Selection Report	EPOCH Consulting
TSF Report (including TSF Geotechnical Study)	EPOCH Consulting
Infrastructure	
Site Plan	NEXT
Area Plan	NEXT
Architectural Drawings	NEXT
Infrastructure Drawings	NEXT
Infrastructure Equipment List (IEL)	Modular Supplier
Plant and Camp Geotechnical Report	EPOCH Consulting
Water Supply Dam Geotechnical Report	InRoads Consulting
Surface Water Supply Report - ANT_2 Dam	GCS
Power	
Power Plant Layout Drawings	Modular Supplier/MET 63
Running Load Estimate	Modular Supplier/MET 63
Single Line Diagram	Modular Supplier/MET 63

Vendor Quotes	Various
Fuel quotes	Various
Water	
Detailed Water Report	GCS Water and Environment
Water Balance	GCS Water and Environment
Dam Site Trade-off Study	GCS Water and Environment
Environmental and Social	
Specialist Studies	GCS Water and Environment & Agetipa
ESIA (Environmental & Social Impact Assessment)	GCS Water and Environment & Agetipa
MOU (Memorandum of Understanding)	Agetipa
TOR (Terms of Reference)	Agetipa
Certification of Investment Amount	GCS Water and Environment & Agetipa
Sensitivity Maps	GCS Water and Environment
Permitting and Stakeholders	
Permit Register	Agetipa
Stakeholder Register	Agetipa
HR and Operational Readiness	
Malagasy Legislation	NEXT
Malagasy Labour Rates	NEXT
Staffing Plan	DRA
Transport and Logistics	
Route Surveys	Unitrans SDV

2.6 Personal Inspections

The following personal inspections were done on the property:

1. Dr. Philip John Hancox between the 8th and 11th of May 2012. During this visit the graphite occurrences at Molo, Seta and Fotsy were investigated and various trenches on Molo were inspected. A second site visit was undertaken between the 19th and 21st of May 2013, during the bulk sampling exercise. During this visit a number of collar beacons from the 2012 drilling campaign were inspected, as well as the trenching, logging and sampling methodologies.
2. Desmond Subramani visited the Molo site between the 15th and 19th of February 2014, during the 2014 drilling campaign. The main aim of this visit was to plan the layout of the additional drilling and trenching required for the resource upgrade. This visit also covered the inspection of various borehole collars and open trenches, as well as a review of the drilling, logging and sampling procedures.
3. Dave Thompson visited the Molo site on 11-13 March 2014. The aim of this visit was to assess the site from a mining perspective.
4. Oliver Peters and John Stanbury have not visited the site.
5. Although not an author of this report, a principal engineering geologist from EPOCH, Mr Colin Wessels, visited the site from 5th to 13th April and 17th to 21st June 2014 to conduct a reconnaissance of the potential tailings dam sites and to supervise geotechnical investigations for the tailings dam, borrow pits and plant site.
6. The following staff from GCS although not QP's on the project also spent time on site and contributed to the study in their various areas of expertise.

Ferdi Pieterse:	11- 13 March 2014
Alkie Marais:	11 - 13 March 2014
Alistair Main:	11 - 14 March 2014
Alvar Koning:	11 - 15 March 2014 and 1 July – 12 July 2014
Hassen Khan:	11 - 15 March 2014 and 1 July – 12 July 2014

3 RELIANCE ON OTHER EXPERTS

This Technical Report has been prepared for Energizer/NEXT and the information, conclusions, opinions, and estimates contained herein are based on:

- Information available at the time of preparation of this report, (effective date being the 6th of February, 2015)
- Assumptions, conditions, and qualifications as set forth in this report, and
- Data, reports, and other information as supplied by Energizer/NEXT and other third party sources

For the purpose of this report, the authors have relied on ownership information provided by Energizer/NEXT. In consideration of all legal aspects relating to the project, CCIC places reliance on NEXT that the information relating to the legal aspects, and the status of surface and mineral rights, are accurate.

Property information in this report is sourced from previous works supplied by Energizer/NEXT and the authors are not responsible for the accuracy of any property data, and do not make any claim, or state any opinion, as to the validity of the property disposition described herein.

For the preparation of this report, the authors relied on maps, documents, and electronic files generated by the current and past exploration crews, contributing consultants, and the technical team of Energizer/NEXT. To the extent possible under the mandate of a NI 43-101 compliant report, the data have been verified with regard to the material facts.

NEXT have received specialist input from the following organizations in the preparation of this report and place full reliance on this information:

- EPOCH (Tailings Storage Facility)
- GCS Water and Environmental (Pty) Ltd & Agetipa (ESIA, Water, Geohydrology, Geochemistry, Water Balance, Environmental, Social, Permitting)
- SDV, Unitrans (Logistics)
- OHMS (Mine Geotechnical)
- Africa Business Solutions (Taxation)

This reliance applies to the following sections of the technical report as per competent persons sign off.

Except for the purposes legislated under provincial securities laws any use of this report by any third party is at that party's sole risk.

4 PROPERTY DESCRIPTION AND LOCATION

4.1 Madagascar overview

The Republic of Madagascar ("Madagascar") is not a traditional or particularly well-known exploration and mining destination and is mostly under-explored, with the country subject to only very little modern era systematic exploration.

4.1.1 Country Overview

Madagascar is the largest island in the Indian Ocean (Figure 1) and the 4th largest island in the world (after Greenland, New Guinea and Borneo). It is located to the southeast of the African continent, from which it is separated by the Mozambique Channel. The country extends over 1,570 km from north to south, and is over 575 km wide, with a surface area of 587,040 km^2 and a 5,000 km long coastline.



Figure 6: Map of Madagascar

Source: http://goafrica.about.com/library/bl.mapfacts.madagascar.htm

The capital of Madagascar is Antananarivo, a city of approximately 1,500,000 people. It is located in the central eastern area of the island approximately 150 kilometres inland from the central-east coast, at an elevation of just over 1,200 metres above mean sea level (“m amsl”).

Madagascar is officially bilingual, with French being the language of government and business. Malagasy (Malgache), a language of Malayo-Polynesian origin, is the official national language. English is taught in schools but is not widely spoken outside of business and government circles.

Madagascar is one of the world's hotspots of endemism and is recognised as one of the planets 17 recognized mega-biodiversity countries (Razafindralambo and Gaylord, 2005). Over 80% of the country's plant and animal species are unique to the island. Vegetation is varied and ranges from dense tropical rain forest in the east, savannah in the central plateau and western coastal plain and spiny dry vegetation in the southern areas, which is where the Molo Graphite Project is located.

4.1.2 Government Policy and Outlook Regarding the Mining Industry

The government of Madagascar embarked on an economic revival plan in 2000. At that time the Ministry of Energy and Mines ("Ministry") had already initiated reform through the Projet de Reforme du Secteur Minier ("PRSM") program, with the introduction of the new Mining Code in 1999, and the establishment of the Mining Titles (Cadastral) Registry (Bureau du Cadastre Minier de Madagascar, or BCMM) in 2000. These initiatives attracted new investors to Madagascar, including both junior and senior mining companies.

During 2003, in furtherance of its economic policy, the Ministry commenced the five-year Projet de Gouvernances des Ressources Minérales program, with the following objectives:

- To further improve and enforce the legal and statutory framework, particularly with respect to mining.
- To promote investment in the minerals sector through the dedicated Agence de Promotion du Secteur Minier.
- To improve the geoscientific knowledge of Madagascar through geophysical surveys, geological mapping, and remote sensing, with appropriate staff training to support mapping projects.
- To address environmental health and safety issues and to contribute to poverty reduction.

4.2 Location

The Molo Graphite Project is located approximately 160 km southeast of Madagascar's port city of Toliara, in the Tulear region (Figure 2) and about 220 km northwest of Fort Dauphin. See Figure 7 below.



Figure 7: Map of Southern Madagascar

4.3 Property Area

The Molo Graphite Project includes 2,119 claims and an area totalling 941.3 km2 See Figure 8 below.. The Project is centered on UTM coordinates 495,289 Easting 7,345,473 Northing (UTM 38S, WGS 84 datum). The Molo Graphite Project is located 11.5 km east-northeast of the town of Fotadrevo and covers an area of 62.5 hectares ("ha") located inside Exploration Permit 3432. The Government of Madagascar designates individual claims by a central LaBorde UTM location point, comprising a square with an area of 6.25 km2.

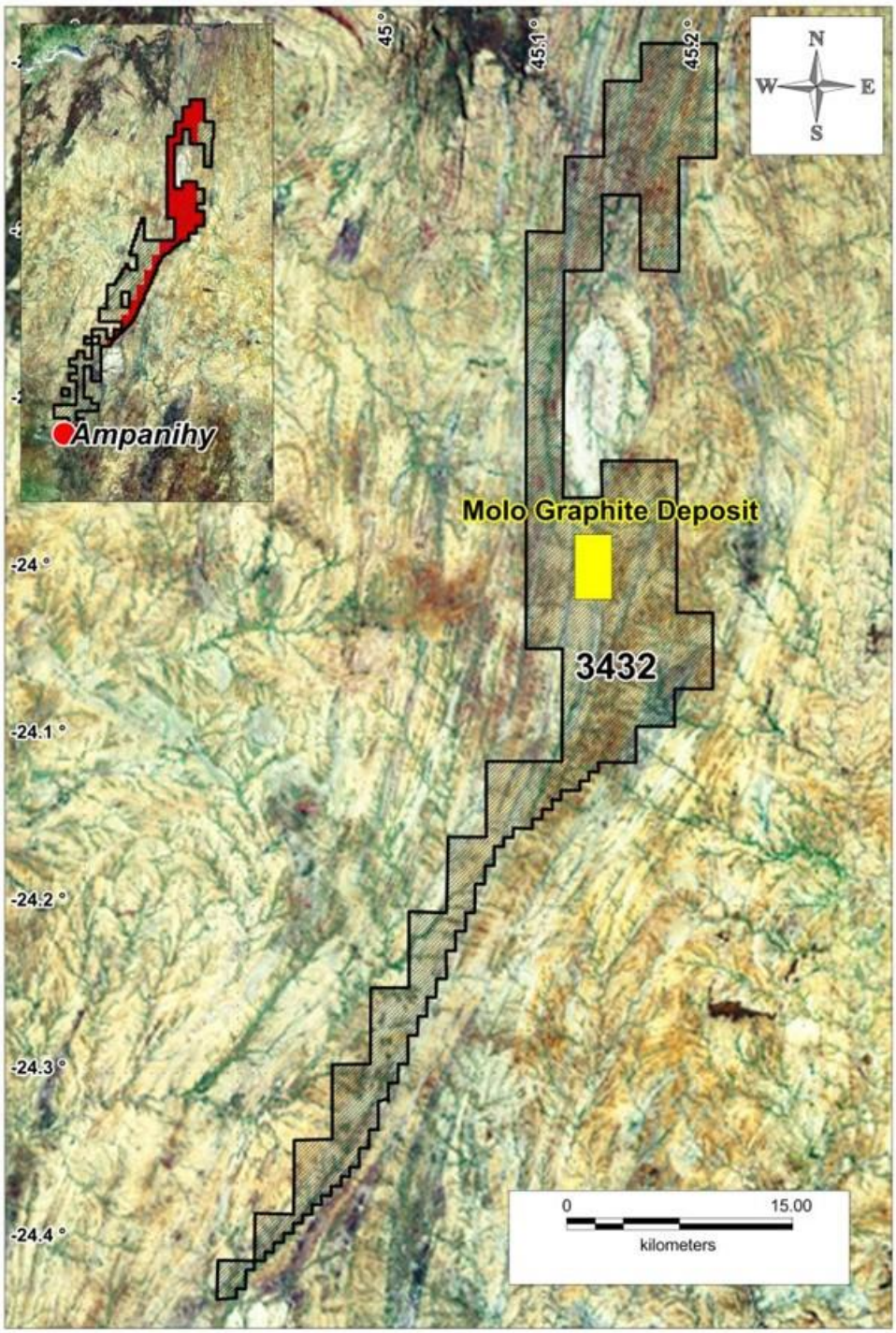


Figure 8: Molo Project - Exploration Permit 3432

Source: NextSource Materials

4.4 Mineral Tenure and Title

On December 14, 2011, the Company entered into a Definitive Joint Venture Agreement ("JVA") with Malagasy Minerals Limited ("Malagasy"), a public company on the Australian Stock Exchange, to acquire a 75% interest to explore and develop a group of industrial minerals, including graphite, vanadium and approximately 25 other minerals. On October 24, 2013, the Company signed a Memorandum of Understanding ("MOU") with Malagasy to acquire the remaining 25% interest in the land position.

On April 16, 2014, Energizer/NEXT signed a Sale and Purchase Agreement and a Mineral Rights Agreement with Malagasy to acquire the remaining 25% interest. Malagasy retains a 1.5% net smelter return royalty ("NSR").

The Molo Graphite Project is located within Exploration Permit #3432 as issued by the Bureau de Cadastre Minier de Madagascar (“BCMM”) pursuant to the Mining Code 1999 (as amended) and its implementing decrees.

CCIC reviewed a copy of the Contrat d’amodiation pertaining to this right and are satisfied that the rights to explore this permit have been ceded to Energizer or one of it’s Madagascar subsidiaries**.**

Energizer/NEXT holds the exclusive right to explore for a defined group of industrial minerals within the permits listed above. These industrial minerals include the following: Vanadium, Lithium, Aggregates, Alunite, Barite, Bentonite, Vermiculite, Carbonatites, Corundum, Dimensional stone (excluding labradorite), Feldspar (excluding labradorite), Fluorspar, Granite, Graphite, Gypsum, Kaolin, Kyanite, Limestone / Dolomite, Marble, Mica, Olivine, Perlite, Phosphate, Potash–Potassium minerals, Pumice Quartz, Staurolite, Zeolites.

Companies in Madagascar first apply for an exploration mining permit with the Bureau de Cadastre Minier de Madagascar (“BCMM”), a government agency falling under the authority of the Minister of Mines. Permits under usual circumstances are generally issued within a month. The number of squares varies widely by claim number.

The updated Decret requires the payment of annual administration fees of Permits Research of ~15,000 Ariary (MGA) for exploitation permits in years one and two. Annual fees increase by multiplying by a factor equivalent to the number of years (plus 1) that the company has held the permit. Exploration permits have an updated duration of five years, with the possibility of two renewals of an additional three years each. Payments of the administration fees are due on the 31st of March of each year, along with the submission of an activity report. Each year the Company is required to pay a similar, although increasing, amount in order to maintain the claims in good standing.

Reporting requirements of exploration activities carried out by the titleholder on a Exploration Permit are minimal. A titleholder must maintain a diary of events and record the names and dates present of persons active on the project. In addition, a site plan with a scale between 1/100 and 1/10,000 showing “a map of the work completed” must be presented. Upon establishment of a mineral resource, Exploration Permits may be converted into Exploitation Permits by application. CCIC is of the opinion that Energizer is compliant in terms of its commitments under these reporting requirements.

The Molo Graphite Project has not been legally surveyed; however, since all claim boundaries conform to the predetermined rectilinear LaBorde Projection grid, these can be readily located on the ground by use of Global Positioning System ("GPS") instruments. Most current GPS units and software packages do not however offer LaBorde among their available options, and therefore defined shifts have to be employed to display LaBorde data in the WGS 84 system. For convenience, all Energizer positional data is collected in WGS 84, and if necessary converted back to LaBorde.

4.5 Royalties

Malagasy retains a 1.5% net smelter return royalty on the Molo Graphite Project.

4.6 Permits

Exploration permit PR 3432 (425 km^2) is currently held under the name of a subsidiary of Malagasy Minerals called, Mada-Aust Sarl. Energizer's/NEXT Madagascar domiciled subsidiary companies and Mada-Aust Sarl have continued to pay all taxes and administrative fees to the Madagascar government and its mining ministry with respect to all the mining permits held in country. These taxes and administrative fee payments have been acknowledged and accepted by the Madagascar government. In addition, Energizer/NEXT continues to diligently work with the Madagascar government to obtain the necessary permits in it's name as the country clears its backlog of applications and amendments.

The exploration permit will be converted into an exploitation permit in due course. When the permit is transformed from an exploration permit to an exploitation permit, the exploitation permit will be issued in the name of NextSource Materials. The exploitation permit is required to advance the Molo Project to the developmental stage.

5 ACCESSIBILITY, CLIMATE, LOCAL RESOURCES, INFRASTRUCTURE, AND PHYSIOGRAPHY

5.1 Access

Access to Molo from Toliara, is initially via a 70 km paved road to the village of Andranovory (Figure 9). From Andranovory, secondary all-season roads continue to Betioky, a distance of 93 km. From Betioky the Property area can be reached via Ambatry to Fotadrevo, a distance of 105 km (268 km total), or from Betioky to Ejeda, then onwards to Fotadrevo, a distance of 161 km (324 km total). This alternate route from Ejeda to Fotadrevo is used by heavy transports and by all vehicles during portions of the rainy season, as the primary route quickly becomes impassable. At the height of the rainy season, both routes to Fotadrevo may be largely impassable. Molo may be reached from Fotadrevo by a fairly well maintained dirt road.

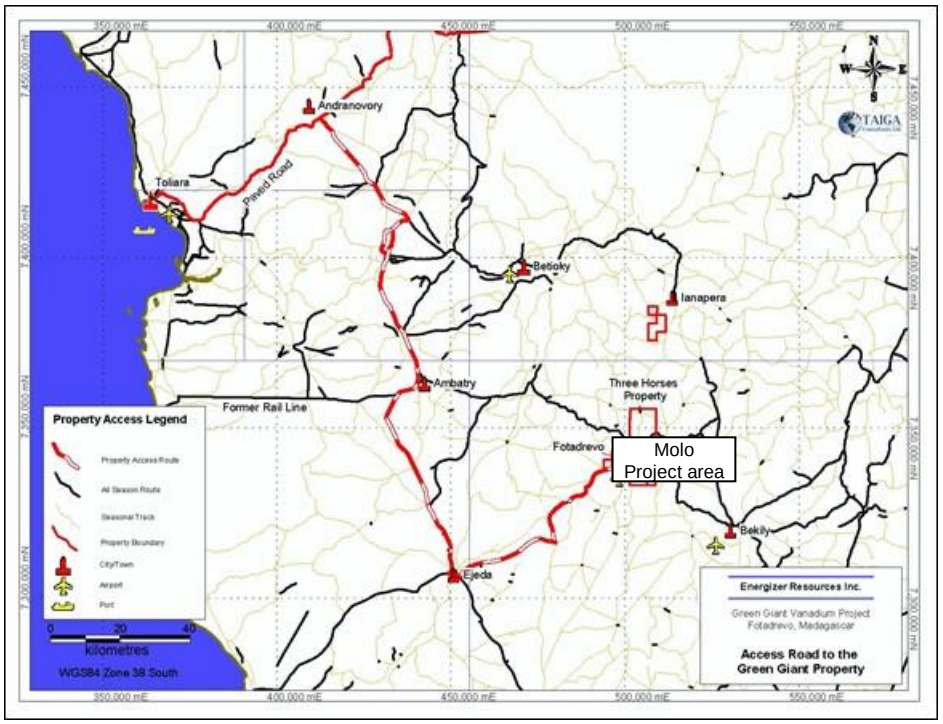


Figure 9: Road Access to the Molo Area from the Town of Toliara

With the upgrading of an existing airstrip at Fotadrevo (Figure 10) to an all-weather airstrip during the 2008 exploration programme, the Molo Project area is now accessible year-round, (except under special circumstance caused by continuous or multiple days of heavy rain) by air, using private aircraft out of Antananarivo. Flying times to Fotadrevo are roughly 2.5 hours from Antananarivo and 45 min from Toliara.



Figure 10: Airstrip at Fotadrevo

Antananarivo is currently serviced by Air France (from Paris), South African Airways (from Johannesburg) and Air Mauritius (Sir Seewoosagur Ramgoolam International Airport in southeast Mauritius). Air Madagascar also provides services to Paris, Johannesburg, Mauritius, Nairobi, and Réunion from Ivato International Airport, which is located 16 km from Antananarivo, the capital of Madagascar. Air Madagascar also has regularly scheduled domestic jet and propjet flights throughout the country, including daily flights between Antananarivo and Toliara.

5.2 Physiography

The Molo deposit area is covered by sparse vegetation (Figure 11) Grass cover is widespread and trees are widely spaced overall, with accumulations near drainage lines and streambeds. In areas of lower relief, alluvial cover is generally shallow and bedrock and/or float are readily observable. Elevations range between 536-565 metres above mean sea level (“m amsl”).



Figure 11: View of the Molo Project Area showing the Nature of the Vegetation

Typical of the tropics, the surface is subject to lateritic weathering. However, full laterite profiles are rarely developed within the southern climatic zone. Previous drilling on the Property indicated that the weathered profile is typically less than 10 m thick in the region, which is roughly one third of that seen in other parts of Madagascar and on the adjacent African continent.

5.3 Climate

Five climatic zones divide Madagascar. The Molo deposit area falls within the semi-desert south zone, with elevated temperatures year round peaking in the hot season at an average of over 30°C. The climate is dominated by southeastern trade winds originating in the Indian Ocean anticyclone, a centre of high atmospheric pressure that seasonally changes its position over the ocean. Madagascar has two seasons, a hot, rainy season from December to March / April, and a cooler dry season from April / May to November. Total rainfall is sparse within the Molo area, with yearly precipitation ranging from 30 cm to 50 cm. The rainy season causes difficulty in travelling off the main highways and for exploration, effectively limiting drilling to the dry season.

5.4 Local Resources and Infrastructure

The village of Fotadrevo (where Energizer has its base camp) is located to the west of the Molo deposit area. The village has been a labour source during the exploration programmes on Molo, and will most likely provide a portion of the workforce during any future development. A few basic goods are commercially available in the village, however, the main centre for support of exploration and development are the cities of Toliara and Antananarivo. Two 40 kVA diesel-powered generators provide power to the Energizer base camp.

A cellular telephone tower is located in Fotadrevo, which provides convenient coverage. No potable water is currently available within the project area. A 123 mm diameter well has been drilled to a depth of 42m within the base camp compound, which provides non-potable water.

5.5 Security

As Madagascar is an island no border issues, or conflicts are known that might affect operations, security, or title in the region. Security of personnel is a company policy directed by management. Considering that the area is predominantly rural, few police, or other security patrols are common in the area. There is always a small possibility that local criminal activity might affect operations, and to mitigate this, the company employs the local military forces to accompany field parties away from secure areas. The Madagascar government provides a requested number of regular military troops, at a cost to NEXT, to ensure security on the Property, on the work site and for the company's equipment.

6 HISTORY

The region around the Property has primarily been explored for base metal type occurrences, although colonial geologic services were alert to all kinds of mineral potential in the region. In 1985 the Bureau de Recherches Géologiques et Minières ("BRGM") (http://www.brgm.fr/) produced a three-volume country scale compilation of all exploration and mineral inventory data in their files. Relatively little exploration and development work has been completed in south-western Madagascar after that of BRGM, and therefore these volumes are key to retracing any historical data. Archival research by Energizer/NEXT has not revealed evidence of mineral exploration in the past fifty years within the Molo Project area.

6.1 Property-Scale Exploration History

Prior to the exploration work completed by Energizer, (then Uranium Star) in 2007 there is no record of any previous exploration activity within the Project area and no historical resource estimates exist for the area, or for Molo. Between 2007 and 2011 Energizer retained Taiga Consultants Limited ("Taiga") to manage exploration activities on the Project. Table 18 shows a summary of the historical exploration activities previously on the property.

Note that only exploration in 2011 is directly related to the exploration of the graphite prospects, and only Phase II of that year concerns the Molo graphite deposit.

Table 18: Historical Activities on the Project

Date	Activity	Company Responsible
2011	Prospecting (538 grab samples) over areas of historical graphitic occurrences (BRGM) on the Project	NextSource Materials
	Diamond Drilling (7 holes). Metallurgical samples selected from Molo-11-07	Boart Longyear
	Trenching programme (1 trench)	NextSource Materials
	Geologic mapping at 1:1000 scale	NextSource Materials
	EM-31 ground geophysical survey (52.2 line kms)	NextSource Materials

Exploration work undertaken in 2011 led to the discovery of the Molo deposit, which then became the focus of the 2012-2014 exploration programmes addressed in the remainder of this Technical Report.

7 GEOLOGICAL SETTING AND MINERALISATION

7.1 Regional Geology

Madagascar comprises a fragment of the African Plate, which rifted from the vicinity of Tanzania at the time of the breakup of Gondwana, some 180 million years ago. At that time Madagascar remained joined with India, moving east-by-south until the late Cretaceous (approximately 70 million years ago), whereupon the two land masses split apart. On a regional scale Madagascar can be described as being formed by two geological entities, a Precambrian crystalline basement, and a much younger Phanerozoic sedimentary cover Figure 12 that hosts potentially economic coal deposits. The central and eastern two-thirds of the island are mainly composed of Neoproterozoic-aged, crystalline basement rocks, composed of a complex mélange of metamorphic schist and gneiss intruded by younger granitic and basic igneous rocks. The Phanerozoic sedimentary cover is largely restricted to the western side of the island and is

Carboniferous to Permian-Triassic. These rocks correlate with the Karoo Super group successions of sub-Saharan Africa, which was widespread in the former supercontinent of Gondwana.

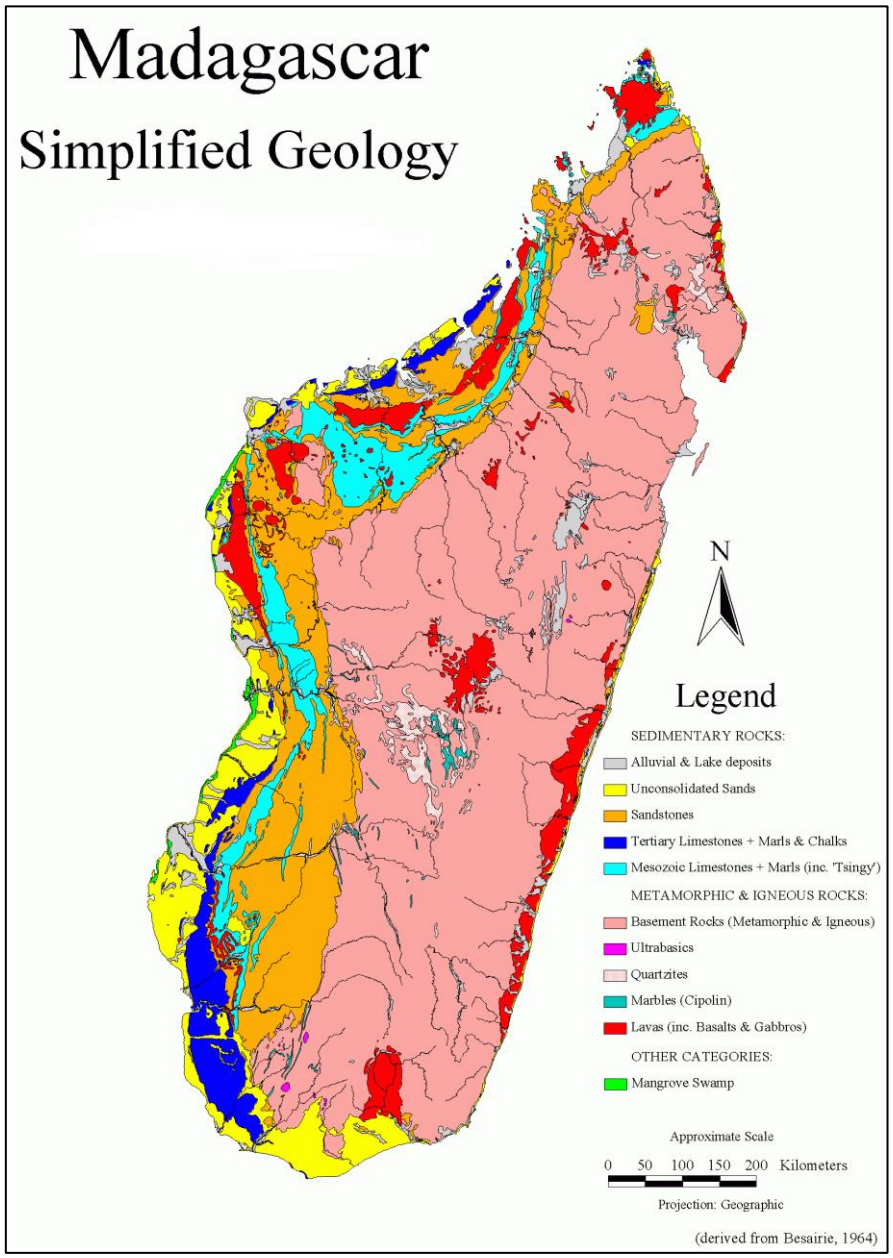


Figure 12: Geological Map of Madagascar showing the Distinctive Crystalline Basement and Sedimentary Basins in the West

Source: Besarie (1964).

The geology of the basement of Madagascar is composed of intercontinental tectonic blocks made up of ancient poly-deformed, high-grade metamorphic rocks and later igneous intrusions. The tectonic and metallogenic basement framework was originally subdivided into four blocks (Besarie, 1967), these being the: northern Bemarivo Block; northeastern Antongil Block; central Antananarivo Block; and the southern Bekily Block. The Molo deposit lies entirely within the bounds of the Bekily Block (Figure 13). Later authors (e.g. Pitfield *et al*., 2006) divided the Precambrian basement of Madagascar in a somewhat different manner, with nine tectono-metamorphic units (Figure 14). In the case of the region around Molo, the tectonic blocks and the tectono-metamorphic units cover a nearly identical area, and as such these divisions can be used interchangeably.

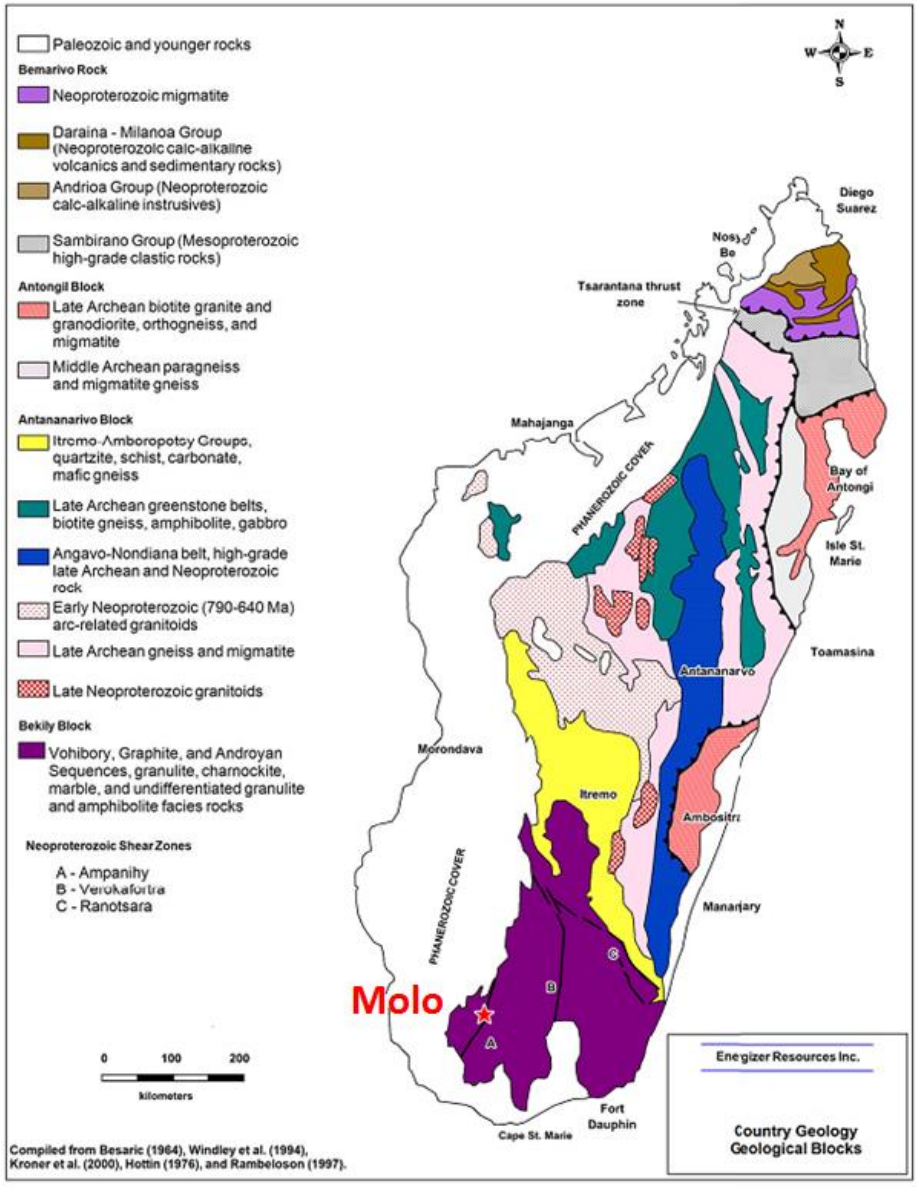


Figure 13: Country Geology: Geological Blocks

Source: AGP Mining Consultants (2011).

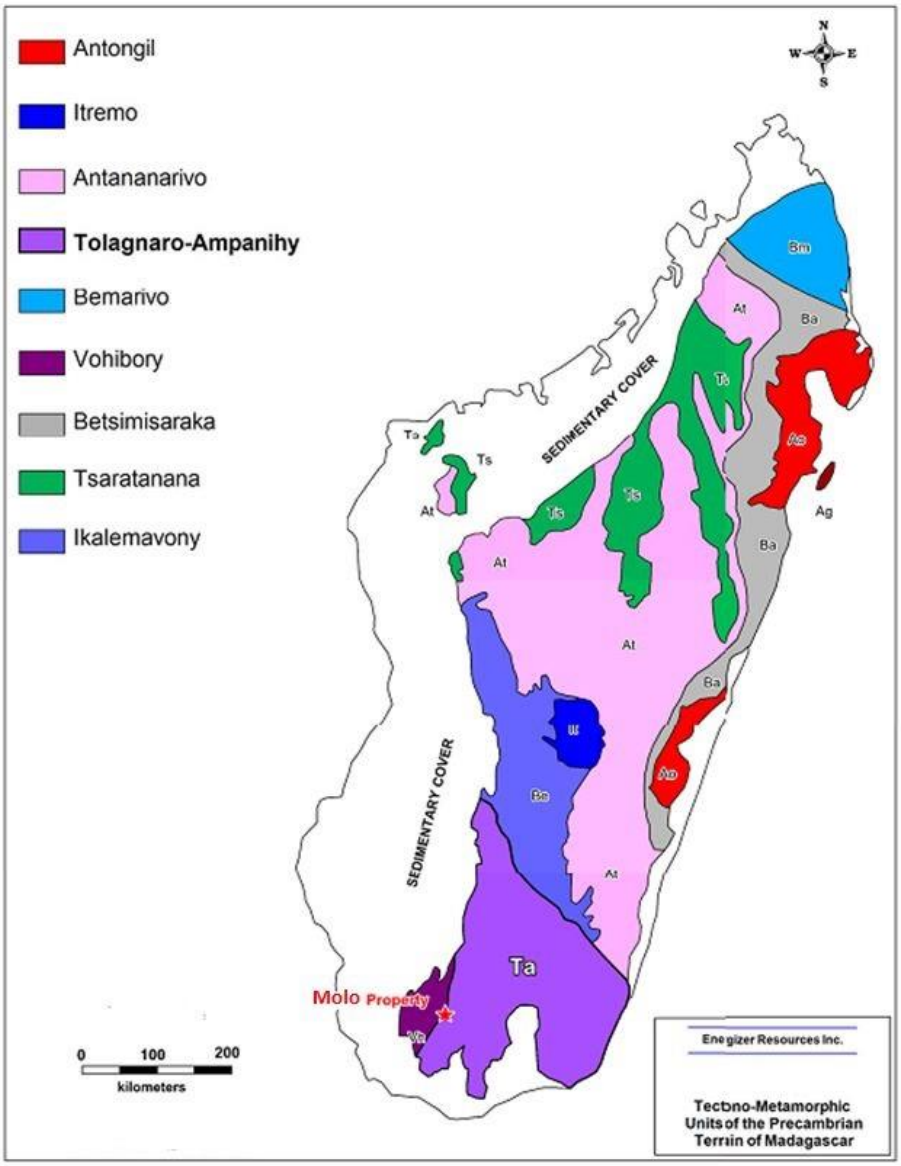


Figure 14: Tectono-metamorphic Units of the Precambrian Terrain of Madagascar (*Source: AGP Mining Consultants, 2011).*

7.1.1 Tectonic History of Southern Madagascar

Southern Madagascar forms part of the Mozambique Mobile Belt and is made up of a section of Lower Proterozoic crust that underwent granulite-facies metamorphism during the Pan-African Orogeny

(Paquette *et al*., 1994). Three crustal units, separated by north-south trending vertical shear zones make up this area (Figure 15). Each of these units experienced granulite facies metamorphism with temperatures between 750˚C and 800˚C. The associated pressures during the Pan-African Orogeny in this area range between 3-11 kilobars ("kbar") with a decreasing trend from west to east (Pili *et al*., 1997).

The Bekily block, (also referred to as the Androyen region, or the Tolagnaro-Ampanihy tectono-metamorphic unit), forms a vast high-grade meta-sedimentary (paragneiss) terrane that has been metamorphosed to granulite facies conditions. This region comprises a complex Neoproterozoic terrain of high grade metamorphic rocks, with a history of polyphase deformation. Two prominent north-south trending late Neoproterozoic ductile shear zones, the Ampanihy and Vorokafotra Shear zones, cross-cut the region. A third set of en-echelon shears forms part of the early Palaeozoic Ranotsara Shear Zone that cuts the basement in a northwest-southeast direction over a strike length of over 400 kms.

De Wit *et al*. (2001) recognize four episodes of deformation and metamorphism. The two early episodes of simple shear deformation (D_1 and D_1), during which northeast verging recumbent sheath folds and ductile thrusts were formed, are dated between 647-627 Ma. Early prolate mineral fabrics (L_1/L_2) are preserved in massif-type anorthosite bodies and their marginal country rocks.

D_1 and D_2 deformation was followed by a 10 to15 Ma period of static, annealing metamorphism when bulk shortening (D_3) took place. D_2 and D_3 deformations are coaxial, but are separated in time by leucocratic dykes that intruded between 620-610 Ma. Between 609 and 607 Ma, D_3 deformation was focused zonally, forming the prominent north–south shear zones. Oblate strain resulted in a strong composite D_2/D_3 fabric defined by sub-vertical S-tectonites and sub-horizontal intersection lineations.

A variety of post-D_3 pegmatites accompanied the following 85 million years of relatively static annealing and metasomatic / metamorphic mineral growth. Numerous occurrences of phlogopite, uranium, and rare earth elements are associated with these pegmatitic bodies. A continuum of concordant monazite dates of between 605 and 520 Ma suggests that this thermal event is part of an extended period of low-pressure (3 to 5 k bar) charnockite-producing event.

The D_4 deformational event recorded within the Ranotsara Shear zone overlaps with the youngest parts of the regional metamorphic conditions. Between 530 to 490 Ma, prevailing low-pressure, high-temperature amphibolite-granulite facies rapidly gave way to greenschist facies conditions.

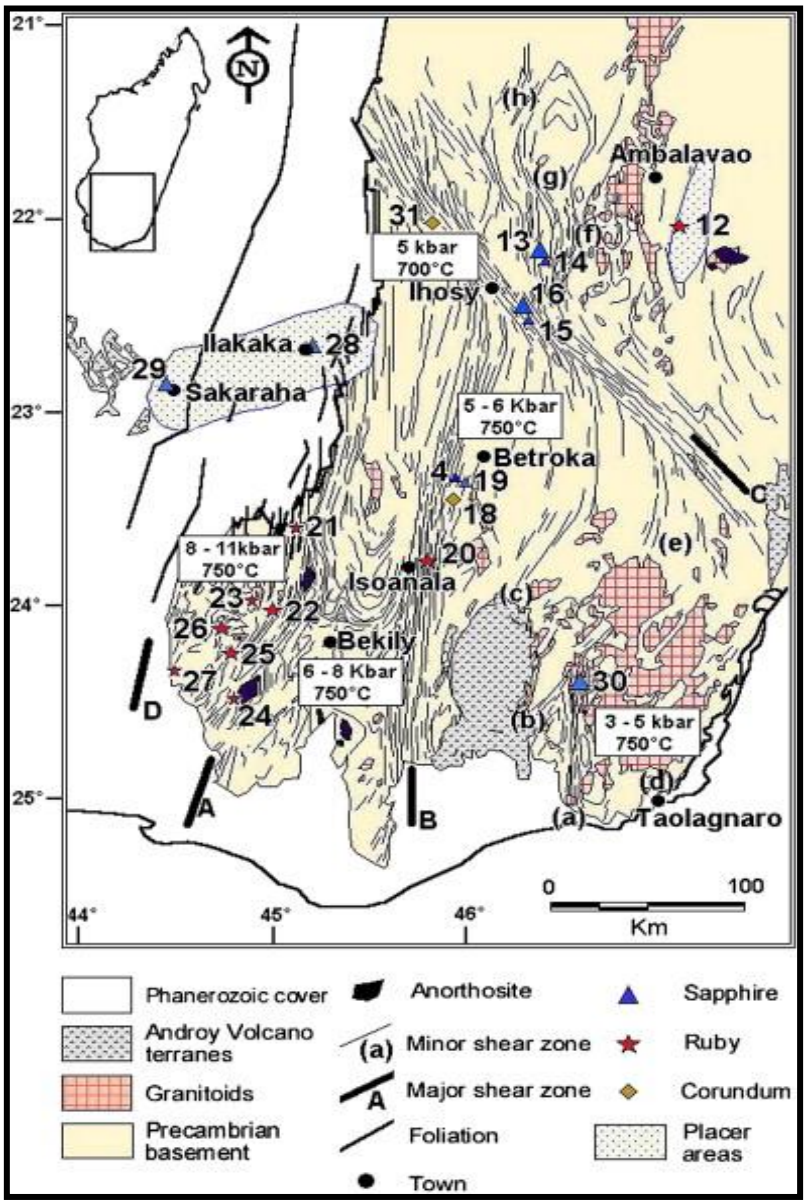


Figure 15: Structural and Lithological Sketch Map of South-east Madagascar showing the positions of the Major Shear Zones (*From: Rakotondrazafy et al.,2008).*

7.2 Regional Geology as it Relates to the Molo Deposit

The Molo deposit occurs within the regional Ampanihy Shear Zone (Figure 16 and 17). The most conspicuous feature of rocks found within this shear zone is their well-developed north-south foliation and vertical to sub-vertical nature. Martelat *et al*. (2000) state that this observed bulk strain pattern is clearly related to a transpressional regime during bulk horizontal shortening of heated crust, which resulted in the

exhumation of lower crustal material. Figure below illustrates the general position of Molo relative to the D2 regional strain pattern, and the resulting Ampanihy Shear zone.

The Molo Project area is underlain by supracrustal and plutonic rocks of late Neoproterozoic age that were metamorphosed under upper amphibolite facies, and deformed with upright north-northeast-trending structures. The supracrustal rocks involve migmatitic (± biotite, garnet) quartzo-feldspathic gneiss, marble, chert, quartzite, and amphibolite gneiss. The metaplutonic rocks include migmatitic (± hornblende / diopside, biotite, garnet) feldspathic gneiss of monzodioritic to syenitic composition, biotite granodiorite, and leucogranite.

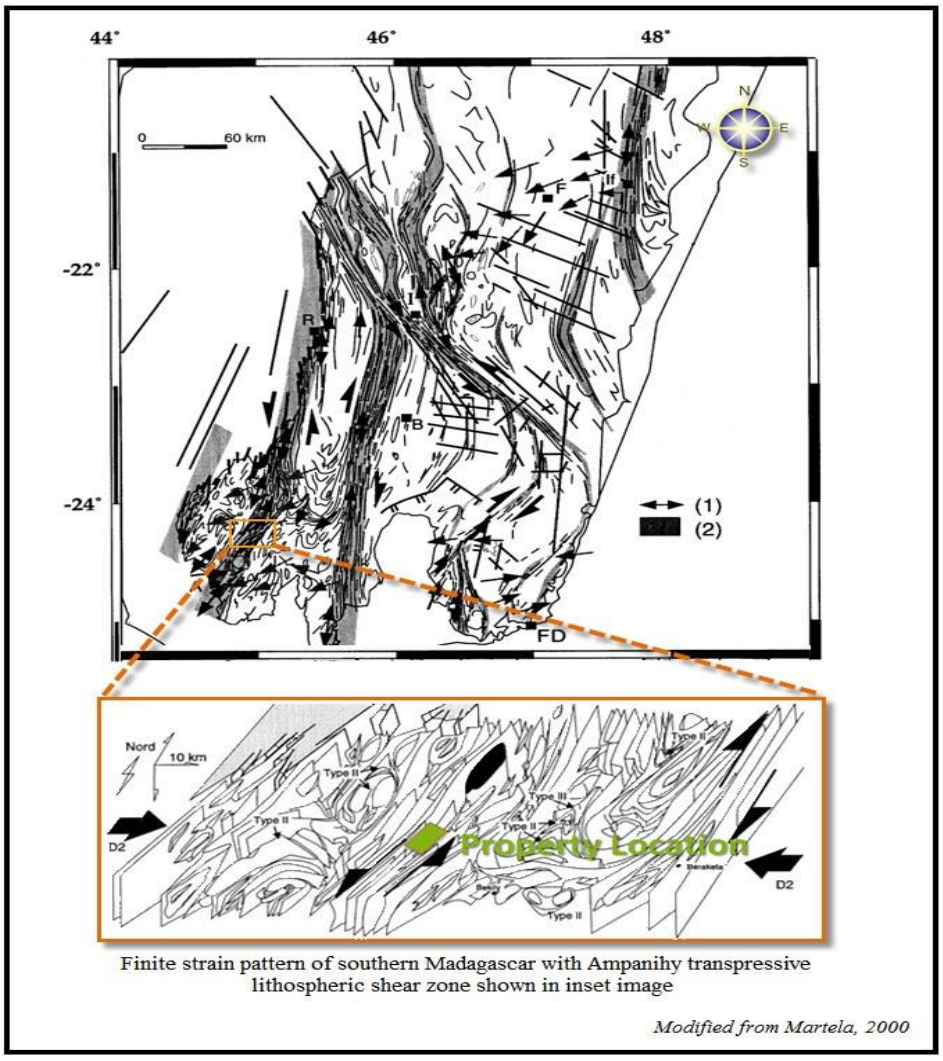


Figure 16: Position of the Molo Project Area within the Overall Strain Pattern Documented for Southern Madagascar

Descriptions of the individual lithological units identified by Energizer, which are relevant to Molo, are included below.

7.2.1 Lithological Descriptions of Individual Rock Formations

7.2.1.1 Amphibolitic Gneiss

Dark grey to black, mesocratic to melanocratic, medium to coarse grained, subequigranular to porphyroblastic amphibolitic gneiss and amphibolite. Amphibolitic gneiss forms one, or more major continuous bands in the eastern part of the permit, intercalated with quartzo-feldspathic gneiss and spatially associated with marble. In the central portion of the detailed map area, amphibolitic gneiss forms local bands, or lenses intercalated with quartzo-feldspathic gneiss and marble.

13.2.1.2 Meta-quartzite

White to greyish-white, weakly to moderately layered and foliated, coarse to medium grained quartzite. Brecciated quartzite with isoclinally folded layering is locally associated with dark brown ferruginous gossan. Un-brecciated quartzite very locally contains narrow, concordant, and discontinuous seams of gossan.

13.2.1.3 Grey-white Chert

Mottled greyish-white, massive to brecciated, hyalocrystalline graphite-bearing chert, (or possibly siliceous rhyodacite). Grey-white chert displays evidence of polyphase brecciation, involving cm to mm scale, angular white siliceous fragments in a relatively early translucent grey siliceous (chalcedony) breccia matrix, and/or a later opaque brown ferruginous gossan breccia matrix.

13.2.1.4 Brown Fe-carbonate Chert

Tawny (yellowish) brown to reddish brown and chocolate brown, massive, hyalocrystalline opaque, graphite-bearing Fe-carbonate chert, variable biotite, and/or specularite. Brown chert, like grey-white chert, contains a small amount (≤1%) of fine-grained disseminated graphite, as well as variably small amounts of fine-grained disseminated biotite and/or specularite. Brown chert represents a widespread Fe-carbonatized alteration facies of grey-white chert, and both occur within the same chert masses. Brown chert is intimately associated with brown marble and ferruginous gossan.

13.2.1.5 Ferruginous Gossan

Dark purplish brown to black, dense, massive to brecciform and quasi-layered, aphanitic to fine-grained, siliceous ferruginous gossan. The gossan is variably highly siliceous to moderately siliceous and pitted,

composed in part of Fe-carbonate (siderite-ankerite) and generally contains disseminated to clustered, fine-grained specularite, biotite, and/or graphite. Siliceous ferruginous gossan occurs as:

- Breccia matrix of late-stage chert breccia and quartzite breccia
- Concordant layers intercalated with chert and marble and discontinuous concordant seams in quartzite discordant masses cutting regional structure in quartzo-feldspathic gneiss and marble.

Siliceous ferruginous gossan is locally associated with cm scale patchy masses of green, opaque calc-silicate, or bright green amorphous and resinous calc-silicate mineral.

13.2.1.6 Quartz Feldspar Gneiss

Light grey to white, migmatitic, well foliated, and locally lineated, leucocratic to hololeucocratic, generally medium-grained (to fine, or coarse grained), ubequigranular to porphyroblastic biotite-garnet Quartzo-feldspatic gneiss comprises a mixture of fundamental constituent lithologies, dependent on the relative abundance, or absence of biotite and garnet.

13.2.1.7 Feldspathic Gneiss

Pinkish grey to pink, migmatitic, foliated, medium to coarse grained, leucocratic (± hornblende / diopside, biotite, garnet) feldspathic gneiss. The feldspathic gneiss is comprised of a mixture of quartz-poor constituent lithologies.

7.2.2 Structural Geology

In 2010 a structural interpretation was undertaken based on the 2007 Fugro Airborne Surveys (http://www.fugroairborne.co.za/) (“Fugro”) helicopter-borne frequency domain electromagnetic (DIGHEM V) multi-coil, multi-frequency, electromagnetic and high sensitivity cesium magnetometer geophysical survey (Butler, 2010; in Desautels et al., 2011). Only magnetite bearing units were capable of being interpreted, except where putative intrusions cross-cut the main fabric in a magnetised area. This work showed the Green Giant Property to be dominated by structures associated with the Ampanihy Shear Zone. Butler (2010; in Desautels *et al*., 2011) specifically identified three magnetic domains associated with the Ampanihy shear system:

1. Zones where magnetic units are parallel, or near parallel to the walls of the domain. In these regions, the shearing has reduced intrafolial folds into sheared out ‘tectonic fish’. There are also broad zones where a low content of magnetite (± pyrrhotite) may be present which most likely represent a different metamorphic mineral assemblage, (different pressure and temperature conditions), or pre-metamorphic alteration and/or rock types.
2. Zones where magnetic units vary from parallel to a high angle at the domain boundary. These regions are interpreted to be the intrafolial fold remnants of sheath folds. The boundary shear of these domains may represent a sheared-out early thrust, or high angle fault.

3. Zones with refolded chaos folds in domain lozenges. These regions occur in the north-central portion of the study area, and may be a remnant of a broad F3 episode enclosed within intense zones of ductility.

7.3 Molo Property Geology

The Molo graphitic zone consists of multi-folded graphitic strata with a surficially exposed strike length of over two kilometres (Figure 1). Outcrop mapping and trenching on Molo has shown the surface geology to be dominated by resistant ridges of graphitic schist (Figure) and graphitic gneiss, with fracture-lined vanadium mineralisation, as well as abundant graphitic schist float.

Geological modelling (Figure) has shown that the deposit consists of various zones of mineralised graphitic gneiss, with a barren footwall composed of garnetiferous gneiss (Figure). The host rock of the mineralised zones is graphitic gneiss.

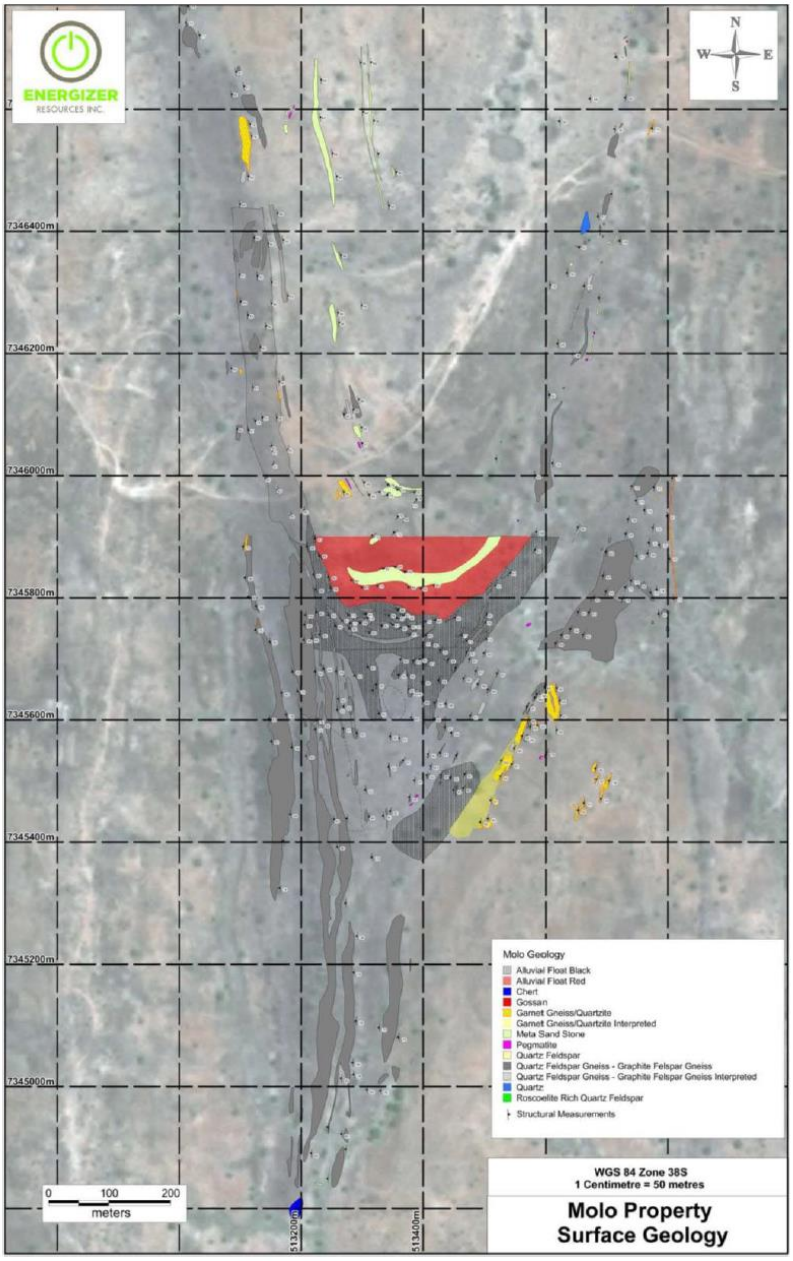


Figure 17: Map showing the Surface Geology of the Molo Deposit



Figure 18: Outcrop Exposure of Graphitic Schist on the Molo Project

Photograph taken during the site visit of the 10th of May, 2012

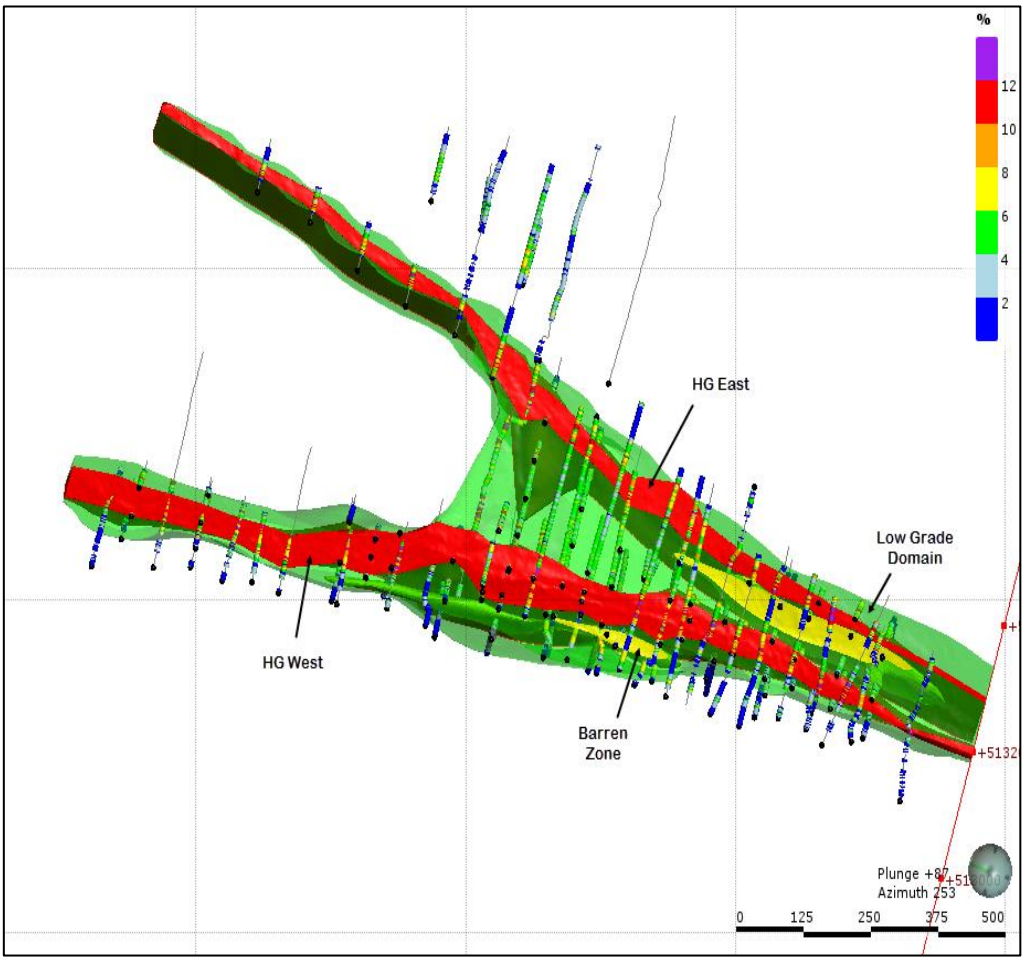


Figure 19: Geological Model of the Molo Deposit showing the Nature of the Two Tightly Oppressed ‘High” Grade (HG East and HG West) Mineralized Zones



Figure 20: Garnet Gneiss in the Footwall of Molo-4 at a Depth of 132 m

No academic studies have been undertaken on the graphitic schists and gneisses of the Molo deposit and at present the deposit is still not fully understood. There is, however, no indication of secondary hydrothermal, or other transported, post-metamorphic graphitic mineralisation or upgrading and the present distribution and crystallinity of the graphite zones seem to be primarily due to regional metamorphic and structural events. The length, width, depth and continuity of mineralisation for the Molo deposit are more fully described under Item 14 “Mineral Resource Estimates”.

8 DEPOSIT TYPES

The Green Giant-JV Project hosts at least two different deposit types:

1) Metamorphosed black shale / roll front redox vanadium deposits, and deposit types.

2) Flake graphite deposits. The metamorphosed black shale / roll front redox vanadium deposits are well described in previous reports (e.g. Scherba and Chisholm, 2008) and are not repeated here.

8.1 Graphite Deposit Types

Graphite is one of the three familiar naturally occurring forms of the chemical element Carbon ("C"). The other two varieties are amorphous carbon, (not to be confused with amorphous graphite) and diamond. Graphite may be synthetically produced, or be from natural source. Most natural sources are considered to be one of three main types, amorphous, flake, or vein.

The following is taken mainly from Kogel *et al.* (2006):

- Graphite is widely distributed throughout the world, occurring in many types of igneous, sedimentary, and metamorphic rocks.
- Many occurrences, however, are of little economic importance.
- The more important occurrences are those found in metasomatic-hydrothermal deposits and in sedimentary rocks that have been subjected to regional, or contact metamorphism

Economic deposits of graphite include five main geological types:

1. Flake graphite disseminated in metamorphosed, silica-rich
2. Sedimentary rocks
3. Flake graphite disseminated in marble
4. Amorphous deposits formed by metamorphism of coal or
5. Carbon-rich sediments
6. Veins filling fractures, fissures, and cavities in country rock
7. Contact metasomatic or hydrothermal deposits in metamorphosed

Natural graphite of economic value can be divided into two main classes, these being:

1. Disseminated flake
2. Crystalline vein (fibrous, or columnar)

Most, if not all, of the world's deposits of flake graphite occur in metamorphic rocks of Precambrian age. Flake graphite is a lamellar form found in metamorphic rocks, such a marble gneiss, and schist. Each flake is separate, having crystallized as such in the rock. In many cases, pegmatitic veins have intruded the rocks.

Crystalline vein graphite (also called lump, or high crystalline graphite) is normally found in well defined veins, or pocket accumulations along intrusive contacts of pegmatites with limestones. Here the enclosing wall rock is not necessarily graphitic. This type of deposit assumes the character of a true lode. The

graphite in these deposits is of two types, foliated and columnar. The Sri Lankan graphite deposits are of vein type.

8.2 Graphite Mineralisation on Molo

Petrographic descriptions undertaken on thin sections of selected rocks of the Manga vanadium deposit submitted for metallurgical analysis to Mintek (www.mintek.co.za/) in 2010 identified 17.17% modal graphite from the silicate composite, and 15.87% modal graphite from the oxide composite samples. Three additional composite samples were submitted to Mintek at the conclusion of the 2010 exploration programme. The Quantitative Evaluation of Minerals by Scanning Electron Microscopy ("QEMSCAN") analysis of these samples quantified a graphite composition of 4.09%, while the head chemical analysis quantified a graphitic carbon content of 3.87%.

The identification of graphite as a potential credit to the Company's NI 43-101 compliant vanadium resources led Energizer geologists to conduct a reconnaissance exploration programme with the goal of delineating new graphitic trends, and comparing them to those associated with vanadium mineralisation. During the course of this reconnaissance exploration programme various surficial graphitic trends were identified on the Green Giant Property. These graphite trends were visually determined to be of both higher carbon content, and larger flake size than those associated with the NI 43-101 compliant vanadium resource mineralisation. Samples from these mineralised zones were submitted to Mintek http://www.mintek.co.za/for analysis, as well as to the North Carolina State University ("NCSU") Minerals Research Laboratory in Asheville, North Carolina.

9 EXPLORATION

The identification of graphite as a potential credit to the Energizer's NI 43-101 compliant vanadium resources (Scherba and Chisholm, 2008) led to a reconnaissance exploration programme being undertaken on the Property in September 2011, with the goal of delineating new graphitic trends. Activities during this phase of exploration included prospecting, grab and trench sampling, and diamond drilling. Based on the results of this programme, Energizer launched a second phase of exploration in November 2011. The objective of this second programme was to use geophysical techniques to delineate additional graphite mineralisation, as well as to drill test the known graphitic.

The signing of the JV agreement with Malagasy in November, 2011 prompted additional exploration to ascertain the industrial mineral potential of the JV Property area. Exploration activities consisted of, geologic mapping, prospecting and sampling, (including metallurgical), ground geophysical surveying (EM-31), trenching, and diamond drilling. As a consequence of the work undertaken during 2011, the Molo graphite prospect was identified and targeted for additional work, which was undertaken between May 2012 and June 2014.

9.1 Geological Mapping

A series of excellent 1/100,000 scale geological maps (1952-53) are available for the region surrounding Molo (Fotadrevo-Bekily, Ianapera, Sakamena-Sakoa), with the area covered by the 1/100,000 scale topographic map #H-60 Fotadrevo.

Various mapping projects have been completed on the entire Green Giant Property, with the major emphasis being strictly dedicated to the commodity of interest at that time. In 2007 Taiga completed a property wide reconnaissance mapping project (1:25,000 scale). Greater detailed (1:5,000 scale) geological mapping was later undertaken to compliment the larger scale version in areas of geologic interest. During the 2008 field season, Taiga again completed a property wide mapping programme, however, at a notably smaller scale than before (1:10,000 scale).

During the 2011 field season mapping activities increased and the identification of the graphitic prospect areas led to smaller scale mapping (1:1000 scale) over areas which appeared to have the greatest graphitic potential. Areas included were Molo (Figure 1) Fondrana, Fotsy and Seta.

9.2 Trenching

No known historical trenching is documented on Molo. During the 2011 field season a number of the new graphite rich areas were trenched including Molo. Initial graphitic carbon results from the 2011 trenching were encouraging in that they showed multiple graphic horizons present in each zone, of significant widths and grades. Because of this, and coupled to the size of the electro-magnetic signature, the 2012 programme focussed on Molo and an additional 22 trenches were excavated. Additional trenching was undertaken on Molo during May of 2013 as part of a bulk sampling exercise (Figure 21). Subsequently an additional nine trenches (totalling 1,876 metres) have been excavated as part of the 2014 exploration programme.



Figure 21: Trenching for the Bulk Sample on Molo, May 2013

A plan map showing the positions and grades of all the trenches excavated on the Molo deposit is provided below as Figure 22.

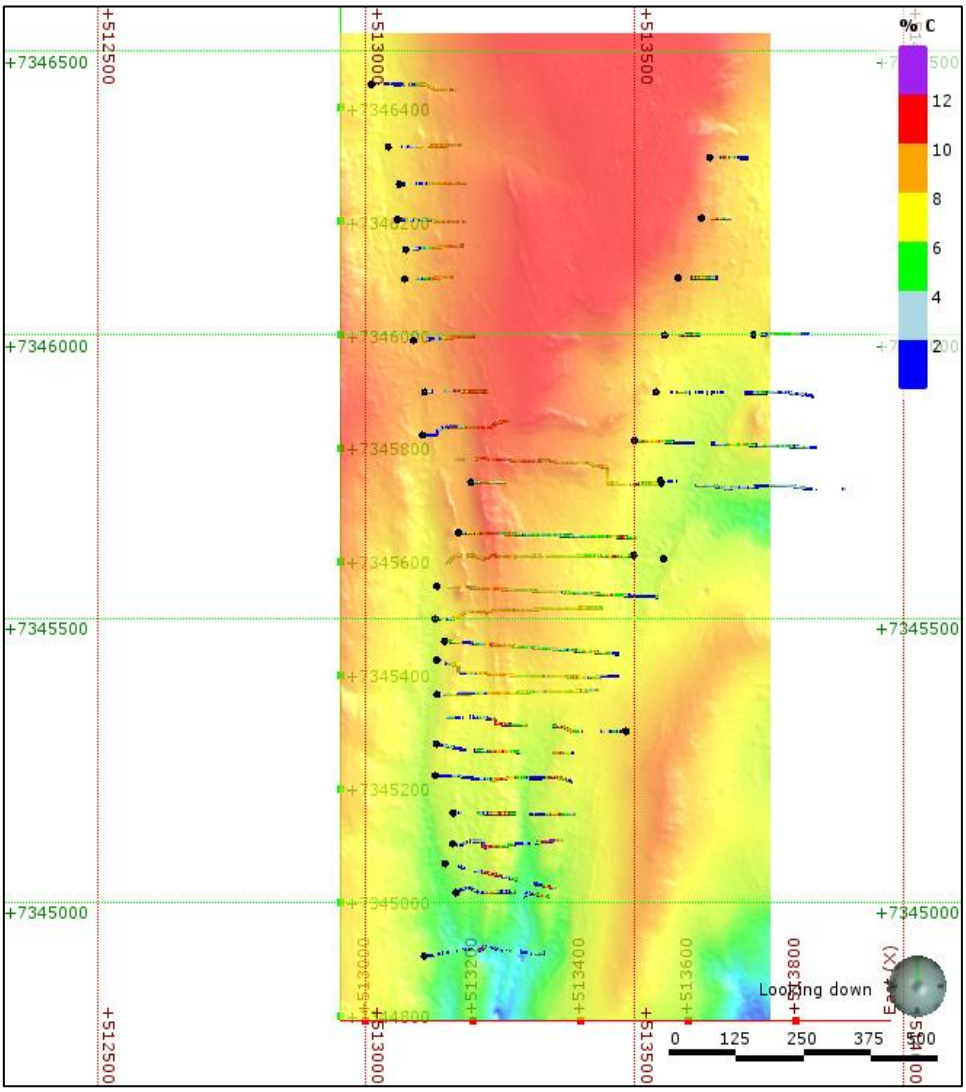


Figure 22: Plan showing the Positions and Grades of all the Trenches Excavated on the Molo Deposit, Overlain on the Topographic Elevation Map

9.2.1 Trench Sampling

Standardized sampling methods include two meter long continuous chip samples approximately 4 cm wide being collected along the northern edge of the trench floor, consisting of about 3 kg to 4 kg of material per sample. The following procedural steps were taken during the sampling and mapping process:

- Plastic sample bags were sequentially numbered with a unique series from pre-printed sample books. The Quality Assurance / Quality Control ("QA/QC") sample numbers are flagged at this point for later insertion

- The trench floor is swept clean with hand brooms to ensure there is no contamination from rubble, or fines
- Two technicians use hammers and chisels to gently dislodge the weathered rock along the channel profile
- A third technician follows behind to collect the sample material, first verifying the sample tag is in the bag, then matching the sample bag number and the sample book interval
- The sample bag was sealed with a zip tie, with the sample tag inside the bag
- Two technicians follow behind the samplers and clean / scrape the north wall of the trench to allow better visual inspection of any structures, and to remove any debris, or 'polishing' which may have occurred during excavation
- A geologist, or qualified technician using scaled paper inspects the north wall of the trench and records structures, mineralisation, depth and any other notable aspects
- All samples are brought back to the camp each night for storage in the secure facility at Fotadrevo until shipment

Samples taken from the 2012-2014 trench exploration programmes were subject to stringent QA / QC and their lengths and percentage carbon are presented in Table 19 below. This data was used in the estimation process.

Table 19: 2012/2014 Molo Trench Results

Trench	From (m)	To (m)	Length (m)	C%
MOLO-TH-12-01	28	318	290	6.58
MOLO-TH-12-02	2.5	358	355.5	6.01
MOLO-TH-12-03	5	380	375	7.74
MOLO-TH-12-04	37	119	82	8.89
MOLO-TH-12-05	32	90	58	7.4
MOLO-TH-12-06	45	125	80	6.56
MOLO-TH-12-07	52	138	86	7.34
MOLO-TH-12-08	88	140	52	7.65
MOLO-TH-12-08	186	286	100	7.25
MOLO-TH-12-09	38	128	90	6.92
MOLO-TH-12-09	166	220	54	8.79
MOLO-TH-12-10	92	121	29	7.18
MOLO-TH-12-10	214	230	16	5.06
MOLO-TH-12-11	34	94	60	5.01
MOLO-TH-12-11	158	194	36	5.74

Trench	From (m)	To (m)	Length (m)	C%
MOLO-TH-12-12	84.5	257	172.5	5.68
MOLO-TH-12-13	16	52	36	4.51
MOLO-TH-12-13	74	320	246	6.55
MOLO-TH-12-14	82	176	94	7.87
MOLO-TH-12-15	84	152	68	6.94
MOLO-TH-12-16	80	96	16	4.37
MOLO-TH-12-18	38	65	27	4.88
MOLO-TH-13	0	299	299	6.14
MOLO-TH-14	44	222	178	6.32
MOLO-TH-15	27.3	112	84.7	5.88
MOLO-TH-16	32.6	108	75.4	6.82
MOLO-TH-17	0	332	332	6.15
MOLO-TH-18	20	351	331	5.58
MOLO-TH-19	24	298	274	5.37
MOLO-TH-20	88	250	162	7.13
MOLO-TH-21	59	212	153	6.93
MOLO-TH-22	48.6	119	70.4	6.57
MOLO-TH-23	3.3	69.3	66	7.26
MOLO-TH-24	27	65	38	8.09
MOLO-TH-25	26	66.6	40.6	6.51
MOLO-TH-26	18.6	46	27.4	7.63
MOLO-TH-27	24.6	50.6	26	6.86

9.3 Ground Geophysical Surveying

During 2011 an EM31-MK 2 (“EM31”) ground conductivity instrument was obtained to aid determination of the overall extents of the graphitic horizons delineated during the previous year’s field mapping and prospecting activities. The EM31 geophysical tool was invaluable in delineating the extents of the graphitic zones, as well as their continuity. Energizer’s geotechnical team conducted a survey consisting of 100m spaced lines and 25m stations. In total, 160.5 line kilometres of EM31 surveying was completed over five target areas, full details of which are available on the Company’s web page

(http://energizerresources.com/projects/green-giant-graphite.html). This data was used to plan the original (2011) boreholes drilled on Molo (Figure).

During the 2011 programme an EM31 geophysical survey was also conducted over the Molo deposit area concurrently with prospecting and subsequent geological mapping of the stronger graphitic zones. The survey (Figure 23) aided in outlining a zone length of over 2 km, with an aggregate EM31 measured strike length of 10 km. This, along with the confirmation of five strong graphitic horizons, supported further trenching and drilling.

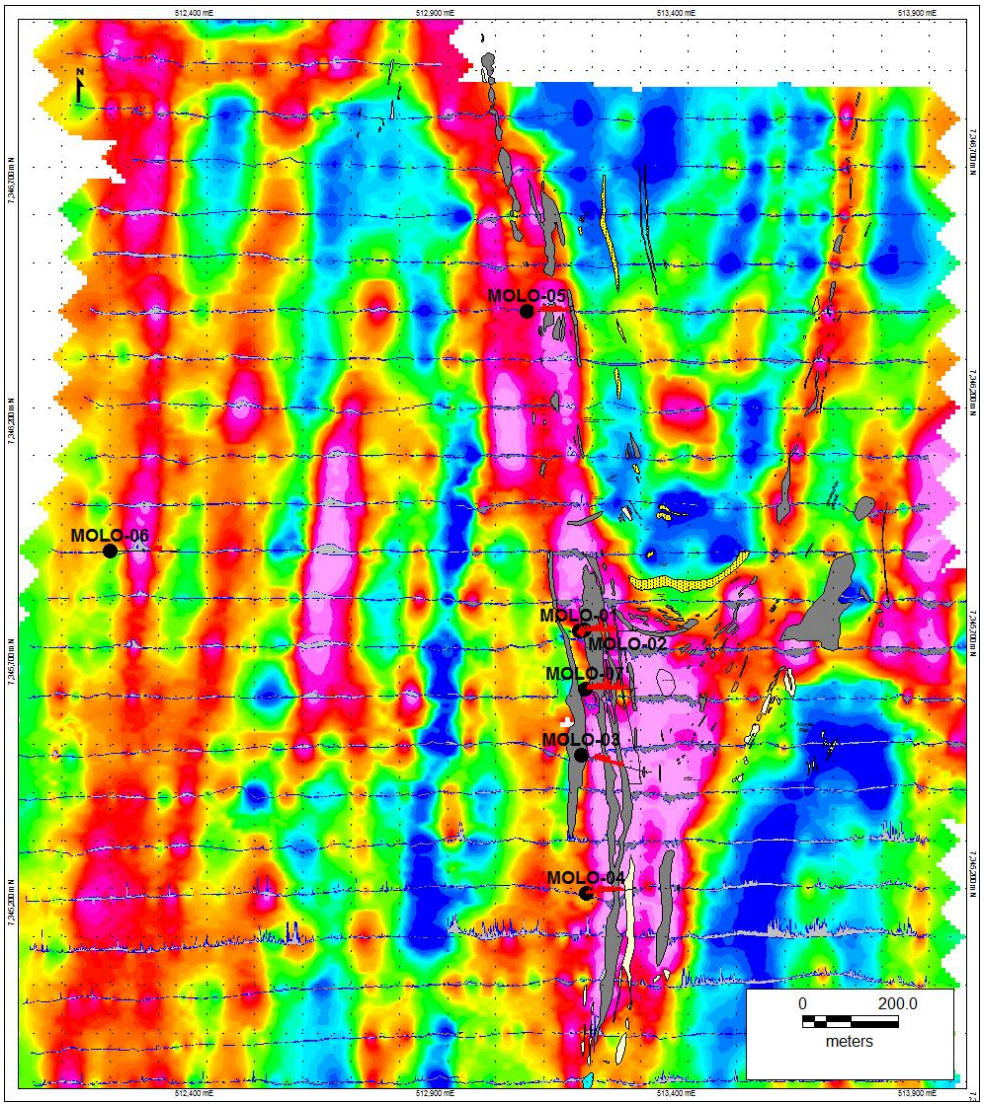


Figure 23: EM31 Geophysical Survey Map of the Molo deposit showing the positions of holes MOLO-01 to MOLO-07 drilled during 2011

Bright Pink areas are interpreted graphitic areas and the grey areas represent surficial / mapped graphite outcrops. The north-eastern limb was the focus of additional work during 2014.

9.4 Prospecting and Sampling

Property scale prospecting and grab sampling was conducted during earlier exploration programmes. Prospecting typically consisted of a preliminary stage in which areas were covered on a large scale to determine Vanadium and Graphite potential. Upon discovery of any notable potential mineralisation, a larger group of prospectors were sent to the area of significance. This then allowed much more of the Property to be 'ground truthed' and, where applicable, sampled in an intensive manner to gain an understanding of all of the zones.

During 2011 Energizer's employees thoroughly covered the Green Giant property with special interest in graphitic showings. With the addition of the JV Property, a much larger area had to be investigated, which required helicopter assistance to access remote and marginally accessible areas. Over the course of six days Energizer's technical team visited a variety of notable graphite localities including Molo. During 2012 Molo was subject to an intensive grab sampling programme, which resulted in a total of 344 samples being collected.

10 DRILLING

No known historical diamond drilling is documented for the Green Giant Property. Numerous diamond drilling programmes have been conducted over the Green Giant (and formerly the Three Horses) property in the past seven years and these have previously been covered in previous reports (Scherba and Chisholm, 2008, McCracken and Holloway, 2009; and Desautels *et al*., 2010). Only work directly, or indirectly pertaining to the Molo deposit is therefore covered here.

Due to the realization that a significant graphitic resource probably existed on the Green Giant-JV Property, a reconnaissance diamond drilling programme was implemented in 2011 to test the viability and potential of the graphitic prospects.

The 2011 diamond drilling commenced in early November and ran through to mid-December. During this programme Energizer entered into a JV agreement with Malagasy Minerals and this phase therefore was re-focussed on the new graphitic prospects on the JV areas. This resulted in 19 holes being drilled by Boart Longyear over the Molo, Fotsy, Fondrana and Seta areas, for a combined 1701 m of diamond drilled core. Of these 19 holes, one larger (PQ) diameter hole was completed and sent to Activation Labs (www.actlabs.com/) ("Actlabs") in Ancaster, Ontario, Canada for metallurgical analysis.

Of the 2011 diamond drilling, seven (Molo-01 to Molo-07) wide spaced holes were drilled on Molo. Six of these (over a strike length of 1.2 km) intersected graphitic mineralisation to a vertical depth of 75m, with down-hole thicknesses of between 60m and 150m in width. Graphite mineralisation intersected in drill core was open along strike, and at depth. Forty one diamond drill holes, comprising 8,502.7m of diamond drilling were completed on Molo during 2012. During 2014 an additional 32 diamond drill holes (totalling 2,063 metres) were completed. With this most recent drill programme, a total of 80 diamond drill holes (Figure

24), (totalling 11,660 meters) have now been completed on Molo, and these were used for the mineral resource estimations.

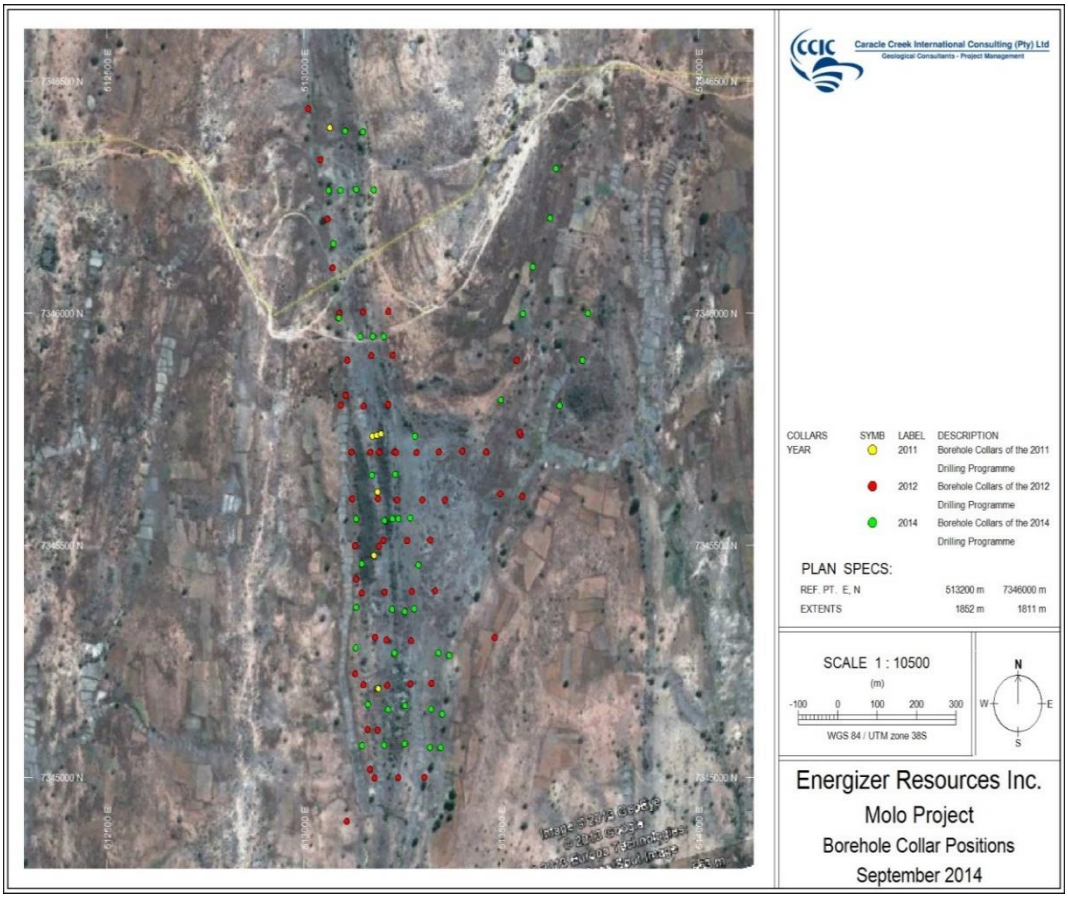


Figure 24: Borehole Collar Positions for all of the Known Boreholes Drilled on the Molo Deposit

10.1 Diamond Drill Contractor and Logistics

Between 2009 and 2014 all diamond drilling on the Green Giant-JV Project was carried out using a Boart Longyear 44 skid-mounted wire-line rig, and a Boart Longyear LF-90 skid-mounted wire-line rig, owned and operated by Boart Longyear™ (http://www.boartlongyear.com/), South Africa. The initial 70 to100m of any borehole was generally completed with HQ core (63.5 mm diameter), and once reasonably competent rock was encountered, this was reduced to NQ (47.6 mm diameter core). On rare occasions, (as noted for the 2011 metallurgical hole) larger diameter PQ sized core (85.0 mm diameter) was extracted.

The drill moves were completed using Boart Longyear's John Deere skidder equipped with a blade and winch. Drill pads and sumps were prepared using a rental CAT 420D backhoe / loader. While drilling, all fluids were pumped directly from the sumps, with all overflow fluids directed back to the sumps. These measures were taken in order to conserve drill fluids and to prevent site contamination by drill additives or metals liberated by the drilling. Water for drilling operations was trucked from streams, creeks, or ponds

sporadically located along the main drainages crossing the property, and stored at the drill site until required.

10.1.1 Core Handling Procedures

Core is delivered from the Molo drill site to the Fotadrevo base camp by pickup truck at the end of every 12 hour shift, under the supervision of the drilling company, or an official designated by Energizer. Drill core is stored in galvanized-steel core boxes 1m in length holding 3m PQ, 5m HQ, or 7m NQ core. The core boxes are laid out on constructed core benches in sequential order. A general review of the core is undertaken and the core is washed, or rinsed of debris and drilling fluids. Energizer's technicians then assess the overall condition and recovery of the core and complete a lithological 'quick log'. Errors in run markers are noted. All drill core is presently stored at Energizer's Fotadrevo camp within a secure, 20m x 25m fenced enclosure.

10.1.2 Core Logging

Energizer utilizes a logging system developed by Taiga, which has subsequently been altered slightly and has become the standard for all Company procedures. At this stage of exploration there is no restricted list of rock units for core logging as the stratigraphy is still being developed. Energizer's geologists, however attempt to utilize a standard set of units, and aim to discuss and agree upon any new units prior to their utilization.

Core logging was previously recorded onto paper logs which were subsequently transferred to computer. The Company has, however, recently purchased Panasonic Field laptops and thus all data is currently entered directly into these units. Core logs contain observations of geology, structure, mineralogy, alteration and sample interval descriptions.

10.1.3 Core Recovery

Trained technicians are responsible for collecting geotechnical data such as rock quality description ("RQD") and core recovery. The data is recorded onto paper forms with entry into computer logs at the end of the day. The core recoveries are considered as being good and fit for resource estimation purposes.

10.1.4 Core Photography

The core is photographed in groups of two boxes (Figure 25) and then forwarded for cutting. Core is typically photographed wet.



Figure 25: Core Photographs of Borehole MOLO-05 Core (Boxes 17 and 18) as Supplied to CCIC by Energizer

10.1.5 Collar Survey

Borehole collar locations are initially established in the field using a hand held global positioning system ("GPS") instrument. Following completion of the hole the collar locations were re-measured, also using a hand-held GPS. The nominal accuracy of these positions, as stated by the manufacturer of the GPS units, is ±3 m. The bore hole collars have not been surveyed by a registered surveyor.

All drill collar sites have been reclaimed and collars marked, with nothing left in the ground, or on the drill site. All holes are plugged and cemented to approximately one metre down the hole. Furthermore, all holes are identified by engraving the collar name into the fresh cement, which when dry is very difficult to destroy (Figure).



Figure 26: Concrete Marker Showing the Collar Position of Borehole MOLO 12-02

10.1.6 Down Hole Surveys

From 2009 till present, Boart Longyear uses single shot Reflex equipment on all diamond drill holes to measure down the hole azimuths and inclinations. Measurements were taken below the level of the surface casing, (generally 10m to 15m depth), every 50m, (unless hole conditions dictated otherwise), with a final measurement taken at the end of the hole.

10.1.7 Geotechnical Logging

Geotechnical logging consisted of RQD measurements and core recovery calculations. The data was collected on paper forms and later transcribed into an Excel spreadsheet. RQD measurements are calculated using a minimum 10 cm core length according to the following formula:

$$RQD = Run\ Length - \frac{(\sum Pieces\ of\ core < 10\ cm)}{Run\ Length}$$

10.1.8 Diamond Drill Core Sampling

The methodology utilized by Energizer for diamond drill core sampling was first established by Taiga during the 2008 exploration programme, and then modified to accommodate specific programme requirements as needed.

The 2012-2014 diamond drill core sampling procedure may be described as follow:

- Sample interval was set at a maximum of 1.5m (run length), and shortened based on lithological breaks
- Sample intervals were recorded in the drill log and in pre-printed sample books. QA/QC samples numbers were flagged at this point for later insertion
- Plastic sample bags were numbered sequentially with the appropriate sample number
- Core was cut by a technician using a clean water spray table rock saw and both halves of the sawn core was placed back in the box
- The geologist who logged the core verified the sample tag with the sample book and placed half of the cut core into the sample bag
- The sample bag was sealed with a zip tie, placed in another larger bag (i.e., double bagged) with a duplicate sample number, and a sample tag was inserted between the sample bags to mitigate against the destruction of the sample tag
- All the samples were stored in a secure facility at Energizer's Fotadrevo campsite until shipment

10.1.9 Diamond Drill Results

All results from the 2011, 2012 and 2014 diamond drill programmes are presented below in Table 10 below. The authors of this Report are of the opinion that there are no drilling, sampling or recovery factors that could materially impact the accuracy and reliability of the nature of the obtained samples.

Table 10: Collar Co-ordinates, Drilled Length and Orientation for the Molo Drill Holes

BHID	EASTING	NORTHING	ELEV	LENGTH	DIP	AZIMUTH
MOLO-01	513173	7345735	553.96	166	-45	90
MOLO-02	513184	7345737	554.52	47	-45	265
MOLO-03	513177	7345478	549.88	207.5	-45	105
MOLO-04	513188	7345191	545.79	137	-45	85
MOLO-05	513065	7346400	551.60	131	-45	90
MOLO-06	512199	7345902	543.51	200	-45	90
MOLO-07	513186	7345615	550.84	142.5	-45	90
MOLO-12-01	513121	7345600	550.78	463.6	-45	90
MOLO-12-02	513185	7345601	550.58	89	-45	270
MOLO-12-03	513236	7345598	551.52	311	-45	90
MOLO-12-04	513300	7345600	553.24	221	-45	90
MOLO-12-05	513360	7345600	553.96	170	-45	90
MOLO-12-06	513150	7345400	548.59	364.5	-50	90
MOLO-12-07	513210	7345400	547.65	299	-50	90
MOLO-12-08	513270	7345400	547.86	212	-50	90
MOLO-12-09	513330	7345400	549.46	137	-50	90
MOLO-12-10	513151	7345199	545.65	320	-50	90
MOLO-12-11	513210	7345197	545.81	221	-50	90
MOLO-12-12	513270	7345200	544.46	182	-50	90
MOLO-12-13	513322	7345202	543.49	95	-50	90
MOLO-12-14	513177	7344998	541.12	260	-50	90
MOLO-12-15	513238	7345001	541.87	194	-50	90
MOLO-12-16	513305	7344999	543.16	80	-50	90
MOLO-12-17	513092	7345801	553.85	258.4	-50	90
MOLO-12-18	513151	7345799	554.37	132	-50	90
MOLO-12-19	513204	7345805	556.96	77	-50	90
MOLO-12-20	513089	7346000	552.99	234	-50	90
MOLO-12-21	513150	7346002	552.38	156.5	-50	90
MOLO-12-22	513215	7346007	554.77	54	-50	90

BHID	EASTING	NORTHING	ELEV	LENGTH	DIP	AZIMUTH
MOLO-12-23	513202	7345517	550.20	126.4	-50	270
MOLO-12-24	513245	7345513	550.21	177.5	-50	270
MOLO-12-25	513210	7345292	546.50	85.5	-50	270
MOLO-12-26	513274	7345295	545.81	186.5	-50	270
MOLO-12-27	513226	7345702	554.22	212	-50	270
MOLO-12-28	513170	7345909	554.69	84	-50	270
MOLO-12-29	513215	7345907	555.68	143	-50	270
MOLO-12-30	513188	7345713	553.67	126.8	-50	270
MOLO-12-31	513322	7345513	552.23	293	-50	270
MOLO-12-32	513119	7345697	553.26	327.5	-50	90
MOLO-12-33	513169	7345702	553.10	252.5	-50	90
MOLO-12-34	513232	7345702	554.33	236	-50	90
MOLO-12-35	513285	7345700	554.94	185	-50	90
MOLO-12-36	513341	7345702	554.59	200	-50	90
MOLO-12-37	513403	7345703	553.26	200	-50	90
MOLO-12-38	513465	7345706	549.95	152	-50	90
MOLO-12-39	513190	7345498	550.05	329	-70	90
MOLO-12-40	513179	7345301	546.95	326	-70	90
MOLO-12-41	513187	7345102	542.80	329	-70	90

11 SAMPLE PREPARATION, ANALYSES AND SECURITY

11.1 Sample Preparation, Assay and Analytical Procedures

At all times during sample collection, storage, and shipment to the laboratory facility, the samples are in the control of Energizer, or their agents.

When sufficient sample material (grab, trench, or core) has been collected, the samples are trucked, or flown to Energizer's storage location in Antananarivo, at all times accompanied by an Energizer employee. From there, samples are further shipped to either South Africa (Mintek, or Genalysis), or Canada (Activation Labs) for ICP-MS analysis.

Drill core samples collected during 2011 were directed to two major laboratories. All samples collected during Phase I of 2011 were sent to Mintek, South Africa. Samples were then tested for Carbon content (Total Organic Carbon and Overall Carbon content), as well as the full range of elements available through ICP-OES (Mintek code FA5) and XRF analysis. The elements tested included Al, Si, P, S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, Ge, As Se, Br, Rb, Sr, Y, Zr, Nb, Mo, Ag, Cd, in, Sn, Sb, Te, I, Cs, Ba, La, Ce, Hf, Ta, W, Hg, Tl, Pb, Bi, Th and U.

The remainder of samples collected during Phase II of the 2011 exploration programme were submitted for analysis to Actlabs, Canada. Samples were again submitted for analysis of Carbon content, as well as for a large range of elemental analysis.

During 2012 all samples were submitted to Intertek Genalysis (www.intertek.com/) ("Genalysis"). All work undertaken by Intertek is performed in accordance with the Intertek Minerals Standard Terms and Conditions of which can be downloaded from their web page.

All analytical results were e-mailed directly by both Genalysis and Mintek to the Green Giant Project Manager, as well as Energizer executive staff, and were posted on a secure website and downloaded by Energizer personnel using a secure username and password. Following the site inspection in May 2012, all analytical results were also e-mailed directly to Dr. Hancox (CCIC) and these were compared against the final data set as presented by Energizer.

All of the laboratories that carried out the sampling and analytical work are independent of Energizer.

11.2 QA/QC

In order to carry out QA/QC protocols on the assays, blanks, standards and duplicates were inserted into the sample streams. This was done once in every 30 samples, representing an insertion rate of 3.33% of the total.

11.2.1 Blanks

Since the 2009 drill programme, Energizer has rigorously implemented a blank protocol. For Molo fine-grained quartz sand sourced from a hardware store in Antananarivo was used as the blank material for the sampling campaign. An additional 93 blanks have been submitted during this campaign, taking the total number of blanks to 301. A detection limit of 0.05% Carbon was used for the purpose of this exercise. To verify the reliability of the blank samples, the detection limit and the blank + 2, and 3 times the detection limit was plotted against the date (and Figure) represents the previous and current campaigns respectively). Blanks for the 2014 campaign shows that that the majority of samples have concentrations that lie within the blank + 3 times detection limit threshold, with the maximum outlier being 0.57% C.

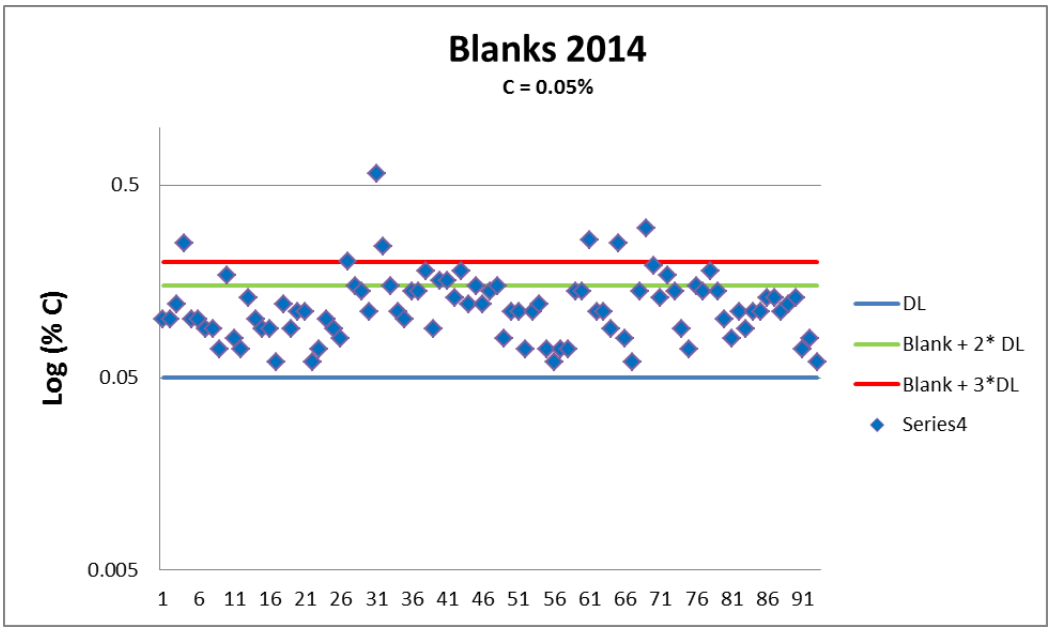


Figure 27: Plot of Log %C versus the Date of the Analysis 2014 for the Blanks

11.2.2 Standards

Because of the difficulty in sourcing certified standard reference material (“CRM”) during the 2012 campaign, Energizer commissioned Actlabs, Canada to create a CRM from the remaining Molo drill core pulps from the 2011 programme. As certified the Actlabs standard (STD 1 C) has a recommended value of 9.11% Carbon. For the 2014 campaign, Energizer sourced two additional CRM’s from GEOSTATS (Proprietary) Limited (“GEOSTATS”), namely GGC-01 and GGC-07. The recommended values for GGC-01 and GGC-07 are 24.97% C and 0.56% C respectively.

To check the reliability of the standard, a plot of the recommended CRM value versus date was created (Figure , 29 and 30).

The upper and lower limits of one, two and three times the standard deviations of the recommended value are also included in the plot. For STD 1 C, all but two results fall outside the acceptable limit of three times the standard deviation. It is however worth noting that the obtained results indicate a slight positive bias

when compared to the recommended value. For GGC-01, all of the obtained results occur within two standard deviations. For GGC-07, four samples occur outside of three standard deviations. This CRM has a mean value of 0.56% C whilst the mean of the obtained values is 0.61% C, indicating a positive bias at low concentrations.

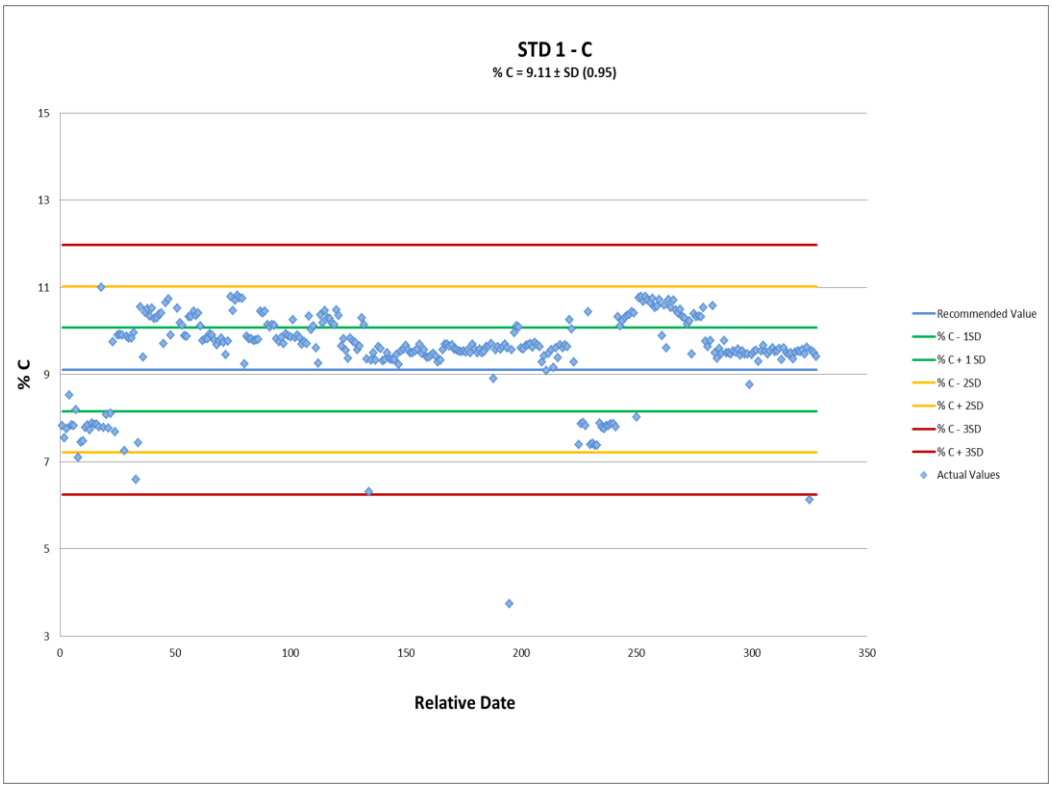


Figure 28: Graph showing Carbon Concentration as Analysed in STD 1C

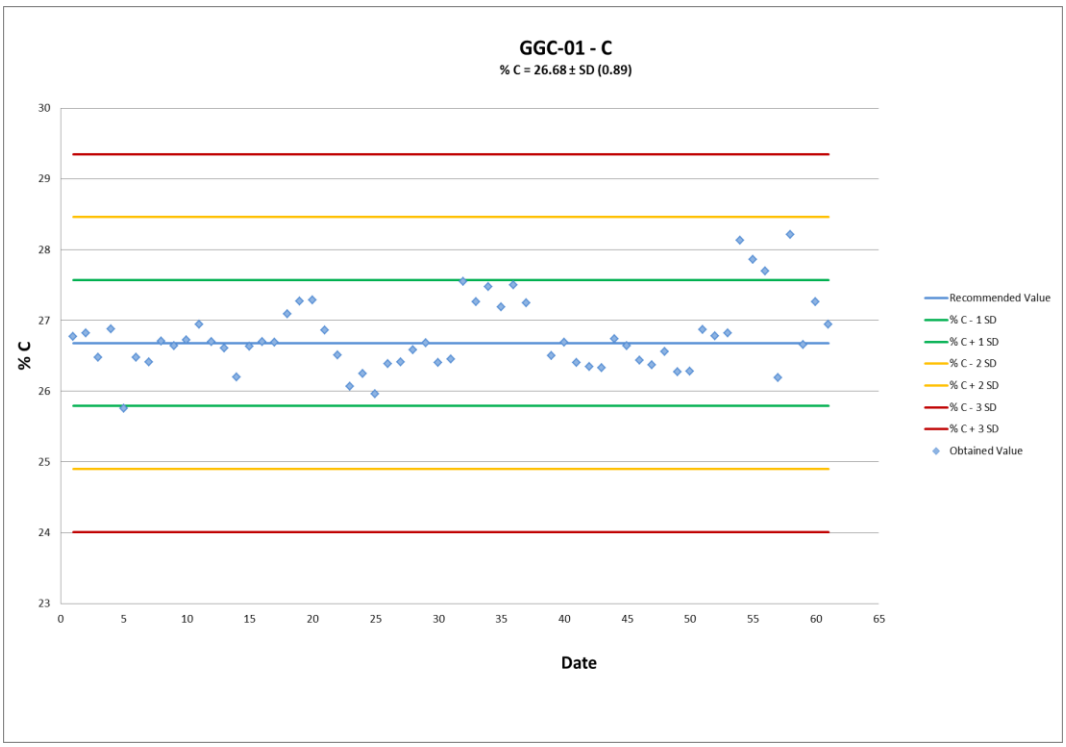


Figure 29: Graph showing Carbon Concentration as Analysed in GGC-01

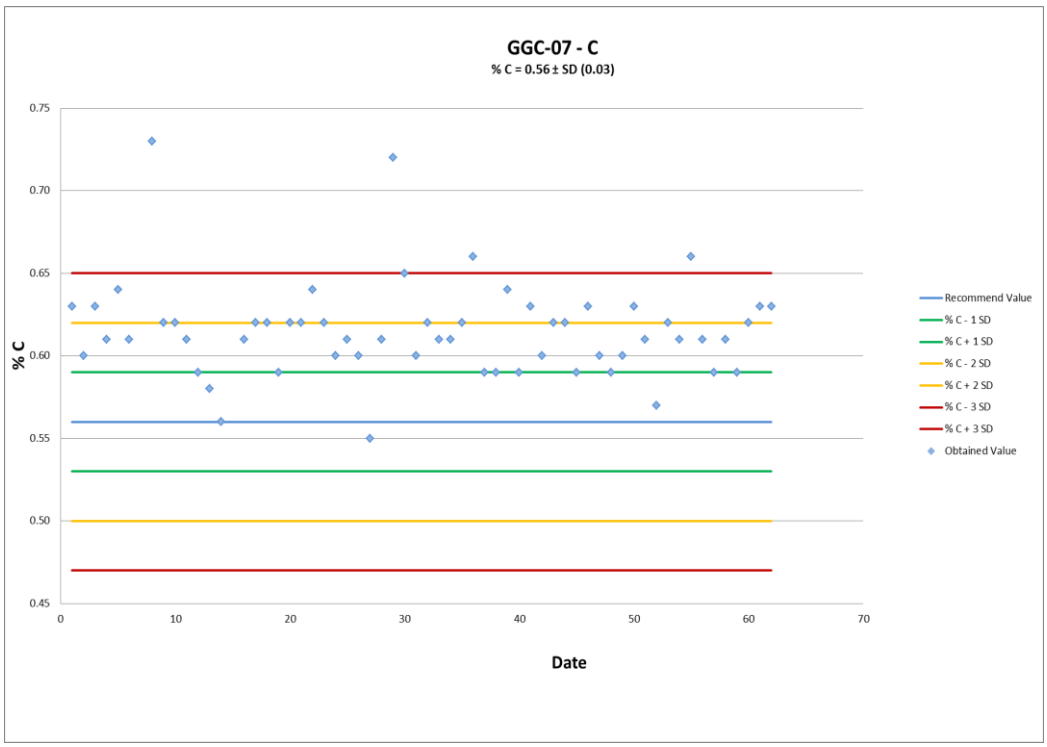


Figure 30: Graph showing Carbon Concentration as Analysed in GGC-07

11.2.3 Field Duplicates

A total of 254 duplicate samples were submitted. To check how close these were to the original samples, a plot of the original samples with a zero, five, and ten per cent difference of the original samples was created. (Figure) 2012 and 2014 samples are shaded in blue and red respectively. The majority of the samples are within the 10% difference limit. The plot also shows a good correlation between the original value and the duplicate, as is evident from the regression line with an R^2 value of 0.96.

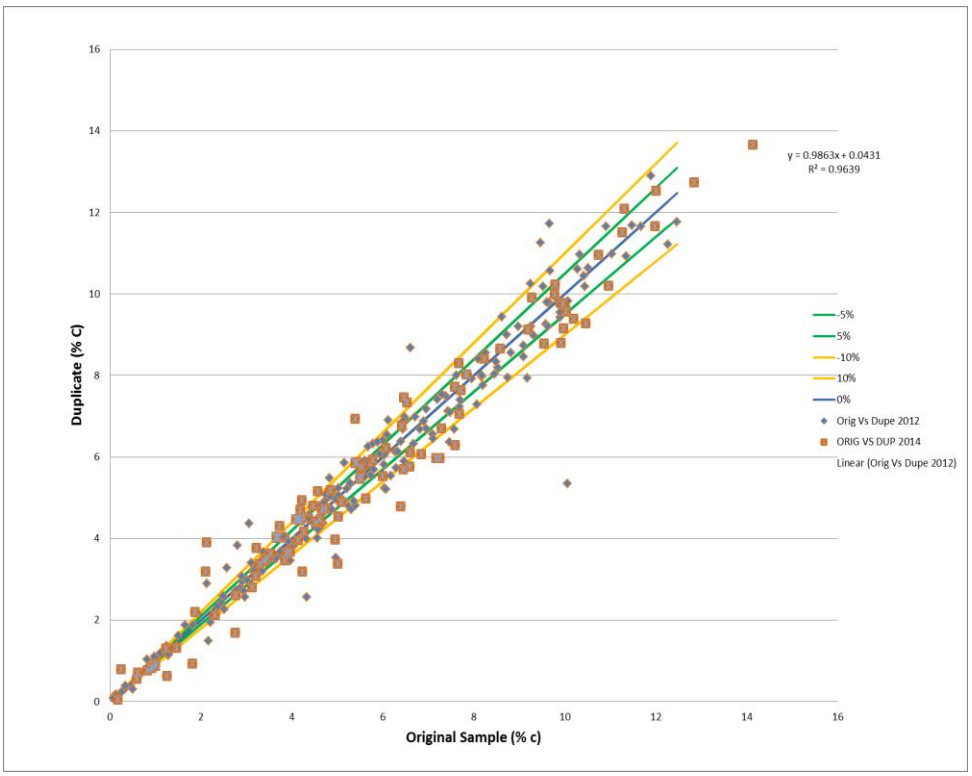


Figure 31: Original (Orig) versus Duplicate (Dupe) Plots

11.3 Relative Density

No additional samples were collected for density measurement during the 2014 drill programme. A total of 226 relative density measurements were contained in the database presented to CCIC for Molo.

The process to measure the relative density is as follow:

- Pieces of whole core were collected and the rock types documented
- The selected section of core is then dipped into wet paraffin wax and allowed to dry. This seals the core to avoid the absorption of moisture
- The pieces of core are weighed dry, followed by weighing in a water bath

All data is collected on paper forms and transferred to a spreadsheet for future calculations.

12 DATA VERIFICATION

Prior to CCIC's involvement with Energizer and the Molo Project, all information published regarding the 2011 exploration programme was reviewed by an independent Qualified Person as it became available. The database received by CCIC from Energizer contained 80 drill holes totalling 11,660 m and data from 35 trenches totalling 8,492m. With regards to the database, CCIC performed various tests to verify the integrity of the collar co-ordinates, logging and sampling procedures, and assay results. Leapfrog™ Geo software (www.leapfrog3d.com/) ("Leapfrog") was used for most of the checks.

12.1 Collar and Down Hole Surveys

During a site visit in 2014, Desmond Subramani randomly selected four drill hole collars to validate. All four drill hole collars were physically located and plotted within the accuracy of the handheld GPS unit being used for validation. While on site, Energizer was in the process of undertaking a topographic survey and a DGPS re-survey of all drill hole collars.

To verify the correct position of the re-surveyed drill hole collars with respect to their elevation, collar co-ordinates were plotted against the surface re surveyed topography of the area (Figure). The results showed that the re-surveyed collars were within a 25 cm of the surface topography, and therefore all collar co-ordinates were deemed to be correct and were used for the geological modelling.

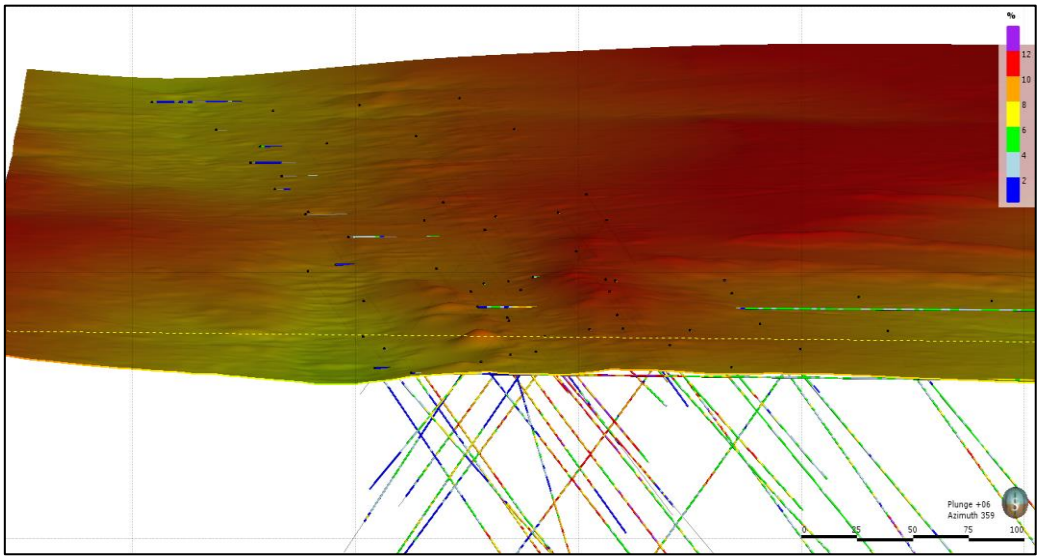


Figure 32: East-West Cross-section Showing the Collar Positions with Respect to Topography

12.2 Drill Logs

During the initial 2012 site visit Dr. Hancox randomly selected two of the 2011 drill holes (Molo-07 and Fotsy-06) to review the log's data against the drill core (Figure). The holes were check logged to verify that the intervals in the logs matched the drill core. No discrepancies were observed. Molo-04 and Molo-05 were also examined.



Figure 33: Borehole Fotsy-06 - One of the Bore Holes Check Logged during May 2012 Site Visit

For the 2014 drilling campaign, a CCIC Geologist (Mr W. Ngangolo) supervised the drilling, logging and sampling. Drill hole logs were checked in the field, prior to uploading into the Energizer Database, managed by Eric Steffler. Dr. Schneiderhan also undertook various check logs during here 2014 site visit.

Database checks undertaken in the Leapfrog™ software ("Leapfrog") included, (but were not limited to) gaps, consistency in the logging codes, and overlaps in the depth 'From' and 'To' entries. No gaps were encountered in the database. There seemed to be some lack of consistency in the sage of the logging codes as initially the graphite bearing unit was termed as either gneiss (Gn) coding, or graphitic gneiss, (coded as GfGn). This was later edited by Energizer and the graphite bearing gneiss was finally coded GpGn.

Whilst a few irregularities were encountered with the data supplied, the authors are of the opinion that following on the validation and verification checks, the data is adequate for the level of geological modelling and resource estimation undertaken.

13 MINERAL PROCESSING AND METALLURGICAL TESTING

13.1 Introduction

A series of metallurgical and mineralogical investigations was completed at Mintek in South Africa and SGS Lakefield in Canada on samples originating from the Molo deposit amongst others, which included Fotsy and Fondrana deposit material in the case of the Mintek testwork. The primary purpose of the programs from the perspective of the Molo material was to:

(a) Develop a robust process flowsheet that produces a combined graphite concentrate grading of at least 95% total carbon.
(b) Demonstrate the robustness of the proposed flowsheet for the expected mill feed during the first few years of operation, and
(c) Generate concentrate and tailings samples for downstream evaluation by potential vendors and off-take partners.

The first scoping level program was completed at Mintek in 2012. This was followed up with a flowsheet development program at SGS Lakefield in June to August 2013. The proposed process flowsheet was employed in a pilot plant campaign, again conducted at SGS Lakefield, in September / October 2013 to confirm the robustness of the flowsheet and to generate concentrate for downstream testing.

A process optimization program was conducted at SGS Lakefield between June and September 2014 to simplify parts of the circuit. This optimized process flowsheet was validated in a concluding variability flotation program between October 2014 and January 2015.

The key economic factors for a graphite project from a metallurgical point of view are graphite recovery, flake size distribution, and concentrate grade.

While there is market for graphite concentrates grading as low as 80% carbon, the price of a product increases with carbon grade. For a flotation graphite concentrate without further purification a product grading between 94% and 97% total carbon is typically targeted.

Large graphite flakes demand higher prices due to a limited supply on the market, while concentrates containing graphite flakes smaller than 200 mesh (-75 microns) are available in abundance and, therefore, create a much lower revenue on a per tonne of concentrate basis. Consequently, a process development program must focus on flake size preservation to maximize the amount of medium and large flakes in a concentrate, while minimizing the percentage of small flakes.

It is pertinent that the decisions made in process development programs consider these economic factors. While not all of them can be optimized at the same time, a balanced approach is required.

13.2 Flowsheet Development – Mintek

A scoping level metallurgical and mineralogical program was completed on five composites at Mintek in South Africa in 2012. These composites originated from the Fondrana, Fotsy, and Molo zones. Only the results for the Molo composite are summarized in this section, which was specified as trench sample Molo-TH-11-01.

The Molo composite graded 10.6% carbon. Three rougher kinetics tests were completed on the composite with a primary grind size of P_{50} of 150 microns. A carbon recovery of almost 99% was achieved on average with rougher tailings grades of 0.1 to 0.2% carbon. The rougher concentrate grades yielded 53.5% to 59.0% carbon. The reagents used in the program were illuminating paraffin as the graphite collector and Dowfroth 200 as the frother.

Two cleaner tests using conditions that were previously established for Fotsy and Fondrana composites produced concentrate grades of 77.4% carbon with the dispersant sodium silicate and 77.5% carbon without sodium silicate at carbon recoveries of 95.9% to 97.5%.

A final cleaner flotation test was conducted using the flowsheet depicted in Figure 34. The second regrind was conducted in a pebble mill with smaller media with a size range of 4 mm to 10 mm instead of the regular pebble mill containing +20 mm gravel. The concentrate grade improved to 82.7% carbon at 92.9% carbon recovery because of this secondary regrinding and cleaning circuit.

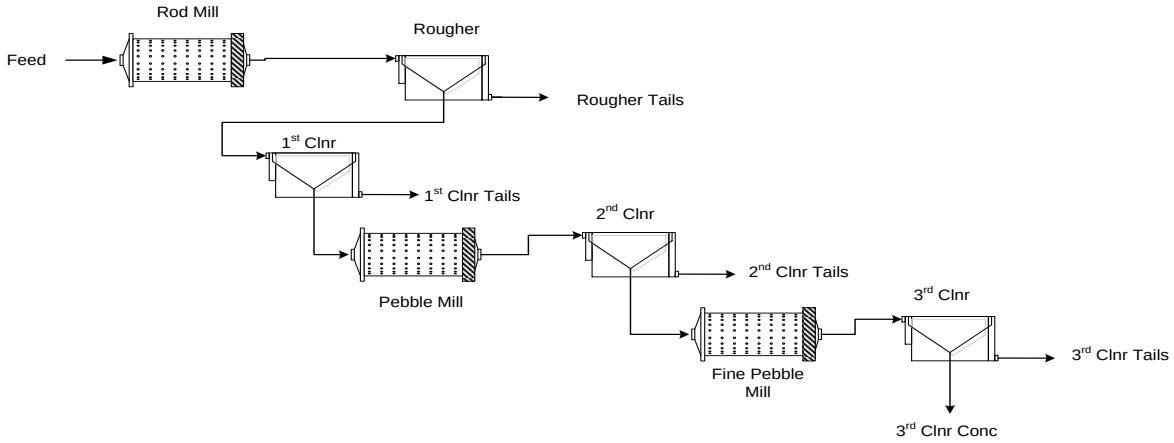


Figure 34: Flowsheet for Molo Mineralization – Mintek

It should be noted that the Mintek test work program focused on carbon recovery optimization and did not focus on flake size preservation.

13.3 Flowsheet Development – SGS

A full flowsheet development program was subsequently initiated at the SGS Lakefield site in June 2013 using a high-grade and a low-grade composite from the Molo deposit. These composites were generated by collecting a sub-sample from the 200-tonne bulk trench sample that was generated for pilot plant testing. For every 2 metres of the total trench length of 160m, approximately 2.5 tonnes of material were extracted for piloting. A 5 kg sub-sample was then removed from each 2.5 tonne sample to form the high-grade and low-grade composite for laboratory scale testing.

A series of eight rougher and cleaner flotation kinetics tests evaluated the flotation performance of each of the two composites, as well as a 50:50 blend of the two composites.

The flotation approach employed a flash flotation stage on test charges that were stage crushed to minus 6 mesh followed by primary grinding and rougher flotation. The cleaner tests employed a primary polishing grind followed by three stages of cleaner flotation.

Since the blended composite produced good metallurgical results a decision was made to use this composite for all further development work as this maximizes the mineral resource of the deposit and simplifies mining.

The following eight rougher kinetics tests evaluated primary grinding with conventional steel rods and ceramic media.

The energy input created by the ceramic media proved insufficient in a primary grinding application and, therefore, steel media was chosen with grind times targeting a mill discharge of P_{80} = 400 to 500 microns.

Four proceeding cleaner tests investigated the conditions of the primary cleaning circuit.

The flash and rougher concentrates were combined and subjected to a polishing grind using ceramic rods.

The polishing times were varied between 7 minutes and 30 minutes.

The polishing mill discharge was upgraded in three stages of cleaner flotation and the 3rd cleaner concentrate was subjected to a size fraction analysis.

A primary polishing time of 22 minutes was identified as the best compromise between maximizing the intermediate concentrate grade and minimizing flake degradation.

Considering the liberation properties of the different flake sizes, the intermediate concentrate was classified at 80 mesh (177 microns) and 150 mesh (106 microns) and each classification product was then subjected to a secondary polishing grind and cleaner flotation.

The remaining four tests F22 to F25 in the flowsheet development program investigated the impact of varying secondary polishing times on the combined concentrate grade. Secondary polishing times of 6 minutes, 8 minutes, and 45 minutes for the +80 mesh, +150 mesh, and -150 mesh size fractions, respectively, achieved the best metallurgical results.

The proposed flowsheet including classification sizes and polishing grind times used in test F24 is depicted in Figure 35 and the size fraction analysis results of the combined concentrate are presented in Table 21. The conditions of test F24 were selected as they constituted the best compromise between maximizing concentrate grades while minimizing graphite flake degradation. All size fractions yielded concentrate grades of at least 95.2% total carbon including the smallest size fraction of -400 mesh (-37 microns).

The mass recovery into the large flake category of +80 mesh (177 microns) was very good at 47.6% and only 18.6% of the mass reported to the fines smaller than 200 mesh (74 microns).

The carbon recovery into the combined concentrate was 83.4% in this open circuit test. Graphite recovery is expected to increase during closed circuit operation as the intermediate streams are circulated rather than treated as tailings.

The significant differences between the metallurgical results obtained in the Mintek and SGS programs were the result of several factors. Firstly, the two Molo composites were collected from different areas of the deposit. Secondly, the Mintek approach focused on maximizing carbon recovery into the graphite concentrate. In contrast, the SGS approach focused on maximizing flake size preservation and concentrate grade.

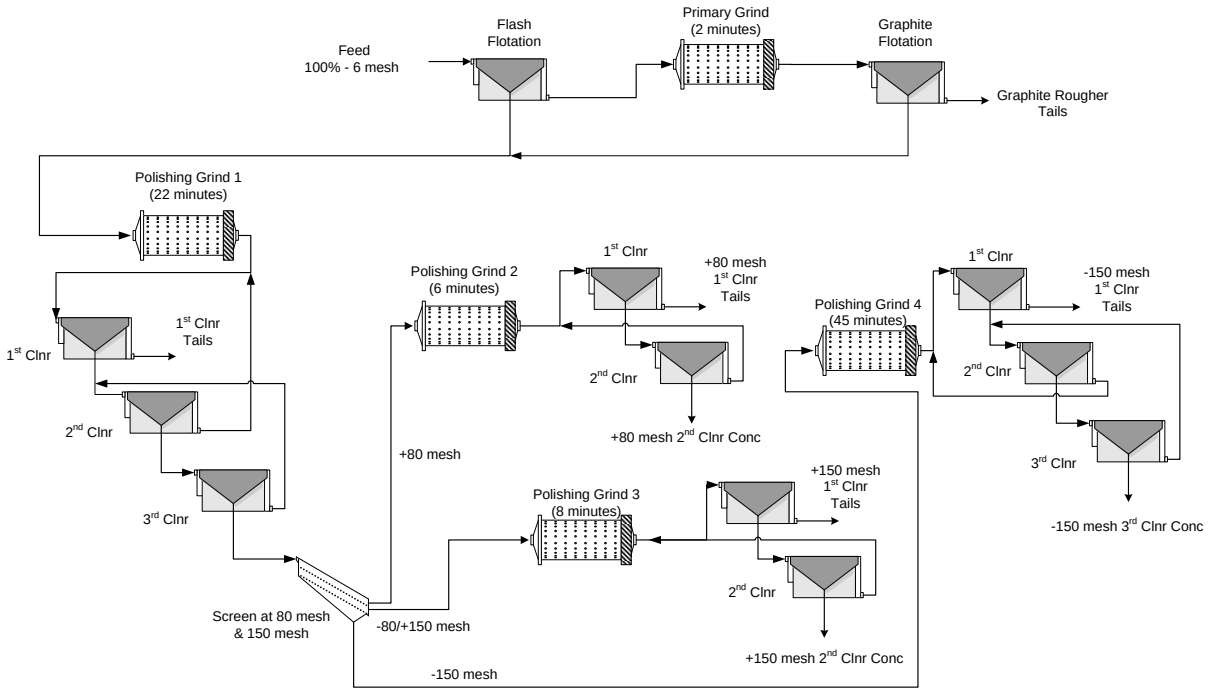


Figure 35: Proposed Molo Mineralization Flowsheet – SGS

Table 21: Size Fractions Analysis Results of Test F24

Product		**Mass (%)**	**Grade (% Total Carbon)**
Mesh	**Microns**		
+48	+297	21.7	97.4
-48/+65	-297/+210	17.9	96.7
-65/+80	-210/+177	8.1	95.7
-80/+100	-177/+149	10.9	96.0
-100/+150	-149/+106	12.5	95.2
-150/+200	-106/+74	10.3	95.3
-200/+325	-74/+44	8.5	96.2
-325/+400	-44/+37	3.0	95.9
-400	-37	7.1	95.7

13.4 Pilot Plant Campaign

A pilot plant campaign using a 200 tonne Molo bulk(trench) sample was conducted at the SGS Lakefield, Canada site in September / October 2013.

The pilot plant campaign was carried out to confirm the robustness of the above SGS proposed flowsheet that was developed in the laboratory program. Further, approximately 10.8 tonnes of graphite concentrate were generated for downstream testing including vendor testing and evaluation of potential off-takers.

The bulk sample that was processed in the pilot plant was collected on site by extracting two samples of approximately 100 tonnes each, one of the low-grade area and one of the high-grade area of the Molo deposit. The aim for the two bulk samples was to be representative of the future plant feed.

The position of the bulk sampling trench is depicted in Figure 36. The first 80m starting from the West were classified as high-grade material and the following 80m as low-grade material. The trench sections were sub-divided into 2 m intervals and approximately 2,500 kg of ore were extracted from each interval after removal of any soil and overburden. At the same time, approximately 5 kg were removed from each interval to generate the material for the SGS laboratory scale flowsheet development program described above.

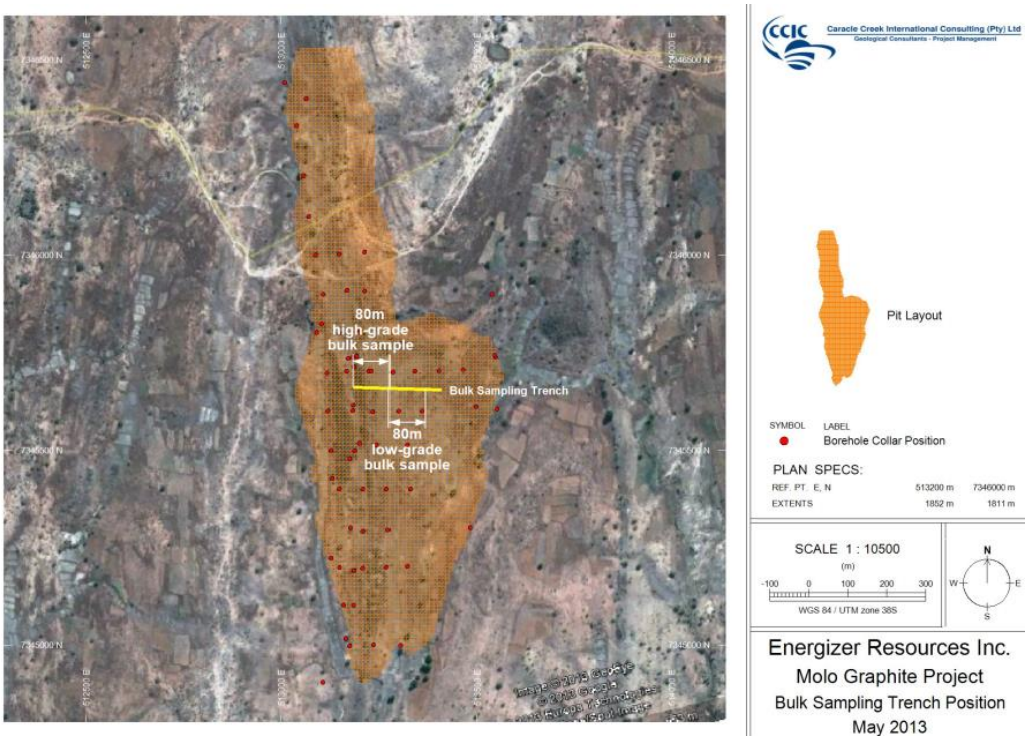


Figure 36: Map showing Position of Bulk Sampling Trench

A single composite was processed in the pilot plant campaign grading 7.98% total carbon. The pilot plant composite was generated by blending high grade and low-grade ore in a ratio of approximately 46:54.

The results of comminution tests that were carried out on the individual composites, as well as the pilot plant blend are summarized in Table 22.

Table 22: Summary of Comminution Test Results for Pilot Plant Composites

Sample	Relative	JK Parameters			RWI	BWI	AI
Name	Density	A x b[1]	A x b[2]	T_a	(kWh/t)	(kWh/t)	(g)
Blend	2.29	199	0	2.28	8.3	11.2	0.129
High Grade	2.08	-	151	1.88	8.7	11.4	0.125
Low Grade	2.37	-	192	2.09	6.9	9.7	0.106

[1] A x b from DWT

[2] A x b from SMC

A total of nineteen pilot plant runs, PP-01 to PP-19, were completed to process the approximately 200 tonnes of the Molo bulk composite using the flowsheet depicted in Figure 37. The only reagents that were employed were fuel oil number 2 (diesel collector) and methyl isobutyl carbinol (MIBC frother) at average dosages of 117 g/t and 195 g/t, respectively.

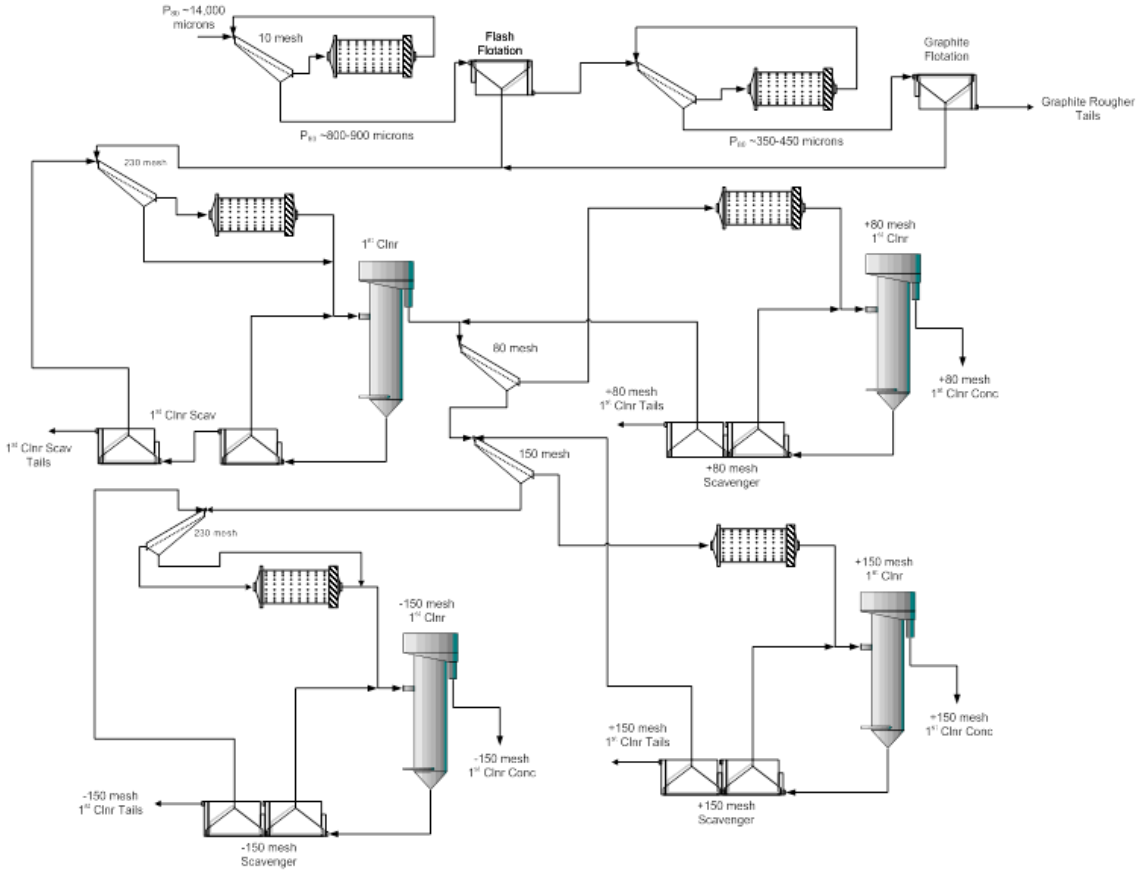


Figure 37: Molo Pilot Plant Flowsheet

A total of fifteen (15) circuit surveys were completed between PP-04 and PP-18. In each survey, up to 36 streams were sampled 5 times over the course of an hour and then submitted for sizing and/or chemical analysis.

All products submitted for chemical analysis were assayed for total carbon and the low-grade tailings streams also for graphitic carbon.

The results were then used to generate full circuit mass balances using the BILMAT^{TM} data reconciliation software.

In addition, hourly grab samples of strategic streams were collected and submitted for chemical analysis or sizing.

Turnaround times of sizing and assay results were typically less than one hour. This approach was chosen to ensure that metallurgical targets were met and to facilitate the optimization of the operating conditions.

The average feed sizes to the flash and rougher flotation circuits were P_{80} = 835 microns and P_{80} = 443 microns, respectively.

The results from pilot plant test PP-17B were selected to generate the process design criteria. The combined concentrate grade yielded 93.1% total carbon at a carbon recovery of 90.6%.

A summary of the mass balance is presented in Table 23.

Table 23: Summary of Mass Balance for Pilot Plant Test PP-17B

Product	Mass (%)	Assay % Total Carbon	Distribution % Total Carbon
+80 mesh Concentrate	4.0	95.9	53.1
+150 mesh Concentrate	1.7	92.7	21.9
-150 mesh Concentrate	1.3	85.1	15.7
Combined Concentrate	7.0	93.1	90.6
Combined Tailings	93.0	0.72	9.4
Plant Feed	100	7.17	100

The product size of the final graphite concentrate from the fifteen surveys yielded an average value of P_{80} = 268 microns.

The average size distribution and total carbon grade of each size fraction are presented in Table 24.

Table 24: Average Combined Concentrate from Fifteen Pilot Plant Surveys

Size Mesh	Size Microns	Mass as Percentage of Total Concentrate Mass in %	Grade % Total Carbon
+48	+297	15.7	97.7
+65	+210	17.6	97.4
+80	+177	10.2	96.7
+100	+149	9.7	96.4
+150	+105	15.0	96.1
+200	+74	10.1	95.2
-200	-74	21.6	88.2

The metallurgical results from the laboratory scale flowsheet development program on the 50:50 high-grade/low-grade composite as well as the results from the laboratory and pilot scale testing of the actual pilot plant composite are summarized in Table 25.

While there were some differences in the results, the data from the three test phases correlated well overall.

The largest difference was the carbon grade of the -150 mesh size fraction in the pilot plant, which was approximately 5% lower compared to the two lab results. It was postulated that this was likely the result of poor polishing efficiency due to dewatering difficulties with the -150 mesh cleaning circuit feed.

Table 25: Comparison of Laboratory and Pilot Plant Metallurgical Results

Product	Laboratory Scale		Pilot Plant
	Master Composite (F24)	Pilot Plant Composite	Pilot Plant Composite
% Mass > 80 mesh	47.6	42.4	43.5
% C(t) > 80 mesh	96.8	96.8	97.4
% Mass -80/+150 mesh	23.5	25.3	24.7
% C(t) -80/+150 mesh	95.6	95.6	96.3
% Mass -150 mesh	28.9	32.3	31.8
% C(t) – 150 mesh	95.7	95.7	90.4

13.5 Optimization and Metallurgical Variability Program

The flowsheet that was employed in the pilot plant campaign provided a fair degree of flexibility to operate the circuit on a relatively *ad hoc* basis to meet specific, prevailing market demands in terms of product quality. However, with a focus on reducing capital and operating costs, as well as improving the ease of operability of the plant, an optimization program was initiated to evaluate the possibility of simplifying the process flowsheet while maintaining the graphite concentrate quality. In May 2014, a review of the metallurgical work completed by Mintek and SGS was accordingly conducted by representatives of DRA and Energizer Resources, in conjunction with the author of this chapter.

The first process option identified consisted of the original front end of the original flowsheet with flash and rougher flotation stages. The combined flash and rougher concentrates are subjected to a polishing grind followed by a cleaner flotation circuit.

The intermediate cleaner concentrate is classified on a screen and the screen oversize constitutes a final graphite concentrate. This necessitates that the primary polishing and cleaner flotation conditions can produce a flotation concentrate grading at least 95% total carbon in the larger size fractions.

The screen undersize comprising of below target concentrate is subjected to a secondary cleaning circuit with a polishing mill and cleaner flotation. The cleaner concentrate from this circuit and the screen oversize then constitute the final combined graphite concentrate.

The second process option was further simplified by eliminating the graphite rougher flotation circuit by incorporating flash flotation only. The flash flotation concentrate is then subjected to a polishing grind and cleaner flotation.

The graphite concentrate generated in this primary cleaning circuit constitutes the final concentrate. This highly simplified process option is based on the postulation that the degree of liberation in the flash concentrate is superior to a rougher concentrate as it contains mostly large graphite flakes that generally are more easily liberated and upgraded in the primary cleaning circuit. By eliminating the rougher circuit, the middlings of graphite and gangue minerals in the primary cleaning circuit feed are reduced significantly, which require more mechanical manipulation to improve mineral liberation.

The increased graphite losses to the flash tailings associated with the simplified flowsheet may be offset by reduced capital and operating costs and a superior graphite concentrate in terms of flake size distribution.

13.5.1 Sample Selection

Based on the sample locations and logs provided by CCIC, DRA in conjunction with geologists from CCIC selected quarter core samples from various locations and depths within the Molo deposit for optimization and variability test work. Twenty (20) drill core samples were selected based on pit location, depth and indicated grade. The samples that were selected are summarized in Table 26.

Table 26: Sample for Optimization and Variability Testing

Description	Drill Core Identification
Year 1-5 High Grade Material	Molo 13, 14, 15, 16, 17, 18, 34, 35 and 36
Year 1-5 Low Grade Material	Molo 45, 46, 47 and 48
Year 5+ North Pit High Grade Material	Molo 37, 38 and 39
Year 5+ South Pit High Grade Material	Molo 29, 30, 31 and 32

As part of the optimization program six comminution composites were generated using drill core from different depths within the 2015 FS 5-year pit layout. Four (4) comminution composites were tested at SGS and two (2) additional composites were shipped to Mintek in South Africa for testing. The make-up of the six (6) comminution composites is shown in Table 27.

Table 27: Comminution Composites – SGS and Mintek

Lab	Description	Depth (m)	Drill Core Identification
SGS	Comminution Composite #1	14-28	Molo 16, 17, and 18
SGS	Comminution Composite #2	57 - 85	Molo 46
SGS	Comminution Composite #3	14 -28	Molo 34 and 35

SGS	Comminution Composite #4	0-14	Molo 29, 30 and 32
Mintek	Grindmill Shallow Composite	0-14	Molo 15, 18, 35, 36, and 39
Mintek	Grindmill Deep Composite	28-56	Molo 15, 29, 37, and 45

13.5.2 Comminution Testing

A summary of the results of the comminution tests conducted at SGS is presented in Table 28 and reveals that the ore is typically very soft or soft with low abrasivity. Only the Bond ball mill grindability tests at the smaller screen size of 212 microns produced indices that placed the ore into the medium hard category.

Table 28: Summary of Comminution Tests - SGS

Sample Name & Depth of the Drill Hole Intervals	Relative Density	JK Parameters		RWI (kWh/t)	BWI (kWh/t) 500 µm	BWI (kWh/t) 212 µm	AI (g)
		Axb	Ta				
Comminution Composite #1 – Medium	2.25	147.6	1.70	9.3	12.1	14.4	0.097
Comminution Composite #2 – Deep	2.36	157.8	1.73	7.1	8.8	12.9	1.116
Comminution Composite #3 – Medium	2.23	126.0	1.46	9.3	12.1	13.2	0.081
Comminution Composite #4 – Shallow	2.29	299.9	3.38	6.0	8.0	12.1	0.030

Two composites containing drill core from the shallow and the deep areas of the 2015 FS 5-year pit layout were shipped to Mintek in South Africa for further Bond ball and rod mill tests, as well as Grindmill tests. The results of these comminution tests are summarized in Table 29. The Bond rod and ball mill test results are consistent with the results obtained for the four composites tested at SGS Lakefield.

Table 29: Summary of Comminution Test - Mintek 2014

Sample Name	Grindmill Feed Top Size -6.7mm		Grindmill Feed Top Size -9.5mm		RWI (kWh/t)	BWI (kWh/t) 500 µm	BWI (kWh/t) 212 µm
	% Passing 425 µm at 3 kWh/t	% Passing 150 µm at 10 kWh/t	% Passing 425 µm at 3 kWh/t	% Passing 150 µm at 10 kWh/t			
MOLO 0-14	89.93	69.81	83.95	70.41	7.2	9.3	13.0
MOLO 28-56	77.43	65.38	76.68	68.05	9.2	10.9	13.7

13.5.3 Optimization Flotation Program

A series of six optimization composites were generated to evaluate the two alternative flowsheet options. The primary two composites were 50:50 blends of high-grade and low-grade mineralization from the shallow section (0 to 14m depth) and the deep section (28 to 56m depth) of the deposit.

Two drill holes of each the high-grade (HG) and the low-grade (LG) mineralization were selected to generate these two composites. A rougher kinetics test was completed on the two composites and the results revealed that the composite from the shallow section produced an inferior metallurgical response.

Since the process plant must be able to treat all ore within the pit layout, a decision was made to proceed with the majority of the optimization program using the more challenging shallow composite.

A series of rougher kinetics tests on the 50:50 LG:HG shallow and deep (F3 to F12) composites was completed to establish the primary grind size required to achieve a combined flash and rougher carbon recovery of 94 to 95%. This grind size was established at P_{80} = 400 to 450 microns.

A series of four open circuit cleaner flotation tests evaluated the possibility of obtaining a flotation concentrate grading at least 94% total carbon with a single polishing and cleaning circuit.

The four tests, (F13 to F16), included a flash flotation circuit only followed by polishing and cleaning to determine if the improved liberation properties of the flash concentrate would result in reduced polishing and cleaning requirements. Even at the longest polishing time tested, the combined concentrate graded only 85.1% carbon.

Consequently, the simplest proposed flowsheet consisting of flash flotation, polishing, and a single cleaning circuit proved insufficient to produce target concentrate grades even if lower graphite recoveries were accepted by employing flash flotation only.

Three open circuit cleaner tests, (F17 to F19), with flash and rougher flotation, polishing grind and cleaner flotation evaluated the polishing time necessary to achieve satisfactory concentrate grades in the coarser size fractions, which tend to display improved liberation properties. A polishing time of 30 minutes proved sufficient to generate an intermediate flotation concentrate that yielded grades more than 95% total carbon in the size fractions larger than 48 mesh (297 microns).

The intermediate cleaner concentrate was classified on a 48 mesh screen and the screen oversize constituted a final concentrate. The screen undersize was subjected to different polishing times followed by secondary cleaning in two cleaner flotation tests (F20 and F21). Both tests failed to produce a final concentrate grade of at least 95% total carbon.

In order to evaluate whether these metallurgical properties were created by an individual sub-sample of the optimization composite, each of the four drill hole intervals included in the optimization composite was subjected to a batch cleaner test using the conditions of test F21, which employed a secondary polishing time of 60 minutes.

The two low grade composites from drill holes MOLO-45 and MOLO-47 produced high combined concentrate grades of 97.4% total carbon and 97.7% total carbon, respectively.

In contrast, the two high grade composites from drill holes MOLO-16 and MOLO-35 yielded lower combined concentrate grades of 83.6% total carbon and 89.0% total carbon, respectively.

To evaluate the variation of metallurgical results for the different composites, a decision was made to proceed with variability flotation testing to develop a better understanding of the metallurgical processing properties.

13.6 Variability Flotation – Phase I

A variability flotation program was carried out in October 2014 using twenty different drill hole composites, which are specified in Table 30.

Table 30: Variability Composites – Phase I

Drill Hole	Depth of Drill Hole Interval		
	0-14m	14-28m	28-56m
MOLO-14	√	√	√
MOLO-16			√
MOLO-17	√	√	√
MOLO-30	√	√	√
MOLO-35			√
MOLO-38	√	√	√
MOLO-46	√	√	√
MOLO-48	√	√	√

The optimized flowsheet and conditions shown in Figure 38 were chosen for the variability flotation program. Each variability composite was subjected to the flowsheet using this flowsheet with minor adjustments to the primary grind time, flotation times, and reagent dosages.

These adjustments were required to address the different hardness of the various composite, as well as observations made during the test with regards to the flotation response.

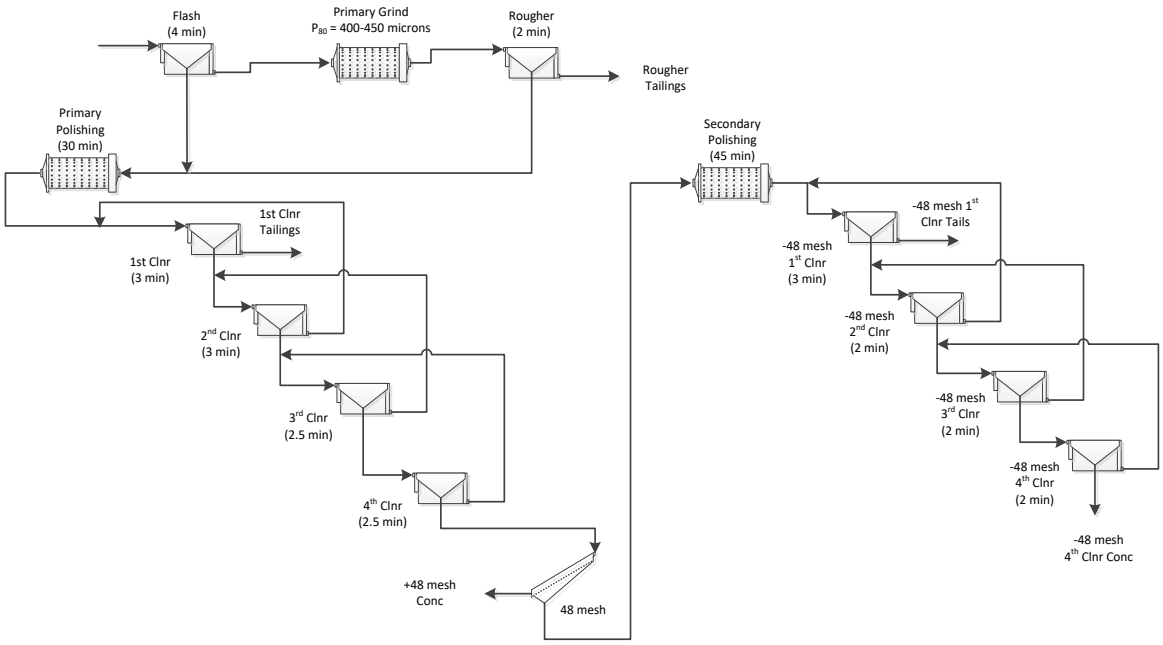


Figure 38: Optimized Flowsheet

Each of the twenty variability composites was subjected to an open circuit flotation test. The mass recovery into the various size fractions is summarized in Figure 39, alongside the average pilot plant results. The chart reveals that the average flake size distribution of the twenty variability composites compared well with the average results of the pilot plant.

The mass recovery into the +48 mesh and +65 mesh size fractions was up to 3.2% better for the variability samples. The range of mass recovery into specific size fractions was significant and the largest for the +48 mesh product.

The lowest mass recovery into the jumbo flake category was 7.4% for the MOLO-46 (0m to 14m) composite while the highest mass recovery into this product of 34.9% was achieved with the MOLO-48 (0m to 14m) composite.

An analysis of different potential factors such as grade and depth of the composite did not produce a strong relationship between the variable and the flake size distribution.

The average mass recovery into the +80 mesh size fractions of concentrates from high-grade composites was 47.4% compared to 46.1% for the low-grade composites.

With regards to depth, the average mass recovery into the +80 mesh size fractions of concentrates from shallow (0 to 14m) and medium (14 to 28m) depth composites was almost identical at 44.6% and 44.4%, respectively. Only the concentrate from deep (28 to 56m) composites contained a slightly higher percentage of +80 mesh material at 50.2% mass recovery.

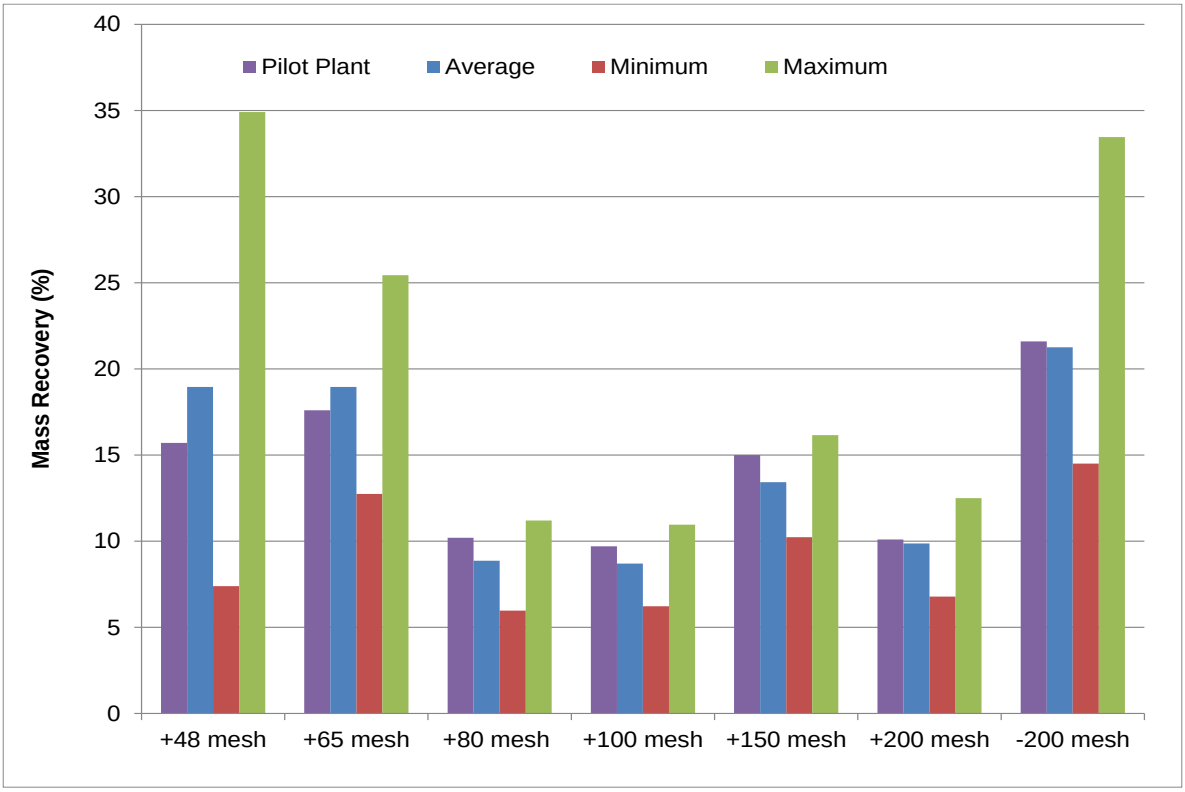


Figure 39: Range of Mass Recovery into Size Fractions (V1 to V32 and Pilot Plant)

The average, minimum, and maximum total carbon grades of tests V1 to V32 for each size fraction are depicted in Figure 40 together with the average pilot plant results. While the maximum grades matched, or exceeded those of the pilot plant, the average concentrate grade was up to 3.5% total carbon lower compared to the pilot plant for all size fractions greater than 200 mesh.

The average grade of these size fractions was less than 94% total carbon and as low as 93.1% total carbon in the -65/+80 mesh size fraction. The minimum grades were 90% total carbon or less for all size fractions greater than 200 mesh.

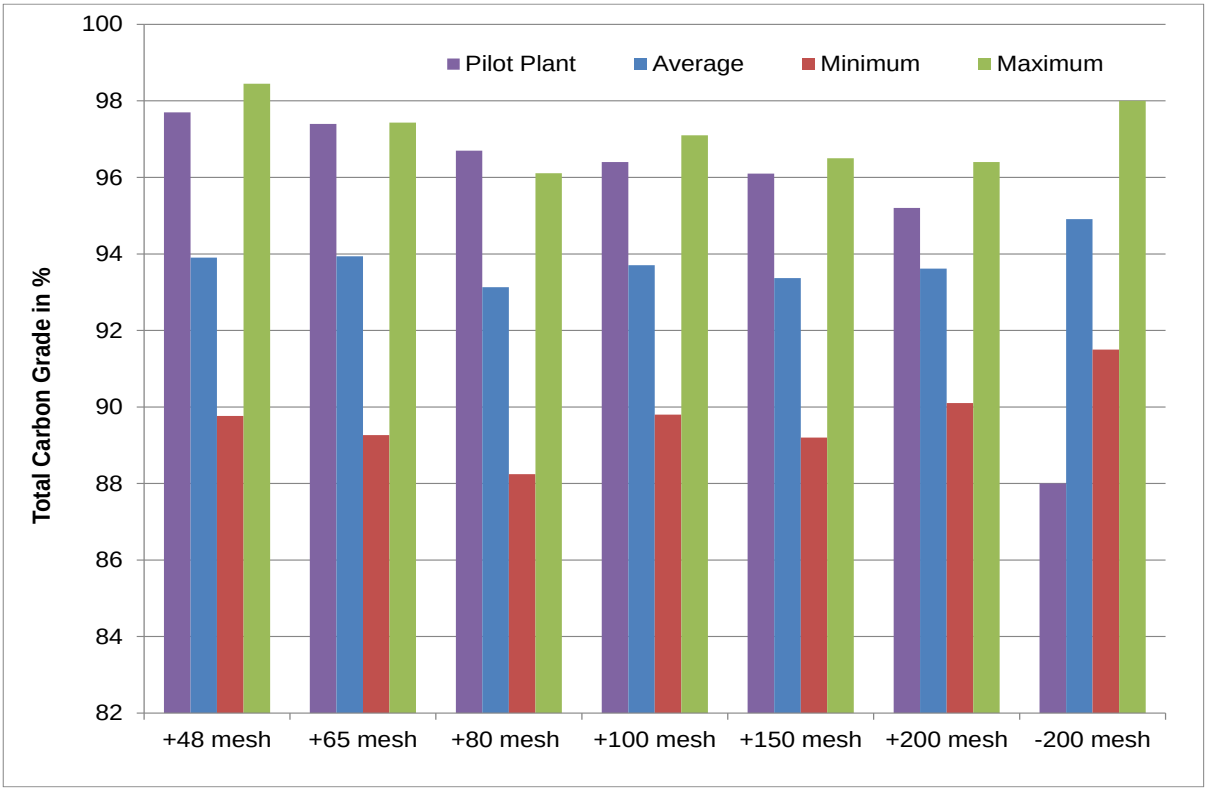


Figure 40: Range of Carbon Grades of Size Fractions (V1 to V32 and Pilot Plant)

The variability in the concentrate grade of the variability composites is further illustrated in Figure 41 which depicts the combined concentrate grade of each of the thirty-two (32) variability flotation tests.

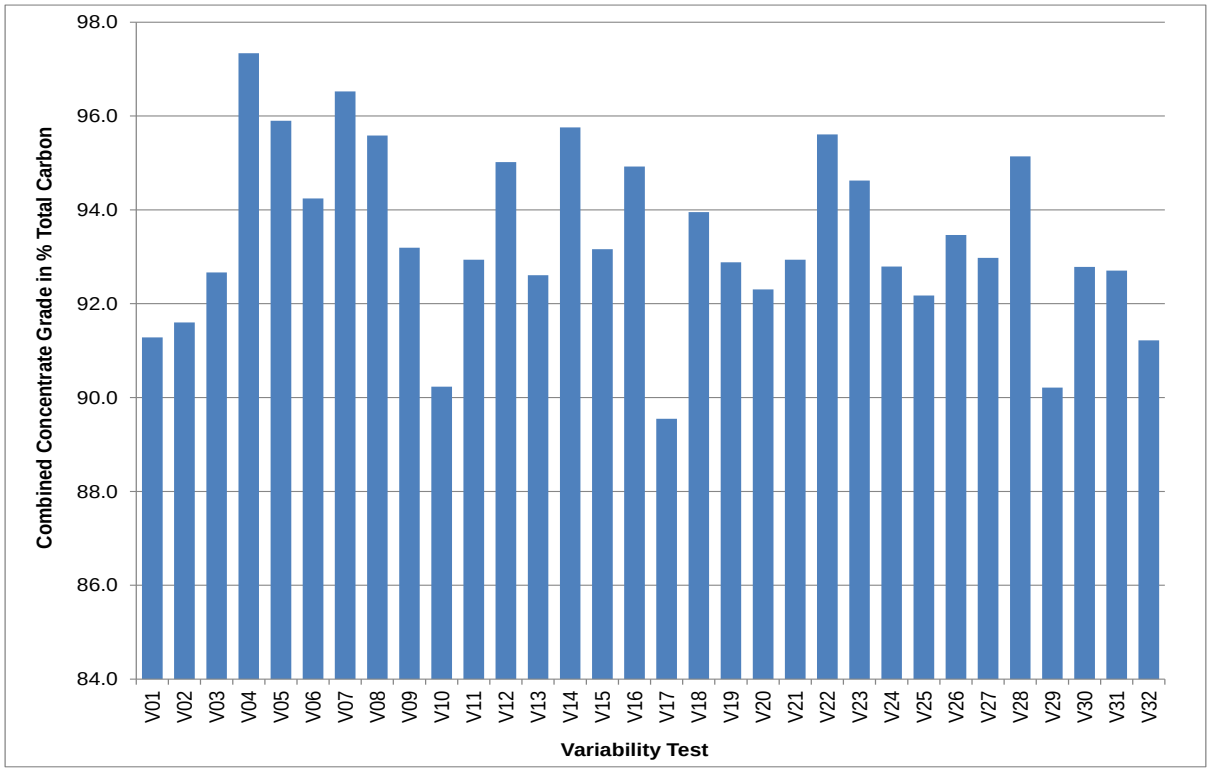


Figure 41: Combined Concentrate Grade of Tests on Variability Composites (V1 to V32)

The location and the metallurgical response of the drill hole intersections that were evaluated in the variability program within the 2015 FS 5-year pit layout of the original 53,000 tpa definitive feasibility study are depicted in Figure 42. The pit outline is demarked by the blue line. The three intersections for each drill hole represent the depth intervals 0 to 14m, 14 to 28m, and 28 to 56m starting from top to bottom.

The colour coding of each depth interval was conducted based on the legend in the figure. The results show that only seven drill hole intersections within the 2015 FS 5-year pit layout achieved a concentrate grade of 94% total carbon, while five composites produced grades of greater than 92% and less than 94% total carbon and two composites graded less than 92% total carbon.

The remaining six composites that were tested fell outside the 5-year pit layout, but the metallurgical response was consistent with the other composites.

The analysis reveals that origin of the composites within the depth interval of the drill hole does not appear to have an impact on the metallurgical response as the three grade ranges were identified in each the three depth intervals.

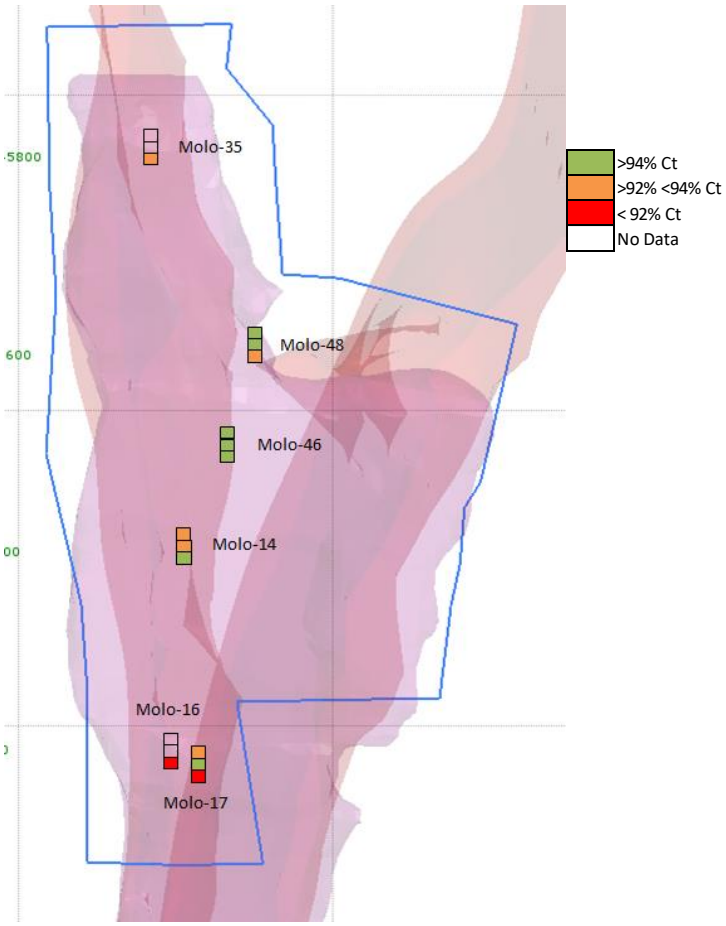


Figure 42: Location and Performance of Phase I Variability Drill Holes

The results obtained in this variability program revealed that the metallurgical response was inconsistent and appears independent of the location of the drill hole and sampling depth.

One limitation of the variability program was the fact that the six drill holes were located on a north-south axis through the deposit and did not cover the east-west extent. In discussions with the project geologist it was postulated that most of these drill holes originated from a transition zone between high-grade and low-grade ore and that this transition zone may be responsible for the inferior flotation properties.

It was paramount to determine if the large variability was linked to this potential transition zone, or if it is encountered throughout the entire mineral resource. If the inferior flotation response is only encountered in a limited and relatively small area, material from this area can be blended with other ore to achieve the flotation concentrate grade target. However, if the substantial variability is encountered throughout the entire mineral resource, upgrading strategies for the concentrate will have to be explored, which would likely result in the addition of an upgrading circuit at the tail end of the proposed process flowsheet. Hence, a decision was made to proceed with a second phase of variability flotation testing.

13.6.1 Optical Mineralogy

In order to develop a better understanding of the lower concentrate grade achieved on some of the variability composites, samples of concentrates grading only 90% to 92% total carbon were submitted for basic optical mineralogy examination.

The optical mineralogy revealed that graphite occurred less than 50 microns to 1,000 microns in size. The graphite was generally free, but contained impurities of non-sulphide gangue (NSG) minerals.

The NSG minerals were fine-grained between 10 and 200 microns, but were interlayered with graphite across its entire length.

One important observation was that less than 1% of the NSG minerals occurred as liberated grains. An example of interlayered graphite particles is displayed in Figure 43. The non-sulphide minerals indicated by the green arrows were interlayered with graphite (red arrows).

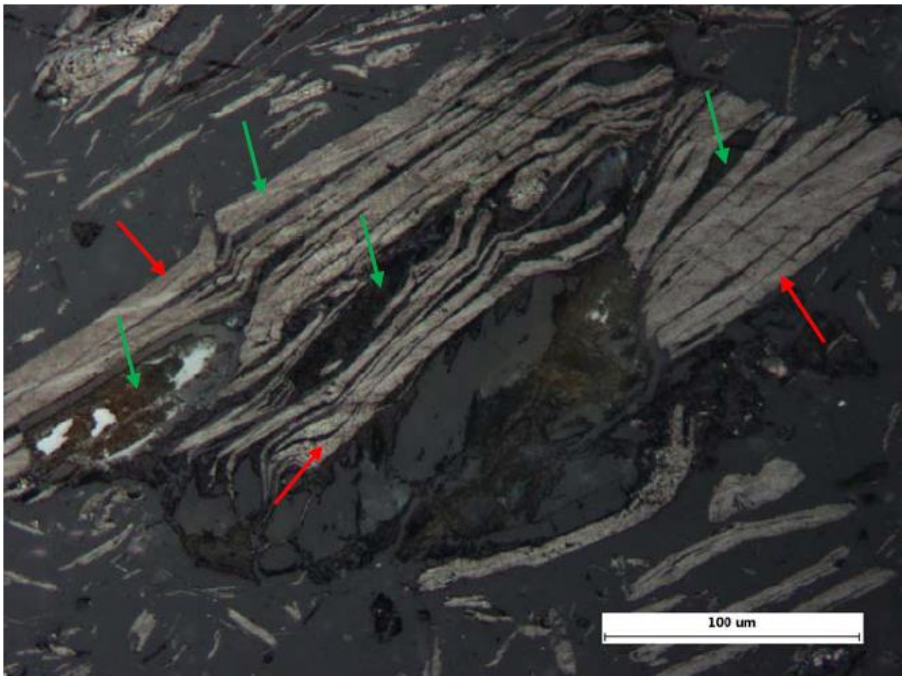


Figure 43: Intercalated Graphite

13.7 Variability Flotation – Phase II

The second phase of variability testing focused on evaluating drill holes in the eastern and western areas of the 2015 FS 5-year pit layout and on developing an understanding of the metallurgical response of the mill feed.

13.7.1 Drill Hole Composites

A total of seven drill holes with three depth intervals were subjected to open circuit cleaner tests to evaluate the metallurgical response of the Molo mineralization in the Eastern and Western areas of the 2015 FS 5-year pit layout.

The drill holes used in this phase of testing were generated in a drilling campaign that was conducted in 2012. Although the core was stored for more than two years and exposed to potential oxidation, it was concluded that any degradation of the core would likely not have an impact on the metallurgical response of the graphite. This assumption was made based on the results from the first phase of variability flotation testing, which did not identify a statistically significant difference in the metallurgical response of weathered shallow material and fresh deep core.

A list of composites that were subjected to the variability flotation tests is shown in Table 31.

Table 31: Variability Composites – Phase II

Drill Hole	Depth of Drill Hole Interval		
	0-14m	14-28m	28-56m
MOLO 12-05	√	√	√
MOLO 12-09	√	√	√
MOLO 12-21	√	√	√
MOLO 12-26	√	√	√
MOLO 12-33	√	√	√
MOLO 12-37	√	√	√
MOLO 12-38	√	√	√

The same flowsheet and conditions as in the Phase I variability program were employed in the twenty-one open circuit flotation tests.

The location and metallurgical performance of the Phase II drill hole composites are depicted Figure 44 and confirms Phase I results.

Good and poor performing composites were frequently encountered in the same drill hole in adjacent depth intervals. Based on the metallurgical results of the individual drill hole composites, no specific area could be characterized as consistently good, average, or inferior performing.

The results suggest that further treatment of the concentrate is required. Repeat tests with longer polishing times using the existing flowsheet failed to produce improved concentrate grades in most cases.

Optical mineralogy that was conducted on concentrates from the Phase II variability program confirmed the metallurgical challenge of intercalated graphite, which will require a different more aggressive upgrading approach than the standard polishing mill grinding.

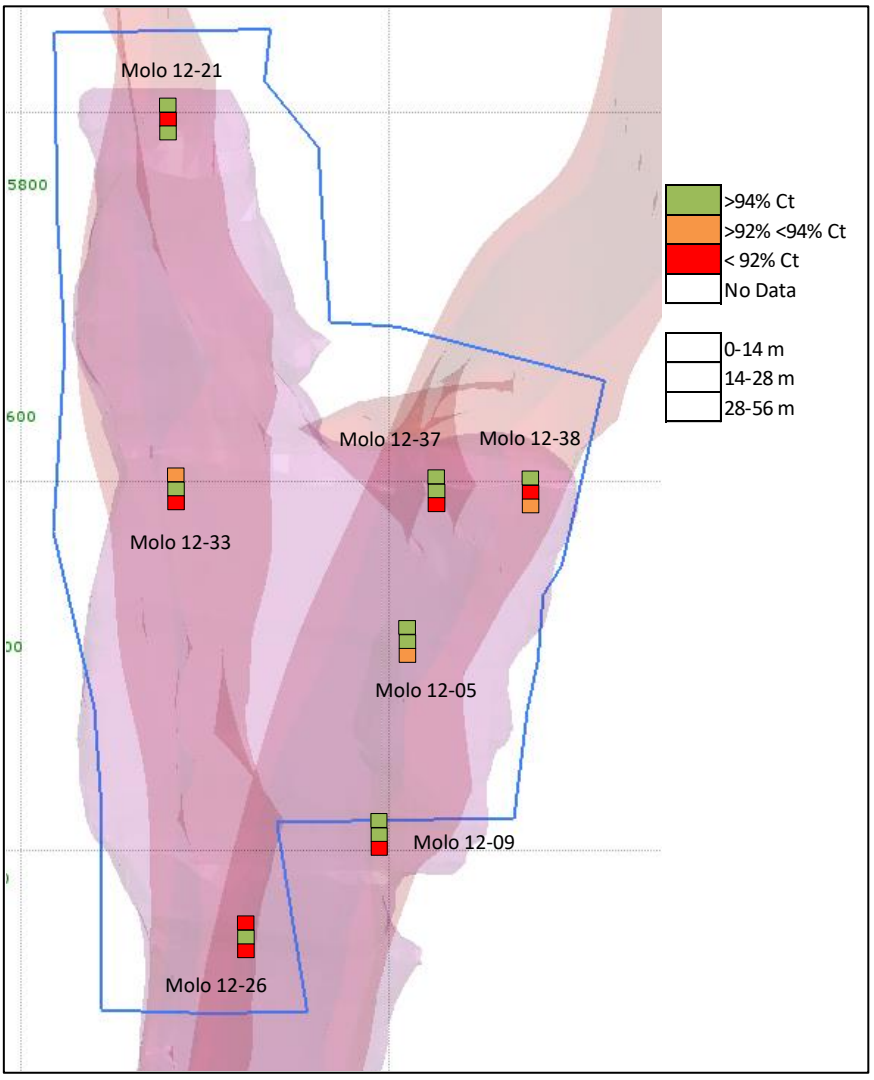


Figure 44: Location and Performance of Phase II Variability Drill Holes

13.7.2 Area Composites

In an attempt to develop a better understanding of the average metallurgical response of the Molo mineralization, area composites were generated, which included samples from all drill holes that were available.

For this purpose, the 2015 FS 5-year mine pit layout was split into five areas and each area composite was then generated by combining sub-samples from all drill holes that fell into a specific area.

The three depth intervals 0 to 14m, 14 to 28m, and 28 to 56m were maintained for the area composites i.e. a total of fifteen area composites were generated. A summary of the drill holes that were included in each area composite is provided in Table 32.

Table 32: Drill Holes Included in Area Composites

Composite ID	Drill Hole ID's
Area Composite 1	MOLO 12-20, 12-21, 12-28, 12-29
Area Composite 2	MOLO 12-01, 12-02, 12-03, 12-18, 12-19, 12-27, 12-30, 12-32, 12-33, 12-34, MOLO-01
Area Composite 3	MOLO 12-04, 12-05, 12-35, 12-37, 12-38
Area Composite 4	MOLO 12-23, 12-24, 12-31, 14-15
Area Composite 5	MOLO 12-07,12-08, 12-09, 12-26, 12-40, 14-17, MOLO-22

The average flake size distribution of the fifteen area composites is shown in Table 33. For comparison purposes, the average flake size distribution of the pilot plant campaign and the two variability programs are presented in the same table.

The data reveals good agreement between the results, which attests to the robustness of the flake size distribution across the Molo mineralization.

Table 33: Comparison of Flake Size Distribution

Screen Size	Area Composites	Variability Phase I	Variability Phase II	Pilot Plant Campaign
+48 mesh	26.5	19.0	26.6	15.7
+65 mesh	17.0	19.0	18.3	17.6
+80 mesh	8.1	8.9	8.3	10.2
+ 100 mesh	6.6	8.7	6.6	9.7
+150 mesh	12.2	13.4	12.0	15.0
+ 200 mesh	8.4	9.9	8.2	10.1

Screen Size	Area Composites	Variability Phase I	Variability Phase II	Pilot Plant Campaign
- 200 mesh	21.2	21.3	19.9	21.6

The grades of the combined concentrates of the fifteen area composites are presented in Figure 45. Only two of the composites produced concentrate grades of greater than 94% total carbon.

Six composites graded between 92% and 94% total carbon and the remaining seven composites produced concentrates of less than 92% total carbon.

The best performing composite was that of Area 3 (0 to 14m) with a concentrate grade of 95.0% total carbon, while the worst performing composite was Area 4 (14 to 28m) which produced a concentrate grading of only 89.4% total carbon.

The average concentrate of all fifteen composites was 92.1% total carbon.

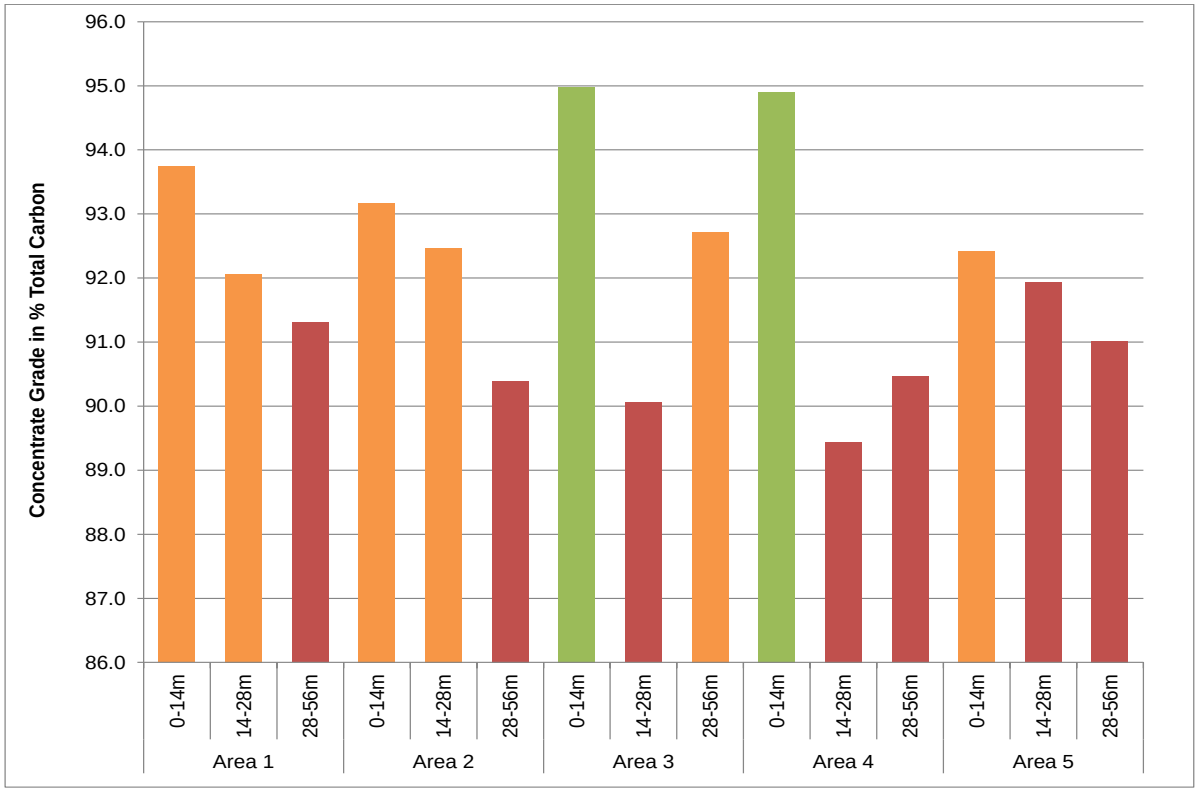


Figure 45: Combined Concentrate Grades of Twenty-One Area Composites

The location of the five areas and the metallurgical response of the fifteen area composites are shown in Figure 46. Only the top 14m of the Area 3 and Area 4 composites produced good concentrate grades, which is consistent with the results of the individual drill holes that originated from that area and depth interval.

The postulation that further upgrading of the graphite flotation concentrate is required was confirmed for the area composites.

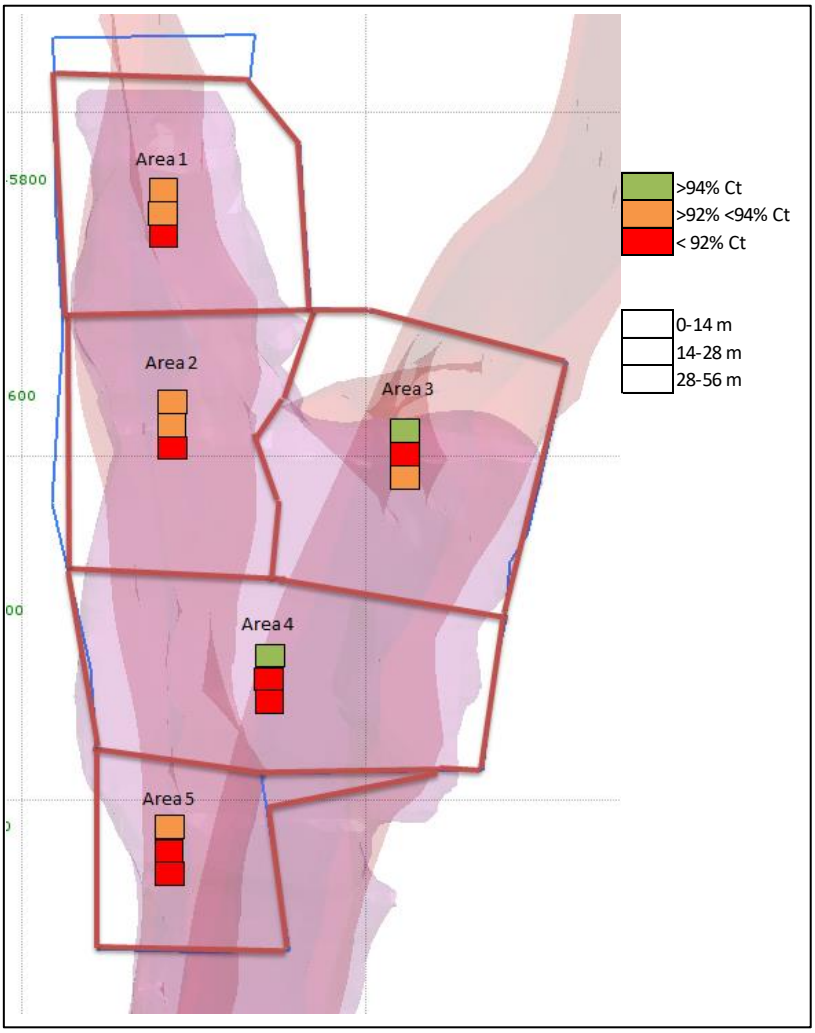


Figure 46: Location and Performance of Area Composites

The average open circuit carbon recovery for the fifteen area composite tests was 87.6% and ranged between 73.2% for the Area 1 (14 to 28m) composite and 93.6% for the Area 3 (28 to 56m) composite.

Since open circuit tests treat the intermediate cleaner tails as final tails, the recoveries are lower compared to closed circuit operation. In order to determine the closed-circuit performance, four locked cycle flotation tests were completed on the Molo mineralization.

The analysis of the results determined that 66% of the carbon units that reported to the intermediate cleaner tails report to the final concentrate in closed circuit operation.

This factor was applied to the fifteen tests using the area composites to arrive at a closed-circuit carbon recovery projection of 90.5%.

13.8 Concentrate Upgrading Tests

The average concentrate grade of 92.1% of the area composites has a significant impact on the economics of the project. Concentrates grading between 94% and 97% total carbon are in higher demand and achieve substantially higher prices compared to a concentrate grading only 90% total carbon. To increase the graphite flotation, concentrate from approximately 92% total carbon to at least 94% total carbon, two upgrading strategies were evaluated.

The first approach applied high temperature drying at 400°C for one hour followed by classification of the dried concentrate on a standard set of sieves. It was postulated that the high temperature drying for an extended period of time could possibly weaken or break the bonds between the graphite layers and non-sulphide gangue minerals within the intercalated graphite flakes.

Screening the product could then result in upgrading of the coarser graphite flakes if the gangue minerals are liberated in the drying process and report to the smaller size fractions.

This upgrading approach failed to improve concentrate grades and a cleaner flotation test conducted on the dried concentrate did not produce further grade improvements.

Optical mineralogy that was conducted on the dried concentrate confirmed the existence of intercalated graphite, which led to the rejection of this upgrading strategy.

The second upgrading strategy evaluated a series of different sized grinding media and grinding mills, as well as sodium silicate as a gangue depressant. A combined concentrate from the Phase II variability program was homogenized and split into equal test charges that were then subjected to five different upgrading conditions.

The most promising results were achieved using an attrition scrubber with 1 mm ceramic media and a stirred media mill with 6 mm steel media.

Ten additional tests were carried out using the attrition mill and attrition scrubber. A weighted combined concentrate of all fifteen area composite tests was generated for those tests, which was a good representation of the average mineral resource.

The variables that were modified in the ten tests were the grinding times and the use of sodium silicate.

While the test using the 1 mm ceramic media in an attrition scrubber produced good combined concentrates grades of more than 96% total carbon, the flake size degradation was significantly higher compared to the tests using the stirred media mill. This is evidenced in Figure 48 and Figure 49 which depict the mass recovery into the size fractions of the final concentrates of tests conducted with the stirred media mill and attrition scrubber, respectively. In order to quantify the degree of flake degradation, the charts also include the data for the feed sample prior to milling or scrubbing.

The degradation of the flakes larger than 65 mesh was less pronounced for the stirred media mill and even at the longest grind time the mass recovery into the +48 mesh size fraction was still 17.1%. In contrast, the shortest grind time in the attrition scrubber reduced the mass recovery into the +48 mesh concentrate to 14.3%. The shortest grind time in the stirred media mill reduced the mass of the +48 mesh and -48/+65 mesh concentrate by only 2.6% and 2.7%, respectively.

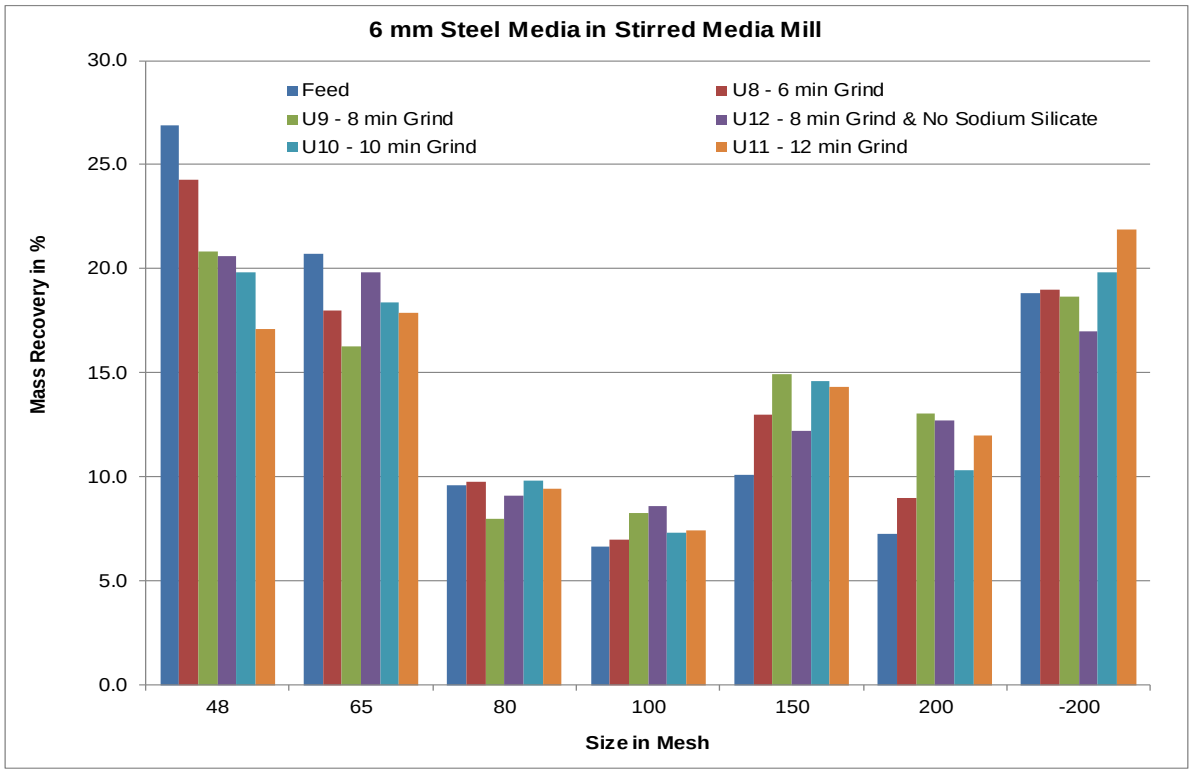


Figure 47: Stirred Media Mill Size Fraction Analysis – Mass Recovery

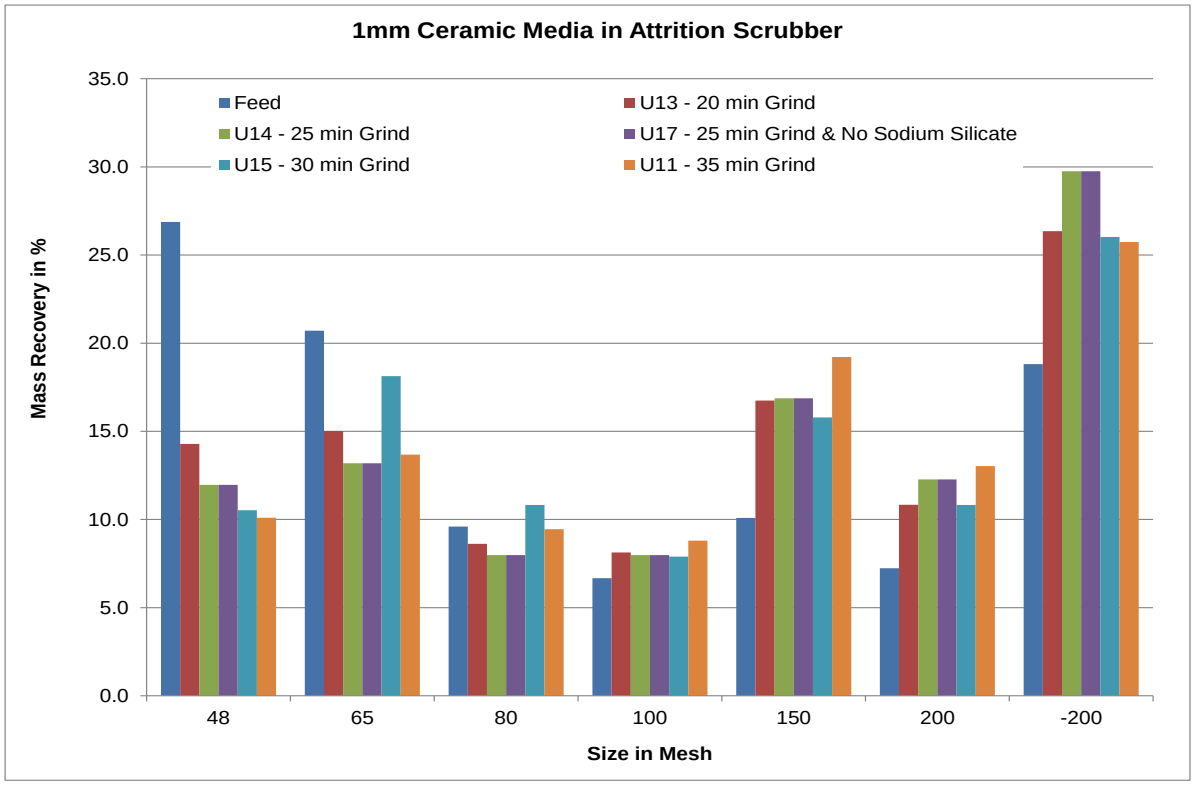


Figure 48: Attrition Scrubber Size Fraction Analysis – Mass Recovery

The total carbon grades into the size fractions of the combined concentrate for the five tests using the stirred media mill are presented in Figure 50. The shortest grind time of 6 minutes produced concentrate grades of 96.9% to 98.1% total carbon for the various size fractions. Even if the worst-case scenario of the relative measurement error of 1.4% associated with the total carbon analysis by LECO SC_632 is applied, the results are consistently above the minimum grade target of 95% total carbon.

Because the flake degradation increased with longer grinding times without a clear improvement in the concentrate grades, the test with the shortest grind time was deemed the most successful one.

It should be noted that all size fractions of the concentrates of the five upgrading tests using the stirred media mill yielded at least 96.5% total carbon, which attests the robustness and repeatability of the upgrading approach.

It may be possible to reduce the amount of flake degradation in the large and jumbo flake categories with the addition of a classification stage of the intermediate concentrate at 80 mesh prior to stirred media milling followed by separate cleaning circuits for the screen oversize and undersize fractions. This approach allows to tailor the final graphite concentrate grade distribution to specific market demands.

A comparison of the results of tests U9 (sodium silicate at 40 kg per tonne of concentrate) and U12 (no sodium silicate) reveals that the gangue depressant only increased the combined concentrate grade by 0.2% from 97.1% to 97.3% total carbon. Since this grade improvement is statistically insignificant, the addition of sodium silicate cannot be justified for inclusion in the upgrading circuit.

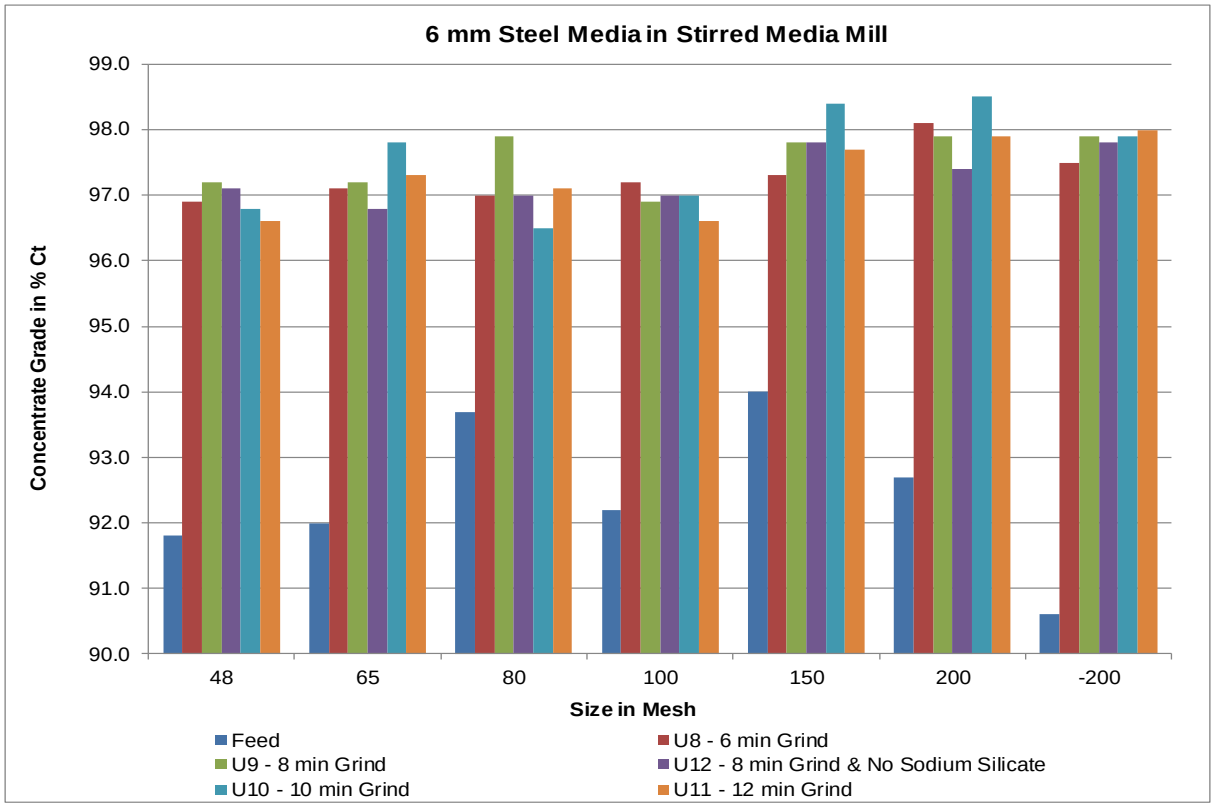


Figure 49: Concentrate Grades of Size Fractions – Stirred Media Mill

The complete Molo flowsheet with the attrition circuit is depicted in Figure 50.

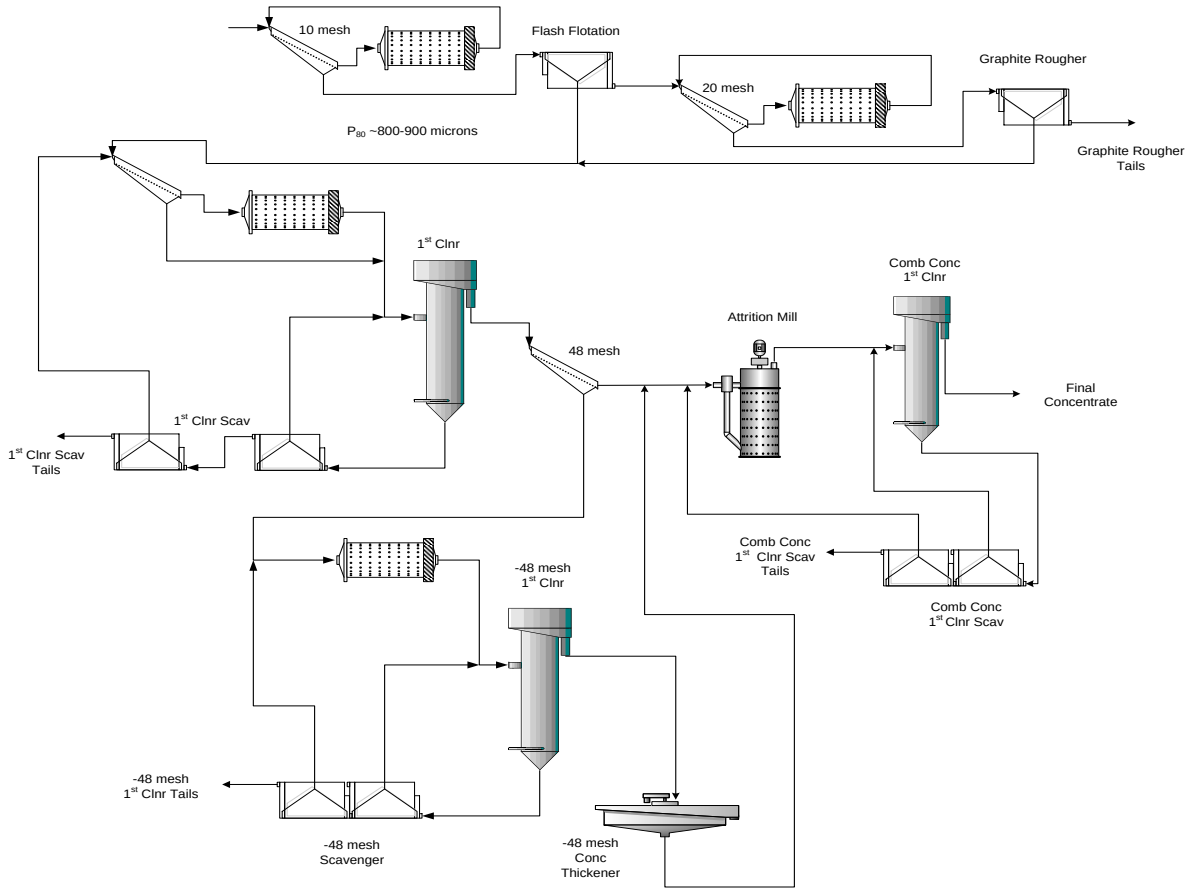


Figure 50: Molo Flowsheet including Stirred Media Mill Circuit

Since the concentrate used in the upgrading tests was a weighted composite of all area composite concentrates, the flake size distribution and concentrate grade of test U8 was considered most representative of the average plant product in the first several years of mining operation.

The mass recovery into the various size fractions and associated concentrate grades are presented in Table 34.

The open circuit carbon recovery into the final concentrate of test U8 was 97%. Although carbon recovery will likely increase in closed circuit operation, this conservative number was applied to the circuit carbon recovery of 90.5% prior to upgrading.

As a result, the combined carbon recovery for the main process flowsheet and the upgrading circuit is 87.8%.

Table 34: Mass Recovery and Total Carbon Grades of Size Fractions of Final Concentrate

Product		Mass (%)	Grade (% Total Carbon)
Mesh	Microns		
+48	+297	24.3	96.9
-48/+65	-297/+210	18.0	97.1
-65/+80	-210/+177	9.8	97.0
-80/+100	-177/+149	7.0	97.2
-100/+150	-149/+106	13.0	97.3
-150/+200	-106+74	9.0	98.1
-200	74	19.0	97.5
Total		100.0	97.2

13.8.1 Optical Mineralogy of Upgraded Concentrate

The seven size fractions of the most successful upgrading test U8 using the stirred media mill were submitted for optical mineralogy. All samples displayed similar mineralogical characteristics.

Non-sulphide gangue (NSG) minerals were generally fine grained (<20 to 500 microns). NSG occurred as minor liberated grains only in the +48 mesh, and sporadically in some of the other fractions.

The bulk of the NSG occurred interlayered with graphite grains. They were developed along the long axis of the graphite particles and are of varied width.

A photomicrograph of graphite flakes in the +48 mesh size fraction of the U-8 3rd cleaner concentrate is depicted in Figure 51 to illustrate the interlayering. The image shows graphite (red arrows) that is largely liberated in the sample. However, non-sulphide gangue minerals (green arrows) are mainly interlayered within graphite.

While the interlayering has not been eliminated in the upgrading stage, the frequency has been reduced significantly, thus resulting in the mean grade improvement of approximately 5% total carbon.

It is postulated that the coarser intercalation between graphite and NSG minerals is separated efficiently in the stirred media mill, but that the thinner layers between graphite and NSG minerals are more difficult to segregate. However, given the more than adequate concentrate grade of 97.2% total carbon in the U8 test, eliminating all interlayering is not required.

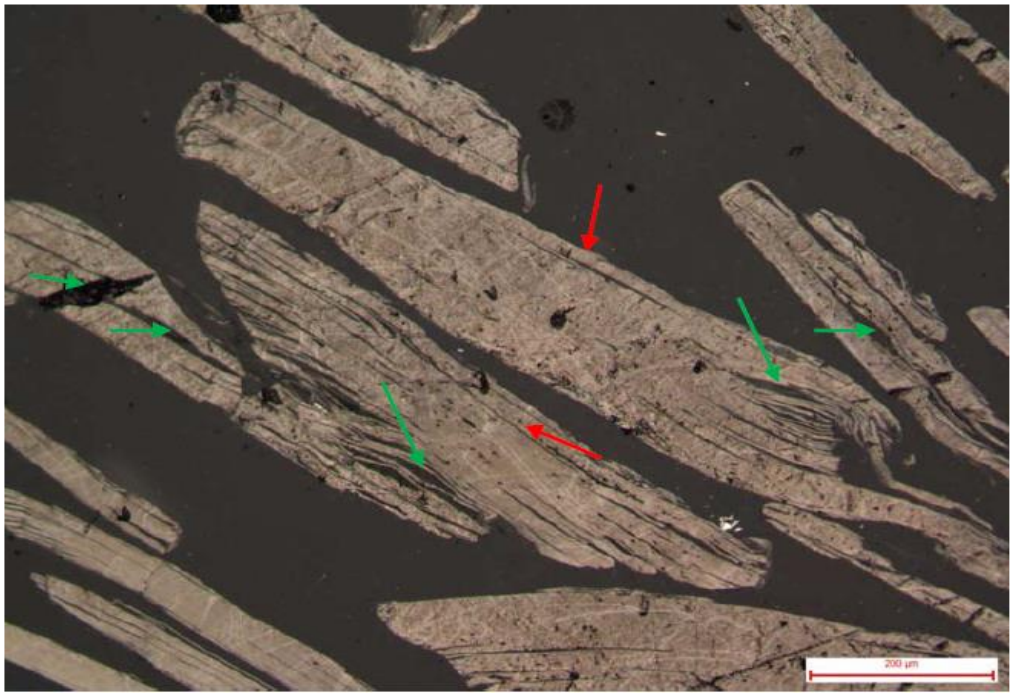


Figure 51: Optical Photomicrographs (PPRL) from the U-8 SFA 3rd Clnr Conc +48 Mesh

13.9 Total Carbon and Graphitic Carbon Assay Methods – SGS

Carbon occurs as organic carbon, carbonate carbon and graphitic carbon. The three types of carbon combined represent the total carbon content of a sample.

The total carbon content of a sample is determined by combusting a pulverized sample followed by infrared detection on LECO instrumentation. Lower grade samples are analyzed with a LECO 844, while samples higher than 30% carbon are analyzed for carbon on the SC632 instrument. Both instruments use high temperature combustion followed by infrared detection of CO_2.

The graphitic carbon content of a sample is determined in a 3-step process using coulometric analysis. The pulverized sample is roasted in an oven at 500°C for 15 minutes to remove any organic carbon. The carbonate carbon is determined by subjecting one aliquot of the roasted samples to coulometric analysis. A second aliquot is used to determine total carbon using a tube furnace. The graphitic carbon is then calculated by the difference between the total carbon and carbonate carbon.

13.10 Additional Testing

The physical properties of graphite are very different to most other commodities because of its particle shape and density. Consequently, it is essential that all unit operations for a proposed graphite processing plant are evaluated in laboratory, or pilot scale trials to obtain robust data for the process design criteria.

Graphite concentrate that was generated in the 2013 pilot plant campaign was shipped to various equipment vendors to evaluate dewatering, drying, and screening applications. These unit operations are required to produce a final saleable product from the initial graphite flotation concentrate.

Further, dewatering tests were carried out on the combined tailings from the pilot plant campaign as poor settling properties of the fine particles in the tailings were observed in laboratory and pilot scale testing.

13.10.1 Thickening

Two equipment vendors conducted thickening testwork on concentrate and tailings samples that were generated in the pilot plant campaign.

Both vendors conducted static settling and dynamic tests to identify a suitable flocculant and to establish process parameters to achieve a high thickener underflow density and clear overflow.

Vendor A quantified a solids loading rate of 0.25 t/m^2/h for the concentrate thickener yielding an underflow density of 36% solids at a flocculant dosage of 5 ppm Magnafloc® 919. The overflow contained 230 ppm solids. The tailings required the addition of a coagulant to achieve satisfactory overflow clarity of less than 100 ppm. The reagent regime consisted of 5 ppm Magnafloc® 1011 and 500 ppm Magnafloc® 370. An underflow density of 50% solids with an overflow containing 70 ppm solids was achieved at a solids loading rate of 0.75 t/m^2/h.

Vendor B quantified the solids loading rate for the concentrate thickener at 0.64 t/m^2/h at a flocculant SNF 905 VHM dosage of 20 g/t. The solids loading rate for the graphite tails was 0.46 t/m^2/h at a flocculant SNF 934 VHM dosage of 140 g/t. The concentrate and tailings thickener underflow solids concentration at 2 hour retention time were 41% and 47% respectively. The overflow clarity for the graphite concentrate was clear, at less than 100 ppm, while the graphite tailings contained a solids concentration of 3,500 ppm.

Vendor A required a large dosage of coagulant Magnafloc® 370 to produce an overflow clarity for the graphite tailings thickener application of less than 100 ppm suspended solids, while vendor B failed to generate an acceptable graphite thickener tails overflow clarity. Two reagent suppliers, supplier A and supplier B, were contracted to carry out a more comprehensive reagent screening to evaluate a reagent regime requiring lower dosages.

Supplier A recommended the use of approximately 125 g/t of flocculant Magnafloc® 24, 155, 1011 or 919 in conjunction with 100 – 150 ppm of coagulant Magnafloc® 1707 to achieve the desired overflow clarity of less than 100 ppm suspended solids in the graphite tailings thickener.

Supplier B did not develop a reagent regime that achieved dosages lower than the ones recommended by equipment Vendor one.

13.10.2 Filtration Tests

Two suppliers conducted filtration test work on concentrate and tailings samples that were generated in the pilot plant campaign.

The first vendor conducted bench scale testing to evaluate filter cloth selection, filter cake thickness, filtration rate, moisture content of the cake, and cake handling characteristics to achieve 15 to 20% w/w moisture in the concentrate cake.

The tests conducted by the first vendor produced concentrate filter cakes with cake moisture content between 11.0% w/w and 20.5% w/w at filtration rates of 179 to 417 kgDS/m^2/h. Filtration tests on the tailings produced filter a cake moisture content between 12.7% and 17.9% w/w at filtration rates of 92 to 218 kgDs/m^2/h.

Vacuum filtration tests conducted by the second vendor produced a concentrate cake moisture content of 23% w/w at a filtration rate of 327 kgDs/m^2/h.

Pressure filtration tests on the concentrate produced a cake moisture content of 23.2% w/w. The vacuum filtration properties of the tailings were poor yielding a cake moisture content of 32% w/w at a filtration rate of 41 kgDs/m^2/h.

13.10.3 Concentrate Drying

Drying tests were conducted using a rotary dryer and a fluid bed dryer.

While the rotary dryer did not operate well treating the as-received graphite concentrate with a moisture content of 32-39% w/w, good performance was obtained when back-mixing some of the dried concentrate to adjust the feed moisture content to 26% w/w.

Since the filtration tests conducted by both vendors produced filter cakes with a lower moisture content than 26% w/w, the rotary dryer is a suitable drying technology to achieve a product moisture content of less than 0.5% w/w.

The fluid bed dryer work failed to produce results.

13.10.4 Wet and Dry Screening Tests

Wet and dry screening tests were carried out at one vendor to evaluate screening applications on intermediate and final graphite concentrates and to determine if screens could be employed in a dewatering application.

Classification of the dried graphite concentrate was performed at 50, 80, and 200 mesh using dried concentrate that was generated during the rotary dryer tests.

The dry screening tests suggested that classification can be carried out at a rate of 1.0 t/h per meter of screen width.

Tests on a wet graphite concentrate to evaluate the classification of the intermediate concentrate at 80 mesh and 140 mesh yielded screening rates of 2.0 to 2.2 t/h per meter of screen width.

Dewatering tests on the -140 mesh material was carried out on a 270 mesh screen deck. The mass recovery into the screen oversize was 63.4% at a moisture content of 49.7% w/w.

14 MINERAL RESOURCE ESTIMATES

Refer to 2015 BFS.

15 MINERAL RESERVE ESTIMATES

Refer to 2015 BFS.

16 MINING METHODS

The surficial, lateral expanse and the massive nature of the Molo deposit make it suitable for open-pit mining methods. It is a typical pipe shaped and steeply dipping ore body, with an extended mineral outcrop along the strike (north-south direction) of the deposit. In this mining method, the following activities are executed:

- The land is cleared, topsoil is removed and stockpiled at designated sites for use in future land rehabilitation. Depending on the extent of the base of weathering, any further waste, or ore that can be removed by free-digging is removed and stockpiled accordingly. The topsoil is planned to be used as a berm around the pit to prevent water flow into the pit and to minimise transportation costs
- In a number of cyclic processes the waste and/or mineralised material is drilled, charged with explosives and blasted, excavated, hauled and dumped in designated sites
- At strategically planned periods the waste around the boundary of the pit is removed in order to mine out deeper ore

The conventional open pit mining activities are carried out with small to medium sized mining equipment including 30t dump trucks, a 2 m^3 excavator and a 8 m^3 Front End Loader.

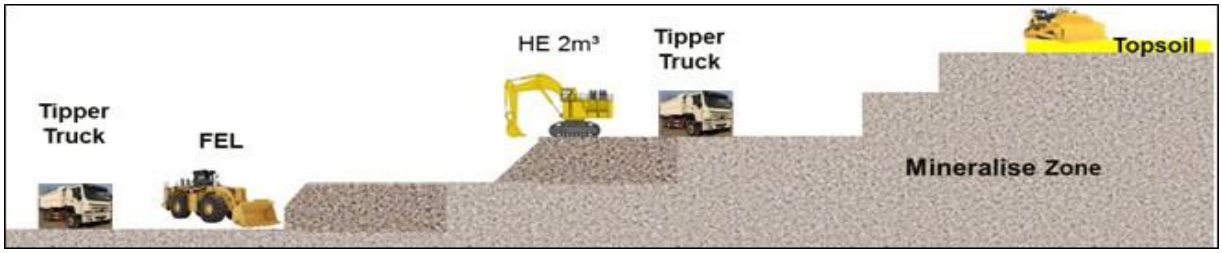


Figure 52: Molo Open Pit Mining Bench Layout

Detailed geotechnical and hydro-geological studies have been conducted and the reports indicate that there are no fatal flaws regarding the adoption of the open pit mining as the preferred mining method.

16.1 Open Pit Optimisation

By using the prepared resource model together with the required economic and technical mine design input parameters, the Whittle Optimization software applies pessimistic and optimistic factors to the product price whilst generating corresponding nested pit shells, or possible pits at their specific total economic values. Whittle executes a number of possible iterations on the product price or revenue in order to obtain the best and optimal pit size and shape in three dimensions. This optimisation process in the Whittle software is based on the Lerchs-Grossman algorithm. The pit shell that ends up with the highest pit value is then selected as the optimal pit and this pit is established as the basis for any further detailed mine design work.

The Molo resource model has been delineated into two grade zones, high grade and low grade zones. The tonnes and grades of these high grade and low grade resources are reported in the resource statement at 4% and 2% cut-off grades, respectively. Since the graphite product is priced according to the flake size distribution and carbon content, test work studies have been conducted in order to determine if there are relationships between the grade of the ore fed to the mill and the flake size and carbon content of the graphite product. These studies initially indicated that the low grade ore yielded larger flake sized product although this was not conclusive and therefore the Whittle optimisation has been run on grade value only. As a result of this the model naturally targets high grade ore early in the LOM.

Table 35: Whittle Input Parameters

Mining	Value	Unit
Max bench height	8	M
Minimum bench width	6.14	m
Batter angle	75	deg

Mining	Value	Unit
Overall Slope angle	46	deg
Minimum pit bottom	30	M
Mining recovery	95	%
Dilution	3	%
Mining operating cost	6.78	USD
Mining re-handle cost	0.56	USD
Processing		
Plant recovery	88.3	%
Mining re-handle cost	0.56	USD
Processing unit cost	19.11	USD
G & A cost	12.64	USD
Mill Throughput	240	Ktpa
Product/Selling		
Product price	1 000	USD
Royalty	0%	%
Selling cost	190.55	USD

19.1.1 Pit Slopes

A detailed geotechnical study at the Molo deposit has been completed and the analysis thereof has yielded recommendations for the optimal pit slope angles aimed at maximising extraction and maintaining pit wall stability. Indications are that an overall pit slope angle of 46^{o} could be adopted although the slope angles in the fresh and hard rock material could be made steeper, up to 48^{o}.

11.2.2 Mining Dilution

Dilution is waste material that is mined together with ore and thus reduces the overall grade of the mined ore and also increases the tonnages of the ROM.

Despite Molo being a massive deposit regarding its strike, dip and width, dilution as a result of mining at the Molo deposit is still expected to be significant due to:

- The high grade zones occur near the outer limits of the deposit and therefore more waste must be mined with depth
- The Molo deposit has an internal waste feature near the central southern section of the deposit and for geotechnical reasons, this waste material must be mined albeit selectively, and
- The transitional nature of the contact between ore and waste

For typical massive deposit types such as Molo, it is generally accepted that the dilution is 3%. Further dilution studies will be investigated at various bench levels once mining has commenced.

16.1.3 Mining Recovery

Of the ore that is planned, or scheduled to be mined, a portion of that mineralised material that is in practice left unmined in the pit due to mineralised material / waste boundaries, geotechnical considerations, water in the pit, or other practical issues depending on the nature of the deposit. The mining recovery of the deposits depends on the process methodology and this can range from 87% to 95%. The massive nature of the Molo deposit, the absence of major geotechnical anomalies and the flexibility benefits from using small equipment indicates that the mining recovery can reasonably be set at 95%.

16.1.4 Plant Recovery & Costs

The plant recovery of 88.3% is based on metallurgical test work results for the Molo samples.

The mining cost is based on owner mining equipment scenario where detailed and up to date quotations by potential suppliers were sourced.

The product price is quoted as either USD$1 000. The lower plant recovery attempts to maximise the low grade ore which is expected to produce larger flake sized product.

16.2 Whittle Scenarios

Five Whittle scenarios were considered in order to select the best optimisation approach regarding the optimal cut-off grade. The cut-off grade was varied from 4.5 to 6.5% in 0.5% increments.

16.3 Whittle Results

The Whittle optimal results for each scenario are tabulated below. The selected scenario as base on the one with the best discounted cash flow (excluding CAPEX) and the ability to produce 240 000 tonne ore per annum for 30 years. Scenario 3 was selected as the go-forward case for the design of the final pit.

Table 36: Whittle Results Summary per Scenario

	Scenario 1	**Scenario 2**	**Scenario 3**	**Scenario 4**	**Scenario 5**
	COG = 4.5%	**COG = 5.0%**	**COG = 5.5%**	**COG = 6.0%**	**COG = 6.5%**
Ore (t)	7 571 370	7 396 615	7 260 943	8 800 261	8 587 081
Waste (t)	2 752 531	2 927 286	3 062 958	4 494 351	4 707 531
Total (t)	10 323 901	10 323 901	10 323 901	13 294 612	13 294 612
Strip Ratio (t)	0.36	0.40	0.42	0.51	0.55
Graphite Feed To Plant (t)	634 481	626 493	619 358	748 902	735 913
Graphite Grade To Plant	8.38%	8.47%	8.53%	8.51%	8.57%
Product Recovery Of Plant (t)	560 247	553 194	546 894	661 281	649 811
Pit Value After Capital NPV @ 10%	41 144 883	42 677 339	43 468 610	39 516 318	39 886 428
LOM (years)	31.5	30.8	30.3	36.7	35.8

The Whittle optimal pit shell for scenario 1 is 1.4 km long (N-S), 130m wide (east-west) and 82m deep. The optimisation runs in Whittle do not include the minimum mining width parameter and therefore, inclusion of this parameter in the final pit design is likely to add more waste to the ultimate results.

16.4 Open Pit Final Design

Using the minimum mining width of 30m suited for the selected mining equipment and the recommended 46º slope angle, the final pit design at Molo was drafted including the following key design parameters;

16.4.1 Ramps

A single ramp was designed in the centre zone of the pit and is designed at a width of 15m. The single ramp is sufficient access to the pit due to the low mining volumes and total mineable volume within the designed pit shell. The ramp width is designed to allow dual way traffic and also satisfies the industry norm of the ramp width at least 3.5 times the width of the largest vehicle. The (30t) articulaed haul trucks at a width of 3m are more than suited for these ramps. Allowance has also been made for the use of bigger haul trucks if needed.

The ramps are designed at a 10% gradient and ramp switchbacks or turns are designed in a 180^{o} turn with a radius of 15m.

16.4.2 Bench Design

The Bench design includes a bench height of 8m, a berm width of 6m and a bench slope, or batter angle of 75^{o} as recommended from the detailed geotechnical study.

16.4.3 Pushback

The final pit design resulted in a pit that is 1.437 km long, 270m wide and 82m deep.

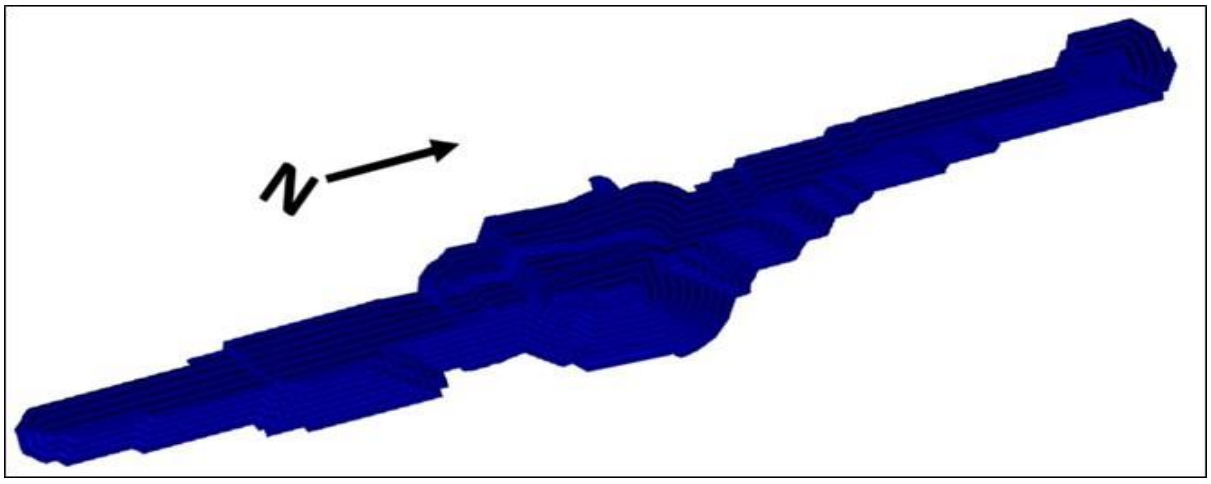


Figure 53: Final Design Pit

16.5 Mine Planning

The final pit mine plan is aimed at maximising the feed grade whilst minimising the strip ratio in the first 5 years of the production. Mining operations are planned to mine out the narrower and shallower southern and northern portions of the pit, before mining the deeper central section through the pit access ramp in the central section of the pit. This is done to ensure that access to this section of the pit is not cut off when the deeper central section of the pit is mined.

The mine plan has been drafted such that a fairly consistent ratio of high grade to low grade ore, as well as a consistent head grade in the run of mine is supplied to the mill. The average high grade to low grade ore ratio in the run of mine is 60% to 100% high grade and the balance low grade, at the average head grade is 8.05%. Ore is drilled, blasted, loaded, hauled and tipped onto ROM stockpiles or in the ROM tip in accordance with the required blending ratio. The material is crushed blended and conveyed to a processing plant which is planned to recover between 88.3% of the graphite. Depending on the ROM feed rate, feed grade and process recovery efficiency in the processing plant, graphite products from 15.3 ktpa to 18.3 ktpa can be produced.

16.5.1 Production Schedule

The final pit production schedule is based on a run of mine production target of 240 000t per annum. To sustain this production rate an average waste to ROM stripping ratio of 0.52 waste tonnes (inclusive of reject ore tonnes) per 1 ROM tonne will be required over the LOM. The material movement in the production schedule is comprised of the high grade ore stockpile, low grade ore stockpile, reject ore stockpile and waste dumps.

The 30 year production schedule is depicted in the following Table 34:

Table 37: Molo Production Schedule for the LOM

Year	Topsoil t	Waste t	HG Ore t	HG Grade %	LG Ore t	LG Ore Grade %	Reject Ore t	Reject Ore Grade %	Total Waste t	Total Ore excluding Reject Ore t	RoM Ore Grade %	Total Mined t	Total Plant Feed t	Total Product t
2018	29 339	117 513	172 594	8.83%	27 406	8.05%	53 867	4.72%	200 718	200 000	8.72%	400 718	200 000	15 404
2019	21 695	113 420	192 804	8.52%	47 196	6.41%	25 604	4.69%	160 718	240 000	8.11%	400 718	240 000	17 179
2020	14 887	137 865	231 764	8.48%	8 236	6.54%	7 966	3.46%	160 718	240 000	8.41%	400 718	240 000	17 821
2021	-	160 716	160 181	8.21%	79 819	7.16%	-	0.00%	160 716	240 000	7.86%	400 716	240 000	16 654
2022	4 957	137 129	174 083	8.21%	65 917	7.92%	18 632	3.24%	160 717	240 000	8.13%	400 717	240 000	17 227
2023	4 408	146 083	192 418	8.13%	47 582	5.51%	10 227	3.29%	160 717	240 000	7.61%	400 717	240 000	16 136
2024	6 904	142 847	208 586	8.38%	31 414	5.80%	10 967	3.74%	160 718	240 000	8.04%	400 718	240 000	17 037
2025	8 972	87 054	240 000	8.06%	-	0.00%	64 692	5.01%	160 718	240 000	8.06%	400 718	240 000	17 083
2026	6 994	71 863	180 347	8.06%	59 653	5.66%	81 861	5.06%	160 718	240 000	7.47%	400 718	240 000	15 822
2027	-	32 581	205 280	8.46%	34 720	5.66%	128 135	4.20%	160 716	240 000	8.05%	400 716	240 000	17 068
2028	-	18 635	234 563	8.24%	5 437	5.35%	142 081	4.20%	160 716	240 000	8.18%	400 716	240 000	17 332
2029	-	51 845	228 518	8.27%	11 482	7.06%	108 871	4.11%	160 716	240 000	8.21%	400 716	240 000	17 402
2030	-	48 263	221 872	8.42%	18 128	7.44%	112 453	5.12%	160 716	240 000	8.35%	400 716	240 000	17 688
2031	-	64 372	240 000	8.46%	-	0.00%	96 344	4.42%	160 716	240 000	8.46%	400 716	240 000	17 937

Year	Topsoil t	Waste t	HG Ore t	HG Grade %	LG Ore t	LG Ore Grade %	Reject Ore t	Reject Ore Grade %	Total Waste t	Total Ore excluding Reject Ore t	RoM Ore Grade %	Total Mined t	Total Plant Feed t	Total Product t
2032	-	8 846	204 918	8.14%	35 082	6.07%	151 870	4.96%	160 716	240 000	7.84%	400 716	240 000	16 604
2033	-	25 094	170 230	8.53%	69 770	5.95%	120 462	4.48%	145 557	240 000	7.78%	385 557	240 000	16 489
2035	-	89 958	148 760	8.29%	91 240	6.40%	70 760	4.28%	160 718	240 000	7.57%	400 718	240 000	16 044
2036	-	34 659	213 170	8.59%	26 830	6.38%	126 060	4.35%	160 718	240 000	8.34%	400 718	240 000	17 678
2037	-	35 721	222 808	8.63%	17 192	5.92%	105 569	4.91%	141 290	240 000	8.44%	381 290	240 000	17 888
2038	422	70 467	239 159	8.46%	841	6.38%	52 791	4.42%	123 679	240 000	8.46%	363 679	240 000	17 920
2039	-	44 791	223 491	8.34%	16 509	6.75%	14 217	4.50%	59 008	240 000	8.23%	299 008	240 000	17 445
2040	-	38 049	209 768	8.46%	30 232	5.39%	19 309	4.70%	57 357	240 000	8.08%	297 357	240 000	17 117
2041	-	9 607	219 195	8.76%	20 805	5.26%	28 173	5.24%	37 780	240 000	8.46%	277 780	240 000	17 930
2042	-	33 852	190 357	8.02%	49 643	5.87%	40 136	4.53%	73 989	240 000	7.58%	313 989	240 000	16 060
2043	-	6 384	179 368	8.45%	60 632	6.47%	3 867	3.44%	10 251	240 000	7.95%	250 251	240 000	16 843
2044	-	18 015	199 846	8.82%	40 154	5.50%	43 635	4.26%	61 650	240 000	8.27%	301 650	240 000	17 515
2045	-	23 068	189 875	8.08%	50 125	5.74%	26 828	4.22%	49 896	240 000	7.59%	289 896	240 000	16 089
2046	-	44 575	192 403	8.80%	47 597	6.53%	28 369	4.41%	72 944	240 000	8.35%	312 944	240 000	17 690
2047	-	9 376	192 262	8.12%	47 738	5.53%	29 878	4.78%	39 254	240 000	7.60%	279 254	240 000	16 113
Totals	**99 404**	**1 865 223**	**6 017 582**	**8.39%**	**1 142 418**	**6.27%**	**1 757 084**	**4.54%**	**3 721 712**	**7 160 000**	**8.05%**	**10 881 712**	**7 160 000**	**509 233**

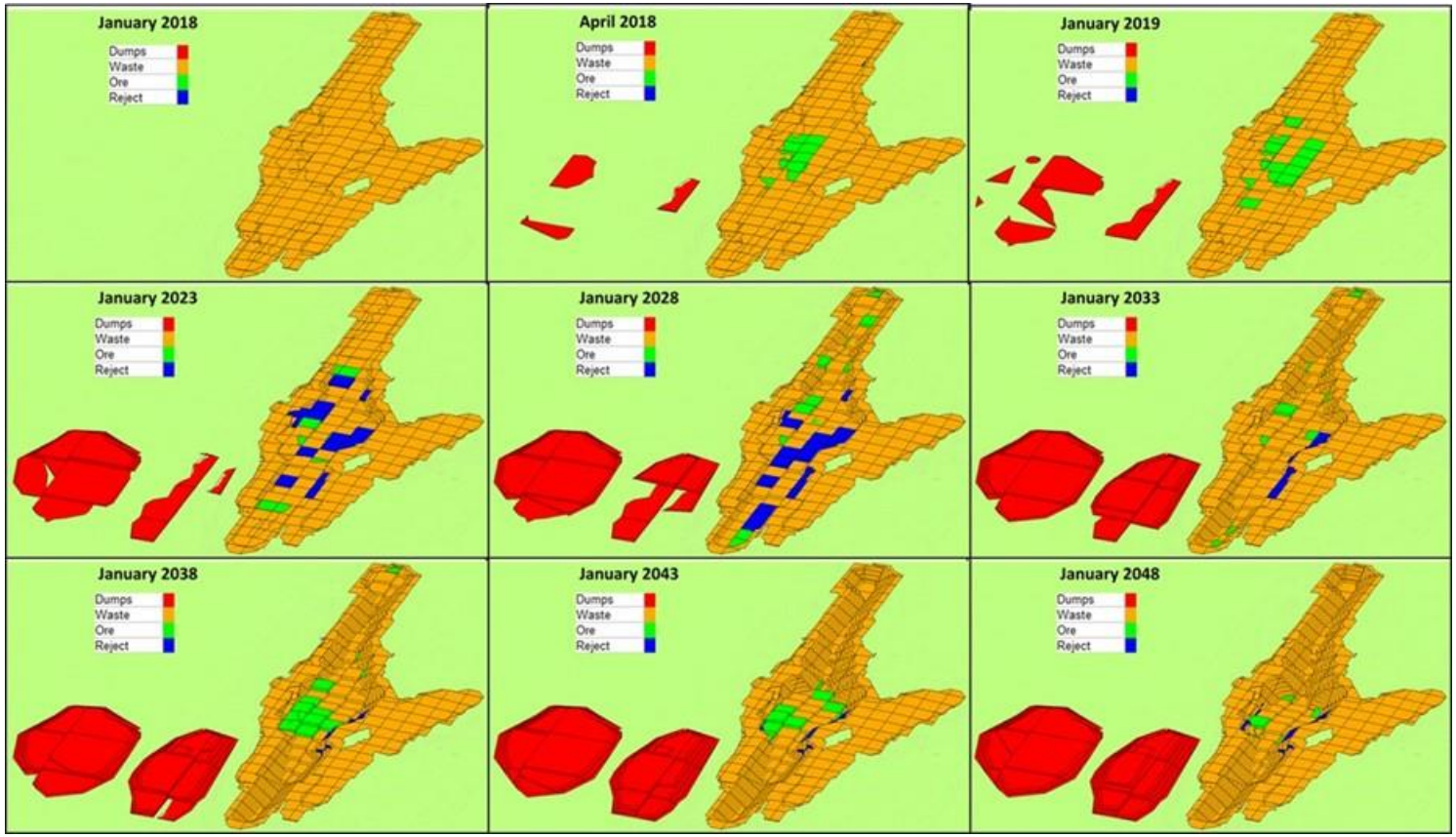


Figure 54: Molo Stage Plans for the LOM

The scheduled ROM tonnes in this LOM schedule add up to a total of 22.4 Mt and this is equivalent to the reported Proven and Probable reserves statement including Measured and Indicated resources at 22.4 Mt.

16.5.2 Production Schedule Results

The following graphs and figures summarise the production schedule results:

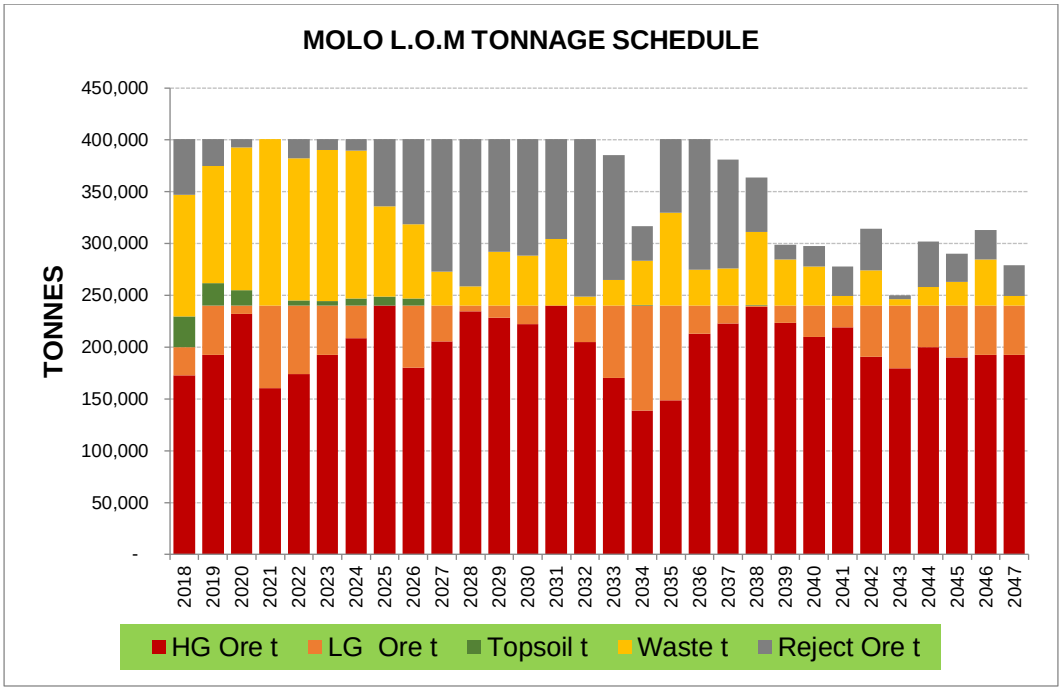


Figure 55: Molo Annual Production Schedule for the LOM

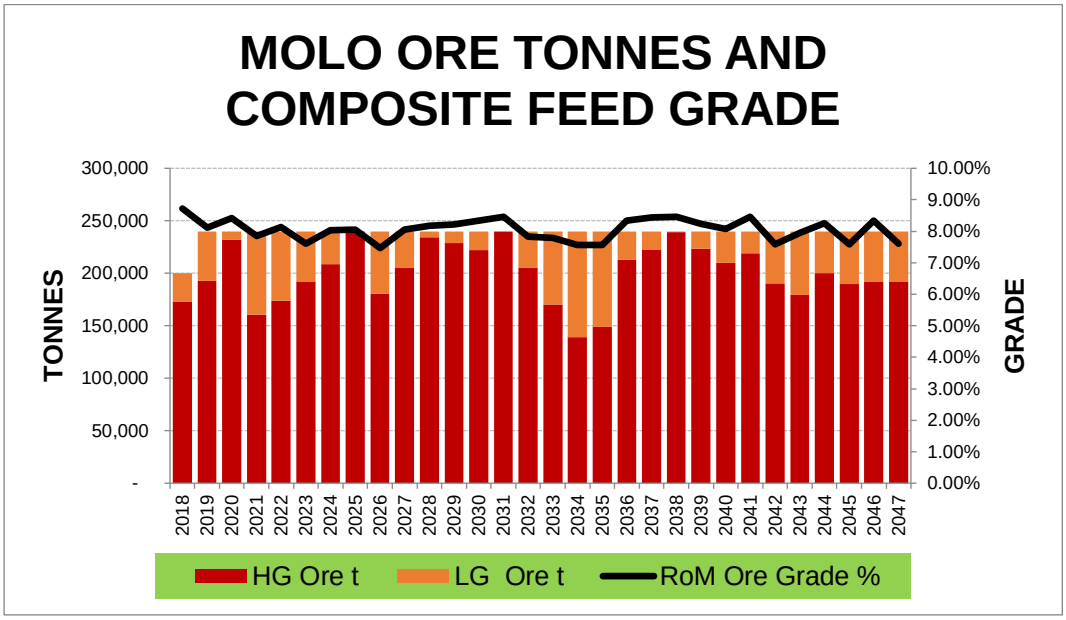


Figure 56: Molo Mill Feed Schedule for the LOM

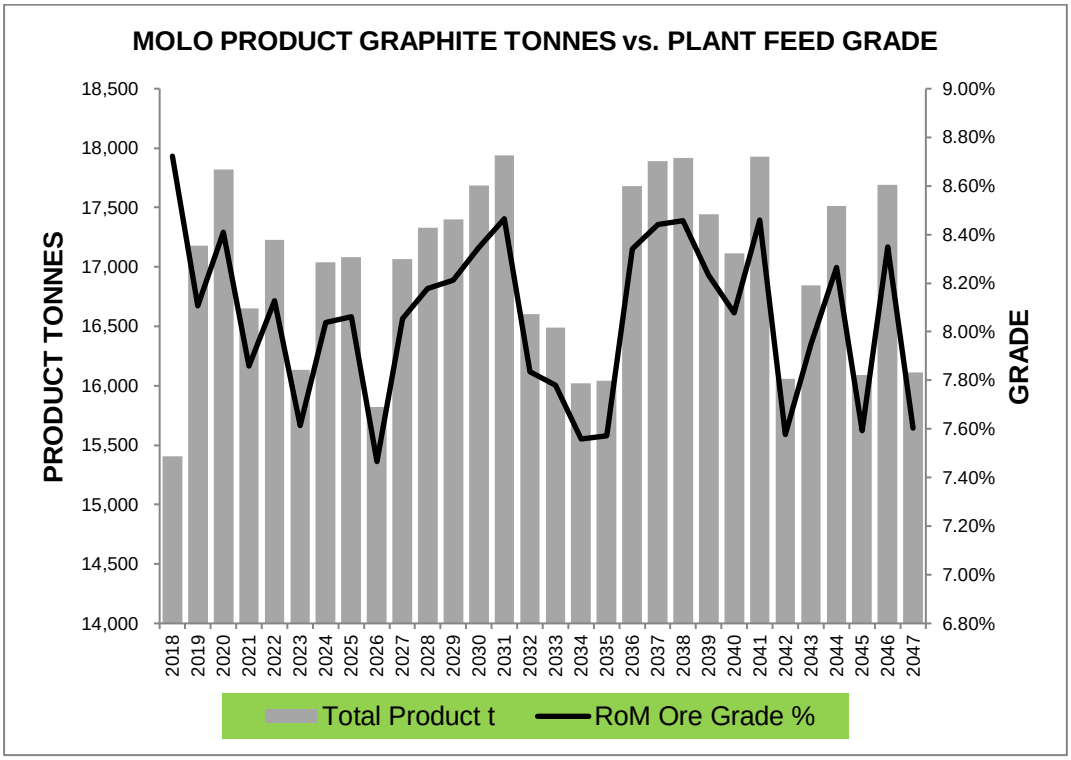


Figure 57: Molo Graphite Content in Feed to Mill

16.6 Mining Operations

16.6.1 Mining Production and Support Equipment

To facilitate the mining and material handling required in the mining cycle the following production and support equipment will be required.

Table 38: Mining Production and Support Equipment

MACHINE / ITEM	REPLC. LIFE (hours)	Equipment Numbers
EXCAVATORS & LOADERS		
SANY SY465H Excavator - 2m^3	15,000	1
LIUGONG Front End Loader 3m^3	15,000	2
HAUL TRUCKS		
SINOTRUK HOWO Tipper Truck 16m^3 (Howa)	15,000	5
SINOTRUK HOWO Water Truck 20000L (Howa)	15,000	1
MOBILE EQUIPMENT		
HOWA Truck Mounted Drill Rig	10,000	1
SANY Motor Grader 200HP	15,000	1
SANY Compactor 10t	15,000	1
SHANTUI SD22W HD Tracked Dozer	15,000	1
SERVICE & SUPPORT EQUIP.		
Buses 60 seater	6 years	2
Maintenance / Diesel Truck	6 years	1
Pump Diesel 50m^3/hr	6 years	2
Supervision Vehicle	6 years	7
Light Plant		
Spares (2 Years) -		
TOTAL		**25**

To maintain the targeted mining production, a mining equipment selection exercise was done on the basis of the estimated annual operating hours, cycle times and the effective equipment capacities. This exercise encompassed the primary mining equipment including all the loaders, haul trucks, drill rigs and support equipment. With the mine operating on a one 10 hour shift per 5 day week, 8 effective hours per shift and 260 days per annum, the production mining equipment selected is capable of moving in excess of 0.4 Mtpa.

One truck mounted drill rig was selected to drill the designed 120 mm blast holes and will be capable of drilling, (5 hours per day 5 day a week) approximately 19,500 metres per annum at a penetration rate of 15 metres per hour.

The initial haulage distances for the tipper trucks are expected to be approximately 1.2 kilometres, from the open pit-pit to the ROM tip, or 2.0 kilometres the pit to stockpile areas.

16.6.2 Labour

The number of Expats to be used in the Molo Project has been limited to as few as possible. This is due to the mining being relatively simple, and the productivity levels required being lower than normal.

This will allow adequate time for operator training and a reasonable production build-up, to be executed.

Table 39: Mining Labour Compliment Fixed Cost per Annum

ENERGIZER STAFF LIST: Mining				M	S	U
Personnel Complement Breakdown	**Responsibility**	**Grade**	**No.**			
Management						
Safety & Training						
Safety Officer	Safety	C4	0.5		0.5	
Training Officer	Training	C4	0.5		0.5	
	Safety & Training		**1**			
Technical Services						
Tech Manager	Technical Services	D3	0			
Surveyor	Technical Services	C4	1		1	
Geologist	Technical Services	D2	1	1		
Mine Planner	Technical Services	C4				
	Technical Services		**2**			
Mining						
Production Foreman	Mining	C4	1		1	
Miner Blaster	Mining	A2	1		1	
Blasting / Grade Assistants	Mining	A2	3			3
Pumping / Cleaning	Mining	A2	2			2
Excavator Operator	Mining	B3	1			1
FEL Operator	Mining	B3	5			5
ADT Operator	Mining	B3	5			5
Drill Operator	Mining	B3	1			1
Dozer Operator	Mining	B3	1			1
Truck W/E Operator	Mining	B3	1			1
Backhoe Operator	Mining	B3	0			0
Comp / Grader Operator	Mining	B3	2			2
Relief Operator	Mining	B3	3			3
		Mining	**26**			
Engineering						
Engineering GES	Engineering	D1	1	1		
Diesel Mechanic	Engineering	C2	2		2	
Auto Electrician	Engineering	C2	1		1	
Boilermaker	Engineering	C1	1		1	
Diesel Assistant	Engineering	A3	3			3
Boiler Assistant	Engineering	A3	1			2

Engineering	**9**			
TOTAL MINING STAFF	**38**	**2**	**8**	**29**

16.6.3 Drill and Blast Design

The drill and blast design parameters are as follows:

The single design is applicable to both ore and waste:

Waste density = 2.65 / Ore Density = 2.36

UCS range = 15 to 32 MPa

The drill and blast products assumed are:

- Anfo
- Emulsion
- Boosters
- Electric Detonators
- Detonating cord
- Basting wire

The drill and blast parameters:

- Hole diameter = 120 mm
- Bench height = 4 m
- Stemming length = 3.0 m
- Burden = 3.6m
- Spacing = 4.0 m
- Sub drill = 0.4 m
- Explosive density = 1.15 g/cm^3
- Powder factor = 0.45
- Charge mass = 26 kg per hole

16.6.4 Mine Infrastructure

Provision has been made at the plant site for a mining office which will accommodate 6 people and parking facilities outside the office. The mine terrace adjacent to the plant site has provision for 2 equipment service workshops, tyre storage and general storage areas, a vehicle

wash bay, brake test ramp and parking for the mine fleet. Additional ablution facilities have been allowed for at the mining infrastructure area.

The change house will be a shared facility which will be utilised by all personnel on the mine, including the plant operators, owners and security personnel.

Unless otherwise specified, all buildings will be prefabricated steel framed buildings installed on a concrete foundation slab. The proposed buildings to be installed on site include:

- 2 x EMV Workshop, wash bay, tyre bay, offices, fuel farm and storage yard
- Mine administration offices
- Change House including dressing room, laundry and boiler room (shared)
- Ablution facilities

16.6.5 Explosives Storage

The contracted explosives supplier shall use an approved system, (Code of Practice) of delivering raw materials and chemicals which should conform to the legal and safety standards on the mine. The raw materials required to obtain the required quality of explosive will be stored separately and blended once required. A demarcated fenced off storage facility shall be used to store the raw materials and chemicals.

An approved mixing machine designed and supplied by the contracted blasting contractor shall be set up on site to produce the daily ANFO requirements. The raw chemicals shall be stored in appropriated shed / silos set up on the mine. All blasting accessories will be stored in approved explosives and accessories magazines. Only daily requirements shall be withdrawn in accordance with the approved procedure.

The mine shall utilise the magazines to be constructed at the mine. The magazines will be capable of storing boosters, detonator cord, safety fuse, packaged explosives and accessories in accordance with Madagascar laws and regulations.

The entire explosives infrastructure shall be located at a safe site that will meet the regulatory and standard requirements.

A maximum consumption of 77 tonnes of explosives per annum is expected.

17 RECOVERY METHODS

This section describes the process design basis adopted in order to define the concentrator process design criteria, develop the mass and water balance, and identify and size the major

equipment required to process the Molo graphite ore deposit in Madagascar in accordance with the mining design basis set out in Section 16 above.

The ore processing circuit consists of three-stage crushing followed by primary milling and classification, a flotation separation and concentrate upgrading circuit, and final graphite product and tailings effluent handling facilities.

The process is designed, based on metallurgical test work conducted, for an expected overall graphite recovery of 88.3% to final concentrate, at the required grade, from an average plant feed head grade of 7.0%. This will produce an estimated average of 15-17 kilotonnes per annum (ktpa) of final concentrate over the LOM, at the design throughput tonnage of 240 ktpa. Negative variations in graphite head grade could be expected to lead to reduced recoveries and/or less graphite product for the same feed tonnage into the plant.

17.1 Process Description

17.1.1 Primary, Secondary and Tertiary Crushing

The crusher circuit is fed with ROM material using a front-end loader (FEL) at a rate of 50 t/h. The ROM material is screened using a ROM static grizzly screen (100-SR-004), located at the top of the primary crusher bin (100-BN-006) to reject rocks larger than 300 mm (oversize material). The oversize material shall be stockpiled near the feed bin and may be manually crushed using rock breakers. The static grizzly undersize material (-300 mm) is further screened using the grizzly feeder (100-FD-008), which is fitted with 70 mm openings; the oversize material (+70 mm) is discharged into the jaw crusher (100-CR-010). The crusher is set to a Closed Side Setting CSS value of 75 mm and is expected to produce 100% -120 mm material. The crusher product and the grizzly undersize are discharged onto the primary crusher discharge conveyor (100-CV-011).

The primary crusher product is fed to the classification screen (100-SR-040) via the classification screen feed conveyor (100-CV-012). The classification screen is fitted with two decks; the top deck is fitted with 35 mm screen panels while the bottom deck is fitted with 16 mm panels. Oversize from the top deck (+35 mm) discharges into the secondary crusher feed bin (100-BN-022) and is fed to the secondary crusher (100-CR-026) via a feed conveyor (100-CV-034) and the secondary crusher feeder (100-FD-024).

Oversize material from the bottom deck (-35+16 mm size fraction) flows by gravity into the tertiary crusher feed bin (100-BN-028) and is fed to the tertiary crusher (100-CR-032) via the tertiary crusher feed conveyor (100-CV-036) and the tertiary crusher feeder (100-FD-030). Products from the secondary and tertiary crushers are combined and recycled back to the classification screen. The bottom deck screen undersize (-16 mm size fraction) from the classification screen is fed to the mill feed bin (200-BN-058) via the mill feed conveyor (100-CV-044).

17.1.2 Primary Milling and Flash Flotation

The crushed material from primary mill feed bin is fed to the primary mill scalping screen (200-SR-070) at the flowrate of 30 t/h via the mill feed bin feeder (200-FD-060) and the primary mill feed conveyor (200-CV-066). The scalping screen is fitted with 2 mm aperture panels. Oversize from the screen (+2 mm) flows into the primary ball mill (200-ML-078) by gravity. Spillage material in the primary milling circuit is pumped to the scalping screen through the mill area spillage pump (200-PP-094).

The mill is expected to produce a product with a grind of 80% passing 500 microns; this product is discharged into the primary ball mill discharge sump (200-TK-082). Slurry from the mill discharge sump is pumped (via the primary mill discharge pump 200-PP-084/086) to the primary mill screen (200-SR-072) which is fitted with a 600 µm aperture panels and discharges the oversize (+600 µm) back into the primary mill.

The -2 mm material from the scalping screen (200-SR-070) flows by gravity into the flash flotation cell; the flash flotation cell is installed to recover graphite flakes liberated at coarse particle sizes. Flash flotation produces a concentrate at a mass yield of 3%. Flash flotation tailings are pumped into the primary mill discharge sump via the flash flotation tails pump (200-PP-090/092).

17.1.3 Rougher Flotation

The rougher flotation feed slurry (-600 µm), which consists of the combination of flash flotation tailings and the primary mill product, flows into the rougher flotation bank (300-FC-110/112/114/116/118) by gravity at the solids flowrate of 29 t/h. Frother and collector reagents are added into rougher cell no.1 (300-FC-110) and rougher cell no.3 (300-FC-114). Rougher concentrate mass pull is expected to be 8%. The flash flotation concentrate and primary rougher concentrate are combined in the total concentrate sump (300-TK-134) and pumped to the primary concentrate cleaning circuit using the pumps (300-PP-136/137).

The tailings from the rougher flotation circuit are discharged into the combined tailings sump (300-TK-138); the combined tailings stream is then pumped to the final tailings thickener (400-TH-310) using the combined tailings pump (300-PP-140/142). Any spillage from the rougher flotation section is pumped to the primary ball mill scalping screen using the rougher flotation spillage pump (300-PP-144).

17.1.4 Primary Concentrate Cleaning Circuit

The combined concentrate is screened on the primary cleaner dewatering screen (300-SR-146); the screen is fitted with 74 µm panels. The oversize from the dewatering screen is discharged into the primary polishing mill (300-ML-148). The mill discharge and the dewatering screen undersize are discharged into the primary polishing mill discharge sump (300-TK-150). The primary mill discharge sump slurry is pumped to the primary cleaner column cell (300-FC-154) using the primary polishing mill discharge sump pump (300-PP-152). The column flotation cell tailings are pumped to the primary cleaner flotation bank (300-FC-164/166/168); the tailings stream from this bank is discharged into the primary cleaner scavenging flotation cell bank, which consists of three flotation cells (300-FC-170/172/174). The primary cleaner flotation concentrate is recirculated back to the primary cleaner column cell. The cleaner scavenger concentrate is recycled back to the polishing mill feed classification screen, while the tails are pumped to the combined tails sump in the rougher flotation area (Area no. 300) via the final cleaner tails sump (300-TK-184) and the final cleaner tails pump (300-PP-186).

The concentrate from the primary cleaner column cell is screened on the primary column flotation cell concentrate screen (300-SR-190), which is fitted with 212 µm screen panels. The oversize from this screen flows by gravity into the fine flake cleaning circuit while the undersize is pumped to this circuit using the primary column cell concentrate undersize pump (300-PP-196).

17.1.5 Fine-Flake Concentrate Cleaning Circuit

The undersize from the primary column flotation cell concentrate (fine flakes stream) is dewatered at 75 µm on the fine flake dewatering screen (300-SR-267). Oversize from the dewatering screen flows into the fine flake polishing mill (300-ML-268); the discharge from the mill and the dewatering screen undersize are discharged into the fine flake polishing mill discharge sump (300-TK-270). The sump slurry is pumped to the fine flake column cell (300-FC-274) using the fine flake polishing mill discharge pump (300-PP-272) to produce a concentrate at a mass pull of about 7%. The fine flake column concentrate is combined with the primary flotation column screen oversize stream from the primary cleaning circuit; this combined stream is pumped to the attrition cleaning circuit (Area no. 360) using the combined cleaner concentrate pump (300-PP-280).

The fine flake column flotation tailings are subjected to cleaning (300-FC-286/288/290) and scavenging (300-FC-292/294) flotation. Concentrate from the cleaner cells is recycled back to the fine flake column cell by gravity while the scavenger concentrate is pumped (300-PP-300) back to the fine flake dewatering screen. The tailings from the scavenger cells flow by gravity back into the final cleaner tails sump in the primary concentrate cleaning circuit (Area no. 310).

17.1.6 Final Concentrate Attritioning and Cleaning Circuit

The cleaner concentrate stream is subjected to thickening in the attrition concentrate thickener (300-TH-001); overflow from the thickener is discharged into the process and storm water tank in the water services area (Area no. 600). The underflow, which has a density of 1.19 RD, is pumped to the attrition mill (300-ML-005). Product from the attrition mill flows into the attrition mill discharge sump (300-TK-010) and this is pumped to the attrition cleaner column flotation cell (300-FC-020) using the attrition mill discharge pump (300-PP-015). Tailings from the attrition column flotation cell are pumped (300-PP-035) to the attrition cleaner (300-FC-040/045) and scavenging (300-FC-050) flotation cells. The concentrate from the cleaners is recirculated by gravity back to the attrition column flotation cell while the scavenger concentrate is pumped (300-PP-060) back to the attrition concentrate thickener. The tailings from the scavenger cells are recycled by gravity back to the final cleaner tails sump in the primary concentrate cleaning circuit (Area no. 310).

17.1.7 Concentrate Handling

The final concentrate is thickened in the final concentrate thickener (500-TH-342). The thickener overflow is discharged into the process water dam in Area no. 600, whereas the underflow is filtered in the final concentrate belt filter (500-FL-358), which is expected to produce a filter cake with less than 20% moisture. The filtrate is pumped back to the final concentrate while the filter cake is discharged onto the final concentrate filter cake conveyor and fed to the final concentrate drying and bagging circuit (Area no. 570).

17.1.8 Concentrate Screening and Bagging

The filter cake concentrate from the belt filter is fed into a diesel-fired dryer (500-DR-376) via a screw conveyor (500-CV-374). The filter cake is dried to a moisture content of lower than 1% (w/w). The dry concentrate is then screened into four size fractions: +48, -48+80, -80+100 and -100 mesh. Each of the size fractions is bagged separately as final product.

17.1.9 Final Tailings Handling and Disposal

Tailings stream from the combined tailings sump (300-TK-138) in the rougher flotation circuit (Area no. 300) is thickened in the final tailings thickener (400-TH-310). The thickener underflow from the thickener, which has a slurry density of 1.51 RD, is pumped to the final tailings filtration circuit and disposal circuit through the final tails thickener underflow pump (400-PP-312/314)

and the final tails pump (400-PP-320/322). The thickener overflow stream flows into the process and storm water tank in the water services area.

This part of the circuit is operated in a semi-batch manner and is expected to produce a filter cake with 15% moisture. The final tailings thickener underflow material from the final filtration feed tank (400-TK-040) is pumped to the final tails filter; the filtrate is discharged into the final tails filtrate sump (400-TK-056) and recycled to the final tails thickener while the filter cake is stockpiled and discarded by an FEL.

17.1.10 Water Services

Thickener overflow streams from the final tails thickener (400-TH-310), final concentrate thickener (500-TH-342) and attritioning concentrate thickener (300-TH-001) are discharged into the plant process tank no.1 (400-TK-470). Process water tank no.1 is interconnected with process water tank no.2 (600-TK-472). Make-up raw water is pumped into process water tank no.1 from a well field and from the storm/pollution control dams (600-TK-478/480/482). Process water is pumped from process water tank no.2 (600-TK-472) using the plant raw water pump (600-PP-425/427) and distributed to the following circuits via process water pump no.1 (600-PP-474) or no.2 (600-PP-476):

- Attritioning
- Fine flake cleaning
- Primary milling
- Rougher flotation
- Primary concentrate cleaning
- Secondary cleaning

A portion of the raw water from the well field is screened using a mesh screen (600-SR-428) and distributed to the following areas:

- Flocculent make-up plant
- Potable water plant
- Gland water service
- Fire water

17.1.11 Air Services

A blower package (600-HB-484) provides low pressure air into the various flotation cells in the plant with the exception of the column cells. Column cells are supplied with air from the instrument air compressor (600-HA-488) via the receiver (600-TK-498).

Instrument air is supplied from the instrument air compressor (600-HA-488), dried using the desiccant air drier (600-DR-492) and fed to the various actuated valves via the receiver (600-TK-496).

Filtration air is supplied by the filtration air compressor (600-HA-491) and the air receiver (600-TK-499).

17.1.12 Reagents

Collector

The collector (diesel) is stored in an isotainer (500-TK-500). This is dosed via an outlet manifold and 13 peristatic reagent dosing pumps.

Frother

The frother is stored in an isotainer (500-TK-524). This is dosed via an outlet manifold and 13 peristatic reagent dosing pumps.

Flocculent

Flocculent is delivered in 25 kg bags and off-loaded into the plant reagent receiving area. It is then transferred to the flocculent make-up area using a forklift. The flocculent make-up plant is a vendor package.

The make-up plant is divided into two: one half of the plant feeds the final concentrate and the attrition thickener while the other feeds the final tailings thickener.

Flocculent powder is fed into the hopper (800-TK-574); this is fed to the mixing tank (800-TK-580) via a screw feeder (800-FD-576). Clean water is introduced into the make-up tank, where the flocculent is prepared to the correct concentration. Flocculent mixed to the correct concentration overflows into the dosing tank (800-TK-584), from which it is dosed to the final concentrate thickener and attrition thickener via the dosing pumps (800-PP-586/587).

Flocculent feeding the final tails thickener is prepared in a manner similar to the flocculent fed to the final concentrate and attrition thickener. It is mixed in the mixing tank (800-TK-558), fed to the mixing tank (800-TK-564) via the screw feeder (800-FD-560) and dosed to the final tailings thickener via the dosing tank (800-TK-568) and dosing pump (800-PP-570).

Collector

Coagulant powder is fed into the hopper (800-TK-594); this is fed to the mixing tank (800-TK-600) via a screw feeder (800-FD-596). Clean water is introduced into the make-up tank, where the coagulant is prepared to the correct concentration. Coagulant mixed to the correct concentration overflows into the dosing tank (800-TK-604), from which it is dosed to the three thickeners via the dosing pumps (800-PP-606/612/615).

17.2 Tailings Storage Facility (TSF)

Due to the substantially reduced tonnages for the project as envisaged, tailings will be dried and co-disposed with the waste rock generated as part of the open cast mining. Despite this co-disposal approach, a detailed design has been completed, complete with environmental and social impact assessment and closure to allow for the upgrade to a more conventional, cyclone facility, should the throughput be increased during the life of the mine. This approach has been pursued to ensure that sufficient flexibility is built into the project development strategy to accommodate the anticipated increase in market demand.

17.3 Water

17.3.1 Baseline Environment

The climate of Madagascar is highly varied, largely due to its geographical position in the Indian Ocean, variable topography and associated microclimates. The climate at Molo Graphite Project site, based on the Köppen-Geiger climate classification system, comprises elements of hot semi-arid and tropical savannah climates.

Rainfall in areas around the site varies between 750 and 850 mm per annum, while site rainfall is simulated at 799 mm per annum. Seasons are nominally divided into a wet and dry season, with relatively small variations in temperature, but a strongly defined rainy season between November and March. The proposed port side at Ford Dauphin has a more temperate climate rainfall of 1500 mm per annum is distributed more evenly across the year. Both sites should expect average annual Symons-Pan evaporation of between 1380 and 1700 mm per annum.

While extreme weather events across Madagascar are dominated by the impacts of Cyclones and Tropical Storms, both sites seem to be fairly isolated and protected from these weather systems. Extreme 1 day rainfall that could be expected, on average, once in 50 years is estimated at 171 mm for the Molo site and 283 mm for Fort Dauphin.

The Molo site is located on the divide of three major river basins: Onilahy River Basin (32 361 km² catchment), Linta River Basin (6 177 km² catchment) and Menarandra River Basin (8 681 km² catchment). The calculated mean annual runoff is about 150 mm per annum or roughly 18.8% of the mean annual precipitation (MAP).

Around the Molo Graphite Project site, all water courses drain either to the north or south, away from the proposed mine infrastructure with most of the proposed mine infrastructure located in the locally southward draining Linta River Basin. Watercourses are dry during the dry season and only flow during the rainy season.

The surface water is generally sodium, calcium, manganese – bicarbonate (chloride) dominant. Stream water quality in general complies with Madagascar and WHO drinking water criteria, except for elevated turbidity.

Local surface water sources are largely underdeveloped and no significant local water demands were identified during water use surveys. There are no known major industrial developments, irrigation schemes, impoundments and/or major abstraction works in the river catchments surrounding the proposed Molo Graphite Project site. The major surface water users are local communities, who use water for drinking, livestock, washing and small scale subsistence agricultural with crops such as rice, cassava, tomatoes and bananas.

The Molo site falls within the Ampanihy shear zone with a regional north-northeast – south-southwestern trend. The local geology consists mainly of crystalline metamorphic rock such as quartzofeldspathic gneiss. No significant faulting or dyke instrusions have been identified with the site. The main aquifer zone is hosted within the weathered (0 to 30 m deep) and lower fractures rock, with most groundwater intersections occurring less than 50 m below surface. The gneiss at the proposed mine site has low to medium aquifer potential, with the marble layers to the west having a highter aquifer potential. Hydrogeological boreholes drilled in the proposed mining site have yields mostly less than 1 l/s.

A wet and dry season hydro census investigation was completed in a 5 km radius of the proposed site, and also around the nearby town of Fotadrevo. Eighteen (18) groundwater features were identified consisting of shallow boreholes, springs and hand dug wells within the study area. Groundwater use in the area is relatively low (15 to 20 m^3/d), mainly for domestic and stock watering purposes. The groundwater depth measurement across the area ranged between 2 and 17.6 metres below ground level.

Groundwater is sodium-bicarbonate and calcium (magnesium)-bicarbonate dominant waters were present at the site, with subordinate sodium-sulphate (chloride) dominant waters. The total dissolved solids contents (TDS) of the groundwater is typically 150 to 550 mg/l and pH levels typically range from 7 to 8.5. Groundwater quality is mostly suitable for human consumption.

17.3.2 Hydro-geochemical assessment of waste material

A hydro-geochemical assessment was undertaken, including laboratory test work and modelling, on tailings material and representative waste rock. The results indicate that most sulphur associated with ore, tailings and waste rock consists of secondary sulphate minerals such as jarosite. The reaction rates associated with the secondary sulphate minerals are generally slow, resulting in relatively low sulphate loads in rainfall run-off and short-term seepage associated with the mine waste facilities. However higher sulphate loads could be expected in the long-term (up to 3 200 mg/l for tailings

and 2 700 mg/l for waste rock). The pH of water emanating from waste facilities will be 6.5 to 8 over the short term, decreasing up to 5.5 in the long-term. Metal concentrations are low.

The result from the geochemical test work and modelling was incorporated into the salt balance and groundwater numerical contaminant transport modelling in order to quantify and mitigate potential impacts. Short-term runoff quality is in general acceptable for discharge based on Madagascar and international criteria.

17.3.3 Raw Water Resources

The preferred raw water make-up supply for proposed 240 ktpa process plant, potable water and dust suppression will be the wellfield proposed in a 5 km radius around the Molo site. The safe yield was calculated for the existing hydrogeological boreholes at 15.3 l/w (55 m^3/hr or 1 322 m^3/d) which is more than the maximum raw water requirements of -23 m^3/hr or 551 m^3/d. The sustainable yield for the 5 km radius wellfield, based on a 20 mm/a recharge rate and allowing for the ecological water requirements, is 101 m^3/hr or 2 429 m^3/d. The sustainable yield for long-term drought conditions is 60 m^3/hr or 1 429 m^3/d and the wellfield will be operated based on this conservative rate.

Two existing boreholes MMB12 and MMB13 have been identified for supplying the raw water to the mine. The boreholes have a combined safe yield of 42.8 m^3/hr. The calculated daily borehole abstraction is impacted on by the dust suppression requirement (seasonal variation and over life of mine) and will vary between 222 and 551 m^3/d. It was concluded that the groundwater resources of the area can with a high degree of confidence supplying the raw water make-up for the proposed mine.

17.3.4 Conceptual Storm Water Management Plan

Mine storm water run-off areas were defined, and storm water management measured were proposed that would mitigate potential surface water risks and ensure compliance with relevant legislation and guidelines in terms of environmental and work safety aspects. Flood peaks were calculated that would facilitate the final design of levees and drainage channels required to contain and control the flow of both “clean” and “dirty” water on the site.

Three (3) lined PCD’s were identified and sized, i.e. pit/reject PCD, plant PCD and co-disposal PCD. Silt control measures were allowed for at all PCD’s.

17.3.5 Water and Salt Balances

The water balance serves to investigate the water availability for the Molo Graphite Project based on the given water demands and available surface or groundwater resources, optimise a responsible water management plan, verify the PCD sizes (and sizing of other infrastructure) and to simulate water quality parameters in a mass transport balance model (Salt Balance).

The raking of water sources to be used in the ore beneficiation process, in order of priority, are 1) Sewage effluent return, 2) PCD water from storm water/seepage from plant, co-disposal, reject dump, ore stockpiles and open pit water, 3) raw water sources (Wellfiled – Module 1).

The operational philosophy of mining operations will be to operate the process water system as a closed system which would not discharge into the environment. PCD water will, as far as possible, be used as a make-up water for dust suppression. The plant PCD will provide buffer storage capacity for this. Discharge from the PCD's will, however, occur and will need to be carefully controlled and monitored. Results from the salt balance, based on information from geochemical tests and modelling, suggests that PCD water under discharge conditions will comply with Madagascar and international criteria.

Both static and dynamic water balance calculations were undertaken fro the Base Case plant (dry tails).

17.3.5.1 Process water

The total process water requirements for the Base Case is 7.58 m^3/hr (clean water) and 0.67 m^3/hr for process top-up.

17.3.5.2 Open pit water

Groundwater numerical modelling suggested a groundwater inflow rate of 8 to 590 m^3/d for different mining stages over the operational life. The average groundwater and storm water volume likely to be reporting to the open pit sump over the life-of-mine is about 900 m^3/d. Allowance was made for a sump pump capacity up to 3 500 m^3/d.

17.3.6 Water Impact Assessment

The potential impact that mining activities are likely to have on surface and groundwater resources in the surrounding environment was analysed. These potential impacts were quantified and a significance rating was undertaken.

Potential impacts relate to mine dewatering, wellfiled abstraction, dirty water runoff, runoff reduction, contaminant seepage from the co-disposal facility and reject dump. None of the identified potential impacts posed a high or serious risk to the downstream environment, and the majority of risks were mitigated by the Water Management Plan, which includes appropriate storm water management measures, dry tailings disposal and post closure residual mine waste capping layers.

18 PROJECT INFRASTRUCTURE

18.1 Mining Infrastructure

18.1.1 Mining Office

The mining office is located on the shared plant and mine terrace and is a pre-fabricated modular structure. The building will provide office space for the mining personnel including the mine manager, technical services manager, geology personnel, survey personnel, maintenance engineers and mining support staff.

The mine office will be constructed using modular pre-fabricated materials which will be shipped to site in a flat-pack configuration and erected and commissioned on site.

18.1.2 Earth Moving Vehicle (EMV) Workshop

The EMV Workshop is the main workshop which will serve the mining fleet (mainly the ADT's) and the LDV fleet on site. It will cater for all maintenance and re-builds of the plant and LDV vehicles and will also be able to serve the haul truck fleet if required.

Figure 58 below is an illustrative layout view of the proposed EMV workshop to be installed as part of the permanent works on site.



Figure 58: Typical illustrative layout of EMV Workshop

The workshop is sized to accommodate two (2) Mine haul trucks at any time. No provision is included for fire hose reels or hydrants. 9 kg hand held dry chemical fire extinguishers will be provided as part of the fire control system.

18.1.3 EMV Wash Bay

The EMV wash bay will be provided for the maintenance and cleaning of vehicles and plant and will service the mining fleet and the LDV fleet. One wash bay has been provided for and has been sized to accommodate the largest vehicle in the mining fleet which would be the mine haul trucks and bulldozers.

18.1.4 ANFO Storage

The ammonium nitrate / fuel oil (ANFO) storage building is located to the north of the mine and plant site, a minimum of 500m away from all proposed and existing infrastructure, villages, product transport route, access road and the mining operation (pit). Access to the ANFO storage building is via an access road off the existing road which runs in an east-west direction past the proposed mine site and is located on an engineered terrace.

Access to the ANFO storage building will be controlled by the blasting contractor who is appointed to undertake the blasting on site and will also be managed in conjunction with the local police services (Gendarmerie Nationale) in the area.

18.1.5 Explosives Magazine

The explosives magazine consists of a totally enclosed reinforced concrete structure on an engineered terrace.

Access to the explosives magazine will be controlled by the blasting contractor who is appointed to undertake the blasting on site and will also be managed in conjunction with the local police services (Gendarmerie Nationale) in the area.

18.1.6 Explosives Accessories Magazine

The explosives accessories magazine consists of a totally enclosed reinforced concrete structure on an engineered terrace.

Access to the explosives accessories magazine will be controlled by the blasting contractor who is appointed to undertake the blasting on site and will also be managed in conjunction with the local police services (Gendarmerie Nationale) in the area.

18.1.7 Access Road to Explosives Magazine and ANPHO Terrace

The access road to the ANFO terrace, explosives accessories magazine and the explosives magazine will be installed as part of the construction works on site. The road will be 6m wide and will comprise an engineered fill layer of no less than 300 mm, installed in 150 mm thick layers.

18.1.8 Main Haul Roads

The main haul roads between the plant and mine terrace and between the pit and the ROM tip ramp will be installed as part of the construction works on site. The main haul roads have been designed to accommodate 40T mine haul trucks.

The haul roads are a minimum of 15m wide and accommodate 2 way traffic with no requirement for a berm in the middle of the haul road. A berm is included on the outer edge of the haul road, min 1.5m high.

18.1.9 Run of Mine (ROM) Tip Ramp

The ROM tip ramp has been included near the pit, south east of the plant and mine terrace, to reduce the haul distance for the mining fleet.

The crushing circuit proposal incorporates a skid-mounted primary crushing plant, secondary and tertiary crushing plant and a screening plant. The ROM tip ramp has a height of 3.5m.

The mining fleet will dump material on a stockpile adjacent to the primary crushing plant and the front-end loader will feed the crusher.

The front-end loader will be included in the plant resource as it will need to be operated as part of the plant and not as part of the mining fleet. (It will operate as per the plant operations, 24/7, not as per the mining fleet which operates one 10 hour shift, 5 days a week).

18.2 Plant Infrastructure

The infrastructure to support the processing plant operation was developed by DRA and positioned to optimise the operation of the plant.

The Plant infrastructure includes for:

- Plant Office
- General Engineering Services (GES) Workshop
- Laboratory
- Process Water Dam
- Raw Water Dam
- Ablution Facilities
- Reagent Stores

18.2.1 Plant Office

The plant office has been designed to accommodate 6 single offices, a reception area with one desk for one receptionist, an open plan area for 20 people (grouped in pods of 4 people each), a boardroom which will accommodate 20 people with audio / visual equipment and bathroom facilities to accommodate up to 30 people (10 female and 20 male). The plant office will also include for a small kitchenette to serve the members of staff and visitors to the mine).

18.3 General Engineering Services (GES) Workshop

The General Engineering Workshop (GES) will serve the plant area on site. It will be located on the plant terrace on a concrete slab which will be installed by the civils and earthworks contractor as part of the overall civil and earthworks package. The GES workshop floor area is approximately 270 m².

The GES workshop area will comprise a concrete slab surrounded on 3 sides by converted shipping container units which will be used as offices, ablution facilities and storage areas. There will be four (4) 6m container offices and eight (8) 12m containers which will be used for storage.

18.4 Laboratory

The laboratory is a bought-out containerized solution which will be located on the plant terrace on concrete slabs which will be installed by the civils and earthworks contractor as part of the overall civil and earthworks package.

The laboratory setup will consist of four 12m containers that have been fitted out to accommodate the laboratory equipment and personnel. The laboratory will be serviced by 13 personnel in total (2 expat and 11 local personnel).

18.5 Raw Water Supply

A dynamic water balance model was used to quantify water demands throughout the proposed life of mine. The re-use of dirty water in mining processes was maximised to reduce raw water demands. Raw water requirements and potential variations in water demands were calculated. Maximum demands for raw water make-up are on average 561 cubic metres per day (m^3/day) in the beginning of the life of mine for the processing plant. As the life of mine progresses maximum raw water make-up will decrease to 222 cubic meters per day on average (m^3/day). The raw water source for the plant and potable water will be groundwater, abstracted from a well field within a 5 km radius of the proposed processing plant. Existing boreholes MMB12 and MMB13 have been verified as feasible boreholes to supply the raw water make-up.

The area covered by the 5 km radius well field is shown Figure 39 indicating existing production boreholes MMB12 and MMB13. The existing test production boreholes drilled in the area identified the marble layers to the west of the site as the most productive aquifer. The existing production boreholes have a combined safe yield of 1,322m^3 per day. The potential sustainable yield of the 5 km radius well field, based on groundwater rainfall replenishment rates and

ecological water requirements, is about 2,430 m^3 per day and 1,430 m^3 per day taking extreme long-term drought conditions into account. The groundwater sustainable yield is substantially higher than the foreseen raw water make-up requirement.

An environmental impact assessment was undertaken for the well field with no major impacts foreseen based on the formulated Water Management Plan.

18.6 Process Plant, Storm Water and Raw Water Supply Dams

A Storm Water Management Plan (SWMP) has been developed in accordance to IFC Environmental Health and Safety Guidelines for Mining (IFC, 2007) to mitigate potential water contamination and to ensure a safe working environment. The SWMP was set up to minimize and manage the loss of the water resource. The dirty water footprint is minimized and the use of dirty water in the ore beneficiation process is optimized.

The proposed SWMP measures include the implementation of three Pollution Control Dams at the processing plant, Co-Disposal Facility and Material Reject Dump and a set of drains and berms. Additional measures proposed include sediment traps where drains flow into the Pollution Control Dams to reduce the amount of silt that deposits in these dams.

The operational philosophy of mining operations will be to operate the process water system as a closed system which would not discharge into the environment. PCD water will, as far as possible, be used as a make-up water for dust suppression. The plant PCD will provide buffer storage capacity for this. Discharge from the PCDs will, however, occur and will need to be carefully controlled and monitored. Results from the salt balance, based on information from geochemical tests and modelling, suggests that PCD water under discharge conditions will comply with Madagascar and international criteria

The ranking of water sources to be used in the ore beneficiation process, in order of priority, are 1) Sewage effluent return, 2) PCD water from storm water/seepage from plant, co-disposal, reject dump, ore stockpiles and open pit water), 3) raw water sources (Wellfield – Module 1). A raw water tank will receive water from the well field system.

Both the process and storm water dam at the plant will be lined with a 2 mm HDPE liner to prevent water losses into the underlying ground and the liner will be installed on an A4 bidim geotextile protection layer.

18.6.1 Ablution Facilities

An ablution facility is provided for at the plant to accommodate the work force at the plant.

18.6.2 Reagent Stores

The reagents building is located adjacent to the plant on the plant and mine complex terrace. The building will serve as storage for the reagents required for the process plant. The building is open on all sides and will store barrels of flocculent and 220 litre drums of reagent.

18.7 Shared Infrastructure and Services

The shared infrastructure and services to support the processing plant operation and the mining operation was developed by Erustrat and positioned to optimise the overall mining and processing operation.

The shared infrastructure and services includes:

- Access Roads
- Terraces and Bulk Earthworks
- Gate House and Turnstile Access Control
- Training Centre
- Refuelling Station
- Waste Water Treatment plant
- Potable Water Treatment Plant
- Storm Water Drainage
- Storm Water Dams
- Consumer Sub-station
- MCC’s
- Fencing
- Fire Water System, Reticulation and Storage
- Potable Water Reticulation
- Potable Water Storage Tank
- Waste Water Reticulation
- Raw Water Supply
- Welding Workshop
- Strategic Spares Storage

- Tyre Storage Yard
- General Storage Yard
- Power Generation Facility
- Fuel Storage Facility

18.7.1 Access Roads

The access roads to be installed include the road to the plant and mine site, the road to the explosives magazine, the road to the ANPHO terrace and the accessories magazine.

The layer works are to be installed in 150 mm thick layers and the road will be 6m wide with 0.5m wide shoulders (7m width in total). The access roads are designed with a 1:50 fall across the road from the centreline to the edge of the shoulder.

No provision is included for access roads on the terraces. Vehicle will drive on the finished terrace surface, there is no provision for surfacing of areas demarcated for roads on the terraces.

Culvert crossings have been allowed for as required along the new access roads to allow for overland water flow to migrate under the roads and continue on with the natural drainage courses.

18.7.2 Terraces and Bulk Earthworks

The main terraces for the works include:

- Plant and Mine Construction Camp
- Permanent Camp
- Surge Bin
- Crushing Circuit

Terraces will be installed as part of the works and will be installed at a minimum of 300 mm above natural ground level in order to reduce the risk of flooding in the rainy season.

The total volume of cut and fill for the project are detailed in Table 40 below:

Table 40: Excavation, Fill Material and Crushing / Processing Summary

Description	Fill Volume (m^3)	Excavation Volume (m^3)
Excavation for Pipes etc		55 011
Hard Rock Excavation for Pipes etc		33 070
Excavation for Civils		8 257
Bulk Excavation		80 208
Hard Rock Excavation for Civils		4 494
Hard Rock Excavation		545 153
Backfill for Pipes etc	12 001	
Backfill (G7)	416 641	
Bulk Excavation at TSF	450 623	
Crushing/Processing	383 030	
Backfill at TSF (Red borrow material)	151 250	
Trench backfill with Aggregate at TSF	13 600	

18.7.3 Gate House and Turnstile Access Control

The gate house and turnstile access to the site will be provided by two 12m containers that have been fitted out as an office and search facilities and a turnstile access unit.

18.7.4 Training Centre

The training centre has been designed to accommodate 6 single offices, a boardroom to seat 50 people and bathroom facilities to accommodate 50 people.

18.7.5 Re-fuelling Station

The re-fuelling station will be centralised on site and will be utilised by the plant and mine LDV fleet, the haul truck fleet and the mining haul truck fleet. The refuelling station is located on the plant terrace central to the site. The re-fuelling station will have a direct feed from the diesel

storage facility on site and no provision has been included for any storage of diesel at the re-fuelling station.

18.7.6 Waste Water Treatment Plant

Provision has been included for two waste water treatment plants on site, one at the plant and mine complex and one at the permanent accommodation camp.

The discharge requirements for the waste water treatment plants to be installed on site are in line with the requirements as set out by the Department of Water Affair (DWA) General Limits, South Africa.

The unit for installation at the permanent camp will initially be utilised for the construction camp operation during construction and will be relocated to the permanent accommodation camp location prior to commissioning of the plant.

The unit has been designed to accommodate the 800 people (120 m³/day) in the construction camp and has been configured in a modular arrangement where one of the two modules can be decommissioned following the construction phase and the plant will be downsized to accommodate the 340 permanent personnel (54 m³/day) at the mine and plant. For the camp, it has been assumed that the water consumption will be 150 litres / person / day for the construction and the operational phase of the project.

The unit for installation at the plant and mine complex will be installed and commissioned as part of the construction works phase of the project. The unit will serve all the temporary ablution facilities on site during the construction phase of the works as there is no waste water treatment facility in the surrounding region of the site where waste water can be discharged.

The unit has been designed to accommodate the 800 people (56 m³/day) in the construction phase and 340 permanent personnel (54 m³/day) during the operation phase of the project. It has been assumed that the water consumption will be 70 litres / person / day for the construction and 150 litres / person / day during the operational phase of the project.

Drying beds have been included for the discharge and drying of the sludge from the units on an annual basis. These concrete drying beds are designed and installed as part of the main earthworks and civil package.

18.7.7 Potable Water Treatment Plant

Provision has been included for two potable water treatment plants on site, one at the plant and mine complex and one at the permanent accommodation camp.

The potable water treatment plants have been designed to accommodate a varying capacity throughput with the use of VSD’s on the pumps during the operational phase of the project.

The two plants have been identically sized for the plant and the mine complex and the accommodation camp. The plant to be installed at the permanent camp will initially be installed at the construction camp and will later be relocated to the permanent camp location.

The plants are designed to provide 7.5 m³/h to support the 800 people in the construction camp and at the plant and mine complex. It has been assumed that each individual on site will require 225 litres / day.

Raw water will be pumped to the two treatment plants from the raw water dam located adjacent to the plant terrace. Treated water will be stored in the potable water storage tanks which will be located on the plant and mine complex and the permanent accommodation camp terraces. The water storage tanks each have a capacity of 516 m³.

18.7.8 Storm Water Drainage

Storm water run-off will be diverted around the plant - mine terrace, the construction camp terrace, the open pit mine, ore stockpile areas, material reject dump and the co-disposal facility by a combination of unlined channels and berms which daylight downstream of the project infrastructure. Material excavated from the unlined channels will be re-used to construct the berms adjacent to the channels.

Storm water falling on the plant and mine terrace, open pit, stockpile areas, material reject dump and the co-disposal facility is considered dirty water and as such, is collected in the storm water dams or Pollution Control Dams (PCDs) located on site and discharge to the environment is limited. All the PCDs on site have been sized to accommodate a minimum of a 24 hour, 1:10 year return period storm event. Discharge from the PCDs will, however, occur and will need to be carefully controlled and monitored. Results from a daily salt balance model, based on information from geochemical tests and modelling, suggests that PCD water under discharge conditions will comply with Madagascar and international quality criteria.

18.7.9 Storm Water Dams

The storm water dam or PCD located adjacent to the processing plant has been sized to accommodate all the storm water run-off from the plant and ore stockpile area. The dam has been sized to accommodate the 24 hour, 1:20 year return period storm event and will accommodate 8,000 m³ of storm water and return water from other storm water dams (if required).

The storm water dam or PCD located adjacent to the material reject dump and open pit, has been sized to accommodate all the storm water run-off from the material reject dump area and water from the pit dewatering operation. This dam will accommodate 5,000 m³ of storm water and pit water. This dam was designed to discharge on a regular basis taking the predictive

water quality analysis results into account, complying with Madagascar and international quality criteria.

The storm water dam located adjacent to the co-disposal facility, has been sized to accommodate all the storm water run-off from the co-disposal facility. The dam has been sized to accommodate the 24 hour, 1:10 year return period storm event and will accommodate 30,000 m³ of storm water.

18.7.10 Consumer/Incomer Substation

The consumer sub-station will be a weatherproof pre-fabricated modular unit and installed on concrete bases and plinths with steel access stairways and landings. Access will be via the ends of the substation with one side having double door openings and pedestrian access on the other side. All guard railing to the landing on the access side will be removable to allow for equipment to be installed and removed as required throughout the duration of the mines life.

The 2 x 1.4 MW, 3-ph, 400Vac diesel generators shall be controlled and connected to this substation, rated at 4,500A, 35kA either being stand-alone or part of the generator panels.

From this Consumer substation, the power shall be distributed at 400Vac, via copper cables, to the 3 x respective plant MCC's (Crusher, Mill & Floatation MCC's) located strategically in the plant, from where the plant loads and some infrastructure shall be supplied.

18.7.11 Plant Substations

The plant substations shall will be a pre-fabricated and installed on concrete bases and plinths with steel access stairways and landings. Access will be via the ends of the substation with one side having a service door and pedestrian access on the other side.

All guard railing to the landing on the access side will be removable to allow for equipment to be installed and removed as required throughout the duration of the mines life.

The 3 plant substations shall be powered form the Consumer Substation, each being of Form 1 separation, rated at minimum of 800A, 35kA, 3-ph, 400Vac, and be of a Form – 1 isolation & construction format.

It is envisaged that the Crusher (MCC11), Mill & Floatation (MCC21 & 22) MCC's placed strategically in order to be closest to the loading, reducing in cable runs and installation costs.

18.7.12 Transformers

As the generators excite at 400Vac + N + E, no distribution transformers are required on this plant, other than that required by control and instrumentation.

18.7.13 Fencing

The project site is located near the village of Fotadrevo (approx. 10 km by road) and smaller local villages (within 2 km of the site) and as such, the tailings storage facility, plant and mine complex, permanent camp and construction camp will be fenced. The security fence is intended to keep both unauthorised people and local livestock out of the areas detailed above.

The security at the plant and mine complex, the permanent and construction camp areas will be 2.4m high diamond mesh security fencing with 3 strands of galvanised barbed wire to the top of the fence. 6m wide access gates together with pedestrian access gates will be located at all the above mentioned areas

Access control by means of booms, turnstiles and security check points will be installed at the various locations as required.

18.7.14 Fire Water System, Reticulation and Storage

The fire water system for the plant and mine area complex will be fed from the raw water dam located adjacent to the plant terrace. Sufficient capacity is included in the raw water tank to accommodate the fire water system requirements. Pump suctions will be installed such that the fire water requirements are not reduced / utilized except for firefighting purposes.

Fire hydrants and hose reels are proposed to be installed at the plant area only, with fire extinguishers (9 kg) being utilised at all the buildings / offices and the mining complex. The final layout of the fire reticulation system will be finalised once the preferred supplier is appointed during the execution phase of the project.

18.7.15 Potable Water Reticulation

Potable water for the project will be supplied via the potable water treatment plants which are fed from the raw water dam. A well field will be installed which will provide all the raw water requirements for the project, including all process, raw and potable water requirements.

The potable water reticulation system will include a network of buried uPVC pipes installed at the permanent camp and the plant and mine complex. This network of pipes will be fed from

the potable water supply storage tanks at the plant and mine terrace and at the permanent camp terrace.

Each storage tank will have a booster pump included in order to ensure adequate pressure is maintained throughout the water supply network on site.

Applications for water extraction permits and permitted water usage will be undertaken at execution stage by the client with the assistance of GCS and Environment.

18.7.16 Potable Water Storage Tank

Provision has been included for two potable water storage tanks, one located at the permanent accommodation camp and one at the plant and mine complex. Both tanks have been sized to accommodate 516 m^3 of water which will provide for 3 days' supply in the event of a failure of the raw water supply system or the potable water treatment plant. It has been assumed that each person on site will require 225 litres / day. For a peak of 800 people on site, the daily requirement for the construction camp will be 180 m^3.

18.7.17 Waste Water Reticulation

The waste water reticulation will comprise a buried network of uPVC pipes, manholes and 2 waste water treatment plants which will collect all waste water from showers, urinals, kitchens, mess, basins, sinks, etc and gravity feed this waste water to the waste water treatment plants.

18.7.18 Welding Workshop

A welding workshop has been provided for which will support both the mining operation and the process plant operations. The workshop includes for two (2) 12m shipping containers which will be refurbished and used as offices and storage. A concrete slab is included at the welding workshop and it is proposed that works will be undertaken in the open air. There is no provision of a roof structure at the workshop. Heavy lifting and cranage will be supplied by the mobile plant purchased for the project by the Client, no separate provision has been included for cranage at the welding workshop.

18.7.19 Strategic Spares Storage

A strategic spares storage area has been provided for which will support both the mining operation and the process plant operations. The storage area includes for two (2) 12m shipping containers which will be refurbished and used as offices and storage.

18.7.20 Tyre Storage Yard

An open area has been identified on the plant terrace for the storage of spare tyres for the plant and mine LDV fleet and the mining fleet. Provision is included for security fencing at this location. An area of 320 m² has been allocated for the tyre storage area.

18.7.21 General Storage Yard

An open area has been identified on the plant terrace for a general storage yard which will be utilised to store oversize equipment and spares for the plant and mine operations that are not stored at the strategic spares storage area. Provision is included for security fencing at this location. An area of 350 m² has been allocated for the general storage area.

18.7.22 Bulk Fuel Storage Facility

During the operational phase of the project, the bulk fuel storage system will consist of five (5) containerised, double-walled fuel storage tanks, with sufficient storage capacity for two weeks operation (approx. 300,000 litres). Each storage tank has 60,000 litres capacity. The advantage of such a system is that very little is required in terms of civil and structural work in order to construct such a system, which in turn reduces capital cost.

During the construction phase of the project, the fuel storage on site will have the capacity to store two weeks supply (approx. 120,000 litres) in two (2) containerised, double-walled fuel storage tanks. The tanks required at operation phase will be procured as part of the early works and mobilization of the project and will be utilized during the construction phase of the project.



Figure 59: Typical Layout of Containerized Fuel Storage Tank

18.8 Power Generation Facility

The objective of the Electrical, Control & Instrumentation scope is to provide independent power to the stand-alone graphite plant, for phase 1 of the Molo Mine.

Independent power shall be supplied by diesel generators, whereas the control & automation shall deliver an integrated state of the art control and data acquisition solution.

The total installed generation capacity equals to 2.8MW. Power to the plant and infrastructure shall be supplied by 2 x 1.4 MW, 3-ph, 400Vac diesel generators, interlocked and operating either in parallel or independently. Power to remote areas, such as the water wells shall be supplied via independent stand-alone 15kVA, 3-ph, 400Vac diesel generators.

Subject to the sequential starting of the larger loads for e.g. the Mill, it might be required during an ore loaded start-up, that both generators run in parallel. Once the plant has reached equilibrium the standby generator shall be stepped back. During continuous normal operation of the plant, one generator will suffice. The second unit shall primarily be used during maintenance and operational rotations.

18.8.1 Generator Loading

A bottom up estimating methodology was used to arrive at a predicted Notified Maximum Demand (NMD) and electrical consumption (excluding standby loads) for the proposed installation, taking into consideration, motor efficiencies, circuit types (for e.g. VSD or DOL) actual load duties and utilisation factors.

Typically, the plant energy requirement is calculated in combination with the plant process philosophy, start-up procedure as well as that presented in the mechanical equipment list. The infrastructure loading includes power to the Water Purification plant, Sewerage plant, Administration & Plant Office, Workshop, Wash bay, Stores, Laboratory, 100-Man Change House, Clinic/Dressing Station, Gate House and plant general lighting.

The static electrical loading on one 1.4MW, 3-ph, 400Vac diesel generator is calculated to be equal to 88% of which the remainder of ± 0.15 MW is allocated to infrastructure.

The running electrical loading including the infrastructure on one 1.4MW, 3-ph, 400Vac diesel generator is calculated to be equal to 76%.

a. Power Demand Summary

The table below indicates the breakdown of the major values pertaining to the electrical power supply as well as the loading of the generators.

Load Centre	Generator			Connected % Loading [Excluding Standby]	Dynamic Variables [No Power Factor Correction]			
	kW Rating	Full Load Current [A]	LV Voltage (kV)		Estimated Run Current	% Volt drop with Largest Motor starting	% Volt drop steady state	% Running Load
SINGLE GEN	1,400	2,127	0.380	88%	1,219	3.68%	2.00%	65%

Table 41: Power Demand Summary

During normal operation, there will only be one unit running, with a second allowed to assist with mill starting, if required.

18.8.2 Control & Instrumentation

18.8.2.1 Plant Control System

The plant control system will consist of a PLC, Remote I/O and SCADA based system, typically as indicated in the figure below.

Due to the conductivity nature of the graphite it is envisaged that the Remote I/O panels be installed in the control room, with the minimum Junction boxes in the field.

Communication in the field and Remote I/O panels shall be Profibus-DP whereas communication amongst the PLC, Scada & Engineering systems shall be done on Ethernet. All instruments and field I/O shall be hard wired to the respective Remote I/O panels.

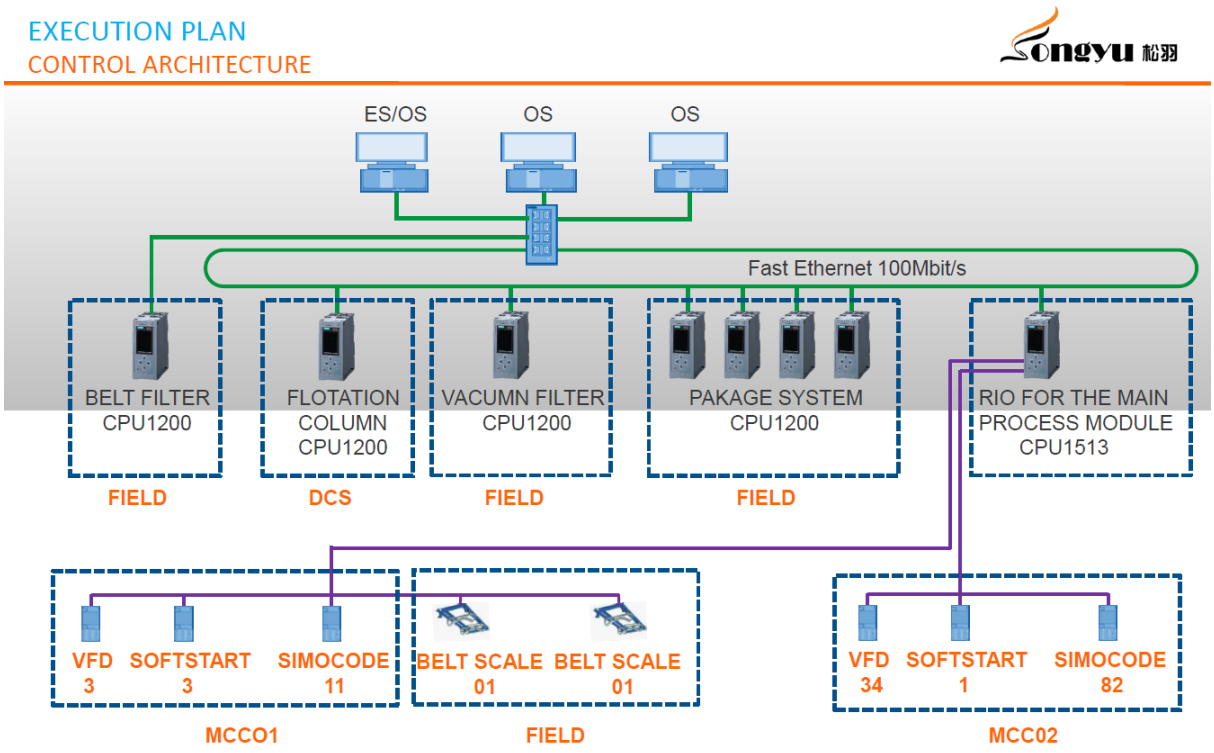


Figure 60 : Plant Control Architecture

All motor control, valve control, interlocking, PID control and sequence start/stops will be controlled via the PLC control system. The PLC's and SCADA's will communicate over a Ethernet network. Managed network switches will be used to minimize network collisions and to help guarantee the data throughput.

18.8.2.2 UPS Power

All PLC's, SCADA's and network equipment will be powered from UPS power.

Provision is be made for a minimum of 30 min backup time at 100% load. The UPS (If Required) in the main Server Room should allow a minimum of 60 min backup time at 100% load.

18.8.2.3 Level of Automation

All equipment must be controlled from the control room unless specified otherwise as a 3-level control mode will be implemented, namely Maintenance, Interlocked and Sequence modes.

Maintenance

This mode is for maintenance only and all process interlocks will be bypassed. Individual drives can be started and stopped in the field.

Interlock

The plant is controlled from the SCADA using the individual Stop/Start buttons on the SCADA. All process interlocks will be active.

Sequence

In sequence mode, the plant will be started and stopped using the PLC sequence logic. The field emergency stop buttons are hardwired to the MCC and can be used in any mode.

All the modes will be PLC controlled.

18.8.2.4 Local Isolator and Start/Stop Stations

All motors will have a local isolator and stop/start station installed as close as possible to the motor. The stop/start station will consist of emergency-stop and maintenance-start buttons.

18.8.2.5 Flow Measurement

There will be magnetic flow measurement of the potable water and industrial water. Flow rates and totalised flows will be monitored and recorded on the SCADA system in accordance with the requirements.

18.8.2.6 Level Measurement

Ultrasonic type level probes will be used for liquid levels. Still-wells should be installed where required. Additional low-low level-switches (if required.) will also be installed on bins where liner protection is required.

18.8.2.7 Scale Weight-Meter

The scales will be installed on a horizontal section. The required accuracy should dictate the type of scale required. A Profibus interface is required on all scales.

18.8.2.8 Densitometers

The densitometers to be installed shall be of the nuclear type.

18.8.2.9 Pressure Transmitter

The pressure transmitters to be installed shall be of the conventional appropriate for the typical application.

18.8.2.10 Control Valves

Control valves will be of the motorized type with position feedback. No pneumatic control valves are considered.

18.8.2.11 Solenoid Valves

All solenoid valves shall be 110VAC powered.

18.9 Tailings Disposal and Storage Facility

Due to the substantially reduced tonnages for the project as envisaged, tailings will be dried and co-disposed with the waste rock generated as part of the open cast mining. Despite this co-disposal approach, a detailed design has been completed, complete with environmental and social impact assessment and closure to allow for the upgrade to a more conventional, cyclone facility, should the throughput be increased during the life of the mine. This approach has been pursued to ensure that sufficient flexibility is built into the project development strategy to accommodate the anticipated increase in market demand.

18.10 Geotechnical Report Assessment and Founding Strategy

EPOCH Consulting (South Africa) (Pty) Ltd (EPOCH) was appointed by Next Source Materials (NEXT) to conduct a geotechnical investigation for the revised plant site and the camp site for the Molo Graphite Mine project. The works included the excavation of 23 test pits, six DCP tests and the drilling of 11 rotary core boreholes. The fieldwork component for the camp site involved the mechanical excavation of 10 test pits and the advancing of five DCP tests.

The bedrock encountered in the test pits and boreholes was variable and ranged from extremely soft rock to hard rock strengths with variable weathering and jointing. The expected allowable bearing capacities for the varying hardness of Gneiss bedrock encountered across the site are summarised below:

Table 42: Expected Allowable Bearing Capacity for Encountered Gneiss Bedrock

Gneiss Bedrock	**Allowable Bearing Capacity (kPa)**
Completely weathered, foliated, Extremely Soft Rock	300
Very closely to moderately closely jointed, highly to slightly weathered, Very Soft Rock	500
Very closely to moderately closely jointed, highly to slightly weathered, Soft Rock	700
Very closely to closely jointed, medium to slightly weathered, Medium hard to Hard Rock	1000

As rock is located at a shallow depth at most locations it is recommended that structures generally be founded on rock rather than the overlying thin soils. However, light structures with loads of less than 100 kPa could be founded on the soils if necessary.

All temporary excavations in excess of 1.5 m must be fully supported or battered back to at least 1v:1.5h in soil and 2v:1h in rock. For excavations over 3.0 m in depth, the soil and rock

conditions should be assessed by a geotechnical engineer or engineering geologist prior to and during excavation and the safe slope angles determined by analysis.

The transported and residual soils classify as G8 and G7 materials respectively and the very soft rock classifies as G6 to G7 class materials. These materials are however thin and of insufficient volumes to be considered as significant sources of construction materials for terrace construction.

The sandy lean CLAY (CL) material present approximately 6 km away from this site at the TSF site has an estimated available volume of 525 000 m³ of this material. The strength of these materials may be increased significantly with the addition of cement and/or lime and may then be suitable as terrace construction materials. Further laboratory testing will be required to determine this.

Due to the frequent rock outcrop and boulders present across the site, surfaces will need to be prepared by a bulldozer prior to trafficking.

Construction fill material for all terrace construction is sourced from the excavation for the return water dam. Approximately 450,000 m³ of material is to be excavated from the return water dam and approximately 383,000 m³ of this excavated material is to be crushed by means of mechanical jaw crushing. The total volume of material required for terraces is approximately 416,000 m³.

Concrete aggregate material for all concrete works on site will be sourced from borrow pit (s) on site, the material will be crushed using a cone crusher, supplied by the client and operated by the earthworks and civil contractor, to produce 19 mm concrete aggregate. The total volume of concrete aggregate is approximately 4,500 m³ (5,800 m³ of concrete).

19 MARKET STUDIES AND CONTRACTS

Please refer to Appendix A – NextSource Materials Graphite Market Study - Roskill Report.

20 ENVIRONMENTAL STUDIES, PERMITTING AND SOCIAL IMPACT

20.1 Description of Available Information

The location of this project, specifically within a French speaking country, and the common intricacies and nuances associated with projects of this nature resulted in the

establishment of a partnership between a South African based Environmental consultancy firm, GCS Water and Environment (Pty) Ltd (GCS) and a Malagasy consultancy firm, L'Agence d'Exécution des Travaux d'Intérêt Public et d'Aménagement communément appelée (Agetipa).

The availability of current and accurate environmental, social and permitting information on the Molo Graphite Project is substantial. The table below provides a summary of the information which complements this Feasibility Study.

Table 43: Information Summary

Environmental and Social Baseline (initial)		2011 - 2012
Environmental Legal Review		
Environmental and Social Sensitivity Study (spatially integrated)		
Final Terms of Reference (ToR) and Final Memorandum of Understanding (MOU) between ERG Madagascar SARLU (NextSource) and the O.N.E. (regulator)	Agetipa and GCS	
Environmental and Social Impact Assessment and Management Plan (ESIA & ESMP) including residual baseline	GCS and Agetipa	
Relocation Action Plan (RAP)	Agetipa	
Conceptual Closure Plan	Globesight	
Permitting and Stakeholder Register	Environmental Law Group	

20.2 Applicable Laws and Standards

This study was undertaken in accordance with Malagasy national legislation, Equator Principles, World Bank and IFC requirements on environmental, cultural, health and safety protection.

20.3 Environmental and Social Sensitivities

The studies preceding the compilation of the ESIA revealed no fatal flaws, or land use restrictions in terms of environmental and/or social baseline conditions and all significant sensitivities were incorporated into the planning and design of the project.

Various options were considered at commencement of the feasibility study regarding the geographical placement of infrastructure, type and volume of water supply, type of electricity supply, tailings storage facility, (location and deposition strategy) and product transportation routes and shipping locations, specifically related to environmental and social benefits. Refer to Figure 118 for a depiction of the environmental sensitivities and final placement of infrastructure. The following final base case and alternatives have been selected and are relevant to this study:

20.3.1 Geographic Placement of Infrastructure

Sensitive areas were superimposed onto the project design and the placement of infrastructure such as roads, processing plant, dams, TSF, camp and other applicable ancillary infrastructure. Placement was undertaken in such a manner as to not have any significant impacts on the environment or on the livelihoods of local inhabitants.

20.3.2 Water Supply

Appendix E contains the detailed water study completed for this report by GCS Water and Environmental Consultants.

20.3.3 Electricity Supply

Base case: Diesel generators.

Alternative: HFO (Heavy Fuel Oil) generators.

A trade-off study was undertaken to assess hybrids such as Diesel / HFO with Solar Photovoltaic (PV) and Diesel / HFO with Concentrated Solar Power (CSP), but none of these proved commercially feasible.

20.3.4 Tailings Storage Facility (TSF)

Due to the substantially reduced tonnages for the project as envisaged, tailings will be dried and co-disposed with the waste rock generated as part of the open cast mining. Despite this co-disposal approach, a detailed design has been completed, complete with environmental and social impact assessment and closure to allow for the upgrade to a more conventional, cyclone facility, should the throughput be increased during the life of the mine. This approach has been pursued to ensure that sufficient flexibility is built into the project development strategy to accommodate the anticipated increase in market demand.

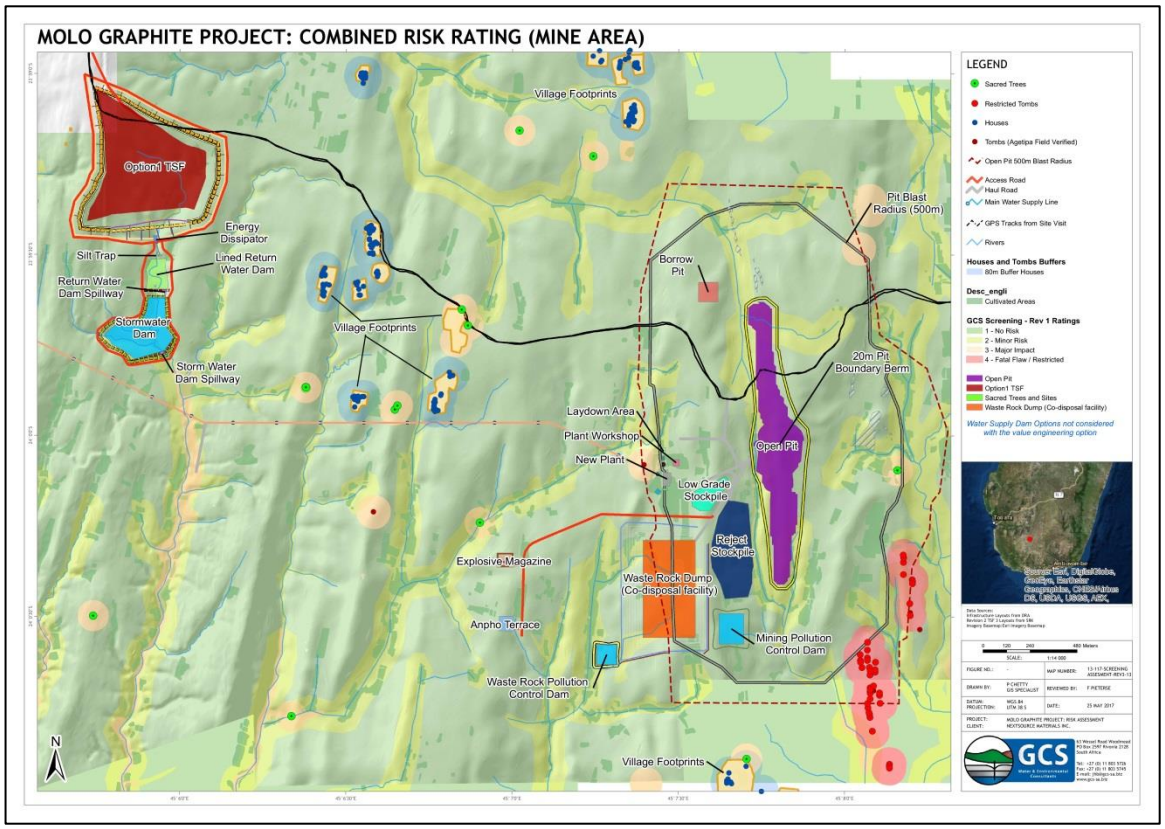


Figure 61: Infrastructure Overlaid on Environmental and Social Sensitivities

20.3.5 Transport Route and Shipping Port

The base case shipping port is Fort Dauphin via the RN10 and/or RN13. Refer to Figure 62.

Three shipping port sites were originally considered. These were Tulear, Soalara (Antseraky) and Fort Dauphin. Information obtained via the detailed Transport and Logistics Study indicated that weight limits on the Tongobory Bridge over the Unilahy River would render the transport of product to Tulear and Soalara (Antseraky) unviable.

This route will in all likelihood be used to bring fuel to the proposed project site. The only remaining feasible option is Fort Dauphin via the RN10 and/or RN13.

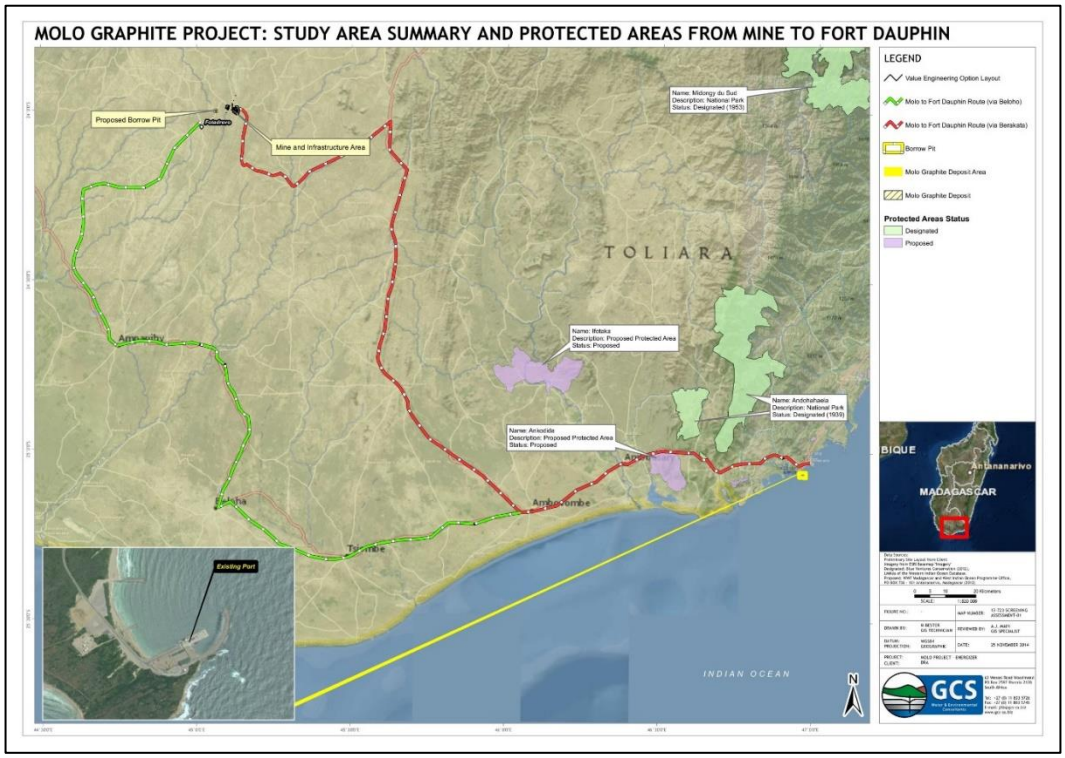


Figure 62: Transport Route Alternatives to Fort Dauphin

20.4 Environmental and Social Impact Assessment and Management Plans

Integrating knowledge of environmental and social sensitivities and risks into project planning and design ensured that the final impact assessment component revealed that there are no fatal flaws from an environmental and social perspective. The significance levels of impacts range from minor to major before any mitigation measures are applied and from minor to average with mitigation measures included. Notably all major risks require significant reduction in risk via stringent controls. These controls have been incorporated into the project design and planning with additional operational controls specified within the various environmental and social management plans.

To this end, the ESIA contains a chapter which details specific management measures which either remove the risks completely, or reduce their significance to an acceptable level.

In addition, each specific environmental and social component has a prescribed monitoring plan which should be followed during each project development phase. This is aimed at monitoring compliance against various specifications such as the baseline environment and predicted impact removal and reduction measures.

Post mitigation impacts are summarised as follows:

20.4.1 Preparation Phase

All potential impacts are rated from minor to average post mitigation. The preparation phase will give way to the construction phase, during which certain potential impacts will continue due to the nature of large scale construction, noting that the potential impacts would be of short duration mostly. Soil compaction at and around the open pit area is seen as a potential average impact and the proposed mitigation measures should be adhered to.

20.4.2 Construction Phase

All potential impacts are rated from minor to average post mitigation. The most notable potential impact during this phase will be the construction of the Waste Rock / Dry Tailings Co-Disposal Facility and potentially the Tailings Storage Facility (TSF), which will have a visual change impact. The proposed mitigation measures are aimed at concurrent rehabilitation of the Co-Disposal and TSF, yet this can only commence once the construction phase gives way to the operational phase. Thus the impact will be noticeable, yet of limited duration until such time as the side slope re-vegetation commences.

20.4.3 Operational Phase

The operational phase's potential impacts are rated from minor to average post mitigation. The most notable potential impact during this phase will again be the development of the Waste Rock / Dry Tailings Co-Disposal and the TSF, which will have a visual change impact. The proposed mitigation measures are to continue with the concurrent rehabilitation of the Waste Rock / Dry Tailings Co-Disposal and the TSF throughout the remaining life of the facilities. Final capping will occur during the closure phase. Thus the impact will be noticeable yet of limited duration until such time as the new terraces are re-vegetated.

20.4.4 Decommissioning and Closure Phase

All potential impacts are rated from minor negative to minor positive post mitigation. A conceptual closure plan has been developed which indicates a positive, achievable and sustainable post closure land use. The post closure land use includes grazing land, agricultural development and managed domestic water supply. Active agriculture and managed domestic water supply are potential improvements on the base case, as these options to not exist at present.

From a conceptual closure perspective the open pit will be left as a void upon closure. Difficulties could be experienced by concurrent in-filling in those cases where the ore body is limited to a single open pit, as is the case with the Molo Graphite Project, and various grades of ore needs to be sourced from the pit. This requires access to the full pit and in-filling could sterilize ore reserves. In these cases, rehabilitation will be facilitated as follows:

The open pit perimeter walls will be rendered safe for humans and domestic animals. This is achieved by means of the following:

- Sloping the perimeter walls of the opencast pit to the pit floor, or to stable groundwater level that could establish within a reasonable period within the opencast pit
- Provide enviro-berms and ditches along the opencast pit perimeter when perimeter wall flattening is not possible
- Owing to removal of the mined product off site, and the creation of permanent mine residue facilities, insufficient material remains and a final void with respect to this project is unavoidable
- Conceptual land use options include a natural water body. Geochemical and hydrological studies indicate that the pit water quality will be suitable for stock watering and controlled irrigation (within limits).

These measure are in line with international practice and the opportunities available to utilise the flooded open pit for livestock watering and controlled irrigation provides a unique opportunity for the project to contribute to a sustainable post mining land use.

Regarding the co-disposal facility, the minimum objectives for the closure and rehabilitation are to stabilise the facility both chemically and physically and thereby prevent air, ground and water pollution, in accordance with the requirements of the relevant regulations and in line with good international practice. The intended end use considers the prior land-use and the location with respect to current and potential future socio-economic development. The walls of the co-disposal facility should be top soiled and vegetated progressively during construction and operation of the dam, whilst the

upper surface may only be top soiled and vegetated once the final fill level has been reached.

20.5 Waste and Water Management

20.5.1 Mine Waste Assessment

A hydro-geochemical assessment was undertaken, including laboratory test work and modelling, on tailings material and representative waste rock. The results indicate that most sulphur associated with ore, tailings and waste rock consists of secondary sulphate minerals such as jarosite. The reaction rates associated with the secondary sulphate minerals are generally slow, resulting in relatively low sulphate loads in rainfall run-off and short-term operational seepage associated with the mine waste facilities. However higher sulphate loads could be expected in the long-term, specifically post-closure. The pH of water emanating from waste facilities will be neutral over the short term, decreasing to slightly acidic in the long-term. Metal concentrations will be low. Appropriate capping systems were specified to manage the long-term post closure water quality emanating from residual waste product.

20.5.2 Surface Water Environment

The Molo Graphite Project site is located on the divide of three major river basins: Onilahy River Basin (32,361 km^2 catchment), Linta River Basin (6,177 km^2 catchment) and Menarandra River Basin (8,681 km_2 catchment). The calculated mean annual runoff is about 150 mm per annum or roughly 18.8 % of the mean annual precipitation (MAP = 799 mm).

Around the Molo Graphite Project site, all water courses drain either to the north or south, away from the proposed mine infrastructure with most of the proposed mine infrastructure located in the locally southward draining Linta River Basin. Watercourses are dry during the dry season and only flow during the rainy season.

Local surface water sources are largely underdeveloped and no significant local water demands were identified during water use surveys.

20.5.3 Groundwater Environment

The Molo Graphite Project site falls within the Ampanihy shear zone with a regional north-northeast – south-southwestern trend. The local geology consists mainly of

crystalline metamorphic rock such as quartzofeldspathic gneiss. No significant faulting or dyke intrusions have been identified with the site.

A number of hydrogeological boreholes were drilled and tested to investigate local aquifer conditions. The main aquifer zone is hosted within the weathered and fractures rock in the upper 50 metres below surface. The gneiss at the proposed mine site has low aquifer potential, with the marble layers to the west having a higher aquifer potential.

Community shallow hand-dug wells and boreholes are sparsely scatters over the area. Groundwater use in the larger area is low, 15 to 20 m^3 per day maximum.

20.5.4 Water Management

The potential impacts that mining activities are likely to have on surface and groundwater resources in the surrounding environment were analyzed. These potential impacts were quantified with different groundwater and surface water models and a significance rating was assigned.

Potential impacts relate to mine dewatering, wellfield abstraction, dirty water runoff, runoff reduction, and potential contaminant seepage from the Co-Disposal Facility and Material Reject Dump. None of the identified potential impacts posed a high or serious risk to the downstream environment, and the majority of risks were mitigated by the Water Management Plan, which includes re-use of water, storm water management measures, water monitoring and waste capping systems.

20.6 Socio-Economics

A comprehensive assessment pertaining to the demographics and economic status of the communities in proximity to the project was undertaken, specifically on those communities within or adjacent to the area of influence. Significant reductions in the overall area of influence was achieved through careful consideration of environmental and social sensitivities, in order to minimize the affected area.

Various avenues of engagement with stakeholders have been undertaken to date. These can be categorized as follows:

- Local and Regional engagement with government and other regulatory stakeholders
- Public consultation
- Land tenure and occupation
- Cultural heritage

- Sources of income

  Engagement outcomes can be summarised as follows:

- Job creation
- Education and skills transfer
- Strengthening of Municipal Resources
- Improvement in local security
- Increasing business opportunities

  Relocation of houses and associated assets (minimum requirement in order to allow for public safety and operational efficiency)

- Loss of grazing land

In this case though, there is a need to relocate crops and grazing land utilised by local inhabitants within close proximity to the project site, for which a Relocation Action Plan (RAP) has been developed.

20.7 Mine Rehabilitation and Closure

The development of a Mine Rehabilitation and Closure Programme (MRCP) creates a platform for a mine to always have the end of the life of the mine in focus and to plan ahead for successful closure. Closure planning is guided internationally by different principles, frameworks, guidelines and local legislation.

The framework for the MRCP specifically for the proposed Molo Graphite Project was compiled from various recognised standards. These being:

- Equator Principals
- International Finance Corporation (IFC) Performance Standards
- IFC Environmental, Health and Safety Guidelines for Mining
- Madagascar Legislation
- The International Council of Mining and Metals (ICMM) guidelines

The proposed Molo Graphite Project is currently in the Feasibility Phase and requires, at this stage, a conceptual mine closure and rehabilitation plan. The conceptual MRCP was developed to reach the following target outcomes and goals:

- That future public health and safety are not compromised

- The after-use of the site is beneficial and sustainable to the affected communities in the long term
- Adverse socio-economic impacts are minimized and socio-economic benefits are maximized
- Make the area of influence healthy and stable, and restore its ability to allow another activity compatible with any form of life and activity in the region where it is located, after the closure of the mining operation

- Ensure the safety of the location during and after the mining operation
  - Reduce the harmful effects of the mining operation on the atmosphere and on the water regime at an acceptable level
  - Integrate the mine and infrastructure landscape through appropriate negotiations and potential arrangements with the local municipality
- Prevent the introduction of pests and weeds in areas where they were not present, and
  - Promote rapid re-generation and renewal of native plant species, or compatible with the ecosystem of the area

Rehabilitation and closure estimates were annualised over the project's life of mine. Refer Table 44 below for the closure estimates, based at end of LOM at present time value of money.

Table 44: Closure Cost Summary

CLOSURE COST SUMMARY			**Year 1**
	Total Life of Mine		**Jan-18**
	Owner Operator Rehabilitation	*Third Party Rehabilitation*	Construction Phase
Plant Area and Associated Infrastructure	$205 336.83	$252 974.98	$205 336.83
Opencast	$558 944.50	$688 619.63	$0.00
Waste Rock Dump / Co-Disposal Facility	$639 426.39	$787 773.31	$0.00
Tailings Storage Facility	$1 570 534.22	$1 934 898.16	$0.00
Explosive Magazine	$11 160.89	$13 750.22	$11 160.89
Roads and Pipeline	$18 377.21	$22 640.72	$18 377.21

CLOSURE COST SUMMARY			Year 1
	Total Life of Mine		Jan-18
Water infrastructure / water supply	$48 237.43	$59 428.51	$48 237.43
Total	**$3 052 017.47**	**$3 760 085.53**	$283 112.36

20.8 Permitting and Stakeholders

As input into the feasibility study, pertinent information on the required permits / licenses to mine, including additional applicable permits / licenses for associated activities, was gathered and compiled into a permit register. A stakeholder database was compiled in support of the permitting register to assist with the identification of and approach to the relevant parties concerned.

Currently, NextSource has progressed significantly in its application for a Global Environmental Permit. The Global Environmental Permit application is supported by the ESIA and RAP, which will be submitted to the O.N.E. (National Environment Office) upon approval of the investment amount by the Ministry of Strategic Resources in July 2017. The processing of the ESIA and RAP will inform the requirement for further sectorial EMP's (small scale reports) which will focus on certain aspects of the project's influence on environmental and social matters. These sectorial EMP's, along with other permits (listed below) will be undertaken during the early project execution phase.

The proposed Molo Graphite Project has triggered the following list of permits / licenses in addition to that which is described above, (list is not exhaustive):

- Authorisation for extracting of borrow materials from a quarry
- Building permit (housing and ancillary infrastructure)
- Authorisation to construct a waste water treatment facility and to discharge treated water
- Water uptake authorisation
- Authorisation to rehabilitate and maintain roads
- Authorisation to generate and distribute electricity
- Permit to operate a domestic landfill site
- Authorisation to circulate haul trucks on public roads
- Authorisation for tree clearing

- Authorisation to beneficiate raw ore into concentrate
- Permits for recruitment of labour
- Lease of the land

The relevant stakeholder groups are (list is not exhaustive):

- Ministries
- Regional Government
- District Government
- Local Decentralized Collectivises, or Municipalities
- NGO's and Public Companies
- Attached Authorities to Ministries; and
- The local population

21 CAPITAL AND OPERATING COSTS

21.1 CAPEX

The project's initial CAPEX is estimated at $18.4 M, including a10% contingency, with an additional $3.1 M required to cover the first 3 months of working capital. Over the life of the mine, sustaining capital of $3.3 M will be required for equipment replacement and for rehabilitation at the end of the project. Table 45 summarizes the capital requirements.

Table 45: Summary of Project CAPEX over Project Life

Capital Cost Breakdown		
Process Equipment	$	8,072,750
Civil & Infrastructure	$	1,842,450
Mining	$	2,292,885
Buildings	$	322,998
Electrical Infrastructure	$	89,670
Project Services/EPCM	$	832,041

Capital Cost Breakdown		
Construction Services	$	1,050,000
Indirect Costs	$	355,000
Environmental & Permitting costs	$	695,074
Owner's Costs	$	1,140,000
Sub-total	**$**	**16,692,871**
Contingency (10%)	$	*1,669,287*
3 Months Working Capital	$	3,100,000
Initial CAPEX TOTAL	**$**	**21,462,158**
Sustaining CAPEX over Life of Mine	**$**	**3,300,000**

21.1.1 BASIS OF ESTIMATE

The capital costs for the Project are built up as follows:

21.1.1.1 Modular Plant

The revision of the previous BFS was motivated by a modular plant, designed at an appropriate size to accommodate current market realities.

The plant has been designed to a +90% accuracy with the only potential variances contributable to final vendor equipment details which are only available post procurement.

A modular engineering and manufacturing company has been part of the project team for multiple months and have provided a lump sum, design, supply, delivery and installation price, complete with allowances for commissioning and spares.

Detailed design reviews were completed and there is a high level of comfort with the accuracy of the design and costing.

Table 46 summarizes the CAPEX breakdown of the turn-key price provided by the modular plant manufacturer.

Table 46: Modular Plant CAPEX

Description	**Cost**
Fixed price offer for Manufacture and Delivery of Process Plant Complete	$ 6,284,800.00
Transportation to Fort Dauphin	$ 570,300.00
Transportation to Site	$ 219,998.00

Plant Installation and Commissioning	$ 644,900.00
Duties	$ 352,752.00
Sub-Total	**$ 8,072,750.00**

21.1.1.2 Earthworks, Civils and Infrastructure

Detail designs have been completed for all of the earthworks and civils, complete with accurate schedules of quantities which have been used to confirm current pricing. Table 47 summarizes the CAPEX requirement for earthworks and civils.

Table 47: Earthworks and Civils CAPEX

Description	Supply	Transportation	Erection	Duties and taxes	Total
Bulk Earthworks					
					$ 545,424
Concrete Works					
					$ 358,587
Preliminary & General					$ 361,604
Infrastructure					
Gabion retaining wall	$ 75,000.00				$ 75,000
Water purification Plant	R 1,938,000.00	R 106,000.00	R 250,000.00	R 232,560.00	R 2,526,560
Sewage treatment works	R 1,026,000.00	R -	R -	R 123,120.00	R 1,149,120
450m3 storage tanks	$ 29,332.00	$ 1,820.00	$ 4,850.00	$ 3,519.84	$ 39,522
Fencing	$ 83,800.00				$ 83,800
Water Reticulation					$ 30,000
Sewer reticulation					$ 15,000
Weighbridge	R 450,000.00	R 106,000.00	R 50,000.00	R 54,000.00	R 660,000
Sub-total					$ 1,842,450

21.1.1.3 Mining

Mining CAPEX have been developed from first principles using an owner mining philosophy where all equipment has been priced for supply and delivery to site. Operational costs are accurately captured based on first principles and expected organograms. Table 48 summarizes the mining CAPEX requirements.

Table 48: Mining CAPEX

Machine	Replacement	COST		Capital
	(hours)			
EXCAVATORS & LOADERS				
SANY SY465H Excavator - 2m3	15000	$ 286,000	1	$ 286,000.00

Machine	Replacement	COST		Capital
	(hours)			
LIUGONG Fromt End Loader 3m3	15000	$ 71,000	2	$ 142,000.00
HAUL TRUCKS				$ -
SINOTRUK HOWO Tipper Truck 16m3 (Howa)	15000	$ 61,000	5	$ 305,000.00
SINOTRUK HOWO Water Truck 20000L (Howa)	15000	$ 61,000	1	$ 61,000.00
MOBILE EQUIPMENT				$ -
HOWA Truck Mounted Drill Rig	10000	$ 216,000	1	$ 216,000.00
SANY Motor Grader 200HP	15000	$ 183,000	1	$ 183,000.00
SANY Compactor 10t	15000	$ 81,000	1	$ 81,000.00
SHANTUI SD22W HD Tracked Dozer	15000	$ 146,000	1	$ 146,000.00
SERVICE & SUPPORT EQUIP.				$ -
Buses 60 seater	6 years	$ 105,570	1	$ 105,570.38
Maintenance / Diesel Truck	6 years	$ 175,000	1	$ 175,000.00
Pump Diesel 50m3/hr	6 years	$ 109,091	1	$ 109,090.91
Supervision Vehicle	6 years	$ 24,763	7	$ 173,341.00
Light Plant				
Spares (1 Years) -		10% of total		$ 109,883.18
Explosive Magazines				$ 200,000.00
TOTAL ESTIMATED CAPITAL SPEND.				**$2,292,885.47**

21.1.1.4 EPCM costs

These costs were built up in detail based on the scope and time frame of the project with an owners engineering philosophy. Table 49 summarizes the project EPCM costs.

Table 49: EPCM CAPEX

Description	Unit	Quantity	Rate	Unit Cost	Allowances	Cost
Engineering Team						
Project Manager	Month	9	$16,000	$144,000		$144,000
Process	Month	6	$11,000	$ 66,000		$ 66,000
Electrical	Month	6	$11,000	$ 66,000		$ 66,000
Civil/structural/infrastructure	Month	6	$11,000	$ 66,000		$ 66,000
Mining	Month	3	$11,000	$ 33,000		$ 33,000
Procurement / Commercial	Month	6	$ 8,000	$ 48,000		$ 48,000
Environmental consultant	Month	12	$ 5,000	$ 60,000		$ 60,000
HR Consultant	Sum	1	$30,000	$ 30,000		$ 30,000
Site Team						
Construction manager	Month	7	$15,000	$105,000	$ 8,750	$113,750
HSE Manager	Month	7	$ 6,500	$ 45,500	$ 3,792	$ 49,292
Electrical Sup	Month	6	$ 9,000	$ 54,000	$ 4,500	$ 58,500
Project Planner	Month	6	$ 6,000	$ 36,000	$ 3,000	$ 39,000
Mining Sup	Month	6	$ 9,000	$ 54,000	$ 4,500	$ 58,500
EPCM Costs						**$832,042**

21.1.1.5 Risk Allowances

A contingency amount of 10% has been allowed for.

This estimate is categorised as a “Feasibility Type” with a combination of detailed, and semi-detailed costs.

The estimate has been produced using Vendor firm and budget quotations and market data

21.1.2 Base Date

The base date for the Capital Cost Estimate is May 2017

21.1.3 Base Currency

The estimate has been presented in the US Dollar currency in present day terms. Prices obtained in other currencies have been converted to US Dollars using the applicable exchange rates.

Fluctuations in the exchange rates from the date of quotation to the date of indention have not been catered for.

21.1.4 Scope

The scope of the estimate covers the total capital cost of the plant areas and the related infrastructure as more fully described in the body of the main study documents. Owner’s costs are all included.

21.1.5 Escalation

Escalation has not been considered in the Capital Cost Estimate.

21.1.6 Transport

Transport costs were included in the modular plant as well as mining equipment costing where appropriate.

21.1.7 OVERALL PHILOSOPHY

The general approach to estimating was to measure / quantify each cost element from the engineering drawings, PFD's, mechanical equipment list, infrastructure equipment list, and motor lists.

21.1.8 ASSUMPTIONS

The estimate for the plant has been based on an assumption of a continuous engineering, procurement and construction effort with no interruption of the implementation programme after funding approval has been obtained.

21.1.9 SPARES, FIRST FILL AND CONSUMABLES

Allowances have been made for the First Fill and for Consumables based on the supplier and the process design engineer estimates.

21.2 OPEX

21.2.1.1 Process Operating Cost Summary

Table 50 below shows the operating costs for the 240 ktpa concentrator process plant. The breakdown of the cost is presented graphically in Figure 63. As was expected, electrical power contributes most of the plant operating costs at 51.6%. This is because of the use of generators for power generation.

Table 50 : Process Plant OPEX Estimate

Description	Annual Cost $/annum	Unit Cost US$/t milled	% Total
Power	1 793 535	7.47	42.7%
Water	8 784	0.04	0.2%
Reagents	309 124	1.29	7.4%
Milling	368 427	1.54	8.8%
Product Dryer	82 137	0.34	2.0%
Tailing	48 000	0.20	1.1%
Labour	1 200 562	5.00	28.6%
Maintenance	191 614	0.80	4.6%
Laboratory	123 188	0.51	2.9%
Miscellaneous Operating Cost	78 000	0.33	1.9%
Total Operating Cost	4 203 370	17.51	100.0%

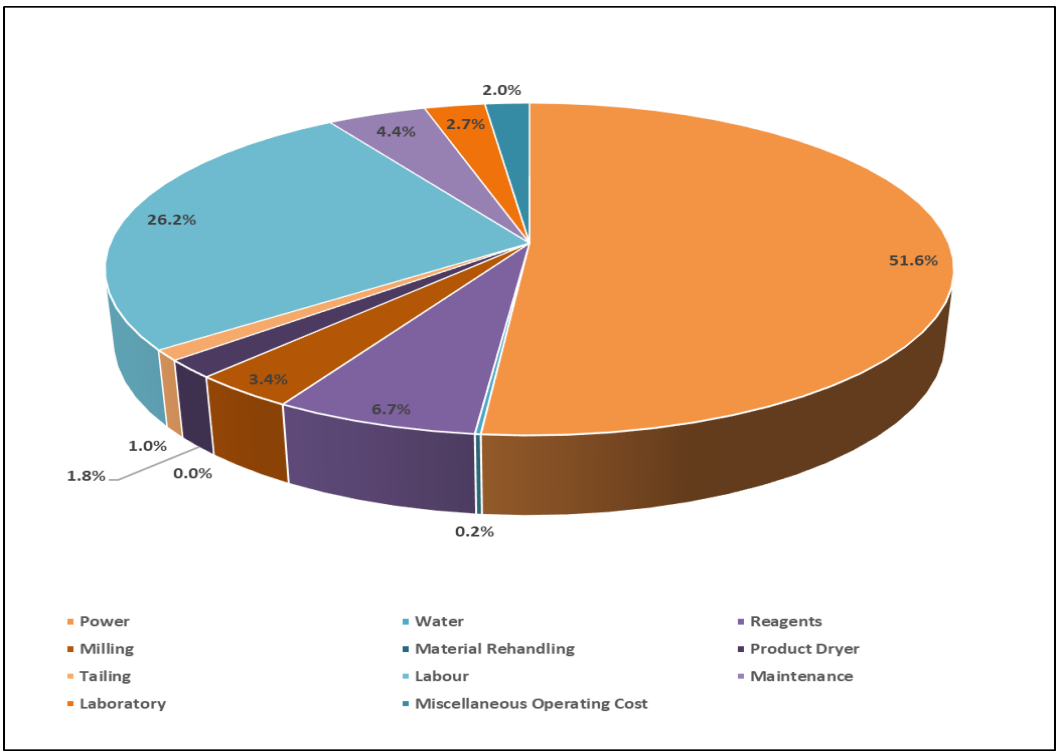


Figure 63 : Process Plant Operating Cost Breakdown

21.2.1.2 Methodology

The processing plant operating cost (OPEX) estimate is based on averaged, steady-state operating conditions of a 240 ktpa run-of-mine (ROM) feedrate and 15 ktpa of final product. Calculations to derive the estimate were informed by the process flowsheets, mass balance outputs, process design criteria and required mechanical equipment, which are detailed in various sections of and annexures to this report. Inputs to the process plant operating costs are discussed in Sections A.2.1 to A.2.10 below.

21.2.1.3 Labour

Labour costs for the plant are based on the staff organogram shown in Figure 64 below. The Process Manager (DU) will be an expatriate appointment while the other employees may be sourced locally.

The staff complement for the project is 79 (see Table 51). The labour cost per ton of ore milled was found to be USD 5.0. The organogram and staffing specifications were based on Met63's experience in the operation of concentrator plants.

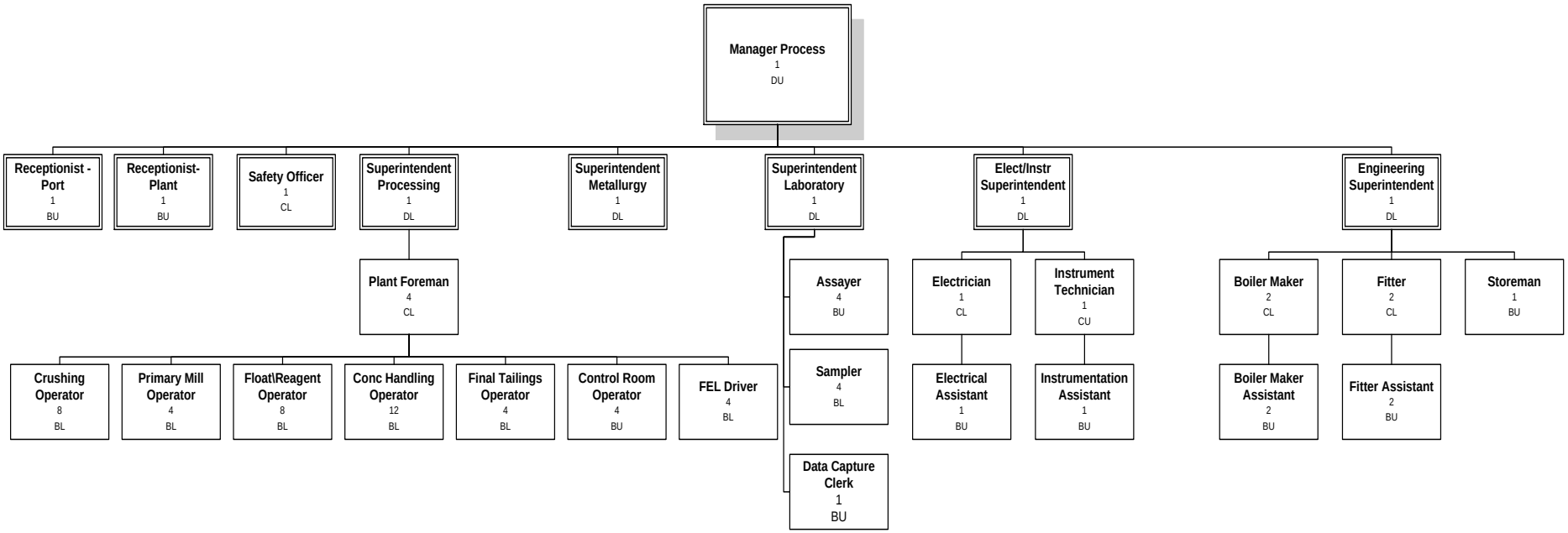


Figure 64: Molo 240 ktpa Graphite Project Staff Organogram

Table 51: Labour Costs

Occupation	Site	Department	Grade	Number	Total	Total Monthly Salary US$	Total Monthly Medical Cost US$	Total Monthly Transport Cost US$	Total Monthly PPE Cost	Monthly Cost US$	Annual Cost US$	Unit Cost US$/t
Manager Process	Plant	Management	DU	1	1	10 327	1 033	100	9	11 469	137 623	0.6
Administrator/Receptionist	Plant	Management	BU	1	1	689	69	100	9	867	10 402	0.0
Administrator/Receptionist	Port	Management	BU	0	1	689	69	100	9	867	10 402	0.0
Elect/Instr Superintendent	Plant	Electrical / Instrumentation	DL	1	1	5 969	597	100	9	6 674	80 091	0.3
Electrician	Plant	Electrical / Instrumentation	CL	1	1	1 165	117	100	9	1 390	16 685	0.1
Instrument Technician	Plant	Electrical / Instrumentation	CU	1	1	1 936	194	100	9	2 239	26 862	0.1
Electrical Assistant	Plant	Electrical / Instrumentation	BU	1	1	689	69	100	9	867	10 402	0.0
Instrumentation Assistant	Plant	Electrical / Instrumentation	BU	1	1	689	69	100	9	867	10 402	0.0
Engineering Superintendent	Plant	Engineering	DL	1	1	5 969	597	100	9	6 674	80 091	0.3
Fitter	Plant	Engineering	CL	1	2	2 330	233	200	18	2 781	33 370	0.1
Fitter	Port	Engineering	CL	0	0	-	-	-	-	-	-	-
Boiler Maker	Plant	Engineering	CL	1	2	2 330	233	200	18	2 781	33 370	0.1
Storeman	Plant	Engineering	BU	1	1	689	69	100	9	867	10 402	0.0
Boiler Maker Assistant	Plant	Engineering	BU	1	2	1 378	138	200	18	1 734	20 804	0.1
Fitter Assistant	Plant	Engineering	BU	1	2	1 378	138	200	18	1 734	20 804	0.1
Superintendent Laboratory	Plant	Laboratory	DL	1	1	5 969	597	100	9	6 674	80 091	0.3
Sampler	Plant	Laboratory	BL	1	4	1 644	164	400	36	2 244	26 929	0.1
Sampler/Assayer	Port	Laboratory	BL	0	0	-	-	-	-	-	-	-
Assayer	Plant	Laboratory	BU	1	4	2 756	276	400	36	3 467	41 607	0.2
Data Capture Clerk	Plant	Laboratory	BU	1	1	689	69	100	9	867	10 402	0.0
Superintendent Processing	Plant	Operations	DL	1	1	5 969	597	100	9	6 674	80 091	0.3
Plant Foreman	Plant	Operations	CL	1	4	4 660	466	400	36	5 562	66 740	0.3
Plant Supervisor	Port	Operations	CL	0	0	-	-	-	-	-	-	-
Crushing Operator	Plant	Operations	BL	2	8	3 288	329	800	71	4 488	53 858	0.2
Primary Milling Operator	Plant	Operations	BL	1	4	1 644	164	400	36	2 244	26 929	0.1
Float/Reagents Operator	Plant	Operations	BL	2	8	3 288	329	800	71	4 488	53 858	0.2
Final Tailings Operator	Plant	Operations	BL	1	4	1 644	164	400	36	2 244	26 929	0.1
Concentrate Handling Operator	Port	Operations	BL	3	12	4 932	493	1 200	107	6 732	80 786	0.3
Control Room Operator	Plant	Operations	BL	1	4	1 644	164	400	36	2 244	26 929	0.1
FEL Driver	Plant	Operations	BL	1	4	1 644	164	400	36	2 244	26 929	0.1
Superintendent Metallurgy	Plant	R&D	DL	1	1	5 969	597	100	9	6 674	80 091	0.3
Safety Officer	Plant	Safety	CL	1	1	1 165	117	100	9	1 390	16 685	0.1
Total				**32**	**79**	**83 130**	**8 313**	**7 900**	**704**	**100 047**	**1 200 562**	**5.0**

21.2.1.4 Power

The breakdown of the power cost is shown in Table 52 below. The total cost per metric ton was found to be USD 7.47/t milled. As was expected, milling, flotation and tailings handling contribute a larger percentage to the overall power consumption. The power cost calculations are based on the use of generator power at a cost of USD 0.22 per kWh.

Table 52 : Breakdown of the Operating Cost for Power

Fixed/Demand Charge		
Max Demand US$/kW		US$/kW/year
Installed Capacity - Crushing	186	kW
Installed Capacity - Mill/Float/Tailings	607	kW
Installed Capacity - Drying/Screen/Bagging	293	kW
Total Variable Power Cost		**US$/year**
Total Variable Power Cost		**US$/t**
Crushing		
Crushing Unit Power Cost	0.22	US$/kWhr
Crushing Power consumption	897 774.08	kWhr/year
Crushing Total Variable Power Cost	**197 510**	**US$/year**
Crushing Total Variable Power Cost	**0.82**	**US$/t**
Mill/Float/Tailings		
Mill/Float/Tailings Unit Power Cost	0.22	US$/kWhr
Mill/Float/Tailings Power consumption	4 893 244.02	kWhr/year
Mill/Float/Tailings Total Variable Power Cost	**1 076 514**	**US$/year**
Mill/Float/Tailings Total Variable Power Cost	**4.49**	**US$/t**
Drying/Screen/Bagging/Utilities		
Drying/Screen/Bagging/Utilities Unit Power Cost	0.22	US$/kWhr
Drying/Screen/Bagging/Utilities Power consumption	2 361 414.10	kWhr/year
Drying/Screen/Bagging/Utilities Total Variable Power Cost	**519 511**	**US$/year**
Drying/Screen/Bagging/Utilities Total Variable Power Cost	**2.16**	**US$/t**
Power		
Anual Power Cost	**1 793 535**	**US$/year**
Monthly Power Cost	**149 461**	**US$/month**
Power Total Unit Cost	**7.47**	**US$/t**

21.2.1.5 Water

The operating costs for water were based on potable water usage of 8 784 m^3/year at a unit cost of USD 1/m^3. Table 53 below shows the water operating costs.

Table 53: Operating Costs for Water

Potable Water Cost		
Potable Water Cost	1.00	US$/m³
Potable Water Consumption	8 784	m³/year
Total Potable Water Cost	**8 784**	US$/year
	0.04	US$/t
Water		
Anual Water Cost	**8 784**	**US$/year**
Monthly Water Cost	**732**	**US$/month**
Water Total Unit Cost	**0.04**	**US$/t**

21.2.1.6 Reagent Costs

The consumption figures used in determining the reagent operating cost estimate were based on the process design criteria information and are supported by the plant mass balance. The reagent costs used were based on imported supply rates obtained from reagent suppliers FOB: Faux Cap, Madagascar. Table 54 shows the reagent operating costs.

Table 54: Reagent Operating Costs

Collector		
Mass Treated	240 000	t/year
Collector Cost	976	US$/t
Collector Dosage Rate	111.0	g/t
Collector Consumption	26.6	t/year
Anual Collector Cost	**26 006**	**US$/year**
Monthly Collector Cost	**2 167**	**US$/month**
Collector Total Unit Cost	**0.11**	**US$/t**

Frother		
Mass Treated	240 000	t/year
Frother Cost	2 957	US$/t
Frother Dosage Rate	165.0	g/t
Frother Consumption	39.6	t/year
Anual Frother Cost	**117 097**	**US$/year**
Monthly Frother Cost	**9 758**	**US$/month**
Frother Total Unit Cost	**0.49**	**US$/t**

Flocculant (Concentrate)		
Mass Treated	240 000	t/year
Flocculant (Concentrate) Cost	2 024	US$/t
Flocculant (Concentrate) Dosage Rate	1.00	g/t
Flocculant (Concentrate) Consumption	0.2	t/year
Anual Flocculant (Concentrate) Cost	**486**	**US$/year**
Monthly Flocculant (Concentrate) Cost	**40**	**US$/month**
Flocculant (Concentrate) Total Unit Cost	**0.00**	**US$/t**

Flocculant (Tailings)		
Mass Treated	240 000	t/year
Flocculant (Tailings) Cost	2 024	US$/t
Flocculant (Tailings) Dosage Rate	125.0	g/t
Flocculant (Tailings) Consumption	30.0	t/year
Anual Flocculant (Tailings) Cost	**60 720**	**US$/year**
Monthly Flocculant (Tailings) Cost	**5 060**	**US$/month**
Flocculant (Tailings) Total Unit Cost	**0.25**	**US$/t**

Coagulant		
Mass Treated	240 000	t/year
Coagulant Cost	2 569	US$/t
Coagulant Dosage Rate	170.0	g/t
Coagulant Consumption	40.8	t/year
Anual Coagulant Cost	**104 815**	**US$/year**
Monthly Coagulant Cost	**8 735**	**US$/month**
Coagulant Total Unit Cost	**0.44**	**US$/t**

Reagent		
Anual Reagent Cost	**309 124**	**US$/year**
Monthly Reagent Cost	**25 760**	**US$/month**
Reagent Total Unit Cost	**1.29**	**US$/t**

21.2.1.7 Milling

The milling costs (shown in Table 55) consist of the grinding media costs as well as the costs for re-lining.

Table 55: Milling Costs

Milling		
Annual Mill Ball Cost	**324 127**	**US$/year**
Annual Mill Liner Cost	**44 300**	**US$/year**
Anual Milling Cost	**368 427**	**US$/year**
Monthly Milling Cost	**30 702**	**US$/month**
Milling Ball Unit Cost	**1.35**	**US$/t**
Milling Liner Unit Cost	**0.18**	**US$/t**
Milling Total Unit Cost	**1.54**	**US$/t**

21.2.1.8 Product Drying

The cost of product drying is USD 0.34/t; this is the same figure as used in the DRA Feasibility Study.

21.2.1.9 Final Tailings Handling

Table 56 shows the cost of tailings handling. The tailings handling unit cost is USD 0.2/t.

Table 56: Final Tailings Handling Costs

Final Tails Handling		
Mass Treated	240 000	t/year
Final Tails Handling Cost	0.2	US$/t
Anual Final Tails Handling Cost	**48 000**	**US$/year**
Monthly Final Tails Handling Cost	**4 000**	**US$/month**
Final Tails Handling Total Unit Cost	**0.20**	**US$/t**

21.2.1.10 Maintenance Costs

The maintenance costs (see Table 57) were estimated according to the capital cost of the mechanical equipment for the crusher, wet plant and dry circuits. The cost was estimated to be 7.5% of the mechanical equipment cost for each circuit.

Table 57: Maintenance Costs

Crusher Equipment Maintenance		
Crusher Equipment Maintenance Capital Equipment Cost	244 511	US$
Crusher Equipment Maintenance Spares Allowance	7.50	% of Capital
Anual Crusher Equipment Maintenance Cost	**18 338**	**US$/year**
Monthly Crusher Equipment Maintenance Cost	**1 528**	**US$/month**
Crusher Equipment Maintenance Total Unit Cost	**0.08**	**US$/t**
Wet Plant Equipment Maintenance		
Wet Plant Equipment Maintenance Capital Equipment Cost	1 926 047	US$
Wet Plant Equipment Maintenance Spares Allowance	7.00	% of Capital
Anual Wet Plant Equipment Maintenance Cost	**134 823**	**US$/year**
Monthly Wet Plant Equipment Maintenance Cost	**11 235**	**US$/month**
Wet Plant Equipment Maintenance Total Unit Cost	**0.56**	**US$/t**
Dry Plant Equipment Maintenance		
Dry Plant Equipment Maintenance Capital Equipment Cost	769 042	US$
Dry Plant Equipment Maintenance Spares Allowance	5.00	% of Capital
Anual Dry Plant Equipment Maintenance Cost	**38 452**	**US$/year**
Monthly Dry Plant Equipment Maintenance Cost	**3 204**	**US$/month**
Dry Plant Equipment Maintenance Total Unit Cost	**0.16**	**US$/t**
Total Plant Maintenance		
Anual Total Plant Maintenance Cost	**191 614**	**US$/year**
Monthly Total Plant Maintenance Cost	**15 968**	**US$/month**
Total Plant Maintenance Total Unit Cost	**0.80**	**US$/t**

21.2.1.11 Laboratory Costs

Table 58 below presents the breakdown of the laboratory costs for the project. The estimated cost to process a single sample is USD 1.0. A total of 144 616 laboratory samples will be processed on a yearly basis, which will result in a laboratory cost per ton of USD 0.6.

Table 58: Laboratory Cost Breakdown

Laboratory Plant Samples		
No of samples	54 750	No/year
Laboratory Plant Samples Cost per sample	1.00	US$/Sample
Anual Laboratory Plant Samples Cost	**54 750**	**US$/year**
Monthly Laboratory Plant Samples Cost	**4 563**	**US$/month**
Laboratory Plant Samples Total Unit Cost	**0.23**	**US$/t**
Laboratory Grade Control Samples		
No of samples	68 438	No/year
Laboratory Grade Control Samples Cost per sample	1.00	US$/Sample
Anual Laboratory Grade Control Samples Cost	**68 438**	**US$/year**
Monthly Laboratory Grade Control Samples Cost	**5 703**	**US$/month**
Laboratory Grade Control Samples Total Unit Cost	**0.29**	**US$/t**
Concentrate Samples		
No of samples	21 429	No/year
Concentrate Samples Cost per sample	1.00	US$/Sample
Anual Concentrate Samples Cost	**21 429**	**US$/year**
Monthly Concentrate Samples Cost	**1 786**	**US$/month**
Concentrate Samples Total Unit Cost	**0.09**	**US$/t**
Laboratory Samples		
No of samples	144 616	No/year
Cost per sample	1.00	US$/Sample
Anual Laboratory Samples Cost	**144 616**	**US$/year**
Monthly Laboratory Samples Cost	**12 051**	**US$/month**
Laboratory Samples Total Unit Cost	**0.60**	**US$/t**

21.2.1.12 Miscellaneous

The miscellaneous costs include stationery and office equipment, lubricants, workshop tools and computer software. The costs were based on Met63 process plant experience and were discussed with NextSource Materials.

Table 59: Miscellaneous Costs

Description	Monthly Cost US$	Annual Cost US$	Unit Cost US$/t
Lubricants	4 000	48 000	0.20
Workshop Tools	1 000	12 000	0.05
Computer Software	1 500	18 000	0.08
Total	**6 500**	**78 000**	**0.33**

22 ECONOMIC ANALYSIS

22.1 General

The economic analysis is based on the results of cash flow forecast financial modelling prepared in Microsoft Excel by HCF International Advisors of London, England. Inputs to the financial model were obtained from the various technical experts where possible, or from third parties considered experts in their field.

Values shown are rounded to an appropriate level; all financial values shown in this report are based in United States Dollars (US $) and nominal terms. Returns are presented on both a pre- and post-tax basis. No provision has been made for debt financing.

22.2 Assumptions

22.2.1 Product Price

Detailed product pricing forecasts were sourced from Roskill Consulting Group Ltd. The applied price of a tonne of average MOLO Graphite (i.e. the blended average) for the Life of Mine is projected to be US $ 1,014 / tonne, CIF Europe.

The applied prices for the forecast achieved grades of each flake size is summarised Table 60 below:

Table 60: Price Forecast Projections for Molo Flake Graphite Conctrate

Year	Product price (USD / tonne @ Rotterdam)			
	Jumbo +50 Mesh Flake	Large -50 +80 Mesh Flake	Medium -80 +100 Mesh Flake	Fine -100 Mesh Flake
2017	$ 1,470	$ 949	$ 902	$ 808
2018	$ 1,519	$ 1,039	$ 937	$ 816
2019	$ 1,537	$ 1,068	$ 984	$ 827
2020	$ 1,520	$ 1,028	$ 958	$ 811
2021	$ 1,540	$ 1,061	$ 946	$ 798
2022	$ 1,572	$ 1,121	$ 937	$ 784
2023	$ 1,575	$ 1,123	$ 917	$ 769
2024	$ 1,619	$ 1,207	$ 913	$ 758

Year	Product price (USD / tonne @ Rotterdam)			
	Jumbo +50 Mesh Flake	Large -50 +80 Mesh Flake	Medium -80 +100 Mesh Flake	Fine -100 Mesh Flake
2025	$ 1,649	$ 1,264	$ 915	$ 754
2026	$ 1,681	$ 1,326	$ 922	$ 742
2027	$ 1,760	$ 1,485	$ 937	$ 734
2028	$ 1,707	$ 1,378	$ 896	$ 713
2029	$ 1,649	$ 1,261	$ 881	$ 705
2030	$ 1,598	$ 1,159	$ 865	$ 689
2031	$ 1,606	$ 1,165	$ 869	$ 692
2032	$ 1,612	$ 1,169	$ 873	$ 695
2033	$ 1,618	$ 1,174	$ 876	$ 698
2034	$ 1,625	$ 1,178	$ 879	$ 700
2035	$ 1,631	$ 1,183	$ 883	$ 703
2036	$ 1,633	$ 1,184	$ 884	$ 704
2037	$ 1,634	$ 1,185	$ 885	$ 705
2038	$ 1,636	$ 1,186	$ 885	$ 705
2039	$ 1,637	$ 1,188	$ 886	$ 706
2040	$ 1,637	$ 1,188	$ 886	$ 706
2041	$ 1,641	$ 1,190	$ 888	$ 707
2042	$ 1,644	$ 1,192	$ 890	$ 709
2043	$ 1,647	$ 1,195	$ 892	$ 710
2044	$ 1,650	$ 1,197	$ 893	$ 712
2045	$ 1,655	$ 1,200	$ 896	$ 714
2046	$ 1,655	$ 1,200	$ 896	$ 714
2047	$ 1,655	$ 1,200	$ 896	$ 714

Source: Prices based on the ranges provided in the Roskill report which is provided in Appendix A.

22.2.2 Mineral Royalties

The project is subject to a 2% Revenue Royalty and a 1.5% Net Smelter Royalty.

22.2.3 Technical Assumptions

The primary technical assumptions used in the financial analyses are presented in Table 61 below.

Table 61: Technical Assumptions for Financial Analysis

Item	Value
Average ore mined per year	240,000 T
Average stripping ratio (waste to ore ratio)	0.52
Life of project	30 years
Average mill feed/head grade (%C)	8.1%
Average concentrate grade (%C)	97.3%
Average mill recovery (%)	88.3%
Average tonnes of concentrate production per year	17,000 T

22.2.4 Economic Assumptions

The primary economic assumptions used in the financial analyses are presented in Table 62 below.

Table 62: Economic Assumptions for Financial Analysis

Item	Value
Currency	US Dollar
Discount Rate (% per year)	8%
Average graphite price	USD $ 1,014/T
Equity	100%
Inflation	0%
Government royalty	2%

Item	Value
Net Smelter Royalty (NSR)	1.5%
Madagascar corporate tax rate	20%
Average production costs of graphite concentrate (at plant)	USD $432.92/T
Average production costs of graphite concentrate (CIF Rotterdam)	USD $688.42/T

22.3 Financial Model and Results

Table 63 summarizes the total revenues and expenditures calculated for the life of mine (30 years). All values are expressed in millions of USD.

Table 63: Financial Analysis Summary

Metric	Value
Revenue	516.4
Government Royalties	10.3
Mining	52.4
Processing	135.4
Transportation	130.1
G&A and Admin	32.7
Net Smelter Return	2.3
Initial Capital Expenditure	18.4
Initial Working Capital	3.1
Income Taxes	27.0
Closure and Rehabilitation Costs	1.9

The financial model results are provided in Table 64 below.

Table 64 - Financial Analysis Results

Year		-1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Values expressed in millions, USD	Total																																
Revenue	516.4	-	15.4	17.5	17.7	16.7	17.5	16.3	17.6	18.0	16.9	19.2	18.6	17.8	17.3	17.6	16.4	16.3	15.9	16.0	17.7	17.9	18.0	17.5	17.2	18.0	16.2	17.0	17.7	16.3	17.9	16.3	-
Government Royalties	(10.3)	-	(0.3)	(0.4)	(0.4)	(0.3)	(0.3)	(0.3)	(0.4)	(0.4)	(0.3)	(0.4)	(0.4)	(0.4)	(0.3)	(0.4)	(0.3)	(0.3)	(0.3)	(0.3)	(0.4)	(0.4)	(0.4)	(0.3)	(0.3)	(0.4)	(0.3)	(0.3)	(0.4)	(0.3)	(0.4)	(0.3)	-
Mining	(52.4)	-	(1.9)	(1.9)	(1.9)	(1.8)	(1.8)	(2.0)	(2.0)	(1.9)	(1.8)	(1.8)	(1.8)	(1.8)	(1.9)	(1.9)	(1.7)	(1.7)	(1.5)	(1.8)	(1.9)	(1.8)	(1.8)	(1.6)	(1.6)	(1.5)	(1.5)	(1.4)	(1.5)	(1.5)	(1.6)	(1.6)	-
Processing	(135.4)	-	(4.0)	(4.5)	(4.5)	(4.5)	(4.5)	(4.5)	(4.5)	(4.5)	(4.5)	(4.5)	(4.5)	(4.5)	(4.5)	(4.5)	(4.5)	(4.5)	(4.5)	(4.5)	(4.5)	(4.5)	(4.5)	(4.5)	(4.5)	(4.5)	(4.5)	(4.5)	(4.5)	(4.5)	(4.5)	(4.5)	-
Transportation	(130.1)	-	(3.9)	(4.4)	(4.6)	(4.3)	(4.4)	(4.1)	(4.4)	(4.4)	(4.0)	(4.4)	(4.4)	(4.4)	(4.5)	(4.6)	(4.2)	(4.2)	(4.1)	(4.1)	(4.5)	(4.6)	(4.6)	(4.5)	(4.4)	(4.6)	(4.1)	(4.3)	(4.5)	(4.1)	(4.5)	(4.1)	-
G&A and Admin	(32.7)	-	(1.1)	(1.1)	(1.1)	(1.1)	(1.1)	(1.1)	(1.1)	(1.1)	(1.1)	(1.1)	(1.1)	(1.1)	(1.1)	(1.1)	(1.1)	(1.1)	(1.1)	(1.1)	(1.1)	(1.1)	(1.1)	(1.1)	(1.1)	(1.1)	(1.1)	(1.1)	(1.1)	(1.1)	(1.1)	(1.1)	-
Net Smelter Return	(2.3)	-	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	-
Working Capital Changes	-	-	(3.3)	0.1	(0.0)	0.2	(0.2)	0.3	(0.3)	(0.1)	0.2	(0.5)	0.2	0.2	0.1	(0.1)	0.3	0.0	0.1	0.0	(0.4)	(0.1)	(0.0)	0.1	0.1	(0.2)	0.4	(0.2)	(0.1)	0.3	(0.3)	0.3	2.9
Initial Capital Expenditure	(18.4)	(17.0)	(1.4)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Closure and Rehabilitation Costs	(1.9)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	(1.9)
Project Cash Flows (pre-tax)	132.9	(17.0)	(0.6)	5.3	5.2	4.8	5.0	4.5	4.9	5.6	5.2	6.4	6.4	5.7	5.0	5.0	4.6	4.4	4.4	4.1	4.9	5.4	5.5	5.4	5.2	5.7	4.9	5.1	5.5	5.0	5.4	5.0	1.0
Corporate Taxes	(27.0)	-	(0.5)	(0.7)	(0.7)	(0.5)	(0.7)	(0.5)	(0.7)	(0.8)	(0.6)	(1.0)	(1.2)	(1.1)	(1.0)	(1.0)	(0.9)	(0.9)	(0.9)	(0.8)	(1.1)	(1.1)	(1.1)	(1.1)	(1.0)	(1.2)	(0.9)	(1.1)	(1.1)	(0.9)	(1.2)	(0.9)	-
Project Cash Flows (post-tax)	105.9	(17.0)	(1.1)	4.6	4.5	4.2	4.3	4.0	4.2	4.8	4.6	5.4	5.2	4.6	4.0	4.0	3.8	3.5	3.5	3.3	3.9	4.3	4.4	4.4	4.2	4.5	4.0	4.0	4.4	4.0	4.3	4.1	1.0

The financial model was also run at discount rates of 10% and 12%. A summary of the project economics based on various discount rates is provided in table 65 below.

Table 65 – Economic Metrics with Varying Discounts

Metric	Unit	Value
Before Tax		
Total Project Cash Flows	USDm	132.9
NPV @ 8%	USDm	34.0
NPV @ 10%	USDm	24.8
NPV @ 12%	USDm	18.0
IRR	%	25.2%
Payback Period	year	4.2
After Tax		
Total Project Cash Flows	USDm	105.9
NPV @ 8%	USDm	25.5
NPV @ 10%	USDm	18.0
NPV @ 12%	USDm	12.4
IRR	%	21.5%
Payback Period	year	4.8

22.4 Sensitivity Analysis

Table 66 presents the key project sensitivities. Ranked in order of sensitivity (highest to least sensitive), they are:

- Selling Price

- Operating Expenses
- Capital Expenditure

Table 66 – IRR Sensitivity

Item assessed	Effect on Project IRR	New Project IRR
No changes (reference point)		21.5%
Operating expenses up 10%	-5.0%	16.6%
Selling Price down 10%	-6.9%	14.6%
Capital expenditure up 10%	-1.7%	19.8%

22.4.1 Spider Sensitivity Analysis

Capital expenditure, operating expenses and selling price sensitivities on project IRR are shown graphically below for both pre-tax and post-tax analyses.

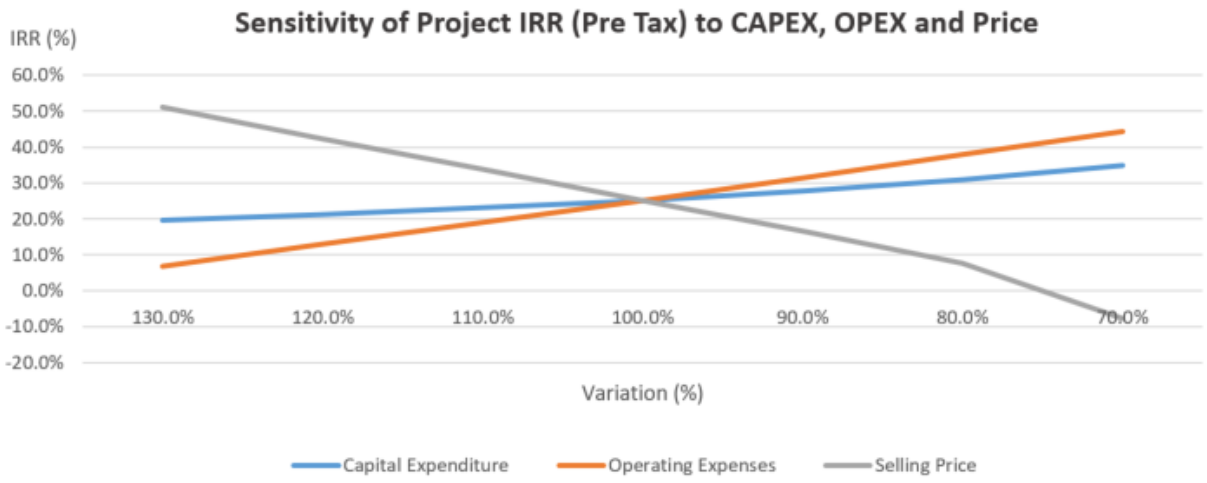


Figure 65: Sensitivity of Project IRR (Pre-tax) to CAPEX, OPEX and Price

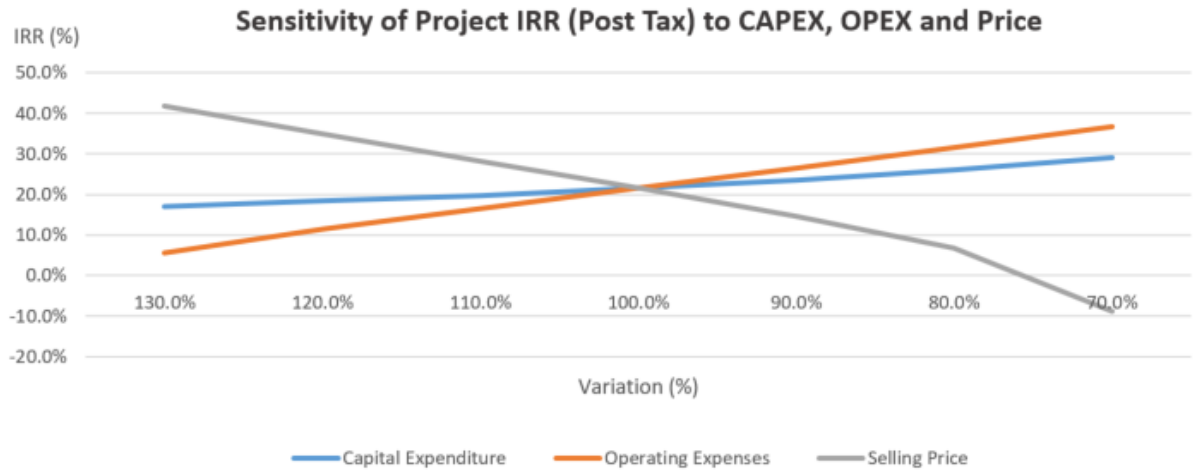


Figure 66: Sensitivity of Project IRR (Post-tax) to CAPEX, OPEX and Price

Similar to the above, capital expenditure, operating expenses and selling price sensitivities on project NPV (8%) are shown graphically below for the post-tax analyses.

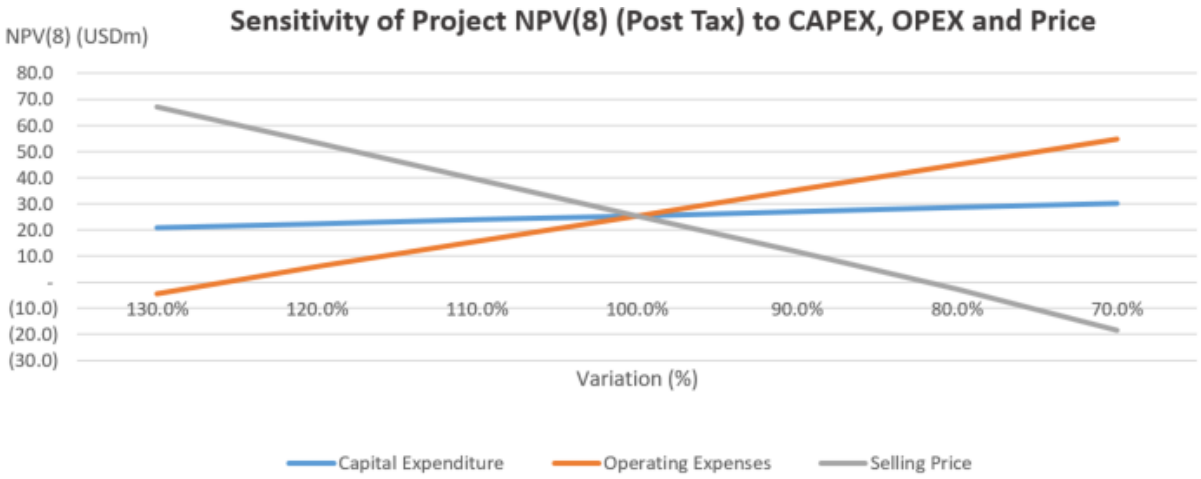


Figure 67: Sensitivity of Project NPV (8) (Post-tax) to CAPEX, OPEX and Price

23 ADJACENT PROPERTIES

No similar graphite deposits are known in south-western Madagascar other than those already detailed in this Technical Report.

24 OTHER RELEVANT DATA AND INFORMATION

The authors are not aware of any other information on the properties that would affect their interpretations, or conclusions regarding the Molo Graphite Deposit. It should, however be noted that Molo is only one of nineteen graphite prospects on the greater Property, only seven of which have been drill tested.

24.1 REPORT ON THE HAZID (HAZARD STUDY 2) STUDY CARRIED OUT ON THE PROPOSED MOLO GRAPHITE PLANT IN MADAGASCAR

Please refer to the complete Hazid reports found in Appendix G (Molo Graphite Project – Hazid on Graphite Dust Exposure) and Appendix H (Molo Graphite Project – Hazid on Silica Dust Exposure) for more detailed information.

24.1.1 Executive Summary

A new graphite mine and processing plant is to be established in the southern part of Madagascar on behalf of NEXT RESOURCES. The plant will process ROM ore and produce pure graphite material for export. The process consists essentially of the following steps:

- Crushing
- Milling and flash flotation
- Rougher flotation
- Cleaner circuits
- Thickening
- Filtration and drying
- Bagging
- Tailings handling

- Reagent storage and supply
- Supply of services

Rod Prior, an experienced Professional Process Safety Engineer, was asked to facilitate the Hazard and Operability (HAZOP) study on the new plant. The HAZOP study was replaced by a HAZID study because of time constraints. HAZID is a higher-level technique which does not examine every pipeline.

The HAZID study was held on the 21 April 2017 and included representatives from the designers, consultants and the owners. A standard HAZID worksheet was used where the possibility of various hazardous events was considered. Where an event was considered credible an analysis followed.

The analysis considered the following:

- Possible causes
- Consequences
- Preventative avoidance measures
- Protective mitigating measures
- Actions needed if the measures were inadequate

The analysis is a form of structured brainstorming with a high reliance on experience.

There were no fundamental issues which required rectification. There are several issues associated with setting up a facility in a remote part of the country. However, the risk of a graphite dust explosion in the Drying and Bagging section of the plant could be significant and requires a detailed study (HAZOP and Risk assessment) to ensure adequate controls are put in place. Attention needs to be paid to workforce training and supervision as these workers will be inexperienced and unfamiliar with industrial practices. There is considerable scope for human error in many aspects of the operations as the plant is not highly automated.

A full HAZOP should be done on the plant when the design is fully completed. Vendor HAZOPs are needed because of the large number of vendor packages used.

24.1.2 Introduction

A plant to produce graphite is to be built in Southern Madagascar. The feed will be high quality graphite ore mined in an adjacent mine. The plant will use standard processing techniques but will use a novel concept of importing the plant in modules. NEXT SOURCE MATERIALS will own and will operate the facility. The plant has been designed by SYNC of China with MET 63 providing process engineering support.

Initially, a HAZARD AND OPERABILITY(HAZOP) Study was requested to identify the safety, health, environmental and operability hazards and additional controls needed

to ensure that the risks posed by the hazards are acceptable. To HAZOP 39 Piping and Instrumentation Drawings would require 3 days. It was agreed that a higher-level Hazard Study HAZID (Hazard Identification) or Hazard Study 2 would be carried out on the 18 Process Flow Diagrams. This could be done in a day. HAZID is effectively a structured brainstorming approach aimed at identifying significant hazards and associated controls.

Rod Prior, an experienced Process Safety Engineer, was invited to facilitate the HAZID. The HAZID sessions were held on the 21 April 2017 at the Waterfall Club in Johannesburg.

The mining operations were first discussed with Dave Thompson, mining consultant, presenting the information.

The High-Level Risk and Opportunity Analysis carried out in 2016 was reviewed by the HAZID team and a number of changes were made. Some of the risks were typical HAZID risks. The revised document is attached as Appendix 3 and should be read together with the HAZID analysis.

24.1.3 Process Description

24.1.3.1 Ore Receiving and Crushing

The crusher circuit is fed with ROM ore using a frontend loader at a rate of 50tph. The material is screened before being fed to a jaw crusher. Size is reduced to < 120mm. The crusher product is fed to a classification screen. Various fractions are fed to secondary and tertiary crushers. Some material is recycled. A single stream is fed to the Milling Section

24.1.3.2 Primary Milling and Flash Flotation

Material is fed to the primary mill (ball) where size is reduced to 80%<500µ. Coarse material at -2mm is fed to the flash flotation cell where diesel and MIBC are added. Froth (concentrate) and tailing streams are produced.

24.1.3.3 Rougher Flotation

The rougher flotation cell bank concentrates the graphite stream. Reagents are added as before.

24.1.3.4 Primary Concentrate Cleaning Circuit

Concentrate is passed through the primary polishing mill to the primary cleaner flotation cell where further concentration takes place.

24.1.3.5 Fine Flake Cleaning Circuit

Concentrate is passed through the fine flake polishing mill where flakes are separated rather than reduced in size. A flotation cell produces further concentration. Tailings from the cell are subjected to cleaner and scavenging flotation cells.

24.1.3.6 Attrition Cleaning Circuit

The cleaner concentrate stream is thickened in the attrition concentrate thickener. The underflow product is processed in the attrition mill. The material is further concentrated in a flotation cell. Tailings are processed in cleaner and scavenging flotation cells.

24.1.3.7 Final Tailings Handling

Tailing streams are combined and processed in the final tailings thickener. The underflow (tailings) into a plate and frame filter. The filter cake is stockpiled and moved to a dump via frontend loader.

24.1.3.8 Final Concentrate Handling Circuit

Combined concentrate is thickened in a thickener. The underflow is dried on a filter belt to produce a filter cake with <20% moisture. The filter cake is dried in a diesel-fired filter to a moisture content of <1%. The concentrate is screened into four size fractions before being bagged.

24.1.3.9 Services

Water is pumped from a well-field. Two water systems feed the plant. Dirty water is supplied to various process applications. Clean water is produced via a water purification plant and is available for drinking purposes and other applications.

Compressed air from two compressors for instrument air duty and filtration. A blower provides low pressure air for the flotation cells.

Diesel and MIBC are stored in small isotainers and pumped to the process.

Flocculant powder is made up into solution in a mixing tank. It is pumped to the two thickeners via dosing pumps.

Coagulant powder is made up into solution in a mixing tank. It is fed into the three thickeners via dosing pumps.

Electricity is generated on site by a diesel driven generator. There is a standby generator to supply a partial supply.

24.1.4 Hazid Procedure

The HAZID procedure identifies safety, health, environmental and operability hazards and associated controls through a structured questioning approach triggered by considering possible incident scenarios. The procedure is normally applied before the detailed design is available and is based on examining the PFDs (Process Flow Sheets). In this study, the HAZID approach was chosen because of limited time available to do a full HAZOP

The following hazardous events (scenarios) were used in the HAZID Study.

EXTERNAL FIRE
INTERNAL FIRE
INTERNAL EXPLOSION
CONFINED EXPLOSION
UNCONFINED EXPLOSION
RUPTURE/BURST
INTEGRITY LOSS
ACUTE HARMFUL/NOXIOUS EXPOSURE
CONTAMINATION / COMPOSITION

SPILLS
POLLUTION
NOISE
VIOLENT RELEASE OF ENERGY
CORROSION / EROSION
POOR QUALITY
MOMENTUM CHANGE
UNAVAILABILITY
OPERABILITY PROBLEM
HUMAN FACTORS
SECURITY BREACH
FINANCIAL PROBLEM

For each hazardous event (scenario), the possibility of the event occurring in the section is considered. This comes from experience or an understanding of the situation. Should a credible scenario be agreed then the following steps are followed:

- DETERMINATION OF CAUSES OF THE HAZARD
- DETERMINATION OF THECONSEQUENCES OF THE HAZARD
- EVALUATION OF ANY EXISTING SAFEGUARDS / CONTROLS (PREVENTATIVE OR MITIGATING)
- NEW SAFEGUARDS IF EXISTING ARE JUDGED INADEQUATE
- ACTION AND RESPONSIBILITIES TO EXECUTE THE ACTION

24.1.5 Assumptions

It was assumed that South African Standards for the Plant would be at least equal, if not higher, than that required in Madagascar.

24.1.6 Recommendations

NODE TITLE	REC	EQUIRED

	NO	
Ore receiving and Crushing	1	Specify appropriate lube oil to minimize fire risk
		Dust need to be analysed particularly for harmful silica content
		Refer to ESIA Report for information on spills, pollution & noise
		Mine plan for Grade control to be followed
		Check that there is sufficient design allowance for loader impact on crusher equipment.
		Apply practical solutions (common sense) to load the crushers when wet material found
		Use HR auditing to check that local inexperienced employees are performing tasks correctly
		Develop Security Protocols to deal with theft & other issues
Primary Milling and Flotation		All dust spillage to be contained in bund areas
		Ops Procedures to specify PPE and medical tests for Mill noise
		Confirm Mill design (handrails, barrier etc.) from a safety/access point of view
		Additional testing by SGS to confirm that flow blockages will be minimized
Rougher Flotation		Lightning and surges to be catered for in design
Cleaner Flotation		Fire detection in the MCC to be linked to the incomer trip
		PPE requirements to be specified for both flocculants
Tailings Thickening		Consider spillage compartments in process water tank

		Ensure that the PM system covers the abrasion effect of coarse silica
		Review functional spec of the thickener with respect to the auto rake lift
		To prevent drownings, consider signage, training and a buddy system
Tailings Filtration		Check vendor package for hydraulic pack for filter having an interlock between pressure release and power feed
		Evaluate wet tailings
		Additional training on filter on filter operation (reliability issue)
Concentrate Filtration		Consider layout change as very close to Drier (fire risk)
		Emphasize cleaning of filter cloths in training and procedures (blinding)
Concentrate Drying and Bagging		Measures to prevent fires & explosions in the burner (Burner Management System) must be reviewed in the Vendor HAZOP
		The risk of a major graphite dust explosion must be thoroughly explored in a specific HAZOP (enclosed building)
		Establish the health risk implications (PPE etc.) of graphite dust inhalation
Water System		Review of the potable treatment philosophy and ops manuals
Compressed Air Circuits		Conduct vendor HAZOP studies on this and all other vendor packages
Reagent Storage & Dosing (Diesel & MIBC)	30	Review storage location and layout to minimize any external fires leading to tank heating
	31	Develop a diesel management plan

	32	Develop a security strategy to deal with theft (diesel and others)
Flocculant Storage & Dosing	33	Conduct vendor HAZOPs on these vendor packages
	34	Emphasize the slipping risk in spillages for operators in training

19.2.3 HAZID Conclusions

The HAZOP team could identify a limited number of hazards and operating issues that required attention. No major safety or operability issues were recorded.

A significant uncertainty was detected with respect to the heat exchanger that cools the motors. The drawings provided were unable to show how the devices worked and need to be examined further with the vendor.

25. INTERPRETATIONS AND CONCLUSIONS

25.1 Geology

NEXT's 2011 exploration programme delineated a number of new graphitic trends in southern Madagascar. The resource delineation drilling undertaken during 2012-2014 focussed on only one of these, the Molo Deposit, and this has allowed for an Independent, CIM compliant, updated resource statement for the Molo deposit.

The total Measured and Indicated Resource is estimated at 100.37 Mt, grading at 6.27% C. Additionally, an Inferred Resource of 40.91 Mt, grading at 5.78% C is stated. When compared to the November 2012 resource statement (Hancox and Subramani, 2013), this shows a 13.7% increase in tonnage, a 3.4 % decrease in grade, and a 9.8% increase in graphite content. The reason for the increase in tonnage is due to the 2014 drilling on the previously untested north eastern limb of the deposit, which added additional new resources. Additionally 23.62 Mt, grading at 6.32% Carbon, have been upgraded by infill drilling from the Indicated to Measured Resource category.

25.2 Mining

Maiden mineral reserves of 7 160 000 tonnes have been declared for the Molo 240ktpa FS 2017 at an average grade of 8.05% and based on the information contained in the feasibility study it is possible to economically mine this deposit.

25.3 Tailings

Due to the substantially reduced tonnages for the project as envisaged, tailings will be dried and co-disposed with the waste rock generated as part of the open cast mining. Despite this co-disposal approach, a detailed design has been completed, complete with environmental and social impact assessment and closure to allow for the upgrade to a more conventional, cyclone facility, should the throughput be increased during the life of the mine. This approach has been pursued to ensure that sufficient flexibility is built into the project development strategy to accommodate the anticipated increase in market demand.

25.4 Risks

In addition to the qualitative risk assessment completed during the previous BFS, a comprehensive HAZID study was completed as part of this study and the findings summarized in the attached document.

25.5 Permitting

Various permits will have to be obtained for the project including an Environmental Permit, a Mining permit, land tenure and land use approvals and finally supplementary sectoral permits. The most urgent permit is for NEXT to obtain the exploitation permit for the right to mine and produce.

25.6 Metallurgical Test Work

Comprehensive metallurgical test programs culminated in a process flowsheet that is capable of treating the Molo ore using conventional and established mineral processing techniques.

Process risks associated with the variability with regards to metallurgical performance have been mostly mitigated through the addition of an upgrading circuit. The upgrading circuit

treated the combined concentrate after the secondary cleaning circuit. Reduced flake degradation and an improved process flexibility may be obtained by employing separate upgrading circuits for the coarse and fine flakes.

26. RECOMMENDATIONS

26.1 Geology

No further recommendations.

26.2 Mining

The Molo Graphite Project will allow for potential optimisation of drilling and blasting designs during execution that could reduce operating costs slightly.

From a pure mining perspective the Molo Graphite Project is very small and provided reasonable levels of short term planning are applied it should have very few challenges in delivering the required tonnages at the required grade to meet the production targets set out in this study.

26.3 Metallurgical Test Work

The following recommendations are made for the detailed engineering stage:

- Investigate the metallurgical impact of different attrition mill technologies such as stirred media mills or attrition scrubbers;
- Evaluate a range of different grinding media (e.g. different size, shape, material) to determine if flake degradation can be reduced without affecting the concentrate grade;
- Develop a grinding energy versus concentrate grade relationship for the best grinding media. This will allow a more accurate prediction of the required attrition mill grinding energy as a function of the final concentrate grade;
- Conduct attrition mill vendor tests to aid in the sizing of the equipment;
- Carry out vendor testing on graphite tailings using the optimized reagent regime proposed by the reagent supplier.

- Complete a series of flotation tests on samples covering mine life intervals for the 2017 FS pit design.

26.4 Recovery Methods

The process plant has been designed to easily optimize the final product grade, this is achieved by having two options in the attrition cleaning step. It is however recommended that additional laboratory testwork be conducted to test the current plant configuration for treatment for highter feed grade material.

26.5 Infrastructure

The following are recommended prior to the detailed design stage:

- Additional geotechnical investigations at the proposed new construction and permanent camp site, particularly at the location of the new potable water storage tanks
- A detailed geotechnical investigation will need to be undertaken to identify and confirm suitable sources of concrete aggregate and concrete sand materials at the location of the project site. This testing will need to include for concrete material testing and the production of concrete trial mixes with the material identified
- The geotechnical information will also need to confirm the suitability for construction of all the material to be excavated from the Return Water Dam. It is proposed that all the material excavated from the Return Water Dam is utilised in the works as processed fill material
- Confirmation as to whether the material from the proposed borrow pit near Fotadrevo (which will be used to supply all fill material for the TSF starter wall construction) can be utilised as fill material, or if this material can be stabilized in some manner and used in the works
- A detailed topographical survey will need to be undertaken of the proposed construction site, borrow pit areas and the access road between Fotadrevo and the mine site. This information is required prior to the final detailed design of the plant layout and associated earthworks

26.6 Water

The following is recommended during the detailed design phase:

- The following is recommended during the detailed design phase:
- Water quality and quantity data is required to provide a baseline for comparison once the Molo Mine is commissioned. To provide the necessary baseline data, regular ground and surface water quality monitoring must be carried out leading up to the date when the Molo Mine will be commissioned. Additionally, proposed monitoring boreholes must be installed. This also should include the installation of flow meters on relevant pipelines to verify the dynamic water balance with measured flow rates during operations
- The installation of a weather station on the Molo Graphite project site should be done as soon as possible.
- Quantitative and predictive water balance, groundwater and geochemical analyses should be undertaken on regular intervals in order to update the water management plan.

26.7 Environmental, Social

- The installation of a suitable weather station at or as near as possible to the proposed project site, even before construction commences, is recommended. Accurate, local weather data is almost non-existent in Madagascar. This data will prove invaluable for model calibration, improvement in baseline understanding and for future energy supply options which could utilise wind and or solar power generation.
- Clean and or renewable energy supply should be considered as a medium to long term target.
- Appointment of a community representative and the establishment of a mandate to sensitise the local communities prior to any project activities.
- Monitoring and auditing to commence at project preparation phase.
- Compilation of Standard Operating Procedures for Environmental and Social aspects requiring direct management and intervention.
- It is recommended that actual activity data, (e.g. kilometres travelled, or litres of diesel consumed) for a financial year is used when a GHG Assessment is being calculated. Given that this project involves an estimation of a future GHG

assessment for activities yet to begin, a series of assumptions have been made in order to obtain the activity data required to undertake this calculation.

- Community recruitment, skills development and training should begin at project preparation phase.

26.8 Permitting

- The receipt of the exploitation permit is a critical step in the larger permitting and licensing regime.
- Security of land tenure is a process and is estimated to take 6-9 months, thus this process should be commissioned as early as possible.
- Application for all other necessary permits (water use, construction, mineral processing, transportation, export, labour and so forth should be undertaken within the ESIA review period (6 months), which is expected to be from September 2017 till February 2018.
- Compilation of a comprehensive legal register.

The permitting and licensing of the proposed Molo Project requires dedicated attention to ensure consistent momentum in application for and delivery of permits and licenses. This is extremely relevant within the Malagasy context.

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28. LIST OF APPENDICES

Appendix A NextSource Materials Graphite Market Study - Roskill Report

Appendix B Geology

Appendix C MET63 (PDL) C1601-PDC-018 – Process Design Criteria

Appendix D MET63 (PFD) C1601-PFD – Process Flow Diagram

Appendix E Section 12 – Environmental & Social

Appendix F Section 13 – Permitting & Stakeholders Report

Appendix G HAZID on Graphite Dust Exposure

Appendix H HAZID on Silica Dust Exposure

Appendix I Financial Model & List of Assumptions

Appendix J Author Certificates

29. CERTIFICATES OF QUALIFIED PERSONS

CERTIFICATE OF AUTHOR

This Certificate has been prepared to meet the requirements of National Instrument 43-101 *Standards of Disclosure for Mineral Projects* ("NI 43-101").

a) **Name, Address, Occupation:**

Johann Knipe de Bruin

Erudite Strategies (Pty) Ltd. 375 Calliandra Street, Wolmaranspoort, South Africa

Mining Development Strategist

b) **Title and Effective Date of Technical Report:**

Molo Feasibility Study, National Instrument 43-101 Technical Report (the "Molo Technical Report")

Effective date: 14 July 2017.

c) **Qualifications:**

B.Eng University of Pretoria, 1993

Registered Professional Engineer with the Engineering Council of South Africa (ECSA) – Reg. No. 970123

Registered Member of the Institute of Civil Engineering Reg No 90533

Involved in multiple studies similar to the Molo Project, not only from a study point of view but also as the responsible person for the ultimate execution. My relevant experience, includes 22 years in the mining and project development industry.

I have read the definition of "qualified person" set out by NI 43-101 and certify that, by reason of my education, affiliation with a professional association (as defined in NI 43-101) and past relevant work experience, I am a "qualified person" for the purpose of NI 43-101.

d) **Site Inspection:**

I visited the site on multiple occasions during the past 8 years.

e) **Responsibilities:**

I am the qualified person responsible for all sections the Molo Technical Report.

f) **Independence:**

I am independent of Nextsource Materials Inc. in accordance with NI 43-101.

g) **Prior Involvement:**

I have been involved with the Molo project in various capacities over the past eight years including served on the Board of the Issuer for a 2 year period ending in 2013.

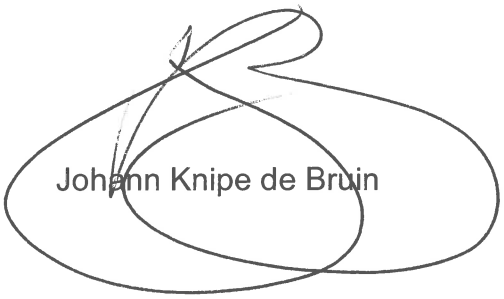
h) **Compliance with NI 43-101:**

I have read National Instrument 43-101 and Form 43-101F1 and the Molo Technical Report has been prepared in compliance with same.

i) **Disclosure:**

As of the effective date of the Molo Technical Report, to the best of my knowledge, information and belief, the Molo Technical Report contains all scientific and technical information that is required to be disclosed to make the Molo Technical Report not misleading.

Dated, 14 July 2017



Johann Knipe de Bruin

CERTIFICATE OF AUTHOR

This Certificate has been prepared to meet the requirements of National Instrument 43-101 Standards of Disclosure for Minerals Project ("NI 43-101"), Part 8.1.

a) **Name, Address, Occupation:**

Sivanesan (Desmond) Subramani

30 7th Avenue, Parktown North, Randburg,Gauteng, South Africa

Principal Resource Geologist

b) **Title and Effective Date of Technical Report:**

Molo Feasibility Study, National Instrument 43-101 Technical Report

Effective date: 6th February 2015.

c) **Qualifications:**

I graduated with a B.Sc. Honours (Geology and Economic Geology) degree from the University of KwaZulu Natal - Durban in 1994.

I am a member in good standing of the South African Council for Natural Scientific Professions (SACNASP No. 400184/06) as well as a Member of the Geological Society of South Africa.

I have practiced my profession since 1995.

I have read the definition of "qualified person" set out by NI 43-101 and certify that, by reason of my education, affiliation with a professional association (as defined in NI 43-101) and past relevant work experience, I fulfill the requirements to be a "qualified person" for the purpose of NI 43-101. My relevant experience, includes 19 years as a Geologist, of which the last 8 years focused on geostatistical resource modelling and estimation.

d) **Site Inspection:**

I visited the site 15th to 19th February 2014.

e) **Responsibilities:**

I was responsible for the following sections: Section 1.6, Section 12, Section 14.

f) **Independence:**

I am independent of Energizer Resources Inc. in accordance with the application of Section 1.5 of NI 43-101.

g) **Prior Involvement:**

I was responsible for the sections 12 and 14 of the previous NI 43-101 technical report, filed on 12th April 2013

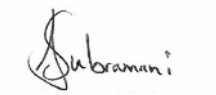
h) **Compliance with NI 43-101:**

I have read NI 43-101 and Form 43-101F1 and the Technical Report has been prepared in compliance with same.

i) **Disclosure:**

As of the effective date of the Technical Report, to the best of my knowledge, information and belief, the Technical Report contains all scientific and technical information that is required to be disclosed to make the Technical Report not misleading.

Dated, 23 March 2015



Desmond Subramani
Principal Resource Geologist

Summary of recent experience

Year	Client	Commodity	Type Of Study	Project Description
2005 - 2006	Katanga Mining	Copper & Cobalt	PFS	Generated Cu and Co Mineral Resources for a Prefeasibility study used in the listing on the Toronto Stock Exchange - DRC
2007	Anglo Platinum	Platinum Group Metals	PFS	Completed PGE Mineral Resource update for Ga Pasha project prefeasibility study – South Africa
2007 - 2008	Lonmin Platinum	Platinum Group Metals	Internal Report	Provided technical advice and supervision in generating mineral resources for Baobab Platinum mine. – South Africa
2011	INV Metals	Copper	Resource Estimate	Mineral Resource Estimations, plus Ni43-101 for Okohongo Cu prospect - Namibia
2011	Nkwe Platinum	Platinum Group Metals	FS	Mineral Resource Estimations for their Garatau PGE project, as part of a Feasibility Study. – South Africa
2011-2014	AngloGold Ashanti	Gold	Annual Resource Report	Annual update and reconciliation of resources for Siguiri Gold Mine. – Guinea Basao.
2011-2012	Metorex Group	Copper	PFS	Update Mineral Resources for Kinsenda Copper project, as part of an ongoing feasibility study. - DRC
2012/2014	Energizer Resources	Graphite	PFS	Mineral Resource Estimations for their Molo graphite project,as part of a Feasibility Study - Madagascar
2013/2014	Helio Resources	Gold	PFS	Mineral Resource Estimation, as part of the Ni43-101 for their SMP deposit. - Tanzania.

CERTIFICATE OF AUTHOR

This Certificate has been prepared to meet the requirements of National Instrument 43-101 Standards of Disclosure for Mineral Projects ("NI 43-101"), Part 8.1.

a) **Name, Address, Occupation:**

Philip John Hancox

30 Seventh Avenue, Parktown North, Randburg, Gauteng, South Africa

General Manager

b) **Title and Effective Date of Technical Report:**

Molo Feasibility Study, National Instrument 43-101 Technical Report

Effective date: 6th February 2015.

c) **Qualifications:**

I graduated with a B.Sc. Honours (1990) and Ph.D. (1998) from the University of Witwatersrand - Johannesburg.

I am a member in good standing of the South African Council for Natural Scientific Professions (SACNASP No. No. 400224/04) as well as a Fellow of the Geological Society of South Africa.

I have practiced my profession since 1998.

I have read the definition of "qualified person" set out by NI 43-101 and certify that, by reason of my education, affiliation with a professional association (as defined in NI 43-101) and past relevant work experience, I fulfill the requirements to be a "qualified person" for the purpose of NI 43-101. My relevant experience includes 17 years as a Geologist, of which the last 11 years focused on exploration.

d) **Site Inspection:**

I visited the site during May of 2012 and 2013.

e) **Responsibilities:**

I am responsible for the following sections: Sections 1.5, 1.7, 1.18.1, 1.19.1, Section 4, Section 5, Section 6, Section 7, Section 8, Section 9, Section 10, Section 11, Sections 25.1, 26.1, 27.1

f) **Independence:**

I am independent of Energizer Resources Inc. in accordance with the application of Section 1.5 of NI 43-101.

g) **Prior Involvement:**

I was responsible for part of Item 1, Items 2 to 13 and items 23 to 27 of the previous National Instrument 43-101, filed on 12th April 2013.

h) **Compliance with NI 43-101:**

I have read NI 43-101 and Form 43-101F1 and the Technical Report has been prepared in compliance with same.

i) **Disclosure:**

As of the effective date of the Technical Report, to the best of my knowledge, information and belief, the Technical Report contains all scientific and technical information that is required to be disclosed to make the Technical Report not misleading.

Dated, 23 March 2015



Philip John Hancox (Pr.Sci.Nat.)

General Manager Africa and Australasia

Caracle Creek International Consulting (Pty) Limited

CERTIFICATE OF AUTHOR

This Certificate has been prepared to meet the requirements of National Instrument 43-101 Standards of Disclosure for Minerals Projects as published 06 February 2105, Part 8.1.

a) **Name, Address, Occupation:**
David Alan Thompson

Beacon Minerals, 133A Villiers Drive, Clarendon, Pietermaritzburg, 3201

Mining Consultant

b) **Title and Effective Date of Technical Report:**
Molo 240ktpa Feasibility Study, National Instrument 43-101 Technical Report

Effective date: 6th February 2015.

c) **Qualifications:**
I graduated with a B.Tech (Mining) degree from the University of Johannesburg - in 2010.

I am a Registered Certificated Engineer with the Engineering Council of South Africa (ECSA) – Reg. No. 201190010 and a Certificated Mine Manager (Coal Mines) No 5066

I have completed various studies as summarized below. I have practiced my profession from 2000 to now.

I have read the definition of "qualified person" set out by National Instrument 43-101 and certify that, by reason of my education, affiliation with a professional association (as defined in NI 43-101) and past relevant work experience, I fulfill the requirements to be a "qualified person" for the purpose of NI 43-101. My relevant experience, includes 12 years as a mining engineer and 3 years as a mining consultant.

d) **Site Inspection:**
I visited the site on 11-13 March 2014.

e) **Responsibilities:**
I was responsible for the following sections: 1.8, 1.18.2, 1.19.2, Section 15, Section 16, Sections 25.2, 26.2, 27.2 of the Molo 240ktpa FS 2017.

f) **Independence:**
I am independent of Next Source Material Inc. in accordance with the application of Section 1.5 of National Instrument 43-101.

g) **Prior Involvement:**
I was responsible for the review and sign off of sections 15 and 16 and section 21.2.1 and 21.3.1 of the previous National Instrument 43-101, filed on 12th April 2013.

I was responsible for the following sections: 1.8, 1.18.2, 1.19.2, Section 15, Section 16, Sections 25.2, 26.2, 27.2 of the previous National Instrument 43-101, filed on 12th April 2013.

h) **Compliance with NI 43-101:**
I have read National Instrument 43-101 and Form 43-101F1 and the Technical Report has been prepared in compliance with same.

i) **Disclosure:**

As of the effective date of the Technical Report, to the best of my knowledge, information and belief, the Technical Report contains all scientific and technical information that is required to be disclosed to make the Technical Report not misleading.

Dated, 30th June 2017

David Alan Thompson
Mining Consultant

Summary of recent experience

Year	Client	Commodity	Type Of Study	Project Description
2000/08	Various	Various	Various	Various
2008	Impala Platinum	PGM	Feasibility Study	Feasibility Study on conventional vs. mechanized mining
2008/9	Kangra Coal	Coal	PFS	Western expansion pre-feasibility
2009	Teal Mining (Konkola South)	Copper	Feasibility Study	Mine Design and Costing
2010	WBJV - Massive	PGM	Feasibility Study	Mine Design and Costing
2010/11	Zululand Anthracite Colliery	Anthracite	Feasibility Study	Feasibility + Execution Ngwabe Expansion
2012/13	BECSA – BHP Billiton	Coal	PFS	Pre-Feasibility Study opencast coal mining -RSA
2013	Global Resource	Coal	Concept Study	Concept Study opencast coal mining - Mozambique
2013	Rockgate Capital	Uranium	PFS	Pre-Feasibility Study uranium mining - Mali
2014/15	ENRC -Estima	Coal	Feasibility Study	Feasibility Study opencast coal mining - Mozambique
2014/15	Elandsfontein Phosphate	Phosphate	Feasibility Study	Feasibility Study
2014/15	Maamba Colliery	Coal	BFS	SAMEC compliant resource to reserve mine planning
2014/15	Energizer Resources	Graphite	DFS	Full DFS 860 ktpa from geology to economic analysis
2015	ICVL	Coal	Concept Study	Concept Study opencast coal mining - Mozambique
2016	Morupule Coal Mine	Open Pit Coal	Feasibility Study	Full feasibility for captive colliery supply to IPP - Botswana
2016	Vale Moatize Colliery	Open Pit Coal	Concept Study	LOM Plan review with IPCC concepts applied - Mozambique

Metpro Management Inc.

CERTIFICATE OF AUTHOR

This Certificate has been prepared to meet the requirements of National Instrument 43-101 Standards of Disclosure for Minerals Projects as published October 7, 2005, Part 8.1.

a) **Name, Address, Occupation:**

Oliver Peters

102 Milroy Drive, Peterborough, Ontario, K9H 7T2, Canada

Metallurgical Consultant

b) **Title and Effective Date of Technical Report:**

Molo Feasibility Study, National Instrument 43-101 Technical Report

Effective date: 23rd June, 2017.

c) **Qualifications:**

I am the Principal Metallurgist with Metpro Management Inc., with a business address at 102 Milroy Drive, Peterborough, Ontario K9H 7T2 Canada.

I am a graduate of the Technical University of Aachen, Germany, 1998, and I have practiced my profession continuously since then.

I am a Professional Engineer licensed by Professional Engineers Ontario (Membership Number 100078050).

I have read the definition of "qualified person" set out in National Instrument 43-101 (NI 43-101 or "the instrument") and certify that, by reason of my education, affiliation with a professional association (as defined in NI 43-101) and past relevant work experience, I fulfil the requirements to be a "qualified person" for the purpose of NI 43-101.

My relevant experience with respect to metallurgy and mining project management includes 18 years' experience in the mining sector covering mineral processing, process engineering, and operations and project management.

d) **Site Inspection:**

No site inspection was conducted

e) **Responsibilities:**

I was responsible for the following sections: 1.9, 1.19.3,13, 25.3 and 26.3 of the Molo 240ktpa FS 2017.

f) **Independence:**

I am independent of Next Source Material Inc. in accordance with the application of Section 1.5 of National Instrument 43-101.

g) **Prior Involvement:**

I was responsible for the review and sign off of Sections 1.9, 1.18.3, 1.19.3, Section 13, Sections 25.3, 26.3, 27.3 of the previous National Instrument 43-101, filed on Feb 6 , 2015.

h) **Compliance with NI 43-101:**

I have read National Instrument 43-101 and Form 43-101F1 and the Technical Report has been prepared in compliance with same.

i) **Disclosure:**

As of the effective date of the Technical Report, to the best of my knowledge, information and belief, the Technical Report contains all scientific and technical information that is required to be disclosed to make the Technical Report not misleading.

Dated, 11th July, 2017



Oliver Peters
Metallurgical Consultant

Summary of Relevant Mineral Processing Experience

Graphite

Northern Graphite	Bisset Creek
Focus Metals	Lac Knife
Energizer Resources	Molo
Canada Carbon	Miller
Mason Graphite	Lac Gueret
Alabama Graphite	Coosa County
Syrah Resources	Balama
Black Rock/Mahenge	Ulanzi/Cascade
Ontario Graphite	Kearny
Graphex Mining	Chilalo
Oy Fennoscandian Resources	Aitolampi
Graphite One	Graphite Creek
Sakura	Vein-type Deposit
Magnesita	São Domingos
Dalgraphite	Soyznoye
UEX	Wolf Lake
Standard Graphite	Mousseau Lake
Valterra Resources	Bobcaygeon Graphite
Noram Ventures	Jumbo
Nouveau Monde	Matawinie
Buxton Resources	Yalbra South
Sovereign Metals	Duwi
Sovereign Metals	Dedza
Sovereign Metals	Malingunde

Cu, Ni, PGM

URSA Major Minerals	Shakespeare	Cu, Ni, PGM
Falconbridge	Kabanga	Cu, Ni, PGM
Kennecott	Eagle	Cu, Ni, PGM
URSA Major Minerals	Shining Tree	Cu, Ni, PGM
Landore Resources	Junior Lake	Cu, Ni, PGM
Polymet	Northmet	Cu, Ni, PGM
Wallbridge Mining	Broken Hammer	Cu, Ni, PGM
Franconia	Birch Lake	Cu, Ni, PGM
Twin Metals Minnesota	Nokomis	Cu, Ni, PGM
Inspiration Mining	Langmuir	Ni
First Nickel	West Graham	Ni
Barrick Gold	Sedibelo	PGM
Falconbridge	Raglan	Cu, Ni
Falconbridge	Fraser Morgan	Cu, Ni
Falconbridge	Bowel Township	Cu, Ni, PGM

Falconbridge	Montcalm	Cu, Ni
Kupferschiefer Lausitz GmbH	Spremberg-Graustein	Cu
Noront Resources	Eagle's Nest	Cu, Ni, PGM
Rio Tinto	Tamarack	Cu, Ni, PGM
Starfield Resources	Ferguson Lake	Cu, Ni, PGM

Mo & Mo/Cu

Quadra Mining	Malmbjerg	Mo
Pacific Comox	Ryan Lake	Mo, Cu
Minera Peru Copper	Toromocho	Mo, Cu
TTM Resources	Chu	Mo

Au & Cu/Au

Pebble Limited Partnership	Pebble	Cu, Au
Anatolia	Copler	Au
Saratoga	Copper King	Cu, Au
Kinross Gold	Cerro Casale	Cu, Au
Iamgold	La Arena	Cu, Au
Dominion Minerals	Cerro Chorcha	Cu, Au
Lakeshore Gold	Bell Creek	Au
Aurizon Mines	Joanna	
Aura Minerals	Serrote	Cu, Au
Carpathian Gold	Rovina/Colnic	Au, Cu
Colossus Minerals	Serra Pelada	Au, PGM
Freeport McMoRan	Kucing Liar	Cu, Au
Freeport McMoRan	Grasberg Block Cave	Cu, Au

Complex Cu, Pb, Zn

Iamgold	Westwood Zinc	Pb, Zn, Au, Ag
Globestar	Cerro de Maimón	Au
Overland Resources	Andrew	Pb, Zn, Ag
Falconbridge	Kidd Creek	Cu, Pb, Zn, Ag
Consolidated Zinc	Plomosas	Pb, Zn, Ag, Au
Overland Resources	Darcy	Zn

Diamonds

Hudson Resources	Garnet Lake
Pele Mountain Resources	Festival

Nickel Laterites

Falconbridge	Koniambo
BHP	Gag Island

Miscellaneous

Golder Associates	Diavik	Granit
Mohawk Garnet		Garnet
Baja Mining	Boleo	Limestone
Crevier Minerals	Crevier	Ta, Nb
Titanium Corporation		Oilsand Tailings
Northland Resources	Hannukainen	Iron

CERTIFICATE OF AUTHOR

This Certificate has been prepared to meet the requirements of National Instrument 43-101 Standards of Disclosure for Minerals Projects as published 23 June 2017, Part 8.1.

a) **Name, Address, Occupation:**

Paul Iain Harvey

Met63, 3rd Floor, Block 12, Fancourt Office Park, Felstead Road, Northriding, South Africa

Process Consultant

b) **Title and Effective Date of Technical Report:**

Molo Feasibility Study, National Instrument 43-101 Technical Report

Effective date: 23 June 2017.

c) **Qualifications:**

I graduated with BSc, MSc Chemical Engineering and MBA degrees from the University of Witwatersrand, Johannesburg; Pr. Eng. Certification with the Engineering Council of South Africa and I am a Chartered Chemical Engineer with the South African Institute of Chemical Engineers.

I have read the definition of "qualified person" set out by National Instrument 43-101 and certify that, by reason of my education, affiliation with a professional association (as defined in NI 43-101) and past relevant work experience, I fulfill the requirements to be a "qualified person" for the purpose of NI 43-101. My relevant experience, includes 20 years of metallurgical process engineering.

d) **Site Inspection:**

I have not visited the site.

e) **Responsibilities:**

I was responsible for the following sections: 1.8, 1.18.2, 1.19.2, Section 15, Section 16, Sections 25.2, 26.2, 27.2 of the Molo 240ktpa FS 2017.

f) **Independence:**

I am independent of Next Source Material Inc. in accordance with the application of Section 1.5 of National Instrument 43-101.

g) **Prior Involvement:**

I have no prior involvement with the Molo Feasibility Study

h) **Compliance with NI 43-101:**

I have read National Instrument 43-101 and Form 43-101F1 and the Technical Report has been prepared in compliance with same.

i) **Disclosure:**

As of the effective date of the Technical Report, to the best of my knowledge, information and belief, the Technical Report contains all scientific and technical information that is required to be disclosed to make the Technical Report not misleading.

Dated, 14th July 2017



Paul Iain Harvey
Director

Summary of recent experience

Year	Client	Project Description
1996/97	Billiton Process Research	Research Metallurgist
1997	Fairview Gold Mine	Plant Metallurgist
1997/99	Billiton Process Research	Principal Research Metallurgist
1999/02	BHP Billiton	Principal Process Engineer
2002/04	Alliance Copper Limited (Chile)	Technology Project Leader
2005	BHP Billiton	Principal Process Engineer
2005	GeoBiotics	Senior Process Engineer
2005/07	GeoBiotics	Manager – Africa
2007/10	GeoBiotics	Vice President – Base Metals
2010/12	Trafigura	Process Analyst
2012/14	Trafigura	General Manager – Mining
2014/15	Datta Burton & Associates	Management Consultant
2015/17	Met63	Director

CERTIFICATE OF AUTHOR

This Certificate has been prepared to meet the requirements of National Instrument 43-101 Standards of Disclosure for Minerals Projects as published 06 February 2105, Part 8.1.

a) **Name, Address, Occupation:**

Hercules Albertus Smit
375 Calliandra Street, Pretoria, 0084
Electrical Consultant

b) **Title and Effective Date of Technical Report:**

Molo Feasibility Study, National Instrument 43-101 Technical Report
Effective date: 6th February 2015.

c) **Qualifications:**

B-Eng Electrical Degree	– University of Pretoria	: 1996
B-Eng Electrical Degree (Honours)	– University of Pretoria	: 2001
Professional Engineer (20000338)	– Engineering Council of SA	: 2000

I have completed various projects & studies as summarized below. I have practiced my profession from 1997 to now.

I have read the definition of "qualified person" set out by National Instrument 43-101 and certify that, by reason of my education, affiliation with a professional association (as defined in NI 43-101) and past relevant work experience, I fulfill the requirements to be a "qualified person" for the purpose of NI 43-101. My relevant experience, includes 12 years as a mining engineer and 3 years as a mining consultant.

d) **Site Inspection:**

I have not attended any site inspection.

e) **Responsibilities:**

I was responsible for the following sections:

i.	1.11.2	Power Supply
ii.	18.8.10	Consumer Sub-station
iii.	18.8.11	MCC's and Transformer Bays
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of the Molo 240ktpa FS 2017.

f) **Independence:**

I am independent of Next Source Material Inc. in accordance with the application of Section 1.5 of National Instrument 43-101.

g) **Prior Involvement:**

None

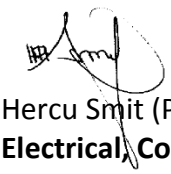
h) **Compliance with NI 43-101:**

I have read National Instrument 43-101 and Form 43-101F1 and the Technical Report has been prepared in compliance with same.

i) **Disclosure:**

As of the effective date of the Technical Report, to the best of my knowledge, information and belief, the Technical Report contains all scientific and technical information that is required to be disclosed to make the Technical Report not misleading.

Dated, 7th July 2017



Hercu Smit (Pr-Eng)
Electrical, Control & Instrumentation Consultant

Summary of recent experience

Year	Client	Commodity	Project Description
1997-2003	Tshwane Utility	Infrastructure	MV & HV Substation Automation, Design & Installation
2003	De Beers	Diamonds	Quickwins : Red Area : EC&I Design, Installation & Commissioning
2004	TransHex	Diamonds	Various Projects : EC&I Design, Installation & Commissioning
2004 - 2012	Eastplats	Platinum	Various Projects : EC&I Design, Installation & Commissioning
2006 - 2014	DRA-SA	Iron Ore, Coal	Various Projects : EC&I Design, Installation & Commissioning. Including BFS, FS & CBE
2007	Letseng Diamonds	Diamonds	Various Projects : EC&I Design, Installation & Commissioning
2012	Tharisa Minerals	Platinum	Various Projects : EC&I Design, Installation & Commissioning. Including BFS, FS & CBE
2008 - 2014	ChromTech	Chrome	Various Projects : EC&I Design, Installation & Commissioning. Including BFS, FS & CBE
2015-2016	UNISA	Solar	EC&I Design, Installation & Commissioning. Including BFS, FS & CBE
2017	MET-63	Nickel-Sulphate	Detail BFS, FS & CBE
2017	MET-63	Chrome	EC&I Management

CERTIFICATE OF AUTHOR

This Certificate has been prepared to meet the requirements of National Instrument 43-101 Standards of Disclosure for Minerals Projects as published 06 February 2105, Part 8.1.

a) **Name, Address, Occupation:**

Etienne van Heerden

EVH Consulting Engineers, 69 Sovereign Drive, Route 21 Corporate Park, Irene, Pretoria, RSA,

Civil and Structural Engineering Consultant

b) **Title and Effective Date of Technical Report:**

Molo 240ktpa Feasibility Study, National Instrument 43-101 Technical Report

Effective date: 6th February 2015.

c) **Qualifications:**

B.Ing. (Civil) degree, Rand Afrkaans Univeristy, 1999

M.Ing. (Engineering Management) degree, University of Johannesburg, 2006

I am a Registered Professional Engineer with the Engineering Council of South Africa (ECSA) – Reg. No. 20080017.

I have completed various studies as summarized below. I have practiced my profession from 2000 to current.

I have read the definition of "qualified person" set out by National Instrument 43-101 and certify that, by reason of my education, affiliation with a professional association (as defined in NI 43-101) and past relevant work experience, I fulfill the requirements to be a "qualified person" for the purpose of NI 43-101. My relevant experience, includes 12 years as a mining engineer and 3 years as a mining consultant.

d) **Site Inspection:**

I have not visited the site.

e) **Responsibilities:**

I was responsible for the following sections:

Civil and infrastructure design and drawings for the process plant and associated infrastructure, as well as the associated works information document

f) **Independence:**

I am independent of Next Source Material Inc. in accordance with the application of Section 1.5 of National Instrument 43-101.

g) **Prior Involvement:**

I was not involved with the previous studies on the project

h) **Compliance with NI 43-101:**

I have read National Instrument 43-101 and Form 43-101F1 and the Technical Report has been prepared in compliance with same.

i) **Disclosure:**

As of the effective date of the Technical Report, to the best of my knowledge, information and belief, the Technical Report contains all scientific and technical information that is required to be disclosed to make the Technical Report not misleading.

Dated, 23rd June 2017



Etienne van Heerden (Pr.Eng)
Civil and Structural Consultant

Summary of recent experience

Year	Client	Commodity	Project Description
2015 to present	Various EVH Consulting Clients (Phalaborwa Mining Company, Khoemachau Mining, Triomf Fertilizers, Screen Doctor, Carmaky Engineering, Sedgman Africa, Execudraw, Watercare Mining)	Various	Managing and directingtheconsulting business and providing design and project management services on various projects. Recent Clients/Projects: • PMC Underground Crushing Station Structural design services • 16 000m2 Fresh Produce market in the DRC (Structural design services) • Khoemachau Mining Infrastructure roads design services • Warehouses and infrastructure • Various high end residential developments • Water treatment plants
2012-2015	Khoemachau Mining	Copper	PFS, FS and DFS for a new copper mine in Botswana
2015	Tulu Kapi Gold	Gold	Engineering manager for the Front End Engineering Design
2013	Coal of Africa	Coal	Vele Colliery Expansion FEED

Year	Client	Commodity	Project Description
2010-2012	SASOL	Oil	CTFE Project (Lead Engineer) EPCM
2008-2010	SASOL	Gas	Temane Expansion Project Mozambique EPCM
2009	SASOL	Diesel	Benzene Reduction Project (EPCM)
2006	Ahafo Gold Mine	Gold	50 Tailings dam HDPE Lining Project
2005	WBHO	Infra	The Innovation Hub Infrastructure Development (Construction)
2003-2005	Bakwena Concession	Infra	Road and Bridge Construction N4 Bakwena Highway
2003	ACSA	Infra	Charlie Apron Infrastructure Construction
2000-2002	Botswana Govt	Infra	Ramotswa Sewer Reticulation project

CERTIFICATE OF AUTHOR

This Certificate has been prepared to meet the requirements of National Instrument 43-101 Standards of Disclosure for Minerals Projects as published 23 June 2017, Part 8.1.

a) **Name, Address, Occupation:**

George Papageorgiou

Epoch Resources (Pty) Ltd, Building A, Viscount Office Park, 8 Viscount Road, Bedfordview, 2008, South Africa

Tailings Engineer

b) **Title and Effective Date of Technical Report:**

Molo Feasibility Study, National Instrument 43-101 Technical Report

Effective date: 23 June 2017.

c) **Qualifications:**

I graduated with BSc, MSc, PhD Civil Engineering degrees from the University of Witwatersrand, Johannesburg.

My relevant experience includes 20 years of Tailings Design Engineering/Consulting.

d) **Site Inspection:**

I have not visited the site.

e) **Responsibilities:**

I was responsible for the following sections: 1.20.3, 17.2, 18.9, 20.3.4, 25.3 of the Molo 240ktpa FS 2017.

f) **Independence:**

I am independent of Next Source Material Inc. in accordance with the application of Section 1.5 of National Instrument 43-101.

g) **Prior Involvement:**

I have no prior involvement with the Molo Feasibility Study

h) **Compliance with NI 43-101:**

I have read National Instrument 43-101 and Form 43-101F1 and the Technical Report has been prepared in compliance with same.

i) **Disclosure:**

As of the effective date of the Technical Report, to the best of my knowledge, information and belief, the Technical Report contains all scientific and technical information that is required to be disclosed to make the Technical Report not misleading.

Dated, 17th July 2017

Dr George Papageorgiou
Director

Summary of recent experience

Dr George Papageorgiou

Position: Director & Founding Partner

Company: Epoch Resources (Pty) Ltd

Profession: Civil Engineer

Date of Birth: 21 July 1969

Years with Company: Since 01 March 2006

Nationality: South African & Greek

Qualifications:

BSc Eng (Civil), University of the Witwatersrand, 1991

MSc Eng (Civil), University of the Witwatersrand, 1994

PhD Eng (Civil), University of the Witwatersrand, 2004

Membership of Professional Institutions:

Gigsa – The South African Chapter of the International Geoosynthetics Society;

SANCOLD – South African Commission of Large Dams;

SAICE – South African Institute of Civil Engineering, Geotechnical Division;

SAIMM – South African Institute of Mining & Metallurgy;

Languages: English (first language)

Afrikaans

Greek

Employment Record: SRK – 1994 to 1995 – Junior Engineer

Metago Consulting Engineers – 1999 to 2006 – Engineer & Director

Key Experience

George Papageorgiou is a Co-Founder and Director of Epoch Resources (Pty) Ltd (*Epoch*) and is based in Johannesburg, South Africa. George has worked in the mining related sector since 1994 specialising in the field of mine residue disposal and specifically in the design, on-going monitoring and associated environmental impacts of tailings dams. George's post graduate studies are in the fields of unsaturated soils, liquefaction and flow slide failures.

George was previously a senior consultant and Director at a consulting engineering company before leaving to co-found Epoch in 2005.

George has been involved in mine residue disposal projects in South Africa and internationally, Lesotho, Botswana, Zimbabwe, Namibia, Australia, Brazil, Burkina Faso, Mali, Ghana, Liberia, Sudan, Saudi Arabia, Democratic Republic of Congo, Ivory Coast, Armenia, Georgia, Tanzania, Angla and Algeria. His experience ranges from pre feasibility through to detail design, construction supervision and on-going monitoring of mine residue facilities, probabilistic water and salt balances, tailings dam seepage assessments, liquefaction and flow slide assessments, storm water management and design, due diligences and technical reviews.

In addition to the technical aspects of mine residue facilities, George has been involved in Environmental Impact Assessments and Environmental Management Reports, providing input on aspects pertaining to mine residue disposal such as seepage assessments, environmental management measures, closure, hydrology, storm water management and overall mine water balances.

George has worked on various projects and commodities for a variety of local and international companies including Randgold Resources, Goldfields, Tati Nickel, Endeavour Mining, DeBeers, Aureus Mining, B2Gold, Shanta Gold, Glencor, DRA and Senet.

Publications

Papageorgiou G (2004) “Liquefaction Assessment and Flume Modelling of the Merriespruit Gold and Bafokeng Platinum Tailings”, PhD Eng (Civil) Thesis, University of the Witwatersrand, Johannesburg, South Africa, 2004

Fourie AB and G Papageorgiou (2001) “Defining an appropriate steady state line for Merriespruit gold tailings”, Canadian Geotechnical Journal, Vol 38, pp 695-706.

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Papageorgiou G, AB Fourie and GE Blight (1999) “Investigation of flow failures by means of a flume model”, Tailings and Mine Waste 1999.

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Papageorgiou G, AB Fourie and GE Blight (1997) “Flow failure and static liquefaction of tailings dams”, Second International Conference on Mining and Industrial Waste Management, South Africa, 1997.

Papageorgiou G (1997) “Investigation of breached tailings dams and flow failures" Civil Engineering, South African Institute of Civil Engineering, February, pp 18-20

Papageorgiou G (1996) “Investigation of breached tailings dams and flow failures"” Young Water, Environmental and Geotechnical Engineers Conference, Bothas Hill, South Africa, 1996.

Fourie AB, G Papageorgiou and GE Blight (1995) “The rapid determination of the moisture retention characteristics of soils” American Society for Testing and Materials, pp 276-285.

Fourie AB and G Papageorgiou (1995) “A technique for the rapid determination of the moisture retention relationship and hydraulic conductivity of unsaturated soils”, Proceedings of the First International Conference on Unsaturated Soils, edited by EE Alanso and P Delage, UNSAT’95, Paris, France, 1995, pp 485-490.

Papageorgiou G (1994) “Evaluation of the moisture retention and hydraulic conductivity characteristics of unsaturated soils”, MSc Eng (Civil) Dissertation, University of the Witwatersrand, Johannesburg, South Africa, 1994.

Papageorgiou G (1993) “Laboratory investigation of the flow of water in saturated/unsaturated soils”, Second Southern African Young Geotechnical Engineers Conference, Stellenbosch, South Africa, 1993.

Selected Key Projects

Name of Project:	Kibali Gold Mine Tailings Storage Facilities
Project Duration:	2010 to 2016
Location:	DRC
Client:	Randgold Resources Ltd
Project Description:	Feasibility, Detail Design and Construction Supervision of 2 HDPE lined & 1 unlined Tailings Dams, the associated Water Storage Dams and Main Concrete Lined Storm Water Diversion Channel
Value of Project:	US$ 140 million
Position & Duties:	Lead Engineer responsible for leading the design and construction supervision team and overseeing all associated aspects of works

Name of Project: Kibali Gold Mine Ambarau Hydropower Facility

Project Duration: 2014 to 2016

Location: DRC

Client: Randgold Resources Ltd

Project Description: Hydrological Study, Detail Design and Construction Assistance of a Hard fill and Earth fill hydropower dam wall

Value of Project: US$ 110 million

Position & Duties: In conjunction with ARQ Consulting Engineers overseeing of the design & construction assistance

Name of Project: Kibali Gold Mine Nzoro Hydropower Facility

Project Duration: 2013 to 2015

Location: DRC

Client: Randgold Resources Ltd

Project Description: Hydrological Study & Detail Design of gabion weir

Value of Project: US$ 5 million

Position & Duties: Lead Engineer, overseeing of the design team and all design aspects

Name of Project: Maseve Platinum Mine Tailings Storage

Project Duration: 2008 to 2016

Location: South Africa

Client: Platinum Group Metals Ltd

Project Description: Feasibility, Detail Design and Construction Assistance of HDPE lined Tailings Dam, the associated Water Storage Dams

Value of Project: ZAR 120 million

Position & Duties: Lead Engineer responsible for leading the design and construction supervision team and overseeing all associated aspects of works

Name of Project: New Liberty Gold Mine Tailings Storage Facility

Project Duration: 2013 to 2015

Location: Liberia

Client: Aureus Minning Company Ltd

Project Description: Feasibility, Detail Design and Construction Assistance of Valley Tailings Dam, the associated Water Storage Dams & River Diversion

Value of Project: US$ 40 million

Position & Duties: Lead Engineer responsible for leading the design team and providing support to the construction supervision team and overseeing all associated aspects of works

\

Name of Project: Kinsenda Copper Mine Tailings Storage Facility

Project Duration: 2013 to 2016

Location: DRC

Client: Metorex (Pty) Ltd

Project Description: Feasibility, Detail Design and Construction Assistance of Tailings Dam, the associated Water Storage Dams

Value of Project: US$ 30 million

Position & Duties: Lead Engineer responsible for leading the design and providing assistance to the construction supervision team and overseeing all associated aspects of works

Name of Project: Tabakoto Gold Mine Tailings Storage Facility

Project Duration: 2012 to 2014

Location: Mali

Client: Endeavour Ltd

Project Description: Feasibility Study, Detail Design and Construction Supervision of HDPE lined Tailings Dam and associated Water Storage Dams

Value of Project: US$ 40 million

Position & Duties: Lead Engineer responsible for leading the design and construction supervision team and overseeing all associated aspects of works

Name of Project: New Luika Gold Mine Tailings Storage Facility

Project Duration: 2011 to 2013

Location: Tanzania

Client: Shanta Gold Ltd

Project Description: Feasibility Study, Detail Design and Construction Assistance of Tailings Dam

Value of Project: US$ 20 million

Position & Duties: Lead Engineer responsible for leading the design, providing assistance to the construction supervision team and overseeing all associated aspects of works

Name of Project: St Helena 1,2, &3 Gold Mine Tailings Storage Facility

Project Duration: 2009to 2010

Location: South Africa

Client: Harmony Gold Ltd

Project Description: Feasibility, Detail Design and Construction Supervision of Tailings Dam, the associated Water Storage Dams

Value of Project: ZAR 90 million

Position & Duties: Lead Engineer responsible for leading the design and construction supervision team and overseeing all associated aspects of works

Name of Project: Tongon Gold Mine Tailings Storage Facility, Water Storage Dam and River Diversion

Project Duration: 2009 to 2010

Location: Ivory Coast

Client: Randgold Resources Ltd

Project Description: Hydrological Study, Feasibility, Detail Design and Construction Supervision of Tailings Dam, 40 million m^3 Water Storage Dam and River Diversion

Value of Project: US$ 40 million

Position & Duties: Lead Engineer responsible for leading the design and construction supervision team and overseeing all associated aspects of works

Name of Project: Gounkoto Gold Mine Water Diversion Dams & Channel

Project Duration: 2011 to 2013

Location: Mali

Client: Randgold Resources Ltd

Project Description: Hydrological Study, Detail Design and Construction Supervision of Diversion Dams & Channel

Value of Project: US$ 30 million

Position & Duties: Lead Engineer responsible for leading the design and construction supervision team and overseeing all associated aspects of works

Name of Project: Perkoa ZInc Mine Tailings Storage Facility

Project Duration: 2006 to 2014

Location: Burkina Faso

Client: Gencor Ltd

Project Description: Hydrological Study, Feasibility, Detail Design and Construction Supervision of HDPE lined Tailings Dams, and associated Water Storage Dams

Value of Project: US$ 20 million

Position & Duties: Lead Engineer responsible for leading the design and construction supervision team and overseeing all associated aspects of works

CERTIFICATE OF AUTHOR

This Certificate has been prepared to meet the requirements of National Instrument 43-101 Standards of Disclosure for Minerals Projects as published 6 February 2015, Part 8.1.

a. Name, Address, Occupation:

Albertus (Alkie) Wynand Christoffel Marais

GCS Water and Environment (Pty) Ltd, 63 Wessel Road, Rivonia, 2128, South Africa

Director Water

b. Title and Effective Date of Technical Report:

Molo Feasibility Study, National Instrument 43-101 Technical Report

Effective date: 13th July 2017.

c. Qualifications:

B.Sc. (Geology) degree from the University of Free State - 1992.

B.Sc. (Hons) (Geology) degree from the University of Free State - 1993.

M.Sc.(Geohydrology) degree from the University of Free State - 1997

I am a registered scientist with the South African Council for Natural Scientific Professions (SACNASP) (Pr.Sci.Nat.) – Earth Sciences – Reg. No. 40001206

I have completed various mining related studies as summarized below. I have practiced my profession from 1994 to now.

I have read the definition of "qualified person" set out by National Instrument 43-101 and certify that, by reason of my education, affiliation with a professional association (as defined in NI 43-101) and past relevant work experience, I fulfill the requirements to be a "qualified person" for the purpose of NI 43-101. My relevant experience includes 3 years as a geologist and 20 years as a hydrogeological consultant.

d. Site Inspection:

I visited the site on 11-13 March 2014.

e. Responsibilities:

I was responsible for the following sections: Sections 18.6, 18.8.8, 18.8.9, Section 20 of the Molo 240ktpa FS 2017, i.e. Water and Environmental.

f. Independence:

I am independent of Next Source Material Inc. in accordance with the application of Section 1.5 of National Instrument 43-101.

g. Prior Involvement:

I was responsible for the review and sign off of sections 11 and 12 of the previous National Instrument 43-101, filed in 2014.

h. Compliance with NI 43-101:

I have read National Instrument 43-101 and Form 43-101F1 and the Technical Report has been prepared in compliance with same.

i. Disclosure:

As of the effective date of the Technical Report, to the best of my knowledge, information and belief, the Technical Report contains all scientific and technical information that is required to be disclosed to make the Technical Report not misleading.

Dated, 13 July 2017



Alkie Marais
Director Water

Summary of recent experience

Year	Client	Commodity	Type Of Study	Project Description
1999 - 2007	Various mining clients	Various	Various	Groundwater/Geochemistry/EIA
2006	Kayelekera Uranium Project, Malawi, Paladin	Uranium	Feasibility Study	Groundwater/Geochem Section
2008/9	Mmamabula Power Station and Serome Coal Mine, Botswana,	Coal	ESIA/Feasibility	Underground Coal Mine and Power Station – Water /Geochem
2008	Sheba's Ridge Project	PGM	Feasibility Study	ESIA
2013	Bomi Hill Mine, Liberia	Iron Ore	Feasibility/ESIA	Groundwater/ESIA
2007-2014	Nkomati Mine	Nickle	BFS/Detailed Design/Optimisation/EIA	Various integrated EIA/Engineering/Dewatering/Waste Management
2013/2014	Bulyanhulu Mine, Tanzania	Gold	Feasibility Study	New TSF – Groundwater/EIA
2013/2014	Pumpi North, DRC	Copper	Feasibility Study	Open pit water management
2014/15	ENRC –Estima, Mozambique	Coal	Feasibility Study	Feasibility Study opencast coal mining – Mozambique - Groundwater
2012/2015	Kinsenda Mine, DRC	Copper	Feasibility Study/Detailed Design	Underground mine dewatering/EIA
2014/15	Mukulu Manganese Project	Manganese	Feasibility Study	Underground and Open Pit – Water Section/EIA

2014/15	Energizer Resources	Graphite	DFS	Full DFS 860 ktpa from geology to economic analysis – Water and Environmental
2015/2016	Vale Moatize Mine, Mozambique	Open Pit Coal	Detailed Design/Optimisation	Various dewatering water supply components
2016/2017	ERG Comide Feasibility Project, DRC	Copper and Cobalt	Feasibility Study	Water Section

Appendix A

Graphite Market Study

Roskill | Approachable. Independent. Expert

Consulting Group Ltd

NextSource Materials Inc

Graphite Market Study and Price Forecast

June 2017

54 Russell Road | London SW19 1QL | United Kingdom | Tel: +44 20 8417 0087 | Fax: +44 20 8417 1308
Email: alison@roskill.com | Website: www.roskill.com

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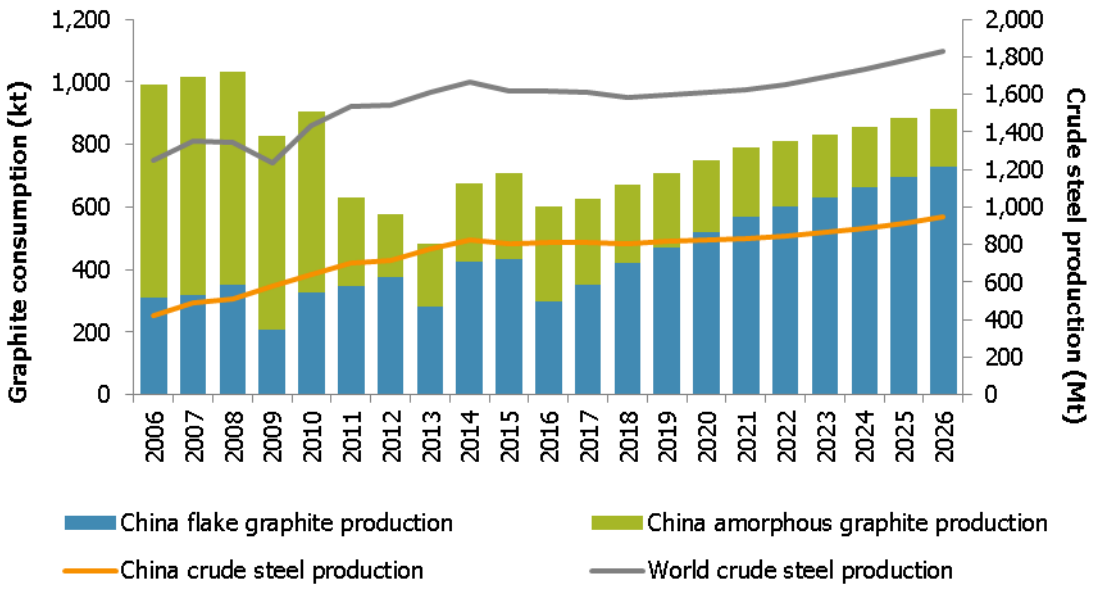
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1. Summary

In the coming years, the graphite industry is set to change from a period of slow scale growth and low pricing to one of rapid growth and price recovery. Graphite consumption has previously been led by steel market applications and Chinese industrialisation but has slowed along with Chinese steel output over the last five years. However, rapid growth in demand for natural flake graphite and synthetic graphite in the lithium-ion battery industry is forecast to underpin total graphite demand growth of 4-6%py between 2016 and 2026. By 2026, consumption of graphite in battery applications could be 5 to 10 times higher than the current level, dependent on the uptake of lithium-ion battery-based electric vehicles (EVs) and other lithium-ion battery applications.

Figure 1 shows the historical link between trends in crude steel and natural graphite, the largest market for which is in steelmaking refractories. Chinese steel production grew every year in the ten years between 2004 and 2014, at an average of 11.7%py, but fell for the first time in 2015 by 18.9Mt (2.3%). Although production recovered by an estimated 7.4Mt (0.9%) in 2016, it is forecast to fall again in 2017 and 2018 after which, it could return to small scale growth. Other traditional markets shaped by crude steel production include electrodes (the largest market for synthetic graphite), recarburising and foundries.

Figure 1: China: Historical and forecast production of natural graphite compared with production of crude steel, 2006-2026



Source: Roskill, World Steel Association

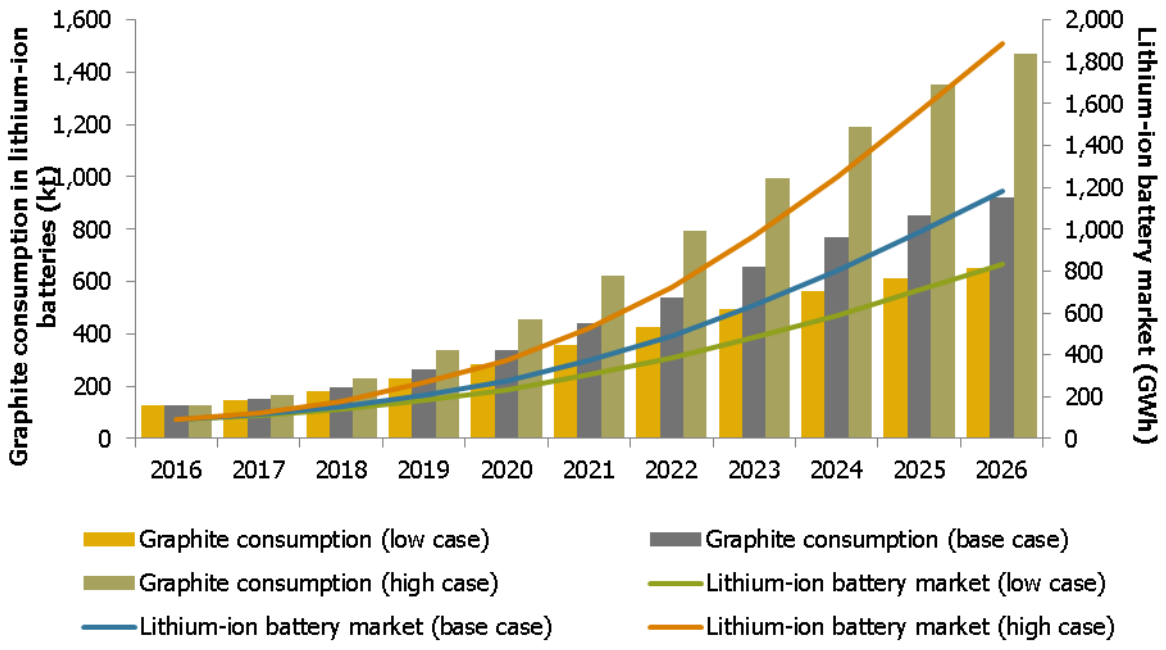
Figure 1 also highlights the uncoupling of steel and graphite trends going forward. Possible future scenarios for graphite consumption growth within the lithium-ion battery market are shown in . Consumption of raw graphite in these batteries could grow by 17.9%py to 28.0%py between 2016 and 2026. Potential growth rates depend on the uptake of emerging lithium-ion battery markets in EVs and, to a lesser extent, energy storage (ESS).

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The majority of EV growth is expected to come from China, where number of incentives are in place to encourage EV purchases and EV public transport schemes are being rolled out. Incentives were temporarily cut in 2016 as a result of widespread corruption but, by 2017, had been reintroduced in different ways. Other countries have very high EV targets and incentives in place as part of plans to help lower city pollution levels.

Outside China, Tesla is ramping up lithium-ion battery production at its US 'Gigafactory'; full capacity could supply batteries for 0.5M electric vehicles (equivalent to output of 35GWh/yr of cells and 50GWh/yr of battery packs). Tesla is expected to announce the location of a second factory for Europe in 2017. Other large lithium-ion battery plants under development include those of BMC in Germany and LG Chem in Poland (both of which are planned to open in 2017), Samsung SDI in Hungary (which plans to produce batteries for 50,000 EVs and could open in 2018), SGF Energy in Sweden and a rumoured plant to be shared between Jaguar Land Rover, BMW and Ford.

Figure 2: Forecast scenarios for raw graphite[1] consumption and lithium-ion battery market, 2016-2026



Source: *Roskill*
Note: *1-Includes flake graphite before processing into spherical graphite*

The total battery market accounted for around 7% of global graphite consumption in 2016 but could grow to account for 26% by 2026. Given such high levels of growth, there will be increased demand for both natural and synthetic graphite in the future of lithium-ion batteries. Synthetic graphite demand in this application is expected to grow at a higher rate than natural graphite as battery supply chains continue to be dominated by China. This is because China is producing an increasing amount of batteries for domestic consumption, some of which have lower specifications and may contain secondary synthetic graphite.

Lithium-ion battery anodes are the major area of competition between natural and synthetic graphite. Synthetic graphite has traditionally been used in applications that require the

highest carbon grades and good consistency in terms of grade and impurities. Since the 1990s, however, the natural graphite industry has become increasingly sophisticated and growing quantities of highly processed products are now available. For use in lithium-ion batteries, natural flake graphite is first purified and ground into a spherical shape; the resulting product, spherical graphite can then compete with synthetic graphite.

After coatings are applied, the price of spherical graphite approaches that of synthetic graphite. In China, where there is higher availability of low value synthetic graphite (including an increasing amount of secondary synthetic graphite available as waste from the electrode sector), synthetic graphite is the most common choice of anode material. In other countries, including Japan, a higher proportion of anodes are produced with spherical graphite, sourced from China. Falling synthetic prices in the last few years are thought to have increased the use of synthetic graphite in the battery market. Currently, it is believed that there is considerable overcapacity for spherical graphite production in China.

In reality, lithium-ion battery anode manufacturers use a mix of graphites and other carbons to achieve the best battery specifications for the final application, such as fast charging speed or long battery life. Almost all of the world's production of lithium-ion battery anode material currently takes place in China. China is also the largest producer of natural graphite suitable for processing into spherical graphite (fine to medium size flake) and the largest producer of synthetic graphite. As EV and associated lithium-ion battery production increases worldwide, there is the potential for battery supply chains to develop outside of China. Spherical graphite production is currently limited to China because of high processing costs. A number of potential graphite producers in the rest of the world are trying to develop alternative spherical graphite techniques, such as thermal purification, and to limit the use of reagents such as strong acids. As of early 2017, these new technologies had yet to be proven commercially.

1.1 Production

Production of graphite was an estimated 2.41Mt in 2015 but fell back to 2.35Mt in 2016 as Chinese production of natural flake graphite declined by around 30% as a result of on-going environmental closures. In 2016, synthetic graphite accounted for around 64% of production (1.50Mt) and natural graphite 36% (0.85Mt). China is the largest producer of natural flake, natural amorphous and synthetic graphite and, as such, controls graphite pricing. Between 2006 and 2016, global graphite production declined by 0.4%py, mostly as a result of falling production of natural amorphous graphite in China.

China continues to encourage production and export of higher value, more heavily processed products through its successive five-year plans and through the imposition of taxes and rebates on traded graphite products. This includes the production of spherical graphite from natural flake graphite for use in lithium-ion battery anodes which has led to serious concerns over the use of strong acids and other chemicals. Government environmental inspecitions and subsequent closures are on-going in the industry.

Consolidation is underway to bring the large number of small scale mining operations under the control of a few major Chinese producers. This process is now complete in the amorphous graphite sector, which is almost entirely under state control. There has been

some consolidation in flake graphite, focusing on backwards integration from lithium-ion battery anode manufacturers such as Shenzhen BTR New Energy Materials. It is thought that further consolidation in flake graphite will be limited by the greater physical distribution of flake graphite deposits than in the amorphous sector.

Synthetic graphite is manufactured from petroleum needle coke through the graphitisation process. This process consumes large amounts of energy and is, therefore, very expensive. The industrial process of synthetic graphite manufacture can be tightly controlled to produce high grade graphite grading over 99% C with a strict set of specifications that suit the intended application. Because synthetic graphite is made with a customer in mind, production is roughly the same as consumption in any given year.

Production of synthetic graphite increased by a CAGR of 1.6%py between 2006 and 2016 as demand for graphite electrodes slowed with weakening global steel markets. Electrode manufacturers have closed capacity in the traditional regions of Europe, North America and Japan over the last five years. Meanwhile, capacity has grown in China and other parts of Asia but demand growth has been limited by a decline in China's transition to EAF steel production as a result of steel scrap shortages. Over the next ten years, rapid growth in the lithium-ion battery market and increasing Chinese electrode demand from EAFs are forecast to drive a higher rate of synthetic graphite production growth of 3.4%py to 4.6%py.

Synthetic graphite production is concentrated in close proximity to end users with China's proportion of ouput growing to 48% of the total in 2016 while the proportion from other regions fell including Japan (19%), USA (11%) and Europe (6%). Major synthetic producers include GrafTech (USA), Fangda (China), Showa Denko (Japan), Sinosteel Engineering & Technology (China) and SGL (Germany); all are leading manufacturers of graphite electrodes.

In recent years, poor performance in electrodes and the synthetic graphite sector as a whole has resulted in restructuring and a series of acquisitions amongst the major players. Synthetic graphite manufacturers are also looking to take advantage of the growing lithium-ion battery market and many have transitioned capacity away from electrodes to lithium-ion battery powders. In August 2015, GrafTech International became a wholly owned subsidiary of Brookfield Asset Management. In October 2016, the Japanese anode material manufacturer Showa Denko agreed to purchase SGL Carbon's synthetic graphite electrode business. In February 2017, Imerys Graphite & Carbon acquired Nippon Power Graphite of Japan, which has a patented CVD coating technology for the production of lithium-ion battery anode materials.

Natural graphite is mined from a number of countries but production is concentrated in China which accounted for approximately 75% of global output in 2015 and 70% in 2016. Global production of natural graphite fell by an average of 3.1%py between 2006 and 2016, because of constraints on Chinese production.

The geological formation of natural graphite creates three types for commercial use: flake graphite (with a distinct flake structure that is categorised by the industry in terms of size as fine, medium or large flake), amorphous graphite (with no flake structure and typically lower carbon grade) and vein graphite (a speciality product only produced in Sri Lanka). Of the 0.85Mt of estimated natural graphite production in 2016, flake graphite accounted for just

over 60% (0.53Mt), amorphous graphite almost 40% (0.32Mt) and vein graphite less than 1%.

China produced an estimated 600kt of natural graphite in 2016, split equally between flake and amorphous types, and accounted for an estimated 57% of global flake graphite and 93% of global amorphous graphite output. Amorphous graphite mining is concentrated in Hunan province. The state-owned enterprise (SOE) South Graphite is the largest producer (following recent consolidation in Hunan) followed by Chenbei Mining Industry. Most flake mining takes place in the provinces of Heilongjiang and Shandong. Major producers include Luobei County Yunshan Graphite Mining, Aoyu Graphite Group, Jixi Changyuan Mining, Jixi Pucheng Graphite, Qingdao Haida Graphite and Qingdao Jinhui Graphite.

The second-largest flake graphite producer is Brazil, which supplied an estimated 95kt in 2016 from one major producer, Nacional de Grafite. This is followed by India, Canada, Ukraine and Pakistan, each producing over 10ktpy. India produces relatively low grade graphite that is mostly consumed domestically. Canada is a processor and exporter of high grade products to international markets. In addition, Norway, Russia, Madagascar and Zimbabwe each produce over 5ktpy of flake graphite while Mexico and Russia each produce over 5ktpy of amorphous graphite.

Global production of flake graphite grew by around 1.4%py between 2006 and 2016. Production is forecast to increase by a CAGR of 6.7%py to 11.1%py between 2016 and 2026 to meet the robust growth expected in lithium-ion battery demand. Large amounts of flake graphite are consumed in the production of spherical graphite for these batteries. All spherical graphite production currently takes place in China.

Large increases in flake graphite production will be required to meet rising demand to 2026 from both new and existing producers. Initially, Chinese producers are expected to increase production at existing capacity. In the longer term, new producers both inside and outside of China will be established. By early 2017, 30 producers outside China had progressed their projects to scoping study or beyond, and the total planned capacity is over 1.35Mtpy. The largest increases are expected to come from Africa where over 1Mtpy of capacity is planned from Madagascar, Malawi, Mozambique, Namibia and Tanzania. Syrah Resources aims to begin production in Mozambique in 2017; its project is the largest under development, with a reported 380ktpy of capacity that could be realised, if markets require. Other projects are also under development in Australia, Canada, India, Russia, Sweden and the USA. However, not all of these projects are expected to come to fruition.

Production of amorphous graphite declined by 7.5%py between 2006 and 2016 as a result of declining demand and the closure of mines in China. Around 210 mines were closed during the South Graphite consolidation programme which began in 2010. Although some of this capacity has now reopened, South Graphite only plans to bring 20 mines back online in the long-term. Combined with falling demand, amorphous production will not return to the levels seen pre-2009.

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1.2 Trade

Trade in synthetic graphite was around 1.8Mt in 2016. The two largest categories were electrodes and artificial graphite, which accounted for 809kt and 513kt respectively in 2016. Artificial graphite has seen the highest level of growth at 3.9%py 2006-2016, while electrode trade has grown marginally at 0.3%py. Trade in other categories declined over the same period. China is the main exporter for four of five synthetic graphite categories (excluding entrepôt trade through the Netherlands).

Since 2009, Malaysia has grown rapidly to become the largest importer of artificial graphite, accounting for less than 1% of imports in 2006 but 46% by 2016, in addition to the traditional import markets of the USA and Japan. Imports of electrodes to Iran also grew through 2012/2013; although imports have since fallen back, Iran was still the largest importer in 2016, accounting for 10% of electrode imports.

Exports of natural graphite have declined over the last decade. Exports reached a high of around 72% of production in 2007 but had fallen to around 40% by 2016 due to China's increasing domestic consumption and its continued shift towards higher value, processed exports. China is still the world's largest exporter, accounting for 239kt (70%) of all natural graphite exports in 2016. In 2017, China removed its long standing 20% tax on exports of natural graphite. Exports of added value products continue to be encouraged; for example, a 13% tax rebate is available for exports of spherical graphite.

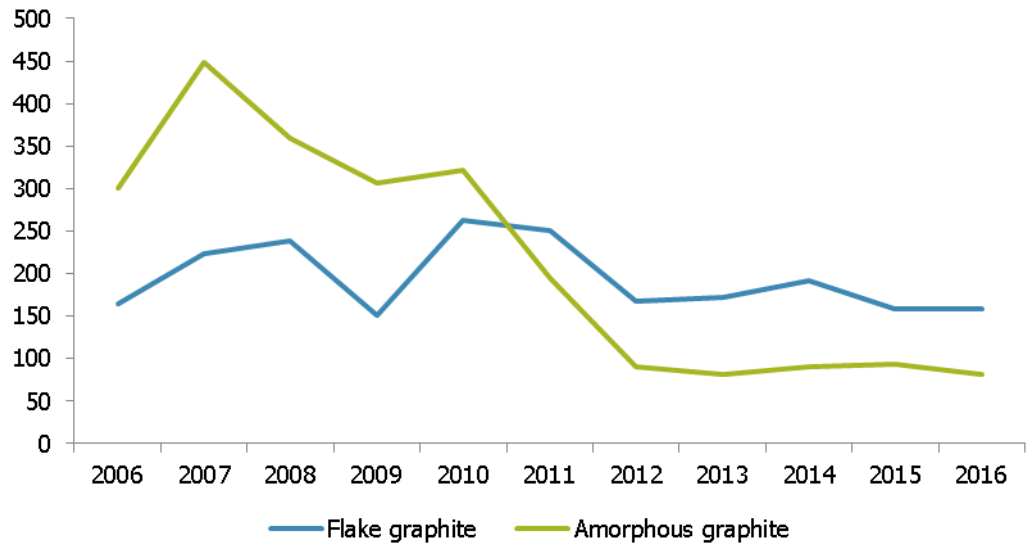
Chinese exports of flake graphite fell by by an average of 0.4%py between 2006 and 2016 (Figure 3). Other large exporters of flake graphite include Brazil, Germany, the USA and Canada. Global exports will increase in future if flake graphite production rises outside China. China could even begin to import flake graphite from new sources, if it maintains its monopoly on the expanding lithium-ion battery supply chain.

Chinese exports of amorphous graphite fell by an average of 12.3%py between 2006 and 2016 in line with falling global demand and cuts to Chinese capacity. The rate of decline is expected to slow in the coming years as the replacement of amorphous graphite with alternative products becomes more complete.

Japan has been the largest destination for natural graphite shipments for many years, but its proportion of global imports fell from 37% in 2006 to 13% by 2016. Germany and the USA are also major importers accounting for a further 11% each in 2016. The largest single trade flow of natural graphite is from China to Japan, which accounted for 12% of all flake graphite and 21% of all amorphous graphite shipments in 2016. This is followed by exports of flake graphite from China to India, Germany and the USA. The USA also imports large amounts of flake graphite from Mexico and Canada. A small number of major companies in North America and Europe import from international mining operations for processing, purification and blending. They then export finished products to international markets.

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Figure 3: China: Exports of flake and amorphous graphite, 2006-2016 (kt)



Source: Global Trade Tracker

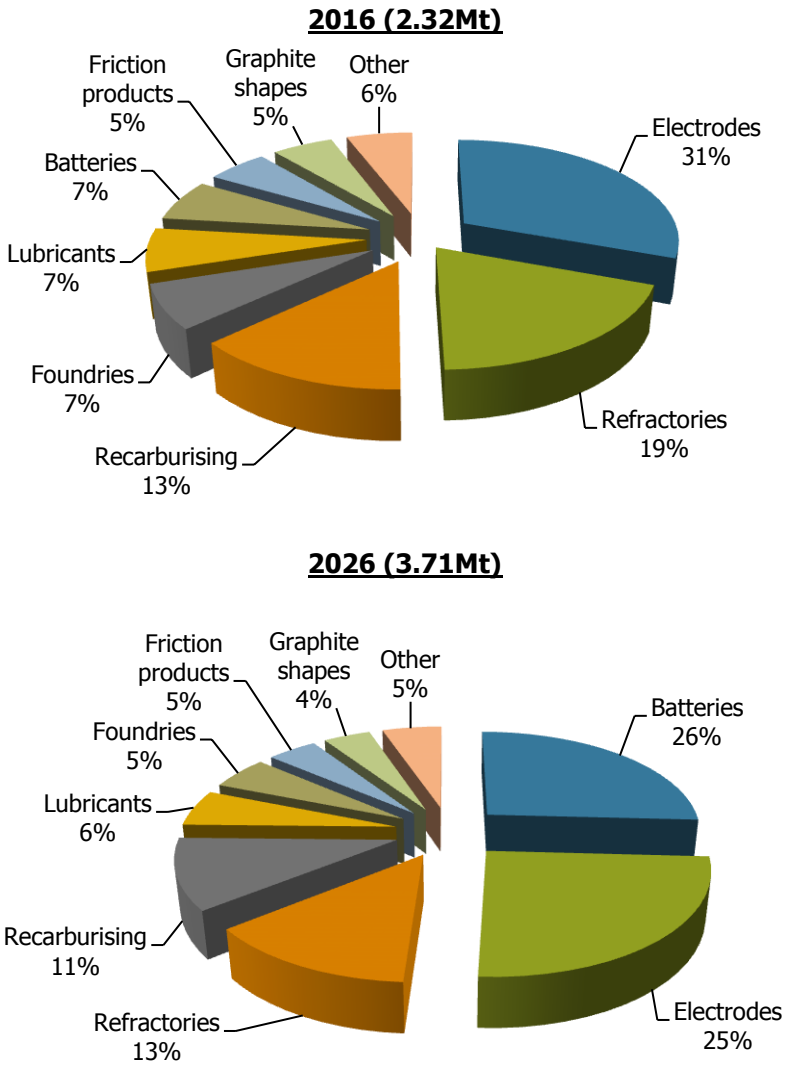
1.3 Consumption

Graphite consumption totalled 2.32Mt in 2016. Synthetic graphite accounted for around two thirds of this consumption and natural graphite a further third. Total consumption increased by 1.9%py between 2006 and 2016 with the largest growth in the consumption of flake graphite, for which demand grew by 3.5%py, led by demand from lithium-ion batteries. Consumption of synthetic graphite grew at around 1.6%py but consumption of amorphous graphite was flat at 0.2%py, as a result of ongoing substitution with other graphite and carbon products.

The main markets for graphite are shown in Figure 4. By 2026, battery applications will grow to become the largest sector accounting for 26% of demand, up from 7% in 2016. Overall growth in graphite demand is forecast to grow by a CAGR 4.8%py to 3.71Mt in 2026, with the highest growth coming from flake graphite (CAGR 8.4%py) and synthetic graphite (CAGR 3.8%py). Although both natural and synthetic graphite will see robust growth from lithium-ion batteries, higher quantities of flake graphite are required per battery to account for the high losses during spherical graphite production.

Primary synthetic graphite is mainly used in UHP electrodes for use in steelmaking in EAF furnaces, 711kt in 2016. Production of EAF steel grew by just 0.5%py between 2006 and 2016 to reach an estimated 418Mt. However, going forward, EAF production is expected to recover by a CAGR of 2.7%py between 2016 and 2026 as higher availability of steel scrap encourages much higher rates production growth in China. Currently, around 26% of crude steel is produced in EAFs worldwide, but the average within China is only 6%. Synthetic graphite demand in electrodes is forecast to increase by an equivalent 2.7%py to 930kt in 2026. While Chinese production increases, capacity in traditional markets of North America, Europe and Japan could continue to close; it is likely that some of this capacity will be given over to lithium-ion battery anode powders.

Figure 4: World: Consumption of graphite by application, 2016 and 2026



Source: Roskill

The major market for natural graphite is in magnesia-carbon and alumina-carbon brick refractories. An estimated 441kt of graphite were consumed in this application in 2016, most of which was natural flake graphite. Total refractory production declined by 2.5%py between 2006 and 2016, but consumption of graphite in refractories grew at around 1.6%py over the same period. As crude steel production starts to recover from 2019 onwards, production of refractories could pick up, growing by around 0.7%py between 2016 and 2026. However, graphite demand is forecast to be just 1.1%py as growth is hampered by falling specific refractory consumption.

Batteries accounted for an estimated 152kt of consumption in 2016 but could see the strongest growth of all applications. Demand from batteries grew by a CAGR of 11.6%py between 2006 and 2016 but, based on Roskill's base case scenario for EV demand, this rate of growth could almost double to 20.2%py over the next decade, with graphite consumption in batteries reaching 957kt in 2026. The full range of possible growth is could be 16.3%py

to 25.8%py, depending on forecast EV adoption rates. Consumption of graphite in lithium-ion batteries currently accounts for around 82% of the battery market for graphite but this could rise to 96% by 2026. Competition between natural and synthetic graphite is expected to continue in lithium-ion batteries with the choice coming down to price, performance and availability. Synthetic graphite consumption by anode manufacturers is expected to grow because of the concentration of the industry in China, but flake graphite demand is forecast to grow at a higher rate because of the high processing losses in the production of spherical graphite.

Demand for graphite in the traditional markets of recarburising, foundries, lubricants, graphite shapes and friction materials is expected to grow by between 2%py and 3%py between 2016 and 2026, at a similar rate of growth to that seen between 2006 and 2016. Demand for recarburisers and foundry castings will be limited by growth in crude steel production. More than 300ktpy of graphite, mainly secondary synthetic, is added to molten iron and steel as a recarburiser. This industry faces increasing competition from other carbon products that are more cost competitive, mainly petroleum coke. At the same time, higher amounts of low cost ultrafine flake graphite are being consumed in the Chinese recarburiser industry, sourced as a by-product from spherical graphite production. A further 160kt of graphite consumption was estimated in foundries in 2016, mainly of natural graphite. Graphite shapes is a growing market for primary synthetic graphite and includes a wide range of applications including electrical and structural parts for aerospace, automotive, chemical processing and other industries.

Natural and synthetic graphite compete more strongly in friction materials and lubricants. Secondary synthetic graphite, amorphous graphite, smaller size flake graphite, vein graphite and highly purified flake fines are all consumed, depending on the use of the final end product. Production of friction materials will increase with the growth of global vehicle output, while lubricants will see growth from both industrial and consumer sectors.

1.4 Prices

Graphite prices have experienced an extended period of inactivity and suppression in recent years as weakening markets and overproduction in China have quelled any market tightness. This is expected to change in the coming years as rapid increases in battery demand push Chinese producers to raise output from installed capacity and will still require the opening of new capacity worldwide. Any lag in the opening and ramp-up of new production could result in a tightening market and rising prices for both natural and synthetic graphite.

Synthetic graphite has a price premium over natural graphite as a result of expensive production costs but is desirable in many applications because of its high grade, low impurity levels and good consistency. Synthetic graphite prices fell rapidly in 2013 from their record levels of 2011 and 2012, mainly because of a slowdown in demand from the EAF steel industry and an accompanying slowdown in the main market of electrodes. Prices have since continued to fall but at a slower rate into 2017 as China's transition to EAF steel production continues to falter. Although Chinese iron ore prices have seen some recovery, from US$40/t at the end of 2015 to around US$80/t in early 2017, low prices compared to steel scrap still continue to encourage BOF over EAF steel production in China. Prices for raw material petroleum needle coke and for synthetic graphite electrodes followed a similar

pattern of decline to that of synthetic graphite. The price of synthetic UHP electrodes in China is thought to have fallen to US$1,500-4,000/t in 2016.

Over the next decade, the tightening market for lithium-ion battery powders could result in synthetic graphite price rises for battery grades. Increasing availability of steel scrap in Asia, as current products reach the end of their lifespan, is also expected to reverse the trend away from EAF steel production and increase electrode demand. Price rises will be tempered by continued low fuel costs and low raw material (petroleum needle coke) prices as well as increasing competition with natural graphite in batteries which could exert a downward pressure on synthetic graphite prices.

Natural flake graphite prices fell sharply in 2012 following artificial prices rises in 2010/2011 and continued to fall steadily to mid-2016, since when, they have seen no change. The previous high came about because of consumer fears that Chinese consolidation in the flake graphite sector, coupled with forecast growth from lithium-ion battery demand, would create a shortage of supply. Producers and traders held on to stocks and speculated on higher prices if supply tightened. These fears were never realised; Chinese flake graphite consolidation has continued but at a slow pace, and lithium-ion-based EV adoption rates were slower than first predicted.

In 2017, EV penetration has picked up and strong lithium-ion battery demand over the next decade is expected to lead to tighter flake graphite markets and price rises. However, prices will not rise as strongly as they did in 2010/2011. It is believed that reduction of China's stocks and production from excess capacity will initially meet rises in demand and sustain any lag in production from new projects. Price rises will be limited in later years with the opening and ramp-up of new capacity worldwide.

Published prices for basic grades of flake graphite in early 2017, range from US$400-450t for medium flake at 85-87% C to US$750-850/t for large flake at 94-97% C. Larger flake sizes and higher carbon grades have always achieved the highest price. The strongest growth in flake prices to 2026 is forecast to come from medium size flake graphite, which is in high demand for use in lithium-ion batteries. Fine flake prices could grow more slowly because of the increasing availability of ultra-fine flake graphite as a waste product from spherical graphite processing.

No price series is published for processed flake graphite products which command a much high price than raw material flake. In 2017, Chinese export prices for uncoated spherical graphite for lithium-ion batteries were reported as US$3,748/t. Once coatings are applied, prices are even higher and almost in line with those of synthetic graphite. The average value of spherical graphite imports to China, which consist mainly of coated products, was US$10,901/t in 2016. Spherical graphite prices have fallen since 2012 with a decline in raw material prices and improvements in processing technology. Prices are expected to rise over the next decade as demand for this product grows strongly in lithium-ion batteries. If spherical graphite prices follow the projected rises in raw materials, the price of uncoated spherical graphite could reach US$4,500-5,000/t.

The price of amorphous graphite is much lower than that of flake; published prices have remained unchanged at US$400-430/t between early 2015 and early 2017. Prices are expected to remain low or fall with declining amorphous graphite consumption.

2. World graphite supply

2.1 Natural graphite: World production review

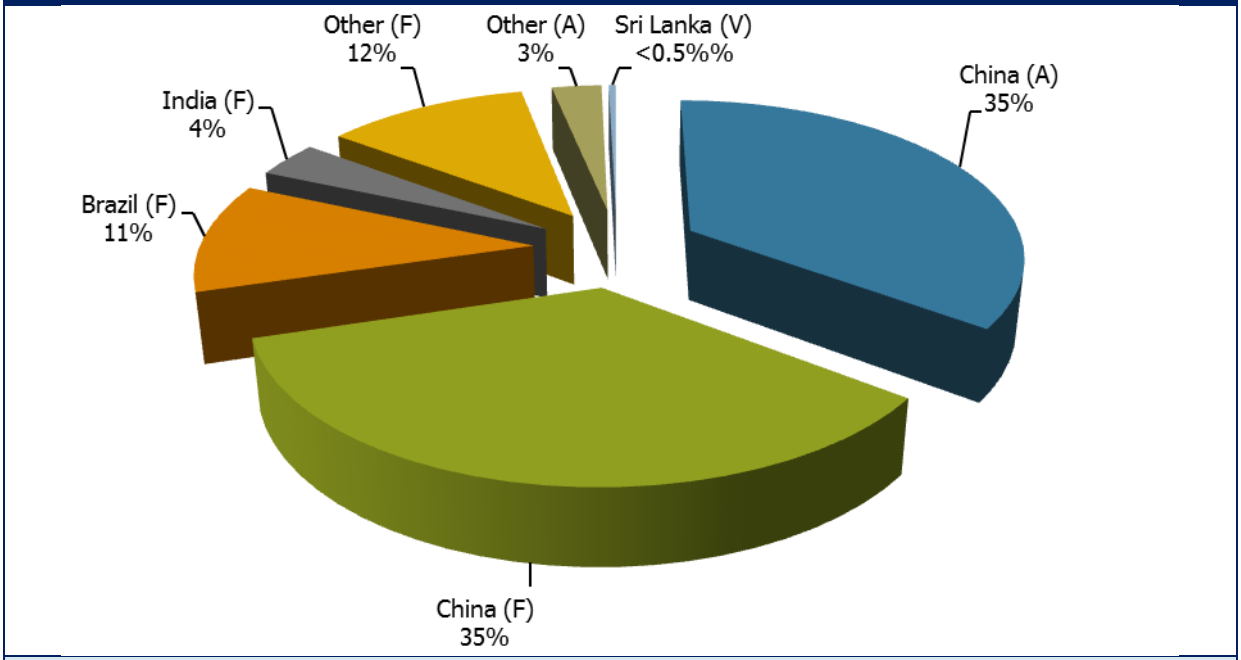
Global production of natural graphite was estimated to be 853kt in 2016 of which, flake graphite accounted for 62%, amorphous graphite 38% and vein graphite less than 0.5%.

China is the largest producer and accounted for around 75% of global production in 2015, falling slightly to 70% in 2016 as the Chinese government closed flake capacity following environmental inspections. Flake production is expected to begin a recovery from 2017. In 2016, China produced around 300kt each of flake and amorphous graphite, accounting for 57% of global flake and 93% of global amorphous graphite production.

Brazil is the second-largest producer and supplied an estimated 95kt of flake graphite in 2016, accounting for 18% of global flake and 11% of all global natural graphite production.

Other major producers of flake graphite are India, Canada, Ukraine and Pakistan (each producing over 10ktpy), followed by Norway, Russia, Madagascar and Zimbabwe (over 5ktpy). Other major producers of amorphous graphite include Mexico and Russia (over 5ktpy). The major producers of each type of natural graphite are shown in Figure 5 for 2016.

Figure 5: World: Estimated production of natural graphite by type, 2016 (853kt)



Source: *Roskill,*
Notes: *F-Flake; A-Amorphous; V-Vein*

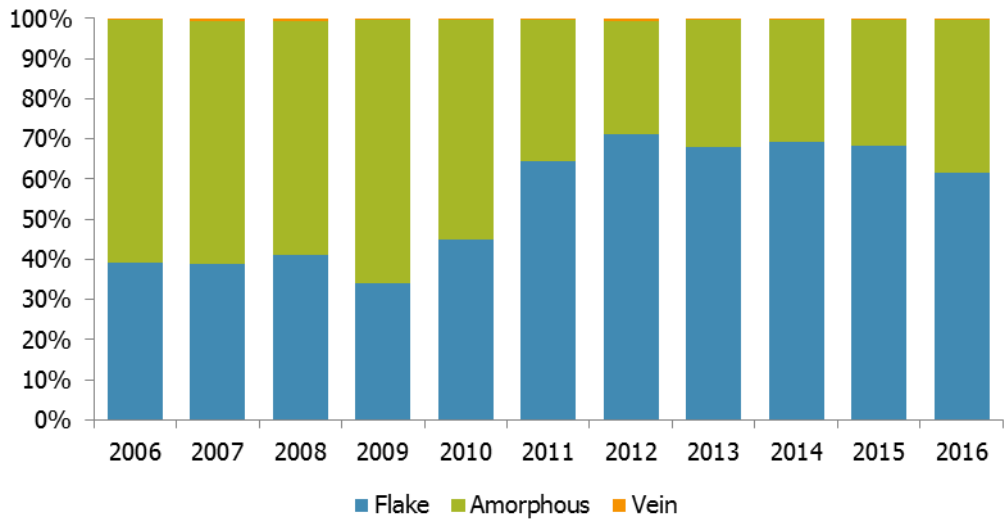
Between 2006 and 2016, overall global production of natural graphite declined by an average of 3.1%py.

Major consolidation in the Chinese amorphous graphite industry from 2010, coupled with declining markets for low-value amorphous throughout the decade, led to an average fall in global amorphous graphite supply of 7.5%py between 2006 and 2016.

Over the same period, global production of flake graphite grew robustly to meet growing demand from the lithium-ion battery market. Flake production grew by 3.9%py 2006-2009 but only 1.4%py between 2006 and 2016 as Chinese flake production fell back by over 30% in 2016.

The proportion of global production accounted for by flake graphite grew from 39% in 2006 to 68% in 2015 before falling slightly to 62% in 2016 (Figure 6).

Figure 6: World: Estimated production of natural graphite by type, 2006-2016 (%)



Source: Roskill

At the beginning of the decade, the amorphous industry in China was in a state of high overcapacity, a situation that worsened with shrinking markets. In 2010, the Chinese Government began consolidating the industry under one company, reducing the number of mines in the major area of amorphous production from 210 to just 20. Global amorphous production fell by almost half in 2011 and again by over 25% in 2012. Production has since recovered slightly but in 2016 was still less than half that at the beginning of the decade.

Consolidation also occurred in the China flake graphite industry but has been nowhere near as dramatic as anticipated. Flake production is distributed among a number of provinces, led by Heilongjiang and Shandong. Rather than consolidation, closures in the flake graphite industry have been associated with increasing environmental restrictions as processors fail to pass increasingly stringent plant inspections. Pollution is a serious issue caused during the processing of flake graphite into high value downstream products, namely spherical graphite and expandable/expanded graphite, which require large quantities of acids and other reagents.

Significant flake graphite closures occurred in China in 2013 and 2016 (and to a lesser extent in 2015, masked by production increases elsewhere). In previous years, inspections

were carried out by local government who are reluctant to enforce closures and lose revenue. Producers upgraded plant equipment but failed to change processing techniques and most were relatively quick to re-open (although some capacity has been lost permanently). In 2016, the national government is thought to have taken more direct control to improve environment problems and production could take two or three years to recover fully.

Along with consolidation and increased state-ownership, the Chinese government has implemented other measures to protect its dominance in the graphite market. It has encouraged the production and export of higher-value downstream products at the expense of lower-value basic grades via a series of export duties. These have included a 20% export tax on basic flake graphite products compared to a 13% tax rebate on exports of spherical graphite. At the same time, imports of higher-value goods are discouraged with a 3% import tax on uncoated spherical graphite and a 6.5% tax on imports of coated spherical graphite.

From January 2017, the 20% export tax on basic flake graphite was removed. This is likely to have little impact on price levels. Chinese exports fell by more than 40% in 2012 and have since remained below 300ktpy. Despite this fall, China remains the largest exporter of natural graphite.

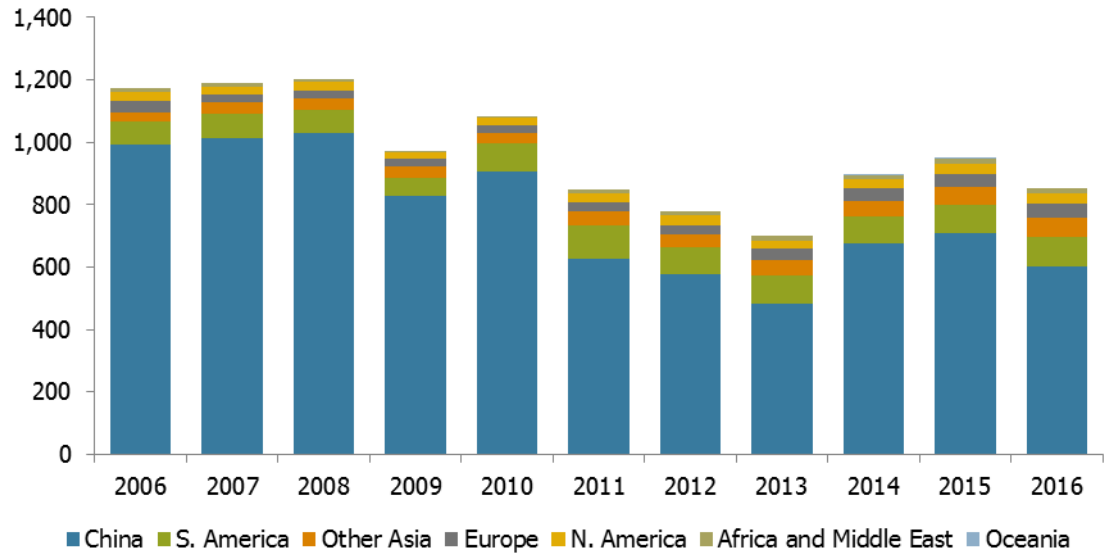
Production costs in China have risen in recent years because of increasing labour and power costs, increasingly stringent environmental constraints (such as limitations on the use of hydrochloric acid in processing and the installation of wastewater cleansing/dust limitation processes), and the move to deeper mines as more accessible reserves expire. China also suffers from logistical constraints and high freight costs. Other higher-value goods and commodities (such as finished electrical goods and coal) take priority on rail and shipping, often causing interruptions to graphite supply.

A breakdown of natural graphite production by region is provided in Figure 7. The fastest growing region between 2006 and 2016 was 'other Asia', which grew by an estimated 7.7%py, mainly from growth in India and Pakistan. India is working hard to increase both the quantity and quality of its production. Low-grade mines in Odisha are shutting down, to be replaced by increasing production in other states (mainly Tamil Nadu). The Indian Government is also exploring for new higher-grade deposits.

Africa and the Middle East together increased production by 3.8%py over the period, as production of flake graphite increased in Madagascar and amorphous graphite increased in Turkey.

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Figure 7: World: Estimated production of natural graphite by region, 2006-2016 (kt)



Source: *Roskill, Section* ***Error! Reference source not found.***

Production of natural graphite by country between 2006 and 2016 is listed in Table 6. The table is based on national production statistics (where available), data published by the BGS, USGS, other country specific geological surveys, company information and Roskill estimates. There are some limitations due to the nature of data collection. For example, while most countries report production in terms of marketable ore, production from China, India, North Korea, Austria and Turkey is reported as run-of-mine ore, so for the purposes of comparison, estimates of marketable ore production have been made.

Table 1: World: Estimated production of natural graphite by country and graphite type, 2006-2016 (kt)

		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Production by region												
Asia												
China	F	310.9	318.8	350.4	206.0	326.3	349.3	375.0	283.0	425.0	435.0	300.0
China	A	680.0	695.0	680.0	620.0	579.0	279.0	200.0	200.0	250.0	275.0	300.0
India[1,2]	F	14.6	15.4	15.9	16.8	15.6	20.7	23.8	26.4	21.0	27.0	31.5
India[1,2]	A	1.6	1.7	1.8	1.9	1.7	2.3	2.6	2.9	2.3	3.0	3.5
N. Korea[1]	F	-	3.5	3.0	5.5	4.5	10.0	2.5	4.5	4.5	4.5	4.5
N. Korea[1]	A	3.0	3.0	3.0	3.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Pakistan[3]	F	-	-	-	0.7	1.0	1.3	0.9	6.2	13.8	14.0	14.0
S. Korea	A	0.1	0.1	0.1	-	-	-	-	-	-	-	-
Sri Lanka	V	5.8	9.6	6.6	3.2	3.4	3.4	4.2	3.1	3.2	3.3	3.5
Uzbekistan	F	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Vietnam	F	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
South America												
Brazil[4]	F	76.2	77.2	74.8	59.4	92.4	105.2	88.1	91.9	87.0	90.0	95.0
Europe												
Austria[1]	A	-	-	0.2	0.7	0.4	0.8	0.2	0.5	0.5	0.7	0.8
Czech Rep.	A	5.0	3.0	3.0	3.0	-	-	-	-	-	-	-
Germany	F	-	-	-	-	-	-	0.1	0.3	0.5	1.0	2.0
Norway	F	9.0	3.0	4.1	4.6	6.3	7.8	7.0	6.2	8.3	8.5	9.0
Russia	F	4.5	3.5	3.4	3.4	3.4	4.6	5.5	6.3	7.0	7.8	8.5
Russia	A	6.6	6.4	5.6	5.6	5.6	7.4	8.0	8.0	8.0	8.0	8.0
Sweden	F	-	-	-	-	-	-	-	-	0.5	1.0	-
Ukraine	F	10.7	8.0	8.0	8.0	8.0	8.0	10.0	12.0	13.8	15.0	15.0
North America												
Canada	F	15.0	15.0	20.0	15.0	20.0	25.0	24.0	20.0	20.0	22.0	25.0
Mexico	A	11.8	9.9	7.2	5.1	6.6	7.3	7.5	7.0	9.2	9.0	9.0
Africa & Middle East												
Madagascar	F	5.5	5.4	4.9	3.4	3.7	4.0	3.5	6.1	5.7	7.5	8.5
Turkey[1]	A	-	-	0.2	0.1	0.0	0.3	1.6	1.4	1.4	1.7	2.0
Zimbabwe	F	6.6	5.4	5.1	2.5	0.7	7.3	7.0	6.9	6.9	7.0	7.0
Oceania												
Australia	F	-	-	-	-	-	-	-	-	0.5	1.0	-
Production by graphite type												
Flake		458.0	460.2	494.7	330.3	486.8	548.1	552.5	474.8	619.5	646.3	525.1
Amorphous		708.1	719.1	701.1	639.4	594.4	298.1	220.9	220.8	272.4	298.4	324.3
Vein		5.8	9.6	6.6	3.2	3.4	3.4	4.2	3.1	3.2	3.3	3.5
Total		1,171.9	1,188.9	1,202.4	972.9	1,084.6	849.6	777.6	698.7	895.1	948.0	852.8

Sources: *Roskill, USGS, BGS, other country commodity reviews*

Notes: *F-Flake; A-Amorphous; V-Vein*

Af. &Mid E.- Africa and Middle East

Red text-Estimated; Orange text-Preliminary

1-Estimated from run-of-mine production

2-Years end 31 March following that stated

3-Years end 30 June of that stated

4-Including beneficiated and directly shipped material

Outside China, natural graphite production grew by an estimated 3.4%py between 2006 and 2016, consisting of a 4.3% rise for flake and a 1.5%py decline for amorphous graphite. The largest increases in flake production outside of China over the last ten years have come from Brazil, India, Pakistan, Canada, Russia, Ukraine and Madagascar. Elsewhere, some production has ceased with the depletion of economic resources. Rising demand for flake graphite has resulted in increased output at some existing operations and encouraged exploration for new flake deposits.

The price of flake graphite rose sharply in late 2010/early 2011 as forecasts of increased flake demand combined with fears over Chinese consolidation (as consumers feared that the extensive shutdowns seen in Chinese amorphous graphite would be applied to flake). Large numbers of exploration companies became involved with graphite discovery and a significant number of graphite projects were developed to the scoping/feasibility study stage.

Perceived future supply shortages were never actually realised as the expected high rate of consolidation in the Chinese flake industry never materialised. Global economies remained depressed longer than forecast, which led to a longer lag time in lithium-ion battery development than previously predicted. This has been reflected in prices. Graphite prices began to fall in the second half of 2012 and, by early 2017, the average price of flake graphite in the ROW was US$617/t (CIF European port, average across all flake sizes 85-97% C). The last time prices were so low was around ten years ago in mid-2007. There has been little price movement since early 2016 and prices have performed poorly for several years.

Because of these factors, only a handful of flake graphite operations have come online, including the Swedish Woxna project and Australian Uley project in 2014 and the small Loharano project in Madagascar in 2013. In 2015, mining was halted at both Woxna and Uley.

Over the last decade, the largest growth in natural graphite output outside of China has come from:

- Brazil - increased production of flake graphite by almost 19kt; production has increased from Nacional de Grafite while from other smaller Brazilian producers it has become minimal or ceased altogether
- India - increased production by almost 19kt, mainly higher-grade flake graphite from Tamil Nadu to satisfy increasing domestic consumption. Much of the production of lower-grade graphite in Odisha has closed.
- Pakistan - began production of flake graphite in 2009 and has slowly increased output to around 14ktpy
- Canada - ramping-up of flake graphite production at Eagle Graphite's Black Crystal mine which reopened in 2009; the largest producer Imerys Graphite & Carbon has moved production to different pits at its Lac-des-Îles operation
- Russia - likely to have increased production of flake graphite for domestic consumption
- Ukraine - the country's only producer, Zavalyevskiy Graphite, may have made some increase to its flake graphite output

- Madagascar - the Loharano flake graphite mine was reopened by Stratmin in 2013 and production had increased to ~1.5ktpy by 2015. Other producers may have also increased production for specific customers.
- North Korea - thought to have increased production of low-grade flake graphite for shipment to China
- Germany - AMG Mining reopened its Kropfmühl mine in 2012 and is producing small amounts of flake graphite
- Turkey - production of amorphous graphite has increased following improvement to the processing facilities at Oysu Graphite Mining
- Austria - the Grafitbergbau Kaisersberg mine reopened in 2008 and is producing small amounts of amorphous graphite
- Zimbabwe - production declined to less than 1ktpy in 2010 (most likely a result of political instability in the country) but has since increased to around 7ktpy
- Norway - ramp-up of flake graphite production following a switch to another deposit at Skaland Graphite in 2007

2.2 Structure of the natural graphite industry

Major producers of natural graphite are listed in Table 2 and have total capacity in excess of 2.5Mtpy. Capacity is only listed for producers with a domestic supply of graphite; it does not include separate plants processing from imports or manufacturing downstream products such as spherical graphite, high-purity flake graphite or expandable/expanded graphite.

Around 80% of capacity is located in China. Chinese capacity is increasing as new flake producers become established and as some previously closed amorphous capacity comes back online. China is in a state of considerable overcapacity, especially for flake graphite where production was less than 30% of capacity in 2015 and less than 20% in 2016 following closures.

The largest producers are located in China. Most amorphous graphite production in the province of Hunan has come under the operation of state-owned South Graphite following consolidation since the late 2010s. Although some capacity has been lost permanently, South Graphite is thought to have reopened around 300ktpy by 2016. Chenbei Mining Industry also operates 100-150kpy of amorphous capacity in Hunan. Most of the smaller amorphous producers have been closed.

In terms of Chinese flake graphite, the largest producer is Luobei County Yunshan Graphite Mining with 200ktpy of capacity in Luobei, Heilongjiang. Five other producers, each with 100ktpy, operate in Heilongjiang and Shandong (Aoyu Graphite Group, Jixi Changyuan Mining, Jixi Pucheng Graphite, Qingdao Haida Graphite and Qingdao Jinhui Graphite). A large number of smaller flake operations, including many under 20ktpy, operate across China.

Outside of China, Brazil is largest graphite producer with an estimated capacity of over 88ktpy operated by state-owned Nacional de Grafite. Two companies mine flake graphite in Canada, two companies mine amorphous graphite in Mexico and there are no operating

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companies in the USA. Imerys Graphite & Carbon of Switzerland and AMG Mining of Germany are significant producers of downstream flake graphite products.

A number of foreign companies have invested in China in order to secure raw material supplies and to manufacture and export downstream products (which are subject to much lower export tariffs than natural graphite); these include Imerys Graphite & Carbon, AMG Mining and SGL Group of Germany.

Table 2: World: Details of graphite operations, 2017

Operator	Location	Type of natural graphite	Facilities	Capacity[e1] (ktpy)	Status
Australia					
Valence Industries	Eyre Peninsula, SA	Flake	Mine, plant	14.0	On hold
Austria					
Grafitbergbau Kaisersberg	Styria	Amorphous	Mine, plant	30.0	Operating
Brazil					
Nacional de Grafite	Minas Gerais	Flake	3 mines, 3 plants	>90.0	Operating
Canada					
Imerys Graphite & Carbon	Québec	Flake	Mine, plant	25.0	Operating
Eagle Graphite	British Columbia	Flake	Mine, plant	20.0	Operating
China					
South Graphite	Chenzhou, Hunan	Amorphous	20 mines, numerous plants	300.0[2]	Operating
Luobei County Yunshan Graphite Mining	Luobei, Heilongjiang	Flake	Mine, plant	200.0	Operating
Aoyu Graphite Group	Luobei, Heilongjiang	Flake	Mine, plant	100.0	Operating
Jixi Changyuan Mining	Jixi, Heilongjiang	Flake	Mine, plant	100.0	Operating
Jixi Pucheng Graphite	Jixi, Heilongjiang	Flake	2 mines, 2 plants	100.0	Operating
Qingdao Haida Graphite	Pingdu, Shandong	Flake	2 mines, 2 plants	100.0	Operating
Qingdao Jinhui Graphite	Pingdu, Shandong	Flake	2 mines, plant	100.0	Operating
Chenbei Mining Industry	Chenzhou, Hunan	Amorphous	Plant	100.0-150.0	Operating
Heilongjiang Pride New Material[3]	Jixi, Heilongjiang	Flake	Mine, plant	80.0	Operating
Yixiang Graphite Group	Luobei, Heilongjiang	Flake	Mine, plant	80.0	Operating
Inner Mongolia Rising New Energy	Xinghe, Inner Mongolia	Flake	Mine, plant	60.0	Operating
Qingdao Heilong Graphite	Pingdu, Shandong/ Heilongjiang	Flake	Mine, plant	60.0	Operating

….Table continues

Operator	Location	Type of natural graphite	Facilities	Capacity[e1] (ktpy)	Status
Jixi Jinhui Graphite	Jixi, Heilongjiang	Flake	Mine, plant	50.0	Operating
Qingdao Xinghe Graphite	Pingdu, Shandong	Flake	…	50.0	Operating
Chenzhou Haixin Graphite & Carbon	Chenzhou, Hunan	Amorphous	Plant	50.0	Operating
Chenzhou Xianglu Graphite Processing Plant	Chenzhou, Hunan	Amorphous	Mine, 3 plants	50.0	Operating
Jilin Graphite Industry	Panshi, Jilin	Amorphous	Mine, plant	50.0	Operating
Luobei South Sea Graphite	Luobei, Heilongjiang	Flake	…	45.0	Operating
Luobei Fuda Graphite	Luobei, Heilongjiang	Flake	…	40.0	Operating
Qingdao Hensen Graphite	Laixi, Shandong	Flake	…	38.0	Operating
Qingdao Tiansheng Graphite	Laixi, Shandong	Flake	…	30.0	Operating
Qingdao Yanxin Graphite	Pingdu, Shandong	Flake	…	28.0	Operating
Aoyu Graphite Group	Jixi, Heilongjiang	Flake	Mine, plant	20.0	Operating
Aoyu Graphite Group	Inner Mongolia	Flake	Mine, plant	20.0	Operating
China Sciences Hengda Graphite	Yichang, Hubei	Flake	…	20.0	Operating
Jixi Fenglu Graphite	Jixi, Heilongjiang	Flake	…	20.0	Operating
Jixi Tiansheng Nonmetal Industry	Jixi, Heilongjiang	Flake	…	20.0	Operating
Chenzhou Shunfeng Graphite Product Plant	Chenzhou, Hunan	Amorphous	Mine, plant	20.0	Operating
Luoyang Guanqi Industry & Trade	Luoyang, Henan	Flake	…	15.0	Operating
Xinghe Xinyi Graphite	Xinhe, Hebei	Flake	…	15.0	Operating
Chenzhou Huayuan Graphite Processing Plant	Chenzhou, Hunan	Amorphous	Plant	10.0	Operating
Chenzhou Lutang Crystallitic Graphite & Carbon	Chenzhou, Hunan	Amorphous	Plant	10.0	Operating
Chenzhou Yinchao Carbon Materials Plant	Chenzhou, Hunan	Amorphous	Plant	10.0	Operating
Germany					
AMG Mining	Hauzenberg, Bavaria	Flake	Mine, plant	20.0	Operating
India					
Tirupati Carbons & Chemicals	Palamu, Jharkhand	Flake	2 mines, 3 plants	15.1	Operating
Tamil Nadu Minerals	Sivaganga, Tamil Nadu	…	Mine, plant	9.2[4]	Operating
Agrawal Graphite Industries	Bolangir, Odisha	…	2 plants	>10.0	Operating
Chotanagpur Graphite Industries	Palamu, Jharkhand	…	Mine, plant	8.0	Operating
T.P. Minerals	Rayagada, Odisha	Flake	Mine, plant	3.0	Operating

Table continued….

….Table continues

Operator	Location	Type of natural graphite	Facilities	Capacity[e1] (ktpy)	Status
North Korea					
Samcheolri, Kores	South Hwanghae	Flake	Mine	11.0[5]	Operating
Madagascar					
Établissements Gallois	Various	Flake	3 mines, plant	10.0	Operating
Bass Metals	Loharano	Flake	Plant	6.0	Operating
Établissements Izouard	Faliarno	Flake	Mine, plant	2.0	Operating
Établissements Rostaing	…	Flake	Mine, plant	1.0	Operating
Société Arséne Louys	Ambatoharanana	Flake	Mine, plant	3.0	Operating
Mexico					
Grafitos Mexicanos de Asbury	Sonora	Amorphous	2 mines, plant	60.0	Operating
Grafito Superio	Sonora	Amorphous	3 mines, plant	25.0	Operating
Norway					
Skaland Graphite	Trælen	Flake	Mine, plant	12.0	Operating
Pakistan					
Mazhar International	…	Flake	…	…	Operating
Others	…	Flake	…	…	
Russia					
Krasnoyarsk Graphite	Krasnoyarsk	Amorphous	Mine, plant	8.0	Operating
Uralgraphite	Chelyabinsk	Flake	Mine, plant	15.0	Operating
Sri Lanka					
Bogala Graphite Lanka	Colombo	Vein	3 mines, 3 plants	>7.3	Operating
Kahatagaha Graphite Lanka	Kurunegala	Vein	Mine, plant	4.0	Operating
RS Mines	Kurunegala	Vein	Mine, plant	…	Operating
Sakura Graphite	Central Sri Lanka	Vein	Mine, plant	2.5	Operating
Sweden					
Leading Edge Materials	Near Edsbyn	Flake	Mine, plant	16.0	On hold
Turkey					
Oysu Graphite Mining	Izmir	Amorphous	Mine, plant	36.0	Operating
Ukraine					
Zavalyevskiy Graphite	Gayvoron, Kirovograd	Flake	Mine, plant	40.0	Operating
Uzbekistan					
Kagansky Graphite-Gypsum Combine	Bukhara	Flake	Mine, plant	>0.1	Unknown
Vietnam					
…	…	Flake	…	5.0	Unknown
Zimbabwe					
Zimbabwe German Graphite Mines	Karoi	Flake	Mine, plant	7.0	Operating
Total				**>2,504.2**	

Source: Roskill

Note: 1-Processing production capacity for graphite from domestic sources 2-Initial capacity was reported as 200ktpy on re-opening in 2012 but is since thought to have increased 3-A subsidiary of Beijing Automotive Group
4-Reported capacity, actual capacity may be higher
5-Crude

2.3 Natural graphite: Forecast supply

Future production of natural graphite relies heavily on changing trends in demand for lithium-ion batteries. Roskill offers a base, low and high case scenario for graphite supply, based on corresponding forecasts for lithium-ion battery growth and graphite demand.

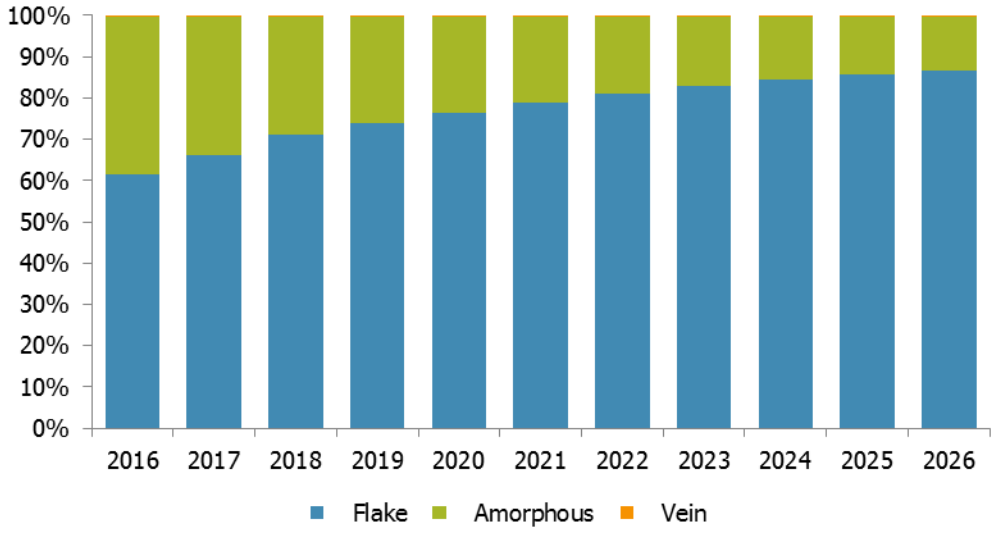
Table 3: World: Forecast supply of natural graphite (base, low and high case scenarios), 2016, 2021 and 2026 (kt)

	2016	2021	2026	CAGR 2016-26 (%py)
Base case	853	1,182	1,575	6.3
Low case	853	1,111	1,423	5.3
High case	853	1,307	2,003	8.9

Source: Roskill

Using the base case scenario, global natural graphite supply could grow by a CAGR of 6.3%py to 1.58Mt in 2026. Most of this growth will come from natural flake graphite production as markets for lithium-ion batteries grow strongly in automotive and energy storage applications (Figure 8). Flake graphite supply could grow by 10.0%py to 1.36Mt in 2026, accounting for 87% of total natural graphite supply.

Figure 8: World: Forecast[1] production of natural graphite by type, 2016-2026



Source: Roskill,
Note: 1-Base case scenario

Flake graphite growth rates will be highest in the first years of the forecast as closed production in China comes back online. Flake supply will then grow steadily from 2019 as new production comes on-line in China and the ROW. Growth rates will begin to slow towards 2026, when existing producers ramp up thier capacity to meet demand.

Amorphous graphite production could fall by an average of 4.3%py to 208kt in 2026 as the traditional markets of refractories, foundries and recarburising continue to decline and there

is increased competition with flake graphite fines produced as by-product from spherical graphite manufacture.

Natural graphite resources in China, although disputed, are thought to be significant (possibly up to 250Mt) and could support substantial new graphite projects in future. In the short term, most increases in graphite production are likely to come from existing capacity as Chinese producers increase output to meet demand and some of the prevailing overcapacity is eliminated. Production of processed products, especially spherical graphite, will increase in China as both the export and domestic markets rise rapidly. Overall, Chinese natural graphite production is forecast to increase by over 4%py to 2026, to reach 912kt in the base case scenario. The proportion of Chinese production accounted for by flake will rise from 50% in 2016 (61% in 2015) to 80% by 2026.

The largest growth in supply to 2026 is expected to be outside China where production of natural graphite is forecast to increase to over double the current level, to around 664kt. As a result, China's proportion of global production could fall from 70% in 2016 (75% in 2015) to around 58% in 2026. A large number of projects are under development and by early 2017, around 30 producers had progressed projects to scoping study or beyond and total planned capacity is over 1.35Mtpy.

The largest increase in supply is expected to come from the Africa, where producers are currently developing flake graphite projects in Madagascar, Malawi, Mozambique, Namibia and Tanzania. A total capacity of over 1.0Mtpy is planned from 11 of the more developed projects in this region that could enter the supply chain by 2026. The largest capacity is planned by Syrah Resources in Mozambique, where production is scheduled to begin in 2017, once construction is completed; capacity could eventually be ramped up to 380ktpy. AMG Mining is also due to open a small 6ktpy operation in Mozambique in 2017.

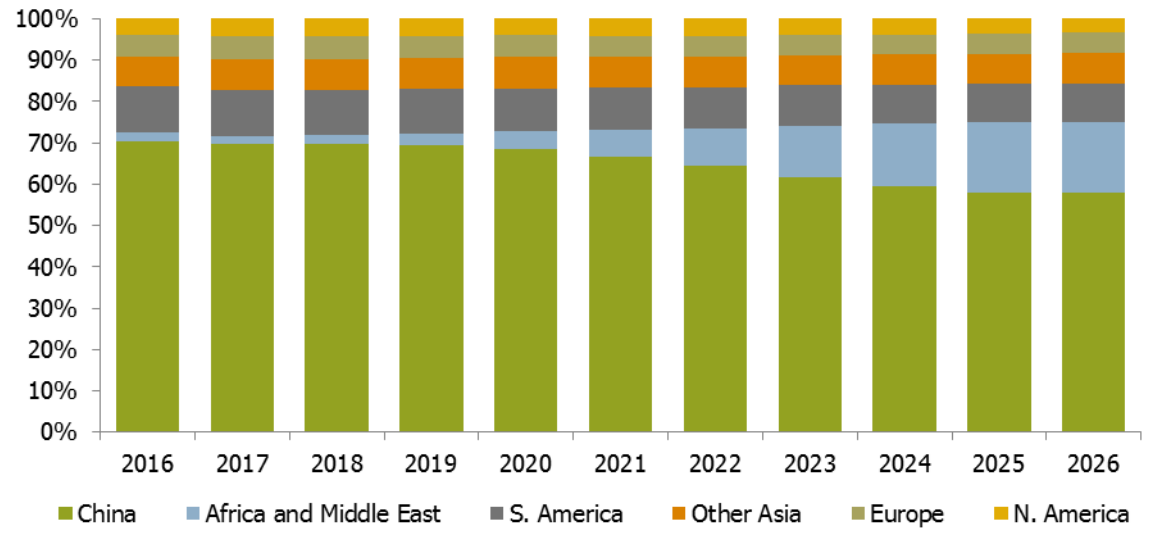
Further projects have been under development in Canada and Australia for a number of years; in Canada, over 0.2Mtpy of capacity is planned. The Uley mine in Australia could also be reopened if prices improve.

Meanwhile in Europe, production could increase from existing flake graphite producers, the Woxna mine in Sweden could reopen, or new capacity could be brought online in Sweden.

Regional forecasts between 2016 and 2026 are shown in Figure 9. They do not represent capacity projections for specific producers but, rather, a suggestion of production that may come online taking into account price, market performance, potential regional competition and other external factors. Proposed production in Africa, for example, represents 30-40% of current proposed capacity.

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Figure 9: World: Forecast[1] production of natural graphite by region, 2016-2026 (%)



Source: *Roskill*
Note: *1-Base case scenario*

Table 4: World: Forecast[1] production of natural graphite by region, 2016-2026 (kt)

	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
China	600	625	670	708	748	789	810	832	855	882	912
Africa[2]	18	19	22	29	48	77	114	169	219	259	272
S. America	95	100	105	110	115	120	125	130	135	140	145
Other Asia	63	67	72	77	83	89	95	100	105	111	118
Europe	43	51	53	55	57	58	61	64	69	74	75
N. America	34	37	41	43	44	49	54	54	54	54	54
Oceania	-	-	-	-	-	-	-	-	-	-	-
Total	**853**	**898**	**962**	**1,020**	**1,094**	**1,182**	**1,258**	**1,348**	**1,436**	**1,520**	**1,575**

Source: *Roskill*
Notes: *1-Base case scenario*
2-and Middle East

A list of natural graphite projects under development (outside China) is shown in Table 5, although not all of this capacity will be realised. Exploration is also being carried out on many sites around the world (a number of which have had a JORC/NI 43-101 resource estimate).

Recent low prices and new project closures have limited the investment available to graphite development projects. Many companies have used the quiet period to conduct further resource expansion, raise capital, upgrade feasibility studies for a higher rate of production, and develop the manufacture of downstream products, in particular spherical graphite. Some projects already have non-binding sales agreements or marketing contracts in place.

Prices are expected to rise in the coming years as growing demand begins to eliminate Chinese overcapacity. As demand continues to increase, rising prices will encourage investment in the graphite supply chain and the development of new projects. Initially, a

small number of the most developed projects are expected to come on-line and ramp up production to meet demand (some have significant capacities planned that, together with increasing Chinese output, could meet increases in demand for a number of years). There is then expected to be a lag time, before other projects start to come online in the second half of the forecast period.

By early 2017, a number of companies outside China were trialling spherical graphite processing technologies or developing spherical graphite production facilities. No non-Chinese company has yet proven commercial scale production or that production can be competitive with that exported from China. Production in the ROW often involves a more expensive process, excluding the use of strong acids and other environmentally-damaging reagents, as is typical in China, by using only thermal purification or other newly developed proprietary processes.

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Table 5: World: Details of graphite development projects, 2017

Operator	Name	Location	Products	Facilities	Capacity[1] (ktpy)	Status
Australia						
Hexagon Resources	McIntosh	Western Australia	Flake	…	…	PFS
Archer Exploration	Campoona	South Australia	Flake	…	…	Scoping study
Graphitecorp	Mt Dromedary	Queensland	Flake	…	…	Scoping study
Lincoln Minerals	Kookaburra Gully	South Australia	Flake	…	…	Scoping study
Canada						
Focus Graphite	Lac Knife	Québec	Flake	Mine, plant	44.3	Feasibility
Focus Graphite	*Sept-Iles*	*Québec*	*Spherical graphite*	*Plant*	*…*	*Feasibility*
Mason Graphite	Lac Guéret	Québec	Flake	Mine, plant	51.9	Feasibility
Northern Graphite	Bissett Creek	Ontario	Flake	Mine, plant	44.2	BFS/ updated PEA
Northern Graphite	*Bissett Creek*	*Ontario*	*High-purity flake/spherical graphite*	*Plant*	*5.0*	*Scoping study*
Northern Graphite	*Bissett Creek*	*Ontario*	*Coated spherical graphite*	*Plant*	*5.0*	*Scoping study*
Zenyatta Ventures	Albany	Ontario	Hydrothermal vein	Mine, plant	30.0	Pilot Plant/PFS
Canada Carbon	Miller	Ontario	Hydrothermal vein	…	…	PFS
Nouveau Monde Graphite	Matawinie	Québec	Flake	Mine/plant	50.0	PEA
Ontario Graphite	Kearney	Ontario	Flake	…	20.0	Permitting
India						
KS Mines	…	Palamu, Jharkhand	Flake	…	36.0	Unknown
Madagascar						
NextSource Materials Resources	Molo	Southern Madagascar	Flake	Mine, plant	53.0	BFS
Tirupati Madagascar Ventures, Stratmin Global Resources	Vatomaina	Toamasina	Flake	Mine, plant	12.0	Environmental permitting
Malawi						
Sovereign Minerals	Duwi	Near Lilongwe	Flake	…	42.0-111.1	Feasibility
Mozambique						
Syrah Resources	Balama	Cabo Delgado	Flake	Mine, plant	380.0	Construction
AMG Mining	Ancuabe	Cabo Delgado	Flake	Mine, plant	6.0-9.0	Feasibility/ construction

….Table continues

Operator	Name	Location	Product	Facilities	Capacity[1] (ktpy)	Status
Russia						
Heilongjiang Pride New Material[3]	Jixi, Heilongjiang		Flake	Mine, plant	80.0	Operating
Yixiang Graphite Group	Luobei, Heilongjiang		Flake	Mine, plant	80.0	Operating
Inner Mongolia Rising New Energy	Xinghe, Inner Mongolia		Flake	Mine, plant	60.0	Operating
Qingdao Heilong Graphite	Pingdu, Shandong/ Heilongjiang		Flake	Mine, plant	60.0	Operating
Dalgrafit	Topolihinsky	Near Amurzet	Flake	Mine, plant	40.0	Design stage
Sweden						
Talga Resources	Vittangi	Svappavaara	Flake	Mine, plant	30.0-40.0	Scoping study
Tanzania						
Kibaran Resources	Epanko	South-eastern Tanzania	Flake	Mine, plant	60.0	Feasibility expansion
Kibaran Resources	Epanko	South-eastern Tanzania	Spherical graphite	Plant	…	Feasibility
Magnis Resources	Nachu	South-eastern Tanzania	Flake	Mine, plant	240.0	BFS
Walkabout Resources	Lindi Jumbo	South-eastern Tanzania	Flake	Mine, plant	40.0	DFS
Graphex Mining	Chilalo	South-eastern Tanzania	Flake	Mine, plant	69.0	Mining licence/PFS
USA						
Alabama Graphite	Coosa	Coosa, Alabama	Flake	Mine, plant	…	Pilot plant testing
Graphite One Resources	Graphite Creek	Seward Peninsula, Alaska	Flake	Mine, plant	…	PEA
Syrah Resources	…	South-eastern USA	Spherical graphite	Plant	…	Engineering/ commercial study
Total					**>1,348**	

Source: Roskill
Note: 1-Processed production capacity

2.4 Synthetic graphite: World production review

Global production of synthetic graphite was estimated to be 1.50Mt in 2016. Production grew slowly by 1.6%y over the last decade (Table 6, Figure 10).

The majority of production is of high-value primary synthetic graphite, manufactured directly for the customer with a specific set of specifications depending on the application. Therefore, production can be considered to be roughly the same as consumption in any given year.

The synthetic graphite industry has evolved into an oligopolistic structure; barriers to entry are high as extensive product and process know-how and other intellectual property are necessary to compete with established producers and graphitisation equipment requires high initial capital investment. Synthetic graphite production also requires high quality raw material sources and a developed energy supply infrastructure.

Table 6: World: Estimated synthetic graphite production by region, 2006-2016 (kt)

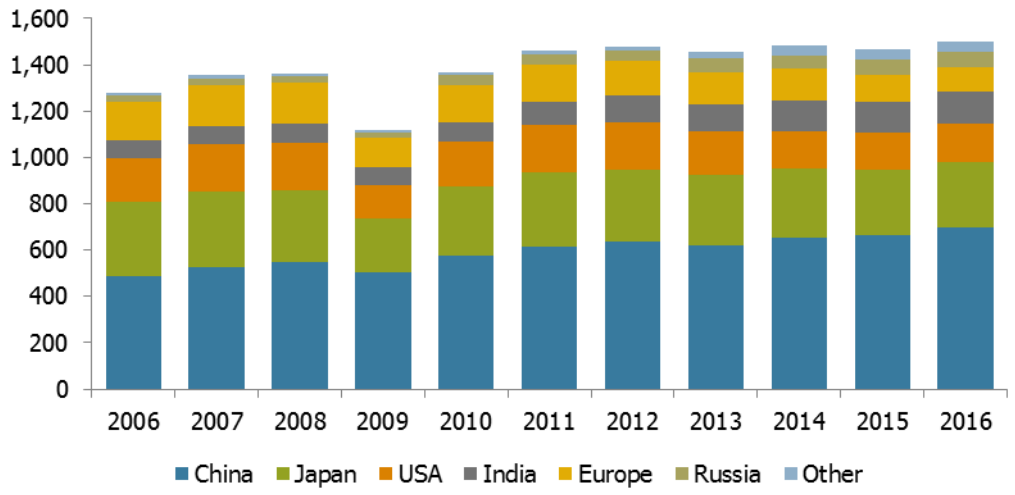
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
China	486	528	546	502	575	613	635	622	653	666	697
Japan	320	325	314	234	301	321	310	302	297	278	285
USA	192	203	205	145	192	204	207	189	163	161	165
India	77	81	82	78	82	102	118	116	134	132	135
Europe[1]	166	176	177	123	164	161	148	138	134	117	105
Russia	26	27	27	22	41	44	44	58	59	66	67
Other[2]	13	14	14	11	14	15	15	29	45	44	45
Total	**1,279**	**1,354**	**1,364**	**1,116**	**1,368**	**1,460**	**1,476**	**1,456**	**1,485**	**1,464**	**1,499**

Sources: *Roskil*

Notes: *1-Includes Austria, France, Germany, Italy, Poland, Spain, Switzerland and Ukraine*

2-Includes Brazil, Canada, Malaysia, Mexico, South Africa and South Korea

Figure 10: World: Estimated synthetic graphite production by region, 2006-2016 (kt)



Source: Roskil

Synthetic graphite can be manufactured into solid articles of varied shape and size, granular materials, and powders. Production is dominated by three principal forms, classified by final application:

- synthetic graphite electrodes - which account for around 80% of synthetic graphite's production/demand
- shapes and speciality products for a range of applications
- battery powders

Synthetic graphite electrodes account for the largest proportion of production, 46% in 2016, or 711kt. The weakening electrode market throughout the 2010s resulted in growth of just 0.5%py in synthetic graphite electrodes between 2006 and 2016. Global crude steel production has slowed while, at the same time, production of EAF steel (the main indicator trend for electrodes) has fallen in recent years as a result of low scrap steel availability in China and other Asian countries. Production of synthetic graphite for many other applications has been limited by poor market recovery following the global economic downturn.

The exception has been uptake of battery-grade synthetic graphite powders, production of which grew by 12%py over the last decade to 45kt. Despite this rapid growth, battery powders were thought to account for just 3% of global synthetic graphite production in 2016. Use of battery powders is growing in lithium-ion battery anodes for use in emerging applications such as electric vehicles and energy storage.

China is the largest synthetic graphite producer, accounting for around 47% of world production in 2016, or an estimated 697kt (Figure 11). China's proportion continues to grow for two main reasons. Firstly, China is increasing production for domestic consumption. Secondly, China's lower cost of production has ensured a competitive edge over rival producers overseas, especially at a time when global electrode markets are weakening.

A large quantity of global electrode capacity has closed since 2013, much of it outside of China; GrafTech estimates that 240ktpy of total electrode capacity (including capacity for synthetic graphite and other types of electrode) has closed worldwide.

The synthetic graphite industry is also undergoing consolidation, both inside China (where there is significant overcapacity) and in the ROW where there has been particular interest in producers of materials for the battery supply chain.

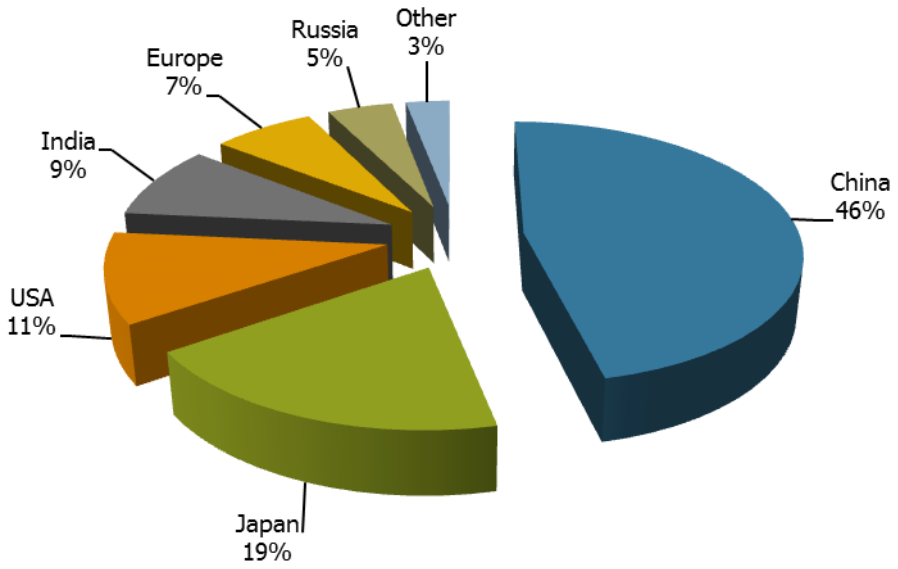
In October 2016, the Japanese anode material manufacturer Showa Denko agreed to purchase SGL Carbon's synthetic graphite electrode business, at a value of €350M.

In February 2017, Imerys Graphite & Carbon acquired the Japanese company Nippon Power Graphite, which owns anode material production capacity in Japan and which has a patented CVD coating technology for the production of lithium-ion battery anode materials. Nippon Power Graphite's facilities supply mainly Asian markets and Imerys hopes to target the growing electric vehicle market.

The principal producers of synthetic graphite products are listed in Table 7 with capacity data where available. The largest producers are the electrode manufacturers GrafTech of the USA and Fangda Carbon New Material in China, both thought to have just under 200ktpy of capacity.

Many synthetic producers are also processors of natural and synthetic graphite and other carbons. They may supply a range of downstream products based on these materials and on graphite and carbon blends.

Figure 11: World: Estimated synthetic graphite production by region, 2016 (1.50Mt)



Source: *Roskill*

Table 7: Principal producers of synthetic graphite by main product

	Electrodes	Shapes	Powders	Other
China				
Fangda Carbon New Material	180ktpy	20ktpy		
Heilongjiang Xinyuan Carbon	25ktpy			·
Jiaozuo Zhongzhou Carbon	*	*		*
Linghai Hongfeng Carbon	*			
Nantong Yangzi Carbon	50ktpy			
Shicuan Shida Carbon Group	40ktpy			
Shijiazhuang Huanan Carbon	6ktpy			
Sinosteel Engineering & Technology	120ktpy	*		*
Tianzhen Jintian Graphite Electrodes	*			
Xing He Muzi Carbon	*			
Xuzhou Jianglong Carbon	*			
France				
Imerys Carbon & Graphite[1]			*	
Mersen Group		*		
	Electrodes	Shapes	Powders	Other
Germany				
SGL Group[2, 3]	<120ktpy	*	*	*
India				
Graphite India	98ktpy	*		
HEG	80ktpy			
Rahul Graphites	*	*	*	
Japan				
Hitachi Chemical			*	
Ibiden		*		
Mitsubishi Rayon				
Nippon Carbon	32ktpy	*	*	
Nippon Graphite Industries			*	*
SEC Carbon	27ktpy	*	*	
Showa Denko Carbon	127ktpy		*	
Tokai Carbon[3]	78ktpy	*		
Toyo Tanso		*		
Russia				
Energoprom Group	85ktpy			
UK				
AMEC Thermosol		*		
USA				
Asbury Graphite Mills				*
GrafTech International	195ktpy	*	*	
Phillips 66			*	
Poco Graphite		*		
Superior Graphite	*			*

Source: *Roskill, company literature*

Notes: *1-Acquired Nippon Power Graphite in February 2017*

2-SGL's core SG electrode business being acquired by Showa Denko in early 2017

3-Excluding SGL Tokai JV in China

2.5 Synthetic graphite: Forecast supply

As with natural graphite, Roskill proposes three scenarios for future synthetic graphite production based on corresponding forecasts for lithium-ion battery growth and graphite demand (Table 8). Using the base case scenario, global production of synthetic graphite is forecast to grow by a CAGR of 3.8%py between 2016 and 2026 to 2.18Mt.

Table 8: World: Forecast supply of synthetic graphite (base, low and high case scenarios), 2016, 2021 and 2026 (kt)

	2016	2021	2026	CAGR 2016-26 (%py)
Base case	1,499	1,749	2,183	3.8
Low case	1,499	1,726	2,100	3.6
High case	1,499	1,799	2,350	4.6

Source: Roskill

Electrodes will continue to dominate production by type but their proportion will fall to an estimated 43% as electrode markets grow relatively slowly and as other types of graphite production grow at a faster rate. The highest growth in demand is expected to come from the battery sector, which uses primary and secondry synthetic graphite powders.

Production of synthetic graphite electrodes will continue to fall in Europe, Japan and, to a lesser extent, the USA. Despite slower rates of crude steel production in China, the rate of EAF steel production is expected to grow relatively strongly once higher levels of steel scrap become available in China and other Asian countries. Global production of synthetic graphite electrodes are predicted to grow by 2.7%py to 930t in 2026 as a result of increased production in China. ROW electrode manufacturers are probably open new capacity in Asia to give them access to this growing market.

Synthetic graphite demand in batteries is predicted to grow by 16.9%py to as much as 26.3%py to 2026 as demand for lithium-ion batteries rises. In China, synthetic graphite is used in lithium-ion batteries over natural graphite because of its competitive cost. ROW markets, however, use much larger quantities of natural graphite. The rate of Chinese synthetic graphite battery powder production will pick up towards the end of the forecast period, as the manufacture of lithium-ion battery anodes increasingly shifts to China and, as Chinese synthetic graphite capacity grows to supply growing domestic lithium-ion battery markets (Table 9, Figure 12).

As well as batteries, by-product secondary synthetic graphite is used in a number of low value applications, such as recarburisers. As production of spherical graphite powders from natural flake graphite increases, a significant amount of by-product ultra-flake fines has become available, some of which now competes with secondary synthetic graphite in Chinese recarburisers.

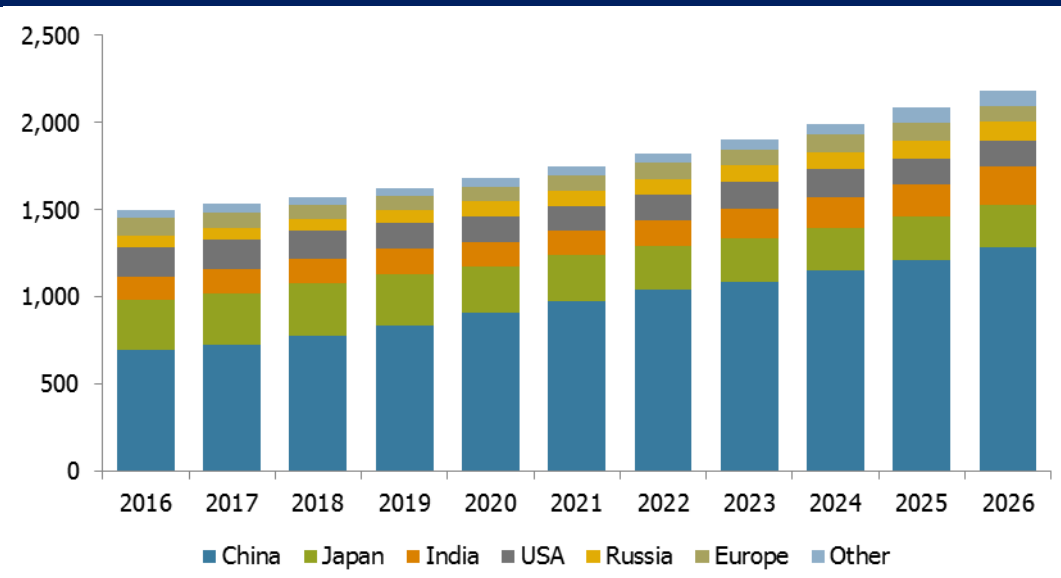
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Table 9: World: Forecast[1] synthetic graphite production by region, 2016-2026 (kt)

	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
China	697	728	780	837	908	979	1,038	1,086	1,155	1,209	1,288
Japan	285	291	299	293	269	262	255	248	239	250	240
India	135	138	142	146	135	140	146	171	179	188	218
USA	165	169	158	146	151	140	146	152	159	146	153
Russia	67	69	71	73	84	87	91	95	100	104	109
Europe[2]	105	92	79	81	84	87	91	95	100	104	87
Other[3]	45	46	47	49	50	52	55	57	60	83	87
Total	**1,499**	**1,533**	**1,575**	**1,626**	**1,682**	**1,749**	**1,822**	**1,905**	**1,992**	**2,084**	**2,183**

Sources: *Roskill*
Notes: *1-Base case scenario*
2-Includes Austria, France, Germany, Italy, Poland, Spain, Switzerland and Ukraine
3-Includes Brazil, Canada, Malaysia, Mexico, South Africa and South Korea

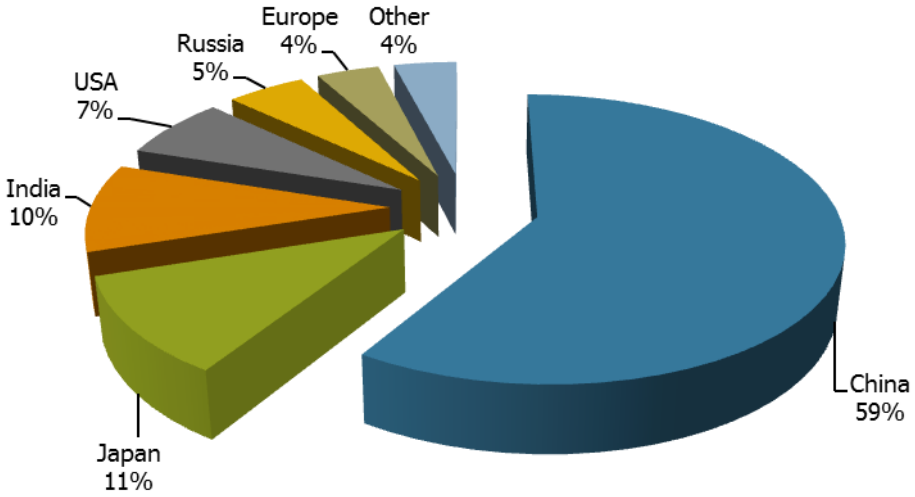
Figure 12: World: Forecast[1] synthetic graphite production by region, 2016-2026 (kt)



Source: *Roskill*
Note: *1-Base case scenario*

China's proportion of synthetic graphite production is forecast to increase considerably to as much as 59% in 2026 (Figure 13). Europe, Japan and the USA will lose significant market position to China. India will be an additional area of supply growth.

Figure 13: World: Forecast[1] synthetic graphite production by region, 2026 (1.97Mt)



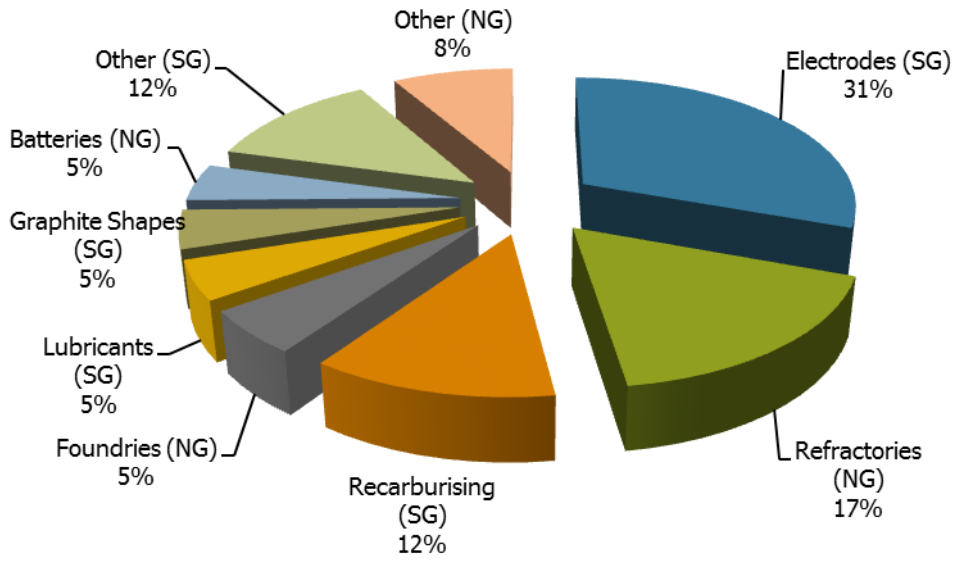
Source: *Roskill*
Note: *1-Base case scenario*

3. Consumption of natural and synthetic graphite

Consumption of graphite grew by a CAGR of 1.9%py between 2006 and 2016 to reach 2.32Mt of which, synthetic graphite accounted for around 65% (1.50Mt) and natural graphite 35% (0.82Mt). The largest growth was in the natural flake graphite sector which grew by a CAGR of 3.5%py to an estimated 0.59Mt.

The two largest markets are electrodes for synthetic graphite and refractories for natural graphite (Figure 14). Electrodes accounted for just under half of all synthetic graphite consumption in 2016 and refractories just under half of all natural graphite consumption. The largest growth has come from the use of both natural and synthetic graphite in battery applications, which now account for around 7% of all graphite consumption.

Figure 14: World: Consumption of graphite by major applications, 2016 (2.32Mt)



Source: *Roskill*
Note: *NG-Natural graphite; SG-Synthetic graphite*

Trends in the steel industry directly influence the markets of electrodes, refractories, recarburising and foundries. Global steel production grew by an average of just 2.6%py between 2006 and 2016, slowing with reduced output from China. Chinese steel production underpins global trends. Although Chinese steel output grew at 6.8%py over the last decade, the rate of growth through this period slowed rapidly and production declined in real terms for the first time in 2015 before recovering slightly in 2016.

Global production of synthetic graphite electrodes/graphite consumption in this application grew by an estimated 0.5%py 2006-16. In addition to poorly performing overall steel production, output of EAF steel, the main use for synthetic graphite electrodes has been particularly weak, as a result of low availability of steel scrap in China and other industrialising countries. Global EAF steel production grew by 0.5%py over the last decade while EAF steel production in China grew by just 1.6%py.

The weak steel industry, coupled with declining specific consumption, resulted in global refractory output falling by 2.5 %py 2006-2016. Graphite consumption in refractories may have seen a slight increase over this period at 1.6%py, because of its use in more specialist refractories, for which demand is more robust.

Consumption of graphite in battery applications has increased by an average of 11.6%py between 2006 and 2016. Most of the graphite is used in the production of lithium-ion battery anode material and the global market for lithium-ion batteries (in terms of MWh power) grew by 24.5%py over the period. Synthetic graphite, natural graphite and blends of graphite and/or other carbons are used depending on price, performance and other factors. Consumption of synthetic graphite is estimated to have grown slightly more strongly, at 12.3%py compared to 11.3%py for natural graphite, because of an increasing abundance of low cost secondary synthetic graphite from the Asian electrode market and a continuing focus on China in the battery supply chain (both in terms of companies transitioning to China and in production to serve the growing domestic market).

A breakdown of global consumption of both natural and synthetic graphite between 2006 and 2016 is given in Table 11. Battery consumption is expected to exceed that of lubricants and foundries in 2017.

Table 10: World: Estimated consumption of natural and synthetic graphite by application[1], 2006-2016 (kt)

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Electrodes	673	732	728	603	713	767	766	729	731	695	711
Refractories[2]	378	367	336	247	380	381	391	409	418	436	441
Recarburising	242	250	261	182	262	276	284	283	301	302	314
Foundries	123	124	125	81	125	143	140	146	150	155	160
Lubricants	135	139	142	135	142	146	149	151	152	155	158
Batteries	51	72	82	68	80	86	90	107	120	148	152
Friction products	95	100	103	77	103	109	112	116	119	123	125
Graphite shapes	93	95	97	92	105	110	111	117	118	123	125
Other[3]	133	134	135	109	130	131	132	134	136	134	135
Total	**1,923**	**2,012**	**2,009**	**1,595**	**2,040**	**2,149**	**2,175**	**2,192**	**2,246**	**2,270**	**2,320**
Natural	**644**	**658**	**645**	**479**	**672**	**688**	**699**	**736**	**760**	**806**	**821**
Synthetic	**1,279**	**1,354**	**1,364**	**1,116**	**1,368**	**1,460**	**1,476**	**1,456**	**1,485**	**1,464**	**1,499**

Source: *Roskill*

Notes: *1-Figures may be revised from previous editions*

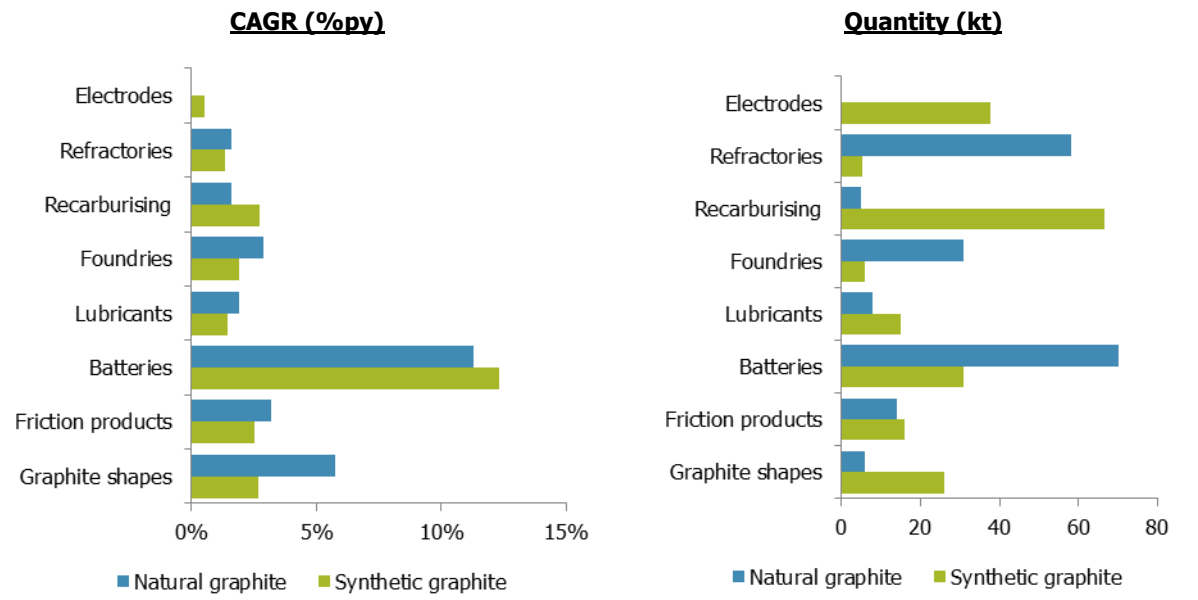
2-Some graphite producers report refractory consumption of natural graphite to be up to 100ktpy higher; Roskill consumption figures are limited by Chinese flake graphite production estimates

3-Includes consumption in nuclear applications, powder metallurgy, fuel cells, pencils, conductive polymers, fire retardants, flexible graphite, carbon-graphite foam, paint and synthetic diamonds

The high growth rate for battery applications is highlighted in Figure 15. For many years, the largest growth in consumption (in terms of quantity) has come from the major markets of electrodes and recarburising for synthetic graphite, and refractories for natural graphite. Over the last decade, large amounts of natural graphite have begun to be consumed in lithium-ion batteries. Low yields in the production of spherical graphite from natural flake graphite for this application mean that much larger amounts of raw material natural graphite are required than synthetic graphite for an equivalent supply of material to anode

manufacturers. Recarburising is a major market for secondary synthetic graphite, which is created as a by-product of electrode manufacture. In recent years, the Chinese recarburising industry has also accepted flake graphite fines created as a by-product of spherical graphite production for the lithium-ion battery industry.

Figure 15: World: Estimated growth in consumption of natural and synthetic graphite by application, 2006-2016



Source: Roskill

A snapshot of estimated consumption by region and application, during 2016, is given in Table 11. Asia was the largest consuming region, accounting for 55% of all natural and synthetic graphite consumption that year. Asian growth during the last decade has been stronger than in any other region.

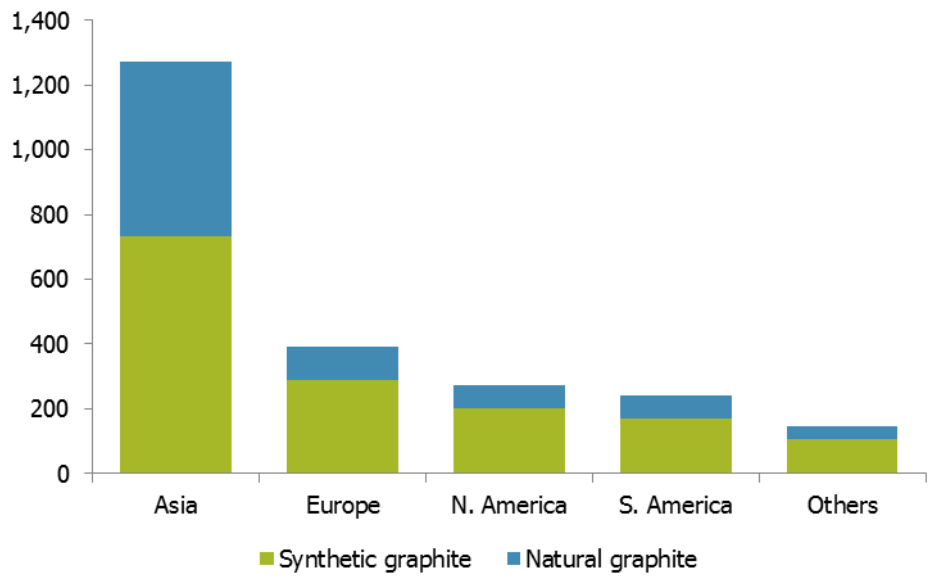
Table 11: World: Estimated consumption of natural and synthetic graphite by region and application, 2016 (kt)

	Asia	Europe	N. America	S. America	Others	Total
Electrodes	327	158	110	27	89	**711**
Refractories	341	43	26	19	11	**441**
Recarburising	186	-	-	127	-	**314**
Foundries	72	34	28	13	13	**160**
Lubricants	47	51	40	11	9	**158**
Batteries	123	8	9	7	5	**152**
Friction products	53	29	19	17	6	**125**
Graphite shapes	57	41	25	1	2	**125**
Other	68	26	16	16	8	**141**
Total	**1,272**	**392**	**273**	**239**	**144**	**2,320**

Source: Roskill

In 2016, synthetic graphite accounted for 58% of total consumption in Asia, 74% in Europe, 74% in North America and around 71% in South/Latin America (Figure 16).

Figure 16: World: Estimated consumption of natural and synthetic graphite by region, 2016 (kt)



Source: Roskill

3.1 Natural graphite: Consumption

Estimated global consumption of natural graphite grew by a CAGR of 2.5%py between 2006 and 2016 to reach an estimated total of 821kt. A breakdown of natural graphite consumption by application is shown in Table 12 with estimates for both flake graphite and amorphous graphite. It is difficult to estimate data accurately to this level of detail and this data should, therefore, be used only as an approximate indicator of market trends.

Table 12: World: Estimated consumption of natural graphite[1] by application, 2006-2016 (kt)

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Refractories[1]	342	332	304	224	347	347	354	370	378	395	400
Flake	*256*	*249*	*228*	*168*	*260*	*260*	*269*	*285*	*296*	*305*	*312*
Amorphous	*85*	*83*	*76*	*56*	*87*	*87*	*85*	*85*	*82*	*90*	*88*
Foundries	94	95	96	61	96	110	108	113	116	121	125
Flake	*51*	*52*	*52*	*30*	*52*	*60*	*58*	*60*	*62*	*67*	*71*
Amorphous	*43*	*44*	*44*	*31*	*44*	*50*	*50*	*53*	*54*	*54*	*54*
Batteries	37	53	60	49	58	62	64	77	86	105	107
Flake	*37*	*53*	*60*	*49*	*57*	*62*	*64*	*76*	*85*	*103*	*105*
Amorphous	*-*	*-*	*-*	*-*	*-*	*-*	*-*	*1*	*1*	*2*	*2*
Friction products	38	40	41	27	41	45	46	48	49	51	52
Flake	*11*	*12*	*13*	*8*	*13*	*15*	*16*	*17*	*17*	*18*	*19*
Amorphous	*27*	*28*	*28*	*19*	*28*	*30*	*30*	*31*	*32*	*33*	*33*
Lubricants[2]	38	40	41	38	41	42	44	44	44	45	46
Flake	*27*	*28*	*29*	*27*	*29*	*30*	*31*	*31*	*31*	*32*	*32*
Amorphous	*11*	*12*	*12*	*11*	*12*	*12*	*13*	*13*	*13*	*13*	*14*
Recarburising	29	30	31	22	31	32	31	31	32	33	34
Flake[3]	*-*	*-*	*-*	*-*	*-*	*-*	*1*	*2*	*3*	*5*	*7*
Amorphous	*29*	*30*	*31*	*22*	*31*	*32*	*30*	*29*	*29*	*28*	*27*
Graphite shapes	8	9	10	7	10	10	11	12	13	13	14
Flake	*6*	*7*	*8*	*5*	*8*	*8*	*9*	*10*	*11*	*11*	*12*
Amorphous	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
Other	58	60	61	50	48	40	40	41	42	43	43
Flake	*30*	*31*	*33*	*25*	*27*	*34*	*34*	*36*	*37*	*33*	*32*
Amorphous	*28*	*28*	*28*	*25*	*21*	*6*	*6*	*6*	*6*	*10*	*11*
Total	**644**	**658**	**645**	**479**	**672**	**688**	**699**	**736**	**760**	**806**	**821**
Flake	*418*	*432*	*423*	*313*	*447*	*469*	*482*	*517*	*542*	*574*	*590*
Amorphous	*225*	*226*	*221*	*166*	*225*	*220*	*216*	*219*	*218*	*232*	*231*

Source: *Roskill*

Notes: *1-Some graphite producers report refractory consumption of natural graphite to be up to 100ktpy higher; Roskill consumption figures are limited by Chinese flake graphite production estimates*

2-Includes small amounts of vein graphite

3-Consumption is increasing in China of ultrafine flake graphite produced as a by-product from spherical graphite manufacture

An estimate of natural graphite consumption on a regional and end use basis for 2016 is shown in Table 13. Asian consumption accounted for an estimated 540kt or 66% of the total compared to 13% for Europe, 9% for North America and 8% for South/Latin America in 2016. Asia is the leading region in terms of consumption because of the size of the

Chinese market and to a lesser degree, markets in Japan and South Korea. The Asian refractories industry is the largest consumer of natural graphite. The main reason is the size of the Chinese refractories industry, which has the capacity to produce over 2Mtpy of shaped products containing natural graphite.

Chinese producers have extensive stocks that supply domestic consumption and exports when operations are closed in winter. Major consumers also maintain stocks in order to avoid having to purchase material when prices are high.

Table 13: World: Estimated total natural graphite consumption by region and application, 2016 (kt)

	Asia	Europe	N. America	S. America	Others	Total
Refractories	308	40	23	18	11	**400**
Foundries	56	26	21	10	11	**125**
Batteries	82	6	6	7	5	**107**
Friction products	22	11	8	8	3	**52**
Lubricants	20	11	8	3	3	**46**
Recarburising	19	-	-	15	-	**34**
Graphite shapes	8	2	1	1	2	**14**
Other	24	5	3	8	2	**43**
Total	**540**	**103**	**71**	**69**	**38**	**821**

Source: Roskill

Flake graphite consumption was an estimated 590kt in 2016, accounting for 72% of total natural graphite use. Consumption of flake graphite has grown steadily over the last ten years (3.5%py) as the lithium-ion battery market becomes more established and as demand grows strongly in the small, emerging market of expandable/expanded graphite (for fire retardants and flexible graphite products). By comparison, consumption of amorphous graphite has grown slowly (0.2%py) as traditional markets decline and as competition increases from high-purity natural flake and synthetic graphite by-products and other carbon materials. By far the largest market for flake natural graphite is in Asian refractories (Table 14). The other major consuming industries are batteries in Asia and refractories in Europe.

Table 14: World: Estimated flake graphite consumption by region and application, 2016 (kt)

	Asia	Europe	N. America	S. America	Others	Total
Refractories	226	40	22	18	7	**312**
Batteries	84	5	5	6	4	**105**
Foundries	24	22	17	2	5	**71**
Lubricants	17	9	6	-	-	**32**
Friction products	8	6	3	2	1	**19**
Graphite shapes	6	2	1	1	1	**12**
Recarburising	6	-	-	-	-	**7**
Other	16	5	3	7	2	**32**
Total	**387**	**88**	**56**	**37**	**21**	**590**

Source: Roskill

3.2 Natural & synthetic graphite: Forecast demand

Between 2016 and 2026, demand for graphite is forecast to grow strongly, driven by robust growth in the lithium-ion batteries sector. Roskill offers a base, low and high case scenario for graphite demand, based on corresponding forecasts for lithium-ion battery growth.

Using the base case scenario, global demand could grow by a CAGR of 4.8%py to 3.71Mt in 2026. The proportion accounted for by synthetic graphite is expected to fall from 65% in 2016 to around 59% in 2026 as larger amounts of natural flake graphite than synthetic graphite are consumed in batteries as feedstock. Natural flake graphite demand could grow by a CAGR of 8.4%py over the next decade.

Table 15: World: Forecast demand for natural and synthetic graphite (base, low and high case scenarios), 2016, 2021 and 2026 (Mt)

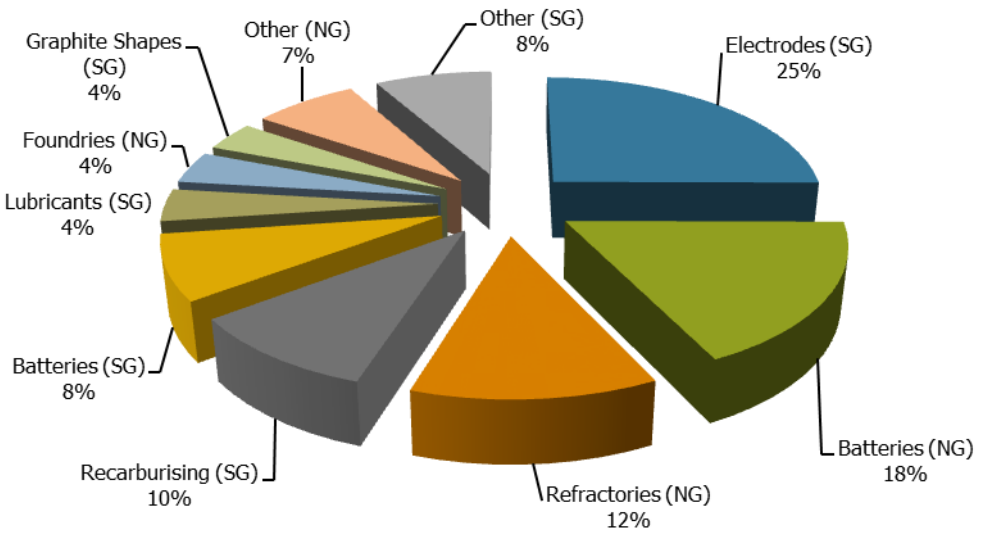
	2016	2021	2026	CAGR 2016-26 (%py)
Base case	**2.32**	**2.87**	**3.71**	**4.8**
Natural	0.82	1.12	1.52	6.4
Synthetic	1.50	1.75	2.18	3.8
Low case	**2.32**	**2.79**	**3.44**	**4.0**
Natural	0.82	1.07	1.34	5.0
Synthetic	1.50	1.73	2.10	3.4
High case	**2.32**	**3.06**	**4.26**	**6.3**
Natural	0.82	1.26	1.91	8.8
Synthetic	1.50	1.80	2.35	4.6

Source: Roskill

Batteries are forecast to grow to become the largest graphite market by 2026, exceeding the traditional leading markets of electrodes and refractories. Market share of electrodes and refractories will also weaken if the steel industry continues to perform poorly (Figure 17). By 2026, electrode share could fall to 43% of all synthetic graphite consumption and refractory share could fall to just 29% of all natural graphite consumption. Demand for all types of graphite in battery applications could grow to account for around 26% of total graphite consumption in 2026.

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Figure 17: World: Forecast[1] consumption of graphite by major application, 2026 (3.71Mt)



Source: *Roskill*
Note: *NG-Natural graphite; SG-Synthetic graphite*
1-Base case scenario

Consumption of raw graphite in battery applications is forecast to grow by 20.2%py 2016-26, using the base case scenario, to 957kt; this is equivalent to an increase of around 6 times the current level of consumption. Low to high case forecast scenarios suggest a possible CAGR range of 16.3%py to 25.8%py. Graphite demand will grow slightly more slowly than the lithium-ion battery market itself as a result of improvements to the manufacturing process that will continue to reduce specific consumption of graphite per MWh of battery output. The lithium-ion battery market (in terms of MWh power) is forecast to grow by an average of 29.4%py between 2016-2026 using the base case scenario; low to high case scenarios suggest that growth could range between 25.0%py and 35.7%py.

There will be room for a significant increase in the use of both natural and synthetic graphite in lithium-ion batteries, especially with the shift towards the use of graphite and carbon blends. In terms of consumption of processed graphite products by the anode material manufacturers, demand for synthetic graphite is expected to rise at a slightly higher rate than spherical graphite because of the preferential use of competitively priced secondary synthetic graphite in batteries in the rapidly growing Chinese market. This will be offset by the higher use of natural flake graphite as a raw material to allow for wastage in the manufacture of spherical graphite from natural flake. Although yields are expected to improve overall, there will be a shift towards the use of the highest grades of spherical graphite with the lowest yields.

Growth in the markets of electrodes and refractories will remain subdued. Although global crude steel production recovered slightly in 2016, it is expected to fall again in 2017 and 2018 before experiencing limited growth over the rest of the decade. Overall, global steel output could slow to an average of just 1.2%py 2016 to 2026 as production growth in China falls to 1.6%py.

In the refractories industry, the rate of decline in China's specific consumption of refractories is expected to decrease but growth in refractory production will be limited by the poor steel market to around 0.7%py. Graphite consumption in refractories could grow at a modest 1.1%py to 2026 as the uptake of specialist graphite-containing refractories slows with competition from other refractory products.

Consumption of synthetic graphite in electrodes is forecast to grow more strongly than in the previous decade, at 2.7%py, in line with forecasts for global EAF steel production. EAF steel output will rise at a faster rate than that of total crude steel as the increasing availability of steel scrap hastens the shift to EAF steel production in China.

A breakdown of forecast global demand for natural and synthetic graphite between 2016 and 2026 (using the base case scenario) by application is given in Table 16.

Table 16: World: Forecast[1] demand for natural and synthetic graphite by application, 2016-2026 (kt)

	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Batteries	152	181	225	293	369	471	574	690	801	889	957
Electrodes	711	724	738	751	765	784	806	831	860	893	930
Refractories	441	446	452	459	467	471	475	479	483	488	494
Recarburising	314	320	326	332	338	346	356	367	380	394	410
Lubricants	158	161	165	170	176	181	187	192	198	204	211
Foundries	160	161	162	166	169	172	176	180	184	188	193
Friction products	125	127	130	134	139	143	146	150	154	158	163
Graphite shapes	125	127	130	132	134	137	140	143	146	149	154
Other[2]	135	141	151	158	166	169	174	178	183	187	194
Total	**2,320**	**2,388**	**2,478**	**2,595**	**2,723**	**2,873**	**3,033**	**3,211**	**3,389**	**3,549**	**3,706**
Natural	**821**	**854**	**903**	**969**	**1,041**	**1,124**	**1,211**	**1,306**	**1,397**	**1,465**	**1,524**
Synthetic	**1,499**	**1,533**	**1,575**	**1,626**	**1,682**	**1,749**	**1,822**	**1,905**	**1,992**	**2,084**	**2,183**

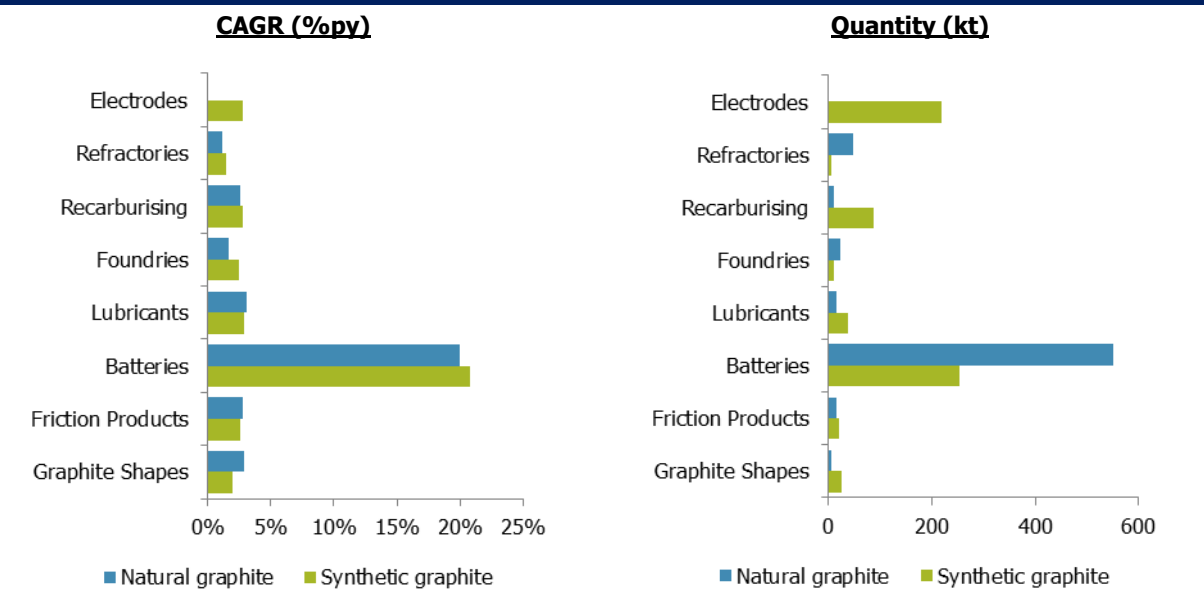
Source: *Roskill*

Notes: *1-Base case scenario*

2-Includes consumption in nuclear applications, powder metallurgy, fuel cells, pencils, conductive polymers, fire retardants, flexible graphite, carbon-graphite foam, paint and synthetic diamonds

Growth in demand for graphite in real terms will be led by electrodes for synthetic graphite (following trends in EAF steel) and batteries for natural graphite (because of the extensive requirement for raw natural graphite in processing). The highest rates of growth will continue to be for both natural and synthetic graphite in batteries.

Figure 18: World: Forecast[1] growth in demand for natural and synthetic graphite by application, 2016-2026



Source: *Roskill*
Note: *1-Base case scenario*

A snapshot of predicted demand by region and application in 2026 is given in Table 17. Asia will remain the largest producing region, accounting for approximately 2.29Mt. Asia's market share is expected to increase to 62%. China will continue to increase its consumption of graphite in the production of downstream products for use domestically and for export. High growth products such as spherical graphite and expandable/expanded/ flexible graphite are almost entirely produced in China. India is also expected to become a much larger consumer of graphite over the next decade.

Table 17: World: Forecast[1] demand for natural and synthetic graphite by region and application, 2026 (kt)

	Asia	Europe	N. America	S. America	Others	Total
Batteries	814	29	30	27	57	**957**
Electrodes	448	198	145	37	103	**930**
Refractories	379	44	27	24	20	**494**
Recarburising	232	2	2	169	5	**410**
Lubricants	79	56	47	18	11	**211**
Foundries	93	39	33	18	10	**193**
Friction products	68	36	26	24	9	**163**
Graphite shapes	72	46	30	2	4	**154**
Other	103	27	17	25	22	**194**
Total	**2,289**	**477**	**357**	**344**	**239**	**3,706**

Source: *Roskill*
Note: *1-Base case scenario*

3.3 Natural graphite: Forecast demand

Forecast demand for natural graphite is forecast to grow by 6.4%py between 2016 and 2026, using the base case scenario, to reach 1.52Mt (Table 18).

Table 18: World: Forecast[1] demand for natural graphite by application, 2016-2026 (kt)

	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Batteries	107	127	159	208	262	334	407	489	566	620	659
Flake	*105*	*125*	*156*	*204*	*257*	*328*	*399*	*479*	*555*	*607*	*644*
Amorphous	*2*	*2*	*3*	*4*	*5*	*6*	*8*	*10*	*11*	*13*	*14*
Refractories	400	404	410	416	424	427	431	434	438	441	447
Flake	*312*	*319*	*330*	*341*	*354*	*359*	*365*	*370*	*376*	*381*	*388*
Amorphous	*88*	*85*	*80*	*75*	*70*	*68*	*66*	*64*	*62*	*60*	*59*
Foundries	119	122	125	128	130	132	135	138	141	144	148
Flake	*65*	*67*	*69*	*72*	*75*	*78*	*82*	*86*	*90*	*94*	*99*
Amorphous	*54*	*55*	*56*	*56*	*55*	*54*	*53*	*52*	*51*	*50*	*49*
Friction products	52	53	54	56	58	60	61	63	65	66	68
Flake	*19*	*19*	*20*	*21*	*23*	*24*	*26*	*27*	*28*	*30*	*32*
Amorphous	*33*	*34*	*34*	*35*	*35*	*35*	*36*	*36*	*36*	*36*	*37*
Lubricants[2]	46	47	48	50	52	54	55	57	59	61	63
Flake	*32*	*33*	*34*	*35*	*37*	*38*	*40*	*41*	*42*	*44*	*46*
Amorphous	*14*	*14*	*14*	*15*	*15*	*15*	*16*	*16*	*16*	*17*	*17*
Recarburising	34	35	36	37	38	39	40	41	42	43	44
Flake	*7*	*9*	*11*	*13*	*15*	*17*	*19*	*21*	*23*	*25*	*27*
Amorphous	*27*	*26*	*25*	*24*	*23*	*22*	*21*	*20*	*19*	*18*	*17*
Graphite shapes	14	15	16	16	15	16	16	17	17	18	19
Flake	*12*	*13*	*14*	*14*	*13*	*14*	*14*	*15*	*15*	*16*	*17*
Amorphous	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
Other	49	51	55	58	62	63	66	67	70	72	76
Flake	*38*	*39*	*43*	*44*	*47*	*49*	*52*	*54*	*57*	*60*	*64*
Amorphous	*11*	*12*	*12*	*14*	*15*	*14*	*14*	*13*	*13*	*12*	*12*
Total	**821**	**854**	**903**	**969**	**1,041**	**1,124**	**1,211**	**1,306**	**1,397**	**1,465**	**1,524**
Flake	***590***	***624***	***677***	***744***	***821***	***907***	***996***	***1,094***	***1,187***	***1,257***	***1,317***
Amorphous	***231***	***230***	***226***	***225***	***220***	***217***	***215***	***212***	***211***	***208***	***207***

Source: *Roskill*

Notes: *1-Base case scenario*
2-Includes small amounts of vein graphite

A forecast for natural graphite demand on a regional and end use basis for 2026 shows that Asian demand could rise to 1.08Mt, accounting for 71% of the global total, followed by Europe (9%), South America (7%) and North America (7%). The majority of growth will come from the Asian battery and, to a lesser extent, Asian refractory markets.

While demand for flake graphite grows strongly, demand for amorphous graphite will continue to fall across almost all applications. Flake graphite's share of the natural graphite market is predicted to increase from 72% in 2016 to 86% in 2026 (Table 19). Demand for flake graphite is forecast to grow at an average of 8.4%py to 2026 while amorphous graphite demand is predicted to decline by 1.1%py.

Table 19: World: Forecast[1] demand for flake graphite by region and application, 2026 (kt)

	Asia	Europe	N. America	S. America	Others	Total
Batteries	604	8	7	8	17	**644**
Refractories	293	41	21	21	12	**388**
Foundries	34	31	21	4	9	**99**
Lubricants	22	9	6	4	4	**46**
Friction products	15	7	4	4	1	**32**
Recarburising	18	2	2	2	2	**27**
Graphite shapes	8	3	2	1	2	**17**
Other	36	9	5	11	4	**64**
Total	**1,030**	**110**	**70**	**56**	**52**	**1,317**

Source: *Roskill*

Note: *1-Base case scenario*

4. Natural flake graphite: Growth markets

4.1 Refractories

Refractories are that second-largest application for all graphite after synthetic graphite electrodes and account for around 20% of global graphite demand. They are a mature and slow growing market that has historically been the driving force behind the natural graphite industry. However, refractories are the largest end use for natural graphite, accounting for more than half of all natural graphite demand and are therefore included as a growth market because of the volumes involved despite the modest predicted growth rates. As demand for graphite in batteries grows in future, this proportion will fall, but refractories will remain the largest market for natural graphite by volume to 2026.

The total refractories market is in decline as steel markets weaken and as specific consumption of refractories per tonne of steel falls in China and other maturing markets. Consumption of graphite in refractories is growing slowing thanks to more specialist use of graphite-containing refractories.

Refractories are non-metallic materials which have chemical and physical properties that make them suitable for use in high temperature environments above 1,000°F (538°C). Refractories are used in linings for furnaces, kilns, incinerators, reactors and are also used to make crucibles.

Graphite is used mainly as an additive in magnesia-carbon and alumina-carbon brick refractories to increase the effectiveness of the final refractory product by:

- increasing thermal conductivity
- decreasing thermal gradient between the hot and cold faces of the product, thereby, reducing expansion
- repelling molten slag
- increasing working life of the product
- increasing ability of the product to withstand thermal shocks/corrosion thereby, improving performance at higher temperatures
- reducing wettability to molten metals so that they do not affect the end-product

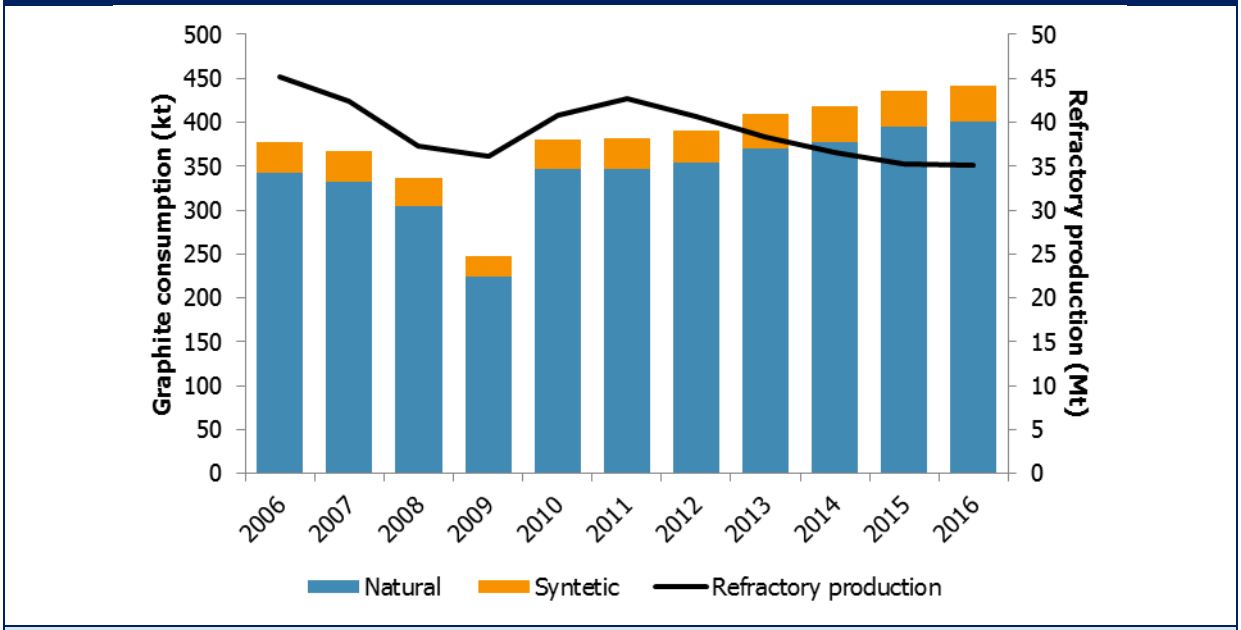
4.1.1 Consumption of graphite in refractories

Consumption of graphite in refractories grew by around 1.6%py between 2006 and 2016 to an estimated 441kt. Over the same period, production of refractories declined by 2.5%py (Figure 19). Much of this decline was market-led as global steel markets slowed and as shaped refractories lost market share to monolithic refractories in the mature refractory markets of the USA, Japan and Europe. Although most graphite-containing refractories are shapes, specialist graphite-containing products have sustained their level of growth while other shaped refractories have declined.

China is the largest refractory market, thought to account for around two thirds of the global total, or 295kt in 2016. Specific consumption of refractories in China per tonne of crude steel is falling in China to be more in line with that of mature markets in Europe, the USA and Japan. Consumption of refractories per tonne of crude steel is around 15kg/t worldwide. Consumption rates in China are around 20kg/t and falling. Chinese consumption of graphite-containing refractories has continued to grow, however.

European consumption of graphite was estimated to be less than 50kt in 2016 and US consumption 20-25kt. Indian consumption is growing strongly but still accounts for less than 5% of the global total. The highest growth rates for consumption of graphite-containing refractories are in found in Asia and other industrialising regions where large amounts of new steel production capacity are being opened.

Figure 19: World: Consumption of graphite in refractories and production of refractories, 2006-2016



Source: Roskill

Natural graphite accounts for over 90% of the graphite consumed in refractories and synthetic graphite the remainder. Natural graphite is preferred because of its lower porosity than synthetic graphite (2-3% compared to 10-15%), which helps to reduce oxidation and other reactions.

Flake graphite accounts for the vast majority of the natural graphite used. Flake graphite is typically higher grade and the flaky shape lends strength to the refractory structure. All sizes of flake are used in refractories, depending on the product. Specifications for natural graphite produced by Imerys Graphite & Carbon for use in refractories are shown in Table 20.

Table 20: Imerys Graphite & Carbon: Specifications of natural flake graphite used in refractories

Grade	Particle size	Guaranteed	Carbon content (%)
Coarse	20 x 50 mesh	80% minimum + 50 mesh (300µm)	94-98
Medium	50 x 80 mesh	80% minimum + 80 mesh (180µm)	94-98
	50 x 100 mesh	80% minimum + 100 mesh (150µm)	94-98
	80 x 150 mesh	80% minimum + 140 mesh (105µm)	94-98
Fine	-100 mesh	80% minimum -100 mesh (150µm)	94-97
	-150 mesh	80% minimum -150 mesh (105µm)	94-97

Source: Imerys Graphite & Carbon

Magnesia-carbon and alumina-carbon bricks typically require flake natural graphite of 50 to -150 mesh particle size and a purity of 94% to 98% C. A trend towards the use of higher grade refractories has resulted in the growing use of graphite with higher carbon content. Magnesia-carbon refractories typically contain 10-25% graphite additions, while alumina-carbon bricks contain smaller additions of 5-15% graphite.

Synthetic graphite and other forms of carbon are also used in some refractories. Those made with synthetic graphite/carbon are much more porous than those made with natural graphite and require firing at temperatures approaching 2,000°C to form a dense graphite structure. These refractories have a low oxidation resistance and cannot be readily exposed to air, carbon dioxide or water vapour at high temperatures; their use is mainly limited to reducing atmospheres.

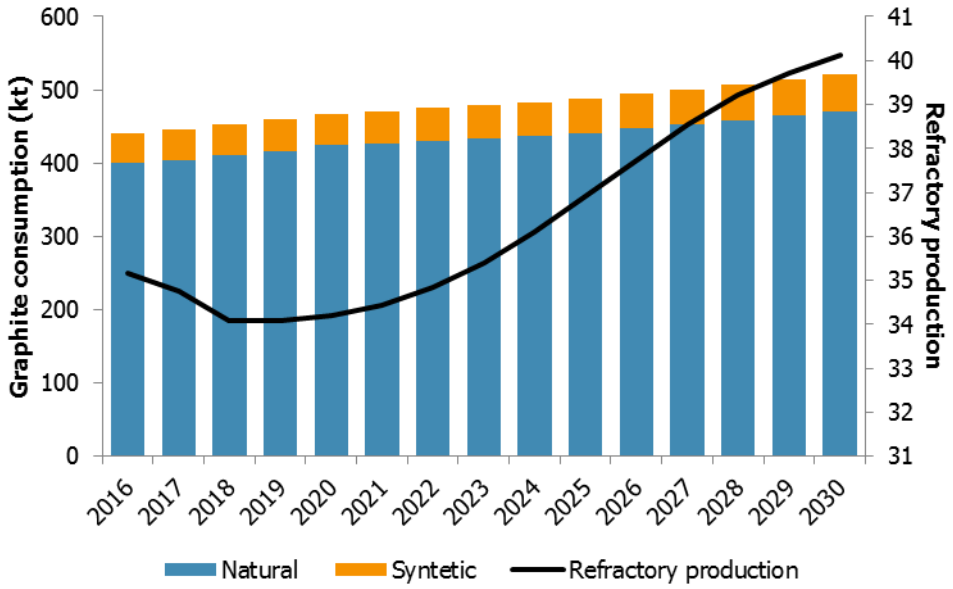
In the past, consumption of carbon per tonne of refractory has declined as manufacturers look to decrease production costs. Manufacturers are finding it increasingly hard to cut back on carbon usage but will continue to do so wherever possible.

4.1.2 Graphite in refractories: Outlook

Over the next ten years, consumption of graphite will be hampered by the low rate of growth forecast for the refractory industry and is predicted to grow by just 1%py (Figure 20). Global refractory production is expected to recover after 2018 as global crude steel output begins to rise once again, although total refractory growth will be limited by falling specific consumption per tonne of steel. Graphite-containing speciality refractories will continue to experience stronger growth than other, more widely used shapes.

Although China will remain the largest consumer of graphite in refractories, it will not return to its previous levels of consumption growth as the Chinese steel industry continues to slow and as Chinese specific refractory consumption rates fall further.

Figure 20: World: Forecast consumption of graphite in refractories and production of refractories, 2016-2030



Source: *Roskill*

Small-scale recovery and reuse of refractory materials has taken place in the steel industry, mainly in Europe. Investment in refractory recycling is on hold until the market improves. If recycling increases in the long-term, it could have an impact on graphite consumption in terms of secondary supply.

4.1.3 Refractories production: Outlook

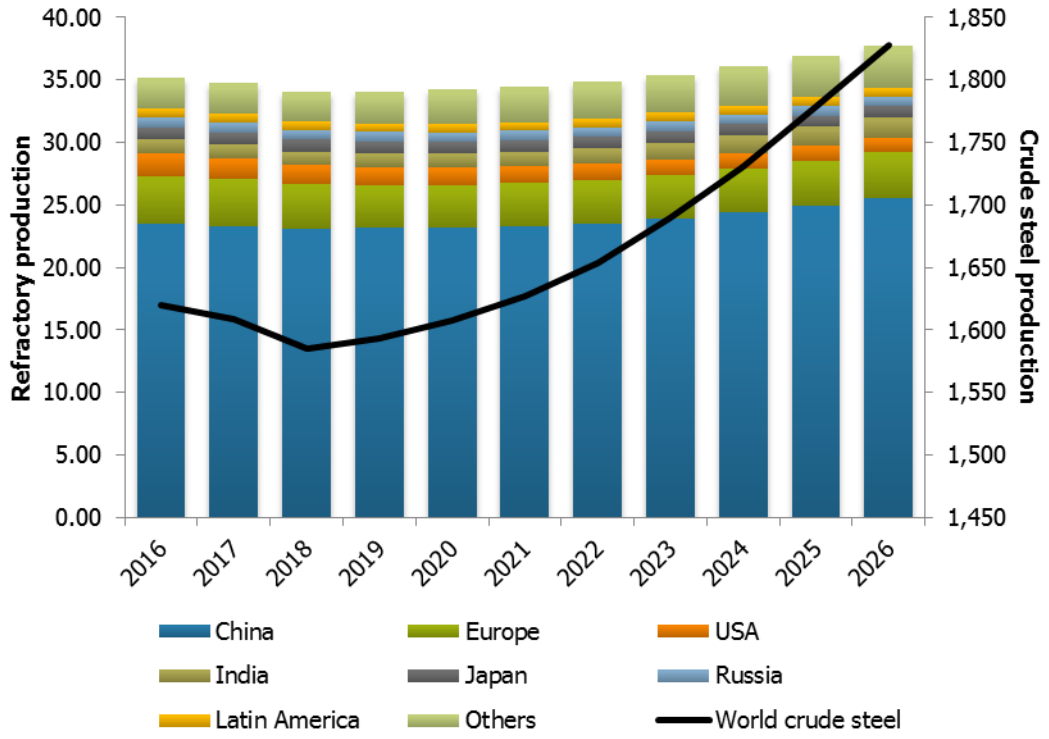
Global refractories production is forecast to grow by 0.7%py between 2016 and 2026 to around 37.7Mt (Figure 21). Production in the first half of the forecast period will continue to decline but by just -0.4%py, followed by global recovery from 2021 of 1.8%py.

Refractory production will grow slightly below the level of global crude steel output as specific consumption continues to fall, especially in China. Global crude steel production is forecast to increase by 1.2%py over the next decade.

Refractory production will not recover to previous highs with further reductions in specific consumption and an overall slowdown in Chinese crude steel production. Refractory output in China could grow by 0.8%py between 2016 and 2026 to reach 25.6Mt, accounting for 68% of global production.

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Figure 21: World: Forecast production of refractories by country/region and global production of crude steel, 2016-2026 (kt)



Source: *Roskill*

4.2 Batteries

Robust growth in the lithium-ion battery market over the next decade is expected to underpin large increases for graphite for both natural and synthetic graphite. The anticipated growth in lithium-ion battery production is a major factor driving the number of natural flake graphite exploration projects currently under development worldwide.

Graphite is used in batteries to improve electrical conductance while remaining chemically inert and stable against corrosion. In lithium-ion batteries, graphite is a main constituent of the anode, acting as a host for the lithium-ions. Graphite is used in smaller amounts in other battery types, mainly as an electrical conductive additive.

In 2016, more than 80% of the raw graphite consumed in this application was in lithium-ion batteries. Demand for lithium-ion batteries is growing strongly, in particular from the emerging applications of new energy vehicles (NEVs) which include both hybrid electric vehicles (HEVs) and full electric vehicles (EVs) and also in energy storage systems (ESS). By 2026, lithium-ion batteries could grow to account for 95-98% of all the graphite used in battery applications.

Minor uses of graphite in battery applications include:

- around 10-15% in primary alkaline batteries (as an additive, lubricant, and processing aid in the cathode)
- <10% in lead-acid batteries (as an additive in the electrodes)
- <10% in other battery types including Zn-air and rechargeable alkaline (as an additive in the positive electrode)

Fuel cells have taken a very small but increasing part of the battery market. While traditional batteries only store electrical energy (either with a limited or rechargeable supply), fuel cells also have generation capability. They are, therefore, discussed separately.

4.2.1 Consumption of graphite in batteries

Consumption of raw graphite across all battery applications grew by an average of 11.6%py over the last decade to an estimated 151.9kt in 2016, equivalent to 7% of global graphite demand. Unusually for graphite applications, both natural and synthetic graphite compete for use in the battery sector; the split is around 70% natural, 30% synthetic (Table 21).

The majority of graphite is consumed in lithium-ion batteries, equivalent to an estimated 124.9kt (82%) in 2016. The effect of strong growth from lithium-ion batteries on the graphite sector is shown in Figure 22. Further details of graphite consumption trends in lithium-ion batteries are discussed in Section 4.2.4.

Use of graphite in other battery applications has also increased. Production of lead-acid batteries has risen with increasing levels of Asian car/e-bike ownership and these batteries have now begun to be used in high capacity ESS applications. There is also continued strong demand for primary alkaline batteries, particularly in Asia. New battery products under development are not expected to have a significant impact on graphite consumption to 2026.

Table 21: World: Consumption of raw graphite[1] in batteries by type, 2006, 2011 and 2016 (kt)				
	2006	2011	2016	CAGR (%py) 2006-16
Lithium-ion batteries				
Natural graphite	28.0	50.9	92.9	12.8
Synthetic graphite	8.4	13.9	32.0	14.4
Sub-total	*36.3*	*64.8*	*124.9*	*13.2*
Other batteries				
Natural graphite	8.7	11.1	13.9	4.7
Synthetic graphite	5.8	10.1	13.1	8.6
Sub-total	*14.5*	*21.2*	*27.0*	*6.4*
All batteries				
Natural graphite	36.7	62.0	106.8	11.3
Synthetic graphite	14.1	24.0	45.1	12.3
Total	**50.8**	**86.0**	**151.9**	**11.6**
Source: *Roskill*				
Notes: *1-Includes raw material flake before processing into spherical graphite*				

It must be noted that the vast majority of natural graphite supplied to the lithium-ion battery industry is first processed into the product known as spherical graphite, 30-70% of which is lost as waste during the spherical graphite manufacturing process. Consumption figures discussed in this section, therefore, represent raw material consumption and not final demand for natural graphite at the anode. Almost all spherical graphite processing is carried out in China because of high costs and the use of strong reagents. Small amounts of flake and amorphous graphite are also used in batteries, mainly as an additive to improve the performance of lithium-ion and other types of battery.

4.2.2 Graphite in batteries: Outlook

Strong growth is expected in the consumption of raw graphite in batteries in 2026, underpinned by the increasing use of lithium-ion batteries in the automotive sector as the emerging market of EVs gathers speed. Individual country targets for EV adoption are very encouraging but a large question remains over the level of demand for lithium-ion batteries that will actually come to fruition. Low, high and base case scenarios for graphite consumption in batteries are shown in Table 22. The base case scenario forecasts an average growth of 17.9% from 151.9kt in 2016 to 957.0kt in 2026.

Such high levels of growth will ensure room for significant increases in both natural and synthetic graphite consumption. Using the base case scenario, graphite demand in batteries could increase by around a factor of six to 2026, with natural graphite demand rising to 658.6kt and synthetic graphite rising to 298.3kt. The vast majority of natural graphite for use in lithium-ion batteries will continue to be processed into spherical graphite with very high levels of wastage. Increasing yield rates will be offset to some extent by the continued shift towards higher grade spherical graphite with the lowest yields.

The price of synthetic graphite is thought to be more competitive with spherical graphite inside China than elsewhere, leading to slightly higher demand growth for synthetic graphite than natural graphite to 2026. Outside of China, natural graphite, in the form of spherical graphite will continue to be used in preference because of price. Natural graphite's proportion of the total battery market is forecast to fall slightly to 69% by 2026. In all

regions, there will be increased use of graphite and carbon blends to improve battery performance and increasing competition from emerging sectors such as silicon-based anodes for lithium-ion batteries.

Table 22: World: Forecast consumption of raw graphite[1] in batteries by type, 2016, 2021 and 2026 (kt)

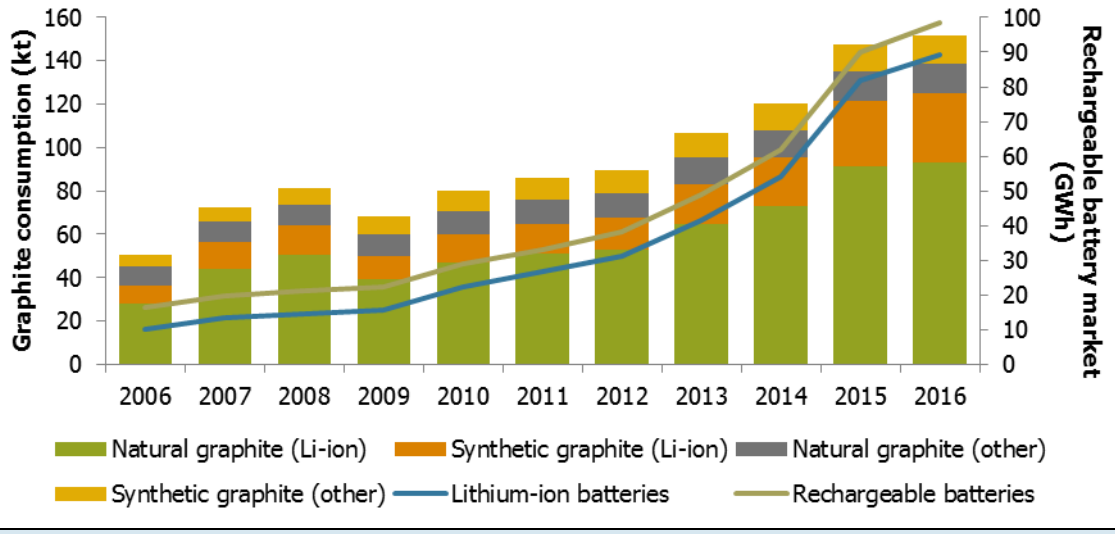
		2016	2021	2026	CAGR (%py) 2016-26
Lithium-ion batteries					
Base case	Natural graphite	92.9	318.3	640.6	21.3
	Synthetic graphite	32.0	120.6	280.5	24.2
	Sub-total	124.9	438.9	921.1	22.1
Low case	Natural graphite	92.9	258.8	452.2	17.1
	Synthetic graphite	32.0	98.1	198.0	20.0
	Sub-total	*124.9*	*357.0*	*650.2*	*17.9*
High case	Natural graphite	92.9	450.7	1,023.9	27.1
	Synthetic graphite	32.0	170.8	448.3	30.0
	Sub-total	*124.9*	*621.4*	*1,472.2*	*28.0*
Other batteries					
	Natural graphite	13.9	15.8	18.0	2.7
	Synthetic graphite	13.1	16.0	17.9	3.1
	Sub-total	*27.0*	*31.8*	*35.9*	*2.9*
All batteries					
Base case	Natural graphite	106.8	334.1	658.6	20.0
	Synthetic graphite	45.1	136.6	298.3	20.8
	Total	**151.9**	**470.7**	**957.0**	**20.2**
Low case	Natural graphite	106.8	274.6	470.2	16.0
	Synthetic graphite	45.1	114.0	215.8	16.9
	Total	**151.9**	**388.6**	**686.1**	**16.3**
High case	Natural graphite	106.8	466.5	1,042	25.6
	Synthetic graphite	45.1	186.8	466.1	26.3
	Total	**151.9**	**653.2**	**1,508**	**25.8**

Source: Roskill
Notes: 1- Includes raw material flake before processing into spherical graphite

Possible future graphite consumption trends are compared with the base case market forecast for lithium-ion batteries and all rechargeable batteries in Figure 25. Graphite consumption is likely to grow at a slightly lower rate than the battery market as improvements to the manufacturing process are expected to reduce the specific consumption of graphite per MWh of lithium-ion battery production.

China will consume an increasing proportion of the world's battery-grade graphite as lithium-ion anode material manufacturing continues to shift to China from Japan (albeit much more slowly than during the last decade) and as China increases anode material manufacturing for domestic consumption.

Figure 22: World: Consumption of graphite[1] by type and battery application compared with the markets for all rechargeable and lithium-ion batteries, 2006-2016



Source: *Roskill*
Note: *1-Raw graphite*

China is the largest consumer of graphite in battery applications accounting for around three quarters of global demand in 2016. It dominates the manufacture of primary and rechargeable batteries and, as battery manufacture has moved to China (from its traditional focus of Japan), component manufacturers and other companies in the supply chain have followed. Being located in China puts the manufacturers close to the growing domestic battery market and close to extensive sources of raw material. China is the largest producer of natural flake graphite (most of which is in the small to medium size flake category preferred for use in battery materials) and the largest producer of synthetic graphite.

4.2.3 Trends in global battery markets

Globally, primary batteries account for the bulk of the battery market in volume terms, but rechargeable batteries, particularly lithium-ion batteries (where the greatest amounts of graphite are used), are growing at a much faster rate. In 2016, the global market for small rechargeable batteries was 98.7GWh (Table 23).

Lithium-ion batteries have now replaced most of the nickel-cadmium (NiCd) and nickel-metal hydride (NiMH) market in portable equipment because of their more attractive power to weight ratio. The NiCd battery market declined by 2.6%py over the last decade while NiMH batteries grew by an average of 9.0%py thanks to their use in hybrid electric vehicles (HEVs). In recent years, lithium-ion batteries have replaced a considerable amount of NiMH batteries in this market also, while HEVs began to lose market share to fully electric vehicles (EVs), which only use lithium-ion batteries.

Lithium-ion battery consumption was 81.8GWh in 2015, which grew by a further 8.8% in 2016 to 89.4GWh, representing an average growth of 27%py since 2000 (Figure 23). The large jump in output in 2015 was because of a surge in electric bus (e-bus) production in China. NiCd battery output has fallen by a third, from 4.4GWh to 2.8GWh; NiMH battery supply, on the other hand, has increased to 6.5GWh from 2.4GWh between 2006 and 2016.

The improved performance of lithium-ion, but also restrictions on cadmium-containing products in certain jurisdictions, has dented demand for NiCd batteries, while NiMH has seen some resurgence in certain applications but most notably in Toyota's HEVs.

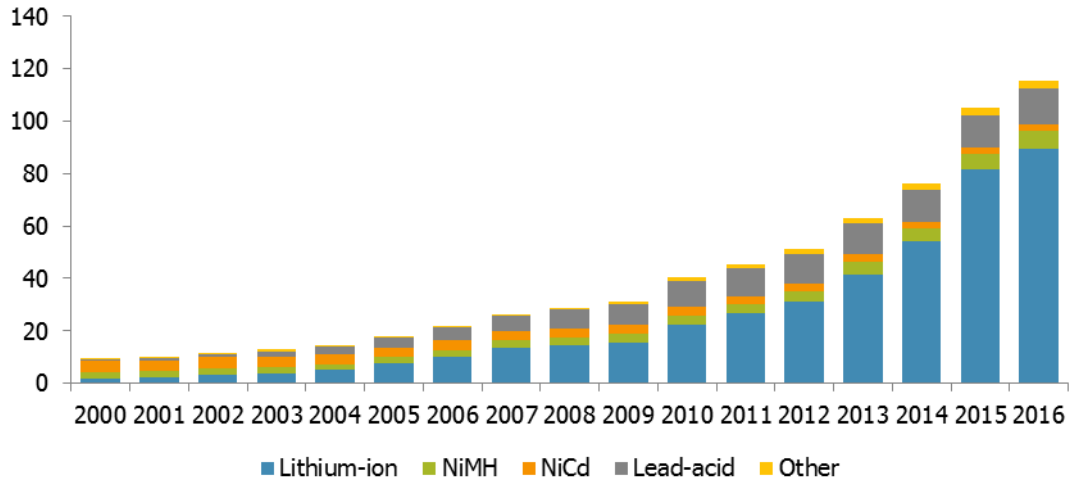
Table 23: World: Forecast rechargeable battery market[1], 2016, 2021 and 2026 (GWh)

	2006	2011	2016	2021[2]	2026[2]	CAGR (%py) 2006-16	CAGR (%py) 2016-26
Lithium-ion	10.0	26.7	89.4	373.5	1,180.5	24.5	29.4
NiMH	2.7	3.6	6.5	9.3	7.7	9.0	1.8
NiCd	3.7	2.8	2.8	3.4	4.3	-2.6	4.1
Total	**16.4**	**33.1**	**98.7**	**386.3**	**1,192.5**	**19.6**	**28.3**

Source: *Roskill*
Note: *1-Small rechargeable*
2-Base case scenario for lithium-ion batteries

Lithium-ion, NiCd and NiMH batteries compete with lead-acid batteries in power and motive, and ESS applications, while other battery types such as sodium-sulphur and redox flow types compete in ESS.

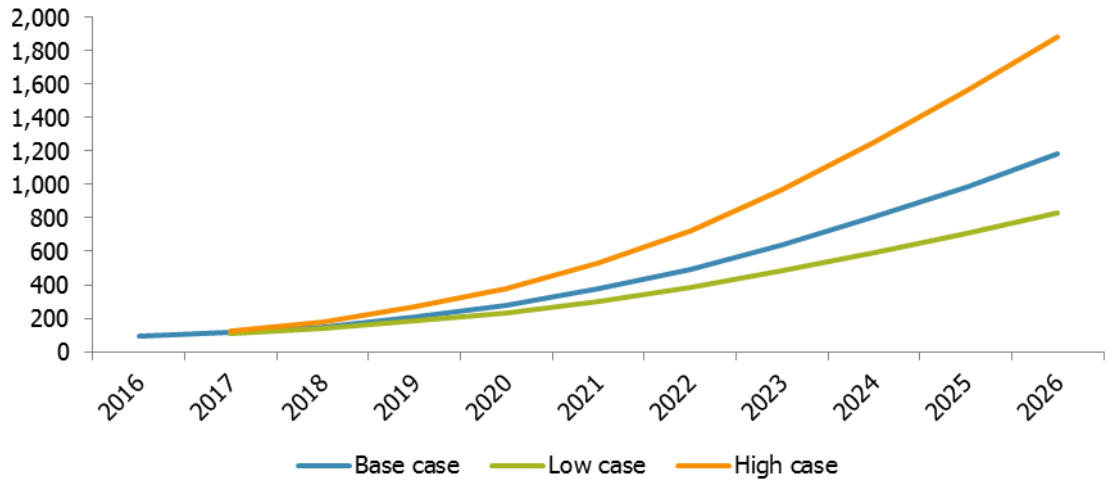
Figure 23: World: Market for rechargeable batteries[1], 2000-2016 (GWh)



Source: *Roskill*
Note: *1–Excludes lead-acid for SLI applications, and rechargeable alkaline batteries*

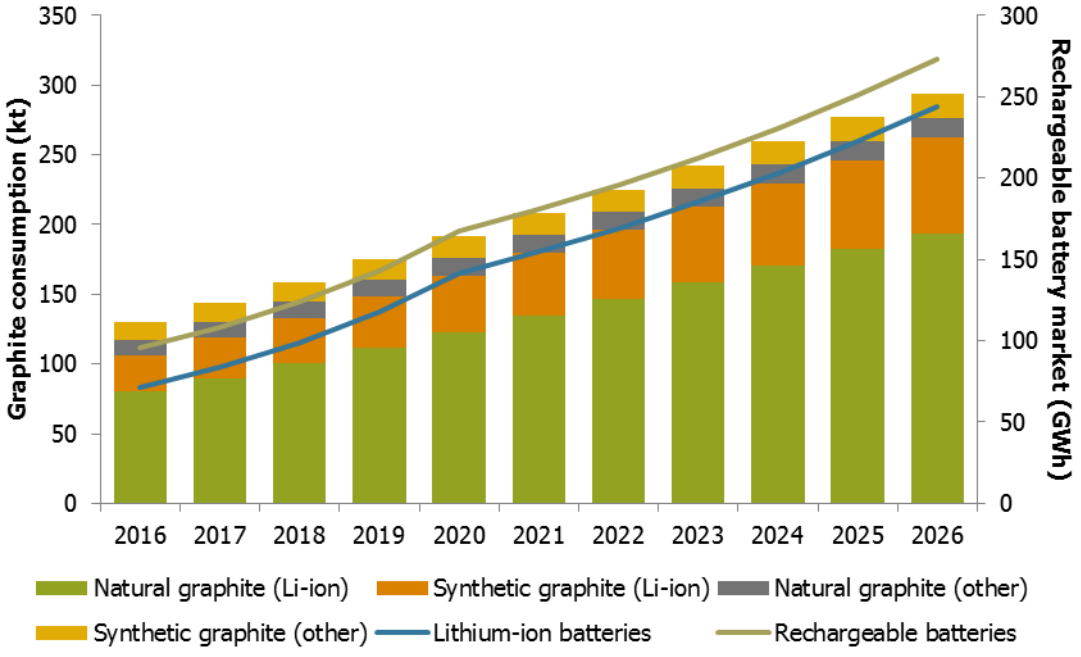
In future, the lithium-ion battery market will continue to grow strongly as demand from the automotive and ESS industries becomes established. Forecast (base case) lithium-ion battery average demand growth of 29.4%py over the next decade could drive overall rechargeable battery growth of 28.3%py. Base, low and high case forecast scenarios for lithium-ion batteries to 2026 are shown in Figure 24; they range from 25%py average growth reaching 833GWh to as high as 36%py average growth reaching 1,887GWh. The large margin of error is attributable to the high level of uncertainty in electric vehicle uptake.

Figure 24: World: Forecast lithium-ion market, 2016-2026 (MWh)



Source: *Roskill*

Figure 25: World: Forecast consumption of graphite[1] by type and battery application compared with the markets for all rechargeable and lithium-ion batteries[2], 2016-2026



Source: *Roskill*
Note: *1-Raw graphite*
2-Base case rechargeable/lithium-ion battery market forecasts

4.2.4 Consumption of graphite in lithium-ion batteries

Consumption of raw graphite in lithium-ion batteries grew by an estimated average of 13.2%py between 2006 and 2016 from 36kt to 125kt (Table 21). Natural graphite accounted for around 93kt (74%) of consumption in 2016 and synthetic graphite 32kt

(26%). Almost all graphite is consumed in anode production with just a few percent consumed in cathode material.

Flake graphite accounts for the vast majority of the natural graphite consumption, around 95% of which is processed into spherical graphite before supply to the anode industry. In 2016, around 87kt of flake graphite was consumed in the production of an estimated 49kt of spherical graphite. High purity natural flake graphite, expanded graphite and small amounts of natural amorphous graphite are also used in lithium-ion battery anodes.

Outside China, a number of potential natural graphite miners are trying to develop spherical graphite production using alternative processing methods. One of the most popular alternative routes is thermal processing which is less environmentally damaging but more expensive than current production methods; they have yet to be commercially operational.

Syrah Resources is looking to bring a new natural graphite project on-line in Mozambique in 2017 and plans to produce spherical graphite. It signed a non-binding memorandum of understanding to supply battery-grade natural graphite to BTR New Energy Materials in March 2017.

Synthetic graphite can be manufactured as a powder specifically for use in batteries, tailored to meet strict specifications that suit the intended application; it has particular use in higher performance lithium-ion battery anodes. Secondary synthetic graphite, sourced as waste from the electrode industry, is also used in batteries. Secondary synthetic graphite is often used in the manufacture of lower performance batteries for the Chinese market.
Graphite consumption has increased with the demand for lithium-ion batteries, which grew by an average of 24.5%py between 2006 and 2016 from 10.0GWh to 89.4GWh, driven by growth in the emerging ESS and automotive industries. Lithium-ion batteries have now reached saturation point in their replacement of NiCd and NiMH batteries in traditional 3C applications.

A comparison of historical growth in graphite consumption and the lithium-ion battery market is shown in Figure 26. Graphite consumption has grown at a slower rate than battery output for several reasons:

- Battery efficiencies have increased so that less graphite (and other raw materials) are required per MWh of battery output
- The emerging use of silicon has replaced a small amount of graphite in the anode of some lithium-ion batteries (typically only a few %, although may be up to 10% in some cases)
- Improvement in the efficiency of spherical graphite manufacture from natural flake graphite has resulted in less waste and less flake graphite required as raw material
- Increasing production of lithium-ion batteries for the Chinese market has resulted in synthetic graphite consumption growing slightly faster than that of natural graphite (low cost secondary synthetic graphite is readily available in China)

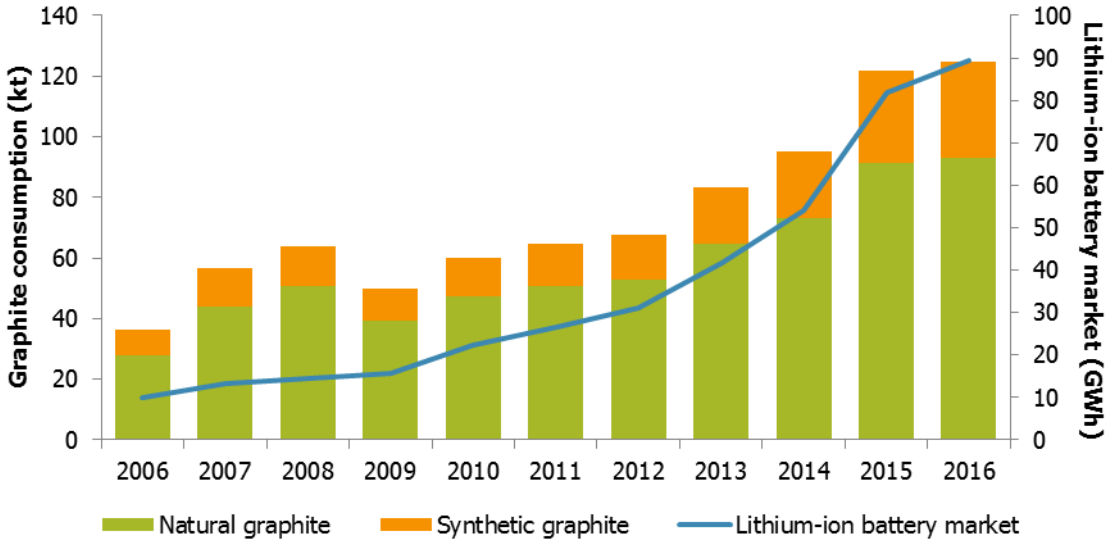
Conversely, consumption of graphite has been encouraged as a result of:

- A shift to the use of higher purity spherical graphite with lower yields (up to 70% losses for the highest grades)

Increasing demand for spherical graphite, especially outside China, because of the competitive price over synthetic graphite. Spherical graphite use has been encouraged by

technological advancements to spherical production, coating technologies and the use of graphite blends.

Figure 26: Consumption of raw graphite and lithium-ion battery market, 2006-2016



Source: Roskill

In reality, batteries are often a blend of natural and synthetic graphite along with other carbon materials. Choice comes down to cost (dependent on location) and specification (dependent on the final battery application). A manufacturer may select graphite depending on local availability, price, quality/consistency and through links it has with the supply chain. Exact combinations and quantities, therefore, vary by manufacturer.

The majority of Chinese anode material production is based on synthetic graphite. There is greater access to lower cost synthetic graphite as a by-product from synthetic graphite electrodes in China than in Japan and the ROW. Increasing production of lower capacity automotive batteries for domestic use (such as those for slow-moving city buses), is also helping to bolster growth in synthetic anode material in China above that of natural graphite anode material. Anode material production outside China, by comparison, has a greater split between natural and synthetic graphite.

Consumption of graphite in the final anode material (accounting for losses in spherical graphite manufacture) is shown in Table 24. CAG rates over the last 10 years for natural and synthetic graphite are much closer than for raw material consumption at 14.0%py and 14.4%py respectively.

Table 24: World: Consumption of processed graphite[1] in anode material by type, 2006, 2011 and 2016 (kt)

	2006	2011	2016	CAGR (%py) 2006-16
Natural graphite	14.8	27.9	55.1	14.0
Synthetic graphite	8.4	13.9	32.0	14.4
Total	**23.2**	**41.8**	**87.2**	**14.2**

Source: Roskill Notes: 1-Includes spherical flake processed from natural flake

4.2.5 Graphite in lithium ion batteries: Outlook

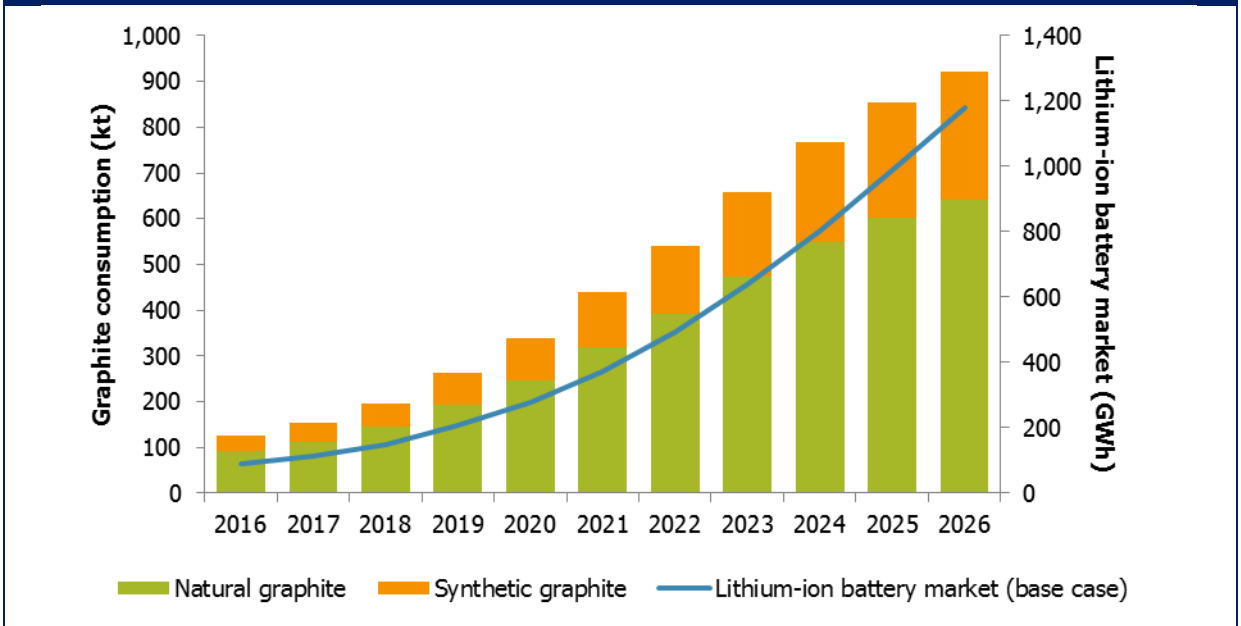
Graphite consumption in lithium-ion batteries will continue to grow strongly and accelerate over the next decade as robust demand growth is expected for these batteries in the automotive sector and, to a lesser extent, ESS applications. Although lithium-ion batteries have reached saturation point in 3C applications, natural growth in this industry will continue from the replacement market and from new regional markets in Asia, South America and Africa.

The base case scenario used for growth sees the lithium-ion battery market increasing by 29.4%py from 89.4GWh in 2016 to 1,181GWh in 2026. A low case forecast scenario, based mainly on fewer countries meeting their EV stock targets by 2026, could see growth of 25.0%py to 833.4GWh. A high case scenario could see growth of 35.7%py up to 1,886.9GWh.

Demand for graphite in lithium-ion batteries was estimated to be 125kt in 2016 but, based on the base case scenario of lithium-ion battery growth, could grow by 22.1%py to an incredible 921kt by 2026. A low case growth scenario predicts 17.9%py growth to 650kt of graphite, while a high case growth scenario could see a rise of 28.0%py to 1.47Mt of graphite (Table 22).

The overall trend in graphite consumption will follow that of battery demand, as shown in Figure 27. The relationship between graphite consumption and MWh battery demand, however, will see an increasing separation as technological improvements in battery components (including lower use of graphite per MWh and the further uptake of silicon to replace graphite in lithium-ion battery anodes) will continue to reduce specific consumption of graphite. On the natural graphite supply side, improvements in overall spherical graphite manufacturing efficiency/raw material flake requirements will continue to be offset by the increased use of higher grade spherical graphites with lower yields.

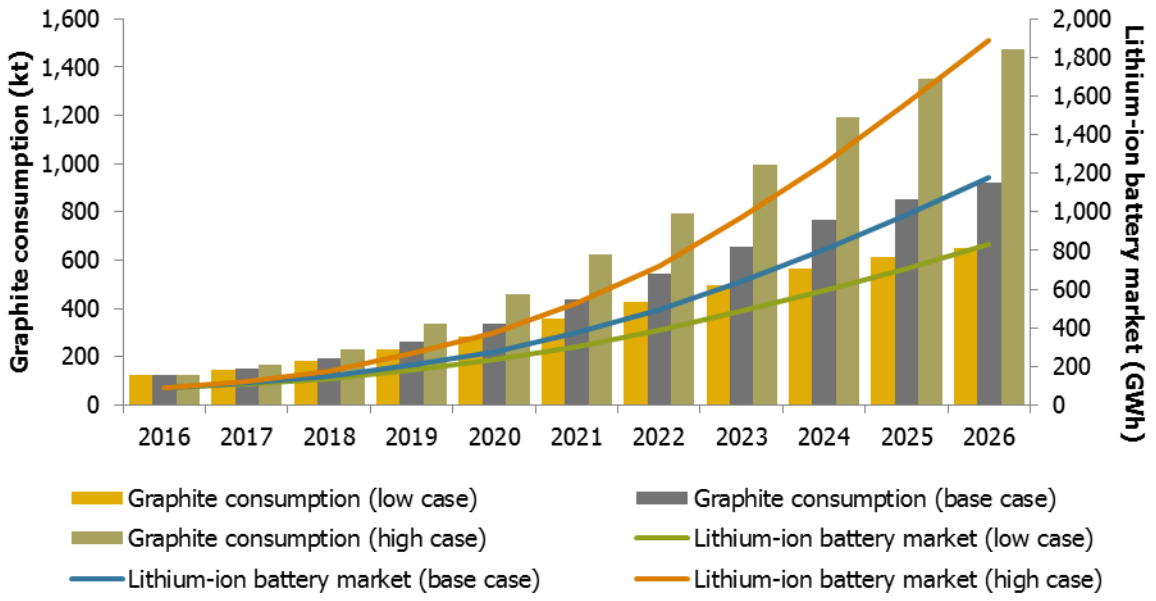
Figure 27: Forecast consumption of raw graphite and lithium-ion battery market, 2016-2026



Source: Roskill

The low, high and base case scenarios for graphite consumption compared to growth in the lithium-ion battery market are compared in Figure 28.

Figure 28: Forecast scenarios for raw graphite consumption and lithium-ion battery market, 2016 to 2026



Source: *Roskill*

Synthetic graphite is expected to take an increasing share of graphite consumption in the next few years as an increasing amount of anode material is produced in China. By the end of the forecast period, however, several new natural graphite projects are expected to come on-line in China and Africa that could increase the amount of natural flake graphite entering the battery supply chain. By 2026, natural graphite is expected to account for around 70% of raw graphite consumption.

Forecast consumption of graphite in the final anode material (accounting for losses in spherical graphite manufacture) is shown in Table 25.

Table 25: World: Forecast consumption of processed graphite[1] in anode material by type, 2016, 2011 and 2026 (kt)

	2016	2021	2026	CAGR (%py) 2016-26
Natural graphite	55.1	196.9	427.9	22.7
Synthetic graphite	32.0	120.6	280.5	24.2
Total	**87.2**	**317.5**	**708.3**	**23.3**

Source: *Roskill*

Notes: *1-Includes spherical flake processed from natural flake*

4.3 Friction materials

Graphite is added to friction linings to improve their performance when used at the contact zone of brake pads/drums and clutches. Brakes and clutches are used mainly in transport applications (motor vehicles, trains, airplanes etc.) and in construction and factory equipment. The contact zone of these products needs to offer a high level of friction to resist the opposing surface and be very hard wearing to ensure a long product lifespan. A mixture of mineral fibres is typically used to offer the best performance: glass, asbestos, metal powders, particles of graphite and/or other carbons.

Graphite consumption follows a similar trend to that of motor vehicle production; the global market for friction products in motor vehicles is very large, despite the fact that specific consumption of graphite in each friction product is very small. Global production of all motor vehicles grew at 3.1%py in the ten years between 2005 and 2015 to reach 90.66M units and is estimated to have increased to 93.38M units in 2016. There is also an extensive replacement market. Larger quantities of graphite are used in friction materials for heavy duty vehicles (heavy trucks, buses and coaches), but these accounted for just 4% of total motor vehicle production in 2015.

During the 1980s and 1990s, specific consumption of graphite in friction materials increased as it became one of the materials to replace asbestos. Graphite content by weight in brake linings rose from traditional levels of 1-2% up to around 20% in some products. In more recent years, use of graphite has fallen with competition from other carbons and alternative materials. Traditional brake pads are facing increasing competition in higher performance products such as ceramic pads, which contain no carbon/graphite.

4.3.1 Consumption of graphite in friction materials

In 2016, an estimated 125kt of graphite was consumed in friction materials. Both synthetic and natural graphite are used and different types of graphite are often blended together and/or blended with other carbon materials before being supplied to the customer.

Graphite for use in friction materials must have a relatively high carbon grade (typically a minimum of 98% C). One of the most important qualities is consistency, in particular consistency of particle size distribution, ash level and ash composition.

Synthetic graphite, both primary and secondary, accounted for less than 60% of consumption in 2016 (an estimated 73kt). An accurate estimate of synthetic graphite consumption is not possible because an unknown amount is sourced as secondary material from electrode scrap. Synthetic graphite is used for its high purity and guaranteed consistency. Synthetic cokes and other types of synthetic carbon products may also be used in addition to/instead of graphite.

Natural graphite, both flake and amorphous, accounted for over 40% of consumption in 2016 (an estimated 52kt). Again, an accurate estimate of consumption is not possible because an unknown amount of secondary material is used. Ultra-fine flake (less than 75µm/-200 mesh) is sourced as a by-product of spherical graphite manufacture.

Historically, amorphous and fine flake graphite made up the majority of natural graphite consumption but, with the increasing availability of low-cost ultra-fine flake since the late

2000s, this material is taking an increasing market share from lower-quality amorphous graphite. Natural graphite often contains particles of quartz or silicon carbide (SiC) that can harm the lining and must be removed by special purification methods at temperatures of over 2,500°C. Ultra-fine flake from spherical processing has already undergone the purification process.

The three commonly used types of brake pad in motor vehicles are shown in Table 26. Organic (or non-asbestos organic, NAO) brake pads were developed as a low-cost alternative to asbestos-containing pads. Semi-metallic brake pads have a longer lifespan and give better braking than organic pads but compromise on noise and dust. They are also heavy, reducing the fuel efficiency of the car. Organic and semi-metallic brake pads are used in the vast majority of motor vehicles worldwide; both contain additions of graphite and/or other carbons.

Ceramic brake pads are preferred for use in higher performance cars and are taking an increasing market share from traditional brake pads. Use in the mainstream automotive market is restricted by their higher cost. No graphite or carbon is used in ceramic brake pads.

Table 26: Common types of brake pad for cars and trucks

Brake pad type	**Materials used**	**Characteristics of pad**	
		Pros	**Cons**
Organic[1]	Fibres such as glass, rubber, carbon/graphite and Kevlar, with filler materials and high temperature resins	• soft pad • low level of noise • low cost	• fast wearing • some dust • limited temp. range
Semi-metallic[2]	30-65% metal, including chopped steel wool or wire, iron powder, copper or graphite, mixed with inorganic fillers and friction modifiers	• durable • good heat transfer • longer life and better breaking than NAO	• heavy • high level of dust • Some noise
Ceramic	Ceramic fibres, non-ferrous fillers such as copper, bonding agents, and possibly small amounts of metal	• low wear • low level of dust • low noise • excellent braking	• very expensive

Source: *Industry press*

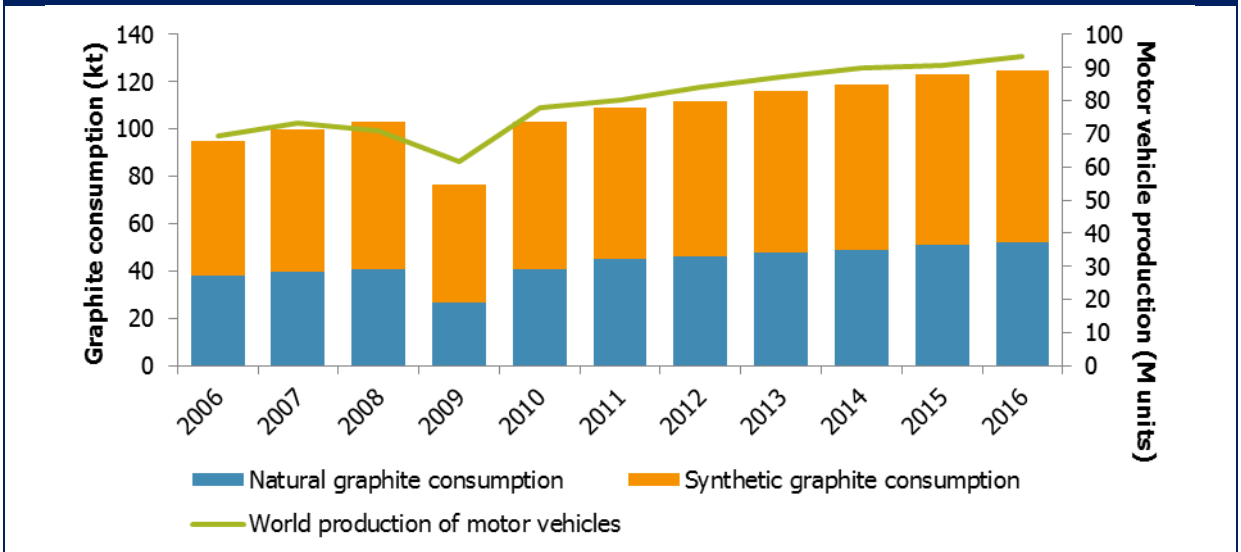
Note: *1-Also known as non-asbestos organic (NAO)*

2-Fully-metallic brake pads also exist (composed simply of sintered steel, they have a very long life but their use is limited to high-performance race cars because of high levels of noise and wear to the rotor)

In the ten years between 2006 and 2016, consumption of graphite in friction materials grew by an estimated 2.8%py, reflecting trends in the global production of motor vehicles (Figure 29). In the 2000s, graphite consumption grew as China and South America increased motor vehicle production to meet increasing domestic consumption. In more recent years, the Chinese motor vehicle market has begun to slow down.

The ratio of synthetic to natural graphite consumption is thought to have changed little, with perhaps a small shift to the use of natural graphite because of the availability of higher ultra-fine grades.

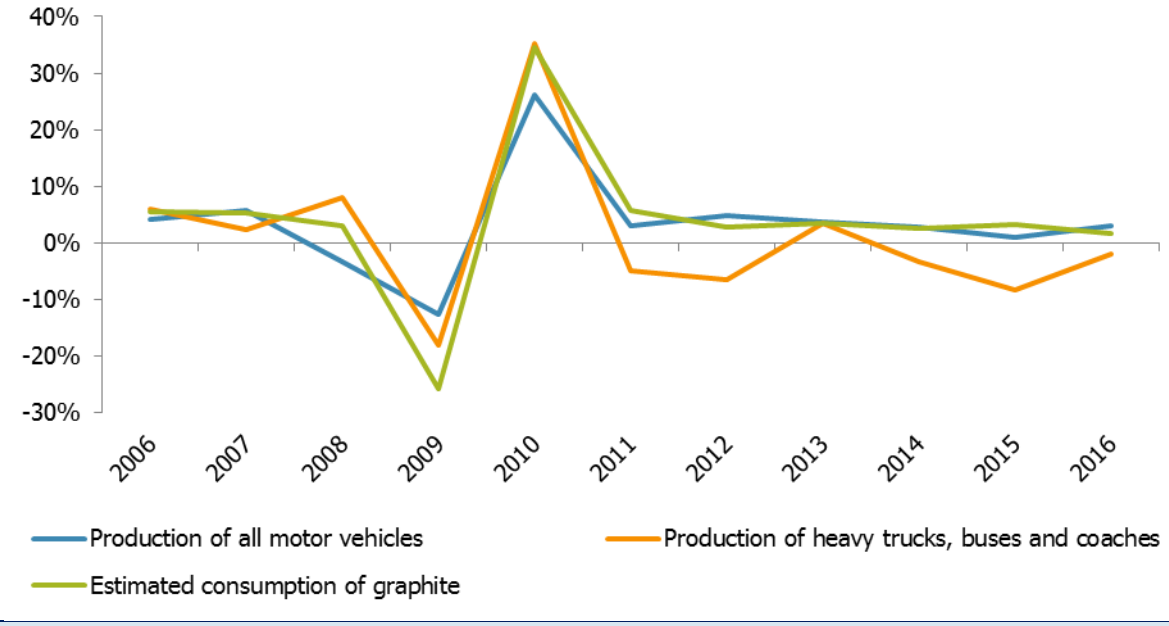
Figure 29: World: Graphite consumption in friction materials and global production of motor vehicles, 2006-2016



Source: Roskill, OICA

Global production of heavy trucks, buses and coaches (friction materials for which, require larger quantities of graphite), is currently in decline. Declining output will have little impact on overall demand for graphite in the short term; these vehicles accounted for 3.75M units in 2015, only a very small fraction of total production. Year-on-year growth in motor vehicle and heavy duty vehicle production are compared to changes in graphite consumption in Figure 30.

Figure 30: World: Year-on-year change in motor vehicle production and graphite consumption in friction materials, 2006-2016 (%)



Source: *OICA, Roskill*

A rough estimate of the quantity of natural graphite consumed in the production of new motor vehicles is given in Table 27. Consumption per unit has been fairly stable at an average of around 1.3kg per unit over the last decade.

Table 27: USA: Estimated unit consumption of graphite in brake linings of new motor vehicles[1,2], 2006-2016

	Global motor vehicle[3] output (k units)	Graphite consumption (kt)			Unit consumption (kg/unit)
		Synthetic	Natural	Total	
2006	69,230	57	38	**95**	1.37
2007	73,260	60	40	**100**	1.37
2008	70,770	62	41	**103**	1.46
2009	61,790	50	27	**77**	1.24
2010	77,910	62	41	**103**	1.32
2011	80,300	64	45	**109**	1.36
2012	84,236	66	46	**112**	1.33
2013	87,311	68	48	**116**	1.33
2014	89,776	70	49	**119**	1.33
2015	90,661	72	51	**123**	1.36
2016[e]	93,377	73	52	**125**	1.34

Source: *OICA, Roskill*

Notes: *1-Assumes that all vehicles use metallic brake pads*

2-Does not take into account the market for friction material replacements throughout the life of a used vehicle

3-Cars, light commercial vehicles, heavy trucks, buses and coaches

A range of graphite and carbon products are supplied by graphite producers to manufacturers of friction products. Those offered by the international producer Imerys Graphite & Carbon are shown in Table 29.

Table 28: Imerys Graphite & Carbon: Typical graphite and carbon products for use in friction materials

Brake pad type	Materials used
Primary synthetic graphite T	99.9% C
Primary synthetic graphite KS	99.9% C
Primary synthetic graphite KC	99.9% C
Natural flake graphite	94.0-96.0% C
Petroleum coke	99.5-99.7% C
C-ThermTM	97.5-99.7% C

Source: Imerys Graphite & Carbon

Superior Graphite of the USA produces a range of graphite and carbon products under the FormulaFX® tradename for this application (Table 29). It has also produces Resilient Graphitic Carbon™ (RGC) using a patented high temperature purification process.

Table 29: Superior Graphite: Typical graphite and carbon products for use in friction materials

Brake pad type	Materials used
Amorphous graphite	60-80% C
Flake graphite	80-99% C
Vein graphite	90-99% C
Synthetic graphite	98.0-99.7% C
Calcined petroleum coke	min. 99% C
Purified flake graphite	99.7-99.9% C
Purified synthetic graphite	99.7-99.9% C
Resilient Graphitic CarbonTM	99.7-99.9% C

Source: Superior Graphite

4.3.2 Friction materials: Outlook to 2026

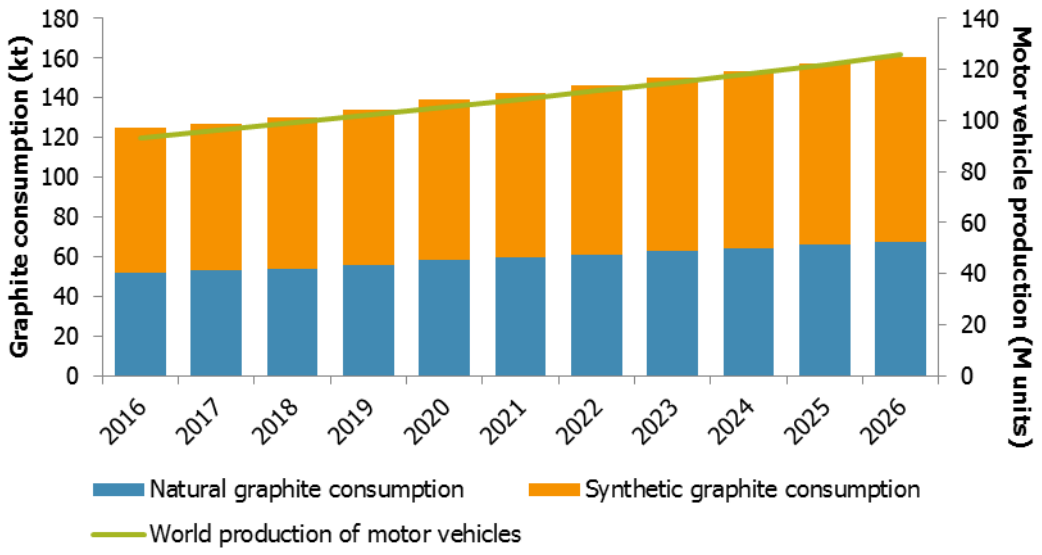
Graphite consumption will continue to follow trends in global motor vehicle production, although demand will also be affected by the established aftersales replacement market and by higher specific consumption in the small market of heavy duty vehicles.

Assuming continued growth of 3%py, global production of motor vehicles is forecast to reach 108.36M units in 2021 and 125.80M units in 2026. Production in China will continue to grow but at a slowing rate, mirroring the contraction of Chinese GDP growth. Meanwhile, output from other regions is expected to grow, including South America. It likely that global production of heavy trucks, buses and coaches will continue to decline by 1%py to 2%py.

Graphite will see increasing competition from the use of graphite-free ceramic brake pads, although these products will continue to be limited to use in higher performance vehicles because of cost.

Overall, graphite consumption in friction materials is forecast to grow at 2.7%py to 143kt in 2021 and 163kt in 2026. Forecast graphite consumption compared to motor vehicle production is shown in Figure 31.

Figure 31: World: Forecast graphite consumption in friction materials and global production of motor vehicles, 2016-2026



Source: Roskill

4.3.3 Trends in motor vehicle production

Global production of motor vehicles grew at 3.2%py between 2005 and 2010. During this period, production declined in North America and Europe as a result of the global economic downturn, but was offset by strong growth of 10%py in Asia with growing demand for car ownership.

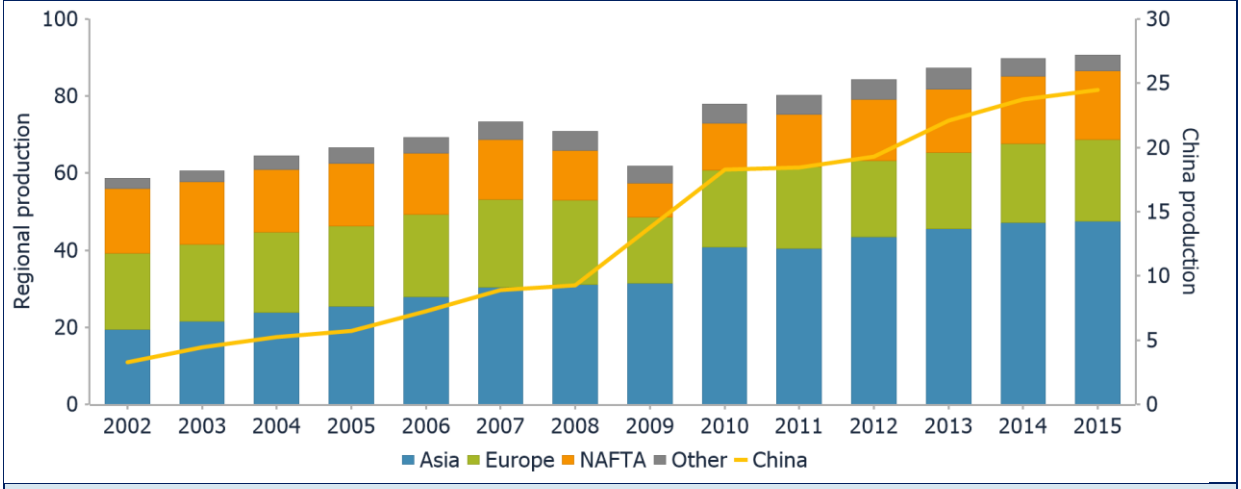
Between 2010 and 2015, global production of motor vehicles increased by a similar 3.1%py. Production levels recovered in the USA and Europe and have continued to grow strongly. Growth in North America was 8.1% over the five year period. At the same time, growth in Asia slowed to 3.1%py as a result of the slowdown in the Chinese economy.

Chinese output of motor vehicles increased by 26.1%py between 2005 and 2010 to reach 18.26M units, but growth slowed to just 6.1%py between 2010 and 2015, reaching 24.50M units. Chinese growth is expected to slow further to just 2-3%py between 2016 and 2026.

In 2015, global production of motor vehicles totalled 90.66M units. Asia accounted for around 53% of production, Europe for 23% and NAFTA for 20% that year (Figure 32). Production of motor vehicles is now concentrated in China, the USA and Japan, which together account for around half the world total.

Roskill Consulting Group Ltd, June 2017. Unauthorised copying prohibited.

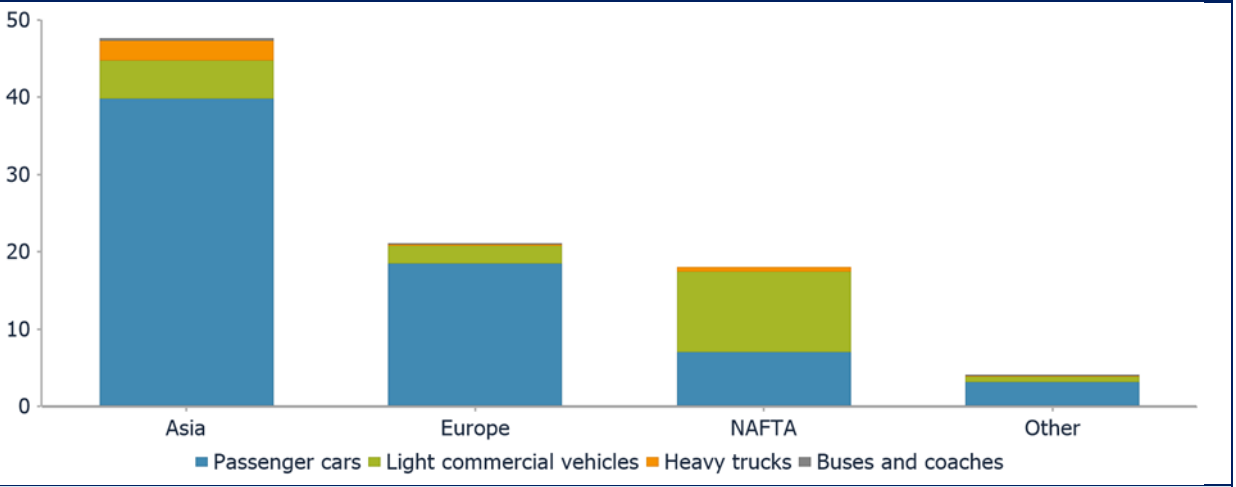
Figure 32: World: Motor vehicle production by region, 2002-2015 (M vehicles)



Source: OICA

Cars and light vehicles together, accounted for 96% of global motor vehicle production in 2015. Heavy duty vehicles (heavy trucks, buses and coaches) accounted for just 4%. Asia leads production of all vehicle types except light commercial vehicles, most of which are produced in North America (Figure 33).

Figure 33: World: Production of motor vehicles by type and region, 2015 (M vehicles)



Source: OICA

Of all motor vehicles, production of cars has grown the strongest at 3.9%py between 2005 and 2015. Production of light commercial vehicles remained flat during this period, growing at just 1.3%py. Production of heavy trucks, buses and coaches grew by just 0.6%py over the same period and has declined almost every year since 2010.

Detailed historical figures for motor vehicle production, by type and by region, are given in Table 30.

Table 30: USA: Estimated unit consumption of graphite in brake linings of new motor vehicles[1,2], 2010 to 2015

	Europe	NAFTA	South America	Asia[1]	Oceania	Africa	World	China	China %
Passenger cars									
2010	17.34	5.08	3.14	32.41	0.21	0.36	**58.55**	13.90	24%
2011	18.33	5.61	3.15	32.48	0.19	0.38	**60.14**	14.49	24%
2012	17.41	6.96	3.17	34.97	0.19	0.38	**63.08**	15.52	25%
2013	17.46	7.11	3.29	37.03	0.17	0.40	**65.46**	18.08	28%
2014	18.05	7.08	2.90	39.10	0.17	0.48	**67.78**	19.93	29%
2015	18.52	7.02	2.38	39.86	0.16	0.60	**68.54**	21.08	31%
CAGR 2010-15 (%py)	*1.3*	*6.7*	*-5.4*	*4.2*	*-5.3*	*10.9*	***3.2***	*8.7*	
Light commercial vehicles									
2010	2.01	6.83	0.78	4.97	0.03	0.12	**14.75**	1.95	13%
2011	2.45	7.45	0.86	4.84	0.03	0.15	**15.78**	1.85	12%
2012	2.08	8.42	0.91	5.44	0.03	0.17	**17.06**	1.87	11%
2013	2.02	8.99	1.03	5.34	0.04	0.19	**17.61**	1.98	11%
2014	2.10	9.86	0.70	5.03	0.01	0.19	**17.90**	1.87	10%
2015	2.28	10.41	0.54	4.94	0.01	0.19	**18.37**	1.79	10%
CAGR 2010-15 (%py)	*2.6*	*8.8*	*-7.2*	*-0.1*	*-23.9*	*9.5*	***4.5***	*-1.6*	
Heavy trucks									
2010	0.48	0.24	0.23	3.26	0.00	0.02	**4.23**	2.26	53%
2011	0.36	0.38	0.26	2.98	0.00	0.03	**4.01**	1.92	48%
2012	0.32	0.42	0.17	2.81	0.01	0.02	**3.74**	1.70	46%
2013	0.30	0.40	0.22	2.94	0.01	0.03	**3.90**	1.88	48%
2014	0.24	0.48	0.16	2.86	0.01	0.04	**3.78**	1.77	47%
2015	0.23	0.52	0.08	2.55	0.01	0.04	**3.43**	1.47	43%
CAGR 2010-15 (%py)	*-13.4*	*16.5*	*-18.7*	*-4.8*	*0.0*	*15.6*	***-4.1***	*-8.3*	
Buses and coaches									
2010	0.06	0.02	0.04	0.25	0.00	0.01	**0.38**	0.16	43%
2011	0.05	0.02	0.05	0.24	0.00	0.01	**0.37**	0.16	44%
2012	0.05	0.00	0.04	0.25	0.00	0.01	**0.35**	0.17	48%
2013	0.05	0.00	0.04	0.25	0.00	0.00	**0.34**	0.17	51%
2014	0.04	0.00	0.04	0.24	0.00	0.00	**0.32**	0.16	51%
2015	0.04	0.00	0.02	0.26	0.00	0.00	**0.32**	0.16	51%
CAGR 2010-15 (%py)	*-6.4*	*-100.0*	*-11.5*	*0.5*	*0.0*	*-34.3*	***-3.2***	*0.3*	
Total									
2010	19.89	12.17	4.19	40.89	0.24	0.51	**77.91**	18.26	23%
2011	21.19	13.46	4.32	40.54	0.22	0.57	**80.30**	18.42	23%
2012	19.86	15.80	4.29	43.47	0.23	0.59	**84.24**	19.27	23%
2013	19.83	16.50	4.58	45.56	0.22	0.63	**87.31**	22.12	25%
2014	20.43	17.42	3.80	47.22	0.18	0.72	**89.78**	23.73	26%
2015	21.07	17.95	3.02	47.61	0.17	0.84	**90.66**	24.50	27%
CAGR 2010-15 (%py)	*1.2*	*8.1*	*-6.4*	*3.1*	*-6.3*	*10.4*	***3.1***	*6.1*	

Source: *OICA*
Note: *1-Including Iran*

4.4 Lubricants

Graphite's unique atomic structure makes it suitable for use in commercial and industrial lubricants. Graphite consists of distinct layers, weakly bonded together so that the layers slide past each other and deposit easily on a contact surface. This structure gives graphite a very low level of friction. Graphite can be used as a lubricant in the form of solid powder, or it may be applied as a film or within a fluid dispersion.

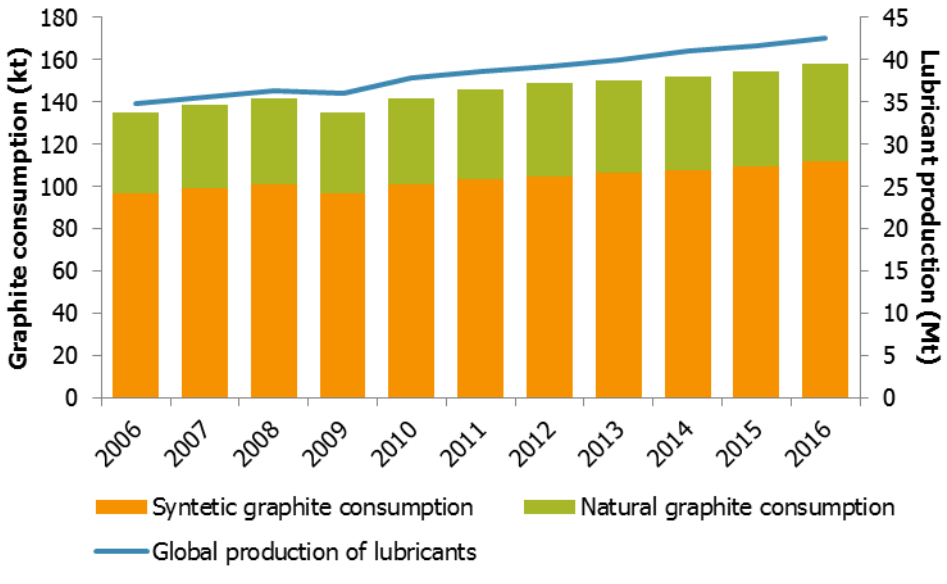
There are many types of lubricant including greases, oils and fluid dispersions. In 2016, the total lubricant market was estimated to be more than 42Mt. The market for additives in lubricants totalled around 4.4Mt that year and is growing by 2-3%py. Graphite additives account for around 4% of all lubricant additives.

The automotive market accounts for around 60% of all lubricant consumption.

4.4.1 Consumption of graphite in lubricants

Graphite lubricants are a specialist market and small amounts of different types of graphite are used depending on the application. An estimated 158kt of graphite were consumed as lubricants in 2016. Of this total, synthetic graphite accounted for around 112kt (70%) and natural graphite 46kt (30%), as shown in Figure 34. Flake, amorphous and vein natural graphite are all used. Asia accounts for around 40% of graphite consumption in lubricants and Europe and North America a further 25% each.

Figure 34: World: Graphite consumption in lubricants and production of lubricants, 2006-2016 (kt)



Source: Roskill

In general, graphite consumed in lubricants needs to have a small particle size so that it disperses easily and prevents clogging. For products requiring maximum lubricating

penetration, a particle size of around 1µm is preferred. This is the smallest size at which the graphitic structure and lubricating properties are retained.

Graphite purity is also very important as it has a direct effect on the lubricity of the end product. Graphite purities of over 98% C are typically required, although some lower-grade applications (such as thread compounds) can use graphite with a purity as low as 95%C. Niche applications (such as lubricants for nuclear plant machinery) may require ultra-high-purity graphite at up to 99.99% C.

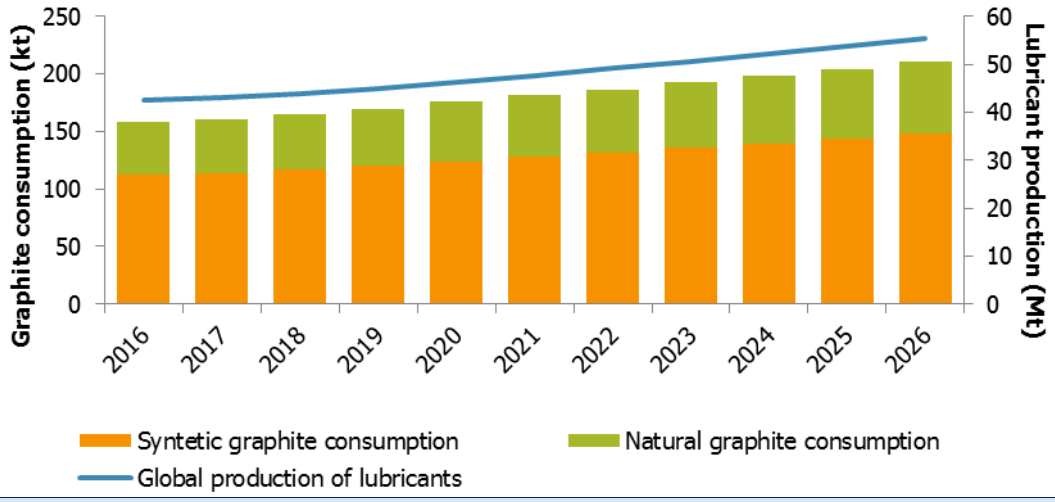
Graphite for use in lubricants is also required to have low moisture (typically less than 0.2%) and a low ash content (typically less than 0.5%). Ash contains silica, an abrasive material that can significantly reduce lubricity by breaking down greases or oils. Low levels of iron and sulphur are also preferred. Other qualities of graphite such as chemical inertness, thermal conductivity and resistance to high temperatures are also useful in lubricant applications.

4.4.2 Lubricants: Outlook

Demand for lubricants will continue to grow at 2-3%py to reach an estimated 48Mt in 2021 and 55Mt in 2026. Asia will take an increasing share as its demand for lubricants strengthens. Growth in the mature markets of Europe and North America will remain steady.

Consumption of graphite is forecast to grow at a similar rate, driven by consumption in forging lubricants, greases, industrial machinery lubricants and consumer lubricants. Consumption of graphite could reach 181kt in 2012 and 211kt (Figure 35). Different types of graphite will continue to be used in small amounts across a large number of specialist lubricant applications. Synthetic graphite will continue to dominate the market, being reliable in terms of both high purity and consistency.

Figure 35: World: Forecast graphite consumption in lubricants and production of lubricants, 2016-2026 (kt)



Source: Roskill

4.5 Graphite shapes

Graphite can be easily machined into a variety of shapes. 'Graphite shapes', 'carbon products' or 'speciality graphite products' are general terms used to describe solid, shaped graphite products used across many industries, often in elevated temperature applications. End users include the aerospace, automotive, industrial machinery and electronics industries.

Graphite shapes can vary in shape, size and complexity, from simple flat plates to complex machined parts, manufactured to extremely tight dimensions and tolerances. Sizes can range from pieces small enough for use in portable electronic devices to several tonnes in weight.

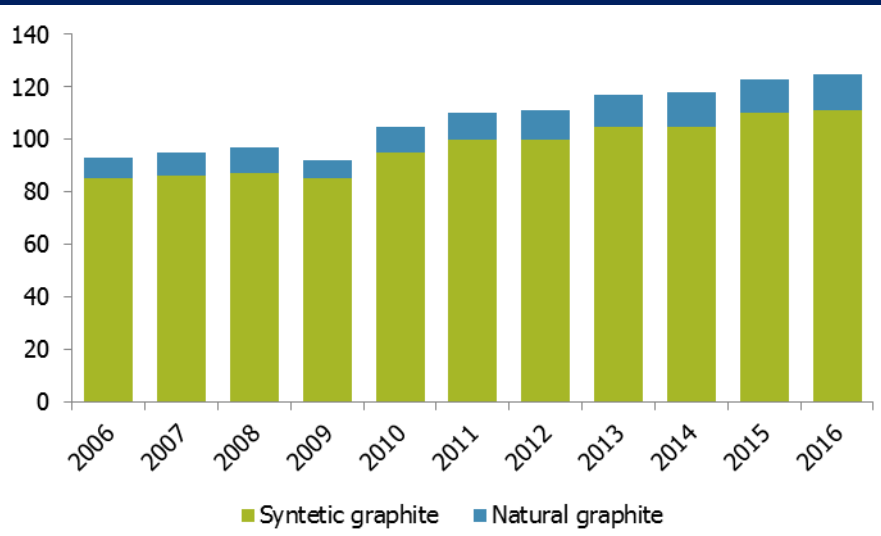
Carbon brushes are the largest application, accounting for as much as two thirds of the graphite consumed in this sector. Other main applications include electrodes for electrical discharge machining (EDM), heat sinks, furnace parts and industrial machinery parts. Thermal management products for use in electronic devices are a growing market.

Graphite shapes do not include synthetic graphite electrodes for EAF steelmaking, graphite anodes for the chemical industries, carbon electrodes for the refining of ferrous alloys, or cathodes for aluminium reduction cells.

4.5.1 Consumption of graphite in graphite shapes

An estimated 125kt of graphite was consumed in graphite shapes in 2016, of which, around 90% was synthetic graphite and 10% natural graphite (Figure 36). Graphite can be selected with specific density, porosity, mechanical, electrical, and thermal properties to best fit the final end use application of the shaped product.

Figure 36: World: Graphite consumption in graphite shapes, 2006-2016 (kt)



Source: Roskill

The raw materials used to produce synthetic graphite shapes include coarse grain electrode graphite, medium grain mould stock, and fine grain isostatically formed graphite, all of which have consistent quality and high purity.

Primary synthetic graphite manufactured for use in shaped products is made specifically to meet customer requirements. Synthetic graphite is manufactured from petroleum needle coke and the choice of petroleum needle coke depends on the final application, economic factors and other technical considerations. Alternative raw materials include pitch tar cokes and metallurgical cokes.

Secondary synthetic graphite is produced as a by-product during the manufacture and machining of primary synthetic graphite products, mainly synthetic graphite electrodes. It is, therefore, much less expansive than primary synthetic graphite and makes up a large proportion of the graphite consumed in shaped applications.

Some lower-performance graphite shapes are based on natural graphite and/or blends of natural and synthetic graphite. Natural graphite is typically lower in purity and less consistent in terms of purity than synthetic graphite.

Carbon/graphite blends are often used to produce shapes with good corrosion resistance, mechanical strength at high temperatures and lubricant qualities.

Graphite has particular properties that make it useful in different shape applications. In carbon brushes, the strong covalent bonds within graphite layers give good mechanical strength and a high melting point which helps to reduce wear; graphite contains delocalised electrons, which makes it an excellent electrical conductor; weakly bonded layers give graphite low levels of friction and high lubricity.

The grade and structure of the graphite used in carbon brushes has a significant effect on the brush's lifespan. The main desirable specifications for carbon brush-grade graphite are:

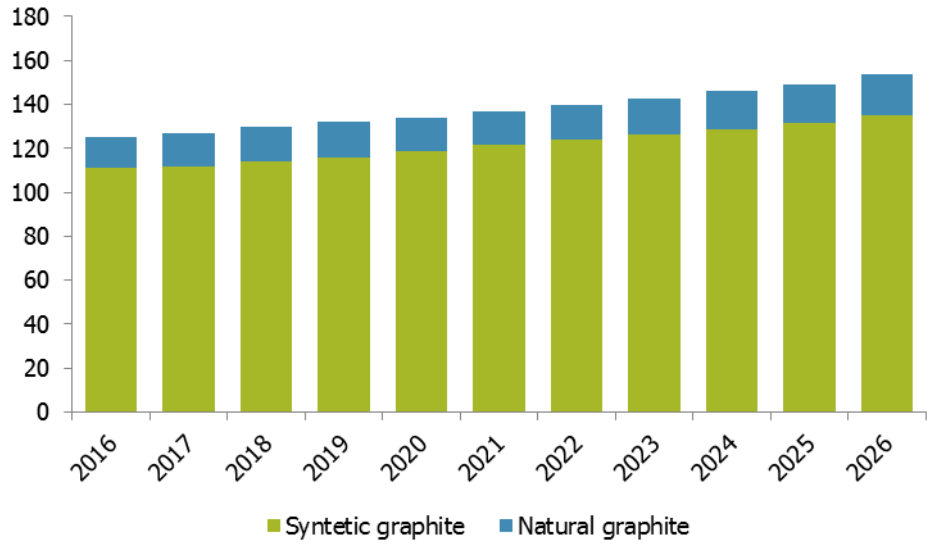
- Typical purity of >98% C natural or synthetic graphite (although some applications tolerate as low as 90% C or require as high as 99.99% C)
- Particle size: powder
- Ash content of <0.5%;
- Moisture level of <0.2%;
- Low levels of silica, iron and sulphur

Synthetic graphite is used for EDM electrodes, in particular those requiring a non-reactive material with good thermal stability and high oxidation resistance. Graphite used for EDM is an isotropic material with a grain size ranging from a few microns to about 20µm. In the 1970's, improvements made by graphite manufacturers (isotropic properties, consistent quality, large-size billets) combined with the emergence of EDM equipped with iso-plus generators, allowed graphite to become the most commonly used material for EDM electrodes.

4.5.2 Graphite shapes: Outlook

Global consumption of graphite in graphite shapes is forecast to grow by 1-3%py to 2026, reaching an estimated 154kt (Figure 37). Synthetic graphite is expected to account for 85-90% of graphite consumption in graphite shapes by 2026. A moderate increase in consumption of high-purity ultra-fine flake graphite could be seen as availability increases of by-product fines from spherical graphite manufacture, although most are currently used up by the Chinese recarburising industry.

Figure 37: World: Forecast graphite consumption in graphite shapes, 2016-2026 (kt)



Source: Roskill

Carbon brushes will continue to be the largest application. Global consumption of carbon brushes is forecast to grow by 2-3%py to 2020, reaching an estimated 325kt. The highest growth is expected to be in Asia.

Growth markets for carbon brushes include industries with large motor installations such as wind power generation (particularly in Asia and Europe), industrial equipment and electric vehicles. Steel markets are not perceived to be growing at all and carbon brushes are only used in the collector roll and generator repair and replacement market in this application.

The trend towards brushless motors in some large-size motor applications (mainly wind turbines and electric vehicles), will limit overall growth rates for carbon brushes to some extent going forward. However, brushless motors will continue to account for a small proportion of the motor market to 2026.

4.5.3 Types of graphite shapes

Synthetic graphite shapes are often categorised by the way the synthetic graphite is produced:

- **Extruded graphite** is produced through extrusion to create simple shapes such as run-out tables, rings, rollers, nozzles, crucibles, mixing rods, wear plates, sleeves, pipes, disks, sintering trays, spacers, furnace susceptors, furnace liners and lubricating blocks for many industries.

- **Isostatic graphite** (also known as isomoulded graphite) is produced through isostatic moulding. Typical applications include EDM electrodes, continuous casting dies, hot press moulds and semiconductor applications.

- **Moulded graphite** is produced through unidirectional moulding. This type of graphite shape is used in tube sheets for heat exchangers, pressure casting moulds, large crucibles and furnace susceptors.

Isostatic graphite has superior mechanical characteristics (two or three times higher density, higher strength and finer grain) than extruded and moulded graphites. The prices of each graphite category differ according to those mechanical characteristics.

From a manufacturing point of view, slightly different machinery is necessary for each type of production process (there is no supply-side substitutability among the three categories) and the production cost difference between isostatic graphite and extruded or moulded graphite is at least 20%.

From the demand-side point of view, the end use determines which of the three types of graphite shape to select. There may be very substantial switching costs between different categories of speciality graphite and customers typically do not switch between extruded, moulded and isostatic categories.

In general, extruded graphite is the most cost-effective way to make synthetic graphite shapes and is, therefore, chosen as a default if it meets end user requirements. Extruded products can be made into very precise shapes and this characteristic, combined with graphite's high thermal resistance, thermal conductivity, anti-corrosion and lubricating properties, makes it useful in a wide range of industrial applications, mainly in the iron and steel, aluminium and chemical industries and in metallurgy.

Moulded synthetic graphite shapes are generally used only in large-scale applications, because they are typically inferior to extruded graphite.

4.5.3.1 Carbon brushes

Carbon brushes (also known as graphite brushes) are sliding contacts used to transmit electrical current from a static to a rotating part in a motor or generator. The brush effectively transfers electric current to a rotating armature while its lubricity minimizes frictional wear. Carbon brushes are held in permanent contact with the slip ring assembly or with the commutator by brush holders. Carbon brushes are used in a very wide range of applications in electric motors, alternators and electric generators.

The global market for carbon brushes was around 290kt in 2016. China is the largest consumer of carbon brushes, accounting for over 20% of the world total. The largest regional consumer is Asia, which accounted for 40%, followed by North America and Europe at 20-30% each.

There are four main types of carbon brush:

- electrographitic brushes
- carbon-graphite brushes
- metal-graphite brushes
- graphite brushes

High-purity synthetic graphite at over 99.9%C is preferred for use in electrographitic brushes. Graphite purity can reach 99.99% C for electrographite brush applications, although volumes for these uses will be low (probably less than 1,000tpy).

Carbon-graphite brushes may be made from synthetic graphite and are more abrasive than the other types, leading to their use in low-speed and lower-current density applications.

Metal-graphite brushes are generally made from natural graphite and fine metal powders or carbon-graphite impregnated with molten metal. High-purity natural graphite powder is typically used in metallic or semi-metallic carbon brushes for low-voltage, high-current appliances such as 12V systems used by the automotive industry. In the industry, these grades appear to be referred to as 'mechanical grades', while purer synthetic grades are used for 'electrical grades'. Copper is the most common metallic constituent, but silver, tin, lead and other metals are also sometimes used.

Metal-graphite brushes are ideal for a variety of applications because of their particularly low resistivity. They are typically used in applications where high brush current densities are encountered. Metal graphites are used for grounding brushes because of their low contact drop. In some metal graphite brush applications (such as forklift and battery truck motors, battery charging and welding generators and slip rings), natural graphite can make up 50% of the content of a particular brush.

The largest end-markets for carbon brushes include automotive motors, equipment for paper mills, steel mills, mining, elevators, power generation, railroad and other industrial applications.

4.5.3.2 End uses for graphite shapes

Graphite is used in many mechanical applications where its natural corrosion resistance, mechanical strength at high temperatures and lubricant qualities are desirable characteristics. Graphite shapes are used for mechanical supporting loads or rotating contact. The successful use of graphite as a sliding contact depends on the selection of additives or impregnants. Mechanical applications include:

- Seals: face, ring and circumferential types
- Bearings: carbon cages for roll and ball bearings, carbon sleeve bearings, carbon thrust bearings or washers, combination sleeve and thrust bearings

- Packing rings: steam and water shaft packing rings and compressor tail rod packing rings
- Non-lubricated compressor parts: wear and piston rings, segments, scuffer shoes, shaft tail rod packing rings, pistons and piston skirts

Graphite shapes are used in furnaces, pumps, bushings, bearings, and other applications that require a non-reactive material that has good thermal stability and high resistance to oxidation. Markets for these products are numerous. Graphite shapes can also be machined into heat sinks, to conduct heat away for electronics or machinery.

Companies in Japan have been at the forefront of developing new applications for graphite shapes, owing in part to a decline in the domestic market for graphite electrodes many years ago.

4.6 Other applications

In 2016, an estimated 135kt of graphite was consumed in 'other applications', comprising around two thirds synthetic graphite and a further third natural graphite.

Graphite is used in nuclear applications, powder metallurgy, fuel cells, conductive polymers, flexible graphite, flame retardants, pencils, carbon-graphite foam, paint and synthetic diamonds. These applications each account for less than 20ktpy of graphite consumption. In addition, graphite is also used in a wide variety of other applications including:

- Aerospace (thermal insulation, nose cones, blast tubes and seals for fuel pumps and shafts
- Small electrodes such as in arc lamps and welding machines
- Graphite composites for medical equipment, chemical industry, semiconductors and other applications

Some of these specialist applications require a reliable and consistent source of a specific type of graphite. For example, nuclear graphite requires very high-purity synthetic graphite. Flexible graphite products and fire retardants are produced from the intermediate product expandable/expanded graphite. This requires large-size natural flake graphite as raw material feedstock, which is then heavily processed through treatment with heat and strong acids to produce the expandable/expanded grades.

Over the decade between 2016 and 2026, consumption in 'other applications' is expected to grow by 3-4%py to an around 194kt. The fastest growing applications will be those based on expandable/expanded graphite, including:

- flexible graphite - sealing and gasket materials, foils, ribbons tape etc. manufactured from expanded graphite; one main end use is in heat management systems where thin layers of graphite are used in portable electrical devices as a cooling device
- fire retardant materials - based on expandable graphite, these expand on contact with heat to form an airtight seal

Demand for expandable/expanded is currently less than 2% of total graphite demand but will provide a growing market for large size natural flake graphite in the coming years.

4.6.1 Nuclear applications

Synthetic graphite is a very suitable material for use in the nuclear industry. It behaves consistently, even after many years of nuclear irradiation and exposure to very high temperatures, retaining good mechanical properties while remaining insoluble and chemically unreactive. It is also relatively easy to handle as waste after reactor decommissioning. The nuclear industry demands very high-purity graphite grades. Even at these purities, graphite is a relatively low cost product compared to other alternative materials.

All graphite used in nuclear applications is synthetic graphite. No natural graphite is currently used as it would not comply with this sector's strict restrictions on the level of impurities. Future reactor designs could potentially use large amounts of natural graphite, but these are not likely to be commercialised until after 2020.

Consumption of graphite in nuclear applications varies widely from year to year depending on the number of projects underway and their status. Demand is thought to average 10-15ktpy. Nuclear applications are, therefore, a sporadic and small, but high-value market for synthetic graphite.

The vast majority of graphite is developed and purchased for a particular nuclear application and is not purchased in along a typical commercial route. The only market that is commercially supplied is that of fuel sleeves.

Synthetic graphite is currently used in the following nuclear applications:

- **Moderators** - graphite is used as the main structural material in the core where it moderates the progress of the reaction - designed for the life of the reactor
- **Reflectors** - a ring of graphite blocks are placed around the moderator core which reflects neutrons back into the moderator and acts as a seal
- **Fuel assembly** – in some reactor designs, a thin graphite casing known as a fuel sleeve is used around the fuel - removed with the fuel and disposed of at every fuel change (the global market for fuel sleeves is US$8-16Mpy). Some designs also use small amounts of graphite in other ways such as the fuel core or as support struts
- **Moulds** for the manufacture of uranium fuel and weapons

4.6.1.1 Nuclear applications:

Consumption varies widely each year in line with orders for new reactor construction but is estimated to be 10-15ktpy; this is not likely to change in the short term. Most future growth is likely to focus on China as a large and increasing energy consumer, as well as other countries with developing economies.

Only synthetic graphite of ultra-high-purity is suitable for use in current reactor designs and much of the graphite used in future designs. There may be the possibility to supply future pebble bed reactor projects with natural graphite if the strict specifications in terms of carbon grade and impurities can be met. The pebble bed project in South Africa has been shelved, however, and even if new projects were commissioned, they would not provide a market for graphite for around 10-20 years. Most growth is likely to be in China and more than likely will be supplied by Chinese graphite producers. China had previously announced plans to build 70GWe of pebble bed nuclear power by 2030; 18 planned plants have been cancelled in recent years, although a small number of new plants have been announced.

4.6.2 Powder metallurgy

Powder metallurgy is the use of metal powder in industrial applications. These applications include:

- **Consolidation** into dense parts and shapes (structural parts, cutting tools, oil-impregnated bushings, filters)
- **Fusion/welding** (solder and brazing pastes, welding and thermal spray, dental amalgams, rapid manufacturing)
- **Other** (conductive inks, chemical, agricultural, food and pharmaceutical)

The majority of graphite is used during consolidation of ferrous powders in the production of powder metal structural parts. In the consolidation process, metal powder is compacted by pressing in a closed metal cavity (the die) under pressure. The compacted powder is then placed in an oven and sintered in a controlled atmosphere at high temperatures until the metal powder melts and forms a solid shape. A second pressing operation (re-pressing) can be carried out before sintering to improve the compaction and the material properties. Any fine metal powder can be used, ranging from steel to titanium. During the sintering phase, graphite almost completely diffuses into the matrix.

Graphite is used in the consolidation process as a source of carbon for sintering, where it acts as a strengthening agent. Graphite also acts as a lubricant to aids the release of powder metal structural parts from the die. The addition of graphite contributes to the self-lubrication of products, in particular with non-ferrous soft metal parts made of brass or copper. Self-lubrication is a useful property in the manufacture of products such as sinter-metallic brake pads, iron, copper or bronze-based bearings and powder metallurgy valve guides. The presence of graphite can also enhance the mechanical performance of the final product (i.e. hardness, tensile properties and fatigue endurance).

Cemented carbides (hard metal alloys) are one example of a product manufactured through the consolidation process. Tungsten carbide is combined with a cobalt binder by hot isostatic pressing to produce a material that is very hard-wearing and primarily used in the manufacture of cutting tools to cut other tough materials. Small quantities of high-purity graphite or other carbon products are required in this application to raise the final carbon content.

4.6.2.1 Consumption of graphite in powder metallurgy

Both natural graphite and synthetic graphite are used with the choice of grade usually made on price and local availability. For the purities required in powder metallurgy, it is not too costly to upgrade natural graphite. Natural graphite accounts for around 65% of the graphite used in powder metallurgy and synthetic graphite 35%. Synthetic graphite is usually reserved for high value and speciality applications, such as medical components. It has the advantage of generally being a purer material than natural graphite but is typically higher in price.

Natural graphite is typically used in the form of powdered flake or higher-value Sri Lankan vein graphite. Amorphous graphite was used in the past, but has been largely replaced by higher purity, flake graphite powder which is retrieved as waste during flake graphite processing. The availability of this material has increased over the last decade with growth in the production of spherical graphite and other processed flake graphite products.

The two main requirements for powder metallurgy-grade graphite are high purity and small particle size. Graphite used in this sector needs to be a minimum of 99% C, however, some applications may require a higher purity of 99.5 to 99.8% C or a lower purity down to around 95% C. Particle size distribution requirements are also tight, with a d^{90} (90% of the particles) being 10 to 50 microns. A fine particle size is required so that the graphite provides a good coating to the metal powders during blending. This aids the sintering process and ensures good homogeneity. Ash content needs to typically be below 0.5% and levels of silica, carbides and vanadium oxide should be low.

A summary of the uses of graphite in powder metallurgy and hard metals markets is shown in Table 31.

Table 31: Graphite applications in powder metallurgy and hard metals markets		
Purpose of graphite	Powder metal materials	Application
Reactivity with metals and oxides	Special alloys (Al, Mg, Ti/oxide, carbides)	Light weight, engineering parts
	Hard metals (WC, TiC, TaC, mixed carbides)	Dies, metal forming (wire, bar), rock drilling, engineering parts
Lubrication and friction modification of the solid part	High Speed Steel (HSS)	Cutting tools
	Fe-PM	Engineering parts, self-lubricating engineering parts, friction products
	Copper/bronze	Bearings, friction parts, clutch facings
Source: Imerys Graphite & Carbon		

Supply of graphite to the powder metallurgy sector is competitive. Major suppliers include Asbury Carbons, Imerys Graphite & Carbon (TIMREX®), Superior Graphite (MetalPURE®), and SGL Group which supply natural and specially manufactured synthetic graphite for powder metallurgical applications. AMG Mining also supplies vein graphite for this application. In May 2015, Zenyatta Ventures announced that it was testing graphite from its Canadian Albany project, for use in powder metallurgy applications.

4.6.2.2 Powder metallurgy: Outlook

By far the largest market for metal powders is in the production of automotive powder metal structural parts. This market is expected to continue driving demand for metal powders. Based on forecast automotive demand of 3%py, production of metal powders is expected to grow by 3-4%py to around 1.7Mt by 2026. The highest growth rate is expected to be in Asia.

Consumption of graphite is forecast to reach 14kt in 2026, based on a similar rate of growth.

4.6.3 Fuel cells

Fuel cells are often classed as a type of battery, but in addition to providing electrical storage, they can also be an independent form of electricity generation. Fuel cells have no moving parts and work electrochemically to generate electrical energy from chemical energy. Energy production is dependent upon the supply of reactants, and so fuel cells require frequent 'refuelling'.

The fuel cell industry is small but growing and potentially offers an alternative source for energy storage and generation that is more efficient and less polluting than existing technologies. Stationary devices have been an area of growth in recent years, particularly in the Japanese consumer market where significant subsidies have encouraged the uptake of small units to provide residential combined heat and power (CHP). From 2015, uptake of high power fuel cells in transport applications has increased strongly.

The proton exchange membrane fuel cell (PEMFC) has become the technology of choice, accounting for 98% of all fuel cell shipments by number and 64% by MW power in 2015. Graphite is the preferred filler mineral for use in the bipolar plates of PEMFCs.

4.6.3.1 Consumption of graphite in fuel cells

An estimated 5.5kt of graphite were consumed in fuel cells in 2016. Natural graphite accounted for around 90% of this figure. Asia accounts for around 60% of graphite consumption in fuel cells, while North America and Europe account for a further 15-20% each.

4.6.3.2 Fuel cells: Outlook

PEMFCs will continue to dominate the fuel cell market to 2026 and be used across all of the main fuel cell applications. This will sustain a small growth market for graphite in the manufacture of PEMFC bipolar plates.

The fuel cell industry is still developing and there remains a diverse range of fuel cell designs, even within the most popular PEMFC product. A large range of carbon products is supplied to fuel cell manufacturers and there is, as of yet, no clearly preferred graphite product. An increasing amount of specialist material is likely to be supplied in future, including spherical and expanded graphite as manufacturers drive for higher performance.

There is large room for error when forecasting graphite consumption in fuel cells because it is only in the early stages of development of the market. Consumption could grow to perhaps 15-30kt by 2026 depending on market conditions, fuel cell uptake and competing fuel cell technologies/raw materials. Although production costs are falling, fuel cells are still an expensive alternative energy product. In the short-term, the market will continue to be determined by government subsidies driving regional consumption.

The market for small-size stationary fuel cells will continue to grow strongly in Japan and is also likely to grow in other parts of Asia and in Europe as a number of companies bring out new products over the next ten years. European governments are likely to offer feed-in tariffs as have been seen in the solar industry.

A market for higher power fuel cells has begun to emerge and could grow strongly over the next decade. However, this is from a very small base and fuel cell vehicles will still account for a very small proportion of total vehicles by 2026.

The market for fuel cells grew strongly 2009-2015 (by 32%py in terms of cell number and 25%py in terms of MW power) thanks to initial uptake from a small base. It is difficult to estimate growth rates in this emerging industry but growth of 10-15%py in cell shipments could result in 200-400kt of shipments in 2026, while growth of 5-10%py in MW power shipments could result in 600-1,000MW shipments. PEMFCs will continue to be the dominant technology thanks to their use in all major transport, stationary and portable applications. China is expected to take an increasing share of production as levels of mass production increase and graphite will be sourced locally.

In the longer-term, beyond 2020, there could be interest in fuel cells from:

- Utility companies seeking energy storage
- Global telecoms companies interested in back-up power
- Commercialisation of fuel cell vehicles if hydrogen infrastructure is established
- Energy generation for countries with no grid system, such as parts of Africa

4.6.4 Conductive polymers and rubbers

Conductive polymers and conductive rubbers are non-metallic materials, such as plastic or rubber, that are used in similar applications to metals but have several benefits. Polymers can be easily extruded and moulded into many shapes and sizes at low cost. In addition, the specific weight of industrial standard plastics is about a third the specific weight of metals, providing considerable weight savings.

4.6.4.1 Consumption of graphite in conductive polymers and rubbers

Consumption of graphite in conductive polymers/rubbers was estimated to be 4-4.5kt in 2016. Graphite, or other forms of carbon, are added to improve thermal and/or electrical conductivity and are compounded in the polymer during manufacture. Graphite cannot be used to improve thermal conductivity when electrical conductivity is not acceptable in the final application.

Both natural and synthetic graphite can be used in conductive polymers, with purities typically ranging from 95% C to 99% C. Small amounts (less than 500tpy) of high purity graphite (over 99% C) are used in specialist applications. Natural graphite and synthetic graphite provide essentially the same thermal properties to conductive polymers, but synthetic graphite is typically used in applications where impurities are detrimental to product performance.

Expandable graphite with a high aspect ratio can also be used and this is much more thermally conductive than standard graphite and carbon fibres. However, expandable graphite is difficult to use with standard polymer feeding and mixing technology, so polymers using it are typically more expensive to produce. Imerys Graphite & Carbon supplies a range of products under the Timrex C-Therm® brand which are claimed to overcome the production issues with expanded graphite. The company also supplies traditional carbon products for use in conductive polymers including fine-grained graphite powders under the Timrex® brand and conductive carbon black under the Enscao® brand.

Natural graphite used as an electrical additive is generally stipulated to have a d90 (90% of particles) passing 40µm. Synthetic graphite particles have a wider range, with a d90 of around 20-75µm. Particle size must be fine so that there is high interconnectivity between the graphite particles, which ensures that the filler has good conductive continuity. If larger particles are required in the polymer – for example because of viscosity requirements – then conductive continuity is improved by ensuring a small percentage of fine particles are added to the mixture.

4.6.4.2 Conductive Polymers and rubbers: Outlook

The emerging conductive polymers market is in its infancy but has the potential for strong growth at 5-6%py. Assuming a similar growth rate for graphite consumption, the market for graphite could rise to 7-7.5kt by 2026.

4.6.5 Flexible graphite

Flexible graphite products are manufactured from expanded graphite. Once expanded, the graphite becomes a large fibrous mass but if pressure is exerted on the flakes, they can combine and be rolled into fragile graphite sheets, also known as graphite foil. This foil is a high-value product, capable of retaining strength at high temperatures and under chemical attack, as well as being fire-resistant and impervious to liquids and gases. Alternatively, it can be moulded into ribbons, sheets, tape and other shapes. Flexible graphite products are typically produced at a grade of 95-99% C but higher purity products are also available at grades of over 99% C.

Flexible graphite is an emerging market but is forecast to be one of the fastest growing end use sectors for graphite to 2026, increasing by as much as 10-20%py.

Graphite foil is primarily used to press gaskets, valve packings and seals, which can withstand high temperatures and pressures. The ability of graphite foil to remain flexible under high temperatures and pressures, as well as its resistance to chemical attack, makes it very useful in the automotive, petrochemical, chemical and nuclear industries, where corrosive or radioactive fluids are common. It is used in relatively small quantities in these applications. The main applications for graphite foil are:

- Gaskets, valve packings and seals
- Bipolar plates for fuel cells and flow batteries (Section 0)
- Heat shields
- Railgun parts
- Maglev train parts

Heat shields are a minor but growing application for graphite foil in small-scale portable devices such as laptops, televisions and mobile phones, which are in high demand around the world. Graphite foil is used because of its thinness, its ability to hold heat and its high melting point and stability. The foil allows heat to spread out in two dimensions, cooling the electrical components, with a higher thermal conductivity than aluminium and similar to copper – more traditional materials.

Flexible graphite is produced around the world but output is concentrated in Asia (China and Japan), North America (USA) and Europe (Germany and the UK). There are a growing number of Chinese manufacturers, many of which are flake graphite producers that have diversified into downstream production.

4.6.6 Flame retardants

Graphite is one of a number of materials that can be used as a flame retardant for wood, foam, plastics and other construction materials. It can be used to improve the performance of other fire retardant additives such as phosphates, halogens and nitrogen compounds.

Expandable graphite is used in this application, an intermediate graphite product with the ability to expand several hundred times its original volume on heating. For example, expandable graphite is used in fire stops around doors; when exposed to fire, it will expand to create an airtight seal that can help to stop the fire from spreading.

Expandable graphite is manufactured specifically from large flake natural graphite which undergoes significant processing, including treatment with heat and a range of strong acids to weaken the bonds between the graphite layers. The use of strong reagents and the high cost of processing means that the majority of expandable graphite and graphite fire retardants are produced in China. This is likely to continue to be the case in the future as the Chinese market grows strongly. China is expected to implement increasingly stringent fire-proofing regulations over the coming years that will encourage the use of fire retardant materials in domestically-made products. In particular, there will be a move towards the use of halogen-free flame retardant (HFFR) materials such as graphite.

China is the largest producer of flame retardant materials; more than 1,000 producers output more than 1Mtpy. China consumes at least three quarters of these materials domestically.

Graphite competes with more conventional HFFR fillers such as aluminium or magnesium hydroxide, carbonate fillers and phosphorus compounds. It also competes with other carbon additives including activated carbon, carbon black and carbon fibre.

Along with flexible graphite products, growth in flame retardants is expected to underpin strong growth in the expandable/expanded graphite sector over the next decade.

4.6.7 Carbon-graphite foam

Carbon-graphite foams are a relatively new and growing application for graphite. They are fabricated using natural or synthetic graphite to form a lightweight and thermally conductive porous structure. Other precursors such as coal, coal tar pitch and petroleum pitch can also be used to produce a range of alternative carbon foams.

Carbon-graphite foams are typically used in batteries, heat exchangers and the cooling systems of heat sinks. Large-scale applications could lie in heat management for airplanes and aerospace technology, while small-scale uses could be in car vehicle radiators and computer chip heat shields.

Oak Ridge National Laboratory (ORNL) of the USA has led the development of this technology and licensed it for manufacture to companies including Poco Graphite and Koppers in the USA which produce the PocoFoam® and KFOAM® brans respectively. In early 2012 it was reported that LED North America had completed a large-scale lighting project at Outpost Solar in Tennessee using ORNL's graphite foam technology to cool LED lamps in streetlights and commercial lighting, so that they operate at lower temperatures.

4.6.8 Synthetic diamonds

Graphite is used as a source of carbon during the manufacture of synthetic diamonds by the two most commonly used methods:

- High pressure high temperature synthesis (HPHT)
- Chemical vapour deposition (CVD)

The HPHT process replicates the process by which natural diamonds are formed. Graphite or diamond powder is placed in a high pressure (50,000 atmospheres) high temperature

(1,500°C) environment in the presence of a metal solvent (iron or nickel) and one or several diamond crystals to act as seeds. This process can produce diamonds up to 10 carats in size, which are generally brown or yellow because of the presence of nitrogen. Other colours can be produced by the addition of suitable dopants and the elimination of nitrogen. This, however, slows the process considerably and causes more irregular growth of the diamond crystals.

In the CVD process, graphite is vaporised in a vacuum chamber and deposited on a diamond seed crystal. Diamonds produced using this method are very pure but small (less than 1 carat) and may have graphite inclusions.

Synthetic industrial diamond production accounts for around 97% of all diamond production (taking into account natural gemstones, natural industrial and synthetic industrial diamonds). According to the USGS, global production of synthetic industrial diamond was around 4.39Gct in 2013 (Table 32).

More than 4Gct of production takes place in China and, in 2013, five countries (China, Ireland, Russia, South Africa and the USA) accounted for 97% of the world's industrial diamond production (both synthetic and natural).

Table 32: World and USA: Production of industrial diamonds, 2008-2013

	2008	2009	2010	2011	2012	2013
World						
Quantity (Gct)	4.62	4.40	4.45	4.51	4.52	4.45
Synthetic (Gct)	>4.55	>4.4	>4.38	4.38	4.48	4.39
Natural (Mct)	>71.8	>55	>63.8	>135	>36.0	>59.9
No. of countries producing	32	30	28	27	…	…
Value (US$Bn)	1.65-2.00	1.65-2.50	1.65-2.50	1.65-2.50	1.65-2.50	1.65-2.50
USA						
Quantity synthetic (Mct)	261	91.0	93.0	98.2	103	108
Value (US$M)	263	65.1	66.4	67.1	70.6	73.2

Source: USGS

Major end uses for synthetic diamond are computer chip production, construction, machinery manufacturing, mining services (drilling for mineral, oil, and gas exploration), stone cutting/polishing and transportation systems (infrastructure and vehicles).

5. Potential competition between natural and synthetic graphite

Graphite, natural and synthetic, has the following specific properties that can be exploited in a diverse range of commercial applications:

- most thermally and electrically conductive non-metal
- high chemical stability and inertness and resistance to oxidation
- resistance to wetting by metals
- strength at high temperatures (melting point of around 3,650^{0}C)
- resistance to thermal shock and limited expansion/shrinkage
- lightweight
- naturally soft and lubricating because the layered structure makes it malleable and easy to compress
- low adsorption of X-rays and neutrons

Natural (flake, amorphous and lump types) and synthetic graphite can be and are used in many of the same applications. The choice between materials is largely determined by their individual properties and/or their cost. Physical characteristics such as porosity, crystal structure, grain size and shape, and the surface morphology can all affect the behaviour of the graphite in the end use application. Some forms of natural graphite, particularly flake, have superior performance in some uses such as refractories.

Over the last 20-30 years, technological advances have reduced the cost of producing synthetic graphite and it has begun to replace natural graphite in some applications such as recarburisers, powder metallurgy and foundries. Since the mid-1990s, however, this trend has been countered by further downstream processing of natural graphite, which has resulted in high-purity and expanded grades, which can be used in a range of applications including batteries and heat sinks.

Table 33 lists applications of natural and synthetic graphite. Of these, there are some areas with a faster growth rate than others

Table 33: Major applications of primary and secondary natural and synthetic graphite

	Natural		Synthetic	
Application	Amorphous	Flake	Primary	Secondary
Batteries				
Alkaline and zinc carbon		X	X	X
Lithium-ion[1]		X	X	X
Conductive coatings		X	X	X
Electrodes				X
Expandable graphite		X		
Foundry coating	X	X		
Friction materials	X	X	X	X
Fuel cells		X	X	X
Flexible products (such as gaskets and seals)[2]		X		
Graphite shapes (including carbon brushes)	X	X	X	X
Lubricants	X	X		X
Pencils	X	X		
Plastics		X	X	X
Powdered metals		X	X	
Refractories	X	X		X
Recarburisers	X			X

Source: *Roskill*
Notes: *1-Made from spherical graphite*
2-Made from expanded graphite

5.1 Competition in batteries

Consumption of raw graphite across all battery applications grew by an average of 11.6%py over the last decade to an estimated 151.9kt in 2016, equivalent to 7% of global graphite demand. Unusually for graphite applications, both natural and synthetic graphite compete for use in the battery sector; the split is around 70% natural, 30% synthetic.

High purity/high cost synthetic graphite may be produced specifically for use in battery applications by synthetic graphite manufacturers worldwide. The synthetic graphite industry is well established outside China in North America, Japan and Europe. Secondary synthetic graphite is also sourced as a by-product from electrode manufacturers. China has increased its consumption of secondary synthetic graphite in battery materials as Asian electrode production increases (at the same time, electrode production elsewhere is declining).

Table 34: Battery applications: Graphite requirements

Application	Graphite specifications	Properties provided to the battery	Recommended graphites
Primary alkaline batteries	• High-purity • High crystallinity • Defined particle morphology • Defined particle size distribution	• High electrical conductivity • High lubricity (reduces wear) • Good compressibility (increases strength) • Chemical stability	○ Graphite and carbon powders ○ Expanded graphite
Lithium-ion battery anode	• High-purity • High crystallinity • High packing density • Spherical particle shape (Mango shaped) • Low surface area • Treated surface (on request)	• High capacity • High stability • High adhesion and easy processing • High rate capability	○ Graphite and carbon powders ○ Spherical graphite
Lithium-ion battery cathode	• High-purity • High crystallinity • Unique particle shape (expanded graphite)	• High electrical conductivity • Good electrolyte absorption • Chemical stability	○ Graphite and carbon powders ○ Expanded graphite ○ Spherical graphite
Fuel cells	• High-purity • High crystallinity • Defined particle morphology • Defined particle size distribution	• High electrical conductivity • High thermal conductivity • High compatibility with binders • No contamination with trace elements	○ Graphite and carbon powders ○ Expanded graphite ○ Spherical graphite
Lead acid batteries	• High-purity • High crystallinity • Defined particle morphology • Defined particle size distribution	• Improved charge acceptance • Extended cycle life	○ Graphite and carbon powders ○ Expanded graphite
Zn-Air batteries	• High-purity • High crystallinity • Unique particle morphology (expanded graphite) • Defined particle size distribution	• High electrical conductivity • High active surface • Good corrosion stability • Inertness	○ Graphite and carbon powders ○ Expanded graphite
Rechargeable alkaline batteries	• High-purity • High crystallinity • Defined particle morphology • Defined particle size distribution	• High electrical conductivity • Good corrosion stability • No contamination with trace elements	○ Graphite and carbon powders ○ Expanded graphite
Other electrochemical systems			○ Graphite and carbon powders ○ Expanded graphite

Source: Superior Graphite, Roskill

China is the largest consumer of graphite in battery applications accounting for around three quarters of global demand in 2016. It dominates the manufacture of primary and rechargeable batteries and, as battery manufacture has moved to China (from its traditional focus of Japan), component manufacturers and other companies in the supply chain have followed. Being located in China puts the manufacturers close to the growing domestic battery market and close to extensive sources of raw material. China is the largest producer of natural flake graphite (most of which is in the small to medium size flake category preferred for use in battery materials) and the largest producer of synthetic graphite.

A large number of companies supply battery-grade graphite. Some companies supply both natural and synthetic product, but in the main, the companies solely supply either product. The vast majority are located in China, supplying the increasing number of battery component manufacturers that have transitioned there from Japan.

BTR New Energy Materials of China is both the world's largest producer of both spherical graphite and lithium-ion battery anode material. Many smaller Chinese producers are also involved with spherical graphite processing, mainly located in Shandong and Heilongjiang provinces, close to natural flake graphite resources.

Major synthetic graphite suppliers to the battery industry include: Fangda Carbon New Material, the world's largest synthetic graphite producer and Nantong Yangzi Carbon (China), Tokai Carbon, Showa Denko and SEC Carbon (Japan); Superior Graphite, GrafTech International and Asbury Carbons (USA); SGL (Germany).

Batteries typically require graphite with a purity of >99.9% C (typically >99.95%); lithium-ion batteries are the most demanding in terms of purity, requiring the use of at least 99.99% C. Impurities should be limited to 100-200ppm. Metallic impurities such as copper and iron are very problematic to battery manufacturers and can cause the battery to 'short' and prevent the flow of charge across the battery; they can also react with the electrolyte. Sulphur must be limited in synthetic graphite but is not typically present in high quantities in natural graphite. In lithium-ion anodes especially, graphite should have a small particle size distribution so that performance is consistent throughout the anode material.

The major Chinese natural graphite producer Aoyu Graphite suggests that spherical graphite products need to have good sphericity, chemical stability, high charge-discharge capacity (first discharge capacity is above 360mAh/g), long cycle life (above 300) and good/safe performance. Particle size and purity are adjustable according to the customer's requirements and specification.

The price of synthetic graphite is thought to be more competitive with spherical graphite inside China than elsewhere, leading to slightly higher demand growth for synthetic graphite than natural graphite to 2026. Outside of China, natural graphite, in the form of spherical graphite will continue to be used in preference because of price. Natural graphite's proportion of the total battery market is forecast to fall slightly to 69% by 2026. In all regions, there will be increased use of graphite and carbon blends to improve battery performance and increasing competition from emerging sectors such as silicon-based anodes for lithium-ion batteries.

5.1.1 Graphite in lithium ion batteries

Untreated **natural graphite** is not pure enough for use in this application and has too many impurities that could react with the electrolyte and lead to decomposition and premature aging of the anode. Flake graphite is therefore purified through acid leaching and thermal treatment to remove impurities and to create a highly ordered crystal structure. The flaky layers are also undesirable as they tend to come apart as the lithium-ions move though the anode. Grinding the flake graphite into a spherical shape and then coating has been found to help prevent degradation of the graphite during battery use. The final product, spherical graphite, can then compete with synthetic graphite use in lithium-ion batteries. The very high costs associated with this processing mean that spherical graphite prices are high compared to traditional flake products, although typically still below those of synthetic graphite (which has its own highly expensive and energy intensive manufacturing process from petroleum coke).

The high costs, energy consumption and environmental impact (relying on a cocktail of acid reagents) have historically limited spherical graphite production to China. Production is exported, mainly to Japan or South Korea, or consumed by domestic anode material producers.

Synthetic graphite can be manufactured as a powder specifically for use in batteries, tailored to meet strict specifications that suit the intended application; it has particular use in higher performance lithium-ion battery anodes. Secondary synthetic graphite, sourced as waste from the electrode industry, is also used in batteries. Secondary synthetic graphite is often used in the manufacture of lower performance batteries for the Chinese market. Graphite consumption has increased with the demand for lithium-ion batteries, which grew by an average of 24.5%py between 2006 and 2016 from 10.0GWh to 89.4GWh, driven by growth in the emerging ESS and automotive industries Lithium-ion batteries have now reached saturation point in their replacement of NiCd and NiMH batteries in traditional 3C applications.

A comparison of historical growth in graphite consumption and the lithium-ion battery market is shown in Figure 26. Graphite consumption has grown at a slower rate than battery output for several reasons:

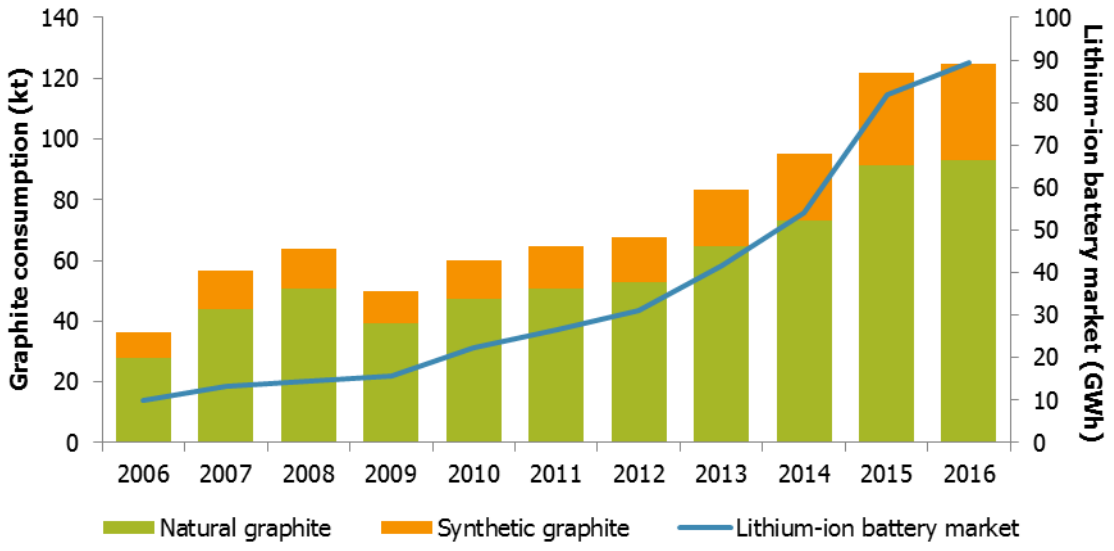
- Battery efficiencies have increased so that less graphite (and other raw materials) are required per MWh of battery output
- The emerging use of silicon has replaced a small amount of graphite in the anode of some lithium-ion batteries (typically only a few %, although may be up to 10% in some cases)
- Improvement in the efficiency of spherical graphite manufacture from natural flake graphite has resulted in less waste and less flake graphite required as raw material
- Increasing production of lithium-ion batteries for the Chinese market has resulted in synthetic graphite consumption growing slightly faster than that of natural graphite (low cost secondary synthetic graphite is readily available in China)

Conversely, consumption of graphite has been encouraged as a result of:

- A shift to the use of higher purity spherical graphite with lower yields (up to 70% losses for the highest grades)

- Increasing demand for spherical graphite, especially outside China, because of the competitive price over synthetic graphite. Spherical graphite use has been encouraged by technological advancements to spherical production, coating technologies and the use of graphite blends

Figure 38: Consumption of raw graphite and lithium-ion battery market, 2006-2016



Source: Roskill

In reality, batteries are often a blend of natural and synthetic graphite along with other carbon materials. Choice comes down to cost (dependent on location) and specification (dependent on the final battery application). A manufacturer may select graphite depending on local availability, price, quality/consistency and through links it has with the supply chain. Exact combinations and quantities, therefore, vary by manufacturer.

The majority of Chinese anode material production is based on synthetic graphite. There is greater access to lower cost synthetic graphite as a by-product from synthetic graphite electrodes in China than in Japan and the ROW.

Increasing production of lower capacity automotive batteries for domestic use (such as those for slow-moving city buses), is also helping to bolster growth in synthetic anode material in China above that of natural graphite anode material. Anode material production outside China, by comparison, has a greater split between natural and synthetic graphite.

Consumption of graphite in the final anode material (accounting for losses in spherical graphite manufacture) is shown in Table 35. CAG rates over the last 10 years for natural and synthetic graphite are much closer than for raw material consumption at 14.0%py and 14.4%py respectively.

Table 35: World: Consumption of processed graphite[1] in anode material by type, 2006, 2011 and 2016 (kt)				
	2006	2011	2016	CAGR (%py) 2006-16
Natural graphite	14.8	27.9	55.1	14.0
Synthetic graphite	8.4	13.9	32.0	14.4
Total	**23.2**	**41.8**	**87.2**	**14.2**

Source: *Roskill*

Notes: *1-Includes spherical flake processed from natural flake*

5.1.2 Competition in lubricants

Synthetic and natural graphite compete for use in many of the same lubricant applications. The choice often comes down to cost and purity. Choices may also be limited by local availability as shipping costs are high in comparison to graphite prices.

The synthetic graphite used typically comes from secondary sources as a by-product of electrode manufacturing. Some electrode manufacturers (including SGL Group, GrafTech and Showa Denko) sell secondary synthetic graphite directly to the consumer, while others upgrade their material, (either themselves or through a third party) for sale at higher prices.

All natural graphite types can be used in lubricants but flake graphite is the most common form as it is typically higher purity. Flake graphite for use in lubricants has to undergo high levels of purification to achieve the correct purity levels, making it a comparable price to synthetic graphite in this application. Amorphous graphite has attractive particle size but lower purity and is used in lower-performance lubricants. Vein graphite is valued for its particle size and high purity and is used in specialist lubricants. It is less readily available than flake or amorphous graphite, however, as production is limited to Sri Lanka.

5.1.3 Competition in graphite shapes

5.1.3.1 Carbon brushes

Graphite typically accounts for less than 10% by weight of a carbon brush. Around three quarters of the graphite used is synthetic graphite and the remainder natural graphite. Natural graphite, primary and secondary synthetic graphite are all used, as well as alternative carbon materials such as carbon black. The choice comes down to a trade between cost and performance. The carbon brush market is very competitive and manufacturers are under pressure to keep costs low, particularly in the automotive carbon brushes sector.

Carbon brush manufacturers prefer to use synthetic graphite over natural graphite in high-performance applications. Natural graphite does not have the consistent, repeatable properties and guaranteed low ash content that electrical-grade brushes require. Lower purity results in a lower performance and friction and heat generation due to uncontrolled ash dispersion in natural graphite, are of particular concern. Synthetic graphite is often perceived as a safer but more expensive choice.

Secondary synthetic graphite is typically used in carbon brushes, often purchased as powder as a by-product of synthetic graphite electrode manufacturing. Many electrode producers (such as SGL Group and GrafTech) sell secondary synthetic graphite directly to consumers. Other secondary producers have agreements in place with traders and processors, who may upgrade the product before selling it on to consumers.

Natural flake graphite is used in some applications to impart an abrasion or cleaning action. In some carbon brush applications, low-purity natural is sufficient and ash abrasion is not a problem, but in many carbon brush applications, it proves too expensive to upgrade natural graphite to the purity levels that can be achieved using synthetic graphite.

5.1.4 Competition in fuel cells

Price is almost always the most important factor in choosing graphite for use in fuel cells. Any graphite used must have a high purity (always over 99% C but typically much higher at around 99.99% C) and high electrical and thermal conductivity. Impurity levels must also be low, in particular, the level of metallic impurities which can impact on fuel cell performance. Purified flake graphite and expandable/expanded graphite (forms of heavily processed flake) are typically used, as well as primary synthetic graphite.

Some fuel cell/plate manufacturers purchase expanded graphite or foils made from expanded graphite, while others purchase expandable graphite and process it themselves. These products ensure that the plates produced are very thin. Graphites are supplied in a variety of sizes ranging from powder through to particle sizes in µm and mm. Small amounts of spherical graphite (also made from natural flake graphite and typically used in battery products), are also used in fuel cell production.

Alternatively, primary synthetic graphite can be used, at over 99.9% C. This has high levels of electrical conductivity but is often expensive. It also creates difficulties when shaping the fuel cell plates, due to the resilience of synthetic graphite. Secondary synthetic graphite is not suitable for this application due to its inconsistent purity and morphology.

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6. Prices for natural flake graphite

Natural graphite prices are not traded on any commodity exchange. Prices are negotiated directly between producers/processors and consumers, often on an annual renewable contract. Prices of natural graphite in this section are taken from several sources, namely:

- reported prices in industry publications
- average values of exported products

The two most important aspects of a natural flake graphite price are the **carbon purity** and the physical aspect and **size** of the flake. Prices also vary widely depending mainly on the location of the supplier and purchaser and any shipping requirements, the agreed contract type and length, graphite specifications as well as underlying production and processing costs.

Major specifications of the graphite that affect the price include the purity (carbon content and presence of impurities) and particle size (fine, medium and coarse flake or powder).

Carbon content is relatively simple to ascertain, and carbon contents are generally standard, often in boundaries for pricing such as 85-89% C, 90-92% C and 94-97% C and greater than 97% C. Flake definitions are more complicated to make direct comparisons between producers. Flake sizes can be defined in mesh sizes (usually ATSM, Tyler and BSS as well as AFNOR and DIN) which can all differ slightly in micron sizes, and again with a different percentage of the flake passing through. For example, Graphit Kropfmůl defines large flake as min 85% >160µm and min 35%>315µm, neither of which figures are align to the recognised international sieve charts, falling between 80 and 100 mesh and 50 to 45 mesh respectively (ASTM). This can make direct comparison of grades difficult.

6.1 Flake graphite prices - background

The price of natural flake graphite increases with

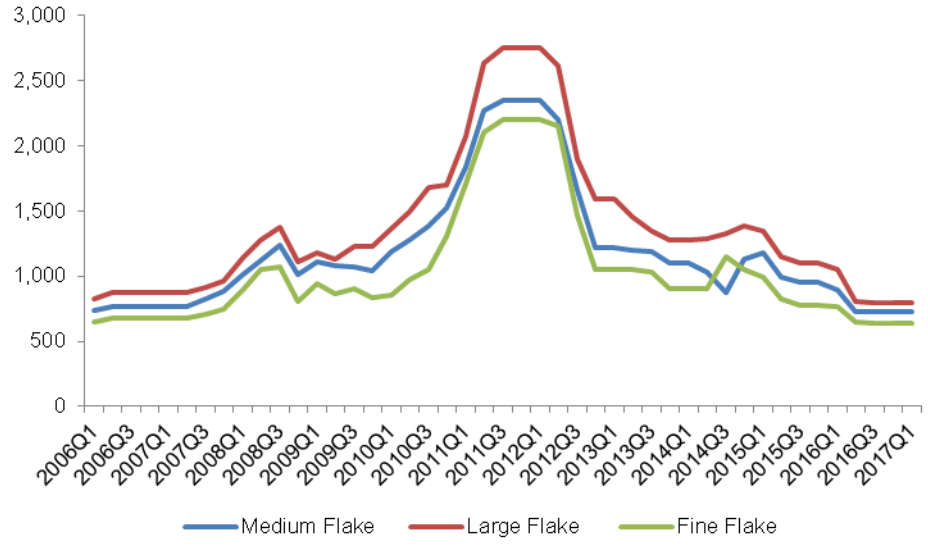
1) Flake size – larger flake sizes can command a premium price. Flake sizes above 80mesh (175µm), and particularly above 50mesh (300µm) are described as large size and jumbo respectively, and command higher prices. If large flakes are combined with a higher carbon content (94-97% C), it represents the high end of the price spectrum for natural graphite.

2) Carbon content – A higher carbon content will dictate higher price levels, owing to the amount of processing. Prices for carbon contents greater than 97% climb more steeply owing to the amount of processing involved.

Published flake graphite prices for fine, medium and large flake sizes are shown in Figure 39 (average of all carbon grades) illustrating the price premium on the large and medium flake sizes. The price of large flake is typically 30% higher than that of fine flake in 2016. There is less of a price differential between fine and medium grades, and the carbon content becomes more important. Typically, after the price hike in 2011 and early 2012, prices have

declined but steadied out in the last quarter of 2016 and early 2017. Jumbo grades (regarded as plus 50 mesh or 300µm) are priced at a premium again over large grades. In Q1 2017, jumbo grades were priced at $1,350-1,440/t FOB China for 94-97% C graphite, representing a 50-60% price premium over large flake.

Figure 39: Average prices of flake graphite by flake size[1], 2006 to 2017 (Q1)



Source: *Industrial Minerals, Asian Metal, Industry sources.*

Notes: *1-Average of all published carbon grades, FCL CIF main European port*
Fine flake -100 mesh, Medium flake +100 mesh, Large flake +80 mesh

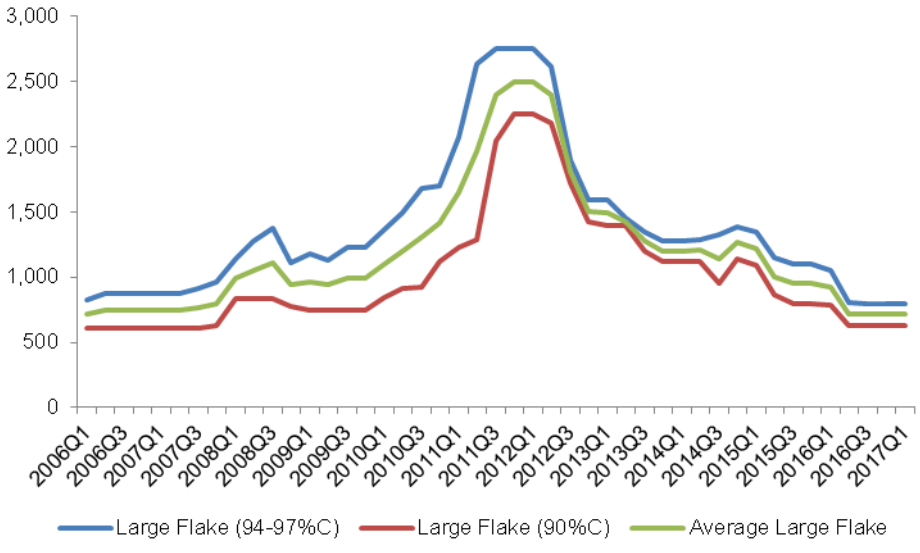
Table 36: Premiums (% price over medium flake 90%C, FCL CIF Europe)

	Flake fines, -100 mesh, CIF Europe, 94-97% C	Flake fines, -100 mesh CIF Europe, 90% C	Medium flakes, +100-80 mesh FCL CIF Europe, 90% C	Medium flakes, +100-80 mesh FCL CIF Europe, 94-97% C	Large flakes, +80 mesh CIF Europe, 94-97% C	Large flakes, +80 mesh CIF Europe, 90% C
2017	2%	-10%	0%	17%	29%	7%
2016	1%	-12%	0%	16%	31%	7%
2015	-3%	-17%	0%	18%	36%	9%
2014	-2%	-19%	0%	2%	30%	13%
2013	-6%	-13%	0%	9%	31%	26%
2012	12%	-8%	0%	21%	44%	31%
2011	32%	4%	0%	42%	64%	16%
2010	16%	-8%	0%	50%	74%	12%
2009	17%	-19%	0%	42%	59%	6%
2008	15%	-20%	0%	31%	47%	5%

Source: Industrial Minerals, Roskill

Published large flake graphite prices for 90%C and 94-97% C grades are shown in Figure 40. The price of 94-97% C large flake is typically 25-30% higher than that of 90% C large flake at US$660-670/t in Q1 2017, illustrating the price premium for higher carbon grades. This applies to all flake sizes, fine, medium, large and jumbo.

Figure 40: Prices of large flake graphite[1], 2006 to 2017Q1



Source: Industrial Minerals

Notes: 1-Large flake, (+80 mesh) FCL CIF main European port

As can be seen from Figure 39, flake graphite prices were relatively stable throughout the 2000s but began to increase in 2010 as concerns over potential supply were voiced in the media. It became apparent that the emergence of a range of new technologies mainly for lithium-ion batteries and flexible graphite products could have a considerable effect on the rate of demand growth over the next decade. Prices for large size flake were the most affected, reaching a peak of US$2,750-3,000/t in Q3 2011 for 94-97% C. The main drivers behind demand at this stage were the traditional automotive and steel industries. Emergent demand for batteries and expanded graphite was in its early stages.

As a result, a large number of new mining projects were proposed, almost all for flake graphite, which could significantly increase capacity outside China. As concerns over availability of supply subsided, flake graphite prices readjusted, falling through 2012 and declining in 2013, before a slight pick-up in the market. Since then prices have headed downwards, particularly feeling the headwinds from oversupply and reduced general industrial activity. Prices for jumbo flake have fared slightly better, but are still lower than three years ago and remained close to the $1,500/t mark. Prices for fine grades and medium grades have plateaued over the last two years, again following the Chinese lead shown in Figure 41.

Overall, prices for flake graphite have fallen over the last five years as the major markets for natural flake have suffered their own slowdowns and in addition supply remains plentiful. Natural graphite is largely used in refractories, particularly iron and steel. However, graphite pricing does not correlate to crude steel production, particularly for fine flake material. The two end markets were there has been growth include batteries and expandable graphite, but these will not provide the volume growth required across the board.

The main driver on pricing appears to be supply rather than demand, inextricably linked to the cost of production. Today, there is overcapacity in the market for any significant price rises to be seen in the mainstream flake graphite grades in the short term. The effect of China in the supply equation is difficult to analyse as it is thought that many of the producers are making very little profit at the moment, even operating at a loss. There may be other financing issues or local employment incentives to keeping Chinese production on-line, which are not visible to the external industry observer.

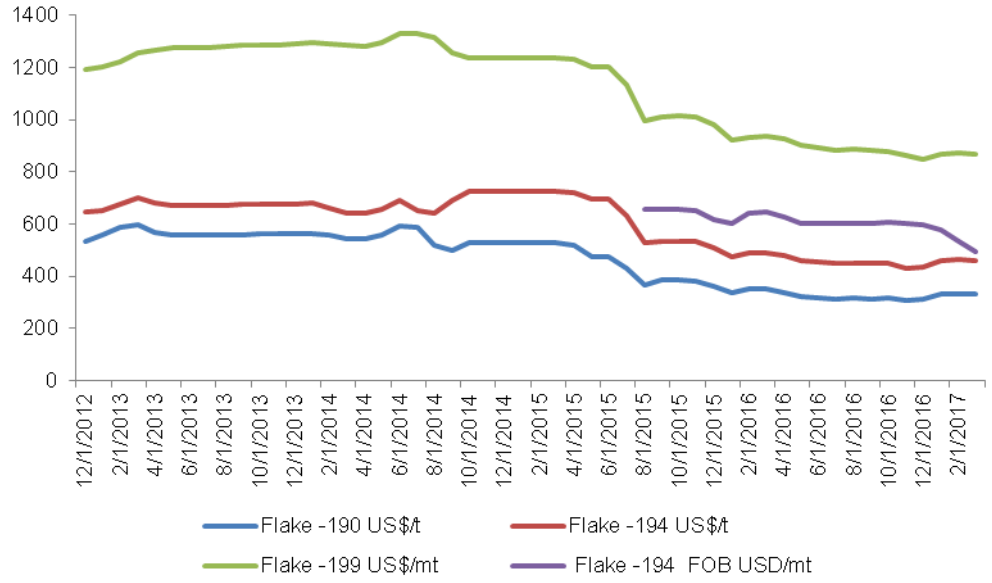
The difference in the prices for fine flake grades (-100mesh) with different carbon contents is aptly illustrated in Figure 41, using domestic Chinese prices as an example with 99% C price fluctuating between US$860-870/t in March 2017, and representing a 90% price premium over 94%C material, and reflecting the much higher processing costs.

The majority of high-purity natural graphite is produced in China, which has traditionally had lower production costs than the ROW, but this situation is changing. The gap between China and ROW prices is narrowing on an annual basis as costs in China increase for raw materials, labour, energy and there is increased investment to address environmental issues. In 2016 there were additional environmental regulations imposed, which came from a national level, rather than regional which has been the case in the past. Additionally a "green tax" will be bought in China in 2018 across heavy polluting industries, which will also affect natural flake graphite producers and potentially increase costs.

No historical series are available for -200 mesh "flake fines" which are often produced as a by-product of the production of large flake fractions. Once purified, high purity fines are used in a growing number of applications, often in place of poorer quality amorphous natural graphite or more expensive secondary synthetic graphite. Production of high purity fines is increasing, in particular with the production of spherical graphite from natural flake graphite. The increasing availability of by-product material is starting to have an impact on traditional fine-sized flake graphite supply, particularly in China.

The graph also shows the difference between the ex-works price of -194 Chinese fine flake graphite and the FOB price for the same grade, with an average of US$110-120/t until December 2016. Since then, the gap between the domestic prices and the ex-works price has been closing with the removal of export duties at the end of the year. In March 2017, the difference between export and domestic prices has been closer to US$30/t.

Figure 41: Domestic & FOB Chinese fine flake graphite prices, 2013 to 2017 (US$/t)



Source: Asian Metal. (-100 mesh grades)

Note: All prices ex-works, with exception of FOB price of -194 Flake.

6.2 The Chinese benchmark

China exports of natural flake graphite dominate international trade, representing almost 60% by tonnage of the global total. China is self-sufficient in graphite and imports very little material from other sources. The Chinese FOB price for graphite is often taken as a benchmark in the industry and in the past has been the one that other producers have to match to be competitive. Figure 42 shows average flake graphite prices exported from China between 2004 and 2016, which shows a strong correlation between the average prices.

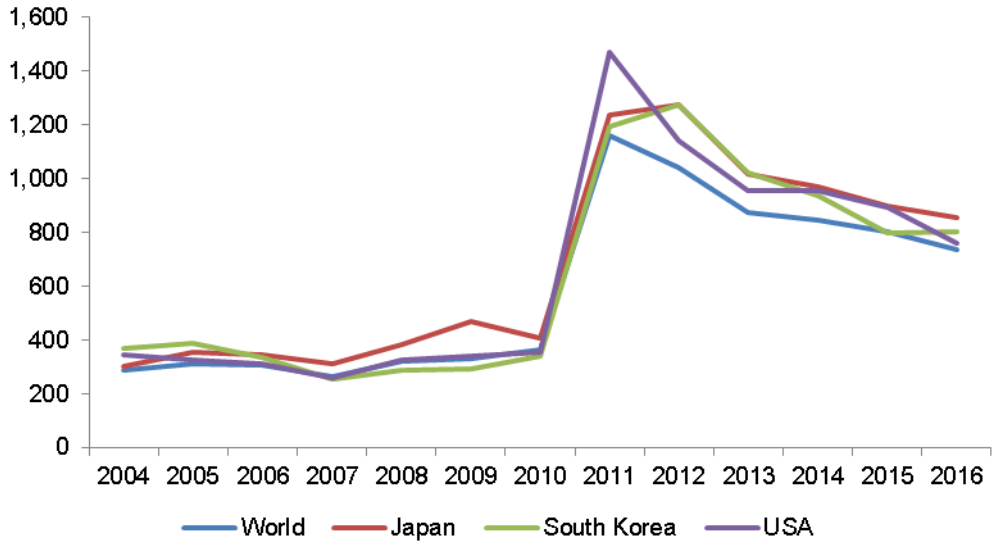
The increasing exports of processed flake graphite and higher grades are reflected in the higher average export values shown in Table 37, and a comparison of Chinese export values against other major graphite exporting countries is shown in Table 38.

Table 37: China: Average value of flake graphite exports to major importing countries, 2006 to 2016(US$/t)

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
World	263	322	334	362	1,161	1,043	873	847	805	736
Japan	312	383	469	407	1,239	1,275	1,019	970	898	856
USA	261	325	341	355	1,471	1,142	955	957	895	761
S Korea	253	288	294	342	1,196	1,276	1,024	937	797	802

Source: GTIT

Figure 42: China: Average value of flake exports to major importing countries, 2004-2016 (US$/t)



Source: GTIT

Table 38: World: Average value of graphite exports, by major producers, 2007 to 2016 (US$/t)

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Brazil	851	954	1,204	1,166	1,460	1,652	1,614	1,452	1,448	1,149
Canada	931	1,074	1,507	1,312	1,430	1,583	1,436	1,533	1,504	1,342
China	240	323	375	435	1,140	1,509	1,440	1,400	1,401	1,327
Germany	979	1,237	1,439	1,212	1,887	1,923	1,663	1,567	1,541	1,685

Source: GTIT Note: Natural graphite in powder or flake form. Powder is defined as -200mesh. China additionally includes spherical graphite in overall exports. Flake natural graphite export values shown in Table 37.

6.3 Madagascan pricing

There is no historical series published for +50 mesh jumbo flake grades, but prices for this fraction are largely at a premium to other grades with the same carbon content. This price premium is justified because of the use of the larger fractions in specialist applications such

as expanded graphite. The actual market size for such fractions is relatively small but is forecast to grow in the next ten years.

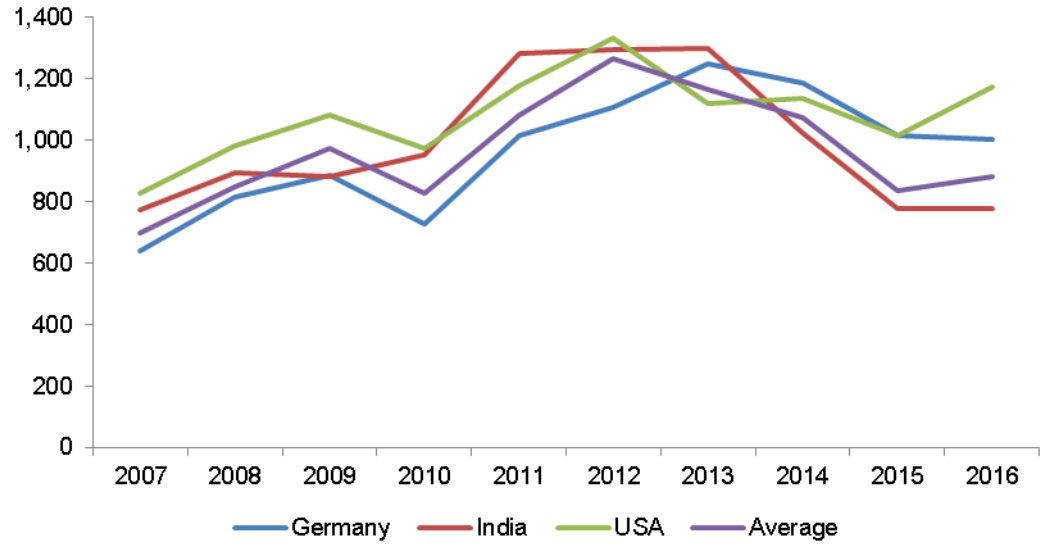
Some of the largest flake sizes commercially available are for Madagascan flake. The country is known for its large flake size production and Madagascan deposits have a high distribution of large size. Madagascan large flake sizes are believed to include material at up to +50 mesh and +35 mesh, but the output of these size fractions is believed to be relatively small. Exports of flake graphite totalled 7,500t in 2016, across all flake sizes, which have doubled since 2013. There are two main producers, as well as production from a number of small scale intermittent miners. No published prices exist for Madagascan flake and no primary export data is available either. The average import price of Madagascan graphite, to the USA and Germany was US$1,000-1,200/t between 2014 and 2016. Similar values were recorded for India up until 2015, when tonnages doubled and lower import prices reported, suggesting a higher proportion of lower flake sizes were included in the imports. This also bought the average export prices down in 2015 and 2016.

Table 39: Madagascar: Flake graphite inferred export average prices US$/t 2007-2016

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Germany	639	816	888	727	1,014	1,110	1,250	1,185	1,017	1,002
India	776	893	882	954	1,281	1,294	1,301	1,025	779	778
USA	830	983	1083	973	1,177	1,332	1,121	1,137	1,016	1,173
Average	697	850	972	828	1,081	1,268	1,164	1,074	835	881

Source: GTIT: Note prices CIF importing country

Figure 43: Madagascar: Flake graphite inferred export average prices US$/t 2007-2016



Source: GTIT. Note: Average of all flake sizes; Implied exports – data taken from imports of destination countries.

6.4 Current pricing

Current average prices of flake graphite by grade and by specific carbon content are shown in Table 40 and in Table 41. As would be expected, ex-works Chinese prices are lower than those in Europe.

Table 40: Average European prices Q1 2017 (converted to US$)

	Min % C	CIF Rotterdam
Fine flake -100 mesh	90-94	500-550
	94-97	630-650
Medium flake +100 mesh -80	90-94	560-610
	94-97	700-750
Large flake +80 mesh	90-94	600-650
	94-97	775-825
Jumbo flake +50 mesh	90-94	1,200-1,250
	94-97	1,300-1,500
	98-99	1,500-1,800

Source: Industrial Minerals, company sources
Note: FCL/20Mt – 1000kg jumbo bags

Table 41: Average Chinese prices Q1 2017 ex-works (converted to US$)

	Min % C	Ex-works
Fine flake -100 mesh	90	330-350
	94	460-500
	95	550-560
	96	600-620
	97	680-690
	99	850-870
Medium flake +100 mesh -80	90	520-590
	94	670-700
	95	725-735
	97	820-840
Large flake +80 mesh	90	570-600
	94	720-750
	95	790-800
	96	830-840
	97	860-870
Jumbo flake +50 mesh	95	1,340-1,360
	96	1,385-1,405
	97	1,430-1,450

Sources: Industrial Minerals, Asian Metal, Company sources
Note: 1000kg jumbo bags

7. Price forecast

Overall natural flake graphite prices are expected to recover gradually in line with supply and demand, and the need to cover increasing costs. The level of price recovery overall will very much depend on the impact of consolidation in the Chinese flake graphite industry and the effects of environmental regulations imposed. Pricing levels will also depend on the number of new supply projects that come on stream in the next five years, of which Roskill has taken a view.

The future price of flake graphite will be shaped by a number of factors to 2030, including:

- The amount of new supply that comes on-line from the opening of new projects and existing expansions in both China and the ROW
- The timing of any new supply
- Possible closures of flake supply from China as the government takes further control, encouraging consolidation and strengthening environmental legislation
- The flake size distribution of new projects in relation to demand
- Growth in the lithium-ion battery market in EVs and energy storage worldwide
- Speed of this lithium-ion up-take - which will depend, to some extent, on the development of global oil prices
- Competition between flake and synthetic graphite, mainly for use in lithium-ion batteries
- Growing use of flake fines as a replacement for amorphous graphite/secondary synthetic graphite
- The location of new supply in relation to new demand from lithium-ion battery material
- An increase in refractory recycling of products on a global basis, such as magnesia-carbon bricks, which could impact graphite demand growth from the refractories industry in the longer term.

The price of flake graphite fell in 2016, as demand from refractories and other steel-related industries remains low. The removal of export duties on Chinese flake graphite has reduced graphite export prices from China in the first quarter of 2017, and put them much closer to domestic prices in China. As growth in the lithium-ion industry picks up speed, prices are expected to recover slightly in 2017 and 2018, although over supply in 2018 could have a dampening effect.

Rapid uptake of lithium-ion batteries between 2017 and 2020, especially in China, will encourage strong growth in the demand for fine and medium size flake graphite. Demand for large flake will also grow with the development of the emerging expandable/expanded graphite market, but this will be on a much smaller scale than the extra demand generated by the battery industry.

Prices will stabilise to 2020 as supply rises to meet this new demand. New supply will come from planned expansions to existing projects, a small number of projects coming on-line (that are currently under development), and possibly from the re-opening of projects that were closed during the period of low prices. Higher prices across most grades could encourage new exploration for flake graphite in China and the ROW but the long time-span

for development means that these new projects are not likely to reach production until 2025-2030.

Between 2020 and 2025, demand from lithium-ion batteries will continue to increase, but at a slower rate than the previous five years, as the market matures. Demand from refractories will remain low. Supply from the ramp-up of new projects is likely to meet increasing demand, resulting in little upward movement in prices over this period. The price of fine flake is expected to fall with increasing competition from by-product fines.

Between 2025 and 2030, growth in lithium-ion batteries will slow further as the market becomes more established. Even so (growth in demand, in terms of tonnage) will remain strong; batteries will continue to see the largest growth of any of the 'major applications'. Demand from refractories could also show some slow recovery by this time as steel production strengthens from emerging regions, resulting in an up-ward trend in prices, especially for large flake graphite as supply tightens. There may be room for several additional new flake graphite projects to come on-line by 2030.

The strongest growth to 2030 will be for the highest carbon flake grades. It is likely that the price for 90% C will decline to be closer to that of the price of 85-87% C as demand shifts towards 94-97% C grades for use directly or for purification into high-purity graphite. Prices of fine flake will decline with greater availability of more the desirable large/medium flake sizes and with the increased by-product manufacture of flake fines.

Historical price analysis, regression analysis, and supply and demand data have all been used to compile a long term forecast for higher carbon graphite grades to 2030. Beyond this point to 2040, global industrial production activity year on year change has been used to base prices price assumptions. Table 42 and Table 43 provide long term forecasts in nominal pricing for high carbon grades of different flake sizes.

Prices presented are in nominal terms, so include the effects of inflation – the price a customer would pay for the large flake graphite at the time. Costs will also increase over the period.

A price forecast in real pricing is also given at the end of the section.

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Table 42: Long term forecast for 94-97%C, large & jumbo flake to 2047, (nominal)

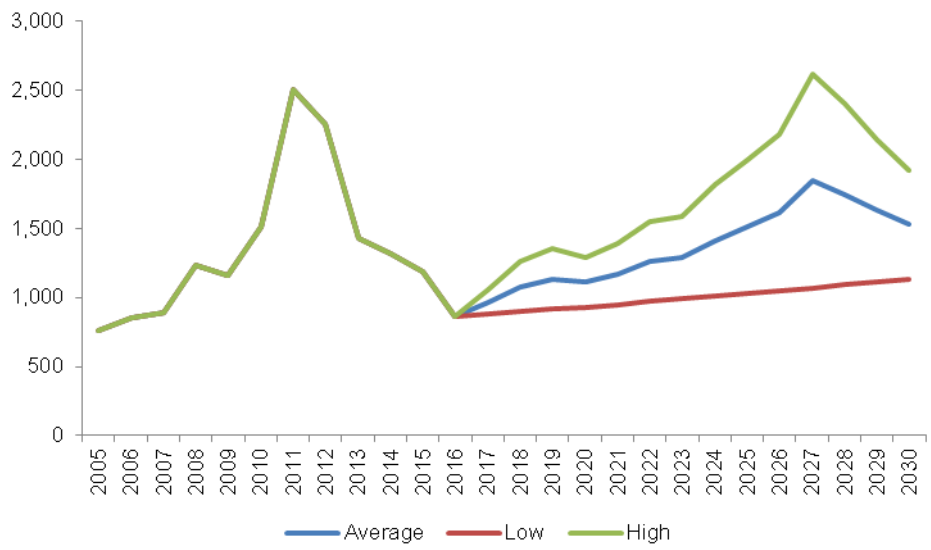
	Large Flake			Jumbo Flake		
	Average	**Base**	**High**	**Average**	**Base**	**High**
2016	861	861	861	1,470	1,470	1,470
2017	968	879	1,057	1,499	1,454	1,544
2018	1,081	896	1,265	1,580	1,511	1,700
2019	1,134	914	1,353	1,631	1,560	1,767
2020	1,113	932	1,294	1,646	1,591	1,722
2021	1,171	951	1,392	1,700	1,623	1,795
2022	1,262	970	1,554	1,770	1,655	1,917
2023	1,290	989	1,590	1,809	1,689	1,943
2024	1,414	1,009	1,819	1,896	1,722	2,115
2025	1,511	1,029	1,993	1,970	1,757	2,246
2026	1,617	1,050	2,184	2,049	1,792	2,389
2027	1,846	1,071	2,621	2,189	1,828	2,716
2028	1,748	1,092	2,403	2,165	1,864	2,553
2029	1,631	1,114	2,148	2,133	1,902	2,362
2030	1,529	1,136	1,922	2,108	1,940	2,192
2031	1,567	1,165	1,970	2,161	1,988	2,247
2032	1,605	1,193	2,017	2,213	2,036	2,301
2033	1,644	1,221	2,066	2,266	2,085	2,356
2034	1,683	1,251	2,115	2,320	2,135	2,413
2035	1,723	1,281	2,166	2,376	2,186	2,471
2036	1,760	1,308	2,211	2,426	2,232	2,523
2037	1,797	1,335	2,258	2,477	2,279	2,576
2038	1,834	1,363	2,305	2,529	2,327	2,630
2039	1,873	1,392	2,354	2,582	2,375	2,685
2040	1,910	1,420	2,401	2,634	2,423	2,739
2041	1,952	1,451	2,454	2,691	2,476	2,799
2042	1,995	1,483	2,508	2,751	2,531	2,861
2043	2,039	1,515	2,563	2,811	2,586	2,924
2044	2,084	1,549	2,619	2,873	2,643	2,988
2045	2,132	1,584	2,679	2,939	2,704	3,057
2046	2,174	1,616	2,733	2,998	2,758	3,118
2047	2,218	1,648	2,788	3,058	2,813	3,180

Source: Roskill

Note: 1-Based on average historical growth rate, regression analysis, nominal pricing long term average and average price premium of jumbo flake over large flake

2 – CIF Full container loads Europe.

Figure 44: Large flake forecast 94-97% C, high and low scenarios. US$/t

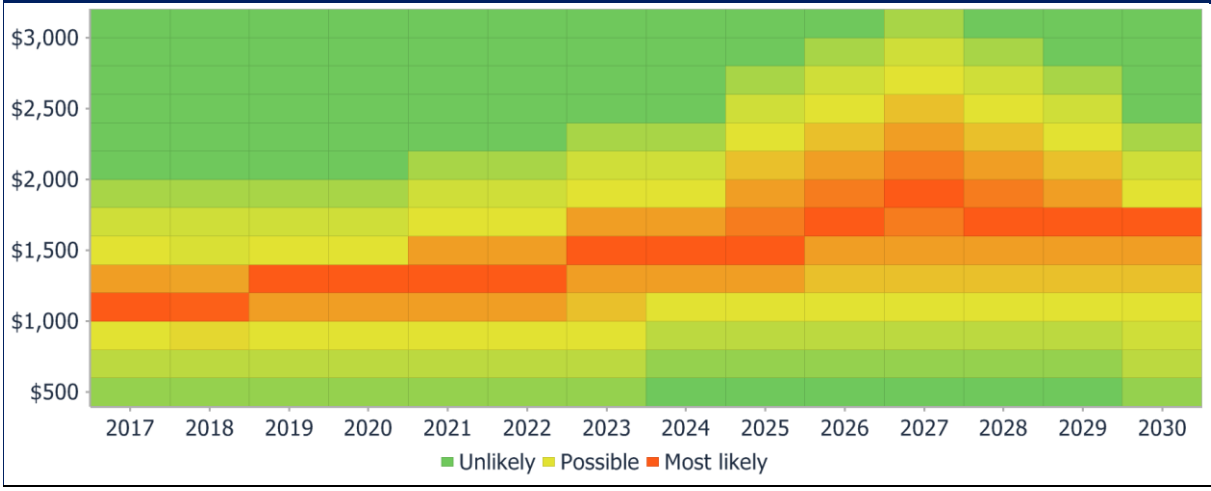


Source: Roskill

Note: Nominal Pricing, CIF Europe FCL

This forecast is illustrated in a heat map to show Roskill's forecast for high carbon flake graphite prices in the form of a probabilistic price outlook. The forecast takes into account risk factors facing the market. Although assumptions may be made about the likely outcomes of these factors, each of these uncertainties contributes to decreased confidence in the price forecast. Roskill's probabilistic heatmap, therefore, indicates the most likely direction of prices, in addition to the upside and downside risks and volatility facing the flake graphite market.

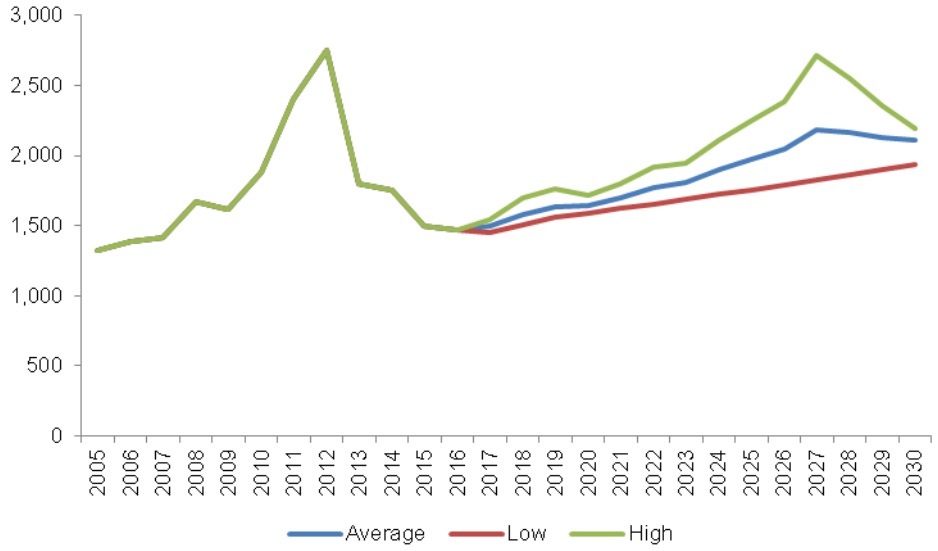
Figure 45: Probabilistic price outlook for 94-97% C large flakes



The warmest colours (red and orange) represent the range that large flake graphite prices are most likely to fluctuate within, while cooler colours (yellow and green) indicate prices

that, as of March 2017, would appear to represent relatively unlikely (but not impossible) scenarios.

Figure 46: Jumbo flake forecast, 94-97% C, high and low scenarios, US$/t

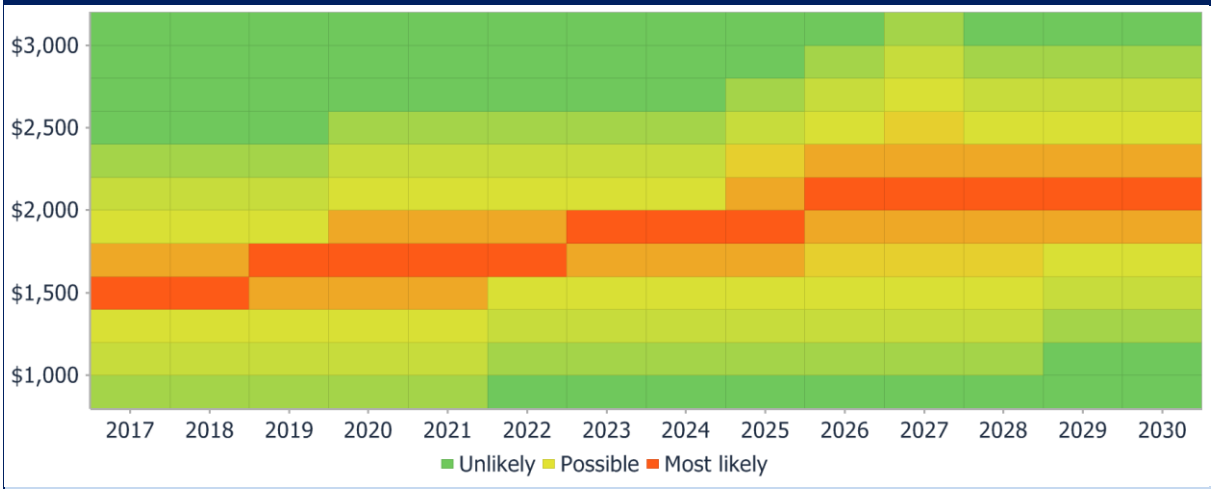


Source: Roskill

Note: Nominal Pricing, CIF Europe, FCL

The forecast is illustrated in a heat map to show Roskill's forecast for jumbo flake graphite prices in the form of a probabilistic price outlook. The forecast takes into account risk factors facing the market and indicates the most likely direction of prices, in addition to the upside and downside risks and volatility facing the flake graphite market.

Figure 47: Probabilistic price outlook for 97% C +50 jumbo flakes



Source: Roskill

Table 43: Long term forecast for 94-97%C, fine and medium flake, CIF Europe US$/t (Nominal)

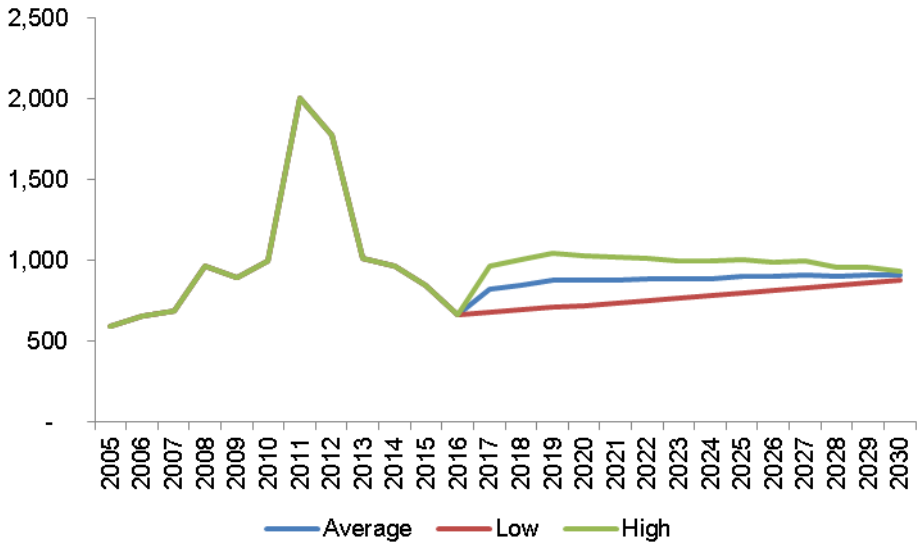
	Fine Flake			Medium Flake		
	Average	**Low**	**High**	**Average**	**Low**	**High**
2016	668	668	668	770	770	770
2017	824	681	967	920	785	1055
2018	849	695	1004	975	801	1149
2019	877	709	1046	1044	817	1271
2020	878	723	1033	1037	833	1240
2021	881	737	1024	1045	850	1239
2022	883	752	1015	1055	867	1243
2023	884	767	1001	1053	884	1222
2024	888	782	994	1070	902	1238
2025	901	798	1004	1094	920	1267
2026	904	814	994	1124	939	1309
2027	913	830	996	1165	957	1372
2028	904	847	962	1136	977	1296
2029	912	864	960	1140	996	1283
2030	909	881	937	1,141	1,016	1,266
2031	932	903	960	1,170	1,041	1,298
2032	954	925	983	1,198	1,066	1,329
2033	977	947	1,007	1,227	1,092	1,361
2034	1,000	970	1,031	1,256	1,118	1,394
2035	1,024	993	1,056	1,286	1,145	1,427
2036	1,046	1,014	1,078	1,313	1,169	1,457
2037	1,068	1,035	1,101	1,341	1,194	1,488
2038	1,090	1,057	1,124	1,369	1,219	1,519
2039	1,113	1,079	1,147	1,398	1,244	1,551
2040	1,135	1,101	1,170	1,426	1,269	1,582
2041	1,160	1,125	1,196	1,457	1,297	1,617
2042	1,186	1,150	1,222	1,489	1,326	1,652
2043	1,212	1,175	1,249	1,522	1,355	1,689
2044	1,239	1,201	1,277	1,555	1,385	1,726
2045	1,267	1,228	1,306	1,591	1,416	1,766
2046	1,293	1,253	1,332	1,623	1,445	1,801
2047	1,318	1,278	1,359	1,655	1,474	1,837

Source: Roskill

Note: 1-Based on average historical growth rate, regression analysis, and nominal pricing long term average.

Nominal Pricing, CIF Europe, FCL

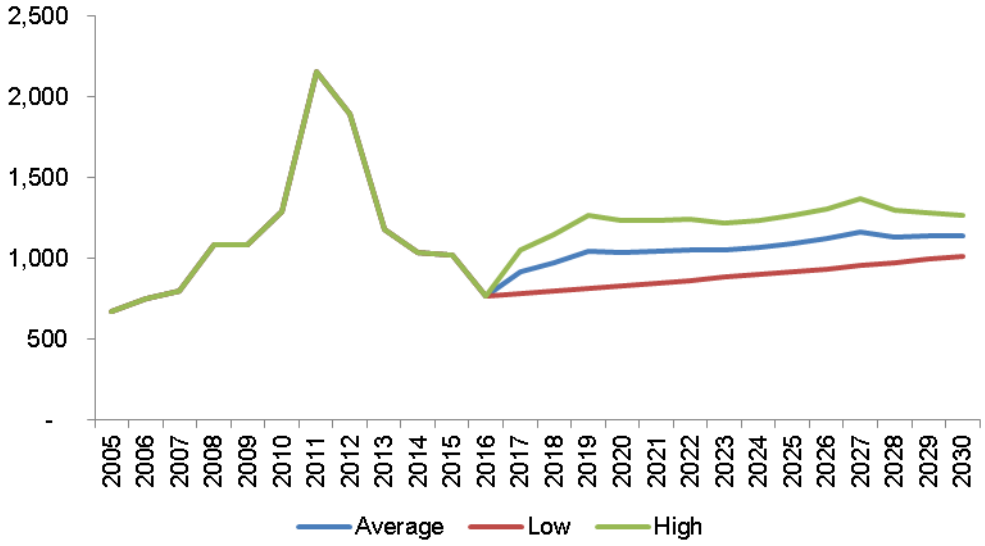
Figure 48; Fine flake forecast, 94-97% C, high and low scenarios, US$/t (nominal)



Source: Roskill

Note: Nominal Pricing, CIF Europe, FCL

Figure 49: Medium flake forecast, 94-97% C, high and low scenarios, US$/t (nominal)



Source: Source: Roskill

Note: Nominal Pricing, CIF Europe, FCL

Real price forecasts relate to the value of a product taking into account inflation, as over longer periods of time, inflation can add up to a significant amount. Forecast real prices are shown in Table 44, and then compared in graphical forms to nominal pricing.

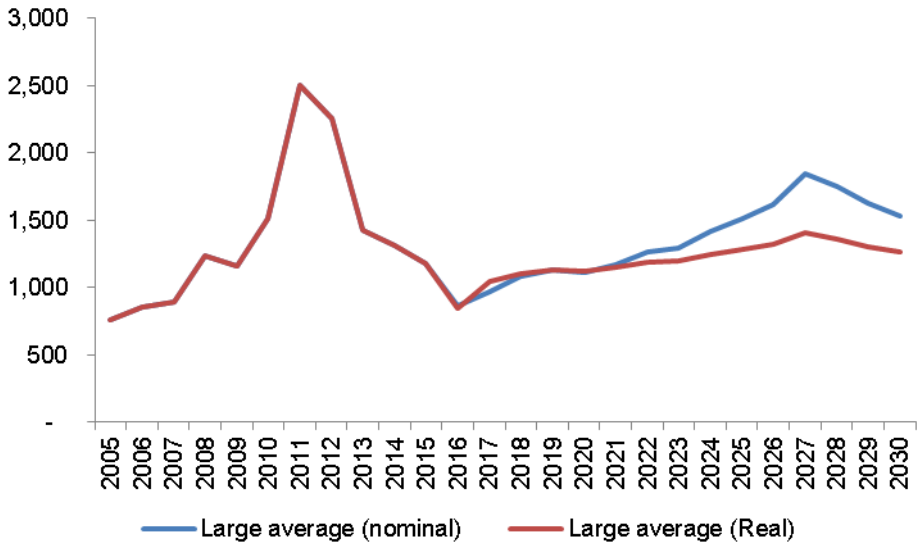
Table 44: Forecast average grades, 90 & 94-97% C, US$/t (real)

	90% C fine average real	90% C medium average real	90% C large average real	94-97% C fine average real	94-97% C medium average real	94-97% C large average real	94-97% C jumbo average real
2016	545	621	663	668	770	861	1470
2017	634	682	745	808	902	949	1470
2018	634	714	794	816	937	1039	1519
2019	635	756	808	827	984	1068	1537
2020	625	735	783	811	958	1028	1520
2021	617	726	800	798	946	1061	1540
2022	608	719	832	784	937	1121	1572
2023	600	704	831	769	917	1123	1575
2024	592	702	877	758	913	1207	1619
2025	587	704	908	754	915	1264	1649
2026	580	712	941	742	922	1326	1681
2027	574	725	1029	734	937	1485	1760
2028	563	692	967	713	896	1378	1707
2029	557	680	898	705	881	1261	1649
2030	548	667	838	689	865	1159	1598
2031	551	670	842	692	869	1165	1606
2032	553	673	845	695	873	1169	1612
2033	555	676	849	698	876	1174	1618
2034	557	678	852	700	879	1178	1625
2035	559	681	855	703	883	1183	1631
2036	560	682	856	704	884	1184	1633
2037	561	682	857	705	885	1185	1634
2038	561	683	858	705	885	1186	1636
2039	562	684	859	706	886	1188	1637
2040	562	684	859	706	886	1188	1637
2041	563	685	860	707	888	1190	1641
2042	564	686	862	709	890	1192	1644
2043	565	688	864	710	892	1195	1647
2044	566	689	865	712	893	1197	1650
2045	568	691	868	714	896	1200	1655
2046	568	691	868	714	896	1200	1655
2047	568	691	868	714	896	1200	1655

Source: Roskill

Note: Real pricing, CIF Europe, FCL 2016=100

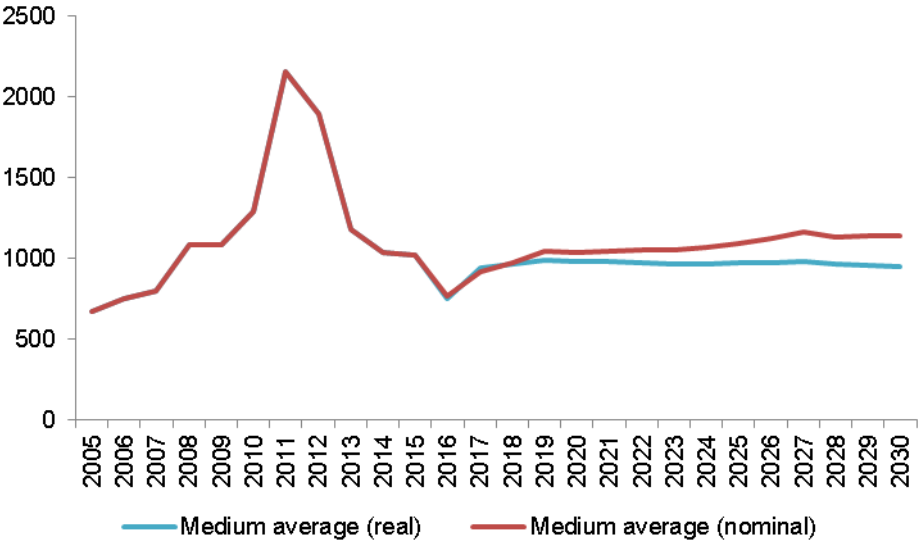
Figure 50: Large flake forecast (real vs nominal prices)



Source: Roskill

Note: Real pricing, CIF Europe, FCL 2015=100, Nominal CIF European port, 94-97% C

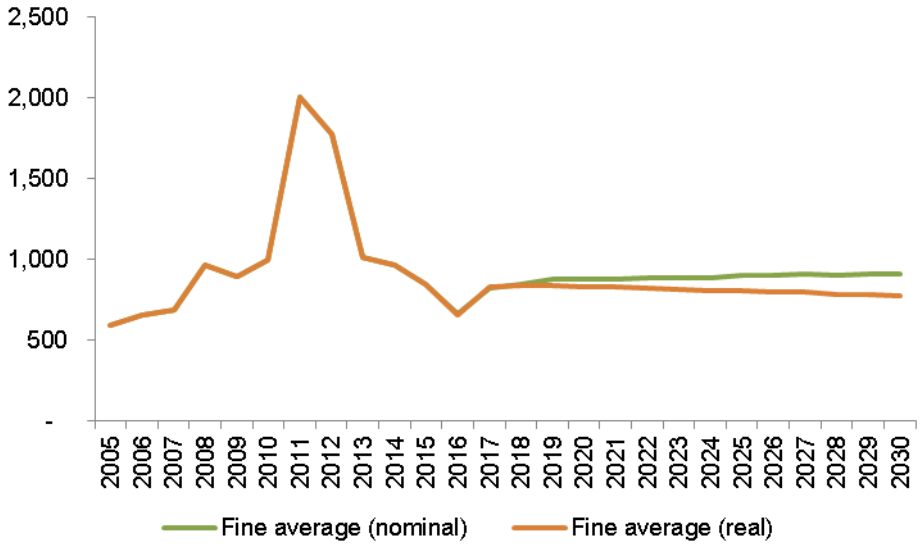
Figure 51: Medium flake forecast (real vs nominal price)



Source: Roskill

Note: Real pricing, CIF Europe, FCL 2015=100, Nominal CIF European port, 94-97% C

Figure 52: Fine flake forecast (real vs nominal price)



Source: Roskill

Note: Real pricing, CIF Europe, FCL 2015=100, Nominal CIF European port, 94-97% C

7.1 High purity graphite (>99%C)

Prices of high purity natural graphite are again not quoted publically. High purity graphite prices for batteries vary widely, depending on the purity, size, shape (spherical or not) and whether coated or uncoated. Prices for natural graphite for use in batteries, carbon brushes, lubricants and powder metallurgy can vary between US$800//t to as much as US$8,000/t. The demand for high grade graphite in batteries has been growing, however, so has the competition to supply the sector with either uncoated spherical purified graphite or coated spherical purified graphite. This has meant the prices for highly purified uncoated spherical graphite (USPG) have been falling over the last three years, from a level of US$3,500/t ex-works China for 99.95%C material to US$2,750/t same basis last year. USPG is usually based on medium flake natural graphite, but can also be produced using large or jumbo flake sizes.

Coated spherical purified graphite prices levels will remain high for the short to medium term, due to a lack of processing capacity, but in the longer term there are lower barriers to entry and prices will come down.

The majority of high-purity natural graphite production will continue to be carried out in China through the purification of flake graphite. Flake graphite production costs will continue to rise in China as overhead costs for mining and processing increase for raw materials, labour, energy and investment in environmental issues. The process involves leaching with acids, including hydrofluoric acid, and neutralising the spent acids is costly.

As production of purified graphite increases, Chinese environmental legislation is likely to become stricter in order to deal with the increasing use of strong acid and other chemicals,

which could raise the cost of production. On the other hand, improvements in processing technology could work to reduce production costs.

A number of flake projects may come online in the ROW over the next five years, with the potential to increase global natural graphite capacity (mainly for flake graphite) with at least an additional 75,000tpy by 2022 is forecast by Roskill. This potential extra supply should work to alleviate concerns over availability of flake supply and prevent further spikes in flake graphite prices paid by ROW purchasers, such as that seen in 2011/12.

8. NextSource Materials Blended Average

Based on the bulk samples test work carried out by SGS, the blended averages are shown in Table 45 giving a weighted average price of US$1,014/t in 2017 in the average case scenario, as US$867/t in the base case scenario and a weighted price average of $1,214/t in 2017 in the high price scenario. The average basket of prices in 2020 is shown in Table 46Table 46, which shows an average basket price of US$1,078/t CIF Europe, with a high case of US$1,233t and a low case of US$927/t.

Table 47 shows real average basket prices through to 2047 from 2016, which assumes that the proportional of flake grades in the production remains consistent over time.

Table 45: SGS Blended Average with Conventional Sales (Europe) 2017 US$/t

Yield (%)	Mesh Size	C%	Average	Average case basket	Low case	Low case basket	High case	High case basket
15.7	Jumbo	98.6	1,499	235	1,454	228	1,544	242
27.8	Large	96.9	1,094	304	879	244	1,503	418
9.7	Medium	96.5	920	89	785	76	1,055	102
46.7	Fine	93.1	824	385	681	318	967	452
Total Basket				1,014		867		1,214

Source: *Roskill*

Note: *Sale Price assumptions, CIF Europe; Roskill's average, base and high price assumptions in 2017 (nominal pricing)*

Table 46: SGS Forecast Blended Average with Conventional Sales (Europe) 2020 US$/t

Yield (%)	Mesh Size	C%	Average	Average case basket	Low case	Low case basket	High case	High case basket
15.7	Jumbo	98.6	1,646	258	1,591	250	1,722	270
27.8	Large	96.9	1,113	309	932	259	1,294	360
9.7	Medium	96.5	1,037	101	833	81	1,240	120
46.7	Fine	93.1	878	410	723	338	1,033	482
Total Basket				1,078		927		1,233

Source: *Roskill*

Note: *Sale Price assumptions, CIF Europe, Roskill's forecast average, base and high price assumptions in 2020 (nominal pricing)*

Table 47: Average basket prices 2016-2047, real prices US$/t

	Average real price				Yield %				Total average basket price US$/t (real)
	Jumbo	Large	Medium	Fine	15.7 Jumbo	27.8 Large	9.7 Medium	46.7 Fine	
2016	1470	861	770	668	231	239	75	312	857
2017	1470	949	902	808	231	264	87	377	959
2018	1519	1039	937	816	238	289	91	381	999
2019	1537	1068	984	827	241	297	95	386	1020
2020	1520	1028	958	811	239	286	93	379	996
2021	1540	1061	946	798	242	295	92	372	1001
2022	1572	1121	937	784	247	312	91	366	1015
2023	1575	1123	917	769	247	312	89	359	1008
2024	1619	1207	913	758	254	335	89	354	1032
2025	1649	1264	915	754	259	351	89	352	1051
2026	1681	1326	922	742	264	369	89	346	1068
2027	1760	1485	937	734	276	413	91	343	1123
2028	1707	1378	896	713	268	383	87	333	1071
2029	1649	1261	881	705	259	351	85	329	1024
2030	1598	1159	865	689	251	322	84	322	979
2031	1606	1165	869	692	252	324	84	323	983
2032	1612	1169	873	695	253	325	85	325	987
2033	1618	1174	876	698	254	326	85	326	991
2034	1625	1178	879	700	255	328	85	327	995
2035	1631	1183	883	703	256	329	86	328	999
2036	1633	1184	884	704	256	329	86	329	1000
2037	1634	1185	885	705	257	330	86	329	1001
2038	1636	1186	885	705	257	330	86	329	1002
2039	1637	1188	886	706	257	330	86	330	1003
2040	1637	1188	886	706	257	330	86	330	1003
2041	1641	1190	888	707	258	331	86	330	1005
2042	1644	1192	890	709	258	331	86	331	1007
2043	1647	1195	892	710	259	332	86	332	1009
2044	1650	1197	893	712	259	333	87	332	1011
2045	1655	1200	896	714	260	334	87	333	1014
2046	1655	1200	896	714	260	334	87	333	1014
2047	1655	1200	896	714	260	334	87	333	1014

Source: Roskill Note: Assuming yield constant proportion. Real prices with 2016=100

Appendix B

Geology

ENERGIZER
RESOURCES INC.

Molo Graphite Project, Fotadrevo, Province of Toliara, Madagascar

Technical Report NI 43-101

Prepared by:
Philip John Hancox, Pr.Sci.Nat. and Desmond Subramani, Pr.Sci.Nat.

September 25, 2014

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Abbreviations, Symbols, and Acronyms

Agence de Promotion du Secteur Minier	ASPM
Ariary Madagascan Currency	MGA
Betsimisaraka Suture	BS
Bureau du Cadastre Minier de Madagascar	BCMM
Bureau de Recherches Géologiques et Minières (France)	BRGM
Carbon	C
Diamond Drill Hole	DDH
Induced Coupled Plasma	ICP
Madagascar Minerals & Resources SARL	MMR
Environmental Commitment Permit	RIM
National Environmental Action Plan	NEAP
National Instrument 43-101	NI 43-101
PEG Mining Consultants Inc.	PEG
Projet de Gouvernances des Ressources Minérales	PGRM program
Projet de Reforme du Secteur Minier	PRSM program
Qualified Persons	QPs
Quality Assurance/Quality Control	QA/QC
Rock Quality Description	RQD
Special Advisory Committee	SAC
Taiga Consultants Ltd.	Taiga
Three Dimensional	3D
Universal Transverse Mercator	UTM
Uranium Star Minerals SARL	USM
Whole Rock Analysis	WRA
X-Ray Fluorescence	XRF

Units of Measurement

Centimetres	cm
Degrees	°
Degrees Celsius	°C
Feet	ft
Grams	g
Hectares	ha
Kilo bar	k bar
Kilogram per tonne	kg/t
Kilograms	kg
Kilovolt-amp	kVA
Metre	m
Metres above mean sea level	m amsl

Millilitres ..... mL
Million tonnes ..... Mt
Parts per million ..... ppm
Percent ..... %
Tonne ..... t

1 SUMMARY

Energizer Resources Incorporated (formerly Uranium Star) is a mineral exploration and development company based in Toronto, Canada, which is currently focused on the exploration and development of its 100%-owned, flagship Molo Project, one of the largest known crystalline flake graphite deposits in the world.

The Molo deposit is situated 145 km southeast of the city of Toliara, in the Tulear region of south-western Madagascar. The deposit occurs in a sparsely populated, dry savannah grassland region, which has easy access via a network of seasonal secondary roads radiating outward from the village of Fotadrevo. Fotadrevo in turn has an all-weather airstrip and access to a road system that leads to the regional capital (and port city) of Toliara. Dry semi-desert climate subject to seasonal cyclonic rainfall characterizes the region, which effectively limits exploration drilling to the dry season.

Geologically Molo is situated in the Bekikiy block (Tolagnaro-Ampanihy high grade metamorphic province) of southern Madagascar. The Molo deposit is underlain predominantly by moderately to highly metamorphosed and sheared graphitic (biotite, chlorite and garnet-rich) quartzo-feldspathic schists and gneisses, which are variably mineralised. Near surface rocks are oxidised, and saprolitic to a depth, usually of less than 5 m.

Molo is one of several surficial graphite trends discovered by Energizer in late 2011 and announced in early January 2012. The deposit was originally drill tested in 2012, with an initial seven holes being completed. Resource delineation drilling and trenching on Molo took place between May and November of 2012, and allowed for a maiden Indicated and Inferred Resource to be stated in early December of the same year. This maiden mineral resource estimate formed the basis for a Preliminary Economic Assessment, which was undertaken by DRA Mineral Projects in 2013. The positive outcome of this assessment lead Energizer to undertake another phase of exploratory drilling and sampling in 2014, which was done under the supervision of Caracle Creek International Consulting (Proprietary) Limited. This phase of exploration was aimed at improving the geological confidence of the deposit and its contained mineral resources, and included an additional 32 diamond drill holes (totalling 2,063 metres) and 9 trenches (totalling 1,876 metres). Caracle Creek were subsequently engaged to update the geological model and resource estimate. The entire database on which this new model and resource estimate is based contains 80 drill holes (totalling 11,660 metres) and 35 trenches (totalling 8,492 metres).

This Technical Report has been prepared by Caracle Creek International Consulting (Proprietary) Limited in order for Energizer to file a current NI 43-101 Technical Report on the System for Electronic Document Analysis and Retrieval in support of their August 14th 2014 disclosure of the updated resource on the Molo graphite deposit. The Technical Report serves to provide background information to this updated resource statement on Molo, and as documentation of the new trenching and diamond drilling undertaken by Energizer during 2014.

The current mineral resource estimate for Molo is summarised in Table 1-1 below. The mineral resources are classified in the Measured, Indicated and Inferred categories according to the Canadian Institute of Mining Definition Standards. Whilst the “High grade” resources occur within the “Low grade”

resources, they are estimated and reported separately. Resources within the "Low grade" domain are stated at a 2 % carbon cut-off, and resources within the "High grade" domains are stated at a 4 % carbon cut-off.

Table 1-1: Mineral Resource Statement for the Molo graphite deposit - September 2014.

Classification	Material Type	Tonnes - Mt	Grade - C%	Graphite - T
Measured	"Low Grade"	13 048 373	4.64	605 082
Measured	"High Grade"	10 573 137	8.40	887 835
Total Measured		***23 621 510***	***6.32***	***1 492 916***
Indicated	"Low Grade"	39 539 403	4.73	1 871 075
Indicated	"High Grade"	37 206 550	7.86	2 925 266
Total Indicated		***76 745 953***	***6.25***	***4 796 341***
Measured + Indicated	"Low Grade"	52 587 776	4.71	2 476 157
Measured + Indicated	"High Grade"	47 779 687	7.98	3 813 101
Total Measured + Indicated		***100 367 464***	***6.27***	***6 289 257***
Inferred	"Low Grade"	24 233 267	4.46	1 080 677
Inferred	"High Grade"	16 681 453	7.70	1 285 039
Total Inferred		***40 914 721***	***5.78***	***2 365 716***
Total Measure + Indicated + Inferred	"Low Grade"	76 821 044	4.63	3 556 834
Total Measure + Indicated + Inferred	"High Grade"	64 461 141	7.91	5 098 140
Grand - Total		***141 282 184***	***6.13***	***8 654 974***

Mt = million tonnes; C% = carbon percentage; Graphite – T = Tonnes of graphite.

Notes:
1-Mineral Resources are classified according to the Canadian Institute of Mining definitions.
2-"Low Grade" Resources are stated at a cut-off grade of 2 % C.
3-"High grade" Resources are stated at a cut-off grade of 4 % C.
4-Eastern and Western high grade assays are capped at 15 % C.
5-A relative density of 2.36 tonnes per cubic metre (t/m^3) was assigned to the mineralised zones for the resource tonnage estimation.

The total Measured and Indicated Resource is estimated at 100.37 million tonnes, grading at 6.27 % carbon. Additionally, an Inferred Resource of 40.91 million tonnes, grading at 5.78 % carbon is stated. When compared to the November 2012 resource statement (Hancox and Subramani, 2013), this shows a 13.7 % increase in tonnage, a 3.4 % decrease in grade and a 9.8 % increase in graphite content. The

reason for the increase in tonnage is due to the 2014 drilling on the previously untested north eastern limb of the deposit, which added additional new resources. Additionally 23.62 million tonnes, grading at 6.32 % carbon, have been upgraded by infill drilling from the Indicated to Measured Resource category.

Energizer believes the Molo graphite project's success will be predicated on rapidly developing a stand-alone graphite mine and flotation plant, as this would enable the Company to quickly establish itself as a graphite producer and supplier. In order to achieve this, Energizer has partnered with DRA Mineral Projects, a world leader in process engineering and metallurgy, who are currently compiling a Feasibility Study of the Molo deposit based on the new geological model and resource estimations presented in this Technical Report.

Various metallurgical and mineralogical test-work has also been undertaken since the maiden resource statement. This has been done by Mintek (South Africa) and the North Carolina State University minerals research laboratory. The aim of these studies was to determine a suitable process route and operating conditions to achieve >95% recovery and 95% grade of carbon from the feed material. As part of the Feasibility Study Energizer recently completed a pilot plant operation, generating twelve tonnes of finished graphite concentrate for the purposes of evaluation by potential strategic partners.

The outcomes of the Feasibility Study will determine whether further resource expansion drilling is necessary. Once completed, further infill drilling may be required to upgrade any Inferred Resources that lie inside the pit shell area.

The effective date of this report is the 25th of September 2014.

2 INTRODUCTION

2.1 Company and Project Name

This Technical Report (the "Report") has been prepared for Energizer Resources Incorporated (http://www.energizerresources.com/) ("Energizer" or "the Company"), a mineral exploration and development company based in Toronto, Canada. Prior to a Special and Annual Shareholders' meeting of the Company held on December 9, 2009, the Company was called Uranium Star Corporation ("Uranium Star"). Under the new title of Energizer, the Company commenced trading on the Toronto Stock Exchange ("TSX") Venture Exchange on May 5, 2010, under the trading symbol EGZ. Energizer is currently focused on the exploration and development of its Molo graphite deposit ("Molo" or "the Project") in south-western Madagascar.

Molo is one of several surficial graphite trends discovered by Energizer in late 2011 and announced in early January 2012. The deposit was originally drill tested in 2012, with an initial seven holes being completed. Resource delineation drilling and trenching on Molo took place between May and November of 2012, and allowed for a maiden Indicated and Inferred Resource to be stated in early December of the same year (Hancox and Subramani, 2013). This maiden mineral resource estimate formed the basis for a Preliminary Economic Assessment ("PEA", which was undertaken by DRA Mineral Projects ("DRA") in 2013. The positive outcomes of this PEA lead Energizer to undertake an additional phase of exploratory drilling and sampling in 2014. This phase of exploration was aimed at improving the geological confidence of the deposit and its contained mineral resources and was done under the supervision of Caracle Creek International Consulting (Proprietary) Limited ("CCIC"; http://caraclecreek.com/). This new work was of a material nature and necessitated an update of the previous geological model and resource estimate, which was also undertaken by CCIC.

2.2 Terms of Reference and Purpose of the Technical Report

This independent resource estimate and updated Technical Report has been prepared in order for Energizer to file a current NI 43-101 Technical Report on the System for Electronic Document Analysis and Retrieval ("SEDAR") in support of their August 14th 2014 disclosure of the updated mineral resource for the Molo graphite deposit (http://www.energizerresources.com/2014/364-energizer-resources-upgrades-molo-graphite-resource-to-measured-status-and-increases-overall-size-of-resource).

CCIC is a privately owned professional geological consulting company that provides a wide range of geological services to the exploration and mining industries. The company has considerable experience in sub-Saharan Africa and Madagascar, having undertaken numerous exploration projects in several countries, for various clients.

Dr Philip John Hancox (General Manager Africa for CCIC) is designated as the Qualified Person regarding the exploration as outlined in this report and is responsible for part of Item 1, Items 2 to 13 and sections 23 to 27. Dr Hancox is a member in good standing of the South African Council for Natural Scientific Professions (SACNASP No. 400224/04) as well as a Member and Fellow of the Geological Society of South Africa ("GSSA") and the Society of Economic Geologists. He is also a lifetime Member of the

Geostatistical Association of South Africa ("GASA"), a Council Member of the Fossil Fuel Foundation and a Core Member of the Prospectors and Developers Association of Canada ("PDAC"). He has 16 years post-doctoral experience in the sub-Saharan African Minerals industries, holds a Ph.D. from the University of the Witwatersrand (South Africa), and has authored over 65 peer reviewed scientific papers on various aspects of economic and sedimentary geology and basin analysis, as well as numerous in-house reports and documents for the Toronto, Australian, London and Johannesburg stock exchanges.

Dr Hancox has been involved in a number of exploration drilling projects, including graphite, stratiform copper-cobalt, gold (conglomerate and vein hosted), Mississippi-Valley Type lead-zinc, iron ore, chromite, platinum, diamonds, rare earth elements, uranium and coal. Aspects covered included drill hole planning, drill rig management, stratigraphic sequence determination, core logging and sampling, and quality assurance/quality control ("QA/QC"). He also has extensive experience in site investigations for various commodities, including projects in countries such as Angola, Botswana, Burundi, the Democratic Republic of the Congo, Ethiopia, Gabon, Ghana, Liberia, Madagascar, Malawi, Mauretania, Mozambique, Namibia, Nigeria, Republic of Congo, Tanzania, Uganda, Zambia and Zimbabwe.

Mr Sivanesan (Desmond) Subramani is designated as the Qualified Person regarding the mineral resource estimation and is responsible for parts of Item 1 and Item 14. Mr Subramani is a member in good standing of the South African Council for Natural Scientific Professions (SACNASP No. 400184/06) as well as a Member of the GSSA and GASA. He has 19 years industry experience, on various commodities, in both operational and consulting environments, having worked for both major mining houses as well as junior explorers. African experience has been focussed on Botswana, the DRC, Ghana, Guinea, Namibia, Madagascar and Zambia. International experience includes assignments in Australia, Canada, China and Saudi Arabia, where he spent two years working on gold deposits. He is a super-user of Leapfrog™ ("Leapfrog"; http://www.leapfrog3d.com/) and Datamine™ Studio 3 ("Datamine"; http://www.dataminesoftware.com), with his core strengths being advanced geological modelling, geostatistical resource estimation and risk assessment.

2.3 Independence

For the preparation of this Technical Report CCIC has no pecuniary or other interests that could reasonably be regarded as capable of affecting its ability to provide an unbiased opinion in relation to Energizer's Molo project or the resources as discussed in this Report. CCIC will receive a fee for the preparation of this Report in accordance with normal professional consulting practice. This fee is not contingent on the outcome of any transaction, or the conclusions or opinions expressed in this Report, and CCIC will not receive any other benefit. As of the date of this Report, neither CCIC, nor any of its directors has (and has not had within the previous five years) any shareholding in Energizer, or the assets or project reported on herein, and consequently CCIC considers itself to be independent of Energizer.

2.4 Sources of Information

Much of the background information in this Technical Report has been sourced and updated from four previous Technical Reports, all of which have been filed on SEDAR.

The oldest report, titled "Geological Evaluation of the Three Horses Property Fotadrevo, Province of Toliara, Madagascar" (Scherba and Chisholm, 2008) was commissioned by Energizer under its former name of Uranium Star. The second report, dated November 27, 2009, is titled "Technical Report Update NI 43-101, Fotadrevo, Province of Toliara, Madagascar" and was authored by T. McCracken and A. Holloway of PEG Mining Consultants (McCracken and Holloway, 2009). The third report dated January the 14th 2011, and titled "Technical Report Update NI 43-101, Green Giant Project Fotadrevo, Province of Toliara, Madagascar" was authored by P. Desautels, T. McCracken and A Holloway of AGP Mining Consultants (Desautels *et al*., 2011). The most up to date report is dated the 15th of January 2013 and is titled "Technical Report NI 43-101 - Molo Graphite Project, Fotadrevo, Province of Toliara, Madagascar" and is compiled by the same authors as this current work (Hancox and Subramani, 2013).

Various other reports were also supplied by Energizer including those to do with metallurgical test work. All documents used in the preparation of this Technical Report are listed under Item 27 (References). All Illustrations are embedded within the body of the Report.

2.5 Personal Inspections of the Property

The personal inspection of the Property was originally conducted by Dr. Philip John Hancox between the 8th and 11th of May 2012. During this visit the graphite occurrences at Molo, Seta and Fotsy were investigated and various trenches on Molo were inspected. A second site visit was undertaken between the 19th and 21st of May 2013, during the bulk sampling exercise. During this visit a number of collar beacons from the 2012 drilling campaign were inspected, as well as the trenching, logging and sampling methodologies.

Desmond Subramani visited the Molo site between the 15th and 19th of February 2014, during the 2014 drilling campaign. The main aim of this visit was to plan the layout of the additional drilling and trenching required for the resource upgrade. This visit also covered the inspection of various borehole collars and open trenches, as well as a review of the drilling, logging and sampling procedures.

Whilst not an author of this Technical Report, Dr. Eva Schneiderhan of CCIC also visited the site during the bulk sampling exercise in May 2013, and most recently between the 10th and 14th of March, 2014. During this latter visit Dr. Schneiderhan undertook various rig checks, as well as a review of the logging and sampling standards and QA/QC procedures.

Personal insights and photographs of the site visits are included in the Technical Report under several of the Items.

2.6 Units of Measure

Unless specified, all measurements in this Technical Report use the metric system. Common measurements are in metric units. Ages of various rock units are given in millions of years before present ("Ma") or billions of years before present ("Ga").

Universal Transverse Mercator ("UTM") co-ordinates are used within this report, and are reported in UTM zone 38S, WGS 84 datum.

3 RELIANCE ON OTHER EXPERTS

This Technical Report has been prepared for Energizer and the information, conclusions, opinions, and estimates contained herein are based on:

- Information available at the time of preparation of this Report (effective date being the 25th of September, 2014);
- Assumptions, conditions, and qualifications as set forth in this Report, and
- Data, reports, and other information as supplied by Energizer and other third party sources.

For the purpose of this Report, the authors have relied on ownership information provided by Energizer. In consideration of all legal aspects relating to the Project, CCIC places reliance on Energizer that the information relating to the legal aspects, and the status of surface and mineral rights, are accurate.

Property information in this Report is sourced from previous works supplied by Energizer and the authors are not responsible for the accuracy of any property data, and do not make any claim, or state any opinion, as to the validity of the property disposition described herein.

For the preparation of this report, the authors relied on maps, documents, and electronic files generated by the current and past exploration crews, contributing consultants, and the technical team of Energizer. To the extent possible under the mandate of a NI 43-101 compliant report, the data have been verified with regard to the material facts.

Except for the purposes legislated under provincial securities laws any use of this Report by any third party is at that party's sole risk.

4 PROPERTY DESCRIPTION AND LOCATION

4.1 Madagascar Overview

The Republic of Madagascar ("Madagascar") is not a traditional or particularly well-known exploration and mining destination, and is mostly under-explored, with the country subject to only very little modern era systematic exploration. The country is however fast emerging as a major exploration target and new mining jurisdiction, and for this reason some relevant country specific facts are included below.

4.1.1 Country Overview

Madagascar is the largest island in the Indian Ocean (Figure 4-1) and the 4th largest island in the world (after Greenland, New Guinea and Borneo). It is located to the southeast of the African continent, from which it is separated by the Mozambique Channel. The country extends over 1,570 km from north to south, and is over 575 km wide, with a surface area of 587,040 km^2 and a 5,000 km long coastline.



Figure 4-1: Map of Madagascar showing the major towns. Source: http://goafrica.about.com/library/bl.mapfacts.madagascar.htm

The capital of Madagascar is Antananarivo, a city of approximately 1,500,000 people. It is located in the central eastern area of the island approximately 150 kilometres inland from the central-east coast, at an elevation of just over 1,200 metres above mean sea level ("m amsl").

Madagascar is officially bilingual, with French being the language of government and business. Malagasy (Malgache), a language of Malayo-Polynesian origin, is the official national language. English is taught in schools but is not widely spoken outside of business and government circles.

Madagascar is one of the world's hotspots of endemism and is recognised as one of the planets 17 recognized mega-biodiversity countries (Razafindralambo and Gaylord, 2005). Over 80 % of the country's plant and animal species are unique to the island. Vegetation is varied and ranges from dense tropical rain forest in the east, savannah in the central plateau and western coastal plain and spiny dry forests in the southern areas.

4.1.2 Environmental Policy

Due to the endemic nature of much of its flora and fauna, the international donor community, led by the World Bank and USAID, has recognized Madagascar as one of the most unique places in the world. As most of Madagascar's population are agrarian, many of the ecosystems on the island have been adversely altered through unsustainable subsistence agricultural practices. In an attempt to reconcile the need for both economic development and the establishment of sustainable environmental policies and institutions, the Malagasy government created the Malagasy Office of the Environment in the late 1980s, and signed the National Environmental Action Plan ("NEAP"), the most ambitious and comprehensive environmental programme in Africa.

According to Razafindralambo and Gaylord (2005), the NEAP was launched operationally in 1991 with the following objectives:

- To manage the national heritage of biodiversity in protected areas, in conjunction with sustainable development of surrounding areas;
- Improve human living conditions through protection and better management of natural resources, emphasizing watershed protection, reforestation, agro-forestry, and improved water supply and sanitation;
- Promote environmental education, training, and communication;
- Improve policy and management ; and
- To establish mechanisms for research, managing data, and monitoring the environment.

4.1.3 Government Policy and Outlook Regarding the Mining Industry

The government of Madagascar embarked on an economic revival plan in 2000. At this time the Ministry of Energy and Mines had already initiated reform through the *Projet de Reforme du Secteur Minier* ("PRSM") program ,with the introduction of the new Mining Code in 1999, and the establishment of the Mining Titles (Cadastral) Registry (*Bureau du Cadastre Minier de Madagascar*, or BCMM) in 2000.

These initiatives have attracted new investors to Madagascar, including both junior and senior mining companies.

During 2003, in furtherance of its economic policy, the Ministry commenced the five-year *Projet de Gouvernances des Ressources Minérales* program, with the following objectives:

- To further improve and enforce the legal and statutory framework, particularly with respect to mining;
- To promote investment in the minerals sector through the dedicated *Agence de Promotion du Secteur Minier*;
- Improvement of the geoscientific knowledge of Madagascar through geophysical surveys, geological mapping, and remote sensing, with appropriate staff training to support mapping projects;
- Addressing environmental health and safety issues and to contribute to poverty reduction.

Energizer has further established a Special Advisory Committee ("SAC") to manage its Malagasy Government affairs in regard to the Green Giant Project. The Committee is chaired by Brian Tobin, P.C., ICD.D, of Fraser Milner Casgrain LLP, who renders political and financial advice to the Company. Contributing to the SAC is Mr. Peter Harder, a former senior bureaucrat in the Department of Foreign Affairs and International Trade Canada. The Committee assists the Company to liaise with the Madagascar government, and also provides direction and assistance in the search for strategic partners and project funding.

Since the date of the filing of the last Technical Report (Hancox and Subramani, 2013) presidential and parliamentary elections were held in Madagascar. Hery Rajaonarimampianina emerged as the new President of the country and whilst this meant a change in government it Energizers' projects in Madagascar have not however been adversely affected by the change in political situation.

4.2 Property Location

The Green Giant Project and the Malagasy JV properties ("Green Giant-JV Project or Property"), including the Molo deposit, are located some 145 km southeast of southeastern Madagascar's administrative capital (and port city) of Toliara, in the Tulear region (Figure 4-2).



Figure 4-2: Green Giant Property location in south-western Madagascar.

The original Green Giant Property includes 36 claims, which encompass an area totalling 225 km^2. The additional JV property includes 2,119 claims and an area totalling 832km^2, nearly three and a half times the size of the original property (Figure 4-3). The Project is centered on UTM coordinates 510,000 E 7,350,000 N (UTM WGS 84). The Government of Madagascar designates individual claims by a central LaBorde UTM location point, comprising a square with an area of 6.25 km^2.

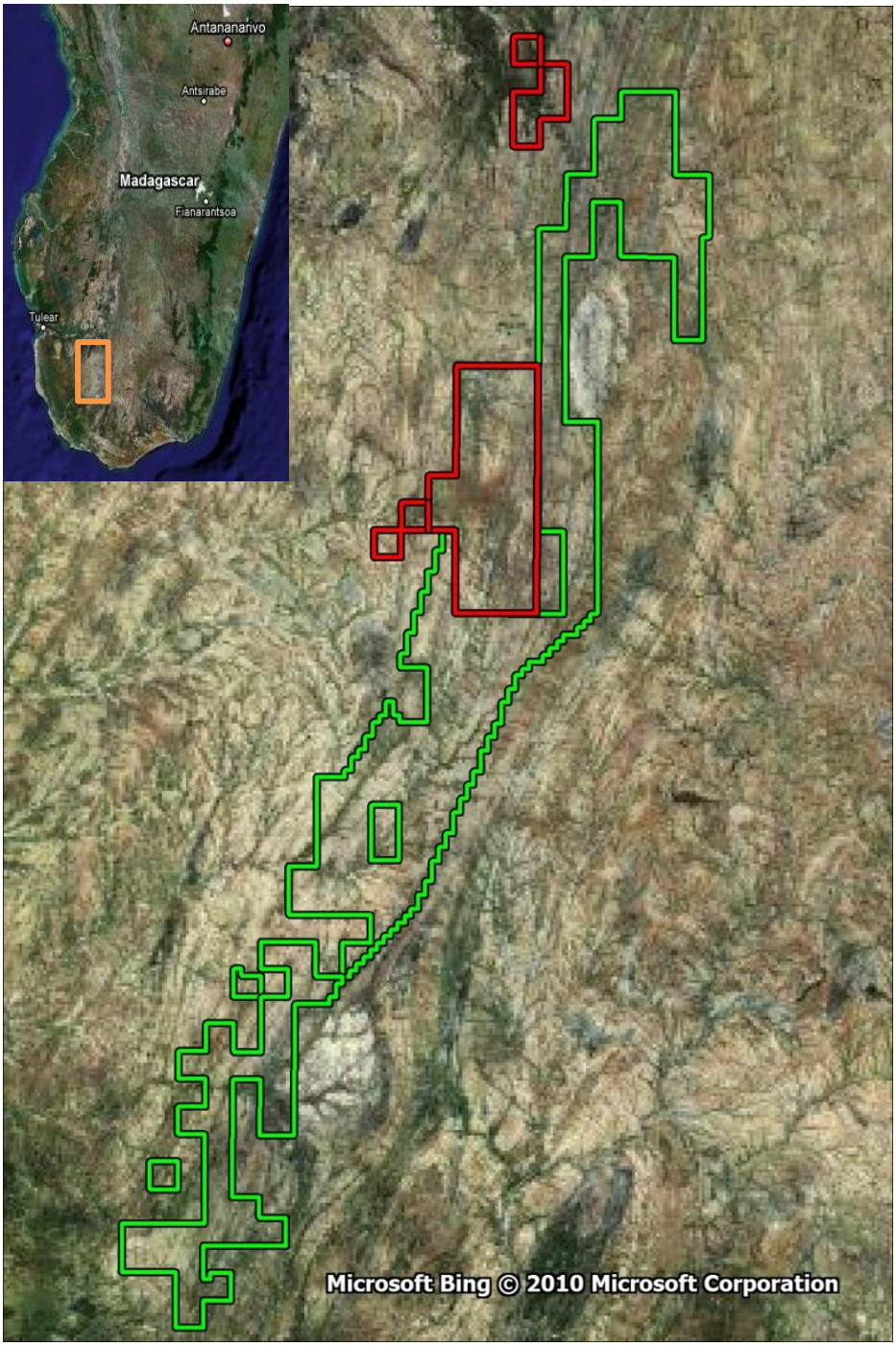


Figure 4-3: Map showing the various claims that make up the total Green Giant Property. Those covering the original Green Giant Property are indicated in red (225 km^2), with those covering the Joint Venture Property in green (832 km^2).

The Molo deposit (Figure 4-4) is located 11.5 km east-northeast of the town of Fotadrevo and covers an area of 62.5 hectares ("ha"). It is centred on 413390 (Easting) and 7345713 (Northing) in UTM 38S, WGS84 datum.

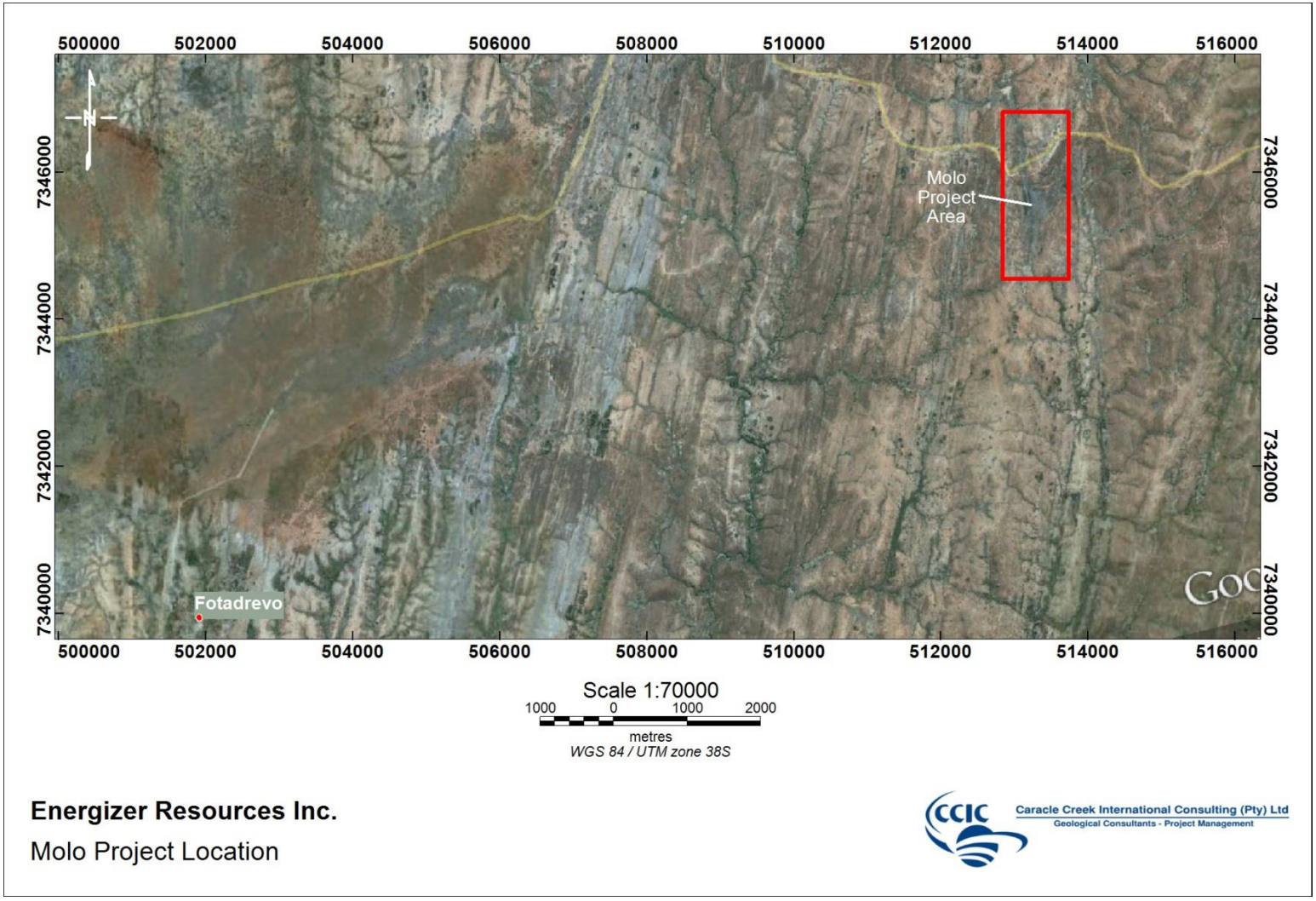


Figure 4-4: Google Earth image showing the position of the Molo Project Area in relation to the town of Fotadrevo.

4.3 Property Title and Land Tenure

The Green Giant Project claims were previously held in the name of Madagascar Minerals and Resources ("MMR"), controlled by Director Cyriaque Mamy Cheung of Antananarivo. A joint venture ("JV") agreement was entered with MMR in 2007, which resulted in Uranium Star Minerals SARL ("URM") owning a 75% interest in the Green Giant Property.

URM and MMR completed a purchase and sale agreement on July 9, 2009, which gave URM the exclusive right to purchase the remaining 25% of the Green Giant project from MMR for the sum of US$100,000. In conjunction with the transaction, URST agreed to grant MMR a 2% Net Smelter Return ("NSR") Royalty with URST having a "buyback" option, but not an obligation, to purchase the first 1% of the NSR for U$ 500,000. Upon exercising its option to purchase the first 1%, URST then has a further "buyback" option, but not an obligation, to purchase the second 1% of the NSR for US$1,000,000. Payments for the purchase of the NSR are payable in cash or common shares at URST's sole discretion.

By way of an Annual Shareholer Meeting on the 9th of December 2009, URM shareholders approved a change of its name to Energizer Resources Minerals SARL ("ERM"). Mining rights to the Property are shown in Table 4-1, Figure 4-3 and Table 4-2. The change of name to Energizer Resources Inc. was officially recognized by the Registrar of Commerce and of Companies in Antananarivo Madagascar on May the 12th 2010.

Table 4-1: Claims Status

		LaBorde Projection		WGS 84, Zone 38 South		Date Granted	Expiration date
Permit	Square #	X	Y	UTMX	UTMY	dd/mm/yyyy	dd/mm/yyyy
Green Giant Property							
PR12306	21275	253750	231250	500104.92	7341934.36	09/11/2004	**09/11/2014**
PR12306	21275	253750	233750	500127.07	7344434.45	09/11/2004	**09/11/2014**
PR12306	21275	256250	223750	502538.59	7334411.96	09/11/2004	**09/11/2014**
PR12306	21275	256250	226250	502560.72	7336912.05	09/11/2004	**09/11/2014**
PR12306	21275	256250	228750	502582.86	7339412.12	09/11/2004	**09/11/2014**
PR12306	21275	256250	231250	502605	7341912.21	09/11/2004	**09/11/2014**
PR12306	21275	256250	233750	502627.16	7344412.3	09/11/2004	**09/11/2014**
PR12306	21275	256250	236250	502649.32	7346912.39	09/11/2004	**09/11/2014**
PR12306	21275	256250	238750	502671.49	7349412.48	09/11/2004	**09/11/2014**
PR12306	21275	256250	241250	502693.66	7351912.57	09/11/2004	**09/11/2014**
PR12306	21275	256250	243750	502715.83	7354412.66	09/11/2004	**09/11/2014**
PR12306	21275	258750	223750	505038.66	7334389.84	09/11/2004	**09/11/2014**
PR12306	21275	258750	226250	505060.8	7336889.92	09/11/2004	**09/11/2014**
PR12306	21275	258750	228750	505082.94	7339389.99	09/11/2004	**09/11/2014**
PR12306	21275	258750	231250	505105.08	7341890.06	09/11/2004	**09/11/2014**
PR12306	21275	258750	233750	505127.24	7344390.14	09/11/2004	**09/11/2014**
PR12306	21275	258750	236250	505149.41	7346890.22	09/11/2004	**09/11/2014**
PR12306	21275	258750	238750	505171.57	7349390.31	09/11/2004	**09/11/2014**
PR12306	21275	258750	241250	505193.75	7351890.4	09/11/2004	**09/11/2014**
PR12306	21275	258750	243750	505215.93	7354390.48	09/11/2004	**09/11/2014**
PR12306	21275	261250	231250	507605.16	7341867.91	09/11/2004	**09/11/2014**
PR12306	21275	261250	233750	507627.32	7344367.99	09/11/2004	**09/11/2014**

PR12306	21275	261250	236250	507649.49	7346868.06	09/11/2004	**09/11/2014**
PR12306	21275	261250	238750	507671.65	7349368.14	09/11/2004	**09/11/2014**
PR12306	21275	261250	241250	507693.83	7351868.22	09/11/2004	**09/11/2014**
PR12306	21275	261250	243750	507716.02	7354368.29	09/11/2004	**09/11/2014**
PR12888	129	251250	231250	497604.82	7341956.51	26/01/2005	**26/01/2015**
PR12887	128	248750	228750	495082.58	7339478.55	26/01/2005	**26/01/2015**
PR12814	126	261250	223750	507538.73	7334367.7	26/01/2005	**26/01/2015**
PR12814	126	261250	226250	507560.86	7336867.77	26/01/2005	**26/01/2015**
PR12814	126	261250	228750	507583.01	7339367.83	26/01/2005	**26/01/2015**
Ianapera Property							
PR13020	132	261250	273750	507982.65	7384369.46	26/01/2005	**26/01/2015**
PR13021	133	261250	266250	507915.92	7376869.15	26/01/2005	**26/01/2015**
PR13021	133	261250	268750	507938.16	7379369.25	26/01/2005	**26/01/2015**
PR13021	133	263750	268750	510438.27	7379347.01	26/01/2005	**26/01/2015**
PR13021	**133**	**263750**	**271250**	**510460.5**	**7381847.12**	**26/01/2005**	**26/01/2015**

The Molo deposit is located within the greater Green Giant-JV Project area, and falls entirely under Permit #3432, relating to a total of 1648 squares. CCIC has had sight of a copy of the Contrat d'amodiation pertaining to this right and are satisfied that the rights to explore this permit have been ceded to ERG (Madagascar).

Under the terms of the JV agreement signed in 2011, Energizer Resources Inc. has the exclusive right to explore for a defined group of industrial minerals within specifically defined permits on the newly expanded land position. These industrial minerals include the following: Vanadium, Lithium, Aggregates, Alunite, Barite, Bentonite, Vermiculite, Carbonatites, Corundum, Dimensional stone (excluding labradorite), Feldspar (excluding labradorite), Fluorspar, Granite, Graphite, Gypsum, Kaolin, Kyanite, Limestone / Dolomite, Marble, Mica, Olivine, Perlite, Phosphate, Potash –Potassium minerals, Pumice Quartz, Staurolite, Zeolites. Table 4-2 below shows the Property according to the mining permits.

Table 4-2: Mining Permits

Permit Number	Number of Squares	Square Kilometres
PR 12306	416	162.5
PR 12888	16	6.25
PR 12887	16	6.25
PR 12814	48	18.75
PR 13020	16	6.25
PR 13021	64	25
Total	**576**	**225**

The claims were acquired by MMR under the rules of the *Code Minier 1999*. Some limited amendments have been instituted to the Code by *Decret 2005-021,* which the Bureau du Cadastre Minier de Madagascar, the administration body for mining permits, published in a handout dated 2006, available from their office in Antananarivo. The amendments relate to the reduction of the permit duration (from 10 years to 5) and *square* size (from 2.5 km x 2.5 km to 625 m x 625 m), and changes to the fees applied. Upon passage of the new decree, pre-existing old squares were converted to new squares, and pre-existing properties are now governed by the tenets of *Decret 2005-021*.

The updated Decret requires the payment of annual administration fees of Permits Research of ~15,000 Ariary (MGA). The conversion rate as on the 24th of September 2014 was 2 617 Ariary to one US dollar (http://www.xe.com/currencyconverter/). Annual fees are equivalent to roughly US$9 for research permits and US$28 for exploitation permits in years one and two. Annual fees increase by multiplying by a factor equivalent to the number of years (plus 1) that the company has held the permit. Research permits have an updated duration of five years, with the possibility of two renewals of an additional three years each. Payments of the administration fees are due on the 31st of March of each year, along with the submission of an activity report.

Reporting requirements of exploration activities carried out by the titleholder on a Research Permit are relatively light. A titleholder must maintain a diary of events and record the names and dates present of persons active on the project. In addition, a site plan with a scale between 1/100 and 1/10,000 showing "a map of the work completed" must be presented. Upon establishment of a resource, Research Permits are readily transferable into Exploitation Permits by application. CCIC is of the opinion that Energizer is compliant in terms of its commitments under these reporting requirements.

The properties (including Molo) have not been legally surveyed; however, since all claim boundaries conform to the predetermined rectilinear LaBorde Projection grid, these can be readily located on the ground by use of Global Positioning System ("GPS") instruments. Most current GPS units and software packages do not however offer LaBorde among their available options, and therefore defined shifts have to be employed to display LaBorde data in the WGS 84 system. For convenience, all Energizer positional data is collected in WGS 84, and if necessary converted back to LaBorde.

4.4 Energizer Resources' Environmental Policy

The NEAP does not have a formalized 'best practices' outline for mining companies to follow. As a consequence, Energizer engages Malagasy environmental consultants from Agence d'Exécution des Travaux d'Intérêt Public d'Antananarivo ("AGETIPA") to ensure compliance with the NEAP. Additionally, Energizer has adopted the Prospectors and Developers Association of Canada ("PDAC") *e3 Plus* exploration guideline (www.pdac.ca/e3plus/) to help it continuously improve its social, environmental, and health and safety performance, and to comprehensively integrate these three aspects into all of their exploration work. This has involved adopting the following principles for responsible exploration:

1. Adopt responsible governance and management
Objective: To base the operation of exploration on sound management systems, professional excellence, the application of good practices, constructive interaction with stakeholders, and the principles of sustainable development.

2. Apply ethical business practices
Objective: To have management procedures in place that promotes honesty, integrity transparency and accountability.

3. Respect human rights
Objective: To promote the principles of the United Nations Universal Declaration of Human Rights by incorporating them into policies and operational procedures for exploration.

4. Commit to project due diligence and risk assessment
Objective: To conduct an evaluation of risks, opportunities and challenges to exploration, and prepare strategies and operational plans to address them before going into the field.

5. Engage host communities and other affected and interested parties
Objective: To interact with communities, indigenous peoples, organizations, groups and individuals on the basis of respect, inclusion and meaningful participation.

6. Contribute to community development and social wellbeing
Objective: To have measures in place which support the social and economic advancement and capacity building of communities whose lives are affected by exploration, while respecting the communities' own vision of development.

7. Protect the environment
Objective: To conduct exploration activities in ways that create minimal disturbance to the environment and people.

8. Safeguard the health and safety of workers and the local population
Objective: To be proactive in implementing good practices for health and safety performance in all exploration activities and seek continual improvement.

Energizer has tried to integrate the *e3 Plus* principles into its exploration activities through:

- Employing an Antananarivo-based Country Manager who is responsible for continuously liaising with government officials and ensuring the Company complies with all environmental and mining policy;
- Having a 'no bribery' policy to prevent the promotion of corruption;
- Ensuring a safe and healthy work place, and protecting all employees, contractors and sub-contractors and affected communities from risks and hazards;
- Providing compensation, benefits and working conditions that comply with national laws, are consistent with international standards, and compatible with local social and economic circumstances;
- Obtaining permission from local land users before conducting any exploration activities;
- In the absence of Malagasy policy, conducting its exploration activities in accordance to Canadian 'best practices';
- Integrating sensitivity to local customs and beliefs in exploration activities through continuous consultation with the community;
- Mitigating environmental degradation;
- Safeguarding workers and the local population by:

- Enclosing all open excavations within a fence to mitigate the risk of people or livestock falling in;

- Providing workers employed on drilling equipment with Personal Protective Equipment and training them in their usage;

- Restricting all vehicles operated by Energizer Resources personnel or its agents to a maximum speed of 10 km/h (trucks) and 20 km/h (small vehicles) while driving in or around villages.

5 ACCESSIBILITY, CLIMATE, LOCAL RESOURCES, INFRASTRUCTURE, AND PHYSIOGRAPHY

5.1 Access

Access to Molo from Toliara, is initially via a 70 km paved road to the village of Andranovory (Figure 5-1). From Andranovory, secondary all-season roads continue to Betioky, a distance of 93 km. From Betioky the Property area can be reached via Ambatry to Fotadrevo, a distance of 105 km (268 km total), or from Betioky to Ejeda, then onwards to Fotadrevo, a distance of 161 km (324 km total). This alternate route from Ejeda to Fotadrevo is used by heavy transports and by all vehicles during portions of the rainy season, as the primary route quickly becomes impassable. At the height of the rainy season, both routes to Fotadrevo may be largely impassable. Molo may be reached from Fotadrevo by a fairly well maintained dirt track.

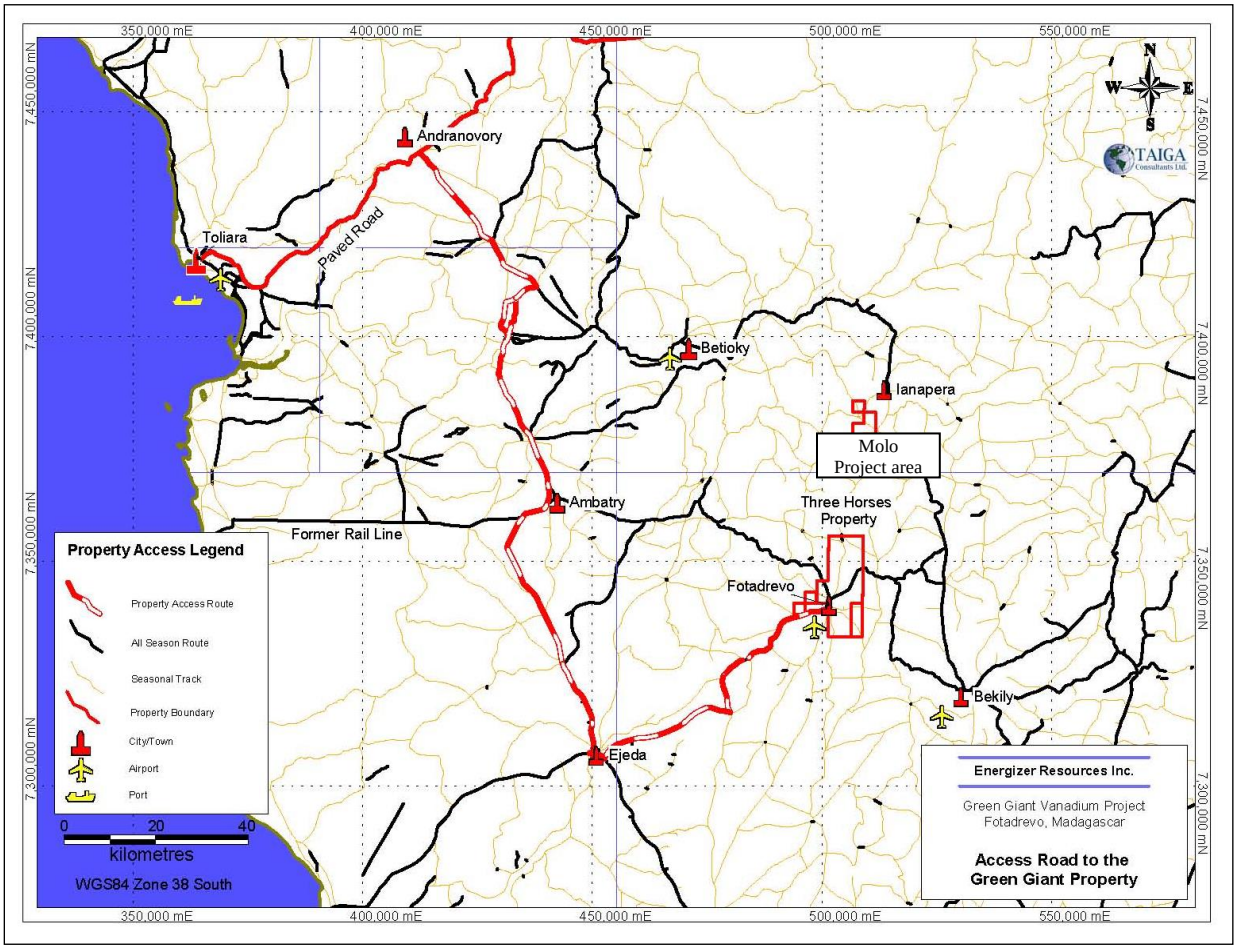


Figure 5-1: Road Access to the Green Giant Property and Molo area from the Town of Toliara.

With the upgrading of an existing airstrip at Fotadrevo (Figure 5-2) to an all-weather airstrip during the 2008 exploration programme, the Molo Project area is now accessible year-round (except under special circumstance caused by continuous or multiple days of heavy rain) by air, using private aircraft out of Antananarivo. Flying times to Fotadrevo are roughly 2.5 hours from Antananarivo and 45 min from Toliara.

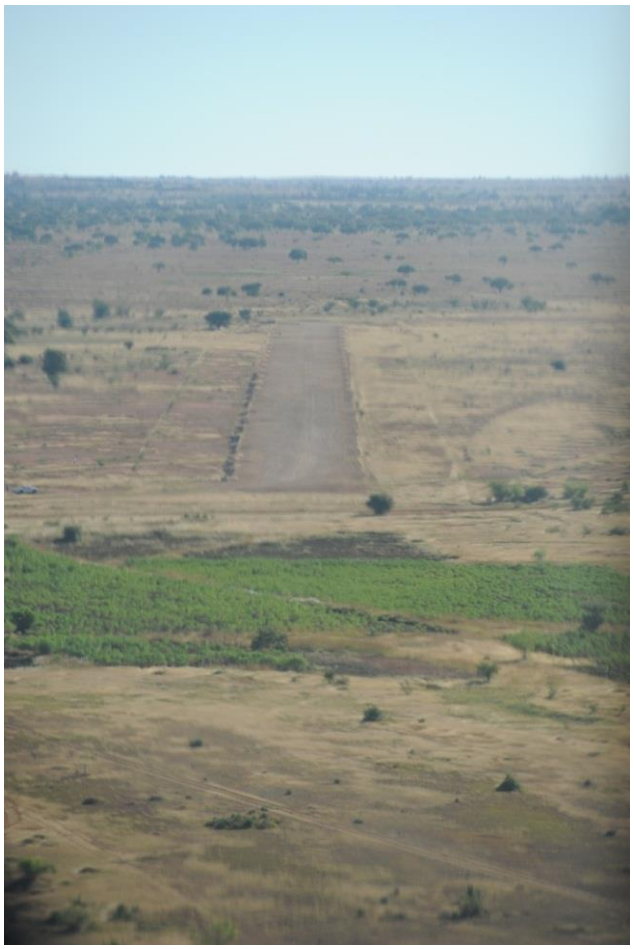


Figure 5-2: Airstrip at Fotadrevo.

Antananarivo is currently serviced by Air France (from Paris), South African Airways (from Johannesburg) and Air Mauritius (Sir Seewoosagur Ramgoolam International Airport in southeast Mauritius). Air Madagascar also provides services to Paris, Johannesburg, Mauritius, Nairobi, and Réunion from Ivato International Airport, which is located 16 km from Antananarivo, the capital of Madagascar. Air Madagascar also has regularly scheduled domestic jet and propjet flights throughout the country, including daily flights between Antananarivo and Toliara.

5.2 Physiography

The Molo deposit area is covered by sparse vegetation (Figure 5-3). Grass cover is widespread and trees are widely spaced overall, with accumulations near drainage lines and streambeds. In areas of lower

relief, alluvial cover is generally shallow and bedrock and/or float are readily observable. Elevations range between 536-565 metres above mean sea level ("m amsl").



Figure 5-3: View of the Molo Project area showing the nature of the vegetation.

Typical of the tropics, the surface is subject to lateritic weathering; however, full laterite profiles are rarely developed within the southern climatic zone. Previous drilling on the Green Giant Property indicated that the weathered profile is typically less than 10 m thick in the region, which is roughly one third of that seen in other parts of Madagascar and on the adjacent African continent.

5.3 Climate

Five climatic zones divide Madagascar. The Molo deposit area falls within the semi-desert south zone, with elevated temperatures year round peaking in the hot season at an average of over 30°C. The climate is dominated by southeastern trade winds originating in the Indian Ocean anticyclone, a centre of high atmospheric pressure that seasonally changes its position over the ocean. Madagascar has two seasons, a hot, rainy season from December to March/April, and a cooler dry season from April/May to November. Total rainfall is sparse within the Molo area, with yearly precipitation ranging from 30 cm to 50 cm. The rainy season causes difficulty in travelling off the main highways and for exploration, effectively limiting drilling to the dry season.

5.4 Local Resources and Infrastructure

The village of Fotadrevo (where Energizer has its base camp) is located to the west of the Molo deposit area (Figure 4-4). The village has been a labour source during the exploration programmes on Molo, and will most likely provide a portion of the workforce during any future development. A few basic goods are commercially available in the village, however, the main centre for support of exploration and development are the cities of Toliara and Antananarivo. Two 40 kVA diesel-powered generators provide power to the Energizer base camp.

A cellular telephone tower is located in Fotadrevo, which provides convenient coverage. No potable water is currently available within the project area. A 123 mm diameter well has been drilled to a depth of 42 m within the base camp compound, which provides non-potable water.

5.5 Security

As Madagascar is an island no border issues or conflicts are known that might affect operations, security, or title in the region. Security of personnel is a company policy directed by management. Considering that the area is predominantly rural, few police or other security patrols are common in the area. There is always a small possibility that local criminal activity might affect operations, and to mitigate this, the company employs the local military forces to accompany field parties away from secure areas. The Madagascar government provides a requested number of regular military troops, at a cost to Energizer, to ensure security on the Property, on the work site, and for the company's equipment.

6 HISTORY

The region around the Green Giant-JV Property has primarily been explored for base metal type occurrences, although colonial geologic services were alert to all kinds of mineral potential in the region. In 1985 the Bureau de Recherches Géologiques et Minières ("BRGM") (http://www.brgm.fr/) produced a three-volume country scale compilation of all exploration and mineral inventory data in their files. Relatively little exploration and development work has been completed in south-western Madagascar after that of BRGM, and therefore these volumes are key to retracing any historical data. Archival research by Energizer has not revealed evidence of mineral exploration in the past fifty years within the Molo Project area.

6.1 Property-Scale Exploration History

Prior to the exploration work completed by Energizer (then Uranium Star) in 2007 there is no record of any previous exploration activity within the Green Giant Project area and no historical resource estimates exist for the area or for Molo. Between 2007 and 2011 Energizer retained Taiga Consultants Limited ("Taiga") to manage exploration activities on the Green Giant Project. Table 6-1 shows a summary of the historical exploration activities previously on the Green Giant Property. Note that only exploration in 2011 is directly related to the exploration of the graphite prospects, and only Phase II of that year concerns the Molo graphite deposit.

Table 6-1: Historical Activities on the Green Giant Project-JV area.

Date	Activity	Company Responsible
2007	Stream sediment sampling (182 samples) Soil sampling (7.5 line km for 1,684 samples) Prospecting (226 grab samples) Property wide reconnaissance mapping (1:25,000 scale) Detailed geological mapping on selected targets (1:5,000 scale) Trenching (11 trenches for 525 m) Construction of camp Construction of gravel airstrip Repair road from camp to airstrip	Taiga
	Remote sensing interpretation	Earth Resource Surveys Inc. (ERSI)
	Airborne DIGHEM EM and magnetic survey (7,856 line km)	Fugro Airborne Systems
2008	Geological mapping entire project at 1:10,000 scale Prospecting (391 grab samples) Soil sampling (110 line km for 3,509 samples) Stream sediment sampling (311 samples) Scintillometer survey (18 km strike length)	Taiga
	Diamond drilling (33 holes for 4,073 m)	Cartwright Drilling

Date	Activity	Company Responsible
	Ground HLEM survey (152 m)	Spectral Geophysics
	Ground magnetics survey (419 km)	
2009	Soil XRF survey on lines 200 m apart covering 18 km of strike length	Taiga
	ground scintillometer surveys on lines 200 m apart covering 18 km of strike	
	Trenching programme (140 Trenches for 17,105 m)	
	Diamond drilling on Jaky Deposit (27 holes for 4,166 m)	Boart Longyear
	Diamond drilling for metallurgical samples on Jaky (3 holes for 344 m)	Boart Longyear
	Diamond drilling on Manga Deposit (24 holes for 4,422 m)	Boart Longyear
2010	Diamond drilling on Manga, Manga North, Manga South, and Mainty deposits (46 holes for 8,952 m)	Boart Longyear
	Prospecting (20 grab samples)	Taiga Consultants Ltd.
	Geologic mapping over Manga and Mainty Deposit at 1:5000 scale	
	ERT ground geophysical survey (5.64 km)	Taiga Consultants Ltd.
	MAG ground geophysical survey (169.53 km)	
	Gradient Array EM ground geophysical survey (128.82 km)	SOING
2011 (Phase I)	Prospecting (132 grab samples) over entire Green Giant property	Energizer Resources
	Diamond Drilling on Fondrana, Fotsy and Boko areas (10 holes for 1157m). Metallurgical samples taken from Fond-11-01 and Fotsy 11-05	Boart Longyear
	Trenching programme (20 trenches for 1912 m) over Fotsy and Fondrana areas	Energizer Resources
2011 (Phase II)	Prospecting (538 grab samples) over areas of historical graphitic occurrences (BRGM) on both Green Giant and JV Property	Energizer Resources
	Diamond Drilling on Fondrana, Fotsy, Molo and Jaky areas (19 holes for 1701 m). Metallurgical samples selected from Molo-11-07	Boart Longyear
	Trenching programme (2 trenches for 258m) over Fotsy and Molo areas	Energizer Resources
	Geologic mapping over Fotsy, Fondrana, Jaky and Molo areas at 1:1000 scale	Energizer Resources
	EM-31 ground geophysical survey (52.2 line kms)	Energizer Resources

Exploration work undertaken in 2011 led to the discovery of the Molo deposit, which then became the focus of the 2012-2014 exploration programmes addressed in the remainder of this Technical Report.

7 GEOLOGICAL SETTING AND MINERALISATION

7.1 Regional Geology

Madagascar comprises a fragment of the African Plate, which rifted from the vicinity of Tanzania at the time of the breakup of Gondwana, some 180 million years ago. At that time Madagascar remained joined with India, moving east-by-south until the Late Cretaceous (approximately 70 million years ago), whereupon the two land masses split apart. On a regional scale Madagascar can be described as being formed by two geological entities, a Precambrian crystalline basement, and a much younger Phanerozoic sedimentary cover (Figure 7-1) that hosts potentially economic coal deposits. The central and eastern two-thirds of the island are mainly composed of Neoproterozoic-aged, crystalline basement rocks, composed of a complex mélange of metamorphic schist and gneiss intruded by younger granitic and basic igneous rocks. The Phanerozoic sedimentary cover is largely restricted to the western side of the island and is Carboniferous to Permian-Triassic. These rocks correlate with the Karoo Supergroup successions of sub-Saharan Africa, which was widespread in the former supercontinent of Gondwana.

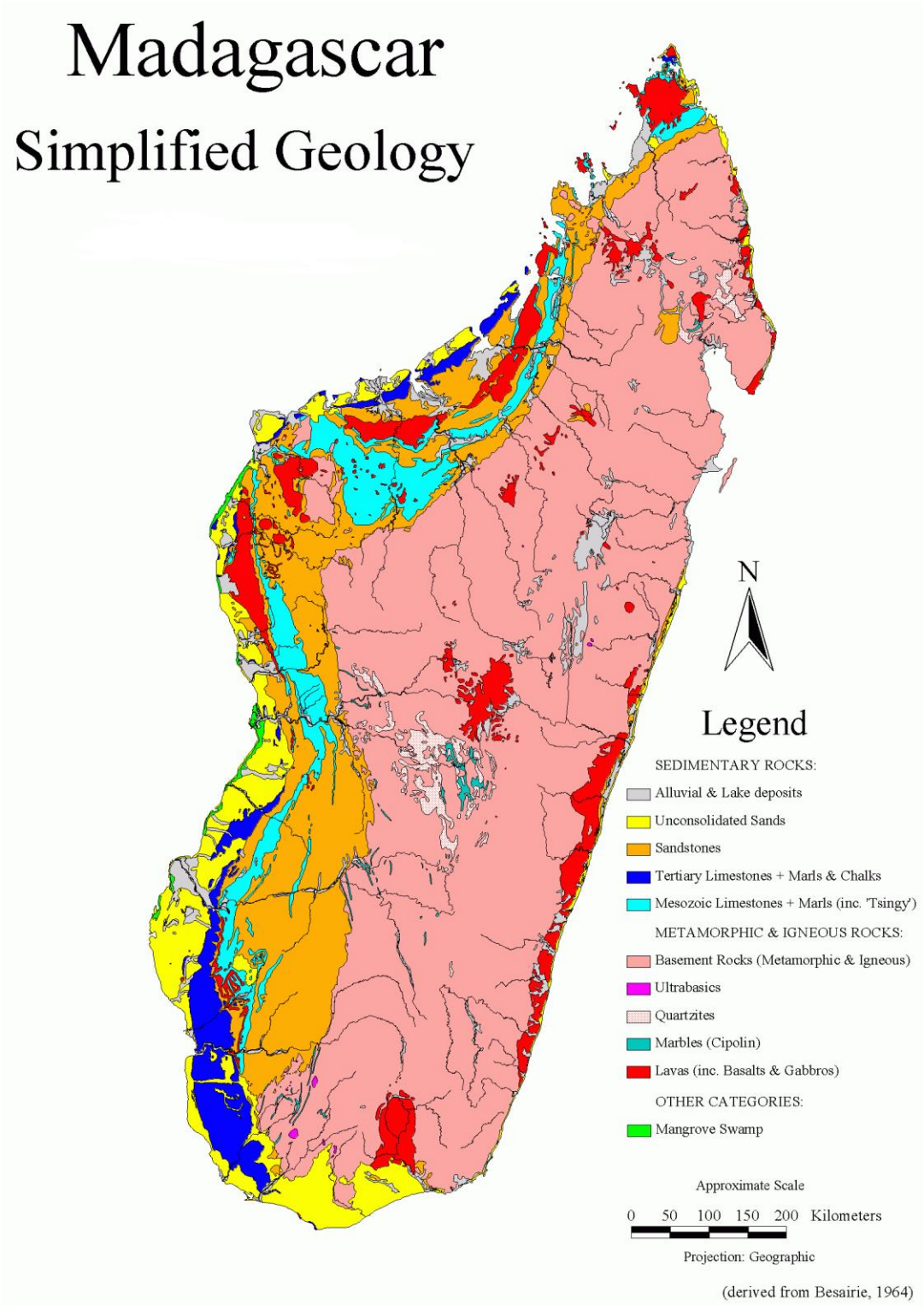


Figure 7-1: Geological map of Madagascar showing the distinctive crystalline basement and sedimentary basins in the west. Source: Besarie (1964).

The geology of the basement of Madagascar is composed of intercontinental tectonic blocks made up of ancient poly-deformed, high-grade metamorphic rocks and later igneous intrusions. The tectonic and metallogenic basement framework was originally subdivided into four blocks (Besarie, 1967), these being the: northern Bemarivo Block; northeastern Antongil Block; central Antananarivo Block; and the southern Bekily Block. The Molo deposit lies entirely within the bounds of the Bekily Block (Figure 7-2). Later authors (e.g. Pitfield *et al.*, 2006) divided the Precambrian basement of Madagascar in a somewhat different manner, with nine tectono-metamorphic units (Figure 7-3). In the case of the region around Molo, the tectonic blocks and the tectono-metamorphic units cover a nearly identical area, and as such these divisions can be used interchangeably.

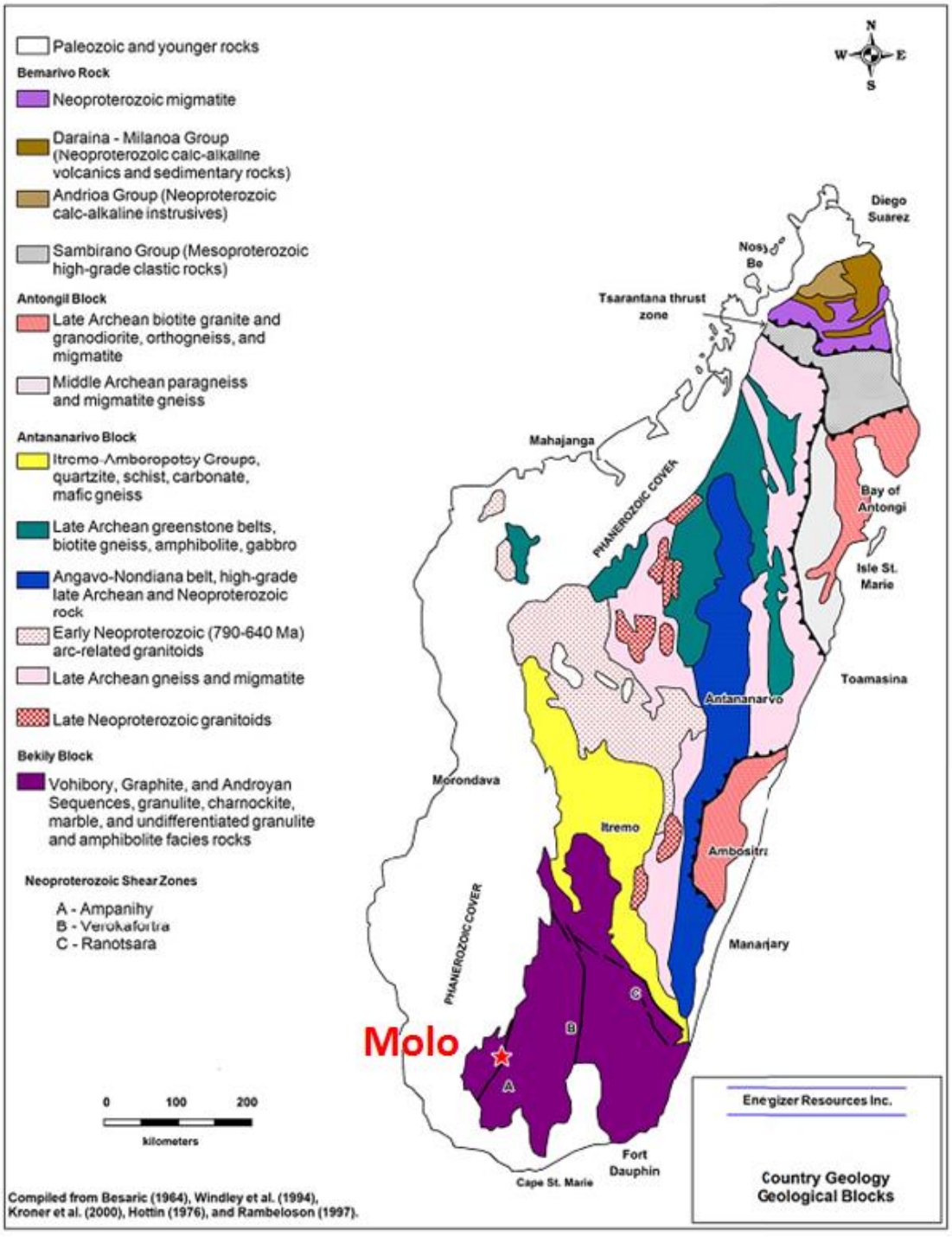


Figure 7-2: Country Geology – Geological Blocks. Source: AGP Mining Consultants (2011).

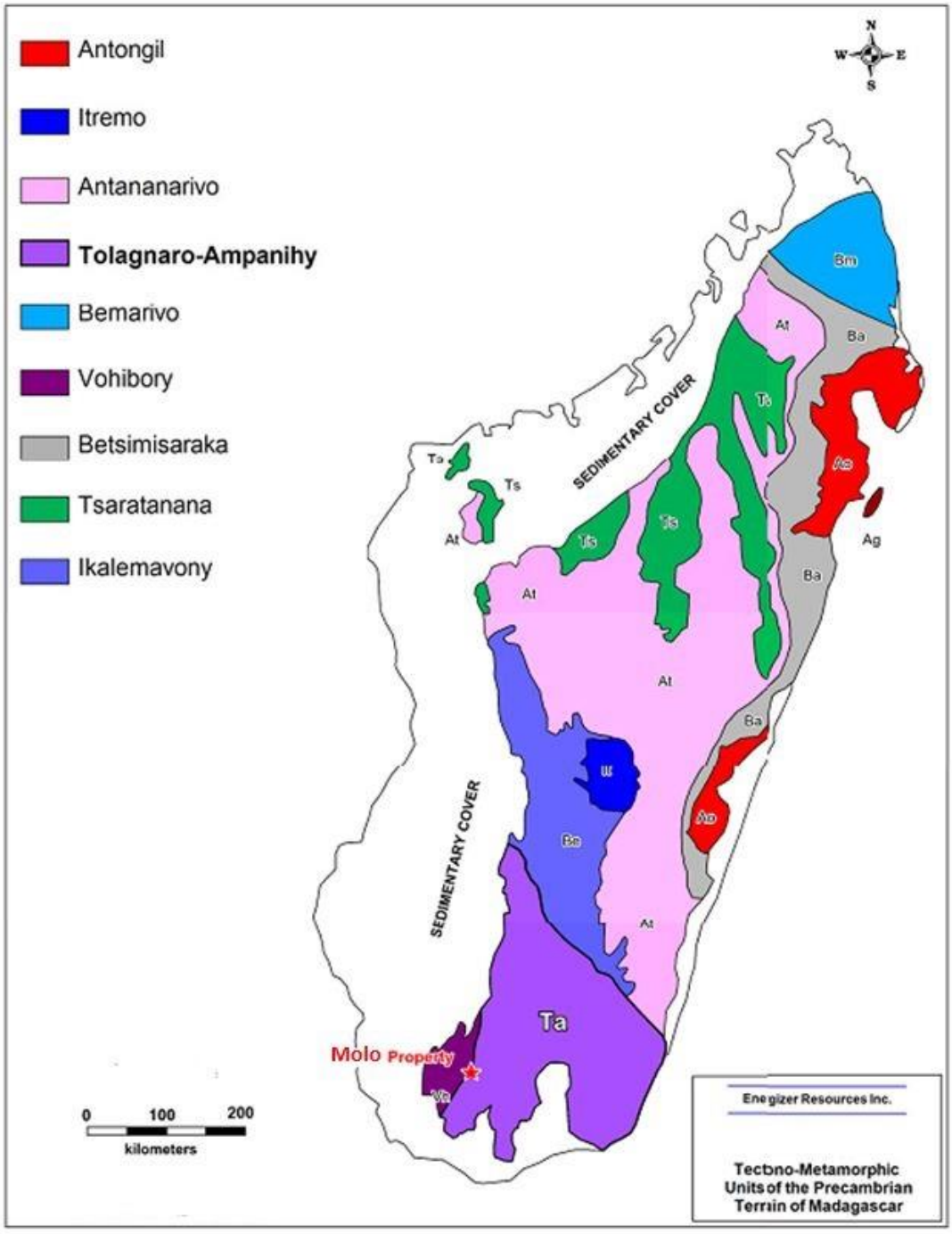


Figure 7-3: Tectono-metamorphic units of the Precambrian terrain of Madagascar. Source: AGP Mining Consultants (2011).

7.1.1 Tectonic history of Southern Madagascar

Southern Madagascar forms part of the Mozambique Mobile Belt and is made up of a section of Lower Proterozoic crust that underwent granulite-facies metamorphism during the Pan-African Orogeny (Paquette *et al*., 1994). Three crustal units, separated by north-south trending vertical shear zones make up this area (Figure 7-4). Each of these units experienced granulite facies metamorphism with temperatures between 750˚C and 800˚C. The associated pressures during the Pan-African Orogeny in this area range between 3-11 kilobars ("kbar") with a decreasing trend from west to east (Pili *et al*., 1997).

The Bekily block (also referred to as the Androyen region or the Tolagnaro-Ampanihy tectono-metamorphic unit), forms a vast high-grade meta-sedimentary (paragneiss) terrane that has been metamorphosed to granulite facies conditions. This region comprises a complex Neoproterozoic terrain of high-grade metamorphic rocks, with a history of polyphase deformation. Two prominent north-south trending late Neoproterozoic ductile shear zones, the Ampanihy and Vorokafotra Shear Zones, cross-cut the region. A third set of en-echelon shears forms part of the early Palaeozoic Ranotsara Shear Zone that cuts the basement in a northwest-southeast direction over a strike length of over 400 kms.

De Wit *et al*. (2001) recognize four episodes of deformation and metamorphism. The two early episodes of simple shear deformation (D_1 and D_1), during which northeast verging recumbent sheath folds and ductile thrusts were formed, are dated between 647-627 Ma. Early prolate mineral fabrics (L_1/L_2) are preserved in massif-type anorthosite bodies and their marginal country rocks.

D_1 and D_2 deformation was followed by a 10–15 Ma period of static, annealing metamorphism when bulk shortening (D_3) took place. D_2 and D_3 deformations are coaxial, but are separated in time by leucocratic dykes that intruded between 620-610 Ma. Between 609 and 607 Ma, D_3 deformation was focused zonally, forming the prominent north–south shear zones. Oblate strain resulted in a strong composite D_2/D_3 fabric defined by sub-vertical S-tectonites and sub-horizontal intersection lineations.

A variety of post-D_3 pegmatites accompanied the following 85 million years of relatively static annealing and metasomatic/metamorphic mineral growth. Numerous occurrences of phlogopite, uranium, and rare earth elements are associated with these pegmatitic bodies. A continuum of concordant monazite dates of between 605 and 520 Ma suggests that this thermal event is part of an extended period of low-pressure (3–5 k bar) charnockite-producing event.

The D_4 deformational event recorded within the Ranotsara Shear Zone overlaps with the youngest parts of the regional metamorphic conditions. Between 530-490 Ma, prevailing low-pressure, high-temperature amphibolite-granulite facies rapidly gave way to greenschist facies conditions.

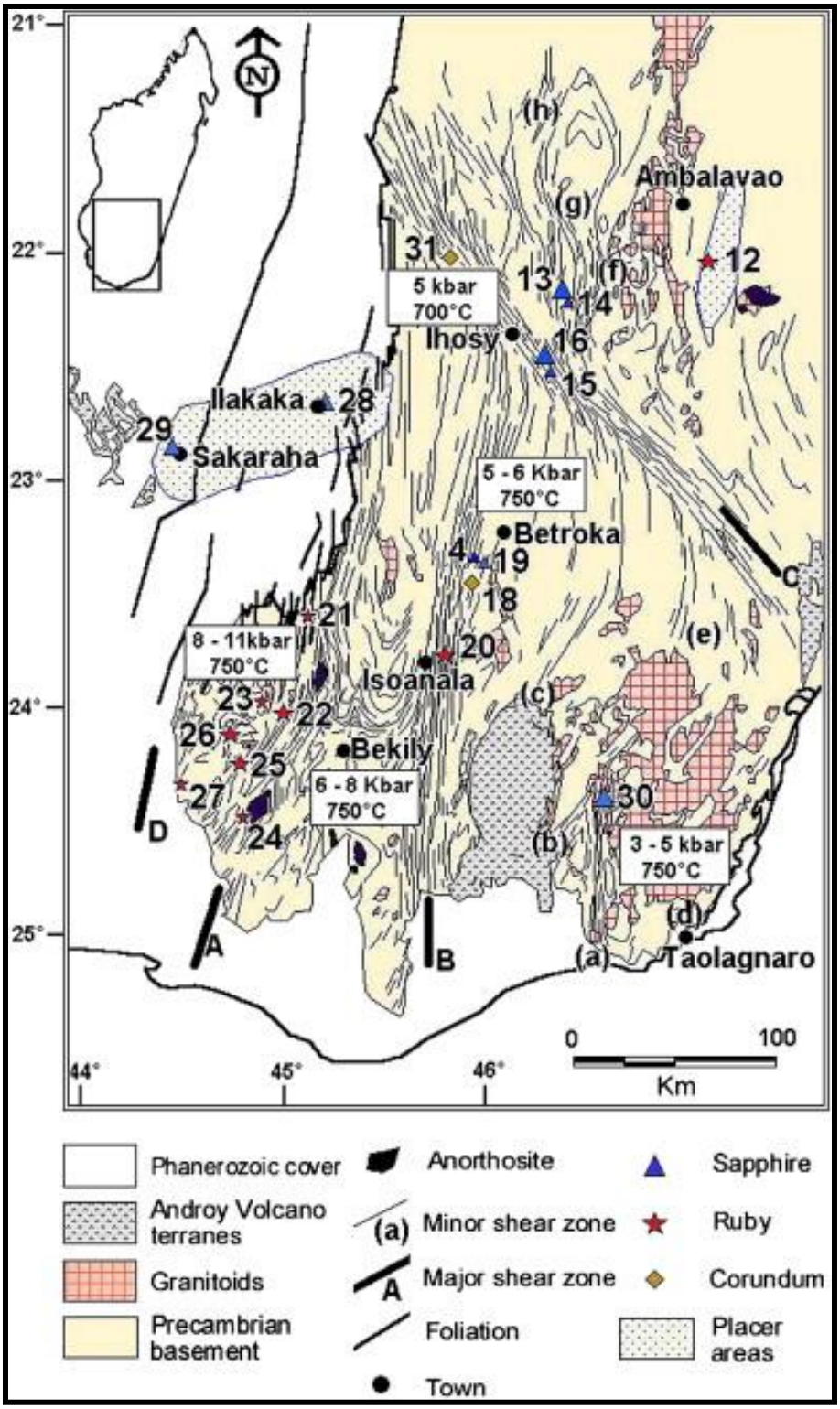


Figure 7-4: Structural and lithological sketch map of southeast Madagascar showing the positions of the major shear zones. From: Rakotondrazafy *et al*. (2008).

7.2 Regional Geology as it relates to the Molo Deposit

The Molo deposit occurs within the regional Ampanihy Shear Zone (Figure 7-2 and Figure 7-3). The most conspicuous feature of rocks found within this shear zone is their well-developed north-south foliation and vertical to sub-vertical nature. Martelat *et al*. (2000) state that this observed bulk strain pattern is clearly related to a transpressional regime during bulk horizontal shortening of heated crust, which resulted in the exhumation of lower crustal material. Figure 7-5 below illustrates the general position of Molo relative to the D2 regional strain pattern, and the resulting Ampanihy Shear Zone.

The Molo Project area is underlain by supracrustal and plutonic rocks of Late Neoproterozoic age that were metamorphosed under upper amphibolite facies, and deformed with upright north-northeast-trending structures. The supracrustal rocks involve migmatitic (± biotite, garnet) quartzo-feldspathic gneiss, marble, chert, quartzite, and amphibolite gneiss. The metaplutonic rocks include migmatitic (± hornblende/diopside, biotite, garnet) feldspathic gneiss of monzodioritic to syenitic composition, biotite granodiorite, and leucogranite.

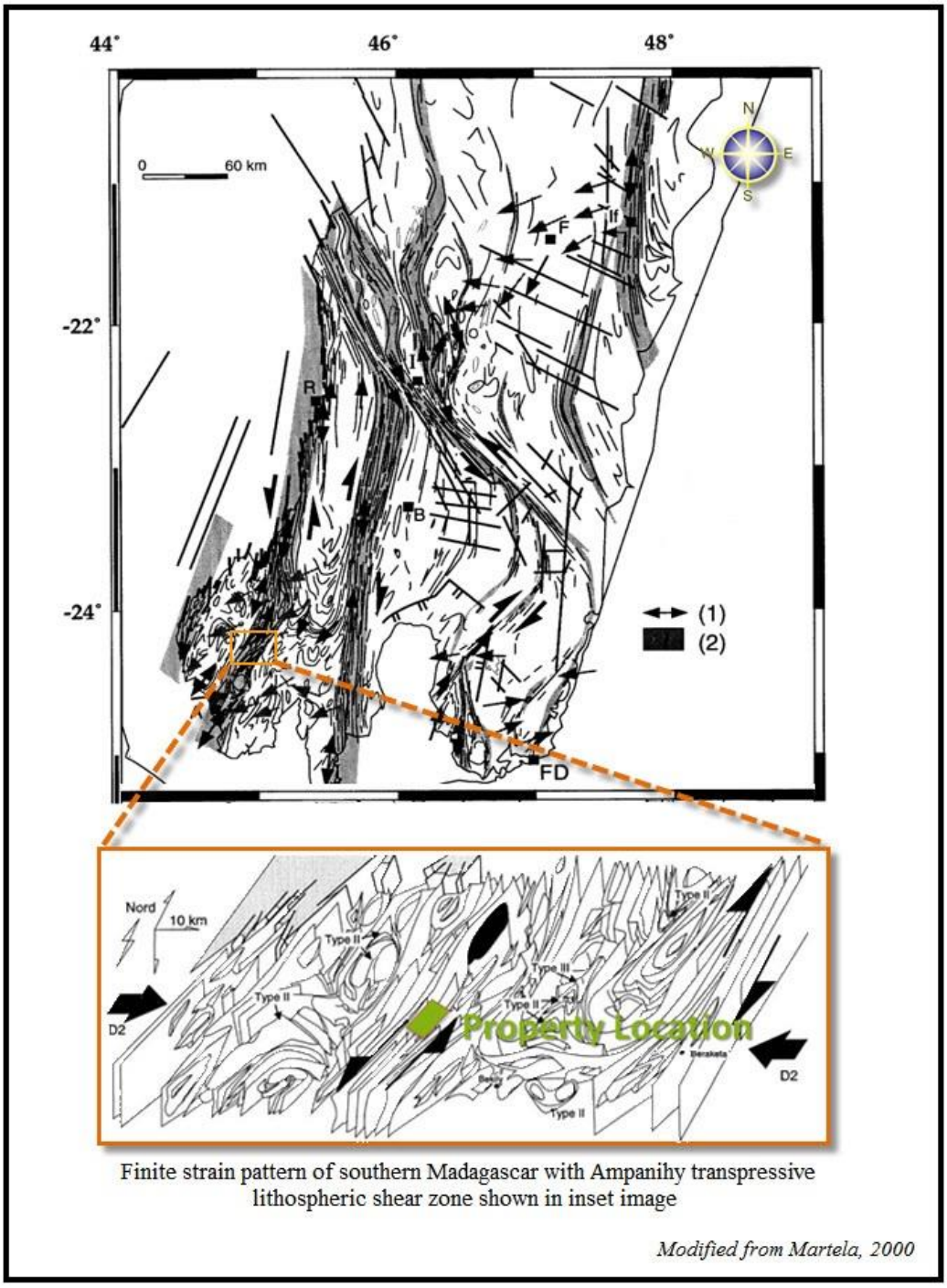


Figure 7-5: Position of the Molo Project area within the overall strain pattern documented for southern Madagascar.

Descriptions of the individual lithological units identified by Energizer, which are relevant to Molo, are included below.

7.2.1 Lithological Descriptions of Individual Rock Formations

Amphibolitic Gneiss

Dark grey to black, mesocratic to melanocratic, medium- to coarse-grained, subequigranular to porphyroblastic amphibolitic gneiss and amphibolite. Amphibolitic gneiss forms one or more major continuous bands in the eastern part of the permit, intercalated with quartzo-feldspathic gneiss and spatially associated with marble. In the central portion of the detailed map-area, amphibolitic gneiss forms local bands or lenses intercalated with quartzo-feldspathic gneiss and marble.

Meta-quartzite

White to greyish-white, weakly to moderately layered and foliated, coarse- to medium-grained quartzite. Brecciated quartzite with isoclinally folded layering is locally associated with dark brown ferruginous gossan. Un-brecciated quartzite very locally contains narrow, concordant, and discontinuous seams of gossan.

Grey-white Chert

Mottled greyish-white, massive to brecciated, hyalocrystalline graphite-bearing chert (or possibly siliceous rhyodacite). Grey-white chert displays evidence of polyphase brecciation, involving cm- to mm-scale, angular white siliceous fragments in a relatively early translucent grey siliceous (chalcedony) breccia matrix, and/or a later opaque brown ferruginous gossan breccia matrix.

Brown Fe-carbonate Chert

Tawny (yellowish) brown to reddish brown and chocolate brown, massive, hyalocrystalline opaque, graphite-bearing Fe-carbonate chert, variable biotite, and/or specularite. Brown chert, like grey-white chert, contains a small amount (≤1%) of fine-grained disseminated graphite, as well as variably small amounts of fine-grained disseminated biotite and/or specularite. Brown chert represents a widespread Fe-carbonatized alteration facies of grey-white chert, and both occur within the same chert masses. Brown chert is intimately associated with brown marble and ferruginous gossan.

Ferruginous Gossan

Dark purplish brown to black, dense, massive to brecciform and quasi-layered, aphanitic to fine-grained, siliceous ferruginous gossan. The gossan is variably highly siliceous to moderately siliceous and pitted, composed in part of Fe-carbonate (siderite-ankerite) and generally contains disseminated to clustered, fine-grained specularite, biotite, and/or graphite. Siliceous ferruginous gossan occurs as:

- breccia matrix of late-stage chert breccia and quartzite breccia
- concordant layers intercalated with chert and marble and discontinuous concordant seams in quartzite discordant masses cutting regional structure in quartzo-feldspathic gneiss and marble.

Siliceous ferruginous gossan is locally associated with cm-scale patchy masses of green, opaque calc-silicate or bright green amorphous and resinous calc-silicate mineral.

Quartz Feldspar Gneiss

Light grey to white, migmatitic, well foliated, and locally lineated, leucocratic to hololeucocratic, generally medium-grained (to fine- or coarse-grained), subequigranular to porphyroblastic, biotite-garnet quartzo-feldspathic gneiss. The quartzo-feldspathic gneiss comprises a mixture of fundamental constituent lithologies, dependent on the relative abundance or absence of biotite and garnet.

Feldspathic Gneiss

Pinkish grey to pink, migmatitic, foliated, medium- to coarse-grained, leucocratic (± hornblende/diopside, biotite, garnet) feldspathic gneiss. The feldspathic gneiss is comprised of a mixture of quartz-poor constituent lithologies.

7.2.2 Structural Geology

In 2010 a structural interpretation was undertaken based on the 2007 Fugro Airborne Surveys (http://www.fugroairborne.co.za/) ("Fugro") helicopter-borne frequency domain electromagnetic (DIGHEM V) multi-coil, multi-frequency, electromagnetic and high sensitivity cesium magnetometer geophysical survey (Butler, 2010; in Desautels *et al*., 2011). Only magnetite-bearing units were capable of being interpreted, except where putative intrusions cross-cut the main fabric in a magnetised area. This work showed the Green Giant Property to be dominated by structures associated with the Ampanihy Shear Zone. Butler (2010; in Desautels *et al*., 2011) specifically identified three magnetic domains associated with the Ampanihy shear system:

1. Zones where magnetic units are parallel or near-parallel to the walls of the domain. In these regions, the shearing has reduced intrafolial folds into sheared out 'tectonic fish'. There are also broad zones where a low content of magnetite (± pyrrhotite) may be present which most likely represent a different metamorphic mineral assemblage (different pressure and temperature conditions), or pre-metamorphic alteration and/or rock types.

2. Zones where magnetic units vary from parallel to a high angle at the domain boundary. These regions are interpreted to be the intrafolial fold remnants of sheath folds. The boundary shear of these domains may represent a sheared-out early thrust or high angle fault.

3. Zones with refolded chaos folds in domain lozenges. These regions occur in the north-central portion of the study area, and may be a remnant of a broad F3 episode enclosed within intense zones of ductility.

7.3 Molo Property Geology

The Molo graphitic zone consists of multi-folded graphitic strata with a surficially exposed strike length of over two kilometres (Figure 7-6). Outcrop mapping and trenching on Molo has shown the surface geology to be dominated by resistant ridges of graphitic schist (Figure 7-7) and graphitic gneiss, with fracture-lined vanadium mineralisation, as well as abundant graphitic schist float.

Geological modelling (Figure 7-8) has shown that the deposit consists of various zones of mineralised graphitic gneiss, with a barren footwall composed of garnetiferous gneiss (Figure 7-9). The host rock of the mineralised zones is graphitic gneiss.

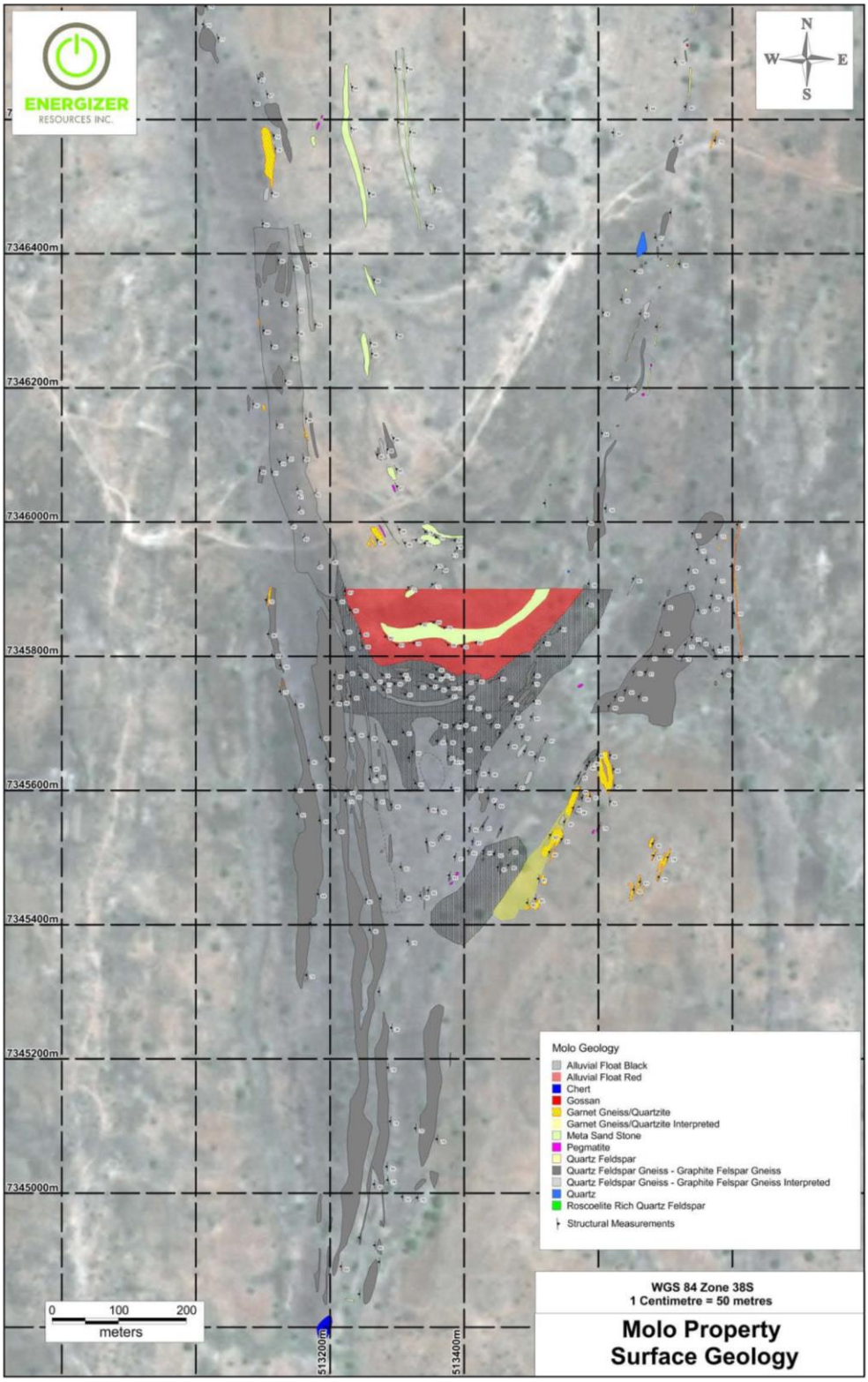


Figure 7-6: Map showing the surface geology of the Molo deposit.



Figure 7-7: Outcrop exposure of graphitic schist on the Molo Project. Photograph taken during the site visit of the 10th of May, 2012.

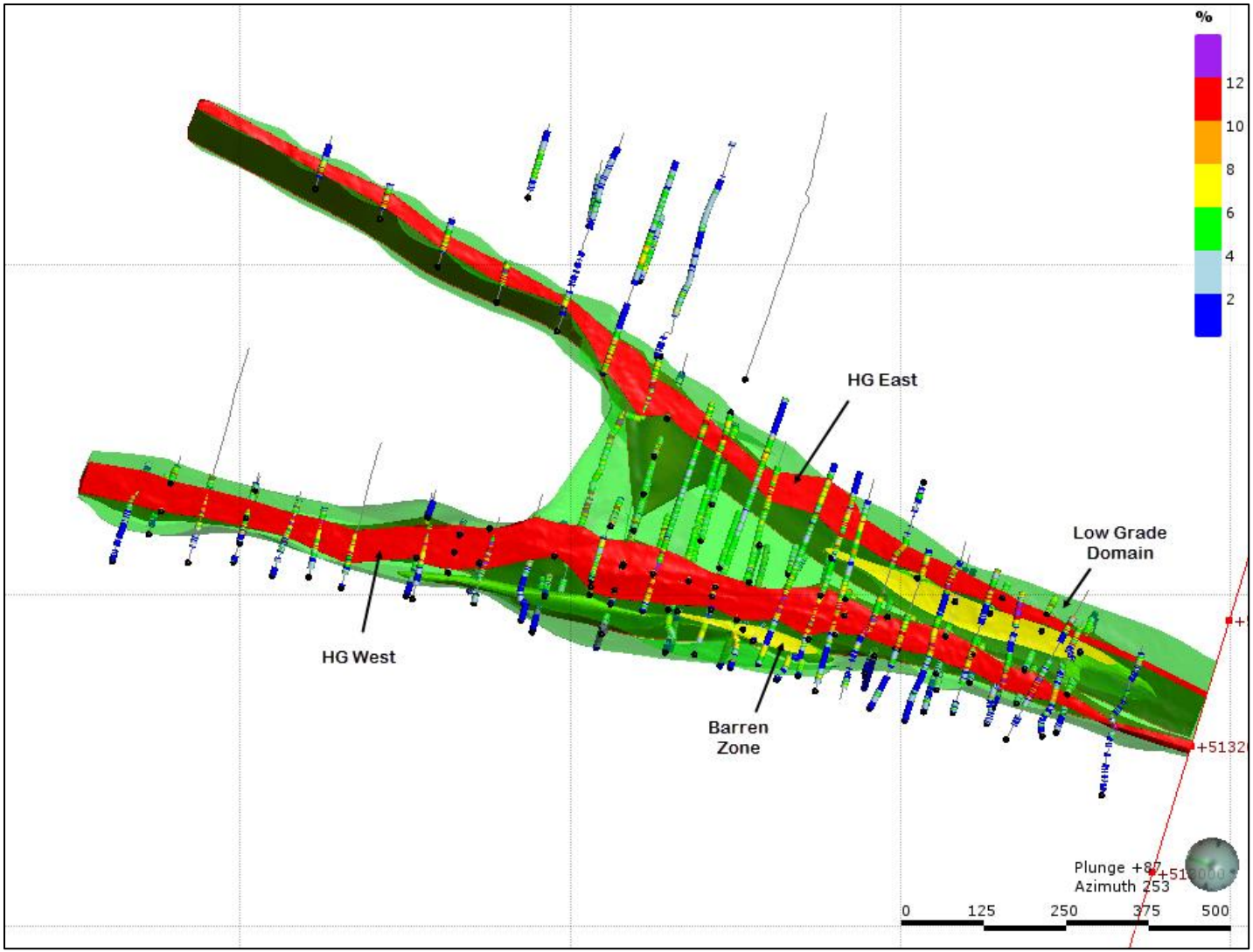


Figure 7-8: Geological model of the Molo deposit showing the nature of the two tightly oppressed 'high" grade (HG East and HG West) mineralized zones.



Figure 7-9: Garnet Gneiss in the footwall of Molo-4 at a depth of 132 m.

No academic studies have been undertaken on the graphitic schists and gneisses of the Molo deposit and at present the deposit is still not fully understood. There is however no indication of secondary hydrothermal or other transported, post-metamorphic graphitic mineralisation or upgrading and the present distribution and crystallinity of the graphite zones seem to be primarily due to regional metamorphic and structural events. The length, width, depth and continuity of mineralisation for the Molo deposit are more fully described under Item 14.

8 DEPOSIT TYPES

The Green Giant-JV Project hosts at least two different deposit types: 1) metamorphosed black shale/roll front redox vanadium deposits, and deposit types: 2) flake graphite deposits. The metamorphosed black shale/roll front redox vanadium deposits are well described in previous reports (e.g. Scherba and Chisholm, 2008) and are not repeated here.

8.1 Graphite Deposit Types

Graphite is one of the three familiar naturally occurring forms of the chemical element carbon ("C"). The other two varieties are amorphous carbon (not to be confused with amorphous graphite) and diamond. Graphite may be synthetically produced or be from natural source. Most natural sources are considered to be one of three main types, amorphous, flake or vein.

The following is taken mainly from Kogel *et al.* (2006):

Graphite is widely distributed throughout the world, occurring in many types of igneous, sedimentary, and metamorphic rocks. Many occurrences, however, are of little economic importance. The more important occurrences are those found in metasomatic-hydrothermal deposits and in sedimentary rocks that have been subjected to regional or contact metamorphism.

Economic deposits of graphite include five main geological types:

1. *Flake graphite disseminated in metamorphosed, silica-rich*
2. *Sedimentary rocks*
3. *Flake graphite disseminated in marble*
4. *Amorphous deposits formed by metamorphism of coal or*
5. *Carbon-rich sediments*
6. *Veins filling fractures, fissures, and cavities in country rock*
7. *Contact metasomatic or hydrothermal deposits in metamorphosed*

Natural graphite of economic value can be divided into two main classes, these being:

1. *Disseminated flake*
2. *Crystalline vein (fibrous or columnar)*

Most, if not all, of the world's deposits of flake graphite occur in metamorphic rocks of Precambrian age. Flake graphite is a lamellar form found in metamorphic rocks, such a marble gneiss, and schist. Each flake is separate, having crystallized as such in the rock. In many cases, pegmatitic veins have intruded the rocks.

Crystalline vein graphite (also called lump or high crystalline graphite) is normally found in well-defined veins or pocket accumulations along intrusive contacts of pegmatites with limestones. Here the enclosing wall rock is not necessarily graphitic. This type of deposit assumes the character of a true lode. The graphite in these deposits is of two types, foliated and columnar. The Sri Lankan graphite deposits are of vein type.

8.2 Graphite Mineralisation on Molo

Petrographic descriptions undertaken on thin sections of selected rocks of the Manga vanadium deposit submitted for metallurgical analysis to MINTEK (www.mintek.co.za/) in 2010 identified 17.17% modal graphite from the silicate composite, and 15.87% modal graphite from the oxide composite samples. Three additional composite samples were submitted to MINTEK at the conclusion of the 2010 exploration programme. The Quantitative Evaluation of Minerals by Scanning Electron Microscopy ("QEMSCAN") analysis of these samples quantified a graphite composition of 4.09%, while the head chemical analysis quantified a graphitic carbon content of 3.87%.

The identification of graphite as a potential credit to the Company's NI 43-101 compliant vanadium resources led Energizer geologists to conduct a reconnaissance exploration programme with the goal of delineating new graphitic trends, and comparing them to those associated with vanadium mineralisation. During the course of this reconnaissance exploration programme various surficial graphitic trends were identified on the Green Giant Property. These graphite trends were visually determined to be of both higher carbon content, and larger flake size than those associated with the NI 43-101 compliant vanadium resource mineralisation. Samples from these mineralised zones were submitted to MINTEK http://www.mintek.co.za/for analysis, as well as to the North Carolina State University ("NCSU") Minerals Research Laboratory in Asheville, North Carolina.

9 EXPLORATION

The identification of graphite as a potential credit to the Energizer's NI 43-101 compliant vanadium resources (Scherba and Chisholm, 2008) led to a reconnaissance exploration programme being undertaken on the Property in September 2011, with the goal of delineating new graphitic trends. Activities during this phase of exploration included prospecting, grab and trench sampling, and diamond drilling. Based on the results of this programme, Energizer launched a second phase of exploration in November 2011. The objective of this second programme was to use geophysical techniques to delineate additional graphite mineralisation, as well as to drill test the known graphitic.

The signing of the JV agreement with Malagasy in November, 2011 prompted additional exploration to ascertain the industrial mineral potential of the JV Property area. Exploration activities consisted of, geologic mapping, prospecting and sampling (including metallurgical), ground geophysical surveying (EM-31), trenching, and diamond drilling. As a consequence of the work undertaken during 2011, the Molo graphite prospect was identified and targeted for additional work, which was undertaken between May 2012 and June 2014.

9.1 Geological Mapping

A series of excellent 1/100,000 scale geological maps (1952-53) are available for the region surrounding Molo (Fotadrevo-Bekily, Ianapera, Sakamena-Sakoa), with the area covered by the 1/100,000 scale topographic map #H-60 Fotadrevo.

Various mapping projects have been completed on the entire Green Giant Property, with the major emphasis being strictly dedicated to the commodity of interest at that time. In 2007 Taiga completed a property-wide reconnaissance mapping project (1:25,000 scale). Greater detailed (1:5,000scale) geological mapping was later undertaken to compliment the larger scale version in areas of geologic interest. During the 2008 field season, Taiga again completed a property wide mapping programme, however, at a notably smaller scale than before (1:10,000 scale).

During the 2011 field season mapping activities increased and the identification of the graphitic prospect areas led to smaller scale mapping (1:1000 scale) over areas which appeared to have the greatest graphitic potential. Areas included were Molo (Figure 7-6), Fondrana, Fotsy and Seta.

9.2 Trenching

No known historical trenching is documented on Molo. During the 2011 field season a number of the new graphite rich areas were trenched including Molo. Initial graphitic carbon results from the 2011 trenching were encouraging in that they showed multiple graphic horizons present in each zone, of significant widths and grades. Because of this, and coupled to the size of the electro-magnetic signature, the 2012 programme focussed on Molo and an additional 22 trenches were excavated. Additional trenching was undertaken on Molo during May of 2013 as part of a bulk sampling exercise (Figure 9-1). Subsequently an additional nine trenches (totalling 1,876 metres) have been excavated as part of the 2014 exploration programme.



Figure 9-1: Trenching for the bulk sample on Molo, May 2013.

A plan map showing the positions and grades of all the trenches excavated on the Molo deposit is provided below as Figure 9-2.

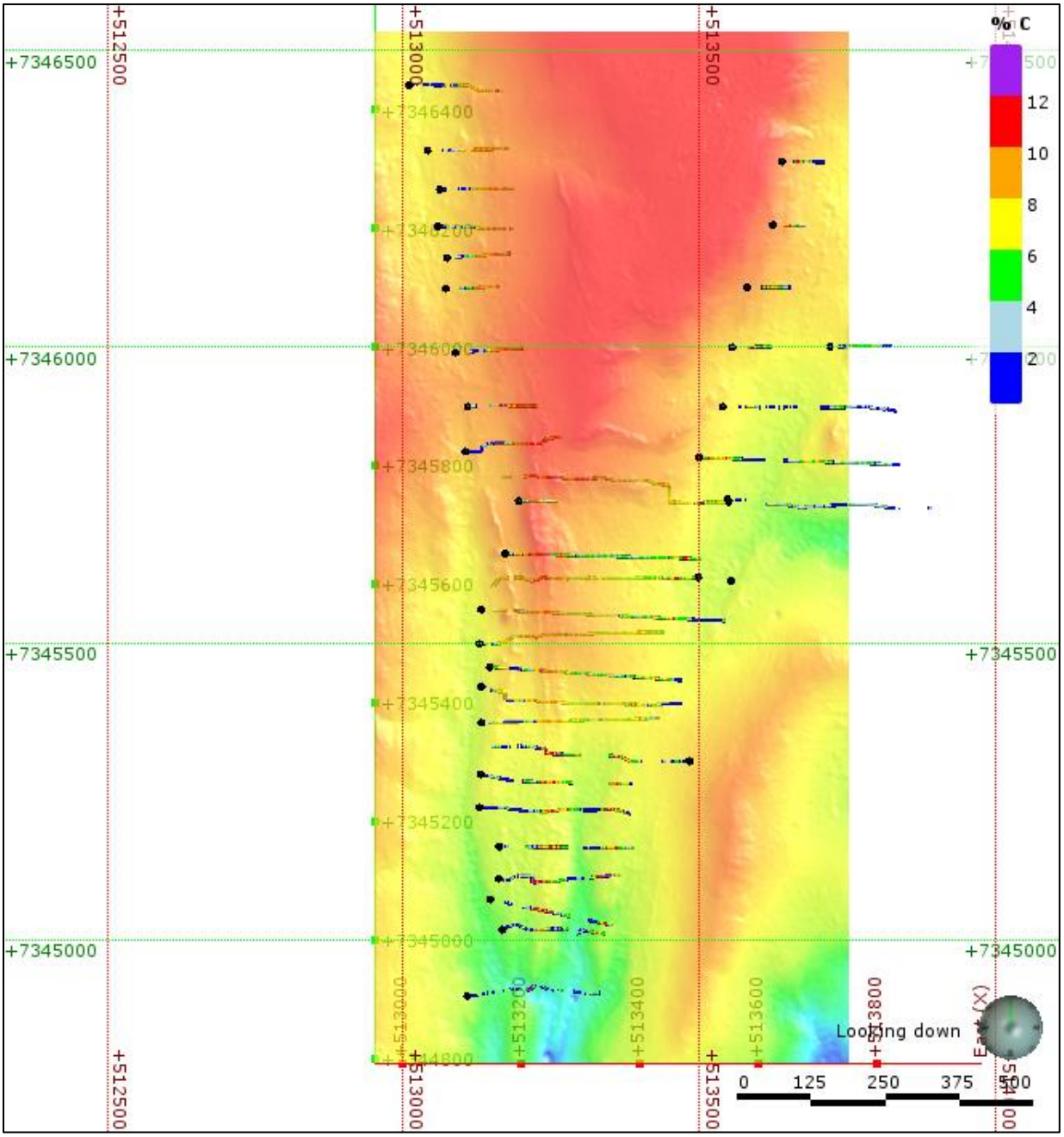


Figure 9-2: Plan showing the positions and grades of all the trenches excavated on the Molo deposit, overlain on the topographic elevation map.

9.2.1 Trench Sampling

Standardized sampling methods include two meter long continuous chip samples approximately 4 cm wide being collected along the northern edge of the trench floor, consisting of about 3 kg to 4 kg of

material per sample. The following procedural steps were taken during the sampling and mapping process:

- Plastic sample bags were sequentially numbered with a unique series from pre-printed sample books. The Quality Assurance/Quality Control ("QA/QC") sample numbers are flagged at this point for later insertion;
- The trench floor is swept clean with hand brooms to ensure there is no contamination from rubble or fines;
- Two technicians use hammers and chisels to gently dislodge the weathered rock along the channel profile;
- A third technician follows behind to collect the sample material, first verifying the sample tag is in the bag, then matching the sample bag number and the sample book interval;
- The sample bag was sealed with a zip tie, with the sample tag inside the bag;
- Two technicians follow behind the samplers and clean/scrape the north wall of the trench to allow better visual inspection of any structures, and to remove any debris or 'polishing' which may have occurred during excavation;
- A geologist or qualified technician using scaled paper inspects the north wall of the trench and records structures, mineralisation, depth and any other notable aspects;
- All samples are brought back to the camp each night for storage in the secure facility at Fotadrevo until shipment.

Samples taken from the 2012-2014 trench exploration programmes were subject to stringent QA/QC and their lengths and percentage carbon are presented in Table 9-1 below. This data was used in the estimation process.

Table 9-1: 2012/2014 Molo Trench Results.

Trench	From (m)	To (m)	Length (m)	C%
MOLO-TH-12-01	28	318	290	6.58
MOLO-TH-12-02	2.5	358	355.5	6.01
MOLO-TH-12-03	5	380	375	7.74
MOLO-TH-12-04	37	119	82	8.89
MOLO-TH-12-05	32	90	58	7.4
MOLO-TH-12-06	45	125	80	6.56
MOLO-TH-12-07	52	138	86	7.34
MOLO-TH-12-08	88	140	52	7.65
MOLO-TH-12-08	186	286	100	7.25
MOLO-TH-12-09	38	128	90	6.92
MOLO-TH-12-09	166	220	54	8.79
MOLO-TH-12-10	92	121	29	7.18
MOLO-TH-12-10	214	230	16	5.06
MOLO-TH-12-11	34	94	60	5.01
MOLO-TH-12-11	158	194	36	5.74
MOLO-TH-12-12	84.5	257	172.5	5.68
MOLO-TH-12-13	16	52	36	4.51
MOLO-TH-12-13	74	320	246	6.55
MOLO-TH-12-14	82	176	94	7.87
MOLO-TH-12-15	84	152	68	6.94
MOLO-TH-12-16	80	96	16	4.37
MOLO-TH-12-18	38	65	27	4.88
MOLO-TH-13	0	299	299	6.14
MOLO-TH-14	44	222	178	6.32
MOLO-TH-15	27.3	112	84.7	5.88
MOLO-TH-16	32.6	108	75.4	6.82
MOLO-TH-17	0	332	332	6.15
MOLO-TH-18	20	351	331	5.58
MOLO-TH-19	24	298	274	5.37
MOLO-TH-20	88	250	162	7.13
MOLO-TH-21	59	212	153	6.93
MOLO-TH-22	48.6	119	70.4	6.57
MOLO-TH-23	3.3	69.3	66	7.26
MOLO-TH-24	27	65	38	8.09
MOLO-TH-25	26	66.6	40.6	6.51
MOLO-TH-26	18.6	46	27.4	7.63
MOLO-TH-27	24.6	50.6	26	6.86

9.3 Ground Geophysical Surveying

During 2011 an EM31-MK 2 ("EM31") ground conductivity instrument was obtained to aid determination of the overall extents of the graphitic horizons delineated during the previous year's field mapping and prospecting activities. The EM31 geophysical tool was invaluable in delineating the extents of the graphitic zones, as well as their continuity. Energizer's geotechnical team conducted a survey consisting of 100 m spaced lines and 25 m stations. In total, 160.5 line kilometres of EM31 surveying was completed over five target areas, full details of which are available on the Company's web page (http://energizerresources.com/projects/green-giant-graphite.html). This data was used to plan the original (2011) boreholes drilled on Molo (Figure 9-3).

During the 2011 programme an EM31 geophysical survey was also conducted over the Molo deposit area concurrently with prospecting and subsequent geological mapping of the stronger graphitic zones. The survey (Figure 9-3), aided in outlining a zone length of over 2 km, with an aggregate EM31 measured strike length of 10 km. This, along with the confirmation of five strong graphitic horizons, supported further trenching and drilling.

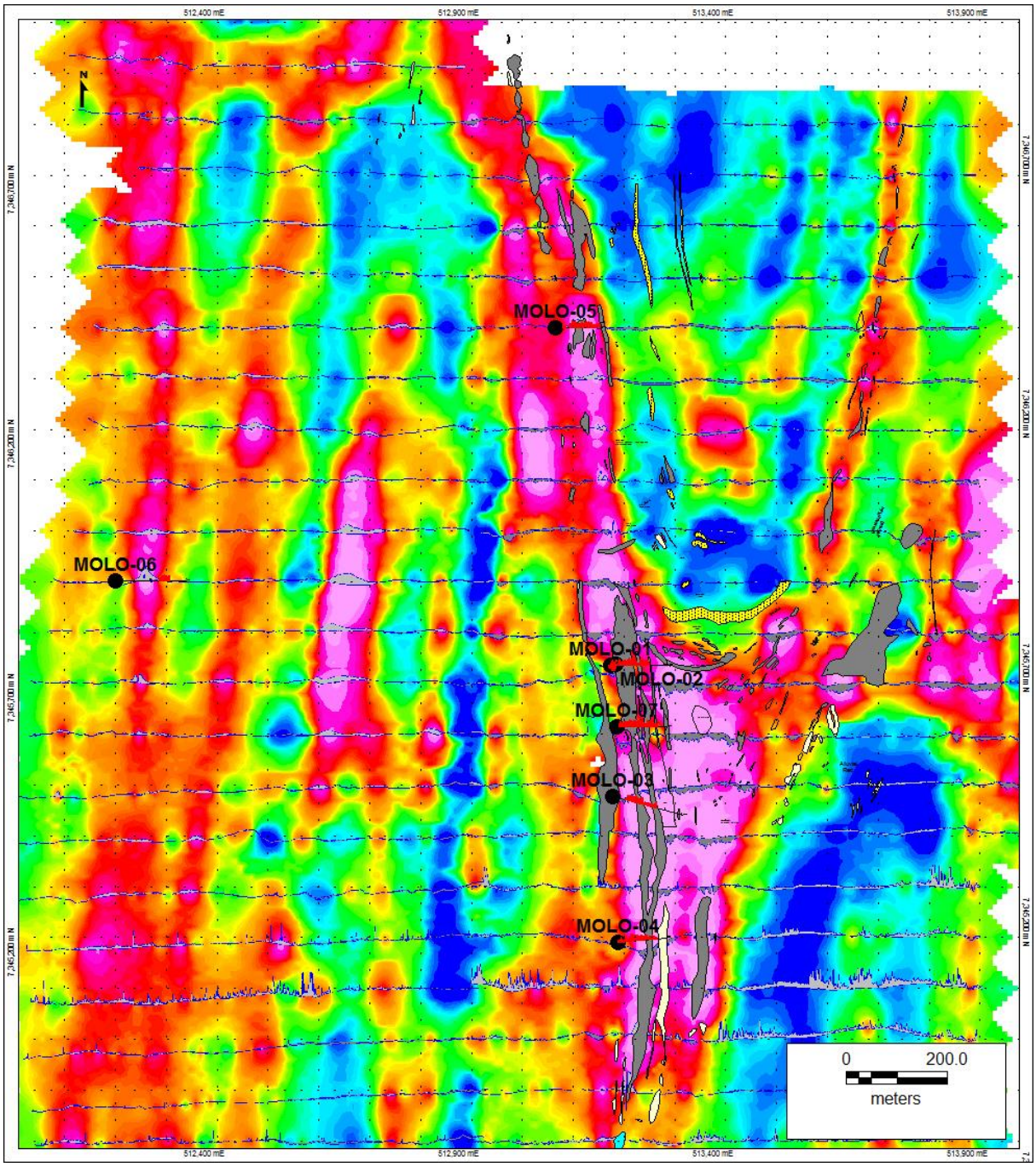


Figure 9-3: EM31 Geophysical Survey Map of the Molo deposit showing the positions of holes MOLO-01 to MOLO-07 drilled during 2011. Bright Pink areas are interpreted graphitic areas and the grey areas represent surficial/mapped graphite outcrops. The north-eastern limb was the focus of additional work during 2014.

9.4 Prospecting and Sampling

Property scale prospecting and grab sampling was conducted during earlier exploration programmes. Prospecting typically consisted of a preliminary stage in which areas were covered on a large scale to determine Vanadium and graphite potential. Upon discovery of any notable potential mineralisation, a larger group of prospectors were sent to the area of significance. This then allowed much more of the Property to be 'ground truthed' and, where applicable, sampled in an intensive manner to gain an understanding of all of the zones.

During 2011 Energizer's employees thoroughly covered the Green Giant Property with special interest in graphitic showings. With the addition of the JV Property, a much larger area had to be investigated, which required helicopter assistance to access remote and marginally accessible areas. Over the course of six days Energizer's technical team visited a variety of notable graphite localities including Molo. During 2012 Molo was subject to an intensive grab sampling programme, which resulted in a total of 344 samples being collected.

10 DRILLING

No known historical diamond drilling is documented for the Green Giant Property. Numerous diamond drilling programmes have been conducted over the Green Giant (and formerly the Three Horses) Property in the past seven years and these have previously been covered in previous reports (Scherba and Chisholm, 2008; McCracken and Holloway, 2009; and Desautels *et al*., 2010). Only work directly or indirectly pertaining to the Molo deposit is therefore covered here.

Due to the realization that a significant graphitic resource probably existed on the Green Giant-JV Property, a reconnaissance diamond drilling programme was implemented in 2011 to test the viability and potential of the graphitic prospects.

The 2011 diamond drilling commenced in early November and ran through to mid-December. During this programme Energizer entered into a JV agreement with Malagasy Minerals and this phase therefore was re-focussed on the new graphitic prospects on the JV areas. This resulted in 19 holes being drilled by Boart Longyear over the Molo, Fotsy, Fondrana and Seta areas, for a combined 1701 m of diamond drilled core. Of these 19 holes, one larger (PQ) diameter hole was completed and sent to Activation Labs (www.actlabs.com/) ("Actlabs") in Ancaster, Ontario, Canada for metallurgical analysis.

Of the 2011 diamond drilling, seven (Molo-01 to Molo-07) wide spaced holes were drilled on Molo. Six of these (over a strike length of 1.2 km) intersected graphitic mineralisation to a vertical depth of 75 m, with down-hole thicknesses of between 60 m and 150 m in width. Graphite mineralisation intersected in drill core was open along strike, and at depth. Forty-one diamond drill holes, comprising 8,502.7 m of diamond drilling were completed on Molo during 2012. During 2014 an additional 32 diamond drill holes (totalling 2,063 metres) were completed. With this most recent drill programme, a total of 80 diamond drill holes (Figure 10-1), (totalling 11,660 meters) have now been completed on Molo, and these were used for the mineral resource estimations.

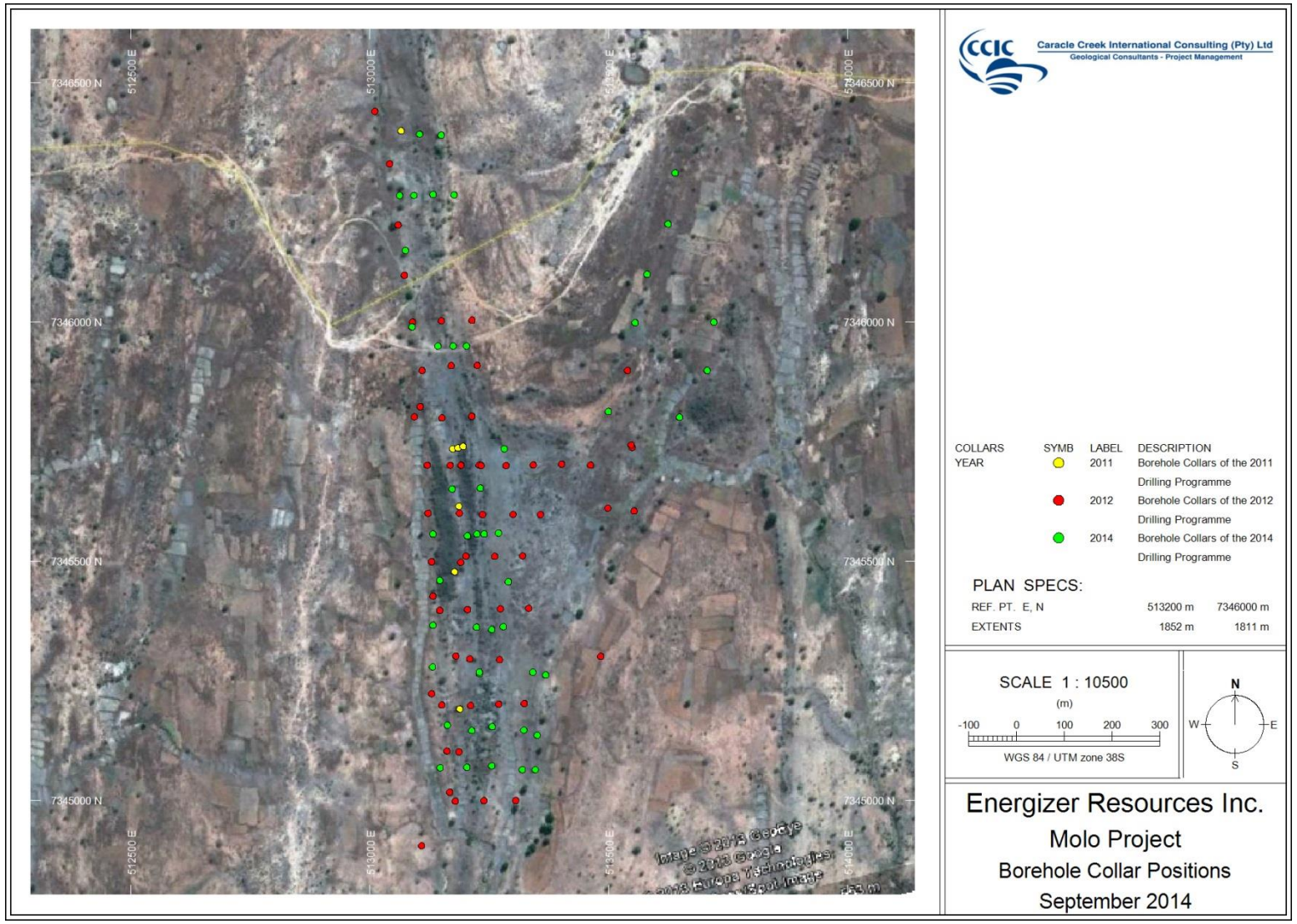


Figure 10-1: Borehole collar positions for all of the known boreholes drilled on the Molo deposit.

10.1 Diamond Drill Contractor and Logistics

Between 2009 and 2014 all diamond drilling on the Green Giant-JV Project was carried out using a Boart Longyear 44 skid-mounted wire-line rig, and a Boart Longyear LF-90 skid-mounted wire-line rig, owned and operated by Boart-Longyear™ (http://www.boartlongyear.com/), South Africa. The initial 70-100 m of any borehole was generally completed with HQ core (63.5 mm diameter), and once reasonably competent rock was encountered, this was reduced to NQ (47.6 mm diameter core). On rare occasions (as noted for the 2011 metallurgical hole) larger diameter PQ sized core (85.0 mm diameter) was extracted.

The drill moves were completed using Boart-Longyear's John Deere skidder equipped with a blade and winch. Drill pads and sumps were prepared using a rental CAT 420D backhoe/loader. While drilling, all fluids were pumped directly from the sumps, with all overflow fluids directed back to the sumps. These measures were taken in order to conserve drill fluids and to prevent site contamination by drill additives or metals liberated by the drilling. Water for drilling operations was trucked from streams, creeks or ponds sporadically located along the main drainages crossing the Property, and stored at the drill site until required.

10.1.1 Core Handling Procedures

Core is delivered from the Molo drill site to the Fotadrevo base camp by pickup truck at the end of every 12-hour shift, under the supervision of the drilling company, or an official designated by Energizer. Drill core is stored in galvanized-steel core boxes 1 m in length holding 3 m PQ, 5 m HQ or 7 m NQ core. The core boxes are laid out on constructed core benches in sequential order. A general review of the core is undertaken and the core is washed or rinsed of debris and drilling fluids. Energizer's technicians then assess the overall condition and recovery of the core and complete a lithological 'quick log'. Errors in run markers are noted. All drill core is presently stored at Energizer's Fotadrevo camp within a secure, 20 m x 25 m fenced enclosure.

10.1.2 Core Logging

Energizer utilizes a logging system developed by Taiga, which has subsequently been altered slightly and has become the standard for all Company procedures. At this stage of exploration there is no restricted list of rock units for core logging as the stratigraphy is still being developed. Energizer's geologists however attempt to utilize a standard set of units, and aim to discuss and agree upon any new units prior to their utilization.

Core logging was previously recorded onto paper logs which were subsequently transferred to computer. The Company has however recently purchased Panasonic Field laptops and thus all data is currently entered directly into these units. Core logs contain observations of geology, structure, mineralogy, alteration and sample interval descriptions.

10.1.3 Core Recovery

Trained technicians are responsible for collecting geotechnical data such as rock quality description ("RQD") and core recovery. The data is recorded onto paper forms with entry into computer logs at the end of the day. The core recoveries are considered as being good and fit for resource estimation purposes.

10.1.4 Core Photography

The core is photographed in groups of two boxes (Figure 10-2) and then forwarded for cutting. Core is typically photographed wet.



Figure 10-2: Core photographs of borehole MOLO-05 core (boxes 17 and 18) as supplied to CCIC by Energizer.

10.1.5 Collar Survey

Borehole collar locations are initially established in the field using a hand held global positioning system ("GPS") instrument. Following completion of the hole the collar locations were re-measured, also using a hand-held GPS. The nominal accuracy of these positions, as stated by the manufacturer of the GPS units, is ±3 m. The bore hole collars have not been surveyed by a registered surveyor.

All drill collar sites have been reclaimed and collars marked, with nothing left in the ground or on the drill site. All holes are plugged and cemented to approximately one metre down the hole. Furthermore, all holes are identified by engraving the collar name into the fresh cement, which when dry is very difficult to destroy (Figure 10-3).



Figure 10-3: Concrete marker showing the collar position of borehole MOLO 12-02.

10.1.6 Down Hole Surveys

From 2009 till present, Boart Longyear uses single shot Reflex equipment on all diamond drill holes to measure down the hole azimuths and inclinations. Measurements were taken below the level of the surface casing (generally 10 m to 15 m depth), every 50 m (unless hole conditions dictated otherwise), with a final measurement taken at the end of the hole.

10.1.7 Geotechnical Logging

Geotechnical logging consisted of RQD measurements and core recovery calculations. The data was collected on paper forms and later transcribed into an Excel spreadsheet. RQD measurements are calculated using a minimum 10 cm core length according to the following formula:

$$RQD = Run\ Length - \frac{(\sum Pieces\ of\ core < 10\ cm)}{Run\ Length}$$

10.1.8 Diamond Drill Core Sampling

The methodology utilized by Energizer for diamond drill core sampling was first established by Taiga during the 2008 exploration programme, and then modified to accommodate specific programme requirements as needed.

The 2012-2014 diamond drill core sampling procedure may be described as follow:

- Sample interval was set at a maximum of 1.5 m (run length), and shortened based on lithological breaks;
- Sample intervals were recorded in the drill log and in pre-printed sample books. QA/QC samples numbers were flagged at this point for later insertion;
- Plastic sample bags were numbered sequentially with the appropriate sample number;
- Core was cut by a technician using a clean water spray table rock saw and both halves of the sawn core was placed back in the box;
- The geologist who logged the core verified the sample tag with the sample book and placed half of the cut core into the sample bag;
- The sample bag was sealed with a zip tie, placed in another larger bag (i.e., double bagged) with a duplicate sample number, and a sample tag was inserted between the sample bags to mitigate against the destruction of the sample tag;
- All the samples were stored in a secure facility at Energizer's Fotadrevo campsite until shipment;

10.1.9 Diamond Drill Results

All results from the 2011, 2012 and 2014 diamond drill programmes are presented below in Table 10-1 below. The authors of this Report are of the opinion that there are no drilling, sampling or recovery factors that could materially impact the accuracy and reliability of the nature of the obtained samples.

Table 10-1: Collar co-ordinates, drilled length and orientation for the Molo drill holes.

BHID	EASTING	NORTHING	ELEV	LENGTH	DIP	AZIMUTH
MOLO-01	513173	7345735	553.96	166	-45	90
MOLO-02	513184	7345737	554.52	47	-45	265
MOLO-03	513177	7345478	549.88	207.5	-45	105
MOLO-04	513188	7345191	545.79	137	-45	85
MOLO-05	513065	7346400	551.60	131	-45	90
MOLO-06	512199	7345902	543.51	200	-45	90
MOLO-07	513186	7345615	550.84	142.5	-45	90
MOLO-12-01	513121	7345600	550.78	463.6	-45	90

BHID	EASTING	NORTHING	ELEV	LENGTH	DIP	AZIMUTH
MOLO-12-02	513185	7345601	550.58	89	-45	270
MOLO-12-03	513236	7345598	551.52	311	-45	90
MOLO-12-04	513300	7345600	553.24	221	-45	90
MOLO-12-05	513360	7345600	553.96	170	-45	90
MOLO-12-06	513150	7345400	548.59	364.5	-50	90
MOLO-12-07	513210	7345400	547.65	299	-50	90
MOLO-12-08	513270	7345400	547.86	212	-50	90
MOLO-12-09	513330	7345400	549.46	137	-50	90
MOLO-12-10	513151	7345199	545.65	320	-50	90
MOLO-12-11	513210	7345197	545.81	221	-50	90
MOLO-12-12	513270	7345200	544.46	182	-50	90
MOLO-12-13	513322	7345202	543.49	95	-50	90
MOLO-12-14	513177	7344998	541.12	260	-50	90
MOLO-12-15	513238	7345001	541.87	194	-50	90
MOLO-12-16	513305	7344999	543.16	80	-50	90
MOLO-12-17	513092	7345801	553.85	258.4	-50	90
MOLO-12-18	513151	7345799	554.37	132	-50	90
MOLO-12-19	513204	7345805	556.96	77	-50	90
MOLO-12-20	513089	7346000	552.99	234	-50	90
MOLO-12-21	513150	7346002	552.38	156.5	-50	90
MOLO-12-22	513215	7346007	554.77	54	-50	90
MOLO-12-23	513202	7345517	550.20	126.4	-50	270
MOLO-12-24	513245	7345513	550.21	177.5	-50	270
MOLO-12-25	513210	7345292	546.50	85.5	-50	270
MOLO-12-26	513274	7345295	545.81	186.5	-50	270
MOLO-12-27	513226	7345702	554.22	212	-50	270
MOLO-12-28	513170	7345909	554.69	84	-50	270
MOLO-12-29	513215	7345907	555.68	143	-50	270
MOLO-12-30	513188	7345713	553.67	126.8	-50	270
MOLO-12-31	513322	7345513	552.23	293	-50	270
MOLO-12-32	513119	7345697	553.26	327.5	-50	90
MOLO-12-33	513169	7345702	553.10	252.5	-50	90
MOLO-12-34	513232	7345702	554.33	236	-50	90
MOLO-12-35	513285	7345700	554.94	185	-50	90
MOLO-12-36	513341	7345702	554.59	200	-50	90
MOLO-12-37	513403	7345703	553.26	200	-50	90
MOLO-12-38	513465	7345706	549.95	152	-50	90
MOLO-12-39	513190	7345498	550.05	329	-70	90

BHID	EASTING	NORTHING	ELEV	LENGTH	DIP	AZIMUTH
MOLO-12-40	513179	7345301	546.95	326	-70	90
MOLO-12-41	513187	7345102	542.80	329	-70	90

11 SAMPLE PREPARATION, ANALYSES AND SECURITY

11.1 Sample Preparation, Assay and Analytical Procedures

At all times during sample collection, storage, and shipment to the laboratory facility, the samples are in the control of Energizer or their agents.

When sufficient sample material (grab, trench or core) has been collected, the samples are trucked or flown to Energizer's storage location in Antananarivo, at all times accompanied by an Energizer employee. From there, samples are further shipped to either South Africa (MINTEK or Genalysis) or Canada (Activation Labs) for ICP-MS analysis.

Drill core samples collected during 2011 were directed to two major laboratories. All samples collected during Phase I of 2011 were sent to MINTEK, South Africa. Samples were then tested for Carbon content (Total Organic Carbon and Overall Carbon content), as well as the full range of elements available through ICP-OES (MINTEK code FA5) and XRF analysis. The elements tested included Al, Si, P, S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, Ge, As Se, Br, Rb, Sr, Y, Zr, Nb, Mo, Ag, Cd, in, Sn, Sb, Te, I, Cs, Ba, La, Ce, Hf, Ta, W, Hg, Tl, Pb, Bi, Th and U.

The remainder of samples collected during Phase II of the 2011 exploration programme were submitted for analysis to Actlabs, Canada. Samples were again submitted for analysis of Carbon content, as well as for a large range of elemental analysis.

During 2012 all samples were submitted to Intertek Genalysis (www.intertek.com/) ("Genalysis"). All work undertaken by Intertek is performed in accordance with the Intertek Minerals Standard Terms and Conditions of which can be downloaded from their web page.

All analytical results were e-mailed directly by both Genalysis and MINTEK to the Green Giant Project Manager, as well as Energizer executive staff, and were posted on a secure website and downloaded by Energizer personnel using a secure username and password. Following the site inspection in May 2012, all analytical results were also e-mailed directly to Dr. Hancox (CCIC) and these were compared against the final data set as presented by Energizer.

All of the laboratories that carried out the sampling and analytical work are independent of Energizer.

11.2 QA/QC

In order to carry out QA/QC protocols on the assays, blanks, standards and duplicates were inserted into the sample streams. This was done once in every 30 samples, representing an insertion rate of 3.33% of the total.

11.2.1 Blanks

Since the 2009 drill programme, Energizer has rigorously implemented a blank protocol. For Molo fine-grained quartz sand sourced from a hardware store in Antananarivo was used as the blank material for the sampling campaign. An additional 93 blanks have been submitted during this campaign, taking the total number of blanks to 301. A detection limit of 0.05% Carbon was used for the purpose of this exercise. To verify the reliability of the blank samples, the detection limit and the blank + 2, and 3 times the detection limit was plotted against the date (and Figure 11-1 represents the previous and current campaigns respectively). Blanks for the 2014 campaign shows that that the majority of samples have concentrations that lie within the blank + 3 times detection limit threshold, with the maximum outlier being 0.57% C

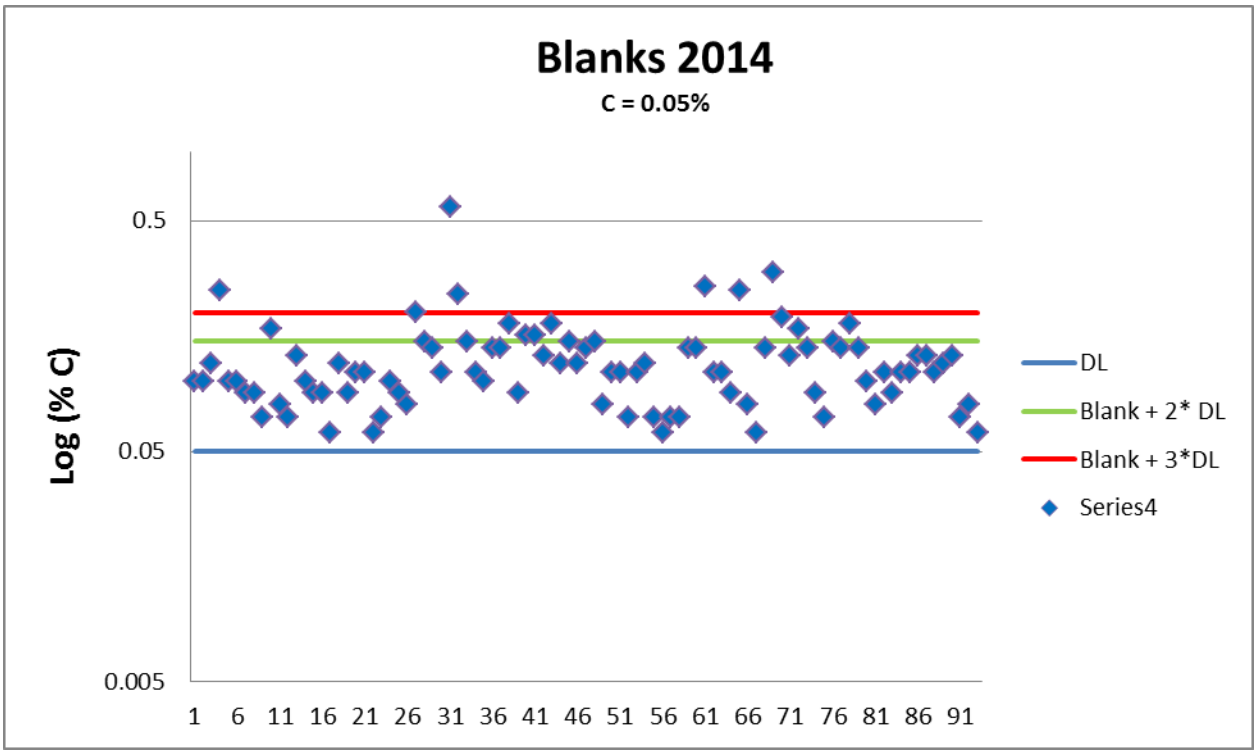


Figure 11-1: Plot of Log %C versus the date of the analysis-2014 for the blanks.

11.2.2 Standards

Because of the difficulty is sourcing certified standard reference material ("CRM") during the 2012 campaign, Energizer commissioned Actlabs, Canada to create a CRM from the remaining Molo drill core pulps from the 2011 programme. As certified the Actlabs standard (STD 1 C) has a recommended value of 9.11 % Carbon. The certificate for STD 1 C from Actlabs is attached as Appendix 1. For the 2014 campaign, Energizer sourced two additional CRM's from GEOSTATS (Proprietary) Limited ("GEOSTATS"), namely GGC-01 and GGC-07, certificates for which are attached in Appendix 1. The recommended values for GGC-01 and GGC-07 are 24.97% C and 0.56% C respectively.

To check the reliability of the standard, a plot of the recommended CRM value versus date was created (Figure 11-2 to Figure 11-4).

The upper and lower limits of one, two and three times the standard deviations of the recommended value are also included in the plot. For STD 1 C, all but two results fall outside the acceptable limit of three times the standard deviation. It is however worth noting that the obtained results indicate a slight positive bias when compared to the recommended value. For GGC-01, all of the obtained results occur within two standard deviations. For GGC-07, four samples occur outside of three standard deviations. This CRM has a mean value of 0.56% C whilst the mean of the obtained values is 0.61% C, indicating a positive bias at low concentrations.

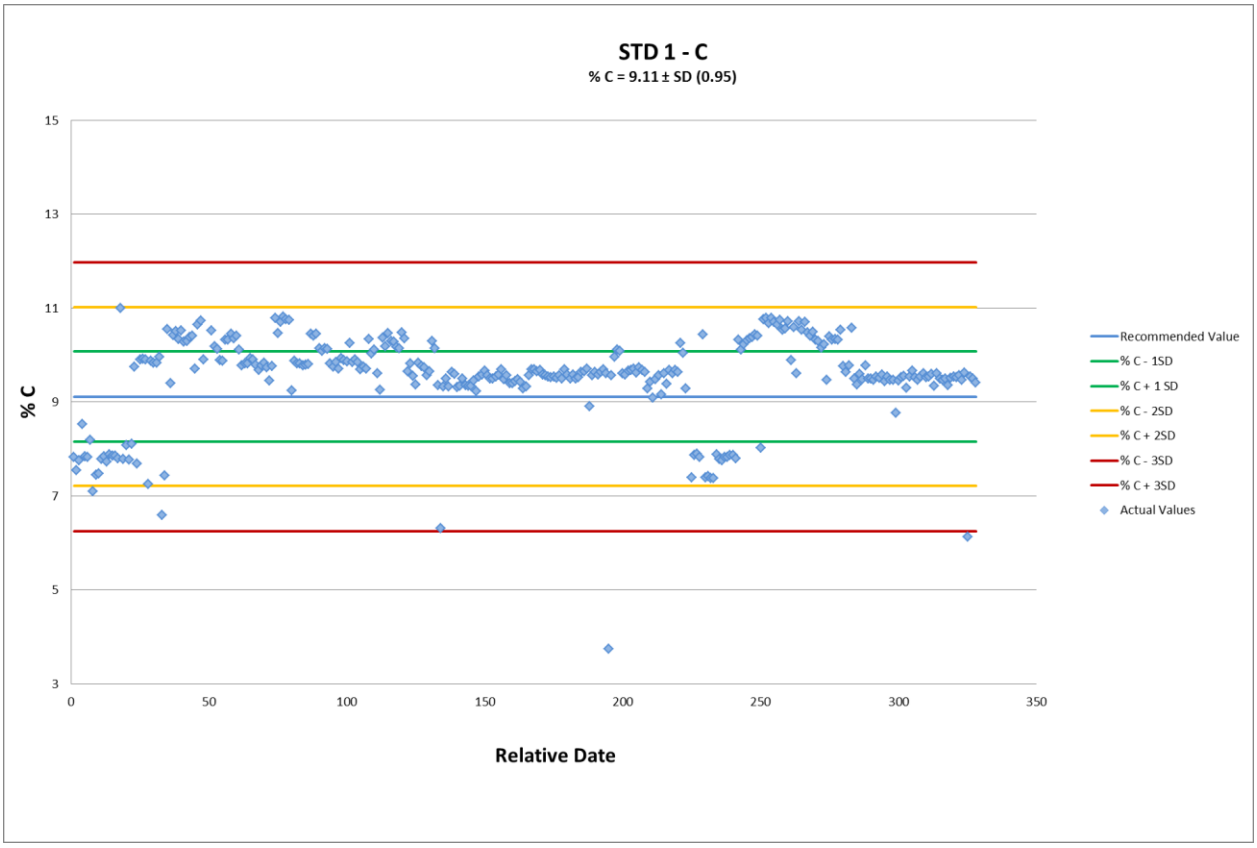


Figure 11-2: Graph showing carbon concentration as analysed in STD 1C.

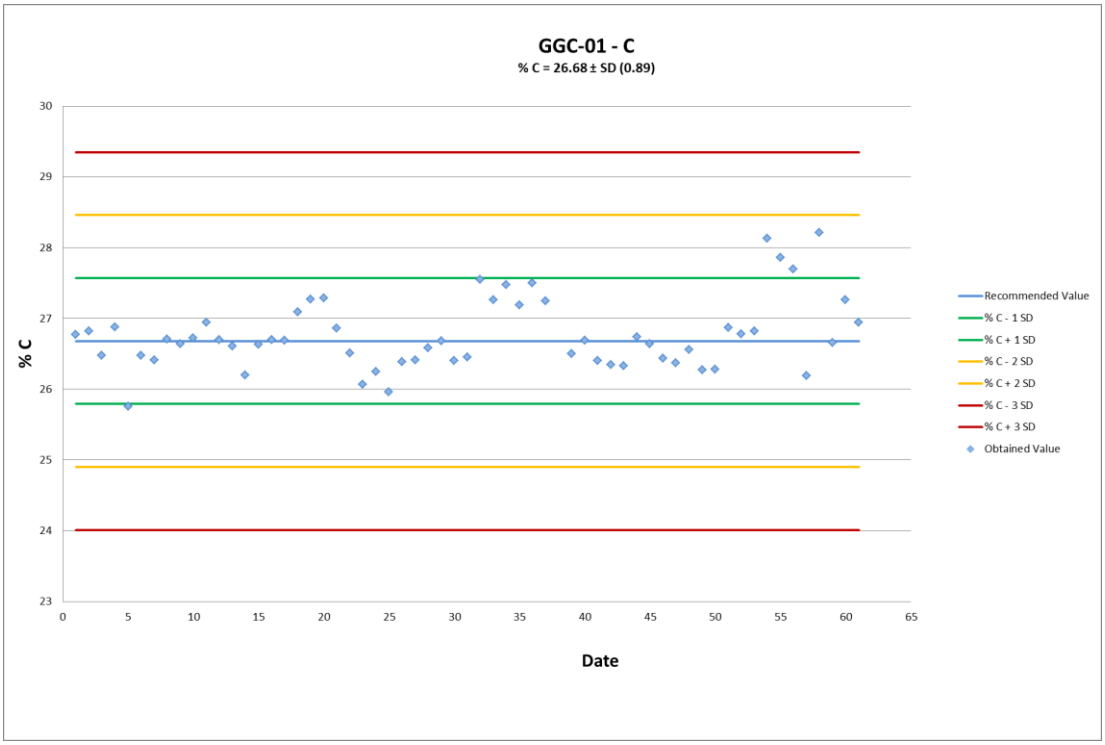


Figure 11-3: Graph showing carbon concentration as analysed in GGC-01.

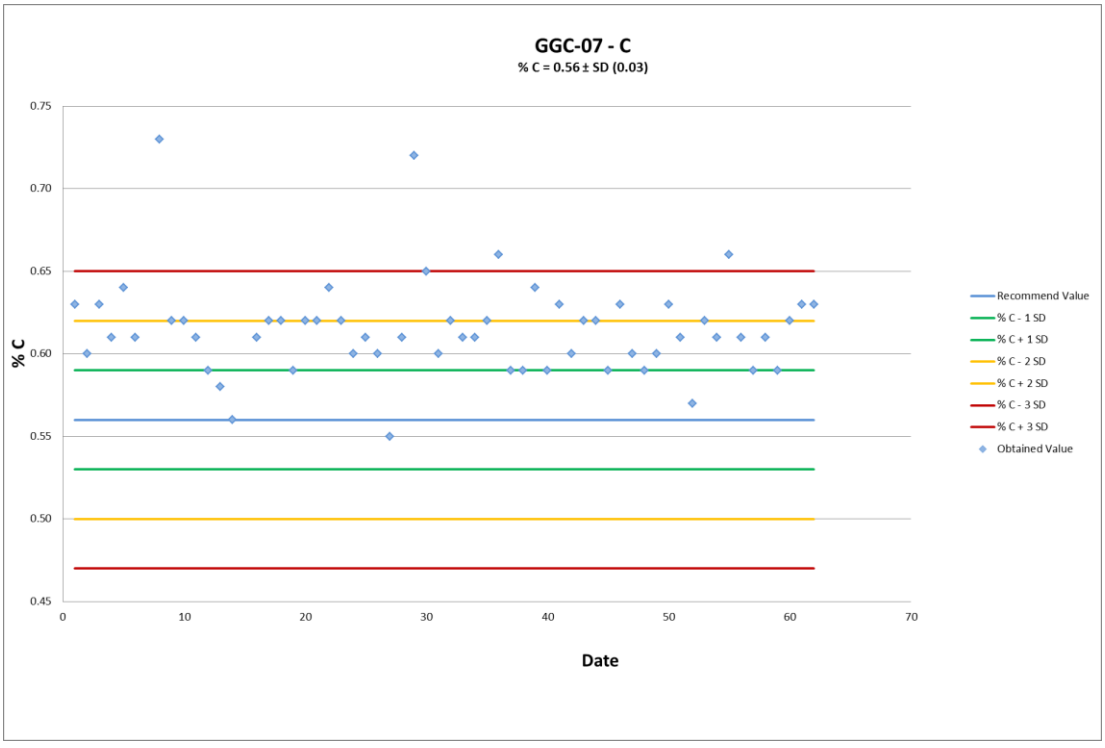


Figure 11-4: Graph showing carbon concentration as analysed in GGC-07.

11.2.3 Field Duplicates

A total of 254 duplicate samples were submitted. To check how close these were to the original samples, a plot of the original samples with a zero, five, and ten per cent difference of the original samples was created (

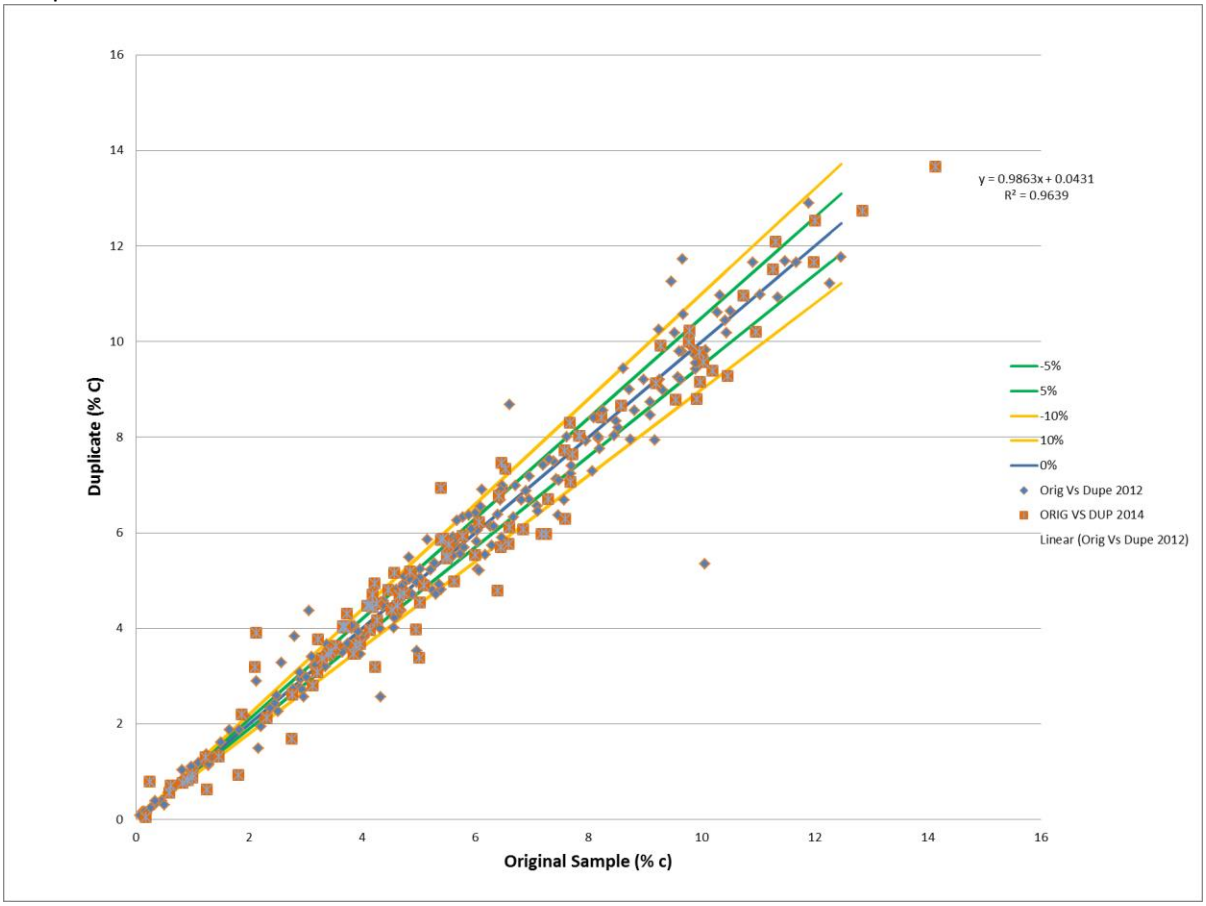


Figure **11-5**). 2012 and 2014 samples are shaded in blue and red respectively. The majority of the samples are within the 10% difference limit. The plot also shows a good correlation between the original value and the duplicate, as is evident from the regression line with an R^2 value of 0.96.

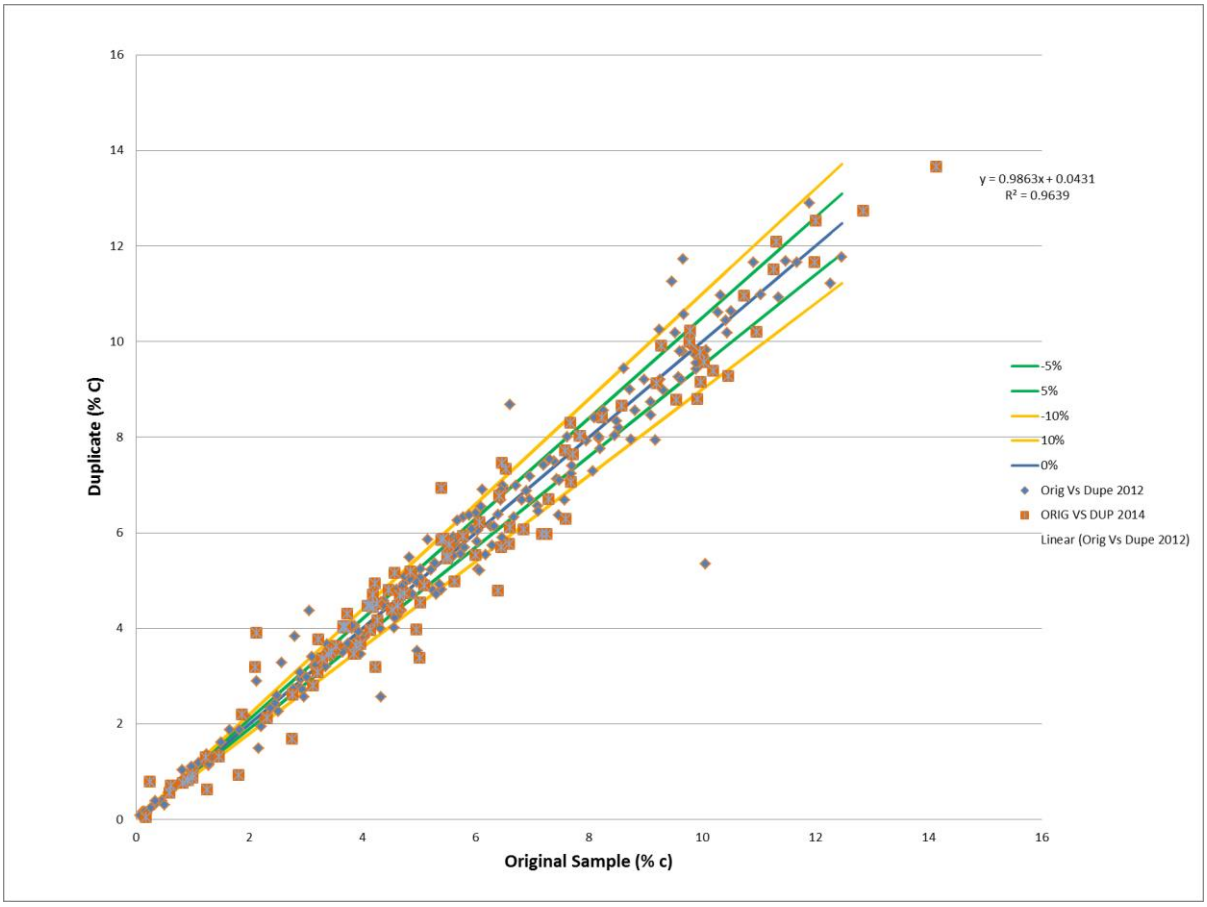


Figure 11-5: Original (Orig) versus Duplicate (Dupe) plots.

11.3 Relative Density

No additional samples were collected for density measurement during the 2014 drill programme. A total of 226 relative density measurements were contained in the database presented to CCIC for Molo.

The process to measure the relative density is as follow:

- Pieces of whole core were collected and the rock types documented;
- The selected section of core is then dipped into wet paraffin wax and allowed to dry. This seals the core to avoid the absorption of moisture;
- The pieces of core are weighed dry, followed by weighing in a water bath.

All data is collected on paper forms and transferred to a spreadsheet for future calculations.

12 DATA VERIFICATION

Prior to CCIC's involvement with Energizer and the Molo Project, all information published regarding the 2011 exploration programme was reviewed by an independent Qualified Person as it became available. The database received by CCIC from Energizer contained 80 drill holes totalling 11,660 m and data from 35 trenches totalling 8,492 m. With regards to the database, CCIC performed various tests to verify the integrity of the collar co-ordinates, logging and sampling procedures, and assay results. Leapfrog™ Geo software (www.leapfrog3d.com/) ("Leapfrog") was used for most of the checks.

12.1 Collar and Down Hole Surveys

During a site visit in 2014, Desmond Subramani randomly selected four drill hole collars to validate. All four drill hole collars were physically located and plotted within the accuracy of the handheld GPS unit being used for validation. While on site, Energizer was in the process of undertaking a topographic survey and a DGPS re-survey of all drill hole collars.

To verify the correct position of the re-surveyed drill hole collars with respect to their elevation, collar co-ordinates were plotted against the surface re surveyed topography of the area (Figure 12-1). The results showed that the re-surveyed collars were within a 25 cm of the surface topography, and therefore all collar co-ordinates were deemed to be correct and were used for the geological modelling.

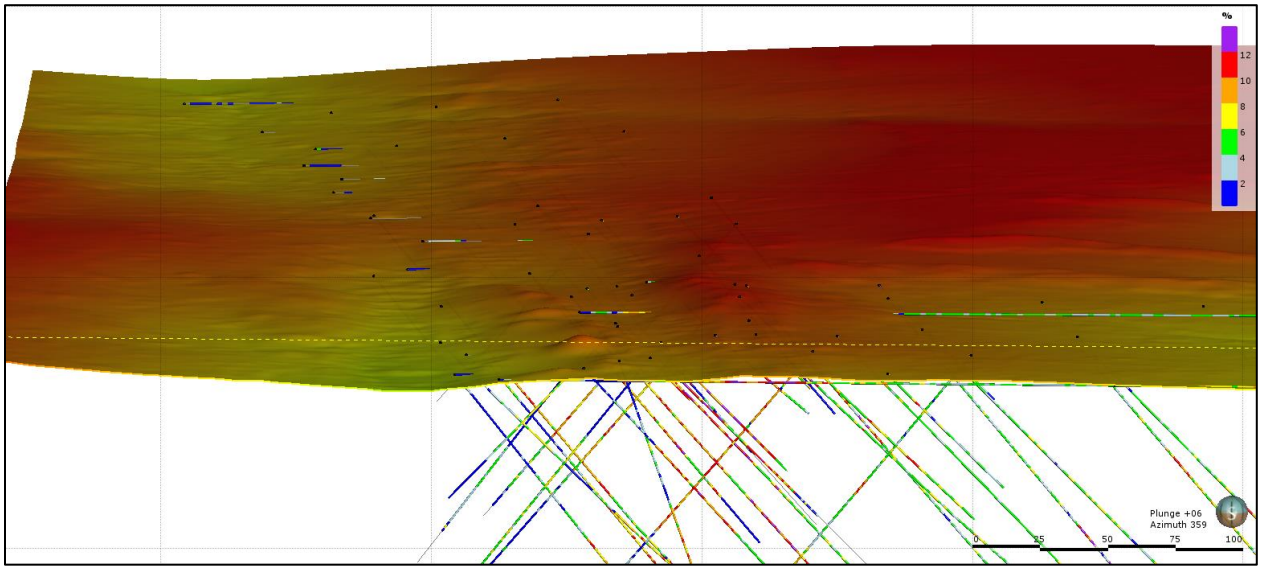


Figure 12-1: East-West cross-section showing the collar positions with respect to topography.

12.2 Drill Logs

During the initial 2012 site visit Dr. Hancox randomly selected two of the 2011 drill holes (Molo-07 and Fotsy-06) to review the log's data against the drill core (Figure 12-2). The holes were check logged to

verify that the intervals in the logs matched the drill core. No discrepancies were observed. Molo-04 and Molo-05 were also examined.



Figure 12-2: Borehole Fotsy-06 - one of the bore holes check-logged during the May 2012 site visit.

For the 2014 drilling campaign, a CCIC Geologist (Mr W. Ngangolo) supervised the drilling, logging and sampling. Drill hole logs were checked in the field, prior to uploading into the Energizer Database, managed by Eric Steffler. Dr. Schneiderhan also undertook various check logs during here 2014 site visit.

Database checks undertaken in the Leapfrog™ software ("Leapfrog") included (but were not limited to) gaps, consistency in the logging codes, and overlaps in the depth 'From' and 'To' entries. No gaps were encountered in the database. There seemed to be some lack of consistency in the sage of the logging codes as initially the graphite bearing unit was termed as either gneiss (Gn) coding, or graphitic gneiss (coded as GfGn). This was later edited by Energizer and the graphite bearing gneiss was finally coded GpGn.

Whilst a few irregularities were encountered with the data supplied, the authors are of the opinion that following on the validation and verification checks, the data is adequate for the level of geological modelling and resource estimation undertaken.

13 MINERAL PROCESSING AND METALLURGICAL TESTING

This item is not required in this Technical Report.

14 MINERAL RESOURCE ESTIMATES

This Mineral Resource Statement is an update on the previous estimate produced by CCIC in December 2012, details of which can be found on Energizer's website (http://www.energizerresources.com/projects/technical-report) or on SEDAR. The approach and methodologies applied in this resource estimation are in accordance with international resource reporting guidelines, including NI 43-101. Leapfrog™ software was used to construct volumetric solids for the zones of mineralisation. The three dimensional resource modeling, as well as the geostatistical techniques for grade estimation was undertaken using Datamine™. The key assumptions and methodologies used for this resource estimate are fully outlined below.

14.1 Geological Database

14.1.1 Topography

A three dimensional ("3D") Digital Elevation Model ("DEM") of the topography was supplied by Energizer Resources as 0.5 m contours in ascii format. These contours were generated from an airborne survey using the SenseFly drones, in 2014. Collar elevations from trenches and drill holes have been resurveyed using a differential GPS and incorporated into the topography. The topography is flat lying, with the highest elevation in the north-western side and dipping gently to the south (Figure 14-1). Elevations within the area of study range from 570 mamsl to 543 mamsl, with an average gradient of 2.0^{o}. The high grade domain on the western side creates a ridge up to 2.0 m in elevation.

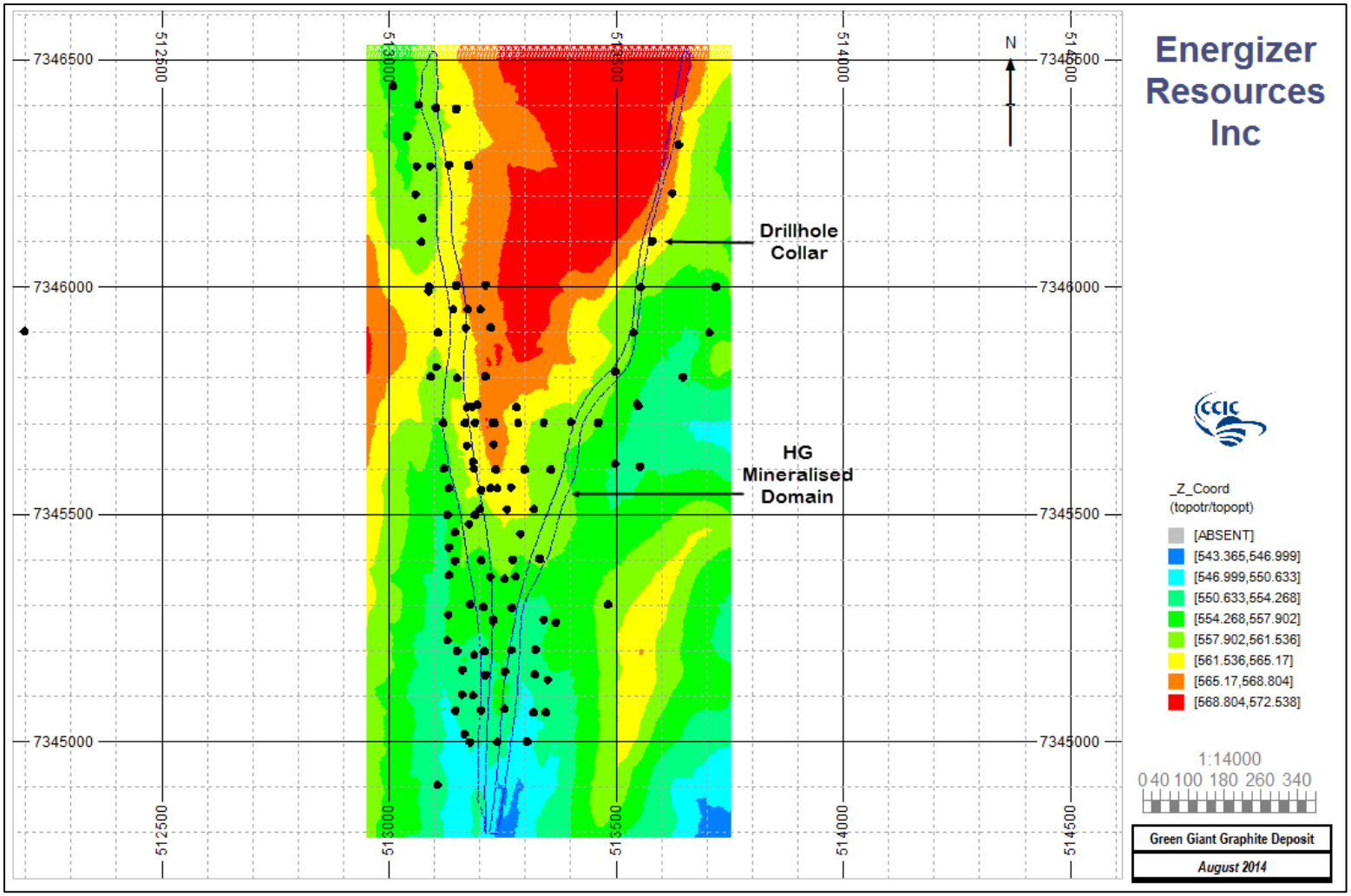


Figure 14-1: Topographic contours. Elevation is in mamsl.

14.1.2 Drill Holes

This Mineral Resource estimate is based on 80 drill holes (total 11,660 m) and 35 trenches (total 8,492 m) drilled by Energizer. Drill spacing varies from 100 m * 100 m in poorly informed areas to 50 m * 50 m in well informed areas. Figure 14-2 below illustrates a plan view of the drill holes and trenches, coloured on % C grades. Drill holes are orientated approximately 45^{o} to the east. The database containing drill hole and trench information was supplied by Energizer in a Microsoft Access format. Logging codes used for lithological modelling are summarised in Table 14-1.

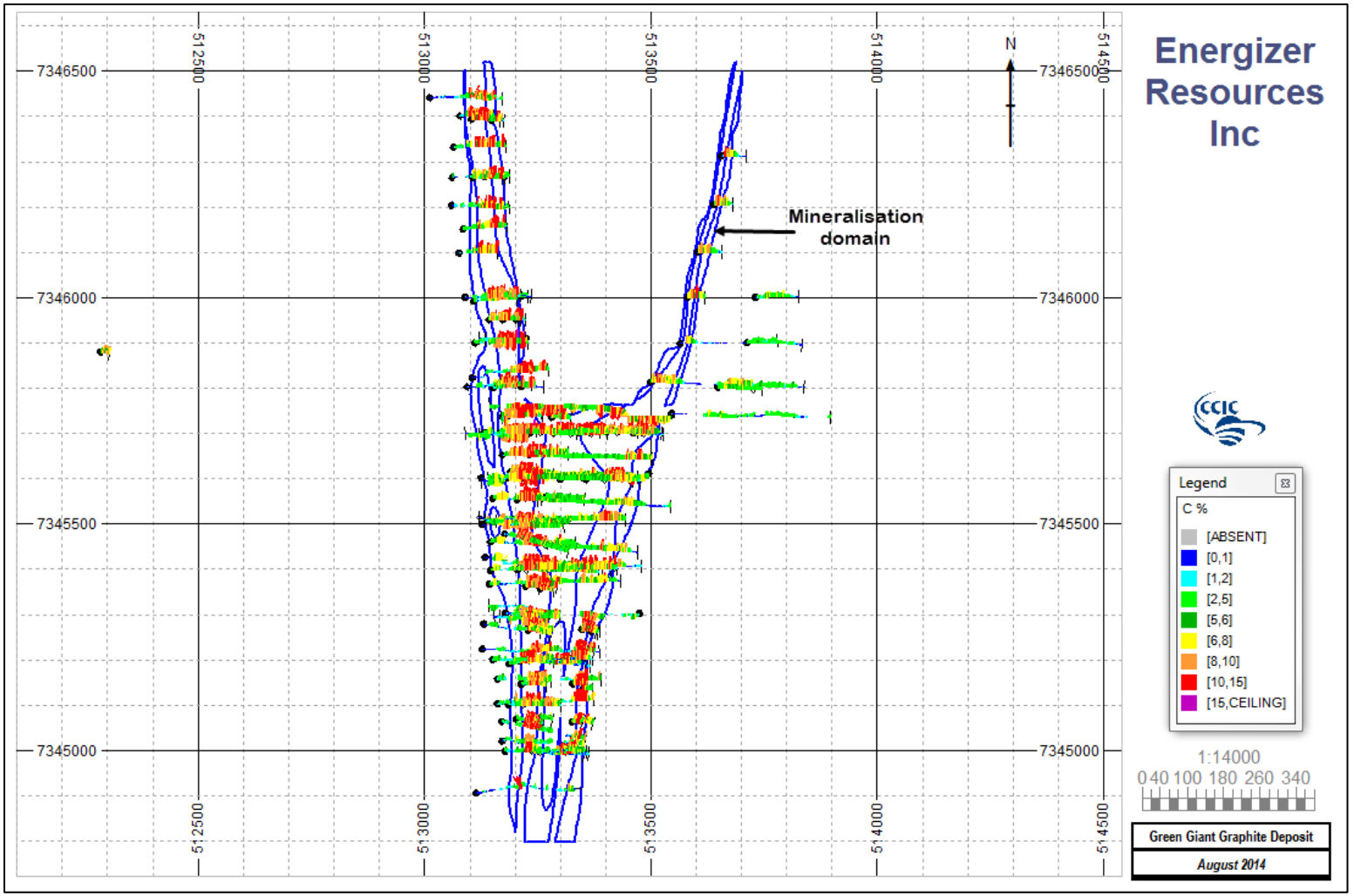


Figure 14-2: Drill hole posting plan coloured on C (%) grades.

Table 14-1: Summary of lithological codes used.

Logging Code	Description
Gp Gn	Graphite Gneiss
Gt Gn	Garnet Gneiss
Mb	Marble
NR	No Return
SAPR	Saprolite
PEG	Pegmatite
OVBN	Overburden

Spatial and statistical comparisons of % C between drill holes and trenches are presented in Figure 14-3 and Figure 14-4. There is good spatial and statistical correlation between the two datasets. Overall, trenches show a slight positive bias for the Mean. Reason for this may be because the infilling drilling program focussed on upgrading the higher grade portions of the deposit.

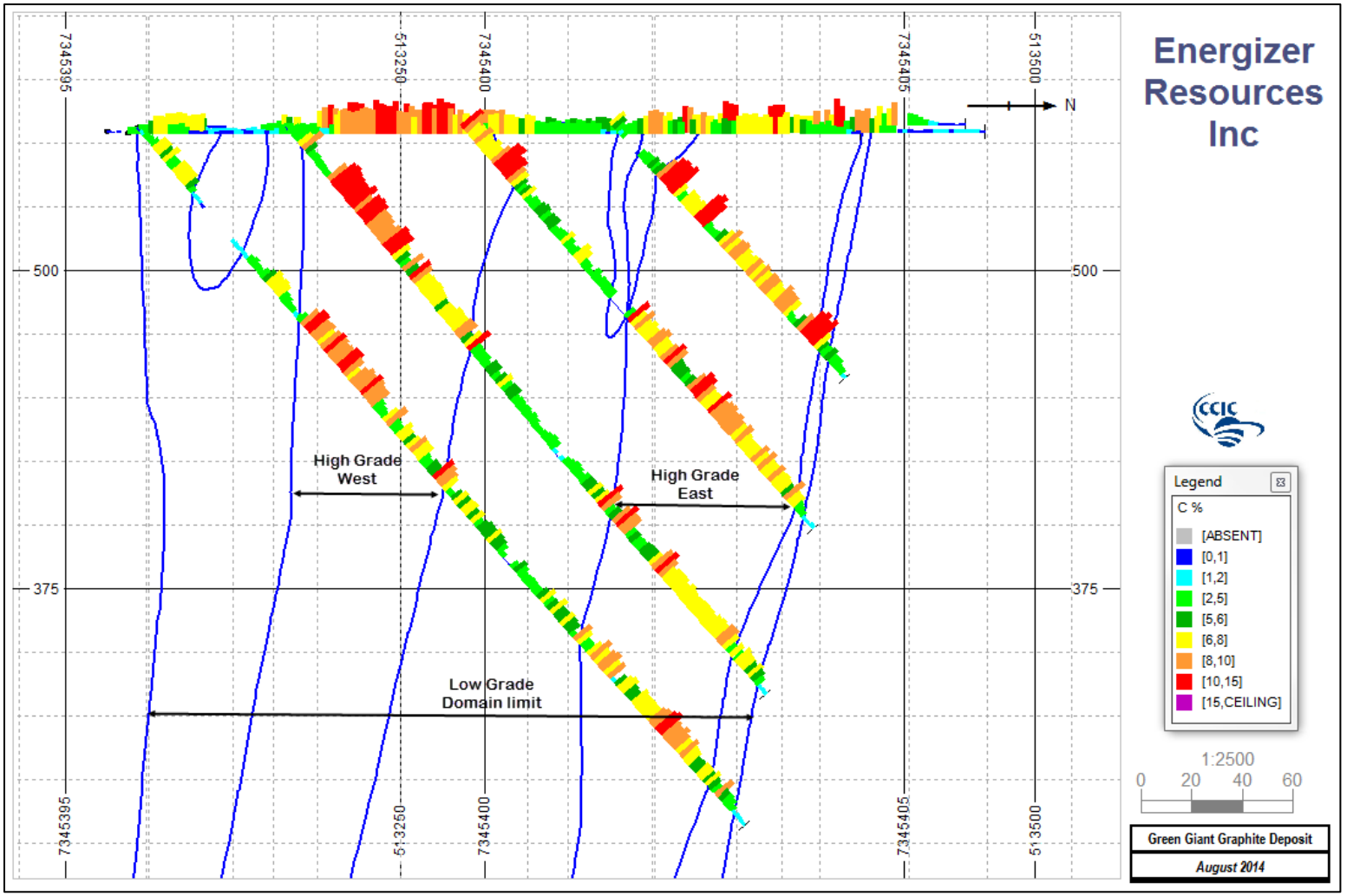


Figure 14-3: Cross Section showing the grade distribution (C %) in the drill holes and trenches.

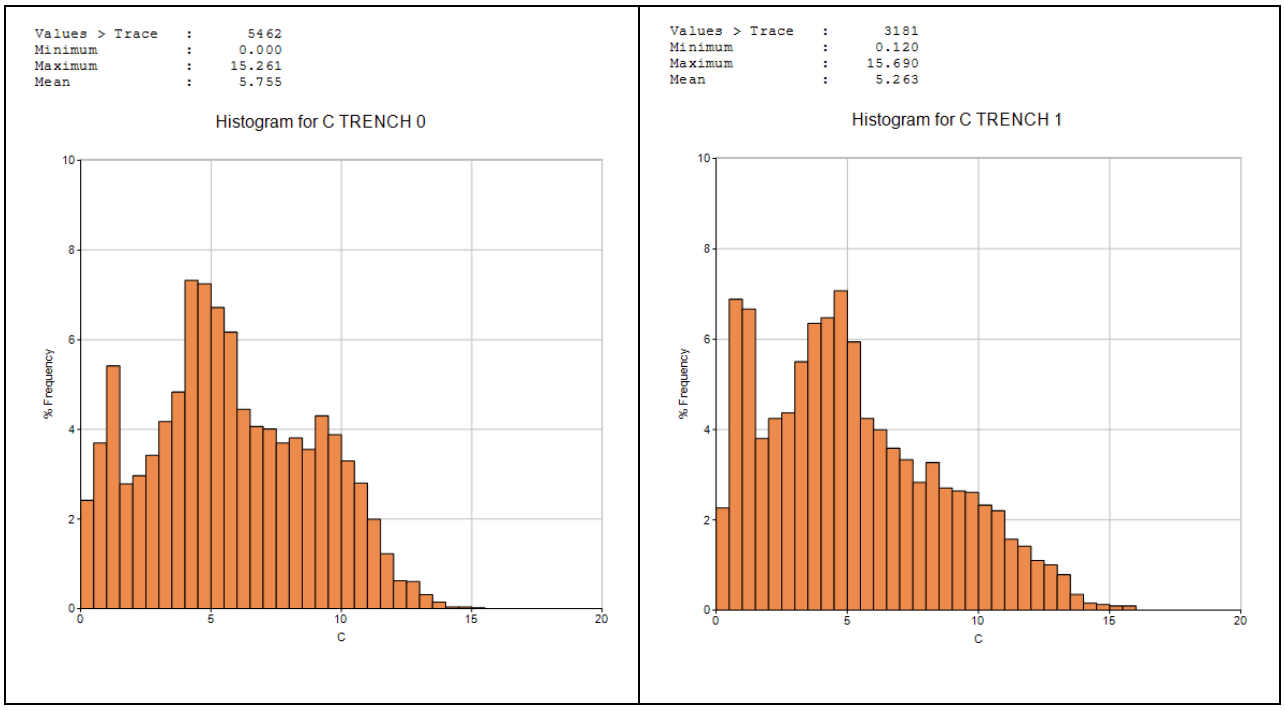


Figure 14-4: Statistical comparisons between diamond drill hole (DD) and trench (TH) samples.

14.1.3 Relative Density

A total of 226 RD measurements are contained in the Molo database, 179 of which were for the graphitic gneiss (GpGn). These are presented as a histogram in Figure 14-5 below. The average RD for all 226 readings is 2.39 t/tm^3. RD values within the GpGn range from 1.59 t/tm^3 to 2.95 t/tm^3, with an average of 2.35 t/tm^3.

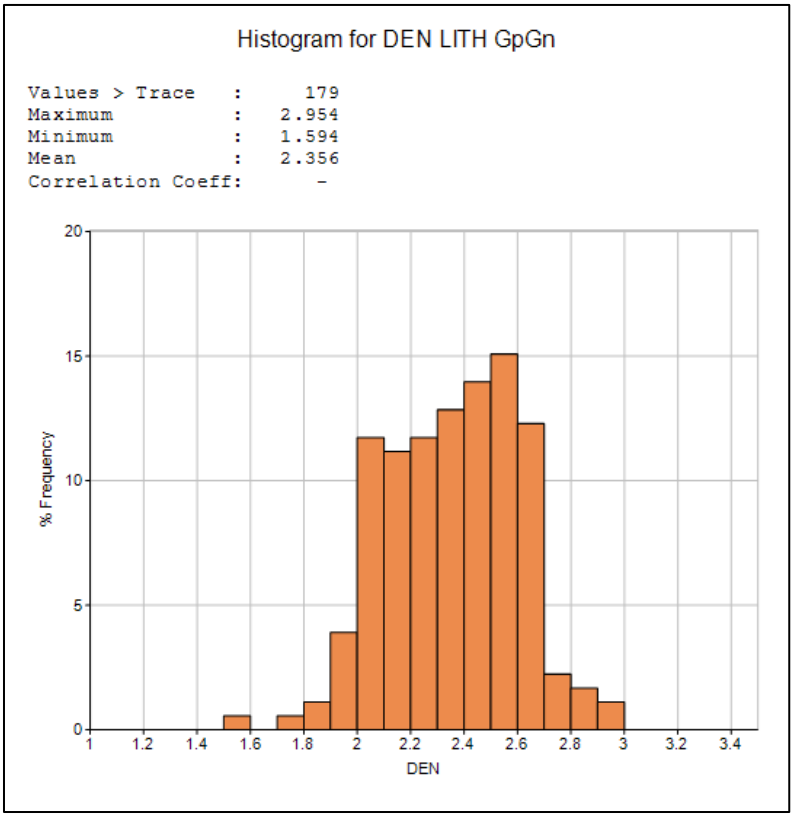


Figure 14-5: Histogram of relative density readings within the graphitic gneiss.

14.2 Geological Model on which the Grade Estimation is based

14.2.1 Grade Domaining

The deposit is split into three domains of mineralisation, namely:

- A "barren" or "unmineralised" domain. This is a lithological boundary that separates the unmineralised Garnet Gneiss from the mineralised Graphitic Gneiss. This boundary was treated as a "hard" boundary during grade domaining and estimation.

- The mineralised Graphitic Gneiss has been sub-domained into separate "low grade" and "high grade" domains, based on C grade characteristics. Histogram (Figure 14-6) of C grades prior to sub-domaining illustrates a bimodal distribution. A threshold grade of 6 % C was therefore used as a guideline to sub-domain the "low' and "high" grade zones, while maintaining spatial continuity.

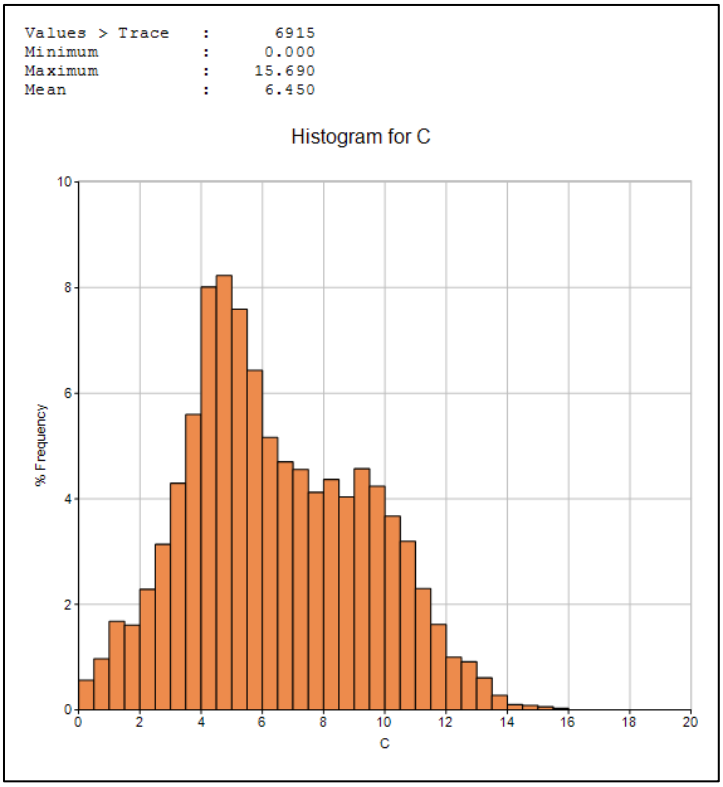


Figure 14-6: Histogram of C distribution.

14.2.2 Grade Domaining using Leapfrog

Leapfrog is an implicit 3D modelling engine that works of a Radial Basis Function. The modelling methodology differs from the traditional way of deterministically digitising out the zones of interest along section lines, then stitching them together to create a 3D wireframe. Leapfrog is instead based on an algorithm that uses all the data points in 3D space, together with geological constraints and parameters to automatically generate volumes of interest. The benefits of using Leapfrog are that:

- Interpretations are not limited to drill holes along a section line. Incorporating drill holes from neighbouring section lines makes the model a full 3D interpretation, ensuring good correlation between section lines;
- The algorithm can generate very complex forms, resulting in more efficient domaining; and
- Because the “low” and “high grade” domains are generated concurrently, there are no overlaps or protrusions between domains.

The contacts for the three domains were flagged using the “Interval Selection Tool” in Leapfrog, which allows the user to interactively determine the intervals that are to be included, or excluded, from the different domains.

The mineralised domain is composed of Graphitic Gneiss, within which occur two lenses of barren Garnet Gneiss. The mineralised domain was further subdivided into a “low grade” domain and two “high grade” lodes. The “high” grade lodes are referred to as “high grade east” and “high grade west” domains. An isometric, and a section view, are illustrated in Figure 14-7 and Figure 14-8 respectively. The mineralisation limits, represented by the graphitic gneiss are shown as pale green, with the barren Garnet Gneiss represented as a white background. Mineralisation strikes approximately north-south, dipping between 75^{o} and 80^{o} to the west. The thickness of the “low grade” zone varies from 60.0 m, where only the “high grade west” domain is developed, to more than 260.0 m in the central portions. “High grade” domains are generally 60.0 m thick, thinning to the south.

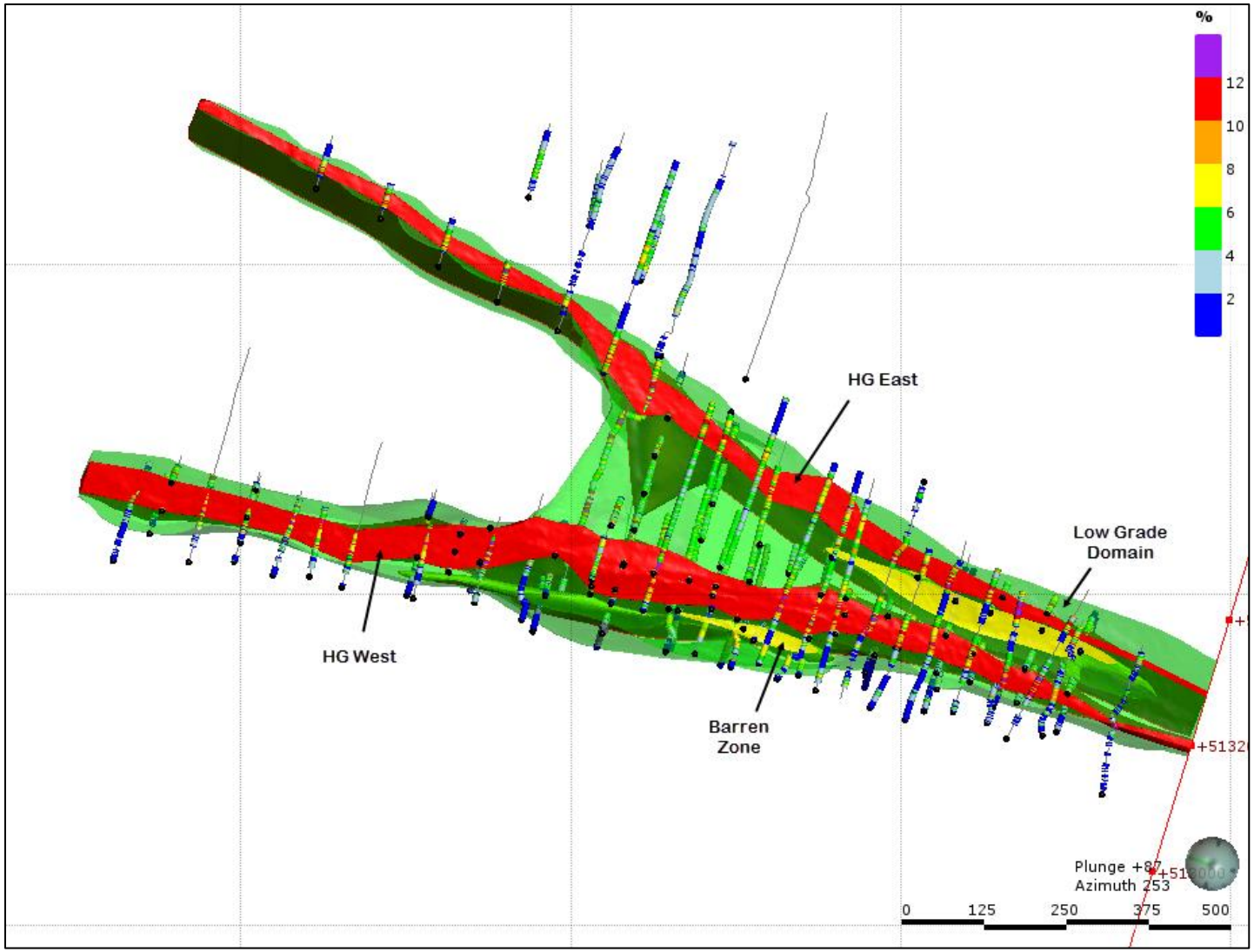


Figure 14-7: Isometric view showing “low” and “high” grade domains.

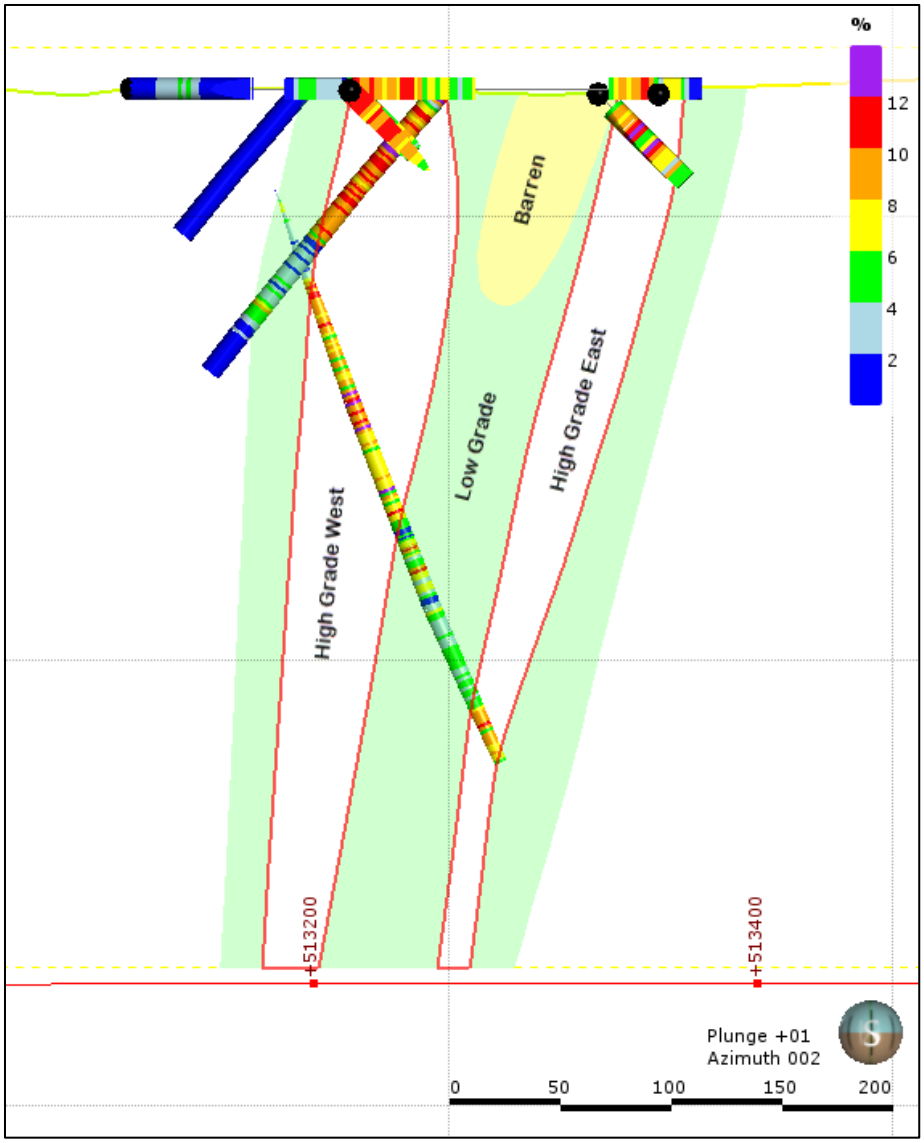


Figure 14-8: West East section showing the "low" and "high" grade domains.

14.2.3 Domaining in Datamine

The envelopes generated in Leapfrog were imported into Datamine for sample and block model flagging. Due to the gradational nature of the boundary between the "low" and "high" grade domains, boundary analysis was undertaken. As illustrated in Figure 14-9, the contact between the "low" and "high" grade zones was treated as a "soft" boundary. A transition of 5.0 m was used to flag samples from the "high" into the "low" grade zones. The boundary was treated as "hard" from "low" into "high" grade.

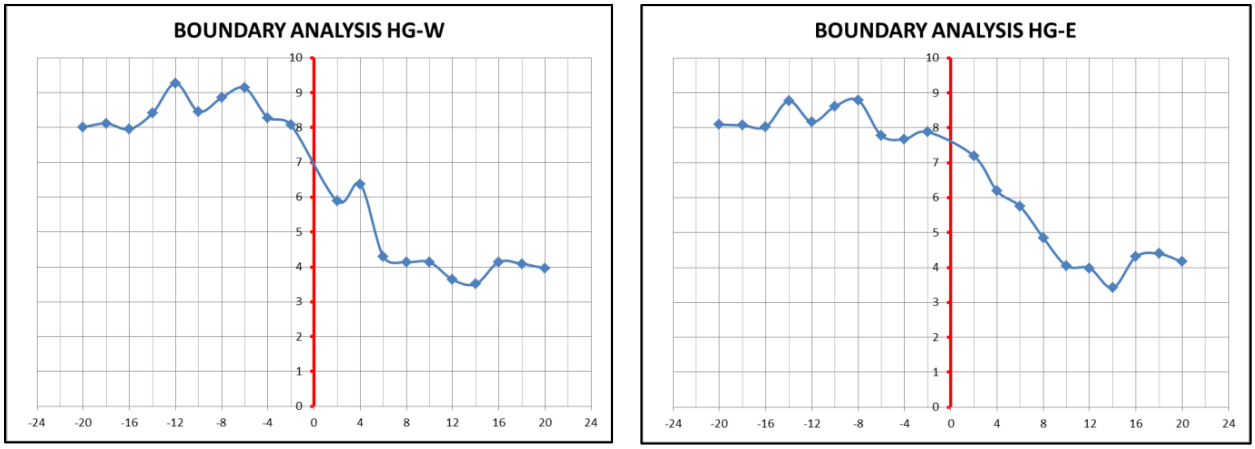


Figure 14-9: "High" and "low" grade boundary analysis.

Zonal flagging in Datamine uses a field called KZONE to distinguish the different grade domains during geostatistical analysis and estimation (Figure 14-10).

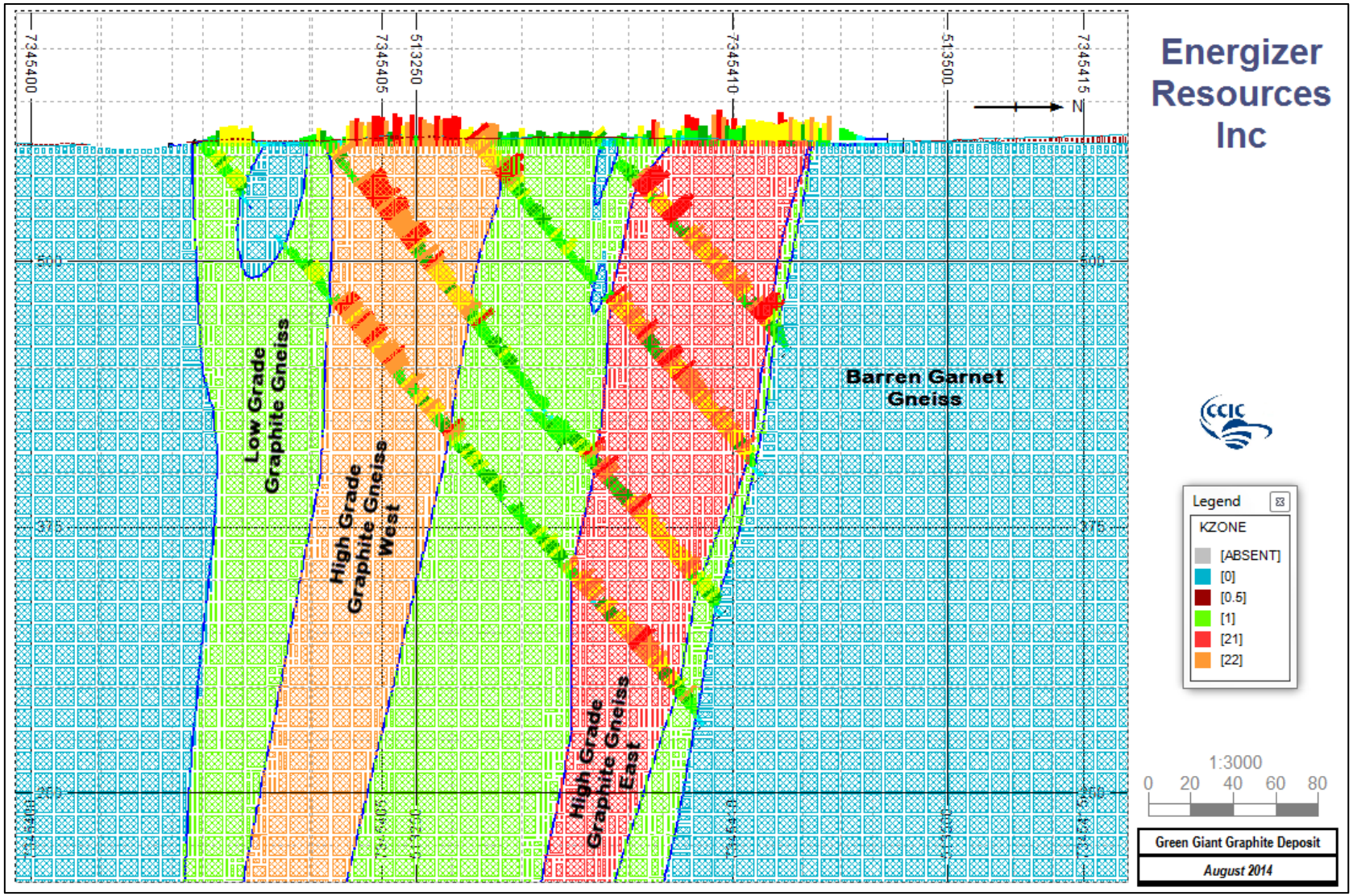


Figure 14-10: Cross-section showing the KZONE flagging in the block model.

A summary of the KZONE flagging undertaken in Datamine is provided below in Table 14-2.

Table 14-2: Summary of KZONE Flagging in Datamine.

Zone Description	KZONE Value	Code Name
Garnet gneiss barren zone	0	WST
Overburden	0.5	OVB
Low Grade mineralised zone	1	LG
High Grade mineralised zone East	21	HG -E
High Grade mineralised zone West	22	HG -W

14.3 Compositing

The predominant sampling interval was either 0.5 m, 1.0 m, 1.5 m or 2.0 m, and hence a composite length of 2.0 m was used to include all samples (Figure 14-11). Compositing used the KZONE to ensure that samples were composited within the different domains. Any samples less than 0.5 m after compositing were excluded from the geostatistical analysis and estimations.

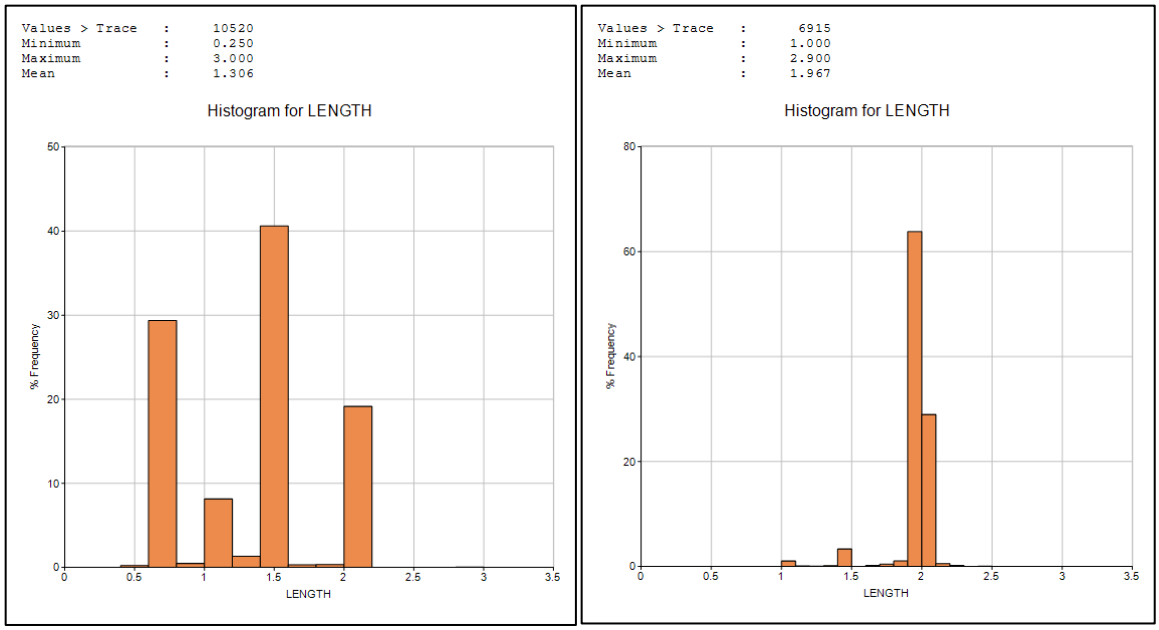


Figure 14-11: Histogram of sample length prior to and after compositing.

14.3.1 Composited Statistics

The sampling protocol for core intervals deemed to be barren with respect to graphite mineralisation is that they were not to be submitted for analyses. All un-sampled intervals have therefore been set to trace prior to compositing and statistical analysis. A statistical summary for the four grade domains is presented in Table 14-3 below.

Table 14-3: Statistical summary of C % per KZONE.

KZONE	0	1	21	22
FIELD	C	C	C	C
NUMTRACE	1730	3274	1282	2359
MINIMUM	0.00	0.00	0.08	0.13
MAXIMUM	15.55	15.31	15.04	15.69
MEAN	**2.07**	**4.63**	**7.72**	**8.30**
VARIANCE	3.10	4.15	5.92	6.97
STANDDEV	1.76	2.04	2.43	2.64
STANDERR	0.04	0.04	0.07	0.05
SKEWNESS	1.88	0.91	-0.06	-0.37
KURTOSIS	5.47	2.36	-0.07	-0.09
LOGESTMN	2.26	5.77	7.93	8.51
CoV	0.85	0.44	0.32	0.32

* STANDDEV = Standard Deviation
* CoV = Coefficient of Variation

The mean of the samples for “LG” (KZONE 1) domain is 4.63 % C, with a positive grade tail up to 15.31% C. The “HGE” (KZONE 21) domain has a mean value of 7.72 % C, Co-efficient of Variance (“CoV”) of 0.32 and a maximum of 15.04 % C. The “HGW” (KZONE 22) domain has a mean value of 8.30, CoV of 0.32 and maximum value of 15.69 % C. Histograms of sample distributions for both Low Grade and High Grade domains are presented in Figure 14-12, Figure 14-13 and Figure 14-4 below. The sample distributions for both the “high grade” domains exhibit very similar statistical characteristics.

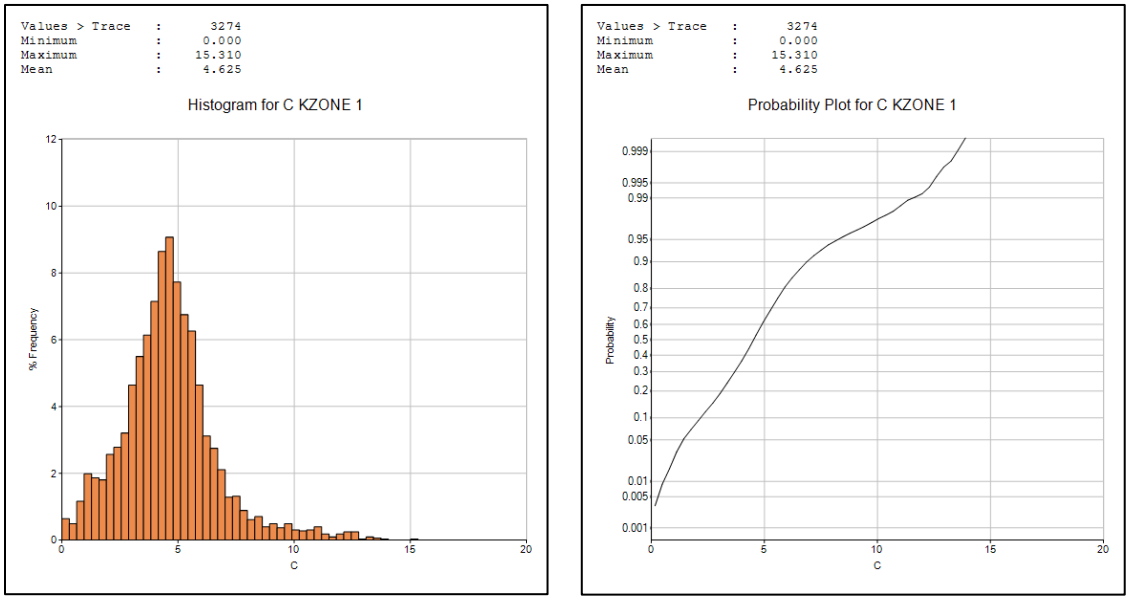


Figure 14-12: Sample distributions for the "low grade" domain.

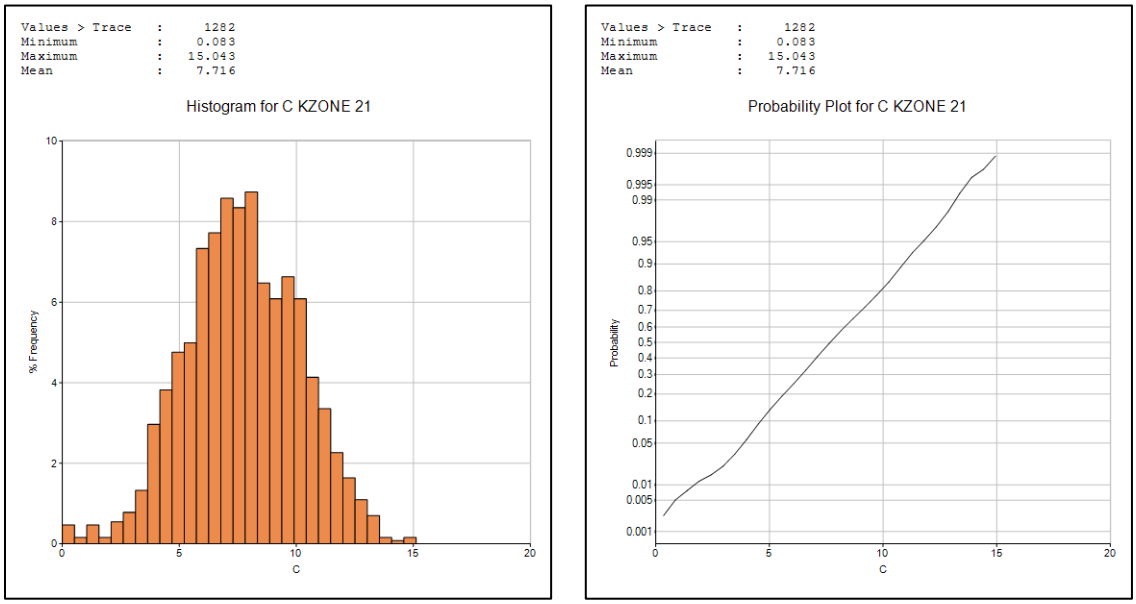


Figure 14-13: Sample distributions for the "high grade east" domain.

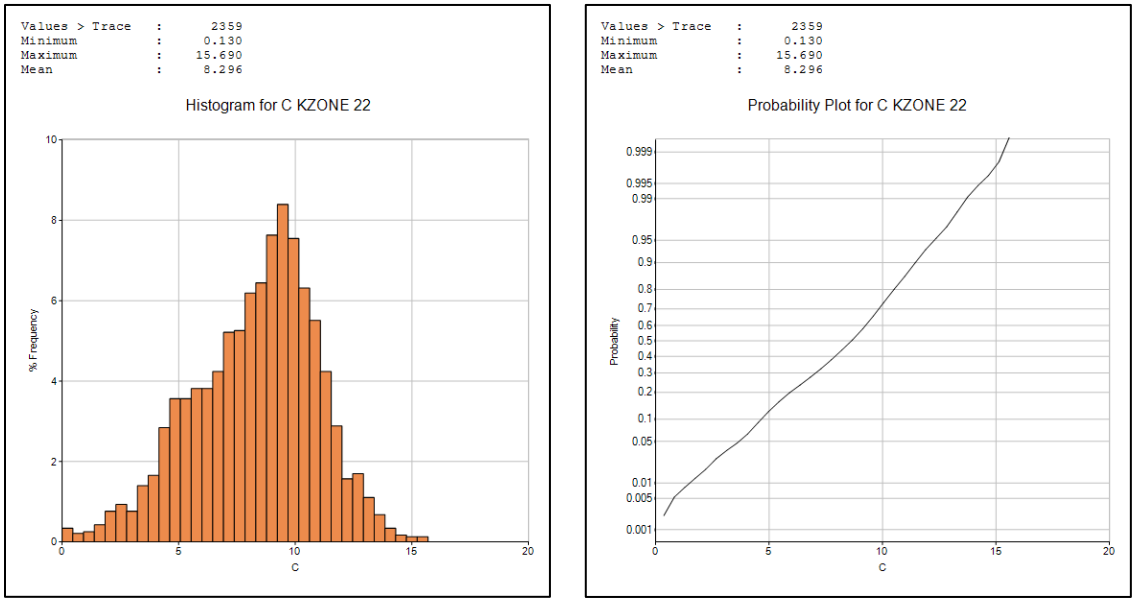


Figure 14-14: Sample distributions for the "high grade west" domain.

14.4 Variography

Variogram analysis and modelling was done using Datamine. Variogram models were generated for % C, for the "low grade", "high grade" east, and "high grade" west domains. The down hole semi-variograms together with their respective Isotropic models are illustrated in Figure 14-15 to Figure 14-17. The nugget for the 'low grade" domain is ~10%, with more than 90% of the spatial variance occurring within the first 120 m. The "high grade" east domain has a nugget of ~10% and a range that extends to 80.0 m. The "High grade" west domain has a nugget of ~10% and a range of 55.0 m. During the grade estimation the isotropic variogram parameters were used in the strike and dip directions, with the down hole parameters resembling the across strike direction.

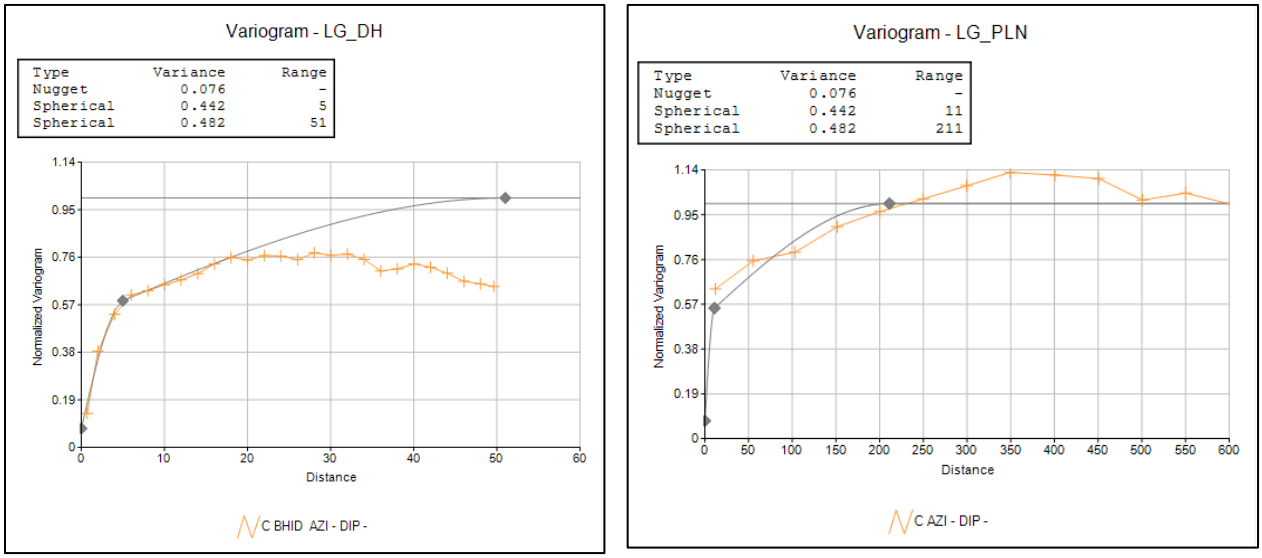


Figure 14-15: Variogram model for "low grade" domain – down hole and isotropic.

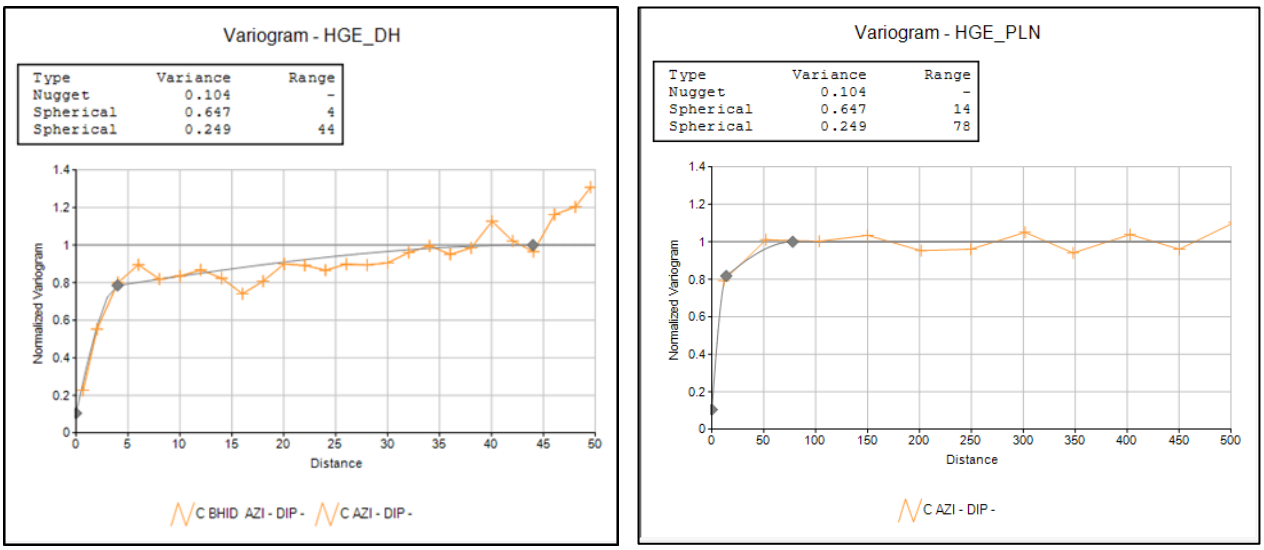


Figure 14-16: Variogram model for the "high grade" east domain – down hole and isotropic.

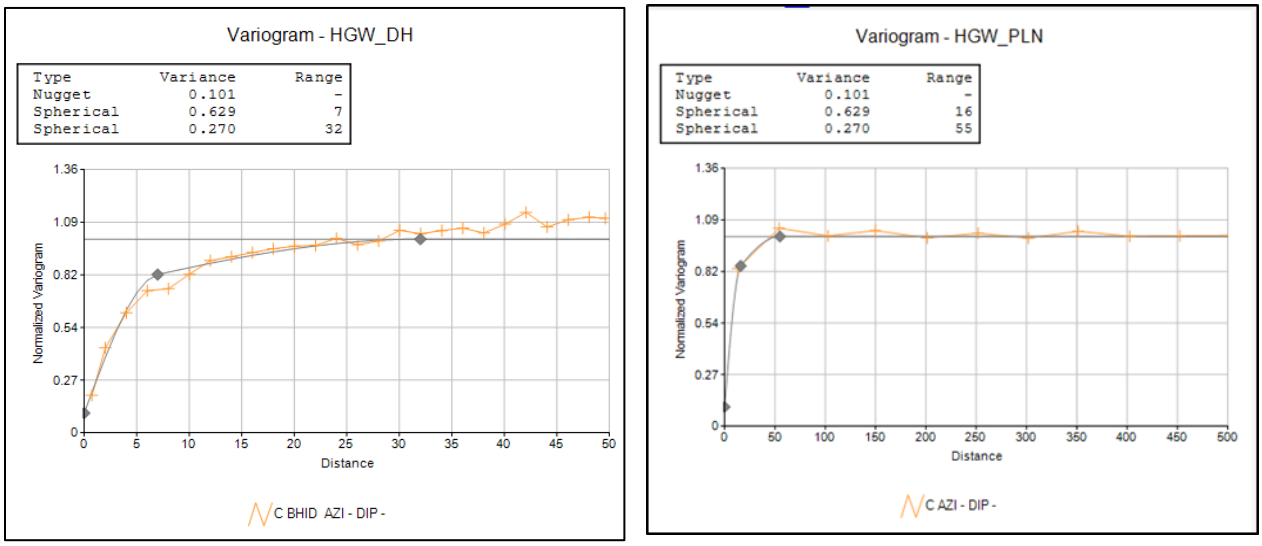


Figure 14-17: Variogram model for the "high grade" west domain – down hole and isotropic.

14.5 Top Capping

The top capping strategy considered various criteria to determine the optimum values. These included:

- Histograms of sample distributions;
- Sample percentiles;
- Spatial locations of "outlier" samples; and
- Validation of model estimates against samples.

A summary of the top capping values that were applied are presented in Table 14-4 below. All samples that were greater than the top capping value were re-set to the top capping value.

Table 14-4: Summary of Top Capping values.

Domain	Capping -% C	Percentile	Number of samples
"LG"	14 % C	99.9%	4
"HGE"	15 % C	99.9%	2
"HGW"	15 % C	99.9%	3

14.6 Grade Estimation

14.6.1 Method

The method of estimations for % C was Ordinary Kriging. Estimations were undertaken using the Estima process in Datamine. Parameters for estimations (i.e. Parent Block size, Search distances and the

number of samples to be used for an estimate) were optimised using Kriged Neighbourhood Analysis, which is explained in more detail below.

14.6.2 Kriged Neighbourhood Analysis

The aim of Kriged Neighbourhood Analysis is to determine the optimal theoretical search and estimation parameters during Kriging so as to achieve an acceptable Kriging Variance and Slope of Regression ("SOR"), whilst ensuring that none or a minimal number of samples are assigned negative Kriging Weights. Once this is determined, practicality is taken into account when deciding on the parameters to be used. This optimisation was based on a representative area within the deposit, using the "high grade" west domain, because this is the most prominently mineralised domain. Figure 14-18 indicates the test location as a block dot with the drill holes coloured on % C values. The following parameters in chronological order were optimised:

- Optimum parent cells size for the block model, in X, Y and Z directions;
- Optimum search distances in the X, Y and Z directions together with determining the appropriate minimum and maximum number of samples required for a reliable estimate.

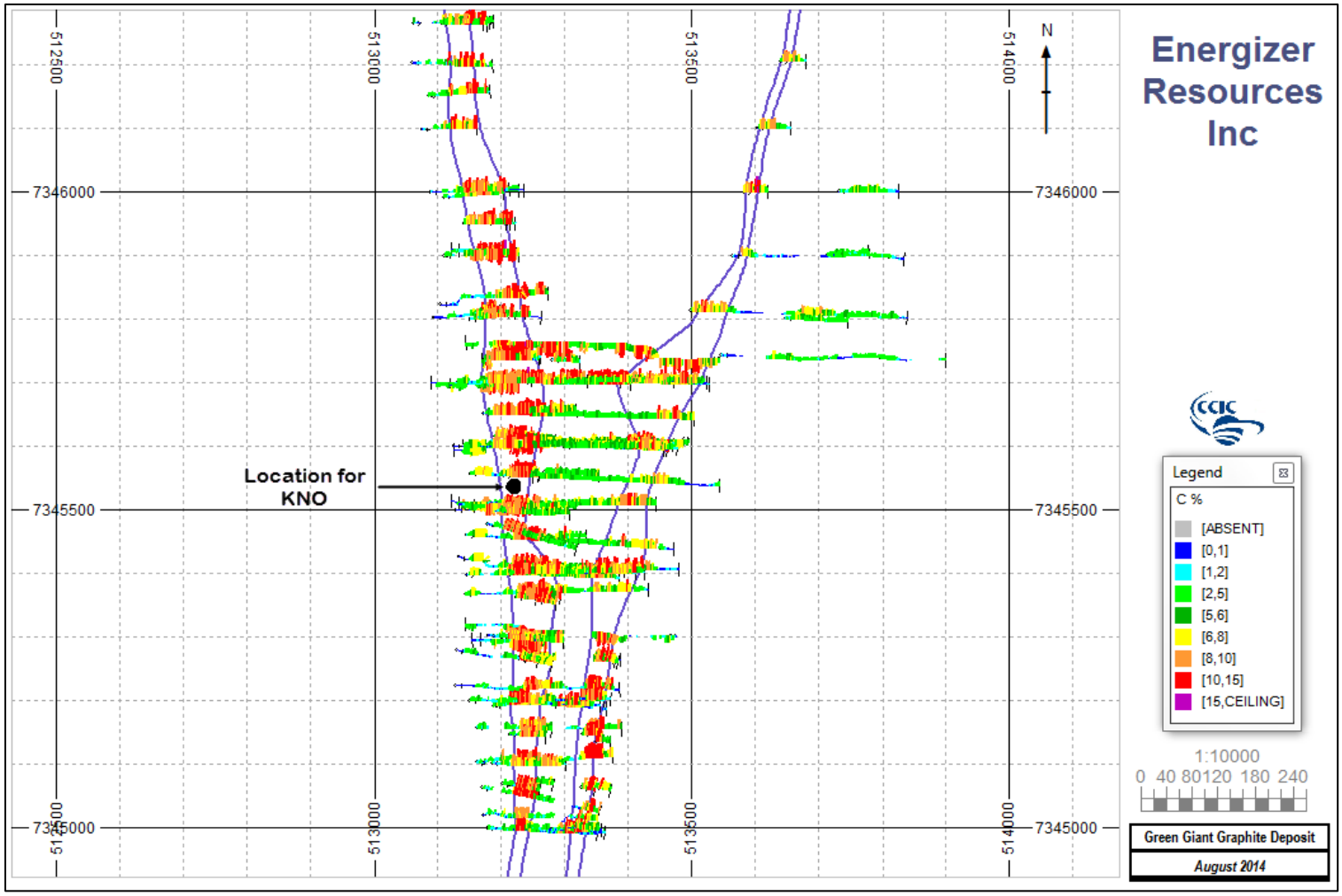


Figure 14-18: Plan showing the location for the Krige optimisations.

During parent cell size optimisation, the approach taken was to use the variogram ranges as a guide to set the search distances, and not to apply any minimum and maximum number of samples to be used. A default parent cell size of 10 m*10 m*10 m was selected using the borehole spacing as a guide. Whilst all parameters remain constant, the parent cell size in the Y direction was set to 5 m and then incrementally increased for each and every estimation. The Estimated Grade (% C), Kriging Variance ("KVAR"), Block Variance ("BVAR"), Kriging Efficiency ("KEF"), SLOR, Number of Samples used ("NUMSAM") and the Percentage of samples with negative Kriging weights ("PCNEGWTH") are recorded for every estimation. These outputs are then plotted against the incremental cell sizes to determine the optimum cell size in the Y direction. The same process is then repeated for the cell sizes in the X direction. Figure 14-19 compares the plot of the incremental parent cell sizes against the KVAR for the Y direction. The optimum parent cell size, taking practical mining constraints into consideration, was set to 40 m*10 m*10 m in the X, Y and Z directions respectively.

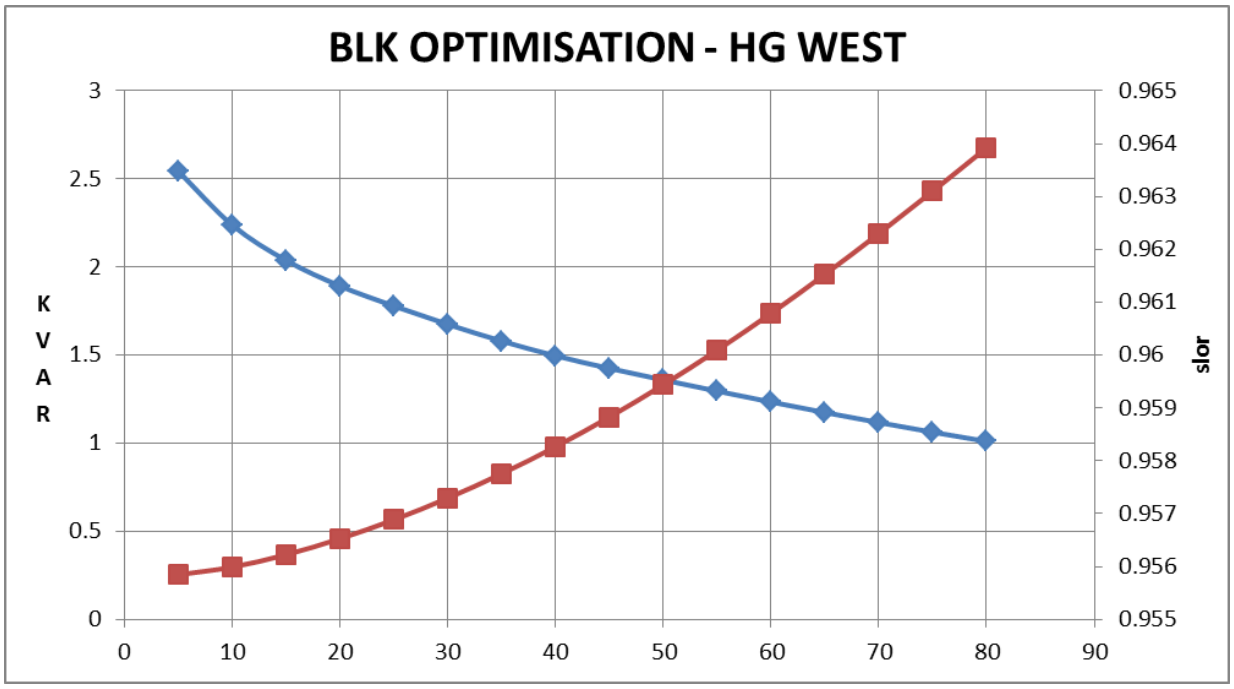


Figure 14-19: Parent cell size optimisations.

During search optimisations, the parent cell size was set to 10 m*40 m*10 m and, as described above, search distance in the X direction was incrementally increased. The results of the search optimisation are plotted in Figure 14-20, which compares both KVAR and SLOR against search distances. Attention is also given the number of samples per estimate and the percentage of samples with negative Kriging weights. The optimum search distance, taking borehole spacing into account, was set as 70 m*40 m*10 m in the X (strike), Y (dip) and Z (across strike) directions respectively. A minimum of 5 and maximum of 100 samples was used per estimate, and was limited to five samples per drill hole.

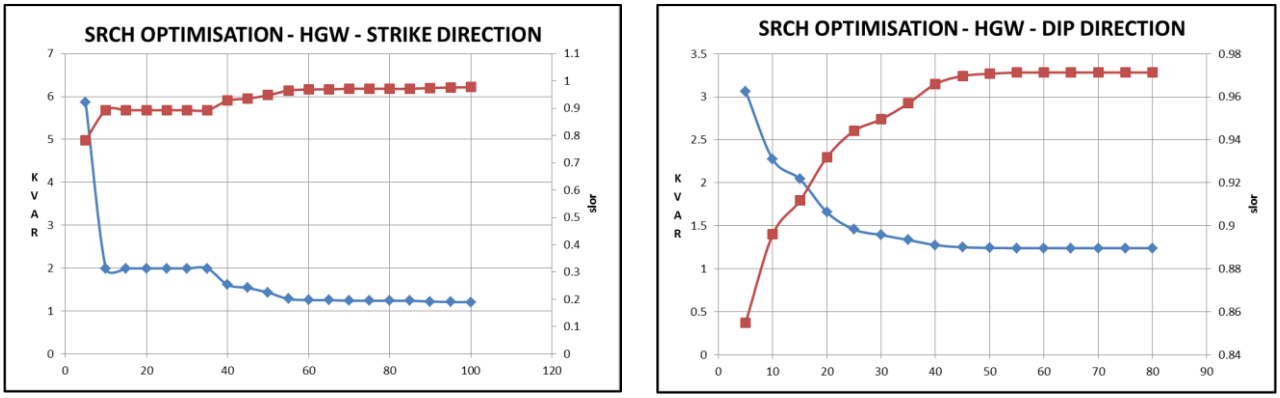


Figure 14-20: Search Distance optimisations.

14.6.3 Model Construction and Parameters

A block model was constructed using a parent cell size of 10 m*40 m*10 m in the X,Y and Z directions, allowing sub-cell splitting to ensure that the volumes of the graphite mineralised zones were represented. Zonal control was applied during grade estimation with each grade domain in the block model assigned a unique KZONE number, as described under Item 14.2.1 (Grade Domaining) above. A section illustrating the block model colour coded by KZONE is shown in Figure 14-21. “Waste” domains have been assigned and estimated for indicative purposes only, and have not been reported in the mineral resource statement.

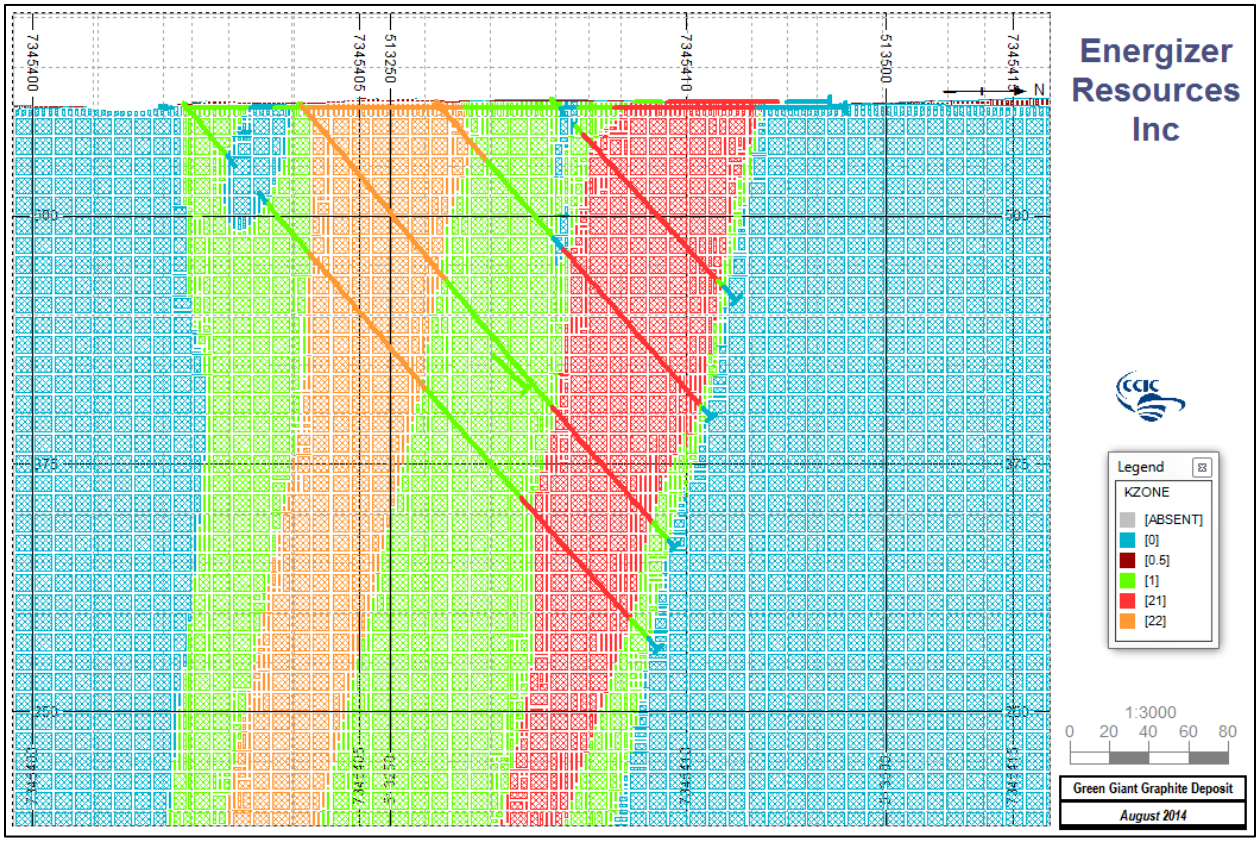


Figure 14-21: Section showing block model coding.

14.6.4 Kriging Parameters

The method for estimating % C was ordinary Kriging. Zonal control was applied, thereby ensuring that samples from a particular domain were constrained to estimating grades only into the block model for that particular domain. The boundaries between the waste and low grade domains were treated as hard boundaries, because it is a distinct lithological contact. Boundaries between the low grade and high grade domains were treated as a soft boundary due to their gradational nature.

Parental cell estimation was used. An expanding search ellipse allowed for cells that were not estimated with the minimum estimation parameters, to be estimated. A second search ellipse was expanded by two times. The following fields are recorded in the estimated block model:

- C – ordinary Kriged estimate for % C;
- KVAR – Estimated Kriging Variance for % C;
- SVOL – Flag to identify which of the two Search Ellipses was used for the % C estimate;
- NUMSAM – Records the number of samples used to estimate % C.

14.7 Model Validation

Model validation included the following:

- Visual comparisons of the estimated grades against the composite sample grades;
- Statistical comparisons for the mean of estimated grades against the mean of the composited samples; and
- Trends (or swath analysis checking) to ensure that the regional grade trends from the drill holes are present in the model. In order to reduce the estimation errors ordinary Kriging tends to have a smoothing effect on the estimates. The objective of this exercise is therefore to ensure that both regional and local trends are best preserved.

A statistical comparison between the composited samples and the model estimates is presented in Table 14-5 below. The mean of the samples is weighted by length, while the model estimates are weighted by volume. The means between sample and model estimates compares favourably.

Table 14-5: Statistical comparisons between the sample and model estimates.

	Sample Composites				Model Estimates	
KZONE	LG	HG-E	HG-W	LG	HG-E	HG-W
FIELD	C	C	C	C	C	C
NSAMPLES	3312	1269	2359	56940	21348	16534
MINIMUM	0.00	0.08	0.13	0.20	0.74	3.85
MAXIMUM	14.00	15.00	15.00	11.60	11.92	11.69
MEAN	**4.68**	**7.75**	**8.36**	**4.58**	**7.56**	**8.17**
VARIANCE	4.41	5.74	6.73	1.71	1.64	1.55
STANDDEV	2.10	2.40	2.59	1.31	1.28	1.25
SKEWNESS	0.95	-0.00	-0.36	0.39	-0.24	-0.17
KURTOSIS	2.20	-0.09	-0.10	1.51	1.40	-0.19
CoV	0.45	0.31	0.31	0.29	0.17	0.15

Block on block analysis compares local trends in the samples against model estimates. The approach here was to divide the study area into 10m*40m*10m blocks in the X, Y and Z direction respectively, and to select samples within each block, and compare their mean against the mean of the model estimates within that same block, per KZONE. Plots comparing the mean of the samples (blue) and mean of the estimates (red) for the high grade domains are illustrated in Figure 14-22 to Figure 14-24. The mean of the estimates are smoother and less variable than that of the samples, while preserving the grade trends of the samples.

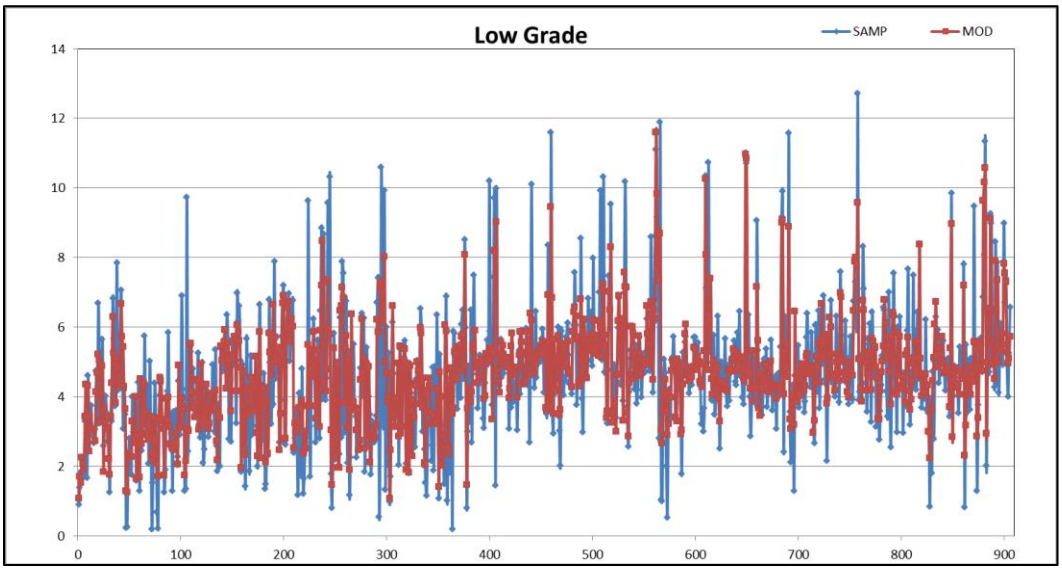


Figure 14-22: Trend Analysis plot for % C, "low" grade domain.

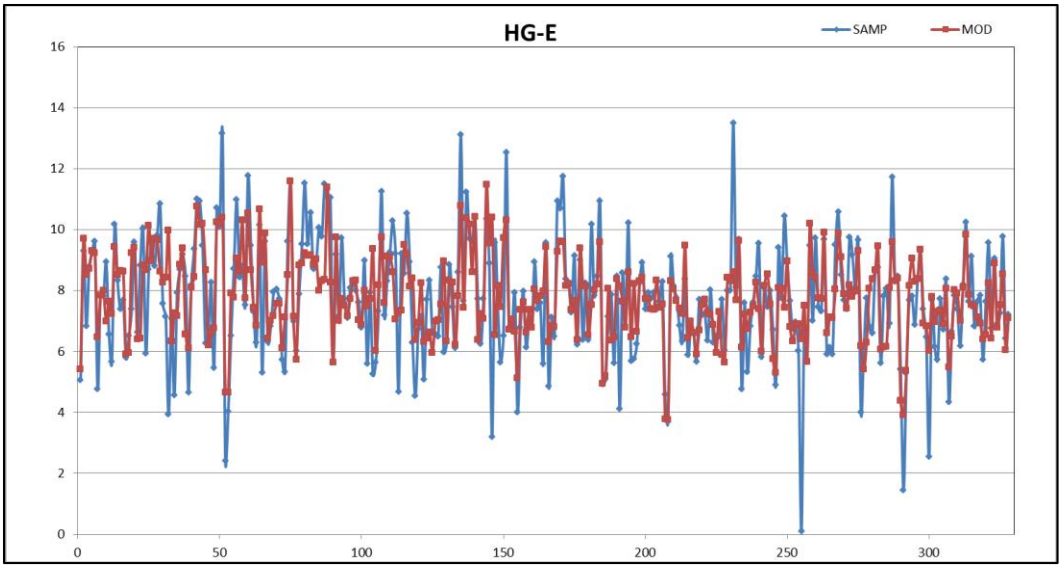


Figure 14-23: Trend Analysis plot for % C, "high" grade east.

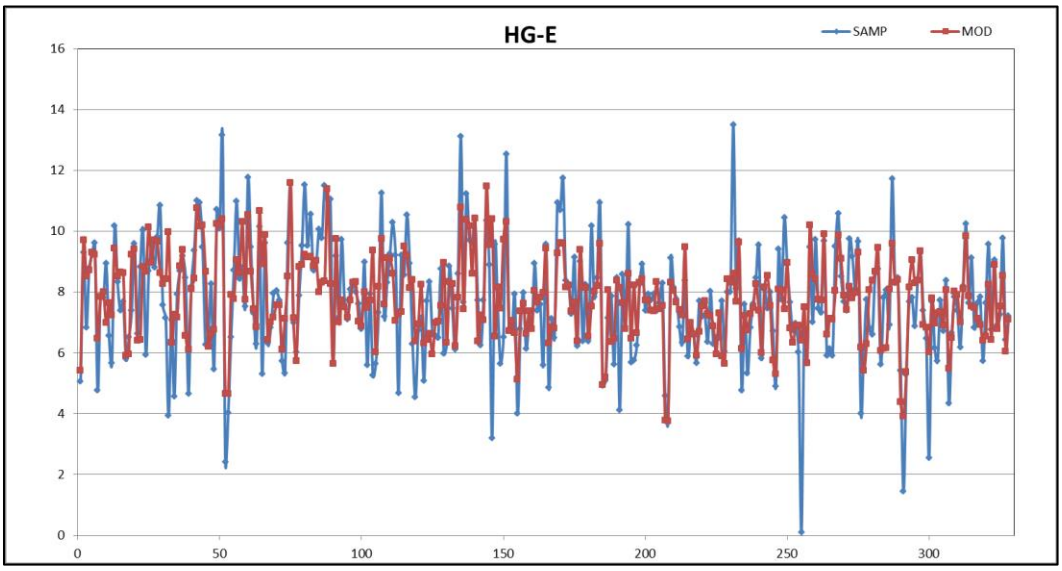


Figure 14-24: Trend Analysis plot for % C, "high" grade west.

14.8 Grade Distribution Plots

Figure 14-25 below is a section illustrating the distribution of the block model superimposed on the drill holes. There is a good correlation between the grades in the drill holes and that of the block model.

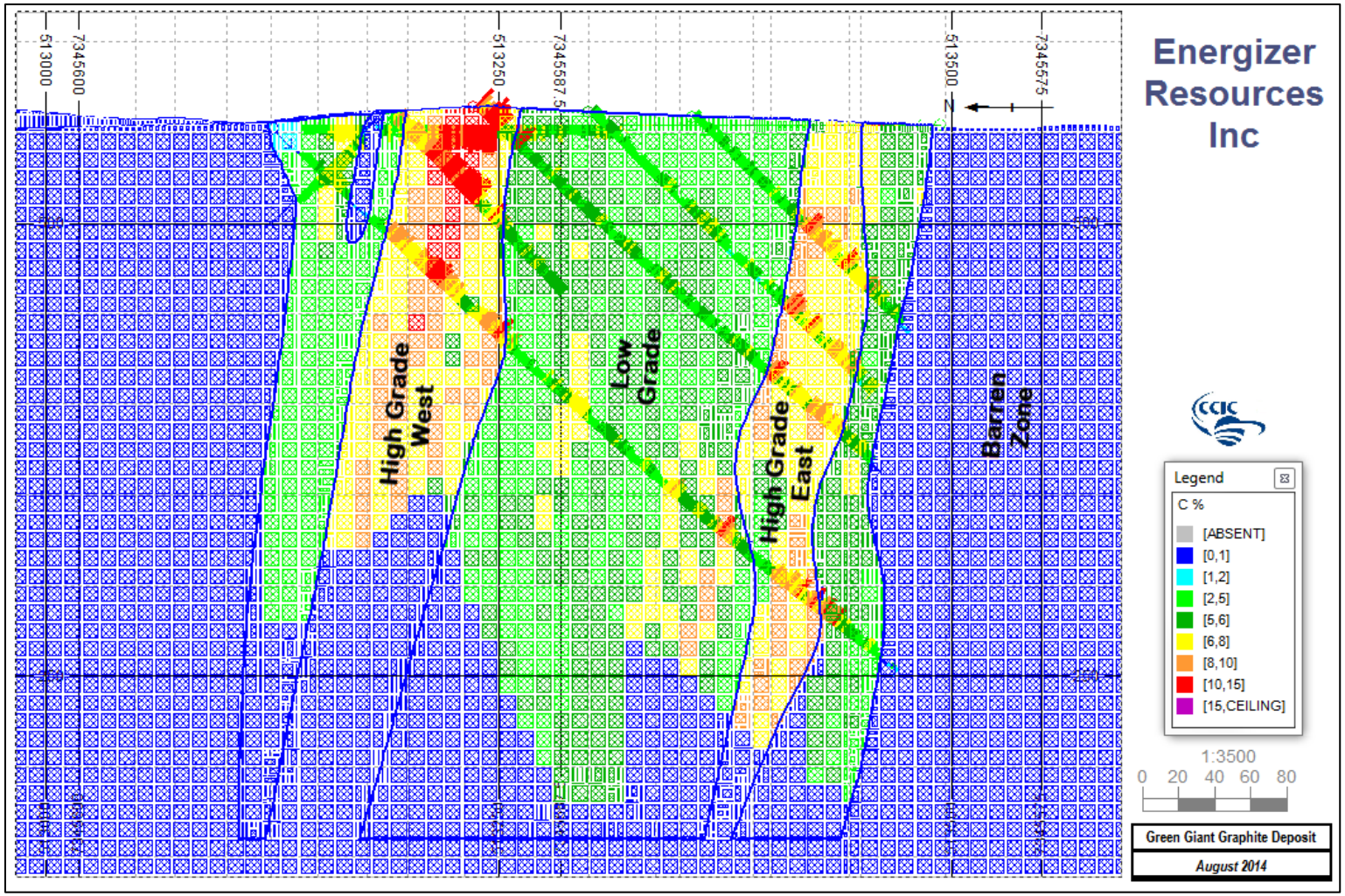


Figure 14-25: Section showing C (%) grade distributions in the model.

The grade tonnage curves for the "low" and "high" grade domains are presented in Figure 14-26 and Figure 14-27. For the "low" grade domain, there is very little variation below a 2% C cut-off, thereafter there is a consistent drop in tonnages and corresponding increase in grade, up to 6.5 % C. For the "high" grade domain, there is very little variation below 4% C, with the majority of this domain occurring between the 6.0 to 10.0 % C range.

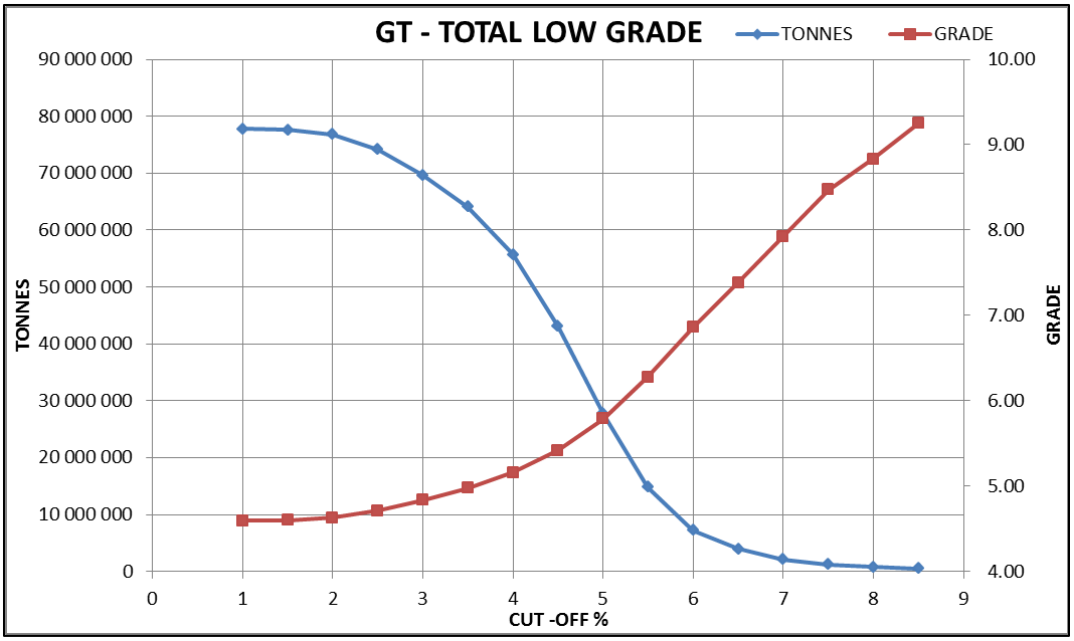


Figure 14-26: Grade Tonnage Curve for the "low" grade domain.

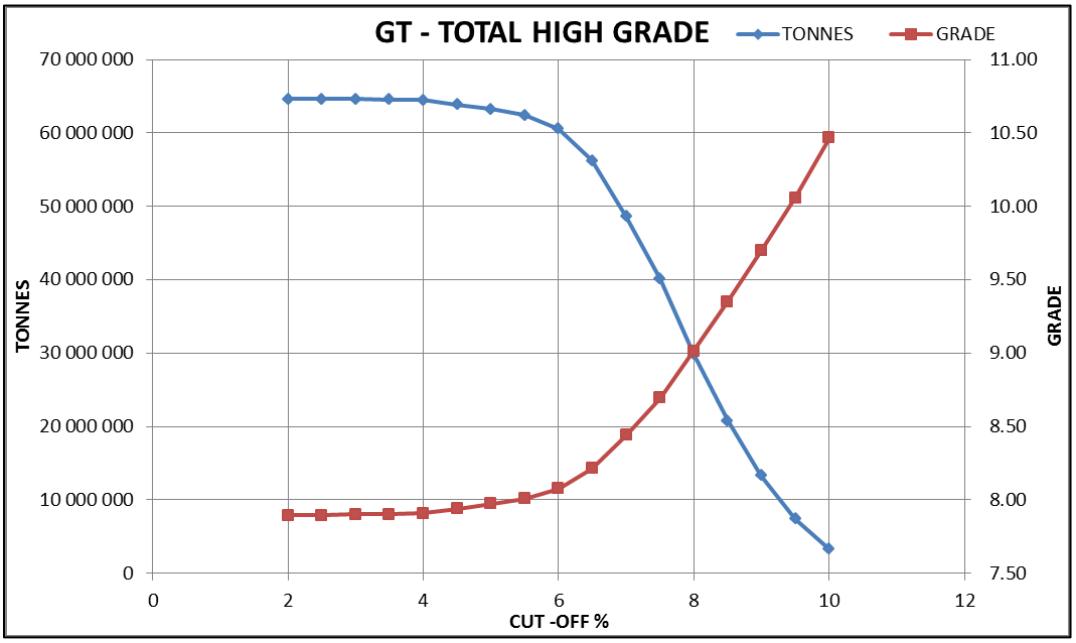


Figure 14-27: Grade Tonnage Curve for the "high" grade domains.

14.9 Resource Classification

The definition of a mineral resource according to the Canadian Institute of Mining ("CIM") reporting code is:

- *A Mineral Resource is a concentration or occurrence of diamonds, natural solid inorganic material, or natural solid fossilized organic material including base and precious metals, coal, and industrial minerals in or on the Earth's crust in such form and quantity and of such a grade or quality that it has reasonable prospects for economic extraction. The location, quantity, grade, geological characteristics and continuity of a Mineral Resource are known, estimated or interpreted from specific geological evidence and knowledge.*

- *Mineral Resources are subdivided, and must be so reported, in order of increasing confidence in respect of geoscientific evidence, into Inferred, Indicated or Measured categories.*

Based on the geological data and information presented in this report, there is sufficient information about the location, shape, size, geological characteristics and continuity of the deposit to declare a resource.

QA/QC protocols and results indicate an acceptable level of confidence in the analysis of the samples for these drill holes and trenches. There is also a reasonable correlation between drill hole and trench data.

Drill hole spacing varies from 100 m by 100 m in some areas, to 50 m by 50 m in other areas especially within the first five years of mining footprint. The well informed areas provide adequate geological confidence to place the resources into the Measured Category. Hence, the resource classification methodology (Figure 14-28 and Figure 14-29) was based on the following criteria:

- Areas with drill spacing less than 50 m by 50 m, was considered for Measured Resources;

- Areas with drilling of 50 m along dip and 10m along strike, was considered for Indicated Resources;

- Areas within the 100 m by 100 m drill spacing, was considered for Inferred Resources.

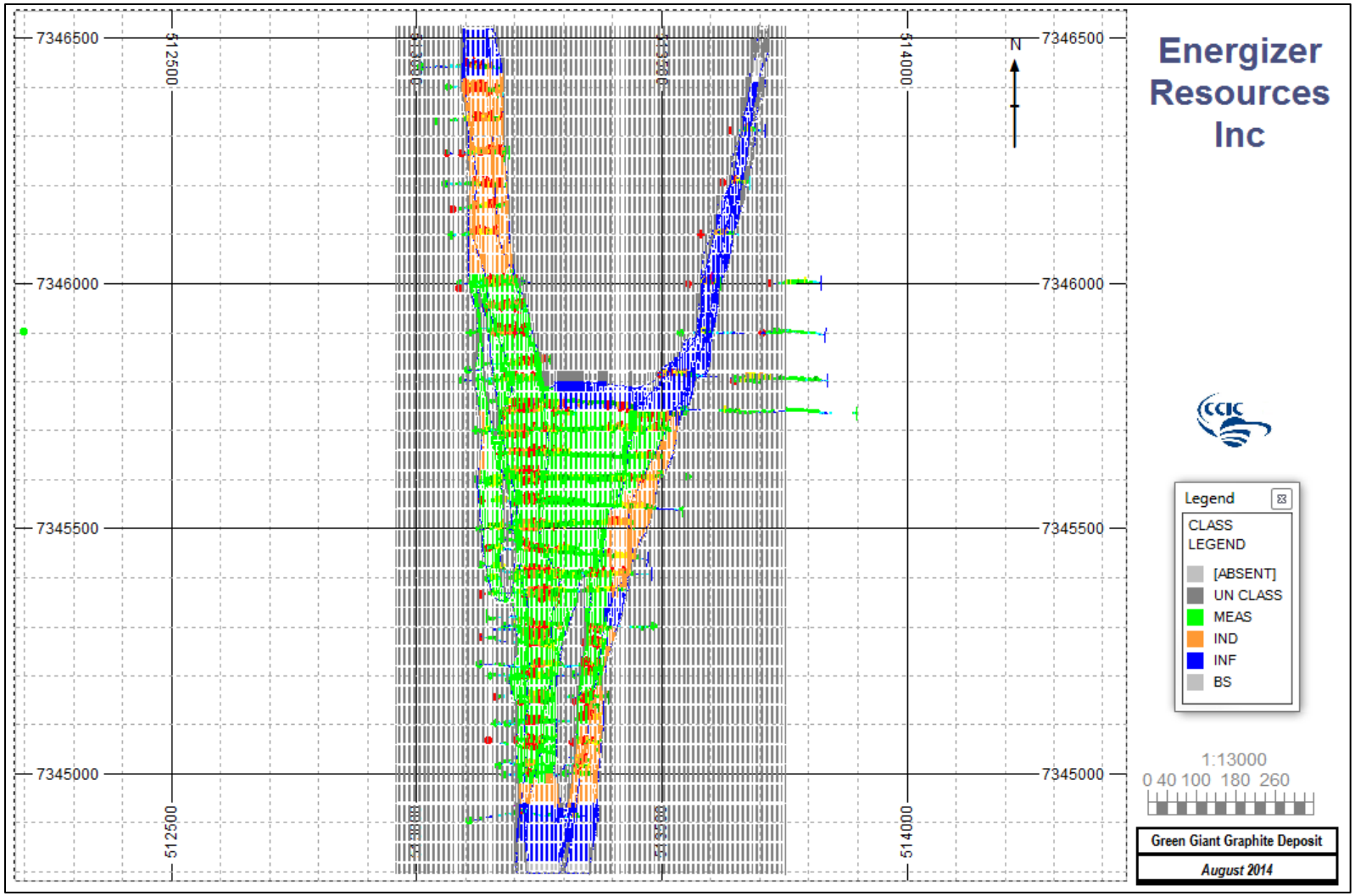


Figure 14-28: Plan showing Mineral Resource Classification.

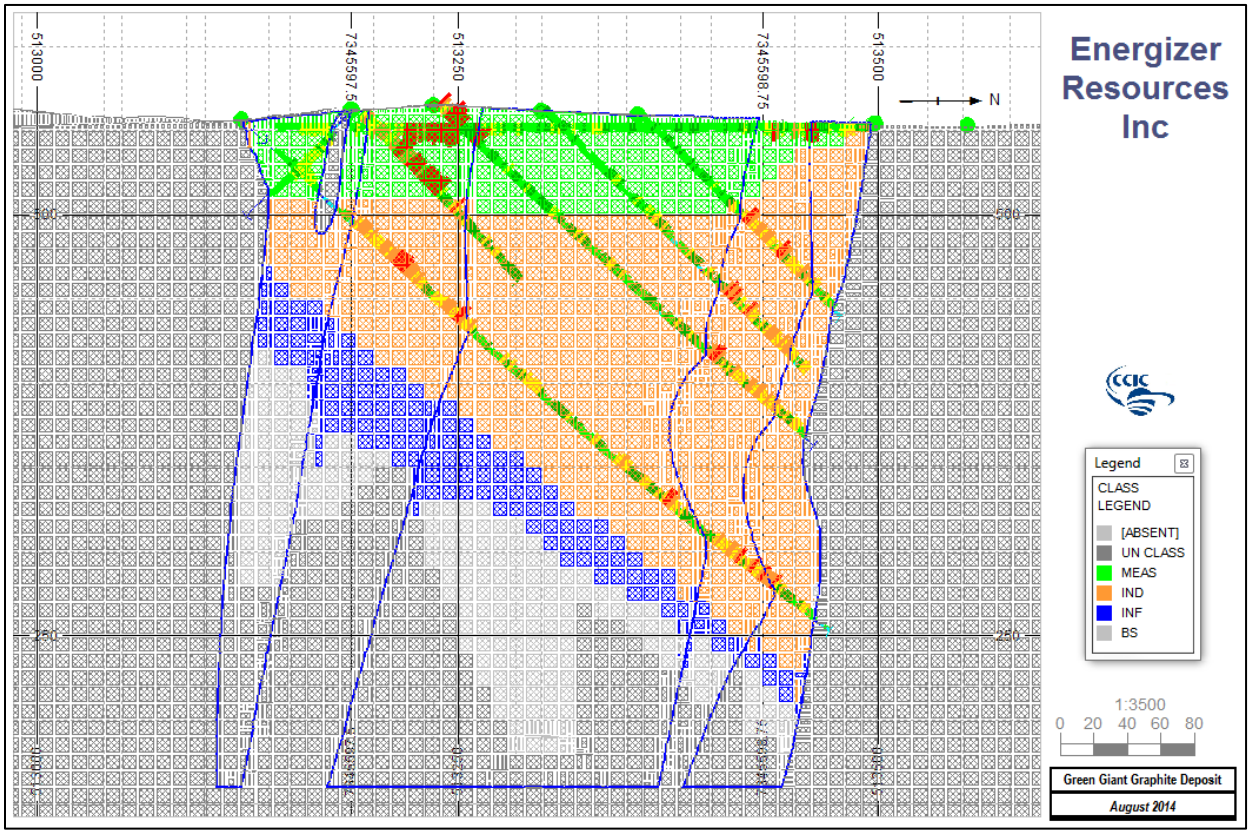


Figure 14-29: Section showing Mineral Resource Classification.

14.10 Resource Tabulation

The current mineral resource estimate for Molo is summarised in Table 14-6 below. A RD of 2.36 t/m^3 was assigned to the mineralised domains. The mineral resources are classified as Measured, Indicated and Inferred categories according to the CIM Definition Standards. Resources within the low grade domain are stated at a 2 % C cut-off, and resources within the high grade domains are stated at a 4 % C cut-off. Whilst the "high grade" resources occur within the "low grade" resources, they are estimated and reported separately. The total Measured and Indicated Resources is estimated at 100.37 Mt, grading at 6.27% C. Inferred Resources is at 40.91 Mt, grading at 5.78% C. When compared to the November 2012 resource statement, this shows a 13.7% increase in tonnage 3.4% decrease in grade and 9.8% increase in graphite content. Reason for the increase in tonnage is due to additional exploratory drilling on the north eastern limb of mineralisation. 23.62 Mt, grading at 6.32% C have been upgraded by infill drilling into the Measure Resource category.

Table 14-6: Mineral Resource Statement for Energizer Resources Molo Graphite deposit – August 2014.

Classification	Material Type	Tonnes - Mt	Grade - C%	Graphite - T
Measured	"Low Grade"	13 048 373	4.64	605 082
Measured	"High Grade"	10 573 137	8.40	887 835
Total Measured		***23 621 510***	***6.32***	***1 492 916***
Indicated	"Low Grade"	39 539 403	4.73	1 871 075
Indicated	"High Grade"	37 206 550	7.86	2 925 266
Total Indicated		***76 745 953***	***6.25***	***4 796 341***
Measured + Indicated	"Low Grade"	52 587 776	4.71	2 476 157
Measured + Indicated	"High Grade"	47 779 687	7.98	3 813 101
Total Measured + Indicated		***100 367 464***	***6.27***	***6 289 257***
Inferred	"Low Grade"	24 233 267	4.46	1 080 677
Inferred	"High Grade"	16 681 453	7.70	1 285 039
Total Inferred		***40 914 721***	***5.78***	***2 365 716***
Total Measure + Indicated + Inferred	"Low Grade"	76 821 044	4.63	3 556 834
Total Measure + Indicated + Inferred	"High Grade"	64 461 141	7.91	5 098 140
Grand - Total		***141 282 184***	***6.13***	***8 654 974***

Mt = million tonnes; C% = carbon percentage; Graphite – T = Tonnes of graphite.

Notes:
1-Mineral Resources are classified according to the CIM definitions.
2-"low grade" Resources are stated at a cut-off grade of 2 % C.
3-"high grade" Resources are stated at a cut-off grade of 4 % C.
4-Eastern and Western high grade assays are capped at 15 % C.
5-A RD of 2.36 t/m^3 was used for the tonnage estimation.

Note: items 15-22 are not required in this Technical Report.

23 ADJACENT PROPERTIES

No similar graphite deposits are known in south-western Madagascar other than those already detailed in this Technical Report.

24 OTHER RELEVANT DATA AND INFORMATION

The authors are not aware of any other information on the properties that would affect their interpretations or conclusions regarding the Molo Graphite Deposit. It should however be noted that Molo is only one of nineteen graphite prospects on the greater Green Giant Property, only seven of which have been drill tested.

25 CONCLUSIONS

Energizer's 2011 exploration programme delineated a number of new graphitic trends in southern Madagascar. The resource delineation drilling undertaken during 2012-2014 focussed on only one of these, the Molo Deposit, and this has allowed for an Independent, CIM complaint, updated resource statement for the Molo deposit.

The total Measured and Indicated Resource is estimated at 100.37 Mt, grading at 6.27 % C. Additionally, an Inferred Resource of 40.91 Mt, grading at 5.78 % C is stated. When compared to the November 2012 resource statement (Hancox and Subramani, 2013), this shows a 13.7 % increase in tonnage, a 3.4 % decrease in grade, and a 9.8 % increase in graphite content. The reason for the increase in tonnage is due to the 2014 drilling on the previously untested north eastern limb of the deposit, which added additional new resources. Additionally 23.62 Mt, grading at 6.32 % Carbon, have been upgraded by infill drilling from the Indicated to Measured Resource category.

Energizer believes the Molo project's success will be predicated on rapidly developing a stand-alone graphite mine and flotation plant, as this would enable the Company to quickly establish itself as a graphite producer and supplier. In order to achieve this, Energizer has partnered with DRA Mineral Projects, who are currently compiling a Feasibility Study. DRA is a world leader in process engineering and metallurgy and has been a provider of full EPCM services since 1984.

As graphite is not traded on the open market (and is rather sold directly to 'end user' consumers) Energizer has already established potential off-take partners, and down-stream users to buy finished product.

26 RECOMMENDATIONS

CCIC recommends that Energizer await the outcomes of the Feasibility Study to see whether further resource evaluation drilling is necessary.

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28 CERTIFICATES OF QUALIFIED PERSONS

28.1 Philip John Hancox, Pri.Sc.Nat.

I, Philip John Hancox, of 11 Cliffside Crescent, Northcliff, Johannesburg the Province of Gauteng, do hereby certify that:

I am a Professional Geologist and am the General Manager of CCIC.

I have practiced my profession continuously since 2000, and am a graduate of the University of the Witwatersrand, with a B.Sc. Honours (Palaeontology and Geology, 1991) and Ph.D. (1998).

I am a member in good standing of the South African Council for Natural Scientific Professions (SACNASP No. 400224/04) as well as a Member and Fellow of the Geological Society of South Africa.

I have direct, successful experience in exploring and developing mineral deposits.

I am a "qualified person" as defined by National Instrument 43-101.

I am not aware of any material fact or material change with respect to the subject matter of the technical report that is not reflected in the technical report, the omission to disclose which makes the technical report misleading.

I am the co-author of this report entitled Molo Graphite Project, Fotadrevo, Province of Toliara, Madagascar *Technical Report NI 43-101* dated January 15, 2013.

I visited the Green Giant-JV Property during May 2012.

I have read National Instrument 43-101 and Form 43-101F1 and the Technical Report has been prepared in compliance with National Instrument 43-101 and Form 43-101F1.

DATED at Johannesburg this 15th day of January A.D. 2012.

Respectfully submitted, signed,

John Hancox

Philip John Hancox (Pri.Sci.Nat.)

28.2 Desmond Subramani, Pri.Sc.Nat.

I, Desmond Subramani, of 90 Beryl Avenue, Bramley North, Johannesburg the Province of Gauteng, do hereby certify that:

I am a Professional Geologist and am the Principal Resource Geologist at CCIC MinRes.

I have practiced my profession continuously since 1995, and am a graduate of the University of KwaZulu-Natal, with a B.Sc. Honours (Geology and Economic Geology, 1994).

I am a member in good standing of the South African Council for Natural Scientific Professions (SACNASP No. 400184/06) as well as a Member of the Geological Society of South Africa.

I have direct, successful experience in exploring and developing mineral deposits.

I am a "qualified person" as defined by National Instrument 43-101.

I am not aware of any material fact or material change with respect to the subject matter of the technical report that is not reflected in the technical report, the omission to disclose which makes the technical report misleading.

I have visited the Green Giant-JV Property from the 15th to 19th February 2014.

I am the co-author of this report entitled Molo Graphite Project, Fotadrevo, Province of Toliara, Madagascar *Technical Report NI 43-101* dated January 15, 2013.

I have read National Instrument 43-101 and Form 43-101F1 and the technical report has been prepared in compliance with National Instrument 43-101 and Form 43-101F1.

DATED at Johannesburg on this 25th day of September A.D. 2014.

Respectfully submitted, signed,

Desmond Subramani

Desmond Subramani (Pri.Sci.Nat.).

Appendix 1

ACTIVATION LABORATORIOS
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CERTIFICATE REFERNCE MATERIAL

STD 1 C- GRAPHICS

Laboratories participating in the round

Activation Laboratories (ACTLABS)

SGS

ACME LABS

ACTIVATION LABORATORIOS
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Statistical Summary

"Recommended Values at 95% Confidence Interval (±2SD)

Constituent	Unit	Recommended value	1s		2s		3s	
			Low	High	Low	High	Low	High
C Graphics	%	**9.11**	8.16	10.07	7.21	11.02	6.25	11.97

	1s	2s	3s			
				8.16	7.21	6.25
C Graphics	0.9536	1.907	2.861	10.07	11.02	11.97

ACTIVATION LABORATORIOS
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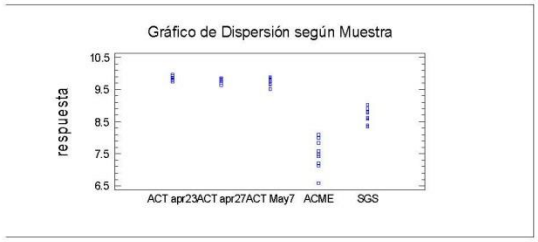
Inter laboratory Statistical Analysis

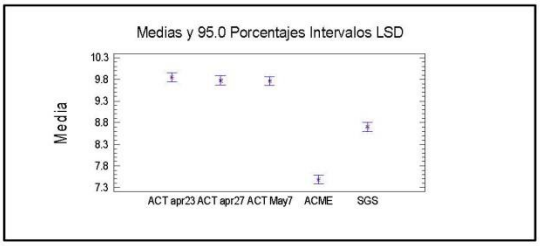
The values associated with graphite analysis have a high dispersion, and therefore test for outliers can not be applied, since over 50% of the population should be eliminated, altering significantly the analysis, so we only work with the probable value with all data obtained by the three laboratories, obtaining only a reference value for the total population of the data delivered.

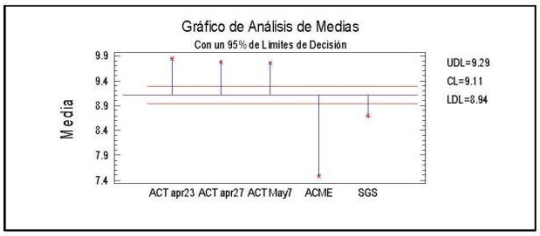
***Values** Table 1. Analysis Graphics*

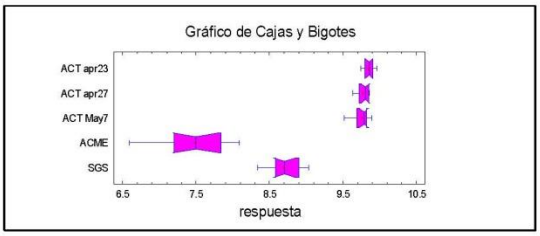
A01A86A12-0054-apr23			A01A86A12-0054-apr27			A01A86A12-0054-May7			A01EVAN12-0025			SGSCA0842-MAY12		
SAMPLE	Cgraph	ZScore 95%	SAMPLE	Cgraph	ZScore 95%	SAMPLE	Cgraph	ZScore 95%	SAMPLE	Cgraph	ZScore 95%	SAMPLE	Cgraph	ZScore 95%
DESCRIPTION	%		DESCRIPTION	%		DESCRIPTION	%		DESCRIPTION	%		DESCRIPTION	%	
MATERIAL-1	9.92	1	MATERIAL-1	9.85	1	MATERIAL-1	9.78	0	MATERIAL-1	6.59	-2	MATERIAL-1	8.62	0
MATERIAL-2	9.74	-1	MATERIAL-2	9.80	0	MATERIAL-2	9.82	1	MATERIAL-2	7.13	-1	MATERIAL-2	8.58	-1
MATERIAL-3	9.74	-1	MATERIAL-3	9.63	-2	MATERIAL-3	9.52	-2	MATERIAL-3	7.60	0	MATERIAL-3	8.90	1
MATERIAL-4	9.86	0	MATERIAL-4	9.81	0	MATERIAL-4	9.68	-1	MATERIAL-4	8.09	1	MATERIAL-4	8.91	1
MATERIAL-5	9.95	2	MATERIAL-5	9.63	-2	MATERIAL-5	9.85	1	MATERIAL-5	7.99	1	MATERIAL-5	8.34	-2
MATERIAL-6	9.80	-1	MATERIAL-6	9.72	-1	MATERIAL-6	9.65	-1	MATERIAL-6	7.43	0	MATERIAL-6	8.39	-1
MATERIAL-7	9.87	0	MATERIAL-7	9.86	1	MATERIAL-7	9.82	1	MATERIAL-7	7.20	-1	MATERIAL-7	8.78	0
MATERIAL-8	9.85	0	MATERIAL-8	9.86	1	MATERIAL-8	9.79	0	MATERIAL-8	7.51	0	MATERIAL-8	9.03	1
MATERIAL-9	9.80	-1	MATERIAL-9	9.75	0	MATERIAL-9	9.78	0	MATERIAL-9	7.48	0	MATERIAL-9	8.63	0
MATERIAL-10	9.91	1	MATERIAL-10	9.85	1	MATERIAL-10	9.89	1	MATERIAL-10	7.84	1	MATERIAL-10	8.80	0
B(ver)	0.01		B(ver)	0.01		B(ver)	0.012		B(ver)	0.197		B(ver)	0.051	
DesV	0.0747		DesV	0.0888		DesV	0.1088		DesV	0.4488		DesV	0.2263	
samplemean	9.84		samplemean	9.78		samplemean	9.76		samplemean	7.49		samplemean	8.70	
RelStd Dev	0.8%		RSD	0.9%		RSD	1.1%		RSD	5.9%		RSD	2.6%	
min	9.7364		min	9.63		min	9.52		min	6.59		min	8.34	
max	9.9576		max	9.86		max	9.89		max	8.09		max	9.03	
MinOutlier	19.51		MinOutlier	18.38		MinOutlier	19.88		MinOutlier	4.55		MinOutlier	6.99	
MaxOutlier	20.37		MaxOutlier	10.64		MaxOutlier	11.09		MaxOutlier	3.07		MaxOutlier	6.48	
numberdatapoints	10		numberdatapoints	10		numberdatapoints	10		numberdatapoints	10		numberdatapoints	10	
N2degrees freedom	8		N2degrees freedom	8		N2degrees freedom	8		N2degrees freedom	8		N2degrees freedom	8	
T	4		T	4		T	4		T	4		T	4	
approxPvalue	0.010		approxPvalue	0.010		approxPvalue	0.010		approxPvalue	0.010		approxPvalue	0.010	
critical value of Z	2.29		critical value of Z	2.29		critical value of Z	2.29		critical value of Z	2.29		critical value of Z	2.29	
significance level	0.05		significance level	0.05		significance level	0.05		significance level	0.05		significance level	0.05	
95% confidence interval	0.05		95% confidence interval	0.05		95% confidence interval	0.07		95% confidence interval	0.28		95% confidence interval	0.14	

ACTIVATION LABORATORIOS
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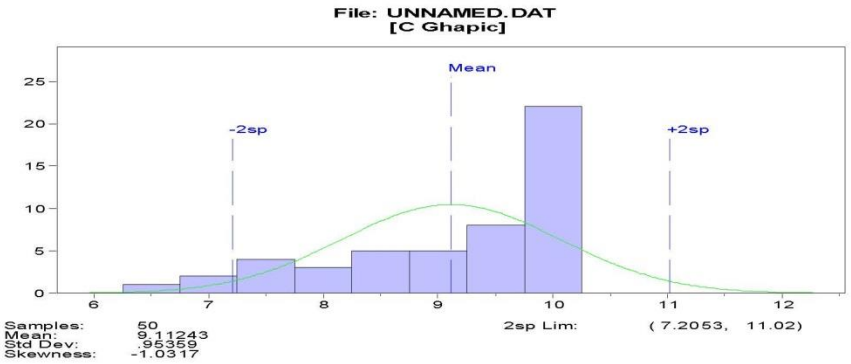
ACTIVATION LABORATORIOS

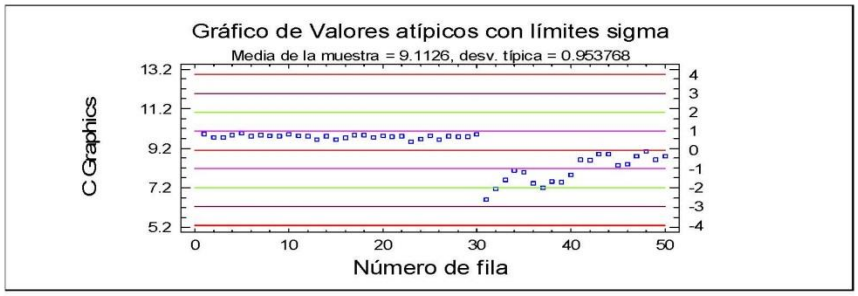
Quality Analysis ...Innovative Technologies

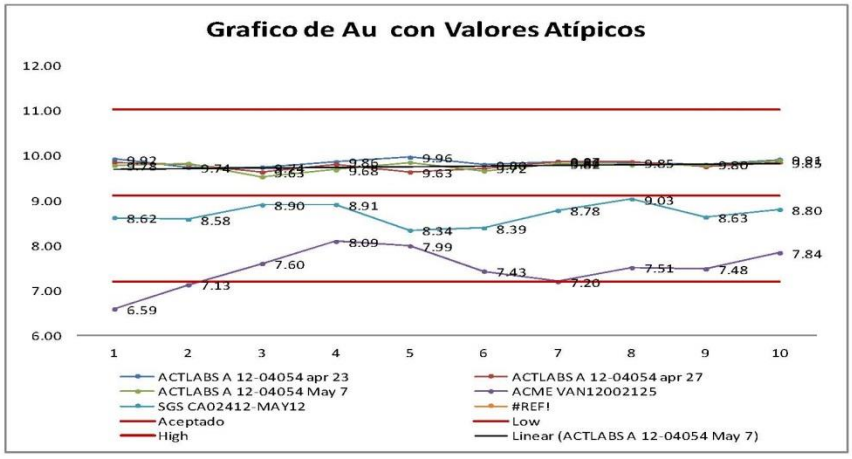
	Laboratory	Sample	C Graphics	Atypical values
1	ACTLABS A 12-04054 apr 23	MATERIAL-1	9.92	
2	ACTLABS A 12-04054 apr 23	MATERIAL-2	9.74	
3	ACTLABS A 12-04054 apr 23	MATERIAL-3	9.74	
4	ACTLABS A 12-04054 apr 23	MATERIAL-4	9.86	
5	ACTLABS A 12-04054 apr 23	MATERIAL-5	9.96	
6	ACTLABS A 12-04054 apr 23	MATERIAL-6	9.80	
7	ACTLABS A 12-04054 apr 23	MATERIAL-7	9.87	
8	ACTLABS A 12-04054 apr 23	MATERIAL-8	9.85	
9	ACTLABS A 12-04054 apr 23	MATERIAL-9	9.80	
10	ACTLABS A 12-04054 apr 23	MATERIAL-10	9.91	
11	ACTLABS A 12-04054 apr 27	MATERIAL-1	9.85	
12	ACTLABS A 12-04054 apr 27	MATERIAL-2	9.80	
13	ACTLABS A 12-04054 apr 27	MATERIAL-3	9.63	
14	ACTLABS A 12-04054 apr 27	MATERIAL-4	9.81	
15	ACTLABS A 12-04054 apr 27	MATERIAL-5	9.63	
16	ACTLABS A 12-04054 apr 27	MATERIAL-6	9.72	
17	ACTLABS A 12-04054 apr 27	MATERIAL-7	9.86	
18	ACTLABS A 12-04054 apr 27	MATERIAL-8	9.86	
19	ACTLABS A 12-04054 apr 27	MATERIAL-9	9.75	
20	ACTLABS A 12-04054 apr 27	MATERIAL-10	9.85	
21	ACTLABS A 12-04054 May 7	MATERIAL-1	9.78	
22	ACTLABS A 12-04054 May 7	MATERIAL-2	9.82	
23	ACTLABS A 12-04054 May 7	MATERIAL-3	9.52	
24	ACTLABS A 12-04054 May 7	MATERIAL-4	9.68	
25	ACTLABS A 12-04054 May 7	MATERIAL-5	9.85	
26	ACTLABS A 12-04054 May 7	MATERIAL-6	9.65	
27	ACTLABS A 12-04054 May 7	MATERIAL-7	9.82	
28	ACTLABS A 12-04054 May 7	MATERIAL-8	9.79	
29	ACTLABS A 12-04054 May 7	MATERIAL-9	9.78	
30	ACTLABS A 12-04054 May 7	MATERIAL-10	9.89	
31	ACME VAN12002125	MATERIAL-1	6.59	
32	ACME VAN12002125	MATERIAL-2	7.13	
33	ACME VAN12002125	MATERIAL-3	7.60	
34	ACME VAN12002125	MATERIAL-4	8.09	
35	ACME VAN12002125	MATERIAL-5	7.99	
36	ACME VAN12002125	MATERIAL-6	7.43	
37	ACME VAN12002125	MATERIAL-7	7.20	
38	ACME VAN12002125	MATERIAL-8	7.51	
39	ACME VAN12002125	MATERIAL-9	7.48	
40	ACME VAN12002125	MATERIAL-10	7.84	
41	SGS CA02412-MAY12	MATERIAL-1	8.62	
42	SGS CA02412-MAY12	MATERIAL-2	8.58	
43	SGS CA02412-MAY12	MATERIAL-3	8.90	
44	SGS CA02412-MAY12	MATERIAL-4	8.91	
45	SGS CA02412-MAY12	MATERIAL-5	8.34	
46	SGS CA02412-MAY12	MATERIAL-6	8.39	
47	SGS CA02412-MAY12	MATERIAL-7	8.78	
48	SGS CA02412-MAY12	MATERIAL-8	9.03	
49	SGS CA02412-MAY12	MATERIAL-9	8.63	
50	SGS CA02412-MAY12	MATERIAL-10	8.80	

B (var)	**0.909**	
DesV	**0.953587**	
sample mean	**9.1124**	*(±2SD)*
min	**6.59**	
max	**9.96**	
Min Outlier	**2.77**	
Max Outlier	**0.93**	
number data points	**50**	
N-2 degrees freedom	**48**	
T	**3.51**	
approx P value	**0.0020**	
critical value of Z	**3.13**	
significance level	0.05	
95% confidence intervals for mean	**0.26**	
Estándar: (8.84154,9.38366)		

ACTIVATION LABORATORIOS
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It can be shown in the graphs of pooled data from the three laboratories, that two of the three laboratories (ACME and SGS) are below the total data population and as mentioned above test for outliers cannot be applied because from 20 to 50 data would be

GEOSTATS PTY LTD

Mining Industry Consultants
Reference Material Manufacture and Sales

Certified Pulp Graphite Reference Material

GGC-01

Certified Control Values

Element	Units	Grade	Standard Deviation	No of Analyses	95% Confidence Interval
Graphitic Carbon	%	24.97	0.94	40	+/- 0.3
Total Carbon	%	26.68	0.89	37	+/- 0.3
Total Sulphur	%	0.04	0.02	50	+/- 0.004

CRM Details

Control Statistic Details
Control values for this material were determined during a certification program.

Certification Date
This material was certified with the above values on:
20/05/2013

Source Material
Prior to homogenisation and testing, this material was sourced from:
Graphite, Eyre Peninsula, South Australia

Material Type
Pulp Graphite Ore, 10g samples.

Usage
This product is for use in the mining industry as reference materials for monitoring and testing the accuracy of laboratory assaying.

Preparation and Packaging
This reference material was dried in an oven for a minimum of 8 hours at 105C. The dry material is then pulverised in a bowl and puck mill and homogenised in a vee-blender. The material is then stored in a sealed, stable container ready for final packaging.

Materials are statistically sampled from stores, then packaged into heat sealed, air tight, plastic packets ready for distribution. All packaging has been chosen to ensure minimal contamination from outside sources during shipment, use and storage.

Assay Testwork
This standard was tested in a dedicated certification program. 10 x 10g samples were sent to 5 laboratories for analysis using a leach process (for graphitic carbon) and a carbon / sulphur analyser. Assay distributions are checked and processed statistically, producing monitoring statistics for these standards. Materials are tested regularly to ensure stability and homogeneity.

10A Marsh Close, O'Connor, Western Australia 6163
Phone : +61 8 9314 2566, Fax : +61 8 9314 3699
e-mail : pjh@geostats.com.au, srr@geostats.com.au
Website http://www.geostats.com.au

GGC-01

Geostats Pty Ltd, Certified GRaphite Reference Material, Product Code:

GEOSTATS PTY LTD

Mining Industry Consultants
Reference Material Manufacture and Sales

Certified Pulp Graphite Reference Material

GGC-07

Certified Control Values

Element	Units	Grade	Standard Deviation	No of Analyses	95% Confidence Interval
Graphitic Carbon	%	0.13	0.04	48	+/- 0.01
Total Carbon	%	0.56	0.03	50	+/- 0.01
Total Sulphur	%	0.51	0.03	40	+/- 0.01

CRM Details

Control Statistic Details
Control values for this material were determined during a certification program.

Certification Date
This material was certified with the above values on:
20/05/2013

Source Material
Prior to homogenisation and testing, this material was sourced from:
Flake graphite, Halls Creek, Western Australia

Material Type
Pulp Graphite Ore, 10g samples.

Usage
This product is for use in the mining industry as reference materials for monitoring and testing the accuracy of laboratory assaying.

Preparation and Packaging
This reference material was dried in an oven for a minimum of 8 hours at 90C. The dry material is then pulverised in a bowl and puck mill and homogenised in a vee-blender. The material is then stored in a sealed, stable container ready for final packaging.

Materials are statistically sampled from stores, then packaged into heat sealed, air tight, plastic packets ready for distribution. All packaging has been chosen to ensure minimal contamination from outside sources during shipment, use and storage.

Assay Testwork
This standard was tested in a dedicated certification program. 10 x 10g samples were sent to 5 laboratories for analysis using a leach process (for graphitic carbon) and a carbon / sulphur analyser. Assay distributions are checked and processed statistically, producing monitoring statistics for these standards. Materials are tested regularly to ensure stability and homogeneity.

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Website http://www.geostats.com.au

GGC-07

Geostats Pty Ltd, Certified GRaphite Reference Material, Product Code:

Appendix C

Process Design Criteria

CRITERIA	UNITS	VALUE	SOURCE
SITE INFORMATION			
Project Location			
Country	-	**Madagascar**	C
Region	-	**Southern**	C
Closest Regional Centre	-	**?**	C
Distance/Direction Closest Centre	-	**?**	C
Elevation			
Plant site above sea level	m AMSL	**?**	C
Pressure	kPa	**?**	C
Ambient Temperature			
Maximum summer temperature	°C	**?**	C
Minimum winter temperature	°C	**?**	C
Rainfall			
Annual mean	mm/y	**?**	C
Annual maximum	mm/y	**?**	C
Annual minimum	mm/y	**?**	C
Mean annual evaporation	mm/y	**?**	C
Wind Conditions			
Wind Direction - Majority of year			
Average	m/s	?	C
Maximum	m/s	?	C
Raw Water Supply			
Main source	-	**Borehole**	C
Alternate Source	-	**TBC**	C
Battery Limits			
Incoming			
Ore	-	**ROM tip ore receiving area**	C
Water	-	**Delivered to Raw water tank**	C
Power	-	**Diesel generation to MCC**	C
Outgoing			
Graphite Concentrate	-	**Bag storage area**	C
Tailings	-	**Dewatered tailings conveyor discharge chute**	C

A **Assumption based on most current, available information**
B **Previously reported**
C **Client Input**
D1 **Based on Testwork results**
D2 **Based on design experience**
D3 **Calculated from other parameters**
D4 **Based on OEM recommendations**
E **No information available**

GENERAL ROM CHARACTERISTICS			
CRITERIA	**UNITS**	**VALUE**	**SOURCE**
Mine			
Annual run-of-mine treatment rate	dmtpa	**240 462**	D3
	dmtpm	**20 039**	D3
Mining method	-	**Open pit**	C
Mine life	y	**TBA**	E
Ore Properties			
Ore Type		**Graphite-mineralized ore**	C
Mineralized Material Consituents			
Major		**Quartzite/gneiss/schist**	C
Minor		**Graphite/biotiticmica/clay minerals/iron oxides/pyrites**	C
ROM moisture content	% mass	**3**	E
Solid Densities			
ROM	t/m³	**2.62**	D1
Water	t/m³	**1.00**	D2
Concentrate density	t/m³	**2.33**	D1
ROM bulk density	t/m³	**1.56**	D1
Filtered concentrate bulk density	t/m³	**1.14**	D1
Angle of repose	degrees	**35**	E
Angle of drawdown	degrees	**65**	E
ROM Feed Size			
Top size (F100)	mm	**400**	A
F80	mm	**280**	E
Comminution Characteristics			
Unconfined Compressive Strength	MPa	**TBC**	
Bond Crushing Work Index	kWh/t	**6.4**	D1
Bond Rod Mill Work Index	kWh/t	**7.9**	D1
Bond Ball Mill Work Index	kWh/t	**10.5**	D1
Abrasion Index	g/t	**0.098**	D1
JK Parameters			
A	-	**70.4**	D1
b	-	**2.82**	D1
Axb	-	**182**	D1
ta	-	**2.07**	D1
DWI	kWh/m³	**1.56**	D1

PRODUCTION SCHEDULE			
CRITERIA	**UNITS**	**VALUE**	**SOURCE**
OPERATING SCHEDULE			
General Concentrator			
Operating schedule	Days/Year	**365**	C
Operating schedule	Hours/Day	**24**	C
Operating schedule	Shifts/Day	**3**	C
Operating schedule	Hours/Shift	**8**	D3
Total available hours per year	Hours/Year	**8 760**	D3
Crushing			
Operating hours per day	hpd	**13**	D2
Crusher annual run hours	hpa	**4 835**	D3
Crusher utilisation/availability	%	**55**	D3
Crusher feed rate	dmtph	**50**	D3
Grinding			
Operating hours per day	hpd	**24**	D2
Mill annual run hours	hpa	**8 015**	D3
Mill utilisation/availability	%	**92**	D3
Mill feed rate	dmtph	**30**	D3
Flotation/Concentrate Handling/Tailing Disposal			
Utilisation/availability	%	**92**	C
Annual run hours	h	**8 015**	D3
CONCENTRATOR PRODUCT PRODUCTION			
Head Grade			
Carbon	% C	**7.04**	C/D1
Recoveries			
Graphite Carbon	% C	**88.3**	D1
Mass Recovery	%	**6.39**	D3
Concentrate PSD			
+50 mesh	%	**23.60**	D1
-50+80 mesh	%	**22.70**	D1
-80+100 mesh	%	**6.90**	D1
-100 mesh		**46.80**	D1
Concentrate Grade			
+50 mesh	% C	**96.90**	D1
-50+80 mesh	% C	**97.10**	D1
-80+100 mesh	% C	**97.20**	D1
-100 mesh	% C	**97.60**	D1
Weighted Overall Grade (ave)	% C	**97.30**	D1
Concentrate Production			
Estimated Concentrate Production (ave)	dmt/h	**1.92**	D3
Estimated Concentrate Production (ave)	dmt/d	**42**	D3
Estimated Concentrate Production (ave)	dmt/a	**15 366**	D3

ORE RECEIVING, CRUSHING & STORAGE			
CRITERIA	**UNITS**	**VALUE**	**SOURCE**
Configuration			
Operating Schedule			
Operating hours per day	hpd	**13**	D2
Shifts per Day	shifts	**3**	C
Hours per shift	hours	**8**	C
Operating days per week	days/week	**7**	C
Crusher annual run hours	hpa	**4 835**	D3
Crusher utilisation/availability	%	**55**	D3
Crusher feed rate	dmtph	**50**	D3
Crushing Circuit Detail			
ROM bin capacity - live	min	**10**	D2
ROM bin capacity - live	m^3	**5**	D3
Crushing Work Index	kWh/t	**6.4**	D1
Vibrating Grizzly			
Screen type	-	**Grizzly Feeder**	D2
Screen feed F100	mm	**300**	D2
Screen feed F80	mm	**280**	D2
grizzly bar aperture	mm	**70**	D2
Screen product P100	mm	**100**	D2
Screen feed rate	t/h	**50**	D3
Selected grizzly area	m^2	**0.64**	D3
Selected Grizzly size	mm	**500 x 2000**	D2
Installed power	kW	**4.6**	D3
Primary Jaw Crusher			
Crusher type	-	**Jaw Crusher**	D2
Crusher feed F100	mm	**300**	D3
Crusher feed F80	mm	**280**	D2
Crusher closed side setting	mm	**75**	D2
Crusher product P100	mm	**120**	D2
Crusher product P80	mm	**80**	D3
Fraction to grizzly screen oversize	%	**71**	D3
Crusher feed rate	t/h	**35.3**	D3
Selected crusher size	-	**20'' x 32'' Single Toggle**	D2
Installed power	kW	**55**	D3
Secondary Cone Crusher			
Crusher type	-	**Cone Crusher**	D2
Crusher feed F100	mm	**120**	D2
Crusher feed F80	mm	**86**	D2
Crusher closed side setting	mm	**35**	D2
Crusher product P100	mm	**44**	D3
Crusher product P80	mm	**35**	D3
Crusher feed rate	t/h	**30.5**	D3
Secondary crusher bin capacity	m^3	**5**	D3
Selected crusher size	-	**900 mm dia Short Head Extra Coarse**	D2
Power installed	kW	**55**	

Tertiary Cone Crusher			
Crusher type	-	**Cone Crusher**	D2
Crusher feed F100	mm	**35**	D2
Crusher feed F80	mm	**21**	D2
Crusher closed side setting	mm	**14**	D2
Crusher product P100	mm	**18**	D3
Crusher product P80	mm	**14**	D3
Crusher feed rate	t/h	**30.5**	D3
Tertiary crusher bin capacity	m^3	**5**	D3
Selected crusher size	-	**900 mm dia Short Head Fine**	D2
Power installed	kW	**55**	
Primary Screen			
Screen type	-	**DD Vibrating Screen**	
Screen feed F100	mm	**120**	D2
Screen feed F80	mm	**86**	D2
Screen appature (Top Deck)	mm	**35**	D2
Screen appature (Bottom Deck)	mm	**16**	D2
Screen product P80 (Top Deck)	mm	**28**	D3
Screen product P80 (Bottom Deck)	mm	**13**	D3
Screen feed rate	t/h	**111**	D3
Selected Screen size	-	**1525 x 3660 DD**	D2
Mill Feed Storage			
Storage method	-	**Bin**	D2
Crushed ore storage capacity	h	**2**	D3
Crushed ore storage capacity	t	**60**	D3
Crushed ore storage capacity	m^3	**38**	D3

MILLING CLASSIFICATION & FLASH FLOTATION			
CRITERIA	**UNITS**	**VALUE**	**SOURCE**
Configuration			
Circuit Overview & Operating Schedule			
Operating hours per day	hpd	**24**	C
Shifts per Day	shifts	**3**	C
Hours per shift	hours	**8**	C
Operating days per week	days/week	**7**	C
Crusher annual run hours	hpa	**8 015**	D3
Crusher utilisation/availability	%	**92**	D3
Mill feed rate	t/h	**30**	D3
Mill feed size, F100	mm	**16**	D3
Mill feed size, F80	mm	**13**	D3
Target mill circuit product size, P80	µm	**500**	D1
Bond Ball Work Index (BBWi)	kWh/t	**10.50**	D1
Primary Milling Circuit			
Scalping screen apperture size	mm	**2**	D2
Scalping screen oversize split	%	**66.0**	D3
Scalping screen oversize rate	dmt/h	**19.8**	D3
Mill feed size, F100	µm	**16000**	D3
Mill feed size, F80	µm	**12800**	D3
Target mill circuit product size, P80	µm	**500**	D1
Mill feed rate (fresh feed)	dmt/h	**30**	D3
Circulating load	%	**118**	D3
Mill feed rate (Total)	dmt/h	**55.2**	D3
Specific Energy	kWh/t	**5.10**	D3
Ball charge	%v/v	**20**	D1
Power at Pinion	kW	**135**	D3
Maximum ball charge	%v/v	**35**	D2
Installed power	kW	**200**	D3
Make-up steel ball size	mm	**75**	D2
Steel ball consumption	g/t	**290**	D1
Ball mill drive speed, % of critical	%	**75**	D1
Ball mill diameter, inside shell	m	**2.10**	D1
Ball mill effective grinding length, EGL	m	**3.57**	D1
Mill discharge arrangement	-	**Grate Discharge**	D2
Mill grate aperture	mm	**12**	D2
Flash Flotation			
Flash float feed rate	dmt/h	**10.2**	D3
Flash float feed solids	% m/m	**36.0**	D1
Flash float slurry flow rate	m^3/h	**22.0**	D3
Number of flash float cells	#	**1**	D1
Flash float cell absolute volume	m^3	**3.2**	D3
Cell type		**Flash float tank cell (Coarse)**	D2
Power input to cell	kW/m^3	**6.8**	D3
Selected installed power	kW	**9.6**	D3
Aeration and mechanical losses	%	**8**	D2
Flash flotation residence time	min	**8**	D1
Mass Pull	%	**3.0**	D3
Air Requirement	m^3/min	**0.59**	D3
Concentrate density	t/m^3	**1.13**	D1
Mill classification screen & discharge sump			
Screen type		**Vibrating single deck**	
Screen apperture size	mm	**0.6 x 8 slotted HF Panels**	D2
Screen feed solids	%w/w	**60**	D1
Screen feed rate	dmt/h	**65.4**	D3
Screen split to oversize	%w/w	**55**	D1
Screen size	m^2	**1.2 wide x 3.0 long (3.6m^2)**	D3
Sump volume	m^3	**2.2**	D3
Mill sump residence time	sec	**90.0**	D2

ROUGHER FLOTATION

CRITERIA	UNITS	VALUE	SOURCE
Configuration			
Roughers			
Feed			
Solids mass flow rate	t/h	**29.1**	D3
Solid SG	t/m³	**2.62**	D1
Slurry solids concentration	%w/w	**27**	D1
Slurry density	t/m³	**1.20**	D1
Slurry flow rate	m³/h	**90**	D3
Flotation Cells			
Cell type	-	**Trough**	D2
Aeration method	-	**Forced air**	D2
Required flotation capacity	m³	**15**	D3
Cell Required Volume (Each)	m³	**2.7**	D3
Cell Selected Absolute Volume (Each)	m³	**3.0**	D3
Aeration & Mechanical Losses %	%	**8**	D2
Design residence time	min	**10.0**	D1
Selected installed power	kW	**7.8**	D3
Power input to cell	kW/m³	**2.6**	D1
Air requirement per cell	m³/min	**1.2**	D3
Number of cells selected	#	**6**	D2
Concentrate			
Mass pull to concentrate	%	**8.3**	D1
Solids mass flow rate	t/h	**2.41**	D3
Solid SG	t/m³	**2.45**	D1
Slurry solids concentration	%w/w	**20**	D1
Slurry flow rate	m³/h	**11**	D3
Slurry density	t/m³	**1.13**	D3

PRIMARY CLEANING CIRCUIT

CRITERIA	UNITS	VALUE	SOURCE
Configuration			
Polishing Milling Circuit			
Dewatering screen feed density	t/m³	**1.12**	D1
Dewatering screen feed rate	dmt/h	**3.74**	D3
Dewatering screen apperture size	µm	**74**	D2
Dewatering screen oversize split	%	**87.4**	D1
Dewatering screen oversize rate	dmt/h	**3.3**	D3
Mill feed size, F100	µm	**425**	D1
Mill feed size, F80	µm	**400**	D1
Mill feed rate (fresh feed)	dmt/h	**3.3**	D3
Circulating load	%	**11.6**	D3
Mill feed rate (Total)	dmt/h	**3.65**	D3
Specific Energy	kWh/t	**0.53**	D1
Ceramic media charge	%v/v	**20**	D1
Power Required at Pinion	kW	**15**	D3
Maximum media charge	%v/v	**35**	D2
Installed power	kW	**20**	D3
Make-up ceramic media size	mm	**13**	D1
Media consumption	g/t	**145**	A
Ball mill drive speed, % of critical	%	**40**	D2
Ball mill diameter, inside shell	m	**1.20**	D3
Ball mill effective grinding length, EGL	m	**2.40**	D3
Mill discharge arrangement	-	**Grate Discharge**	D2
Mill grate aperture	mm	**2**	D2
Column Flotation			
Column float feed rate	dmt/h	**4.44**	D3
Column float feed solids	% m/m	**16.7**	D1
Column float feed density	t/m³	**1.11**	D3
Column float slurry flow rate	m³/h	**24.1**	D3
Number of column float cells	#	**1**	D1
Column cell dimensions		**2m dia x 6.0m height**	D3
Column float cell absolute volume	m^3	**18.8**	D3
Column carrying capacity	$(t/m^2)/h$	**1.5**	D1
Column concentrate solids	%	**18.0**	D1
Column flotation residence time	min	**48**	D1
Mass Pull	%	**7.17**	D1
Air Requirement	m³/min	**0.90**	D3
Concentrate density	t/m³	**1.12**	D3
Cleaner Flotation			
Feed			
Solids mass flow rate	t/h	**2.29**	D3
Solid SG	t/m³	**2.58**	D1
Slurry solids concentration	%w/w	**14.4**	D1
Slurry density	t/m³	**1.10**	D3
Slurry flow rate	m³/h	**14.5**	D3
Flotation Cells			
Cell type	-	**Trough**	D2
Aeration method	-	**Forced air**	D2
Required flotation capacity	m³	**0.73**	D3
Cell Required Volume (Each)	m³	**0.26**	D3
Cell Selected Volume (Each)	m³	**0.25**	D3
Aeration & Mechanical Losses %	%	**8**	D2

Design residence time	min	**3.0**	D1
Selected installed power	kW	**0.8**	D3
Power input to cell	kW/m³	**3.9**	D2
Air requirement per cell	m³/min	**0.5**	D3
Number of cells selected	#	**3**	D2
Concentrate			
Mass pull to concentrate	%	**2.3**	D1
Solids mass flow rate	t/h	**0.7**	D3
Solid SG	t/m³	**2.56**	D1
Slurry solids concentration	%w/w	**10**	D1
Slurry flow rate	m³/h	**6.6**	D3
Slurry density	t/m³	**1.06**	D3
Cleaner Scavenger Flotation			
Feed			
Solids mass flow rate	t/h	**1.6**	D3
Solid SG	t/m³	**2.59**	D1
Slurry solids concentration	%w/w	**19**	D1
Slurry density	t/m³	**1.13**	D3
Slurry flow rate	m³/h	**7.4**	D3
Flotation Cells			
Cell type	-	**Trough**	D2
Aeration method	-	**Forced air**	D2
Required flotation capacity	m³	**0.43**	D3
Cell Required Volume (Each)	m³	**0.16**	D3
Cell Selected Volume (Each)	m³	**0.25**	D3
Aeration & Mechanical Losses %	%	**8**	D2
Design residence time	min	**3.5**	D1
Selected installed power	kW	**0.8**	D3
Power input to cell	kW/m³	**3.9**	D2
Air requirement per cell	m³/min	**0.4**	D3
Number of cells selected	#	**3**	D2
Concentrate			
Mass pull to concentrate	%	**1.2**	D1
Solids mass flow rate	t/h	**0.36**	D3
Solid SG	t/m³	**2.40**	D1
Slurry solids concentration	%w/w	**10**	D1
Slurry flow rate	m³/h	**3.4**	D3
Slurry density	t/m³	**1.06**	D3
Concentrate Classification			
Concentrate screen apperture size	µm	**212**	D1
Concentrate screen feed rate	dmt/h	**2.15**	D3
Concentrate screen oversize solids concentration	%	**48**	D1
Concentrate screen split to oversize	%	**76**	D1

FINE FLAKE CLEANING CIRCUIT			
CRITERIA	**UNITS**	**VALUE**	**SOURCE**
Configuration			
Polishing Milling Circuit			
Dewatering screen feed density	t/m³	**1.03**	D1
Dewatering screen feed rate	dmt/h	**0.55**	D3
Dewatering screen apperture size	µm	**74**	D2
Dewatering screen oversize split	%	**67.0**	D1
Dewatering screen oversize rate	dmt/h	**0.37**	D3
Mill feed size, F100	µm	**212**	E
Mill feed size, F80	µm	**190**	D1
Mill slurry retention time	min	**14.8**	D2
Mill feed rate (fresh feed)	dmt/h	**0.52**	D3
Circulating load	%	**5.9**	D3
Mill feed rate (Total)	dmt/h	**0.5**	D3
Specific Energy	kWh/t	**0.78**	D3
Ceramic media charge	%v/v	**20**	D1
Power Required at Pinion	kW	**12**	D3
Maximum media charge	%v/v	**35**	D2
Installed power	kW	**20**	D3
Make-up ceramic media size	mm	**13**	D1
Media consumption	g/t	**145**	A
Ball mill drive speed, % of critical	%	**40**	D1
Ball mill diameter, inside shell	m	**1.20**	D3
Ball mill effective grinding length, EGL	m	**2.40**	D3
Mill discharge arrangement	-	**Grate Discharge**	D2
Mill grate aperture	mm	**2**	D2
Column Flotation			
Column float feed rate	dmt/h	**0.90**	D3
Column float feed solids	% m/m	**8.1**	D1
Column float feed density	t/m³	**1.04**	D3
Column float slurry flow rate	m³/h	**10.7**	D3
Number of column float cells	#	**1**	D2
Column cell dimensions		**1.25 dia x 6.0 height**	D3
Column float cell absolute volume	m^3	**8.4**	D3
Column carrying capacity	$(t/m^2)/h$	**1.0**	D1
Column concentrate solids	%	**19.5**	D1
Column flotation residence time	min	**47**	D3
Mass Pull	%	**1.7**	D1
Air Requirement	m³/min	**1.00**	D3
Concentrate density	t/m³	**1.14**	D3
Cleaner Flotation			
Feed			
Solids mass flow rate	t/h	**0.4**	D3
Solid SG	t/m³	**2.33**	D1
Slurry solids concentration	%w/w	**5**	D1
Slurry density	t/m³	**1.03**	D3
Slurry flow rate	m³/h	**8.3**	D3
Flotation Cells			
Cell type	-	**Trough**	D2
Aeration method	-	**Forced air**	D2
Required flotation capacity	m³	**0.42**	D3
Cell Required Volume (Each)	m³	**0.15**	D3
Cell Selected Volume (Each)	m³	**0.25**	D3

Aeration & Mechanical Losses %	%	**8**	D2
Design residence time	min	**3.0**	D1
Selected installed power	kW	**0.8**	D3
Power input to cell	kW/m³	**3.9**	D2
Air requirement per cell	m³/min	**0.7**	D3
Number of cells selected	#	**3**	D2
Concentrate			
Mass pull to concentrate	%	**1.0**	D1
Solids mass flow rate	t/h	**0.3**	D3
Solid SG	t/m³	**2.35**	D1
Slurry solids concentration	%w/w	**10**	D1
Slurry flow rate	m³/h	**2.9**	D3
Slurry density	t/m³	**1.06**	D3
Cleaner Scavenger Flotation			
Feed			
Solids mass flow rate	t/h	**0.10**	D3
Solid SG	t/m³	**2.38**	D1
Slurry solids concentration	%w/w	**2**	D1
Slurry density	t/m³	**1.01**	D3
Slurry flow rate	m³/h	**6.3**	D3
Flotation Cells			
Cell type	-	**Trough**	D2
Aeration method	-	**Forced air**	D2
Required flotation capacity	m³	**0.48**	D3
Cell Required Volume (Each)	m³	**0.26**	D3
Cell Selected Volume (Each)	m³	**0.25**	D3
Aeration & Mechanical Losses %	%	**8**	D2
Design residence time	min	**4.5**	D1
Selected installed power	kW	**0.8**	D3
Power input to cell	kW/m³	**3.9**	D2
Air requirement per cell	m³/min	**0.6**	D3
Number of cells selected	#	**2**	D2
Concentrate			
Mass pull to concentrate	%	**0.2**	D1
Solids mass flow rate	t/h	**0.06**	D3
Solid SG	t/m³	**2.25**	D1
Slurry solids concentration	%w/w	**10.0**	D1
Slurry flow rate	m³/h	**0.57**	D3
Slurry density	t/m³	**1.06**	D3

ATTRITION CLEANING CIRCUIT			
CRITERIA	**UNITS**	**VALUE**	**SOURCE**
Configuration			
Attrition Milling Circuit			
Thickener feed density	t/m³	**1.25**	D1
Thickener feed solids concentration	%	**18.2**	D3
Thickener feed rate	dmt/h	**2.2**	D3
Thickener feed slurry flow rate	m³/h	**6.8**	D3
Thickener flux	$(t/m^2)/h$	**0.25**	D1
Thickener diameter			
Required area	m^2	**9**	D3
Required diameter	m	**3.4**	D3
Selected	m	**4**	D2
Thickener overflow clarity	ppm	**<100**	D2
Thickener underflow % solids	%	**28.0**	D1
Thickener underflow density	t/m³	**1.19**	D3
Mill feed size, F100	µm	**950**	D1
Mill feed size, F80	µm	**500**	D1
Mill slurry retention time	min	**TBC**	D2
Mill feed rate (fresh feed)	dmt/h	**2.24**	D3
Circulating load	%	**0.0**	D3
Mill feed rate (Total)	dmt/h	**2.24**	D3
Specific Energy	kWh/t	**2.69**	D2
Media charge	%v/v	**20**	D1
Power Required at Pinion	kW	**4.5**	D3
Maximum media charge	%v/v	**30**	D2
Installed power	kW	**18.5**	D3
Make-up media size	mm	**6**	D1
Media consumption	g/t	**145**	A
Mill configuration	-	**Open circuit stirred media mill / attritor**	D2
Column Flotation			
Column float feed rate	dmt/h	**2.6**	D3
Column float feed solids	% m/m	**22.8**	D1
Column float feed density	t/m³	**1.15**	D3
Column float slurry flow rate	m³/h	**9.9**	D3
Number of column float cells	#	**1**	D2
Column cell dimensions		**1.25m dia x 6.0m height**	D3
Column float cell absolute volume	m^3	**10.6**	D3
Column carrying capacity	$(t/m^2)/h$	**1.0**	D1
Column concentrate solids	%	**18.7**	D1
Column flotation residence time	min	**65**	D3
Mass Pull	%	**6.4**	D3
Air Requirement	m³/min	**1.27**	D3
Concentrate density	t/m³	**1.14**	D3
Cleaner Flotation			
Feed			
Solids mass flow rate	t/h	**0.7**	D3
Solid SG	t/m³	**2.46**	D1
Slurry solids concentration	%w/w	**16**	D1
Slurry density	t/m³	**1.10**	D3
Slurry flow rate	m³/h	**3.9**	D3
Flotation Cells			
Cell type	-	**Trough**	D2
Aeration method	-	**Forced air**	D2

Required flotation capacity	m^3	**0.19**	D3
Cell Required Volume (Each)	m^3	**0.11**	D3
Cell Selected Volume (Each)	m^3	**0.25**	D3
Aeration & Mechanical Losses %	%	**8**	D2
Design residence time	min	**3.0**	D1
Selected installed power	kW	**0.8**	D3
Power input to cell	kW/m^3	**3.9**	D2
Air requirement per cell	m^3/min	**0.5**	D3
Number of cells selected	#	**2**	D2
Concentrate			
Mass pull to concentrate	%	**1.1**	D1
Solids mass flow rate	t/h	**0.34**	D3
Solid SG	t/m^3	**2.28**	D1
Slurry solids concentration	%w/w	**15**	D1
Slurry flow rate	m^3/h	**2.13**	D3
Slurry density	t/m^3	**1.09**	D3
Cleaner Scavenger Flotation			
Feed			
Solids mass flow rate	t/h	**0.33**	D3
Solid SG	t/m^3	**2.49**	D1
Slurry solids concentration	%w/w	**15**	D1
Slurry density	t/m^3	**1.10**	D3
Slurry flow rate	m^3/h	**2.1**	D3
Flotation Cells			
Cell type	-	**Trough**	D2
Aeration method	-	**Forced air**	D2
Required flotation capacity	m^3	**0.21**	D3
Cell Required Volume (Each)	m^3	**0.22**	D3
Cell Selected Volume (Each)	m^3	**0.25**	D3
Aeration & Mechanical Losses %	%	**8**	D2
Design residence time	min	**6.0**	D1
Selected installed power	kW	**0.8**	D3
Power input to cell	kW/m^3	**3.9**	D2
Air requirement per cell	m^3/min	**0.6**	D3
Number of cells selected	#	**1**	D2
Concentrate			
Mass pull to concentrate	%	**0.4**	D1
Solids mass flow rate	t/h	**0.12**	D3
Solid SG	t/m^3	**2.30**	D1
Slurry solids concentration	%w/w	**10**	D1
Slurry flow rate	m^3/h	**1.16**	D3
Slurry density	t/m^3	**1.06**	D3

SECONDARY ATTRITION CLEANING CIRCUIT			
CRITERIA	**UNITS**	**VALUE**	**SOURCE**
Configuration			
Attrition Scrubbing Circuit			
Concentrate screen apperture size	µm	**350 - TBC**	C
Concentrate screen feed rate	dmt/h	**2.31**	D3
Concentrate screen oversize solids concentration	%	**35**	D1
Concentrate screen split to oversize	%	**50**	C
Scrubber feed size, F100	µm	**500**	D1
Scrubber feed size, F80	µm	**120**	D1
Scrubber slurry retention time	min	**TBC**	D2
Scrubber feed rate (fresh feed)	dmt/h	**2.31**	D3
Circulating load	%	**0.0**	D3
Srubber feed rate (Total)	dmt/h	**2.31**	D3
Specific Energy	kWh/t	**2.69**	D2
Ceramic media charge	%v/v	**20**	D1
Power Required at Pinion	kW	**4.5**	D3
Maximum media charge	%v/v	**30**	D2
Installed power	kW	**2 x 11**	D3
Make-up media size	mm	**6**	D1
Media consumption	g/t	**145**	A
Mill configuration	-	**Open circuit attrition scrubber**	D2
Column Flotation			
Column float feed rate	dmt/h	**1.3**	D3
Column float feed solids	% m/m	**24.9**	D1
Column float feed density	t/m³	**1.16**	D3
Column float slurry flow rate	m³/h	**4.6**	D3
Number of column float cells	#	**1**	D2
Column cell dimensions		**1.25m dia x 6.0m height**	D3
Column float cell absolute volume	m³	**4.9**	D3
Column carrying capacity	(t/m²)/h	**1.0**	D1
Column concentrate solids	%	**14.59**	D1
Column flotation residence time	min	**65**	D3
Mass Pull	%	**3.3**	D3
Air Requirement	m³/min	**0.59**	D3
Concentrate density	t/m³	**1.14**	D3
Cleaner Flotation			
Feed			
Solids mass flow rate	t/h	**0.3**	D3
Solid SG	t/m³	**2.46**	D1
Slurry solids concentration	%w/w	**12**	D1
Slurry density	t/m³	**1.08**	D3
Slurry flow rate	m³/h	**2.6**	D3
Flotation Cells			
Cell type	-	**Trough**	D2
Aeration method	-	**Forced air**	D2
Required flotation capacity	m³	**0.13**	D3
Cell Required Volume (Each)	m³	**0.07**	D3
Cell Selected Volume (Each)	m³	**0.25**	D3
Aeration & Mechanical Losses %	%	**8**	D2
Design residence time	min	**3.0**	D1
Selected installed power	kW	**0.8**	D3
Power input to cell	kW/m³	**3.9**	D2
Air requirement per cell	m³/min	**0.3**	D3

Number of cells selected	#	**2**	D2
Concentrate			
Mass pull to concentrate	%	**0.6**	D1
Solids mass flow rate	t/h	**0.17**	D3
Solid SG	t/m³	**2.28**	D1
Slurry solids concentration	%w/w	**11**	D1
Slurry flow rate	m³/h	**1.42**	D3
Slurry density	t/m³	**1.07**	D3
Cleaner Scavenger Flotation			
Feed			
Solids mass flow rate	t/h	**0.17**	D3
Solid SG	t/m³	**2.49**	D1
Slurry solids concentration	%w/w	**12**	D1
Slurry density	t/m³	**1.08**	D3
Slurry flow rate	m³/h	**1.3**	D3
Flotation Cells			
Cell type	-	**Trough**	D2
Aeration method	-	**Forced air**	D2
Required flotation capacity	m³	**0.13**	D3
Cell Required Volume (Each)	m³	**0.14**	D3
Cell Selected Volume (Each)	m³	**0.25**	D3
Aeration & Mechanical Losses %	%	**8**	D2
Design residence time	min	**6.0**	D1
Selected installed power	kW	**0.8**	D3
Power input to cell	kW/m³	**3.9**	D2
Air requirement per cell	m³/min	**0.4**	D3
Number of cells selected	#	**1**	D2
Concentrate			
Mass pull to concentrate	%	**0.6**	D1
Solids mass flow rate	t/h	**0.17**	D3
Solid SG	t/m³	**2.30**	D1
Slurry solids concentration	%w/w	**10**	D1
Slurry flow rate	m³/h	**1.64**	D3
Slurry density	t/m³	**1.06**	D3

TAILINGS HANDLING

CRITERIA	UNITS	VALUE	SOURCE
Tailing Thickener			
Thickener type	-	**Conventional**	
~~Guard cyclone feed density~~	~~t/m³~~	~~**1.17**~~	D1
~~Guard cyclone feed rate~~	~~dmt/h~~	~~**28.1**~~	D3
~~Guard cyclone underflow density~~	~~t/m³~~	~~**1.6**~~	D1
~~Guard cyclone overflow density~~	~~t/m³~~	~~**1.04**~~	D1
~~Guard cyclone split to overflow~~	~~w/w%~~	~~**21.0**~~	D1
Thickener feed rate	t/h	**28.1**	D3
Thickener feed density	t/m³	**1.04**	D3
Thickener flux rate	$(t/m^2)/h$	**0.5**	D1
Thickener diameter			
Required area	m^2	**56**	D3
Required diameter	m	**8**	D3
Selected	m	**9**	D2
Underflow			
Solids content	% solids	**55.0**	D1
slurry density	t/m³	**1.51**	D3
slurry flow rate	m³/h	**33.8**	D3
Final Tailings Sump			
Sump volume	m³	**2.8**	D3
Combined tailings flow rate	m³/h	**33.8**	D3
Combined tailings density	t/m³	**1.51**	D1
Combined tailings solid content	% solids	**54.7**	D1
Tails sump storage	hrs	**0.1**	D2
Tailings Filtration			
Filter feed tank storage capacity	hrs	**2**	D2
Filter feed tank storage capacity	m³	**67.6**	D3
No of filter feed tanks	#	**1**	D3
Feed rate	t/h	**28.1**	D3
Filtration rate	$kg/h/m^2$	**150**	D2
Filtration area required	m²	**187.2**	D3
Filter type installed	-	**Plate and Frame Pressure**	D2
Filter availability	%	**50**	D2
Plate size (effective)	m^2	**1.50**	D2
Number of filters installed	#	**1.00**	D2
Number of plates installed per filter	-	**147**	D3
Effective filtration area installed	m²	**220.3**	D3

CONCENTRATE HANDLING

CRITERIA	UNITS	VALUE	SOURCE
Configuration			
Concentrate Thickener			
Thickener type	-	**Conventional**	D2
Thickener feed rate	t/h	**1.92**	D3
Thickener feed density	t/m^3	**1.13**	D1
Thickener flux rate	$(t/m^2)/h$	**0.25**	D1
Thickener diameter			
Required area	m^2	**8**	D3
Required diameter	m	**3.1**	D3
Selected	m	**4**	D3
Underflow			
Solids content	% solids	**35.0**	D1
slurry density	t/m^3	**1.24**	D3
Final Concentrate Tank			
Tank capacity	h	**4**	D2
Flow rate	m^3/h	**4.4**	D3
Tank capacity	m^3	**18**	D3
Concentrate Filtration			
Feed rate	t/h	**1.92**	D3
Feed density	t/m^3	**1.24**	D3
Filtration rate	$kg/h/m^2$	**322**	D1
Filtration area required	m^2	**6.0**	D3
Filtration area selected	m^2	**9.9**	D3
Filter type installed	-	**Plate and Frame Pressure**	D2
Filter availability	%	**92**	D2
	m^2	**1.00**	D2
Number of filters installed	#	**1.00**	D3
	-	**3**	D3
Effective filtration area installed	m^2	**10.0**	D3
Cake moisture	%	**<20**	D2
Concentrate Drying, Sizing and Bagging			
Feed rate	t/h	**1.9**	D3
Dryer dimensions	m	**1.5 dia x 15 length**	D3
Dryer installed power	kW	**30**	D3
Diesel burner heating capacity	GJ	**TBC**	E
Bulk bag volume	m^3	**1**	D2
Bulk bag capacity	kg	**600**	D3
Production number of bags per hour	#	**3**	D3

REAGENTS AND GRINDING MEDIA			
CRITERIA	**UNITS**	**VALUE**	**SOURCE**
Collector			
Type	-	**Diesel (fuel oil 2)**	
Delivery			
Physical form	-	**liquid**	D2
Package form	-	**tanker**	D2
Packaged net weight	m^3	**20**	D2
Dosing concentration	%w/v	**As received**	D2
specific gravity	t/m^3	**0.832**	D1
Calculated total dosing rate (ROM feed based)	g/t	**111**	D1
Dosage rate, flash flotation	g/t	**18**	D1
Dosage rate, rougher flotation	g/t	**44**	D1
Dosage rate, primary cleaning	g/t	**24**	D1
Dosage rate, fine flake cleaning	g/t	**20**	D1
Dosage rate, attrition cleaning	g/t	**4**	D1
Frother			
Type	-	**MIBC**	D1
Delivery			
Physical form	-	**liquid**	D2
Package form	-	**IBC / drums**	D2
Packaged net weight	m^3	**0.21 to 1**	D2
Dosing concentration	%w/v	**As received**	D2
specific gravity	t/m^3	**0.802**	D1
Calculated total dosing rate (ROM feed based)	g/t	**165**	D1
Dosage rate, flash flotation	g/t	**40**	D1
Dosage rate, rougher flotation	g/t	**86**	D1
Dosage rate, primary cleaning	g/t	**15**	D1
Dosage rate, fine flake cleaning	g/t	**15**	D1
Dosage rate, attrition cleaning	g/t	**10**	D1
Flocculant			
Type	-	**Magnafloc M919**	D1
Delivery			
Physical form	-	**Powder**	D2
Package form	-	**Bags**	D2
Packaged net weight	kg	**25**	D2
Dosing concentration	%w/v	**0.25**	D2
specific gravity	t/m^3	**1**	D2
Calculated total dosing rate (ROM feed based)	g/t	**1**	D1
Dosage rate, attrition thickener	g/t	**0.5**	D1
Dosage rate, final concentrate thickener	g/t	**0.5**	D1
Type	-	**Magnafloc M24**	D1
Delivery			
Physical form	-	**Powder**	D2
Package form	-	**Bags**	D2
Packaged net weight	kg	**25**	D2
Dosing concentration	%w/v	**0.25**	D2
specific gravity	t/m^3	**1**	D2
Calculated total dosing rate (ROM feed based)	g/t	**125**	D1
Dosage rate, tailings thickener	g/t	**125**	D1
Coagulant			
Type	-	**Magnafloc M1707**	D1
Delivery			
Physical form	-	**Powder**	D2
Package form	-	**Bags**	D2
Packaged net weight	kg	**25**	D2
Dosing concentration	%w/v	**0.25**	D2
specific gravity	t/m^3	**1**	D2
Calculated total dosing rate (ROM feed based)	g/t	**170**	D1
Dosage rate, attrition thickener	g/t	**37.4**	D1
Dosage rate, final concentrate thickener	g/t	**37.4**	D1
Dosage rate, tailings thickener	g/t	**20.6**	D1

AIR RETICULATION			
CRITERIA	**UNITS**	**VALUE**	**SOURCE**
Configuration			
Low Pressure Flotation Air			
Source	-	**Blowers**	
Blower type	-	**GM 25 L**	D3
Installed motor	kW	**30**	D3
Number of units		**1**	D2
Configuration		**Duty**	D2
Delivery pressure	kPa (g)	**40**	D2
Cell air demand			
Rougher Circuit	m^3/min	**7.9**	D3
Cleaner Circuit	m^3/min	**3.5**	D3
Fine Flake Circuit	m^3/min	**4.4**	D3
Attritioning Circuit	m^3/min	**2.8**	D3
Secondary Attrition Circuit	m^3/min	**2.8**	D3
Final Concentrate Filtration Circuit	m^3/min	**TBC**	
Total air demand	m^3/min	**21.5**	D3
High Pressure Air			
Source		**High pressure plant air compressors**	
Plant Air			
Service pressure	bar (g)	**10**	D2
Air demand	FAD m^3/min	**4.5**	D3
Unit capacity	FAD m^3/min	**5**	D3
Unit type		**Screw type air compressor**	D2
Installed motor	kW	**30**	D3
Number of units		**1**	D2
Configuration		**Duty**	D2
Air drying		**Yes**	D2

WATER RETICULATION			
CRITERIA	**UNITS**	**VALUE**	**SOURCE**
Raw Water Usage			
Source	-	**Borehole**	
Dust suppression			
Gland seal water	m^3/h	**1.9**	D3
Reagent make-up	m^3/h	**4.3**	D3
Potable water make-up	m^3/h	**1.0**	D3
Process water make-up	m^3/h	**2.2**	D3
Dust suppression water make-up	m^3/h	**2.1**	D3
Fire water make-up	m^3/h	**0.3**	D3
Total raw water usage	m^3/h	**11.7**	D3
Process water requirement	m^3/h	**87.8**	D3
Return water to plant	m^3/h	**N/A**	
TSF water recovery to plant	%	**N/A**	
Storage capacities			
Process water dam	m^3	**878**	D3
Process water tank	m^3	**45**	D3
Clean water tank	m^3	**45**	D3
Fire water	m^3	**Raw water**	D2
Clean water	m^3	**Manifold with electric and diesel pumps**	

Appendix D

Process Flow Diagram

120 / 4 TERTIARY CRUSHER PRODUCT → 7

120 / 7 SECONDARY CRUSHER PRODUCT → 6



PROCESS PLANT

MINING

Oversize Material

100-SR-004

100-BN-006

1

100-FD-008

3

2

100-CR-010

4

100-CV-011

600 / 22 CLEAN WATER

100-TK-018

100-PP-020

100-EE-046

100-CV-012

5

120 / 1 CLASSIFICATION SCREEN

100-ZM-069

100-BN-048

120 MILL FEED BIN CONVEYOR

Description	Open Pit ROM	Grizzly Feeder Oversize	Grizzly Feeder Undersize	Jaw Crushing Product	Screen Feed	Secondary Crusher Product	Tertiary Crusher Product
Stream No.	1	2	3	4	5	6	7
Solids (tph)	50.00	35.49	14.51	35.49	111.05	30.52	30.52
Water (m3/h)	1.55	1.10	0.45	1.60	5.16	1.55	1.55
% solids (m3/h)	97%	97%	97%	96%	96%	95%	95%
SG	2.60	2.60	2.60	2.60	2.60	2.60	2.60
Max Solids (tph)	60.00	42.58	17.42	42.58	133.26	36.63	36.63
Max Slurry (m3/h)	1.76	1.25	0.51	1.82	5.87	1.77	1.77
Bulk (t/m3)	1.58	1.58	1.58	1.58	1.58	1.58	1.58
Size Max (mm+)	400	400	120	120	120	120	18

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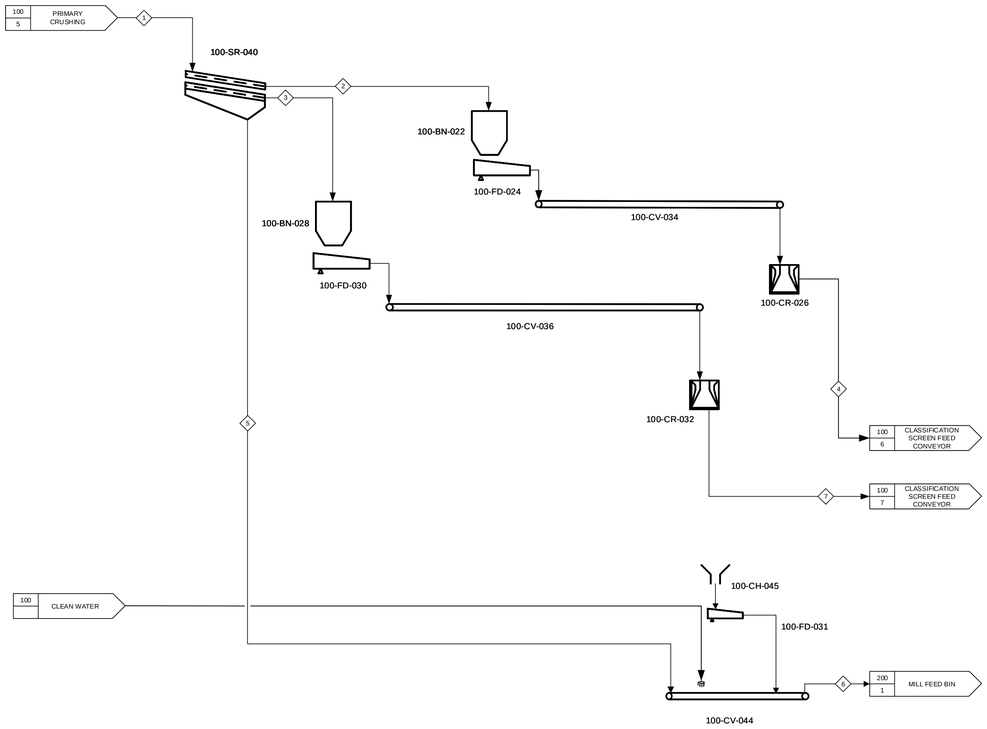
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Energizer Resources

Molo 240 ktpa Graphite Concentrator Project

Ore Receiving & Primary Crushing

MATERIAL	SCALE	DRAWING NUMBER	REV
	N.T.S	C1601-PFD-100	D



Description	Classification Screen Feed	Secondary Crusher Feed	Tertiary Crusher Feed	Secondary Crusher Product	Classification Screen U/F	Primary Mill Feed Bin	Tertiary Crusher Product
Stream No.	1	2	3	4	5	6	7
Solids (tph)	111.05	30.52	30.52	30.52	50.00	50.00	30.52
Water (m3/h)	5.66	1.55	1.55	1.55	2.55	2.55	1.55
% solids (m3/h)	95%	95%	95%	95%	95%	95%	95%
SG	2.60	2.60	2.60	2.60	2.60	2.60	2.60
Max Solids (tph)	133.26	36.63	36.63	36.63	60.00	60.00	36.63
Max Slurry (m3/h)	6.44	1.77	1.77	1.77	2.90	2.90	1.77
Bulk (t/m3)	1.58	1.58	1.58	1.58	1.58	1.58	1.58
Size Max (mmw)	120	120	35	44	16	16	16

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Energizer Resources

Molo 240 ktpa Graphite Concentrator Project

Screening, Secondary and Tertiary Crushing

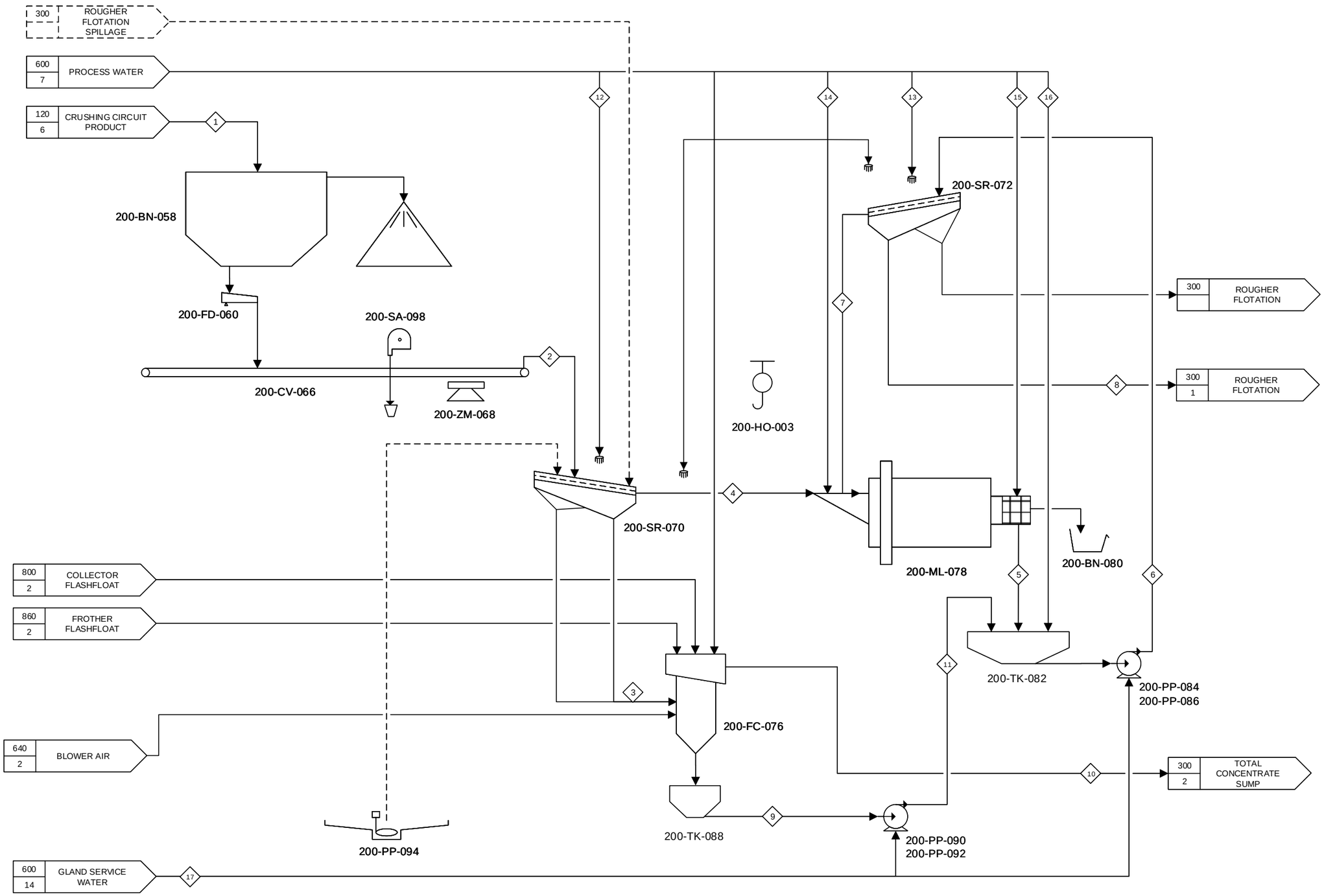
SCALE	DRAWING NUMBER	REV
N.T.S	C1601-PFD-120	D

Equipment List

Displayed Text	Description
100-BN-022	SECONDARY CRUSHER FEED BIN
100-BN-028	TERTIARY CRUSHER FEED BIN
100-BN-048	SECONDARY CRUSHING TRAMP METAL BIN
100-BN-049	TERTIARY CRUSHING TRAMP METAL BIN
100-CH-045	Tertiary Crusher Surge Bin Overflow Chute
100-CR-026	SECONDARY CRUSHER
100-CR-032	TERTIARY CRUSHER
100-CV-034	SECONDARY CRUSHER FEED CONVEYOR
100-CV-038	CRUSHER DISCHARGE CONVEYOR
	CRUSHER DISCHARGE CONVEYOR
100-CV-044	MILL FEED BIN CONVEYOR
100-EE-046	SECONDARY CRUSHING TRAMP METAL MAGNET
100-EE-047	TERTIARY CRUSHING TRAMP METAL MAGNET
100-FD-024	SECONDARY CRUSHER FEEDER
100-FD-030	TERTIARY CRUSHER FEEDER
100-PP-052	CONE CRUSHING DUST SUPPRESSION PUMP
100-SR-040	CLASSIFICATION SCREEN
100-TK-050	CONE CRUSHING DUST SUPPRESSION TANK

Instrument List

Displayed Text	Description	Manufacturer	Area	Equipment Number	Equipment Code
100-LT-001	Tertiary Crusher Surge Bin Level Transmitter		100	1	LT
100-LT-002	Secondary Crusher Surge Bin Level Transmitter		100	2	LT



Description	Classification Screen U/F	Mil Circuit Feed	Scalping Screen U/S	Scalping Scrren O/S	Primary Mill Discharge	Primary Mill DIscharge Sump	Primary Mill Screen O/S	Primary Mill Screen U/S	Flash Float Tails	Flash Float Concentrate	Flash Float Tails Pump	Scalping Screen Spray Water	Primary Mill Screen Spray Water	Primary Mill Dilutation Water	Primary Mill Trommel Spray Water	Primary Mill Discharge Dilution Water	Primary Mill GSW
Stream No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Solids (tph)	50.00	30.00	10.21	19.79	55.18	64.49	35.38	29.10	9.31	0.90	9.31	0.00	0.00	0.00	0.00	0.00	0.00
Water (m3/h)	2.55	1.53	18.62	6.76	24.47	43.50	11.89	79.24	14.93	3.68	15.25	23.85	47.64	5.25	0.56	3.40	0.70
Slurry (m3/h)	21.78	13.07	22.54	14.37	45.69	68.30	25.50	90.44	18.49	4.05	18.80	23.85	47.64	5.25	0.56	3.40	0.70
% solids	95%	95%	35%	75%	69%	60%	75%	27%	38%	20%	38%	0%	0%	0%	0%	0%	0%
SG	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.62	2.42	2.62	1.00	1.00	1.00	1.00	1.00	1.00
RD	2.41	2.41	1.28	1.85	1.74	1.58	1.85	1.20	1.31	1.13	1.31	1.00	1.00	1.00	1.00	1.00	1.00
Max Solids (tph)	60.00	36.00	12.25	23.75	66.21	77.38	42.46	34.92	11.17	1.08	11.17	0.00	0.00	0.00	0.00	0.00	0.00
Max Slurry (m3/h)	24.8	14.9	25.7	16.4	52.0	77.8	29.0	103.0	21.0	4.6	21.4	27.2	54.2	6.0	0.6	3.9	0.8

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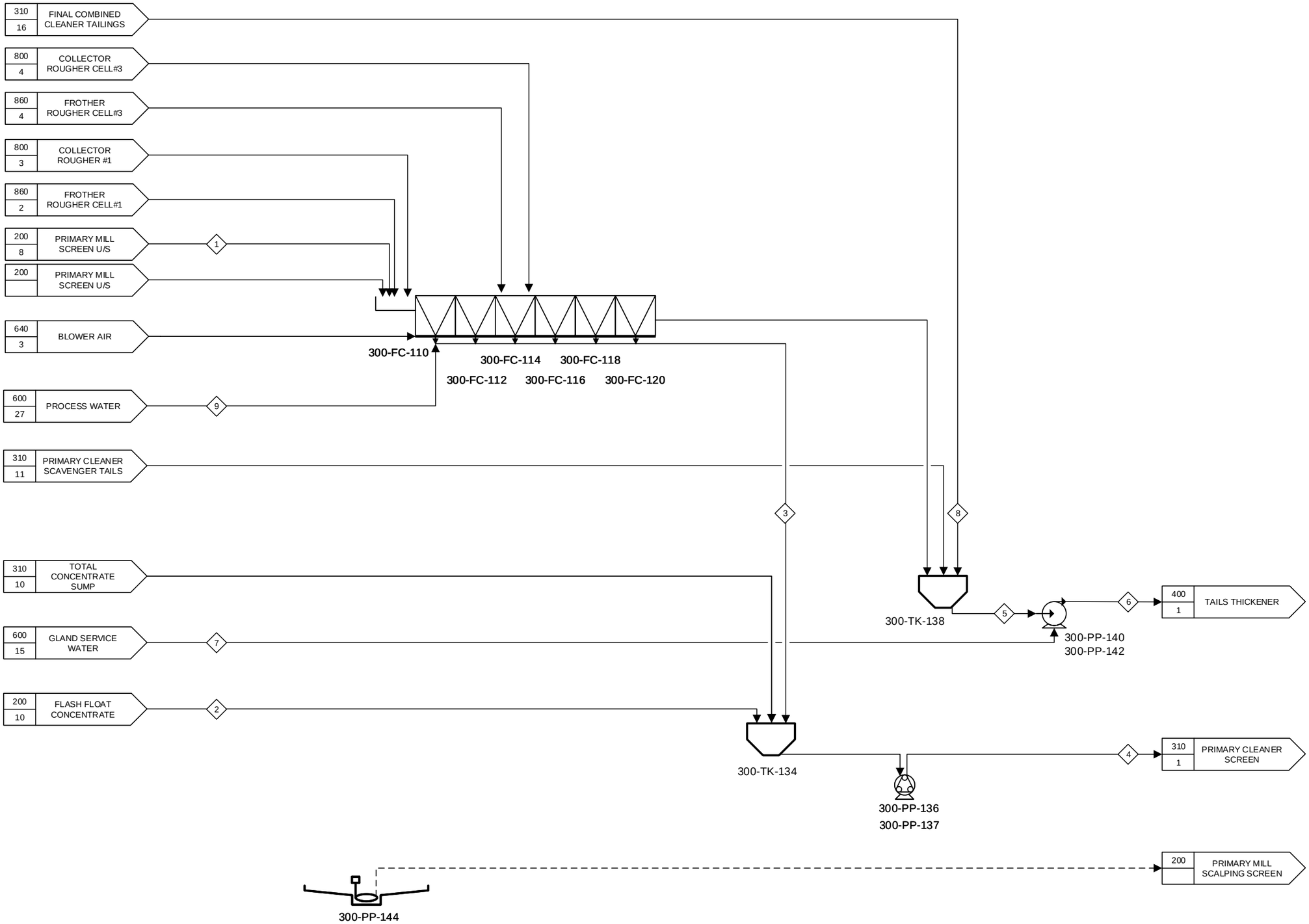
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Energizer Resources

Molo 240 ktpa Graphite Concentrator Project

Primary Milling and Flash Flotation

MATERIAL	SCALE	DRAWING NUMBER	REV
	N.T.S	C1601-PFD-200	D



Description	Primary Mill Screen U/S	Flash Float Concentrate	Rougher Float Concentrate	Combined Concentrate	Combined Float Tails	Combined Tails Pump	Rougher GSW	Final Cleaner Tails Pump	Wash Water
Stream	1	2	3	4	5	6	7	8	9
Solids (tph)	29.10	0.90	2.49	3.75	28.08	28.08	0.00	0.24	0.00
Water (m3/h)	78.99	3.64	9.40	17.09	81.26	81.46	0.20	6.28	0.50
Slurry (m3/h)	90.19	4.01	10.42	18.63	91.98	93.17	0.20	6.37	0.50
% solids	27%	20%	21%	18%	26%	26%	0%	4%	0%
SG	2.60	2.42	2.45	2.44	2.62	2.40	1.00	2.59	1.00
RD	1.20	1.13	1.14	1.12	1.19	1.18	1.00	1.02	1.00
Max Solids (tph)	34.92	1.08	2.99	4.50	33.70	33.70	0.00	0.29	0.00
Max Slurry (m3/h)	102.7	4.6	11.9	21.2	104.7	106.1	0.2	7.3	0.6

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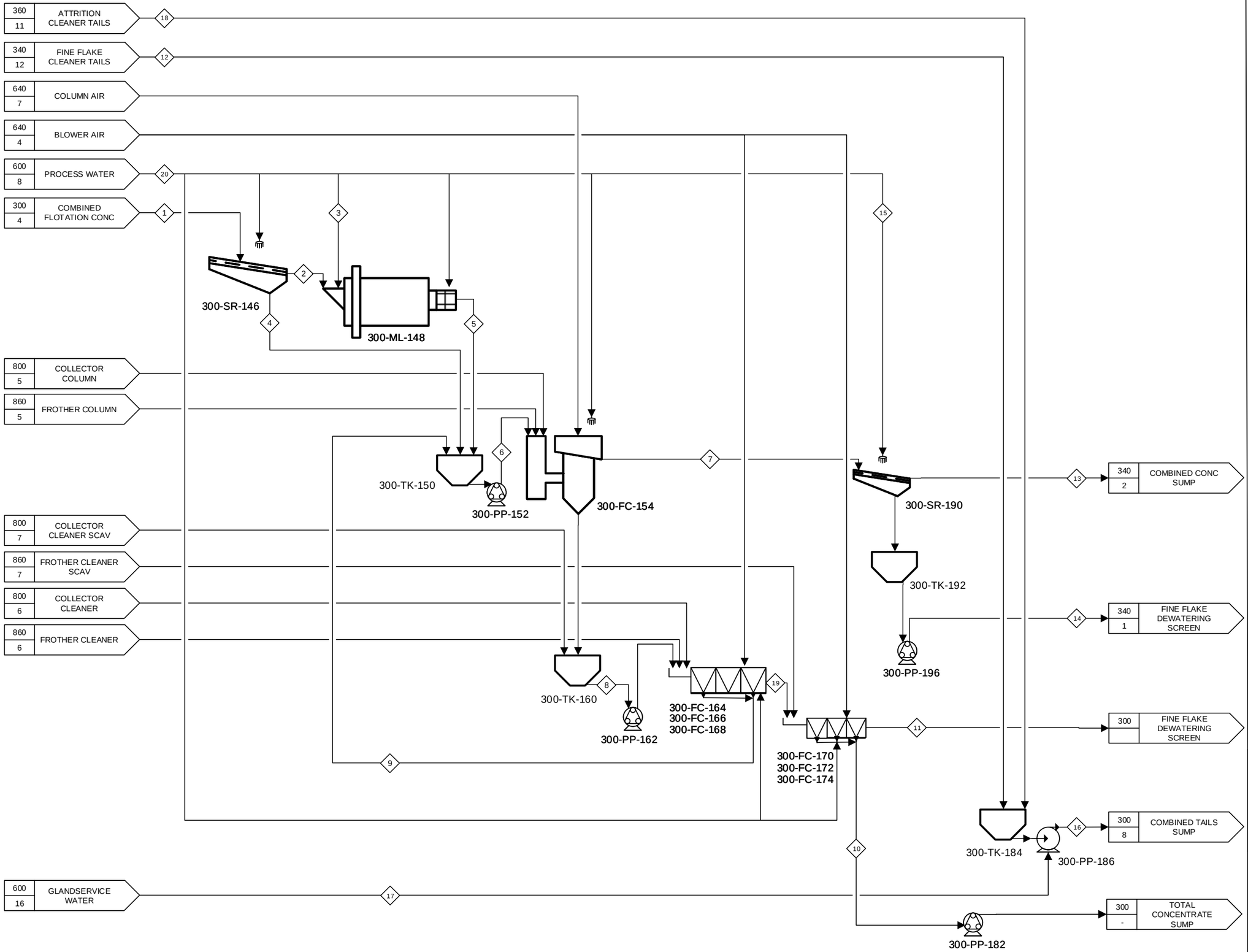
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Energizer Resources

Molo 240 ktpa Graphite Concentrator Project

Rougher Flotation

MATERIAL	SCALE	DRAWING NUMBER	REV
	N.T.S	C1601-PFD-300	D



Description	Combined Concentrate	Primary Cleaner Screen O/S	Primary Cleaner Mill Dilution Water	Primary Cleaner Screen U/S	Primary Polish Mill Discharge	Primary Polish Mill Discharge Pump	Primary Cleaner Column Concentrate	Primary Cleaner Column Tails	Cleaner Column Float Conc	Primary Cleaner Scavenger Float Conc	Primary Cleaner Scavenger Tails	Fine Flakes Cleaner Tails	Primary Column Conc Screen O/S	Primary Column Conc Screen U/S	Primary Column Conc Screen Spray Water	Final Cleaner Tails Pump	Primary Cleaner GSW	Attrition Cleaner Tails	Cleaner Column Float Tails	Primary Cleaner Process Water
Stream	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Solids (tph)	3.75	3.29	0.00	0.46	3.29	4.45	2.16	2.29	0.70	0.36	1.23	0.03	1.62	0.53	0.00	0.24	0.00	0.21	1.59	0.00
Water (m3/h)	17.09	3.28	0.55	13.81	3.83	23.90	8.70	15.20	6.26	4.05	4.89	5.87	1.56	7.94	0.80	6.28	0.20	0.21	8.94	1.35
Slurry (m3/h)	18.63	4.63	0.55	14.00	5.18	25.70	9.61	16.09	6.53	4.19	5.36	5.88	2.25	8.16	0.80	6.37	0.20	0.29	9.56	1.35
% solids	18%	50%	0%	3%	46%	16%	20%	13%	10%	8%	20%	1%	51%	6%	0%	4%	0%	50%	15%	0%
SG	2.44	2.45	1.00	2.45	2.45	2.47	2.36	2.58	2.56	2.56	2.60	2.50	2.36	2.36	1.00	2.59	1.00	2.53	2.59	1.00
RD	1.12	1.42	1.00	1.02	1.38	1.10	1.13	1.09	1.07	1.05	1.14	1.00	1.42	1.04	1.00	1.02	1.00	1.43	1.10	1.00
Max Solids (tph)	4.50	3.95	0.00	0.55	3.95	5.34	2.59	2.75	0.84	0.43	1.48	0.04	1.95	0.64	0.00	0.29	0.00	0.25	1.91	0.00
Max Slurry (m3/h)	21.2	5.3	0.6	15.9	5.9	29.3	10.9	18.3	7.4	4.8	6.1	6.7	2.6	9.3	0.9	7.3	0.2	0.3	10.9	1.5

REVISION				
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	D	UPDATE FOR EXECUTION	15/12/2016	
	C	UPDATE FROM REVIEW 2	18/10/2016	
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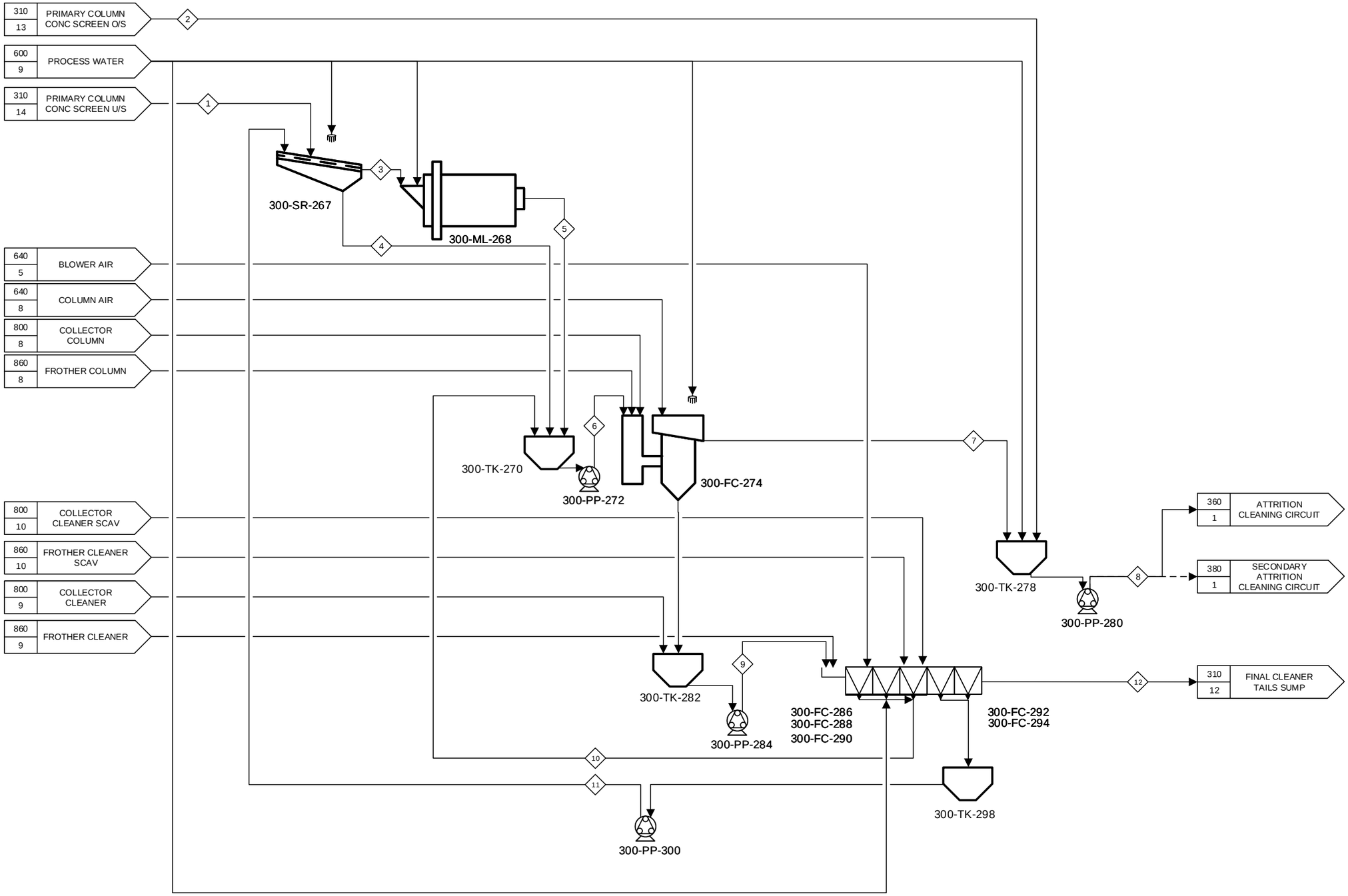
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Energizer Resources

Molo 240 ktpa Graphite Concentrator Project

Primary Concentrate Cleaning Circuit

MATERIAL	SCALE	DRAWING NUMBER	REV
	N.T.S	C1601-PFD-310	D



Description	Primary Column Conc Screen U/S	Primary Column Conc Screen O/S	Fine Flake Cleaner Screen O/S	Fine Flake Cleaner Screen U/S	Fine Flake Polish Mill Discharge	Fine Flake Polish Mill Discharge Pump	Fine Flake Polish Coloumn Concentrate	Combined Cleaner Concentrate	Fine Flake Column Tails	Fine Flakes Cleaner Conc	Fine Flake Cleaner Scavenger Conc	Fine Flakes Cleaner Tails								
Stream	1	2	3	4	5	6	7	8	9	10	11	12								
Solids (tph)	0.53	1.62	0.39	0.15	0.39	0.57	0.51	2.13	0.06	0.02	0.01	0.02								
Water (m3/h)	7.94	1.56	0.40	7.71	0.40	8.31	2.07	3.63	6.24	0.19	0.18	5.87								
Slurry (m3/h)	8.16	2.25	0.57	7.78	0.57	8.55	2.29	4.54	6.26	0.20	0.18	5.88								
% solids	6%	51%	49%	2%	49%	6%	20%	37%	1%	11%	6%	0.4%								
SG	2.36	2.36	2.35	2.35	2.35	2.35	2.35	2.35	2.35	2.33	2.34	2.50								
RD	1.04	1.42	1.39	1.01	1.39	1.04	1.13	1.27	1.01	1.06	1.04	1.00								
Max Solids (tph)	0.64	1.95	0.47	0.18	0.47	0.68	0.61	2.56	0.07	0.03	0.01	0.03								
Max Slurry (m3/h)	9.3	2.6	0.6	8.9	0.6	9.7	2.6	5.2	7.1	0.2	0.2	6.7								

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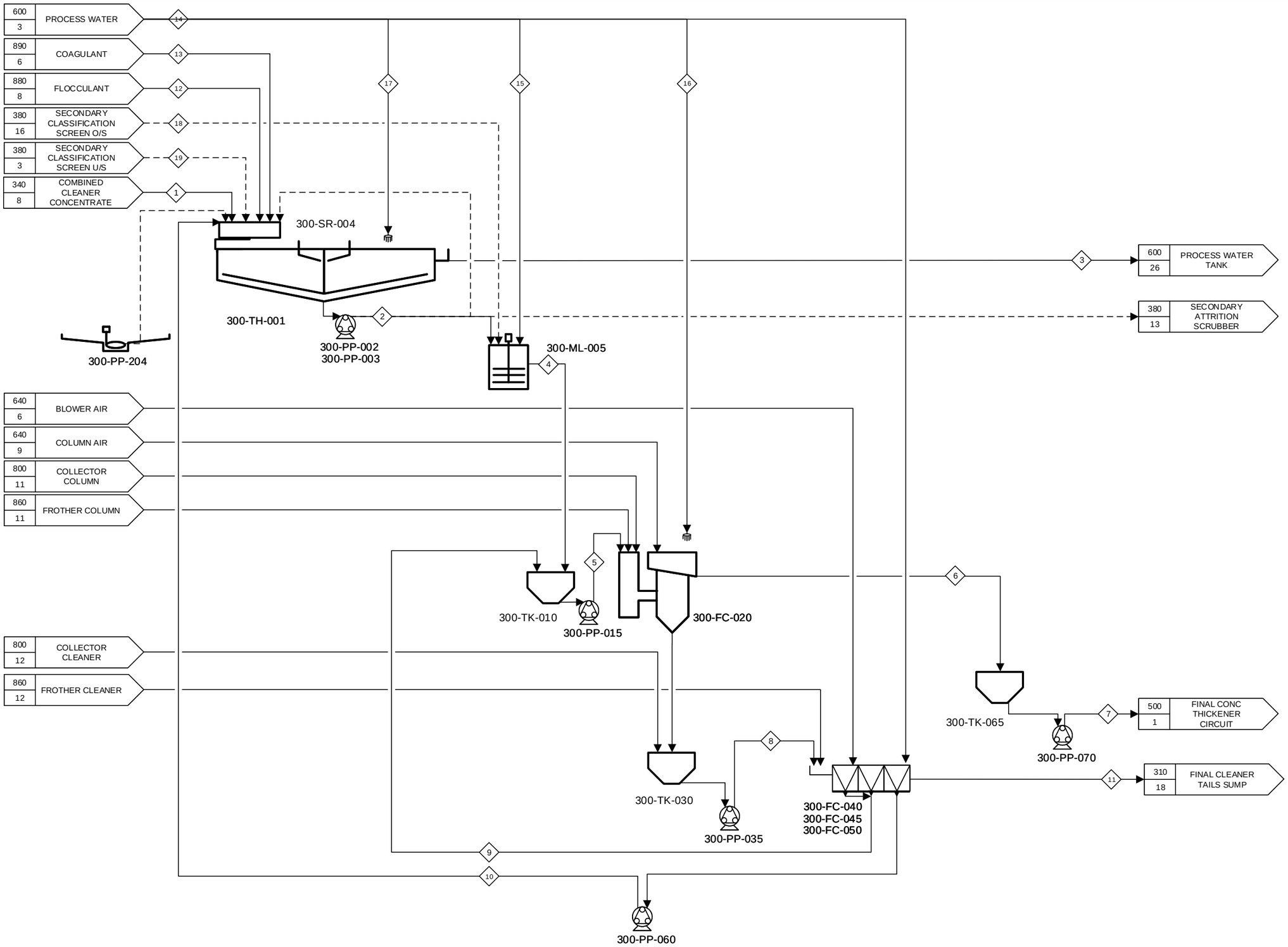
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Energizer Resources

Molo 240 ktpa Graphite Concentrator Project

Fine Flake Cleaning Circuit

MATERIAL	SCALE	DRAWING NUMBER	REV
	N.T.S	C1601-PFD-340	C



Description	Combined Cleaner Concentrate	Attrition Concentrate Thickener U/F	Attrition Concentrate Thickener O/F	Attrition Mill Discharge	Attrition Mill Discharge Pump	Attrition Column Concentrate	Final Concentrate	Attrition Column Tails	Attrition Cleaner Conc	Attrition Cleaner Scavneger Conc	Attrition Cleaner Tails	Attrition Thickener Flocculant	Attrition Thickener Coagulant	Attrition Cleaner Process Water	Attrition Mill Dilution	Attrition Cleaner Dilution Water	Attrition Thickener Spray Water			
Stream	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17			
Solids (tph)	2.13	2.22	0.00	2.22	2.52	1.92	1.92	0.59	0.30	0.09	0.21	0.00	0.00	0.00	0.00	0.00	0.00			
Water (m3/h)	3.63	5.15	0.70	5.65	7.16	5.30	5.30	2.87	1.51	1.22	0.13	0.00	0.50	2.00	0.50	1.00	0.50			
Slurry (m3/h)	4.54	6.09	0.70	6.59	8.23	6.12	6.12	3.11	1.64	1.26	0.21	0.00	0.50	2.00	0.50	1.00	0.50			
% solids	37%	30%	0%	28%	26%	27%	27%	17%	16%	7%	62%	0%	0%	0%	0%	0%	0%			
SG	2.35	2.36	1.00	2.36	2.37	2.34	2.34	2.46	2.43	2.41	2.53	1.00	1.00	1.00	1.00	1.00	1.00			
RD	1.27	1.21	1.00	1.19	1.18	1.18	1.18	1.11	1.11	1.04	1.59	1.00	1.00	1.00	1.00	1.00	1.00			
Max Solids (tph)	2.56	2.67	0.00	2.67	3.02	2.31	2.31	0.71	0.36	0.10	0.25	0.00	0.00	0.00	0.00	0.00	0.00			
Max Slurry (m3/h)	5.2	6.9	0.8	7.5	9.4	7.0	7.0	3.5	1.9	1.4	0.2	0.0	0.6	2.3	0.6	1.1	0.6			

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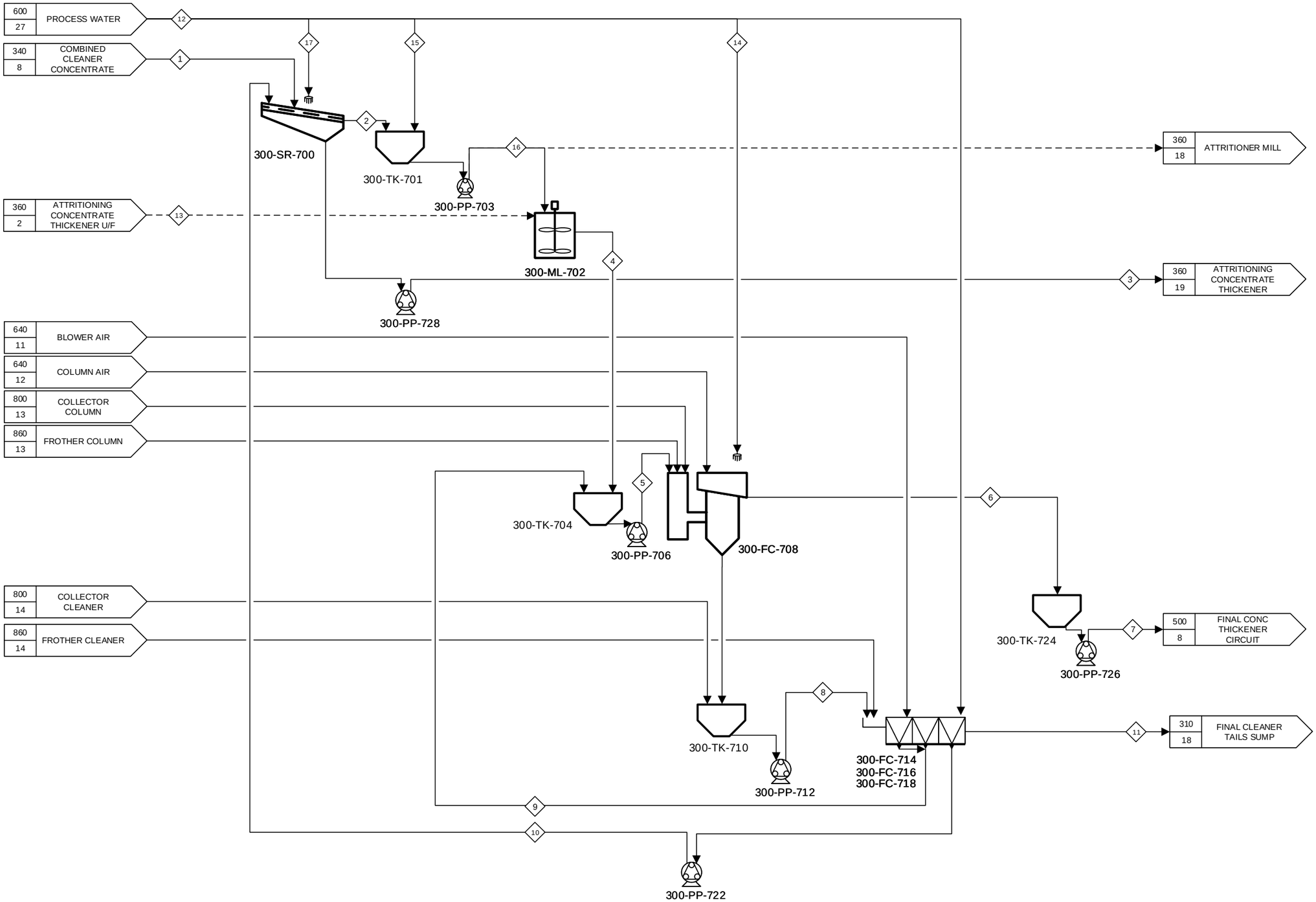
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Energizer Resources

Molo 240 ktpa Graphite Concentrator Project

Attrition Cleaning Circuit

SCALE	DRAWING NUMBER	REV
N.T.S	C1601-PFD-360	C



Description	Secondary Attrition Feed	Secondary Attrition Screen Overflow	Secondary Attrition Screen Underflow	Scrubber Discharge	Secondary Attrition Column Feed	Secondary Attrition Column Concentrate	Secondary Attrition Final Concentrate	Secondary Attrition Column Tails	Secondary Attrition Cleaner Conc	Secondary Attrition Cleaner Scavneger Conc	Secondary Attrition Cleaner Scavneger Tails	Secondary Attrition Cleaning Water	Attrition Concentrate Thickener U/F	Secondary Cleaner Classification Cleaner Dilution Water	Secondary Attrition Mill Dilution	Scrubber Feed	Secondary Attrition Screen Dilution			
Stream	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17			
Solids (tph)	2.13	1.15	1.15	1.15	1.32	0.40	0.40	0.92	0.17	0.17	0.59	0.00	2.22	0.00	0.00	1.15	0.00			
Water (m3/h)	3.63	1.55	2.88	5.55	6.32	1.19	1.19	5.13	0.77	0.78	3.57	5.64	5.15	1.63	4.00	5.55	0.01			
Slurry (m3/h)	4.54	2.04	3.36	6.04	6.88	1.36	1.36	5.52	0.84	0.85	3.82	5.64	6.09	1.63	4.00	6.04	0.01			
% solids	37%	43%	29%	17%	17%	25%	25%	15%	18%	17%	14%	0%	30%	0%	0%	17%	0%			
SG	2.36	2.36	2.36	2.36	2.36	2.37	2.34	2.34	2.46	2.42	2.41	1.00	2.36	1.00	1.00	2.36	1.00			
RD	1.27	1.33	1.20	1.11	1.11	1.17	1.17	1.10	1.12	1.11	1.09	1.00	1.21	1.00	1.00	1.11	1.00			
Max Solids (tph)	2.56	1.38	1.38	1.38	1.58	0.48	0.48	1.11	0.20	0.20	0.71	0.00	2.67	0.00	0.00	1.38	0.00			
Max Slurry (m3/h)	5.2	2.3	3.8	6.9	7.8	1.5	1.5	6.3	1.0	1.0	4.3	6.4	6.9	1.9	4.6	6.9	0.0			

REVISION	No	DESCRIPTION	DATE	CHECK
	E	UPDATE FROM 90% REVIEW	04/4/2017	
	D	UPDATE FOR EXECUTION	15/12/2016	
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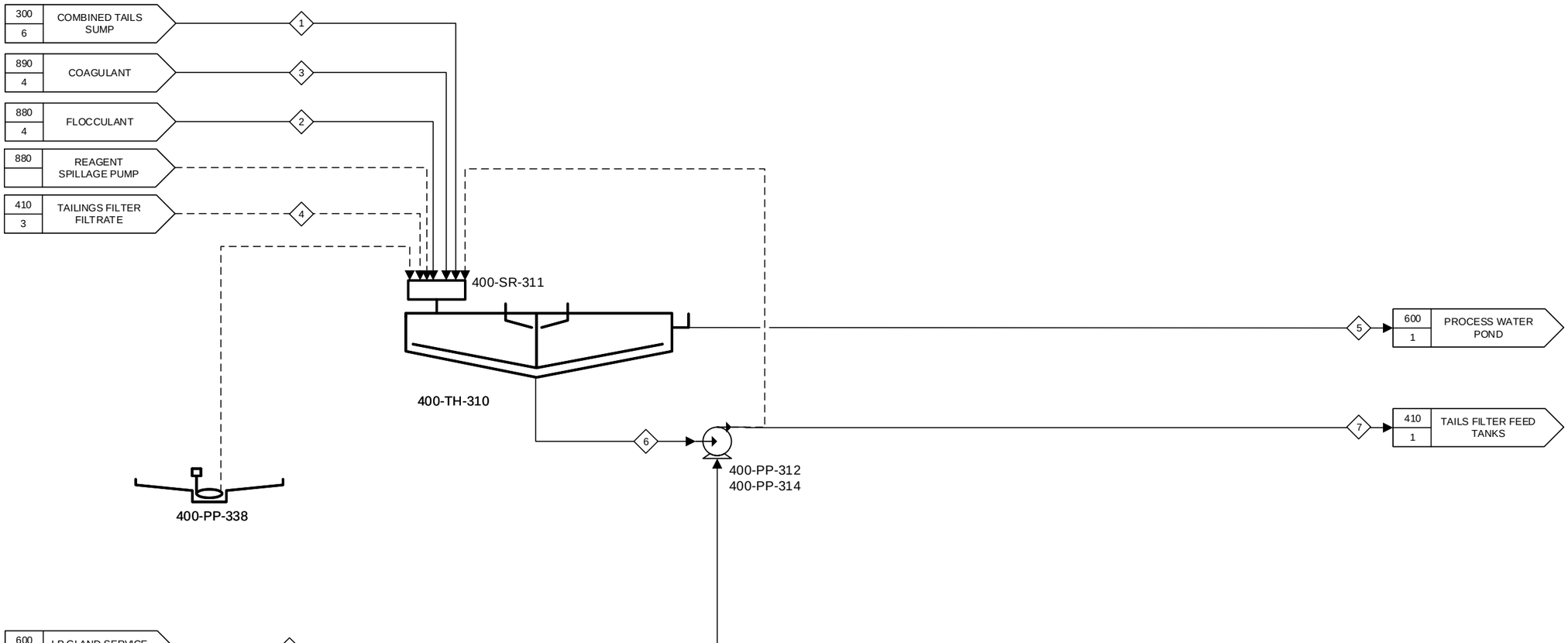
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Energizer Resources

Molo 240 ktpa Graphite Concentrator Project

Secondary Attrition Cleaning Circuit

SCALE	DRAWING NUMBER	REV
N.T.S	C1601-PFD-380	D



Description	Combined Tails Pump	Tails Thickener Flocculant	Tails Thickener Coagulant	Tailings Filtration Combined Filtrate	Tails Thickener O/F	ails Thickener U/F	Tails Thickener U/F Pump		Tails Thickener U/F GSW											
Stream	1	2	3	4	5	6	7		9											
Solids (tph) (max)	28.08	0.00	0.00	0.00	0.00	28.08	28.08		0.00											
Water (m3/h)	81.38	1.76	0.98	19.89	76.97	27.04	27.24		0.20											
Slurry (m3/h)	92.10	1.76	0.98	19.89	76.97	45.64	45.84		0.20											
% solids	25.6%	0.0%	0.0%	0.0%	0.0%	50.9%	50.8%		0.0%											
SG	2.62	2.62	1.00	1.00	1.00	1.51	1.51		1.00											
RD	1.19	1.00	1.00	1.00	1.00	1.21	1.21		1.00											
Max (tph)	33.69	0.00	0.00	0.00	0.00	33.69	33.69		0.00											
Max (m3/h)	104.8	2.0	1.1	22.6	87.6	52.0	52.2		0.2											

REVISION	No	DESCRIPTION	DATE	CHECK
	D	UPDATE 30% 3D DESIGN REVIEW	9/1/2017	
	C	UPDATE FROM REVIEW 2	18/10/2016	
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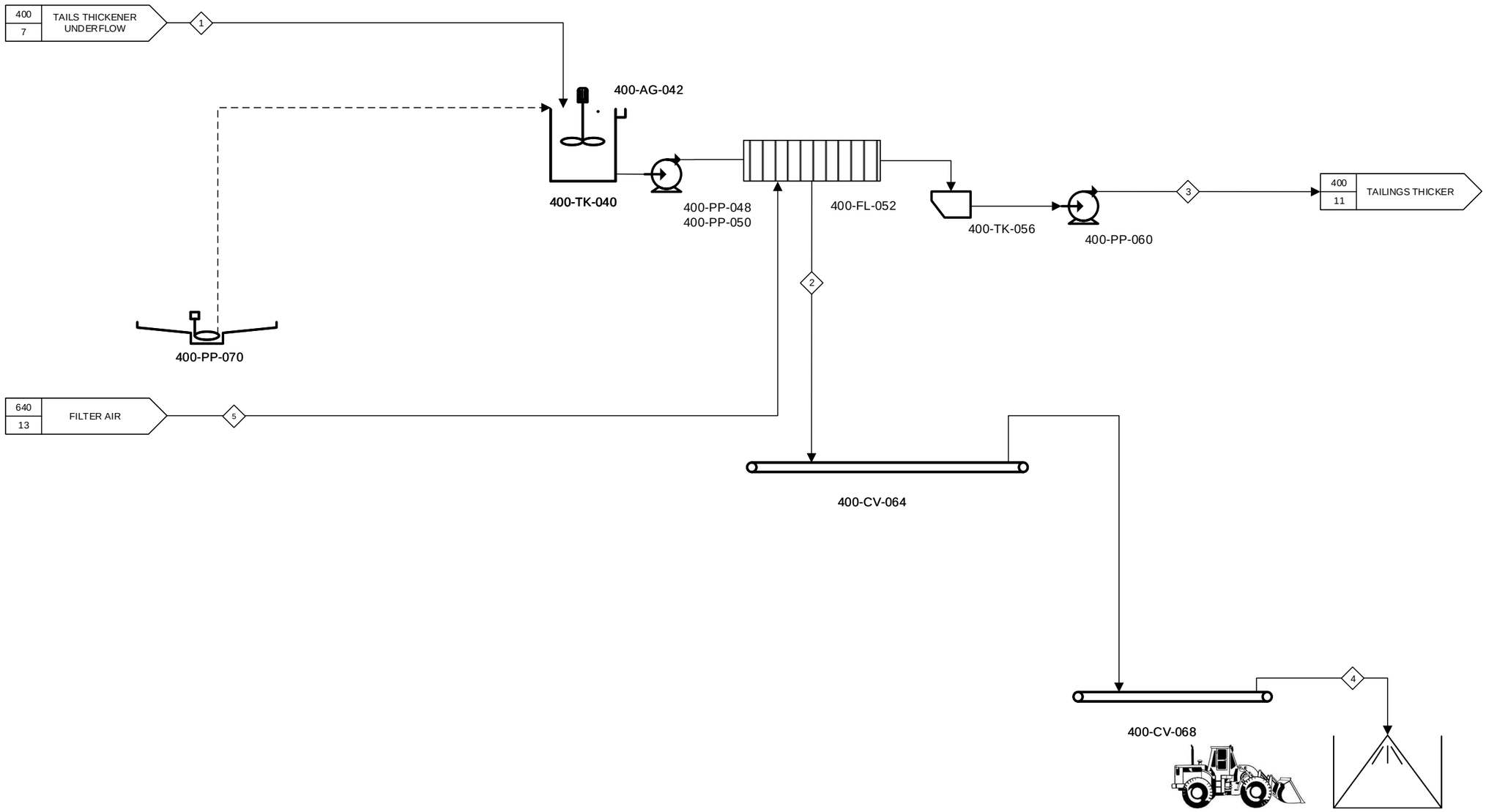
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Energizer Resources

Molo 240 ktpa Graphite Concentrator Project

Final Tails Handeling & Disposal Circuit

MATERIAL	SCALE	DRAWING NUMBER	REV
	N.T.S	C1601-PFD-400	C



Description	Tailings Thickener U/F	Tailings Filtration Combined Cake	Tailings Filtration Filtrate 1	Tailings Filtration Combined Cake	Tailings Filtration Air
Stream	1	2	3	4	5
Solids (tph) (max)	28.08	28.08	0.00	28.08	0.00
Water (m3/h)	27.24	7.36	19.89	7.36	0.00
Slurry (m3/h)	37.96	18.20	19.89	18.20	0.00
% solids	50.8%	79.2%	0.0%	79.2%	0.0%
SG	2.62	2.59	1.00	2.59	-
RD	1.46	1.95	1.00	1.95	0.00
Max (tph)	33.69	33.69	0.00	33.69	0.00
Max (m3/h)	43.2	20.7	22.6	20.7	0.0

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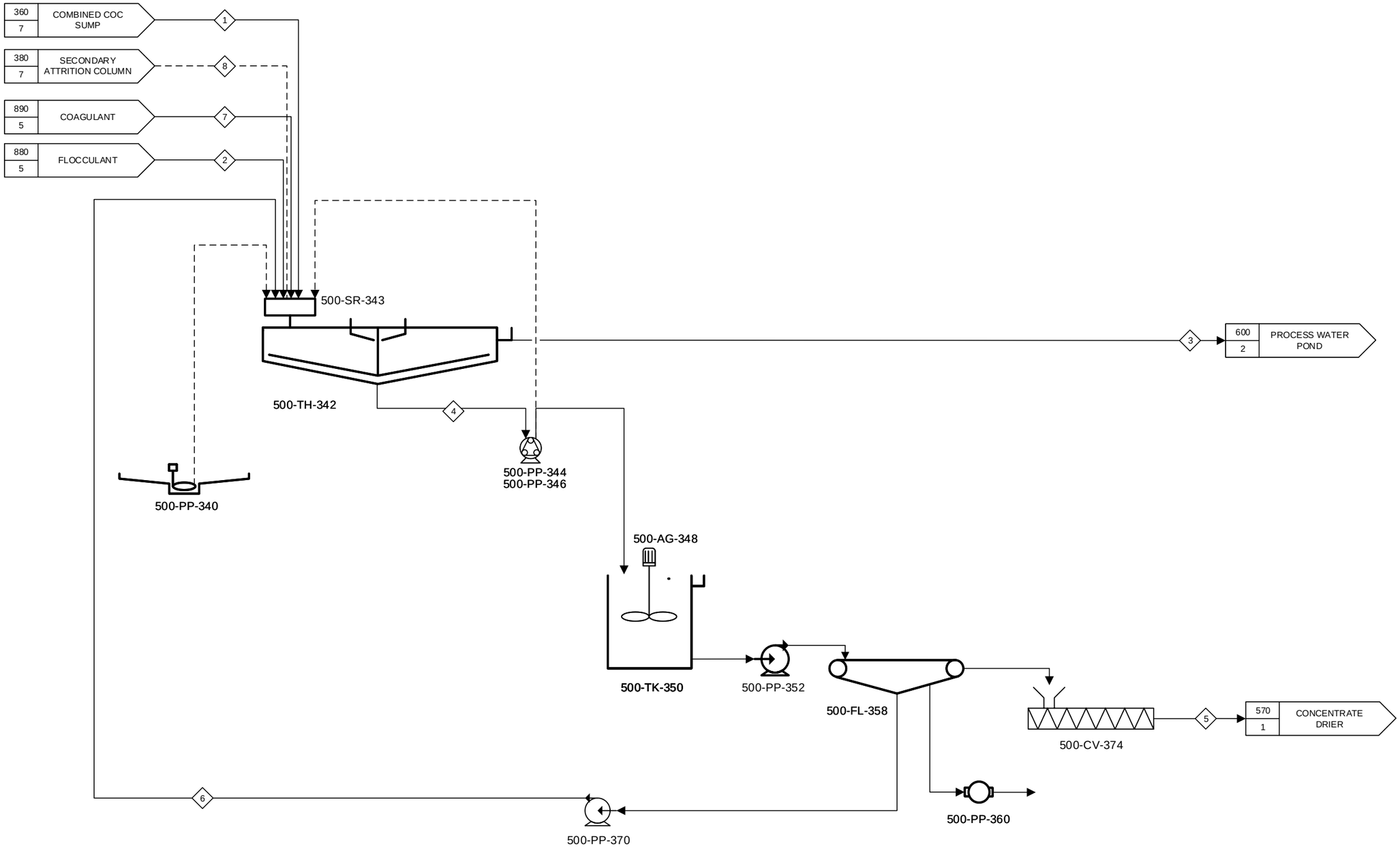
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Energizer Resources

Molo 240 ktpa Graphite Concentrator Project

Final Tails Filtration & Disposal Circuit

SCALE	DRAWING NUMBER	REV
N.T.S	C1601-PFD-410	D



Description	Final Concentrate	Concentrate Thickener Coagulant	Final Conc Thickener O/F	Final Conc Thickener U/F	Final Conc Belt Filter Cake	Final Conc Belt Filtrate	Concentrate Thickener Coagulant	Secondary Attrition Column Concentrate
Stream	1	2	3	4	5	6	7	8
Solids (tph)	1.92	0.00	0.00	1.92	1.92	0.00	0.00	0.40
Water (m3/h)	5.30	0.98	6.62	3.56	0.64	2.92	0.98	1.19
Slurry (m3/h)	6.22	0.98	6.62	4.49	1.57	2.92	0.98	1.36
% solids	27%	0%	0%	35%	75%	0%	0%	25%
SG	2.08	1.00	1.00	2.08	2.08	1.00	1.00	2.34
RD	1.16	1.00	1.00	1.22	1.64	1.00	1.00	1.17
Max (tph)	2.31	0.00	0.00	2.31	2.31	0.00	0.00	0.48
Max (m3/h)	7.1	1.1	7.5	5.1	1.8	3.3	1.1	1.5

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	E	UPDATE FROM 90% REVIEW	01/4/2017	
	D	UPDATE 30% 3D DESIGN REVIEW	9/1/2017	
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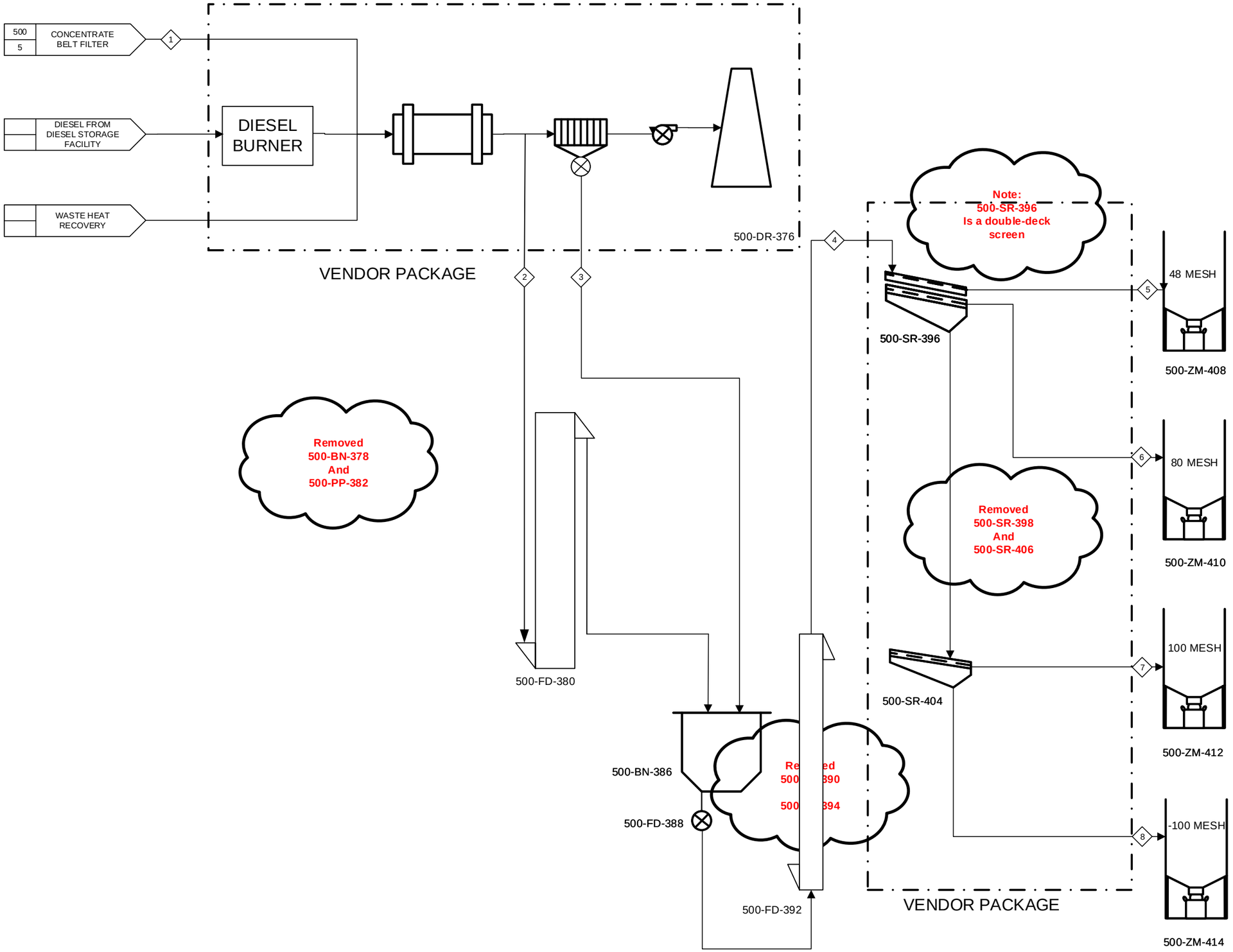
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	N.T.S	C1601-PFD-500

Energizer Resources

Molo 240 ktpa Graphite Concentrator Project

Final Concentrate Handling Circuit

REV: C



Description	Final Conc Belt Filter Cake	Coarse Dry Graphite Flakes	Fine Dry Graphite Powder	Dry Graphite Transfer	50 Mesh Graphite Product	80 Mesh Graphite Product	100 Mesh Graphite Product	Graphite Graphite Powder
Stream	1	2	3	4	5	6	7	8
Solids (tph)	1.92	1.63	0.29	0.96	0.45	0.45	0.13	0.90
Water (m3/h)	0.64	0.01	0.00	0.00	0.00	0.00	0.00	0.01
Slurry (m3/h)	1.46	0.71	0.12	0.42	0.19	0.19	0.05	0.39
% solids	75%	100%	100%	100%	100%	100%	100%	99%
SG	2.34	2.34	2.34	2.34	2.34	2.34	2.34	2.34
RD	1.75	2.32	2.32	2.32	2.34	2.34	2.34	2.30
Max (tph)	2.30	1.96	0.35	1.15	0.54	0.54	0.15	1.07
Max (m3/h)	1.66	0.80	0.14	0.47	0.22	0.22	0.06	0.45

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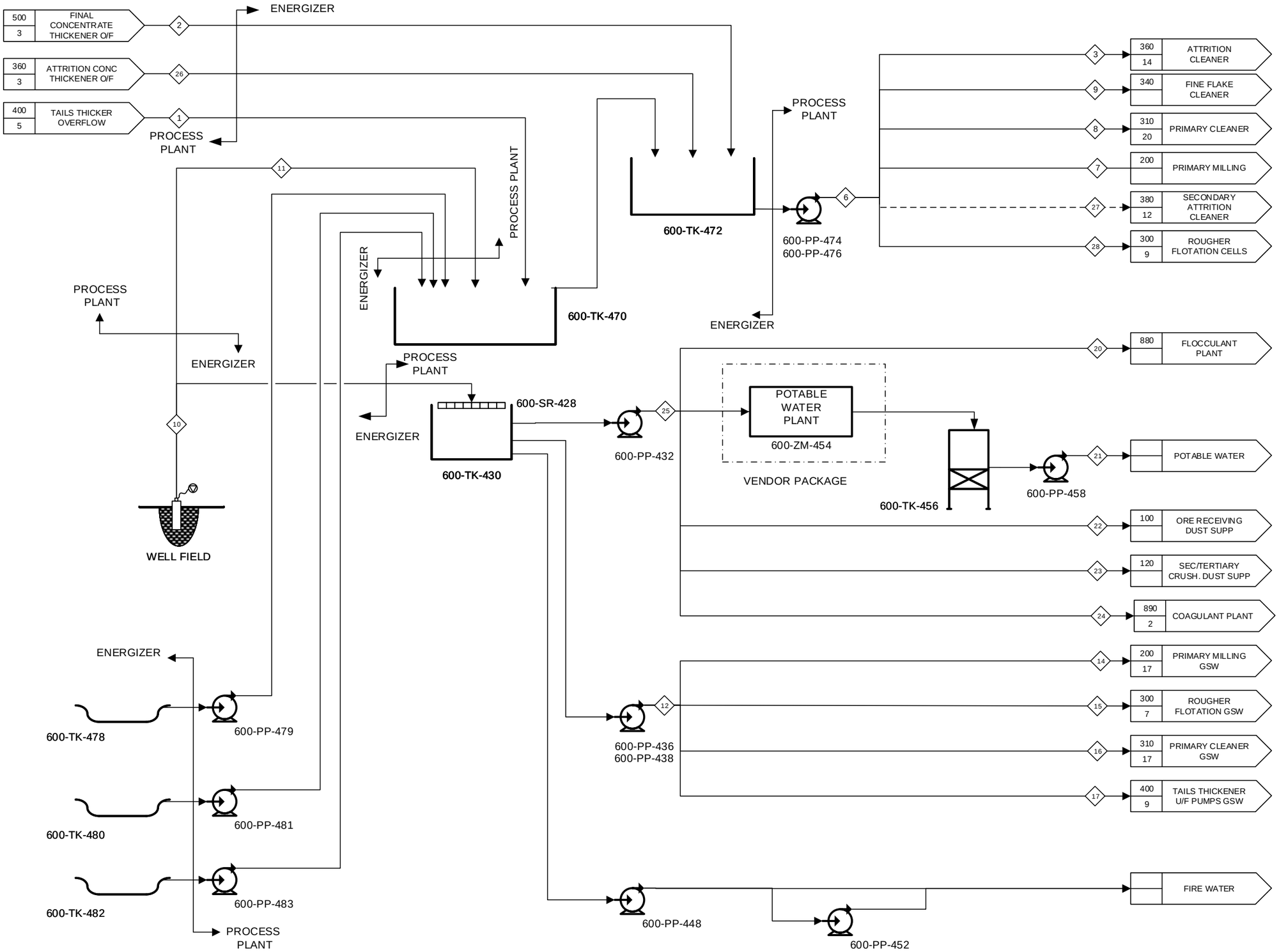
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Energizer Resources

Molo 240 ktpa Graphite Concentrator Project

Concentrate Drying and Bagging

MATERIAL	SCALE	DRAWING NUMBER	REV
	N.T.S	C1601-PFD-570	C



Description	Tails Thickener O/F	Rougher Float Concentrate	Attrition Cleaner Process Water	Final Tails Pump	TSF Return Water	Interplant Process Water Usage	Primary Mill Process water	Primary Cleaner Process Water	Fine Flake Cleaner Process Water	Raw Water Demand	Process Water Top-up	Total GSW	Primary Mill GSW	Rougher GSW	Primary Cleaner GSW	Tails Thickener U/F GSW	Flocculant Plants makeup water	Potable Water	Ore Receiving Dust suppression	Sec/Tertiary Crushing Dust suppression
Stream	1	2	3	4	5	6	7	8	9	10	11	12	14	15	16	17	20	21	22	23
Solids (tph)	0.00	2.49	0.00	28.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Water (m3/h)	60.56	9.98	5.76	23.33	15.05	87.97	80.70	1.29	0.01	11.73	2.19	1.89	0.84	0.28	0.28	0.28	1.77	1.00	1.00	1.11
Water (m3/h) Max	60.56	11.00	5.76	34.06	15.05	87.97	80.70	1.29	0.01	11.73	2.19	1.89	0.84	0.28	0.28	0.28	1.77	1.00	1.00	1.11

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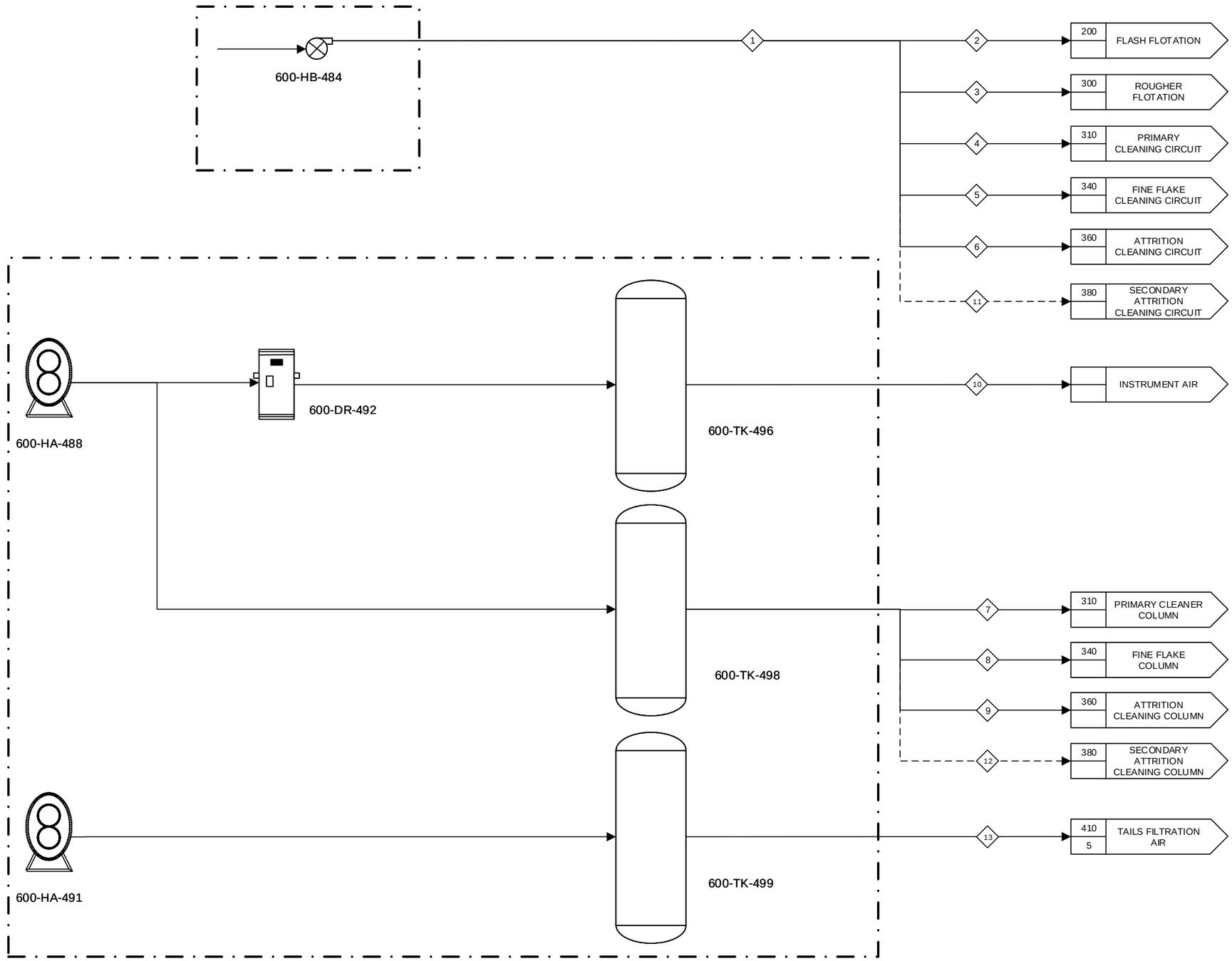
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ENG ELEC		
MATERIAL		

Energizer Resources

Molo 240 ktpa Graphite Concentrator Project

Water Services

SCALE	DRAWING NUMBER	REV
N.T.S	C1601-PFD-600	C



Description	Flotation Blower Air Demand	Flash Flotation Air	Rougher Flotation Air	Primary Cleaner Air	Fine Flake Cleaner Air	Attrition Cleaner Air	Primary Cleaner Column Compressed Air	Fine Flake Column Compressed Air	Attrition Column Compressed Air	Total Instrument Air	Secondary Cleaner Column Compressed Air	Tailings Filtration Air
Stream	1	2	3	4	5	6	7	8	9	10	12	13
Air (Nm3/min)	18.10	1.26	8.83	2.18	1.94	1.94	0.69	0.51	0.51	0.51	1.94	14.17

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	D	UPDATE 30% 3D DESIGN REVIEW	9/1/2017	
	C	UPDATE FROM REVIEW 2	18/10/2016	
	B	UPDATE FROM REVIEW 1	12/9/2016	
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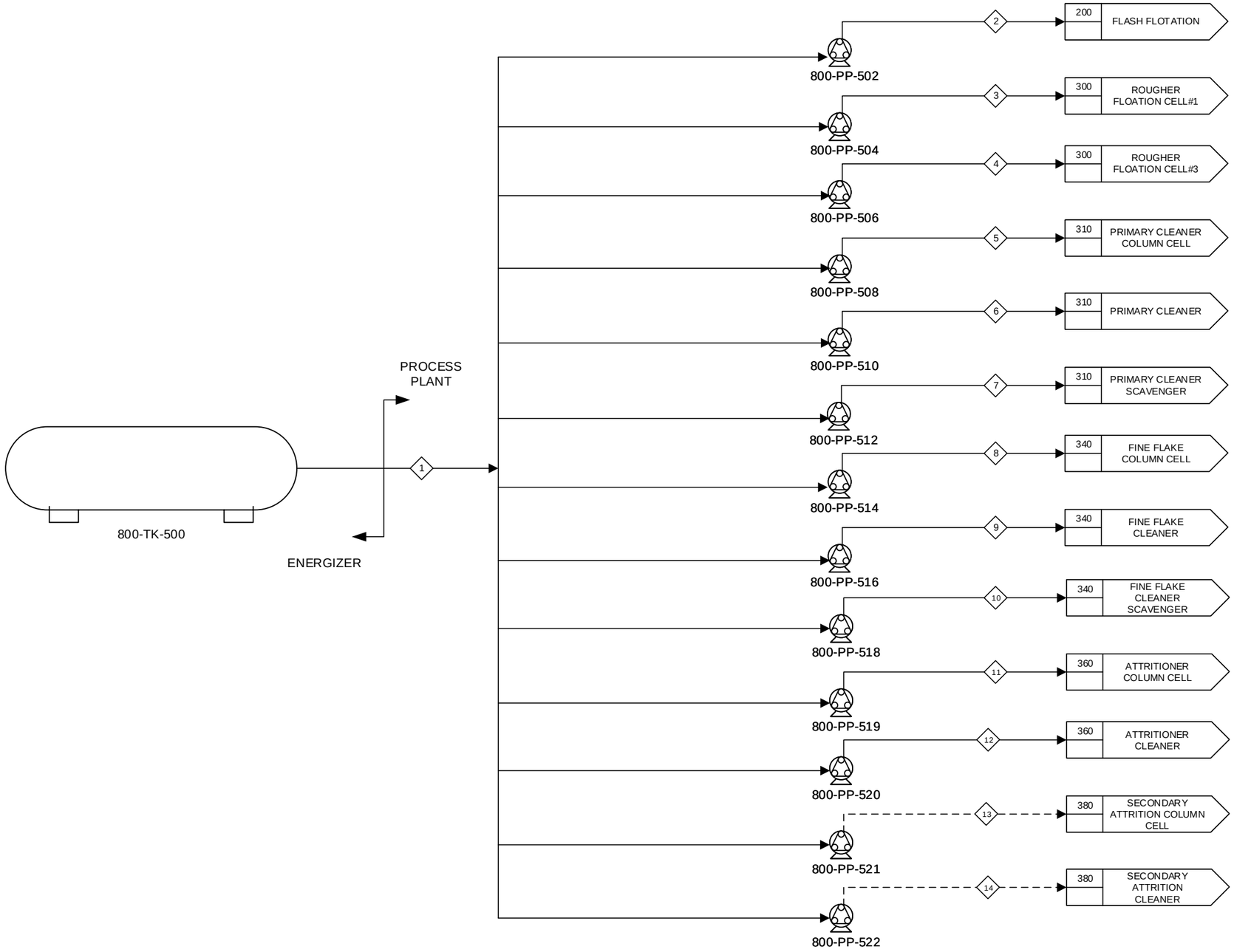
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Energizer Resources

Molo 240 ktpa Graphite Concentrator Project

Air Services

SCALE	DRAWING NUMBER	REV
N.T.S	C1601-PFD-640	C



Description	Total Collector	Flash Flotation Collector	Rougher Flotation Cell #1 Collector	Rougher Flotation Cell #3 Collector	Primary Cleaner Column Cell Collector	Primary Cleaner Collector	Primary Cleaner Scavenger Collector	Fine Flake Column Cell Collector	Fine Flake Cleaner Collector	Fine Flake Cleaner Scavenger Collector	Attrition Column Collector	Attrition Cleaner Collector	Secondary Attrition Column Collector	Secondary Attrition Scavenger Collector						
Stream	1	2	3	4	5	6	7	8	9	10	11	12	13	14						
Reagent (kg/h)	11.96	1.88	2.68	2.14	1.61	0.53	0.53	1.61	0.27	0.27	0.22	0.22	0.22	0.22						
Reagent (L/h)	14.37	2.26	3.22	2.58	1.94	0.64	0.64	1.94	0.32	0.32	0.26	0.26	0.26	0.26						
Reagent (L/min)	0.24	0.04	0.05	0.04	0.03	0.01	0.01	0.03	0.01	0.01	0.00	0.00	0.00	0.00						
Reagent (kg/h) Max	17.94	2.82	4.02	3.22	2.42	0.80	0.80	2.42	0.40	0.40	0.33	0.33	0.33	0.33						
Reagent (L/h) Max	21.56	3.38	4.83	3.87	2.90	0.96	0.96	2.90	0.48	0.48	0.39	0.39	0.39	0.39						
Reagent (L/min) Max	0.36	0.06	0.08	0.06	0.05	0.02	0.02	0.05	0.01	0.01	0.01	0.01	0.01	0.01						

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D	UPDATE FROM 90% REVIEW	01/4/2017	
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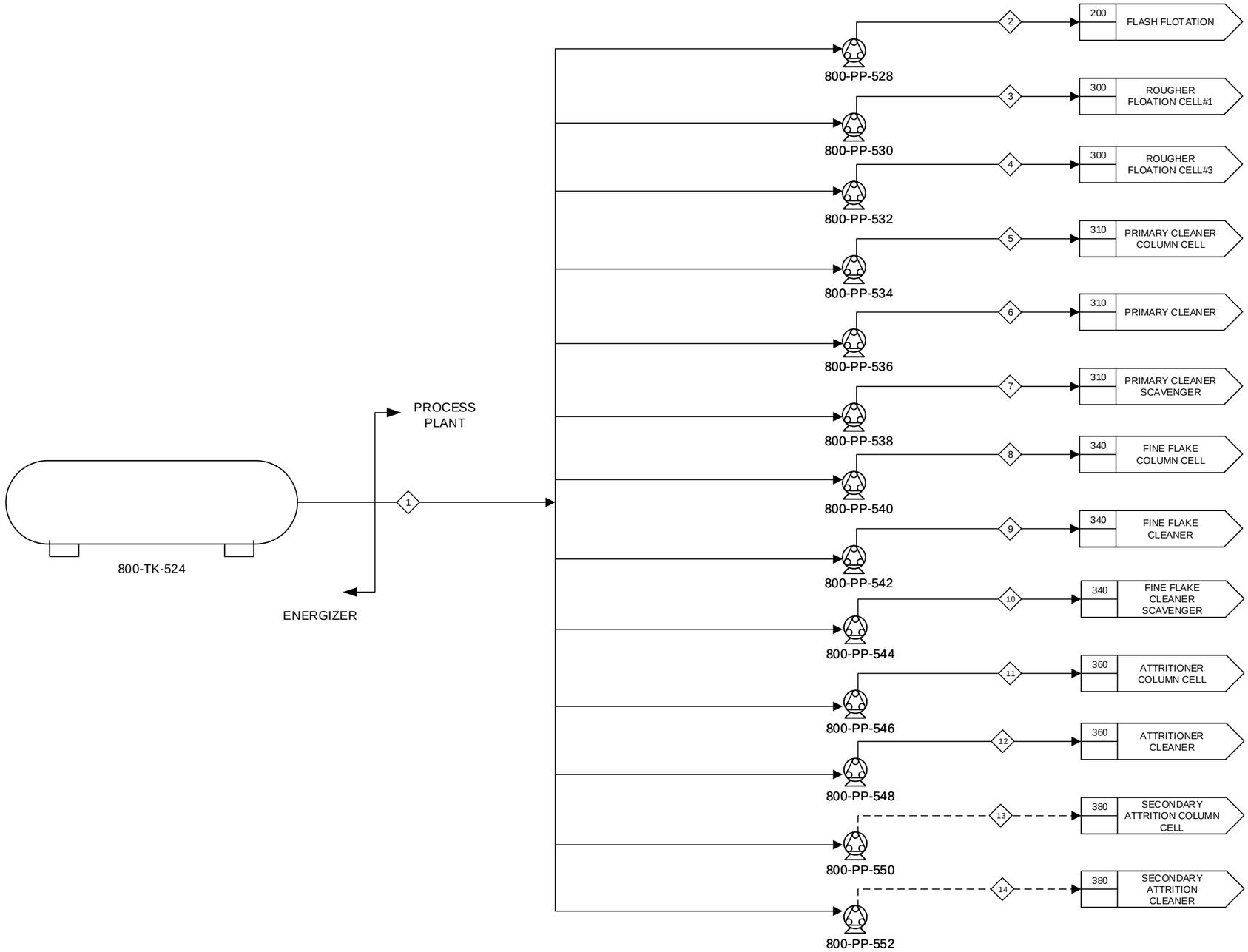
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Energizer Resources

Molo 240 ktpa Graphite Concentrator Project

Collector Storage and Dosing

SCALE	DRAWING NUMBER	REV
N.T.S	C1601-PFD-800	C



Description	Total Frother	Flash Flotation Frother	Rougher Flotation Cell #1 Frother	Rougher Flotation Cell #3 Frother	Primary Cleaner Column Cell Frother	Primary Cleaner Column Cell Frother	Primary Cleaner Scavenger Frother	Fine Flake Column Cell Frother	Fine Flake Cleaner Frother	Fine Flake Cleaner Scavenger Frother	Attrition Column Frother	Attrition Cleaner Frother	Secondary Attrition Column Frother	Secondary Attrition Scavenger Frother
Stream	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Reagent (kg/h)	14.90	3.59	4.46	3.12	0.45	0.44	0.44	0.44	0.44	0.44	0.53	0.53	0.53	0.53
Reagent (L/h)	17.91	4.31	5.37	3.75	0.54	0.53	0.53	0.53	0.53	0.53	0.64	0.64	0.64	0.64
Reagent (L/min)	0.30	0.07	0.09	0.06	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Reagent (kg/h) Max	22.35	5.38	6.70	4.68	0.67	0.66	0.66	0.66	0.66	0.66	0.80	0.80	0.80	0.80
Reagent (L/h) Max	26.86	6.47	8.05	5.63	0.80	0.80	0.80	0.80	0.80	0.80	0.96	0.96	0.96	0.96
Reagent (L/min) Max	0.45	0.11	0.13	0.09	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02

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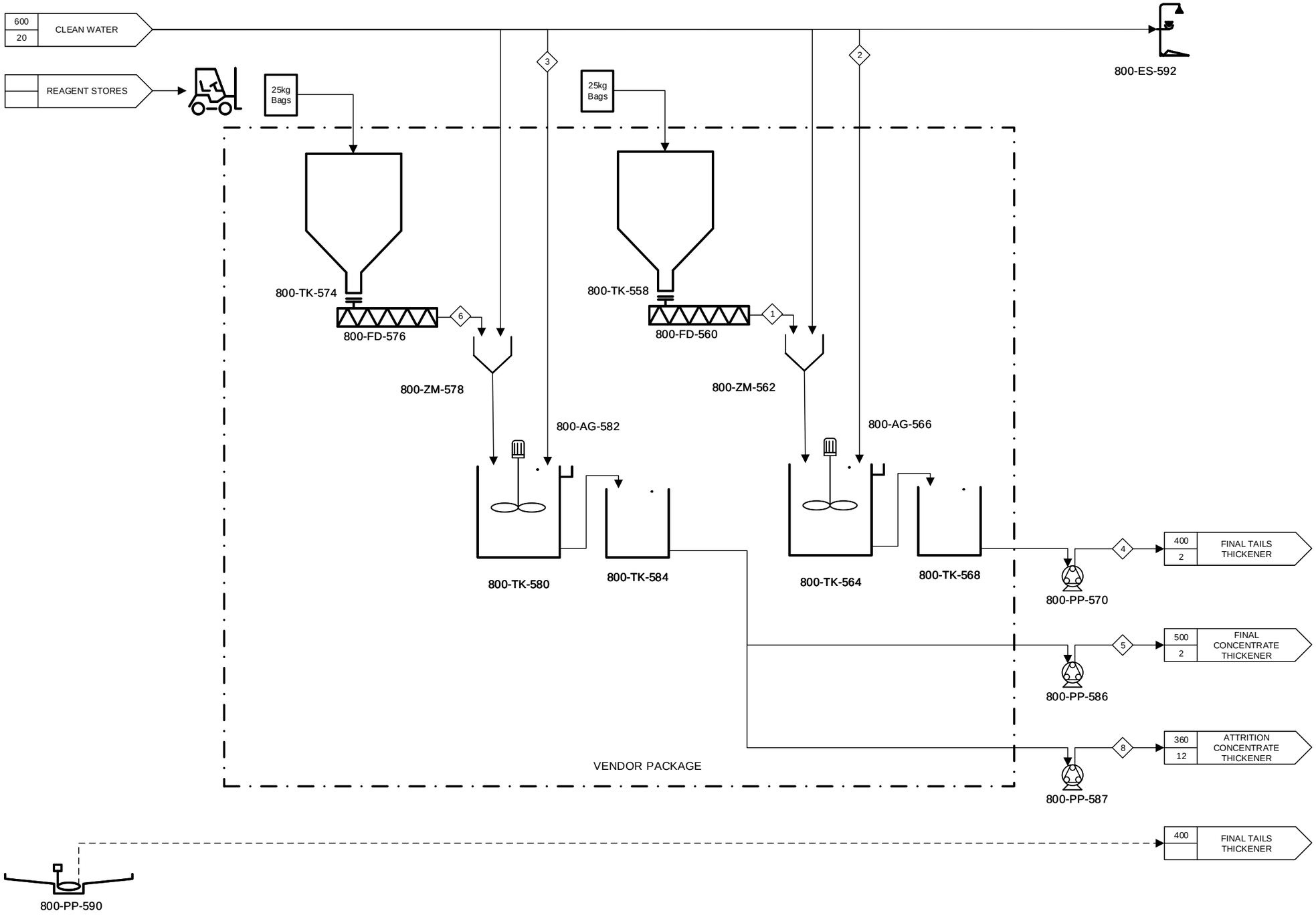
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Energizer Resources

Molo 240 ktpa Graphite Concentrator Project

Froth Storage and Dosing

SCALE	DRAWING NUMBER	REV
N.T.S	C1601-PFD-860	C



Description	Dry Tails Flocculant	Tails Flocculant Make-up Water	Concentrate Flocculant Make-up	Tails Thickener Flocculant	Concentrate Thickener Flocculant	Dry Concentrate Flocculant	Attrition Thickener Flocculant
Stream	1	2	3	4	5	6	8
Reagent (kg/h)	2937.06	1462.93	7.35	1462.93	3.85	0.00	3.50
Reagent (L/h)	3530.11	1758.32	8.84	1758.32	4.63	0.00	4.21
Reagent (L/min)	58.84	29.31	0.15	29.31	0.08	0.00	0.07
Reagent (kg/h) Max	4405.58	2194.39	11.03	2194.39	5.78	0.00	5.25
Reagent (L/h) Max	5295.17	2637.49	13.25	2637.49	6.94	0.00	6.31
Reagent (L/min) Max	88.25	43.96	0.22	43.96	0.12	0.00	0.11

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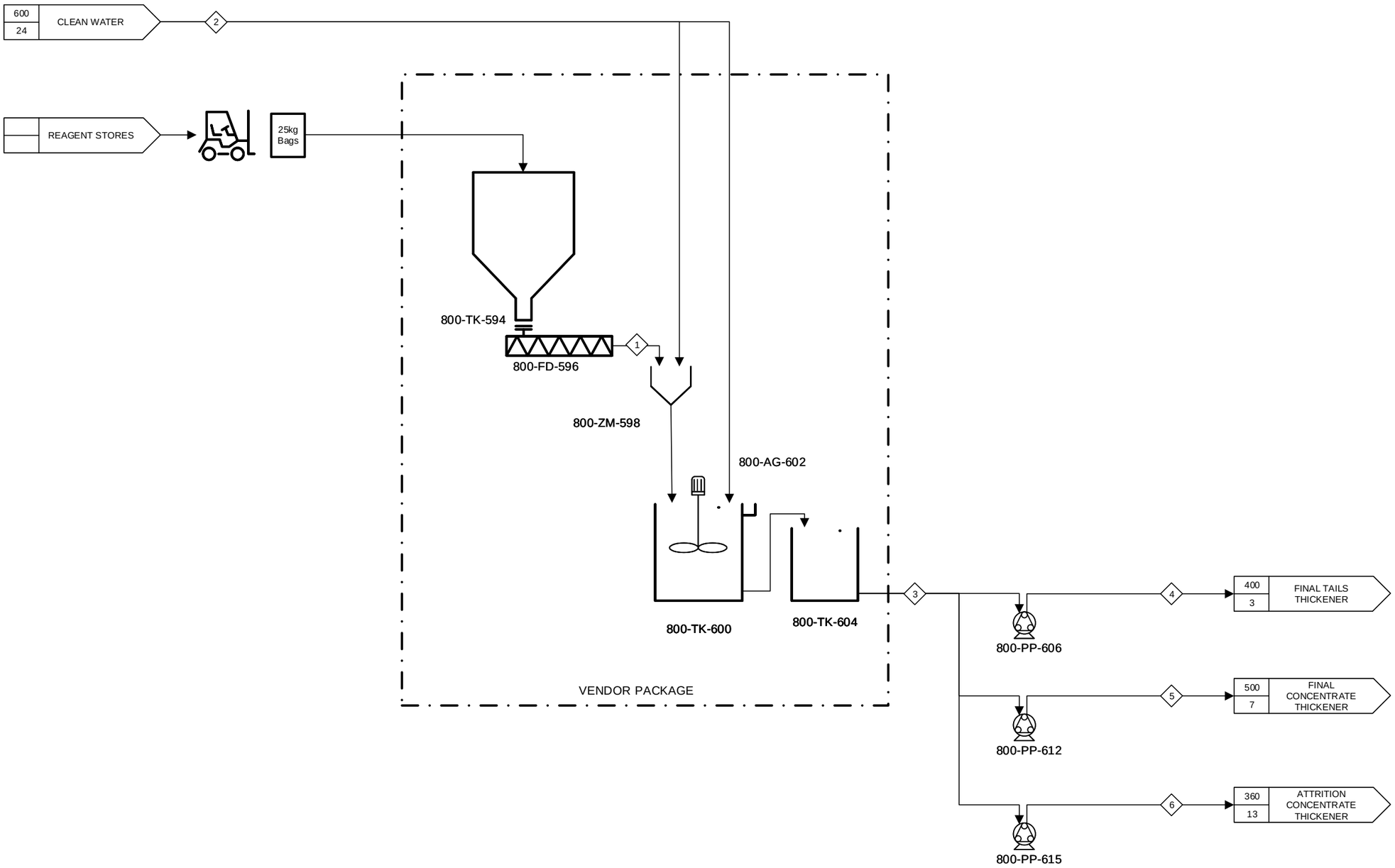
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Energizer Resources

Molo 240 ktpa Graphite Concentrator Project

Flocculant Mixing and Dosing

MATERIAL	SCALE	DRAWING NUMBER	REV
	N.T.S	C1601-PFD-880	C



Description	Dry Coagulant	Coagulant Plant Make-up	Diluted Coagulant	Tails Thickener Coagulant	Concentrate Thickener Coagulant	Attrition Thickener Coagulant
Stream	1	2	3	4	5	6
Reagent (kg/h)	6313.35	2104.45	2104.45	815.26	815.26	473.92
Reagent (L/h)	7588.16	2529.39	2529.39	979.88	979.88	569.62
Reagent (L/min)	126.47	42.16	42.16	16.33	16.33	9.49
Reagent (kg/h) Max	9470.02	3156.67	3156.67	1222.90	1222.90	710.88
Reagent (L/h) Max	11382.24	3794.08	3794.08	1469.83	1469.83	854.43
Reagent (L/min) Max	189.70	63.23	63.23	24.50	24.50	14.24

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Energizer Resources

Molo 240 ktpa Graphite Concentrator Project

Coagulant Mixing and Dosing

MATERIAL	SCALE	DRAWING NUMBER	REV
	N.T.S	C1601-PFD-890	C

Primary Crusher Bin
Primary Crusher
Secondary Crusher
Tertiary Crusher
Scalping Screen
Flash Flotation
Primary mill
Linear Screen
Rougher Flotation
Final Tails Thickener
Primary Cleaner Dewatering Screen
Primary Cleaner Column Cell
Primary Cleaner & Scavenger Cells
Primary Polishing Mill
Primary Column Concentrate Classification Screen
Fine Flake Dewatering Screen
Fine Flake Cleaner Column Cell
Fine Flake Cleaner & Scavenger Cells
Fine Flake Polishing Mill
Tails Filter Feed Tank
Tails Filter
Final Tailings
Secondary Attrition Dewatering Screen
Attrition Concentrate Thickener
Attrition Mill
Attrition Cleaner Column Cell
Attrition Cleaner & Scavenger Cell
Secondary Attrition Scrubber
Secondary Attrition Column Cell
Secondary Attrition Cleaner & Scavenger Cell
48 Mesh and 80 Mesh Double Deck Screen
100 Mesh Screen
48 Mesh Bagging Plant
80 Mesh Bagging Plant
100 Mesh Bagging Plant
-100 Mesh Bagging Plant
Process Water Tanks
To Portable Water Plant
Raw Water Well Field
Final Concentrate Thickener
Final Concentrate Storage Tank
Final Concentrate Belt Filter
Concentrate Drying Plant
Final Concentrate Surge Bin

Water flow
Base flowsheet
Optional flowsheet

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Energizer Resources
Molo 240 ktpa Graphite Concentrator Project
Block Flow Diagram

MATERIAL	SCALE	DRAWING NUMBER	REV
	N.T.S	C1601-PFD-001	A

Appendix E

Environmental And Social

Globesight

ADVISORY | CONSULTING | TRAINING



NextSource Resources Inc: Molo Feasibility Study – Section 12: Environmental and Social

Report Status – Final

Report Reference – Molo_24oktFS

Report Date – 15 June 2017

Globesight (Pty) Ltd— 10 Musketeer Street, Helderkruin, 1724

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Configuration

Document Name:	NextSource Resources Inc: Molo Feasibility Study – Section 12: Environmental & Social	Status:	Final
Client Name:	NextSource Materials Inc	Attention:	Mr Johann de Bruyn
Report Reference:	Molo_24oktFS	Issue Date:	2017/06/15
Author:	Ferdi Pieterse	Revision:	Final
Approved:		Approval Date:	2017/06/15

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LIST OF ABBREVIATIONS

Agetipa	L'Agence d'Exécution des Travaux d'Intérêt Public et d'Aménagement communément appelée - The Execution of Public Interest Works Agency and Planning
ANDEA	Autorité Nationale de l'Eau et de l'Assainissement - National Authority of Water and Sanitation
BCMM	Bureau du cadastre Minier de Madagascar
CEM	Malagasy Environment Charter
CSP	Concentrated Solar Power
ESIA	Environmental and Social Impact Assessment
EPs	Equator Principles
EPFIs	Equator Principles Financial Institutions
Fokontany	Traditional Malagasy Village
GIS	Geographical Information Systems
HFO	Heavy Fuel Oil
IFC	International Finance Corporation
PAP	Potentially Affected Population
Joro	Ritual / Traditional Ceremony
mamsl	Meters above mean sea level
PV	Photovoltaic
PZI	Potential Zone of Influence
RAMSAR	The Convention on Wetlands of International Importance

Ray Aman-Dreny	Principal / Head
RAP	Relocation Action Plan
SRTM	Shuttle Radar Topography Mission
TSF	Tailings Storage Facility
UCS	Uniaxial Compressive Strengths
UNESCO	Convention Concerning the Protection of the World Cultural and Natural Heritage
VIA	Visual Impact Assessment
WWF	World Wildlife Fund

1. Environmental and Social – Study Description

1.1 About the authors

The location of this project, specifically within a French speaking country, and the common intricacies and nuances associated with projects of this nature resulted in the establishment of a partnership between a reputable South African based Environmental consultancy firm, GCS Water and Environment (Pty) Ltd (GCS) and an equally reputable Malagasy consultancy firm, L'Agence d'Exécution des Travaux d'Intérêt Public et d'Aménagement communément appelée (Agetipa).

This partnership strengthened the team's ability, specifically via Agetipa to anticipate, comprehend, consider and ensure that compliance with Malagasy practices in terms of regulation, applicable standards, local context, subjective experience, cultural sensitivities and language preference (French and Malagasy) are met. In addition, with the combination of experience throughout the African continent, with specific scientific track record in areas such as Hydrogeology, Hydrology, Carbon Footprint management, legal support, Ecology, GIS and project management, GCS provided valuable input into the planning and design aspects of the project.

This combination has proved to be invaluable to the project where two firms have been working closely together to achieve a common goal which is to produce sound advice and direction on matters of sustainable development with the added ability to assist the project to plan for and meet the required in-country and international standards which are applicable to a project of this nature.

1.2 Section Structure

This Environmental and Social Section's structure facilitates the representation of information of particular value to the overall Molo Graphite Project's Feasibility Study. Therefore Section 12 contains the following information:

- Introduction
- Approach and Applicable Standards
- Environmental Screening
- Biophysical and Social Studies
- Environmental and Social Impact Assessment and Management Plan
- Relocation Action Plan
- Conclusions and Recommendations
- Gaps / Limitations
- Environmental and Social Expenses (excluding closure and rehabilitation costs – these are contained in Section 16 of the main Feasibility Report)

1.3 Introduction and Approach

An integrated and multi-disciplinary approach was adopted for the Molo Graphite Project's Feasibility Study. Environmental and Social Management practices have evolved significantly in recent years and do not only facilitate

formal Environmental and Social Impact Assessment (commonly known as ESIA) processes, but provide tangible input into the concept, pre-feasibility and feasibility phases of project development. This is achieved through early engagement of environmental and social input from a number of sources. The main sources of information can be described as follows:

- Regulatory Framework (host country and international)
- Policy and Standards (as applicable)
- Environmental Screening
- Bio-physical and Social Baseline Assessment
- A selection of project alternatives

Major risks and potential fatal flaws are identified early on in order to inform planning and decision making throughout the feasibility study. Pro-active environmental and social awareness goes a long way in achieving long-term sustainable project development goals.

For the Molo Graphite Project the integrated approach kicked off with an Environmental and Social Risk / Screening Study, which essentially entailed the following process:

- Gather desktop and baseline info (environmental / social / land tenure)
- Consolidate information using risk matrixes
- Overlay spatially with Geographical Information Systems (GIS)
- Represent environmental and social sensitivities in order to influence project development and design

The next phase in the integrated approach required the determination of applicable laws and standards (Malagasy and International). This provides a framework within which the science and engineering components can function, specifically due to the projects requirement to obtain mining, environmental and social licenses and permits). Refer to Section 13 of the Feasibility Report for details with regards to Permitting.

Following the above-mentioned phase was a detailed environmental and social assessment on the proposed activities associated with the project. At this stage, most of the risk would have been reduced / removed from the project via the influence of the Screening Study. Invariably development will have impacts on the current environmental and social conditions, be it negative, or positive. As a result, the process also identifies mitigating factors and opportunities for benefit.

This is then all put together and an ESIA and associated Management Plan is compiled for the proposed project. This formal document will play an important role for the project as it defines and captures not only scientific and project information, but also encapsulates the responsibility of the project proponent to the environmental and social wellbeing and management for the duration of the proposed project.

In this case, there is also a need to relocate inhabitants within close proximity to the project site, for which a Relocation Action Plan (RAP) has been developed.

As is to be expected, projects develop over time and there are always slight variations in the final plan and design, and therefore this study also lists potential gaps which would require evaluation should the project enter an execution phase. Certain limitations to the studies are listed along with the gaps to create the required context where applicable.

Finally the study will provide input into the financial modelling associated with a Feasibility Study. Environmental and social management requires capital and operational provision. Long over are the days of provision for final closure only. This report contains an estimation of planning and operational costs associated with environmental and social management and sustainable project development. The Mine Rehabilitation and Closure Plan and Costs is contained in Section 16 of the Feasibility Report.

1.4 Applicable Standards

This project incorporates guidelines, legislation, local and international customary best practise. This includes international law, local Malagasy law, and local customary beliefs and best practise to ensure that the relevant impact and complexities of the Molo Graphite Project are evaluated.

1.4.1 Equator Principals (per Equator Principals guidance document)

The Equator Principles (EPs) is a credit risk management framework for determining, assessing and managing environmental and social risk in Project Finance transactions. Project Finance is often used to fund the development and construction of major infrastructure and industrial projects.

The EPs are adopted by financial institutions and are applied where total project capital costs exceed US$10 million. The EPs are primarily intended to provide a minimum standard for due diligence to support responsible risk decision-making. The EPs are based on the International Finance Corporation Performance Standards on social and environmental sustainability and on the World Bank Group Environmental, Health, and Safety Guidelines (EHS Guidelines).

1.4.2 World Bank and IFC Standards

The project study approach is largely based on the International Finance Corporation Performance Standards on Environmental and Social Sustainability (2012) and aims to achieve compliance with these standards to facilitate a wider pool of funding options and encourage best practice.

1.4.2.1 Malagasy Law and Regulations

The following Malagasy laws were applicable to this assessment (this list is not exhaustive, refer to Section 13; Permitting and Stakeholders for a complete list):

- Provisions in respect of Environmental Impact Assessment in terms of the Mining Code
- Provisions regulating water activities in terms of the Water Code;
- Provisions relating to effluent quality standards in terms of Decree No. 2003/464 of 15 April 2003
- Provisions relating to protected areas in terms of Law N° 2001/05; and
- Provisions relating to sensitive areas in terms of Order No. 4355/97 of 13 May 1997

1.4.3 International Conventions

Any international conventions applicable to the environment, including conventions such as the 1972 UNESCO (Convention Concerning the Protection of the World Cultural and Natural Heritage), the Convention on Wetlands of International Importance (RAMSAR), and any other applicable conventions applicable to the natural environment were considered. The closest RAMSAR protected site was identified as the Tsimanampetsotsa National Park over 100 km away from the study area.

1.4.4 International Best Practice

Where a lack of applicable legislation, guidelines, or conventions was available, international best practice was applied.

1.4.5 Local Malagasy Customs and Best Practice

The rural populations of the Malagasy have numerous cultural, religious and social beliefs pertaining to all aspects of everyday life. These religious and cultural beliefs, central to the Malagasy culture are governed by Malagasy Customary Rights. Many of these Customary Rights are not detailed by written legislation, or guidelines, but where a project may, or will impact on the local customary belief, negotiation with the relevant owners or tribal leaders are necessary. (Agetipa, 2014). Refer to Section 6 which contains the RAP study component for specific information regarding project sensitivities and measure to ensure compliance with Malagasy customs and practice is understood, observed and ensured.

2. Environmental and Social Sensitivity Screening

The Environmental and Social Screening Assessment's main aim was to consolidate various environmental specialist data to identify sensitive areas that would assist in the decision making and mine design phases by providing a sensitivity and suitability map that informed decision making through consideration of high risk areas that should be avoided where possible and considered otherwise. Subsequently, the exercise was expanded to include more detailed social information, land rights / ownership and additional information pertaining to the water supply options. Refer to Figure 2 for the overall study area and general sensitivities.

For the purpose of this study, a GIS model was used to determine the most sensitive biophysical and socially sensitive areas within the project area (incorporating the mine and infrastructure area, the borrow pit area and the water supply dams). The following specialist information has been incorporated into the GIS model:

- Ecology (incorporating wetlands)
- Hydrogeology (groundwater)
- Hydrology (surface water)
- Visual
- Social (incorporating cultural significance, proximity to villages, proximity to tombs, and sacred trees)
- Land Ownership / Land Rights / Stakeholders (this is based on the Bureau du cadastre Minier de Madagascar [BCMM] cadastral dataset received from Agetipa in Madagascar).

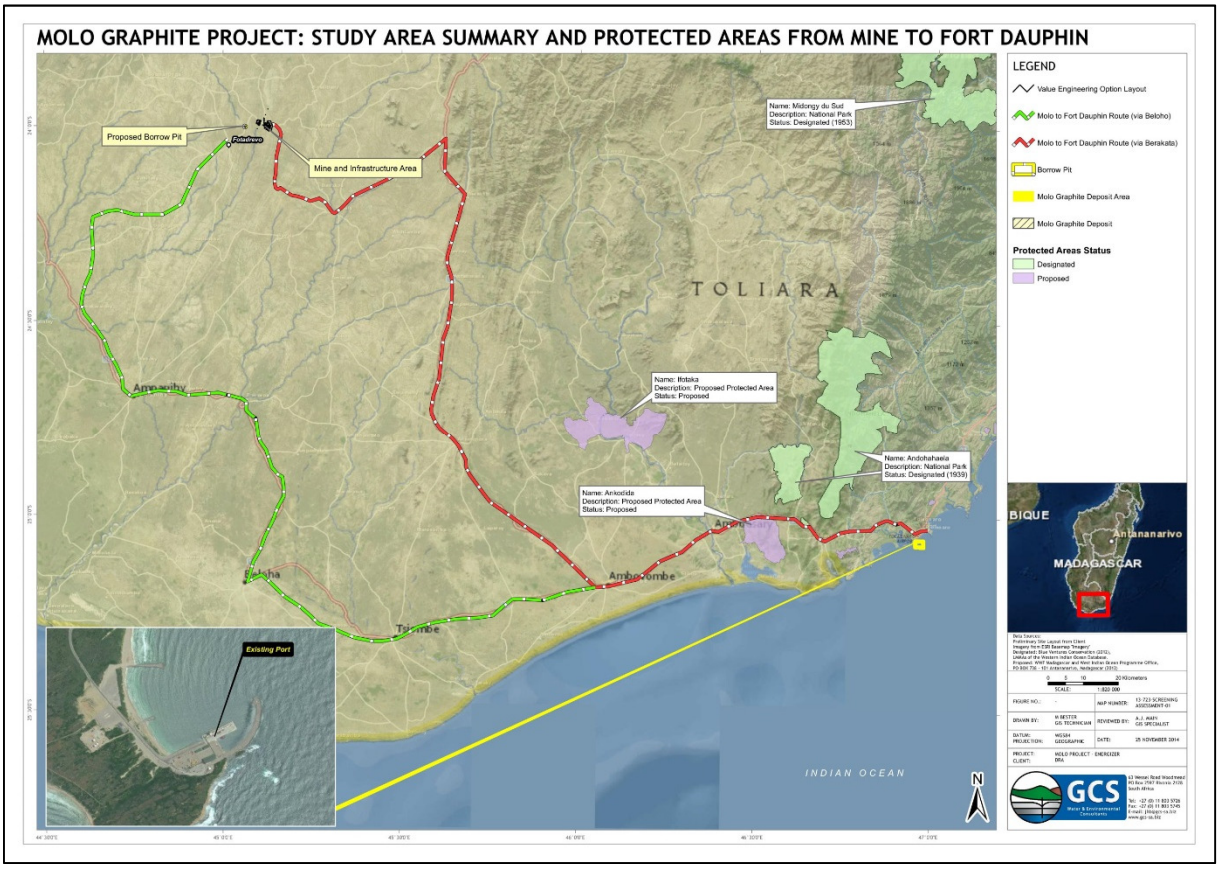


Figure 1: Study Area, Protected Areas and Transport Route options

The proposed infrastructure (refer to Figure 2) included in this Environmental Screening Assessment includes:

- Opencast Operation (Open Pit)
- Beneficiation Plant (Process Plant including ancillary infrastructure including offices, workshops, supporting facilities and stockpiles)
- Ground water extraction (base case water supply option)
- Waste Rock / Dry Tailings Co-Disposal Facility and Wet Tailings Storage Facility
- Borrow Pit(s)
- Two transport corridors from the Molo Graphite Project to the existing port at Fort Dauphin (Fort Dauphin is an established port that has been assessed to be the most feasible port option)

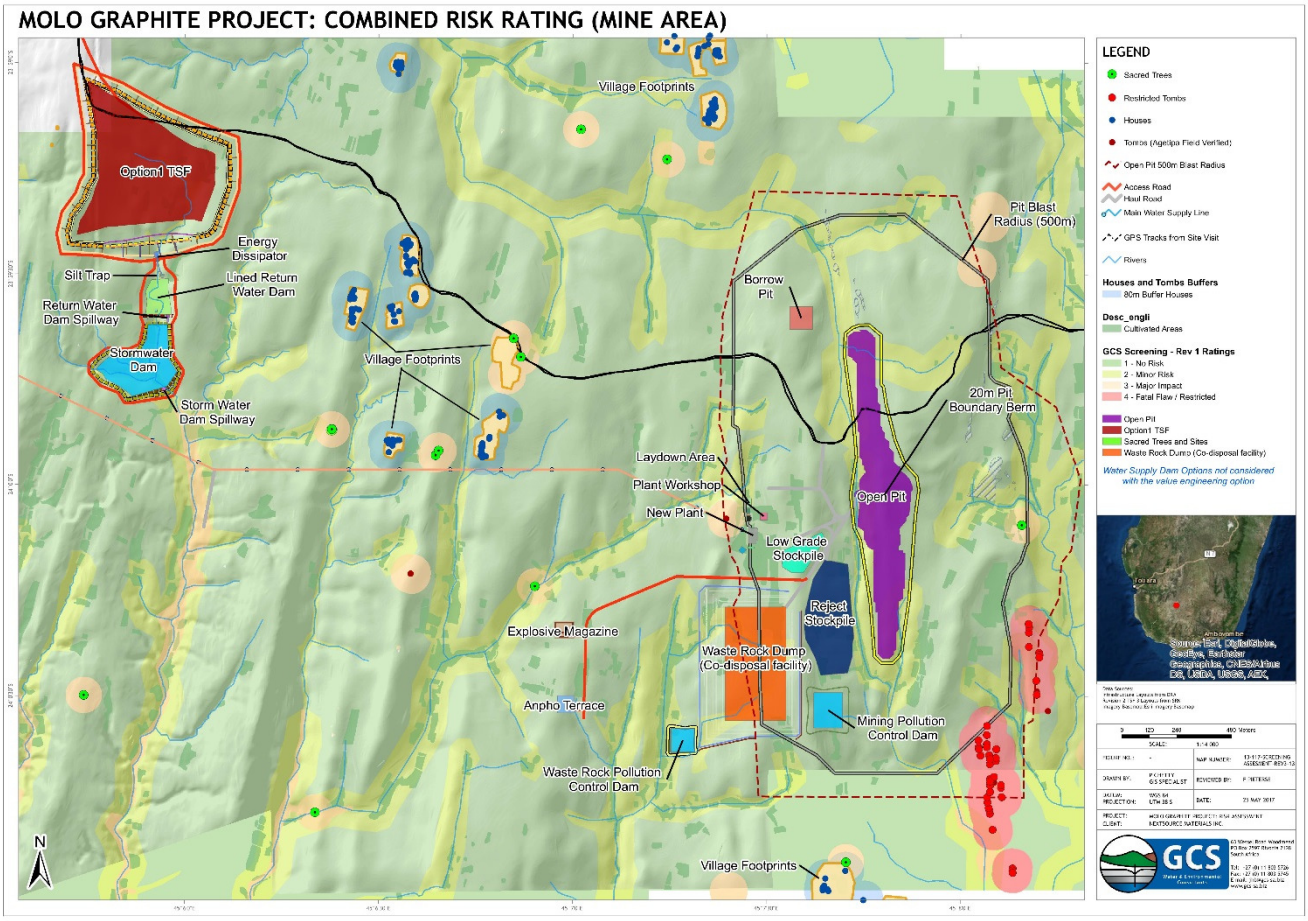


Figure 2: Environmental and Social Sensitivities for the Project Development Area

2.1 Study Objectives

The objective of the project screening assessment was to incorporate as much project information (biophysical environment, social, legal (land rights and stakeholders, engineering and yield analysis) into an integrated risk management plan. Information has been consolidated through various specialist studies carried out for the Molo Graphite project, and this assessment's main objective was to consolidate and integrate such information to facilitate decisions that will be used in the mine planning and implementation phases.

This assessment had the following primary objectives:

- To provide a suitability map to influence the mine design phase. Certain environmental and social factors have a very high sensitivity and could potentially be a fatal flaw for the project, such as the presence of tombs, sacred trees, and certain villages and homesteads, so the suitability map provides a medium and format that facilitates visual representation of such risks
- To bring any potential legalities (international and Malagasy law) to light to ensure that the mine considers potential implications prior to the construction and operation of the mine

- To consolidate environmental, social, and stakeholder / land rights information to allow for integrated decision-making that incorporates information from various disciplines that could potentially have impacts on the project going forward
- To facilitate best practice of environmental, social, rights, and engineering considerations that has a direct implication on the biophysical and social environment
- To detail any potential risks with the available information to allow for pre-emptive decision-making to plan for potential impacts that may impact on the project
- To detail information and data gaps that provides an ancillary risk to a project of this size

2.2 Study Results

2.2.1 Ecology

Potential infringement associated with the riparian areas present within the proposed infrastructure footprint, could result in major impacts. These riparian zones are also the transition zone between aquatic and terrestrial ecosystems that result in this area being rich in biodiversity (refer to Figure 3). Careful consideration of these sensitive areas led to the placement of infrastructure outside of riparian areas where sensitivities exist.

Refer to Section 2.2.1 in the Ecological Baseline and impact assessment and management measures components (Appendix to ESIA).

2.2.1.1 TSF

The wetlands present within the study area have all been impacted on by anthropogenic activities. These activities include grazing and rice cultivation. These wetlands have suffered in terms of biodiversity richness. Impacts to these wetland areas were predicted as being of minor impact.

The impact on the terrestrial ecology of the proposed TSF is expected to be of no risk. This rating can be attributed to the homogenous characteristics of the terrestrial ecosystem.

2.2.1.2 Open Pit

Based on the site survey and the comprehensive assessment conducted, the open pit will be of Minor Impact. The open pit will be situated within a large amount of wetland areas. However, as previously mentioned, these wetlands are of low importance due to their impacted state. No fatal flaws exist for the open pit in terms of the ecological assessment.

2.2.1.3 Processing Plant

The processing plant and the proposed expansion of this plan will be of Minor Impact. The processing plant is situated largely within the terrestrial ecosystem which is of low significant importance.

2.2.1.4 Borrow Pits

Large areas of the borrow pit to the west have been transformed into agricultural land. The remaining natural vegetation was heavily overgrazed therefore the borrow pit areas was not classified as sensitive.

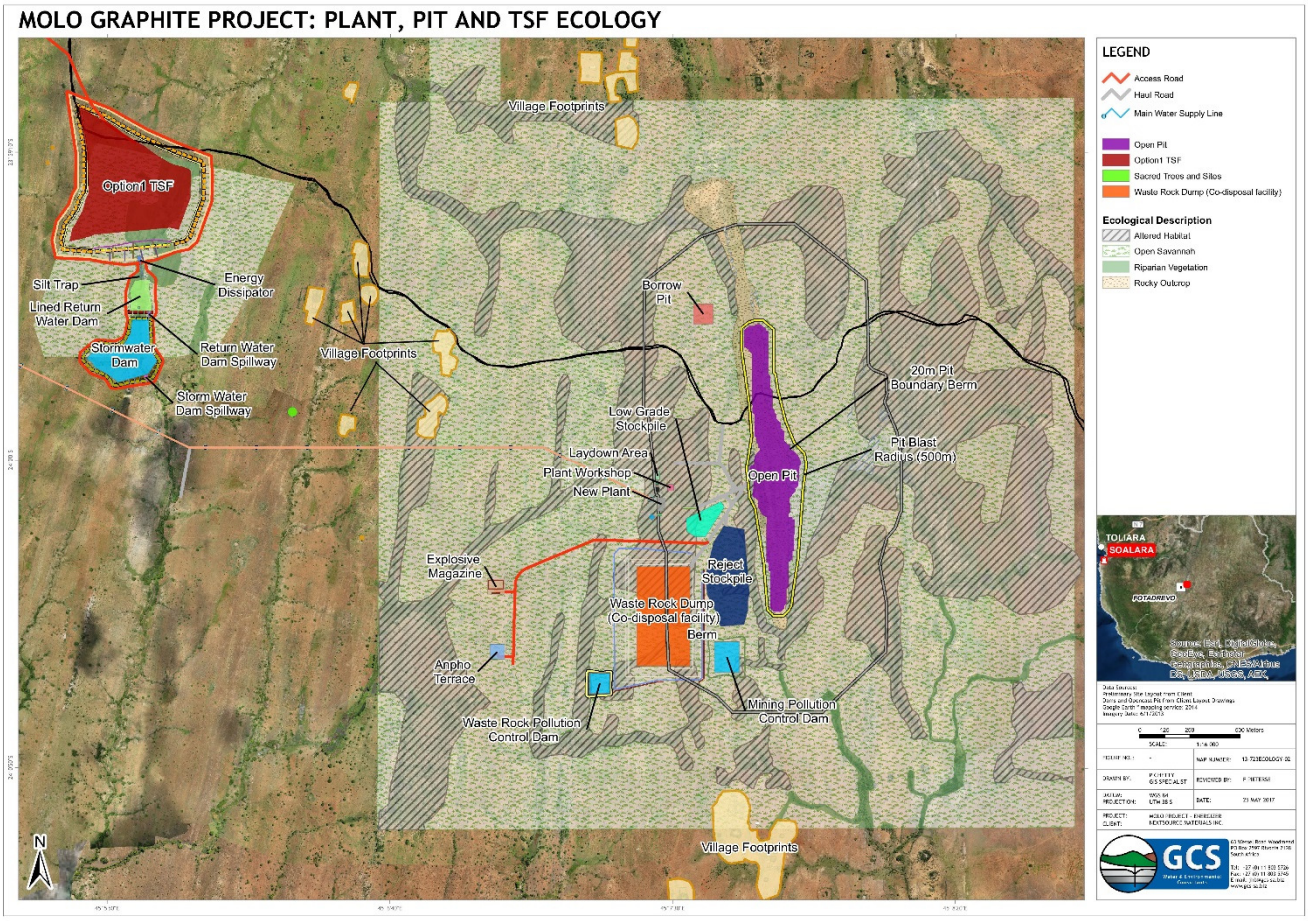


Figure 3: Ecological Sensitivities

2.2.2 Hydrogeology

2.2.2.1 General Geology

The site is located in the intercontinental tectonic Bekily block of Southern Madagascar, made up of ancient poly-deformed, high-grade metamorphic rocks (upper amphibolite facies), and later igneous intrusions. The site furthermore falls within the Ampanihy shear zone with a regional north-northeast – south-southwestern trend. The rocks found within this regional shear zone have a similar roughly north-south foliation and/or layering that are vertical to sub-vertical in nature. Folding with axes mainly parallel to the shear direction occur in different parts of the study area, including at the main Molo graphite ore zone.

No significant faulting, or dyke intrusions have been identified with the proposed Molo mining site. Previous drilling on the greater Green Giant property indicated that the weathered profile is typically less than 10 m thick in the region (DRA, April 2013).

Dominant lithologies occurring at the site consist mainly of migmatitic (biotite, hornfels, garnet) quartzofeldspathic gneiss with graphite schist and gneiss bands of the Ampanihy litho-metamorphic group (Madagascar Geological Map Ampanihy-Bekily, F60-G60-H-60-I60-F61-G61-H61-I61, 1958). Quartzofeldspathic gneiss containing amphibolite gneiss and marble bands of the Vohibory litho-metamorphic group occur toward the west of the site. Anorthosite intrusive rock occurs as a shear zone inclusion in the Ankafotra region north of the site. Younger calcrete deposits overlay the metamorphic rock towards Fortradrevo. Local, recently deposited sandy alluvial was deposited along some drainage lines.

2.2.2.2 Hydrocencus

Two hydrocensus' were undertaken on 13 to 16 March 2014 (wet season), and 27 to 30 May 2014 (dry season) by GCS around the proposed Molo Graphite Project site. The hydrocensus was concentrated within a 5 km radius around the Molo site and at the nearby town of Fotadrevo.

A total of 18 hand dug wells, boreholes and springs were identified in and around the Molo Graphite Project site. Figure 4 shows the locality of these points. Thirteen (13) of these points are currently utilized for stock watering and domestic water. It is likely that the fractured bedrock aquifer and shallow (potentially) perched aquifer in the weathered basement rock and/or younger river sediments are tapped. The localities of shallow wells are often close to drainage lines. The summary of data collected during the hydrocensus is provided in Table 1 below:

Table 1: Hydrocensus Summary

Site ID	Locality	Site Type	Status	Equipment	Primary Water Usage	Abstraction (l/d)	TDS* (mg/l)	Depth of Groundwater Level (m)
GWH1	East of proposed Molo open pit, Sambalahy region	Spring	Used	None	Stock watering	Unknown	63	-
GWH2	Sonjorano	Percussion borehole	Unused	None	-	-	102	2
GWH3	Sonjorano	Spring	Used	None	Drinking	Unknown	-	-
GWH4	Fortadrevo	Hand dug well	Used	None	Stock watering, drinking water	Unknown	-	5.02
GWH5	Beamalo Centre	Hand dug well	Used	None	Drinking	Unknown	-	5.2
GWH6	Beamalo centre	Percussion borehole	Used	Mono foot pump	Stock watering, drinking water	5000	248	7.3

Site ID	Locality	Site Type	Status	Equipment	Primary Water Usage	Abstraction (l/d)	TDS* (mg/l)	Depth of Groundwater Level (m)
GWH7	Amandabe	Spring	Used	None	Drinking	1250	60	-
GWH8	Ambatofotsy (North)	Hand dug well	Used	None	Stock watering, drinking water	1500	70	6.05
GWH9	Ambatofosy (South)	Hand dug well	Used	None	Stock watering, drinking water	1750	395	0.3
GWH10	Ambatofosy (South)	Percussion borehole	Unused	Mono foot pump (not working)	-	-	-	2.55
GWH11	Fortadrevo	Hand dug well	Unused	None	-	-	-	No access
GWH12	Fortadrevo	Hand dug well	Used	None	Stock watering, drinking water, washing	1740	379	5
GWH13	Fortadrevo	Hand dug well	Used	None	Stock watering, drinking water	1500	284	1.19
GWH14	Sonjorano	Percussion borehole	Used	Mono foot pump	Drinking	5000	-	17.6
GWH15	Analamasy	Percussion borehole	Unused	None	-	-	-	3.41
GWH16	Analamasy	Hand dug well	Used	None	Drinking	2900	463	1.33
GWH17	Energizer Exploration Camp, Fortadrevo	Percussion borehole	Used	Submersible	Washing, cooking, toilets	5000	982	No access
GWH18	Fortadrevo	Percussion borehole	Unused	Mono foot pump (not working)	-	-	-	No access

*- TDS – Total dissolved solids

The total dissolved solids content (TDS) of the groundwater is typically 60 to 500 mg/l.

2.2.2.3 Aquifer Classification

Weathered and fractured aquifers in the metamorphic rocks of the Molo site are the main sources of groundwater. Local shallow alluvium is also tapped by hand dug wells. Hydrogeological drilling and testing was undertaken as part of the feasibility study in order to characterize the local aquifer conditions. Refer to the Section 11: Water Report within the main Feasibility Study Report.

Work conducted by the South African Development Community (SADC Hydrogeological Mapping Project, November 2009) indicates that the proposed project location is in an area with "moderate" aquifer productivity. Average withdrawals in this area have been noted to range between 1 and 5 m3/hr, however, rates greater than 10 m3/hour have also been reported.

2.2.2.4 Findings

TSF (Revised Site 3)

The geology of all TSF Revised Site 3 consists mainly of quartzofeldspathic gneiss. No specific hydrogeological structures were identified from the desktop work that could impact on the TSF, or potential groundwater contaminant migration. A detailed, site specific hydrogeological study has been undertaken for the preferred TSF site.

The proposed TSF Revised Site 3 is situated in minor drainage lines which are classified as being minor risk areas. The location of the TSF means that it does not pose a major risk, because it is situated in the upper reaches of the drainage lines where groundwater levels are relatively deep compared to downstream where local seasonal and/or perennial groundwater base flow occur.

No shallow groundwater seepage and/or inter-flow were identified during the March 2014 site visit in the footprint area of the TSF. The closest community borehole discovered to the TSF site is over 1km away, and based off the numerical groundwater model as part of the comprehensive assessment there is little risk of contamination of community water sources, refer to Figure 4.

Open Pit

No restrictive or fatal flaw groundwater risks have been identified for the open pit. No major hydrogeological structures were identified, limiting any impact from possible mine dewatering.

The impact of mine dewatering on groundwater and surrounding community water supply boreholes will be quantified. Most community boreholes are situated further than 1 km from the proposed open pit with the exception of an unequipped school borehole to the south of the site. The upper reaches of drainage lines may be impacted on; however, the risk is likely to be small and manageable. Any associated impacts on communities and community boreholes will be addressed through the Groundwater and the Social Impact Assessment.

Dirty water from the open pit must be contained in a lined pollution control dam (PCD) and the re-use of water should be addressed by the process plant engineers.

Processing Plant

The proposed processing plant and ancillary infrastructure, such as the waste dump and stockpiles are situated in close proximity to a minor drainage line which could have associated deep groundwater levels but little potential seasonal shallow groundwater seepage and/or inter-flow. The groundwater risk is minor, as represented by Figure 4.

Borrow Pits

No major groundwater risks are anticipated for the proposed borrow pit sites. The sites are therefore classified as having "no risk" in terms of groundwater for the proposed land use activity.

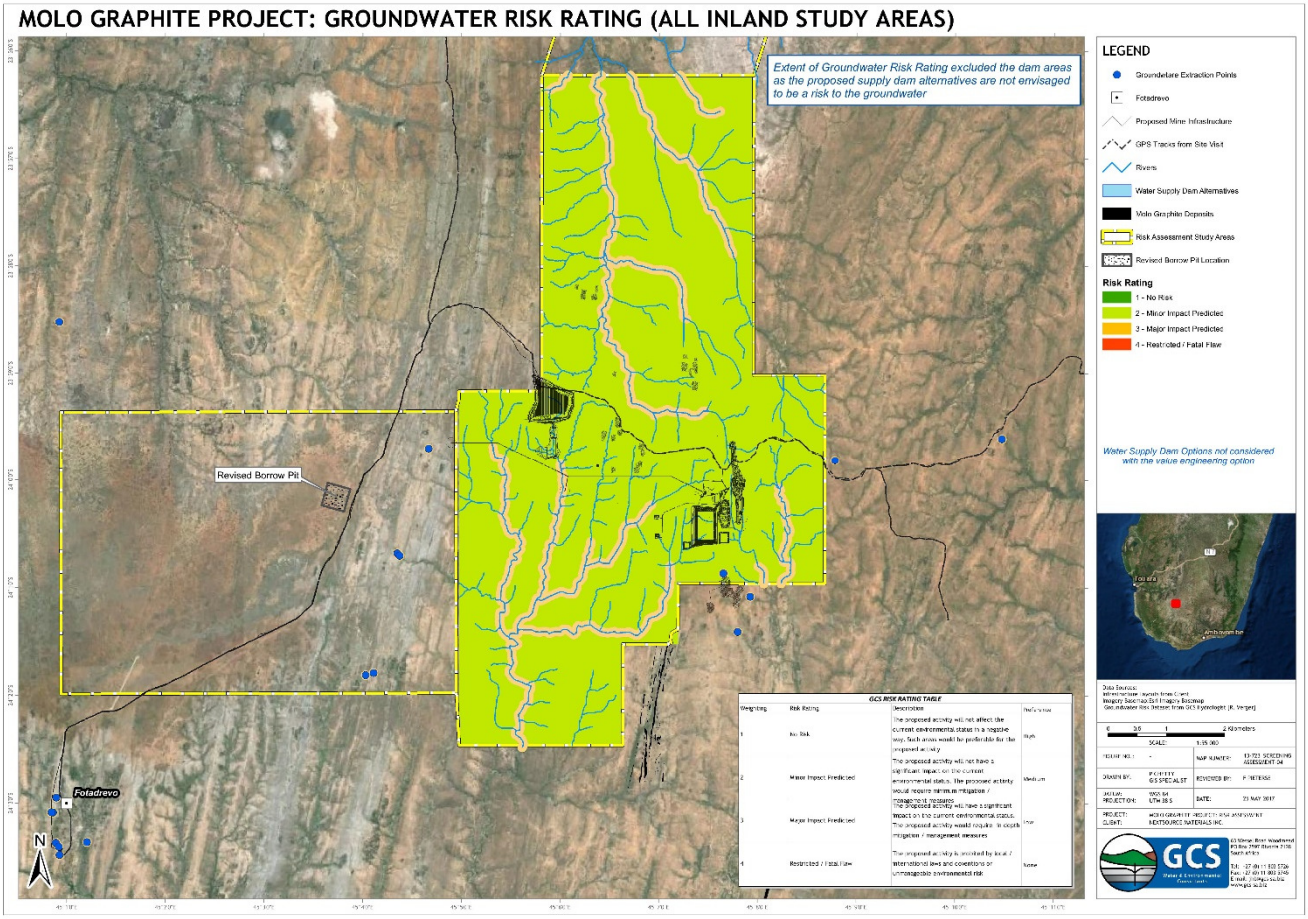


Figure 4: Groundwater Sensitivity

2.2.3 Hydrology (Surface Water)

2.2.3.1 Responsible Water Authority

The responsible water authority in Madagascar is ANDEA (Autorité Nationale de l'Eau et de l'Assainissement) (National Authority of Water and Sanitation).

2.2.3.2 Catchment Analysis

The 2012 Energizer Baseline Study (Energizer, 2012) found that three distinct drainage basins can be delineated within the study area, the largest of which flows into the Onilahy River. The southern perimeter drains to the Linta River and the eastern section is drained by the Menarandra River. Topographic maps of the area show a dense network of non-perennial rivers and ponds. During the dry season most rivers, streams and local lakes are dry or serve as stagnant ponds as a results of the construction of small, handmade dams. These rivers are therefore classified as non-perennial. The

water sources in the area are largely underdeveloped. There are no known major industrial developments, towns, irrigation schemes, impoundments and major abstraction works in the river catchments surrounding the mine (UWP, 2012). Rivers were delineated using GIS procedure using high resolution UAV imagery (re-sampled to 1 m horizontal resolution) from the Client at a scale of 1:10 000.

2.2.3.3 Area Feasibility

The October 2012 Energizer Baseline Studies on Soil, Surface Water and Groundwater (Energizer, 2012) includes a dry-season description of the rivers within the project. Water levels were measured during the dry season and estimates of the water levels during the wet season were obtained from local residents. The study found that the Andranobe River, located in the North of Fotadrevo is highly polluted and that, during the dry season, the Savazy River is almost stagnant. The Beamalo River is partially occupied by hydrophilic plants during the dry season, but during the rainy season the water level is estimated to increase 3, or 4 m above its current level. Bebakaka's well fields supply the main valley of Bebakaka with water. The Beseva River is a permanent river with a water depth of 40 cm during the dry season, estimated to be around 2.5 m higher in the wet season. The Ambilany River is non-perennial and partially colonized by hydrophilic plants with a water depth of 20 cm, rising to 2m above its dry-season level during the wet season. The Manakaralahy River is a permanent river with a consistently low flow regime. During the dry season, the water depth is around 20 cm, rising to 3 m after heavy rains (Energizer, 2012).

2.2.4 Findings

2.2.4.1 TSF (Revised Site 3)

For all the areas specified below, the methodology outlined hereunder was adopted:

Major Impact Predicted / Zone 3 areas (Please refer to the rating table), from a surface water perspective, were delineated based on the size of these rivers, calculated based on a grid generation of 10 x 10 m from a 5 m contour shapefile. Flow accumulation cells were then calculated. A threshold of 10 000 cells (based on an approximate 100 ha catchment size, resulting in approximately 100 cell per hectare) was selected based on a combination of a desktop river analysis and a site surface water analysis. Rivers falling above this threshold, as well as an 80 buffer zone from these rivers, were deemed to be Major Impact Predicted / Zone 3 areas. As mentioned, a buffer of 80 m was chosen based on specifications of Malagasy Law (Article 105 of the Mining Code.

TSF Revised Site 3 lies within an area covering watercourses that fall within a Minor Impact Predicted / Zone 2 area, refer to Figure 5.

2.2.4.2 Processing Plant

The proposed processing plant and ancillary infrastructure has been relocated to a low risk area following the findings of the Revision 1 Screening Assessment. There are some minor drainage lines within these footprint areas, however, these are minor and hence the plant area falls within a Minor Impact / Zone 2 area with no major impacts predicted, refer to Figure 5.

2.2.4.3 Borrow Pits

The proposed borrow pits are located in an area with three minor drainage lines, that have been severely altered by anthropogenic activities. These are minor and therefore the borrow pits fall within Minor Impact / Zone 2 area with no major impacts predicted.

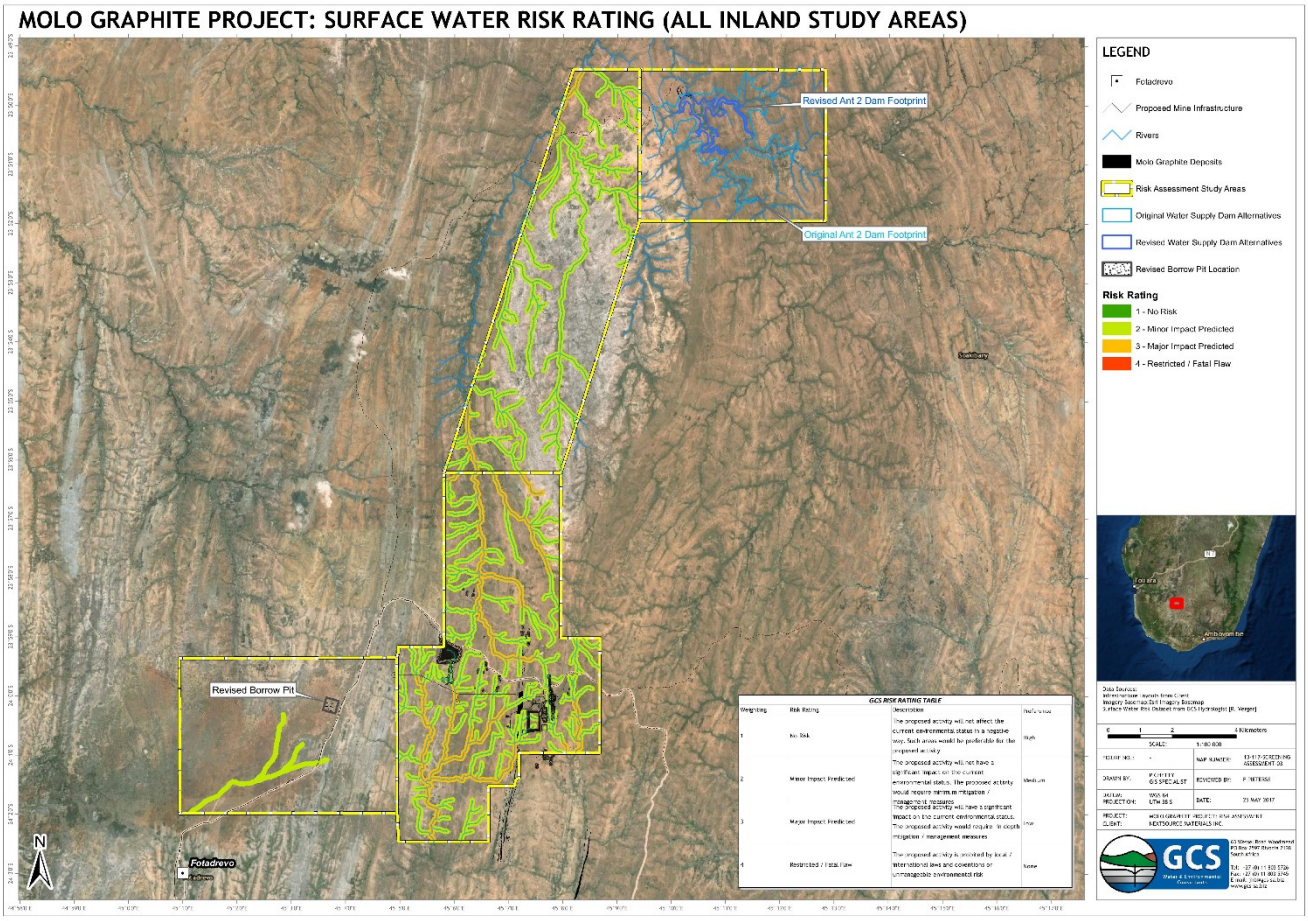


Figure 5: Surface Water Sensitivities

2.2.5 Visual

2.2.5.1 Sensitive Landscapes and Topographic Description

Information collected during baseline, scoping investigations and during the site visit in the second week of March indicate that the study area does not fall within sensitive landscapes or any protected areas. The 'Mine and Infrastructure Area' is generally flat with elevation ranging from 570 meters above mean sea level (mamsl) in the highest extent where the proposed open pit is located to 480 mamsl in the lower extents of proposed TSF Revised Site 3 area. The undulating terrain means that there is limited screening vegetation.

The proposed water supply dam sites are located in terrain that is less uniform, with the proposed dam sites in areas ranging from 550 mamsl to 450 mamsl.

2.2.5.2 Vegetation, Land cover and Visual Screening Potential

Information extracted from the ecology study reveals that the vegetation of the study area and surrounds is predominantly Grassland savannah, wooded grassland, degraded dry thickets and gallery forest in riparian areas (Agetipa Miscellaneous Baseline Studies, 2012).

Based on the site visit, the vegetation remains uniform across much of the landscape with little visual screening potential.

2.2.5.3 Sensitive / Critical Receptors

Sensitive and critical receptors include the following:

Residents

Various villages are found within close and immediate proximity of the proposed mining operations. Whilst, there is no legal requirement that limits the height or design of the proposed operations, it must be noted that mining activities are not permitted within 80 m of a village, or site of archaeological importance as stipulated by Article 105 of the Mining Code.

In order to assign ratings, all identified villages were buffered by 1 km (determined by international models to be the zone at which a proposed visibility of a development is highest), whilst a provisional view shed using coarse data from the global SRTM 90 m Digital terrain Model was used to produce a view shed.

This identified which areas are most susceptible to being affected by the visual impact of the proposed mine. The resulting intercepting areas were classified as areas with a minor impact (risk rating 2) given there are no legal requirements that provide a risk to the feasibility of the project.

Motorists

Motorists travelling roads are considered receptors of lower significance and therefore were not rated in this screening assessment.

Tourists

It is unlikely that many tourists will be impacted by the proposed mining operations with the closest national park over 100 km away from any of the proposed mining activities

Findings

2.2.6.1 TSF Revised Site 3

The TSF Revised Site 3 is likely to have the largest impact of all proposed infrastructure on the surrounding environment and sensitive receptors, especially the villages of Soaseranana (this village is however set to be relocated), it is currently approximately 200 m west of the proposed TSF.

2.2.6.2 Open Pit

The open pit and associated waste rock dump will have a visual impact on the surrounding environment. The receptors with the largest exposure and potential impact include the large village approximately 800 m south of the proposed open pit and the town of Beamalo approximately 1.2 km north of the open pit.

2.2.6.3 Processing Plant

The proposed plant and ancillary infrastructure (contractor camp, waste dump and associated stockpiles) is located immediately east of the village of Soaseranana. With relocation of this village expected, the closest other receptors will be the villages 800 m south of the pit, and the village of Beamalo approximately 1.5 km north of the processing plant, refer to Figure 6.

2.2.6.4 Borrow Pits

The proposed borrow pits are located immediately east of the village of Ankazoata and approximately 1 km south of Ankilibe. The impact associated with the visual alterations, along with the above infrastructure, will be of Minor Impact, based on the aforementioned risk rating criteria.

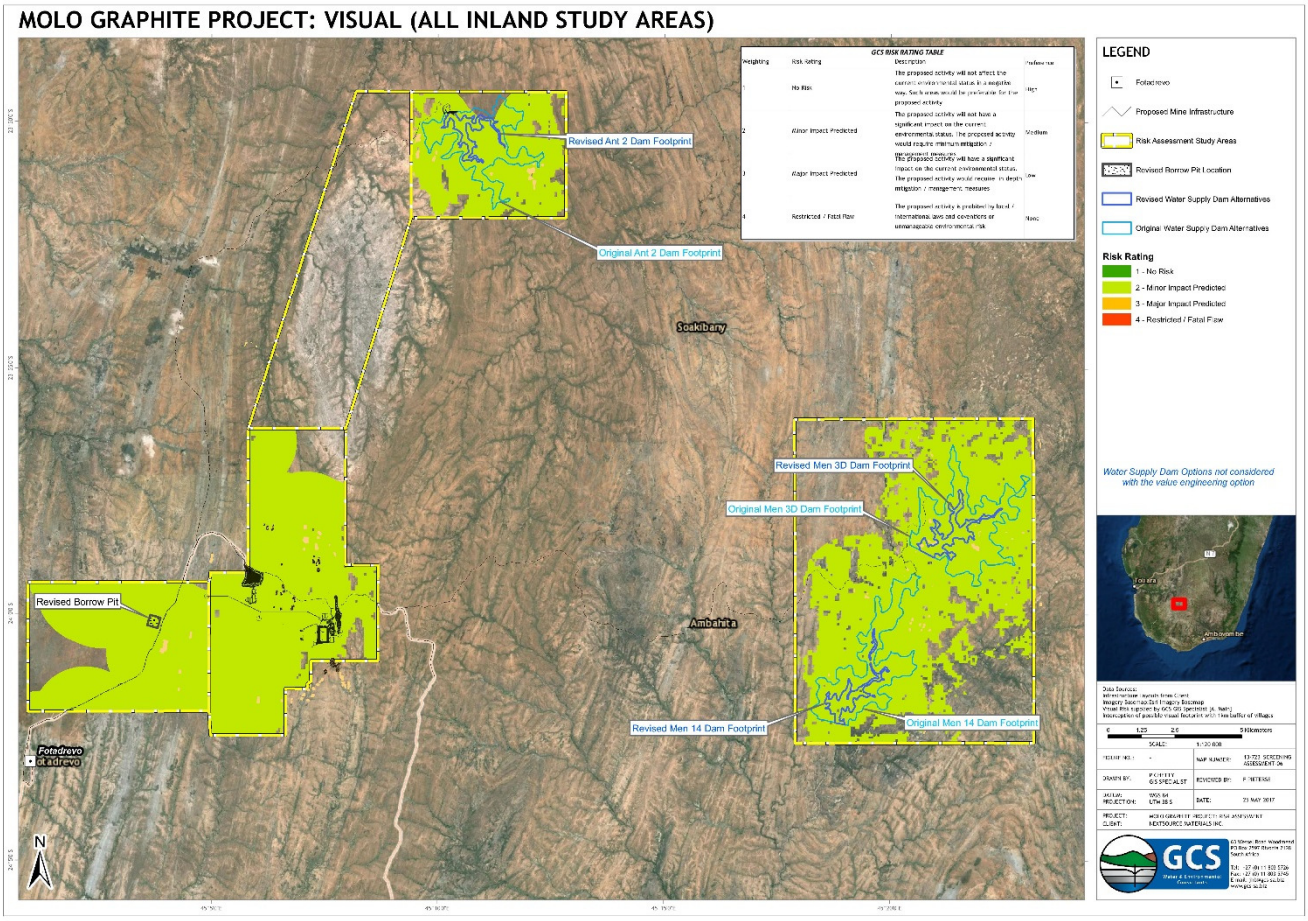


Figure 6: Visual Sensitivities

2.2.7 Social

2.2.7.1 Background Description

Impacts on social dynamics are a critical component of any project of this nature. As a part of the project screening assessment, it became clear that a detailed assessment on the interconnectivity of the proposed project and the local communities which could be affected be undertaken. A detailed assessment was undertaken and is summarized in Section 5 of this report and the full Relocation Action Plan report is contained in Appendix D.

For the sake of assigning a risk, simplification of this intricate component is necessary. For the sake of the social component, three critical components were incorporated into this assessment, whilst only two were used for the social risk ratings. These include:

Cultural Aspects

- This screening assessment used information received from the social consultant conducting the ESIA (Agetipa) to assign ratings to two important cultural features that have become prominent through the relevant baseline

and social studies taking place. These include the presence of Tombs and Sacred Trees which has no legal framework and is based on Malagasy Customary Rights

- As a result of there being no legal framework, the ratings in Table 2 were assigned to delineated features collected through a combination of detailed field work by Agetipa and information collected using GIS collection of high resolution aerial imagery collected by the UAV survey conducted by the Client

NB: Information obtained during the field survey by Agetipa, identified certain tombs that cannot be relocated. This risk has been mitigated through careful plotting of the location of these tombs in order to avoid any disturbance. In addition, effects from blasting were assessed and suitable measures will be in place to manage any potential associated risk. Refer to Section 3.7 for information on the blasting implications and management measures.

Human Settlement

Similar to the Cultural Aspects, there is no specific legal framework that determines the exact implications on villages, isolated homestead and towns. Such documentation to determine willingness / non-willingness of villages is detailed as part of the RAP (again, refer Section 5) and a summary of the issues raised during the public participation phase. This will further be addressed in Section 5.

Land-use

The land-use associated with anthropogenic activity has been captured through field (ground survey).

Table 2: Social Description of Ratings

	Risk Factors	Risk Rating	Description
Social	Proximity (80 m) of Tombs / Sacred Trees	¾	Certain tombs cannot be moved (Rating 4). Other tombs and Sacred Trees that are based on a ceremony (Rating 3)
	Proximity (80 m) of Homesteads / Villages	¾	No available information of villages legal situation (Rating 3)
	Land use (Cultivation, Vacant Grasslands, etc)	2-3 (not included)	

It must be noted that the ratings above were assigned to the delineated feature with an 80 m buffer. It must also be noted that no field survey data has been collected / provided for the Men Dam sites by Agetipa.

Findings

2.2.7.2 TSF (Revised Site 3)

Based on the delineated and field captured information, refer to Figure 7, the TSF Revised Site 3 does not fall within any sites of significant social or cultural importance (tombs, homesteads or sacred trees). There are cultivated activities that fall within the TSF footprint, however the overall risk associated with cultivated areas is not deemed to be major. The closest significant social features include the tombs approximately 100 m west of the proposed TSF site.

2.2.7.3 Open Pit

The proposed pit does not have sites of significant social importance within 200 m of its proposed location. The main areas of social importance lie within the 500 m blast radius where a number of tombs lie south east of the proposed pit. The presence of a sacred tree within the blast radius is also of relevance, however, information available indicates that sacred trees can be removed with community permission and a small ceremony. There are cultivated activities that fall within the open pit, the overall risk associated with cultivated areas is not deemed to be major.

2.2.7.4 Processing Plant

The proposed plant, including ancillary activities such as the waste dump, stockpiles and contractor camp do not intercept any significant cultural activities. The village of Soaseranana, lies immediately west to the proposed plant location, however this village is set to be relocated, refer to Figure 7.

2.2.7.5 Borrow Pits

The proposed borrow pits have two main social impacts, the presence of the Ankazoata villages immediate west of the proposed borrow pit extent and a Kily Sacre sacred tree within the proposed borrow pit location. The presence of the sacred tree within the borrow pit is of relevance, however, information available indicates that sacred trees can be removed with community permission and a small ceremony.

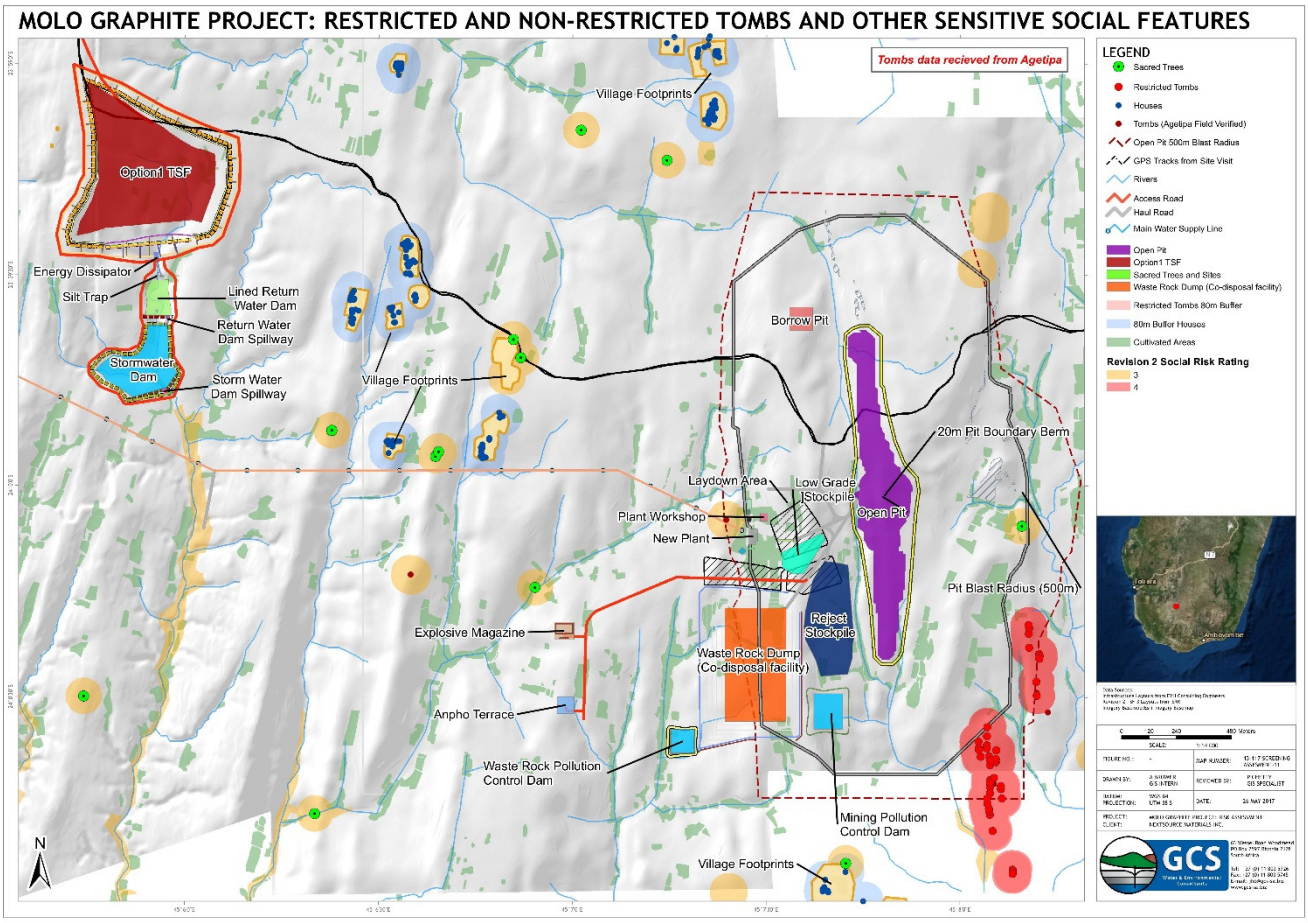


Figure 7: Restricted and Other Sensitivities

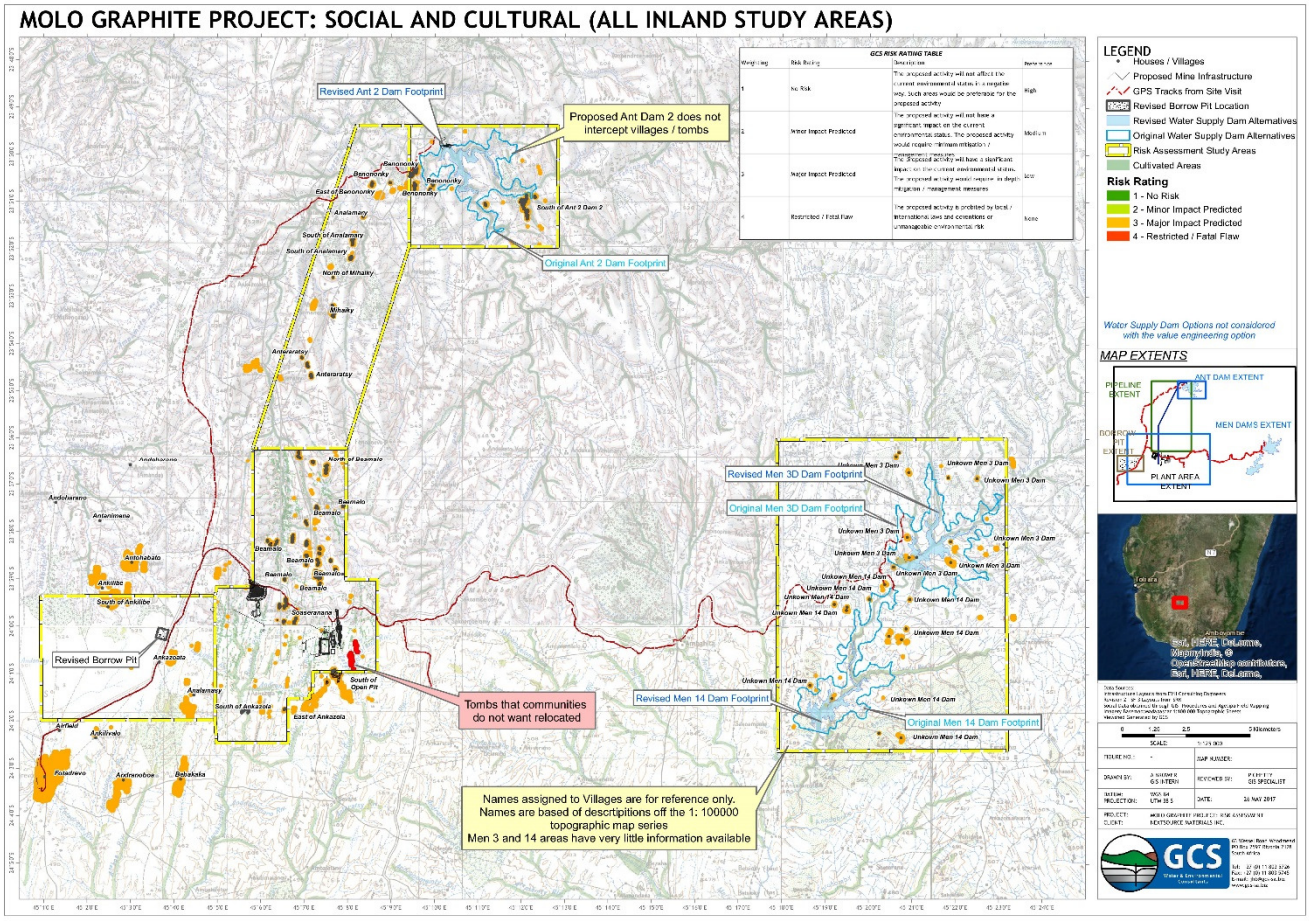


Figure 8: Social and Cultural Information of Importance

The results from the combined GIS risk assessment (refer to Figure 9 and Figure 10) illustrates the combined bio-physical and social assessment for the project areas. The most significant risk lies approximately 300m south-east of the open pit site where there are tombs present within the 500m blasting radius. These tombs are not subject to relocation, but stringent measures have been detailed to ensure the protection of these. Refer to Section 3.4 for specific details on these.
Overall Conclusions

Various recommendations have been implemented and the location of most infrastructure avoids sensitive areas where impacts would be the highest.

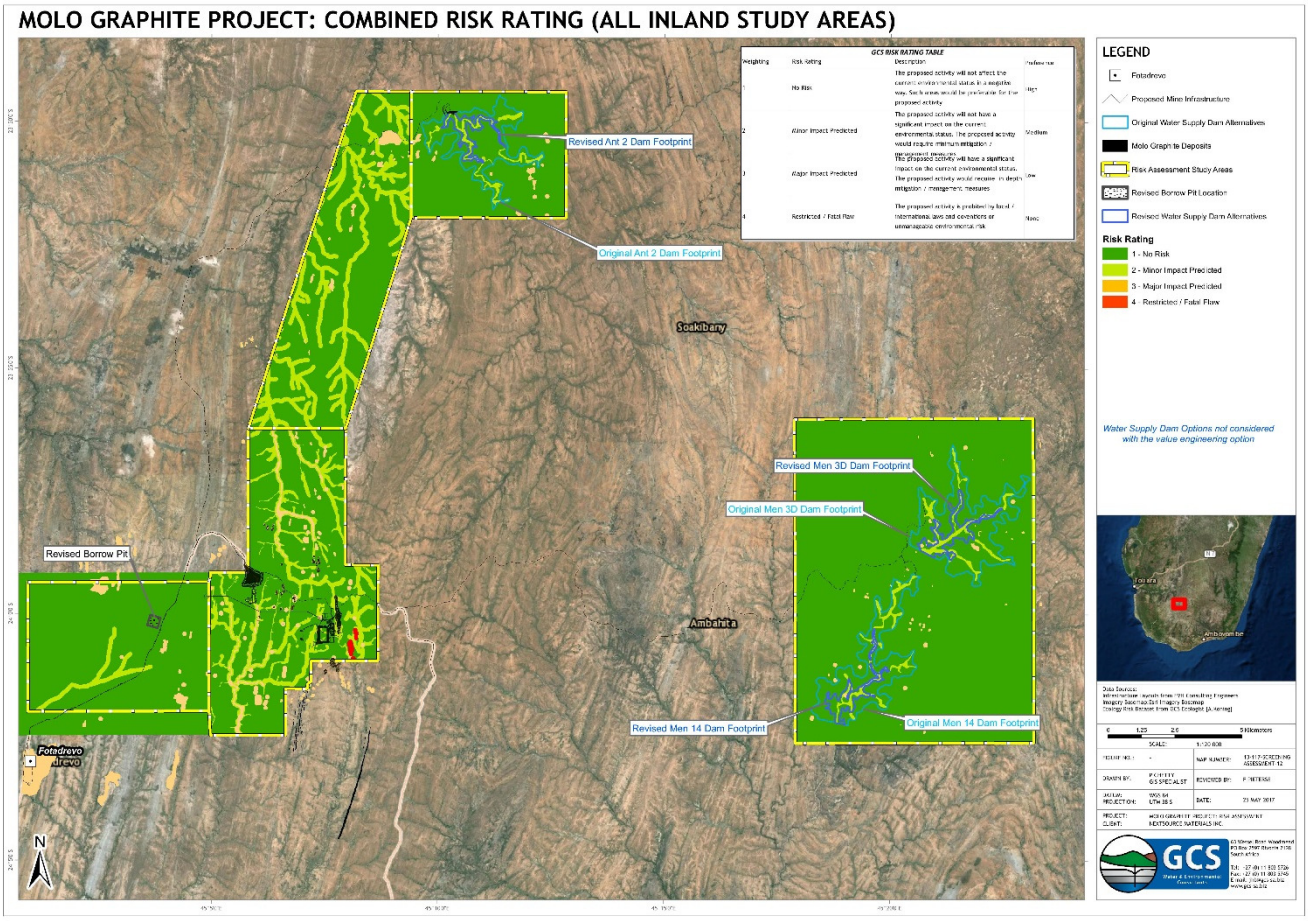


Figure 9: Combined Environmental Risk including future water supply dam options

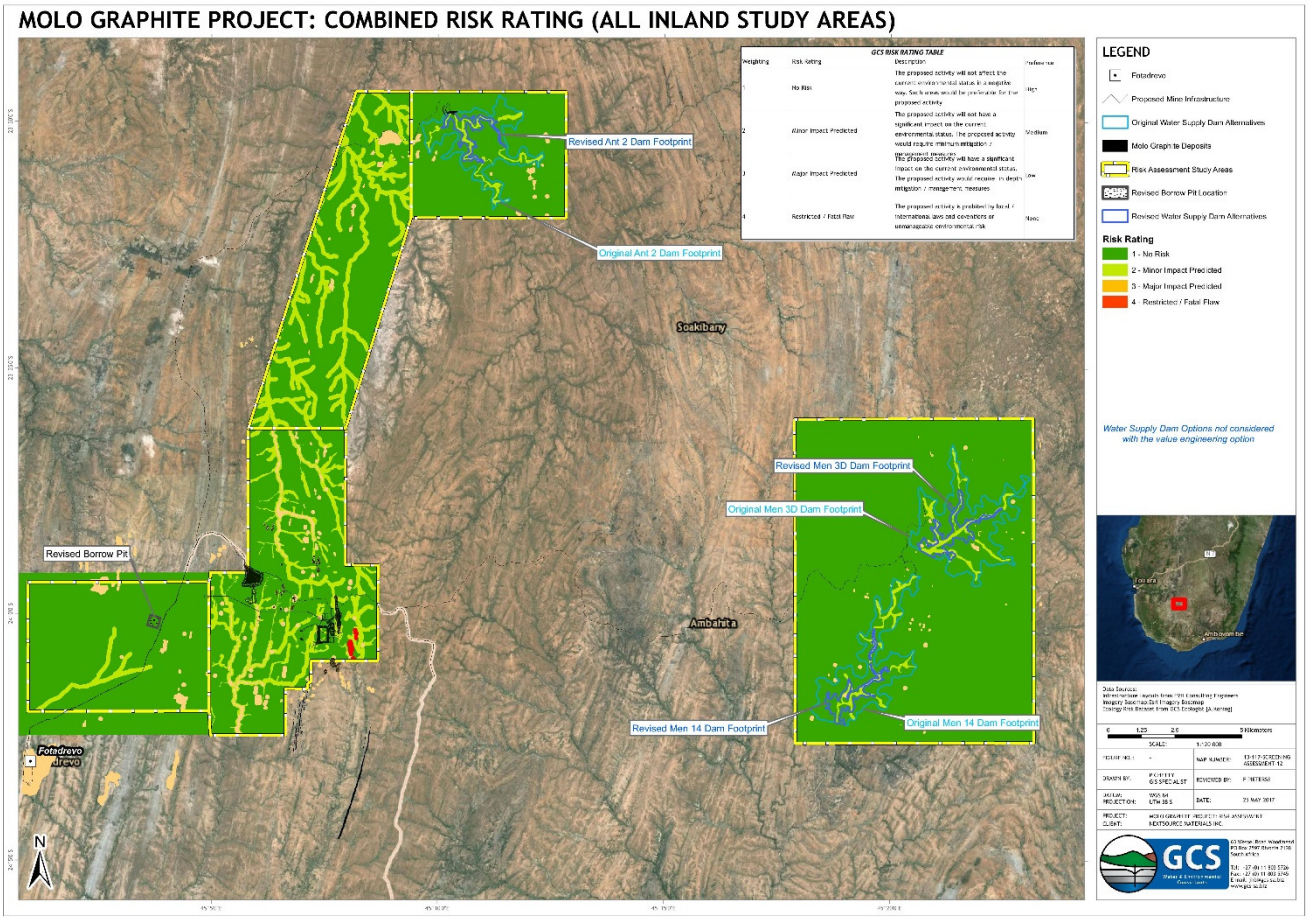


Figure 10: Combined Environmental Risk for main project area

A summary of the results for the main infrastructure is detailed below:

2.2.7.6 TSF (Revised Site 3)

The combined risk of the site is limited to a maximum of a Minor Impact. No major social or environmental impacts are anticipated for the proposed TSF site. The closest social risk occurs approximately 100 m west of the proposed site where tombs were identified and the Soasalerana village 300 m east of the site which is planned to be relocated.

2.2.7.7 Open Pit

There no major risks in the open pit based on the risk assessment, but impacts will result in areas where there are drainage lines. The major social risk occurs within the 500 m blasting zone of the open pit where there are restricted tombs that the community does not want relocated. Mitigation measures are required to limit any impact on these tombs.

2.2.7.8 Processing Plant and ancillary infrastructure

The processing plant falls within a combined risk rating of 1 and 2, the higher risk areas resulting from the watercourses in the footprint area of the proposed plant area, resulting in higher impacts in such areas, and a tomb within the footprint

of the haul road. This tomb, however, is not classified as restricted. The waste dump is situated in a small drainage line, constituting a risk rating of 2.

2.2.7.9 Borrow Pits

The proposed borrow pits have a maximum risk rating of 2, due to the small drainage lines occurring to the southern extent of the most westerly located borrow pit. There is a Kily Sacre tree located in the borrow pit, however the removal of this tree is not foreseen to be a major risk. The small village of Ankazota has a risk rating of 3, but falls outside of the borrow pit footprint area.

3 Biophysical and Social Study Components

3.1 Soils, Land Use and Land Capability Study

3.1.1 Baseline Description

The Molo Deposit Project is centred on open pit mining graphite in southern Madagascar. A soils study of the Molo Graphite Project area was undertaken in order to classify the soils present at the proposed Molo Plant Area, Tailings Storage Facility (TSF) and Mining Pit areas.

Such a classification enables the establishment of the risks that the proposed study may pose to these soils, in accordance with the IFC Framework and Equator Principles that state that a risk assessment must be undertaken for all potential environmental risks. The soil classification undertaken within this study is based on the South African Taxonomic system (Soil Classification Working Group, 1991), as agreed-upon prior to commencement of this study. This system enables the grouping of soil types in such a way that their capabilities and risks can be understood, in order to apply best practices relative to the soils in question.

Prior to the soils site visit at the Molo Graphite Project site, soils information was obtained from the Baseline Studies (Energizer, 2012): Chapter 2: Soil, Surface Water and Groundwater Studies (Agetipa, 2012) and from the geotechnical pit profile descriptions taken on-site at the proposed TSF candidate sites by SRK Consulting (SRK, 2014). The Agetipa 2012 study identified deep, well-drained soils adjacent to the current proposed project area, which was verified by both SRK and GCS' findings on site. Still prior to the GCS site visit and based on the geotechnical test pit information and results of soil sample analyses undertaken by Agetipa (2012) and provided by SRK, it appeared that the soils at the proposed TSF sites are shallow, rocky soils. This was verified by the GCS site visit findings.

The Molo soils site visit was undertaken between the 30th June and the 10th July, 2014. Thirty-eight survey holes were dug using hand-held bucket augers to depths of 1.2 m, where possible, in order to classify the soil forms identified. The following survey points were observed; see Table 7 and Figure 13.

Table 7: Molo Survey Points

Site	Termed	Number of points	Typical Soil Types
Borrow Pit	BP	7	Deep, well-drained

Site	Termed	Number of points	Typical Soil Types
Plant Area	PA	8	Shallow, rocky
Graphite Pit	Pit	14	Shallow, rocky
Tailings Storage Facility	TSF3	3	Shallow, rocky

The deepest, best-drained soils were found at the borrow pit site. The plant area comprised shallow, rocky soils such as those identified in the pre-site baseline study. The graphite pit comprised largely shallow, rocky soils, with some deeper soils. TSF3 comprised a soil form very similar to that deduced from the pre-site baseline study (shallow and rocky). See Figure 12 for the distribution thereof.

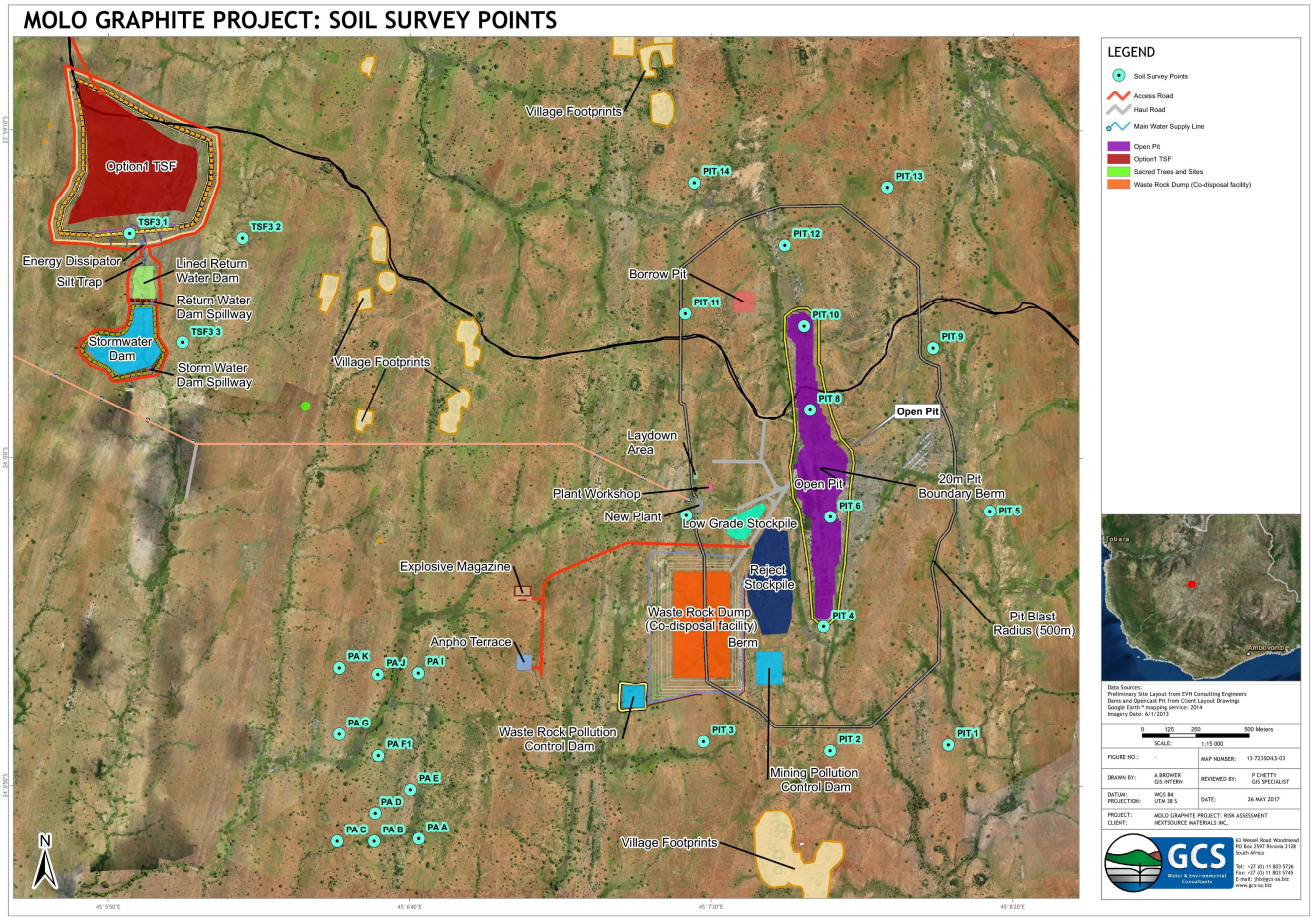


Figure 13: Molo Soils Survey Points

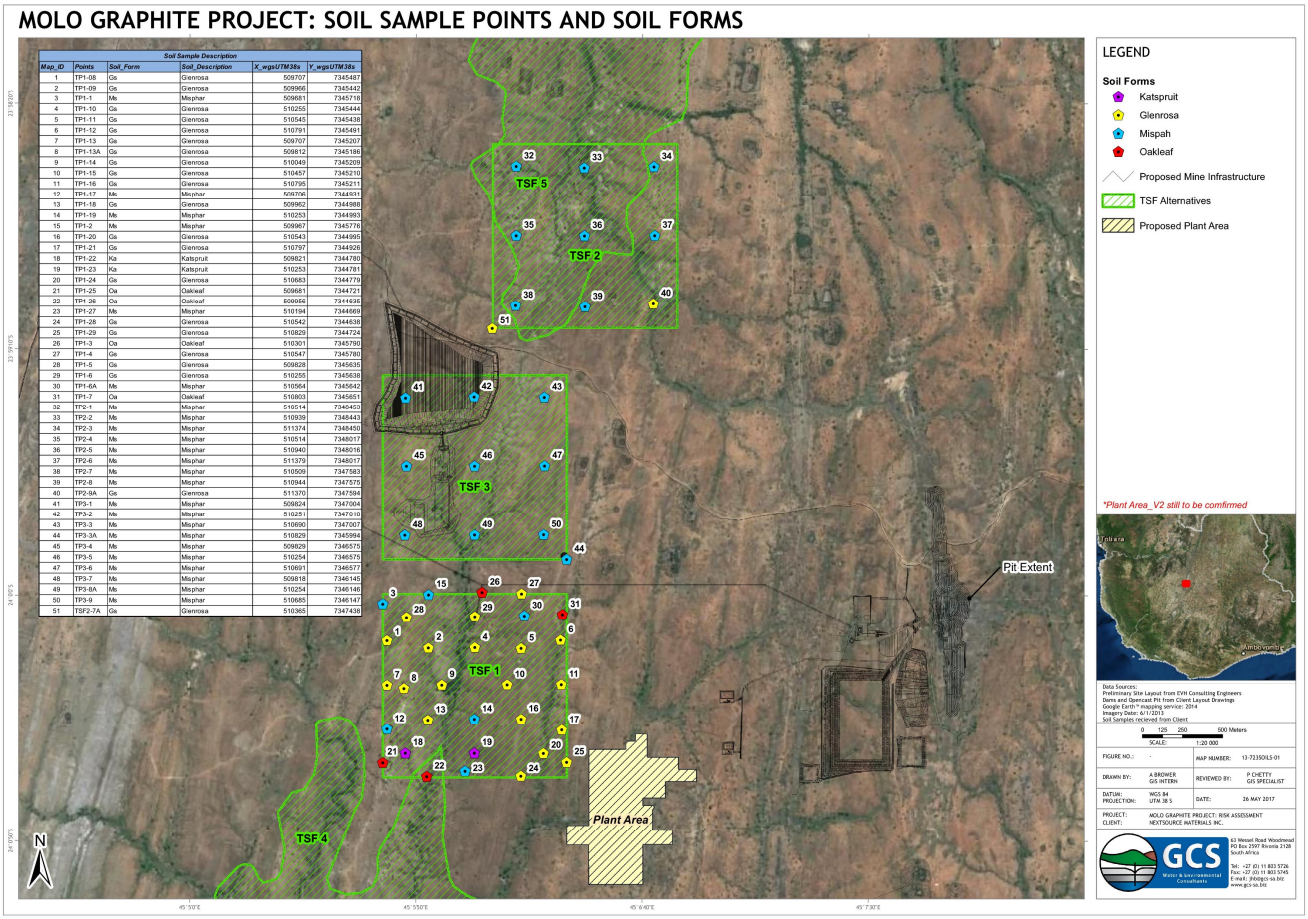


Figure 14: Distribution of Soil Forms Soil Chemistry

Twelve samples were collected at seven of the aforementioned thirty eight survey points and sent to Eco-Analytica laboratories for analysis. See Figure 15 for the positions of these sampling points. Two kilogram samples were collected per sample point and submitted to Eko-Analytica Laboratory (University of Potchefstroom) for analysis for sulphates (SO_4), nitrates (NO_3), pH, Electrical Conductivity (EC), Aluminium (Al), Phosphorus (P), Vanadium (V), Strontium (Sr) and Lead (Pb). Table 7 lists the locations of the sampling points.

Table 8: Soil Sample Locations

Site Name	Horizon Sampled	Latitude	Longitude
BP D	A and B	-24.0137500037	45.0398609787
BP G	A and B	-23.9970280230	45.0587780122

PA 8	A	-24.0103610326	45.0596390013
PIT 5	A and B	-24.0022500325	45.1378060319
PIT 8	A and B	-23.9979439974	45.1295279805
TSF 3b	A and B	-23.9906939864	45.1033890154

The data obtained from the soil analysis indicates that each area has its own specific soil chemistry conditions, and therefore serves as the baseline for pre-mining development in the area. Samples taken within the planned open pit area show acidic soil conditions in the middle region of the planned opencast pit. The soil in the TSF area is generally of good agricultural potential; this is relevant post-mine closure for rehabilitation purposes. Samples taken at the planned borrow pit area suggest that acidic soil conditions will be present in the general area.

3.1.2 Potential Impacts as Identified

3.1.2.1 Impact Description

The underlying section serves as a description of the identified risks to soils that the mine may incur. The following environmental risks associated with the soils identified at the Molo site were identified. Erosion, contamination and compaction of soils could occur as a result of:

Erosion (This is a medium / average risk):

Loss of soil-binding roots and breakdown of soil structure from areas cleared ahead of mining:

- Erosion of soils at clean storm water discharge points due to point source discharges of high velocity flows, and
- Erosion of excavated, inadequately stockpiled soils

Contamination (This is a high / major risk):

- The waste dump, ore stockpiles and TSF could be disturbed during the operational phase, resulting in contaminated seepage into soils
- Contamination of soil owing to the potential (although unlikely) decanting of water from the mine post closure, as well as seepage from the TSF
- Release of chemicals associated with and used in the mining process seeping into the soil, and
- Truck oils and fuel could leak and seep into the soil

Compaction (This is a medium / average risk):

- Soil compaction in areas traversed by trucks and heavy machinery will result in compacted, non-arable soils devoid of structure

3.1.3 Management Measures

3.1.3.1 Mitigation Measures

The underlying mitigation measures address the aforementioned potential risks and have been broken into three groups of likely risks to the soils as a result of the Molo Graphite Project; Erosion, Contamination and Compaction.

Erosion (Medium Risk)

- Every effort should be made to avoid disturbing the waste dump and tailings facility during the operational phase, as this will cause instability, resulting in soil erosion
- Areas cleared ahead of mining should be kept to a minimum and soil should be stockpiled to heights not exceeding 3-5 m and no larger than surrounding infrastructure (EPA, 2010)
- Water flow velocities at clean storm water discharge points should be limited, as point source discharges of high velocity flows will lead to erosion of the soils in the vicinity
- Stockpiled soils should be grassed as soon as possible to avoid erosion of these soils

Contamination (High Risk)

- Dirty water emanating from the waste dump should be captured and contained as a part of a Storm Water Management Plan. This will prevent contamination of the soil from these sources
- The TSF and all dirty water storage areas should be properly lined, as seepage from these areas will result in contamination of soil
- All oils and fuels should be stored in bunded areas and any spillages should be managed immediately in accordance with the mine's project Emergency Response Plan. The Emergency Response Plan should be provided by contractors
- The size of contaminated areas should be minimized
- Seepage from the waste dump, stockpiles and TSF should be minimized
- Overflows should be prevented and seepage losses from Pollution Control Dams and consequent prevention of soil contamination should be minimized
- Some of the proposed infrastructure will generate dirty water. This water will also be classified as 'dirty' in terms of the IFC Health and Safety Mining Guidelines (IFC, 2007b). Every effort should be made to separate clean and dirty water areas by containing runoff from 'dirty' areas in order to prevent soil contamination

Compaction (Medium Risk)

- Any vehicles that are not required on the site should be kept off the site. Vehicles that are required on site should be limited to specific pathways, where possible, to limit the extent of soil compaction

3.1.4 Topsoil Management

Topsoil stripped at the start of mining should be stockpiled for rehabilitation. It is recommended that the top 50 cm of soil be stripped, where possible (not in the Mispah, or Glenrosa areas) according to the guidelines below, (see Figure 16 for the locations of the deep soils in the site area);

- Demarcate the area to be stripped clearly, so that the contractor does not strip beyond the demarcated boundary
- The top 0.5 m of the entire opencast area should be stripped, where the soils are deep enough (see Figure 16) and relocated by truck along set removal paths

- The area to be stripped requires storm water management; the in-flow of water should be prevented with suitable structures
- Prepare the haul routes prior to stripping
- Stripping should not begin in wet conditions
- Within each stripping unit, segments should be stripped progressively, ensuring that the dump truck used to move the soils does not drive over the area to be stripped, but rather behind it on the basal layer, in order to avoid compaction and degradation of the topsoil properties (Humphries Rowell Associates, 2000)
- When stockpiled soils have been replaced during rehabilitation, the soil fertility should be assessed to determine the level of fertilisation required to sustain normal plant growth. The fertility remediation requirements need to be verified at time of rehabilitation. The topsoil should be uniformly spread onto the rehabilitated areas and care should be taken to minimise compaction that would result in soil loss and poor root penetration (Viljoen and Associates, 2012)

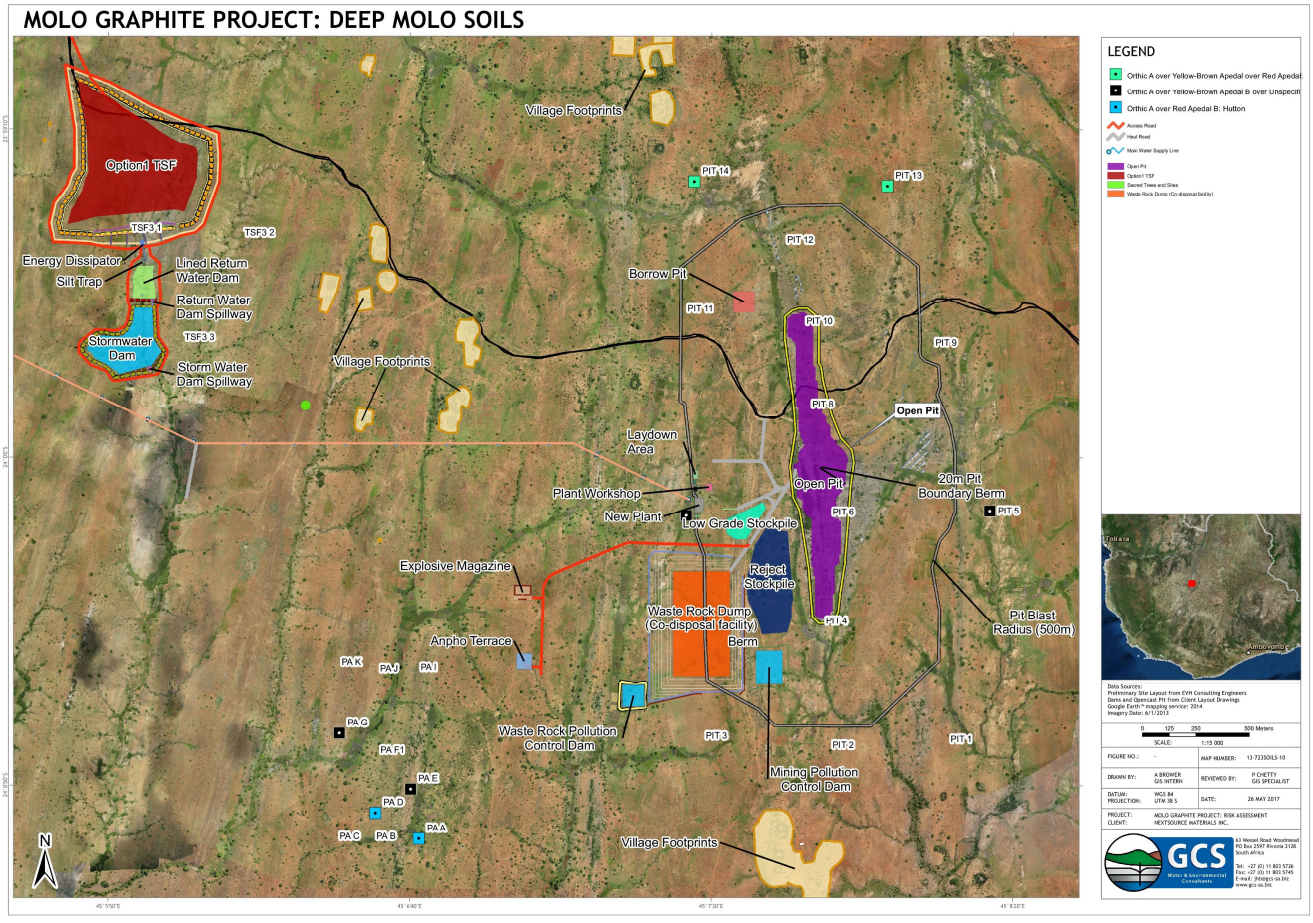


Figure 15: Deep Soils at the Molo Project Site

3.1.5 Soil Monitoring Plan (High Risk Mitigation)

The soils should continue to be monitored for contaminants at the places at which samples have been taken previously, for the same chemical suite (see below). This provides the opportunity to monitor soil contamination and to compare these against baseline values. These results should also be compared against those of the surface water monitoring plan, bearing in mind that some contaminants will accumulate within soils for longer periods of time than they will in water (Sisodia, 2011). Standard monitoring should be conducted bi-annually, and reactive monitoring should be conducted after a storm event. Sampling should be undertaken as follows; Biannually 2 kg samples of all soil horizons at the sampling positions at which deep soils exist (See Figure 0.1) should be collected in soil sampling bags, which should be sealed, labelled, the coordinates of which noted, and sent to an accredited laboratory for analysis of SO_4, NO_3, pH, EC, Al, P, V, Sr and Pb. These results should be graphed, per chemical, and thereby compared against the results of the baseline and prior sampling event results.

3.1.6 Surface Water Monitoring Plan (High Risk Mitigation)

As contamination of surface water leads directly to contamination of soils if not managed, the Surface Water Monitoring Plan applicable to the Molo Graphite Project is also applicable to this study. Please refer to Section 12 Water Report within the main Feasibility Report.

3.1.7 Recommendations

In order to better determine the possible future impacts of the graphite mine, and the effects of mining infrastructure development on the soils in the area, the following actions are recommended:

- Ongoing monitoring to collect further data over time, and
- More monitoring points be sampled to better understand the area and the natural geochemical processes that take place in the area, before mining commences

3.2 Ecology Study

3.2.1 Introduction and Baseline Description

The area associated with the proposed mine infrastructure falls within the Madagascar succulent woodland ecoregion. This succulent woodland is located in south western and central western Madagascar. Its southern limit is the start of the spiny thicket and northern limit the lower end of the dry deciduous forest. The southern portion of the succulent woodland ecoregion is inland from the spiny thicket and further north this ecoregion meets the sea around Belo-Tsiribihina. The eastern extent of the ecoregion, at the 600 meters (m) to 800 m contour, is contiguous with the sub-humid forests ecoregion, and to a large extent coincides with the south western limit of the central highlands. The fauna and flora of the succulent woodlands have some overlap and similarities with the spiny thickets and dry deciduous forests. Previous descriptions of phytogeographical regions of Madagascar had grouped the succulent woodlands with the dry deciduous forests as a "western domain", but here this domain is separated to better differentiate between the spiny thicket and the dry deciduous woodlands. In many ways the succulent woodland ecoregion is a transitional habitat type between these two other ecoregions (WWF, 2014).

The succulent woodland ecoregion has a tropical dry climate with a distinct dry season between May and October. During the wet season, November to April, rainfall may reach 750 millimetres (mm), within a yearly range of 575 mm to 1,330 mm. The annual average daily temperature for the region is between 25°C and 31°C (WWF, 2014).

The geology of the western part of the ecoregion comprises unconsolidated sands on the coast and tertiary limestones and sandstones inland. In the southern part of the ecoregion, there are also metamorphic and igneous basement rocks.

The soil is generally sandy with richer alluvial soils around river areas. The terrain is relatively flat but there are some notable rock outcrops and deep precipitous valleys (e.g., in the Makay region). The vegetation of the region is similar to dry deciduous woodland but is characterized by more xerophytic species. These species often have water storage adaptations, stem photosynthesis, and remain without leaves for long periods. Forests of the ecoregion may reach 15 m in height, with the endemic baobabs (Bombaceae family) Adansonia za and A. grandidieri as distinctive emergent species. Other canopy species belong to the families Euphorbiaceae and Leguminosae including several endemic species of Pachypodium. The shrub layer consists of the families Sapindaceae, Euphorbiaceae, Anacardiaceae, and Burseraceae (WWF, 2014).

In the southwest the coastal Mikea Forest between Manombo and Morombe have some species characteristic of southern "spiny thickets," such as Didierea madagascariensis of Madagascar's endemic family, Didiereaceae. These forests grow on sandy soils and in a semi-arid climate with annual precipitation as low as 350 mm. The canopy, which rarely exceeds 12 m, is shorter than that of the forests inland and of those further north. The plant families forming the canopy include Leguminosae, Euphorbiacae, Burseraceae, and Bombaceae. The shrub layer is comprised mainly of Croton sp. (Euphorbiaceae), Aloe vaombe (Aloaceae) and lianas such as Dioscorea sp. (Dioscoreaceae) (WWF, 2014)

As with many of the habitat of Madagascar, the major threat to the succulent woodlands is fire - both intentional burning for expansion of agricultural lands and unintentional wildfires. Further, the conversion of hardwoods into charcoal occurs in this region. Although it is not known whether the ecoregion comprised only dry woodland, or a mosaic of woodland and grassland prior to human settlement, the increased incidence of fire in recent times has certainly led increasingly fragmented and isolated patches of native vegetation (WWF, 2014).

The Malagasy endemic tree Hazomalania voyroni is at risk of becoming extinct through traditional forest exploitation for construction wood. Some attempts have been made to propagate and replant this species. In addition to this species, there are several other endemic trees that are removed from the forests, mainly for construction purposes including Givotia madagascariense, Cedrelopsis grevei, and Commifora arofy. Various endemic species are also collected for charcoal production, which is considered a grave problem here and in the spiny thicket ecoregion (WWF, 2014).

Traditional hunting continues in the ecoregion even within protected areas. With increasing populations and greater movement of people, these traditional activities are possibly becoming locally unsustainable. The main species threatened by hunting are the tenrec (Tenrec ecaudatus), fruit bats (Pteropus rufus and Eidolon helvum), and the red-fronted brown lemur. In many parts of the ecoregion, cattle and goat grazing are degrading the forests. Wood exploitation for charcoal production has caused massive deforestation. Honey collection, through the felling of trees, is a traditional activity that threatens the forests of the ecoregion to lesser degree. (WWF, 2014)

The area associated with the proposed mining site and infrastructure comprises mainly of open savannah. Some perennial streams where also identified and assessed. Riparian vegetation is associated with the perennial streams (Figure 16). Large areas of the project consisted of altered habitat. All agricultural fields and village footprints were classified as such. The wetlands present within the pit area were highly degraded due to anthropogenic impacts within the catchment and close proximity to these wetlands. No endangered species were recorded during the site visits. However, some Malagasy sacred trees were identified to be present within the proposed project area. This is discussed within the social assessment. All impacts associated with the project were classified as average.The 2012 Energizer Baseline Study (Energizer, 2012), described the veld type associated with the mining area as savanna. The site visits confirmed this veld type. The veld type can be described as open Heteropogon contortus – Sclerocarya birrea veld.

Some perennial watercourses were also identified during the site visits. These areas were mainly dominated by Ficus cocculifolia and Tamarin dusindica trees. Tamarin dusindica is not native to Madagascar and had to be introduced. These trees produce legumes that are utilized by cattle and other herbivores. The seeds are then spread by the runoff water present in these perennial watercourses.

The Malagasy Tree Aloe, Aloe vahombe also occurs within the study area. This tree aloe is native to Madagascar, but is not listed as a protected species under the IUCN (International Union for Conservation of Nature).

3.2.2 Potential Impacts as Identified

Large areas of the project consisted of altered habitat. All agricultural fields and village footprints were classified as such. The wetlands present within the pit area were highly degraded due to anthropogenic impacts within the catchment and close proximity of these wetlands. No endangered species were recorded during the assessment. During the Impact Assessment, all the impacts were classified as average.

3.2.2.1 Pit Area (Refer to Figure 16)

The following potential impacts were identified:

- Pollution due to runoff water from potential spills and oil and grease leaks during preparation, construction and operation;
- Pollution of surface water due to seepage and runoff from waste dumps and stockpiles during operation;
- Polluted runoff from mining site during operation;
- Habitat loss and habitat degradation due to clearing for mining infrastructure during construction phase;
- Dust pollution due to mine traffic during construction and operational phase; and
- Hydrocarbon spills during preparation, construction and operational phase.

All these impacts were rated as average.

3.2.2.2 Tailings Storage Facility Areas (Refer to Figure 16)

- Pollution due to runoff water from potential spills and oil and grease leaks during preparation, construction and operation;
- Pollution of surface water due to seepage and runoff from waste dumps and stockpiles during operation;
- Habitat loss and habitat degradation due to clearing for mining infrastructure during construction phase;
- Dust pollution due to mine traffic during construction and operational phase; and
- Hydrocarbon spills during preparation, construction and operational phase.

All impacts were rated as Average.

3.2.2.3 Plant Area (Refer to Figure 16)

- Habitat loss and habitat degradation due to clearing for mining infrastructure;
- Dust pollution due to mine traffic during construction and operational phase; and
- Hydrocarbon spills during preparation, construction and operational phase.

All impacts were rated as Average.

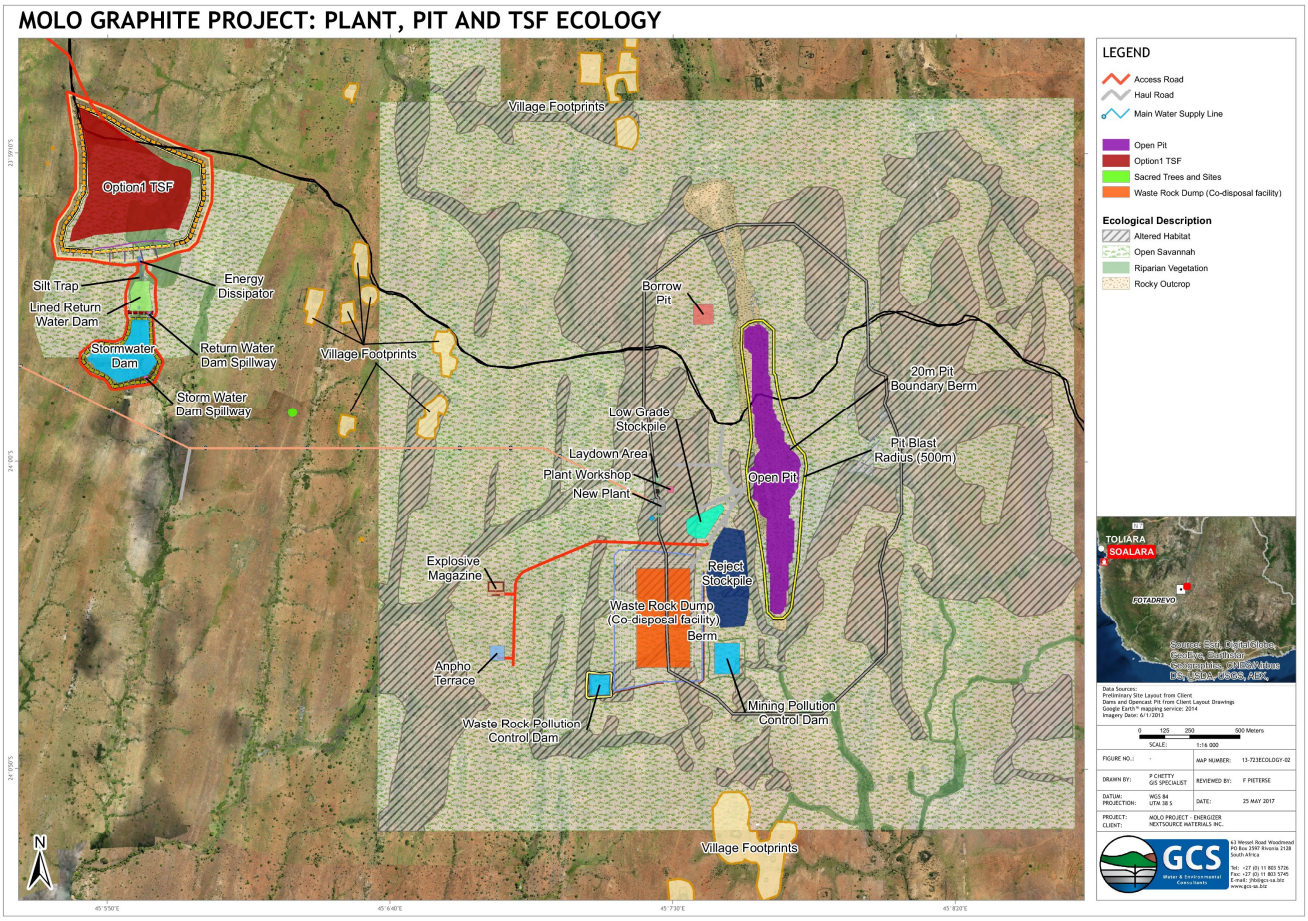


Figure 16: Pit, Plant and TSF Ecology

3.2.3 Management Measures and Recommendations

3.2.3.1 Ecological Management Plan

The following criteria need to be implemented as part of the EMP:

- No fauna encountered during all phases of the mine development, can be killed
- Identify operational protocol that will allow for the protection of animals
- Environmental awareness must be maintained. This can be done by conducting environmental inductions to all contractors
- Alien invasive species like Opuntia ficus indica and Agave sisalana should be removed as far as possible
- Fires on site must be prohibited. Run away fires can result in loss of habitat
- The necessary fish ladders must be constructed, during the construction of the dams. These fish ladders must be constructed at the dam wall, to ensure that fish species can migrate in an upstream direction. The dam wall

will act as a barrier if this is not done. The fish ladder must contain off channel slow areas where smaller fish can rest, while swimming up the fish ladder; and

- Barriers for example conveyer belts, must be constructed in such a way to ensure the free moving of animals, over or under these barriers

3.3 Blasting and Vibration Study

3.3.1 Introduction

A review of potential impacts associated with the blasting activities during the proposed opencast mining operation was undertaken. Ground vibration, air blast, fly rock and fumes are some of the impacts which could be expected from blasting activities. This report is intended to detail the potential risks which would require mitigation, as is typical with any similar type of mining operation.

The effects of blasting need to be addressed within a radius of 600m from the outer pit boundary. All structures that have human habitation should be relocated as a safety precaution and any other structures found such as tombs should be monitored. The project area consists of one opencast pit area that is 1,500m long by 500m wide.

The project area currently has subsistence farming, people and farm animals in and around the operations. To limit the amount of land sterilised by the mining operation only the pit edge perimeter is planned as the boundary for fencing. Normal agricultural activities can continue at close distances to the boundary fence of the operations. Only when blasting is planned on a twice weekly basis should these immediate areas be cleared as per the blasting procedure.

Structures outside the pit areas radius of 600m will be photographed and blast vibration monitoring points should be established to measure and record all blasting activities. Ground vibration mitigation measures will include; limiting the size of any one blast, ensuring adequate delays are used and ensuring limited powder factors are used.

Forty five (45) points of interest were identified that could possibly be influenced by blasting activities and could therefore require mitigation during drilling and blasting operations. One area of concern is the location of an existing road that is routed directly through the pit area. Re-routing of the road will be required in any event to accommodate the open pit mining activities.

Air blast levels are less of a concern than ground vibration. Levels predicted are such that damage is not expected but it could lead to complaints from people and as such all dwelling in outside the 600m radius will be closely monitored. Complaints from air blast are normally based on the actual effects that are experienced due to rattling of roofs, windows, doors etc. These effects could startle people and raise concern of possible damage.

Due to the fact that most secondary free faces will be in the direction of the mining complex, fly rock being directed toward habituated areas is of minor concern and fly rock is not expected to exceed 300m from the pit boundary. The most notable area of concern are the tombs which are located to the south eastern side of the pit and this risk is mitigated due to the fact that no blasting is planned to take place in the southern 500m of the pit in the first 5 years. In addition, the use of various blasting patterns and accessories will be tested over time to ensure that the optimal configuration is found prior to mining activities reaching the safety barrier of 600m to any sensitive receptor.

3.3.2 Baseline Description

The project is an open cast graphite mine and mineral processing facility located in SW Madagascar approximately 160 km inland from the port of Tulear (Toliara), and about 12 km NE of the village of Fotadrevo. The project is located at coordinates 24°0'7.20"S, 45° 7'49.93"E.

The base line information for the project is based on zero influence with regards to blast impacts. The project is currently not active and as such no blasting operations are being undertaken at present. There are also no other mining activities in the direct vicinity of the project that could have an influence on the baseline conditions.

3.3.3 Impacts as identified

The impacts identified as having the biggest possible influence are as follows: ground vibration, air blast and fly rock inside a 600m radius.

Major impacts can be expected from ground vibration, air blast and fly rock on nearby houses / structures. These impacts will be mitigated by relocating all houses / structures within the 600m radius to a distance of +1,000m form the proposed pit boundary.

Impacts of lesser degree are the potential impacts relating to ground vibration impact on boreholes and roads. There are no boreholes and one road that will be relocated. The impact of fumes on houses will be mitigated by the 600m blasting radius that will be cleared and the prevailing wind direction.

Blasting is planned to take place twice a week during daylight hours and will involve charging and blasting between 22 and 28, 130mm drill holes, with between 2,000kg and 2,500kg of anfo explosives and accessories.

3.3.4 Geotechnical Consideration

A comprehensive geotechnical study was done on site that showed the various rock types to have average Uniaxial Compressive Strengths (UCS) as shown in the table below:

Table 9: Rock types average strengths

Rock type	UCS
High Grade	14.9Mpa
Low Grade	15.8Mpa
Waste	32.0Mpa

As result of this the Molo ore body can be described as medium strength in general requiring explosive powder factors of between 0.4kg/m³ to 0.75kg/m³.

This report focuses on the waste blasting upper limit powder factors.

3.3.5 Management measures

Management measures should include the following:

- Consider the area to be blasted in relation to nearest structures and prepare a design for the blast. The design should anticipate ground vibration and air blast levels.
- The use of suitable accessories and delay timing should be tested.
- Certain potential high risk areas may require charge mass per delay limited to a maximum of 250 kg per delay. Potential high risk area is as indicated in Figure 19.
- Monitoring each blast for ground vibration and air blast. Monitor locations are discussed in Section 3.4.7.

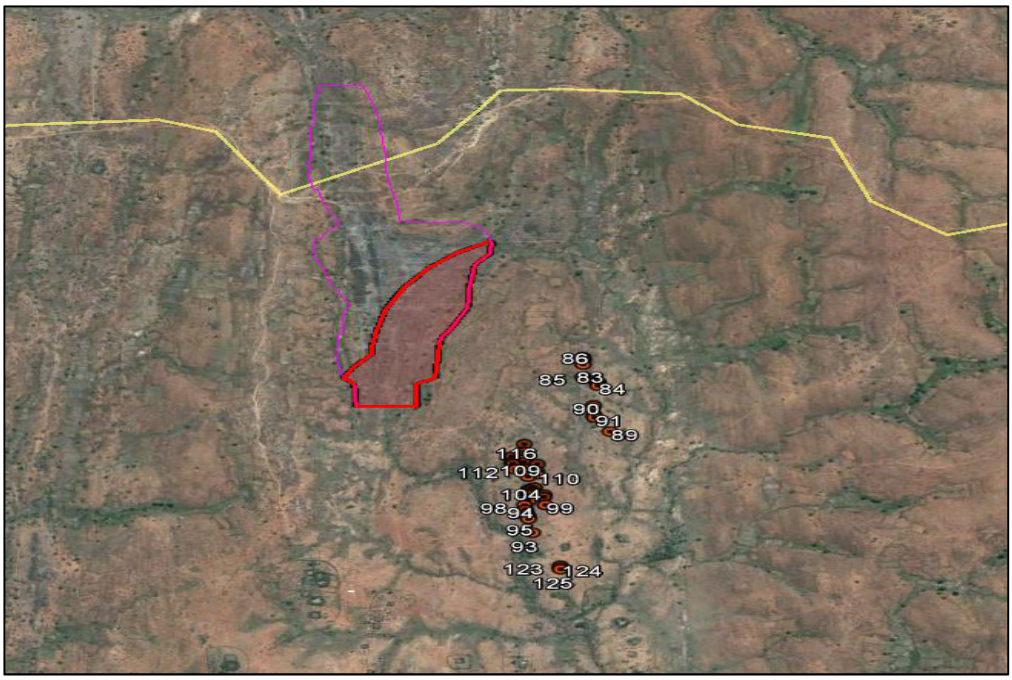


Figure 17: Specific Area of Specific Blast Design

3.3.6 Recommendations

The following recommendations are proposed:

3.3.6.1 Monitoring

A blast monitoring program will be put in place. This will include monitoring ground vibration and air blast during each blast. Ground vibration and air blast will be monitored using a seismograph. Monitoring can be done in permanent stations or on ad hoc basis – per blast basis monitoring. Additionally each blast will be recorded as a standard. Monitoring of ground vibration and air blast is done to ensure that the generated levels of ground vibration and air blast comply with acceptable levels. Currently 7 monitoring positions were identified. Monitor positions are indicated in Figure 20. Levels at these monitoring stations should not exceed the levels recommended as given in Section 3.4.6.6 (Table 10). The monitoring of ground vibration will also qualify the expected ground vibration and air blast levels and assist in mitigating these aspects properly. This will also contribute to proper relationships with neighbouring communities.

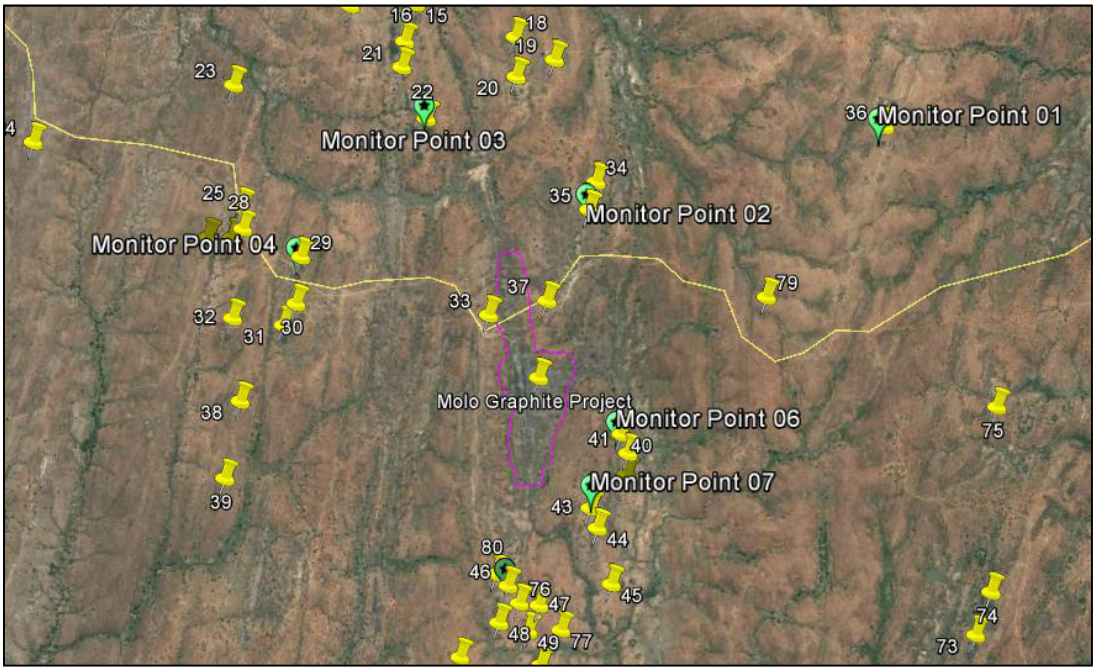


Figure 18: Monitoring Positions suggested

3.3.6.2 Safe Blasting Distance from Communities

A minimum safe distance of 500m from the pit edge is required but it is recommended that a minimum of 600m must be maintained from any blast being done.

In general practice, a blaster is appointed and has a legal obligation concerning the safe distance and the obligation to determine this distance. Figure 21 shows radius of safe distance required with areas influenced.

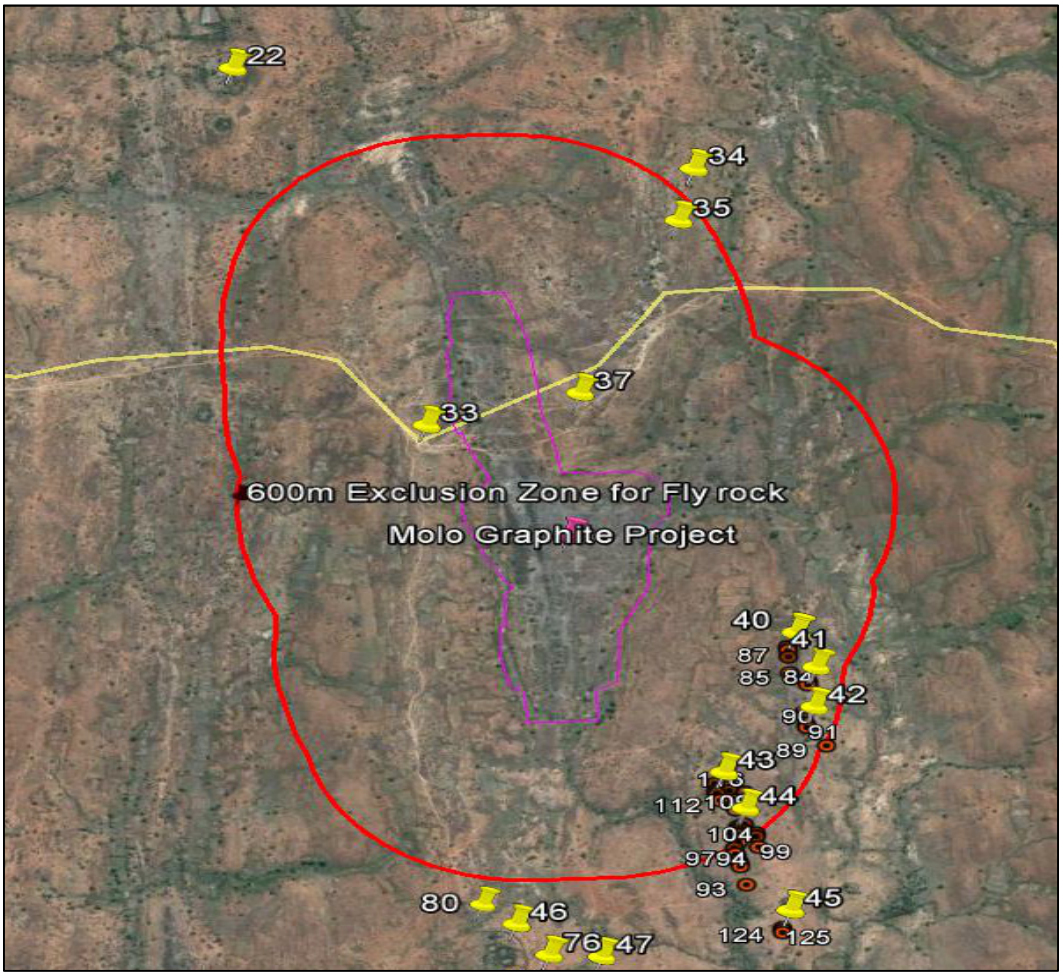


Figure 19: Fly Rock Safety Zone required

3.3.6.3 Evacuation

All persons and animals within 600m from a blast must be cleared for the period of blasting. Evacuation must be conducted with all the required pre-blast warnings and notices.

3.3.6.4 Road Closure

There is a gravel road on the northern side and that is routed directly through the project area. Re-routing of this road will be required around the pit area. Re-routing should be attempted such that the new road is at least 600 m from pit boundary, yet if this is not possible, it will be required that the road must be closed for the period of time when blasting is done.

3.3.6.5 Photographic Inspections

The option of photographic surveys is recommended for all structures with 1500 m from the pit boundary. This would create a detailed record of structures and the status of the structures prior to blasting. All cracks will be defined, photographed and recorded. At 1500m radius a ground vibration level of 1.5 mm/s is expected. This level of ground vibration is already perceptible and people occupying structures could experience ground vibration negatively.

Figure 22 shows the 1500m radius within which structures occur.

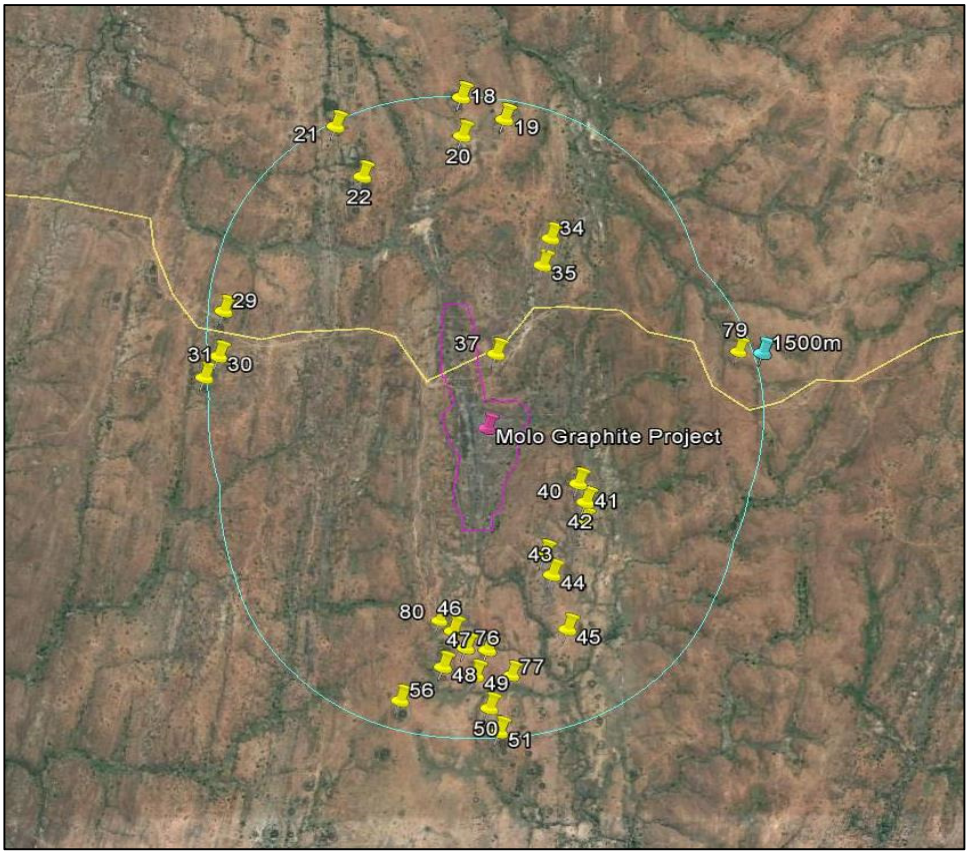


Figure 20: 1500 m Area around Pit Identified for Structure Inspections

3.3.6.6 Recommended Ground Vibration and Air Blast Levels

The following ground vibration and air blast levels are recommended for blasting operations in this area. Table 10 overleaf gives limits for ground vibration and air blast.

Table 10: Recommended ground vibration air blast limits

Structure Description	Ground Vibration Limit (mm/s)	Air Blast Limit (dBL)
National Roads/Tar Roads:	150	N/A
Electrical Lines:	75	N/A

Railway:	150	N/A
Transformers	25	N/A
Water Wells	50	N/A
Telecoms Tower	50	134
General Houses of proper construction	USBM Criteria or 25 mm/s	Shall not exceed 134dB at point of concern but 120 dB preferred
Houses of lesser proper construction	12.5	
Rural building – Mud houses	6	

3.3.6.7 Explosives Products

The current design calls for emulsion based and Anfo products as main charges. Initiation systems are shock tube and detonating cord. Without describing too much detail the following should be considered:

- The use of various accessories will be tested to ensure noise levels are kept as low as possible. This blast noise will be limited to two blasts per week so as not to upset people especially in this rural country environment.

3.3.6.8 Stemming Length

The current proposed stemming lengths of 2.6m is sufficient for the original blast design as equates to 20 times the drill hole diameter of the blast holes.

The alternative blast design equals approximately 25 times the drill hole diameter of the blast holes. Both these designs and other alternatives will be tested to determine the best suited design to the conditions.

These deigns may differ for various areas of the pit and may also be restricted further in certain areas of the pit.

Table 11 below shows a comparison of original blast design and the proposed alternative where stemming is increased.

Table 11: Alternative Design

Technical Aspect	Original	Alternative
B/H Diameter (mm)	130	110
Explosive Density (g/cm^3)	1.15	1.15

Burden (m)	3.7	3
Spacing (m)	3.7	3
Bench Height (m)	8	8
Blast Hole Depths Incl. Sub-drill (m)	8.5	8.5
Linear Charge Mass (kg)	15.3	10.9
P/F Blast hole (kg/m^3)	0.75	0.75
Stemming Length (m)	2.6	2.75
Column Length (incl. Sub-drill.) (m)	5.38	4.94
Explosives Per B/H (incl. Sub-drill and airgap) (kg)	82.1	54.0
Sub-drill (m)	0.5	0.5
Stemming Length vs BHDia	20	25

3.3.6.9 Blasting Times

Blasting operation are planned to take place twice a week between 14Hoo and 16Hoo if the weather conditions are good. It is recommended:-

- not to blast in the morning.
- to blast during daylight hours.
- not to blast in fog.
- not to blast when strong winds are blowing.
- not blast when there are low overcast clouds.

These recommendations stem from the influence that weather has on air blast. It is recommended that a standard blasting time is fixed and blasting notice boards are set up at various routes around the project area that will inform the community of blasting dates and times

3.3.7 Conclusion

The Molo graphite operation is currently planned to blast twice per week with 20 to 30 holes being initiated in any one blast.

The timing of these blast holes will be done in such a way as to minimise blasting noise, vibration and other potential hazards.

The area where mining in planned to start is in the centre of the deposit and as such there will be sufficient time for testing to be performed to determine the optimal blasting patterns suitable to this type of deposit.

The operational personnel will draft a code of practice for drilling, charging and blasting that will be approved by the Mine Manager which will be used to set the standard for all explosive handling and blasting activities.

The site will have the recommended monitoring site and will stringently monitor all buildings and sites of interest within a radius of 1,500m to the pit boundary.

The relocation of houses within a radius of 600m to the pit boundary will be done within the first year of operations once all the consultations and approvals have been received by all concerned.

3.4 VISUAL IMPACT STUDY

3.4.1 Introduction

As part of the ESIA, a Visual Impact Assessment (VIA) was undertaken in order to identify any potential visual impacts resulting from the construction and operation of the proposed Molo Graphite Project.

This visual report investigated the potential impacts of the proposed operations that include:

- Opencast Operation (Open Pit)
- Beneficiation Plant (Process Plant including ancillary infrastructure including waste dump, stockpiles, and contractor camp)
- Ground water extraction (base case water supply option)
- Tailings Storage Facility
- Borrow Pits

The expected results and anticipated impacts for each component of the project will differ given the variance in natural terrain, vegetation, land-use, and the intricacies of social distribution within the different areas in which the proposed mining activities are planned. Refer to Figure 23 for the local topography.

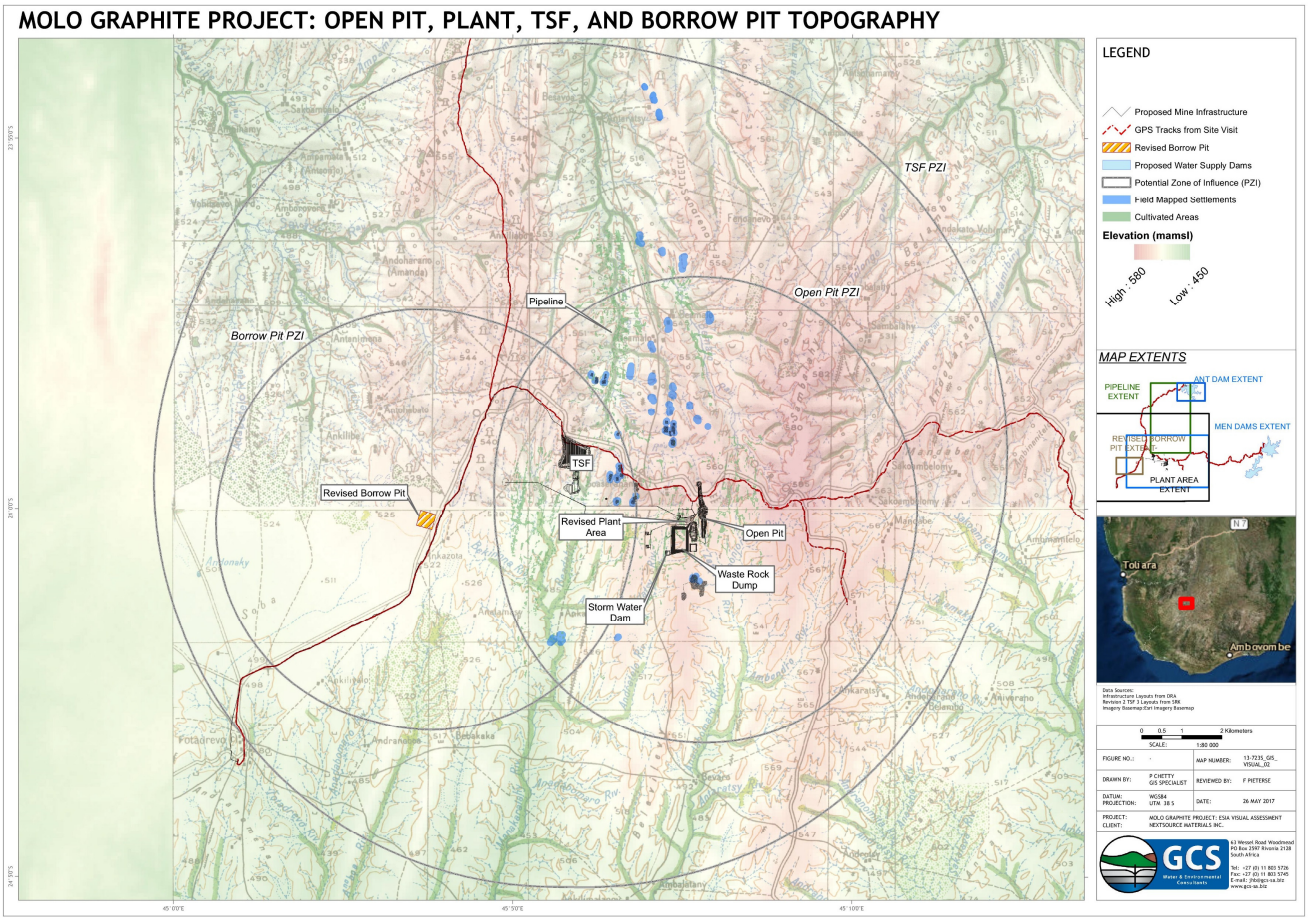


Figure 21: Open Pit, Plant, TSF and Borrow Pit Topography

3.4.2 Applicable International Standards

There are no specific international standards, or guidelines for visual impact assessment. The approach used for this assessment has therefore been developed and refined using a number of sources including:

- IFC Performance Standards No-1 for the Assessment and Management of Environmental and Social Risks and Impacts, IFC Performance Standards No-6 for Biodiversity Conservation and Sustainable Management of Living Natural Resources, and IFC Performance Standards No-8 for Cultural Heritage. These guidelines have the following primary objectives (IFC Performance Standards on Environmental and Social Sustainability, 2012):

  i. To identify and evaluate environmental and social risks and impacts of the project.

  ii. To adopt a mitigation hierarchy to anticipate and avoid, or where not possible, minimize, and where residual impacts remain, compensate / offset for risks and impacts to workers, affected communities and the environment. To promote improved environmental and social performance of Clients through the effective use of management systems.

iii. To promote improved environmental and social performance of clients through the effective use of management systems.

iv. To ensure grievances from affected communities and external stakeholders are responded to and managed appropriately.

v. To promote and provide means for adequate engagement with affected communities on issues that affect them and to ensure that relevant environmental and social information is disclosed and disseminated.

- South African "Guideline for Involving Visual and Aesthetics in EIA Processes' (Oberholzer, 2005)
- 'Guideline for Landscape and Visual Impact Assessment (British Landscape Institute of Environmental Management and Assessment, 2002)

3.4.3 Description of the Receiving Environment

The receiving environment can be defined as the area expected to be impacted by any of the proposed activities as a result of alterations to the natural visual and landscape character. The area that is envisaged to be impacted is larger for proposed infrastructure with a larger vertical offset. This area is named the 'Potential Zone of Influence' and it differs given the vertical offset of the proposed infrastructure, with a 5 km PZI assigned to infrastructure less than 15 m high, and 10 km for infrastructure greater than 15 m high. The 'PZI' for the proposed infrastructure was determined and is depicted in Table 12.

Table 12: Proposed Infrastructure Vertical Offset and PZI

Proposed Infrastructure and Vertical Offsets		
Description	**Vertical Offset (m)**	**Potential Zone of Influence (km)**
Borrow Pit	2	5
Tailings Storage Facility	35	10
Process Plant	15	5
Waste Dump Rock	15	5
ROM Tip	15	5
Open Pit	2	5

A brief description of the each of the surrounding natural environments in terms of terrain, vegetation, land-use, scenic / tourism value, social distribution can be found below:

3.4.4 Proposed Open Pit

The proposed open pit is located on undulating terrain with a small ridge running through the proposed location of the pit. Elevations range from 555 mamsl at the top of the ridge to 540 mamsl at the lowest elevations. The land-use of the proposed pit is a mixed land-use with a combination of cultivated, free range livestock and disturbed areas as a result of exploration and prospecting activities. The vegetation of the immediate open pit site is the savannah ecosystem characterized by open plains of grassland with small to medium sized trees not conducive to visual screening (refer to Figure 24).



Figure 22: Proposed Open Pit looking in an Eastern direction

The surrounding terrain within the PZI can also be described as undulating with elevations ranging from 580 mamsl at the top of the Sambalahy ridge in the east of the PZI to 480 mamsl in the valley of the Manakakaralahy River to the south west of the proposed pit. The PZI is defined by mixed land-use, with a combination of residential villages (permanent human settlement), cultivated land, and free ranging livestock within the PZI. The main settlements include the towns of Soaseranana 1.5 km west of the proposed pit and the unnamed village 800m south of the proposed pit, refer to Figure 25.



Figure 23: Proposed Open Pit looking from Village 800 m South of Pit in Northern direction

The predominant vegetation within the combined PZI is the savannah ecosystem characterized by open plains of grassland with small to medium sized trees. Trees are more densely populated and taller in riparian areas and other areas where water is found. Such vegetation is not susceptible to visual screening in open grasslands, however, in riparian zones and areas where trees are more densely populated, such vegetation will provide a higher degree of visual screening.

Based on the distance of the open pit PZI from any protected areas, national parks, or tourism attractions, the study area is not a major tourism area, and it is unlikely that the proposed mining operations will have an impact on tourists. No major tourism facilities were observed during the site visit of March 2014.

3.4.5 Proposed Process Plant (including ancillary activities)

The proposed plant, waste rock dump, and stockpile area is located on undulating terrain approximately 150 – 250 meters west of the location of the open pit. Elevations range from 555 mamsl at the top of the ridge on which the plant and contractor camp is located to 540 mamsl at the lowest elevations. The land-use of the proposed pit is a mixed land-use with a combination of cultivated, free range livestock and cultivated areas. The vegetation of the immediate open pit site is the savannah ecosystem characterized by open plains of grassland with small to medium sized trees not conducive to visual screening (refer to Figure 26).



Figure 24: Proposed Plant and Infrastructure Area looking from Access Road looking in Eastern direction

The surrounding terrain within the plant and infrastructure PZI is very similar to that of the open pit. The PZI is defined by mixed land-use, with a combination of residential villages (permanent human settlement), cultivated land, and free ranging livestock within the PZI. The main settlements include the towns of Soaseranana 1.5 km west of the proposed pit and an unnamed village 800 m south of the proposed pit.

The predominant vegetation within the combined PZI of the plant and infrastructure has very little screening potential. No major tourism activities were identified win the PZI.

3.4.6 Proposed Tailings Storage Facility

The proposed Tailings Storage Facility is located within the valley of the Beadabo River with elevations ranging from 540 mamsl at the highest extent of the TSF to 510 mamsl at the lowest extent. The land use of the TSF is a mixed land use with a combination of predominantly vacant land with sparse areas of cultivated land to the southern extent of the TSF, and free range livestock. The vegetation of the immediate open pit site is a combination of the savannah ecosystem characterized by open plains of grassland with small to medium sized trees not conducive to visual screening, and riparian vegetation in the valley bottom in proximity of the three tributaries of the Beadabo river within the immediate TSF footprint area, refer to Figure 25.



Figure 25: Proposed TSF looking in an Eastern direction

The surrounding terrain within the TSF PZI is characterized by undulating topography ranging from elevation highs of 580 mamsl at the plateau of the Sambalahy ridge to 420 mamsl at the lowest extents of the Manakaralahy River valley. The PZI is defined by mixed land use, with a combination of residential villages (permanent human settlement), cultivated land, and free ranging livestock within the PZI. The main settlements include the village of Soaseranana (refer to Figure 28) 300 m east of the TSF site, Beamalo 1.5 km east of the north-east of the TSF and numerous rural settlements and homesteads within 5km of the TSF.



Figure 28: Photos of the Village of Soaseranana 300 m East of the TSF

The predominant vegetation within the combined TSF PZI is characterized by vegetation with very little screening potential. No major tourism activities were identified win the PZI.

3.4.7 Proposed Borrow Pit Areas

Of the proposed borrow pits, the largest one is located on a relatively flat plateau approximately 5 km west of the plant area, and 3 km west of the pit. Elevations range from 530 mamsl to the north east of the borrow pit to 505 mamsl at the south eastern extent of the borrow pit. The land-use of this area is characterized by cultivated and vacant land. The vegetation of the immediate open pit site is the savannah ecosystem characterized by open plains of grassland with small to medium sized trees not conducive to visual screening (Figure 29).



Figure 29: Proposed Borrow Pit looking in a Northern direction

The surrounding terrain within the Borrow Pit PZI is characterized by undulating topography ranging from elevation highs of 550 mamsl at the ridges to the north of the borrow pit to 460 mamsl at the lowest extents of the Manakaralahy River valley.

The PZI is defined by mixed land-use, with a combination of residential villages (permanent human settlement), cultivated land, free ranging livestock, and vacant land within the PZI. There is also the Fotadrevo airstrip immediately south of the borrow pit. The main settlements include the villages of Ankillibe and Antohabato approximately 1 km north of the site, Analamasay and Ankiliyalo 1.5 km east and south of the borrow pit and Fotadrevo approximately 3km south-west of the borrow pit site.

The predominant vegetation within the combined PZI of the plant and infrastructure has very little screening potential.

No major tourism activities were identified within the PZI.

3.4.8 Study Results

The potential visual impact of the proposed surface infrastructure has been evaluated against internationally accepted criteria, based on standards and guidelines from various countries, adapted to determine the impact it will have on the landscape character and the viewers that have been identified in the study area.

Visual impacts will result from the construction, operation and closure phase of the expansion of the mining activities. Specifically, impacts will result from the construction, expansion and operation of the TSF, waste rock dump, borrow pit and plant area in terms of the viewshed, viewing distance and visual absorption capacity on the receiving environment.

It was determined that the significance of visual impacts are as follows:

3.4.8.1 Open Pit

The potential visual impact on the residents and motorists will be of Minor Negative significance during the construction phase, Average Negative significance during the operational phase and Average Positive significance post-closure provided the mitigation measures are effective (Figure 30).

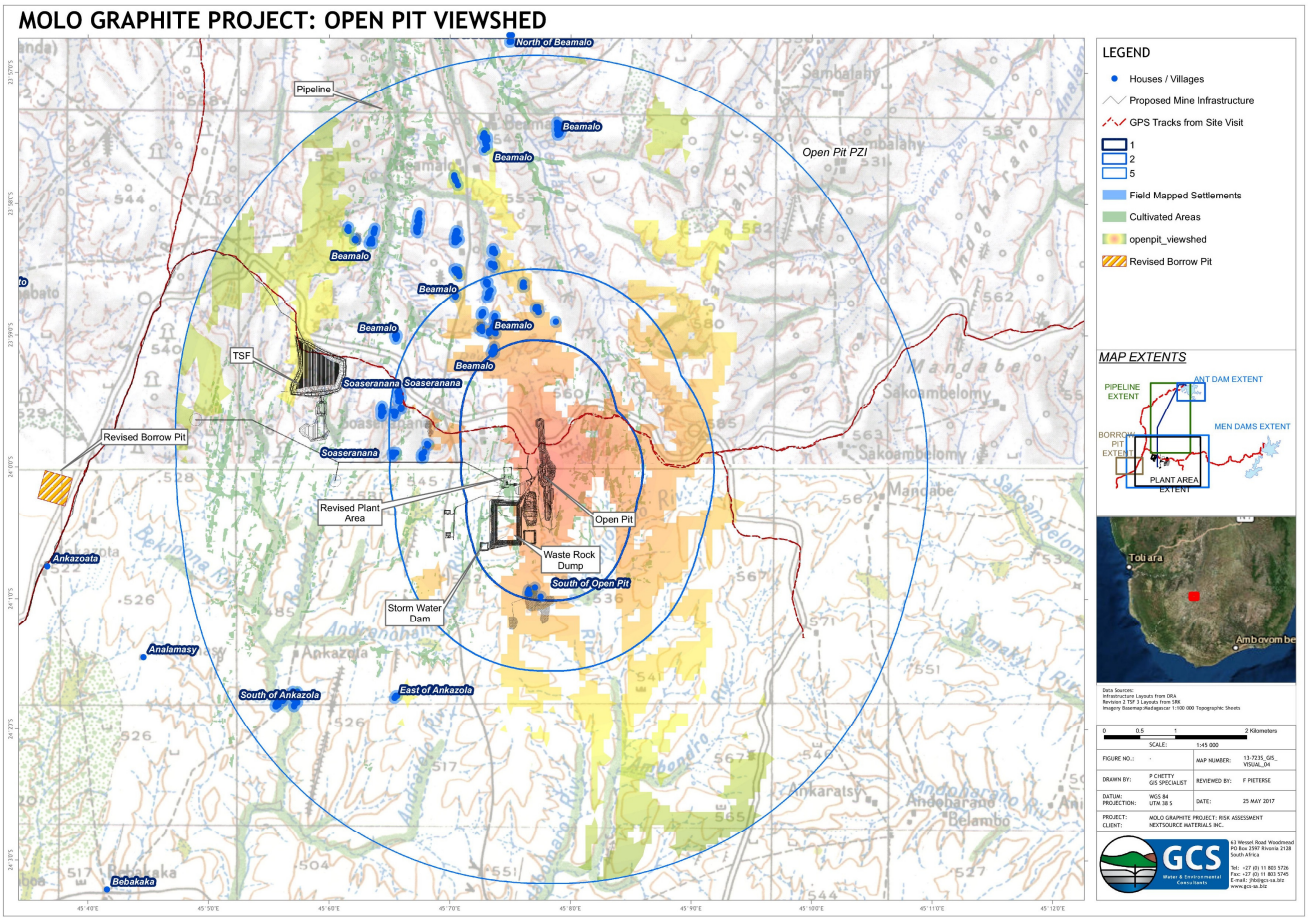


Figure 30: Open Pit View Shed

3.4.9 Proposed Process Plant (including ancillary activities)

The potential visual impact on the residents and motorists will be of Minor Negative significance during the construction phase, Average to Major Negative significance during the operational phase and Minor Negative significance post-closure provided the mitigation measures are effective (Figure 31).

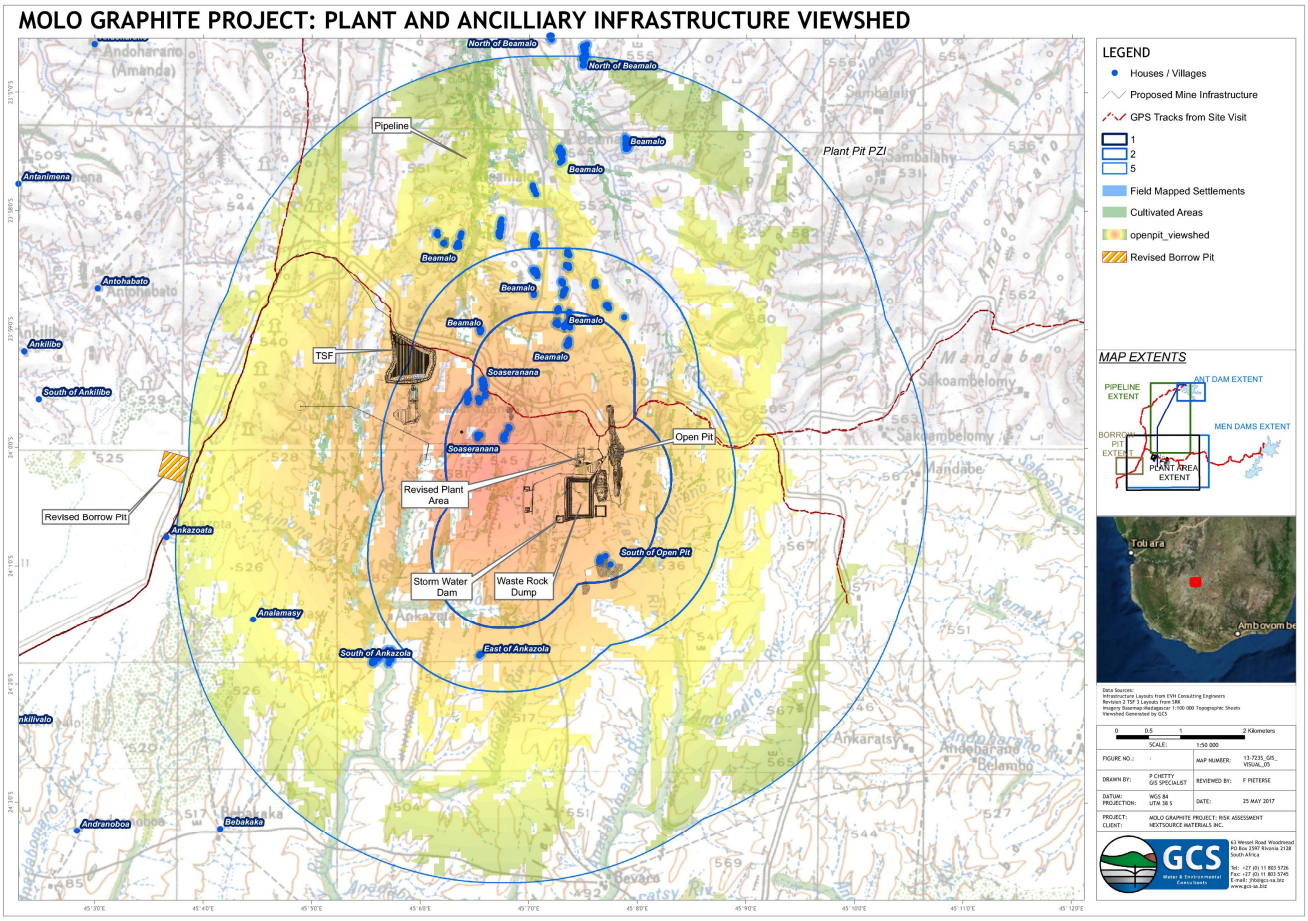


Figure 31: Plant and Ancillary Infrastructure View Shed

3.4.10 Proposed TSF

The potential visual impact on the residents and motorists will be of Minor to Average Negative significance during the construction phase, Major Negative significance during the operational phase and Average Negative significance post-closure provided the mitigation measures are effective (Figure 32).

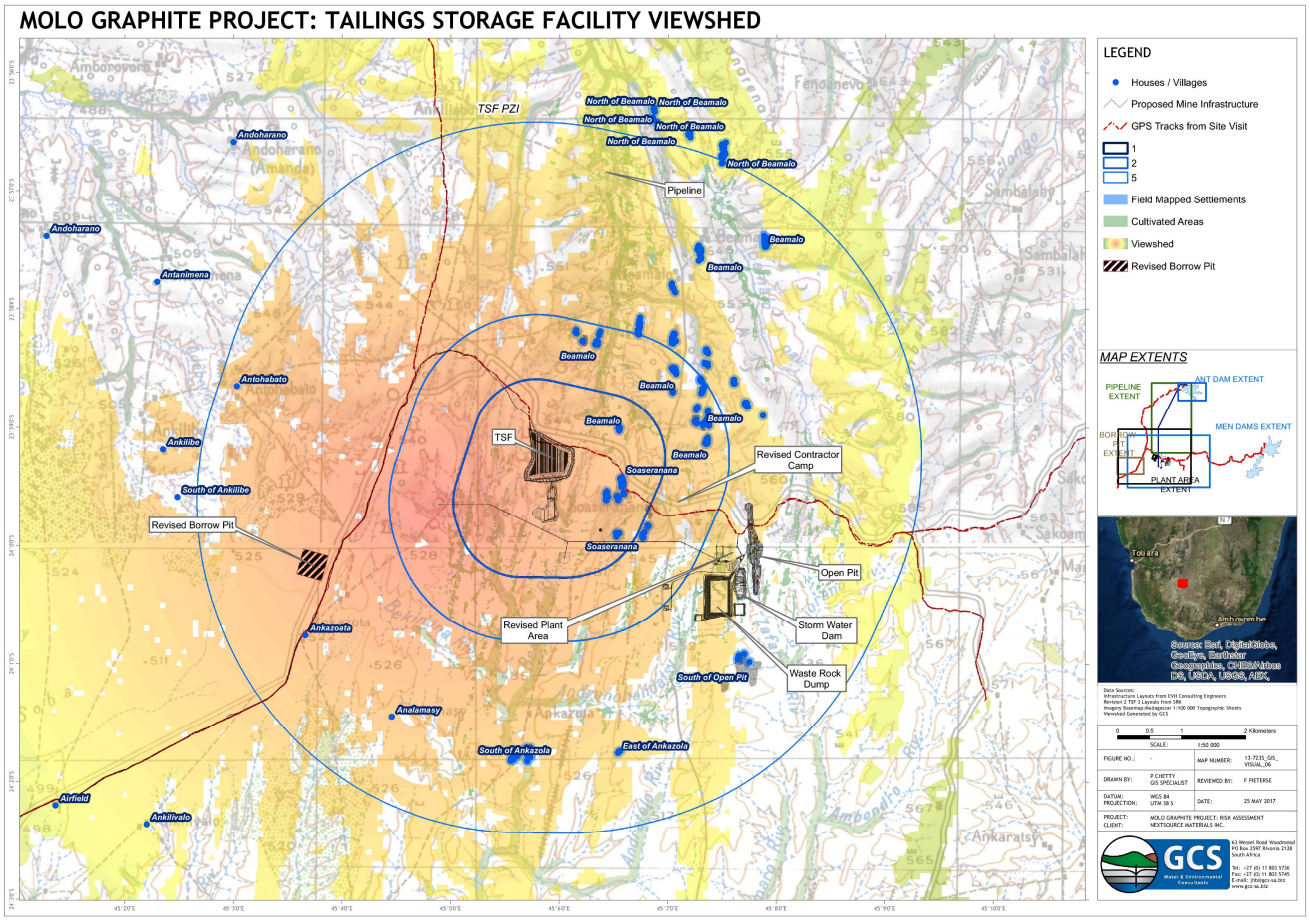


Figure 32: Tailings Storage Facility View Shed

3.4.11 Proposed Borrow Pit

The potential visual impact on the residents and motorists will be of Minor Negative significance during the construction phase, Major Negative significance during the operational phase and Minor Negative significance post-closure provided the mitigation measures are effective (Figure 33).

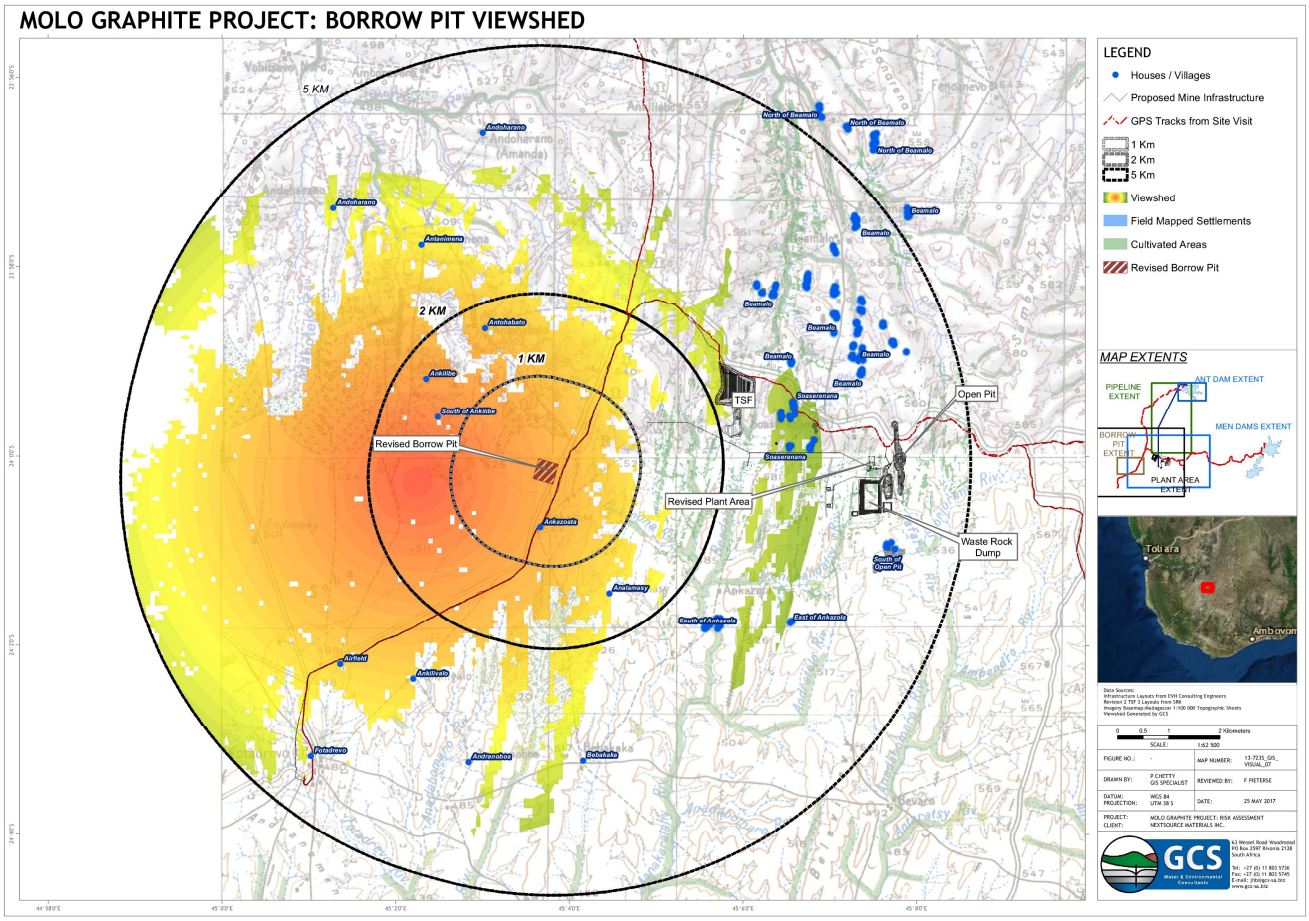


Figure 33: Borrow Pit View Shed

4 Environmental and Social Impact Assessment and Management Plan

4.1 Introduction

The main purpose of the Environmental and Social studies is to tackle the environmental permitting process according to both the national legislation and the Equator Principals, World Bank and IFC requirements on environmental protection.

Related activities in Madagascar include environmental impact assessment on biophysical and social aspects. The study therefore identified and assessed environmental issues and impacts on their direct and/or cumulative biophysical and social effects, ensuring that such impacts would be minimized where they are expected to be negative and maximized where they are expected to be positive.

For this purpose, the following was undertaken:

- Environmental (biophysical) and socio-economic baseline studies
- Characterisation of all environmental components which may be affected
- Prediction and analyses of possible negative and positive impacts of the proposed project
- Trade off selection of alternatives which could be less harmful to the environment
- Proposed mitigation measures to minimize the predicted negative impacts and enhancement measures to maximize the positive ones
- Compilation of a project environmental management plan (P/EMP) with appropriate indicators
- Comprehensive planning of environmental management and monitoring within the project area, identification of broad institutional, resources and technological needs at an early stage
- A basis for collaboration and coordination across administrative boundaries and between Authorities in the various sectors involved and avoidance (where possible) of any contradictions in policy and planning while enhancing efficiencies
- A vehicle for public participation in shaping the future development of the project area, thereby building public support for the process.

Once consolidated and compiled, this set of documents will be submitted to the National Environment Office (O.N.E) in order to obtain the required Global Environmental Permit.

Refer to Appendix C for the full ESIA report.

4.2 Applicable Standards

4.2.1 National policy and regulatory framework

The general environmental legal framework according to local legislation which governs all types of investment is the following:

4.2.1.1 Common legal framework

- Law no.90.033 of 12/21/90 amended by laws 97.012 and 2004/015 governing the Malagasy Environment Charter (CEM): it establishes the guiding principles of the management of the Environment in Madagascar while insisting upon the linkage between development and environmental protection. The CEM also appeals to the concept of public order which calls upon the rules necessary to the social life from which it cannot be waived by particular conventions
- Ministerial decree no.6830/2001 pertaining to public participation in impact assessments
- Malagasy road charter (Charte Routière Malagasy)
- Law no.99.022 modified by law no.2005-022 related to the Mining Code and its regulations
- Law n°98.029 dated 12/18/98 related to the Water Resources Code.
- Law no.99.021 of the 08/19/99 governing policy of management and control of industrial pollution

4.2.1.2 Specific legal framework

- The decree no.99.954 modified by the decree no.2004/167 relating to the compatibility of investments with the Environment (or MECIE): in accordance with the provisions of the CEM and to the declaration of Rio, all public/private investments likely to damage the Environment are subject to an environmental impact assessment
- The inter-ministerial decree no.4355/97 of May 13, 1997 governing the definition of the sensitive areas and their delimitation
- Inter-ministerial decree no.6830/2001 pertaining to public participation in impact assessment
- The decree n° 2003/793 of 15th July 2003 Establishing procedures for granting water uptake authorizations
- Law N° 98-032 of 20th january1999 governing the reform of the electricity sector
- The decree n° 2001/173 fixing the terms and conditions of application of Law No. 98-032

4.2.2 Triggered IFC standards

All IFC standards are likely to be triggered by the activities of the GGG project:

- Performance Standard 1: Social & Environmental Assessment & System Management
- Performance Standard 2: Labour and Working Conditions
- Performance Standard 3: Pollution Prevention and Abatement
- Performance Standard 4: Community Health, Safety and Security
- Performance Standard 5: Land Acquisition and Involuntary Resettlement
- Performance Standard 6: Biodiversity Conservation and Sustainable Natural Resource Management
- Performance Standard 8: Cultural Heritage

4.2.3 Triggered World Bank Safeguards policies

- OP 4.01: Environmental assessment
- OP 4.11: Cultural heritage
- OP 4.12: Involuntary resettlement

4.3 Base Case

The base case processes 240,000 tonnes / annum of ROM and produces an average of 15,000 tonnes / annum of graphite concentrate for export through Fort Dauphin. This resulted in a selection of two new transport route options from the mining site to Fort Dauphin (refer Figure 1).

The life of mine is determined as 30 years, depending on final plant sizing.

Various options were considered at commencement of the feasibility study regarding water supply, electricity supply, tailings storage facility (location and deposition strategy). The following final base case and alternatives have been selected and are relevant to this study:

- The base case is groundwater supply with the alternative being a water supply dam (Three options exist, Ant 2 preferred, with MEN 3 & 14 as alternatives).
- The electricity supply base case is diesel generation with Heavy Fuel Oil (HFO) as alternative. A trade off study was undertaken to assess hybrids such as Diesel/HFO with Solar Photovoltaic (PV) and Diesel/HFO with Concentrated Solar Power (CSP) but none of these proved commercially feasible.
- The base case tailings handling is co-disposal of dry tailings for operational year 1 – 3 and wet tailings handling at the Tailings Storage Facility (TSF) as thickened tailings from year 4 onwards.

4.4 Receiving Environment

4.4.1 Biophysical

Initial baseline investigations on the following biophysical components were undertaken by Agetipa during 2012:

- Atmospheric environment
- Climate
- Air quality (dust deposition)
- Soil and geochemistry
- Flora and vegetation
- Wildlife
- Aquatic environment, hydrology (surface water and groundwater), water chemistry, aquatic insects

With the increase in level of detail which is associated with a feasibility study, it was possible to delineate the project's area of influence, and subsequently undertake further detailed baseline investigations to fill in any gaps from the initial 2012 assessment and finally compliment to a complete baseline assessment. These studies included the expansion and inclusion of:

- Risk/Screening (Environmental and Socio-Economic)
- Soils
- Ecology (terrestrial and aquatic)
- Visual
- Blasting & Vibration
- Air Quality and Noise
- Climate
- Hydrogeology
- Hydrology
- Geochemistry
- Green House Gasses
- Traffic

This phase was undertaken and concluded during the period March 2014 to September 2014, which allowed for seasonal assessments where required. The content and outcomes of these assessments are summarized and contained in Sections

2 & 3 of this report, with the main water related study content and results contained in Section 11: Water Study within the main Feasibility Report.

4.4.2 Socio-Economics

A comprehensive assessment pertaining to the demographics and economic status of the communities in proximity to the project was undertaken, specifically on those communities within or adjacent to the area of influence. Significant reductions in the overall area of influence was achieved through careful consideration of environmental and social sensitivities, in order to minimize the affected area, as well as through various trade-off studies related to the project components (TSF, roads, water supply, electricity supply, plant and contractors camp locations, and associated infrastructure).

Various avenues of engagement with stakeholders have been undertaken to date. These can be categorized as follows:

- Public consultation
- Land tenure and occupation
- Cultural heritage
- Sources of income.

4.4.3 Engagement Outcomes (refer to Section 5: Relocation Action Plan, for further details)

4.4.3.1 Expected Positive Impacts

- Job creation
- Education and skills transfer
- Strengthening of Municipal Resources
- Improvement in local security
- Increasing business opportunities

4.4.3.2 Expected Negative Impacts

- Relocation of houses and associated assets (minimum requirement in order to allow for public safety and operational efficiency)
- Loss of grazing land

4.5 Stakeholder Engagement

Stakeholder engagement is and will remain one of the most important components requiring detailed focus during a process such as this. Without due consideration of potentially affected communities, traditional authorities,

municipalities, regional and national government, interest groups and local customs; a project will not be fully aligned with sustainable development principals and location based nuances.

During this ESIA process, stakeholder engagement has occurred on numerous levels, and as per Malagasy law, will continue via a government led stakeholder and information disclosure process post submission of the ESIA.

To date, formal engagement with numerous stakeholders (refer to the full EISA for further particulars) has been undertaken, with the following producing comments and results:

4.5.1 O.N.E. comments

After submission of the project Terms of Reference to the O.N.E., a formal response was received, which is summarized below:

- Applicant to include land tenure agreement/title with the application for the global environmental permit
- Instructions on format and content of the ESIA
- An detailed explanation of the challenges experienced during the project development and assessment
- A write-up of trade-off studies and motivations for alternatives selected as preferred options
- A write-up on the project's water supply component
- A waste management plan is required
- Detailed monitoring programmes need to be stipulated, especially with regard to groundwater levels
- Regional public consultation is also required

Suffice to say that all of the above requirements are included in the ESIA and addressed comprehensively.

4.5.2 Local Community and municipality comments

Engagement with the local community and municipality has resulted in the following information:

- Fotadrevo wants a successful completion of the project for the development of the Municipality.
- The realization of the project improves security in the city of Fotadrevo.
- The project is beneficial for the municipality but at the health level, the City is still disabled because the villages are far away from existing health centre. If the project could provide a solution, that would be a good thing. This is highly likely.
- If there is cutting of sacred tree, planting a young plant of the same specie and a joro must be implemented.
- Before commencing with any mining related activities, the promoter must consult the Ray Aman-dreny and the municipality officials
- There was no opposition to the project, but some communities do not wish to move their tombs. But they understand that the mining activities will be undertaken within close proximity. These tombs have specifically been encompassed into the project's design and management plan to ensure that they are not directly affected by the project.
- The community supports the project, and requests that consultation and negotiation with the owners of land and tombs be undertaken prior to the construction phase.
- No problem about the project. They are ready to move their crop fields, tombs and home but it is necessary to negotiate finally with the owners.

- Ceremonial rites must be exercised in sacred places and the project should not cut down any sacred trees or backfill sacred water because these are the burial sites of newborn umbilical cords. All of the sacred sites have been delineated and marked in order to ensure that the project does not influence these areas.
- The community requests that local youth will be recruited in priority for any corresponding job.

4.6 Impact Assessment

A detailed environmental and social impact assessment has been undertaken in relation to the aspects associated with the Molo Graphite Project. The assessment reflects the possible impacts associated with project aspects during the pre-construction, construction, operation and decommissioning and closure project phases.

Impact assessment is universally applied during project development and planning and could follow various scientific and project oriented methodologies. Malagasy practice requires a specific impact assessment methodology. The applicability of this methodology also complies with IFC Performance Standard requirements and was therefore selected for use during this assessment (Refer to Appendix C for more information).

Impacts have been identified and described within the ESIA under the following headings:

- Land Use
- Land Acquisition
- Groundwater
- Surface Water
- Soils
- Noise
- Visual
- Ecology
- Air Quality
- Traffic

Backwards integration of environmental and social sensitivities and risks ensured that the final impact assessment component revealed that there are no fatal flaws from an environmental and social perspective. The significance levels of impacts range from minor to major before any mitigation measures are applied and from minor to average with mitigation measure included. Notably all major risks require significant reduction in risk via stringent controls. These controls have been incorporated into the project design and planning with additional operational controls specified within the various environmental and social management plans listed in the next section.

4.7 Project Environmental and Social Management Plan

Any environmental and social impacts (being positive or negative) require management and or mitigation measures to a certain degree. The extent to which these measures are applied is complex and often subjective, depending on the in-country laws and regulations, the expectations from the lead review authority, the sensitivities of the receiving environment and finally international and local best practices and acceptable risk.

To this end, the ESIA contains a chapter which details specific management measures which either remove the risks completely, or reduce their significance to an acceptable level.

Control Plans are specific to each environmental and social component in relation to the distinctive project aspects. These control plans follow the same structure as those listed with the Impact Assessment section above. These control plans will hold the proponent legally responsible towards environmental and social management from commencement to final closure of the project.

In addition, each specific environmental and social component has a prescribed monitoring plan which will be followed during each project development phase. This is aimed at monitoring compliance against various specifications such as the baseline environment and predicted impact removal and reduction measures.

For full particulars, please refer to Appendix C.

3. Relocation Action Plan and Socio-Economic Considerations

5.1 Introduction

In order to reduce any potential impact on inhabitants, the Risk Assessment added tremendous value in designing a project which will have as minimal as possible impact on local inhabitants. That said, with all practical precautions taken to prevent that occupied plots will be impacted, land acquisition and relocation of one settlement proved unavoidable. Thus, the preparation and implementation of the project requires an involuntary Resettlement Action Plan (RAP).

Initially, once the need for relocation and compensation was established, the main focus of the study revolved around the determination of the affected settlement (human inhabitation), their associated assets and land and very importantly engagement with the local community regarding this potential act.

Further work is required to complete all of the necessary regulatory approvals and agreements within the Malagasy context; being subject to the advancement of this project from feasibility into execution.

This section therefore represents studies related to the identification of affected communities and assets, engagement with said community and the compilation of a framework within which any further action post the feasibility study will occur.

This section has been designed to comply with the provisions of the national legislation and IFC Performance Standards.

5.2 Predicted Impacts

5.2.1 Expected positive impacts

The main positive outcomes of this mining project are:

- Creation of new jobs
- The region is currently undervalued, despite being the second most visited region on the island, there is significant lack of infrastructure thus access is very difficult.

Increasing Resources of the municipality

According to the new Inter-ministerial Order no. 8887/2014 defining the modalities of distribution and utilization of mineral rebates from certain mining projects:

- A certain percentage of dividends received are to be distributed for the benefit of mining communities in respect of certain operational components.

Thus, the Fotadrevo Municipality will invest in new infrastructure to improve the living conditions of its inhabitants.

Improvement in security in the area

Fotadrevo is one of the risk areas and is sometimes subject to victimisation through bandits, mostly related to the zebu (cattle) theft.

With the implementation of the project, security in the area in relation to this problem will be greatly improved.

Business increasing opportunity

Certainly with newcomers, new needs will be created. Farmers and ranchers in the area will be able to take advantage of new business opportunities for selling their products.

5.2.2 Predicted negative impacts

However, the planned activities will result in negative impacts also:

- Loss of residential housing (huts): The small village of Soaserana will be part of households to be relocated.
- Losses of assets: mostly crop fields: Fields such as dry crops and rice will be affected by the land requirements of the project.
- Loss of pastures: Part of the pastures of the area will also be affected by the acquisition of land for the project.

Note that pastures have no strict delineation. Once the grass species meets the needs of the livestock, the site in question is used as pasture.

5.3 Objectives of the RAP

The objectives of the RAP in the context of the implementation of the project are as follows:

- To minimize, as far as possible, involuntary resettlement and land acquisition by exploring all viable alternatives in the project design – this was conducted successfully up to where the practical implementation of the project is adversely affected.
- To ensure that affected people are consulted and given the opportunity to participate in all key stages of the development process and implementation of the activities of involuntary resettlement and compensation;
- To ensure that compensation is determined in relation to the corresponding impacts, and to ensure that any affected people are not penalized disproportionately;
- To ensure that those affected people are assisted in their efforts to improve their livelihoods and standards of living, or at least to restore them, in real terms, at their level before the relocation or before the implementation of the resettlement plan, whichever is more beneficial to them;

- To ensure that the activities of involuntary resettlement and compensation are designed and executed as sustainable development programs, providing enough investment resources for affected people by the project have the opportunity to share profits.

All these measures will apply to both affected merchants and other entities where applicable.

5.4 Census

The census of affected households was methodically done (refer to Figure 35 for the original census area):

- Buildings and crop fields were delineated using aerial imagery of high resolution.
- Based on the plot plans, ground surveys were conducted to identify the owners and the heads of the Fokontany and associated parcel boundaries.
- Lists of affected households were established on the basis of these surveys.

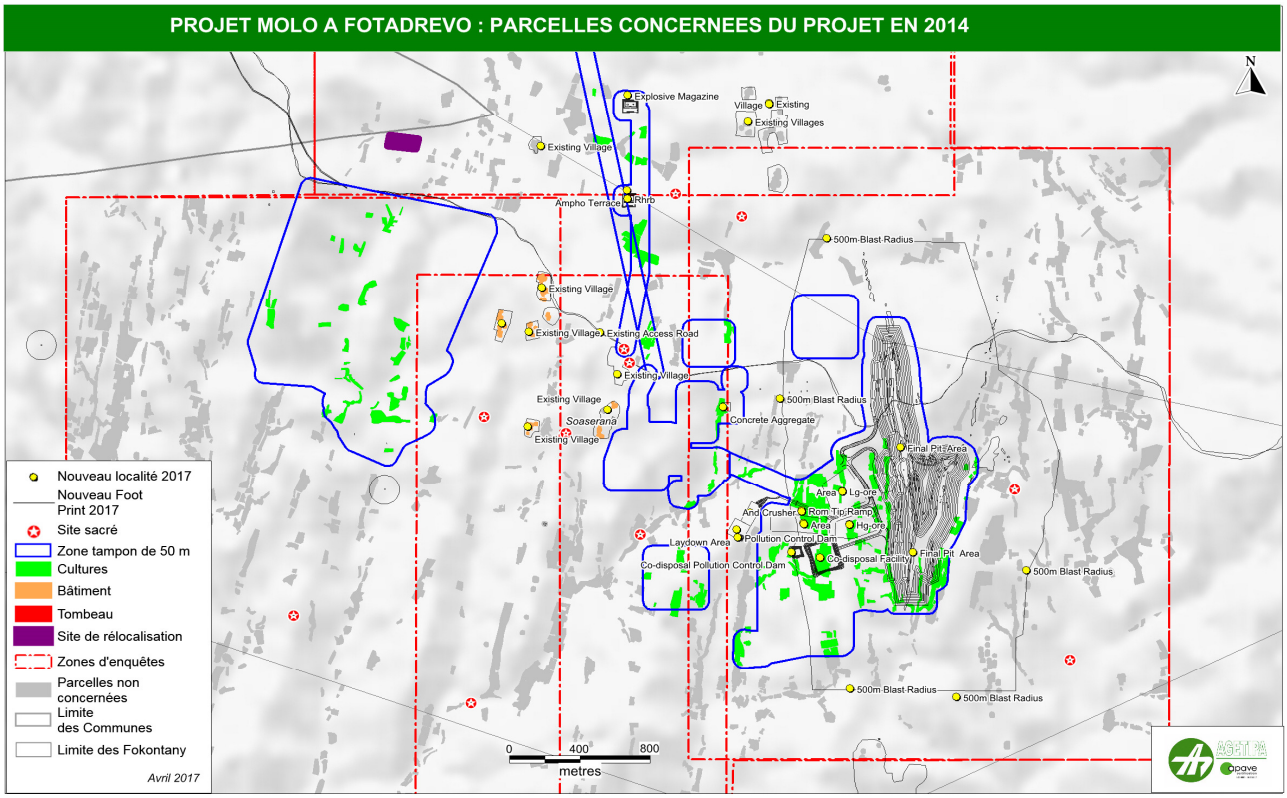


Figure 30: Census area

5.5 Public participation for the preparation of the RAP

During the preparation of this plan, all villagers were fully informed and consulted about the mining project and the process relating thereto.

The main demands of households are as follows:

- Fotadrevo wants a successful completion of the project for the development of the Municipality.
- The realization of the project improves security in the city of Fotadrevo.
- The project is beneficial for the municipality but at the health level, the City is still disabled because the villages are far away from existing health centre. If the project could provide a solution, that would be a good thing. This is highly likely.
- If there is cutting of sacred tree, planting a young plant of the same specie and a joro must be implemented.
- Before commencing with any mining related activities, the promoter must consult the Ray Aman-dreny and the municipality officials
- There was no opposition to the project, but some communities do not wish to move their tombs. But they understand that the mining activities will be undertaken within close proximity. These tombs have specifically been encompassed into the project's design and management plan to ensure that they are not directly affected by the project.
- The community supports the project, and requests that consultation and negotiation with the owners of land and tombs be undertaken prior to the construction phase.
- No problem about the project. They are ready to move their crop fields, tombs and home but it is necessary to negotiate finally with the owners.
- Ceremonial rites must be exercised in sacred places and the project should not cut down any sacred trees or backfill sacred water because these are the burial sites of newborn umbilical cords. All of the sacred sites have been delineated and marked in order to ensure that the project does not influence these areas.
- The community requests that local youth will be recruited in priority for any corresponding job.

5.6 Evaluation and Compensation of Losses

5.6.1 Loss categories

5.6.1.1 Loss of crops and rice fields

Loss of dry crops and rice fields are associated with the relocation. Compensation will be monetary.

A total area of approximately 35.5ha of dry crops and rice fields are within the affected area.

5.6.1.2 Existing crop yield losses

When the project starts, it is likely that households will already have planted crops. However, in accordance with the requirements of IFC Performance Standard 5, compensations include monetary compensation until the first harvest.

5.6.2 Compensation Costs

Compensation will be provided in the following categories:

- Monetary compensation for loss of crop fields
- Compensation for households and construction of new huts
- Relocation support
- Environmental measures (water and sanitation)

The associated costs have been incorporated in to the overall project estimate.

5.6.3 Additional Measures

Additional support measures will include the following:

- Restoration of income sources via socio-economic programmes
- Support to economically vulnerable households via donations towards clothing for school children and food aid

5.7 Administrative Aspects

5.7.1. Management of Complaints and Disputes

For all cases where disputes arise, the process will be as follows:

- First, every effort should be made to ensure that the PAPs are informed about procedures and to try to resolve disputes fairly, including consultation with traditional authorities and community leaders to evaluate the merits of the dispute. Subsequently the process will be done on three levels:
- Mutual agreement
- Use of third party arbitration
- Legal action to the Court of First Instance of Ampanihy.

Mutual agreement

When a dispute arises, the parties are called upon to solve the problem first in front of the Elders of the village to reach an arbitration solution. This applies for example in cases of dispute related to the allocation of houses.

If this is not possible, the parties move on to another step:

Resort to arbitration

This procedure permits to involve local or municipal authorities:

- First, local authorities which consist of officers of Fokontany of the dispute place and the PAPs look to find an adequate solution to the problems. To this end, they make to the PAP a register of complaints and take the

initiative to advance tangible solutions. If the parties accept, minutes are drafted and signed by all participants. The minutes have a mandatory value as well as the law to the parties concerned. Failing to find a resolution, the dispute may be referred to the Municipality.

- At the Municipality, the resolution is the same as that at the Fokontany. Complaints collected at the Fokontany will be received by a committee for settling disputes which will be composed of the following representatives: PAPs Local district, and notables. This Committee will subsequently act as arbitrator.

Justice recourse

This procedure assumes that individuals have the financial and intellectual means to take their cases to court. However, it is clear that few households PAPs are able to take advantage of such an appeal. Also, the project acknowledges that a quick informal resolution litigation is often more effective than long formal procedures.

Moreover, if several cases of disputes arise in the group, people affected with litigation will be able to designate a representative unanimously after a meeting in which all have been invited to participate. This representative will be in charge of representing them in a conciliation process that will be undertaken with the Committee for settling disputes. In such a case, all disputes will be recorded and reported against discharge of the Committee for evaluation.

In short, as a final resort (undesired), the unsatisfied affected people may introduce their dispute with the Court of First Instance of Ampanihy.

Financial provision will be provided by the project for possible cases where ester to the Court is required.

5.8 Monitoring and Evaluation

Main objectives of Monitoring / Evaluation:

- Evaluate the system implementation of the RAP and suggest possible improvements
- Prepare reports independently, following on-site monitoring
- Manage the database of PAPs:

A computerized database and complete data on each of the affected people has been created effective end of the detailed surveys. The base contains:

- Information on the concerned households
- Losses incurred
- The file of compensation: payable compensation, received compensation, evolution of the situation of PAP

In this context, the following indicators can be used:

- Proportion of individuals who received their compensation and allowances due
- Number of displaced households
- Number and types of litigation on the total number of cases

- Time and quality of the grievance on the total number of grievances
- Evolution of turnover of the affected people
- Number of individuals who have changed jobs

6 Appendices

Please note that copies of the figures have been placed at the back of this document in Appendix A in A3 format. The figures numbers are the same as those used in the body of the report.

Appendix A: Environmental Screening/Risk Assessment

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Molo Graphite Project: Feasibility Study Section 11 – Water

Report (Next Source Annex 11.1: Water Report)

Version – 5

23 June 2017

Next Source Materials Inc.

GCS Project Number: 17-0023

Report (Next Source Annex 11.1: Water Report)
Version 5

23 June 2017

Next Source Materials Inc.

17-0023

DOCUMENT ISSUE STATUS

Report Issue	Version 4 03/03/15		
GCS Reference Number	GCS Ref - 17-0023		
Client Reference			
Title	Molo Graphite Project: Feasibility Study Section 11 - Water		
	Name	**Signature**	**Date**
Authors	Roxane Schmidt		June 2017
	Robert Verger		June 2017
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Director	Alkie Marais		June 2017

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ACRONYMS

ARD	acid rock drainage, also referred to as acid mine drainage (AMD)
CD	Constant discharge pumping test
EC	electrical conductivity (mS/m)
EPFIs	Equator Principles Financial Institutions
ERT	Electro-Resistivity
ESIA	Environmental and Social impact Assessment
IDF	Intensity-duration-frequency
IFC	International Finance Corporation
K	hydraulic conductivity (m/d)
km	kilometre
l/s	Litre per second
m	metre
mamsl	metres above mean sea level
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
mbgl	metres below ground level
m^3/d	cubic metres per day
m^3/hr	cubic metres per hr
mg/l	milligram per litre
mS/m	milliSiemen per metre
NDWF	Normal Dry Weather Flow
PCD	pollution control dam
T	transmissivity (m^2/d)
TDS	total dissolved solids (mg/l)
TSF	tailings storage facility
S	storativity
SANAS	South African National Accreditation System
RAWT	Raw Water Tank
WHO	World Health Organization

11 WATER

11.1 Baseline Description

11.1.1 Climate

11.1.1.1 *General Overview*

Climate data was collected, processed and was extensively discussed in the GCS Climate Assessment as presented in Annexure 11 A. The following is a summary of climate associated with the Molo Graphite Project, southern Madagascar.

The climate of Madagascar is highly varied, largely due to its geographical position in the Indian Ocean, its wide range of altitudes and associated different microclimates. Madagascar is composed of nine different regions with very diverse climates according to the Köppen–Geiger climate classification system (Kottek *et al.*, 2006). The Molo Graphite Project site and Fort Dauphin, the port site are situated in the following climate zones according to the Köppen–Geiger climate classification system (Kottek *et al.*, 2006):

- Molo Graphite Project mine site – border of hot semi-arid climates and tropical savannah climate; and
- Fort Dauphin (preferred export port) – border of the wetter tropical savannah climate, tropical monsoon climate and tropical rainforest climate.

All project site areas have two seasons; a hot, rainy season from December to March/April, and a cooler dry season from April/May to November. Potential water shortages are most likely to be experienced during the dry season. However, the south-eastern tip at Fort Dauphin also has occasional rainfall during the dry season.

Rainfall varies within the vicinity of the Molo Graphite Project Site from 750 to 850 mm per annum with an average wettest month in December which exceeds the average driest month (August) by near 10 times. For Fort Dauphin, rainfall varies around 1 500 mm per annum and also shows a winter rainfall component. The average wettest month is January and average driest month is September.

The mean monthly temperature of Fotadrevo varies greatly throughout the year. Average low temperatures range from roughly 9.8°C in June in the dry season and high temperatures are 32.8°C in the wet season. Mean Monthly Temperatures for Fort Dauphin ranges from 16.1°C in July a mean low temperature and mean high is 30.0°C in January and February.

In general humidity is higher during the warmer, summer months. Humidity readings were Minimum humidity values range from 52 to 65 % humidity at Fort Dauphin and 25 to 45 % humidity at Fotadrevo. Maximum humidity values range from 91 to 94% humidity at Fort Dauphin and 83 to 98 % humidity at Fotadrevo (see Annexure 11 A).

Annual Symons Pan Evaporation for Fotradrevo (Molo Project Site) was estimated at 1 681 mm (Table 11.1). For the candidate port site, it was estimated that the average annual Symons Pan Evaporation for Fort Dauphin is relatively similar to Fotadrevo, around 1 690 mm (see Annexure 11 A).

Table 11.1: Estimated Mean Monthly Symons Pan Evaporation near Fotadrevo (mm)

Monthly Symons-Pan Evaporation (mm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Fotadrevo	193	162	160	123	97	78	85	114	138	169	176	185	1681
Fort Dauphin	198	168	161	120	100	81	88	118	139	168	168	183	1691

11.1.1.2 *Rainfall*

The initially rainfall data collected and processed are discussed in the Molo Graphite Climate Assessment (Annexure 11 A). The rainfall for the proposed Molo Graphite Project mine is discussed in detail below in terms of:

- Available rainfall data;
- Synthesized rainfall simulations with additional rainfall measurements as input for dynamic water balance calculations (Section 11.6); and
- Satellite Rainfall as input to complement measured data in a data scarce region, especially in terms of the rainfall spatial variability. (Section 11.1.1.2.3).

Rainfall depths and design storms for sizing storm water infrastructure as input for the storm water management plan (SWMP) are discussed under Section 11.5.

11.1.1.2.1 Measured and Satellite Rainfall Records

A complete set of daily rainfall data measured at Fotadrevo, very near to the Molo Graphite Project, from the 1st November 1959 to the 31st October 1976, were received from The Meteorological Department of Madagascar (Nimbol, 2014). The mean monthly rainfall is listed in Table 11.2 and monthly rainfall probability is graphically shown in Figure 11.1.

Daily rainfall data for Fort Dauphin (preferred export port) were also received from the Meteorological Department of Madagascar (Nimbol, 2014) from 1983 until 2012 (Table 11.2 and Figure 11.2).

Additional daily rainfall data (Nimbol, 2014) were obtained from weather stations situated in the vicinity of Fotadrevo. These locations were Ejeda (1942-1996) and Betioky Sud (1929-1996) and are located respectively 60 km southwest and 75 km northwest from Fotadrevo. The data is summarised in Table 11.2 and the rainfall probability is graphically shown in Figure 11.3 to Figure 11.4.

Table 11.2: Average Monthly Rainfall Measurement Summary

Monthly Average Rainfall (mm)				
Month	**Betioky Sud (1929-1996)**	**Ejeda (1942-1996)**	**Fort Dauphin (1983-2012)**	**Fotadrevo (1959-1976)**
January	166.6	145.8	194.2	173
February	113.1	124.2	188.5	155.4
March	67.3	67.2	170.7	107.9
April	21.9	26.2	164.6	26.4
May	12.1	15.6	121.4	26.8
June	8.0	10.5	103.7	18.6
July	4.6	7.5	110.1	14.3
August	5.8	7.1	79.3	14.1
September	10.7	14.0	51	25.5
October	22.0	29.1	78	48.5
November	62.8	57.0	97.5	54.7
December	136.7	135.2	143.8	195.2
MAP	**632**	**639**	**1503**	**860**

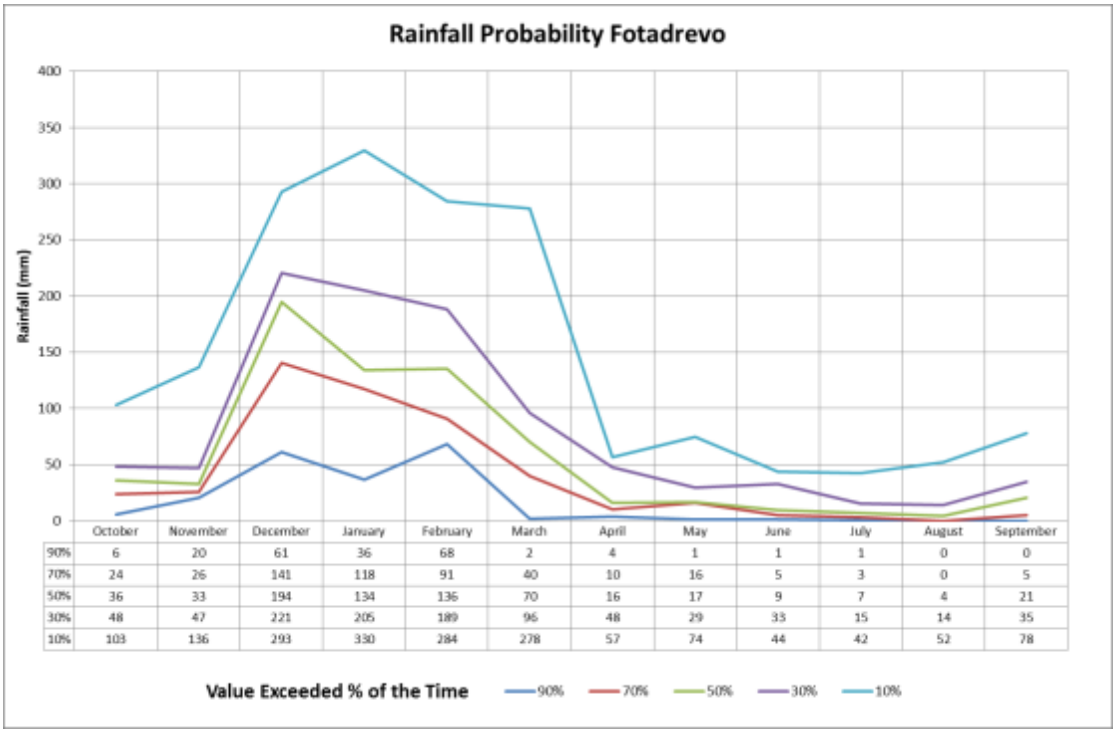
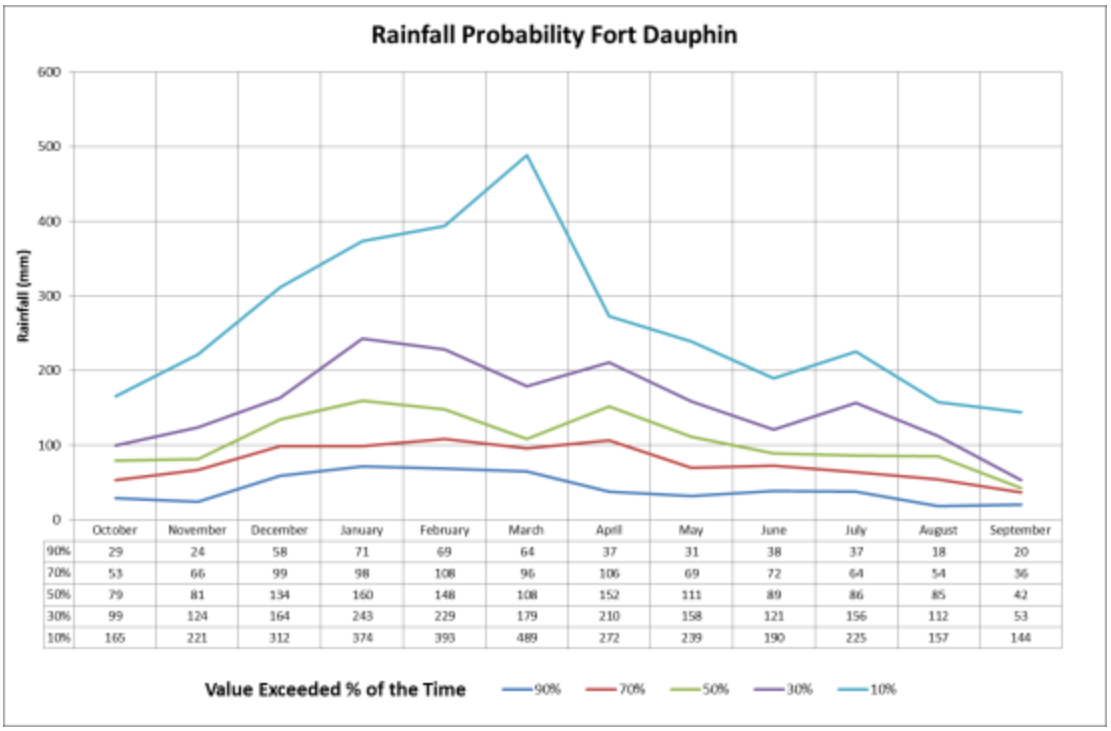
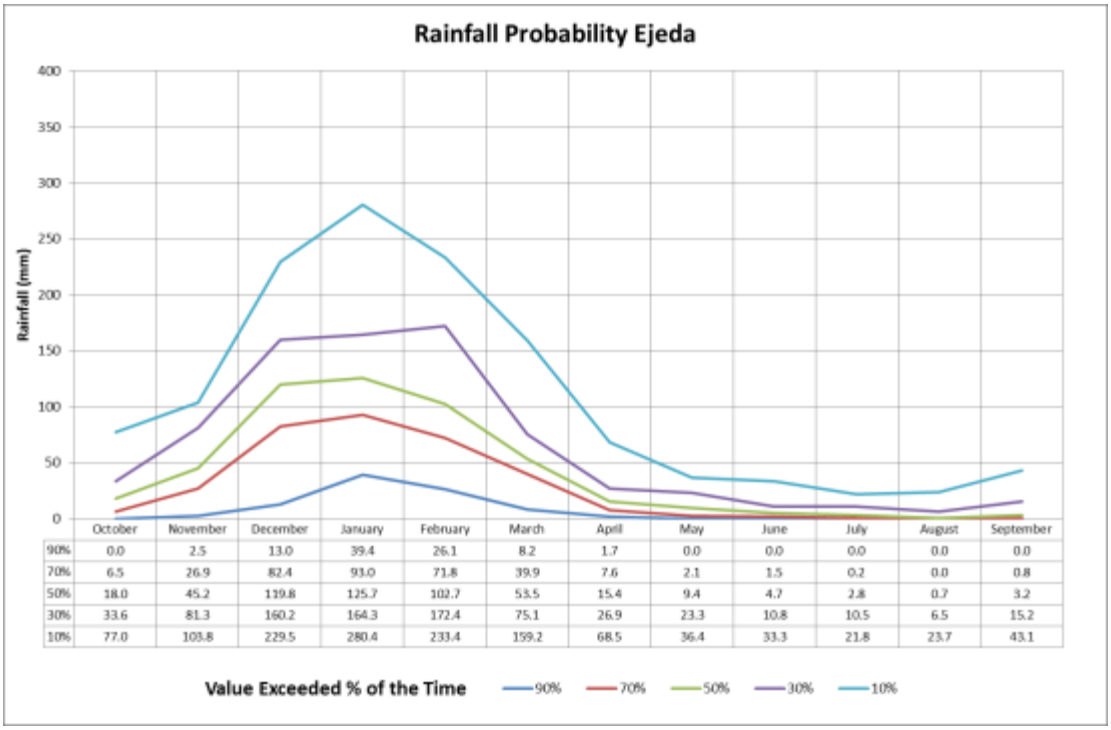


Figure 11.1: Monthly Rainfall Probability Fotadrevo (1959-1976)



	October	November	December	January	February	March	April	May	June	July	August	September
90%	29	24	58	71	69	64	37	31	38	37	18	20
70%	53	66	99	98	108	96	106	69	72	64	54	36
50%	79	81	134	160	148	108	152	111	89	86	85	42
30%	99	124	164	243	229	179	210	158	121	156	112	53
10%	165	221	312	374	393	489	272	239	190	225	157	144

Figure 11.2: Monthly Rainfall Probability Fort Dauphin (1983-2012)



	October	November	December	January	February	March	April	May	June	July	August	September
90%	0.0	2.5	13.0	39.4	26.1	8.2	1.7	0.0	0.0	0.0	0.0	0.0
70%	6.5	26.9	82.4	93.0	71.8	39.9	7.6	2.1	1.5	0.2	0.0	0.8
50%	18.0	45.2	119.8	125.7	102.7	53.5	15.4	9.4	4.7	2.8	0.7	3.2
30%	33.6	81.3	160.2	164.3	172.4	75.1	26.9	23.3	10.8	10.5	6.5	15.2
10%	77.0	103.8	229.5	280.4	233.4	159.2	68.5	36.4	33.3	21.8	23.7	43.1

Figure 11.3: Monthly Rainfall Probability Ejeda (1942-1996)

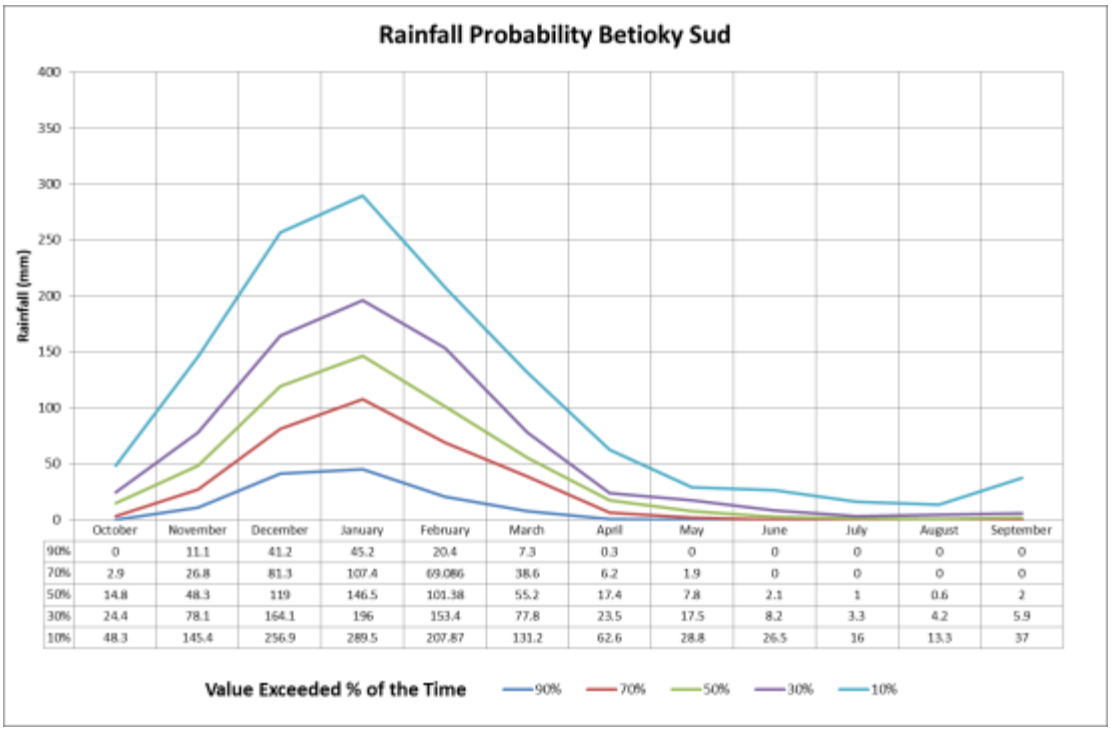


Figure 11.4: Monthly Rainfall Probability Betioky Sud (1929-1996)

11.1.1.2.2 Simulated Monthly Rainfall

A 55-year rainfall simulated rainfall record was modelled to simulate local runoff which will be representative for the Molo Graphite Project site and to be used for the dynamic water balance calculations (Section 11.6).

The 17-year local rainfall record (Fotadrevo) was considered to be too short for meaningful hydrological modelling and indicated a Mean Annual Precipitation (MAP) of 860 mm (this 17 year period seems to have been an unusually wet period). The nearest longer record (Betioky Sud, 1929-1996) indicated a MAP 632 mm and was used to upgrade the Fotadrevo rainfall record to a 55-year record.

Both records contained record gaps and were incomplete. Records from Betioky Sud and Ejeda (1942-1996) were used to cross-patch and fill gaps in both the Fotadrevo and Betioky Sud records for the 17 year period that rainfall records overlap.

On a monthly basis, 3 months of rainfall was ranked, plotted and a quadratic curve-fit was made to the data (Example for the month of January, data from December to February was analysed).

For each month, formulae were derived to modify the Betioky Sud record to reflect the values and variability found in the Fotadrevo record. The modified Betioky Sud record was de-ranked and then used to cross-patch and fill gaps in and also to extend the Fotadrevo record. A 55-year simulated rainfall record for Fotadrevo (and the site) was produced reflecting a MAP of 799 mm per annum and rainfall distribution of this simulated record is represented in Figure 11.5. The monthly rainfall distribution calculated from the simulated rainfall record is shown in Figure 11.6. The full table can be seen in Annexure 11 B Table 1.

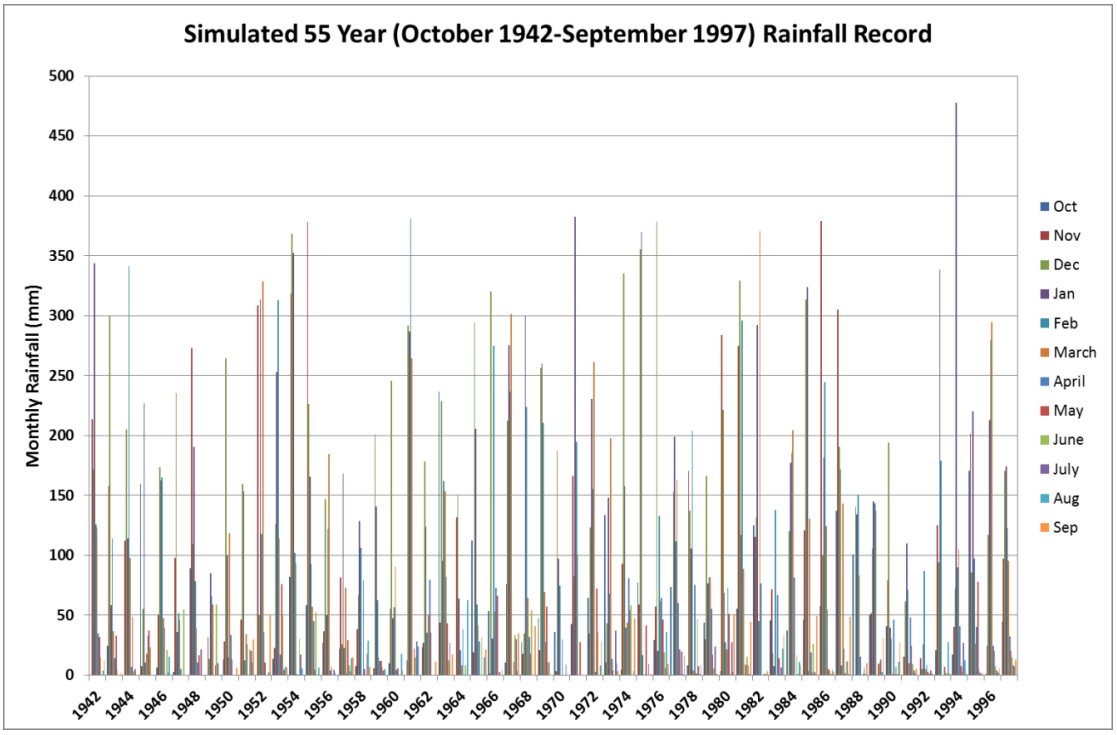
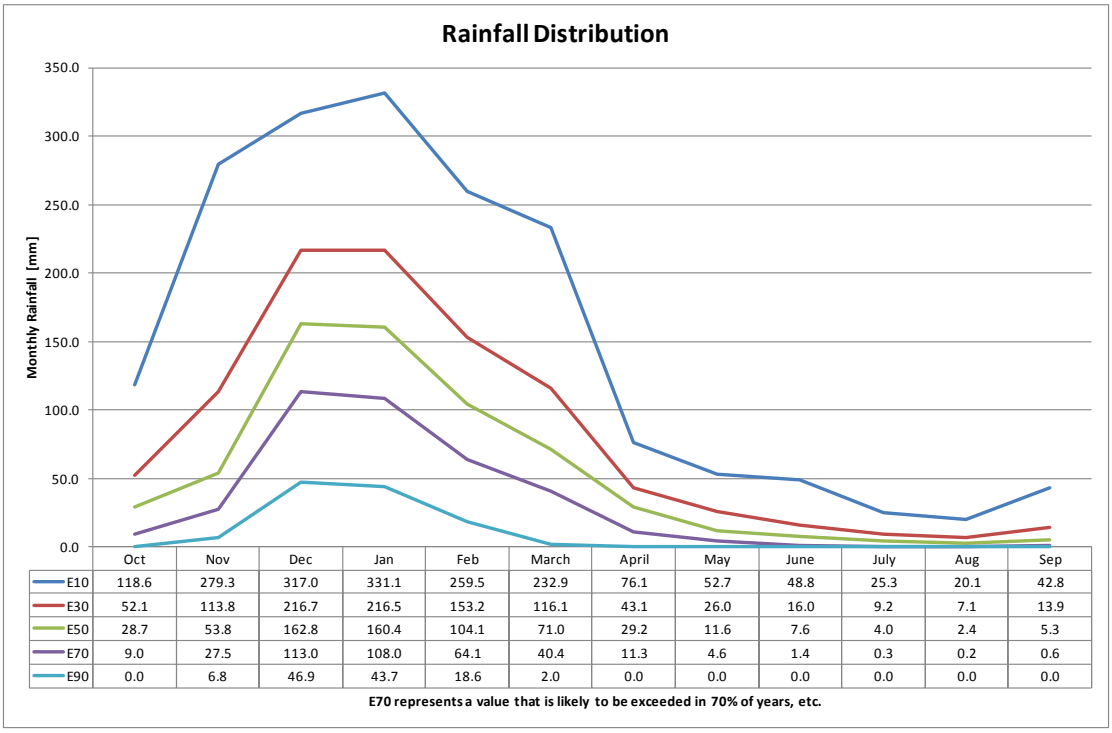


Figure 11.5: Simulated Rainfall (1942-1997) for Fotadrevo



	Oct	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug	Sep
E10	118.6	279.3	317.0	331.1	259.5	232.9	76.1	52.7	48.8	25.3	20.1	42.8
E30	52.1	113.8	216.7	216.5	153.2	116.1	43.1	26.0	16.0	9.2	7.1	13.9
E50	28.7	53.8	162.8	160.4	104.1	71.0	29.2	11.6	7.6	4.0	2.4	5.3
E70	9.0	27.5	113.0	108.0	64.1	40.4	11.3	4.6	1.4	0.3	0.2	0.6
E90	0.0	6.8	46.9	43.7	18.6	2.0	0.0	0.0	0.0	0.0	0.0	0.0

E70 represents a value that is likely to be exceeded in 70% of years, etc.

Figure 11.6: Rainfall Distribution derived from simulated and patched rainfall at Fotadrevo

11.1.1.2.3 Satellite Rainfall

Satellite data is useful to complement rainfall station measured data in data scarce regions, especially in terms of the rainfall spatial variability.

The satellite data is available from National Oceanic and Atmospheric Administration's Climate (NOAA) satellite rainfall and downloadable from January 2001 to date (NOAA, 2013). This data is at a spatial resolution of 0.1 of a degree and is available at a daily temporal resolution. This data is readily available and provides wider coverage for any part of Africa compared to point rainfall stations.

Figure 11.7 shows higher rainfall in the north than at Fotadrevo and a general increase of MAP towards the north-eastern portions of the Onilahy River catchment.

The simulated rainfall record at Fortadrevo and the satellite measured rainfall at same point to grid (pixel) are 799 mm and 866 mm respectively (error in MAP of 8%). Similarly, the measured rainfall at Ejeda station and the satellite measured rainfall at same point to grid (pixel) are 596 mm and 634 mm respectively (in MAP of 6%). The satellite rainfall over-estimates the MAP for the study area, but the error margin is both small and consistent. Satellite data could not be used as direct hydrological model inputs without using measured data to calibrate the synthesised record (Sawumyama & Hughes, 2008).

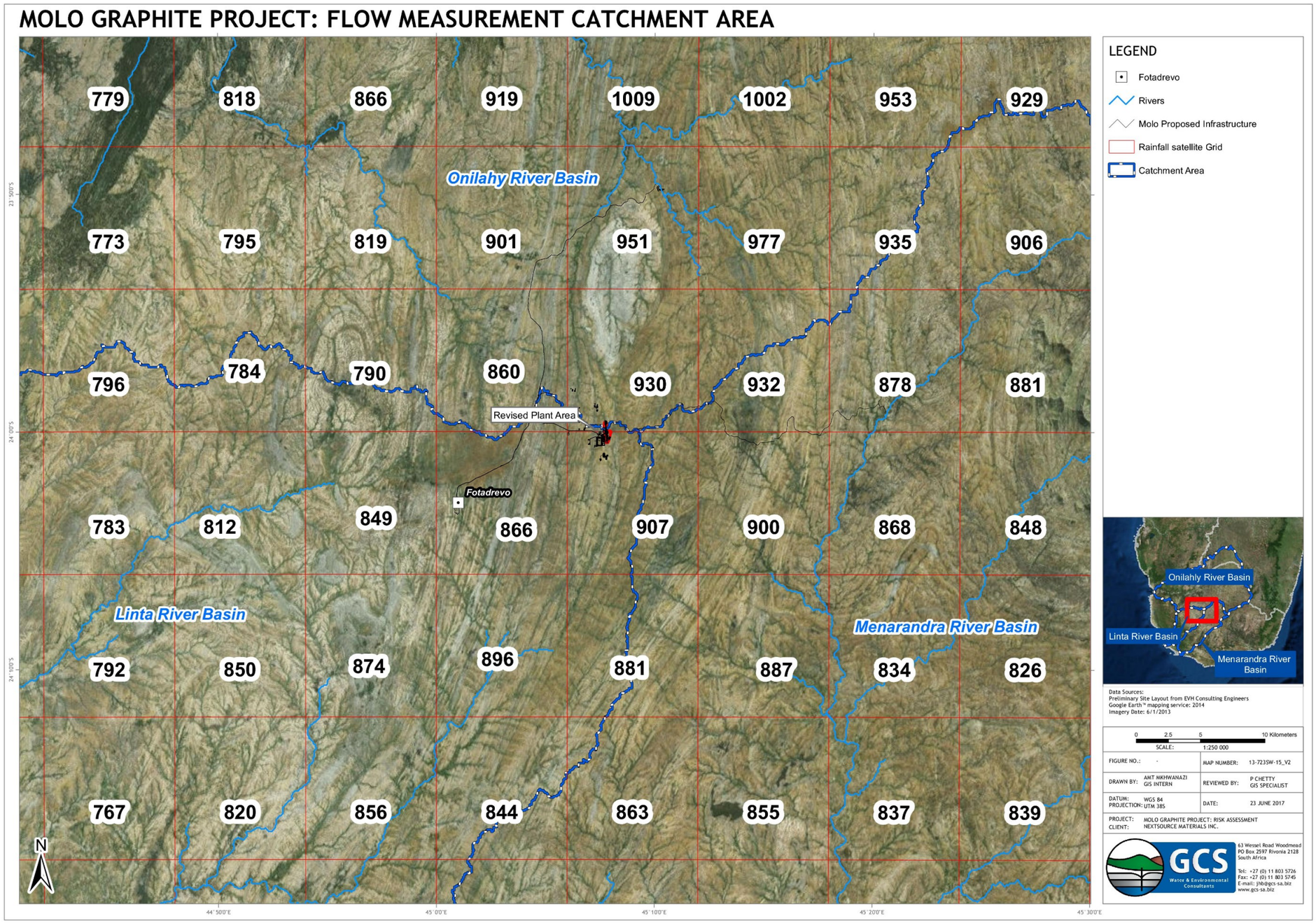


Figure 11.7: Hydrological sub catchments overlaid with satellite rainfall grid showing MAP

11.1.2 Hydrology

11.1.2.1 Drainage and Catchments

The main drainage basins for the proposed Molo Graphite Project are shown in Figure 11.7. The site is located on the divide of three major river basins:

- The Onilahy River Basin;
- The Linta River Basin; and
- The Menarandra River Basin.

The Onilahy River (catchment of about 32,361 km^2) originates from the eastern highlands, flows west and discharges into the sea near the town of Tulear. The Linta River Basin (catchment of about 6,177 km^2) originates in the area of the project site. It flows in a south-westerly direction and terminates near the coastal town of Androka. The Menarandra River (catchment of about 8,681 km^2) originates from the highlands east of the project site. It flows in a south-westerly direction and flows into the seas near the coastal town of Bevoalavo.

At the Molo Graphite Project site, local water courses drain either to the north or south, away from the proposed mine infrastructure. This is related to the north-south orientation of geological foliation and layering, with associated differences in weathering potential. Regional rivers and tributaries are shown in Figure 11.8. Most water courses are ephemeral, dry during the dry season and only flow during the rainy season. Proposed mine infrastructure is mainly located in the Linta River Basin.

The proposed open pit area is located across the watershed of the Linta and Onilahy River Basins (Figure 11.7). Drainage to the north would flow into the Ankilitelo River, an upper tributary in the Onilahy River Basin, and to the south along the Zafaro River, an upper tributary in the Linta River Basin.

The proposed plant area is located in the Linta River Basin. Drainage will flow southward to the Beadabo River and further downstream, the Manakaraly River (Figure 11.7).

The planned co-disposal, reject dump and ore stockpiles are located in the upper catchment of the Andranohabdatsy River, which feeds into the Manakaraly River (Figure 11.7).

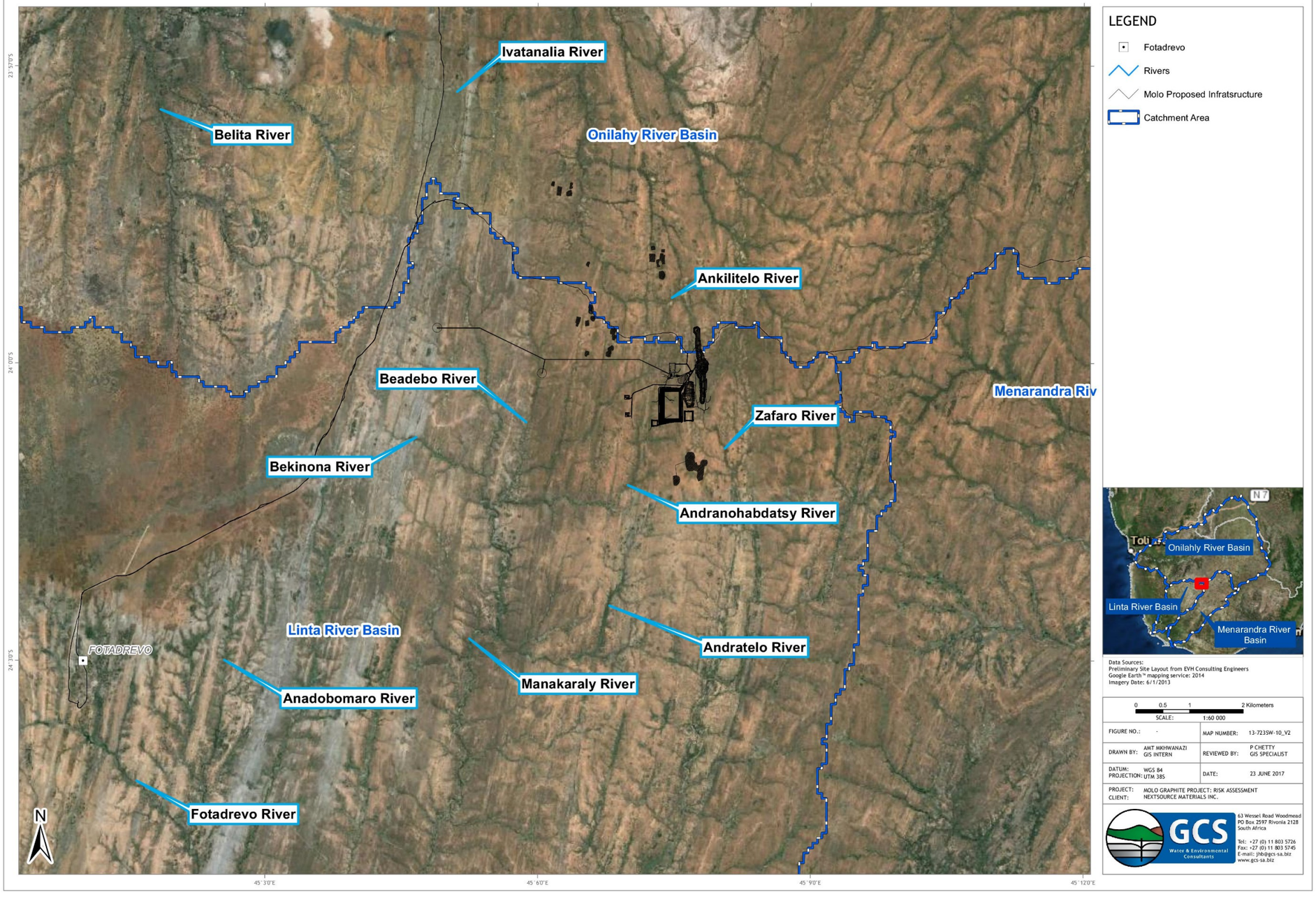


Figure 11.8: Overview of local rivers in the vicinity of the Molo Graphite Project site

11.1.2.2 *Rainfall Depth and Design Storms*

The daily rainfall records at the two rainfall stations of Fotadrevo and Fort Dauphin were used to calculate the peak 24 hour rainfall depths for different return periods. These values are used to estimate Intensity-duration-frequency (IDF) curves for the site and are used as design inputs to calculate sizes of storm water management infrastructure if required.

Probability distributions were derived from annual maximum daily rainfall depths. The annual maximum daily rainfall depths based on hydrological years (October to September) were analysed using Log-normal, Gumbel and Log Pearson 3 distributions (Table 11.3 and Table 11.4). Extreme rainfall events, however, appear to be most accurately predicted by using a Log normal distribution.

Table 11.3: 24-hours rainfall depth Fotadrevo for several distributions

Return periods (years)	Log-Normal (mm)	Gumbel (mm)	Log-Pearson 3 (mm)
2	77	77	75
5	103	102	96
10	119	119	113
20	134	135	132
50	154	155	160
100	169	171	185
200	184	186	214

Table 11.4: 24-hours rainfall depth Fort Dauphin for several distributions

Return periods (years)	Log-Normal (mm)	Gumbel (mm)	Log-Pearson 3 (mm)
2	116	117	113
5	161	161	150
10	190	190	180
20	218	218	213
50	255	254	263
100	283	281	307
200	312	308	358

Adamson (1981) suggests that 24-hour peak rainfall depths calculated using a Log-normal distribution should be increased by a factor of 1.11 to obtain more accurate or conservative estimates. The recommended 24-hour rainfall depths for different recurrence intervals are summarised in the table below.

Table 11.5: Recommended 24 hour rainfall depths for different recurrence intervals

Return periods (years)	Fotadrevo (mm)	Fort Dauphin (mm)
2	86	129
5	114	178
10	132	211
20	149	242
50	171	283
100	188	314
200	204	346

Rainfall intensities expected for storms of less than 24 hour duration must be estimated or derived. Intensity-Duration-Frequency (IDF) curves are needed for storm durations of less than 24 hours to provide design rainfall inputs.

IDF curves for Madagascar were not found during the data collection process. In the absence of short duration storm data, these curves were generated using the following approach:

Op Ten Noort (1983) fitted IDF curves to the available Southern African rainfall data. Curves were developed for the coastal and inland regions (Op Ten Noort, 1983). The Molo Graphite Site would be considered an inland region and the candidate port sites would be considered a coastal region. The applicable equation describing the IDF curves for inland regions is:

$$I = \frac{(7.5 + 0.034MAP)R^{0.3}}{(0.24 + t)^{0.89}} \qquad \text{(Equation 11.1)}$$

Where 'I' is the average rainfall intensity (mm/hr) for a storm of duration 't' (hr) and recurrence interval 'R' (years).

For coastal areas, the applicable equation describing the IDF curves is:

$$I = \frac{(3.4 + 0.023MAP)R^{0.3}}{(0.2 + t)^{0.75}} \qquad \text{(Equation 11.2)}$$

The 24-hour rainfall depths were generated using the Equations 11.1 and 11.2 using the MAP for the two sites and is presented in Table 11.6.

Table 11.6: 24-hours rainfall depth using Op ten Noort (1983)

Return periods (years)	Fotadrevo (mm)	Fort Dauphin (mm)
2	64	101
5	84	134
10	103	164
20	136	216
50	167	266
100	206	328
200	253	404

The comparison shows that the general Op ten Noort (1983) equation provides lower values for 24-hour rainfall depths than those calculated using direct statistical analysis of rainfall at both Fotadrevo and Fort Dauphin. The values of the statistical analysis were used to develop IDF curves for Fotadrevo and Fort Dauphin.

The IDF curves developed using the selected methods for different storm durations and recurrence intervals are shown in Table 11.7 and Table 11.8.

Table 11.7: Average rainfall intensities (mm/hr) calculated for Fotadrevo for different storm durations and recurrence

Return Period						
Storm Duration (mm/hr) Fotadrevo	2	10	20	50	100	200
0.1	118.1	191.5	235.7	310.3	382.1	470.4
0.25	85.3	138.3	170.3	224.2	276.0	339.8
0.5	59.1	95.8	118.0	155.3	191.2	235.4
1	37.4	60.5	74.5	98.1	120.8	148.7
2	22.1	35.8	44.0	58.0	71.4	87.8
3	15.9	25.7	31.7	41.7	51.4	63.3
4	12.5	20.3	25.0	32.8	40.4	49.8
5	10.4	16.8	20.7	27.2	33.5	41.2
6	8.9	14.4	17.7	23.3	28.7	35.3
8	6.9	11.2	13.8	18.2	22.4	27.6
10	5.7	9.2	11.4	15.0	18.4	22.7
12	4.9	7.9	9.7	12.8	15.7	19.4
18	3.4	5.5	6.8	9.0	11.0	13.6

Table 11.8: Average rainfall intensities (mm/hr) calculated for Fort Dauphin for different storm durations and recurrence

Return Period						
Storm Duration (mm/hr) Fort Dauphin	2	10	20	50	100	200
0.1	188.5	305.4	376.0	495.0	609.4	750.2
0.25	136.1	220.6	271.6	357.5	440.2	541.9
0.5	94.3	152.9	188.2	247.7	305.0	375.5
1	59.6	96.6	118.9	156.5	192.6	237.2
2	35.2	57.0	70.2	92.4	113.8	140.1
3	25.3	41.1	50.6	66.6	81.9	100.9
4	19.9	32.3	39.8	52.4	64.5	79.4
5	16.5	26.8	33.0	43.4	53.4	65.8
6	14.1	22.9	28.2	37.1	45.7	56.3
8	11.0	17.9	22.0	29.0	35.7	44.0
10	9.1	14.7	18.2	23.9	29.4	36.2
12	7.8	12.6	15.5	20.4	25.1	30.9
18	5.4	8.8	10.9	14.3	17.6	21.7

11.1.2.3 *Runoff Calculations*

11.1.2.3.1 Natural Runoff Modelling

A customized hydrological model was constructed to predict local runoff for the Molo Graphite Project site.

Recorded flow data at neighbouring rivers (Linta, Menarandra and Olihaly River Basins) suggests that runoff is equivalent to between 16 and 24% of the MAP as given by Bresson (1959) and ORSTOM (1990). Local soils are generally shallow and well drained, contributing to the relatively high runoff percentages. The relatively small percentage of water that infiltrates these soils is stored in the soil profile. Thirdly, in this tropical region it should be warm enough that if water is available, natural vegetation will make use of available water for growth. There will be a small seasonal variation in crop factors that determine plant water demand.

Given these parameters, a runoff model was constructed that simulates on average 150 mm per annum runoff (18.8 % runoff). This simulated runoff is represented in Figure 11.9 and Figure 11.10. Mean Annual Runoff (MAR) and Normal Dry Weather Flow (NDWF) were calculated from this time series and are indicated in Table 11.9. NDWF is defined as that flow in a watercourse that can be seen to be exceeded 70% of the time. The full runoff records can be seen in Annexure 11 B Table 2.

Table 11.9: MAR and NWDF for the proposed Molo Graphite Project

Mean Annual Runoff (mm)	150
Normal Dry Weather Flow (mm)	18.9

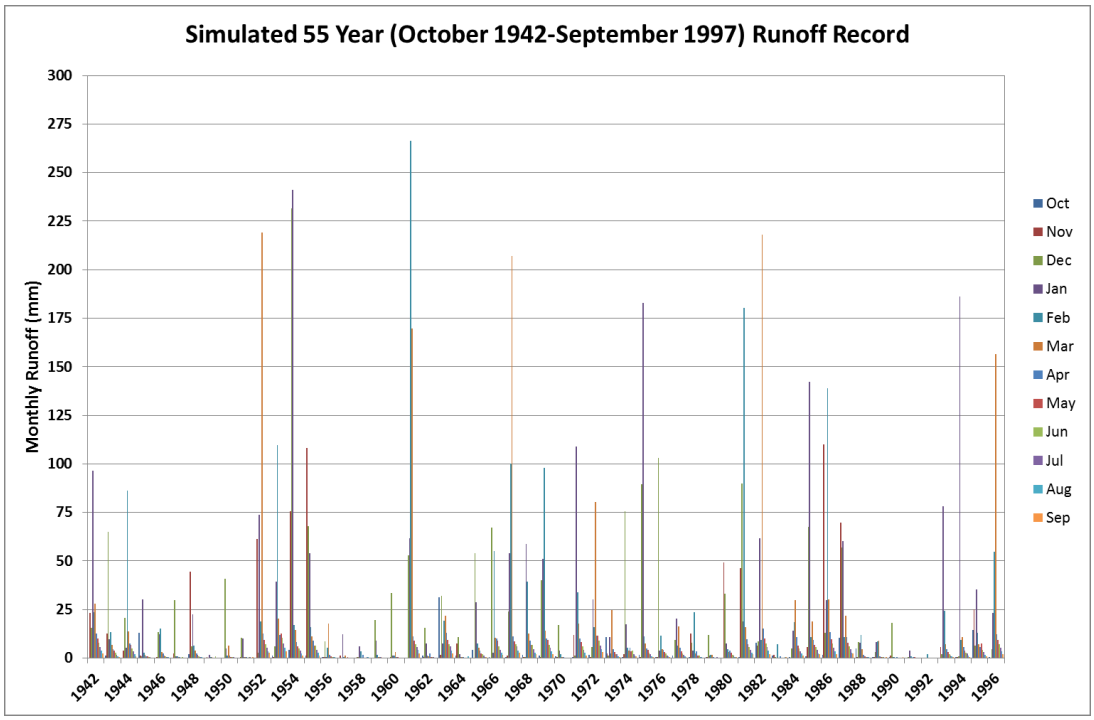
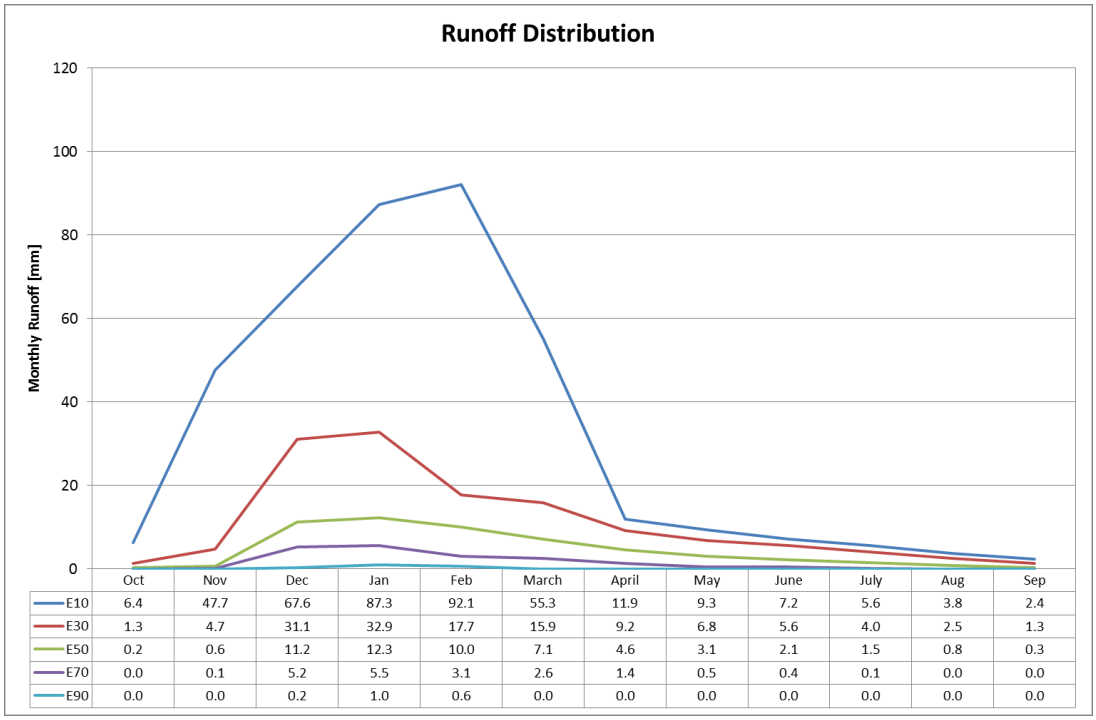


Figure 11.9: Simulated Runoff for Molo Graphite Project site based on simulated and patched rainfall at Fotadrevo

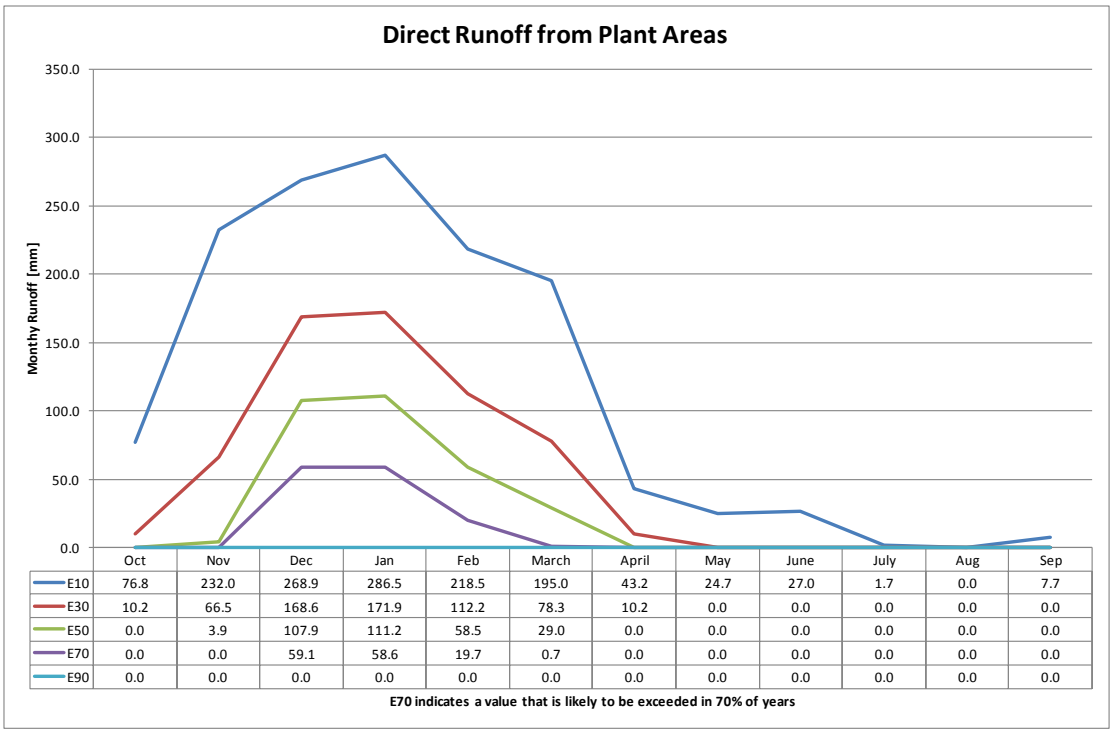


	Oct	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug	Sep
E10	6.4	47.7	67.6	87.3	92.1	55.3	11.9	9.3	7.2	5.6	3.8	2.4
E30	1.3	4.7	31.1	32.9	17.7	15.9	9.2	6.8	5.6	4.0	2.5	1.3
E50	0.2	0.6	11.2	12.3	10.0	7.1	4.6	3.1	2.1	1.5	0.8	0.3
E70	0.0	0.1	5.2	5.5	3.1	2.6	1.4	0.5	0.4	0.1	0.0	0.0
E90	0.0	0.0	0.2	1.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Figure 11.10: Simulated Runoff Distribution (mm) for the Molo Graphite Project site

11.1.2.3.2 Runoff Modelling for the Plant Area

Runoff is a direct function of rainfall and likely losses that result from interception and direct evaporative losses. It is accepted that direct runoff from roads and roofs will, on average, be in the order of 65% of rainfall. The plant area also contains other surfaces where some rainfall will infiltrate and increased interception will occur. Runoff from Plant Areas is estimated at an average of 515 mm per annum and is likely to be distributed as presented in Figure 11.11.



	Oct	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug	Sep
E10	76.8	232.0	268.9	286.5	218.5	195.0	43.2	24.7	27.0	1.7	0.0	7.7
E30	10.2	66.5	168.6	171.9	112.2	78.3	10.2	0.0	0.0	0.0	0.0	0.0
E50	0.0	3.9	107.9	111.2	58.5	29.0	0.0	0.0	0.0	0.0	0.0	0.0
E70	0.0	0.0	59.1	58.6	19.7	0.7	0.0	0.0	0.0	0.0	0.0	0.0
E90	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

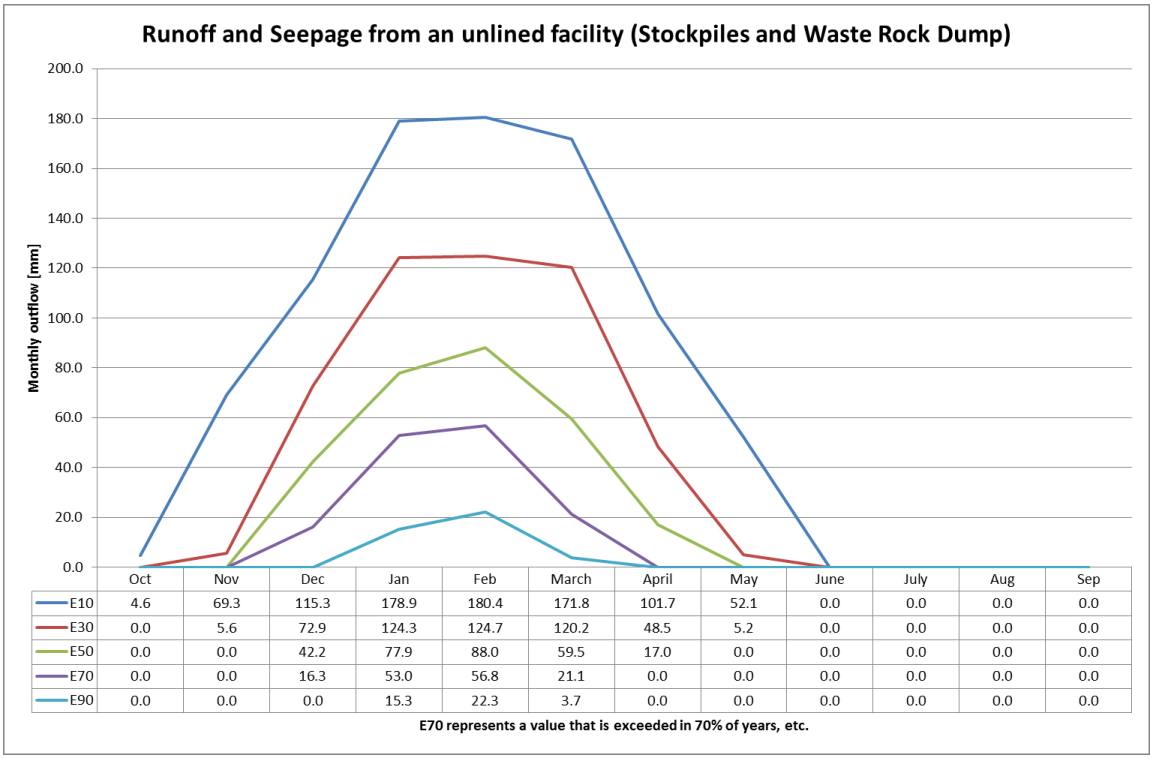
E70 indicates a value that is likely to be exceeded in 70% of years

Figure 11.11: Runoff from plant area

The full simulated runoff records can be seen in Annexure 11 B, Table 3.

11.1.2.3.3 Retarded Runoff

For an unlined facility (product stockpile or waste rock dump), volumes of water similar to estimated plant runoff are likely to infiltrate into the facilities. It is, however, assumed that the soils below these unlined facilities will be compacted, but not lined and limited infiltration into the soil will occur. The majority of water that infiltrates will seep from the base at a retarded and more constant rate. Outflows from these unlined facilities would be likely to follow the following pattern as shown in Figure 11.12.



	Oct	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug	Sep
E10	4.6	69.3	115.3	178.9	180.4	171.8	101.7	52.1	0.0	0.0	0.0	0.0
E30	0.0	5.6	72.9	124.3	124.7	120.2	48.5	5.2	0.0	0.0	0.0	0.0
E50	0.0	0.0	42.2	77.9	88.0	59.5	17.0	0.0	0.0	0.0	0.0	0.0
E70	0.0	0.0	16.3	53.0	56.8	21.1	0.0	0.0	0.0	0.0	0.0	0.0
E90	0.0	0.0	0.0	15.3	22.3	3.7	0.0	0.0	0.0	0.0	0.0	0.0

E70 represents a value that is exceeded in 70% of years, etc.

Figure 11.12: Runoff from am unlined facility (stockpiles and waste rock dump)

The full simulated runoff records can be seen in Annexure 11 B Table 4.

11.1.2.3.4 Runoff from other Areas

It is estimated that all other runoff for the site can be represented as a weighted average of the above runoffs.

11.1.2.4 *Surface Water Quality*

A baseline water quality analysis was undertaken on eight (8) sampling points in and around the proposed Molo Graphite Site. The localities of sampling points are shown in Figure 11.13. The sample locations were chosen based on the locality of the proposed mine infrastructure. The surface water quality point coordinates are provided in Table 11.10.

Table 11.10: Surface water quality sample coordinates

Point	E	S	Em_UTM 38S, WGS84	Sm_ UTM 38S, WGS84
SWH1	45° 7' 48.258" E	24° 0' 33.285" S	513228.6	7344743.9
SWH2	45° 5' 30.511" E	24° 1' 37.471" S	509336.0	7342772.8
SWH3	45° 6' 37.691" E	24° 0' 31.855" S	511235.2	7344789.5
SWH4	45° 6' 32.358" E	23° 57' 25.716" S	511088.8	7350514.0
SWH5	45° 7' 23.272" E	23° 59' 23.488" S	512524.7	7346890.9
SWH6	45° 20' 48.452" E	23° 58' 50.545" S	535278.0	7347866.1
SWH7	45° 6' 28.606" E	23° 58' 12.724" S	510981.7	7349068.4
SWH11	45° 7' 33.89"E	23° 57' 30.09"S	512828.0	512828.0

Sampling was undertaken during March 2014 and serves as a baseline description of the surface water quality at the end of the rainy season. A second round of sampling was undertaken during July 2014 for the dry season.

The water samples were submitted to Waterlab (Pty) Ltd for chemical analysis. Waterlab is a South African National Accreditation System (SANAS) accredited laboratory according to ISO/IEC 17025:2005 standards No: T0391. Water quality results for March and July 2014 are presented in Table 11.11 and Table 11.12, respectively. Water quality results are being compared for reference to the Madagascan Drinking Water Standards (Decret No. 2004-635 Modification 2003-941 Surveillance de l'eau Normes eau Potable) and World Health Organisation Guideline Values for Drinking Water (2011). The International Finance Corporation (IFC) Environmental, Health, and Safety Guidelines for Mining (2007) concentrations are also listed with the Molo water quality results.

The water qualities of the 7 wet season surface water samples (Table 11.11), compared against the Madagascar and WHO drinking water criteria, were generally good with the exception of elevated turbidity. This will not impose any risk to human health, but due to the aesthetic reasons it will not be recommended to use it as drinking water without proper treatment.

SWH3 had a fluoride value above the relevant human drinking water guideline, probably associated with localised apatite identified in the gneiss. All metals analysed for were found to be below the detection limit. The pH values for all samples were about 8.

Only 5 water quality sample points were analysed for the dry season, due to lack of stream flow. The water quality of the 5 surface water samples (Table 11.12) was also good compared against the Madagascar and WHO drinking water criteria. Turbidity values, as expected, were mostly elevated. SWH3 and SWH11 had fluoride concentrations of 2.3 and 1.9 mg/l respectively, exceeding the WHO guideline value of 1.5 mg/l. Elevated fluoride levels may impose a risk to human health. SWH1 also have an ammonia concentration above the drinking water guideline value.

The surface water is generally sodium, calcium, manganese – bicarbonate (chloride) dominant. Suspended solids (geology) and evaporation have an impact on the water character.

Table 11.11: Baseline surface water quality data for the wet season

Parameter (mg/l)	Decret No. 2004-635 (Madagascan Drinking Water Standard)[1]	WHO Drinking Water (2011)[2]	IFC Guidelines for Mining Effluent (2007)[3]	SWH1	SWH2	SWH3	SWH5	SWH6	SWH7	SWH9
pH at 25ºC	6.5-9.5	NS	6 - 9	7.8	8.5	8.5	8.1	7.9	7.7	8.3
Conductivity mS/m @ 25˚C	NS	NS	NS	74.7	64.9	55.3	14.3	28.8	39.8	41.9
Total Dissolved Solids @ 180ºC*	NS	*1000*	NS	522	446	378	102	214	282	284
Turbidity (in N.T.U)	5	1	NS	16	0.5	2.8	98	2.9	33	4.7
Total Acidity as $CaCO_3$*	NS	NS	NS	8	BDL	BDL	BDL	BDL	BDL	BDL
Total Alkalinity as $CaCO_3$	NS	NS	NS	232	2647	292	72	144	184	204
P-Alkalinity as $CaCO_3$*	NS	NS	NS	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Bicarbonate as HCO_3*	NS	NS	NS	283	346	356	102	175	224	249
Chloride, Cl	250	*250*	NS	78	103	21	8	12	15	19
Sulphate, SO_4	250	*250*	NS	76	46	16	11	9	25	13
Fluoride,F	NS	1.5	NS	0.6	1.3	2.2	0.3	0.7	0.8	0.9
Nitrate as NO_3	50	50	NS	2.7	BDL	BDL	BDL	BDL	BDL	BDL
Nitrite as NO_2	0.1	3	NS	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Total Phosphate as P*	NS	NS	NS	BDL	0.2	BDL	0.2	BDL	0.3	0.2
Free and Saline Ammonia as NH_4	0.5	*1.5*	NS	0.2	BDL	0.2	0.3	BDL	0.3	0.2
Aluminium, Al	NS	NS	NS	BDL	BDL	BDL	1.59	BDL	BDL	BDL
Antimony, Sb	NS	0.02	NS	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Arsenic, As	NS	0.01	0.1	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Barium, Ba	NS	0.7	NS	0.181	0.177	0.094	0.107	0.111	0.118	0.156
Berillium, Be	NS	NS	NS	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Bismuth, Bi	NS	NS	NS	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Boron, B	NS	2.4	NS	0.089	0.033	0.042	0.038	BDL	0.029	BDL
Cadmium, Cd	NS	0.003	0.05	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Calcium, Ca	NS	NS	NS	37	50	29	6	20	22	35
Chromium, Cr	NS	0.05	0.1	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Cobalt, Co	NS	NS	NS	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Copper, Cu	NS	2	0.3	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Iron, Fe	0.3	*0.3*	2	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Lead, Pb	NS	0.01	0.2	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Lithium, Li	NS	NS	NS	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Magnesium, Mg	NS	NS	NS	20	26	23	5	10	13	16
Manganese, Mn	NS	0.4	NS	BDL	BDL	BDL	BDL	BDL	0.028	BDL
Molybdenum, Mo	NS	NS	NS	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Nickel, Ni	NS	0.07	0.5	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Phosphorous, P	NS	NS	NS	0.033	0.184	0.025	0.046	BDL	0.163	0.047
Potassium, K	NS	NS	NS	6.3	3.3	BDL	4.0	1.9	4.2	2.9
Selenium, Se	NS	0.04	NS	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Silicon, Si	NS	NS	NS	14.8	21	21	9.76	14.2	18.7	18.2
Silver, Ag	NS	NS	NS	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Sodium, Na	NS	*200*	NS	83	56	60	13	23	37	31
Strontium, Sr	NS	NS	NS	0.232	0.256	0.251	0.054	0.145	0.157	0.223
Tin, Sn	NS	NS	NS	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Titanium, Ti	NS	NS	NS	BDL	BDL	BDL	0.055	BDL	0.031	BDL
Tungsten, W	NS	NS	NS	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Vanadium, V	NS	NS	NS	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Zink, Zn	NS	4	0.5	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Zirconium, Zr	NS	NS	NS	BDL	BDL	BDL	BDL	BDL	BDL	BDL

1 - Decret No. 2004-635 Modification 2003-941 Surveillance de l'eau Normes eau Potable (Madagascan Drinking Water Standards)

2 - World Health Organisation Guideline Values for Drinking Water (2011)

3 - International Finance Corporation Environmental, Health, and Safety Guidelines for Mining (2007)

NS – Not Specified

BDL - Below Detection Limit

Limits in italics indicate aesthetic parameters (i.e. taste)

* - ICP-OES Scan (Dissolved)

X	Does not comply with Madagascar standards for drinking water
X	Does not comply with WHO guideline values
X	Does not comply with IFC guideline values
X	Does not comply with two or more of the standards / guidelines

Table 11.12: Baseline surface water quality data for the dry season

Parameter (mg/l)	Decret No. 2004-635 (Madagascan Drinking Water Standard)[1]	WHO Drinking Water (2011)[2]	IFC Guidelines for Mining Effluent (2007)[3]	SWH1	SWH2	SWH3	SWH4	SWH11
pH at 25ºC	6.5-9.5	NS	6 - 9	7.7	8.5	8	7.4	8.1
Conductivity mS/m @ 25°C	NS	NS	NS	143	64.5	58.9	61.1	79.2
Total Dissolved Solids @ 180ºC*	NS	*1000*	NS	888	408	388	412	506
Total Acidity as $CaCO_3$*	NS	NS	NS	16	<5	12	20	12
Total Alkalinity as $CaCO_3$	NS	NS	NS	324	260	264	212	372
P-Alkalinity as $CaCO_3$*	NS	NS	NS	BDL	BDL	BDL	BDL	BDL
Bicarbonate as HCO_3*	NS	NS	NS	395	317	322	258	453
Chloride, Cl	250	*250*	NS	168	39	24	23	27
Sulphate, SO_4	250	*250*	NS	195	46	43	83	52
Fluoride, F	NS	1.5	NS	0.7	1.5	2.3	0.8	1.9
Nitrate as NO_3	50	50	NS	BDL	BDL	BDL	BDL	BDL
Nitrite as NO_2	0.1	3	NS	BDL	BDL	BDL	BDL	0.7
Total Phosphate as P*	NS	NS	NS	0.3	0.3	0.2	0.8	0.3
Free and Saline Ammonia as NH_4	0.5	*1.5*	NS	7.9	0.3	0.5	0.8	0.8
Aluminium, Al	NS	NS	NS	0.10	BDL	BDL	BDL	BDL
Antimony, Sb	NS	0.02	NS	BDL	BDL	BDL	BDL	BDL
Arsenic, As	NS	0.01	0.1	BDL	BDL	BDL	BDL	BDL
Barium, Ba	NS	0.7	NS	0.17	0.14	0.17	0.33	0.13
Beryllium, Be	NS	NS	NS	BDL	BDL	BDL	BDL	BDL
Bismuth, Bi	NS	NS	NS	BDL	BDL	BDL	BDL	BDL
Boron, B	NS	2.4	NS	0.11	0.03	0.03	BDL	0.03
Cadmium, Cd	NS	0.003	0.05	BDL	BDL	BDL	BDL	BDL
Calcium, Ca	NS	NS	NS	55	40	30	33	50
Chromium, Cr	NS	0.05	0.1	BDL	BDL	BDL	BDL	BDL
Cobalt, Co	NS	NS	NS	BDL	BDL	BDL	BDL	BDL
Copper, Cu	NS	2	0.3	BDL	BDL	BDL	BDL	BDL
Iron, Fe	0.3	*0.3*	2	0.03	BDL	0.32	0.10	BDL
Lead, Pb	NS	0.01	0.2	BDL	BDL	BDL	BDL	BDL
Lithium, Li	NS	NS	NS	BDL	BDL	BDL	BDL	BDL
Magnesium, Mg	NS	NS	NS	39	24	25	20	35
Manganese, Mn	NS	0.4	NS	0.60	BDL	0.72	4.80	0.08
Molybdenum, Mo	NS	NS	NS	0.05	BDL	BDL	BDL	BDL
Nickel, Ni	NS	0.07	0.5	BDL	BDL	BDL	BDL	BDL
Phosphorous, P	NS	NS	NS	0.12	0.14	0.09	BDL	0.14
Potassium, K	NS	NS	NS	26.00	3.40	2.10	2.30	3.00
Selenium, Se	NS	0.04	NS	BDL	BDL	BDL	BDL	BDL
Silicon, Si	NS	NS	NS	11.10	14.20	25	19.10	22
Silver, Ag	NS	NS	NS	BDL	BDL	BDL	BDL	BDL
Sodium, Na	NS	*200*	NS	166	57	57	59	69
Strontium, Sr	NS	NS	NS	0.36	0.23	0.26	0.25	0.33
Sulphur, S	NS	NS	NS	105	22	15	52	26
Tin, Sn	NS	NS	NS	BDL	BDL	BDL	BDL	BDL
Titanium, Ti	NS	NS	NS	BDL	BDL	BDL	BDL	BDL
Tungsten, W	NS	NS	NS	BDL	BDL	BDL	BDL	BDL
Vanadium, V	NS	NS	NS	BDL	BDL	BDL	BDL	BDL
Zink, Zn	NS	4	0.5	BDL	BDL	BDL	BDL	BDL
Zirconium, Zr	NS	NS	NS	BDL	BDL	BDL	BDL	BDL

1 - Decret No. 2004-635 Modification 2003-941 Surveillance de l'eau Normes eau Potable (Madagascan Drinking Water Standards)

2 - World Health Organisation Guideline Values for Drinking Water (2011)

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X	Does not comply with two or more of the standards / guidelines

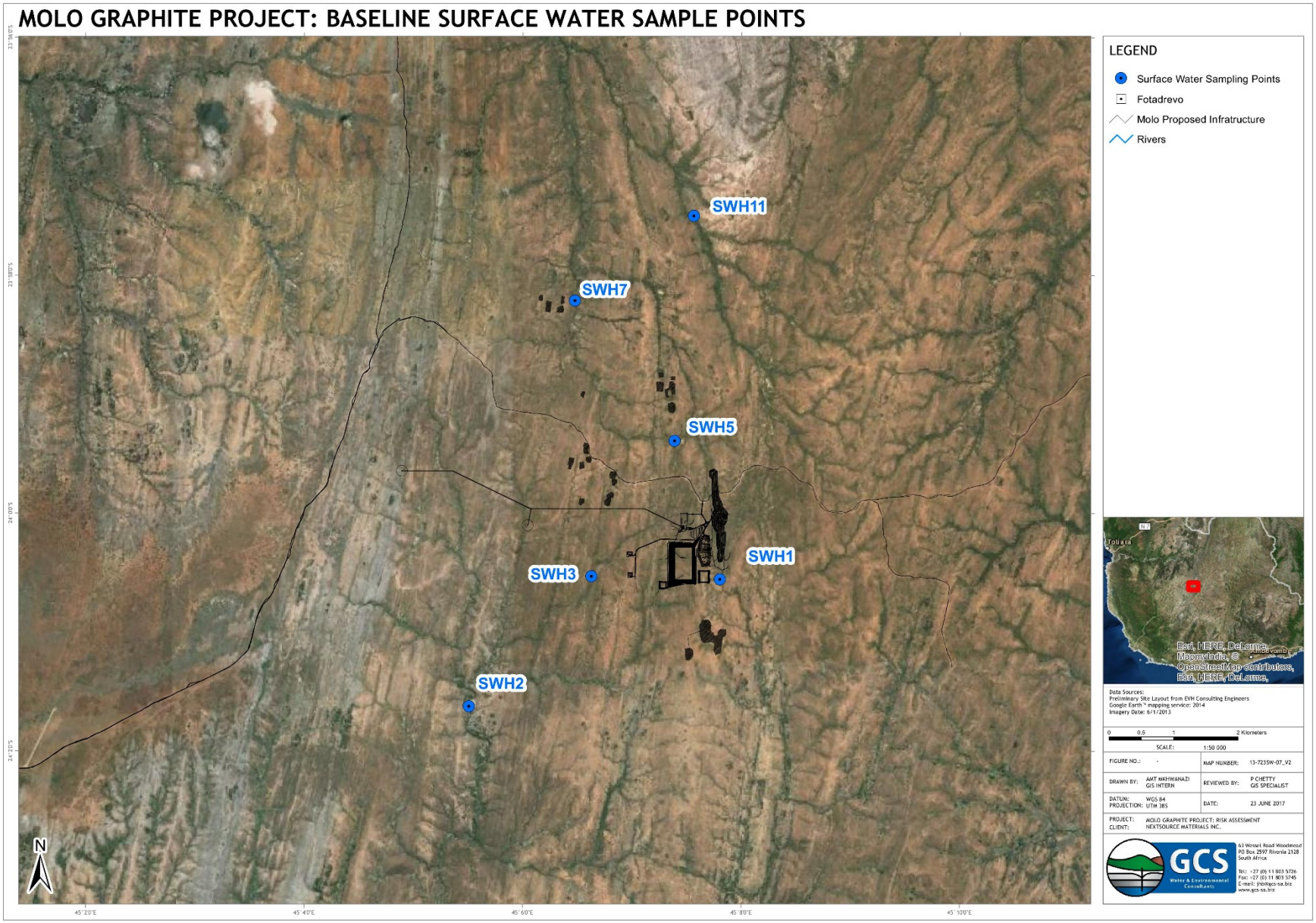


Figure 11.13: Surface water quality sample locations

11.1.2.5 *Downstream Surface Water Users*

Two site visits were conducted, in April 2014 at the end of the rainy season and in July 2014 in the dry season, to identify the potential water users in the vicinity of the Molo Graphite Project site.

In general, the surface water sources in the Molo Graphite Project area are largely underdeveloped. There are no known major industrial developments, irrigation schemes, impoundments and major abstraction works in the river catchments surrounding the proposed Molo Graphite Project Site.

The major surface water users are local communities, using water for drinking, livestock, washing and small scale subsistence agricultural with crops such as rice, cassava, tomatoes and bananas. More information is also presented as part of the Social Assessment (Section 12 of Feasibility Report).

The following photos provide an impression of the undeveloped region around the proposed Molo Graphite Project Site.



Figure 11.14: Rice paddies and banana crops downstream of the plant area



Figure 11.15: Cassava crops downstream in a southerly direction from the open pit area



Figure 11.16: Beadebo River looking in a southerly direction



Figure 11.17: Overview in the vicinity of the Molo Graphite Project site looking in a north westerly direction

11.1.3 Hydrogeology

11.1.3.1 *Methodology*

11.1.3.1.1 Desktop Review and Site Visit

An initial site visit was conducted to the Molo Graphite Project by the project team, 10 to 14 March 2014 in order to gain a conceptual understanding of the site, as well as to collect site-specific information from the client. The field investigation was planned based on the information obtained from the site visit. During the desktop review all the relevant data and information made available to GCS by the client and collected from the public domain was reviewed. The data reviewed included the following:

- Previous consultant reports for the site, including:
    - Energizer Resources Inc., 2012. *Green Giant Project: Fotadrevo, Province of Toliara, Madagascar*. Technical Report Update NI 43-101.
    - DRA (Pty) Ltd, 2013. *Molo Graphite Project: Fotadrevo, Province of Toliara, Madagascar. Preliminary Economic Assessment Technical Report Update (NI 43-101).*

- Agetipa, 2012. *Baseline Studies, Chapter 2: Soil, Surface and Ground Water Studies*. Agetipa Document No. 04/PR/HRZ.
- Dillon Consulting Ltd, 2012. *Preliminary Assessment of Groundwater-sourced Production and Potable Water for the Green Giant Graphite Project, Madagascar*. Dillon Consulting Project No. 12-6742.

- Geological maps for the site area;
- Open source geological reports for the site region;
- Geological exploration data;
- Previously undertaken airborne geophysical data;
- Topographic survey data for the site area; and
- Climatic data.

11.1.3.1.2 Hydrocensus Investigation

A hydrocensus investigation was completed in March and June 2014 within a 5 km radius of the proposed site, as well as around the nearby town of Fotadrevo. The hydrocensus was undertaken during the end of the wet season and a follow-up hydrocensus was undertaken for the dry season.

During the hydrocensus groundwater features (e.g. boreholes, hand dug wells, springs) were identified and the following information recorded:

- GPS Coordinates (X and Y coordinates in UTM 38S, WGS84);
- Groundwater levels (where applicable);
- Depth of borehole/hand dug well;
- Usage status of the feature (i.e. in use or not in use);
- General condition of the feature; and
- Where applicable, how much water is abstracted at the point.

Eighteen (18) groundwater features were identified within the study area and the hydrocensus results are discussed in the Section 11.1.3.3. The localities of the hydrocensus features identified are shown in Figure 11.18 and summarized in Table 11.13. Eleven (11) water samples were collected at selected groundwater features during the hydrocensus. Samples were collected using the installed equipment of the borehole and hand dug wells or via an open ended bailer. Field parameters such as pH, electrical conductivity (EC) and oxidation reduction potential (ORP) were also taken on site. The samples were filtered using a 0.45 micron filter system and preserved in a fridge. Samples were submitted for analysis to Waterlab (Pty) Ltd in Pretoria, South Africa. Waterlab is a South African National Accreditation System (SANAS) accredited laboratory according to ISO/IEC 17025:2005 standards No: T0391.

11.1.3.1.3 Geophysical Survey and Borehole Siting

A surface geophysical survey was completed using the electrical resistivity method in March 2014, during which eighteen (18) traverses were completed at lengths between 500 and 1200 m. The geophysical traverses were conducted near to the proposed open pit, co-disposal facility and plant areas and were completed in order to identify potential targets for the installation of hydrogeological boreholes. Lines were also undertaken regionally for the proposed raw water supply wellfield and the alternative wet tailings storage facility (TSF) site. The 2D measured resistivity data were accordingly edited, processed and ultimately inverted using a 2D forward modelling program. In this work, the inversion algorithm RES2Dinvx64 software package by Geotomo Software was used. The RES2DINV inversion routines involves a cell-based inversion technique where it automatically divides the 2D pseudo-section into a large number of rectangular blocks that are loosely tied to the distribution of the data points in the pseudo-section. An iterative non-linear smoothness-constrained least-squares optimization technique was used to calculate the resistivity of the model blocks that provide a model response which agrees with the observed data (deGroot-Hedlin and Constable, 1990).

The resultant 2D tomographs were then interpreted based on the scientifically proven link between apparent resistivity characteristics and subsurface material properties in order to delineate favourable areas to place hydrogeological borehole targets to be drilled. Table 11.14 summarizes the geophysical traverses and the resultant targets and Figure 11.19 shows the geophysical traverses and target localities. The resultant resistivity sections are presented in the Annexure 11 C.

11.1.3.1.4 Hydrogeological Borehole Installation and Testing

Borehole Drilling:

Sixteen (16) drilling sites were selected for the hydrogeological drilling program based on the ERT geophysics survey, geological features and locality of proposed mine infrastructure. The boreholes were installed between 9 May and 20 June 2014. The drilling results are discussed in Section 11.1.3.5 and the borehole localities are shown in Figure 11.18. Borehole logs are presented in Annexure 11 D.

The drilling program consists of the following boreholes:

- Six (6) open pit hydrogeological boreholes installed to a maximum depth of 110 m: MMB1, MMB2, MMB3, MMB6, MMB8 and MMB10;

- Six (6) monitoring boreholes were installed to a maximum depth of 51 m in the general area of the processing plant, co-disposal facility and alternative wet TSF (not currently part of the Base Case project): MMB4, MMB5, MMB7, MMB9, MMB11 and MMB12. These borehole positions took into account the preliminary mine infrastructure block plan and additional monitoring boreholes are proposed in Section 11.8.5;
- Four (4) regional water resource test boreholes were drilled north, south and west of the Molo site: MMB13 and MMB15. Two (2) of the water resource boreholes (MMB14 and MMB16) were drilled into the marble, west of the Molo site.

Lanoe Forages ARL, a Malagasy company, was contracted by GCS to install the hydrogeological boreholes. Lanoe Forages ARL used two (2) percussion (down the hole hammer) drilling rigs, each coupled to an air compressor unit.

Boreholes were completed to final diameters between 128 and 203 mm (5 to 8 in.) and constructed using 140 or 152 mm OD uPVC casing. Borehole logs are presented in Annexure 11 D. A summary of the boreholes drilled is provided in Table 11.14.

Aquifer Testing:

Pumping tests were undertaken by Lanoe Forages ARL (the contractor) upon completion of the hydrogeological boreholes in June. The pumping test results were used to characterise groundwater response to abstraction, borehole safe yield, determine important aquifer hydraulic parameters (e.g. transmissivity) and to aid in further classification of the site aquifer systems. The pumping test specifications per borehole are as follows:

- A three (3) hour variable rate discharge test (step test), which was conducted in order to determine the optimum abstraction rate to be used in the proceeding constant discharge test;
- Sixteen (16) constant discharge tests ranging in duration between 90 and 2880 minutes, with pumping rates ranging between 0.2 and 3.8 l/s;
- Recovery was measured in each of the boreholes following the constant discharge testing until the water level within the borehole has recovered to 95% of the original level. However, due to technical failure of the contractor's equipment a number of boreholes' recovery was measured to a lesser extent. The duration of the recovery recording period varied between 51 and 1 200 minutes.

Pumping test data was interpreted using Cooper-Jacob, Flow Characteristics (FC) and Theis methods. Pumping test results are summarised in Table 11.15 and is discussed in Section 11.1.3.5.

11.1.3.2 *Regional Aquifer Description*

11.1.3.2.1 General Geology

The Molo Graphite Project site is located in the intercontinental tectonic Bekily Block of Southern Madagascar, made up of ancient poly-deformed, high-grade metamorphic rocks (upper amphibolite facies), and later igneous intrusions. The site furthermore falls within the Ampanihy shear zone with a regional north-northeast – south-southwestern trend. The rocks found within this regional shear zone have a similar roughly north-south foliation and/or layering that are vertical to sub-vertical in nature. Folding with axes mainly parallel to the shear direction occur in different parts of the study area, including at the main Molo graphite ore zone.

No significant faulting or dyke intrusions have been identified with the proposed Molo mining site. The depth of weathering is generally shallow, varying between 0 and 20 m below ground level in the topographic high and low zones, respectively.

Dominant lithologies occurring at the site consist mainly of migmatitic (biotite, hornfels, garnet) quartzofeldspathic gneiss with graphite schist and gneiss bands of the Ampanihy litho-metamorphic group (Madagascar Geological Map Ampanihy-Bekily, F60-G60-H-60-I60-F61-G61-H61-I61, 1958). Quartzofeldspathic gneiss containing amphibolite gneiss and marble bands of the Vohibory litho-metamorphic group occur toward the west of the site. Anorthosite intrusive rock occurs as a shear zone inclusion in the Ankafotra region north of the site.

Younger calcrete deposits overlay the metamorphic rock towards Fortradrevo. Local, recently deposited sandy alluvial was deposited along some drainage lines.

11.1.3.2.2 General Aquifer Description

Davies (2008) describes three types of aquifer in the Malagasy crystalline basement formations, namely:

- Valley Bottom alluvial sediment aquifer comprised of porous residual and transported materials under unconfined conditions. The static water levels vary between 2-3 m below ground level and the aquifers are exploited typically using shallow hand dug wells or shallow boreholes (i.e. < 10 m total depth). Generally this aquifer shows specific capacities between 3 and 6 l/s/m;

- The upper weathered zone aquifer, referred to in this report as the intergranular or weathered hydrogeological unit, has water levels between 2 and 5 m below ground level and shows specific capacities between 0.2 and 0.6 l/s/m; and
- The lower weathered and fissure basement rock aquifer (referred to in this report as the fractured hydrogeological unit) is an unconfined to semi-confined aquifer with a typical thickness of 5 m and specific capacities between 0.2 and 1.4 l/s/m.

The British Geological Survey (BGS, 2011) produced a groundwater productivity map of Africa, as well as a groundwater storage map. According to these maps the site aquifers exhibit water levels between 1 and 10 m below ground level and yield between 0.1 and 10 l/s.

The conceptual hydrogeological model is described in more detail in Section 11.1.3.8.

11.1.3.3 *Hydrocensus Investigation*

The results of the hydrocensus are summarized in Table 11.13 and localities are shown in Figure 11.18.

The wet and dry season hydrocensus investigations were conducted between 13 and 16 March 2014 and 27 to 30 June 2014, respectively. A total of eighteen (18) groundwater features were identified, consisting of seven (7) boreholes, three (3) springs and eight (8) hand-dug wells.

Near to the Fotadrevo village four (4) hand dug wells and one (1) percussion borehole were in use and one (1) hand dug well and one percussion borehole not in use (GWH5, 17, 4, 13, 11, 12, 18). The total known abstraction of groundwater resources for domestic use and livestock watering for boreholes GWH12 and 17 was 8.2 m^3/d.

Groundwater abstraction to the west of the proposed Molo site was for domestic use and took place via three (3) hand dug wells (GWH8, 9, 16) and one (1) percussion borehole (GWH6). Two unused percussion boreholes were also identified west of the proposed Molo site (GWH 10, 15). Total known abstraction for the area was 11.2 m^3/d.

In the vicinity of the proposed open pit area three (3) groundwater springs were identified (GWH1, 3, 7) and two (2) percussion boreholes (GWH2, 14). GWH3, the closest groundwater feature to the open pit, is situated 750 m to the south and the closest borehole, GHW2, about 1.1 km to the south. All three springs and one borehole (GWH14) were in use for domestic purposes and livestock watering, but the abstractions were unknown. However the total groundwater abstraction, within a 5 km radius of the proposed mine (this zone excludes Fotadrevo) is estimated to be about 15 to 20 m^3/d.

Table 11.13: Hydrocensus investigation summary

Site ID	Locality	Coordinates		Site type	Status	Equipment	Primary water usage	Abstraction (l/d)	Total dissolved solids (mg/l) results		Depth of Well (m mbgl)	Depth of groundwater level (m)	
		E (UTM 38S, WGS) (m)	S (UTM 38S, WGS) (m)						Wet Season	Dry Season		Wet Season	Dry Season
GWH1	East of proposed Molo open pit, Sambalahy region	514887	7346109	Spring	Used	*None*	stock watering	*Unknown*	78	128	*N/A*	-	0
GWH2	South of the proposed Molo open pit	513432	7343769	Percussion borehole	Unused	*None*	-	-	129	252	23	2	2.15
GWH3	South of the proposed Molo open pit	512975	7344167	Spring	Used	*None*	drinking	*Unknown*			*N/A*	-	DRY
GWH4	Fortadrevo	501510	7339561	Hand Dug Well	Used	*None*	stock watering, drinking water	*Unknown*		422	6	5.02	5.5
GWH5	Beamalo centre	501571	7339351	Hand Dug Well	Used	*None*	drinking	*Unknown*		643	5.5	5.2	6
GWH6	Beamalo centre	501570	7348503	Percussion borehole	Used	Mono Foot Pump	stock watering, drinking water	5000	318	285	34.9	7.3	No access
GWH7	East of proposed Molo open pit	517757	7346483	Spring	Used	*None*	drinking	1250	73.8	187	*N/A*	-	0
GWH8	Ambatofotsy (North)	507912	7346320	Hand Dug Well	Used	*None*	stock watering, drinking water	1500	87.4	499	15.5	6.05	15.04
GWH9	Ambatofotsy (South)	507374	7344514	Hand Dug Well	Used	*None*	stock watering, drinking water	1750	502	928	2.02	0.3	1
GWH10	Ambatofotsy (South)	507412	7344473	Percussion borehole	Unused	Mono Foot Pump (not working)	-	-			20	2.55	3.34
GWH11	Fortadrevo	501459	7340077	Hand Dug Well	Unused	*None*	-	-			*Unknown*	No access	No access
GWH12	Fortadrevo	501517	7340331	Hand Dug Well	Used	*None*	stock watering, drinking water, washing	1740	482	513	8	5	4.14
GWH13	Fortadrevo	502045	7339570	Hand Dug Well	Used	*None*	stock watering, drinking water	1500	361	510	7.57	1.19	7.15
GWH14	South of the proposed Molo open pit	513218	7343169	Percussion borehole	Used	Mono Foot Pump	drinking	5000		531	34.6	17.6	No access
GWH15	Analamasy	506964	7342468	Percussion borehole	Unused	*None*		-			51.1	3.41	4.56
GWH16	Analamasy	506829	7342427	Hand Dug Well	Used	*None*	drinking	2900	586	619	4.25	1.33	2.15
GWH17	Energizer Exploration Camp, Fotadrevo	501560	7339491	Percussion borehole	Used	*Submersible*	washing, cooking, toilets	5000	1.2		40	*No access*	No access
GWH18	Fortadrevo	501431	7340081	Percussion borehole	Unused	Mono Foot Pump (not working)	-	-			*Unknown*	*No access*	No access

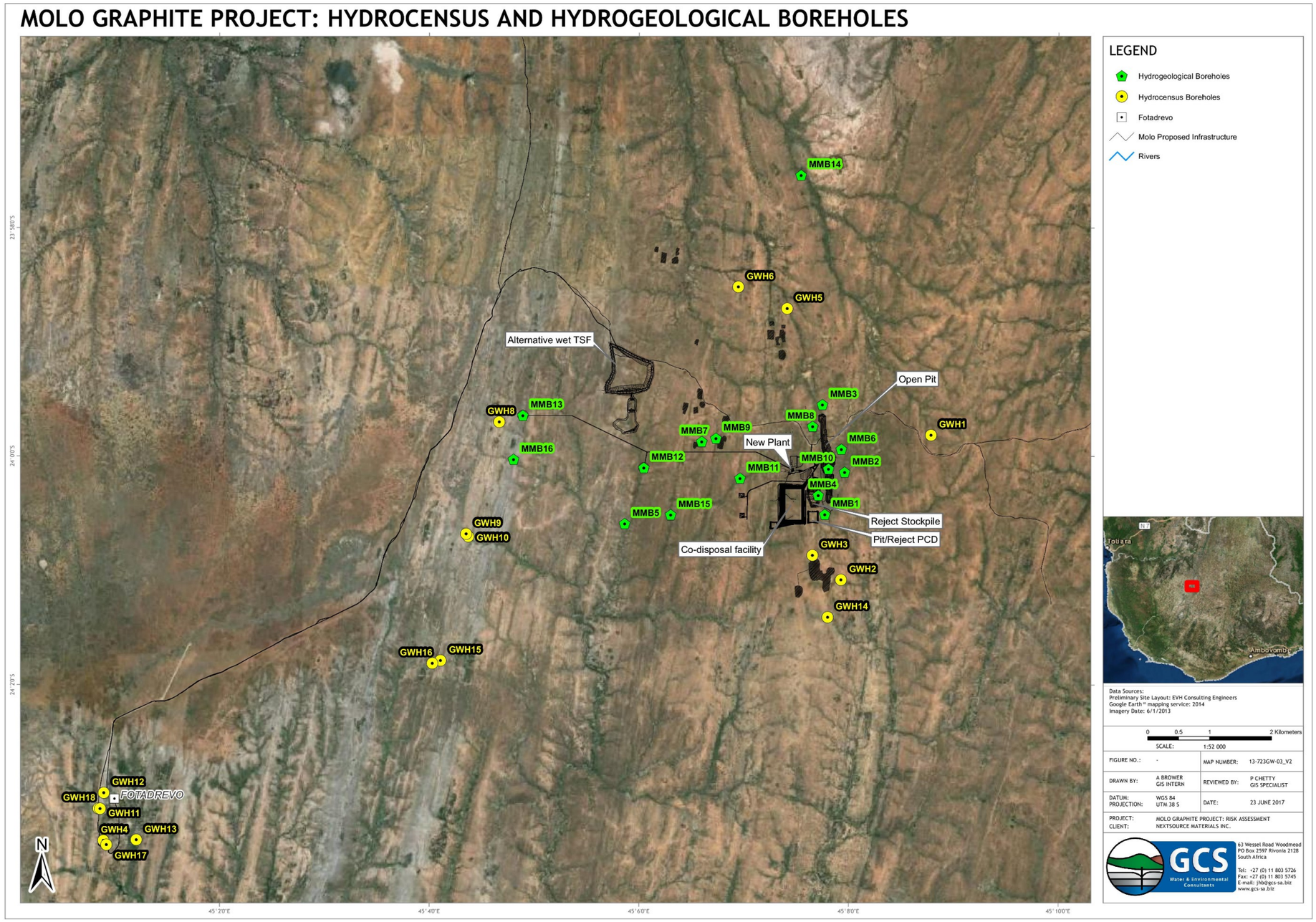


Figure 11.18: Hydrocensus and hydrogeological borehole locality map

11.1.3.4 *Geophysics Survey*

The resistivity survey was completed in March 2014 and consisted of eighteen (18) geophysical traverses conducted to distances ranging between 500 and 1 200 m, totalling 14 600 m. The geophysical traverses are summarized in Table 11.14 and the localities are shown in Figure 11.19. The resultant modelled resistivity profiles are presented in Annexure 11 C.

Traverse MOL01 was completed at the northern extent of the proposed Molo open pit to a final length of 600 m in a W-E direction. The resultant resistivity profile (refer to Appendix A) was interpreted and one (1) potential drilling target (MOL01_325) was identified at 325 m, which was interpreted as preferential weathering or subvertical structural feature.

Traverse MOL02 was completed at the northern extent of the proposed Molo open pit to a final length of 600 m in a W-E direction. The resultant resistivity profile (Annexure 11 C) was interpreted as being the graphitic zone, with targets assigned to the more conductive zone at 170 m and the contact with the surrounding gneiss at about 240 m (MOL02_170 and MOL02_240).

Traverse MOL03 was completed at the southern extent of the proposed Molo open pit to a final length of 600 m in a W-E direction. The resultant resistivity profile was interpreted and one (1) target was identified within a potential contact zone at 220 m (MOL03_220). The anomaly is associated with the graphite ore zone contact with potential weathering or higher moisture between 160 and 220 m.

Traverse MOL04 was completed at the eastern extent of the proposed Molo open pit to a final length of 1 000 m in an S-N direction. The resultant resistivity profile was interpreted and two (2) potential targets were identified at 665 and 835 m (MOL04_665 and MOL04_835). The higher conductance in depth between 665 and 835 m could be indicative of saturation.

Traverse MOL05 was completed at the eastern extent of the proposed Molo open pit to a final length of 1,000 m in an S-N direction. A potential target was identified at 140 m, targeting a potential subvertical conductive zone, potentially a structural or lithological feature (MOL05_140).

Traverse MOL06 was completed at the western perimeter of the proposed Molo open pit to a final length of 1 000 m in an S-N direction. A potential target was identified at 400 m, targeting a subvertical higher conductive zone, potentially a structural or lithological feature (MOL06_400).

Traverse MOL07 was completed at the eastern extent of the proposed Molo open pit to a final length of 1 000 m in an S-N direction. The resultant resistivity profile (Annexure 11 C) was interpreted and two (2) potential targets were identified at 620 and 895 m (MOL07_620 and MOL07_895), targeting zones of higher conductance, potential subvertical structural or lithological features.

Traverse MOL08 was completed to the south of the alternative wet TSF complex to a final length of 1 000 m in a W-E direction. Three (3) potential targets were identified at 420, 605 and 800 m (MOL08_420, MOL08_605 and MOL08_800), targeting zones of lower resistivity which may be represent subvertical structural or lithological features. The low conductance zone at surface, followed by higher conductance with depth could furthermore be related to water saturation. Target MOL08_800 is associated with weathering.

Traverse MOL09 was completed at the southwest of the proposed Molo infrastructure to a final length of 700 m in a W-E direction. Three (3) potential targets were identified at 280, 420 and 495 m (MOL09_280, MOL09_420 and MOL09_495), targeting a large zone of lower resistivity which may be representative of saturated structural or lithological features.

Traverse MOL10 was completed northwest of the proposed processing plant to a final length of 600 m in a W-E direction. Two (2) potential targets were identified at 230 and 465 m (MOL10_230 and MOL10_465), targeting potential higher conductance subvertical structural or lithological features.

Traverse MOL11 was completed southwest of the proposed Molo infrastructure a final length of 1,000 m in an S-N direction. The resultant resistivity profile was interpreted and two (2) potential targets were identified at 355 and 610 m (MOL11_355 and MOL11_610), both targeting potential higher conductance subvertical structural or lithological features.

Traverse MOL12 was completed west of the proposed Co-disposal facility area to a final length of 1 000 m in a W-E direction. A total of four (4) targets were identified from the resultant resistivity profile (Annexure 11 C). The targets were identified at 200, 280, and 565 and 760 m. Targets MOL12_200 and MOL12_280 targeted a potential shallow weathered material, while targets MOL12_565 and MOL12_760 targeted potential higher conductance subvertical structural or lithological features. The higher conductive zone in depth could potentially indicate high moisture content.

Traverse MOL13 was completed in the central region of the proposed Molo open pit to a final length of 600 m in a W-E direction. Three (3) potential targets were identified from the resultant resistivity profile (Annexure 11 C) at 215, 320 and 450 m. Targets MOL13_215 and MOL13_450 both targeting potential higher conductance subvertical structural or lithological features, while MOL13_320 targeted a horizontal contact that was interpreted as being associated with a lithological contact and/or zone of higher moisture content.

Traverse MOL14 was completed west of the Molo site to a final length of 1 200 m in a W-E direction. Three (3) potential targets were identified from the resultant resistivity profile (Appendix A) at 205 m, 505 m and 785 m. All of the targets (i.e. MOL14_205, MOL14_505 and MOL14_785) target potential higher conductance subvertical structural or lithological features.

Traverse MOL15 was completed west of the Molo site to a final length of 600 m in a W-E direction. Two (2) potential targets were at 200 and 450 m. Both MOL15_200 and MOL15_450 targeted potential higher conductance subvertical structural or lithological features.

Traverse MOL16 was completed approximately 3 km north of the proposed Molo open pit to a final length of 700 m in a W-E direction. Three (3) potential targets were at 260, 295 and 370 m. All of the targets (i.e. MOL16_260, MOL16_295 and MOL16_370) targeted potential higher conductance subvertical structural or lithological features.

Traverse MOL17 was completed approximately 6 km south west of the proposed plant area in a W-E direction to a final length of 900 m. One (1) target was identified at 585 m, a potential higher conductance subvertical structural or lithological feature.

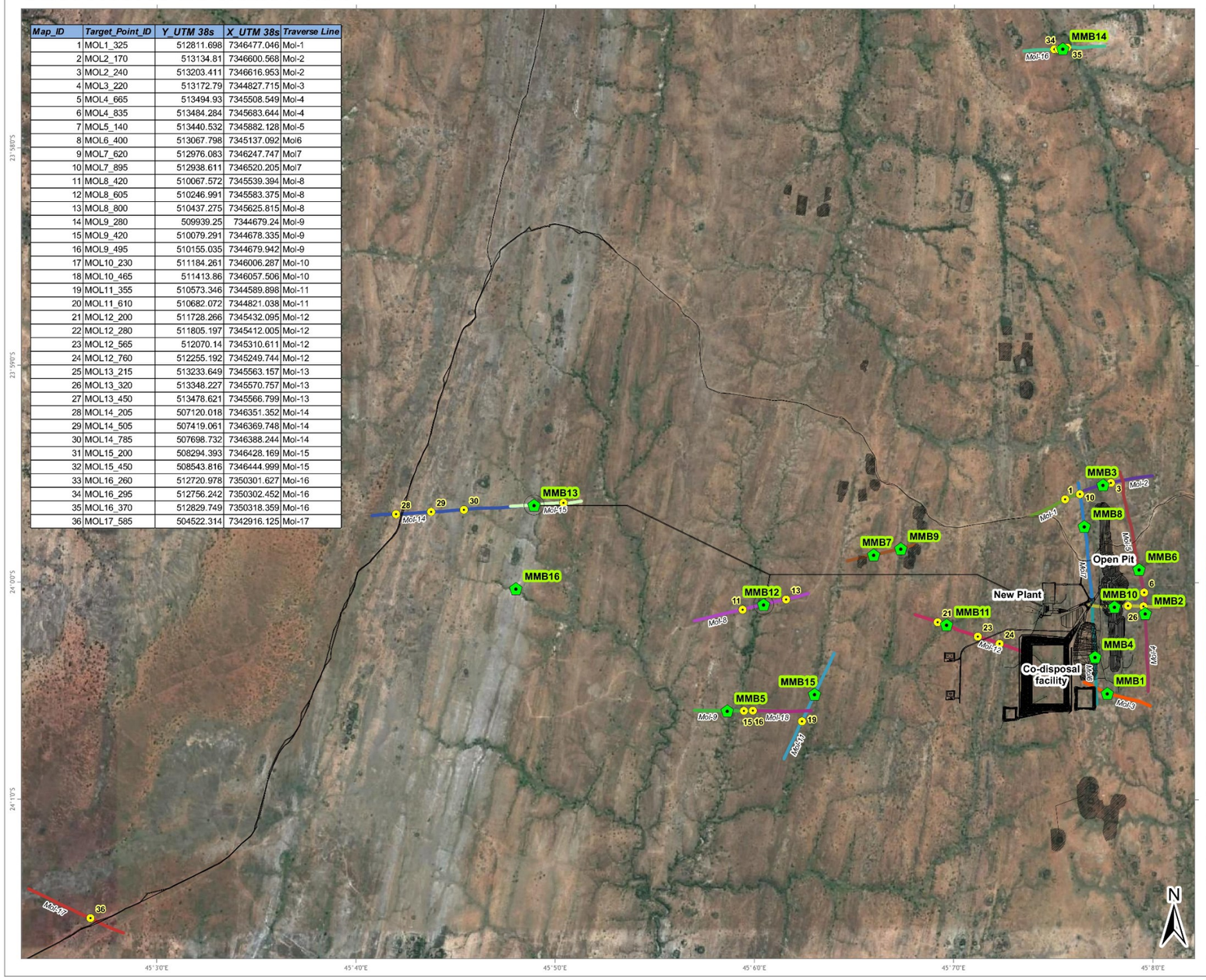
Traverse MOL18 was conducted to the southwest of the proposed Molo infrastructure to a final length of 500 m. The traverse was conducted on a steep slope with exposed bedrock and no drilling targets were identified for MOL18.

Table 11.14: Electrical resistivity survey summary

Traverse ID	Coordinates (UTM38S, WGS84)				Direction of Survey	Total Length (m)	Location	Target ID	Anomaly Description	Target Coordinates (UTM38S, WGS84)		Designation
	Start Em	Start Sm	End Em	End Sm						Em	Sm	
MOL01	512521	7346335	513067	7346583	W-E	600	Open Pit	MOL1_325	Weathering or subvertical structural feature	512811	7346477	Open pit/Monitoring
MOL02	512972	7346551	513555	7346677	W-E	600	Open Pit	MOL2_170	Graphitic zone	513134	7346600	Open pit
								MOL2_240	Graphitic zone contact	513203	7346616	Open pit
MOL03	512973	7344921	513535	7344720	W-E	600	Open Pit	MOL3_220	Graphitic zone	513172	7344827	Open pit
MOL04	513518	7344844	513456	7345834	S-N	1,000	Open Pit	MOL4_665	Higher conductance zones – potential saturation	513494	7345508	Open pit
								MOL4_835		513484	7345683	Open pit/Monitoring
MOL05	513469	7345745	513275	7346711	S-N	1,000	Open Pit	MOL5_140	Potential higher conductance subvertical structural or lithological feature	513440	7345882	Open pit
MOL06	513083	7344737	513032	7345737	S-N	1,000	Open Pit/CDF	MOL6_400	Potential higher conductance subvertical structural or lithological feature	513067	7345137	Open pit/Monitoring
MOL07	513040	7345631	512924	7346618	S-N	1,000	Open Pit	MOL7_620	Potential higher conductance subvertical structural or lithological feature	512976	7346247	Open pit
								MOL7_895		512938	7346520	Open pit
MOL08	509659	7345443	510626	7345676	W-E	1,000	South of Alternative wet TSF	MOL8_420	Higher conductance zones – potential saturation	510067	7345539	Monitoring
								MOL8_605		510246	7345583	Monitoring
								MOL8_800	Weathering	510437	7345625	Monitoring
MOL09	509659	7344684	510651	7344680	W-E	700	Regional	MOL9_280	Higher conductance zones	509939	7344679	Water resource testing
								MOL9_420		510079	7344678	Water resource testing
								MOL9_495		510155	7344679	Water resource testing
MOL10	510961	7345951	511534	7346090	W-E	600	Plant	MOL10_230	Potential higher conductance subvertical structural or lithological features	511184	7346006	Monitoring
								MOL10_465		511413	7346057	Monitoring
MOL11	510847	7345169	510420	7344270	S-N	1,000	Regional	MOL11_355	Potential higher conductance subvertical structural or lithological features	510573	7344589	Water resource testing
								MOL11_610		510682	7344821	Water resource testing
MOL12	511538	7345495	512474	7345173	W-E	1,000	CDF	MOL12_200	Weathered Zone Contact	511728	7345432	Monitoring
								MOL12_280	Weathered Zone Contact	511805	7345412	Monitoring/ Open pit
								MOL12_565	Potential higher conductance subvertical structural or lithological features	512070	7345310	Monitoring
								MOL12_760		512255	7345249	Monitoring/ Open pit
MOL13	513019	7345574	513613	7345561	W-E	600	Open Pit	MOL13_215	Potential higher conductance subvertical structural or lithological feature	513233	7345563	Open pit
								MOL13_320	Weathered Zone Contact	513348	7345570	Open pit
								MOL13_450	Potential higher conductance subvertical structural or lithological feature	513478	7345566	Open pit
MOL14	506916	7346336	508696	7346461	W-E	1,200	Regional - - West	MOL14_205	Potential higher conductance subvertical structural or lithological features	507120	7346351	Water resource testing
								MOL14_505		507419	7346369	Water resource testing
								MOL14_785		507698	7346388	Water resource testing
MOL15	508095	7346417	508696	7346461	W-E	600	Regional - West	MOL15_200	Potential higher conductance subvertical structural or lithological features	508294	7346428.	Water resource testing
								MOL15_450		508543	7346445	Water resource testing
MOL16	512461	7350288	513149	7350329	W-E	700	Regional - North of Pit	MOL16_260	Potential higher conductance subvertical structural or lithological features	512720	7350301	Water resources testing
								MOL16_295		512756	7350302	Water resources testing
								MOL16_370		512829	7350318	Water resources testing
MOL17	503993	7343165	504802	7342789.02	W-E	900	Regional - Southwest	MOL17_585	Potential higher conductance subvertical structural or lithological feature	504522	7342916	Water resource testing
MOL18	510156	7344678	510651	7344680	W-E	500		No Targets Identified				

GEOPHYSICS LOCALITY MAP

Map_ID	Target_Point_ID	Y_UTM 38s	X_UTM 38s	Traverse Line
1	MOL1_325	512811.698	7346477.046	Mol-1
2	MOL2_170	513134.81	7346600.568	Mol-2
3	MOL2_240	513203.411	7346616.953	Mol-2
4	MOL3_220	513172.79	7344827.715	Mol-3
5	MOL4_665	513494.93	7345508.549	Mol-4
6	MOL4_835	513484.284	7345683.644	Mol-4
7	MOL5_140	513440.532	7345882.128	Mol-5
8	MOL6_400	513067.798	7345137.092	Mol6
9	MOL7_620	512976.083	7346247.747	Mol7
10	MOL7_895	512938.611	7346520.205	Mol7
11	MOL8_420	510067.572	7345539.394	Mol-8
12	MOL8_605	510246.991	7345583.375	Mol-8
13	MOL8_800	510437.275	7345625.815	Mol-8
14	MOL9_280	509939.25	7344679.24	Mol-9
15	MOL9_420	510079.291	7344678.335	Mol-9
16	MOL9_495	510155.035	7344679.942	Mol-9
17	MOL10_230	511184.261	7346006.287	Mol-10
18	MOL10_465	511413.86	7346057.506	Mol-10
19	MOL11_355	510573.346	7344589.898	Mol-11
20	MOL11_610	510682.072	7344821.038	Mol-11
21	MOL12_200	511728.266	7345432.095	Mol-12
22	MOL12_280	511805.197	7345412.005	Mol-12
23	MOL12_565	512070.14	7345310.611	Mol-12
24	MOL12_760	512255.192	7345249.744	Mol-12
25	MOL13_215	513233.649	7345563.157	Mol-13
26	MOL13_320	513348.227	7345570.757	Mol-13
27	MOL13_450	513478.621	7345566.799	Mol-13
28	MOL14_205	507120.018	7346351.352	Mol-14
29	MOL14_505	507419.061	7346369.748	Mol-14
30	MOL14_785	507698.732	7346388.244	Mol-14
31	MOL15_200	508294.393	7346428.169	Mol-15
32	MOL15_450	508543.816	7346444.999	Mol-15
33	MOL16_260	512720.978	7350301.627	Mol-16
34	MOL16_295	512756.242	7350302.452	Mol-16
35	MOL16_370	512829.749	7350318.359	Mol-16
36	MOL17_585	504522.314	7342916.125	Mol-17



LEGEND

- Boreholes
- Target Points
- Proposed Mine Infrastructure

Geophysics Traverse Lines

- Mol-1
- Mol-10
- Mol-11
- Mol-12
- Mol-13
- Mol-14
- Mol-15
- Mol-16
- Mol-17
- Mol-18
- Mol-2
- Mol-3
- Mol-4
- Mol-5
- Mol-8
- Mol-9
- Mol6
- Mol7



Data Sources:
Preliminary Site Layout from EVH Consulting Engineers
Google Earth™ mapping service: 2014
Imagery Date: 6/1/2013

0 0.25 0.5 1 Kilometers
SCALE: 1:30 000

FIGURE NO.:	-	MAP NUMBER:	13-723GW-08V4
DRAWN BY:	A BROWER GIS INTERN	REVIEWED BY:	P CHETTY GIS SPECIALIST
DATUM: PROJECTION:	WGS 84 UTM 38 S	DATE:	23 JUNE 2017
PROJECT: CLIENT:	MOLO GRAPHITE PROJECT: RISK ASSESSMENT NEXTSOURCE MATERIALS INC.		

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Figure 11.19: Locality of electrical resistivity lines

11.1.3.5 *Hydrogeological Borehole Installation and Aquifer Testing*

Borehole localities are shown in Figure 11.18. A summary of the borehole drilling and pumping test results are provided in Table 11.15 and Table 11.16 respectively. Borehole logs are presented in Annexure 11 D and pumping test data are presented in Annexure 11 E. The drilling and pumping test data for each of the hydrogeological boreholes are discussed below.

Borehole **MMB1** was drilled and constructed between 9 and 15 May 2014 to a final depth of 97.7 m below ground level at a final diameter of 8 inches. During drilling highly weathered residual gneiss was intersected until 10 m, where after more competent gneiss was encountered to final depth. A seepage water strike was intersected at 9 m below ground level at the weathered-competent rock contact zone. Additional water strikes were encountered in fractured zones at 27, 51, 61, 65, 86 and 89 m below ground level, contributing to the final borehole blow yield[1] of 1.5 l/s. The borehole was constructed using 152 mm outer diameter (OD) PVC casing, with slotted casing placed at the water strike zones intersected during drilling. No variable rate drawdown tests were done on this borehole.

The constant drawdown test was done over a period of 910 minutes at a pumping rate of 3.78 l/s. Maximum drawdown was 39.77 m and the borehole recovered 91% in 320 minutes. Pumping test data was interpreted using Cooper-Jacob and Theis residual drawdown methods. Transmissivity[2] values are 1.7 and 1.2 m^2/d for these two methods respectively.

Borehole **MMB2** was completed 19 May 2014 to a final depth of 110 m below ground level at a final diameter of 8 inches. During drilling highly weathered residual gneiss was intersected until 6 m, where after more competent gneiss, with localized pegmatite, was encountered to final depth. Water strikes were encountered in fractured zones at 35, 40, 46 and 105 m below ground level, contributing to the final borehole blow yield of 1 l/s. The borehole was constructed using 152 mm outer diameter (OD) PVC casing, with slotted casing placed at the water strike zones intersected during drilling.

[1] Blow out yield: provides an initial indication of the borehole yield measuring the flow by displacing the water from the borehole by compressed air from the drill rig compressor. It is undertaken over a relatively short period of time (0.5 to 2 hrs) and is therefore often an overestimation of long-term borehole yield.

[2] Transmissivity is a measure of the ease with which groundwater flows in the subsurface. It is the rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient. It is expressed as the product of the average hydraulic conductivity and thickness of the saturated portion of an aquifer.

A variable rate drawdown test was done in three steps of 60 minutes (step 1), 50 minutes (step 2) and 45 minutes, with pumping rates of 0.28, 0.48 and 0.70 l/s, respectively. Maximum drawdown for step 1 was 5.4 m, 15.4 m for step 2 and 34.37 m for step 3. Subsequently a pumping rate of 1.1 l/s was chosen for the constant drawdown with a duration of 910 minutes. Maximum drawdown was 42.1 m and the borehole recovered 75% in 51 minutes. Pumping test data was interpreted using Cooper-Jacob and Theis residual drawdown methods. Transmissivity values are 1.85 and 0.8 m^2/d for these two methods, respectively.

Borehole **MMB3** was drilled and constructed between 15 and 20 May 2014 to a final depth of 77 m below ground level at a final diameter of 8 inches. During drilling highly weathered residual gneiss was intersected until 8 m, where after competent gneiss was encountered to final depth. A single water strike was encountered at a fractured zone within the competent gneiss at a depth of 32 m, yielding 0.1 l/s. The borehole was constructed using 152 mm outer diameter (OD) PVC casing, with slotted casing placed at the water strike zones intersected during drilling.

The constant drawdown test was done over a period of 270 minutes at a pumping rate of 0.2 l/s. Maximum drawdown was 4.65 m and the borehole recovered 100% in 300 minutes. Pumping test data was interpreted using Cooper-Jacob and Theis residual drawdown methods. Transmissivity values are 0.09 and 0.08 m^2/d for these two methods, respectively.

Borehole **MMB4** was drilled and constructed between 23 and 25 May 2014 to a final depth of 100 m below ground level and at a final diameter of 8 inches. Highly weathered granitic phyllite was intersected to 34 m, followed by slightly weathered gneiss to 64 m and fresh gneiss to total depth. A water strike was encountered at the contact zone between weathered and competent rock at 32 m, yielding 0.75 l/s. Additional water strikes were intersected at fractured zones within the gneiss at 51, 58 and 72 m, contributing to the final blow yield of 3.2 l/s. The borehole was constructed using 152 mm OD PVC casing, with slotted casing placed at the water strike zones.

A variable rate drawdown test was done in four steps of 60 minutes each, with pumping rates of 1, 2, 2.85 and 3.33 l/s, respectively. Maximum drawdown for step 1 was 11.87 m, 28.43 m for step 2, 41.12 m for step 3 and 48.23 m for step 4. Subsequently a pumping rate of 2.1 l/s was chosen for the constant drawdown with a duration of 760 minutes. Maximum drawdown was 69.8 m and the borehole recovered 47% in 270 minutes. Pumping test data was interpreted using Cooper-Jacob and Theis residual drawdown methods. Transmissivity value is about 0.8 m^2/d.

Borehole **MMB5** was completed on 25 May 2014 to a final depth of 45 m below ground level and at a final diameter of 6 inches. Highly weathered granitic gneiss was intersected to 18 m, followed by slightly weathered gneiss to total depth. A water strike was encountered at the contact zone between weathered and competent rock at 16 m, yielding 0.8 l/s. Additional water strikes were intersected at fractured zones within the gneiss at 39 and 42 m, contributing to the final blow yield of 1.3 l/s. The borehole was constructed using 140 mm OD PVC casing, with slotted casing placed at the water strike zone.

A variable rate drawdown test was done in three steps of 60 minutes each, with pumping rates of 0.8, 1.25 and 1.66 l/s, respectively. Maximum drawdown for step 1 was 5.15 m, 6.88 m for step 2 and 20.56 m for step 3. Subsequently a pumping rate of 1.7 l/s was chosen for the constant drawdown with a duration of 120 minutes. Maximum drawdown was 26.89 m and the borehole recovered 100% in 480 minutes. Pumping test data was interpreted using Cooper-Jacob and Theis residual drawdown methods. Transmissivity values are 2.3 and 1.1 m^2/d for these two methods, respectively.

Borehole **MMB6** was completed on 28 May 2014 to a final depth of 51 m below ground level and at a final diameter of 6 inches. Moderately weathered quartzite was intersected to 31 m, followed by hard and competent quartzite to final depth. Water strikes were encountered in fractured zones at 29 and 40 m below ground level, contributing to the final borehole blow yield of 0.6 l/s. The borehole was constructed using 140 mm OD PVC casing, with slotted casing placed at the water strike zones.

A variable rate drawdown test was done in three steps of 60 minutes each, with pumping rates of 0.2, 0.4 and 0.85 l/s, respectively. Maximum drawdown for step 1 was 5.91 m, 13.76 m for step 2 and 29.48 m for step 3. Subsequently a pumping rate of 0.46 l/s was chosen for the constant drawdown with a duration of 390 minutes. Maximum drawdown was 25.48 m and the borehole recovered 99% in 65 minutes. Pumping test data was interpreted using Cooper-Jacob and Theis residual drawdown methods. Transmissivity values are 0.9 and 0.3 m^2/d for these two methods, respectively.

Borehole **MMB7** was completed on 28 May 2014 to a final depth of 30 m below ground level and at a final diameter of 5 inches. Highly weathered gneiss and graphitic gneiss were intersected to 13 m, followed by more competent quartzite to final depth. A single water strike was encountered in the fractured quartzite at 18 m below ground level, contributing to the final borehole blow yield of 0.1 l/s. The borehole was constructed using 125 mm OD PVC casing, with slotted casing placed at the water strike zone.

A variable rate drawdown test was done in two steps of 60 minutes each, with pumping rates of 0.17 and 0.30 l/s, respectively. Maximum drawdown for step 1 was 9.94 m and 18.8 m for step 2. Subsequently a pumping rate of 0.2 l/s was chosen for the constant drawdown with a duration of 270 minutes. Maximum drawdown was 16.75 m and the borehole recovered 100% in 210 minutes. Pumping test data was interpreted using Cooper-Jacob and Theis residual drawdown methods. Transmissivity values are 0.7 and 0.6 m^2/d for these two methods, respectively.

Borehole **MMB8** was completed on 31 May 2014 to a final depth of 100 m below ground level and at a final diameter of 6 inches. Highly weathered and fresh granodiorite was intersected to 41 m, followed by moderately and highly weathered schist to final depth. A seepage water strike was intersected at 36 m below ground level at the fresh granodiorite zone. Additional water strikes were encountered in highly weathered schist at 65 and 70-100 m below ground level, contributing to the final borehole blow yield of 3 l/s. The borehole was constructed using 140 mm OD PVC casing, with slotted casing placed at the water strike zones.

A variable rate drawdown test was done in two steps of 60 minutes each, with pumping rates of 1 and 2 l/s, respectively. Maximum drawdown for step 1 was 26.22 m and 75.2 m for step 2. Subsequently a pumping rate of 2.5 l/s was chosen for the constant drawdown with a duration of 90 minutes. Maximum drawdown was 68.17 m and the borehole recovered 99% in 960 minutes. Pumping test data was interpreted using Cooper-Jacob and Theis residual drawdown methods. Transmissivity was calculated as 0.6 m^2/d with both methods.

Borehole **MMB9** was completed on 31 May 2014 to a final depth of 17 m below ground level and at a final diameter of 5 inches. Highly weathered gneiss was intersected to 7 m, followed by competent siliceous gneiss to final depth. A single water strike was encountered at the contact zone between the weathered and competent rock at 7 m below ground level, contributing to the final borehole blow yield of 0.8 l/s. The borehole was constructed using 125 mm OD PVC casing, with slotted casing placed at the water strike zone.

A Variable rate drawdown test was done in four steps of 60 minutes each, with pumping rates of 0.2, 0.29, 0.44 and 0.8 l/s, respectively. Maximum drawdown for step 1 was 0.86 m, 1.5 m for step 2, 2.86 m for step 3 and 7.59 m for step 4. Subsequently a pumping rate of 0.2 l/s was chosen for the constant drawdown with a duration of 212 minutes. Maximum drawdown was 9.12 m and the borehole recovered 97% in 358 minutes. Pumping test data was interpreted using Cooper-Jacob and Theis residual drawdown methods. Transmissivity values are 1 and 3 m^2/d for these two methods, respectively.

Borehole **MMB10** was completed on 2 June 2014 to a final depth of 60 m below ground level and at a final diameter of 6 inches. Highly weathered and moderately to slightly weathered graphitic gneiss were intersected to 47 m, followed by slightly weathered quartzite to final depth. Water strikes were encountered in the graphitic gneiss as well as at the contact zone between the graphitic gneiss and quartzite at 15, 18, 37 and 47 m below ground level, contributing to the final borehole blow yield of 0.7 l/s. The borehole was constructed using 140 mm OD PVC casing, with slotted casing placed at the water strike zones.

A variable rate drawdown test was done in three steps of 60 minutes each, with pumping rates of 0.55, 0.9 and 1.33 l/s, respectively. Maximum drawdown for step 1 was 1.15 m, 1.66 m for step 2 and 3.96 m for step 3. Subsequently a pumping rate of 1.8 l/s was chosen for the constant drawdown with a duration of 190 minutes. Maximum drawdown was 31.92 m and the borehole recovered 99% in 360 minutes. Pumping test data was interpreted using Cooper-Jacob and Theis residual drawdown methods. Transmissivity values are 0.8 and 2 m^2/d for these two methods, respectively (early and late time).

Borehole **MMB11** was completed on 3 June 2014 to a final depth of 17 m below ground level and at a final diameter of 5 inches. Highly and moderately weathered gneiss was intersected to 13 m, followed by moderately to slightly weathered siliceous gneiss to final depth. Water strikes were encountered in the weathered gneiss as well as at the contact zone between the gneiss and siliceous gneiss at 7, and 14 m below ground level, contributing to the final borehole blow yield of 1.3 l/s. The borehole was constructed using 125 mm OD PVC casing, with slotted casing placed at the water strike zones.

A variable rate drawdown test was done in three steps of 60 minutes each, with pumping rates of 0.44, 0.8 and 1.33 l/s, respectively. Maximum drawdown for step 1 was 2.06 m, 4.68 m for step 2 and 8.47 m for step 3. Subsequently a pumping rate of 1.1 l/s was chosen for the constant drawdown with a duration of 540 minutes. Maximum drawdown was 6.69 m and the borehole recovered 100% in 210 minutes. Pumping test data was interpreted using Cooper-Jacob and Theis residual drawdown methods. Transmissivity values are 10 and 14 m^2/d for these two methods, respectively.

Borehole **MMB12** was completed on 3 June 2014 to a final depth of 55 m below ground level and at a final diameter of 6 inches. Highly weathered gneiss was intersected to 12 m, followed by weathered, but competent, quartzite to final depth. Water strikes were encountered in the weathered gneiss, as well as fractures in the gneiss and quartzite at 8, 12, 25 and 45 m below ground level, contributing to the final borehole blow yield of 14 l/s. The borehole was constructed using 140 mm OD PVC casing, with slotted casing placed at the water strike zones.

A variable rate drawdown test was done in four steps of 60 minutes each, with pumping rates of 1, 2, 3.33 and 3.75 l/s, respectively. Maximum drawdown for step 1 was 0.38 m, 0.83 m for step 2, 1.6 m for step 3 and 1.91 m for step 4. Subsequently a pumping rate of 3.8 l/s (maximum capacity of pumping test equipment) was chosen for the constant drawdown with a duration of 2,880 minutes. Maximum drawdown was 2.92 m and the borehole recovered 77% in 1,200 minutes. Pumping test data was interpreted using Cooper-Jacob and Theis residual drawdown methods. Transmissivity was calculated as 81 m^2/d with both methods.

Borehole **MMB13** was completed on 11 June 2014 to a final depth of 60 m below ground level and at a final diameter of 6 inches. Highly to moderately weathered marble was intersected to 51 m, followed by highly to modestly weathered schist to final depth. Water strikes were encountered in the weathered marble, as well as the contact between the marble and schist at 11, 18, 25, 35, 38, 48 and 51 m below ground level, contributing to the final borehole blow yield of 14 l/s. The borehole was constructed using 140 mm OD PVC casing, with slotted casing placed at the water strike zones.

A variable rate drawdown test was done in three steps of 60 minutes each, with pumping rates of 1, 2.5 and 3.75 l/s, respectively. Maximum drawdown for step 1 was 0.04 m, 0.06 m for step 2 and 0.1 m for step 3. Subsequently a pumping rate of 3.8 l/s (maximum capacity of pumping test equipment) was chosen for the constant drawdown with a duration of 2880 minutes. Maximum drawdown was 0.18 m and the borehole recovered 100% in 210 minutes. Pumping test data was interpreted using Cooper-Jacob and Theis residual drawdown methods. Transmissivity values are 483 and 433 m^2/d for these two methods, respectively.

Borehole **MMB14** was completed on 11 June 2014 to a final depth of 34 m below ground level and at a final diameter of 6 inches. A single water strike was encountered in the weathered zone at 11 m below ground level, contributing to the final borehole blow yield of 1 l/s. The borehole was constructed using 140 mm OD PVC casing, with slotted casing placed at the water strike zones.

The constant drawdown test was done over a period of 480 minutes at a pumping rate of 1.5 l/s. Maximum drawdown was 5.8 m and the borehole recovered 73% in 210 minutes. Pumping test data was interpreted using Cooper-Jacob and Theis residual drawdown methods. Transmissivity values are 20 and 10 m^2/d for these two methods, respectively.

Borehole **MMB15** was completed on 17 June 2014 to a final depth of 31 m below ground level and at a final diameter of 6 inches. Highly weathered and slightly weathered graphitic gneiss were intersected to 28 m, followed by siliceous gneiss to final depth. A single water strike was encountered at the contact between the graphitic and siliceous gneiss at 28 m below ground level, contributing to the final borehole blow yield of 1.2 l/s. The borehole was constructed using 140 mm OD PVC casing, with slotted casing placed at the water strike zones.

The constant drawdown test was done over a period of 210 minutes at a pumping rate of 1 l/s. Maximum drawdown was 18.14 m and the borehole recovered 21% in 360 minutes. Pumping test data was interpreted using Cooper-Jacob and Theis residual drawdown methods. Transmissivity values are 0.5 and 1.5 m^2/d for these two methods, respectively.

Borehole **MMB16** was completed on 20 June 2014 to a final depth of 38 m below ground level and at a final diameter of 6 inches. Highly weathered marble was intersected to 28 m, followed by moderately weathered and oxidized gneiss to final depth. A seepage water strike was intersected at 10 m below ground level in the weathered marble. Additional water strikes were encountered in weathered marble as well as at the contact between the marble and gneiss at 10, 13, 16, 18, 19, 22 and 28 m below ground level, contributing to the final borehole blow yield of 3 l/s. The borehole was constructed using 140 mm OD PVC casing, with slotted casing placed at the water strike zones.

The constant drawdown test was done over a period of 2,880 minutes at a pumping rate of 3.4 l/s. Maximum drawdown was 5.29 m and the borehole recovered 100% in 210 minutes. Pumping test data was interpreted using Cooper-Jacob and Theis residual drawdown methods. Transmissivity values are 97 and 46 m^2/d for these two methods, respectively.

Table 11.15: Hydrogeological borehole summary

Borehole ID	Target ID	Drilling Completion Date	Original Purpose/Target	Locality	Coordinates (UTM, Zone 38S, Datum WGS84)		Borehole Final Depth (m)	Lithological Type	Aquifer Type	Depth to Water Strike (m)	Blow Out Yield (l/s)	Depth to Groundwater Level (m)
					E (m)	S (m)						
MMB1	MOL3-220	15-May-14	Open Pit	Open Pit	513173	7344828	97	Gneiss	Weathered & Fractured	9, 27, 57, 61, 86	5	3.05
MMB2	MOL4-665	19-May-14	Open Pit	Open Pit	513495	7345509	110	Gneiss	Fractured	35, 40, 105	1.5	4.06
MMB3	MOL2-170	20-May-14	Open Pit	Open Pit	513135	7346601	77	Gneiss	Weathered contact	32	0.05	6.7
MMB4	MOL6-400	25-May-14	Open Pit/ Monitoring	Open Pit & CDF	513068	7345137	100	Gneiss	Weathered & Fractured	32, 51, 72	3.2	2.1
MMB5	MOL9-280	26-May-14	Water Resources	West of site	509939	7344679	45	Graphitic Gneiss	Weathered contact	16, 39	1.5	9.62
MMB6	MOL5-140	28-May-14	Open Pit	Open Pit	513441	7345882	51	Gneiss	Weathered & Fractured	29, 40	0.6	8.7
MMB7	MOL10-230	28-May-14	Water Resources	West of plant	511184	7346006	30	Quartzite Gneiss	Weathered contact	18	0.1	7.63
MMB8	MOL7-620	31-May-14	Open Pit	Open Pit	512976	7346248	100	Schist	Weathered & Fractured	36, 65, 70-100	3	5.78
MMB9	MOL10-465	31-May-14	Water Resources /Monitoring	West of plant	511414	7346058	18	Gneiss	Weathered contact	7	0.8	4.9
MMB10	MOL13-215	02-Jun-14	Open Pit	Open Pit	513234	7345563	60	Graphitic Gneiss (Quartz)	Weathered & Fractured	15, 37, 47	0.7	13.38
MMB11	MOL12-280	03-Jun-14	Monitoring	West of plant	511805	7345412	17	Gneiss	Weathered contact	7, 14	1.3	2.39
MMB12	MOL8-605	03-Jun-14	Water Resources/ Monitoring	South of alternative wet TSF	510247	7345583	53	Quartzite Gneiss	Weathered & Fractured	8, 12, 25, 45	14	4.4
MMB13	MOL15-200	11-Jun-14	Water Resources	Regional (West of Molo)	508294	7346428	60	Marble	Fractured	11, 18, 25, 35, 48	14	8.88
MMB14	MOL16-335	15-Jun-14	Water Resources	Regional (North of Molo)	512793	7350309	34	Quartzite Gneiss	Fractured	11	1	4.7
MMB15	MOL11-610	17-Jun-14	Water Resources	Regional (Southwest of Molo	510682	7344821	31	Graphitic Gneiss	Fractured	28	1.2	3.58
MMB16	TM001	20-Jun-14	Water Resources	Regional (West of Molo)	508140	7345717	38	Marble	Weathered & Fractured	10, 16, 22, 28	3	7.5
						Total	**921**				**50.95**	

Table 11.16: Pumping test summary

Borehole ID	Available Drawdown (m)	CD Test Rate (l/s)	CD Rate Duration (min)	Maximum Drawdown (m)	Recovery Duration (min)	Recovery (%)	Transmissivity - Cooper Jacob (m^2/d)	Transmissivity - Theis Residual Drawdown (m^2/d)
MMB1	30	3.78	910	39.77	320	91	1.7	1.2
MMB2	30	1.1	330	42.1	51	75	1.85	0.8
MMB3	25	0.2	270	40.65	300	100	0.09	0.08
MMB4	15	2	760	69.8	270	47	0.8	3.5
MMB5	15	1.7	120	26.89	480	100	2.3	1.1
MMB6	25	0.46	390	25.48	65	99	0.9	0.3
MMB7	10	0.2	270	16.75	210	100	0.7	0.6
MMB8	60	2.5	90	68.17	960	99	0.6	0.6
MMB9	2	0.2	212	9.12	358	97	1	3
MMB10	24	1.8	190	31.92	360	99	0.8	2
MMB11	12	1.1	540	6.69	210	100	10	14
MMB12	20	3.8	2880	2.92	1200	77	81	81
MMB13	25	3.8	2880	0.18	210	100	483	433
MMB14	6	1.5	480	5.8	210	73	20	10
MMB15	21	1	210	18.14	360	21	0.5	1.5
MMB16	20	3.4	2880	5.29	210	100	97	46

CD – Constant rate

11.1.3.6 *Groundwater Levels and Flow Direction*

The depth of groundwater levels measured in existing boreholes and hand dug wells during March and June 2014 are listed in Table 11.13. The groundwater level data recorded in hydrogeological site boreholes are listed in Table 11.15.

Groundwater levels vary as a function of aquifer type intersected, the position of the hand dug wells or boreholes in terms of topographic highs or lows (near drainage lines), and impact of existing abstraction. It is also anticipated that shallow aquifers, including those next to drainage lines, may exhibit seasonal water level variations.

Groundwater depth measurements across the area ranged between 2 and 17.6 metres below ground level (mbgl). The measured depth of the groundwater table at the proposed main infrastructure areas are summarized below:

Open Pit – 3 to 14 mbgl
Co-disposal facility – 2 to 10 mbgl
Processing Plant – 2 to 10 mbgl
Alternative wet TSF – 4 to 8 mbgl (shallow groundwater are expected along the drainage line)

Figure 11.20, shows groundwater level elevation versus surface elevation. A relative good linear relationship exists which suggests that the groundwater elevation mimics topography. A reason for this linear relationship is that most boreholes intercepted groundwater on the contact with the weathered and more competent rock contact. This contact appears to follow topography (on the scale of the graph).

The Molo site is situated on major catchment divide of the Onilahy River Basin and the Linta River Basin. The majority of the site is situated in the Linta River Basin and groundwater flow is generally from north to south. A northerly groundwater flow direction is anticipated along the northern perimeter of the site. The interpreted groundwater elevation contour map for area is presented in Figure 11.20.

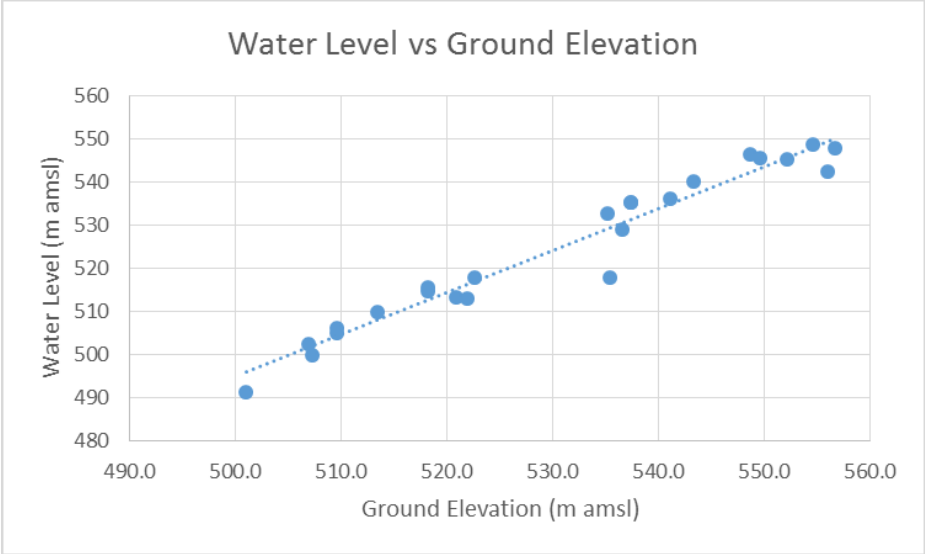


Figure 11.20: Groundwater level versus topographic elevation

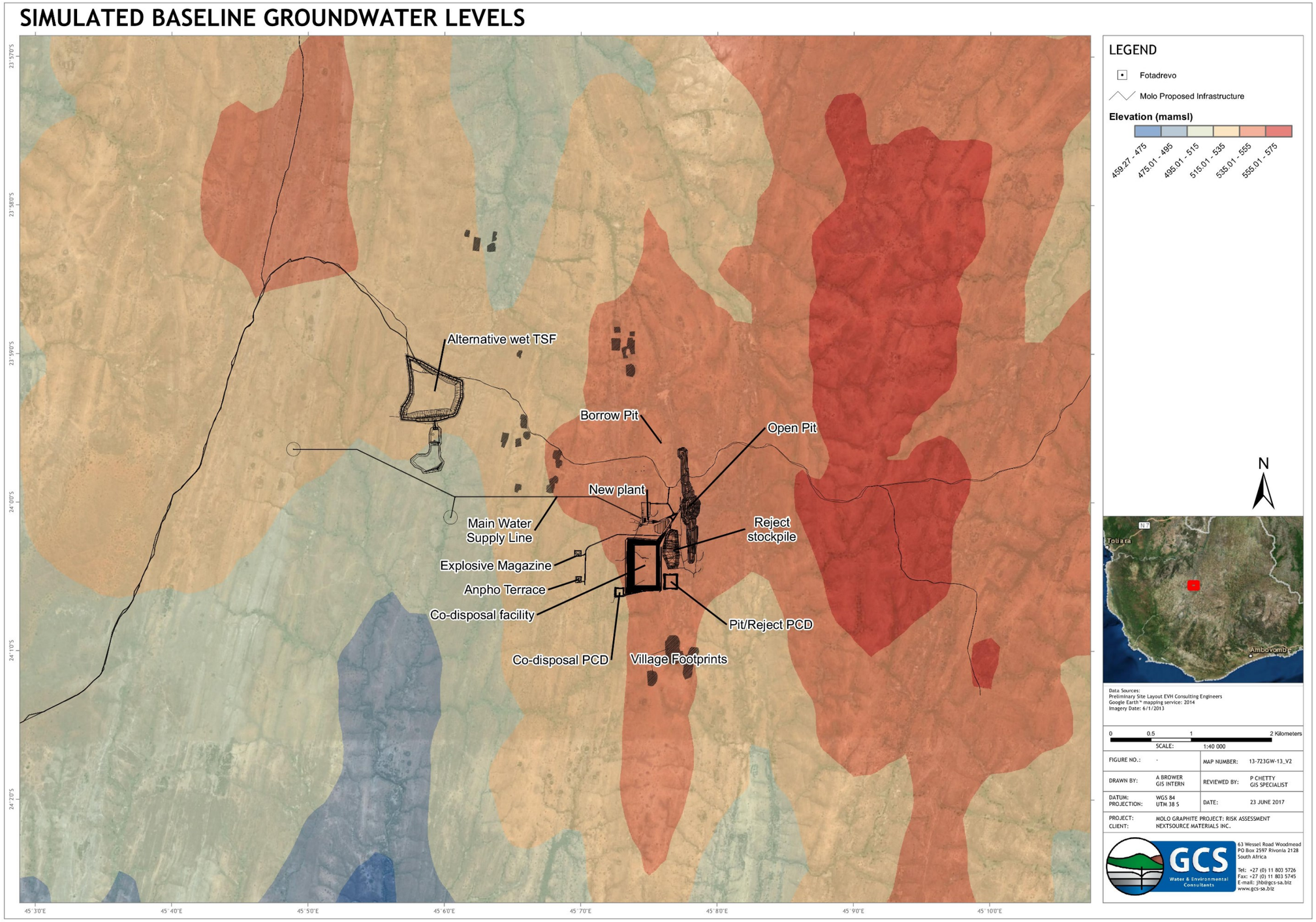


Figure 11.21: Interpreted groundwater elevation contour map

11.1.3.7 *Groundwater Quality*

Groundwater samples were taken at the following points:

- Two (2) samples were taken from springs east of the proposed Molo open pit during the wet and dry season hydrocensus - GWH1 and GWH7;
- Three (3) samples were taken from percussion boreholes, drilled by the Madagascan government, during the wet and dry season hydrocensus – GWH2, GWH6 and GWH17
- Six (6) samples were taken from hand dug wells during the wet and dry season hydrocensus – GWH4, GWH8, GWH9, GWH12, GWH13, and GWH16.
- Fifteen (15) samples were taken from the Molo hydrogeological boreholes– MMB1, MMB2, MMB3, MMB4, MMB5, MMB6, MMB7, MMB8, MMB9, MMB10, MMB11, MMB12, MMB14, MMB15 and MMB16.

The samples were submitted to Waterlab (a South African National Accreditation System accredited laboratory according to ISO/IEC 17025:2005 standards No: T0391) in Pretoria, South Africa.

11.1.3.7.1 Groundwater quality compared to water criteria guidelines/standards

The groundwater quality data was compared to the following three standards/guidelines:

- Decret No. 2004-635 Modification 2003-941 Surveillance de l'eau Normes eau Potable (Malagasy Drinking Water Standards);
- World Health Organisation Guidelines for Drinking Water (WHO, 2011);
- International Finance Corporation Environmental, Health, and Safety Guidelines for Mining Effluent.

Table 11.17, Table 11.18 and Table 11.19 show the sample analysis results compared to the relevant standards for the wet season hydrocensus, dry season hydrocensus and hydrogeological boreholes respectively. The total dissolved solids content (TDS) of the groundwater is typically 150 to 550 mg/l and pH levels typically range from 7 to 8.5. However, a number of groundwater points have higher TDS values, up to 2 860 mg/l. The majority of constituents analysed for were in compliance with all three standards/guidelines, with exception of the following:

- Elevated TDS levels, in terms of WHO Guidelines for Drinking Water Quality(>1 000 mg/l TDS), were observed in five (5) samples, typically associated with elevated chloride and sodium concentrations (GWH 20, GWH 21, MMB1 and MMB8) or elevated nitrate concentrations in the case of GWH17. Elevated Na and Cl in water do not necessarily pose a health risk to humans, but water may have a displeasing taste. The elevated nitrate concentration at GWH17, 389.5 mg/l NO_3, is most likely the cause of an adjacent, up-gradient pit latrine noticed during the hydrocensus.
- Elevated sulphate concentrations, in terms of Decret No. 2004-635 Modification 2003-941 *Surveillance de l'eau Normes eau Potable* and WHO Guidelines for Drinking Water Quality (i.e. 250 mg/l SO_4), were observed in three (3) samples (MMB1, MMB4 and MMB8). According to WHO standards, however, this is an aesthetic parameter, and therefore may have an influence on the taste or smell of the water. Sulphur minerals (sulphide minerals and secondary sulphate salts) were identified from Leco, XRF and XRD analysis from rock associated with the ore. The total sulphur analysed from rock samples were mostly <1 % S, however, measurements as high as 2.2 % S was analysed. A number of these higher sulphur zones occur in the Ampanihy litho-metamorphic group which could result in naturally elevated SO_4 concentrations. Biologically derived SO_4 from nearby stream environments which contains rice patties could also contribute to the anomalous SO_4 concentrations.
- Slightly elevated iron concentrations, in terms of Decret No. 2004-635 Modification 2003-941 *Surveillance de l'eau Normes eau Potable* and WHO Guidelines for Drinking Water Quality, and/or manganese and/or zinc concentrations, in terms of WHO Guidelines for Drinking Water Quality, are observed in some boreholes (GWH1, GWH2, GWH7, MMB1, MMB2, MMB4, MMB8, MMB9 and MMB15). These guideline levels are aesthetic based and do not necessarily pose a health risk to humans.
- Slightly elevated concentrations of nickel, in terms of International Finance Corporation Environmental, Health, and Safety Guidelines for Mining Effluent, are observed in two (2) samples (MMB2 and MMB8). These elevated levels do not pose a risk to human health at current concentrations, as they are still below the WHO Guideline for Drinking Water Quality.

Groundwater quality in general, especially for the higher yielding hydrogeological boreholes, is suitability for concrete making purposes, i.e. TDS < 2 000 mg/l, Cl < 500 mg/l, Alkalinity <1 000 mg/l, SO_4 <1 000 mg/l. Down-the-borehole EC, temperature and oxygen logging were furthermore undertaken for the hydrogeological boreholes. The results showed no obvious stratification of water quality.

11.1.3.7.2 Quality characteristics

Baseline groundwater quality data is visually presented with Piper diagrams[3] (Figure 11.22, Figure 11.23 and Figure 11.24) and showed the following dominant groundwater types:

- Sodium – bicarbonate dominant waters;
- Calcium (magnesium) - bicarbonate dominant waters; and
- Subordinate sodium – sulphate (chloride) dominant waters were present at the site.

Albite (plagioclase feldspar) is a predominant mineral in the mainly gneiss rock of the site. This mineral contains sodium ($NaAlSi_3O_8$) which could partially explain the sodium dominance in groundwater. Figure 11.25 shows groundwater and surface water chloride versus sodium concentrations. Chloride to sodium ratios of close to 1, especially those samples with a higher salt content, could be indicative of mixing with evaporative salts or older groundwater. The site is known for streams drying up during the dry season, possibly increasing evaporative sodium and chloride along stream banks. Figure 11.25 however shows that most samples are enriched with sodium versus chloride, suggesting that sodium is enriched mostly by weathering of sodium containing rock and ion exchange processes. The origin of sulphate is discussed in Section 11.2 and could also be related to the local geology. Other rock types such as marble and calcrete within the area could also contribute to calcium and magnesium in the groundwater.

[3] The Piper diagram is a trilinear plot that groups the water chemistry of the samples according to their environment properties and characteristics.

Table 11.17: Wet season groundwater hydrocensus water quality

Parameter (mg/l)	Decret No. 2004-635 (Madagascan Drinking Water Standard)[1]	WHO Drinking Water (2011)[2]	IFC Guidelines for Mining Effluent (2007)[3]	GWH1	GWH2	GWH4	GWH6	GWH7	GWH8	GWH9	GWH12	GWH13	GWH16	GWH17
pH at 25ºC	6.5-9.5	NS	6 - 9	6.2	6.9	8.1	7.4	7.8	7.9	8.2	8.2	7.9	7.7	7.5
Conductivity mS/m @ 25°C	NS	NS	NS	15.6	16.3	43.6	47.5	9.3	12.1	78.2	75.2	63.7	90	214
Total Dissolved Solids @ 180ºC*	NS	*1000*	NS	120	118	346	396	59	116	504	498	540	608	1 522
Chloride, Cl	250	*250*	NS	16	12	28	26	BDL	11	109	81	53	88	240
Sulphate, SO_4	250	*250*	NS	BDL	8	15	49	BDL	38	25	47	79	35	88
Nitrate as NO_3	50	50	NS	BDL	BDL	25.7	4.0	BDL	11.1	BDL	11.5	3.5	4.9	389.5
Nitrite as NO_2	0.1	3	NS	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.985
Fluoride, F	NS	1.5	NS	0.3	BDL	0.3	1.5	0.7	0.2	0.6	0.8	0.5	1.3	1
Calcium, Ca	NS	NS	NS	2	7	42	17	2	2	45	35	74	51	132
Magnesium, Mg	NS	NS	NS	3	3	13	18	2	2	31	24	21	35	75
Sodium, Na	NS	*200*	NS	15	9	28	47	14	20	68	82	54	96	171
Potassium, K	NS	NS	NS	1.7	12.6	2.1	BDL	BDL	BDL	8.4	4.6	5.2	4.8	15.0
Free and Saline Ammonia as NH_4	0.5	*1.5*	NS	BDL	1.3	0.2	BDL	BDL	BDL	0.2	0.3	0.3	0.2	BDL
Bicarbonate as HCO_3*	NS	NS	NS	68	73	214	205	58	44	312	341	322	458	444
Total Acidity as $CaCO_3$*	NS	NS	NS	BDL	8	12	16	12	8	BDL	8	8	16	24
Total Alkalinity as $CaCO_3$	NS	NS	NS	44	60	176	168	48	36	256	256	264	376	364
P-Alkalinity as $CaCO_3$*	NS	NS	NS	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Total Phosphate as P*	NS	NS	NS	BDL	1.1	0.9	0.2	BDL	0.4	0.6	BDL	BDL	BDL	0.5
Aluminium, Al	NS	NS	NS	0.212	BDL	BDL	BDL	1.09	5.35	0.111	BDL	0.111	0.103	0.132
Antimony, Sb	NS	0.02	NS	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Arsenic, As	NS	0.01	0.1	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Barium, Ba	NS	0.7	NS	BDL	0.082	0.481	0.041	0.025	0.124	0.171	0.136	0.064	0.192	0.297
Beryllium, Be	NS	NS	NS	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Bismuth, Bi	NS	NS	NS	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Boron, B	NS	2.4	NS	BDL	BDL	0.037	BDL	BDL	BDL	0.045	0.124	0.109	0.081	0.150
Cadmium, Cd	NS	0.003	0.05	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Chromium, Cr	NS	0.05	0.1	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Cobalt, Co	NS	NS	NS	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Copper, Cu	NS	2	0.3	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Iron, Fe	0.3	*0.3*	2	0.179	0.695	BDL	BDL	2.12	3.90	0.047	BDL	BDL	BDL	BDL
Lead, Pb	NS	0.01	0.2	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Lithium, Li	NS	NS	NS	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Manganese, Mn	NS	0.4	NS	BDL	0.271	BDL	BDL	BDL	0.025	BDL	BDL	BDL	BDL	0.670
Molybdenum, Mo	NS	NS	NS	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Nickel, Ni	NS	0.07	0.5	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Phosphorous, P	NS	NS	NS	BDL	0.866	BDL	0.064	BDL	0.157	0.271	BDL	BDL	0.066	0.431
Selenium, Se	NS	0.04	NS	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Silicon, Si	NS	NS	NS	18.5	5.9	28	47	24	33	19.3	19.9	26	40	34
Silver, Ag	NS	NS	NS	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Strontium, Sr	NS	NS	NS	BDL	0.026	0.220	0.109	BDL	BDL	0.252	0.240	0.268	0.279	0.718
Tin, Sn	NS	NS	NS	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Titanium, Ti	NS	NS	NS	BDL	0.027	BDL	BDL	0.025	0.177	BDL	BDL	0.030	BDL	BDL
Tungsten, W	NS	NS	NS	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Vanadium, V	NS	NS	NS	BDL	BDL	0.025	BDL	BDL	BDL	BDL	0.070	0.063	0.051	0.040
Zinc, Zn	NS	4	0.5	BDL	0.057	BDL	BDL	BDL	0.031	BDL	BDL	BDL	BDL	BDL
Zirconium, Zr	NS	NS	NS	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL

1 - Decret No. 2004-635 Modification 2003-941 Surveillance de l'eau Normes eau Potable (Madagascan Drinking Water Standards)

2 - World Health Organisation Guideline Values for Drinking Water (2011)

3 - International Finance Corporation Environmental, Health, and Safety Guidelines for Mining (2007)

NS – Not Specified

BDL - Below Detection Limit

Limits in italics indicate aesthetic parameters (i.e. taste)

* - ICP-OES Scan (Dissolved)

x	Does not comply with Madagascar standards for drinking water
x	Does not comply with WHO guideline values
x	Does not comply with IFC guideline values
x	Does not comply with two or more of the standards / guidelines

Table 11.18: Dry season groundwater hydrocensus water quality

Parameter (mg/l)	Decret No. 2004-635 (Madagascan Drinking Water Standard)[1]	WHO Drinking Water (2011)[2]	IFC Guidelines for Mining Effluent (2007)[3]	GWH1	GWH2	GWH4	GWH5	GWH6	GWH7	GWH8	GWH9	GWH12	GWH13	GWH14	GWH16	GWH20	GWH21
pH at 25ºC	6.5-9.5	NS	6 - 9	6.9	6.7	7.7	8.1	7.5	7.7	7.7	7.3	7.6	7.5	7.4	7.6	7.6	7.9
Conductivity mS/m @ 25°C	NS	NS	NS	17.2	35.5	62.7	94.1	42.3	27.9	71.6	138	75	74.6	76.9	89.6	367	511
Total Dissolved Solids @ 180ºC*	NS	*1000*	NS	132	246	398	590	342	224	484	792	464	480	532	556	2144	2864
Chloride, Cl	250	*250*	NS	12	19	47	53	19	23	7	230	63	41	60	79	963	1483
Sulphate, SO_4	250	*250*	NS	BDL	BDL	24	62	48	7	33	42	45	84	177	33	209	219
Nitrate as NO_3	50	50	NS	BDL	BDL	57.6	BDL	3.1	8	11.5	BDL	7.5	2.2	0.9	3.1	21	38
Nitrite as NO_2	0.1	3	NS	BDL	BDL	1.3	0.3	BDL	BDL	1.3	BDL	BDL	0.7	BDL	BDL	BDL	BDL
Fluoride, F	NS	1.5	NS	0.4	0.3	0.3	1.5	1.8	1.2	3.7	0.8	0.4	0.8	1.7	1.2	0.4	0.9
Calcium, Ca	NS	NS	NS	2	6	48	15	16	3	7	58	31	60	11	45	112	76
Magnesium, Mg	NS	NS	NS	3	9	19	23	16	5	10	57	22	22	18	34	70	95
Sodium, Na	NS	*200*	NS	23	36	40	155	49	50	153	135	89	57	108	89	518	789
Potassium, K	NS	NS	NS	4.00	9.30	3.20	5.60	1.00	BDL	1.70	9.90	4.80	4.80	6.50	4.40	43.00	89.00
Free and Saline Ammonia as NH_4	0.5	*1.5*	NS	1.03	7.7	0.6	5.5	0.6	0.4	0.6	1.03	0.6	0.3	0.3	10.6	BDL	BDL
Bicarbonate as HCO_3*	NS	NS	NS	73	190	224	463	185	156	424	458	317	322	122	429	346	161
Total Acidity as $CaCO_3$*	NS	NS	NS	16	40	12	8	8	24	8	20	<5	16	32	24	12	8
Total Alkalinity as $CaCO_3$	NS	NS	NS	60	156	184	380	152	128	348	376	260	264	100	352	284	132
P-Alkalinity as $CaCO_3$*	NS	NS	NS	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Total Phosphate as P*	NS	NS	NS	0.2	0.8	0.5	0.3	0.4	0.5	0.5	0.5	<0.2	0.3	0.4	0.3	BDL	BDL
Aluminium, Al	NS	NS	NS	0.29	BDL	BDL	BDL	BDL	1.35	0.15	BDL	BDL	BDL	BDL	BDL	0.17	0.16
Antimony, Sb	NS	0.02	NS	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Arsenic, As	NS	0.01	0.1	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Barium, Ba	NS	0.7	NS	0.08	0.13	0.58	0.15	0.03	0.07	0.13	0.18	0.14	0.07	BDL	0.18	0.06	BDL
Beryllium, Be	NS	NS	NS	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Bismuth, Bi	NS	NS	NS	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Boron, B	NS	2.4	NS	0.03	0.07	0.05	0.11	0.03	0.03	0.08	0.07	0.12	0.10	0.15	0.07	0.39	0.44
Cadmium, Cd	NS	0.003	0.05	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Chromium, Cr	NS	0.05	0.1	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Cobalt, Co	NS	NS	NS	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Copper, Cu	NS	2	0.3	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Iron, Fe	0.3	*0.3*	2	0.94	0.67	BDL	0.05	BDL	1.79	0.12	0.18	BDL	BDL	0.07	BDL	BDL	BDL
Lead, Pb	NS	0.01	0.2	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Lithium, Li	NS	NS	NS	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Manganese, Mn	NS	0.4	NS	0.36	0.70	BDL	0.35	BDL	BDL	BDL	0.20	BDL	BDL	0.06	BDL	BDL	BDL
Molybdenum, Mo	NS	NS	NS	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Nickel, Ni	NS	0.07	0.5	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Phosphorous, P	NS	NS	NS	BDL	0.95	0.05	0.15	0.09	0.04	0.35	0.16	0.03	0.04	BDL	0.04	BDL	0.05
Selenium, Se	NS	0.04	NS	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Silicon, Si	NS	NS	NS	16.40	28	27	30	44	41	21	24	18.70	22	33	35	13.00	5.10
Silver, Ag	NS	NS	NS	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Strontium, Sr	NS	NS	NS	BDL	0.06	0.28	0.18	0.10	BDL	0.09	0.41	0.24	0.27	0.08	0.28	1.65	2.93
Tin, Sn	NS	NS	NS	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Titanium, Ti	NS	NS	NS	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Tungsten, W	NS	NS	NS	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Vanadium, V	NS	NS	NS	BDL	BDL	0.03	BDL	BDL	BDL	0.03	BDL	0.07	0.06	BDL	0.05	BDL	BDL
Zinc, Zn	NS	4	0.5	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Zirconium, Zr	NS	NS	NS	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL

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NS – Not Specified
BDL - Below Detection Limit
Limits in italics indicate aesthetic parameters (i.e. taste)
* - ICP-OES Scan (Dissolved)

x	Does not comply with Madagascar standards for drinking water
x	Does not comply with WHO guideline values
x	Does not comply with IFC guideline values
x	Does not comply with two or more of the standards / guidelines

Table 11.19: Hydrogeological borehole water quality

Parameter (mg/l)	Decret No. 2004-635 (Madagascan Drinking Water Standard)[1]	WHO Drinking Water (2011)[2]	IFC Guidelines for Mining Effluent (2007)[3]	MMB1	MMB2	MMB3	MMB4	MMB5	MMB6	MMB7	MMB8	MMB9	MMB10	MMB11	MMB12	MMB14	MMB15	MMB16
pH at 25ºC	6.5-9.5	NS	6 - 9	6.8	6.9	8	6.8	7.9	7.3	8	7.6	7.4	7.7	7.1	7.8	7.6	6.3	7.6
Conductivity mS/m @ 25°C	NS	NS	NS	218	116	56.1	150	62.5	31.3	28.9	285	27	62.8	43.8	39.4	59	46.4	71.2
Total Dissolved Solids @ 180ºC*	NS	*1000*	NS	1440	776	408	990	460	266	248	1770	191	442	326	306	414	412	426
Chloride, Cl	250	*250*	NS	430	178	36	208	12	12	10	649	8	30	26	12	31	29	32
Sulphate, SO_4	250	*250*	NS	387	210	28	354	87	12	13	272	16	42	37	16	45	110	12
Nitrate as NO_3	50	50	NS	BDL	BDL	1.33	BDL	1.77	3.10	0.89	1.33	0.89	1.77	2.21	2.21	3.54	BDL	7.53
Nitrite as NO_2	0.1	3	NS	BDL	BDL	BDL	BDL	BDL	0.33	BDL	BDL	BDL	BDL	BDL	0.33	BDL	BDL	BDL
Fluoride, F	NS	1.5	NS	0.9	0.6	1.9	0.6	1.1	0.9	1.2	0.8	1.1	0.8	2.2	0.9	1.8	1.1	0.5
Calcium, Ca	NS	NS	NS	106	44	17	38	50	9	15	96	9	29	5	34	31	12	42
Magnesium, Mg	NS	NS	NS	60	35	8	48	18	5	5	73	3	14	8	16	24	7	43
Sodium, Na	NS	*200*	NS	230	126	85	187	58	48	35	379	41	84	72	24	51	60	40
Potassium, K	NS	NS	NS	12.40	11.20	1.90	14.60	3.10	1.10	1.50	15.20	1.40	4.60	1.10	1.90	BDL	3.40	3.30
Free and Saline Ammonia as NH_4	0.5	*1.5*	NS	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Bicarbonate as HCO_3*	NS	NS	NS	185	171	297	156	341	156	176	317	161	322	185	224	332	63	419
Total Acidity as $CaCO_3$*	NS	NS	NS	48	20	BDL	28	BDL	12	BDL	12	12	8	12	16	BDL	48	BDL
Total Alkalinity as $CaCO_3$	NS	NS	NS	152	140	244	128	280	128	144	260	132	264	152	184	272	52	344
P-Alkalinity as $CaCO_3$*	NS	NS	NS	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Total Phosphate as P*	NS	NS	NS	0.5	0.5	0.2	0.6	0.4	1	0.3	1.2	1.1	0.9	0.9	0.2	0.5	2.7	0.2
Aluminium, Al	NS	NS	NS	0.18	0.14	BDL	0.12	0.13	0.15	BDL	0.18	0.74	BDL	BDL	0.11	BDL	0.85	0.13
Antimony, Sb	NS	0.02	NS	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Arsenic, As	NS	0.01	0.1	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Barium, Ba	NS	0.7	NS	0.05	0.03	0.10	0.05	0.06	0.06	0.04	0.07	0.07	0.12	0.09	0.03	0.03	0.11	0.17
Beryllium, Be	NS	NS	NS	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Bismuth, Bi	NS	NS	NS	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Boron, B	NS	2.4	NS	0.12	0.13	0.07	0.17	0.03	0.04	BDL	0.13	BDL	0.08	0.07	BDL	BDL	0.06	0.06
Cadmium, Cd	NS	0.003	0.05	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Chromium, Cr	NS	0.05	0.1	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Cobalt, Co	NS	NS	NS	BDL	BDL	BDL	0.17	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Copper, Cu	NS	2	0.3	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Iron, Fe	0.3	*0.3*	2	BDL	0.05	BDL	BDL	BDL	0.09	BDL	0.03	1.20	BDL	BDL	BDL	BDL	1.26	BDL
Lead, Pb	NS	0.01	0.2	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Lithium, Li	NS	NS	NS	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Manganese, Mn	NS	0.4	NS	0.86	0.28	BDL	1.69	BDL	BDL	BDL	0.30	BDL	BDL	BDL	BDL	BDL	0.48	BDL
Molybdenum, Mo	NS	NS	NS	BDL	BDL	BDL	BDL	0.03	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Nickel, Ni	NS	0.07	0.5	0.10	BDL	BDL	0.11	BDL	BDL	BDL	0.03	BDL	BDL	BDL	BDL	BDL	0.03	BDL
Phosphorous, P	NS	NS	NS	BDL	BDL	0.05	BDL	0.11	0.19	0.09	BDL	0.47	0.04	0.32	0.08	0.10	0.85	BDL
Selenium, Se	NS	0.04	NS	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Silicon, Si	NS	NS	NS	45.00	45.00	45.00	41.00	40.00	44.00	45.00	37.00	42.00	44.00	42.00	51.00	59.00	56.00	28.00
Silver, Ag	NS	NS	NS	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Strontium, Sr	NS	NS	NS	0.26	0.13	0.11	0.28	0.19	0.05	0.04	0.64	0.04	0.18	0.04	0.14	0.18	0.05	0.18
Tin, Sn	NS	NS	NS	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Titanium, Ti	NS	NS	NS	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.04	BDL
Tungsten, W	NS	NS	NS	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Vanadium, V	NS	NS	NS	BDL	BDL	0.03	BDL	0.04	BDL	BDL	BDL	0.04	0.04	0.09	0.06	BDL	BDL	BDL
Zinc, Zn	NS	4	0.5	0.22	0.68	BDL	0.31	BDL	BDL	BDL	0.92	BDL	0.05	BDL	BDL	BDL	0.04	BDL
Zirconium, Zr	NS	NS	NS	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL

1 - Decret No. 2004-635 Modification 2003-941 Surveillance de l'eau Normes eau Potable (Madagascan Drinking Water Standards)
2 - World Health Organisation Guideline Values for Drinking Water (2011)
3 - International Finance Corporation Environmental, Health, and Safety Guidelines for Mining (2007)
NS – Not Specified
BDL - Below Detection Limit
Limits in italics indicate aesthetic parameters (i.e. taste)
* - ICP-OES Scan (Dissolved)

x	Does not comply with Madagascar standards for drinking water
x	Does not comply with WHO guideline values
x	Does not comply with IFC guideline values
x	Does not comply with two or more of the standards / guidelines

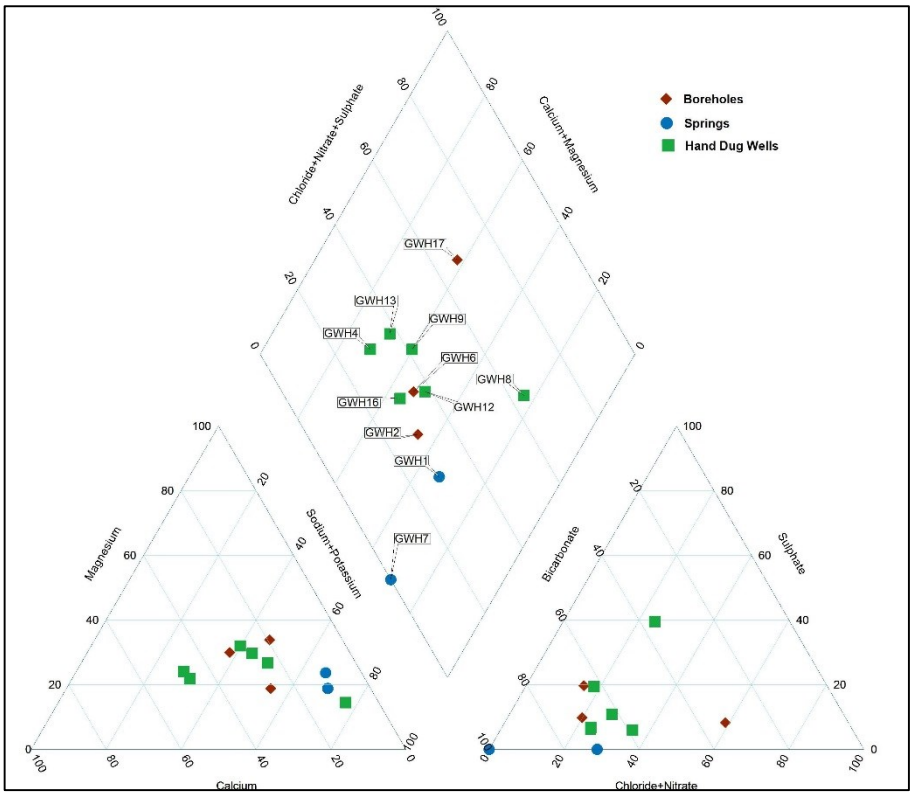


Figure 11.22: Piper diagram of samples from wet season hydrocensus

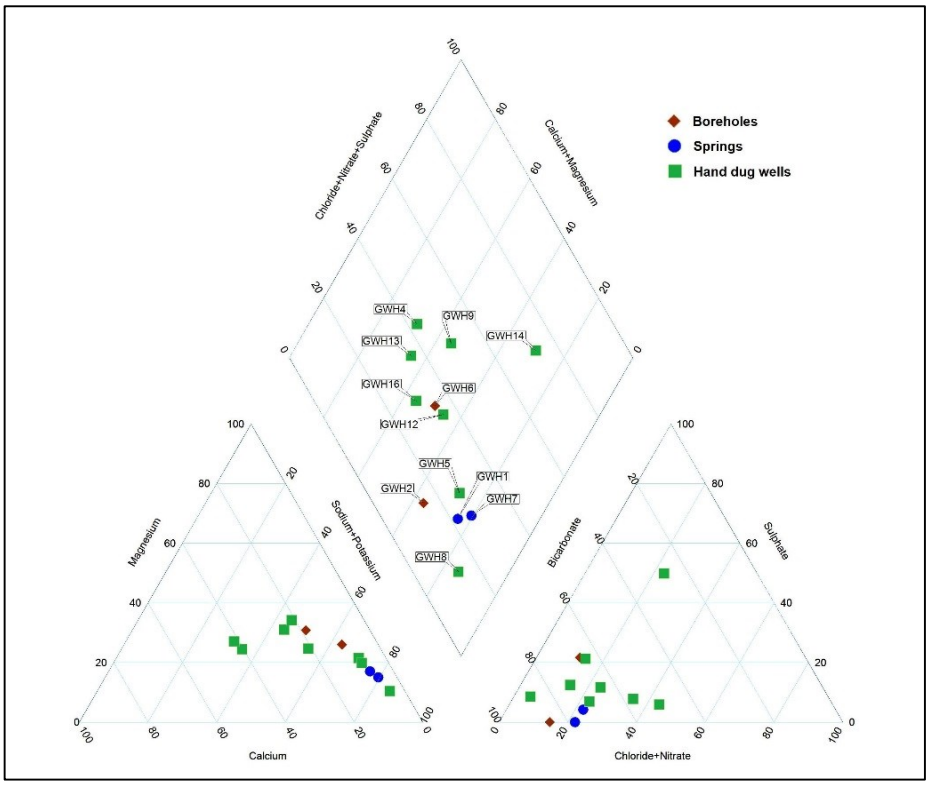


Figure 11.23: Piper diagram of samples from dry season hydrocensus

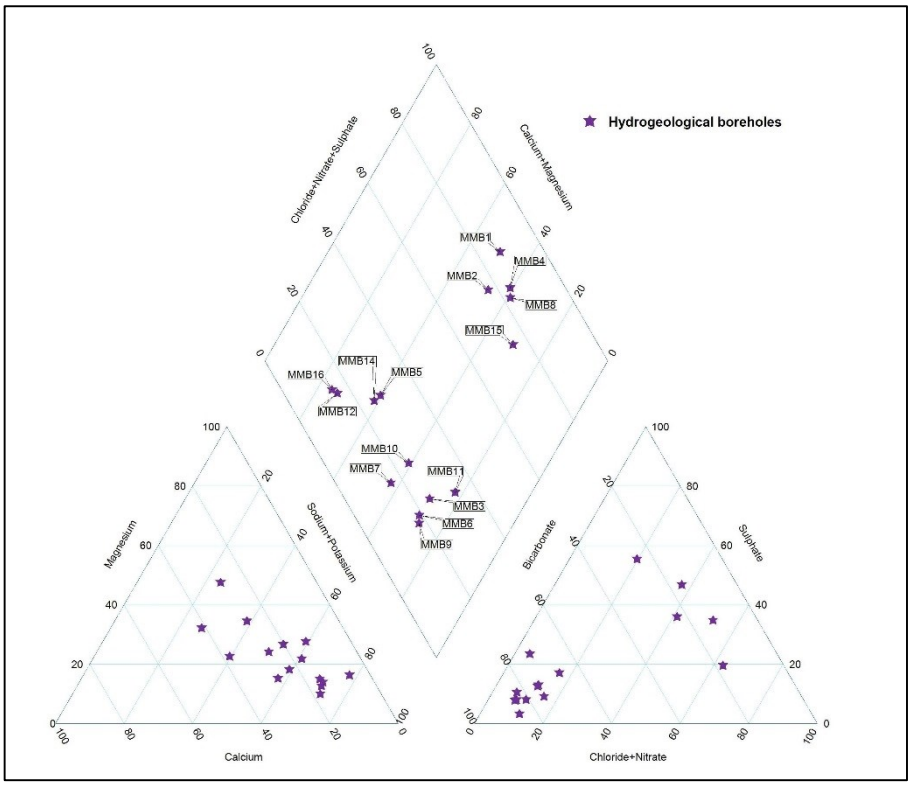


Figure 11.24: Piper diagram of samples from hydrogeological boreholes

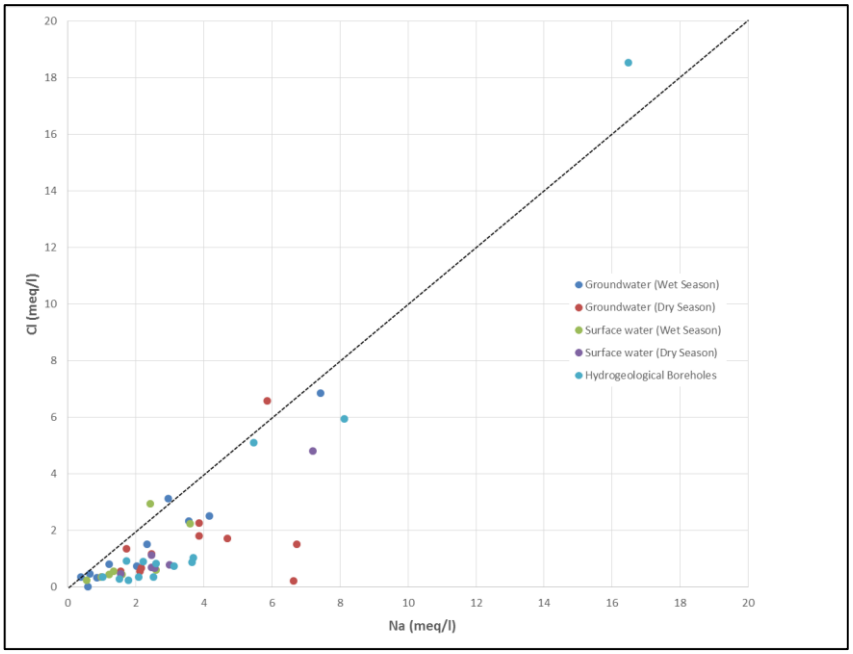


Figure 11.25: Chloride versus sodium concentrations

11.1.3.8 *Conceptual Hydrogeological Model*

The site is underlain predominantly by metamorphic lithology units which all dip sub-vertically and strike approximately north-south. The topography of the site is undulating with the ridges appearing to be related to more competent lithology and striking north-south. Numerous non-perennial rivers are present in the valleys at the site, generally flowing towards perennial rivers at the outer boundaries of the site. Some of these drainage lines contain sandy alluvial deposits, although not well developed close to the proposed mine site. Based on the results of the hydrocensus and hydrogeological borehole installation campaign (Table 11.15) four hydrogeological units or aquifers are present at the site, namely:

- Localised alluvial deposits down-stream of the proposed mine site (primary alluvial aquifer or hydrogeological unit).
- Secondary aquifer:
    - The upper weathered or intragranular hydrogeological unit.
    - The upper fractured rock hydrogeological unit.
    - The lower fractured rock unit.

Main aquifer at the proposed mine site

Figure 11.28 shows a conceptual hydrogeological cross-section of the proposed Molo Graphite Project site. The different aquifer units and properties of the conceptual model are discussed below.

Sandy (weathered gneiss) alluvial deposits were noted along some of the river channels. Alluvial deposits are not well developed in the vicinity of the proposed main mining activities i.e. open pit, processing plant and co-disposal facility which is located on local catchment divides. Alluvial aquifers are likely further downstream of the Molo site as confirmed by the locality of hand-dug wells. A hydraulic conductivity of around 1 m/d for alluvial material is estimated with thickness not likely to exceed 5 m.

Most streams are non-perennial and bank storage (from alluvial and saprolite material) could contribute to recharge of the secondary aquifer under localised (seasonal) loosing stream conditions or when abstraction of the secondary aquifer takes place adjacent to streams (induced leakage).

The upper weathered unit is comprised of highly to medium weathered saprolite and saprock often associated with drainage features. The geology of the area has a north - south trend with drainage lines following the lithological units that preferentially weathers. The unit is approximately 10 to 30 m thick along valley sides and bottom and typically has a transmissivity value of less than 1 m^2/day. Weathering at the proposed open pit is typically less than 24 metres in depth as derived from geotechnical drilling.

The upper fractured hydrogeological unit is comprised of fractured, slightly (to medium) weathered gneiss, graphitic gneiss, minor quartzite/quartz veins and marble and is the highest yielding hydrogeological unit at the site. The depth of the unit was defined using groundwater intersection data recorded during the drilling of hydrogeological boreholes. Figure 11.26 shows the water strike distribution with depth. Figure 11.27 shows the approximate blow-out yield per groundwater intersection depth. Most groundwater intersections were encountered above 50 metres below ground level, taking all boreholes deeper than 60 metres into account. The groundwater intersection data also suggests that the yield generally decreases with depth. The weathered zone and upper fractured unit are likely to be mostly inter-connected and does not necessarily act as discreet aquifers and a large number of water strikes were recorded around the contact of the two units. The fractured rock up to a depth of about 50 m and upper weathered zone (and alluvial material where applicable) are interpreted as the **main aquifer** zone based on groundwater frequency and blow-out yield data.

Pumping tests indicate a large distribution range of transmissivity values, as can be expected from fractured aquifers. The gneiss, more siliceous zones and quartzite lithologies have transmissivity values, based on the pumping test data in Table 11.15, between 0.1 and 100 m^2/d, with a mean value of about 2 m^2/d. Two boreholes were drilled in marble with transmissivity values of 97 and 483 m^2/d, respectively. The drilling data suggests that the secondary aquifer properties are better developed in the marble, quartzite/siliceous layers and other preferentially weathered units. The Vohibory litho-metamorphic group geology (Section 11.1.3.2.1) situated towards the west of the Molo Graphite Project site, containing marble and amphibolite gneiss, and has in general much better aquifer characteristics than the mainly quartzofeldspathic gneiss of the Ampanihy litho-metamorphic group associated with the proposed mining site.

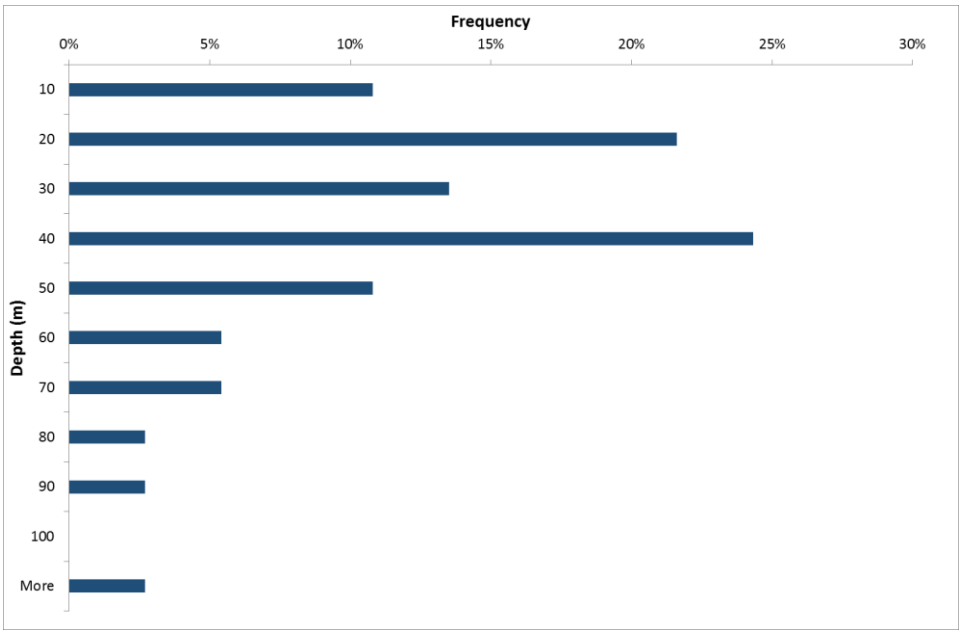


Figure 11.26: Depth distribution of groundwater intersections recorded in hydrogeological boreholes

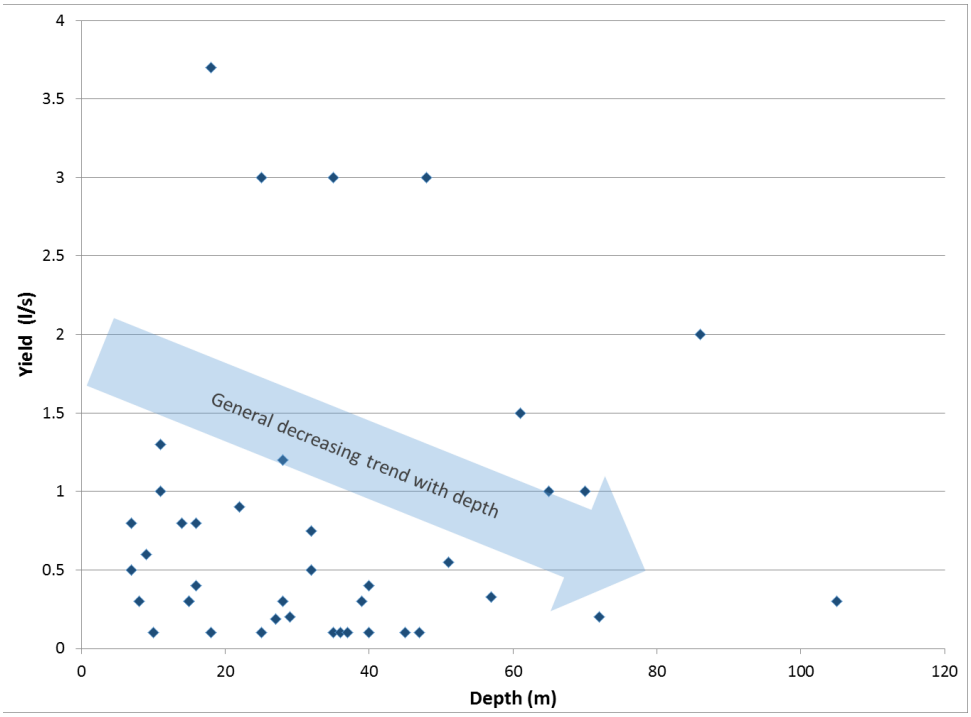


Figure 11.27: Blow-out yield versus depth

The lower fractured rock unit is comprised of generally competent lithology with localized sub-vertical fracture zones. The lower frequency of fractures results in an overall lower aquifer potential. Fractures are furthermore likely to close with depth.

The upper weathered unit and or fractured unit are the receptor for recharge from rainfall. Recharge for the area is given as 20 mm to 100 mm (UNESCO, 2008). Groundwater modelling (Annexure 11 F) suggests that the regional effective rainfall recharge is towards the lower value of about 20 mm per annum, i.e. 2.5 % of MAP (799 mm/a). However, higher groundwater recharge is likely for the higher yielding marble aquifer units. Preliminary Chloride Mass Balance (CMB) calculations, although not suitable for calculating recharge in all the aquifer types at site, confirmed that recharge is at least 20 mm or even slightly higher.

A number of springs have been identified at drainage lines during the hydrocensus and it is interpreted that these springs contribute to stream baseflow. However, the sodium – chloride nature of some hand-dug wells/boreholes close to drainage lines may suggest evaporative influences along non-perennial streams, i.e. localised loosing streams, abstraction induced loosing stream conditions and/or confined to stream alluvial deposits. Springs, stream wetlands and seeps are seen as the main discharge areas for groundwater.

Crystalline rock has typically specific yields around 0.1 to 1 % (Heath, 1983). Localised higher storage properties are likely in certain weathered lithologies and the alluvial sediments.

The main groundwater flow direction for the site is from north to south at the plant and open pit areas. Anisotropic flow conditions may occur, preferentially in a southern or northerly directions based on the north – south trend of geological layers.

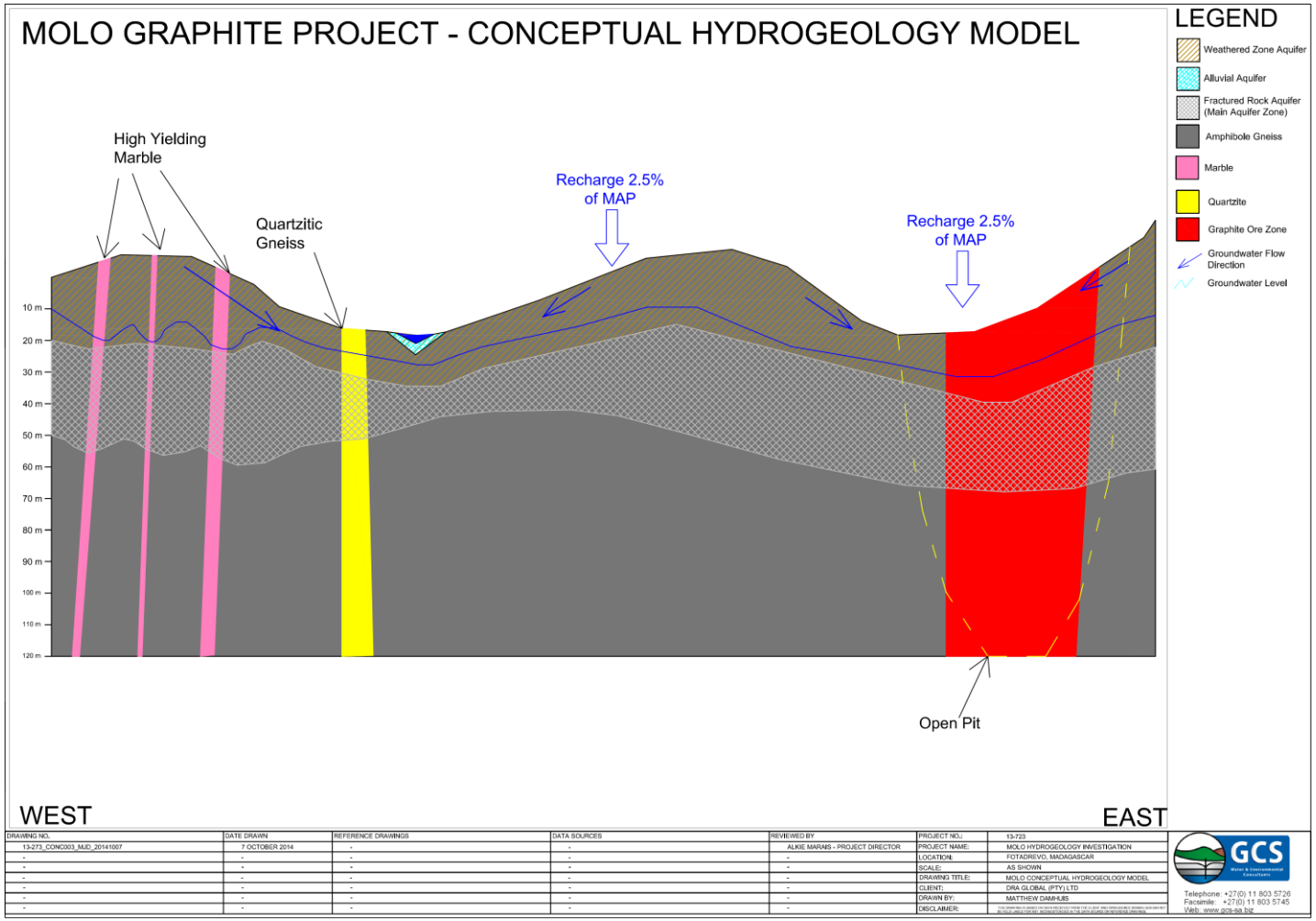


Figure 11.28: Conceptual hydrogeological section

11.2 Hydro-geochemical Assessment

11.2.1 Sampling and Test Results

11.2.1.1 *Sampling*

Thirty-four (34) waste rock samples and 1 prepared tailings sample were sourced for geochemical testing. A description of the rock samples is given in Table 11.20, including the lithologies and degree of weathering.

All waste rock samples were collected from the ore exploration boreholes by the site geologists. The tailings sample was generated by SGS Minerals Services (Lakefield, Ontario) from the trench bulk sample and exploration borehole core. All geochemical test work, as well as the preparation was performed by SGS.

The following samples were submitted for geochemical testing:

- 1 prepared tailings sample;
- 6 unspecified garnetiferous gneiss samples;
- 15 garnet gneiss samples;
- 2 biotite gneiss samples;
- 2 amphibolitic gneiss samples;
- 7 quartz feldspathic gneiss samples; and
- 2 pegmatite samples.

} Waste rock

The following comments relate to the sample representativeness:

- Lateral distribution: Waste rock samples were collected by the mine personnel from 11 exploration boreholes distributed over the mine boundary;
- Vertical distribution: Gneiss samples were collected from various depths and from both fresh to weathered rock;
- Geochemical heterogeneity: In terms of acid generation, heterogeneity was present between deep, fresh gneiss and gneiss in the weathered zone. In shallow samples, heterogeneity (in terms of AMD generation) was reduced laterally by weathering present in the gneiss.

Table 11.20: Description of samples received for geochemical testing

Borehole ID/ Site	Depth (m)	*	Rock Type	Description
Tailings	-		Tailings	Tailings prepared at SGS
W1466240	-		garnetiferous gneiss	-
W1466241	-		garnetiferous gneiss	-
W1466242	-		garnetiferous gneiss	-
W1466307	-		garnetiferous gneiss	-
W1466308	-		garnetiferous gneiss	-
W1466309	-		garnetiferous gneiss	-
MOLO26	33-34		Garnet gneiss	Moderately weathered
MOLO26	38-39		Garnet gneiss	Highly weathered
MOLO26	45.5-46.5		PEG	Moderately weathered; Pegmatite
MOLO38	64.17-65.17		QF gneiss	Highly weathered; Quartz feldspathic gneiss
MOLO38	67-68		Garnet gneiss	Fresh
MOLO38	69-70		Garnet gneiss	Fresh
MOLO31	0.5-1.5		QF gneiss	Decomposed; Quartz feldspathic gneiss
MOLO31	4-5		QF gneiss	Decomposed; Quartz feldspathic gneiss
MOLO31	9.26-10.26		QF gneiss	Decomposed; Quartz feldspathic gneiss
MOLO40	98-99		Garnet gneiss	Fresh
MOLO39	8-9		QF gneiss	Highly weathered; Quartz feldspathic gneiss
MOLO39	17.1-17.6		Amphibolitic gneiss	Fresh
MOLO39	18-19		PEG	Moderately weathered; Pegmatite
MOLO39	29-30		Garnet gneiss	Highly weathered
MOLO37	1.5-2.5		Garnet gneiss	Highly weathered
MOLO37	15-16		Garnet gneiss	Moderately weathered
MOLO37	17-18		QF gneiss	Highly weathered; Quartz feldspathic gneiss
MOLO43	116-117		Biotite gneiss	Moderately weathered
MOLO43	132-133		Garnet gneiss	Fresh
MOLO43	149-150		Garnet gneiss	Fresh
MOLO27	1-2		Garnet gneiss	Moderately weathered
MOLO27	5.3-6.3		Garnet gneiss	Fresh
MOLO27	7.5-8.5		QF gneiss	Decomposed; Quartz feldspathic gneiss
MOLO30	39-40		Garnet gneiss	Moderately weathered
MOLO32	39-40		Garnet gneiss	Fresh
MOLO41	37.5-38.5		Amphibolitic gneiss	Highly weathered
MOLO41	47-48		Biotite gneiss	Fresh
MOLO41	59-60		Garnet gneiss	Fresh

*** Red = Garnet Gneiss, Brown = Biotite Gneiss, Yellow = Amphibolitic Gneiss, Blue = QF Gneiss, Green =PEG**

11.2.1.2 *Mineralogy and Total Element Analyses*

Mineralogy and total element analyses of the tailings are presented as follows:

- Tailings X-ray diffraction (XRD) results and a simplified classification of the minerals are presented in Table 11.21 below;
- A simplified classification of minerals identified with QEMSCAN (Quantitative Evaluation of Minerals by SCANning electron microscopy) are listed in Table 11.22;
- Comparison between assay and QEMSCAN analysis in Table 11.23;
- QEMSCAN high definition mineralogical analysis in Table 11.24;
- Mineralogical content identified by QEMSCAN diagram in Figure 11.29;
- Sulphide images (of the only 2 sulphide containing waste rock samples) are depicted in Figure 11.30 to Figure 11.37;
- Major oxides determined by X-ray diffraction (XRF) (fusion disk) on the tailings sample are listed in Table 11.25;
- Trace elements determined by ICP-OES/MS (strong acid digestion) on the tailings is presented in Table 11.26;
- Major oxides for waste rock samples determined by XRF (fusion disk) are listed in Table 11.27; and
- Trace elements determined by ICP-OES/MS (strong acid digestion) on the waste rock are presented in Table 11.28.

The following comments could be made with regard to the mineral composition of the tailing and waste rock samples:

- The XRD results are only semi-quantitative and especially the trace and accessory minerals will not be accurately identified and quantified. The detection limit is reported as varying between 0.5 and 2 % depending on crystallinity of the minerals. However, some minerals below this detection limit are still reported by the laboratory;
- Quartz is present as a dominant mineral and comprises more than 50 % of the tailings sample but only 1 - 32 % of the waste rock samples;
- Albite and orthoclase are present as major and minor minerals in all samples;
- Garnet is present as a major mineral in the garnet gneiss;
- Two sulphides are present in tailings XRD namely pyrite and chalcopyrite. Pyrrhotite was also identified in the QEMSCAN. Electron microscope images for two waste rock samples with an elevated S% are presented in Figure 11.30 to Figure 11.37. Figure 11.31, Figure 11.32 and Figure 11.34 shows that pyrite is frequently replaced with marcasite. This indicates that the conditions were once slightly acidic in the rock as marcasite forms under more acidic conditions than pyrite.

- Jarosite is present as a secondary sulphate mineral formed from the weathering of sulphides. These minerals will contribute to acid generation in the tailings. Note that both chalcopyrite and jarosite contains 2 mol S and produces 3 mol of acidity, whereas pyrite contains 2 mol S but produce 4 mol (25% more) acidity ($Fe(OH)_3$(ppd) + $2SO_4^{2-}$ + $4H^+$).

  Equation 11.3:
  pyrite + $3.75O_2$(aq) + $3.5H_2O \rightarrow Fe(OH)_3$(ppd) + $2SO_4^{2-}$ + $4H^+$

  Equation 11.4:
  chalcopyrite + $3.5H_2O$ + $4.25O_2$(aq) $\rightarrow Fe(OH)_3$(ppd) + $CuOH^+$ + $2SO_4^{2-}$ + $3H^+$

  Equation 11.5:
  jarosite-K + $3H_2O \rightarrow 3Fe(OH)_3$(ppd) + K^+ + $2SO_4^{2-}$ + $3H^+$

- Carbonate minerals (e.g. calcite, dolomite) were present at low concentrations in the QEMSCAN. The tailings and waste rock will therefore have a relatively low neutralisation potential in order to neutralise acid generation. Any neutralisation potential will mostly originate from the weathering of silicate minerals;
- Overall, the litho-stratigraphy is relatively deeply weathered which would have resulted in the oxidation of pyrite and the occurrence of natural acid rock drainage. Recrystallisation of Fe-sulphide in deeper rock (where no oxidation was present) resulted in the formation of marcasite. The natural acidic conditions resulted in the total consumption of carbonate minerals that would explain the relative absence of calcite and dolomite, although carbonate minerals are also naturally low in gneiss. The gneiss contains relatively high Na and K (with respect to Ca and Mg). Jarosite and alunite precipitates under the natural acidic conditions (pH < 3) as an abundance of Fe/Al, Na/K and SO_4 were present. This natural acid rock drainage did occur in recent geological time upon weathering (Quaternary Period) and not during the formation of the gneiss;
- 1 highly weathered (logged as decomposed) overburden (waste rock) sample from borehole MOLO31 taken from 4-5 m contains a significant jarosite and alunite content (S% 0.89; jarosite 5.55 wt%; alunite 1.05; the highest jarosite in all samples tested), and has a paste pH of 6.79 (representative of the pH of the interstitial water). Jarosite had enough time to weather and to generate net acidity (based on the high acid generation potential of the jarosite and low neutralisation potential (NP) in the sample) as the rock decomposed. The sample is also high in oxides (6.81 wt%; probably goethite) that indicates that some jarosite already reacted according to the following incongruent reaction:

  Equation 11.6:
  jarosite-K $\rightarrow$ $3H^+$ + 3goethite (yellow stains on rock) + $2SO_4^{2-}$ + K+

The sample has however a near neutral pH which indicates that acidity must have been consumed in some way by the sample. This could only be explained by the weathering of silicate minerals. The sample is also high in clays which indicate silicate mineral dissolution and a high degree weathering over time;

- Typical mineral reactions that will be present in the tailings and waste rock (including silicate dissolution) are further discussed in the geochemical model results in Section 11.2.2.6.

The following comments relate to the elemental composition of the samples:

- No major elements (expressed as oxides) are significantly elevated in the samples above the average upper crust of Rudnick and Gao (2003) except 1), except for P_2O_5 which is elevated more than 5 times in the tailings and 2) CaO in two gneiss samples (MOLO 41 37-38m and 47-48m). The elevation of P_2O_5 can be contributed to the presence of apatite in the tailings. Apatite generally often shows concentration in pegmatite;
- Trace elements elevated 3 to 5 times above the AUC in the tailings, include Cu, Sr; and those more than 5 times: Ba, Cd, Mo, Se, Tl, U and V;
- Trace elements elevated 3 to 5 times above the AUC in some waste rock samples are Ba, Cd, Cu, V and those more than 5 times: Se (all samples), Cd, Mo, Ni and Zn;
- Various of the elevated traces are chalcophile elements (preference for sulphur) such as Cd, Cu, Ni, Se and Zn and is associated with sulphides e.g. Cu in chalcopyrite and Ni in pyrrhotite etc.;
- The high Ba is notable and it is mostly associated with K in orthoclase. Upon weathering of orthoclase (and the release of Ba) $BaSO_4$ may form in trace amounts. $BaSO_4$ is fairly insoluble and will not contribute to acid generation as jarosite discussed above; and
- Elevation above the average upper crust is however not an indication of the leachability of these trace elements and metals. The leachability will be assessed through leaching tests.

Table 11.21: Semi-quantitative X-ray diffraction results of tailings (%)

(detection limit 0.5-2% varying upon crystallinity)

Sample ID / Description/Rock Type	Tailings (%)	*	Theoretical formula	Mineral Type/Group	Sub-group
Quartz	52.5		SiO_2	Tectosilicate	Tectosilicate
Albite	22.9		$NaAlSi_3O_8$	Tectosilicate	Plagioclase series
Orthoclase	14.1		$KAl_3Si_3O_8$	Tectosilicate	K(Na, Ba) Feldspar group
Graphite	3.1		C	Native Elements	Carbon Polymorph
Chlinochlore	1.7		$(Mg,Fe^{2+})5Al(Si_3Al)O_{10}(OH)_2 \cdot (Mg,Fe)_3(OH)$	Phyllosilicates	Chlorite Group
Pyrite	1.3		FeS_2	Sulphides	Pyrite Group
Magnetite	1.1		Fe_3O_4	Multiple Oxides	Spinel Group (Iron subgroup)
Rutile	0.9		TiO_2	Simple Oxides	Rutile Group
Jarosite	0.9		$KFe(III)_3(SO_4)_2(OH)_6$	Anhydrous Sulphate	Jarosite Subgroup
Chalcopyrite	0.6		$CuFeS_2$	Sulphides	Chalcopyrite
Hydroxylapaptite	0.4		$Ca_5(PO_4)_3(OH)$	Anhydrous Phosphates	Apatite Group
Stibnite	0.3		Sb_2S_3	Sulphides	Stibnite Group

*** Mineral Type:** Grey = Fe/Al/Ti-Oxides and hydroxides Blue = Phosphates, Yellow = Sulphides and Sulphates, Red = Phyllosilicates, Green = Ino-, Tecto- and Cyclosilicates, Orange = Native Elements

Table 11.22: Identified minerals with QEMSCAN

Mineral	*	Formula	Mineral type/group	Sub-group
Pyrite		FeS_2	Sulphides	Pyrite group
Pyrophyllite		$Al(Si_4O_{10})(OH)_2$	Phyllosilicate 2:1 layer	Phyrophyllite-talc group
Quartz		SiO_2	Tectosilicates	Tectosilicate
Feldspar		$KAlSi_3O_8$ - $NaAlSi_3O_8$ - $CaAlSi_3O_8$	Tectosilicates	
Mica		$^{(1)}X_2Y_{4-6}Z_8O_{20}(OH,F)_4$	Phyllosilicates	
Chlorite		$(Mg,Fe^{2+})_5Al(AlSi_3O_{10})(OH)_8$	Phyllosilicate 1:1; 2:1 layer	Chlorite group
Amphibole/ Pyroxene		$^{(2)}$ $XYSi_6O_{22}$ /$XYSi_2O_6$	Inosilicates	
Garnet		$^{(3)}$ $XY(SiO_4)_3$	Nesosilicate	
Oxides			Simple/ Multiple Oxides	
Gypsum		$Ca(SO_4) \cdot 2H_2O$	Sulphates	Gypsum
Barite		$BaSO_4$	Sulphates	Barite Group
Alunite		$KAl_3(SO_4)_2(OH)_6$	Anhydrous Sulphate	Alunite Group
Jarosite		$K(Fe_3(SO_4)_2(OH)_6$	Anhydrous Sulphate	Jarosite Subgroup
Calcite		$CaCO_3$	Anhydrous Carbonates	Calcite group
Dolomite		$CaMg(CO_3)_2$	Anhydrous Carbonates	Dolomite group
Siderite		$FeCO_3$	Anhydrous Carbonates	Calcite group

*** Mineral Type:** Grey = Fe/Al/Ti-Oxides and hydroxides Blue = Phosphates, Yellow = Sulphides and Sulphates, Red = Phyllosilicates, Green = Ino-, Tecto-, Cyclo- and Nesosilicates, Orange = Native Elements

(1)X= K, Na, Ca; Y= Al, Mg, Fe and Z = Si, A l(2)X= Ca, Na, Fe2+, Mg and Y= Al Fe3+, Mg (3)X= Ca, Mg, Fe2+, Mn and Y= Al, Fe3+, Cr

Table 11.23: Comparison between assay and QEMSCAN analysis

Sample/ Element	Tailings	MOLO26 (33-34m)	MOLO31 (4-5m)	MOLO43 (116-117m)	MOLO43 (132-133m)	MOLO41 (47-48m)
*						
Al (QEMSCAN)	4.42	7.03	0.20	3.48	7.75	4.60
Al (Chemical)	5.40	8.42	7.41	5.98	8.42	7.73
Ca (QEMSCAN)	1.16	2.24	1.49	8.64	1.92	12.20
Ca (Chemical)	0.76	1.46	0.80	6.49	1.49	12.20
Fe (QEMSCAN)	1.84	6.41	7.00	10.70	6.07	4.65
Fe (Chemical)	1.99	5.24	5.39	8.88	7.06	6.83
K(QEMSCAN)	1.58	1.92	1.18	0.71	1.26	1.50
K (Chemical)	1.64	1.28	0.94	0.56	1.10	1.83
Mg (QEMSCAN)	0.12	2.52	0.87	4.67	3.91	4.27
Mg (Chemical)	0.11	1.31	0.36	3.72	2.47	2.67
Mn (QEMSCAN)	0.02	0.04	0.05	0.02	0.00	0.01
Mn (Chemical)	0.01	0.08	0.00	0.11	0.09	0.18
Na (QEMSCAN)	1.28	1.78	1.54	0.84	1.94	1.48
Na (Chemical)	1.21	2.24	1.68	0.86	2.31	0.94
P (QEMSCAN)	0.10	0.02	0.01	0.05	0.11	0.06
P (Chemical)	0.21	0.06	0.08	0.09	0.19	0.05
S (QEMSCAN)	0.64	0.67	1.03	2.21	1.97	0.14
S (Chemical)	0.77	0.58	0.89	2.21	1.55	0.16
Si (QEMSCAN)	36.60	28.60	29.00	23.80	28.40	25.90
Si(Chemical)	34.20	27.80	28.80	22.20	27.20	21.80
Ti (QEMSCAN)	0.57	0.50	0.85	0.48	0.90	0.30
Ti (Chemical)	0.31	0.62	0.57	0.53	0.73	0.36

Table 11.24: High definition mineralogical analysis (QEMSCAN)

Mass (%)	Tailings	MOLO26 (33-34m)	MOLO31 (4-5m)	MOLO43 (116-117m)	MOLO43 (132-133m)	MOLO41 (47-48m)
*						
Pyrite	0.01	0.01	0.01	4.10	2.96	0.05
Pyrrhotite	0.00	0.00	0.01	0.01	1.00	0.26
Other Sulphides	0.00	0.00	0.01	0.01	0.02	0.02
Quartz	54.10	22.90	32.10	9.15	21.00	1.12
Feldspar	30.10	36.80	27.00	16.3	38.40	39.30
Mica	1.09	14.70	6.61	6.76	6.66	4.26
Chlorite	0.15	0.31	0.33	0.48	0.18	0.18
Clays	5.89	7.10	18.40	9.37	0.57	0.04
Amphibole/Pyroxene	0.72	0.12	0.17	42.5	0.06	42.20
Garnet	0.24	10.70	0.61	0.59	26.40	0.39
Other Silicates	1.22	0.41	1.14	1.71	0.09	7.26
Oxides	1.69	2.01	6.81	3.88	1.62	0.32
Gypsum	0.00	0.00	0.01	0.04	0.01	0.00
Barite	0.49	0.00	0.00	0.00	0.00	0.00
Alunite	1.44	0.10	1.05	0.00	0.00	0.00
Jarosite	1.75	4.61	5.55	0.01	0.00	0.00
Fe-sulphate	0.10	0.01	0.01	0.04	0.00	0.00
Calcite	0.01	0.01	0.00	0.02	0.01	4.24
Dolomite	0.01	0.00	0.00	0.01	0.01	0.01
Siderite	0.01	0.02	0.01	4.60	0.39	0.00
Other	1.00	0.13	0.12	0.43	0.69	0.35
Total	100	100	100	100	100	100

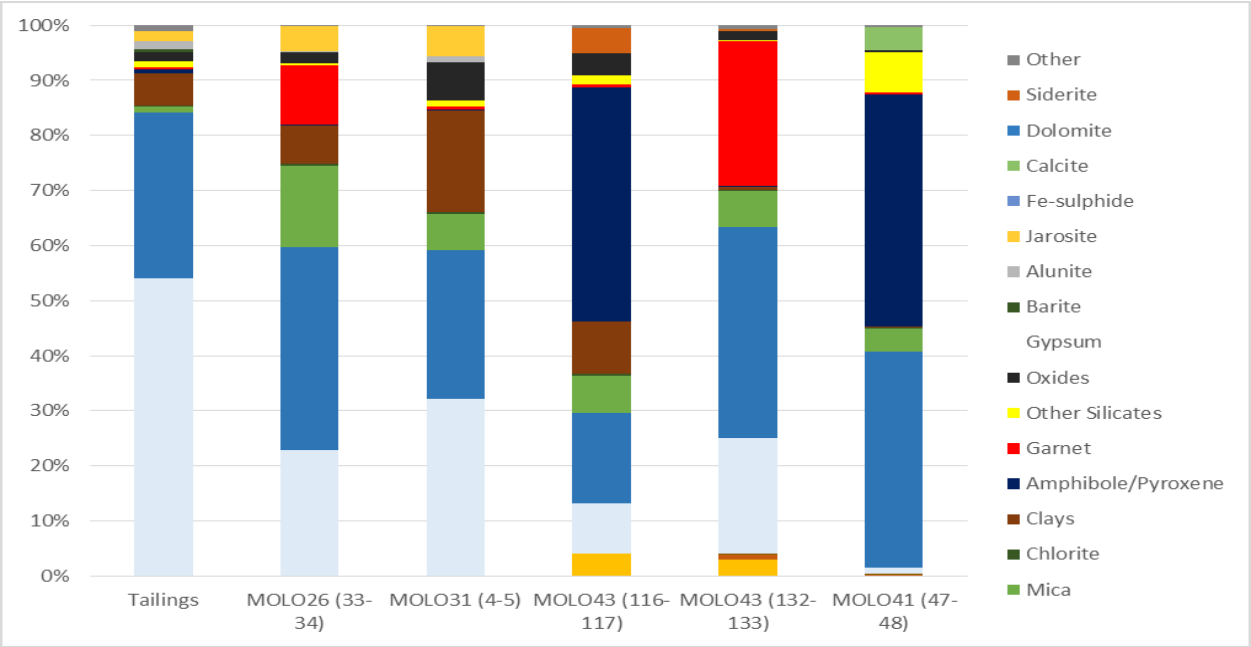


Figure 11.29: Mineralogical content identified by QEMSCAN

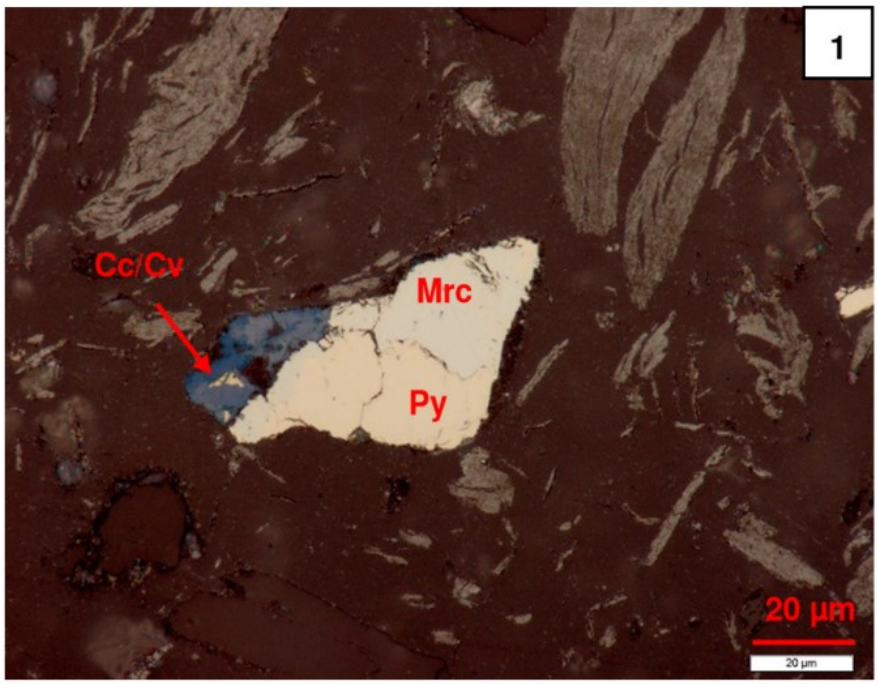


Figure 11.30: Marcasite, pyrite, chalcosite/ covalite in MOLO43 (116-117m)

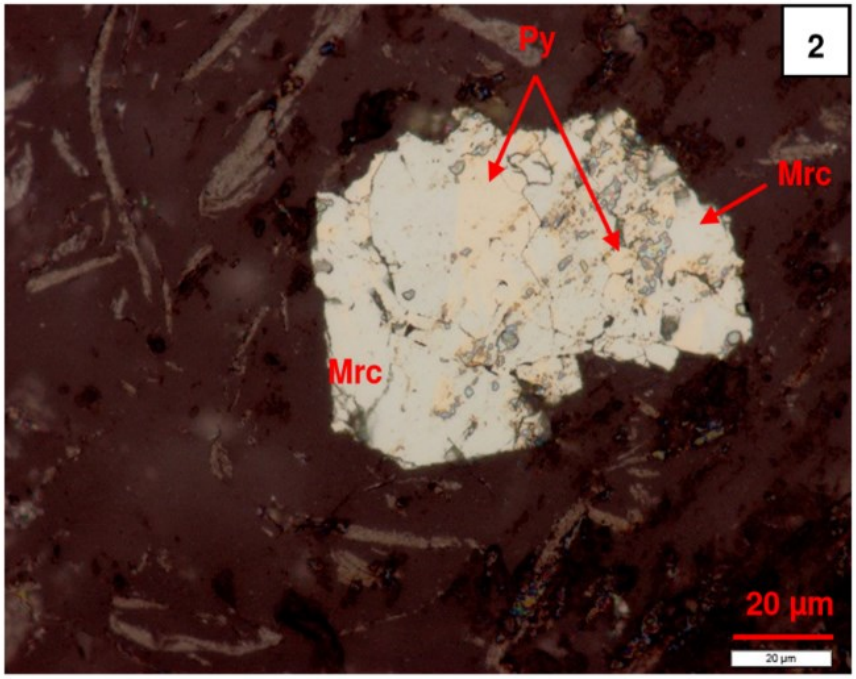


Figure 11.31: Marcasite and pyrite in MOLO43 (116-117m)

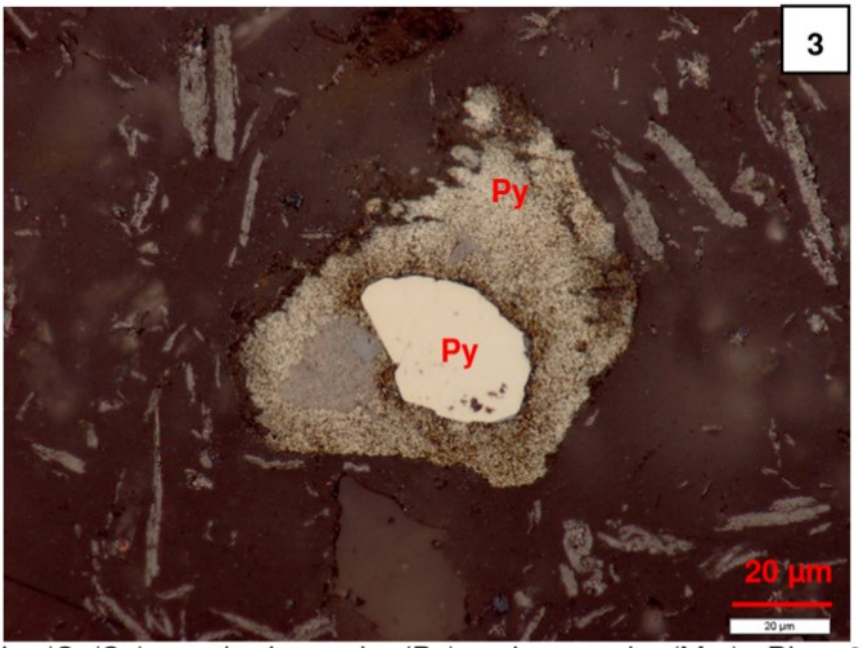


Figure 11.32: Pyrite in MOLO43 (116-117m)

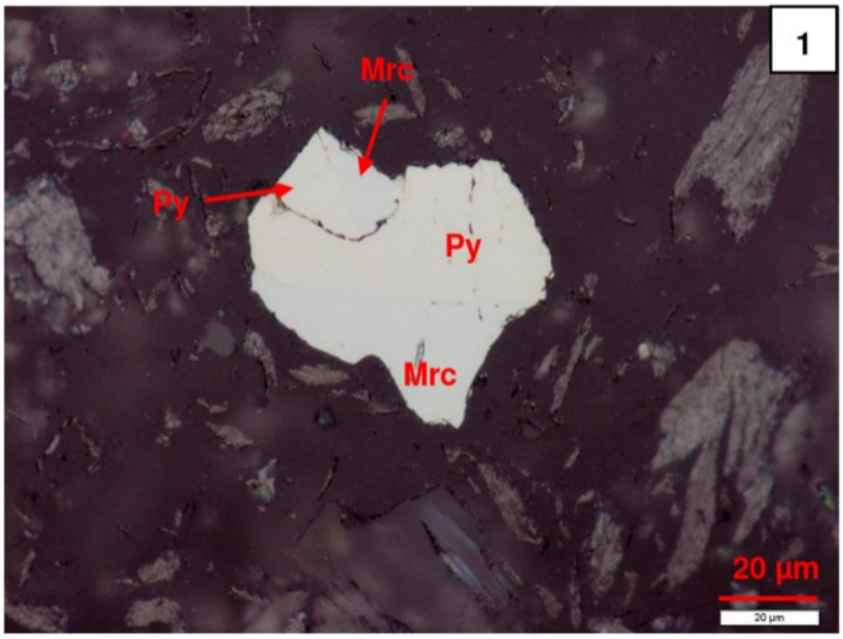


Figure 11.33: Pyrite and marcasite in MOLO43 (116-117m)

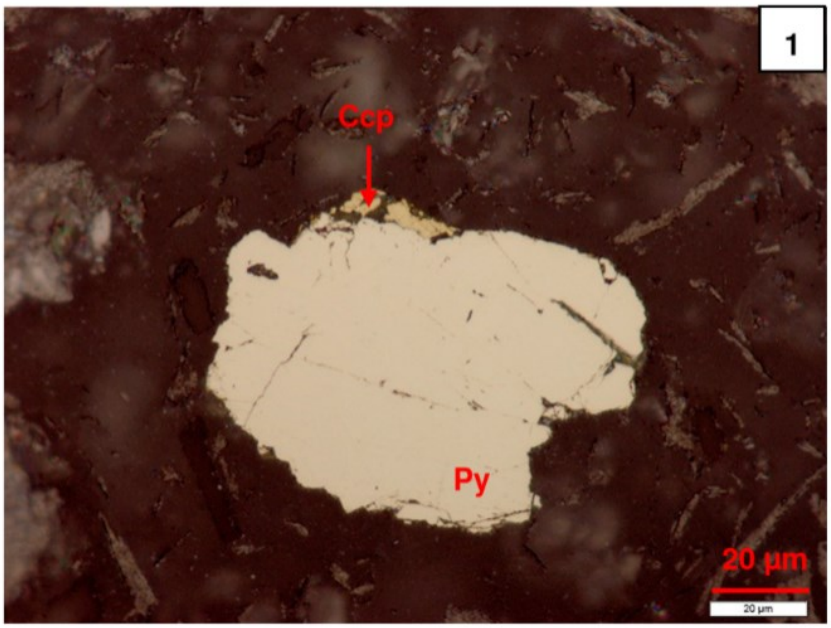


Figure 11.34: Chalcopyrite and pyrite in MOLO43 (132-133m)

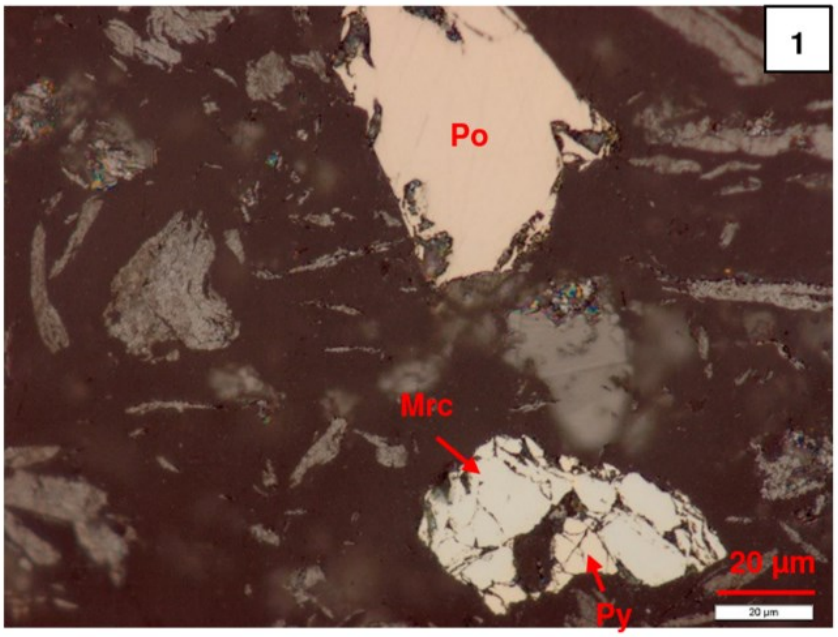


Figure 11.35: Pyrrhotite, pyrite and marcasite in MOLO43 (132-133m)

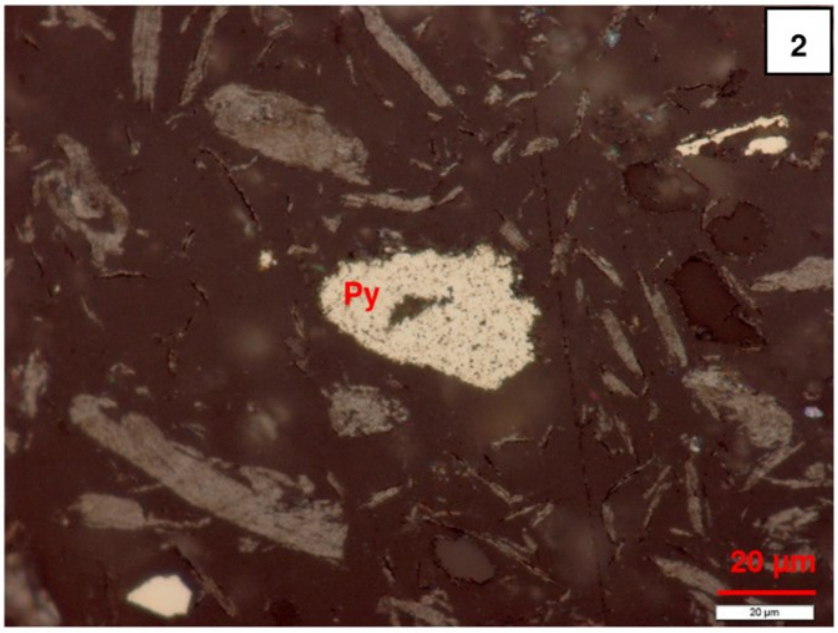


Figure 11.36: Partially porous pyrite in MOLO43 (132-133m)

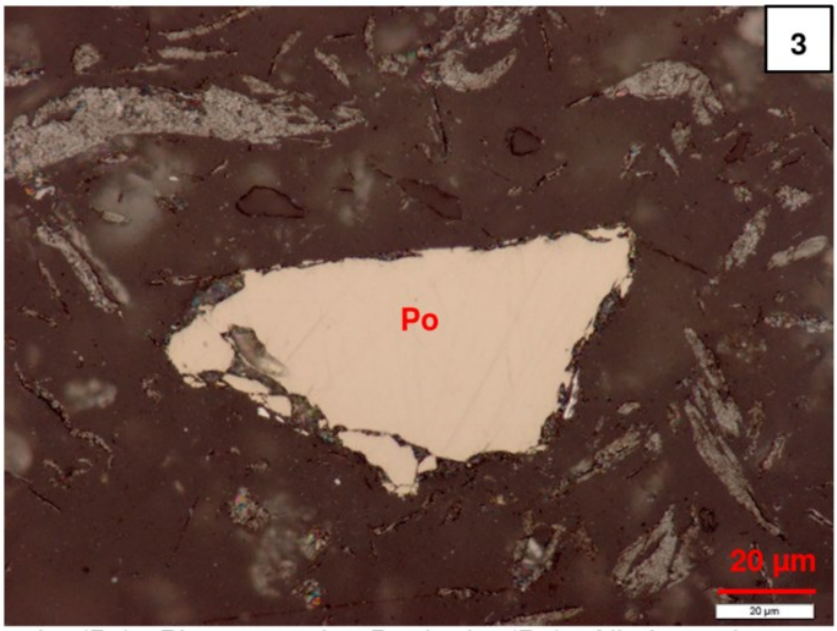


Figure 11.37: Pyrrhotite in MOLO43 (132-133m)

Table 11.25: XRF major oxide results (weight %) (Tailings sample)

Sample	LOI	Al_2O_3	CaO	Cr_2O_3	Fe_2O_3	K_2O	MgO	MnO	Na_2O	P_2O_5	V_2O_5	SiO_2	TiO_2	Sum
Tailings	10.3	11.00	0.90	0.05	4.02	2.16	0.31	<0.01	1.33	0.79	0.24	67.50	0.62	99.1
*Above AUC	-	15.40	3.59	0.01	11.20	2.80	2.48	0.10	3.27	0.15	173.16	66.60	0.64	-
>3-5 times	-	46.2	10.77	0.04	33.6	8.4	7.44	0.3	9.81	0.45	519.48	199.8	1.92	-
>5 times	-	77	17.95	0.07	56	14	12.4	0.5	16.35	0.75	865.8	333	3.2	-

Table 11.26: Strong acid digestion ICP-OES/MS trace elements results (ppm) (Tailings sample)

Sample ID	Ag	Al	As	B	Ba	Be	Bi	Ca	Cd	Co	Cr	Cu	Fe	Hg	K	Li	Mg	Mn
Tailings	0.67	51000	6.8	<1	5300	1.9	0.23	5200	0.67	5.7	130	99	27000	<0.05	19000	3	1500	58
*Above AUC	53	-	4.8	17	624	2.1	0.16	-	0.09	17.3	92	28	-	0.05	-	21	-	-
>3-5 times	159	-	14.4	51	1884	6.3	0.48	-	0.27	51.9	276	84	-	0.15	-	63	-	-
>5 times	265	-	24	85	3140	10.5	0.8	-	0.45	86.5	460	140	-	0.25	-	105	-	-
Sample ID	Mo	Na	Ni	P	Pb	Sb	Se	Sn	Sr	Th	Ti	Tl	U	V	W	Y	Zn	
Tailings	67	8000	110	3300	28	<0.8	19	1.2	1000	7.8	2400	2400	22	900	2.1	48	200	
*Above AUC	1.1	-	47	-	17	0.4	0.09	2.1	320	10.5	-	0.9	2.7	97	1.9	21	67	
>3-5 times	3.3	-	141	-	51	1.2	0.27	6.3	960	31.5	-	2.7	8.1	291	5.7	63	201	
>5 times	5.5	-	235	-	355	2.0	0.45	10.5	1600	157.5	-	4.5	13.5	485	9.5	105	335	

Table 11.27: XRF major oxide result for waste rock samples

Sample	Depth (m)	*	Al_2O_3	CaO	Cr_2O_3	Fe_2O_3	K_2O	MgO	MnO	Na_2O	P_2O_5	SiO_2	TiO_2	V_2O_5	LOI	Sum
MOLO26	33-34		15.9	2.04	0.04	7.49	1.54	2.18	0.1	3.02	0.14	59.4	1.03	0.04	6.73	99.6
MOLO26	45.5-46.5		14	0.99	0.02	1.53	5.73	0.05	< 0.01	2.89	0.03	73	0.13	0.02	1.11	99.5
MOLO38	64.17-65.17		11.9	1.79	0.02	16.3	3.95	0.64	0.08	1.94	0.6	54.7	0.55	0.08	6.93	99.5
MOLO31	4-5		14	1.12	0.03	7.71	1.13	0.59	< 0.01	2.26	0.18	61.7	0.95	0.06	9.99	99.6
MOLO37	15-16		16.3	2.05	0.04	6.27	1.82	2.1	0.06	3.03	0.14	62.3	0.99	0.05	5.25	100.3
MOLO41	37.5-38.5		13.7	11.5	0.02	13.2	0.6	2.05	0.36	2.03	0.18	50.7	0.65	< 0.01	4.59	99.5
MOLO41	47-48		14.6	17.1	0.06	9.76	2.2	4.43	0.23	1.27	0.12	46.6	0.6	0.02	2.75	99.7
MOLO41	59-60		12.2	3.89	0.03	5.93	0.72	1.77	0.14	2.77	0.1	70.9	0.44	< 0.01	0.44	99.3
MOLO43	116-117		11.3	9.08	0.03	12.7	0.67	6.17	0.14	1.16	0.21	47.6	0.88	0.04	9.37	99.3
MOLO43	132-133		15.9	2.08	0.04	10.1	1.33	4.1	0.11	3.11	0.44	58.3	1.22	0.04	2.64	99.5
*AUC	Above AUC		15.40	3.59	-	11.20	2.80	2.48	0.10	3.27	0.15	66.60	0.64	-	-	-
	> 3-5 times		46.2	10.77	-	33.6	8.4	7.44	0.3	9.81	0.45	199.8	1.92	-	-	-
	> 5 times		77	17.95	-	56	14	12.4	0.5	16.35	0.75	333	3.2	-	-	-

* Red = Garnet Gneiss, Brown = Biotite Gneiss, Yellow = Amphibolitic Gneiss, Blue = QF Gneiss, Green =PEG

Table 11.28: Strong acid digestion ICP-OES/MS trace elements results (ppm) (waste rock samples)

Para-meters (mg/l)	Strong Acid Digestion										*AUC		
Samples ID	MOLO26 (33-34 m)	MOLO26 (45.5-46.5m)	MOLO38 (64.17-65.17 m)	MOLO31 (4-5 m)	MOLO37 (15-16 m)	MOLO41 (37.5-38.5m)	MOLO41 (47-48 m)	MOLO41 (59-60 m)	MOLO43 (116-117m)	MOLO43 (132-133m)	AUC	3-5 times higher	> 5 times higher
Al	75000.0	66000	62000	65000	63000	71000	74000	63000	55000	81000	-	-	-
As	1.2	1.2	2.2	0.7	< 0.5	0.9	0.8	0.7	2.6	0.8	4.8	14.4	24
Ba	670	250	2600	570	650	1100	2100	170	460	550	624	1884	3140
Be	1.3	3.2	2.6	0.98	0.73	1.3	0.59	0.77	1.2	0.73	2.1	6.3	10.5
Bi	0.10	< 0.09	0.17	0.09	< 0.09	< 0.09	0.10	< 0.09	0.12	< 0.09	0.16	0.48	0.8
Ca	14000	6500	14000	7900	9300	79000	120000	27000	63000	15000	-	-	-
Cd	0.51	0.25	0.85	0.38	0.73	0.41	0.24	0.23	0.6	0.22	0.09	0.27	0.45
Co	24	2.7	30	2.6	3.5	25	48	5.5	25	27	17.3	51.9	86.5
Cr	220	88	170	160	180	98	270	130	180	220	92	276	460
Cu	64	10	96	55	66	42	43	6.3	44	57	28	84	140
Fe	51000	10000	110000	53000	39000	89000	66000	41000	87000	66000	-	-	-
K	13000	46000	34000	9400	13000	5200	19000	6200	5600	11000	-	-	-
Li	16	4	4	7	12	13	16	10	14	20	21	63	105
Mg	12000	270	3500	3000	10000	12000	26000	10000	35000	23000	-	-	-
Mn	830	190	680	74	410	3270	1850	1290	1220	790	-	-	-
Mo	3.5	3.8	8.2	6.4	5	1.7	1.7	2.8	7.8	3	1.1	3.3	5.5
Na	21000	20000	13000	16000	13000	14000	9000	20000	8200	22000	-	-	-
Ni	79	15	500	39	52	290	60	3.9	120	50	47	141	235
Pb	11	39	24	9.3	7.5	5.9	7.1	5.4	5.9	11	17	51	355
Sb	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8	0.4	1.2	2.0
Se	2.5	1.7	4	2.5	5.7	2.5	0.9	1.1	3.3	3.2	0.09	0.27	0.45
Sn	< 0.5	< 0.5	0.7	< 0.5	< 0.5	0.8	0.9	< 0.5	0.8	< 0.5	2.1	6.3	10.5
Sr	320	94	690	370	350	370	300	410	220	190	320	960	1600
Ti	3100	320	3200	2700	2200	4000	3900	2500	3500	1400	-	-	-
U	1.7	4.5	5.1	5.2	3.3	0.73	0.25	0.48	2	0.7	2.7	8.1	13.5
V	230	140	480	380	260	27	190	32	250	190	97	291	485
W	0.65	0.56	1.4	0.11	0.45	0.66	1.1	0.05	0.38	0.47	1.9	5.7	95
Zn	170	28	900	110	130	990	78	87	170	110	67	201	335

* Red = Garnet Gneiss, Brown = Biotite Gneiss, Yellow = Amphibolitic Gneiss, Blue = QF Gneiss, Green =PEG

11.2.1.3 *Acid-base Accounting (ABA)*

The ABA test results are presented as follows:

- The ABA results are presented in Table 11.30 below. The results were screened as discussed below as *Rock Type I to IV*;
- A summary of the ABA results for the various lithologies is presented in Table 11.31;
- Sulphur speciation results are presented in Table 11.32; and
- The classification of the rock samples in terms of %S and NP/AP is depicted in Figure 11.38.

The following relates to the ABA terminology and methodology:

- Acid-base accounting (ABA) is a static test where the net potential of the rock to produce acidic drainage is determined. The percentage sulphur (%S), the Acid Potential (AP), the Neutralization Potential (NP) and the Net Neutralization Potential (NNP) of the rock material are determined in this test, as an important first order assessment of the potential leachate that could be expected from the rock material;
- If pyrite is the only sulphide in the rock the AP (acid potential) is determined by multiplying the percentage sulphur (%S) with a factor of 31.25. The unit of AP is kg $CaCO_3$/t rock and indicates the theoretical amount of calcite neutralized by the acid produced;
- The NP (Neutralization Potential) is determined by treating a sample with a known excess of standardized hydrochloric or sulphuric acid (the sample and acid are heated to ensure reaction completion). The paste is then back-titrated with standardized sodium hydroxide in order to determine the amount of unconsumed acid. NP is also expressed as kg $CaCO_3$/t rock as to represent the amount of calcite theoretically available to neutralize the acidic drainage; and
- NNP is determined by subtracting AP from NP.

In order for the material to be classified in terms of their acid-mine drainage (AMD) potential, the ABA results could be screened in terms of its NNP, %S and NP:AP ratio as follows:

- A rock with NNP < 0 kg $CaCO_3$/t will theoretically have a net potential for acidic drainage. A rock with NNP > 0 kg $CaCO_3$/t rock will have a net potential for the neutralization of acidic drainage. Because of the uncertainty related to the exposure of the carbonate minerals or the pyrite for reaction, the interpretation of whether a rock will actually be net acid generating or neutralizing is more complex. Research has shown that a range from -20 kg $CaCO_3$/t to 20 kg $CaCO_3$/t exists that is defined as a “grey” area in determining the net acid generation or neutralization

potential of a rock. Material with a NNP above this range is classified as *Rock Type IV - No Potential for Acid Generation*, and material with a NNP below this range as *Rock Type I - Likely Acid Generating*;

- Further screening criteria could be used that attempts to classify the rock in terms of its net potential for acid production or neutralization. The following screening methods given in Table 10 below, as proposed by Price (1997), use the NP:AP ratio to classify the rock in terms of its potential for acid generation; and
- Soregaroli and Lawrence (1998) further states that samples with less than 0.3% sulphide sulphur are regarded as having insufficient oxidisable sulphides to sustain long term acid generation. Material with a %S below 0.3% is therefore classified as *Rock Type IV - No Potential for Acid Generation*, and material with a %S of above 0.3%, as *Rock Type I - Likely Acid Generating*.

From the ABA test results the following observations could be made:

- The NP/AP indicates the potential for the rock to generate acid drainage, whereas the %S indicated whether this drainage will be over the long term;
- The total S% (determined in a LECO induction furnace ±2 000°C + fluxes) was used to determine the acid potential of the rock. In Table 11.30 it is shown that almost no acid leachable SO_4 is present although sulphate (more specifically jarosite and alunite) was identified through QEMSCAN. Other fairly insoluble sulphates that will not contribute to acid generation e.g. $BaSO_4$ (as discussed in Section 11.2.1.2) may also be present;
- It was assumed that all sulphur could be attributed to pyrite and that the oxidation of pyrite will be the only contributor to acidity. This is an overestimation of the acid potential as other sulphides and sulphates are present. The proportion of the sulphur bearing minerals could however not be quantified for all the samples;
- Based on ABA results the tailings sample has a %S of 0.77%. It has a substantially higher acid generation potential than neutralization potential and would classify as potentially net acid generating in terms of the ABA results. However, it seems that fairly insoluble sulphate minerals (identified as barite, jarosite and alunite) are present and that the pyrite is much lower (than estimated assuming only pyrite is present) in the sample. The NAG test of the tailings indicates no potential for acid generation;

- Of the 34 waste rock samples only 13 have a %S higher than 0.3 %. With a relative high acid potential and a low neutralization potential these samples would classify as potentially net acid generating in terms of the ABA results. However, fairly insoluble sulphate minerals (identified as barite, jarosite and alunite) are present and pyrite is therefore much lower (than estimated assuming only pyrite is present) in the waste rock;
- The NAG test indicates that only 2 of the 34 waste rock samples actually have potential for acid generation. These 2 samples are from the Molo-43 borehole at a depth of well over 100 m and are logged as "fresh" which adds to the hypothesis that weathering of the gneiss has resulted in less sulphides being present in the weathered samples as in contrast to deep fresh gneiss; and
- Overall the tailings and waste rock samples does not have a significant potential to generate acid mine drainage (of below pH 4) because of the absence of pyrite in the QEMSCAN analyses. Most sulphur is actually from jarosite and alunite that 1) is slow reacting minerals and 2) generate slightly less acidity that pyrite.

Table 11.29: Screening methods using the NP:AP ratio (Price, 1997)

Potential for acid generation	NP:AP screening criteria	Comments
Rock Type I. Likely Acid Generating.	< 1:1	Likely AMD generating.
Rock Type II. Possibly Acid Generating.	1:1 – 2:1	Possibly AMD generating if NP is insufficiently reactive or is depleted at a faster rate than sulphides.
Rock Type III. Low Potential for Acid Generation.	2:1 – 4:1	Not potentially AMD generating unless significant preferential exposure of sulphides along fracture planes, or extremely reactive sulphides in combination with insufficient reactive NP.
Rock Type IV. No Potential for Acid Generation.	>4:1	No further AMD testing required unless materials are to be used as a source of alkalinity.

Table 11.30: Acid-base accounting (ABA) results

(assuming all S% could be attributed to pyrite which may not be correct - see discussion)

Sample	Depth (m)	*	Paste pH	Total %S	AP $CaCO_3$ kg/t	NP $CaCO_3$ kg/t	NNP $CaCO_3$ kg/t	NP/AP	Rock Type NNP	Rock Type %S	Rock Type NP/AP
Tailings	-		8.25	0.77	25.00	2.40	-22.60	0.10	I	I	I
W1466240	-		7.47	0.46	14.70	3.60	-11.09	0.25	IV	I	I
W1466241	-		6.92	0.87	28.10	4.30	-23.82	0.15	IV	I	I
W1466242	-		7.39	0.11	2.81	2.90	0.09	1.03	Uncertain	IV	II
W1466307	-		6.98	0.08	2.50	3.90	1.40	1.56	Uncertain	IV	II
W1466308	-		7.08	0.16	5.62	2.70	-2.92	0.48	IV	IV	I
W1466309	-		6.84	0.42	13.40	2.70	-10.74	0.20	IV	I	I
MOLO26	33-34		7.12	0.58	18.40	4.20	-14.24	0.23	IV	I	I
MOLO26	38-39		6.78	0.65	19.70	3.30	-16.39	0.17	IV	I	I
MOLO26	45.5-46.5		8.30	<0.005	0.31	3.60	3.29	11.50	Uncertain	I	IV
MOLO38	64.17-65.17		7.45	0.04	1.25	10.00	9.05	8.24	Uncertain	IV	IV
MOLO38	67-68		8.93	0.02	0.31	21.00	20.30	65.90	IV	IV	IV
MOLO38	69-70		9.35	0.11	2.19	23.00	21.20	10.70	IV	IV	IV
MOLO31	0.5-1.5		7.09	0.12	4.06	2.90	-1.16	0.71	IV	IV	I
MOLO31	4-5		6.79	0.89	27.80	2.40	-25.41	0.09	IV	I	I
MOLO31	9.26-10.26		6.76	0.48	15.60	2.70	-12.92	0.17	IV	I	I
MOLO40	98-99		9.47	0.05	1.25	16.00	14.40	12.50	Uncertain	IV	IV
MOLO39	8-9		7.88	0.07	1.88	4.20	2.32	2.24	Uncertain	IV	III
MOLO39	17.1-17.6		9.46	0.01	0.31	12.00	11.50	38.10	Uncertain	IV	IV
MOLO39	18-19		8.71	0.05	0.62	6.70	6.08	10.70	Uncertain	IV	IV
MOLO39	29-30		9.45	<0.005	0.31	6.90	6.59	22.30	Uncertain	I	IV
MOLO37	1.5-2.5		7.95	0.06	1.56	3.30	1.74	2.11	Uncertain	IV	III
MOLO37	15-16		7.32	0.37	9.38	3.30	-6.08	0.35	IV	I	I
MOLO37	17-18		7.27	0.11	3.12	3.30	0.18	1.06	Uncertain	IV	II
MOLO43	116-117		4.89	2.21	51.90	6.70	-45.18	0.13	IV	I	I
MOLO43	132-133		6.73	1.55	34.40	9.10	-25.28	0.26	IV	I	I
MOLO43	149-150		9.71	0.23	3.44	16.00	12.20	4.54	Uncertain	IV	IV
MOLO27	1-2		7.39	0.12	3.44	3.60	0.16	1.05	Uncertain	IV	II
MOLO27	5.3-6.3		7.26	0.24	6.88	3.80	-3.08	0.55	IV	IV	I
MOLO27	7.5-8.5		6.58	0.70	23.10	3.20	-19.92	0.14	IV	I	I
MOLO30	39-40		6.60	0.59	20.30	3.30	-17.01	0.16	IV	I	I
MOLO32	39-40		7.17	0.57	18.80	2.80	-15.95	0.15	IV	I	I
MOLO41	37.5-38.5		8.80	0.03	0.31	25.00	24.90	80.60	IV	IV	IV

Sample	Depth (m)	*	Paste pH	Total %S	AP $CaCO_3$ kg/t	NP $CaCO_3$ kg/t	NNP $CaCO_3$ kg/t	NP/AP	Rock Type NNP	Rock Type %S	Rock Type NP/AP
MOLO41	47-48		9.35	0.16	3.44	62.00	58.90	18.10	IV	IV	IV
MOLO41	59-60		9.62	0.01	0.31	9.90	9.59	31.90	Uncertain	IV	IV

* Red = Garnet Gneiss, Brown = Biotite Gneiss, Yellow = Amphibolitic Gneiss, Blue = QF Gneiss, Green =PEG

Table 11.31: Acid-base accounting (ABA) results average for different lithologies

(assuming all S% could be attributed to pyrite which may not be correct - see discussion)

Lithology	*	Number of samples	Total %S	AP ($CaCO_3$ kg/t)	NP ($CaCO_3$ kg/t)	NNP ($CaCO_3$ kg/t)	NP/AP	Rock Type NNP	Rock Type %S	Rock Type NP/AP
Garnet Gneiss		15	0.37	9.38	8.63	10.77	10.19	Uncertain	I	IV
Biotite Gneiss		2	1.19	27.67	34.35	58.90	9.12	IV	I	IV
Amphibolite Gneiss		2	0.02	0.31	18.50	18.20	59.35	Uncertain	IV	IV
QF Gneiss		7	0.35	10.97	4.10	3.85	1.81	Uncertain	I	II
PEG		2	0.05	0.47	5.15	4.69	11.10	Uncertain	IV	IV

* Red = Garnet Gneiss, Brown = Biotite Gneiss, Yellow = Amphibolitic Gneiss, Blue = QF Gneiss, Green =PEG

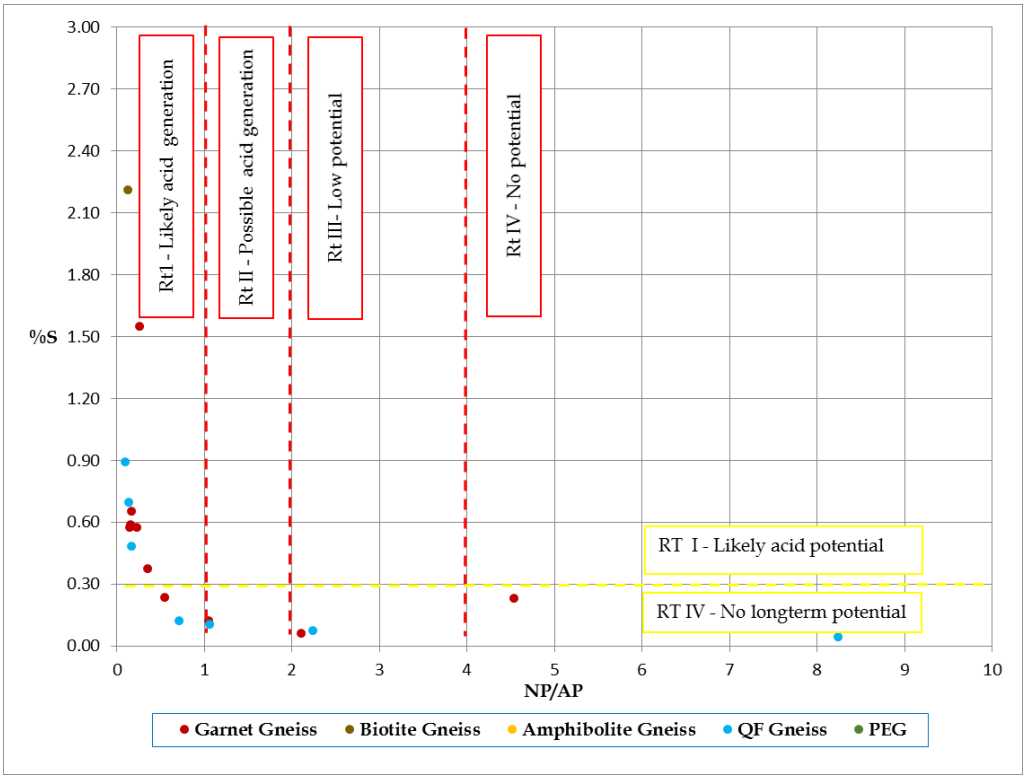


Figure 11.38: Classification of samples in terms of total %S (< 3%) and NP/AP (< 10) (assuming all S% could be attributed to pyrite which may not be correct - see discussion)

Table 11.32: Sulphur speciation results

Sample ID	Depth (m)	*	Total S%	Acid leachable SO_4-S	Sulphide S%
Tailings	-		0.774	<0.01	0.80
W1466240	-		0.457	<0.01	0.47
W1466241	-		0.868	<0.01	0.90
W1466242	-		0.107	0.02	0.09
W1466307	-		0.078	<0.01	0.08
W1466308	-		0.162	<0.01	0.18
W1466309	-		0.424	<0.01	0.43
MOLO26	33-34		0.577	<0.01	0.59
MOLO26	38-39		0.652	0.02	0.63
MOLO26	45.5-46.5		<0.005	<0.01	0.01
MOLO38	64.17-65.17		0.044	<0.01	0.04
MOLO38	67-68		0.018	<0.01	0.01
MOLO38	69-70		0.109	0.04	0.07
MOLO31	0.5-1.5		0.121	<0.01	0.13
MOLO31	4-5		0.894	<0.01	0.89
MOLO31	9.26-10.26		0.483	<0.01	0.50
MOLO40	98-99		0.054	<0.01	0.04
MOLO39	8-9		0.073	<0.01	0.06
MOLO39	17.1-17.6		0.006	<0.01	<0.01
MOLO39	18-19		0.030	0.02	0.01
MOLO39	29-30		<0.005	<0.01	<0.01
MOLO37	1.5-2.5		0.062	<0.01	0.05
MOLO37	15-16		0.374	0.07	0.30
MOLO37	17-18		0.106	<0.01	0.10
MOLO43	116-117		2.210	0.55	1.66
MOLO43	132-133		1.550	0.45	1.10
MOLO43	149-150		0.233	0.12	0.11
MOLO27	1-2		0.124	0.01	1.25
MOLO27	5.3-6.3		0.236	0.02	0.22
MOLO27	7.5-8.5		0.696	<0.01	0.74
MOLO30	39-40		0.587	<0.01	0.65
MOLO32	39-40		0.574	<0.01	0.60
MOLO41	37.5-38.5		0.030	0.02	0.01
MOLO41	47-48		0.162	0.05	0.11
MOLO41	59-60		0.012	0.01	<0.01

* Red = Garnet Gneiss, Brown = Biotite Gneiss, Yellow = Amphibolitic Gneiss, Blue = QF Gneiss, Green =PEG

11.2.1.4 *Net-acid Generation (NAG)*

The NAG test results are presented as follows:

- The NAG test results are presented in Table 11.34 below. The results were screened as discussed below as *Rock Type I to IV*; and
- Sequential NAG test results for the tailings are presented in Table 11.35 below; and.
- NAG test results for waste rock samples are presented in Table 11.36 and Table 11.37.

The following pertains to the NAG methodology:

- In the Net-acid Generating (NAG) test hydrogen peroxide (H_2O_2) is used to oxidize sulphide minerals in order to predict the acid generation potential of the sample;
- The NAG test provides a direct assessment of the potential for a material to produce acid after a period of exposure (to a strong oxidant) and weathering. The test can be used to refine the results of the ABA predictions;
- In general, the static NAG test involves the addition of 25 ml of 15% H_2O_2 to 0.25 g of sample in a 250 ml wide mouth conical flask, or equivalent. The sample is covered with a watch glass, and placed in a fumehood or well-ventilated area. Once "boiling" or effervescing ceases, the solution is allowed to cool to room temperature and the final pH (NAG pH) is determined. A quantitative estimation of the amount of net acidity remaining (the NAG capacity) in the sample is determined by titrating it with sodium hydroxide (NaOH) to pH 4.5 (and often pH 7.0) to obtain the NAG Value; and
- In order to determine the acid generation potential of a sample, the screening method of Miller et al. (1997) is used. See Table 14 below.

The following pertains to the NAG test results:

- In contrast to the ABA test, the NAG test of the tailings indicates no potential for acid generation. However, it seems that an insoluble SO_4 is present and that the pyrite is much lower (than estimated through the total S%) in the tailings;
- In Table 11.35 the sequential NAG test results of the tailings are presented. The results indicate that only a small portion (about 0.077 of 0.77) of the %S could be leached from the tailings upon repeated addition of peroxide which indicate that a large fraction of the sulphur in the rock is insoluble and could also not be oxidized;

- Although 13 of the 34 waste rock samples have a %S higher than 0.3% and also have a low neutralisation potential, the NAG test indicates that only 2 of the 34 waste rock samples actually have potential for acid generation. These 2 samples are from the Molo-43 borehole at a depth of well over 100 m and is logged as "fresh" which adds to the hypothesis that weathering of the gneiss has resulted in less sulphides to be present in the weathered samples as in contrast to deep fresh gneiss; and
- Overall, the tailings and waste rock samples does not have a significant potential to generate acid mine drainage (at pH below 4.5).

Table 11.33: NAG test screening method (edited from Miller et al., 1997)

Rock Type NAG	NAG pH	NAG (kg H_2SO_4/t) pH 4.5	NNP ($CaCO_3$ kg/t)
Rock Type Ia. High Capacity Acid Forming.	< 4.5	> 10	Negative
Rock Type Ib. Lower Capacity Acid Forming.	< 4.5	≤ 10	-
Uncertain, possibly Ib.	< 4.5	> 10	Positive
Uncertain.	≥ 4.5	0	Negative (Reassess mineralogy)*
Rock Type IV. Non-acid Forming.	≥ 4.5	0	Positive

* If low acid forming sulphides is dominant then Rock Type IV.

Table 11.34: NAG test results

Sample ID	Depth (m)	*	NAG pH: (H_2O_2)	NAG (kg H_2SO_4/t) pH 4.5	NAG (kg H_2SO_4/t) pH 7	NNP ($CaCO_3$ kg/t)	Rock Type NAG
W1466240	-		6.22	0.00	2.70	-11.09	Uncertain
W1466241	-		7.09	0.00	0.00	-23.82	Uncertain
W1466242	-		6.13	0.00	2.20	0.09	Rock Type IV. Non-acid Forming
W1466307	-		7.31	0.00	0.00	1.40	Rock Type IV. Non-acid Forming
W1466308	-		6.52	0.00	1.40	-2.92	Uncertain
W1466309	-		6.65	0.00	1.00	-10.74	Uncertain
MOLO26	33-34		6.22	0.00	0.90	-14.24	Uncertain
MOLO26	38-39		6.13	0.00	0.70	-16.39	Uncertain
MOLO26	45.5-46.5		6.33	0.00	2.40	3.29	Rock Type IV. Non-acid Forming
MOLO38	64.17-65.17		6.49	0.00	2.80	9.05	Rock Type IV. Non-acid Forming
MOLO38	67-68		7.48	0.00	0.00	20.30	Rock Type IV. Non-acid Forming
MOLO38	69-70		9.29	0.00	0.00	21.20	Rock Type IV. Non-acid Forming
MOLO31	0.5-1.5		6.45	0.00	1.50	-1.16	Uncertain
MOLO31	4-5		4.80	0.00	2.80	-25.41	Uncertain
MOLO31	9.26-10.26		5.13	0.00	2.80	-12.92	Uncertain
MOLO40	98-99		7.88	0.00	0.00	14.40	Rock Type IV. Non-acid Forming
MOLO39	8-9		6.64	0.00	3.30	2.32	Rock Type IV. Non-acid Forming
MOLO39	17.1-17.6		7.62	0.00	0.00	11.50	Rock Type IV. Non-acid Forming
MOLO39	18-19		7.07	0.00	0.00	6.08	Rock Type IV. Non-acid Forming
MOLO39	29-30		7.06	0.00	0.00	6.59	Rock Type IV. Non-acid Forming
MOLO37	1.5-2.5		6.16	0.00	3.20	1.74	Rock Type IV. Non-acid Forming
MOLO37	15-16		5.76	0.00	2.20	-6.08	Uncertain
MOLO37	17-18		6.13	0.00	2.70	0.18	Rock Type IV. Non-acid Forming
MOLO43	116-117		2.91	12.00	37.00	-45.18	Rock Type Ia. High Capacity Acid Forming.
MOLO43	132-133		2.41	25.00	32.00	-25.28	Rock Type Ia. High Capacity Acid Forming.
MOLO43	149-150		5.69	0.00	3.50	12.20	Rock Type IV. Non-acid Forming
MOLO27	1-2		6.26	0.00	17.00	0.16	Rock Type IV. Non-acid Forming
MOLO27	5.3-6.3		7.15	0.00	0.00	-3.08	Uncertain
MOLO27	7.5-8.5		6.66	0.00	2.00	-19.92	Uncertain

Sample ID	Depth (m)	*	NAG pH: (H_2O_2)	NAG (kg H_2SO_4/t) pH 4.5	NAG (kg H_2SO_4/t) pH 7	NNP ($CaCO_3$ kg/t)	Rock Type NAG
MOLO30	39-40		6.55	0.00	2.60	-17.01	Uncertain
MOLO32	39-40		6.54	0.00	1.30	-15.95	Uncertain
MOLO41	37.5-38.5		9.56	0.00	0.00	24.90	Rock Type IV. Non-acid Forming
MOLO41	47-48		11.22	0.00	0.00	58.90	Rock Type IV. Non-acid Forming
MOLO41	59-60		7.72	0.00	0.00	9.59	Rock Type IV. Non-acid Forming

*** Red = Garnet Gneiss,** Brown = Biotite Gneiss, Yellow = Amphibolitic Gneiss, Blue = QF Gneiss, Green =PEG

Table 11.35: Sequential NAG testing of tailings

Combined Tailings	13117	13118	13119
Sample Weight (g)	1.51	1.51	1.51
Volume H_2O_2 (ml)	150	150	150
Final pH	6.65	6.21	5.26
NAG (kg H_2SO_4/t)	27.00	2.00	2.90
Volume Recovered (ml)	123	123	123
SO_4 (mg/l)	28	6	<1
SO_4- S %	0.077	0.016	<0.01
Sulphide remaining %	0.80	0.72	0.72

11.2.1.5 *Kinetic Net Acid Generation Test*

The kinetic NAG test results are presented as follows:

- Kinetic NAG test results are listed in Table 11.36;
- System parameters in Table 11.37;
- NAG test results with analysis are listed in Table 11.38; and
- Diagrams depicting pH, EC and temperature for the different samples in Figure 11.39 to Figure 11.44.

The following pertains to the kinetic NAG test results:

- Only MOLO 34 (132-133 m), that also contain a high pyrite content, showed some significant increase in temperature with the addition of peroxide;
- MOLO 43 (116-117 m) also contains pyrite but showed no reaction (no increase in temperature) and also no acidification. This should either imply that the same sample was not homogenized well enough or that pyrite is secluded from the reaction;

- MOLO 41 (47-48 m) only contains a small amount of pyrite, showed a small rise in temperature and eventually acidified;
- No rise in temperature due to the oxidation of pyrite occurred in the other samples (including the tailings) that confirm the absence of pyrite as determined by QEMSCAN; and
- ICP analyses on the NAG extraction indicated the metals were only released into solution in samples where pyrite was oxidized and includes several chalcophile elements, e.g. Cd, Cu, Fe, Ni, Pb and Se.

Table 11.36: Kinetic NAG Test

Samples ID	Depth (m)	*	NAG pH: (H_2O_2)	NAG pH 4.5 (kg H_2SO_4/t)	NAG pH 7 (kg H_2SO_4/t)
Tailings	-		5.00	0	17.05
MOLO26	33-34		4.61	0	11.86
MOLO31	4-5		4.64	0	14.41
MOLO43	116-117		6.04	0	3.14
MOLO43	132-133		2.64	28.22	42.92
MOLO41	47-48		2.16	24.70	33.22

*** Red = Garnet Gneiss, Brown = Biotite Gneiss, Yellow = Amphibolitic Gneiss, Blue = QF Gneiss, Green =PEG**

Table 11.37: Kinetic NAG system parameters

Combined Tails				MOLO26 (33-34m)			
Reaction Time (hr)	Temperature (˚C)	pH	EC (µS/cm)	Reaction Time (hr)	Temperature (˚C)	pH	EC (µS/cm)
0.00	22.0	5.04	236	0.00	22.0	5.09	241
0.25	22.5	5.12	237	0.25	22.5	5.09	242
0.50	22.5	5.07	239	0.50	22.5	5.13	247
0.75	22.5	5.09	241	0.75	22.5	5.14	251
1.00	22.5	5.06	245	1.00	26.0	5.17	254
1.25	26.0	5.06	247	1.25	27.0	5.17	258
1.50	26.5	5.08	248	1.50	27.5	5.20	258
1.75	26.5	5.07	251	1.75	28.0	5.17	264
2.00	27.0	5.08	255	2.00	28.5	5.21	264
2.50	27.5	5.11	252	2.50	28.5	5.17	268
3.00	28.0	5.05	257	3.00	28.5	5.21	267
3.50	28.0	5.12	254	3.50	29.0	5.21	269
4.00	27.5	5.07	258	4.00	28.5	5.20	267
5.00	28.5	5.08	252	5.00	29.5	5.17	264
6.00	29.0	5.02	252	6.00	30.5	5.14	268
7.00	29.0	5.03	252	7.00	30.0	5.17	264
8.00	28.5	5.03	252	8.00	29.5	5.17	269
24.00	28.5	4.74	262	24.00	29.5	4.87	272
MOLO31 4-5(m)				MOLO43 (116-117m)			
Reaction Time (hr)	Temperature (˚C)	pH	EC (µS/cm)	Reaction Time (hr)	Temperature (˚C)	pH	EC (µS/cm)
0.00	23.0	5.08	244	0.00	22.0	5.67	308
0.25	24.0	5.11	251	0.25	24.0	5.79	327
0.50	24.5	5.13	262	0.50	24.5	5.74	338
0.75	24.5	5.13	263	0.75	26.0	5.77	343
1.00	25.0	5.14	262	1.00	26.0	5.74	354
1.25	25.0	5.12	261	1.25	26.5	5.75	359
1.50	25.5	5.15	255	1.50	26.5	5.77	360
1.75	26.0	5.20	232	1.75	27.0	5.75	364
2.00	26.0	5.19	246	2.00	27.0	5.76	363
2.50	26.5	5.20	260	2.50	27.0	5.70	367
3.00	26.5	5.19	266	3.00	28.0	5.71	369
3.50	27.0	5.23	263	3.50	28.0	5.73	363
4.00	26.5	5.27	268	4.00	28.0	5.65	377

5.00	26.5	5.22	265	5.00	29.0	5.70	369
6.00	27.0	5.19	261	6.00	28.5	5.78	377
7.00	28.5	5.15	259	7.00	28.5	5.71	390
8.00	29.0	5.02	260	8.00	---	---	---
24.00	28.5	4.78	260	24.00	30.0	5.38	415
MOLO34 (132-133m)				**MOLO41 (47-48m)**			
Reaction Time (hr)	Temperature (˚C)	pH	EC (µS/cm)	Reaction Time (hr)	Temperature (˚C)	pH	EC (µS/cm)
0.00	23.0	3.50	305	0.00	22.5	4.74	257
0.25	23.5	2.15	1033	0.25	24.0	2.61	509
0.50	27.5	1.90	1723	0.50	25.0	2.26	761
0.75	30.5	1.82	2070	0.75	25.5	2.13	1050
1.00	34.0	1.75	2330	1.00	26.0	2.00	1292
1.25	39.5	1.66	2590	1.25	27.0	2.00	1481
1.50	53.0	1.47	3080	1.50	27.5	1.97	1592
1.75	89.0	1.38	3120	1.75	28.0	1.97	1590
2.00	63.0	1.77	3450	2.00	28.5	1.96	1705
2.50	44.5	2.13	3040	2.50	29.5	1.96	1747
3.00	35.5	2.27	2700	3.00	31.5	1.94	1852
3.50	32.5	2.35	2600	3.50	33.5	1.94	1905
4.00	29.5	2.35	2470	4.00	36.5	1.91	2060
5.00	28.5	2.41	2430	5.00	37.0	1.97	2120
6.00	28.5	2.36	2310	6.00	36.0	2.06	2160
7.00	30.0	2.34	2280	7.00	34.0	2.11	2220
8.00	31.0	2.31	2230	8.00	-	-	-
24.00	29.0	2.48	1970	24.00	28.5	2.38	2000

*** Red = Garnet Gneiss, Brown = Biotite Gneiss, Yellow = Amphibolitic Gneiss, Blue = QF Gneiss, Green =PEG**

Table 11.38: Net acid generation test with analysis

Para-meters (mg/l)	Peroxide Leach						WHO 2011		
*	Tailings	MOLO26 (33-34 m)	MOLO31 (4-5 m)	MOLO43 (116-117m)	MOLO43 (132-133m)	MOLO41 (47-48 m)	0-50% of guideline	50%-100% of guideline	Above guideline
Al	0.14	0.06	0.04	3.8	8.17	13.5	<0.45	0.45-0.9	>0.9*
As	0.0007	< 0.0002	< 0.0002	< 0.0002	0.0007	0.0005	<0.005	0.005-0.01	>0.01
Ba	0.624	0.00702	0.0773	0.0792	0.435	0.341	<0.35	0.35-0.7	>0.7
Be	0.000011	< 0.000007	0.000054	< 0.000007	0.00246	0.000591	-	-	-
Bi	< 0.000007	< 0.000007	< 0.000007	< 0.000007	< 0.000007	< 0.000007	-	-	-
Ca	1.1	2.15	3.1	83.1	52.3	24.3	-	-	-
Cd	0.000106	0.00016	0.000288	0.000004	0.00413	0.0015	<0.0015	0.0015-0.003	>0.003
Co	0.000628	0.003861	0.002585	0.000067	0.205	0.248	-	-	-
Cr	0.0949	0.0397	0.0483	0.0296	0.0055	0.0971	<0.025	0.025-0.05	>0.05
Cu	0.00117	0.00093	0.00131	0.00095	0.145	0.546	<1	1-2	>2
Fe	0.106	0.035	0.002	0.011	152	20.1	<1	1-2	>2**
K	1.17	4.86	6.59	12.3	11.7	15	-	-	-
Li	0.000874	0.00117	0.00175	0.000282	0.0158	0.0211	-	-	-
Mg	0.747	1.18	3.13	0.006	14.4	8.83	-	-	-
Mn	0.02252	0.225	0.05333	0.00026	4.15	0.457	<0.25	0.25-0.5	>0.5**
Mo	0.04931	0.00794	0.00636	0.00512	0.00021	0.00014	-	-	-
Na	2.56	2.77	4.27	2.71	2.82	5.13	-	-	-
Ni	0.0028	0.0038	0.0111	< 0.0001	0.959	0.591	<0.035	0.035	>0.07
Pb	0.00009	0.00003	0.00003	0.00002	0.00117	0.0108	<0.005	0.005-0.01	>0.01
Sb	0.0006	0.0004	0.0004	0.0003	< 0.0002	0.0003	<0.01	0.01-0.02	>0.02
Se	0.011	0.001	0.002	< 0.001	0.015	0.02	<0.02	0.02-0.04	>0.04
Si	0.00037	0.00023	0.00008	0.0005	0.00012	0.00009	-	-	-
Sn	0.0378	0.00981	0.0581	0.12	0.512	0.0575	-	-	-
Sr	9.79	12.1	14	2.45	56.4	26.2	-	-	-
Ti	0.0152	0.00604	0.00325	0.00009	0.00237	0.00307	-	-	-
U	0.000539	0.000116	0.000708	0.000007	0.00132	0.00101	<0.0015	0.0015-0.03	>0.03
V	0.571	0.137	0.325	0.0124	0.00499	0.00561	-	-	-
W	0.005	0.005	0.011	< 0.001	1	0.431	-	-	-
Zn	0.00363	0.00187	0.0022	0.00052	0.00019	0.00009	-	-	-

* Red = Garnet Gneiss, Brown = Biotite Gneiss, Yellow = Amphibolitic Gneiss, Blue = QF Gneiss, Green =PEG

* World health organisation (WHO): chemicals for which guideline values have not been established.

** No established WHO guideline values. Derived from research in WHO (2011) report also similar to SANS 241:2011 drinking water standard.

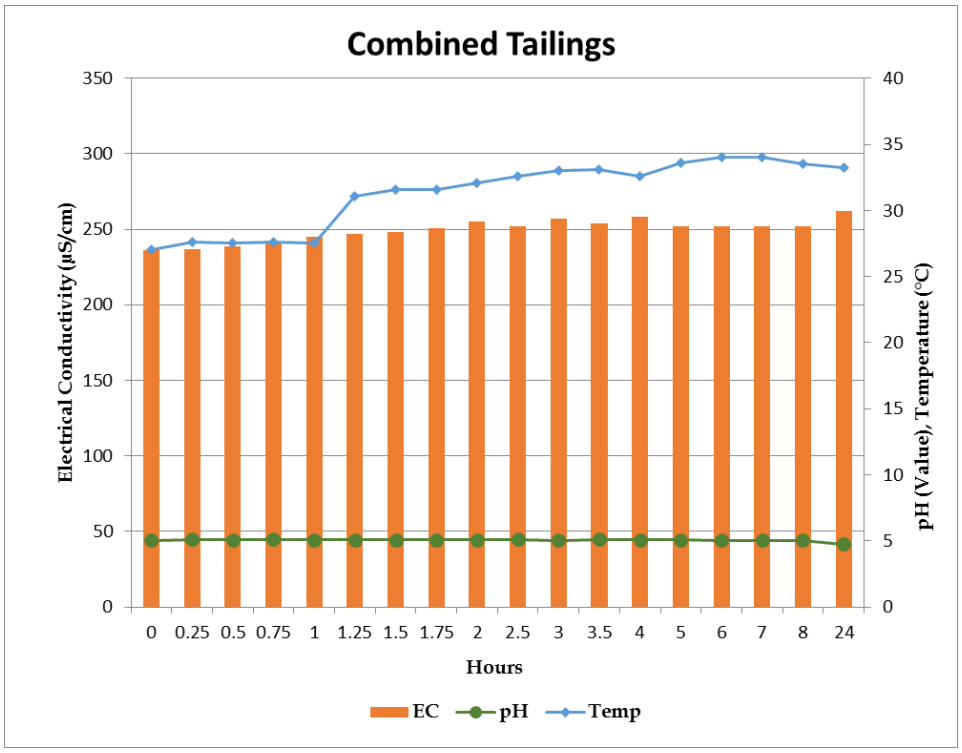


Figure 11.39: Combined Tailings EC (mS/m), pH (value) and hours

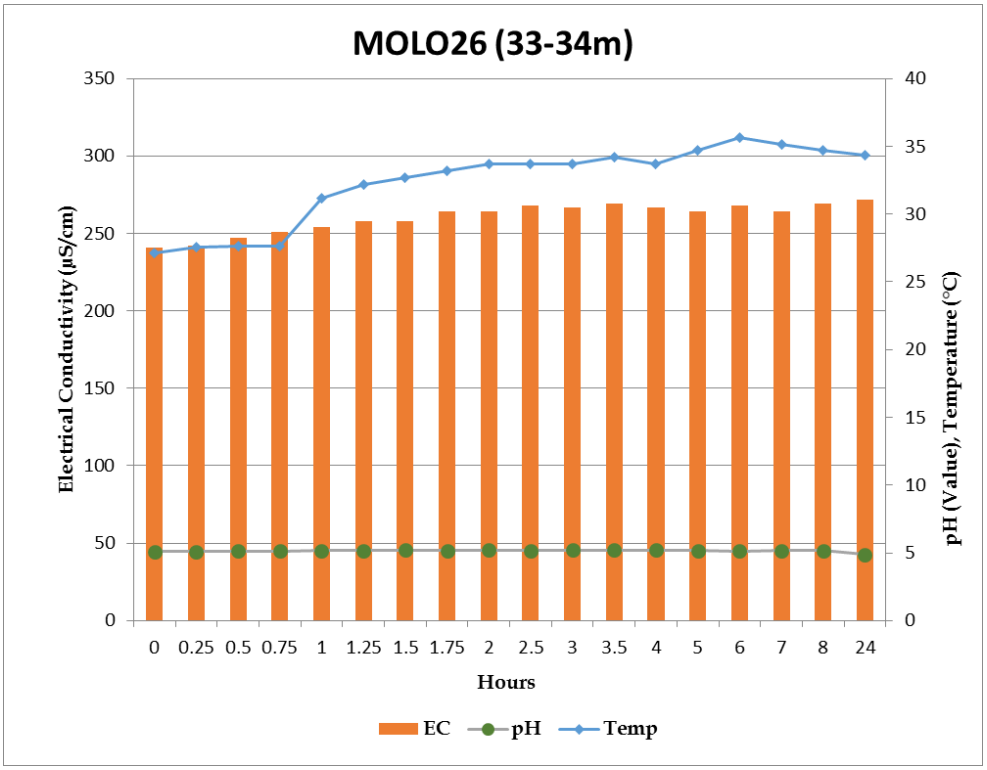


Figure 11.40: MOLO26 (33-34m) EC (mS/m), pH (value) and hours

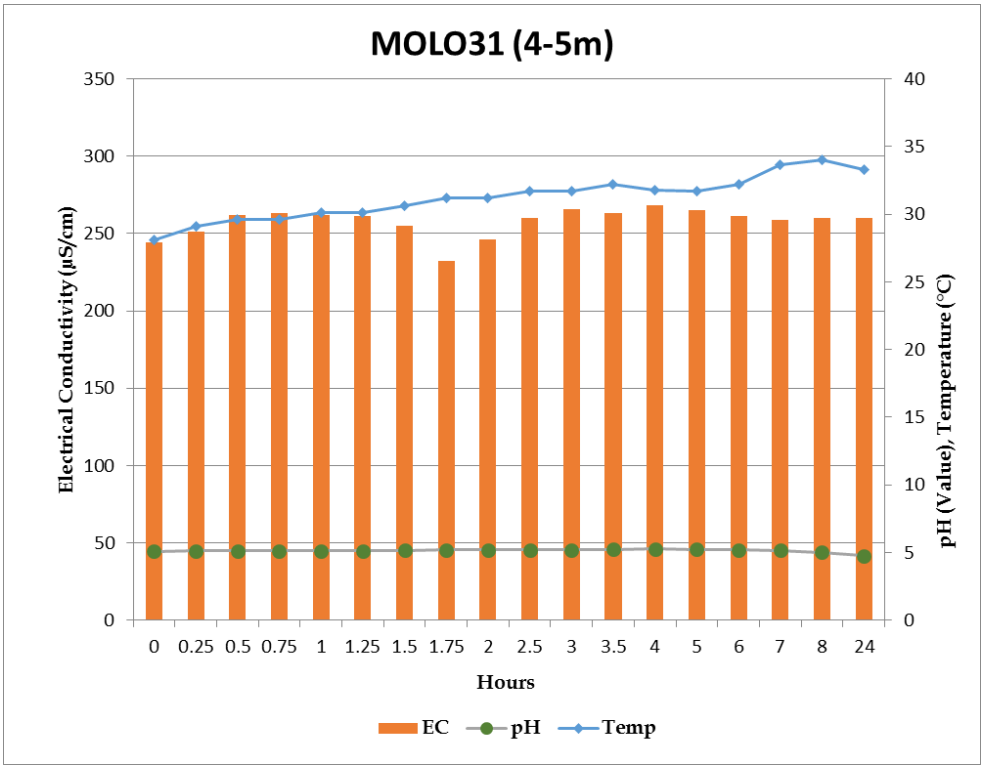


Figure 11.41: MOLO31 (4-5m) EC (mS/m), pH (value) and hours

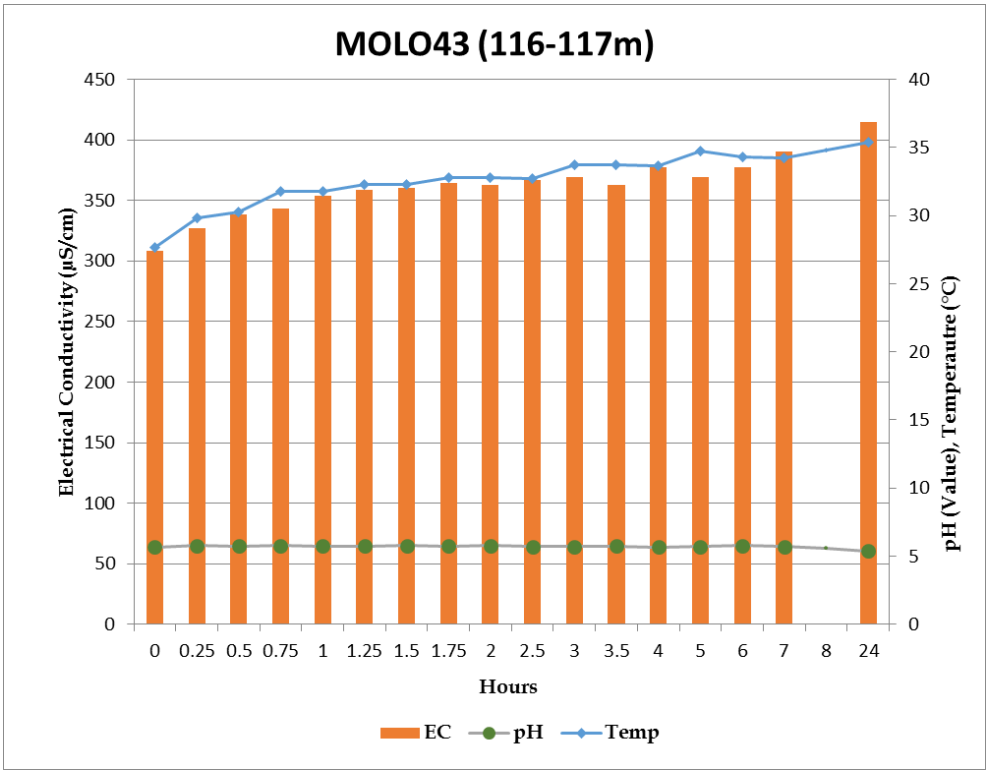


Figure 11.42: MOLO43 (116-117m) EC (mS/m), pH (value) and hours

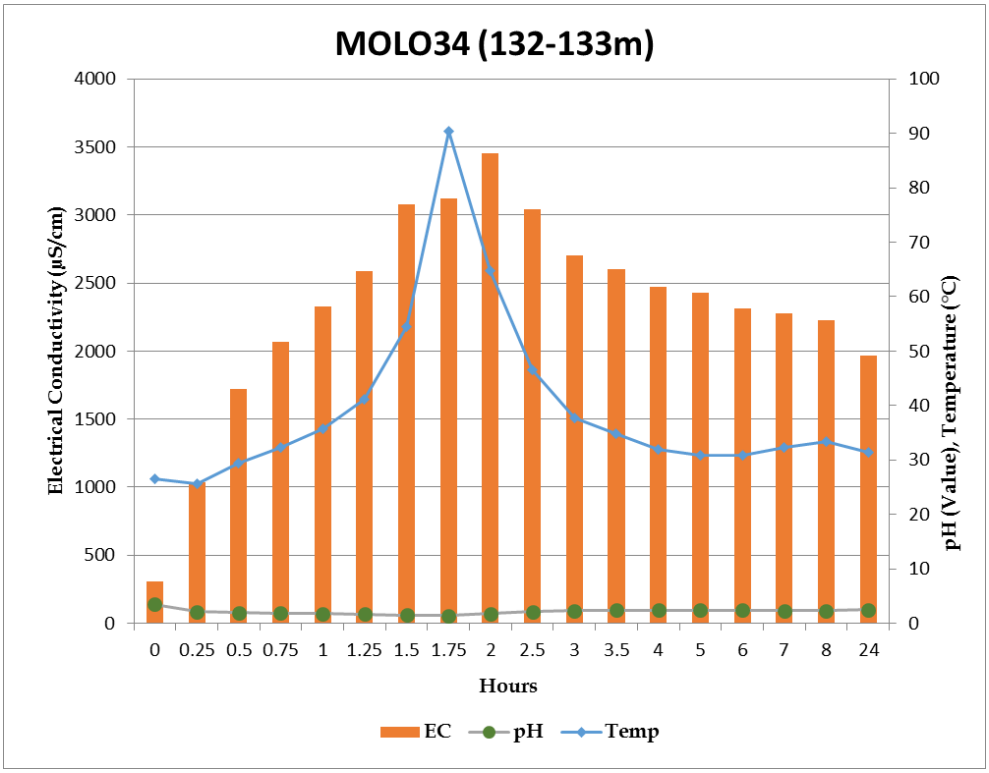


Figure 11.43: MOLO34 (132-133m) EC (mS/m), pH (value) and hours

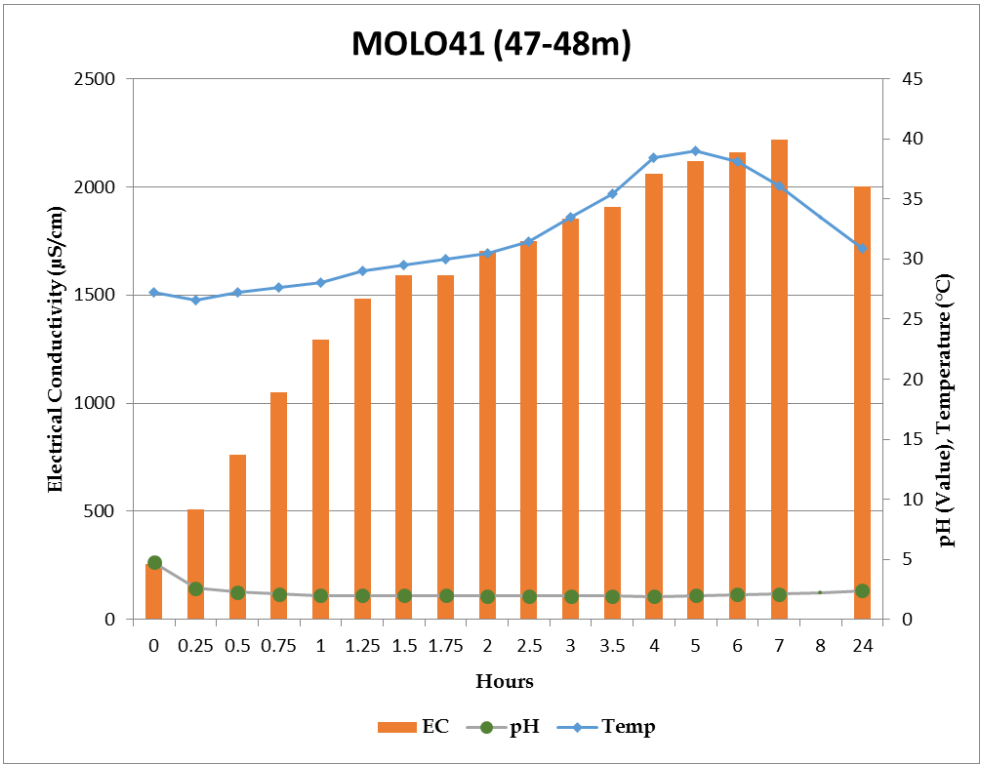


Figure 11.44: MOLO41 (47-48) EC (mS/m), pH (value) and hours

11.2.1.6 *Kinetic Column Leaching*

Column leach testing was performed on the tailings sample. The results are presented as follows:

- The system parameters as well as anions measured in all leachate are listed in Table 11.39 below;
- ICP-MS/OES results are listed in Table 11.40; and
- Figure 11.45 depicts the SO_4, EC and pH values of the weekly leach.

From the kinetic leaching test results the following observation could be made:

- Kinetic column leaching test indicates the chemicals that will leach out from the rock material over time as well as the oxidation rate of the sulphide minerals in the material;
- Samples were subjected to kinetic leach testing. A rock/water ratio of 1:1 was used where 1 kg of samples was leached with 1L distilled water weekly. The leachate was analysed for several parameters;
- The %S and NP of the samples were measured as follows before leaching:

Sample	Tailings
Paste pH	8.25
% S	0.77
AP	25.00
NP	2.40
NNP	-22.60
NP/AP	0.10

- The pH decreased slightly from pH ~7.5 in Week 0 to pH ~6.5 in Week 30;
- SO_4 leached at an elevated concentration during the first 3 weeks (50 to 21 mg/l) but decreased almost 10 times after 10 weeks where after it stabilized at between 4.9 to 2.7 mg/l;
- The sulphide %S is at 0.77 but SO_4 did not leach at significantly high concentrations after the initial few weeks which is in concurrence with the sequential NAG test results where only a small fraction of the sulphur in the rock was shown to be soluble;
- The neutralization potential of the tailings is low and the alkalinity decreased from 45 mg/l in Week 0 to only 6 mg/l in Week 10 and to <2 mg/l in Week 30;

- Metals did not leach at significant concentrations from the tailings except Al and Fe that were elevated during the first few weeks. The elevated Al, Fe and SO4 during the first few weeks could be directly attributed to the leaching of jarosite (and probably alunite or other Al(Fe)-sulphates). Ba also leached at slightly elevated values. In the fairly neutral leachate no other metals were present.

Table 11.39: Analyses of weekly leach

Week	Leachate Vol	pH (Value)	Acidity	Total Alkalinity (mg/l)	EC (uS/cm)	SO_4 (mg/l)
0	1018.00	7.56	<2	45.00	246.00	50.00
1	981.00	7.43	<2	21.00	134.00	34.00
2	995.00	7.23	<2	11.00	82.00	21.00
3	967.00	6.98	<2	11.00	60.00	14.00
4	960.00	7.16	<2	12.00	51.00	10.00
5	957.00	6.80	<2	12.00	45.00	9.20
6	1010.00	6.84	<2	8.00	38.00	8.20
7	954.00	7.00	<2	6.00	36.00	7.70
8	960.00	7.04	<2	5.00	28.00	6.00
9	958.00	6.84	<2	4.00	26.00	5.30
10	955.00	6.96	<2	6.00	22.00	4.30
11	945.00	6.81	<2	5.00	25.00	4.90
12	945.00	6.82	<2	4.00	23.00	4.00
13	947.00	6.65	<2	3.00	17.00	3.80
14	959.00	6.82	<2	7.00	22.00	3.60
15	988.00	6.49	<2	4.00	18.00	3.40
16	953.00	6.49	<2	3.00	15.00	3.50
17	963.00	6.82	<2	4.00	19.00	3.20
18	978.00	6.77	<2	3.00	14.00	2.90
19	965.00	6.80	<2	3.00	14.00	2.90
20	926.00	6.44	<2	2.00	14.00	3.50
21	842.00	6.76	<2	3.00	15.00	3.40
22	884.00	6.74	<2	2.00	15.00	3.20
23	927.00	6.53	<2	3.00	15.00	2.80
24	947.00	6.78	<2	3.00	14.00	2.90
25	896.00	6.58	<2	4.00	14.00	3.10
30	906.00	6.61	<2	<2	11.00	2.70

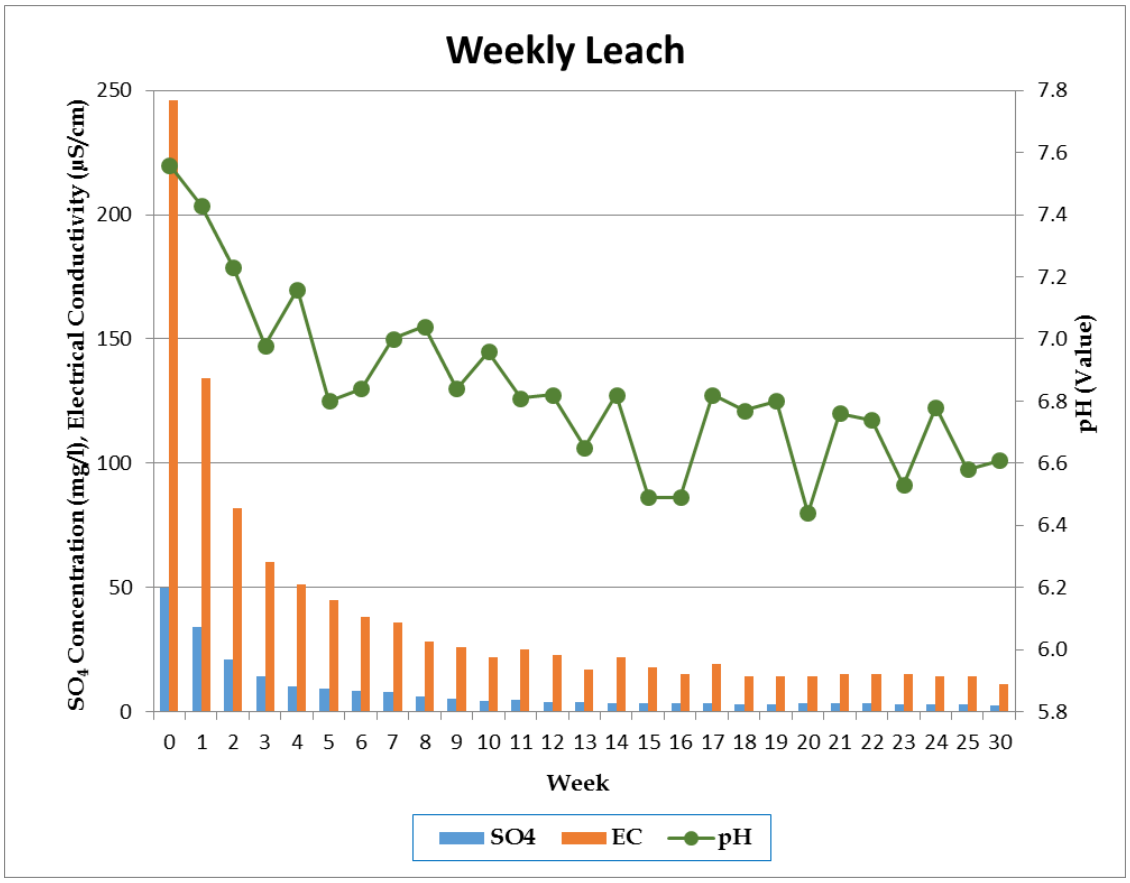


Figure 11.45: Weekly leach SO_4 (mg/l), EC (µS/cm) and pH (value)

Table 11.40: ICP-OES results of weekly leach

Para-meters (mg/l)	Tailings											WHO 2011		
												0-50% of guideline	50%-100% of guideline	Above guideline
Week	0	1	2	3	4	5	10	15	20	25	30			
Ag	0.00002	0.00003	<0.00001	0.00001	<0.00001	<0.00001	0.00001	<0.00001	<0.00001	0.000011	<0.000002	-	-	-
Al	2.02	3.08	0.28	0.54	0.62	1.62	0.6	0.33	0.03	0.07	0.13	<0.45	0.45-0.9	>0.9*
As	0.0015	0.0013	0.001	0.0009	0.0005	0.0004	0.0003	<0.0002	0.0003	0.0003	0.0003	<0.005	0.005-0.01	>0.01
B	0.0174	0.0081	0.0046	0.0031	0.0071	0.0023	0.0008	0.001	0.0013	0.001	0.00004	<1.2	1.2-2.4	>2.4
Ba	0.642	0.337	0.213	0.274	0.198	0.239	0.266	0.272	0.237	0.258	0.223	<0.35	0.35-0.7	>0.7
Be	0.00018	0.00011	0.00004	0.00007	0.00003	0.00004	0.00004	<0.0002	<0.00002	<0.000007	0.000013	-	-	-
Bi	<0.00001	<0.0001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.000007	<0.000007	-	-	-
Ca	1.78	0.72	0.49	0.52	0.49	0.57	0.74	0.76	0.66	0.71	0.61	-	-	-
Cd	0.000112	0.000132	0.000025	0.000031	0.000014	0.00002	0.000044	0.000013	0.000012	0.000007	0.000014	<0.0015	0.0015-0.003	>0.003
Co	0.00275	0.00212	0.000887	0.00115	0.000708	0.000735	0.000612	0.000433	0.000307	0.0000248	0.000169	-	-	-
Cr	0.0099	0.0147	0.0023	0.0115	0.0046	0.0028	0.0036	<0.0005	<0.0005	0.00008	0.00051	<0.025	0.025-0.05	>0.05
Cu	0.0168	0.0143	0.0049	0.011	0.0053	0.005	0.0034	0.0012	0.0009	0.00144	0.00098	<1	1-2	>2
Fe	2.17	2.94	0.377	0.566	0.611	1.43	0.514	0.269	0.032	0.064	0.085	<1	1-2	>2**
Hg	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.003	0.003-0.006	>0.006
K	1.19	0.673	0.411	0.364	0.303	0.36	0.162	0.097	0.071	0.061	0.047	-	-	-
Li	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.000138	0.000094	-	-	-
Mg	1.3	0.621	0.363	0.382	0.333	0.465	0.58	0.588	0.511	0.504	0.449	-	-	-
Mn	0.0295	0.0167	0.0117	0.0107	0.00861	0.0099	0.0112	0.0106	0.00801	0.00689	0.00496	<0.25	0.25-0.5	>0.5**
Mo	0.1	0.0545	0.0181	0.0119	0.00785	0.00689	0.00441	0.00252	0.003	0.00505	0.00615	-	-	-
Na	45.4	22.5	14.1	10	7.38	7.02	2.39	1.23	0.85	0.68	0.52	-	-	-
Ni	0.0301	0.0314	0.0075	0.0197	0.0087	0.0067	0.0064	0.0023	0.002	0.0025	0.0022	<0.035	0.035-0.07	>0.07
P	0.231	0.201	0.093	0.08	0.093	0.117	0.036	0.052	0.04	0.035	0.049	-	-	-
Pb	0.00094	0.0007	0.00014	0.00053	0.00025	0.00021	0.000022	0.00002	<0.00002	0.00004	0.0004	<0.005	0.005-0.01	>0.01
Sb	0.0028	0.0022	0.0011	0.0012	0.0007	0.0006	0.0004	<0.0002	0.0002	0.0002	<0.0002	<0.01	0.01-0.02	>0.02
Se	0.006	0.003	0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.02	0.02-0.04	>0.04
Si	15.4	19.8	9.15	8.61	7.41	10.3	6.01	4.44	3.59	3.61	3.59	-	-	-
Sn	0.00065	0.00043	0.00026	0.00029	0.00024	0.00017	0.0002	0.00033	0.0007	0.000034	0.00027	-	-	-
Sr	0.0497	0.0401	0.0139	0.0158	0.0151	0.0268	0.023	0.0213	0.0157	0.0167	0.0149	-	-	-
Ti	0.0258	0.0537	0.0046	0.0384	0.0146	0.008	0.0145	0.0007	0.0006	0.00297	0.00252	-	-	-
Tl	0.0004	0.0004	<0.00002	0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.000005	<0.000005	-	-	-
Th	0.000498	0.000371	0.000119	0.000177	0.000107	0.000074	0.00008	0.00001	0.000006	0.00001	0.00001	-	-	-
U	0.00203	0.00141	0.000588	0.000678	0.000431	0.000393	0.000244	0.000107	0.000064	0.000131	0.000069	<0.0015	0.0015-0.03	>0.03
V	0.0733	0.0894	0.0379	0.06856	0.0392	0.0304	0.0247	0.0128	0.0149	0.0183	0.0156	-	-	-
W	0.00026	0.0004	0.00013	0.0001	0.00014	<0.00003	<0.00003	<0.00003	0.00007	<0.00002	<0.00002	-	-	-
Y	0.0187	0.0101	0.00529	0.0063	0.00399	0.00405	0.00184	0.000956	0.000285	0.000527	0.000451	-	-	-
Zn	0.031	0.047	0.002	0.008	0.009	0.024	0.009	0.005	0.002	0.003	0.002	-	-	-
Zr	-	0.0055	0.00133	0.00333	0.00149	0.00089	0.00106	0.00015	0.00006	<0.002	<0.002	-	-	-

*World health organisation (WHO): chemicals for which guideline values have not been established.

**No established WHO guideline values. Derived from research in WHO (2011) report also similar to SANS 241:2011 drinking water standard.

11.2.1.7 *Distilled Water Leach*

Selected material was submitted for distilled water extraction. The following pertain to the leaching test method used:

- The distilled water extraction is based on the principle that reactive minerals in the solid phase will equilibrate with the water phase. Especially some recently formed hydrated secondary minerals can be extracted through this method;
- Leaching tests identify the elements that will leach out of waste but do not reflect the site-specific concentration of these elements in actual seepage as a different water/rock ration and contact time will be present in the field; and
- The material was leached by distilled water extraction. A water/rock ratio of 1:4 was used where 100 g of the waste sample was reacted with 400ml of solution for 24 hr.

The results are presented as follows:

- System parameters and anions measured in the extraction are listed in Table 11.41; and
- The ICP-OES results for metals are listed in Table 11.42.

For leaching test results the following observations could be made:

- The pH of the leachate for all the samples are near neutral, except for 1 sample (MOLO 43 116-117m) with a more acidic pH of 4.59. This sample also contains a significant pyrite content;
- The EC (electrical conductivity) were at very low levels in the leachate. MOLO 43 with a lower pH have a higher conductivity;
- No significant elevations of NO_3, Cl or F were present in the extractions;
- SO_4 leached at very low levels in all the samples; and
- Very few metals leached from the waste rock samples under near neutral conditions. Metals that leached at elevated concentrations from only 1 or 2 samples include: Al, Fe, Mn and Ni.

Table 11.41: System parameters and major anions in distilled water extraction

Sample ID	Depth (m)	*	pH (Value)	EC (µS/cm)	SO_4 (mg/l)	Total Alkalinity (mg/l)	Cl (mg/l)	Nitrate as N (mg/l)	Ammonia as N (mg/l)	F (mg/l)
MOLO26	33-34		8.05	54	8.7	10	1.1	< 0.03	< 10	0.39
MOLO26	45.5-46.5		8.69	45	1.7	15	2.2	< 0.03	< 10	0.19
MOLO38	64.17-65.17		9.30	85	3.8	37	1.2	< 0.03	< 10	0.83
MOLO31	4-5		8.73	69	8.5	20	2.6	< 0.03	< 10	0.29
MOLO37	15-16		8.75	63	7.4	17	1.1	< 0.03	< 10	0.41
MOLO41	37.5-38.5		8.20	106	2.7	51	0.6	< 0.03	< 10	0.26
MOLO41	47-48		7.63	59	1.1	28	0.3	< 0.03	< 10	0.11
MOLO41	59-60		8.12	52	0.5	25	0.2	< 0.03	< 10	< 0.06
MOLO43	116-117		4.59	348	140	< 2	2.7	< 0.03	< 10	< 0.06
MOLO43	132-133		6.16	72	23	< 2	0.4	< 0.03	< 10	0.08

* Red = Garnet Gneiss, Brown = Biotite Gneiss, Yellow = Amphibolitic Gneiss, Blue = QF Gneiss, Green =PEG

Table 11.42: ICP-OES results of the distilled water extraction

Para-meters (mg/l)	Distilled Water Leach										WHO 2011		
Sample ID	MOLO26 (33-34 m)	MOLO26 (45.5-46.5m)	MOLO38 (64.17-65.17 m)	MOLO31 (4-5 m)	MOLO37 (15-16 m)	MOLO41 (37.5-38.5m)	MOLO41 (47-48 m)	MOLO41 (59-60 m)	MOLO43 (116-117m)	MOLO43 (132-133m)	0-50% of guideline	50%-100% of guideline	Above guideline
Al	0.19	0.3	0.73	0.33	0.36	0.05	0.36	0.31	0.06	< 0.01	<0.45	0.45-0.9	>0.9*
As	0.0006	0.0015	0.0027	0.0007	0.0005	0.0004	0.001	< 0.0002	0.0004	< 0.0002	<0.005	0.005-0.01	>0.01
Ba	0.0046	0.00209	0.0267	0.00256	0.00482	0.0055	0.00435	0.00141	0.0528	0.00389	<0.35	0.35-0.7	>0.7
Be	< 0.000007	0.000008	0.00015	< 0.000007	< 0.000007	< 0.000007	< 0.000007	< 0.000007	0.000586	< 0.000007	-	-	-
Bi	< 0.000007	< 0.000007	0.000079	< 0.000007	< 0.000007	< 0.000007	< 0.000007	< 0.000007	< 0.000007	< 0.000007	-	-	-
Ca	0.4	0.11	0.66	0.17	0.14	5.5	6.69	4.9	22.6	2.37	-	-	-
Cd	0.000008	0.00001	0.000111	< 0.000003	0.00001	0.000003	< 0.000003	< 0.000003	0.0011	0.000003	<0.0015	0.0015-0.003	>0.003
Co	0.000384	0.000194	0.00405	0.00005	0.000062	0.000147	0.000014	0.000028	0.0404	0.000732	-	-	-
Cr	0.00116	0.00039	0.0139	0.00266	0.00115	0.00064	< 0.00003	< 0.00003	< 0.00003	< 0.00003	<0.025	0.025-0.05	>0.05
Cu	0.00123	0.00072	0.0189	0.00072	0.00123	0.00066	0.00028	0.00036	0.00696	0.0036	<1	1-2	>2
Fe	0.138	0.071	1.51	0.142	0.242	0.194	< 0.002	0.064	0.692	0.003	<1	1-2	>2**
K	1.34	1.45	0.783	0.409	0.563	2.01	3.86	2.14	5.56	4.1	-	-	-
Li	0.00182	0.000547	0.00108	0.000729	0.00112	0.00118	0.00128	0.00162	0.01528	0.00395	-	-	-
Mg	0.159	0.03	0.3	0.108	0.08	1.53	0.874	0.968	20.5	2.1	-	-	-
Mn	0.00374	0.0075	0.117	0.00039	0.00044	0.0167	0.0005	0.00107	0.568	0.0234	<0.25	0.25-0.5	>0.5**
Mo	0.00202	0.00148	0.00954	0.0011	0.00091	0.00169	0.00029	0.00029	0.00004	0.0009	-	-	-
Na	9.52	8.62	18.2	13.8	12.8	15.1	1.96	3.76	5.95	4.41	-	-	-
Ni	0.0023	0.0007	0.0794	0.0006	0.0013	0.0022	< 0.0001	< 0.0001	0.185	0.0035	<0.035	0.035-0.07	>0.07
Pb	0.0002	0.00035	0.00106	0.00003	0.00005	0.00003	0.00001	0.00001	0.00008	0.00004	<0.005	0.005-0.01	>0.01
Sb	0.0003	0.0003	< 0.0002	0.0003	< 0.0002	0.0002	0.0002	< 0.0002	< 0.0002	< 0.0002	<0.01	0.01-0.02	>0.02
Se	< 0.001	< 0.001	0.009	< 0.001	< 0.001	0.002	< 0.001	< 0.001	0.003	< 0.001	<0.02	0.02-0.04	>0.04
Si	6.91	3.82	11.3	7.35	6.41	8.65	3.91	5.73	9.81	2.54	-	-	-
Sn	0.00003	0.00008	0.0012	0.00004	0.00009	0.00004	< 0.00001	0.00006	0.00005	0.00004	-	-	-
Sr	0.0018	0.0009	0.004	0.0017	0.003	0.0171	0.0199	0.0156	0.0847	0.0121	-	-	-
Ti	0.0289	0.00273	0.592	0.0111	0.0157	0.00268	< 0.00005	0.00208	0.00041	0.00012	-	-	-
U	0.00004	0.000167	0.000904	0.000036	0.000064	0.00004	0.000005	0.000048	0.000069	< 0.000002	<0.0015	0.0015-0.03	>0.03
V	0.0064	0.0544	0.062	0.00667	0.0107	0.00179	0.0118	0.00399	< 0.00001	0.00019	-	-	-
W	0.00028	0.00042	0.00249	0.0002	0.00037	0.00015	0.00042	0.00014	0.0001	0.00007	-	-	-
Zn	< 0.002	< 0.002	0.037	< 0.002	0.009	0.004	< 0.002	< 0.002	0.12	< 0.002	-	-	-

* Red = Garnet Gneiss, Brown = Biotite Gneiss, Yellow = Amphibolitic Gneiss, Blue = QF Gneiss, Green =PEG

World health organisation (WHO): chemicals for which guideline values have not been established.

**No established WHO guideline values. Derived from research in WHO (2011) report also similar to SANS 241:2011 drinking water standard.

11.2.1.8 *Peroxide Leach*

The samples were leached with a 15% hydrogen peroxide solution. The following pertain to the leaching test method used:

- The static peroxide test is based on the principle that sulphuric acid produced from the oxidation reaction of pyrite, will mobilize certain chemical from the rock; and
- A rock/water ratio of 1:100 was used where 4 g of sample was reacted with 400 ml of 15% hydrogen peroxide.

The results are presented as follows:

- System parameters and anions measured in the leachate are listed in Table 11.43; and
- The ICP-OES results for metals are listed in Table 11.44.

From the above data the following observations could be made:

- It is important to note that the peroxide extraction simulates extreme conditions where all the pyrite is oxidized at once, which will never happen under field conditions. Under field conditions 1) not all pyrite will be oxidized as some minerals are physically shielded by the rock matrix, and 2) oxidation will occur over a long period of time;
- The pH for all the samples are near neutral;
- SO_4 leached from the samples are very low;
- Ammonia leached at elevated concentrations from the samples;
- No Cl, F and NO3 leached from the samples;
- Few metals leached at marginal concentrations from some of samples. Metals and trace elements leached from the samples include Al, Cr, K, Mn, Se, Si, and V.

Table 11.43: System parameters and major anions in peroxide extraction test

Sample ID	Depth (m)	*	pH (Value)	EC (µS/cm)	SO_4 (mg/l)	Total Alkalinity (mg/l)	Cl (mg/l)	Nitrate as N (mg/l)	Ammonia as N (mg/l)	F (mg/l)
MOLO26	33-34		6.44	58	3.4	31	< 5	< 0.3	17.2	0.17
MOLO26	45.5-46.5		5.94	26	< 2	10	< 5	< 0.3	18.0	0.06
MOLO38	64.17-65.17		6.99	127	15	50	< 5	< 0.3	22.5	0.25
MOLO31	4-5		6.39	56	2.6	31	< 5	< 0.3	118	0.15
MOLO37	15-16		6.53	70	2.3	34	< 2	< 0.3	115	0.11
MOLO41	37.5-38.5		6.66	64	2.5	36	< 5	< 0.3	110	0.15
MOLO41	47-48		6.48	60	< 2	34	< 2	< 0.3	111	0.14
MOLO41	59-60		6.41	59	4.1	30	< 2	< 0.3	125	0.13
MOLO43	116-117		7.85	73	< 2	35	< 2	< 0.3	< 10	< 0.06
MOLO43	132-1322		6.63	72	3.5	39	< 5	< 0.3	21.7	< 0.06

*** Red = Garnet Gneiss, Brown = Biotite Gneiss, Yellow = Amphibolitic Gneiss, Blue = QF Gneiss, Green =PEG**

Table 11.44: NAG ICP results of peroxide extraction test

Para-meters (mg/l)	Peroxide Leach										WHO 2011		
Sample ID	MOLO26 (33-34 m)	MOLO26 (45.5-46.5m)	MOLO38 (64.17-65.17m)	MOLO31 (4-5 m)	MOLO37 (15-16 m)	MOLO41 (37.5-38.5m)	MOLO41 (47-48 m)	MOLO41 (59-60 m)	MOLO43 (116-117m)	MOLO43 (132-133m)	0-50% of guideline	50%-100% of guideline	Above guideline
Al	0.10	0.04	0.24	0.15	0.21	0.12	0.20	0.13	0.11	0.04	<0.45	0.45-0.9	>0.9*
As	0.0005	0.0007	0.0011	0.0003	0.0006	0.0005	0.0005	0.0003	< 0.0002	< 0.0002	<0.005	0.005-0.01	>0.01
Ba	0.0168	0.00534	0.0251	0.0209	0.0803	0.0252	0.0254	0.0189	0.00756	0.0087	<0.35	0.35-0.7	>0.7
Be	< 0.000007	0.000012	0.000013	< 0.000007	0.00001	< 0.000007	< 0.000007	< 0.000007	< 0.000007	< 0.000007	-	-	-
Bi	< 0.000007	< 0.000007	< 0.000007	< 0.000007	< 0.000007	< 0.000007	< 0.000007	< 0.000007	< 0.000007	< 0.000007	-	-	-
Ca	2.8	0.74	4.77	2.15	3.44	2.63	2.58	2.23	12.9	13.5	-	-	-
Cd	0.000024	0.000214	0.000064	< 0.000003	< 0.000003	< 0.000003	< 0.000003	0.000028	< 0.000003	0.00001	<0.0015	0.0015-0.003	>0.003
Co	0.00207	0.0039	0.00778	0.00148	0.00417	0.00277	0.000906	0.000219	0.000025	0.000432	-	-	-
Cr	0.02734	0.00722	0.0093	0.00825	0.013	0.00623	0.00487	0.0112	0.00565	0.00516	<0.025	0.025-0.05	>0.05
Cu	0.00088	0.00089	0.00268	0.00125	0.00226	0.00214	0.00193	0.001	0.00192	0.00053	<1	1-2	>2
Fe	0.101	0.015	0.904	0.262	0.265	0.178	0.268	0.093	0.012	0.023	<1	1-2	>2**
K	1.50	2.59	2.62	1.58	1.19	1.87	2.47	1.67	2.17	2.52	-	-	-
Li	0.00129	0.000484	0.000975	0.00113	0.00123	0.00167	0.00155	0.00142	0.000492	0.00161	-	-	-
Mg	1.12	0.33	2.08	1.17	1.47	1.14	1.24	1.03	0.04	1.78	-	-	-
Mn	0.0428	0.196	0.396	0.0192	0.219	0.118	0.106	0.00238	0.00112	0.138	<0.25	0.25-0.5	>0.5**
Mo	0.00471	0.00154	0.0204	0.00114	0.00042	0.00113	0.00048	0.00071	0.00227	0.00488	-	-	-
Na	11.10	1.47	20.40	11.60	11.00	13.00	11.70	12.60	1.91	1.10	-	-	-
Ni	0.0041	0.0056	0.0239	0.0038	0.0061	0.0024	0.0008	0.0018	0.0002	0.0005	<0.035	0.035-0.07	>0.07
Pb	0.00003	0.00004	0.00034	0.00016	0.00009	0.00018	0.00011	0.00002	0.00003	0.00003	<0.005	0.005-0.01	>0.01
Sb	0.0005	0.0005	0.0004	0.0004	0.0003	0.0003	0.0003	0.0003	0.0004	0.0003	<0.01	0.01-0.02	>0.02
Se	0.001	< 0.001	0.007	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	<0.02	0.02-0.04	>0.04
Si	4.68	1.84	5.47	3.66	3.52	3.12	2.82	3.26	7.21	2.59	-	-	-
Sn	0.00036	0.00038	0.00098	0.00088	0.0115	0.00087	0.0159	0.00058	0.00028	0.00043	-	-	-
Sr	0.0054	0.0087	0.0145	0.0162	0.0149	0.0111	0.0084	0.0073	0.039	0.0264	-	-	-
Ti	0.0098	0.00174	0.0693	0.0383	0.0721	0.0119	0.0936	0.0106	0.00011	0.00571	-	-	-
U	0.000725	0.00144	0.000398	0.000248	0.000074	0.00007	0.000136	0.000469	0.000005	0.000069	<0.0015	0.0015-0.03	>0.03
V	0.0537	0.0557	0.145	0.0974	0.0228	0.0305	0.0115	0.0547	0.00445	0.00469	-	-	-
W	0.004	0.00202	0.00188	0.00155	0.00161	0.00101	0.00141	0.00093	0.00024	0.00115	-	-	-
Zn	0.014	0.01	0.02	0.014	0.008	0.008	0.015	0.019	< 0.002	0.003	-	-	-

***** Red = Garnet Gneiss, Brown = Biotite Gneiss, Yellow = Amphibolitic Gneiss, Blue = QF Gneiss, Green =PEG

*World health organisation (WHO): chemicals for which guideline values have not been established.
**No established WHO guideline values. Derived from research in WHO (2011) report also similar to SANS 241:2011 drinking water stand

11.2.2 Numerical Geochemical Model

11.2.2.1 *Introduction*

Geochemical modelling was performed in order to estimate the long-term seepage water quality of the residue facilities, i.e. the tailings dam, the waste rock dump and the pit lake. Analytical results cannot be used directly to establish the changes in the seepage water quality over time. Due to the complexity in the interaction between the solid, water and gas phases, numerical modelling was used to predict the Acid Mine Drainage (AMD).

11.2.2.2 *Model Limitations*

The following relates to the model limitations:

- The quality of the model input and model results are inherently limited by the representativeness of the samples, the geochemical test work performed as well as assumptions on the post-closure physical environment. The model is at best an estimation of the typical reactions and water quality that could be expected;
- The model simulated the typical mineral reactions that will be present in the residue material. However, some mineral reactions were not included as the minerals might not be characterized adequately by the geochemical test results performed;
- The tailings model was calibrated using the kinetic humidity cell test results of the tailings. However, a solid:water ratio of 1:1 was used and some parameters like Cl not analysed. Although a 1:1 ratio may be a "standard procedure" it resulted in very low leachate concentrations which made it difficult to simulate in the model. The concentrations were also close to the detection limit for some parameters and the analytical error would therefore be high. It is recommended that the kinetic leach test is repeated using more ideal conditions;
- Due to project time restrictions humidity cells were not performed for the waste rock. The jarosite content of some waste rock samples are high and would give a good indication of the mineral reaction rate as well as the reaction of other minerals of interest; and
- The model should be updated after further mineralogical studies and be validated and calibrated also with site specific data.

11.2.2.3 *Model Assumptions*

The following assumptions were made:

- It was assumed that the samples tested were representative of the residue material. The tailings sample was prepared by SGS Lakefield. Chemicals that will be added at the plant were not considered in the long-term seepage water quality prediction;
- Only rainfall infiltration was assumed for the post-closure residue dumps;
- Silicate minerals are usually considered too slow reacting to neutralize acid mine drainage. However, all major silicate minerals were incorporated into the model, although some silicate minerals could not be included as the end-members present were not reported by SGS, e.g. amphibole/pyroxene;
- All minerals were incorporated in proportions according to the QEMSCAN analyses in Table 11.24, except sulphur and carbonate bearing minerals that were proportionally calculated from the average S% and the average Neutralisation Potential (NP) respectively;
- Both K- and Na-jarosite were modelled in separate scenarios in the simulation of the tailings humidity cell test (see model scenarios). Because the model were not very sensitive to which is present, only K-jarosite and K-alunite (generally the more common end-member, see Zahrai et al (2013)) were used in most of the models;
- The jarosite dissolution rate was obtained from Zahrai et al (2013) that compiled rates for both K- and Na-jarosite from various studies. Comparison between the reaction rate of K- and Na-jarosite from the author is depicted in Figure 11.46 below;
- All other mineral reaction rates were obtained from Palandri and Kharaka (2004);
- The surface area of the minerals incorporated in the model were calculated from their average diameter determined by QEMSCAN given in Table 11.45; and
- The interaction between the mineral-, water- and the gas phases was modelled using the Geochemist's Workbench Professional. The model solves the hydro-chemical and mineral reactions with the equilibrium model and the kinetic rate law for mineral dissolution.

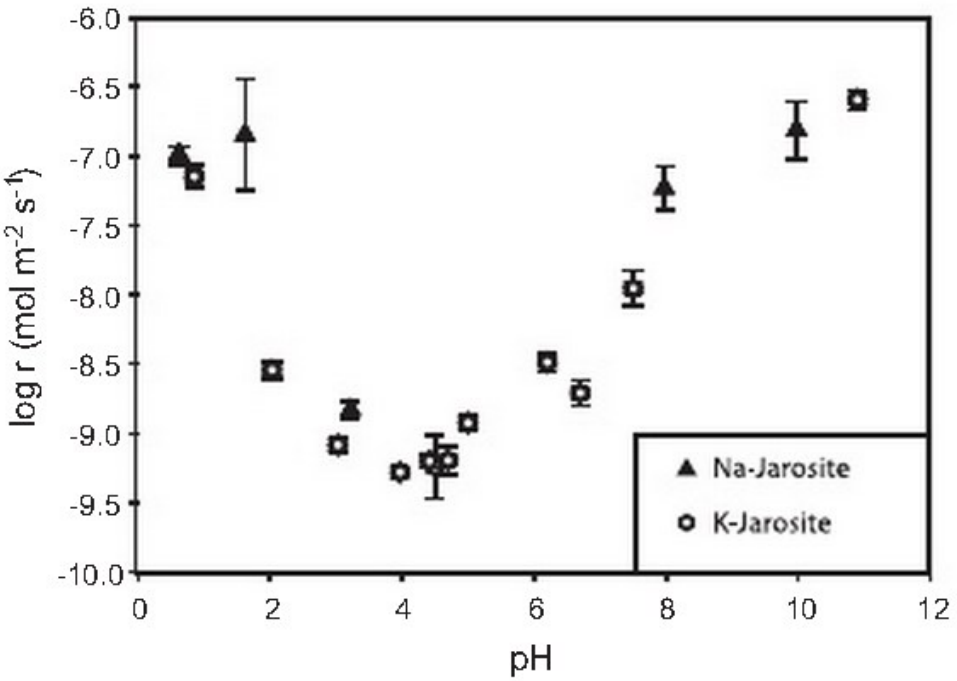


Figure 11.46: Comparison between K- and Na-jarosite dissolution rate from various studies (Zahrai et al, 2013)

Table 11.45: Mean grain size (□m) by frequency (QEMSCAN)

Mineral	Tailings (n = 1)	Average waste rock (n = 4)
Quartz	24	21
Orthoclase and plagioclase	22	22
Biotite and muscovite	10	11
Chlorite	6	5
Gypsum	8	8
Alunite	12	7
Jarosite	13	11
Calcite	10	10
Dolomite	19	5
Siderite	5	5

11.2.2.4 *Model Scenarios*

Five (5) numerical models were compiled as summarized in Table 11.46:

- **Model A** simulated the test results of the tailings humidity cell test performed by SGS Lakefield;

- **Model B Scenario 1 & 2** extended the 30 weeks tailings humidity cell test to a period of 20 years. In Scenario 1 and Scenario 2 K- and Na- jarosite were respectively modelled;
- **Model C Scenario 1 - 4:** Estimated the seepage water quality of the tailings (Co-disposal facility) at different unsaturated thicknesses/depths: 1 m, 5 m, 10 m and 20 m respectively;
- **Model D Scenario 1 - 4:** Estimated the seepage water quality of the waste rock (Co-disposal facility) at different thicknesses/depths: 1 m, 5 m, 10 m and 20 m respectively;
- **Model E Scenario 1 & 2:** Estimated the post-closure water quality of the open mine pit assuming steady state conditions at Year 4 and Year 100 after flooding of the pit;

Table 11.46: Average %S and NP used in numerical model

Model Scenario	Description	Total (%S)	NP $CaCO_3$ (kg/t)
Model A, B and C	Tailings	0.77	2.40
Model D and E	Waste rock	0.31	7.90

11.2.2.5 *Geochemical Model Output/Results*

Model output

Model A to E model results are depicted in Figure 11.47 to Figure 11.52 below.

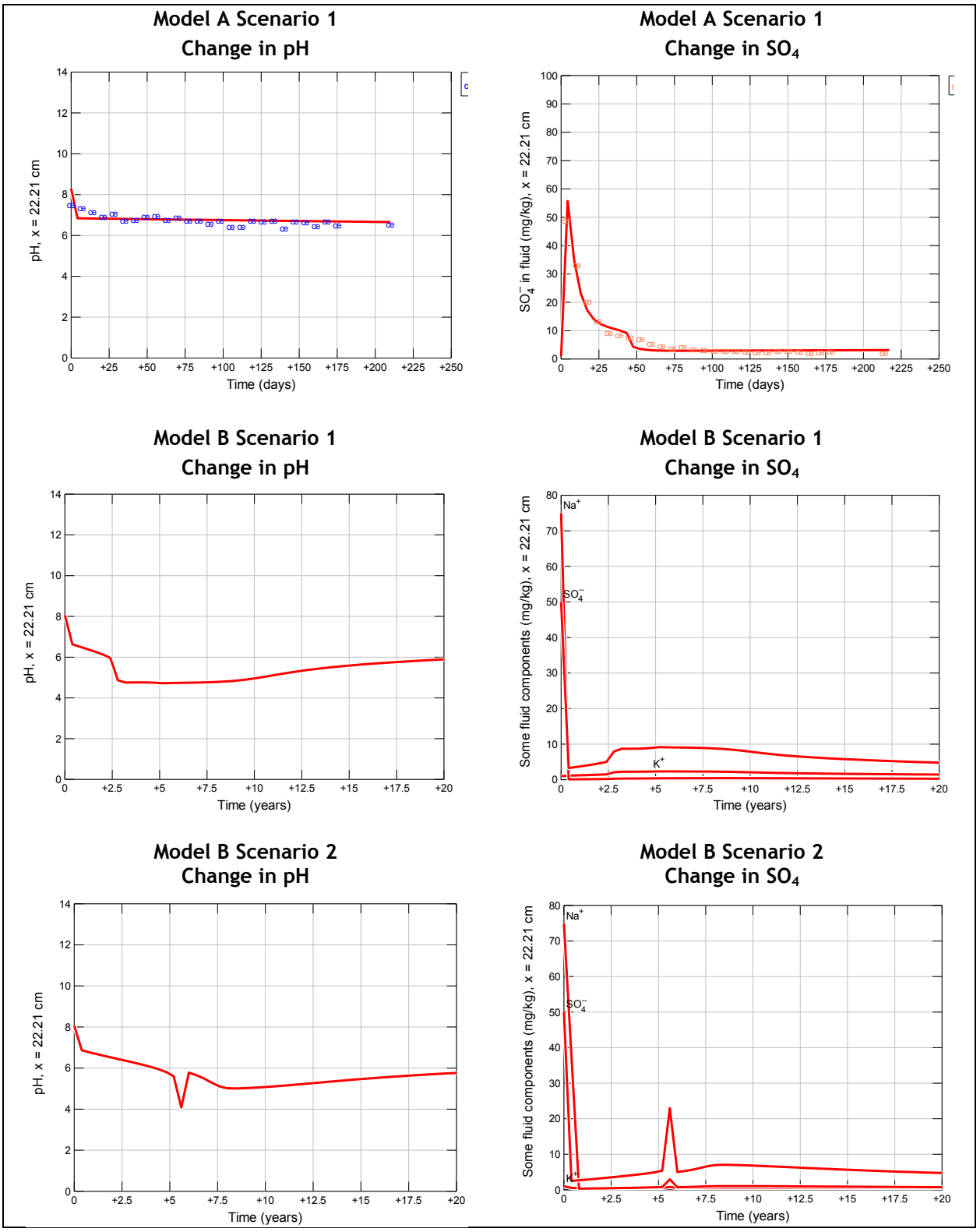


Figure 11.47: Modelled pH and SO_4 in Model A and B (tailings humidity cell)

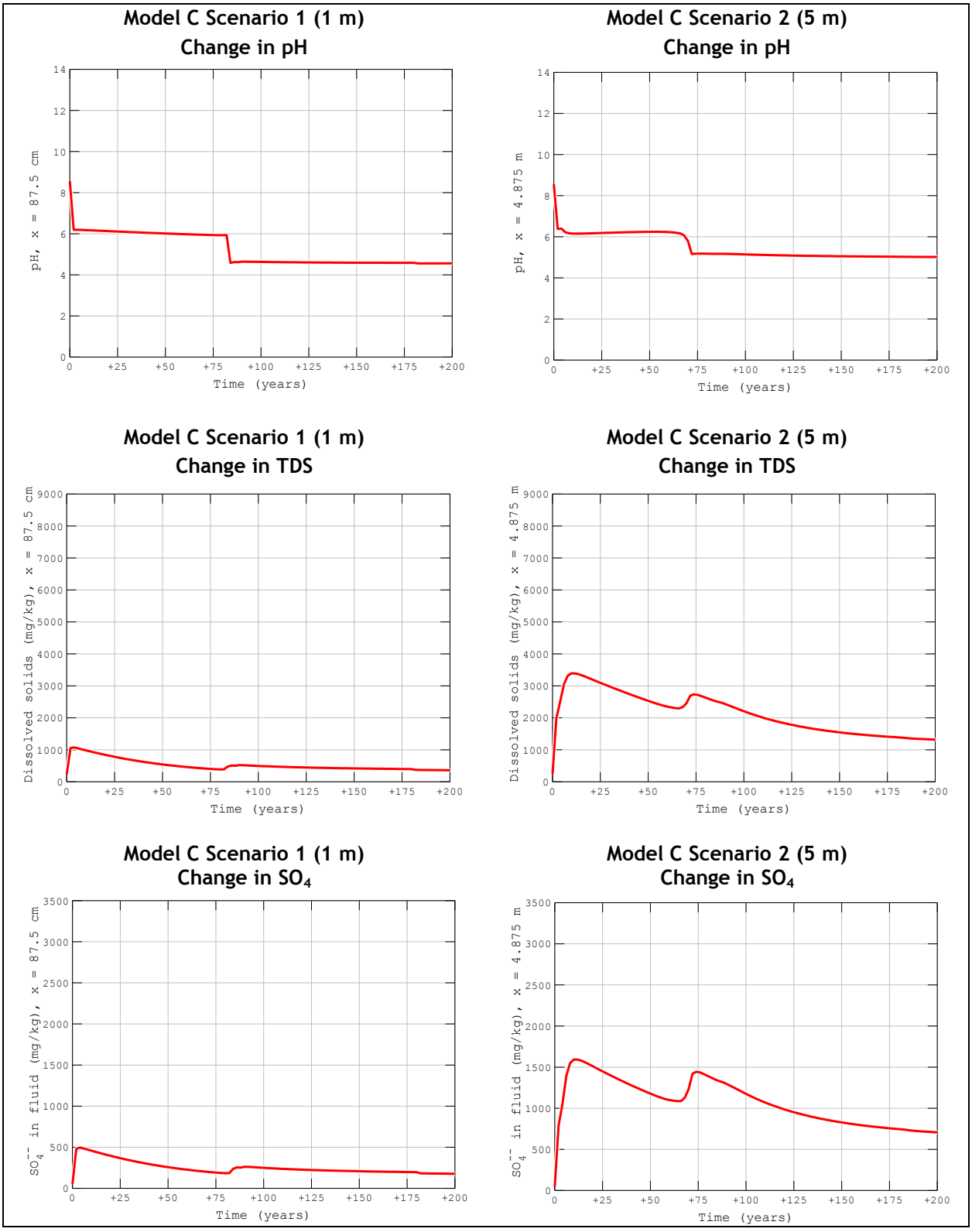


Figure 11.48: Modelled pH and SO_4 in Model C Scenario 1 & 2 (tailings - Co-disposal facility)

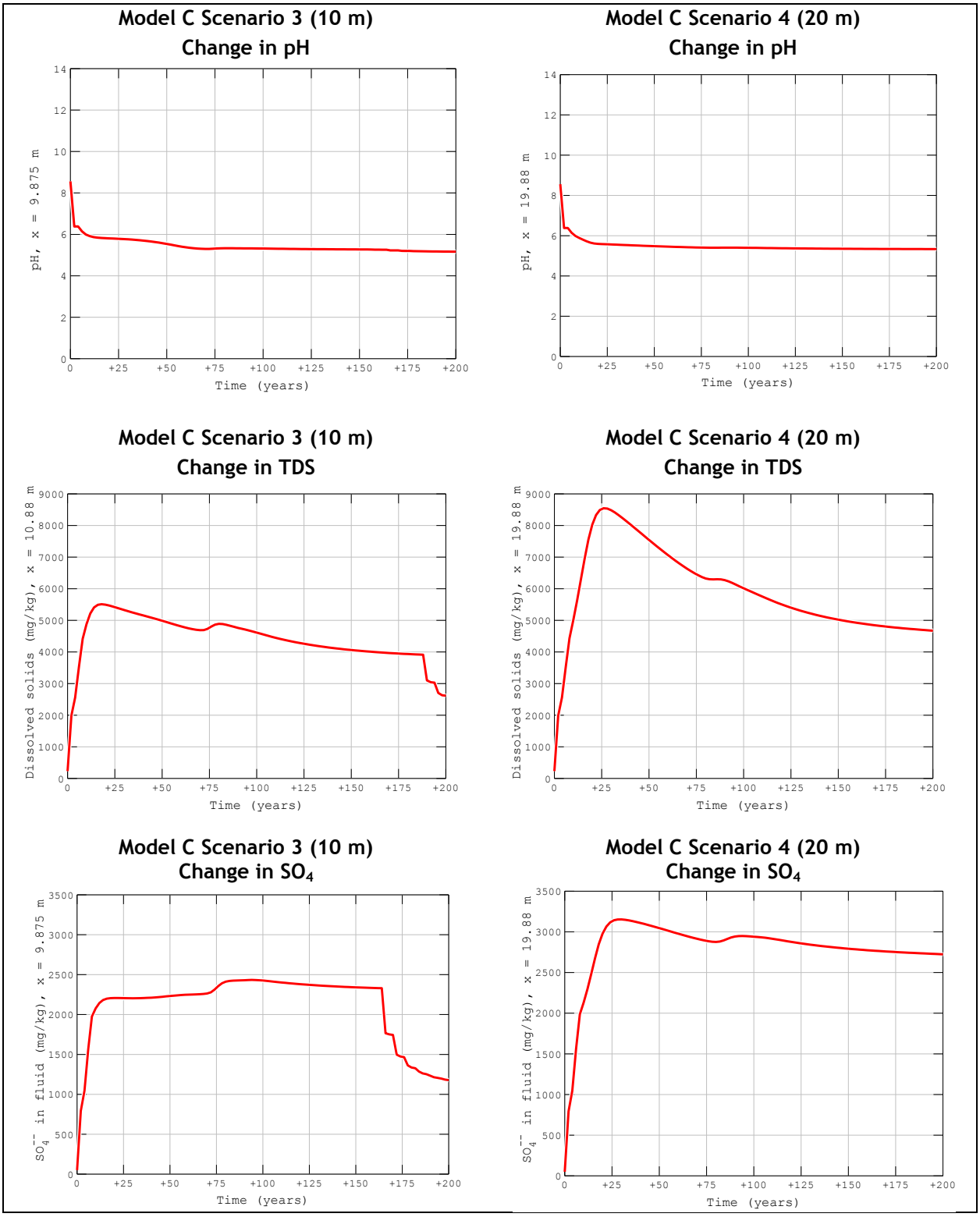


Figure 11.49: Modelled pH and SO_4 in Model C Scenario 3 & 4 (tailings - Co-Disposal Facility)

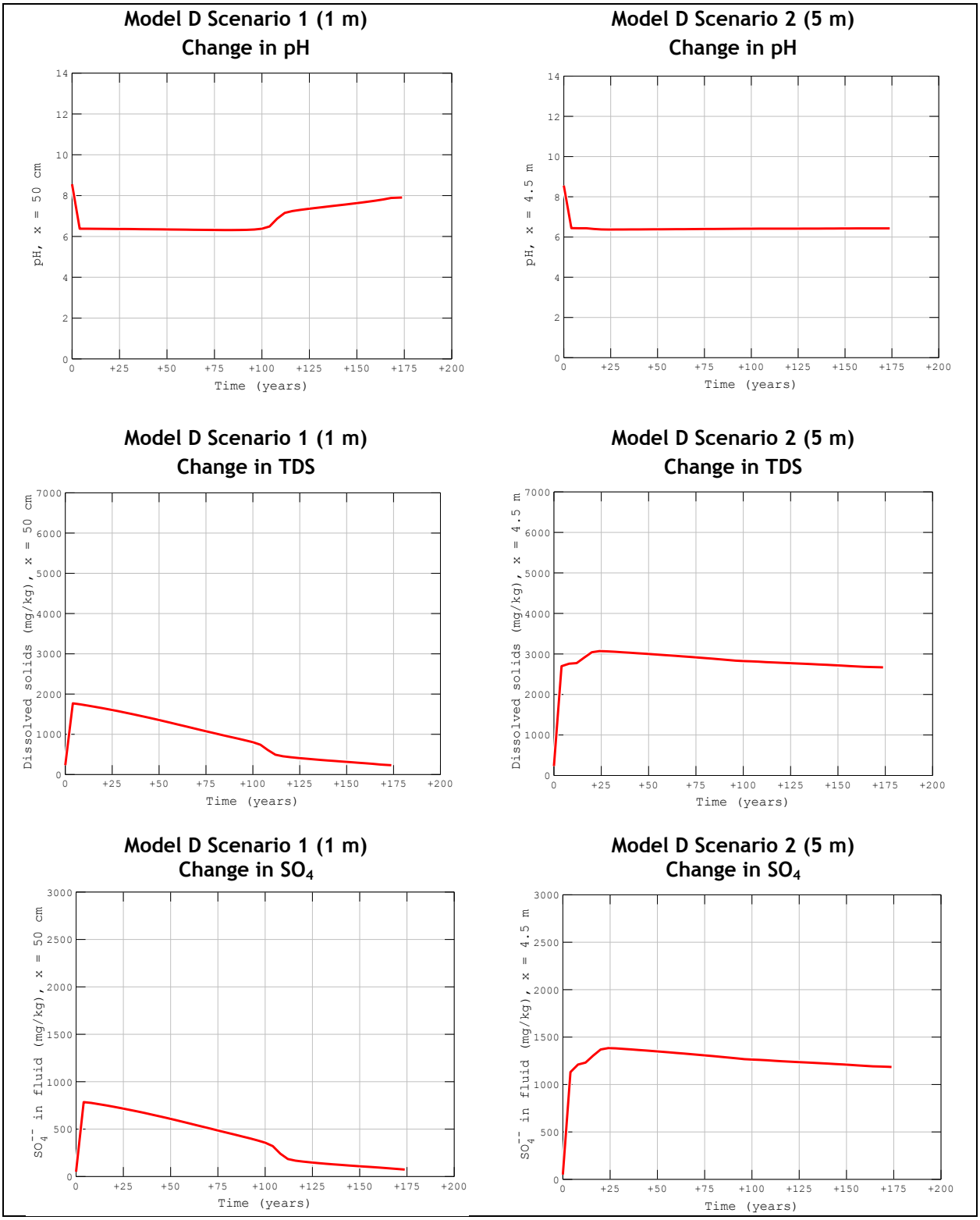


Figure 11.50: Modelled pH and SO_4 in Model D Scenario 1 & 2 (waste rock - Co-Disposal Facility)

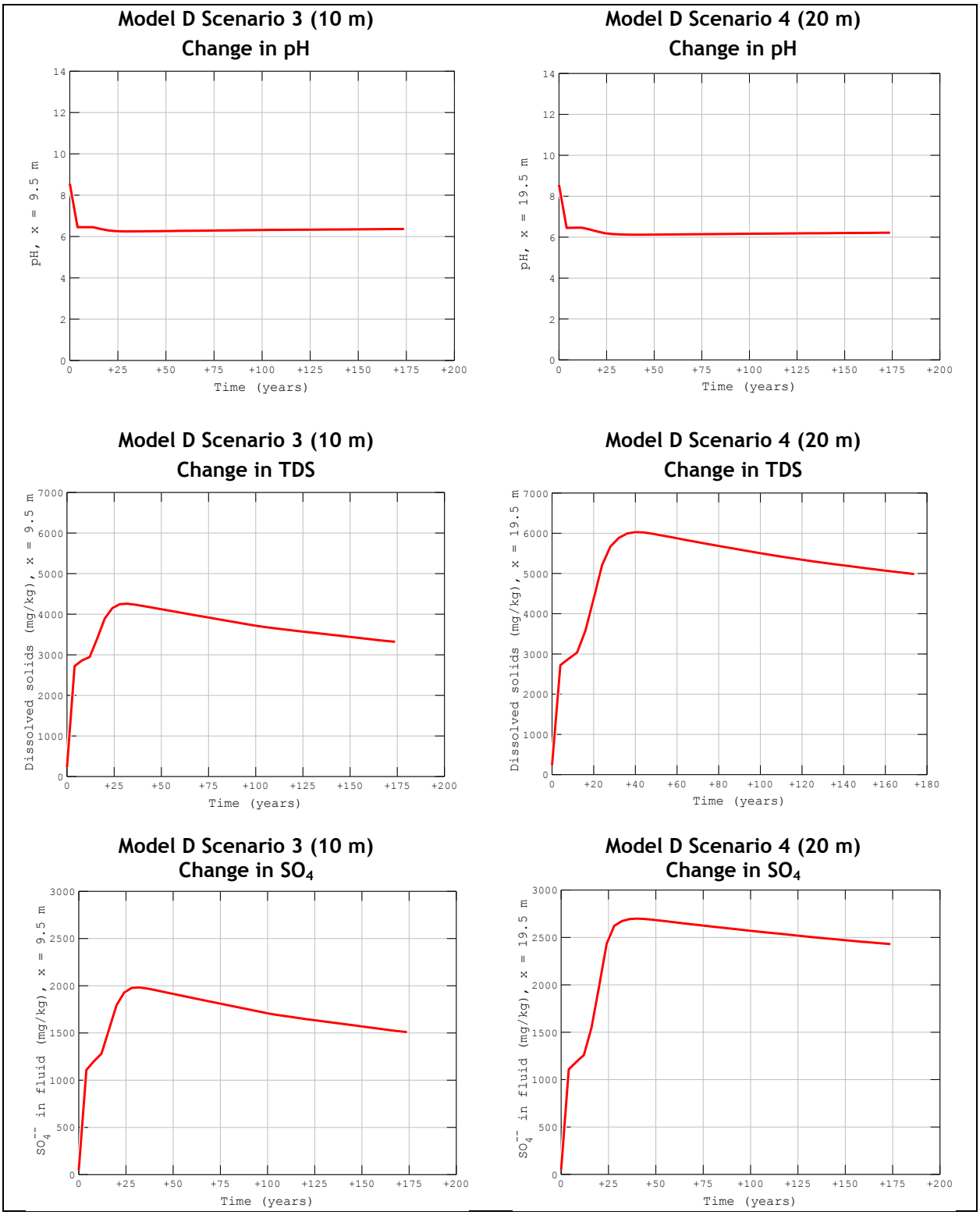


Figure 11.51: Modelled pH and SO_4 in Model D Scenario 3 & 4 (waste rock - Co-Disposal Facility)

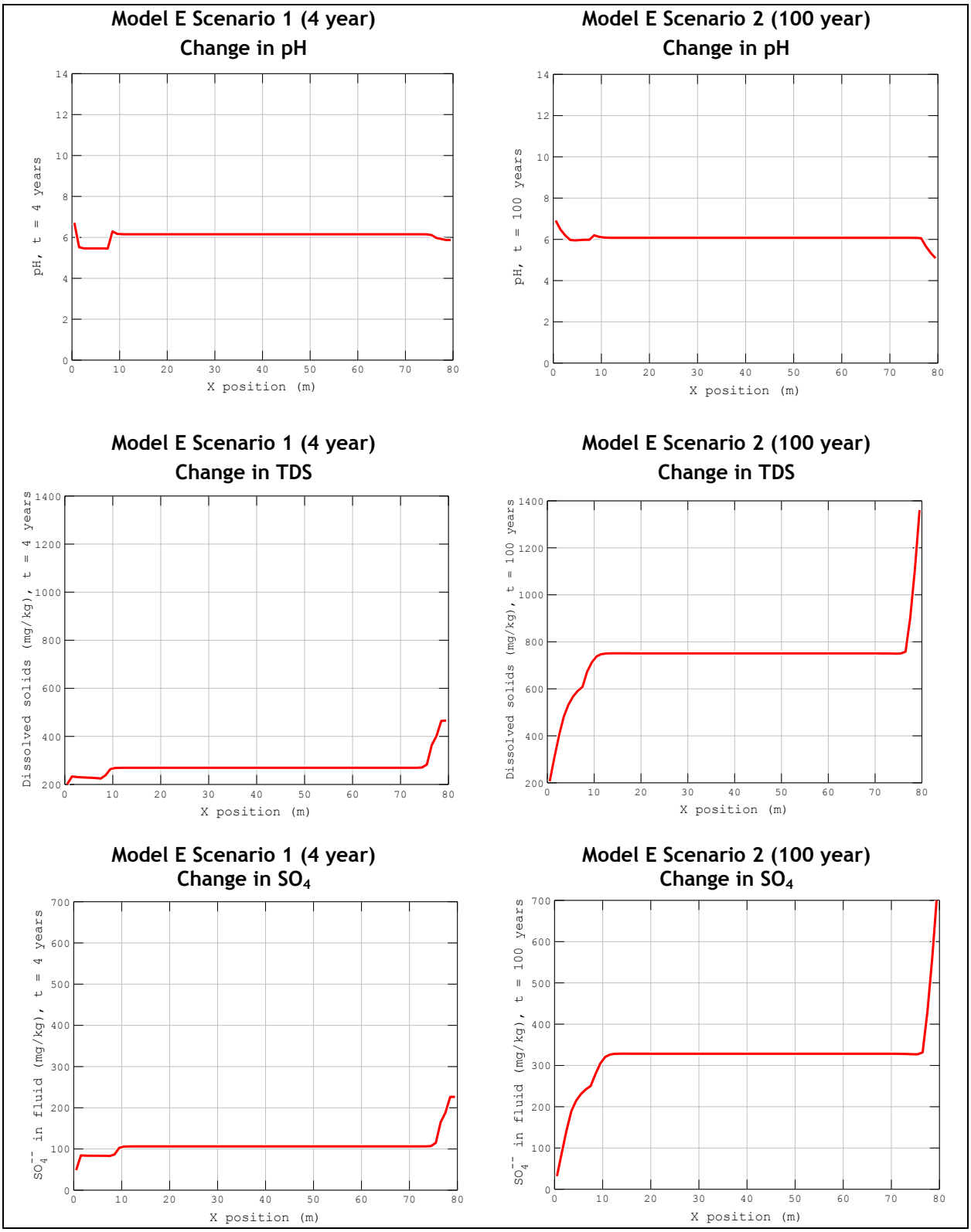


Figure 11.52: Modelled pH and SO_4 in Model E (pit lake)

11.2.2.6 *Model Discussion*

Model A and B - Tailings humidity cell

- The tailings humidity cell was leached for 30 weeks;
- Almost no pyrite were identified in the tailings by QEMSCAN (which is more quantitative than the XRD) and the SO_4 was present at low concentrations (<5 mg/l after 10 weeks);
- Soluble Na- and Fe-sulphates leached during the first 10 weeks. After Week 10 the SO_4 leached at a fairly constant rate for the remainder of the test (Week 30). The SO_4 release rate could be modelled in Model A using literature values for jarosite dissolution. The conditions in the column were also unsaturated which enhanced the jarosite dissolution. In contrast jarosite dissolution was much lower in the modelling of the residue waste because of more saturated conditions present;
- Both the K and Na in the leachate were fairly low and it was not possible to determine whether either K- or Na-jarosite is present. However, the SO_4/Na molar ratio was closer to the ratio in Na-jarosite than the SO_4/K molar ratio was to the ratio in K-jarosite. However, the concentration of the ions was very low and the test should be repeated using more optimal conditions. Further mineralogical tests should also be performed to confirm the end-member present;
- The column simulation was extended to a period of 20 years using K-jarosite in Model B Scenario 1 and Na-jarosite in Model B Scenario 2; and
- In both scenarios the pH dropped to pH 4 - 5 after about 2.5 to 5 years and increases up to pH 6 at the end of the simulation (Year 20).

Model C & D - tailings and waste rock (Co-Disposal Facility)

- Except for mineralogical constraints, the SO_4 in seepage from the residue dumps will also depend on the thickness of the dumps. Therefore, if the dump consists of several benches, these will all have slightly different seepage concentrations. The SO_4 concentration increases because of accumulation of SO_4 in the vertically transported solution. In the tailings dam the SO_4 concentrations at 1 m, 5 m, 10 and 20 m were modelled at 500 mg/l, 1,500 mg/l, 2,500 mg/l and 3,000 mg/l. In the waste rock the SO_4 concentrations at the same depths are 400 mg/l, 1,400 mg/l, 1,800 mg/l and 2,500 mg/l.
- The increase in SO_4 becomes less deeper down the dump as the jarosite becomes saturated because of the increase in SO_4, K and Na in the interstitial water; and
- In the tailings the pH drops from pH 8 to pH 6 over 25 years and to pH 4.5 - 5.5 thereafter. In the waste rock the pH does not drop to below pH 6.

Model E - Open pit lake

- The pit lake model is based on steady state conditions (inflow = outflow) as no water balance was provided for the pit lake. There will however be a constant increase in the pit TDS because of groundwater inflow, surface run-off and evaporation;
- The estimated SO_4 concentration was only about 100 mg/l after the pit was flooded. This increased to about 350 mg/l after 100 years. However, the pit may be much more saline if the pit has a negative water balance (dominated by evaporation). It is actually recommended that the pit is flooded as soon as practically possible after closure. If the pit water is of good quality, storm water should even be diverted into the pit (however local environmental regulations should first be consulted);
- The SO_4 will be the lowest at the top (rainwater dilution) and the lowest at the bottom. Similarly the pH will be the lowest at the bottom because of interaction with bottom material; and
- The water at the top of the pit lake will probably be suitable for animal and some agricultural use.

Based on the geochemical model results, the estimated seepage qualities for a 20 m thick tailings and waste rock material are summarized in Table 11.47 and Table 11.48 below. Concentrations will be lower in seepage on sides and beneath thinner terraces.

Table 11.47: Estimated seepage water quality from the tailings material

Component (mg/l)	Short Term Operational Range	Medium Term Post-closure (± 0 – 25 Year)	Long term Post-closure (25 – 200 Year)
pH (range)	8.0 - 6.5	6.5 - 5.5	6 - 4.5
TDS	1 500 - 3 600	1 500 - 8 000	8 000 - 5 000
Ca and Mg	5 - 250	250 - 500	<500
Na and K	50 – 450	250 - 1 600	1 600– 1 300
SO_4	200 - 1 200 Average 500	500 - 3 200	3 200 - 2 600
Cl	250 - 1300	1 300 - 100	< 100
Alkalinity (as $CaCO_3$)	50 – 150	< 100	< 100
Al	< 5	< 5	< 5
Fe	< 5	< 5	< 5
Mn	< 0.5	< 0.5	< 0.5

* Estimated concentrations for 20 m thick tailings. Concentrations will be lower in seepage on sides and beneath thin terraces.

Table 11.48: Estimated seepage water quality from the waste rock

Component (mg/l)	Short Term Operational Range	Medium Term Post-closure (± 0 – 26 Year)	Long term Post-closure (26 – 200 Year)
pH (range)	8.0 - 6.5	6.5 - 5.5	6.5 - 5.5
TDS	30 - 1900	1 000 - 6 000	6 000 - 5 000
Ca and Mg	5 - 200	40 - 600	<600
Na and K	10 – 400	100 - 1 800	1 800– 1 400
SO_4	15 – 1 000 Average 500	500 - 2 700	2 700 - 2 500
Cl	50 - 300	300 - 50	300 - 50
Alkalinity (as $CaCO_3$)	50 – 150	< 100	< 100
Al	< 5	< 5	< 5
Fe	< 5	< 5	< 5
Mn	< 0.5	< 0.5	< 0.5

* Estimated concentrations for 20 m thick waste rock. Concentrations will be lower in seepage on sides and beneath thin terraces.

Table 11.49: Estimated sulphate and TDS of run-off

Process	Sulphate (SO_4) (mg/l)			Total Dissolved Solids (TDS) (mg/l)		
	Low	Mean	High	Low	Mean	High
Boreholes/Groundwater	15	25	40	200	450	1200
Runoff from Plant area	40	50	150	100	125	375
Runoff from Ore Stockpile area	40	50	150	100	125	375
Runoff from Waste Rock	15	25	90	30	52	190
Runoff from Tailings	15	50	150	100	125	375
Runoff inside Open Pit area	20	30	120	40	55	250

Model Summary

- From the literature it is not clear whether acid mine drainage will occur if only jarosite and alunite (and no pyrite) are present in rock. Various sources state that jarosite dissolution is too slow to generate long-term acid generation whereas others found paste pH of jarosite containing rocks to be acidic (Hammarstroma et al, 2004);

- One (1) highly weathered (logged as decomposed) overburden (waste rock) sample from borehole MOLO 31 taken from 4-5 m contains a significant jarosite and alunite content (S% 0.89; jarosite 5.55 wt%; alunite 1.05; the highest jarosite in all samples tested), and has a paste pH of 6.79 (representative of the pH of the interstitial water). Jarosite had enough time to weather and to generate net acidity (based on the high acid generation potential of the jarosite and low neutralisation potential (NP) in the sample) as the rock decomposed. The sample is also high in oxides (6.81 wt%; probably goethite) that indicates that some jarosite already reacted according to the following incongruent reaction:

  $jarosite\text{-}K \rightarrow 3H^{+} + 3goethite\ (yellow\ stains\ on\ rock) + 2SO_4^{2-} + K^{+}$

  The sample has however a near neutral pH which indicates that acidity must have been consumed in some way by the sample. This could only be explained by the weathering of silicate minerals. The sample is also high in clays which indicate silicate mineral dissolution and a high degree weathering over time;
- The QEMSCAN did not identify the clay present but in the geochemical model kaolinite was assumed (as it forms frequently from feldspars). The kaolinite and K-feldspar were the only silicates that reacted in the model. K-feldspar produces kaolinite and consume some acidity according to the following incongruent reaction:

  $K\text{-}feldspar + 0.5H_2O + H^{+} \rightarrow K^{+} + 0.5kaolinite + 2SiO_2(aq)$

  And kaolinite as follows:

  $kaolinite + H_2O \rightarrow 2Al(OH)_3 + 2SiO_2(aq)$

  The rock therefore does not have enough immediate available neutralization potential in the form of calcite and dolomite, but rather some long-term neutralisation potential available from silicate weathering;
- Another factor influencing the acid generation potential is the slow rate of jarosite dissolution. Jarosite became quickly saturated in the models because of the high SO_4, K or Na present in solution. This further slows down the dissolution rate of the jarosite. Often the jarosite dissolution rate becomes so slow in the model that it is overtaken by alunite dissolution;
- A small amount of Al and Fe are very soluble as indicated in the leach testing performed. This indicates the presence of soluble Fe-Al hydrated sulphates present in the rock. The Fe, Al, SO_4, K and Na in interstitial water all contribute to saturation of the jarosite in the rock. Goethite is however thermodynamically more stable than the jarosite and jarosite dissolution will however still occur albeit very slowly;

- Factors are therefore influencing the acid generation capacity of the in-situ samples, namely: 1) the slow dissolution rate of the jarosite, 2) the saturation of jarosite (because of Fe, Al, SO_4, K and Na in interstitial water), and 3) the protons (acidity) is produced at a slow rate and could be consumed by the slow but steady dissolution of silicates that weather incongruently to clay;
- It could therefore be concluded that 1) the SO_4 concentration in the seepage from the residue material will be high (2 000 – 3 000 mg/l but down to 500 – 2 000 mg/l on sides and below thin terraces), 2) conditions will only be slightly acidic (pH 4. 5 - 6.5), 3) slight elevation in Al and Fe might be present in seepage (average 1 mg/l but up to 5 mg/l); and
- Storm water run-off water qualities were calculated for the operational salt balance of the mine. The estimated water qualities were obtained from 24-48 h water-rock interaction in the models and it was also validated with the 24h distilled water leach test results. Overall, the run-off from some dirty water areas (waste rock, tailings, plant area, ore stockpiles etc.) will have a SO_4 of about 25 to 50 mg/l, reaching values of up to 90 to 150 mg/l. However, in standing water and sumps this will reach higher values if water is not quickly pumped to pollution control facilities.

11.2.3 Conclusions

The following conclusions could be reached from the test results:

Mineralogy

- Overall, the litho-stratigraphy is relatively deeply weathered which would have resulted in the oxidation of pyrite and the occurrence of natural acid rock drainage. Recrystallisation of pyrite in deeper rock (where no oxidation was present) resulted in the formation of marcasite. The natural acidic conditions resulted in the total consumption of carbonate minerals that would explain the relative absence of calcite and dolomite. The gneiss contains relatively high Na and K (with respect to Ca and Mg). Jarosite and alunite precipitates under the natural acidic conditions (pH < 3) as an abundance of Fe/Al, Na/K and SO_4 were present. This natural acid rock drainage did occur in recent geological time (Quaternary Period) and not during the formation of the rock;
- One (1) highly weathered (logged as decomposed) overburden (waste rock) sample from borehole MOLO 31 taken from 4-5 m contains a significant jarosite and alunite content (S% 0.89; jarosite 5.55 wt%; alunite 1.05; the highest jarosite in all samples tested), and has a paste pH of 6.79 (representative of the pH of the interstitial

water). Jarosite had enough time to weather and to generate net acidity (based on the high acid generation potential of the jarosite and low neutralisation potential (NP) in the sample) as the rock decomposed. The sample is also high in oxides (6.81 wt%; probably goethite) that indicate that some jarosite already reacted. The sample has however a near neutral pH which indicates that acidity must have been consumed in some way by the sample. This could only be explained by the weathering of silicate minerals. The sample is also high in clays which indicate silicate mineral dissolution and a high degree weathering over time;

ABA and NAG test

- A summary of the acid generation potential of the lithologies are presented in Table Table 11.50 and Table 11.51 below;
- In contrast to the ABA test, the NAG test of the tailings indicates no potential for acid generation. However, insoluble sulphate minerals are present and that the pyrite is much lower (than estimated using the total S% as in the ABA) in the tailings;
- In the sequential NAG test only a small portion (about 0.077 of 0.77) of the %S could be leached from the tailings upon repeated addition of peroxide which indicate that a large fraction of the sulphur in the rock is insoluble and could also not be oxidized;
- Although 13 of the 34 waste rock samples have a %S higher than 0.3% and also have a low neutralisation potential, the NAG test indicates that only 2 of the 34 waste rock samples actually have potential for acid generation. These 2 samples are from the Molo-43 borehole at a depth of well over 100 m and is logged as "fresh" which adds to the hypothesis that weathering of the gneiss has resulted in less sulphides to be present in the weathered samples as in contrast to deep fresh gneiss;
- Overall the tailings and waste rock samples does not have a significant potential to generate acid mine drainage (to pH below 4.5);

Leach test results

- No acidification was present in the kinetic leach test over the 30 week leaching period;
- The tailings sulphide %S is at 0.77 but SO_4 did not leach at significantly high concentrations after the initial few weeks which is in concurrence with the sequential NAG test results where only a small fraction of the sulphur in the rock was shown to be soluble; and

- Metals did not leach at significant concentrations from the tailings except Al and Fe that were elevated during the first few weeks. The elevated Al, Fe and SO_4 during the first few weeks could be directly attributed to the leaching of Al-Fe-sulphates. In the fairly neutral leachate no other metals were present.

Model results

- Three (3) factors are therefore influencing the acid generation capacity of the in-situ samples, namely: 1) the slow dissolution rate of the jarosite, 2) the saturation of jarosite (because of Fe, Al, SO_4, K and Na in interstitial water), and 3) the protons (acidity) is produced at a slow rate and could be consumed by the slow but steady dissolution of silicates that weather incongruently to clay; and
- It could therefore be concluded that 1) the SO_4 concentration in the seepage from the residue material will be high (2 000 - 3 000 mg/l), 2) conditions will only be slightly acidic (pH 4. 5 - 6.5), 3) slight elevation in Al and Fe might be present in seepage (average 1 mg/l but up to 5 mg/l).

Table 11.50: Potential for various lithologies to generate acidic drainage (ABA test results)

(assuming all S% could be attributed to pyrite which may not be correct - see discussion)

Criteria	No of samples	%S >0.3 NP/AP <2	%S >0.3 NP/AP >2	%S 0.1 - 0.3 NP/AP <2	%S 0.1 - 0.3 NP/AP >2	%S <0.1 NP/AP <2	%S <0.1 NP/AP >2
Tailings	1	100%	0%	0%	0%	0%	0%
Garnet Gneiss	15	40%	7%	0%	0%	13%	40%
Biotite Gneiss	2	50%	0%	0%	0%	0%	50%
Amphibo-litic Gneiss	2	0%	0%	0%	0%	0%	100%
QF Gneiss	7	43%	0%	0%	0%	29%	29%
PEG	2	0%	50%	0%	0%	0%	50%
Potential for acid mine drainage		Likely/possibly acid generating. High salt load.	Low to medium potential for acid generation. Medium salt load.	Low potential for acid generation. Low to medium salt load.	Very low potential for acid generation. Very low to low salt load.	No potential for acidic drainage. Very low/no salt load.	No potential for acidic drainage. Very low/no salt load.

Table 11.51: Potential for various lithologies to generate acidic drainage (NAG test results)

Criteria	No of samples	NAG pH <4.5 NAG Val >10	NAG pH <4.5 NAG Val >0	NAG pH >4.5 NAG Val = 0
Tailings	1	0	0	100%
Garnet Gneiss	15	7% (1 sample)	0	93%
Biotite Gneiss	2	50% (1sample)	0	50%
Amphibolitic Gneiss	2	0	0	100%
QF Gneiss	7	0	0	100%
PEG	2	0	0	100%
Potential for acid mine drainage		Likely/possibly acid generating. High salt load.	Low to medium potential for acid generation. Medium salt load.	Low to no potential for acid generation. Low to medium salt load.

11.3 Numerical Modelling: Groundwater Dewatering and Contaminant Transport

A finite difference numerical groundwater flow and contaminant transport model was constructed, calibrated and verified with available monitoring data and the conceptual model developed for the site. The model was constructed using Processing MODFLOW (Version 8, Simcore Software), a pre- and post-processing package for MODFLOW and MT3DMS. MODFLOW is a three-dimensional groundwater flow model published by the United States Geological Survey (USGS). MODFLOW is a widely used simulation code and well documented. The numerical model was constructed based on the ASTM (2010) standards for the construction and application of a numerical model for the solution of a site-specific problem. The steps as per the ASTM (2010) are shown in Annexure 11 F.

The model was constructed to represent the three hydrogeological units as described in Section 11.1.3.8, with the upper weathered unit represented by layer 1, the upper main fractured unit represented as layer 2 and the lower fractured unit represented by layer 3. Table 11.52 shows a summary of the model layers. The model thickness was set as 120 m, in order to accommodate the maximum proposed mining depth. Model boundary selection was challenging due to the locality of the Molo site on the divide of three major catchments, the lack of known geological and near-site hydraulic boundaries. Groundwater in-out flow boundaries (simulated by general head cells) were selected in a 10 km radius around the proposed mining site as not to impact on model results. Model assumptions and limitations are discussed in Annexure 11 F.

Table 11.52: Model Layer Summary

Layer Properties			
Layer	**Type**	**Description**	**Thickness (m)**
1	3: Confined/Unconfined (Transmissivity Varies)	Upper Weathered Zone	20
2	3: Confined/Unconfined (Transmissivity Varies	Upper Fractured Unit	30
3	0: Confined	Lower Fractured Unit	70

Both steady state and transient state flow models were constructed and calibrated for the site using measured groundwater levels and pumping data. No time-series stream flow measurements were available at or down-stream of the site for calibration. The water balance of local streams, simulated as drain cells (close to the mine site), were however interrogated in order to produce realistic baseflow results. Hydraulic conductivity values are based on the pumping test data (Section 11.1.3.5) and were varied in a narrow realistic range for the site. Recharge values were assigned according to the UNESCO (2008) published rates and was optimised during the calibration process. The model parameters and calibration process are discussed in Annexure 11 F. The transient state flow model incorporated the period between January 2014 and December 2146 (i.e. from present day to 100 years post closure). The flow modelling was followed by contaminant transport modelling with the scenarios discussed in Section 11.3.2.

A two dimensional tailings facility seepage model was furthermore setup in the SVFlux variable saturated- unsaturated finite element flow model based on a cross section through the alternative wet TSF, seepage mitigation measures and underlying vadose zone and groundwater system (SoilVision Systems, 2014). However, a dry tailings deposition (truck and shovel) was selected as the Base Case. Tailings will be stored with waste rock at the co-disposal facility. Rainwater infiltration would be the only driver of seepage from the mine/plant residue material.

11.3.1 Open pit groundwater inflow rates

The proposed 30 year open pit depletion plan (DRA, 2017) was used to simulate the groundwater inflow rates into the open pit. The mine schedule was provided in 5 year increments. In order to address the heterogeneity of the aquifer the overall aquifer transmissivity was varied by 20%. The open pit was simulated as transient drain cells in order to simulate in-pit dewatering. Borehole dewatering was not seen as an effective option due to the relatively low yielding nature of the fractured aquifer present.

Figure 11.53 shows the simulated groundwater inflows into the open pit over the life-of-mine. For the first 2 years, mining will mainly take place above the groundwater table. The simulated mine groundwater inflows are very low in the first 10 years, below 300 m^3/d. This will increase to 600 m^3/d for the remainder of the mining. Most groundwater inflow is expected in the first 50 metres of the geological succession. Deeper groundwater intersections will occur, however, the frequency will decrease with depth. Hydrogeological drilling results also suggest that the yield of water intersections may decrease slightly with depth. However, blasting will create a fractured pit shell which could drain groundwater to the lower parts of the open pit.

The open pit water make will be drained to a sump, from where it will be pumped to a lined pit/reject PCD (Section 11.5). Water will be discharged into the environment from the pit/reject PCD as detailed in Section 11.6. An open pit sump pump capacity of 3 500 m^3/d is proposed in Section 11.6.1.4.3.

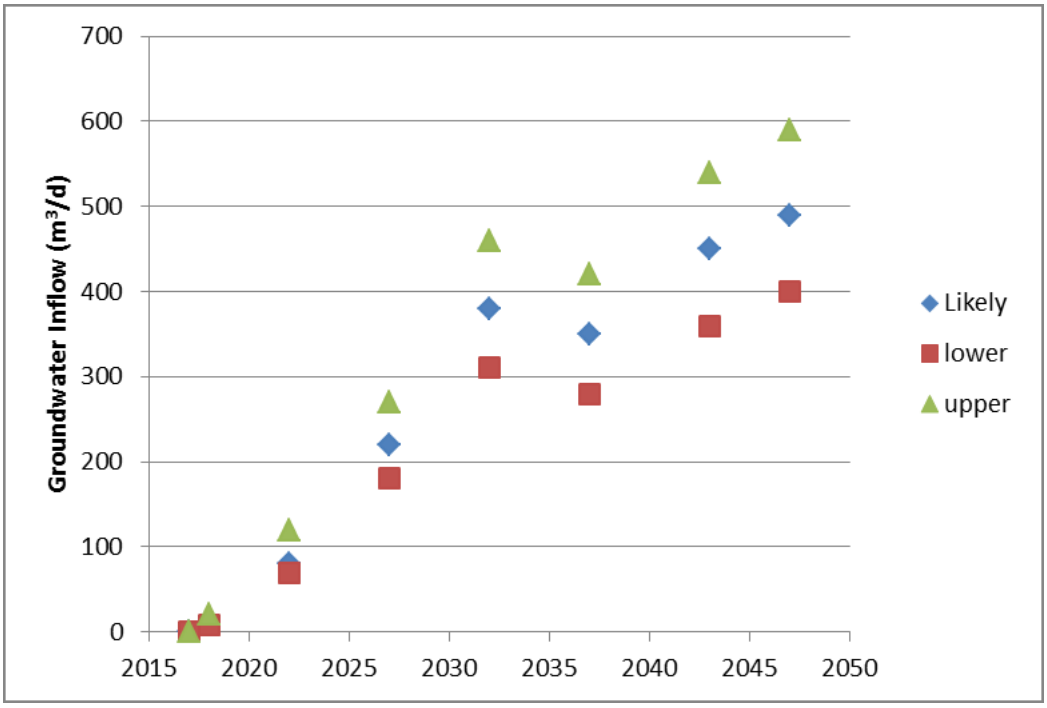


Figure 11.53: Simulated Mine Inflows for LOM

11.3.2 Contaminant transport modelling

The calibrated flow models were used to construct a contaminant transport model for the site surface infrastructure. The major sources of potential contamination on the site are the co-disposal facility and reject dump (only operational phase). The co-disposal facility has predominantly a long-term groundwater contaminant risk (this is due to the relatively slow reaction rates of the secondary sulphur minerals).

11.3.2.1 *Source water quality*

Sulphate (SO_4) was selected as the indicator contaminant, based on the results of the geochemical study (Section 11.2.2.6). A maximum SO_4 operational concentration of 1 200 mg/l (500 mg/l average) was calculated for the co-disposal facility and reject dump. Chloride concentration is also expected to be relatively high in the tailings water (Table 11.47). The pH will be around neutral during the operational phase and neutral to slightly acidic in the long-term. Metal leach concentrations (mainly Al, Fe and Mn) from the waste facilities will be relatively low and was not modelled.

The concentration for the co-disposal facility (tailings and waste rock) seepage in the MT3DMS contaminant transport model was initially set at 500 mg/l and 1 200 mg/l for the latter operational period (based on the modelled quality for tailings material) and the post closure concentrations were set as 3 200 mg/l. These concentrations are representative of the worst case quality scenario.

Rainfall infiltration will be the main driver of seepage and subsurface infiltration below the dump will be more than natural recharge due to seasonal water/moisture accumulation at the base of the co-disposal facility. The potential impact from the Co-disposal facility will be minimised by interim (5 year intervals) and final capping with lower permeable material and a closure evapotranspirative capping layer (vegetation). The aim of the capping layers is to minimise rainwater infiltration. The closure capping design will be undertaken to ensure that the groundwater infiltration rate does not exceed 3 % of the MAP.

Water management details are discussed in Section 11.8.

11.3.2.2 *Simulated groundwater contaminant plumes*

The modelled groundwater sulphate contaminant plumes are shown in Section 11.7.4:

- Figure 11.88: Simulated groundwater sulphate contaminant plumes - Operational Phase
- Figure 11.89: Simulated groundwater sulphate contaminant plumes - Closure Phase

The simulated groundwater plumes indicate the following:

- The co-disposal facility and reject dump groundwater contaminant plumes are likely to be impacted on by the mine dewatering at the adjacent open pit. This will slow the migration of the contaminant plume and draw it towards the open pit.

- The long-term closure co-disposal facility groundwater plume (100 years post close) will migrate towards the southwest, over a distance of less than 1 km. The simulated results suggest that the groundwater plume would not impact on receptors.

11.4 Water Resources

Different surface water and groundwater options were investigated as part of the feasibility study in order to supply water for the raw water make-up demand. A groundwater raw water supply was seen as the most feasible water supply option for the mine. The raw water make-up requirement is discussed in Section 11.6.1 (Water Balance). An alternative raw water dam, Ant2 Dam, was investigated for a site in the Fangorano River, about 20 km north of the proposed Molo mine site. The dam yield investigation for the dam is discussed in *Energizer Molo Graphite Feasibility Study Water Report_DRA Annex11_1 GCS 13_723 ver2c 28Oct14* (GCS, October 2014).

11.4.1 Groundwater Resource

An assessment of the available groundwater resource for the Molo site area was completed using the hydrogeological drilling data, pumping test results and available recharge data for the site. The groundwater resources are discussed in terms of:

- Borehole safe yield for existing hydrogeological boreholes, using the pumping test data.
- Potential sustainable yield for the local aquifer with rainfall recharge as the main driver.

11.4.1.1 *Existing Hydrogeological Boreholes*

The pumping testing data was interpreted using the Flow-Characteristic (FC) method (van Tonder *et al.*, 1998) in order to determine the borehole safe yields. The FC sheets that were used for the interpretations are shown in Annexure 11 E. The FC method makes use of the constant discharge data and plots the groundwater level drawdown derivatives against time to better characterize the abstraction response of the borehole. Drawdown derivative data versus time allows for the better identification of boundaries and flow characteristics. The analytical method furthermore considers the calculated hydraulic flow parameters (transmissivity and storage), available borehole drawdown, theoretical no-flow boundaries and recharge in calculating borehole safe yield. The borehole safe yield is defined as the abstraction rate that is sustainable without dewatering the aquifer, i.e. not drawing the water level below the aquifer intersection (available drawdown). It is assumed that the borehole will risk running dry if the abstraction lowers the borehole water level beyond the available drawdown level. It is therefore the maximum rate of withdrawal that can be sustained by a borehole without causing an unacceptable decline in the hydraulic head or borehole yield.

The recharge for the region is reported to vary between 20 and 100 mm/a (i.e. 2 to 10 % of MAP). The lower value of 20 mm was found to better represent effective recharge for the regional basement aquifer using numerical modelling and considering hydraulic aquifer flow parameters from the pumping tests (Section 11.3). However, the higher yielding marble zones are likely to have higher recharge rates. From the climate study (Section 11.1.1), the dry weather Mean Annual Precipitation (70 percentile) was estimated to be 470 mm/a versus the 799 mm MAP. The rainfall recharge under these conditions are estimated to be less than 12 mm/a. The 12 mm/a recharge rate was used to simulate a more conservative safe yield.

The FC method allows for four types of no-flow boundaries, i.e. no boundaries, 1 no-flow, 2 no-flow and fully closed aquifer systems. Two parallel boundaries were selected for the Molo Graphite Project site. The site is characterized by north – south trending, subvertical layering and associated aquifer features, justifying the two parallel no-flow boundaries.

The safe yield calculation for the existing hydrogeological boreholes is listed in Table 11.53. Safe yield values less than 0.5 l/s were excluded from the total safe yield of existing hydrogeological boreholes.

The total available borehole safe yield for the existing boreholes is 15.3 l/s (55 m^3/hr or 1,322 m^3/d). The boreholes are relatively spread out over the Molo Graphite Project area and the risk of inter-borehole impact during abstraction is therefore relatively low.

The highest yielding boreholes are MMB12 and MMB13 (combined safe yield of 42.8 m^3/hr). These boreholes are situated relatively close to drainage lines which could recharge the borehole under abstraction (induced river leakage or bank storage).

Table 11.53: Borehole safe yields

Borehole ID	Blow Out Yield (l/s)	Available Drawdown (m)	Safe Borehole Yield (l/s)	Proposed depth of pump (m)
			2 no-flow Boundaries, 12 mm/a recharge	
MMB1	5	30	<0.5	33
MMB2	1.5	30	<0.5	34
MMB3	0.05	25	<0.5	32
MMB4	3.2	15	<0.5	17
MMB5	1.5	15	<0.5	25
MMB6	0.6	25	<0.5	34
MMB7	0.1	10	<0.5	18
MMB8	3	60	<0.5	66
MMB9	0.8	2	<0.5	10
MMB10	0.7	24	<0.5	37
MMB11	1.3	12	1.0	14
MMB12	8	20	5.0	24
MMB13	14	25	6.9	34
MMB14	1	6	0.6	11
MMB15	1.2	21.4	<0.5	25
MMB16	3	20	1.9	28
Total	44.95		15.3 (55 m^3/hr or 1322 m^3/d)	

11.4.1.2 *Available Groundwater Safe and Sustainable Yield*

Safe aquifer yield is the annual amount of water that can be taken from a source of supply over a period of years without depleting that source beyond its ability to be replenished naturally in wet years. Borehole safe yield furthermore is based on drawdown criteria as described above. The safe yield does not necessarily take into account the impact on the total hydrological cycle, e.g. stream baseflow reduction and water dependable ecosystems. The groundwater extraction regime should be based on acceptable levels of stress with adequate protection allowed for dependent environments in order to ensure sustainable abstraction.

The safe and sustainable yield is driven by the ability of the aquifer to be replenished, i.e. aquifer recharge. A groundwater balance calculation was undertaken, taking the recharge rate over a specific aquifer area into account. The Molo Graphite Project site is situated on the divide of three main catchment basins. The groundwater catchment area for which the safe or sustainable yield calculations are applicable was defined within a 5 km radius around the site, based on practical consideration such as the development of water reticulation. Areas outside the Next Source Material (Energizer Resources) exploration permit zone were excluded, i.e. mostly the area to the east of the proposed open pit (Figure 11.54). The areas calculated for the 5 km radius zone (excluding areas outside the exploration permit areas) are 59 km^2.

The calculated safe yield for the 5 km radius zone, taking into account a recharge rate of 20 mm/a is shown in Table 11.53. The ecological and human demand allocation for the area is a specialist study in itself that falls outside the scope of this assessment. However, the ecological water requirement (stream flow) is often as a first approximation estimated based on the 90 percentile rainfall runoff (90 percentile MAP is about 200 mm/a). A similar approach was followed for the groundwater sustainable yield calculation which results in a 25 % reduction in recharge which is being allocated to the ecological water requirement. The sustainable yield for wellfield abstraction in the 5 km radius zone has been calculated to be 101 m^3/hr. A reduced recharge rate (based on the drought calculated 70 percentile MAP for the area) was also used to account for sustainable groundwater abstraction during long-term drought conditions. A sustainable yield for the 5 km radius zone, under long-term drought, of 60 m^3/hr (1 429 m^3/d) has been calculated (Table 11.53).

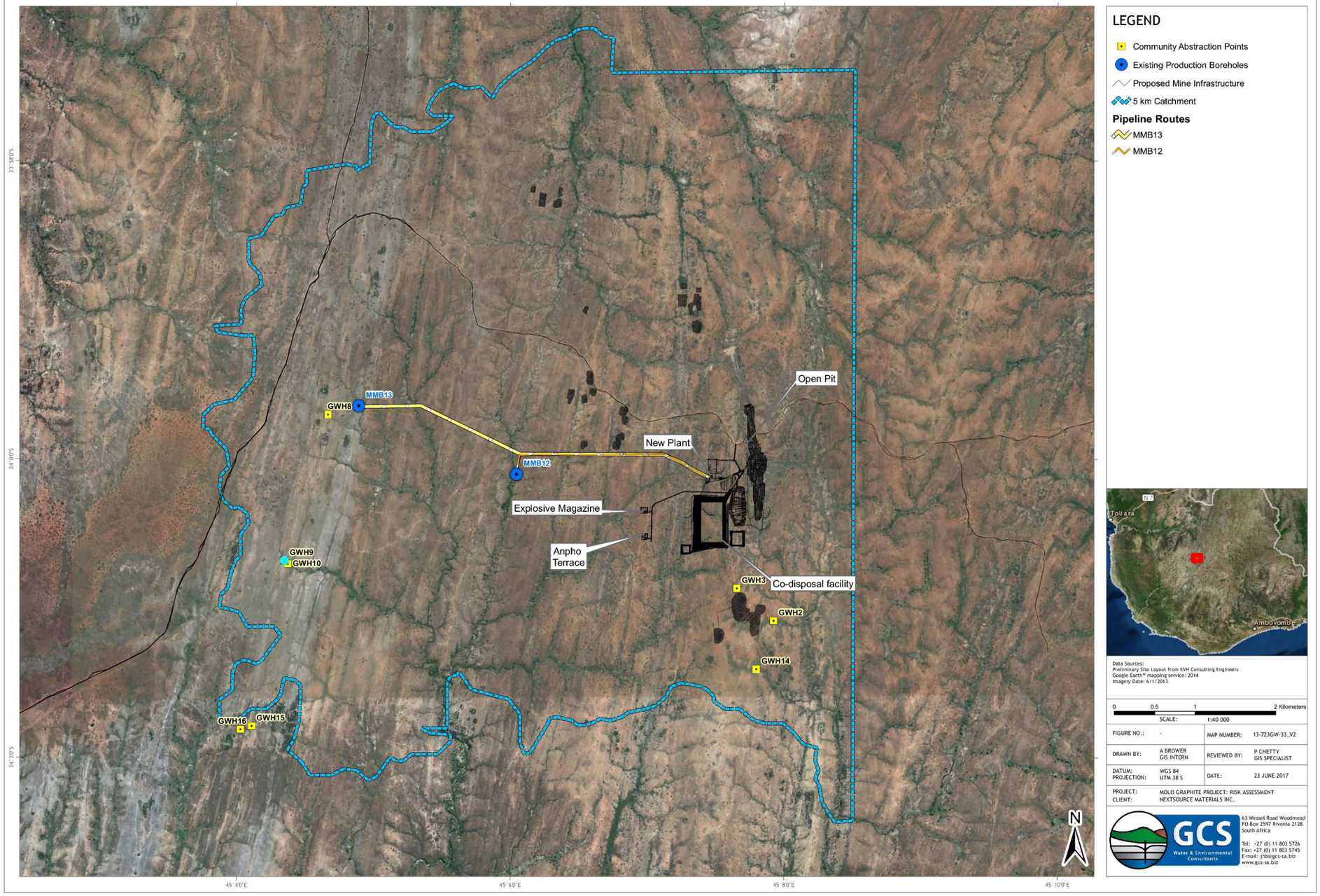


Figure 11.54: Proposed wellfield

Table 11.54: Groundwater safe and sustainable yield

Method/Scenario		Aquifer potential yield		
		(m^3/hr)	(l/s)	(m^3/d)
Existing boreholes – Total Safe Borehole Yield		55	15.3	1322
Catchment balance - Safe Yield[4]	5km	135	38	3240
Catchment balance - Sustainable Yield[5]		101	28	2429
Catchment balance - Sustainable Yield (Drought scenario)[6]		60	17	1429

11.4.2 Groundwater as a Raw Water Make-up Source

Figure 11.57 shows the monthly abstraction requirements in order to meet the raw water make-up demand requirements for the proposed (Base Case) processing plant, potable water and dust suppression. The average clean raw water plant make-up requirement is 7.58 m^3/hr (~182 m^3/d). A further 1.7 m^3/hr (~40 m^3/d) potable water is required while the maximum dust suppression requirement is estimated to be about 13.7 m^3/hr (~329 m^3/d). However, dust suppression has a seasonal demand and site run-off/open pit water will be used as a preferential dust suppression source. However, groundwater influx into the open pit will be low in the first half of the LoM (Section 11.2.2.4) and borehole water is required for dust suppression during the dry season.

Figure 11.55 shows the borehole raw water supply requirement over the LoM. Borehole abstraction will initially be higher due to the greater initial dust oppressions demand. Dust suppression could be completely supplied by runoff/open pit water in the latter part of the LoM, and borehole abstraction will be equal to the clean water demand, i.e. 9.25 m^3/hr or 222 m^3/d. The average borehole abstraction in the first 3 years will vary between 255 and 561 m^3/d as shown in Figure 11.56. Also shown in Figure 11.57 is the borehole abstraction for the first 12 years.

Current boreholes MMB12 and MMB 13 has a combined safe yield of 42.8 m^3/hr or 1 028 m^3/d, which is more than the Base Case maximum raw water make-up requirement of ~23 m^3/hr or ~551 m^3/d. The raw water make-up demand is less than the aquifer sustainable yield for the proposed 5 km radius wellfield under drought conditions (i.e. 1,429 m^3/d or 60 m^3/hr), indicating that groundwater can supply the make-up demand for the proposed mine. It is proposed to equip existing boreholes MMB12 and MMB13 as the initial water supply source with a combined pump capacity of 36 m^3/hr or 864 m^3/d.

[4] Groundwater recharge estimation of 20mm/a (UNESCO, 2008)

[5] Ecological water requirement of 25% of resource (based on 90 percentile rainfall allocation)

[6] Drought rainfall – 470 mm/a (70 percentile)

The start-up requirement for plant will be managed by utilizing the storage capacity of the plant raw water reservoir.

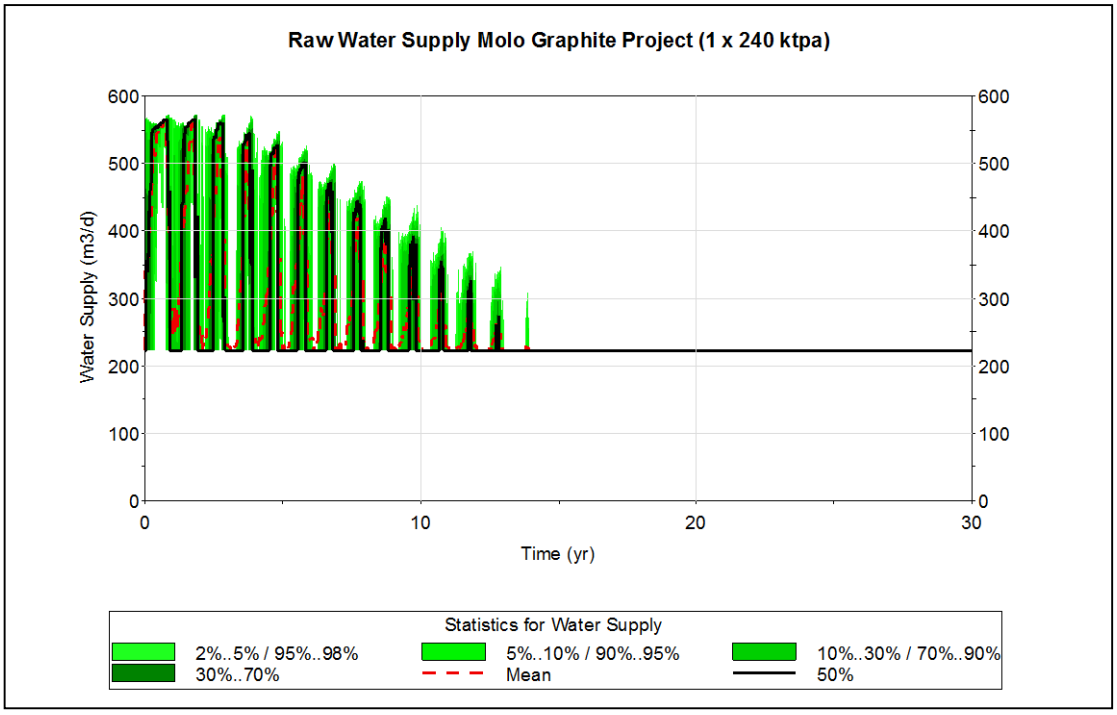


Figure 11.55: Raw water supply demand over time for boreholes

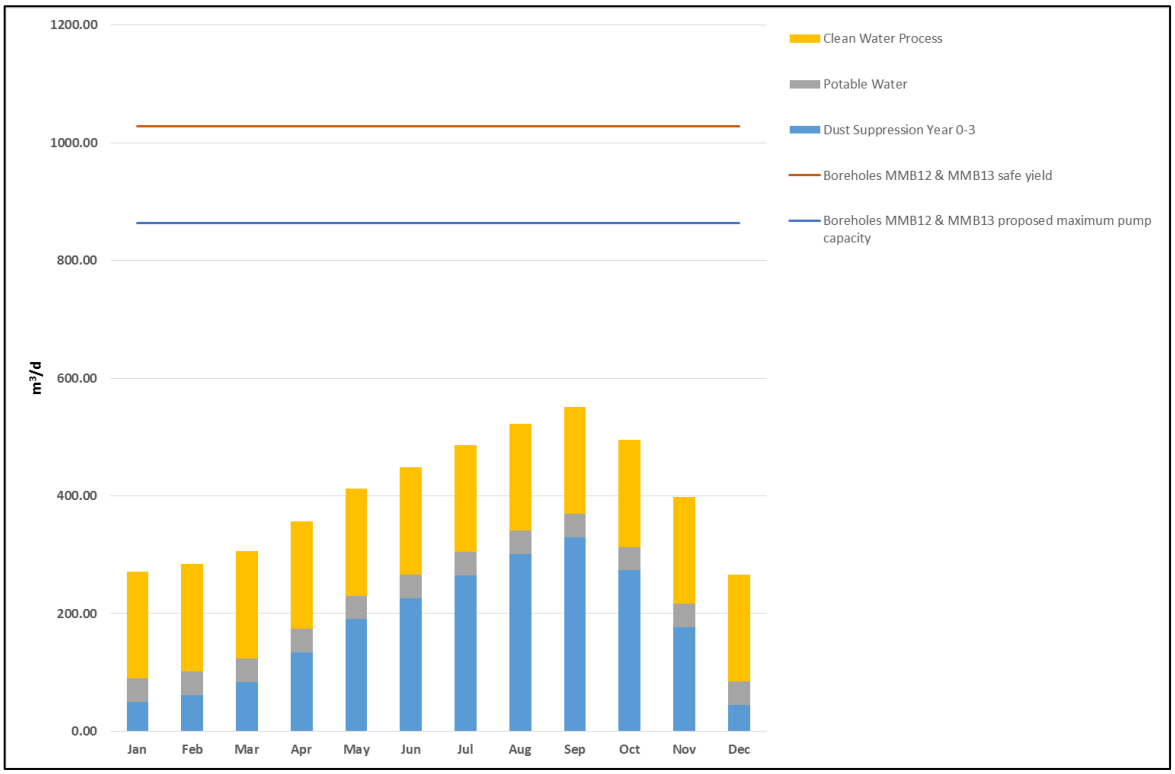


Figure 11.56: Monthly groundwater abstraction requirements – year 1 to 3

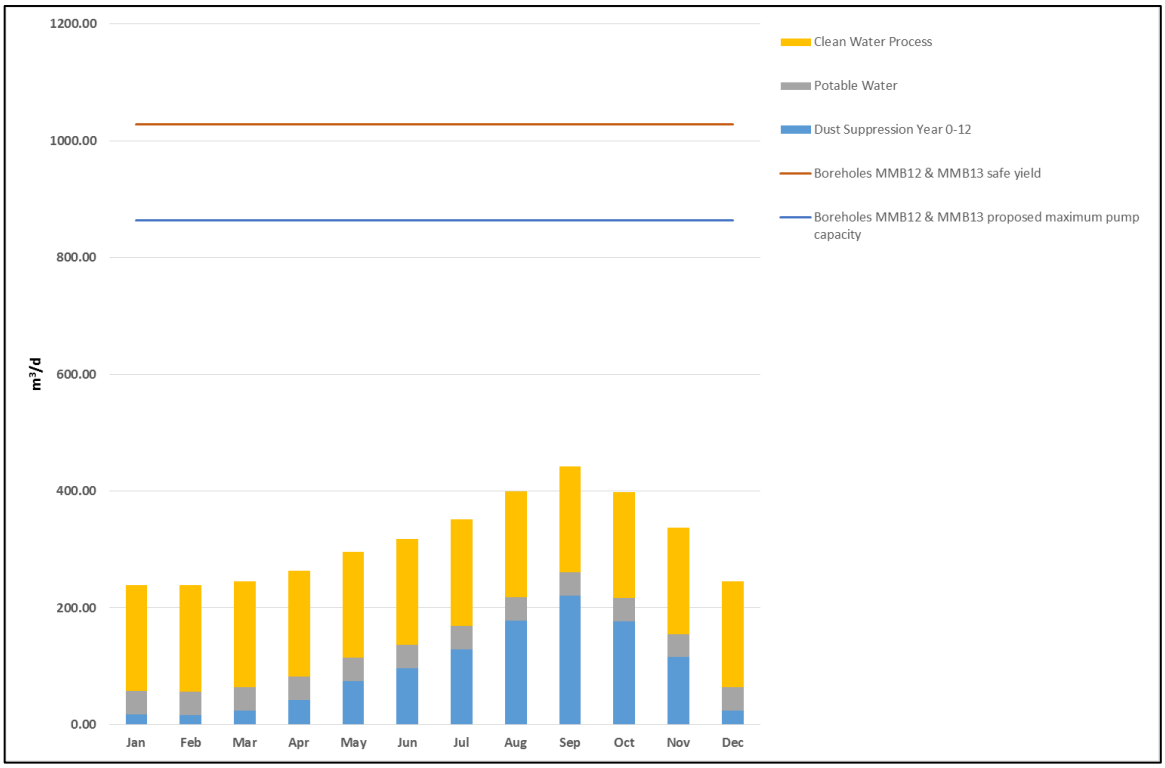


Figure 11.57: Monthly groundwater abstraction requirements - year 1 to 12

11.4.3 Wellfield Operation

The current proposed borehole abstraction (and any future proposed wellfield extension) should preferably target the Ampanihy litho-metamorphic group (west of the Molo site), containing marble layers which have a higher aquifer potential (Figure 11.54). . The most productive two existing boreholes, MMB12 and MMB13, were selected to supply the water for the raw water requirement of the proposed Molo Graphite Mine.

The wellfield design and management principles are based on the following:

- It is recommended to fit all boreholes with real time data loggers to make informed decisions on changing abstraction rates or detect potential breakages and/or stoppages. Borehole levels and abstraction volume should be considered as the minimum parameters to measure. Provision must be made for fitment of water level measuring devices within the abstraction boreholes;
- Pumps must be installed above the main groundwater intersection depth;
- Borehole should preferably be pumped at less than 80 % of the calculated borehole safe yield;
- Adequate security must be added to all abstraction boreholes and boreholes/reticulation must be inspected daily;

- Variable speed drives for the pumps should be considered to allow for adjustment of the abstraction rate with time or to allow for flexibility when relocating the pump to a different borehole;
- Section 11.8.5 describes the proposed regional groundwater monitoring program which includes monitoring of community wells.

11.5 Conceptual Storm Water Management Plan

The purpose of a Storm Water Management Plan (SWMP) is to prevent the pollution of water resources in and around mining areas, or areas where mining-related activity occurs. It also prevents flooding and a safe working environment during extreme events. The Environmental, Health and Safety Guidelines for Mining (IFC, 2007b) published by the World Bank Group is a technical reference document with general and industry-specific examples of Good International Industry Practice (GIIP). This set of guidelines can be applied to countries with no defining regulations. The Environmental Health and Safety Guidelines for Mining contain storm water measure guidelines which have been deemed to be suitable to base the SWMP on. This is applicable to open pit mining and alluvial mining (IFC, 2007b).

11.5.1 Delineation Dirty Water Catchments

EVH Consulting provided GCS with a set of infrastructural designs, indicating proposed Pollution Control Dam PCD, berms and drainage channels (Reference Drawing: 2017-06-20-17038-BLOCKPLAN.DWG) (Figure 11.58).

Based on this supplied information, dirty water areas were defined, as well as the propose SWMP measures in order to mitigate potential surface water risks in order to comply with the relevant legislation.

Dirty water areas were delineated based on topography and mine infrastructural plans. The mine site was broken up into five (5) potential main dirty areas; the

1. Processing Plant;
2. Ore Stockpile;
3. Co-Disposal Facility;
4. Reject Material Dump; and
5. Open Pit.

These three areas had different drainage characteristics, therefore separate SWMPs were drawn up for each area. The potentially dirty areas were mapped out and can be seen in Figure 11.58. Figure 11.58 shows the dirty areas in green. A summarised overview of all dirty areas, listing the footprint sizes, is given in the Table 11.55.

The processing plant area and ore stockpiles are seen as a dirty water areas and a plant PCD is proposed and designed. The processing plant comprises three (3) dirty water areas to divert storm water runoff into the proposed plant PCD.

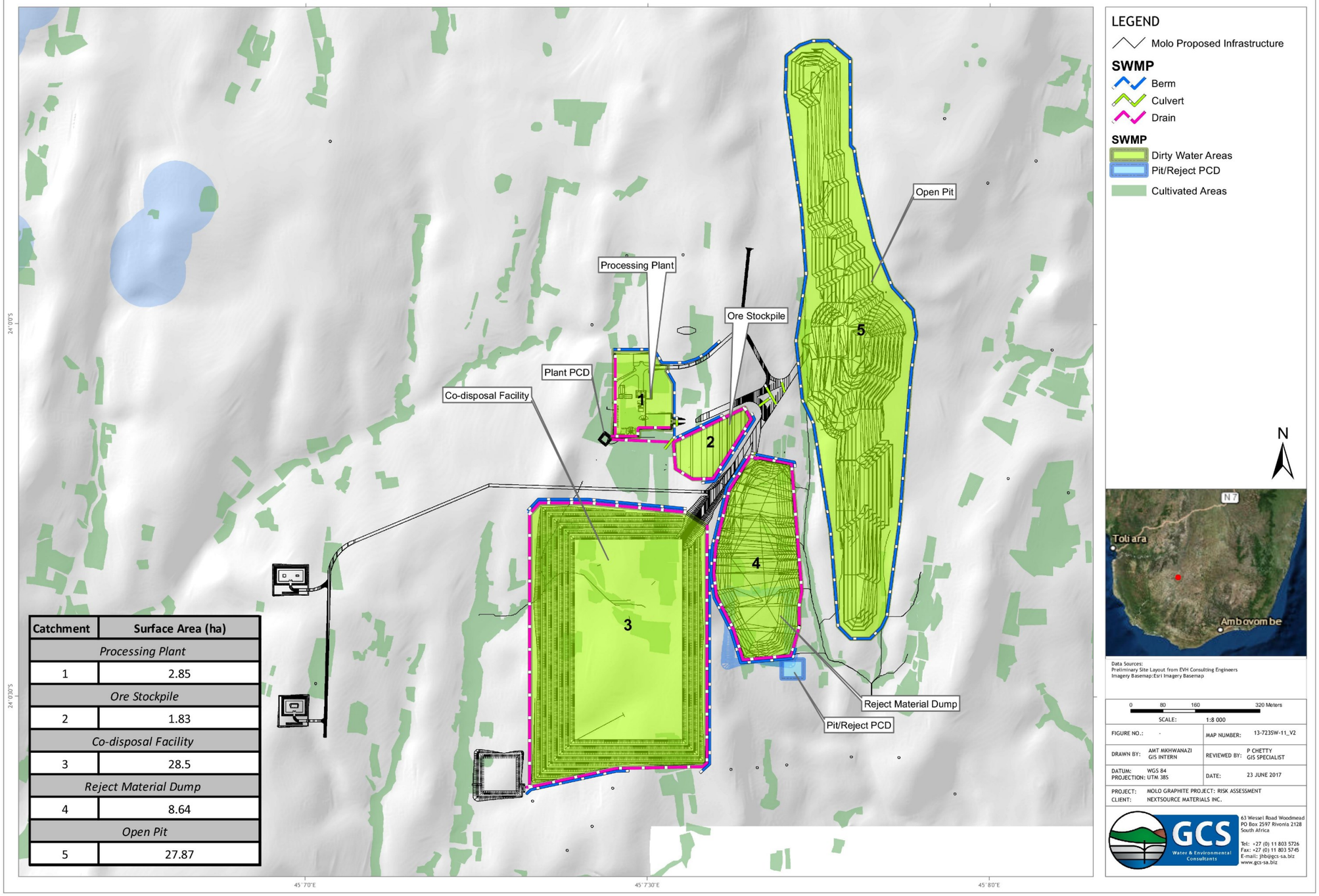
The entire co-disposal facility was classified as dirty water area. Seepage and runoff from this area will be contained in the co-disposal PCD located west of the co-disposal facility. Water from the co-disposal PCD will be pumped to the plant PCD for re-use for dust suppression in the mining operations, if required.

Similarly the reject material dump was classified as a dirty water area and the runoff from this area will be contained in the pit/reject PCD located southeast of the reject material dump.

The SWMP for the open pit area differs from the other two in that water that falls into the pit will be initially stored in the pit. A sump(s) will be needed at the lowest point of the pit and water collected in the sump system will be pumped into the pit/reject PCD. Water generated in the pit will have a high sediment load which will initially settle in the silt trap. After settlement, water from the pit/reject PCD will be discharged into the environment at water quality that must comply with Malagasy and international standards. (Section 11.6.2).

Table 11.55: Overview of all delineated dirty water areas in the vicinity of the Molo Graphite Project area

Catchment	Surface Area (ha)
Processing Plant	
1	2.85
Ore Stockpile	
2	1.83
Co-disposal Facility	
3	28.5
Reject Material Dump	
4	8.64
Open Pit	
5	27.87



Catchment	Surface Area (ha)
Processing Plant	
1	2.85
Ore Stockpile	
2	1.83
Co-disposal Facility	
3	28.5
Reject Material Dump	
4	8.64
Open Pit	
5	27.87

Figure 11.58: Overview of the conceptual storm water management plan of the Molo Graphite Project area

11.5.2 SWMP Management Measures

It was also advisable that sediment traps should be placed before entering the PCDs to reduce the amount of silt that deposits in these dams, which is likely to affect the storage areas of these dams. The design and locations of the sediment traps were also included in the provided information.

Drains should be placed in and around the dirty water areas of the processing plant, ore stockpiles, co-disposal facility and the reject material dump, to stop clean water from mixing with the dirty water as the storm water measures. Drains should be placed on the inside of the berm to direct the dirty water towards the allocated PCDs. This dirty water should then be pumped and utilised for dust suppression and/or in the mining processes. This was taken into account in the Dynamic Mine Water Balance (Section 11.6).

The entire area of the open pit was classified as dirty. Water that falls in this area will carry a high sediment load. This water should be discharged to the pit/reject PCD via the proposed silt trap. Similar to the co-disposal and reject dump, re-use of storm water for dust suppression in the mining process should be promoted and was also taken into account in the Water Balance (Section 11.6).

Rainfall captured in the open pit, reject/pit PCD and the co-disposal PCD will be used to supply the plant PCD for dust suppression. Sumps should be placed at the lowest point of the pit and water collected here should be pumped into the pit/reject PCD. A pump installation should also be installed to provide water from the pit/reject PCD, co-disposal PCD and plant PCD. Berms around the pit should be placed to prevent clean runoff entering the open pit.

Table 11.56 summarises all proposed PCDs for the Molo Graphite Project. The PCD volumes were dimensioned not to spill more than once in the 10 year on average (plant PCD) and/or a 24-hour storm event with a return period of 50 years (co-disposal PCD and pit/reject PCD) depending on water quality. The capacity and discharge qualities of the proposed PCD volumes will be further evaluated in Section 11.6.

Table 11.56: Proposed dams (PCDs) and calculated volumes

Dam	Capacity (m^3)
Plant PCD	8 000
Co-disposal PCD	30 000
Pit/reject PCD	5 000

11.5.3 Design Flood Peaks

The rational method was used to calculate the design flood peaks for the relevant delineated dirty areas. This is one of the most widely-used methods of peak flow calculation and the study site characteristics fit the criteria for the use of this method (SANRAL, 2007). The SWMP is based on future land cover conditions that will cause an increase in impervious areas and steep slopes, thus the best flood peak determination methods is the rational method as this method incorporates a runoff factor that is based on surface slope, perviousness (ability of water to infiltrate into the ground) of the site and vegetation.

Subsequently, by using the Manning's equation, the required depth (d) of the drain can be established. A typical drain is presented in Figure 11.59. All rational method calculation sheets are provided in Annexure G.

Table 11.57: Design Flood Peaks for relevant dirty water catchments at the Molo Graphite Project in which drains will be constructed

Catchment	Surface Area (ha)	Rational Method Design Flood Peak (m^3/s) Return Periods (Years)						
Processing Plant		*2*	*5*	*10*	*20*	*50*	*100*	*200*
1	2.85	4.8	5.9	7.9	9.7	12.7	15.7	19.3
Ore Stockpile								
2	1.83	2.5	3.0	4.0	4.9	6.5	8.0	9.8
Co-disposal Facility								
3	28.5	7.2	8.7	11.6	14.3	18.9	23.2	28.6
Reject Material Dump								
4	8.64	4.8	5.8	7.8	9.6	12.6	15.6	19.2

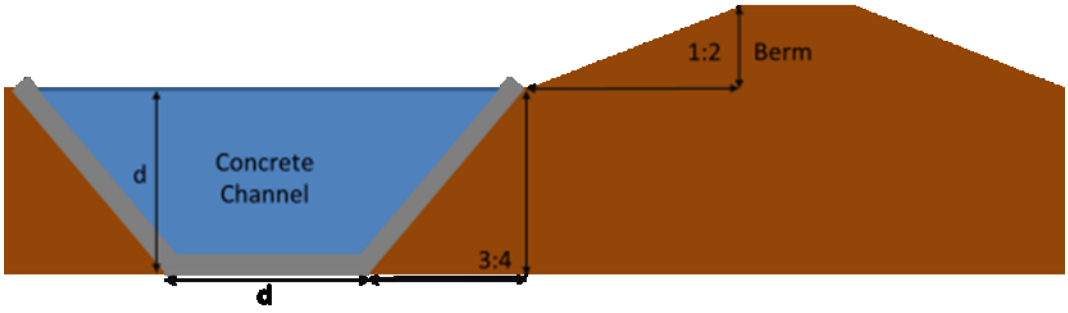


Figure 11.59: Conceptual Design of Berms and drains

11.6 Water and Salt Balance

11.6.1 Water Balance

This section describes the mine water and salt balance–of the Molo Graphite Project for the Base Case: One x 240ktpa Plant. The main purpose of the water and salt balance is to investigate the water availability for the Molo Graphite Project based on the given water demands and available surface or groundwater resources and verify the PCD sizes (Section 11.5) and to simulate water quality parameters (sulphates and TDS) in a mass transport balance model (Salt Balance).

Consequently all water volumes and water flow directions in the project area were simulated in a daily water balance. The software package used to develop the water balance model is Goldsim (Goldsim Technology Group, 2014).

11.6.1.1 Process Flow Diagrams

To setup a dynamic water balance model, a Process Flow Diagram (PFD) was made to create insight into all water-linked flows within the Molo Graphite Project operations for the dry tailings base case. The base case PFD, shown in Figure 11.60. The locations of all dams are presented in Figure 11.58. The following explanation summarises the PFDs:

- Volumes indicated are average annual values. A dynamic water balance is discussed in Section 11.6.1.3 with results presented in Sections 11.6.1.5. The static PFDs, however, illustrate the water balance concept.
- Raw water (make-up) supply will be from a groundwater supply (wellfield). The groundwater resource is discussed in Section 11.4. Raw water will be pumped from the source to a raw water tank at the process plant.
- The re-use of dirty water is encouraged where possible, however, the plant requires a minimum daily clean raw water rate of 7.58 m^3/hr for gland seal water, reagent make up and potable water (plant) for the Base Case.
- The raw water could be treated in a small water treatment plant based on quality criteria and will provide all the potable water requirements for the plant and mine complex. A water treatment plant will be located at the plant site which will provide potable water for the plant. Average annual plant water requirements were received from Met63 for the Base Case and are presented in Figure 11.61.
- Average mine dust suppression requirements were received from DRA for the Base Case and this was estimated at 13.33 m^3/hr (~320 m^3/d).
- The available on-site surface water resources are rainfall and runoff captured from the co-disposal facility, reject dump, plant area, laydown area, ore stockpile and the open pit area in PCDs.

- The open pit also receives water from groundwater ingress. The expected groundwater ingress volumes will vary over time and was calculated in Section 11.3.1. Groundwater inflow volumes range between 0 m^3/d at the beginning of and 490 m^3/d at the end of life of mine.
- Treated sewage will be pumped to the processing plant for re-use in the process and it is expected that treated effluent return will be sufficient to make-up for process water top-up (0.67 m^3/hr, Figure 11.61).
- Water from the processing plant, co-disposal facility, reject dump and open pit and reject dump will be captured in the plant PCD, co-disposal PCD and pit/reject PCD. The water from the PCDs will be used where possible to compensate for the dust suppression make-up demand in preference of clean raw water sources and will be stored in the plant PCD on the available dam capacity. Water stored in the plant PCD can be used during the dry season.
- Preferential discharges will however take place at the pit/reject PCD and the processing plant PCD. This management philosophy is based on discharge water quality criteria (Sections 11.2 and 11.6.2) which have to comply with Malagasy and IFC guidelines. Calculations indicate that the co-disposal and pit/reject PCDs have a potential to discharge during wet periods.

Molo Graphite Mining Project
1 x 240 ktpa (ROM) at
8760 hours/annum
Dry Tailings

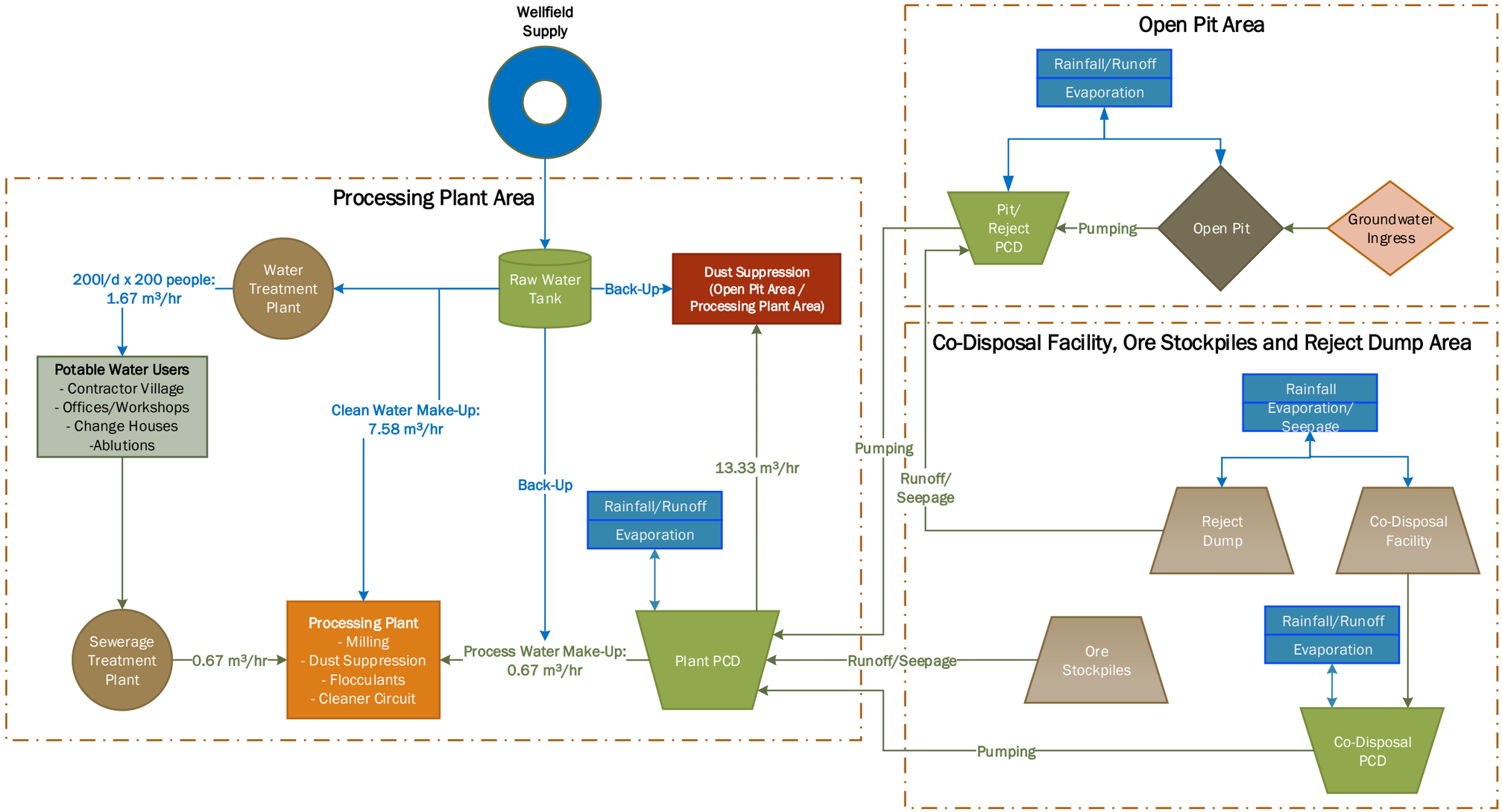


Figure 11.60: Average Annual PFD for the Base Case 240ktpa Dry Tails

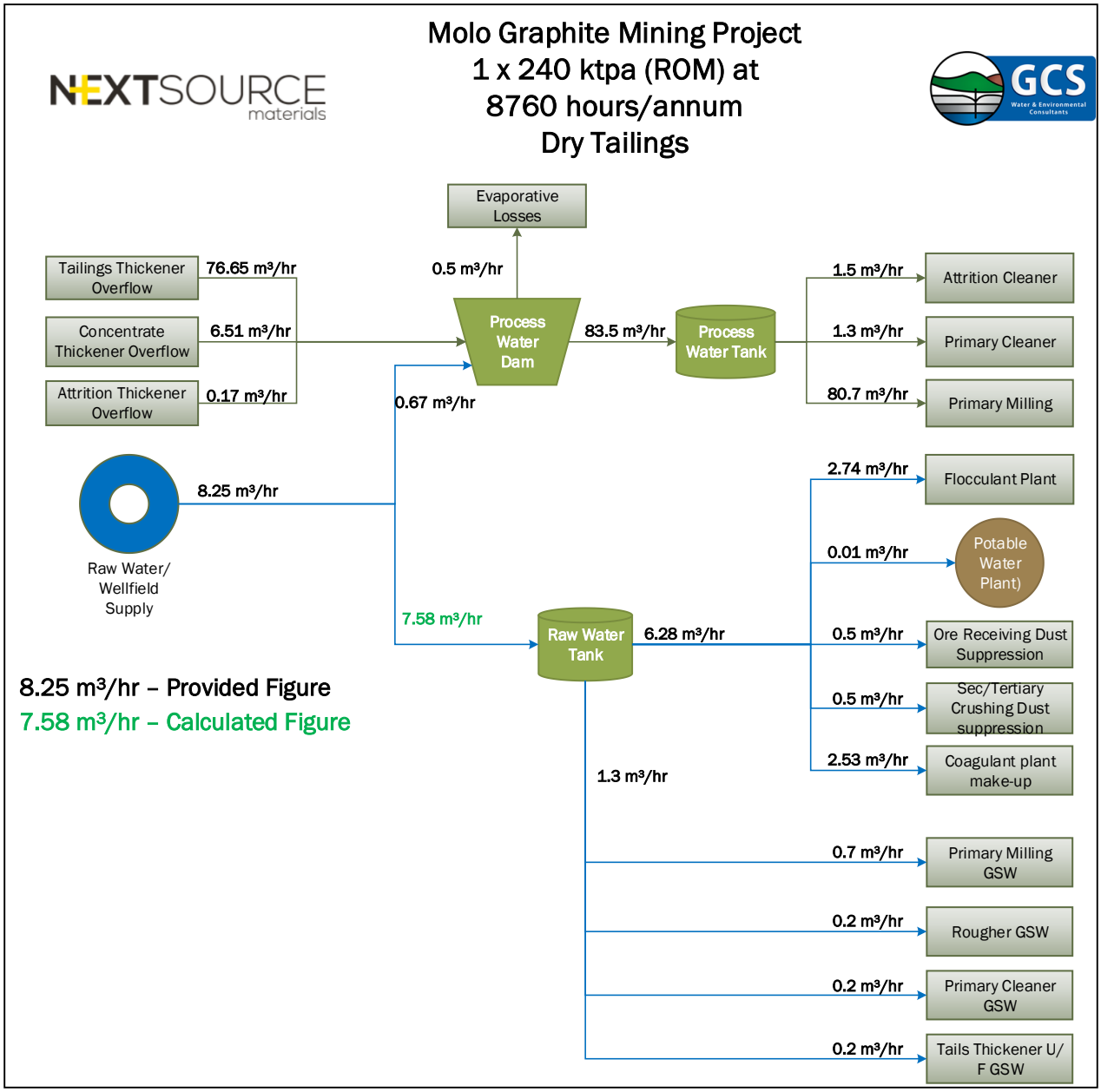


Figure 11.61: Provided Average Annual Plant Water Balance and Make-Up Requirement for the Base Case

11.6.1.2 Raw Water

A groundwater resource assessment (Section 11.4.1) was conducted to evaluate the guaranteed raw water supply to the Molo Graphite Project shown in Figure 11.60. The wellfield is seen as a viable and preferred option for the raw water supply of the proposed Base Case processing plant.

The proposed wellfield within a 5 km radius around the site (and within the NextSource Materials permit area) has a current sustainable yield of 101.2 m^3/hr (~2 429 m^3/d) and an assured dry weather sustainable yield of 55 m^3/hr (~1 322 m^3/d) (Section 11.4.1).

The water balance assumes that two proposed existing boreholes MMB12 and MMB13 will be used as a groundwater water supply source, which has a combined safe yield of 42.8 m^3/hr (~1 027.2 m^3/d). These two boreholes will be equipped with two pumps of 36 m^3/hr (~864 m^3/hr), which will be the maximum ceiling for groundwater abstraction.

The maximum groundwater requirement for the Molo Graphite Project (22.61 m^3/hr (~542.64 m^3/d)) will include clean process water for the plant (7.58 m^3/hr), potable water users for the camp (1.7 m^3/hr) and dust suppression on the processing plant and open pit area (in case of drought) (13.33 m^3/hr).

This will imply that the maximum ceiling for groundwater abstraction is significantly larger than the maximum groundwater requirement

To reserve groundwater for make-up for potentially dirty water in the process and dust suppression, a total of 26.72 m^3/hr (~641.28 m^3/d) of groundwater will be available after deducting the potable water users (1.7 m^3/hr) for the camp and clean process water for the plant (7.58 m^3/hr).

11.6.1.3 Dynamic Water Balance Model Setup

11.6.1.3.1 General Model Description

The dynamic water balance model was set up using a top-down approach. This implied starting with a broad overview of the water balance, and then going down to the next level of detail if available and if required.

The mine water balance is dynamic and depends on many factors including rainfall, mine infrastructure plan, open pit area and mine water requirements.

The Molo Graphite Project will use a system of dams, pumping systems, water supply and management options such as re-use process water and evaporation to manage the water on the Molo Graphite Mine complex. The following elements have been included in the model to represent the Molo Graphite Project Water Management System:

- Climate element;
- Surface runoff element;
- Dam element; and
- Open Pit Element.

The time steps used in the model is dependent on the objective of the model. A monthly time step accounts for the seasonal variations and can be used to provide an indicative sizing of storage facilities such as pollution control dams. The monthly time step can also be used to provide an indication of the capacities of the pumping pipelines infrastructure needed to convey the water between storage elements. A daily time step model allows for a more accurate determination of the PCD sizes and pump capacities. Daily time steps have been used for the Molo Graphite Project Model.

11.6.1.3.2 Climate Element

Rainfall

Water management for the Molo Graphite Project is complex due to an unpredictable and seasonal character of rainfall in this region. Therefore, a stochastic rainfall generator was developed to simulate various rainfall circumstances. A daily stochastic rainfall generator was considered. Due to the short daily rainfall record of Fotadrevo and complexity of patching daily rainfall records with lower rainfall (Ejeda and Betioky Sud), it was decided to use a monthly stochastic rainfall generator.

The stochastically generated monthly rainfall record was used to assess the performance of the management system for future scenarios. This allows different sequences of monthly rainfall to be generated within the model to determine the probability of water use requirements, spills of dams and water supply for a particular water management strategy.

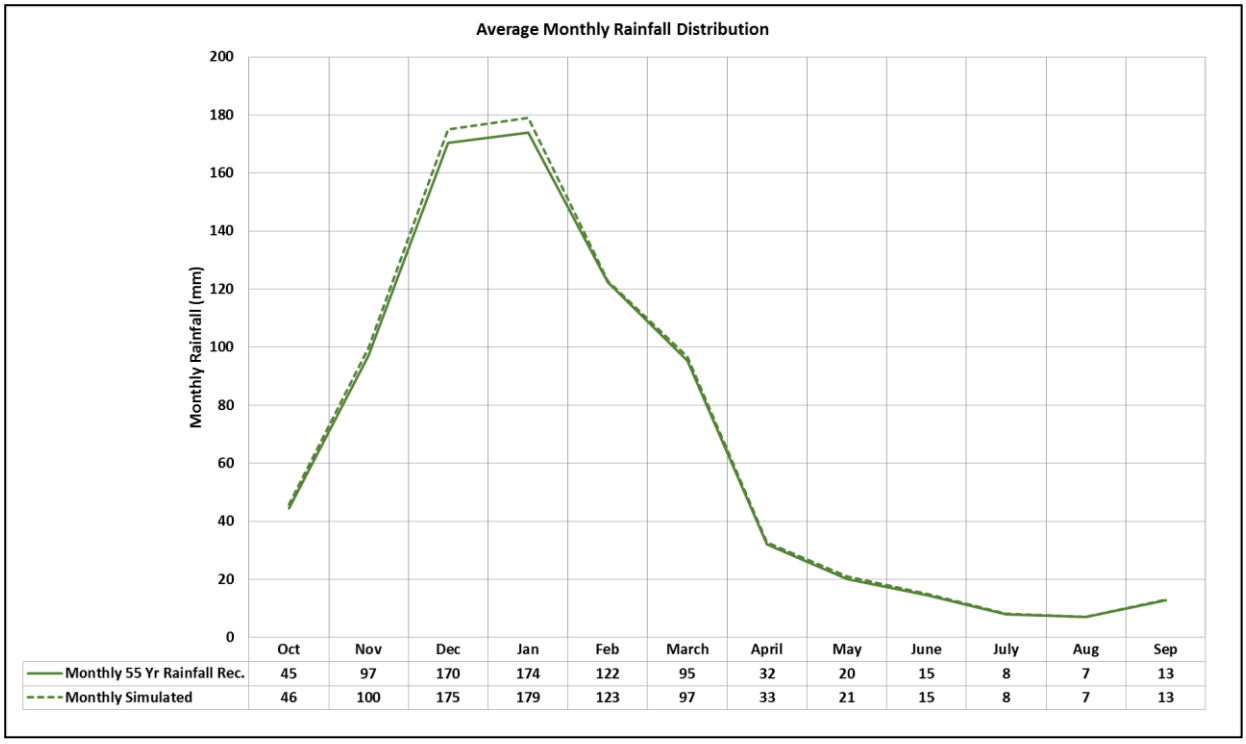
The parameters of the stochastic model are determined by fitting the model to the simulated monthly rainfall record based on the 55 year simulated rainfall record discussed in Section 11.1.1. This is a monthly patched rainfall record from surrounding rainfall stations of Fotadrevo, Ejeda and Betioky Sud. The monthly rainfall record covered the period October 1942 to September 1997.

A gamma distribution was found suitable to simulate the monthly rainfall. The input data were average monthly rainfall and the monthly standard deviations. These parameters of the stochastic model were determined by fitting the model to the 55 year simulated rainfall record considered to be representative of the area.

The following statistics were compared to test the fit of the stochastic model to the measured monthly rainfall depths:

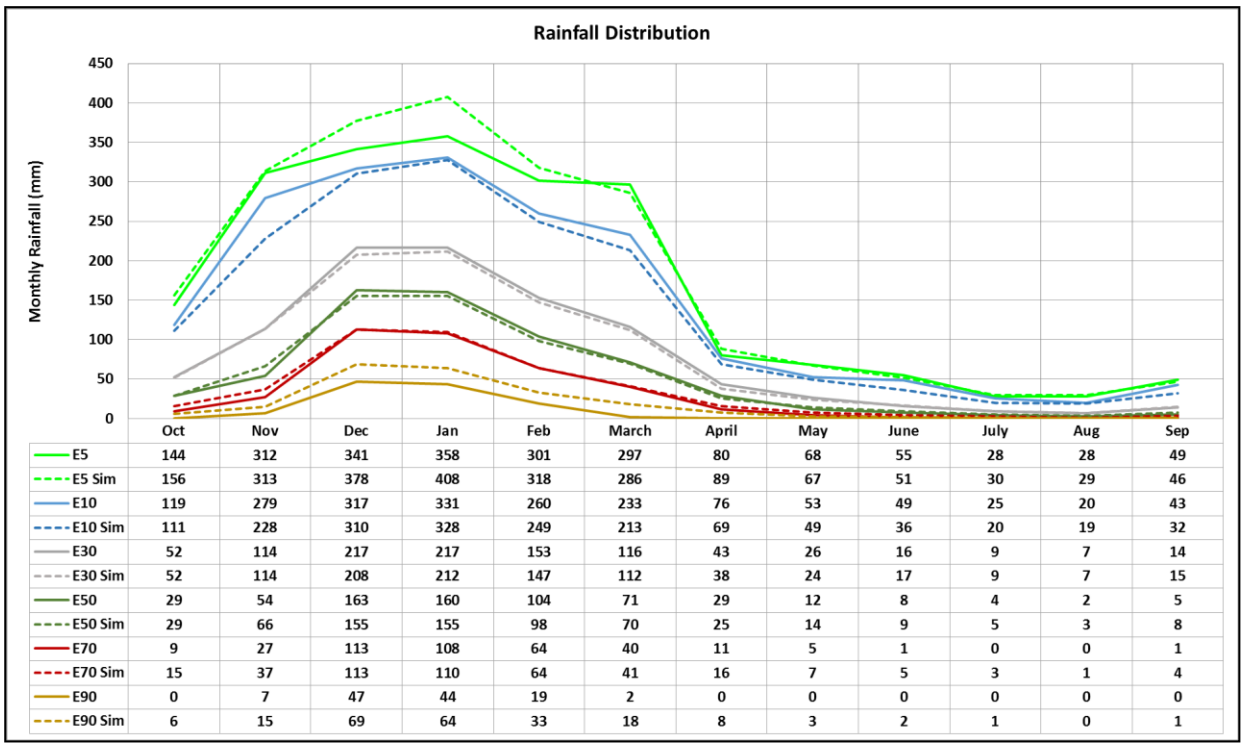
- Monthly average rainfall (see Figure 11.62); and
- The probability distribution of the measured and stochastic monthly rainfall depths (Figure 11.63).

The plots show that the stochastic model fits the average monthly rainfall data sufficiently well. The stochastic model was run to generate 50 sequences of 365 days each. The plots also show that the stochastic model was generating a range of monthly rainfall depths and the seasonality was well captured.



	Oct	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug	Sep
Monthly 55 Yr Rainfall Rec.	45	97	170	174	122	95	32	20	15	8	7	13
Monthly Simulated	46	100	175	179	123	97	33	21	15	8	7	13

Figure 11.62: Comparison of average monthly rainfall



	Oct	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug	Sep
E5	144	312	341	358	301	297	80	68	55	28	28	49
E5 Sim	156	313	378	408	318	286	89	67	51	30	29	46
E10	119	279	317	331	260	233	76	53	49	25	20	43
E10 Sim	111	228	310	328	249	213	69	49	36	20	19	32
E30	52	114	217	217	153	116	43	26	16	9	7	14
E30 Sim	52	114	208	212	147	112	38	24	17	9	7	15
E50	29	54	163	160	104	71	29	12	8	4	2	5
E50 Sim	29	66	155	155	98	70	25	14	9	5	3	8
E70	9	27	113	108	64	40	11	5	1	0	0	1
E70 Sim	15	37	113	110	64	41	16	7	5	3	1	4
E90	0	7	47	44	19	2	0	0	0	0	0	0
E90 Sim	6	15	69	64	33	18	8	3	2	1	0	1

Figure 11.63: Comparison of the monthly rainfall distribution (E50 is 50% of time exceeded)

Evaporation

The mean monthly evaporation for the Molo Graphite Mine Area as presented in Section 11.1.1 were used in the model.

11.6.1.3.3 Surface Runoff Element

The Surface Runoff Element was directly connected to the stochastic rainfall generator and evaporation in the Climate Element. By establishing this direct link, runoff from the plant, reject dump and co-disposal facility area were also generated stochastically.

11.6.1.3.4 Dam Element

The inflows to a typical dam element are:

- **Runoff from a catchment surface area:** using the catchment surface areas and the climate element.
- **Pumping inputs:** inflow from mine workings or pumping from other dams in the system.

- **Rainfall:** rainfall falling directly on the surface of the dam and was calculated by monthly rainfall depth times the water surface area of the dam.

The typical outflows from a dam are:

- **Evaporation from the surface of the dam**: the product of the evaporation depth for water body times the water surface area.
- **Seepage:** this was not calculated since all water dams are assumed to be lined.
- **Pumping from the dam**: pumping outputs could be to meet local water demands or to support the supply drawn from other dams in the system.
- **Spillage**: this occurs if the dam is full and overflows.

11.6.1.3.5 Open pit Element

The Open Pit Element is basically similar to a Dam Element. The difference is that the model assumes that the water is pumped from the workings sump into a dam (pit/reject PCD). The working sump surface area was linearly interpolated and determined by a stage – surface area relation of the open pit area. For the first five years, a maximum pit surface area was assumed at 28 164 m^2 and from year three (3) to year thirty (30) a maximum pit surface area of 278 673.5 m^2 was used. The maximum working pump surface (sump) was assumed at maximum 2% of the open pit surface area.

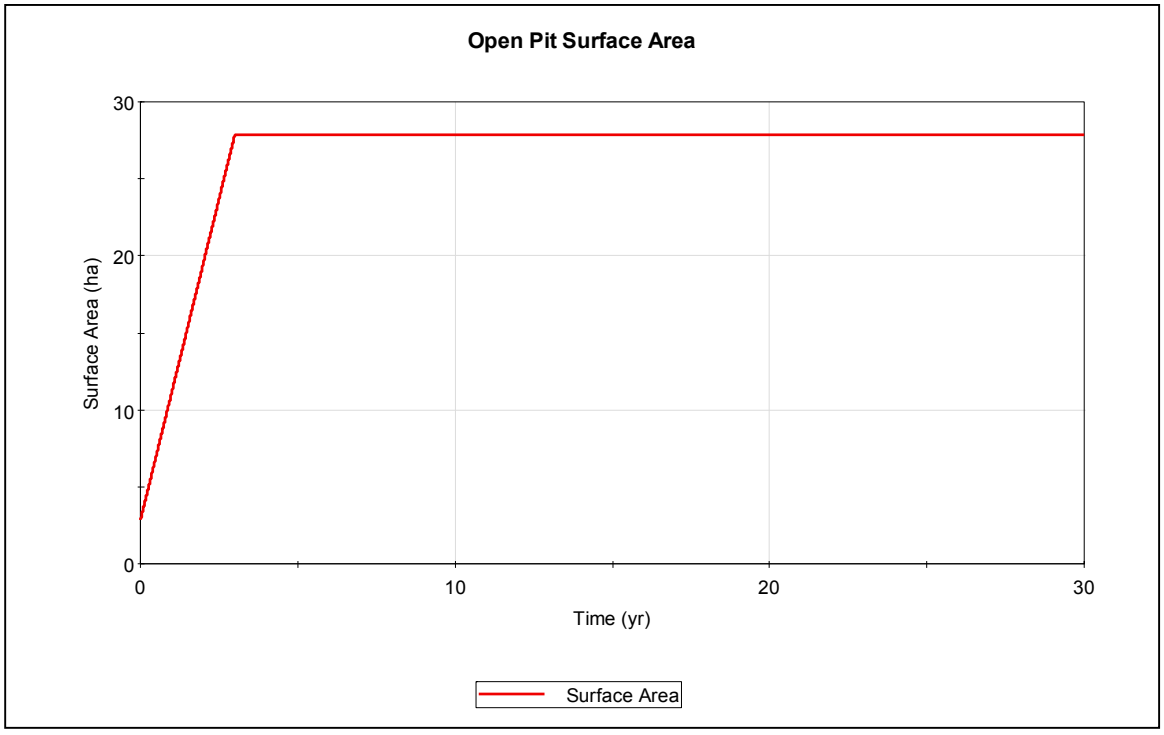


Figure 11.64: Open pit surface area during the life of mine (30 years)

The pumping rate from the sump to the dam (pit/reject PCD) was limited by the sump pump capacity which is input to the model. The operating rule for the sump pump is that the pumping to the pit/reject PCD always take place to the pit/reject PCD.

11.6.1.4 Input Data

11.6.1.4.1 Simulation Period

The model was simulated for a thirty (30) year period for the dry tailings base case (1 x 240ktpa). The model was run for 50 realizations. The model simulates the water system for various rainfall sequences and stores the results for 50 realizations.

On completion of the 50 realizations, the model statistically summarises the results and presents consolidated result sets. If required, detailed results of any water related variable from each model realization are also available in the model outputs.

Detailed results of any water related variable from each model rainfall sequence are also available in the model outputs if required.

11.6.1.4.2 Dam Capacities and Areas

Dam capacities and surface footprint area are presented in Table 11.58.

Table 11.58: Assumed Dam Volumes and Footprint Areas

Dam	Capacity (m^3)	Maximum Footprint Area (m^2)
Plant PCD	5 000	2 000
Co-disposal PCD	21 000	11 500
Pit/reject PCD	8 000	4 100

11.6.1.4.3 Pump Capacities

Maximum pump capacities are presented in Table 11.59.

Table 11.59: Assumed maximum pump capacities

Location	Maximum Pump Capacity (m^3/d)
Co-disposal PCD -> Plant PCD	2 000
Open Pit -> Pit/reject PCD	3 500
Pit/reject PCD -> Plant PCD	2 000
RAWT -> Plant PCD	641

11.6.1.4.4 Model Assumptions

The following assumptions were made and operational philosophy adopted to develop the water balance model in GoldSim (Goldsim Technology Group, 2014):

- A daily groundwater ingress inflow (m^3/d) in the open pit area was linearly simulated over the life of mine according to Table 11.60 and Figure 11.65 based on calculated groundwater ingress in Section 11.3; and
- Maximum raw water supply source from the groundwater wellfield was based on long term sustainable yield (allows for drought conditions). This was discussed in Section 11.6.1.2 and was assumed at 26.72 m^3/hr (~641.28 m^3/d) available for process water after deducting other clean raw water requirements (such as potable water for staff accommodation and clean process water).

Table 11.60: Groundwater ingress model input

Period	Groundwater Ingress (m^3/d)		
	Low	Mean	High
Final value at 10 Years	176	220	264
Final value at 15 Years	304	380	456
Final value at 20 Years	280	350	420
Final value at 30 Years	392	490	588

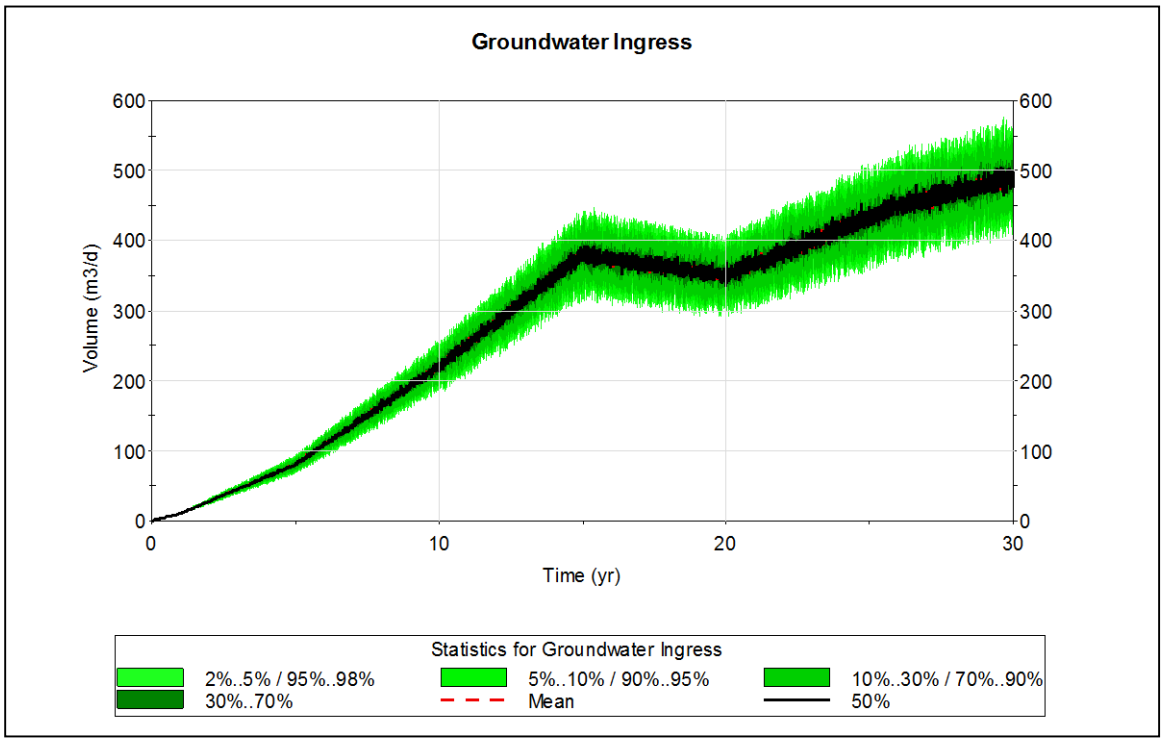


Figure 11.65: Simulated groundwater ingress over the life of mine

11.6.1.5 Base Case: Dry Tails Plant Operation

The following discussion concerns the investigation of raw water supply for the Base Case plant operation with dry tailings. The plant produces dry tailings for 30 years that will be deposited on the co-disposal facility.

The Base Case operation was investigated in more detail for thirty (30) years and simulated at fifty (50) sequences. The simulation was based on solely groundwater supply from the wellfield as a raw water source. Furthermore, re-use of storm water and pit water was included to optimise and reduce the raw water usage.

The probabilistic raw water requirement simulated over 50 sequences is presented in Figure 11.66. The median (50% exceedance) of the maximum raw water make-up requirement is 566 m^3/d as shown in Table 11.61 and 574 m^3/d in 2% of the time. This will occur during the beginning of the life of mine when open pit water availability will be very limited.

Sufficient water for re-use from the PCDs becomes available after approximately 12 years. However, the raw water source (groundwater) must continuously supply clean water to the plant (9.28 m^3/hr ~ 622 m^3/d, Figure 11.66). This implies that the peak raw water supply lies within the reserved yield capacity of the groundwater wellfield.

Table 11.61: Maximum daily raw water make-up (E98 = 98% of the time exceeded)

Probability	30 Years
	1x 240 ktpa (m^3/d)
E98	534
E50	566
E2	574

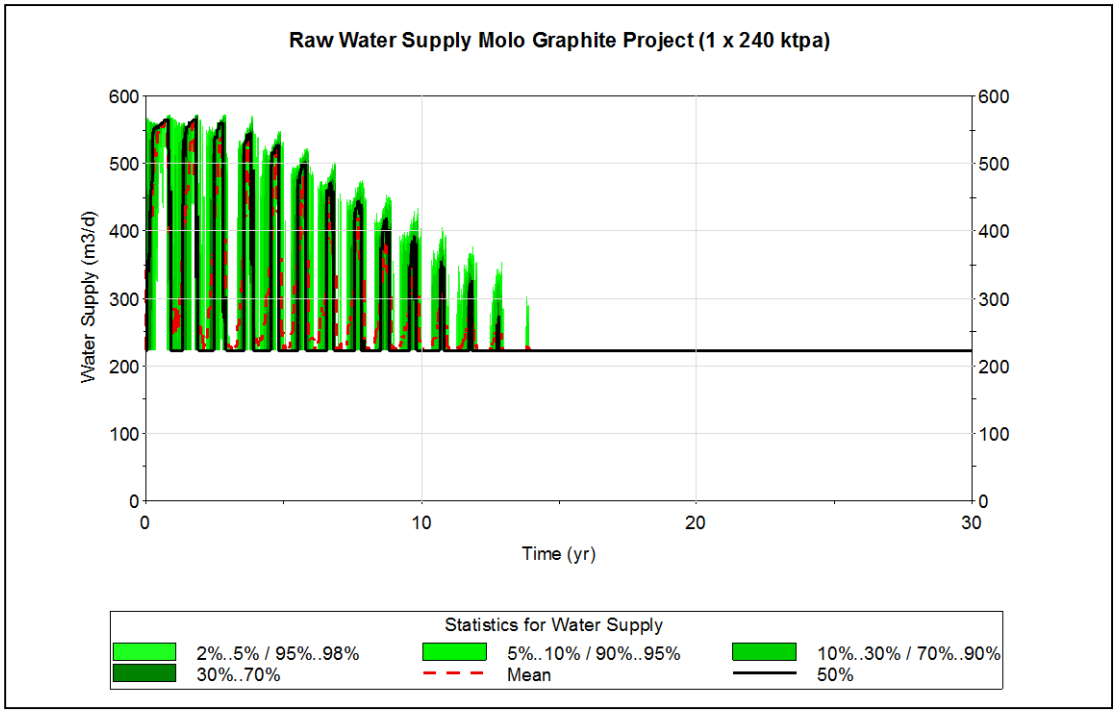


Figure 11.66: Simulated total raw water supply from the wellfield for the Base Case during the life of mine

Average monthly raw water supply requirements and the water supply from the PCDs (re-use water) for the first three years of life of mine are plotted in Figure 11.67. When make-up water was required for dust suppression, the co-disposal PCD and pit/reject PCD start to supply water to the plant PCD. The co-disposal PCD received water from storm water and seepage from the co-disposal facility and the pit/reject PCD from the open pit area and storm water and seepage from the reject dump. The plant PCD received water from storm water on the plant area and storm water and seepage from the ore stockpile area.

Results showed that, on average, 247 m^3/d was received for dust suppression from the PCDs (co-disposal and pit/reject) and a maximum of 286 m^3/d in May. An additional average raw water supply from groundwater was required (~86 m^3/d on average in September) besides clean water supply and potable water to make-up for process water demands.

A static mean annual water balance of the Molo Graphite Project is presented in Figure 11.69.

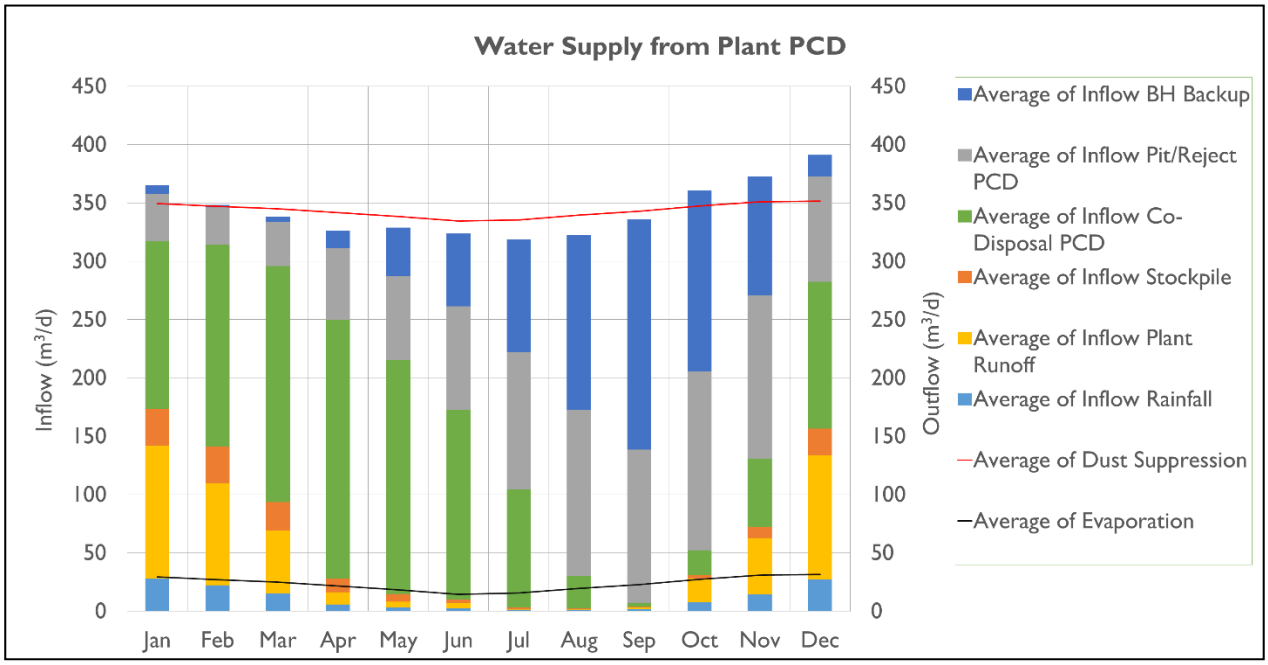


Figure 11.67: Average monthly results of the raw water requirements and re-use of water from PCDs for dust suppression purposes (Base Case)

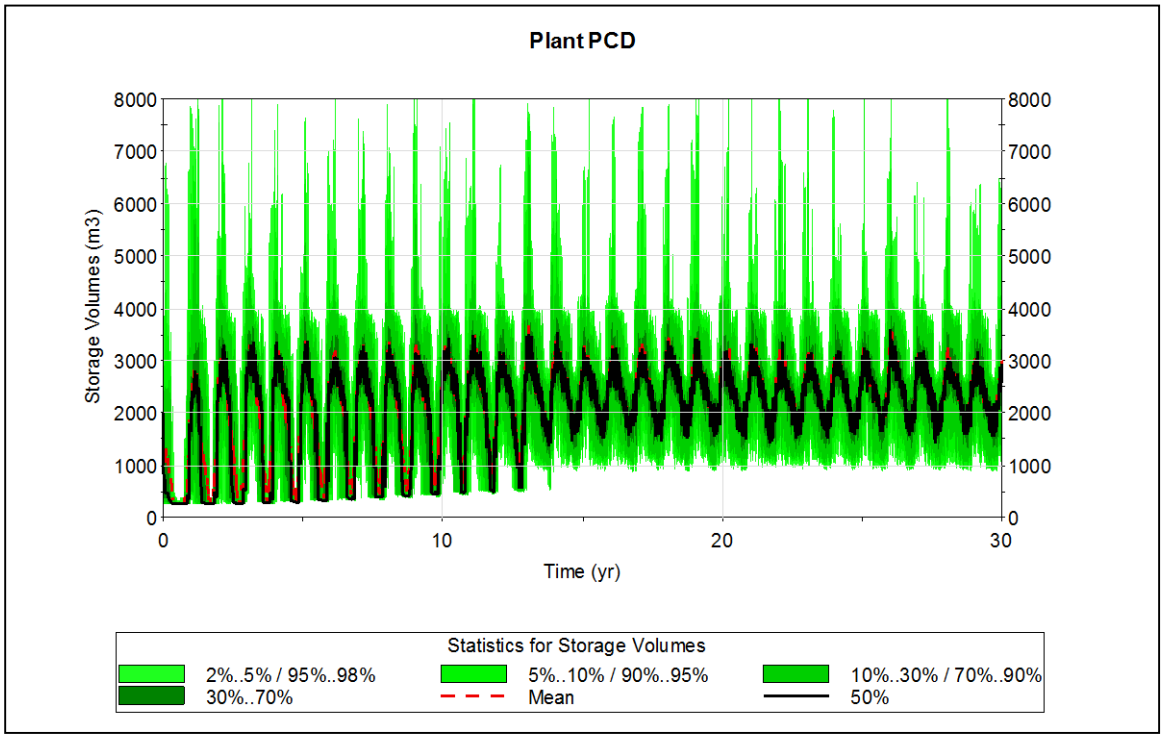


Figure 11.68: Simulation of the plant PCD volume during the life of mine

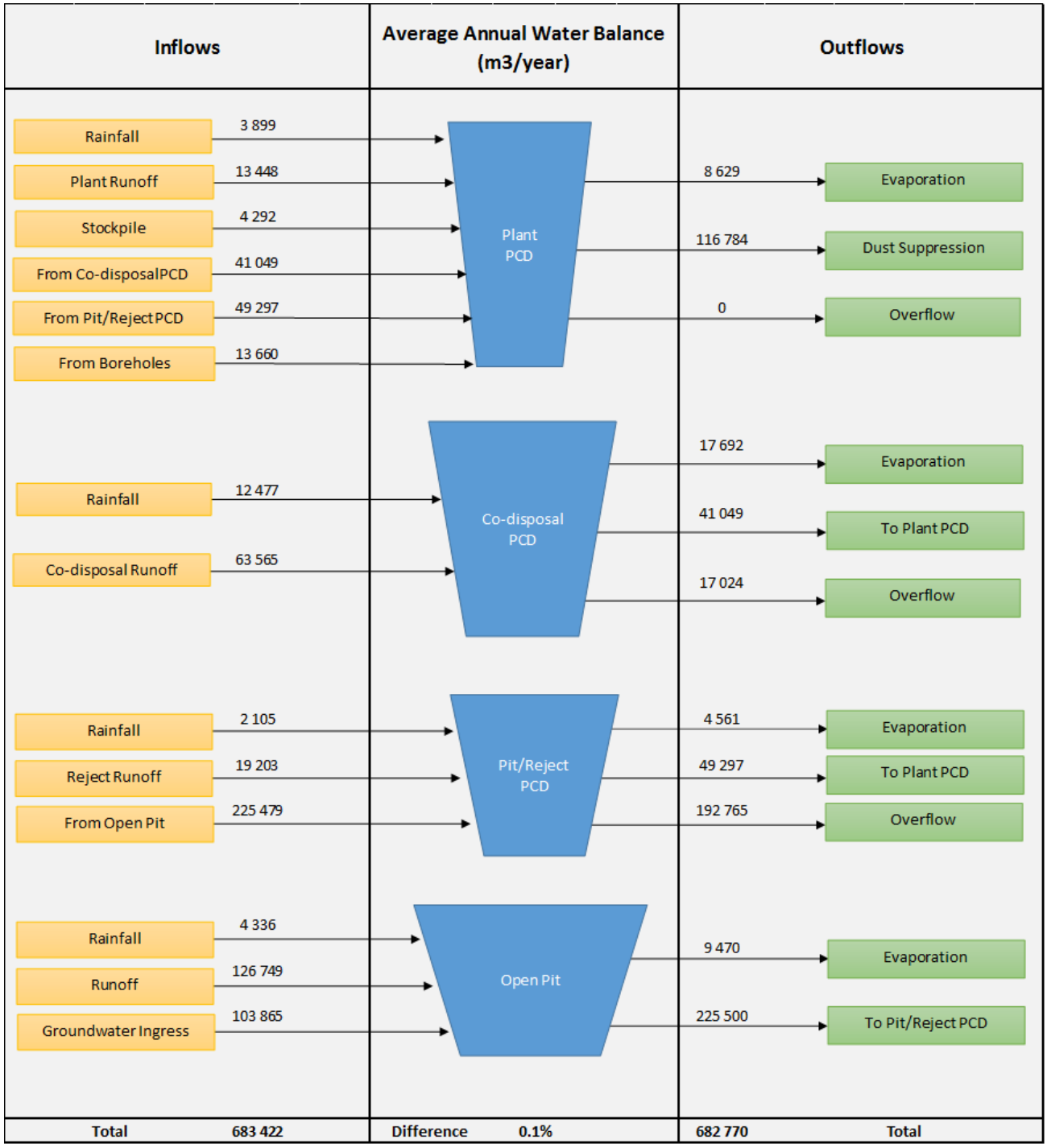


Figure 11.69: Average annual water balance for the Base Case

11.6.1.6 Mine Discharges

As the described in Section 11.6.1.1, during the operations of the mine, spillages are expected owing to relatively low water requirements. Figure 11.70 to Figure 11.72 show the simulated overflow during the wet season from the plant PCD, co-disposal PCD and pit/reject PCD.

Average potential overflow in the wet season over the life of mine from the plant PCD was calculated at 0.65 m^3/d, co-disposal PCD was calculated at 46 m^3/d and for the pit/reject PCD a substantial 529 m^3/d.

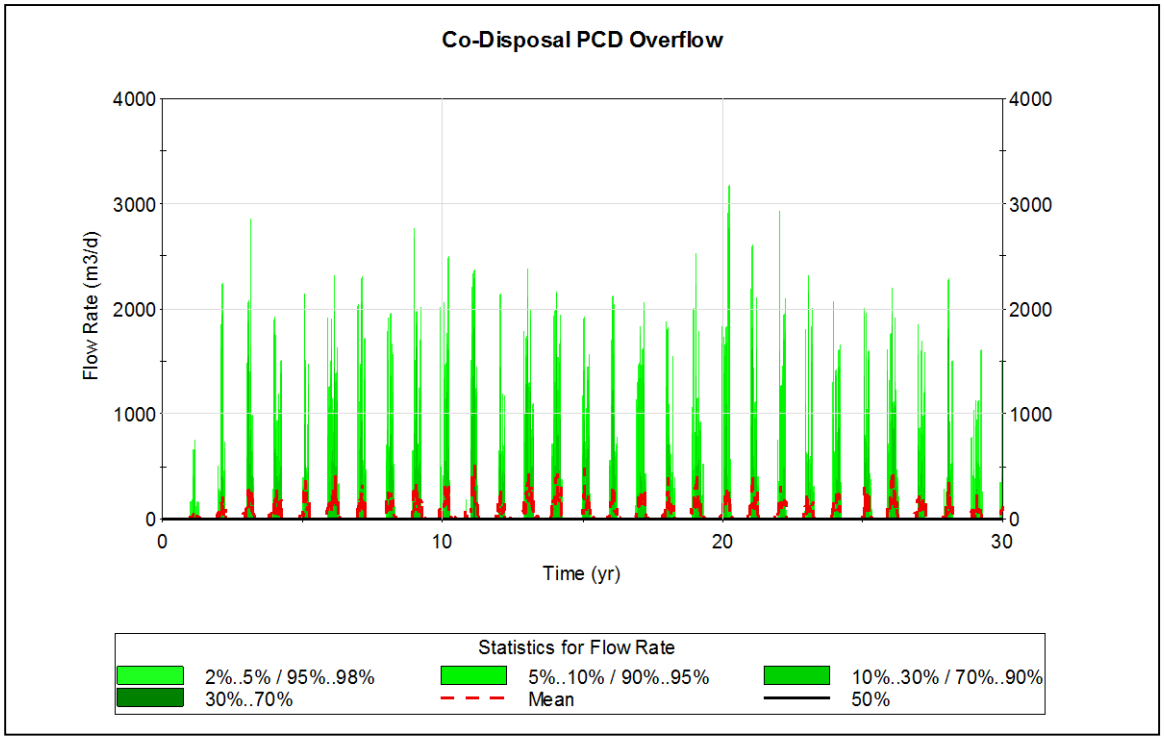


Figure 11.70 : Overflow from the co-disposal PCD for the Base Case as pumped to the plant PCD during the life of mine

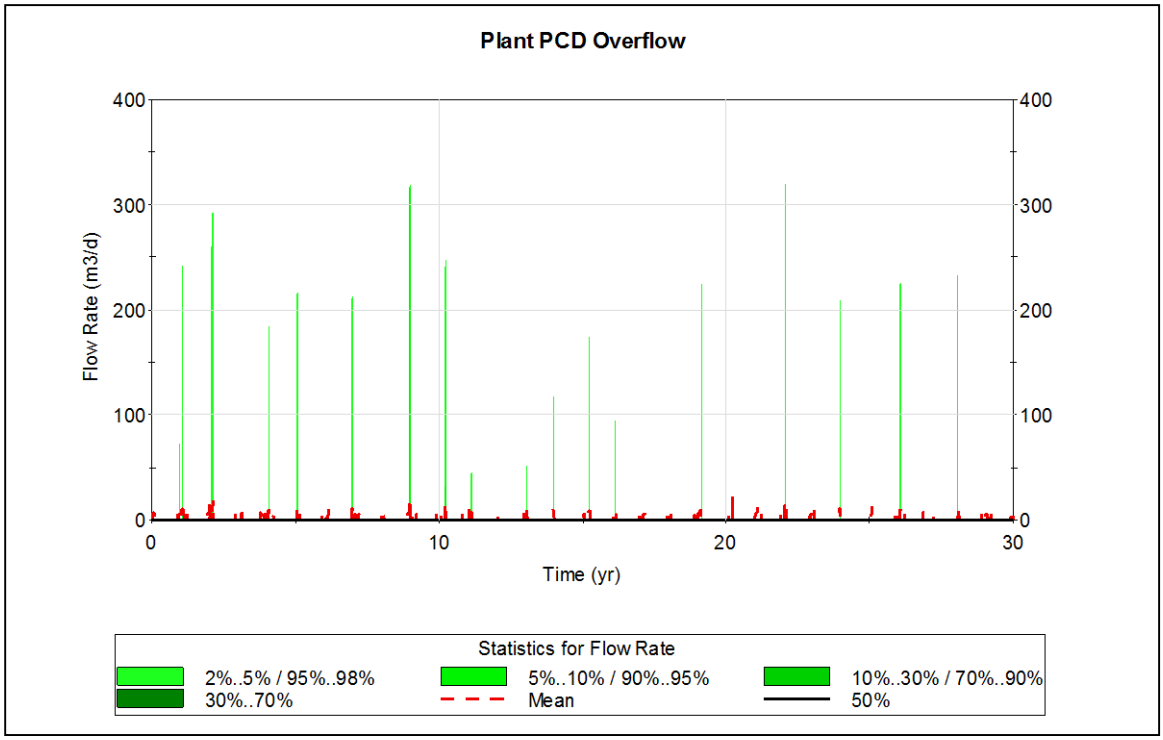


Figure 11.71: Overflow from the plant PCDs for the Base Case as used for dust suppression during the life of mine

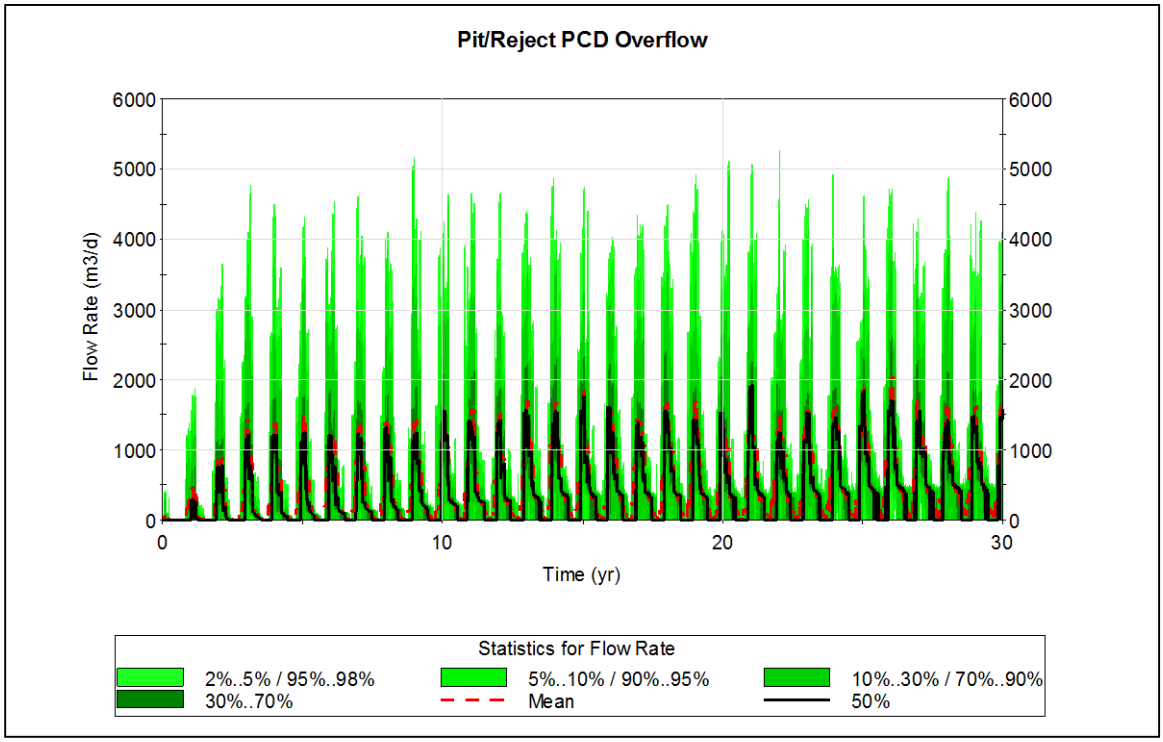


Figure 11.72: Overflow from the pit/reject PCD for the Base Case during the life of mine

11.6.1.7 Open Pit Sump Water

The open pit water will receive water, as the described in Section 11.6.1.1, from rainfall in the sump, runoff in the open pit and ground water ingress. The total inflows of the open pit are shown in Figure 11.73. Average inflow in the pit was calculated at 650 m^3/d at the end of the life of mine.

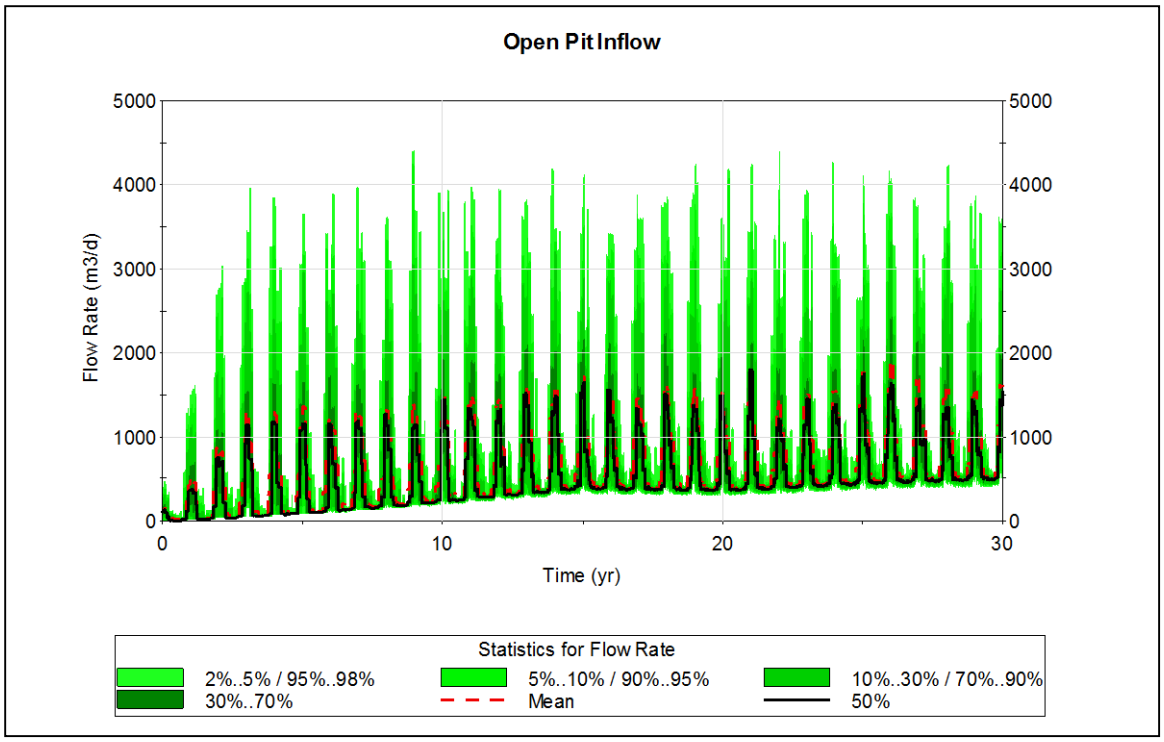


Figure 11.73: Open Pit Inflow for the Base Case over the life of mine

11.6.1.8 Open Pit: Closure

After the life of mine (30 years) the open pit will fill up with water (rainfall, runoff and groundwater ingress). The dynamic water balance was able to determine how long it approximately will take to reach a steady state condition in the open pit.

The runoff into the open pit area from surrounding catchments was a delineated natural catchment surface area of 15.5 ha.

The time to reach a steady state in the open pit was calculated at 100 years reaching a vertical water column of approximately 52 m (at an elevation of about 545 mamsl). The pit will initially fill up quickly, however the rate of water level rise will decrease after the first 10 years and will slow down considerably after 25 years. The pit-lake will not overflow on surface into the environment.

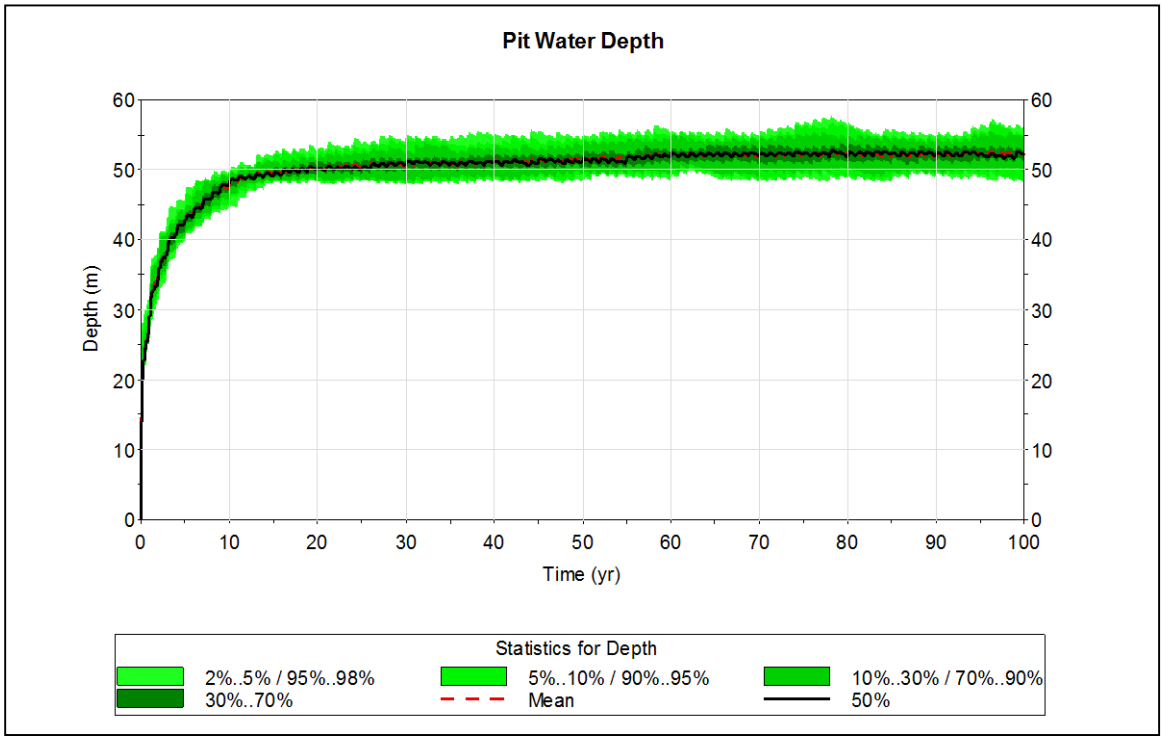


Figure 11.74: Open pit flooding curve simulation

11.6.2 Salt Balance

The co-disposal PCD, pit/reject PCD, and the plant PCD are likely to overflow during the wet season. The analysis of water quality concentration at the PCDs was necessary to determine the potential discharge point water quality. This was conducted in a salt mass balance. The salt mass balance approach provides a mechanism for tracking changes of volume of water and specific elements in the water system depending on the loads that are flowing between various storage areas. This approach provides a good indication of the general water quality in a water system.

All potential spillages from the PCDs must comply with the Malagasy and international water quality objectives and, consequently, spillages are allowed to be discharged into the environment.

Sulphate (SO_4) was chosen as an element, because it was one of the main indicator constituents to identify potential impact by the mining activities. The ore contains mainly secondary sulphur minerals as well as minor sulphide minerals. The TDS was also selected to present the total salt load. The reactions of TDS and sulphate on biological and physical processes were ignored. Neutral drainage can be expected for the operational life with only low concentrations of aluminium, iron and manganese. A metal balance was not undertaken due to the very low metal concentrations and the complexity of reaction in the system (Section 11.2).

Table 11.62 details the calculated sulphate and TDS concentrations used as model input. The values based on results from the hydro-geochemical analysis results (Section 11.2).

Table 11.62: Assumed Sulphates and TDS concentrations

Process	Sulphate (SO_4) (mg/l)			Total Dissolved Solids (TDS) (mg/l)		
	Low	Mean	High	Low	Mean	High
Boreholes/Groundwater ingress	15	25	40	250	310	400
Runoff from Plant area	40	50	150	100	125	375
Runoff from Ore Stockpile, Reject Dump and Co-Disposal area	40	50	150	100	125	375
Seepage from Ore Stockpile, Reject Dump and Co-Disposal	200	500	1000	500	1000	2000
Runoff inside Open Pit area	20	30	120	40	55	250

11.6.2.1 Element Modelling

Input mass loads were simulated by multiplying the assumed concentrations by the volumes of water generated in the water balance for those specific areas. Initial concentrations for the boreholes, open pit water, runoff from the processing plant and runoff and seepage from the co-disposal facility, reject dump and ore stockpiles were assumed based on input values provided in Table 11.62.

The concentrations at the dam element outflows (C-end) were simulated using the principle that load "in" would be equal to load "out" plus any changes in load due to evaporation and rainfall:

$$Cend = \frac{load_{in} + \Delta load_{dam}}{volume_{end}} \qquad \text{(Equation 11.7)}$$

11.6.2.2 Base Case: Dry Tails Plant Operation

Concentrations of sulphate and TDS in the co-disposal PCD, the pit/reject PCD and plant PCD, were stochastically simulated. The salt balance model was simulated for both modules for the life of mine (30 years) and for fifty (50) sequences. Results are presented in Figure 11.75 to Figure 11.80.

Sulphate and TDS concentrations will increase during the wet season in the PCDs (November-April). This is because the co-disposal and pit/reject PCDs cannot pump water to the plant PCD, whereas it keeps receiving sulphate and TDS loads from seepage, runoff and pit water.

The build-up of sulphate concentration was not exceeding 180mg/l at its maximum values during the wet season at the pit/reject PCD and plant PCD (Figure 11.77 and Figure 11.79). Sulphate concentration simulated for the overflow of the co-disposal PCD was not exceeding 220 mg/l at the 5% exceedance probability. Spillages from this PCD must be monitored continuously during the life of mine. Similarly, TDS concentrations were also generally low for all PCDs (<600mg/l).

Overall, this implies that the water quality from the PCD overflow will comply with Malagasy and international standards.

It was calculated that sulphate and TDS concentrations are significantly higher in the co-disposal PCD than concentration in the plant PCD and pit/reject PCD due to relatively large seepage inflow from the co-disposal facility. Sulphate concentrations pumped back to the processing plant are ranging between 250 mg/l and 750 mg/l and TDS varies between 600 mg/l and 1700 mg/l (Figure 11.81 and Figure 11.82) However, peak values can be higher if the co-disposal PCD is filling up during high return flow periods (wet season). Therefore, it will be recommended to clean up the co-disposal PCD and regularly from silts and conduct continuous water quality monitoring.

Static mean annual salt balances of sulphates and TDS loads for the Molo Graphite Project are presented in Figure 11.85 and Figure 11.86.

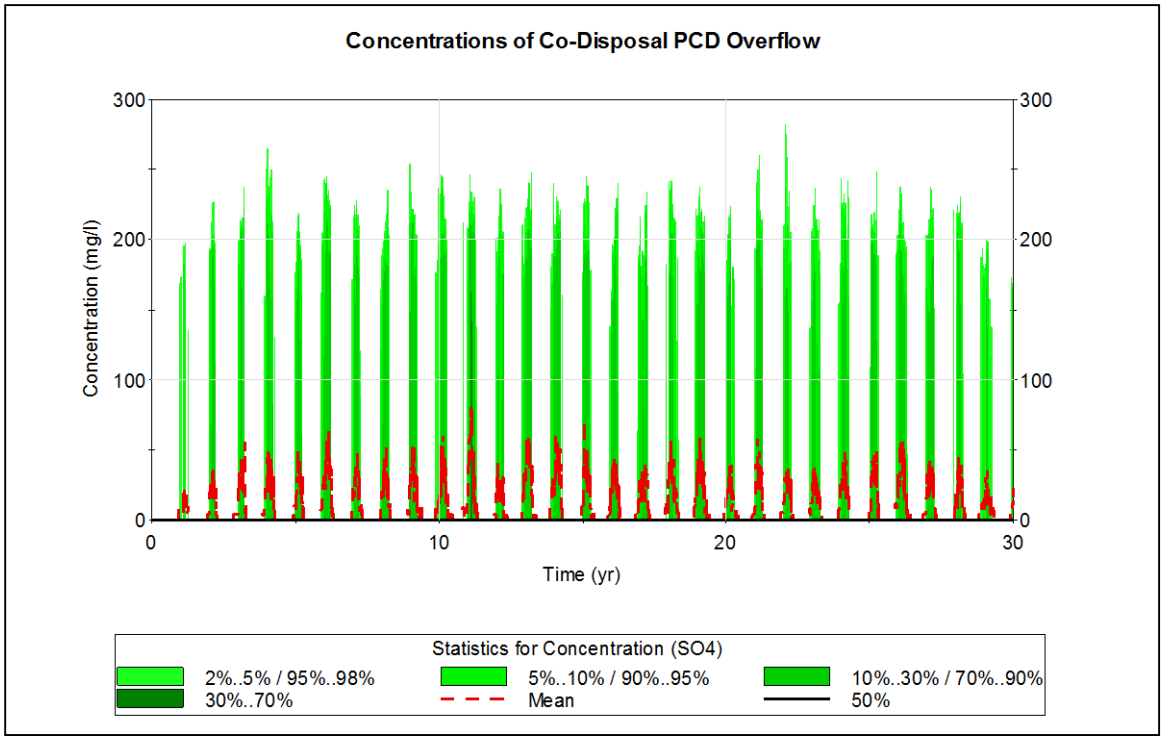


Figure 11.75: SO_4 concentrations at the Central PCD during overflow over the life of mine

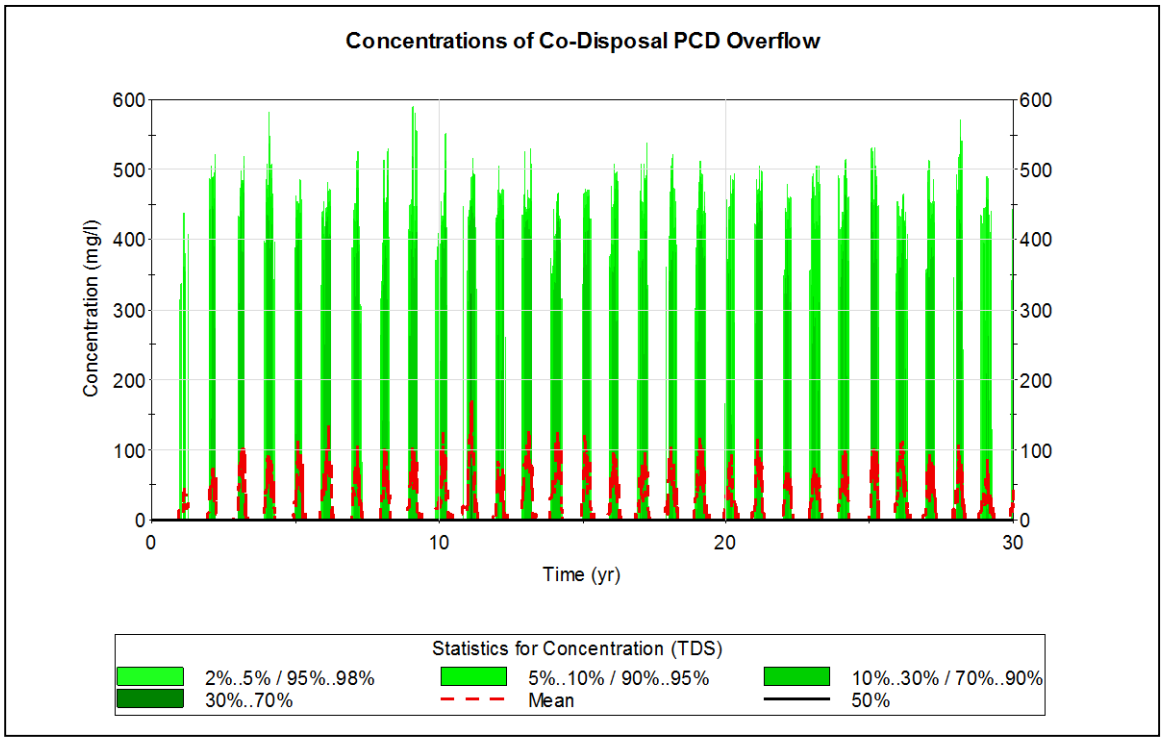


Figure 11.76: TDS concentrations at the Central PCD during overflow over the the life of mine

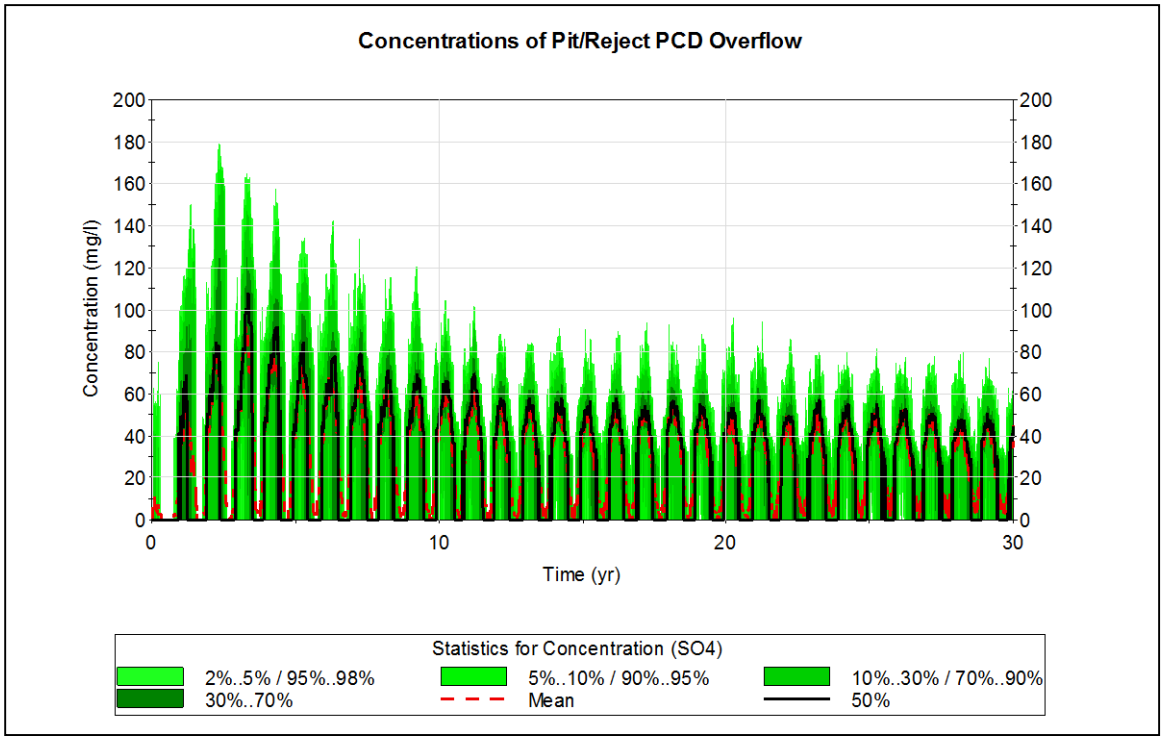


Figure 11.77: SO_4 concentrations at the Pit/Reject PCD during overflow over the life of mine

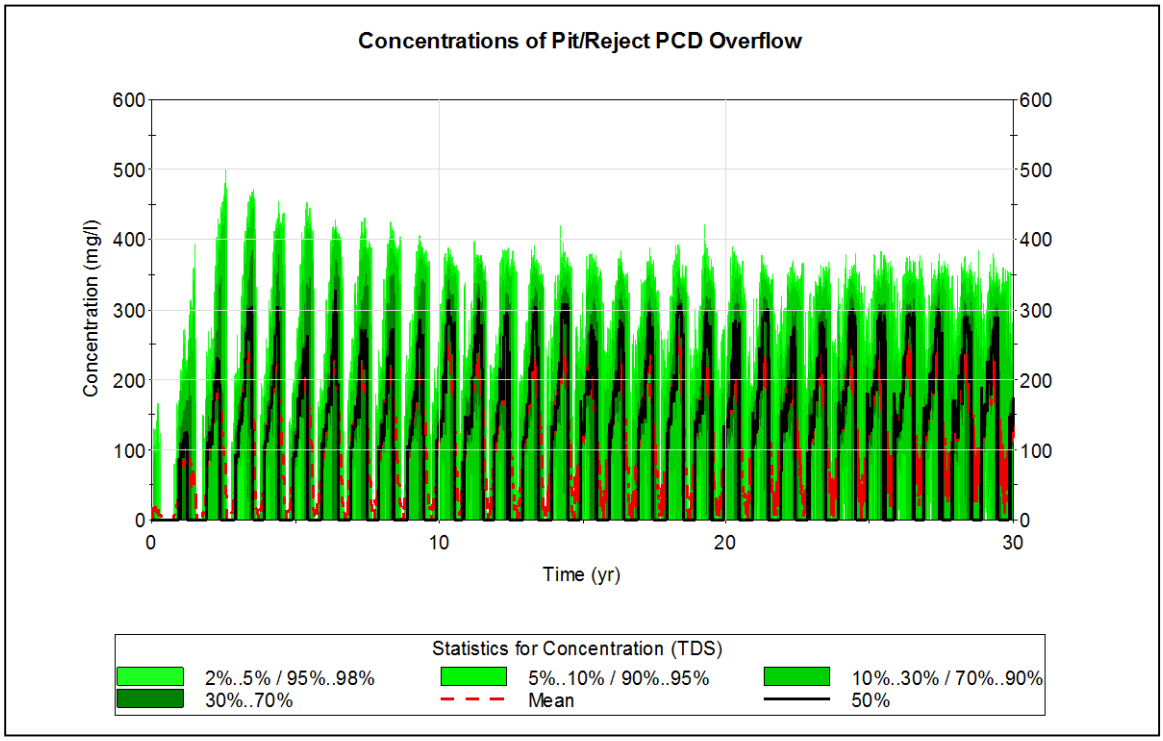


Figure 11.78: TDS concentrations at the Pit/Reject PCD during overflow over the life of mine

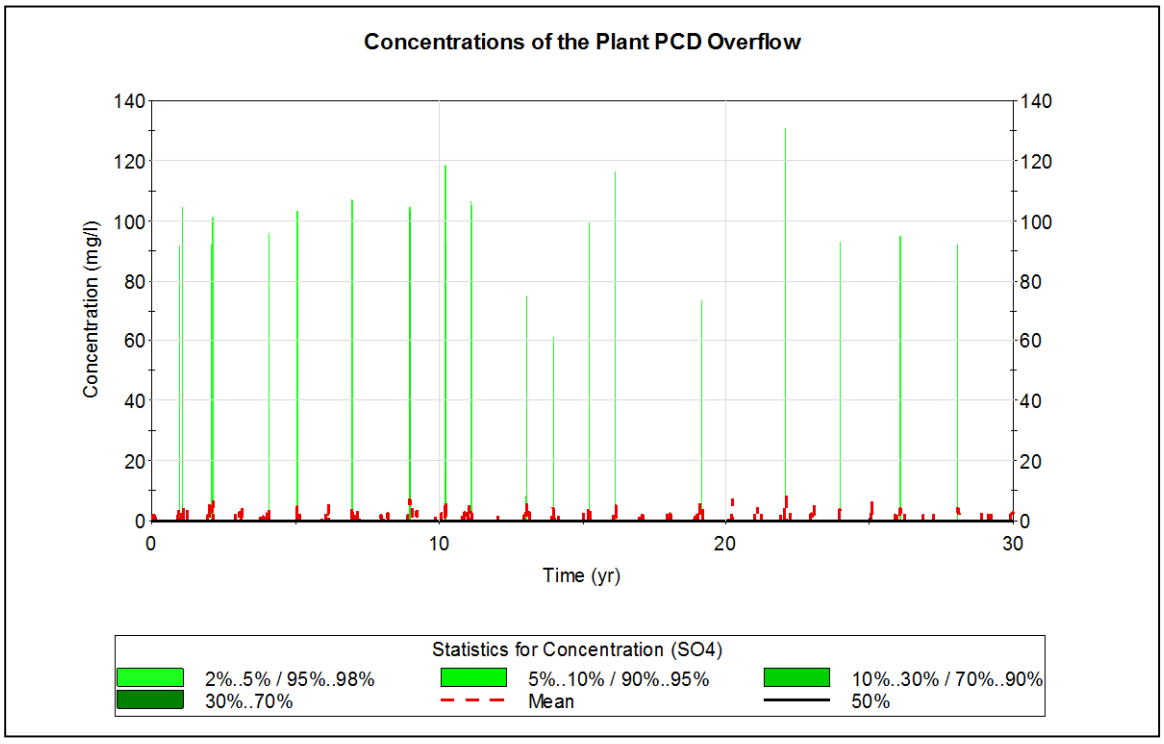


Figure 11.79: SO_4 concentrations at the Plant PCD over the life of mine

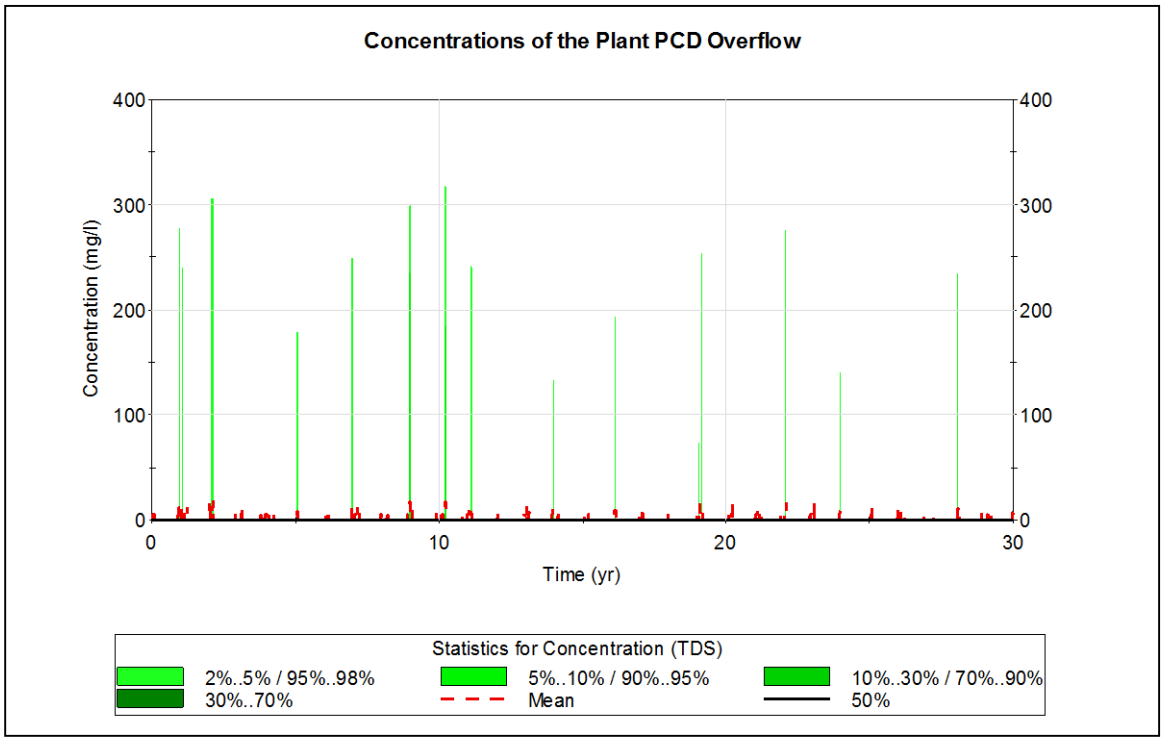


Figure 11.80: TDS concentrations at the Plant PCD over the life of mine

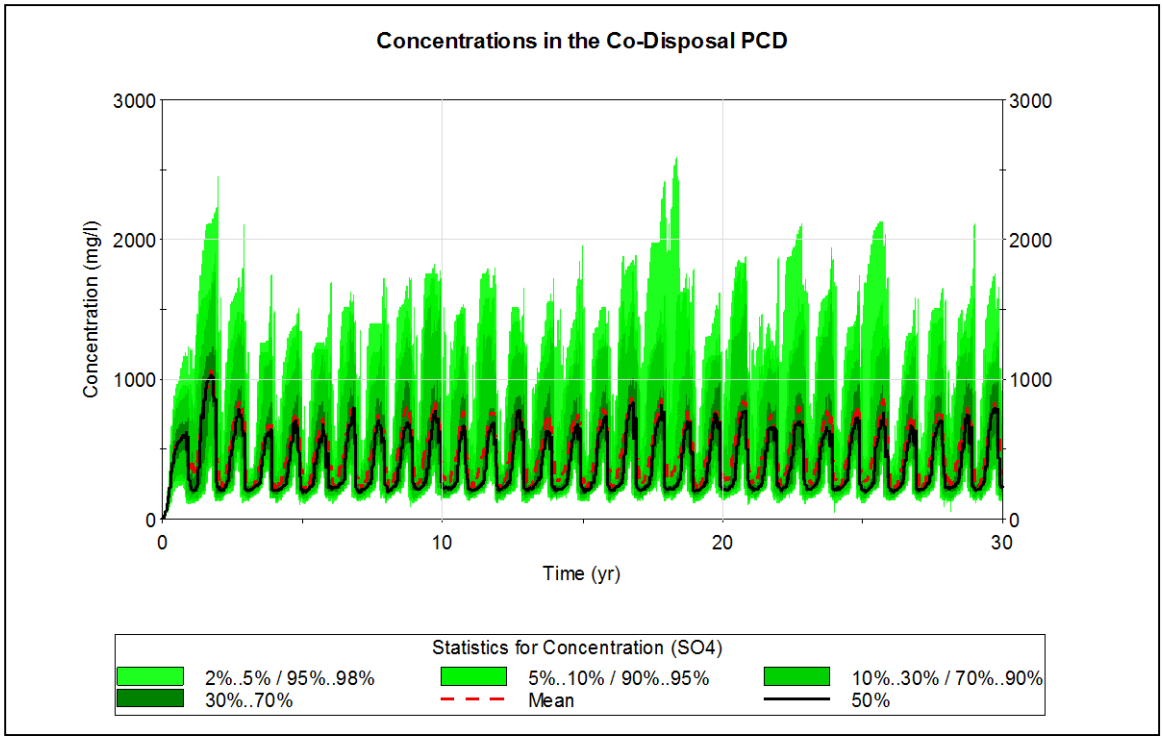


Figure 11.81: SO_4 concentration in the Co-Disposal PCD

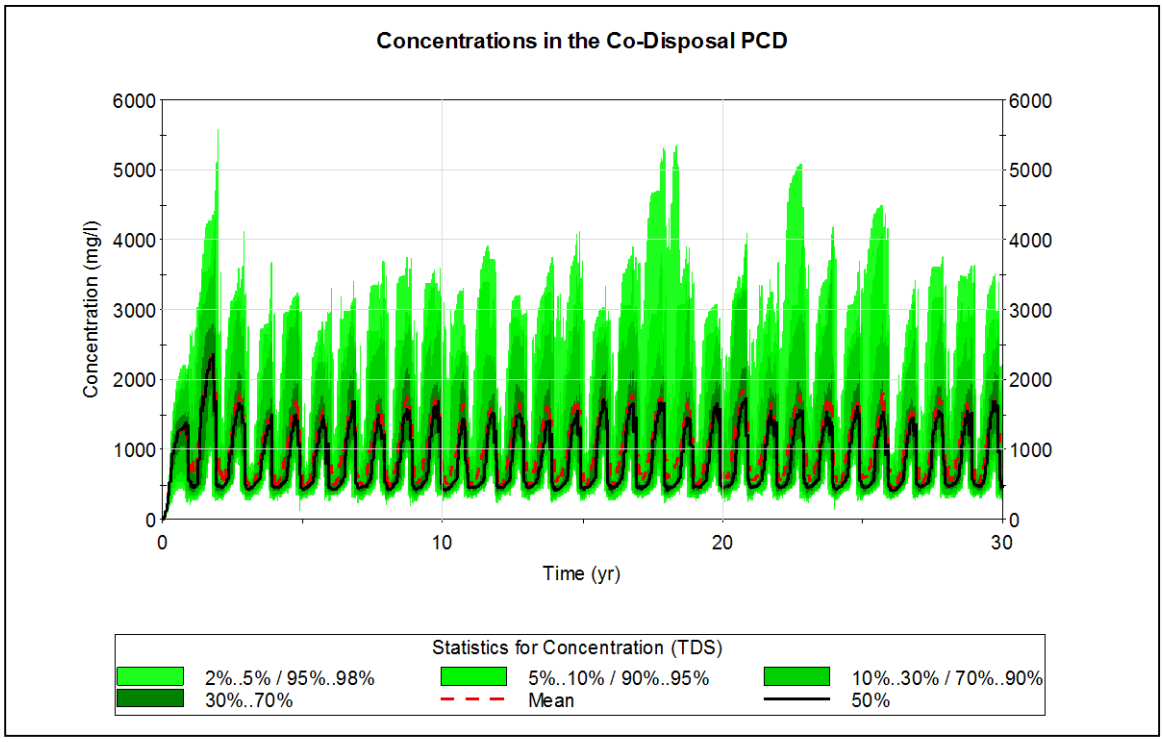


Figure 11.82: TDS concentration in the Co-Disposal PCD

11.6.2.3 *Co-Disposal PCD Closure*

After the life of mine (30 years), seepage from the co-disposal facility should be contained in the co-disposal PCD as water quality will worsen over time (Section 11.2.3).

The co-disposal will be capped/vegetated and sloped towards the co-disposal PCD so that seepage into the co-disposal will be limited to an estimated 3.5% of MAP and surface runoff from the co-disposal facility will be clean.

The dynamic water balance was able to determine whether the co-disposal PCD will be able to spill within compliance objectives of Malagasy and international water quality objectives. The seepage, runoff into the co-disposal PCD and evaporation were simulated for seventy-five (75) years.

It was calculated that overflows from the co-disposal PCD will comply with the Malagasy and international water quality standards with respect to sulphates and TDS (Figure 11.83 and Figure 11.84).

Static mean annual salt balances of sulphates and TDS loads for the Molo Graphite Project are presented in Figure 11.85 and Figure 11.86.

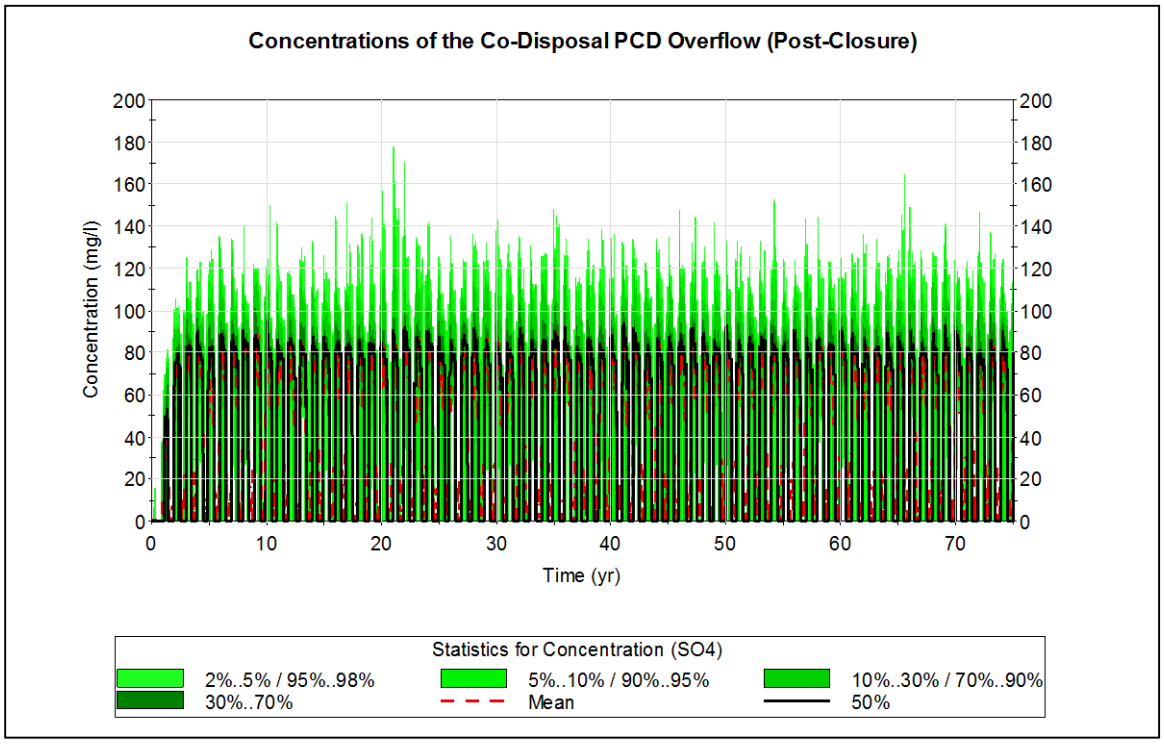


Figure 11.83: Simulation of SO_4 from the co-disposal PCD overflow after closure

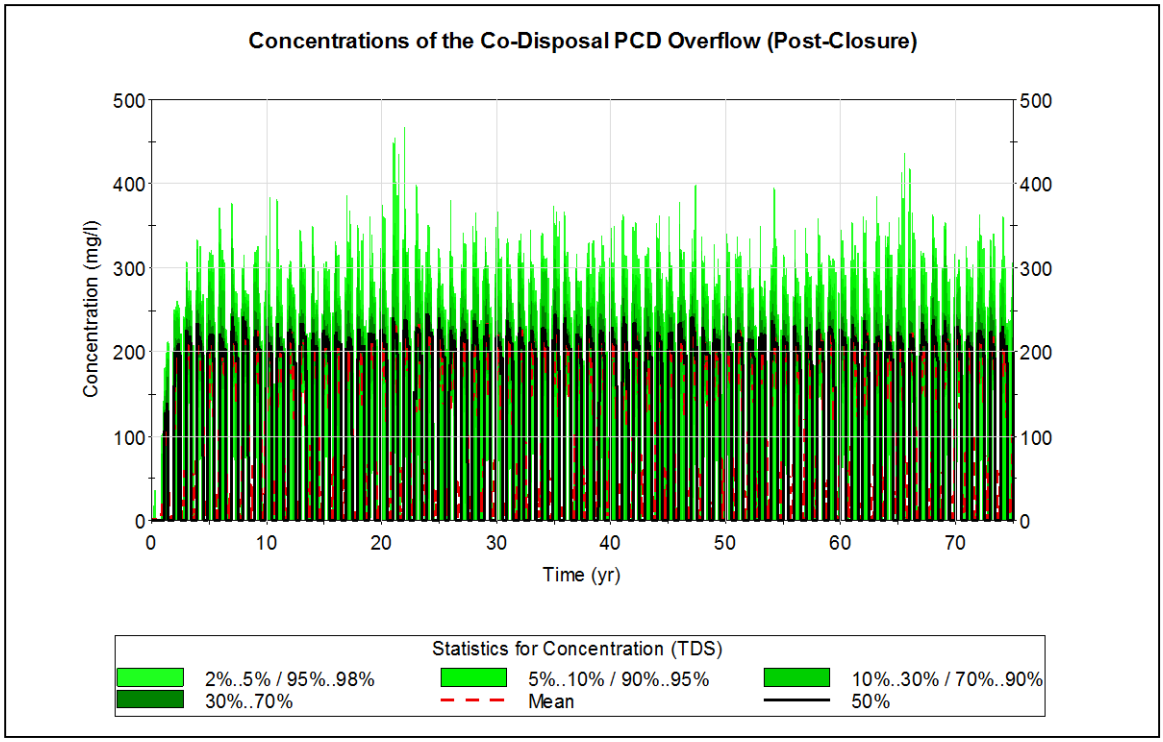


Figure 11.84: Simulation of TDS from the co-disposal PCD overflow after closure

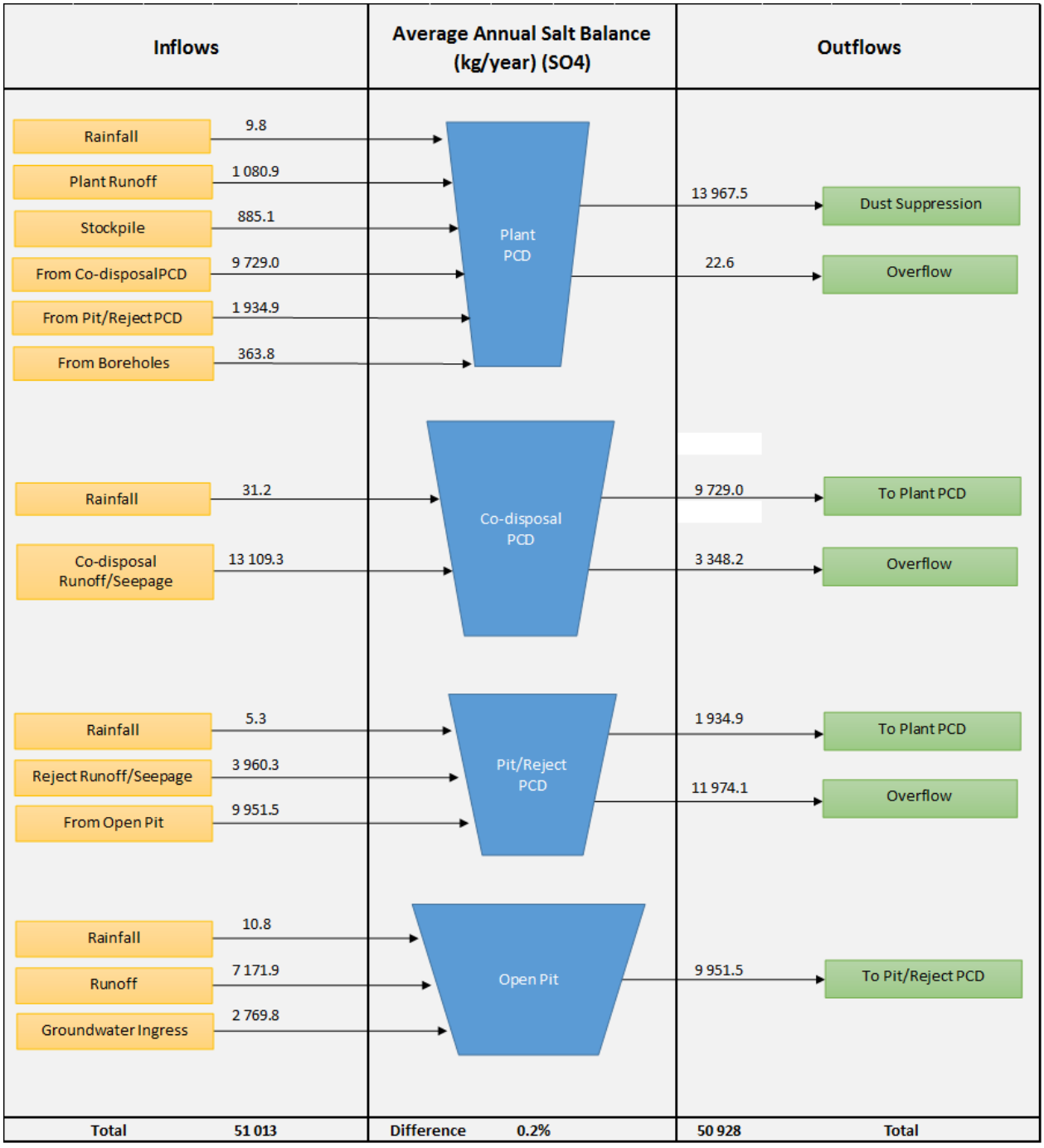


Figure 11.85: Average annual sulphate balance for Base Case

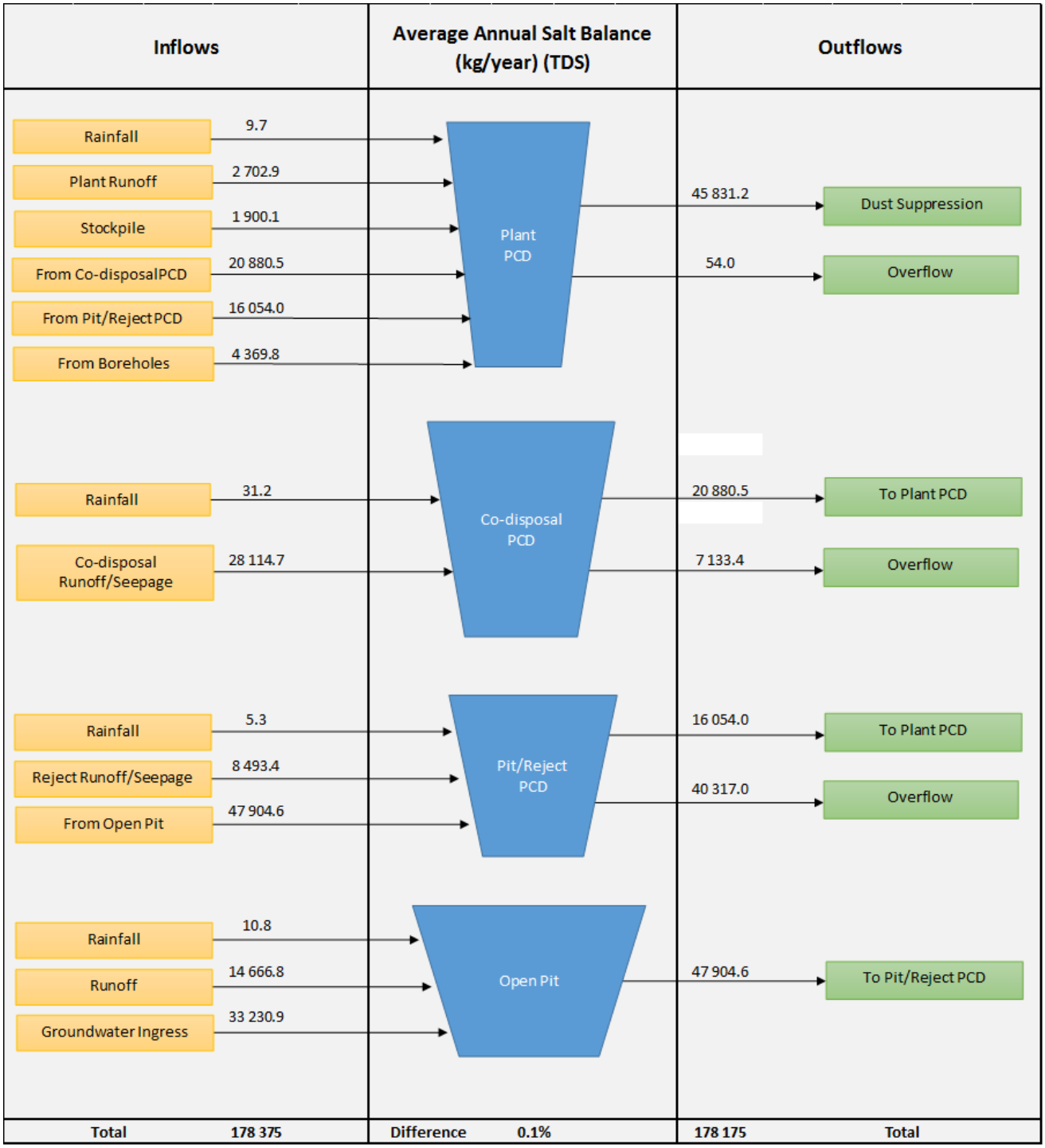


Figure 11.86: Average annual TDS balance for Base Case

11.7 Water Impact Assessment

11.7.1 Legal Requirements

11.7.1.1 *Equator Principles*

The Equator Principles provide a benchmark for the financial industry to determine, assess and manage social and environmental risks in project financing. Financial institutions voluntarily adopting these Principles are known as Equator Principles Financial Institutions (EPFIs).

The Principles aim to ensure that projects financed by EPFIs are developed in a manner that is socially responsible and reflect sound environmental management practice. Adherence to these Principles should ensure that negative impacts on project-affected ecosystems and communities are avoided where possible, and if these impacts are unavoidable, they should be reduced, mitigated and/or compensated for appropriately.

The EPFI will require that the Assessment process of the proposed Molo Graphite Project evaluates compliance with applicable IFC Performance Standards on Environmental and Social Sustainability and the World Bank Group Environmental, Health and Safety Guidelines (EHS Guidelines) (Exhibit III) (IFC, 2007a).

The Equator Principles includes the following illustrative list of issues that should be considered in the Assessment, however, the scope of the Environmental Social Impact Assessment (ESIA) should be tailored to be relevant to the project being assessed:

a) Assessment of the baseline social and environmental conditions;
b) Consideration of feasible environmentally and socially preferable alternatives;
c) Requirements under host country laws and regulations, applicable international treaties and agreements;
d) Protection of human rights and community health, safety and security (including risks, impacts and management of project's use of security personnel);
e) Protection of cultural property and heritage;
f) Protection and conservation of biodiversity, including endangered species and sensitive ecosystems in modified, natural and critical habitats, and identification of legally protected areas;
g) Sustainable management and use of renewable natural resources (including sustainable resource management through appropriate independent certification systems);
h) Use and management of dangerous substances;
i) Major hazards assessment and management;
j) Labour issues (including the four core labour standards), and occupational health and safety;
k) Fire prevention and life safety;

l) Socio-economic impacts;
m) Land acquisition and involuntary resettlement;
n) Impacts on affected communities, and disadvantaged or vulnerable groups;
o) Impacts on indigenous peoples, and their unique cultural systems and values;
p) Cumulative impacts of existing projects, the proposed project, and anticipated future projects;
q) Consultation and participation of affected parties in the design, review and implementation of the project;
r) Efficient production, delivery and use of energy; and
s) Pollution prevention and waste minimisation, pollution controls (liquid effluents and air emissions) and solid and chemical waste management.

11.7.1.2 *International Finance Corporation Performance Standards and EHS Guidelines*

The IFC Performance Standards are designed to assist the client in designing and implementing a project in a manner where risks and impacts associated with the project are identified and mitigated to ensure the project is completed sustainably. For the hydrogeological investigation the IFC Performance Standard 1 (IFC PS1), "Assessment and Management of Environmental and Social Risks and Impacts", was applied. IFC PS1 is applicable to all projects which pose potential risk and may have an impact on the receiving environment and was applied in conjunction with both the IFC General and Mining Specific Environmental, Health and Safety (EHS) Guidelines.

IFC PS1 (2012) states that should the host country have legislative control for the management of the environment that overlaps with the guidelines of the IFC standards, the more stringent measure should be implemented for the project. For the Molo Graphite Project the Malagasy water quality standards were applied.

The objectives of IFC PS1 (2012), where applicable to the hydrogeology investigation, are summarized as follows:

- The identification and quantification of environmental risks and impacts associated with the project, as well as the identification of mitigation measures to be implemented at the site to minimize or avoid said risks and impacts;
- To encourage and ensure that the client runs the project as sustainably as possible using efficient and effective environmental management plans; and
- To ensure that relevant stakeholders (e.g. local communities, government, etc.) are aware of the project and their respective communications and queries are responded to and managed effectively.

A number of relevant documents pertaining to the hydrogeological investigation include:

- IFC Performance Standard 1 – Social and Environmental Assessment and Management System requires free, prior and informed consultation and informed participation of affected communities for projects with significant adverse impacts on them and also requires broad community support for the project within the affected communities.
- IFC Performance Standard 3 – Pollution Prevention and Abatement refers to the Pollution Prevention and Abatement Handbook and to the IFC Environmental Health and Safety Guidelines and relates to management of wastes, recycling and reuse, and numerical guidelines for effluent disposal.
- IFC Performance Standard 4 – Community Health and Security specifically relates to protection of community health against adverse impacts related to changes in water quality.
- IFC Performance Standard 6 – Biodiversity Conservation and Sustainable Natural Resource Management in the context of the Molo Graphite project relates to sustainability and efficiency of water use and protection of biodiversity from adverse impacts related to surface water or groundwater pollution, or to excessive water level drawdown in areas of groundwater abstraction such as mines and wellfields.
- IFC Environmental, Health, and Safety General Guidelines, Subsection 1.3 applies to projects that have the potential to generate process wastewater, sanitary (domestic sewage), or storm water to the environment and requires that necessary precautions be incorporated to avoid, minimize and control adverse impacts to human health, safety, or the environment. The wastewater and water quality monitoring program, with adequate resources and management oversight, should be developed and implemented to meet the objectives of the monitoring program.
- IFC Environmental, Health, and Safety General Guidelines, Subsection 1.4 relates to water conservation. General recommendations include:
    - Storm water harvesting and use.
    - Zero discharge design and use of treated wastewater to be included in project design processes.
    - Use of dry process technologies.
    - Process water system pressure management.
    - Project design to have measures for adequate water collection, spill control and leakage control systems.

- IFC Environmental, Health, and Safety General Guidelines, Subsection 3.1 states that project activities involving wastewater discharges, water extraction, diversion or impoundment should prevent adverse impacts to the quality and availability of groundwater and surface resources. Drinking water sources, whether public or private, should at all times be protected so that they meet applicable national guidelines or in their absence the current edition of WHO guidelines for drinking water quality.

11.7.1.2.1 Water Use

Mining operations may potentially use/dewater large quantities of water during the various phases of mining (i.e. exploration, construction, operational and post-closure phases). The IFC EHC Guidelines (2007) recommend the following practices should be implemented for water management at a mining site:

- Inform the mine infrastructure design phase using a water balance for the site, including the mine operations and the associated infrastructure (e.g. the plant and tailings complexes);
- Develop a water management plan for both groundwater and surface water resources where the impact of the operations is minimized and most sustainable;
- Investigate potential recycling circuits for the plant operations, as well as potential reclamation of storm water runoff or tailings dam water, in order to minimize the impact of the mining site on the water balance; and
- Communication with existing communities within the project area in order to determine their dependency on the groundwater resources (i.e. hydrocensus).

11.7.1.2.2 Water Quality

Poor quality water is potentially generated from a number of sources within the mining project environment, these sources include by-product from processing (e.g. tailings), process water, leachate from waste rock dumps and stockpiles. In order to effectively manage the impact of operations on the water quality a baseline, or ambient, water quality must be determined (refer to Section 11.1.3.7).

Table 11.63 shows the mine effluent discharge guidelines (IFC, 2012) and Table 11.64 shows the Malagasy guidelines for mine effluent discharge (Decret No. 2003-464, 2003). These limits were not applied to chemistry results for the Molo site for the hydrogeological investigation as the current conditions represent baseline, ambient conditions.

Further to the guidelines as stipulated in the Malagasy water quality guidelines define various classes of effluent, as shown Table 11.65 and Table 11.66. These classifications will be applied to the impact assessment for the site and suitable mitigation measures will be identified.

The World Health Organisation (WHO) guidelines for drinking water quality (WHO, 2011) and the Malagasy Standards for drinking water quality (Decret No. 2004-635, 2004), both summarised in Table 11.67, were also used for comparative purposes with the baseline water quality.

Table 11.63: Effluent Guidelines (after IFC, 2007)

Pollutants	Units	Guideline Value
Total Suspended Solids	mg/l	50
pH	S.U.	6 to 9
COD	mg/l	150
BOD	mg/l	50
Oil & Grease	mg/l	10
Arsenic, As	mg/l	0.1
Cadmium, Cd	mg/l	0.05
Chromium (VI), Cr	mg/l	0.1
Copper, Cu	mg/l	0.3
Cyanide, CN	mg/l	1
Free Cyanide	mg/l	0.3
Cyanide WAD	mg/l	0.5
Iron (Total), Fe	mg/l	2
Lead, Pb	mg/l	0.2
Mercury, Hg	mg/l	0.002
Nickel, Ni	mg/l	0.5
Phenols	mg/l	0.5
Zinc, Zn	mg/l	0.5
Temperature	C	<3 degree differential

Table 11.64: Malagasy Effluent Quality Standards (Decret No. 2003-464)

Parameter (mg/l)	Decret No. 2003-464
pH at 25°C	6 - 9
Conductivity mS/m @ 25°C	20
Chloride, Cl	250
Sulphate, SO_4	250
Nitrate as NO_3	20
Nitrite as NO_2	0.2
Total Phosphate as P*	3.26
Free and Saline Ammonia as NH_4	15
Aluminium, Al	5
Arsenic, As	0.5
Cadmium, Cd	0.02
Chromium, Cr	2
Iron, Fe	10
Manganese, Mn	5
Nickel, Ni	2
Lead, Pb	0.2
Selenium, Se	0.02
Zinc, Zn	0.5

Table 11.65: Effluent Water Classification (after Decree 2003-464, 2003)

Parameters	Class A	Class B	Class C	Ungraded
Biological Factors				
Dissolved Oxygen (mg/l)	5<OD	3<DO<5	2<OD<3	OD<2
DBO (mg/l)	DBO<5	5<DBO<20	20<DBO<70	70<DBO
DCO (mg/l)	DCO<20	20<DCO<50	50<DCO<100	100<DCO
Pathogens	None	None	None	None
Physio-Chemical Factors				
pH	6<pH<8.5	5.5<pH<6.0 OR 8.5<pH<9.5	pH<5.5 OR ph>9.5	
Suspended Solids (mg/l)	SS<30	30<SS<60	60<SS<100	SS>100
Electrical Conductivity (EC) (mS/m)	EC<25	25<EC<50	50<EC<300	EC>300

Table 11.66: Effluent Classification Summary

Class	Quality	Comments
Class A	Good	Possible multiple uses
Class B	Average	Recreational use, limited consumption
Class C	Poor	Not for consumption
Ungraded	Excessively Poor	Must be contained and not used at all

Table 11.67: Drinking Water Quality Guidelines

Parameter (mg/l)	Decret No. 2004-635	WHO Drinking Water (2011)
pH at 25°C	6.5-9.5	NS
Turbidity (in N.T.U)	5	1
Chloride, Cl	250	250
Sulphate, SO_4	250	250
Fluoride, F	NS	1.5
Nitrate as NO_3	50	50
Nitrite as NO_2	0.1	3
Total Phosphate as P*	NS	NS
Free and Saline Ammonia as NH_4	0.5	NS
Arsenic, As	NS	0.01
Boron, B	NS	2.4
Barium, Ba	NS	0.7
Cadmium, Cd	NS	0.003
Chromium, Cr	NS	0.05
Copper, Cu	NS	2
Iron, Fe	0.3	NS
Sodium, Na	NS	50
Nickel, Ni	NS	0.07
Lead, Pb	NS	0.01
Antimony, Sb	NS	0.02
Selenium, Se	NS	0.04
NS - Not Specified		

11.7.2 Environmental Impact Significance Rating Methodology

To ensure uniformity, the assessment of potential impacts will be addressed in a standard manner so that a wide range of impacts is comparable. For this reason a clearly defined rating scale will be provided to the specialist to assess the impacts associated with their investigation.

Each impact identified will be assessed in terms of probability (likelihood of occurring), scale (spatial scale), magnitude (severity) and duration (temporal scale). To enable a scientific approach to the determination of the environmental significance (importance), a numerical value will be linked to each rating scale.

The following criteria will be applied to the impact assessment for the EIA/EMP:

Occurrence

- Probability of occurrence (how likely is it that the impact may occur?); and
- Duration of occurrence (how long may impact last?).

Severity

- Magnitude (severity) of impact (will the impact be of high, moderate or low severity?); and
- Scale/extent of impact (will the impact affect the national, regional or local environment, or only that of the site?).

Status of Impact

- +: Positive impact
- -: Negative impact
- N: Neutral (no impact)

In order to assess each of these factors for each impact, the following ranking scales were used:

Probability:=P	*Duration:=D*
5 – Definite/don't know	5 – Permanent
4 – Highly probable	4 - Long-term (ceases with the operational life)
3 – Medium probability	
2 – Low probability	3 - Medium-term (5-15 years)
1 – Improbable	2 - Short-term (0-5 years)
0 – None	1 – Immediate
Scale:=S	*Magnitude:=M*
5 – International	10 - Very high/don't know
4 – National	8 – High
3 – Regional	6 – Moderate
2 – Local	4 – Low
1 – Site only	2 – Minor
0 – None	
Status of Impact	
+: Positive	
-: Negative	
N: Neutral	

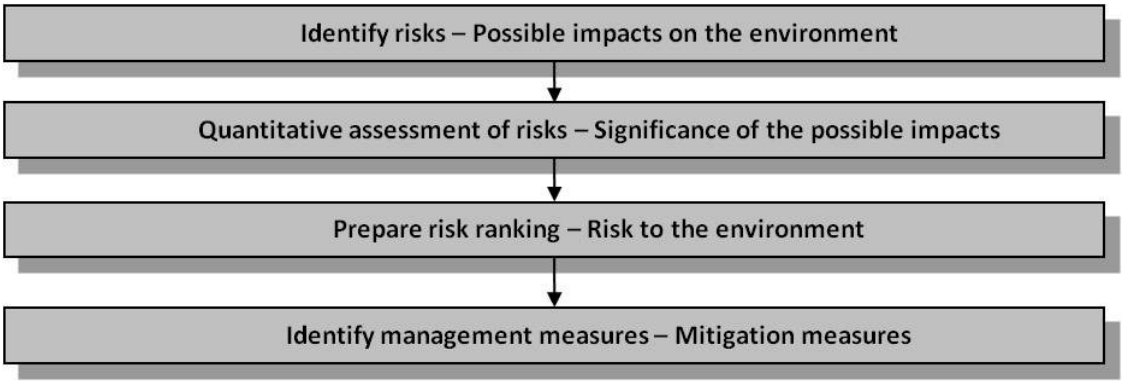
Once the above factors have been ranked for each impact, the environmental significance of each was assessed using the following formula:

SP = (magnitude + duration + scale) x probability

The maximum value that can be achieved is 100 Significance Points (SP).Environmental effects were rated as follows:

Significance	*Environmental Significance Points*	*Colour Code*
High (positive)	>60	H
Medium (positive)	30 to 60	M
Low (positive)	<30	L
Neutral	0	N
Low (negative)	>-30	L
Medium (negative)	-30 to -60	M
High (negative)	<-60	H

The following process will be followed:



11.7.3 Surface Water Impact Assessment

11.7.3.1 *Construction Phase*

11.7.3.1.1 Runoff Reduction

The construction of the Molo Graphite Project (open pit, processing plant, co-disposal and reject dump) will potentially reduce the local runoff and water availability for downstream users. No additional measures, apart from the SWMP (Section 11.5) and monitoring, are proposed to mitigate this impact during construction phase. The maximum likely impact is that runoff from a dirty water area of about 1.25 km^2 that falls within the catchment of the Ankilitelo River would be curtailed for a defined period of time. The catchment of the Ankilitelo River is some 6177.5 km^2 in extent, and on this larger scale, mining activity could reduce stream-flow in this river by approximately 0.02%. On a local scale, a greater, but still relatively small, impact would be expected on the next down-stream water user in the river system.

11.7.3.1.2 Increased Sediments

Blasting of surfaces, footprint clearance on the sites of the proposed processing plant and other infrastructure, and other excavations in the mining area are likely to lead to increased sediment in runoff water. Measures such as containment and silt traps to mitigate this potential impact are contained in a Storm-water Management Plan (SWMP). The SWMP should be implemented as early as possible.

11.7.3.1.3 Dust Suppression

Dust created by construction activities could both impact on air quality and also settle in areas where it would be taken up in surface runoff and contribute to sediment loads in local river systems. Dust suppression activities are part of the Water Management Plan and should be implemented as early as possible. During the construction phase, dust suppression activities are likely to be limited to spraying surfaces to stabilise fine materials and prevent dust dispersion.

11.7.3.1.4 Waste Management and Handling of Hydrocarbons and Hazardous Materials

The transport, handling and storage of fuels, chemicals construction materials and waste could lead to contamination of soil surfaces and water resources. Measures must be taken to ensure safe handling and storage of hazardous substances and prevent contamination of soil and water resources. This Water Management Plan will include provision of bunded storage areas for storage of fuels and hazardous materials and disposal of domestic waste in a designed land-fill facility.

Table 11.68: Surface Water Construction Phase Impacts

Potential Environmental Impact	Activity	Environmental Significance Before Mitigation						Recommended Mitigation Measures/ Remarks	Environmental Significance After Mitigation					
		M	D	S	P	TOTAL	SP		M	D	S	P	TOTAL	SP
Water quality														
Construction activity and transport of material could increase the quantity of airborne particles. Dust could settle on surfaces and be washed off, contributing to sediment loads in local surface water resources	Footprint Clearance / Construction	4	2	2	4	-32	M	Implement stormwater management infrastructure as soon as possible (drains, dams, silt traps). Conduct dust suppression on regular intervals during construction.	2	2	2	2	-12	L
Blasting of surfaces, footprint clearance on the sites of the proposed processing plant and other infrastructure, and other excavations in the mining area are likely to lead to increased sediments in runoff water.	Sediment loads	4	2	2	4	-32	M	Capture dirty water and the provision silt traps. Control slopes and provide drains to divert water for capturing	2	2	2	3	-18	L
The transport, handling and storage of fuels, chemicals construction materials and waste could lead to spills that contaminate soil surfaces and water resources.	Waste / hydrocarbon Handling	4	2	1	3	-21	L	Waste must be discarded in an approved manner. Fuel and oil storage areas should be bunded. Spills should be cleaned up immediately.	2	1	1	2	-8	L
Runoff Reduction														
The footprint area of all infrastructure will reduce the surface area for potential clean water runoff and potentially reduce the water availability for downstream users. The SWMP keeps the dirty water footprint area (reduced runoff are) as small as possible	Footprint Clearance / Construction	3	2	2	4	-28	L	No additional mitigation possible. Monitoring of stream flow and quality are proposed.	3	2	2	4	-28	L

11.7.3.2 *Operational Phase*

11.7.3.2.1 Runoff Reduction

Runoff reduction will occur due to the capturing and re-use of dirty runoff over the mine infrastructure areas. Runoff from the process plant and other defined dirty water areas (where a potential exists for water to become polluted) must be captured, stored and re-used as much as possible. These activities will lead to reduced local runoff. The impact of this runoff reduction on larger rivers is likely to be small. Mining activity could reduce stream-flow in the Ankilitelo River by approximately 0.02%. On a local scale, a greater, but still relatively small, impact would be expected on the next down-stream water user in the river system.

11.7.3.2.2 Control of Dirty Water Runoff

Surface water runoff from defined dirty water areas, which include the process plant could pollute local surface water resources. A SWMP and Water Balance stipulate measures to capture dirty water and make provision for this dirty water to be controlled in pollution control dams and/or re-used in the plant process. The runoff water quality is discussed in Section 11.2 and a salt balance, discussing the discharge quality, is presented in Section 11.6.2. In summary: Runoff water quality in general have relatively low salt and metal concentrations due to slow reactions related to the secondary sulphur minerals and neutral drainage conditions. Water may contain suspended solids. The salt balance indicates that water overflow from the PCDs is acceptable for discharge according to Malagasy and international standards. However, discharge will only take place when the storage capacity has reached a critical limitation. However, water in the co-disposal PCD will have, however, a higher probability on high salt content due to the character of the ore/tailings (higher sulphur content). This water system must therefore be managed and monitored continuously.

A wide range of specific storm water management measures to control dirty water runoff will be implemented at different points on the mine:

Open pit water: Runoff from areas within the mined pit will be captured in a sump and pumped to storage (pit/reject PCD) before being re-used as water for dust suppression in the plant PCD. Results of hydro-geochemical assessment (Section 11.2) showed the likelihood for elevated metals and salts are small due to the slow reaction rates of secondary sulphur minerals. The expected runoff sulphate and TDS concentrations are presented in Table 11.62. Dominant metals such as aluminium, manganese, and iron will occur in low concentrations (Table 11.47). The SWMP includes measures to prevent the inflow of 'clean' runoff into the pit. Dirty runoff in the open pit will be re-used as much as possible for production purposes. With these mitigations a low negative impact can be expected.

Flow from co-disposal facility, reject dump and ore stockpiles: Contaminated runoff and seepage from the co-disposal facility and ore stockpiles area could potentially impact on the downstream surface water. The results of hydro-geochemical assessment (see Section 11.2) did, however, indicate only slightly elevated concentrations of sulphate, aluminium, manganese and iron from these areas. Seepage/runoff from the ore stockpiles and co-disposal facility will have TDS concentrations lower than 400 mg/l (mean about 125 mg/l). The seepage migrating through the facilities will however be of poorer quality due to longer chemical residence times. Mitigation measures include interim capping of the co-disposal facility, storm water management and a lined PCD (co-disposal PCD and pit/reject PCD). The potential impact is classified as medium negative due to the mixing of runoff with poorer quality seepage from the co-disposal facility, however, the impact will be low negative with the proper mitigation measures.

Runoff from process plant area: The runoff generated in areas that include the process plant could potentially impact the quality downstream water resources. However, the quality in general, will not be high in salts and metals, with acceptable discharge qualities predicted (Section 11.6.2) SWMP measures make provision for a lined plant PCD to capture potential dirty runoff from the plant area and ore stockpiles. Separation of clean and dirty water areas will take place via with drains and berms.

11.7.3.2.3 Control of Sediments

Silt and other sediments arising on site could contaminate local surface water resources. Sedimentation will reduce effective storage capacity and increase downstream silt loads. SWMP measures will include measures to prevent soil erosion and limit activities that generate sediments. Sediments that do occur will be captured in silt traps and removed to land-fill disposal sites.

A wide range of specific storm water management measures to control sediments will be required at different points on the mine:

Open pit water: Sediments from areas within the mined pit will be captured in the sump.

Runoff from process plant area: Sediments will take the form of settled dust particles, material spills and soil erosion in areas where drainage is poorly controlled. Measures to control sediments will include planned drains around roads and other infrastructure, silt traps to capture sediments contained in runoff and measures to prevent spillage of mined materials.

Flows from co-disposal facility, reject dump and ore stockpiles: Very small sediment loads are expected in seepage and return flows. Surface runoff from the outer surfaces of these structures are, however, likely to contain fines that would settle in storage facilities. Higher sediment loads can be expected from these facilities. The SWMP makes provision for drains to divert the water into proposed PCD silt traps for each PCD.

Roads and Borrow pits: Soil erosion on, or alongside roads and other disturbed areas could add to sediment loads. The design of roads and borrow pit areas should include measures to control slopes, runoff velocities and drainage paths in a manner that will reduce or prevent surface erosion.

11.7.3.2.4 Dust Suppression

Dust created by mining activities could both impact on air quality and also settle in areas where it would be taken up in surface runoff and contribute to sediment loads in local river systems. The potential impact of dust on surface water resources can be mitigated by regular, planned dust suppression activities, reducing impacts to a low negative impact. Dust suppression activities should be included in the SWMP, but will vary for different areas within the mine:

Open pit: Blasting activities and the operation of machinery within the mine pit are likely to generate dust. Controlled blasting to reduce dust creation and the use of water carts to spray surfaces ad suppress dust will mitigate the impact of dust generated within the pit.

Haul roads: The use of water carts to spray surfaces of haul roads will limit dust generated by the passage of vehicles.

Processing plant: Air filters at the crusher plant and a wet process grading of materials will reduce the quantity of dust released into the atmosphere.

11.7.3.2.5 Waste Management and Handling of Hydrocarbons and hazardous materials

The transport, handling and storage of fuels, chemicals construction materials and waste could lead to contamination of soil surfaces and water resources. Measures must be taken to ensure safe handling and storage of hazardous substances and to prevent contamination of soil and water resources. Specific requirements are identified for the handling and disposal of waste generated though a range of activities on the mine. It is important to consider the likely impacts of spillages of hydrocarbons or other hazardous materials, particularly the potential impact of spills that contaminate water resources.

The impact of spills on surface water resources can be reduced through ensuring that waste is discarded in designated, bunded waste facilities. Solid waste must either be stored on site in an approved waste disposal area, or removed by credible contractors. Fuel and oil storage areas should be bunded. Spills should be cleaned up immediately and sewage should be treated in a sewerage plant. These measures will mitigate the risk of contamination of water resources to a low negative impact risk rating.

Table 11.69: Surface Water Operational Phase Impacts

Potential Environmental Impact	Activity	Environmental Significance Before Mitigation						Recommended Mitigation Measures/ Remarks	Environmental Significance After Mitigation					
		M	D	S	P	TOTAL	SP		M	D	S	P	TOTAL	SP
Surface water runoff from defined dirty water areas could pollute local surface water resources: Open pit	Runoff Control	4	4	2	4	-40	M	Runoff from areas within the mined pit will be captured in a sump and pumped to the pit PCD before being re-used as water for dust suppression	4	4	1	2	-18	L
Surface water runoff from defined dirty water areas could pollute local surface water resources: co-disposal facility, reject dump and ore stockpiles	Runoff Control	4	4	3	4	-44	M	SWMP with lined toe drains and a lined PCD	4	4	1	2	-18	L
Surface water runoff from defined dirty water areas could pollute local surface water resources: Plant	Runoff Control	4	4	2	4	-40	M	Collection of dirty water in lined drains. Containment in a Pollution Control Dam	4	4	1	2	-18	L
Silt and other sediments arising on site could contaminate local surface water resources. Sedimentation will reduce effective storage capacity and increase downstream silt loads: Open pit	Sediment Loads	4	4	2	4	-40	M	Sediments from areas within the mined pit will be captured in the sumps. Dust suppression	4	4	2	1	-10	L
Silt and other sediments arising on site could contaminate local surface water resources. Sedimentation will reduce effective storage capacity and increase downstream silt loads: Plant	Sediment Loads	4	4	2	4	-40	M	Drains around roads and other infrastructure, silt traps to capture sediments contained in runoff and measures to prevent spillage of mined materials	4	4	2	1	-10	L
Silt and other sediments arising on site could contaminate local surface water resources. Sedimentation will reduce effective storage capacity and increase downstream silt loads: co-disposal facility, reject dump and ore stockpiles	Sediment Loads	4	4	2	4	-40	M	SWMP including silt traps at collector drain for each PCD	4	4	2	2	-20	L
Silt and other sediments arising on site could contaminate local surface water resources. Sedimentation will reduce effective storage capacity and increase downstream silt loads: Roads and Borrow Pits	Sediment Loads	4	4	2	4	-40	M	The design of roads and borrow pit areas should include measures to control slopes, runoff velocities and drainage paths in a manner that will reduce or prevent surface erosion. Dust suppression	4	4	2	2	-20	L
Runoff Reduction														
No runoff will result from the open pit. Runoff from the process plant and other defined dirty water areas (where a potential exists for water to become polluted) must be captured, stored and re-used as much as possible. These activities will lead to potential reduced local runoff.	Runoff Control	3	3	1	4	-28	L	No additional mitigation measures identified. Monitoring will take place.	3	3	1	4	-28	L
Waste Management														
The transport, handling and storage of fuels, chemicals construction materials and waste could lead to contamination of soil surfaces and water resources.	Waste Handling	4	2	1	3	-21	L	Waste needs to be discarded in an approved manner and spills cleaned up immediately.	2	1	1	3	-12	L

11.7.3.3 *Closure Phase*

11.7.3.3.1 Reduced Runoff

After closure, the open pit will be flooded. This will reduce the potential runoff from that particular area and also potentially reduces the water availability for downstream users. An average negative impact will be expected due to little downstream users and a maximum runoff reduction of ~45 600 m^3/year will be expected (Mean Annual Runoff x Catchment Surface Area). An average negative impact will be foreseen and no mitigation will be possible.

11.7.3.3.2 Contaminated Runoff and Seepage

Contaminated runoff and seepage from the co-disposal facility could potentially pollute the downstream river after closure.

It is recommended that the co-disposal should be capped and surfaces re-vegetated to create a clean water runoff area and reduce this impact. The lined co-disposal PCD will remain as evaporation dam to control post closure seepage. This will reduce this potential impact of contaminated seepage from the co-disposal facility to a low negative impact risk rating.

Table 11.70: Surface Water Closure Phase Impacts

Potential Environmental Impact	Activity	Environmental Significance Before Mitigation						Recommended Mitigation Measures/ Remarks	Environmental Significance After Mitigation					
		M	D	S	P	TOTAL	SP		M	D	S	P	TOTAL	SP
Water Quantity														
The footprint area of all infrastructure will reduce the surface area for potential clean water runoff and potentially reduces the water availability for downstream users.	Open Pit Mining	4	4	2	4	-40	M	Rehabilitation of all infrastructure (vegetating, capping or shaping). Only open pit will remain open	2	4	1	2	-14	L
Water Quality														
Contaminated runoff and seepage from co-disposal facility could potentially pollute the downstream river after closure	Co-disposal Facility	4	5	2	4	-44	M	The co-disposal facility should be capped and surfaces re-vegetated to reduce this impact	2	5	2	2	-18	L

11.7.4 Groundwater Impact Assessment

11.7.4.1 *Construction Phase*

11.7.4.1.1 Hydrocarbon Spills and Leaks

Potential impacts to the receiving groundwater environment include hydrocarbon contamination due to:

- Spills at the construction workshops and yellow metal laydown areas,
- Direct leaks from machinery that has broken down,
- Spill or leaks from fuel, oil/grease storage areas.

Management includes containment of spills and leaks at the workshops and fuel depots by construction of confined concrete areas and oil traps. Contingency measures will be put in place to clean up (mitigate) potential spills.

The potential impact due to hydrocarbon spills will be of low intensity and site specific. This impact, with the correct management procedures, is seen as having a minor significance (Table 11.71).

11.7.4.1.2 Groundwater Abstraction

During construction the groundwater resource will be used to supply water for both domestic use and for use in the construction process. Boreholes MMB12 and MMB13 are considered for abstraction.

Proposed borehole abstraction will be conservative compared to the available groundwater resources in the area (sustainable abstraction). This is likely to result in localized dewatering at the abstraction boreholes. The wellfield abstraction is discussed in more detail in Section 11.4.3.

The impact rating for dewatering during construction was low because the impact would be over a relatively short period and it is unlikely to impact the water supply points of neighbouring communities. The borehole abstraction should be closely monitored and managed correctly.

Table 11.71 shows the impact ratings table for the construction phase.

Table 11.71: Groundwater Construction Phase Impacts

Potential Environmental Impact	Activity	Environmental Significance Before Mitigation						Recommended Mitigation Measures/ Remarks	Environmental Significance After Mitigation					
		M	D	S	P	TOTAL	SP		M	D	S	P	TOTAL	SP
Water quality														
During the construction phase hydrocarbon contamination may occur due to spills at the construction workshops and yellow metal laydown areas; direct leaks from machinery and spills at hydrocarbon storage areas	Hydrocarbon Spills	1	2	1	3	-12	L	Spills would be contained at the workshops and fuel depots via the construction of confined concrete areas and oil traps, as well as training on and implementation of appropriate response plans should spills occur	1	2	1	2	-8	L
Water quantity														
Groundwater resources (MMB12 & MMB13) will be used to supply both construction and domestic water, resulting in potential localized lowering of the groundwater table	Groundwater Abstraction	4	2	1	3	-21	L	The wellfield abstraction boreholes should be monitored continuously. Total wellfield abstraction should be less than the sustainable yield determined for long term drought conditions (Section 11.3.2). Monitoring will take place and communities will be compensated in the unlikely event of being impacted on by wellfield abstraction.	4	2	1	2	-14	L

11.7.4.2 *Operational Phase Impacts*

During the operational phase the potential impacts include groundwater dewatering at the open pit, wellfield abstraction of the groundwater resource, potential groundwater contamination at the co-disposal facility and reject dump. The potential groundwater impact at Fort Dauphin is negligible as the site is an existing port.

Ore, waste rock and tailing material contain secondary sulphur minerals with a lesser degree of sulphide mineralisation. The reaction rates of the secondary sulphur minerals are slow and neutral rock drainage is expected during the operational phase (Section 11.2.2.6). Leachate emanating from these waste rock and tailings will have sulphate concentrations varying from 15 to 1 000 (average 500) mg/l and 200 to 1 200 (average 500) mg/l respectively. The tailings seepage quality is also likely to contain chloride concentrations between 250 and 1 300 mg/l. Relatively low concentrations of metals such as aluminium (< 5 mg/l and on average 0.5 mg/l), iron (<5 mg/l and on average 0.1 mg/l) and manganese (<0.5 mg/l and on average 0.05 mg/l) are furthermore expected. Slightly elevated nitrate concentrations compared to ambient quality may also initially leach from waste rock due to the use of ammonium-nitrate explosives in the mining process.

Both the co-disposal facility and reject dump will be unlined (Base Case). Mitigation measures include interim and final capping systems to minimise rainfall ingress and storm water management berms and trenches. All pollution control dams (PCDs) will be lined with geomembrane liner systems.

A detailed description of embedded management procedures and mitigations measures are described in the groundwater management plan as presented in Section 11.8.

11.7.4.2.1 Mine Dewatering

During mining the open pit will be dewatered to ensure a safe and workable environment. This will result in the dewatering of the surrounding aquifer and associated lowering of groundwater levels, also known as the dewatering cone.

The simulated groundwater inflows (Figure 11.53) to the pit range between 8 and 590 m^3/day during the life of mine and are discussed in Section 11.3.

The simulated dewatering cone at the open pit extends to a maximum of ~1.2 km from the final pit boundary at the northern, western and southern pit edge, and ~500 m at the eastern pit edges. Figure 11.87 shows the groundwater levels at the open pit area over time during the life of mine in 5 year intervals. The results indicate that mine dewatering would not impact any existing community boreholes or hand-dug wells. However, the dewatering activity could potentially impact, during the latter part of the operational phase, on the spring or shallow seep GWH3. This spring is currently being used by local community members. This community is likely to be relocated. Monitoring of the spring will however take place and a replacement water source could be provided (same quantity and quality), should it be required.

Mine dewatering could potentially impact negatively on a site scale on the baseflow contribution (which could be seasonal) of the upper Zafaro and Ankilitelo rivers. The upper reaches of the Zafaro and Ankilitelo rivers is mainly dry during the dry season, suggesting seasonal or a very low groundwater (including spring flow)/inter-flow contribution to stream baseflow. The groundwater model suggests a potential average loss of about 180 m^3/d for both river systems. Streamflow monitoring should take place to better quantify the potential loss of this source.

The overall impact significance for the open pit activity is seen as low negative (Table 11.72). No active mitigation measures are possible for the open pit dewatering impact, however the monitoring of surrounding groundwater and surface water resource will take during operational phase in order to identify potential negative trends.

11.7.4.2.2 Mine Water Quality

Groundwater flowing into the open pit will be exposed to suspended solids (dust) and nitrate salts originating from ammonium-nitrate explosives. The sulphate concentration will be relative low (around 120 mg/l SO_4 and TDS about 250 mg/l) due to slow reaction rates of the secondary sulphur minerals.

The water will be collected in an in-pit sump from where it will be pumped to the lined pit/reject dump pollution control dam (PCD). The water will be discharged into the Zafaro River during the wet season. Salt balance calculations (Section 11.6.2) indicate that water quality will be acceptable for discharge.

11.7.4.2.3 Wellfield Abstraction

During the operational phase groundwater will be used to supply the mine raw water make-up, i.e. between 222 and 551 m^3/d (Section 11.4.1). The maximum abstraction rate is much less than the regional wellfield abstraction potential of 3,240 m^3/d and the sustainable yield of 2,429 m^3/d. In summary, the groundwater abstraction and abstraction upper limit are conservative compared to the aquifer potential.

No existing large scale community or agricultural groundwater abstraction takes place in the area of the proposed Molo Graphite Mine. However a number of hand-dug wells (such as GWH5, 8, 9, and 16) are situated within the wellfield area. Percussion boreholes GWD2, 10 and 15 are not currently in use, however, GWH6 is being used by the Beamalo community. GWH6 is situated to the southwest, more than 5 km from the wellfield zone. Hand-dug wells often abstract shallow seasonal perched groundwater sources and/or alluvial water which are at lesser risk of being impacted on by the wellfield. Community groundwater abstraction is furthermore small, i.e. <3 m^3/d per hand dug well and <5 m^3/d for the percussion borehole, totalling about 15 to 20 m^3/d for the area.

Hand-dug well GWH8 is situated about 400 m to the west of proposed wellfield abstraction borehole MMB13. It was furthermore noticed that GWH8 was nearly dry during the dry season hydrocensus, with a water level drop of about 9 m from the wet season measurements (Table 11.13). This suggests a shallow, potential seasonal groundwater resource which is not likely to be impacted on by the proposed abstraction at MMB13. All nearby hand-dug wells and boreholes will be included in the monitoring program and an alternative water supply (of same quantity and quality) will be provided in the event of being impacted on..

The potential impact of abstraction from the proposed wellfield boreholes is not likely to impact on the surrounding community and the impact significance would be low with the correct management measures in place (Table 11.72).

11.7.4.2.4 Co-Disposal Facility – Groundwater Quality

The co-disposal facility (CDF) is a potential source of contamination to groundwater due to poor quality leachate from waste rock and tailings material. The maximum simulated SO_4 concentration likely to be emanating from the waste rock material for the late operational phase was 1,000 mg/l (average 500 mg/l) and 1,200 mg/l (average 500 mg/l) for tailings material. Metal concentrations, mainly Al, Mn and Fe, are not seen as a risk due to low concentrations.

Contaminant groundwater modelling (Section 11.3.2) suggests some contaminant migration towards the open pit. The neighbouring open pit dewatering cone captures the groundwater contaminant plume emanating from the co-disposal facility. The simulated contaminant plumes for the various time periods are shown in Figure 11.88. The groundwater sulphate concentration away from the co-disposal facility is less than 450 mg/l. No receptors are impacted on by the potential groundwater contaminant plume emanating from the co-disposal facility.

Based on the long-term contaminant potential (Section 11.7.4.3), it is proposed that the co-disposal facility is covered at 5 year stages with low permeable capping material (where practical) in order to minimise groundwater contamination. Other management and rehabilitation principles will consist of storm water management and capturing of dirty runoff in the lined co-disposal facility PCD, levelling and compaction of all non-active areas to minimize ponding of water.

The potential contamination of groundwater resources from the co-disposal facility has been rated of low significance (Table 11.72) based on the mitigation measures and due to the effect of the nearby open pit mine dewatering.

11.7.4.2.5 Reject Dump – Groundwater Quality

The potential impact of the reject ore dump will be similar to that of the co-disposal facility. Runoff is channelled to the lined pit/reject dump PCD. Contaminant groundwater migration is likely to be towards the open pit. The neighbouring open pit dewatering cone captures the groundwater contaminant plume emanating, resulting in insignificant lateral migration towards surrounding receptors. The potential impact from this facility is seen as being of low significance.

11.7.4.2.6 Ore and Product Stock Piles – Groundwater Quality

Storm water management at the ore and product stockpiles is aimed at minimizing the dirty footprint from where water will be captured in the lined plant PCD system. The stockpiles are temporary and relatively clean water is expected with the slow reaction rates of the secondary sulphur minerals.

Containment of potential dirty seepage towards the underlying aquifer will result in a very low intensity risk of site specific nature. The sulphate and TDS concentrations of runoff-seepage could be <150 mg/l and <375 mg/l respectively. The potential impact significance on groundwater quality is therefore rated in Table 11.72 as being low

11.7.4.2.7 Processing Plant – Groundwater Quality

No significant groundwater quality impacts are foreseen from these areas. Management measures will include:

- Storm water management and capturing of dirty runoff in a lined PCD;
- Containment of oil, fuel and chemical spills in designated areas;

The processing plant and offices are seen as a potential low intensity groundwater quality risk of local nature (site specific) which can be managed to acceptable levels and was excluded from further interpretation.

11.7.4.2.8 Other

The following infrastructure or activities pose a negligible risk of impacting on the groundwater environment and were therefore not rated. These include the transport route and Fort Dauphin loading facility.

Table 11.72: Groundwater Operational Phase Impacts

Potential Environmental Impact	Activity	Environmental Significance Before Mitigation						Recommended Mitigation Measures/ Remarks	Environmental Significance After Mitigation					
		M	D	S	P	TOTAL	SP		M	D	S	P	TOTAL	SP
Water quality														
Impacting on aquifer quality and down-stream receptors – co-disposal facility	Poor quality seepage from co-disposal facility	2	4	1	4	-28	L	The co-disposal facility contaminant plume will be captured by the open pit dewatering cone, ensuring a site specific extent with no impact on receptors. Interim, 5 year capping of water material to minimise rainfall infiltration, Storm water management will divert dirty water to a lined PCD and active, un-rehabilitated areas should be kept to a minimum. Groundwater quality monitoring should be conducted continuously and the risk associated with the co-disposal facility will be re-evaluated regularly.	2	4	1	3	-21	L
Impacting on aquifer quality and down-stream receptors – reject dump	Poor quality seepage from reject dump	2	3	1	4	-24	L	The reject dump contaminant plume will be captured by the open pit dewatering cone, ensuring a site specific extent with no impact on receptors. Storm water management will divert dirty water to a lined PCD and active, un-rehabilitated areas should be kept to a minimum. Groundwater quality monitoring should be conducted continuously and the risk associated with the reject dump will be re-evaluated regularly.	2	3	1	3	-18	L
Impacting on aquifer quality and down-stream receptors - ore and product stockpiles	Seepage from stockpiles	2	3	1	3	-18	L	The stockpile areas should be temporary and the ore/product should be moved as quickly as possible. Water quality will meet discharge standards, however, could be poorer when compared to ambient water quality. Storm water management measures should be in place to capture any dirty water runoff and monitoring of water quality in the area should be continuous.	2	3	1	2	-12	L
Water quantity														
The aquifer/s surrounding the open pit area would be dewatered in order to ensure safe mining conditions during operations. This could impact surrounding groundwater users. However, no large scale groundwater abstraction takes place close to the open pit. Predictive groundwater modelling suggests that the mine dewatering cone would not impact on future community groundwater abstraction. Potential loss of the groundwater contribution to baseflow of the upper Zafaro and Ankilitelo rivers on a site/local scale.	Open Pit Dewatering	6	4	2	2	-24	L	Surrounding aquifer monitoring will be put in place to identify any negative impacts. This will include monitoring of GWH3. Communities will be compensated if required.	6	4	2	2	-24	L
The aquifer/s where abstraction takes place would experience localized dewatering. This could impact surrounding groundwater users.	Wellfield abstraction	6	4	2	2	-24	L	Mine water with an acceptable water quality would be used preferentially for dust suppression. This will decrease borehole abstraction. Total wellfield abstraction will be less than the sustainable yield determined for long term drought conditions (Section 11.3.2). Community groundwater use is minor and not likely to be impacted on. Monitoring will take place and communities will be compensated if required.	6	4	2	2	-24	L

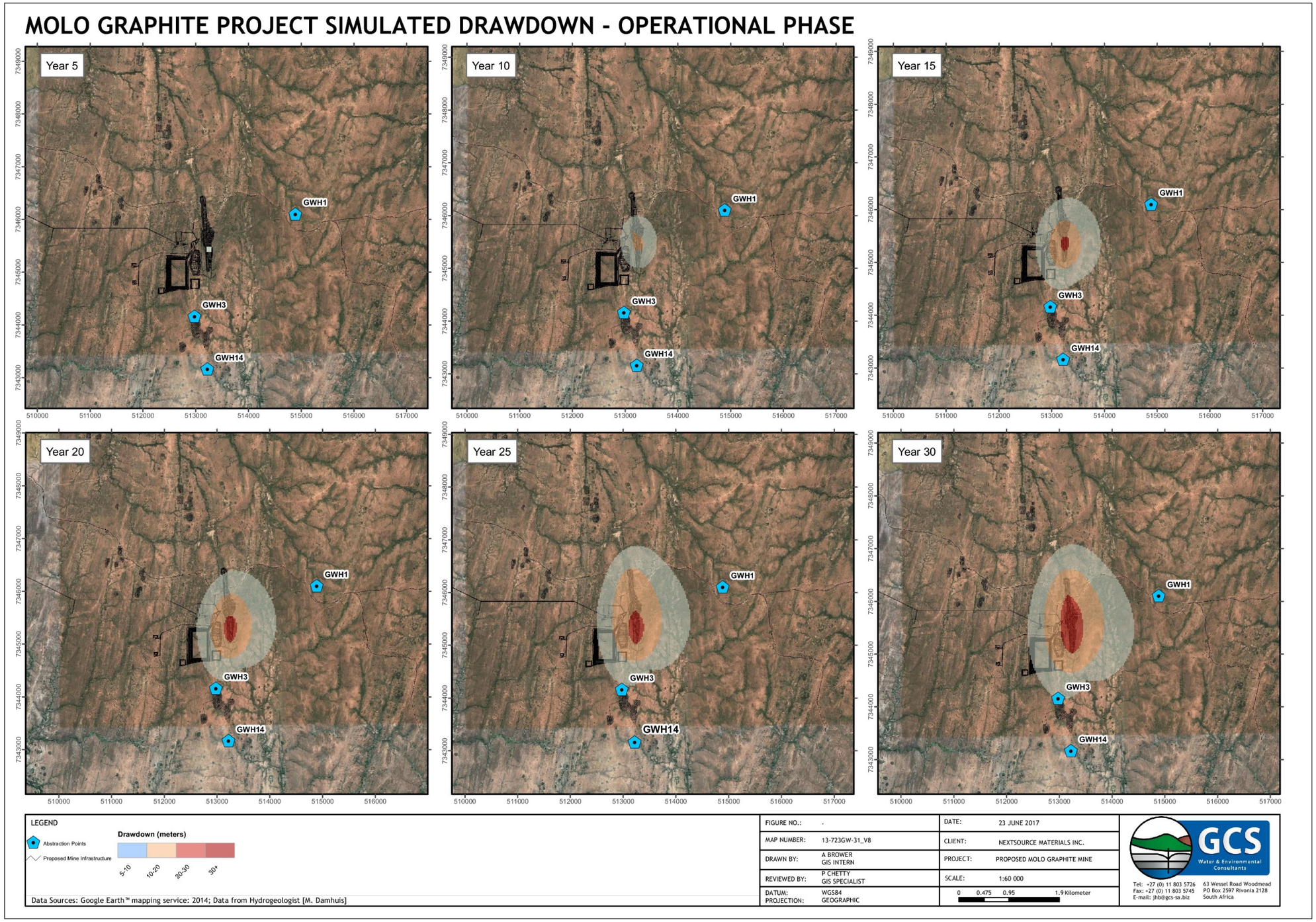


Figure 11.87: Groundwater dewatering cone due to open pit mining

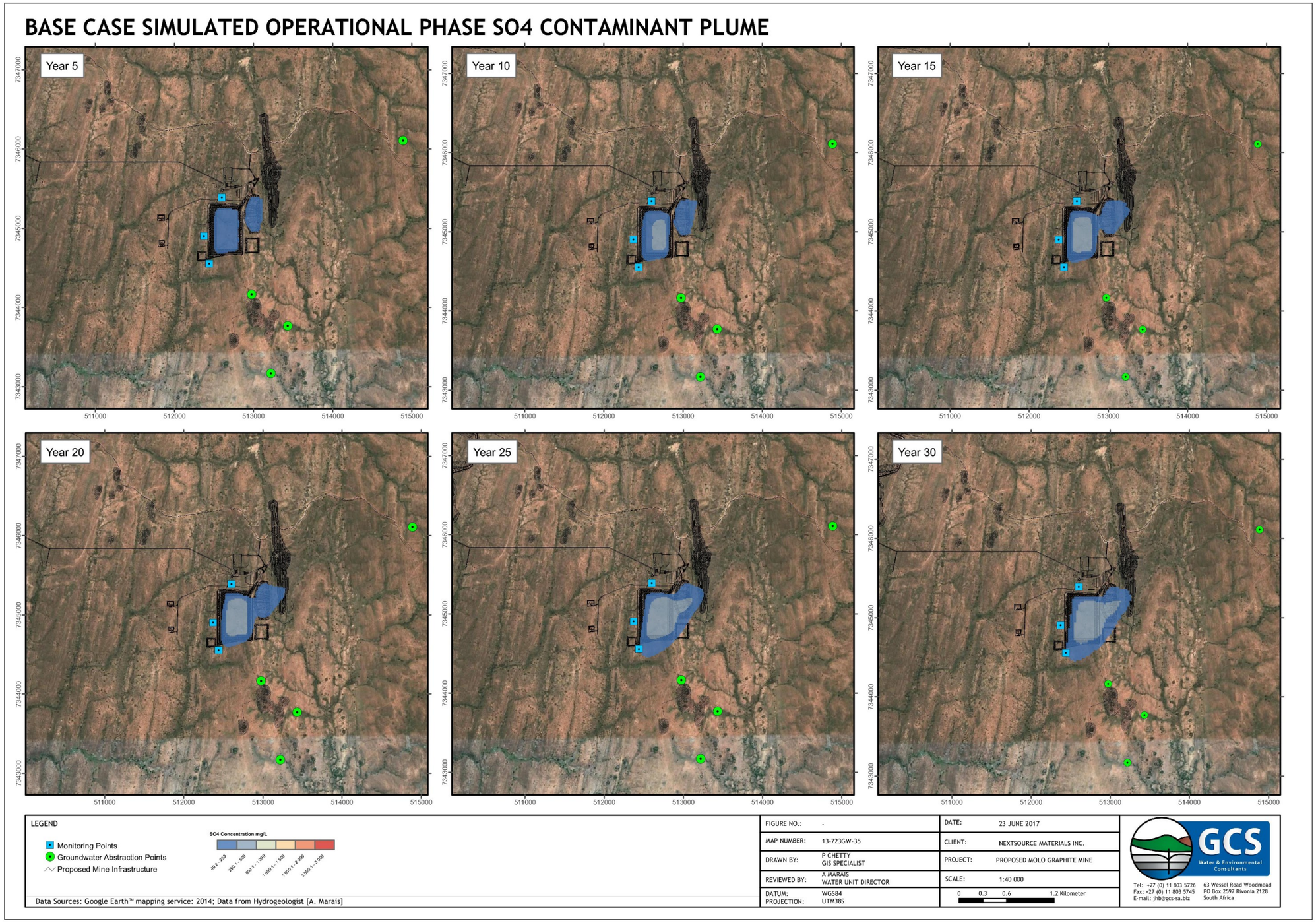


Figure 11.88: Simulated groundwater sulphate contaminant plumes - Operational Phase

11.7.4.3 *Closure Phase*

This phase includes decommissioning of infrastructure and mining activities, rehabilitation and ongoing monitoring to meet closure objectives. During the closure phase of the mine the potential residual impacts to the site groundwater resource are addressed, including the rebound of water levels at the open pit area and potential post-closure contaminant plume migration from the co-disposal facility. It is assumed that all reject material will be processed.

11.7.4.3.1 Open Pit

The rebound of groundwater levels will take place adjacent to the open pit. This impact is seen as positive as the natural, pre-mining groundwater flow regime will be restored over time.

During the closure phase the open pit will not be backfilled and will be allowed to fill with water to form a pit lake. The steady state pit like is likely to have a relatively good water quality due to the relative low sulphide minerals present, especially in the upper oxidised zone. The quality of the pit-lake is discussed in Section 11.2.2.6. Figure 11.52 shows the sulphate and TDS concentration with depth. The upper pit-lake water quality will be around ambient water quality, however, the sulphate and TDS concentrations with depth would be around 350 and 750 mg/l respectively.

Figure 11.74 shows the modelled flooding of the pit with time. The pit flooding is relatively fast with steady state conditions reached after 25 years at a level around 545 mamsl. The pit lake will not decant on surface.

Possible contamination of groundwater resources due to the migration of pit lake water into the aquifer is therefore seen as having a low impact significance (Table 11.73). Receptors will not be impacted by the poorer water quality at depth.

11.7.4.3.2 Co-disposal facility

During the closure phase the co-disposal facility will receive a final cap using inert borrow material, saprolite and soil in order to reduce rainwater infiltration and oxidation of the waste material. A store-and –release capping with vegetation or a similar low infiltration capping is proposed.

Figure 11.89 shows the simulated contaminant plume migration for the co-disposal facility post closure for a period of 100 years at different time stages. The simulated contaminant plume continued about 1 km towards the southwest of the co-disposal facility. It reached a maximum sulphate concentration in groundwater of 2 300 mg/l in the co-disposal facility footprint area (upper weathered aquifer unit), however, degreases rapidly to less than 500 mg/l away from the facility. The long-term groundwater quality closer to the drainage line towards the west (receptor) is less 100 mg/l SO_4. Other chemical constituents associated with the source will also attenuate to levels that do not pose an environmental risk.

The impact significance for the co-disposal facility during closure has been rated as medium (Table 11.73) based on the high likelihood of impacting groundwater quality. However, it is important to note that the impact on groundwater is site specific and that associated risks to community and surface water receptors are negligible to minor. The overall groundwater impact is therefore acceptable with no additional remediation required.

Table 11.73: Groundwater Closure Phase Impacts

Potential Environmental Impact	Activity	Environmental Significance Before Mitigation						Recommended Mitigation Measures/ Remarks	Environmental Significance After Mitigation					
		M	D	S	P	TOTAL	SP		M	D	S	P	TOTAL	SP
Water Quantity														
Groundwater levels within the pit area will rebound towards ambient conditions.	Groundwater rebound around the open pit	4	5	1	5	50	M	No mitigation required	4	5	1	5	50	M
Water Quality														
Potential contamination of the surrounding water resources by the pit lake. Water quality of the pit lake is of relatively good quality relatively.	Post closure flooding of the open pit	4	5	1	1	-10	L	The water quality predictions of the pit lake will be updated during the operational phase in order to update mitigation measures. The lower part of the pit may contain more sulphide minerals and it will be good practice to remove the storm water measures in order to assist in the initial flooding of the open pit.	4	5	1	1	-10	L
Impacting on aquifer quality and down-stream receptors - co-disposal facility	Poor quality seepage from co-disposal facility	4	5	2	5	-55	M	The co-disposal facility should be capped using inert borrow material and vegetated and contoured to minimize infiltration of rainwater	2	5	1	4	-32	M

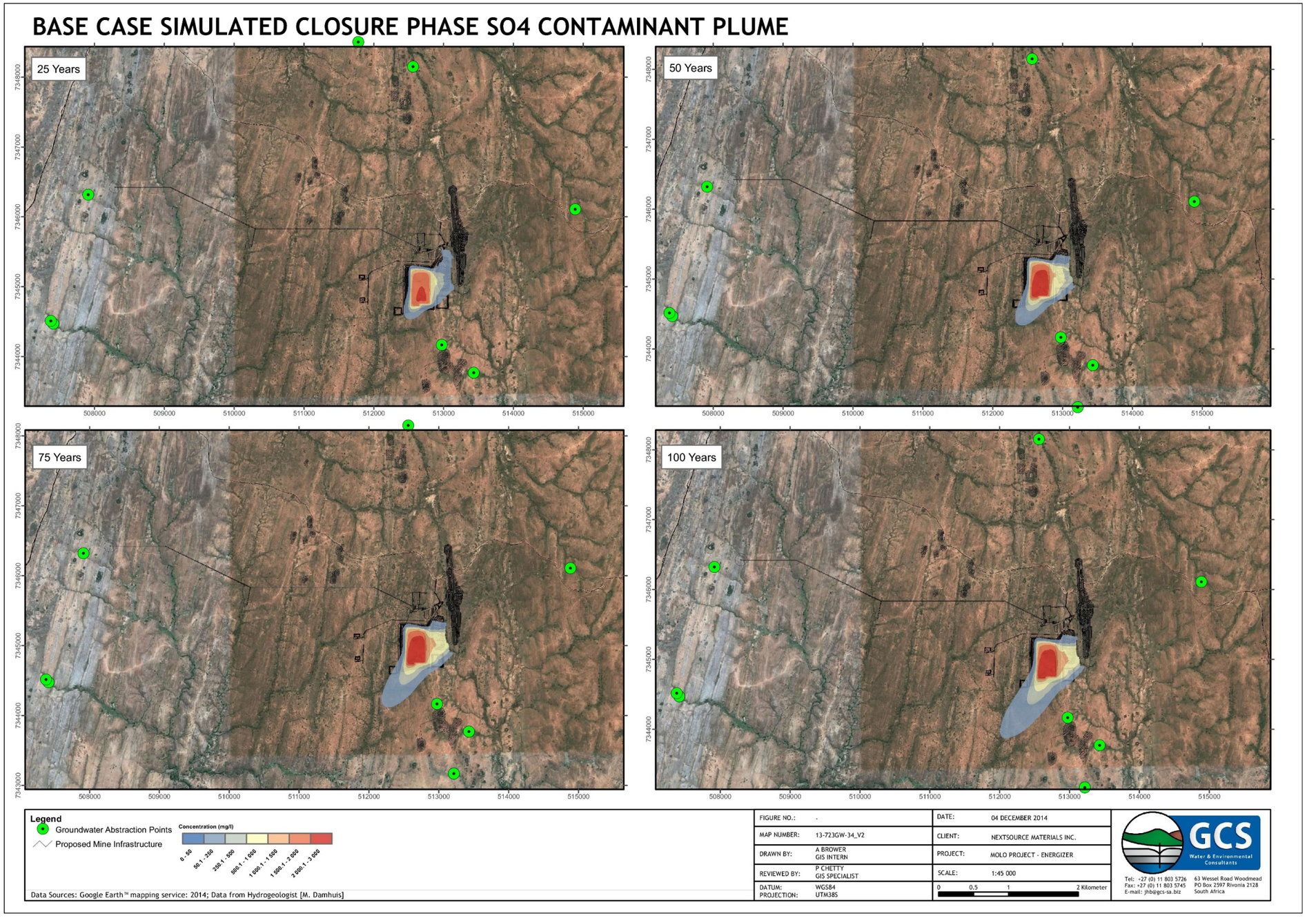


Figure 11.89: Simulated groundwater sulphate contaminant plumes - Closure Phase

11.8 Water Management Plan

The Water Management Plan (WMP) was compiled for the site taking into account the available hydrogeological information available and the potential risks and impacts as discussed in Section 11.7. The WMP is discussed in the following sections:

- Objectives;
- General Approach;
- Water Management Controls (including embedded controls and mitigation measures for different phases of mining); and
- Water monitoring program and response plan.

11.8.1 Objectives

The main objectives of the WMP are to ensure that all relevant regulatory requirements are met, including those specified in the following documents (as described in Section 11.7.1):

- Equator Principles;
- IFC Performance Standards and Environmental, Health and Safety General Guidelines;
- Malagasy guidelines for mine effluent discharge (Decree No. 2003-464, 2003); and
- Malagasy standards for drinking water quality (Decree No. 2004-635, 2004).

The applicable best practice guidelines should be employed at site to manage, prevent and minimize the impact of mining operations on the surrounding groundwater aquifers. The following will form part of the embedded water management procedures:

- Maintenance of an effective response mechanism to deal with issues, including unexpected events and complaints; and
- Insurance of groundwater quality monitoring results' compliance with the relevant and applicable criteria.

11.8.2 General Approach

The key principles to the WMP approach are as follows:

- Minimize and manage the loss of the water resource;
- Minimize and manage the dirty water footprint (i.e. keep clean water clean);
- Manage dirty water, in order of priority:
    - Prevent clean water from becoming dirty;
    - Use dirty water in mine processes;

    - Manage the discharge of dirty water in such a manner as to minimize the impact;
    - Treat dirty water (where necessary);
    - Remediation of the environment or receptors, including compensation; and
- Measure, monitor, evaluate and update management measures continuously through the life of mine.

11.8.3 Water Management Controls

Embedded controls, mitigation measures and unexpected events for each of the life-of-mine phases are discussed in terms of general, mine water, raw water and mine waste waters in Table 11.74 to Table 11.77.

Table 11.74: Water Management Controls (General Management Controls)

Issue/Component	Objective	Control Measure	Construction	Operational	Closure	Embedded Management	Mitigation	Unexpected Event
General Management Controls								
Training and Awareness	Comply with IFC and Equator Principles	• Make all employees aware of: ○ Water conservation/water demand management ○ Water pollution avoidance and minimization measures ○ Reporting procedure and registry of incidents • Train all employees: • To reduce water consumption ○ Make one (1) individual person at a management level responsible for the management of the overall mine water balance. Train departmental heads in the managing of water balance, water pollution and water conservation within their sectors. ○ In the implementation of standard operating procedures (SOP's) (e.g. hydrocarbon management, sewerage plant management, monitoring and record keeping). ○ Arrangements shall be implemented to support water resources, aquatic environments, ecosystem services and conservation research efforts carried out by local, regional and national research groups in order to further knowledge and understanding of such attributes in the areas of operation;	√	√		√		
Management of process and stormwater reticulation	Re-use and minimising dirty water	• All process water tanks and PCDs (pit/reject PCD, co-disposal PCD, Plant PCD) will be lined to minimise seepage. • The process plant will use the following water sources in order of priority: 1) Sewage effluent return 2) PCD water (storm water from plant, co-disposal, reject dump, ore stockpiles and open pit water) 3) Raw water sources (Wellfield – Module 1). • Update the mine water balance on a regular basis. Implement a metering system. • All PCDs will be fitted with concrete silt traps. • The following maximum pump capacities are recommended (see Section 11.6.1.4.3): 1. PCD (Plant PCD) -> Dust suppression 320 m^3/d 2. Co-disposal PCD -> plant PCD 2 000 m^3/d	√	√		√		

Issue/Component	Objective	Control Measure	Construction	Operational	Closure	Embedded Management	Mitigation	Unexpected Event
General Management Controls								
		3. Open Pit -> Pit/Reject PCD 3 500 m^3/d						
		4. Pit/Reject PCD -> Plant PCD 2 000 m^3/d						
		5. Raw Water Tank -> Plant PCD 641 m^3/d						
	Mine water discharge management.	• Process water will be managed in such a way that it would not spill under normal operating conditions.	√	√		√		
	Minimising water quality impacts.	• Discharge will take place from the plant PCD, pit/reject PCD and co-disposal PCD. The water quality from these facilities are acceptable in terms of discharged into the environment (Section 11.6.2)	√	√		√		
		• However, discharges will be minimized by re-using stored water in the plant PCD for dust suppression when capacity is available. All other PCDs will be connected with the plant PCD. The RWD capacity is about 8 000 m^3.						
		• A monitoring network will be implemented to monitor PCD and discharge quality, as well as discharge volumes. Discharge will only take place when the quality is acceptable in terms of Malagasy guidelines.						
		• Silt traps should be inspected and emptied on a regular basis						

Table 11.75: Raw Water Management Controls

Issue/Component	Objective	Control Measure	Construction	Operational	Closure	Embedded Management	Mitigation	Unexpected Event
Mine Water Management								
Wellfield	Sustainable abstraction	• Wellfield abstraction in general should not exceed the sustainable yield (long-term drought conditions), i.e. 1 429 m^3/d. The proposed combined abstraction from MMB12 and MMB13 is between 222 and 551 m^3/d.	√	√		√		
		• Borehole abstraction will be minimised by using run-off water and open pit water for dust suppression where the quality allows.						
		• If new boreholes are required in the future: New boreholes should as a rule not be sited within 500 m of community water supply points. All newly drilled boreholes will be tested to calculate a safe borehole yield. The individual boreholes should preferable be managed at an abstraction rate lower than the borehole safe yield.						
	Monitoring, wellfield management and compliance	• Groundwater levels monitoring – automated system • Abstraction volumes – automated system	√	√		√		
		• Communities impacted on will be compensated	√	√		□	√	√

Table 11.76: Water Management Controls (Mine Water Management)

Issue/Component	Objective	Control Measure	Construction	Operational	Closure	Embedded Management	Mitigation	Unexpected Event
Mine Water Management								
Open Pit Dewatering	Minimise and manage the loss in water resource	• SWMP will be implemented to minimize runoff ingress.	√	√		√		
	Minimise the dirty water footprint	• Allow for in-pit sumps to be installed with a capacity of up to 3 500 m^3/day groundwater discharge and prevent ponding of water within the open pit to minimize contamination. Water should be pumped on a continuous basis to minimise chemical contact time with surrounding rock. Water will be pumped from the sump to the lined pit/reject PCD and process water dam for re-use in the ore beneficiation process.		√		√		
	Allow for a safe working environment	• Allow for an in-pit sump, enough capacity for groundwater and surface water and back-up in-pit dewatering pump capacity. In-pit water make volumes are discussed in Section 11.6.1.7.		√		√		√
	Community water supply	• Should the dewatering activities have any effect on neighbouring groundwater users a sufficient alternative supply should be implemented	√	√	√		√	√
	Monitoring, Compliance with Malagasy guidelines	• Implement a groundwater monitoring program, which includes:						
		○ Groundwater levels and quality	√	√	√	√		
		○ In-pit water quality (i.e. at the sump)		√	√	√		
		○ Discharge quality and volume		√		√		

Table 11.77: Water Management Controls (Mine Waste Management)

Issue/Component	Objective	Control Measure	Construction	Operational	Closure	Embedded Management	Mitigation	Unexpected Event
Mine Waste Management								
Co-Disposal Facility	Increase the stability of the waste facility and long-term sustainability	• Storm Water control measures should be designed and implemented to divert clean runoff and divert dirty runoff appropriately, as well as to minimize the amount of rainfall infiltration to the co-disposal facility. The SWMP is discussed in Section 11.5.	√	√	√	√		
	Minimize the dirty water footprint	• Rehabilitation should be an ongoing operational process, taking place concurrent with waste disposal in order to minimise the dirty footprint area and rainwater infiltration. Rehabilitation should include ongoing levelling and compaction of waste material. An interim capping of low permeable material should be introduced in 5 year cycles. • The storm water management plan must minimise the dirty water footprint. • Closure objectives must minimize erosion and sediment load in run-off. The Co-Disposal Facility slope design, together with the closure cover design, must account for long-term sustainability. • A store-and-release or low infiltration capping must be designed with a growth layer for re-vegetation.	√	√	√	√	√	
	Water monitoring and reporting Monitoring, Compliance with Malagasy guidelines	• Implement a groundwater monitoring program, which includes:						
		○ Groundwater levels and quality	√	√	√	√		
		○ Stream water quality	√	√	√	√		
		○ Stormwater Dam quality	√	√	√	√		
Ore beneficiation processes	Minimise the dirty water footprint	• Chemicals must be stored with the correct liner and spillage collection system to prevent water quality contamination. A soil and water clean-up strategy must be developed in terms of unexpected spillage • SWMP must be implemented with four lined PCDs (Section 11.5).	√	√		√	√	√
	Minimise and manage the loss in water resource	• Implement a groundwater monitoring program, which includes:						
		○ Groundwater levels and quality	√	√	√	√		
		○ Stream water quality	√	√	√	√		
		○ Storm Water Dam quality	√	√	√	√		
Ore and product stockpiles	Minimize and monitor the dirty water footprint	• Ore and product stockpiles must be kept on a compacted area that will minimise infiltration of seepage. Liner is not required, however, levelling and compaction must be undertaken. • The storm water management system must minimise the dirty footprint area and capture dirty runoff in the lined plant PCD.		√		√		
Mine Support Services								
Fuel and Oil Storage Management (Depots and Workshop)	Protection of groundwater quality	• Implement and appropriate leakage inspection monitoring at fuel depots	√	√		√		
		• Design and implement the correct spillage control such as fuel and oil traps at workshops, vehicle washing bays and oil/fuel depots.	√	√		√	√	√
		• Have oil spill kits available at areas where oil spills are likely and clean up oil spills immediately and dispose on prepared bunkered area or bioremediation site.	√	√		√	√	√
		• Implement a groundwater quality monitoring system at the work shop areas and fuel depots.	√	√		√		
		• A soil and water clean-up strategy must be developed in terms of unexpected spillage	√	√				√

11.8.4 Surface Water Monitoring Plan

A monitoring programme is recommended in terms of the IFC Environmental, Health and Safety General Guidelines (IFC, 2007a) and World Health Organisation drinking water standards (WHO, 2011).

It is recommended that any water containment facilities on site be monitored for water quality and quantity on a monthly basis. The quantity should be monitored to ensure the facilities are of a sufficient size for the water volumes they are expected to contain.

The water quality results should meet applicable standards or ensure that water released into the environment, either intentionally or unintentionally, are of appropriate quality (Section 11.7.1) and associated risks are well understood. Should there be any streams or natural drainage lines with flowing water within the catchment of the site (zone of impact) these should be monitored on a monthly basis upstream and downstream of the site.

More details of the proposed monitoring programme are presented in Table 11.78. Figure 11.90 shows twelve (12) proposed locations for surface water monitoring and Table 11.80 the coordinates.

Table 11.78: Proposed surface water monitoring programme

Water Type	Details	Monitoring Frequency	Monitoring Frequency	Monitoring Frequency
		Construction Phase	Operational Phase	Closure Phase
Surface Water Streams	Sample point upstream and downstream of the Open Pit Area, Processing Plant Area, Co-Disposal Facility, Reject Dump and Ore Stockpiles (see Figure 11.90)	Monthly water samples	Monthly water samples	Quarterly water samples
Drinking Water (pipe lines, boreholes)	Any supplied water used for domestic purposes should be monitored for parameters such as total and faecal coliform;	Monthly water samples	Monthly water samples	
Process Water	Outlet of the silt traps, wash bays, PCDs, Raw Water Tanks, the Process Water Tanks and sewage treatment facilities	Monthly water samples	Continuous monitoring during discharge	

Table 11.79: Surface Water Monitoring Parameters

Indicator Parameters
pH
Electrical Conductivity
Total Dissolved Solids
Alkalinity
Turbidity
Sulphate
Phosphates
Chloride
Nitrates (as NO_3/N)
Ammonium (as NH_3)
Aluminium
Manganese
Iron
Barium (Ba)
Other Major Anions
Other Major Cations
Total Hydrocarbons*[1]
Bacteria (*E.Coli, Total Coliforms*)*[2]
Full Metal ICP-OES Scan

*[1] Only workshop, fuel depot – plant area (bi-annual)

*[2] Potable water only (bi-annual)

Table 11.80: Coordinates of the proposed surface water monitoring programmes

NAME	E	S	Em UTM 38S, WGS85	Sm UTM 38S, WGS85
PSW1	45° 7' 50.226" E	24° 0' 34.997" S	513 284.30	7 344 691.00
PSW2	45° 6' 19.408" E	24° 0' 46.580" S	510 718.40	7 344 336.90
PSW3	45° 7' 23.272" E	23° 59' 23.488" S	512 524.80	7 346 890.90
PSW5	45° 6' 45.950" E	23° 59' 58.080" S	511 469.40	7 345 827.90
PSW6	45° 6' 47.423" E	24° 0' 23.140" S	511 510.40	7 345 057.20
PSW7	45° 7' 19.189" E	24° 0' 1.859" S	512 408.40	7 345 710.90
PSW8	45° 8' 9.733" E	24° 0' 1.784" S	513 836.40	7 345 711.90
PSW9	45° 7' 8.400" E	24° 0' 46.930" S	512 102.40	7 344 325.10
PSW10	45° 5' 29.951" E	24° 1' 31.592" S	509 320.30	7 342 953.60
PSW11	45° 7' 9.732" E	23° 59' 54.225" S	512 141.40	7 345 945.90
PSW17	45° 6' 1.818" E	24° 0' 5.167" S	510 222.40	7 345 610.90
PSW18	45° 8' 26.435" E	24° 2' 5.314" S	514 304.51	7 341 912.42

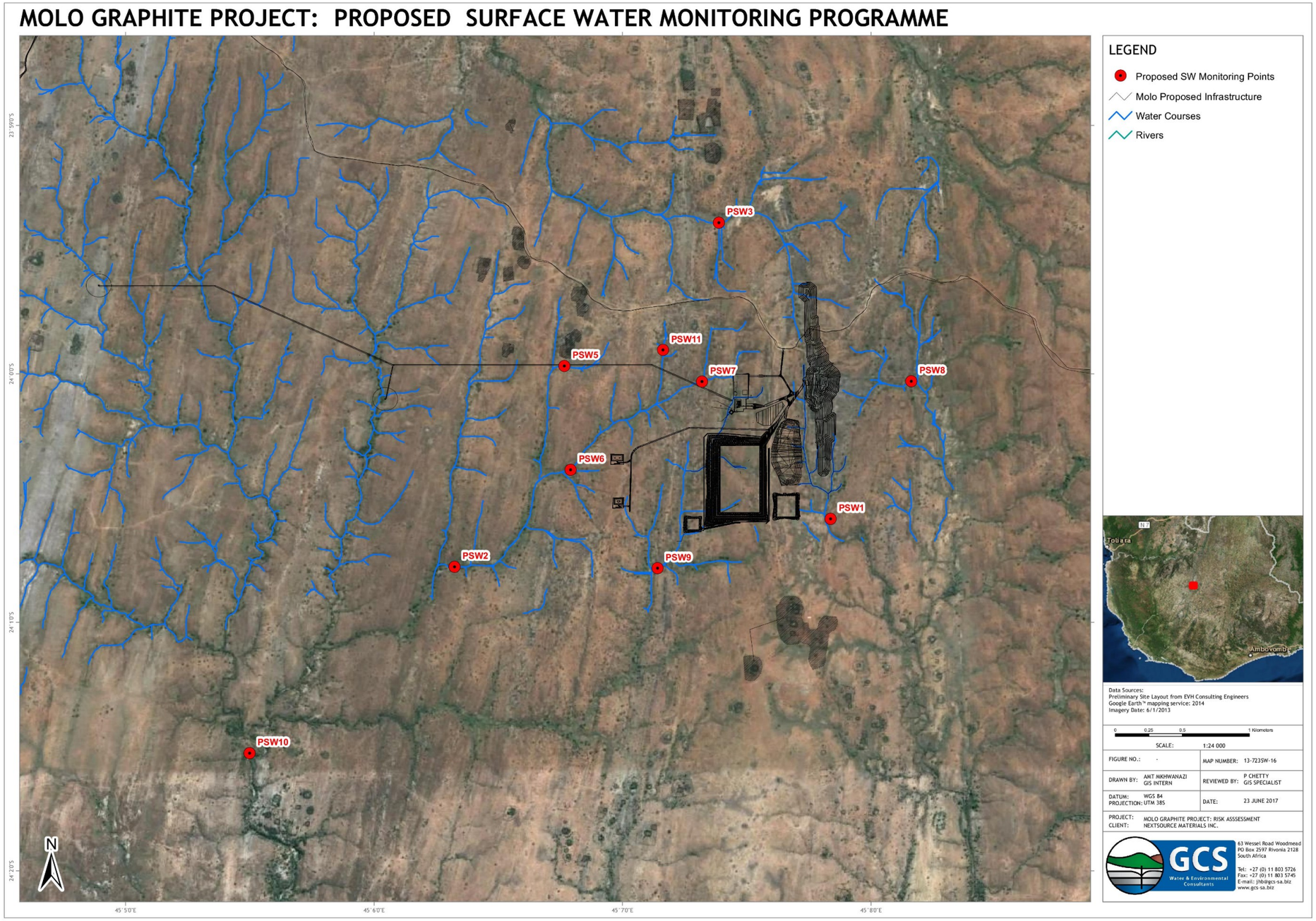


Figure 11.90: Proposed surface water monitoring network

11.8.5 Groundwater Monitoring Plan

The groundwater monitoring program for the site should be operated in all phases of the mine life (i.e. from construction through to the closure phase) in order to identify the site impacts promptly and ensure compliance with the relevant standards as specified in Section 11.7.1. The groundwater monitoring program was designed according to the international best practice guidelines that were available and incorporated the following aspects:

- Monitoring Network;
- Monitoring Parameters; and
- Monitoring Frequency.

11.8.5.1 *Monitoring Network*

Based on the numerical modelling results, as described in Section 11.7.4, the potential contaminant plume from the co-disposal facility were identified, as well as the potential extent of open pit dewatering were determined. The impacted areas were localized to the respective infrastructure areas, however, both regional and localized monitoring should be conducted at the site in terms of groundwater quality and quantity (i.e. water levels and pit inflow volumes). The proposed monitoring network per phase of the life of mine is summarized in Table 11.81 and shown in Figure 11.91. It is proposed that an additional three (3) monitoring boreholes are installed at the site during the construction phase. These boreholes should be installed south and west of the co-disposal facility and west of the processing plant. All wellfield boreholes will be monitored (water level, abstraction volume and quality). Automated water level and abstraction rate recorders are proposed for wellfield boreholes.

Table 11.81: Proposed Monitoring Network

Borehole ID	X (UTM38S, WGS84)	Y (UTM38S, WGS84)	Locality Description	Construction Phase	Operational Phase	Closure Phase	Water level	Quality	Quality - Bacterial	Quality - Organic	Abstraction rate/ Flow
MMB1	513173	7344828	Open Pit Perimeter	✓	✓	✓	✓	✓			
MMB2	513495	7345509	Open Pit Perimeter	✓	✓	✓	✓				
MMB3	513135	7346601	Open Pit Perimeter	✓	✓	✓	✓				
MMB4	513068	7345137	Open Pit Perimeter	✓	✓	✓	✓	✓			
MMB6	513441	7345882	Open Pit Perimeter	✓	✓	✓	✓				
MMB8	512976	7346248	Open Pit Perimeter	✓	✓	✓	✓				
MMB10	513234	7345563	Open Pit Perimeter	✓	✓	✓	✓	✓			
MMB11	511805	7345412	Southwest of plant area	✓	✓	✓	✓	✓			
MMB12	510247	7345583	Production Borehole west of the Molo site	✓	✓		✓	✓	✓		✓
MMB13	508294	7346428	Production Borehole west of the Molo site and within Marble	✓	✓		✓	✓	✓		✓
MMB16	508140	7345717	West of the Molo site	✓	✓		✓				
MMB17	TBC	TBC	Proposed monitoring borehole downgradient of plant	✓	✓	✓	✓	✓		✓	
MMB18	TBC	TBC	Proposed monitoring borehole, down-gradient (west) of the Co-Disposal Facility	✓	✓	✓	✓	✓			
MMB19	TBC	TBC	Proposed monitoring borehole, down-gradient (south) of the Co-Disposal Facility	✓	✓	✓	✓	✓			
GWH8	507912	7346320	Hand dug well - Ambatofotsy (North)	✓	✓		✓				
GWH3	512975	7344167	Spring/seep, south of the open pit	✓	✓	✓		✓			✓
Open Pit Seepage	TBC	TBC	Within the Open Pit		✓	✓		✓			✓
Pollution Control Dam Water	TBC	TBC	Water within the Pollution Control Dam		✓	✓		✓			
		TBC - To Be Confirmed									

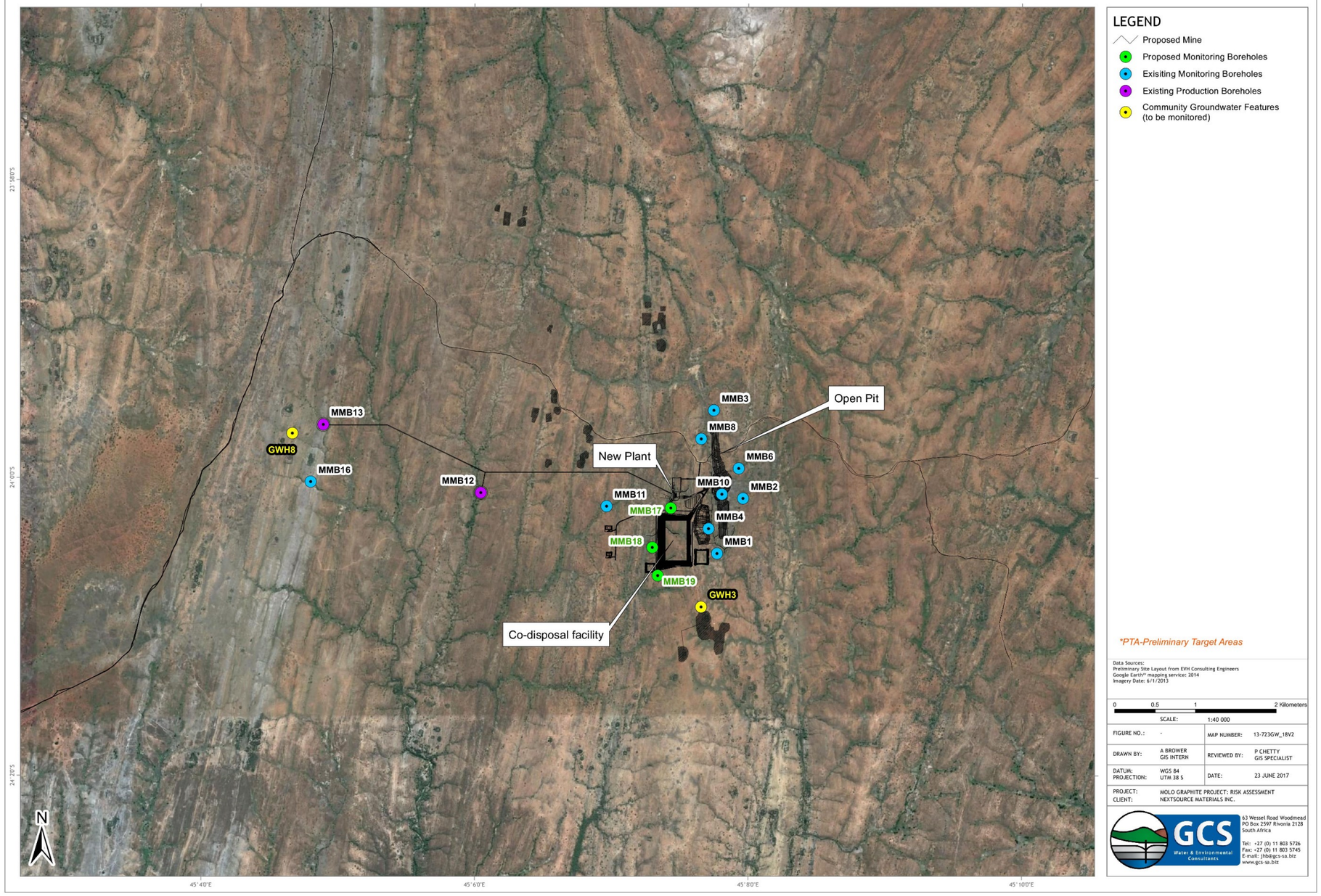


Figure 11.91: Proposed Monitoring Network

11.8.5.2 *Monitoring Parameters*

The potential impacts due to the proposed mining activities were identified for both groundwater quality and groundwater quality. The key indicator parameters to be analysed for in terms of groundwater quality impacts due to mining were pH, electrical conductivity, total dissolved solids, sulphate, chloride, aluminium, manganese and iron, with secondary parameters including major anions and cations, barium, total hydrocarbons and bacteriological sampling. The hydrochemical sampling should be conducted on a quarterly basis (i.e. every three months) for the entire life of mine, with the exception of total hydrocarbons and bacteriological sampling which is only applicable during the construction and operational phases and should be conducted annually. Bacteriological monitoring could be challenging due to the remote locality of the site. It is however proposed an initial bacterial monitoring of all production boreholes be undertaken. This can be followed by annual bacterial monitoring only from the raw water and potable water reservoirs. Monitoring for closure must be re-assessed towards the end of the operational phase. It is however proposed to at least continue for 2 years after cessation of mining.

Groundwater levels and abstraction rates of production boreholes should be recorded on a continual basis. Water levels in monitoring boreholes must be measured monthly. During the operational and closure phases the open pit inflow volumes (pumping hours, flow meter readings) should be measured daily or weekly. The proposed indicator parameters and monitoring frequency per phase of life of mine is shown in Table 11.82.

The data collected during the monitoring program should be collated into an electronic database and the results interpreted in order to identify potential trends in the data (positive or negative) and allow for pro-active planning of mitigation measures that may be required for the site.

Table 11.82: Monitoring Parameters and Frequency

Indicator Parameters	Impact	Frequency	Construction Phase	Operational Phase	Decommission/ Closure Phase
pH	Groundwater Quality	Quarterly	✓	✓	✓
Electrical Conductivity		Quarterly	✓	✓	✓
Total Dissolved Solids		Quarterly	✓	✓	✓
Sulphate (SO_4)		Quarterly	✓	✓	✓
Alkalinity		Quarterly	✓	✓	✓
Aluminium (Al)		Quarterly	✓	✓	✓
Chloride (Cl)		Quarterly	✓	✓	✓
Nitrate (NO_3/N)		Quarterly	✓	✓	✓
Manganese (Mn)		Quarterly	✓	✓	✓
Iron (Fe)		Quarterly	✓	✓	✓
Other Major Anions		Quarterly	✓	✓	✓
Other Major Cations		Quarterly	✓	✓	✓
Barium (Ba)		Quarterly	✓	✓	✓
Total Hydrocarbons		Annually	✓	✓	
Bacteria (*E.Coli, Total Coliforms*) – Only Potable Water Reservoir		Annually	✓	✓	
Full Metal ICP- Scan		Quarterly for first 2 years (identification of elements of concern), Bi-Annually	✓	✓	✓
Groundwater Level	Groundwater Quantity	Monthly	✓	✓	✓
Open Pit Inflow Volumes		Daily/Weekly		✓	
Abstraction Borehole Volumes and Water Levels		Continuous	✓	✓	

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ANNEX 11 A: CLIMATE ASSESSMENT

ANNEX 11 B: 55 YEAR SIMULATED RAINFALL AND 55 YEAR SIMULATED NATURAL RUNOFF

ANNEX 11 C: RESISTIVITY SECTIONS

ANNEX 11 D: BOREHOLE LOGS

ANNEX 11 E: PUMPING TEST DATA

ANNEX 11 F: GROUNDWATER NUMERICAL MODELLING

ANNEX 11 G: PEAK FLOW CALCULATION (RATIONAL METHOD)

Appendix F

Permitting and Stakeholders

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NEXTSOURCE RESOURCES INC.: MOLO FEASIBILITY STUDY – SECTION 13: PERMITTING AND STAKEHOLDERS

NEXTSOURCE materials

Wednesday, 14 June 2017

DOCUMENT ISSUE STATUS

Document Name:	NextSource Resources Inc.: Molo Feasibility Study – Section 13: Permitting and Stakeholders	**Status:**	Rev 0 – Final
Client Name:	Environmental Law Group (Pty) Ltd	**Attention:**	Mr Johann de Bruyn
Report Reference:	Molo_240ktFS	**Issue Date:**	2017/06/14
Author:	Adv. Lana van der Westhuizen	**Revision:**	Rev 0 – Final
Approved:		**Approval Date:**	

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1. Introduction

1.1 Context and Approach

NextSource Resources Inc. (NextSource), previously operating as Energizer Resources Inc., is a mineral exploration and development company based in Toronto, Canada; which is currently focused on the exploration and development of its Molo Graphite Project in south-western Madagascar. The Molo Graphite Project is located approximately 145 km south east of the city of Toliara, in the Tulear region, and covers an area of 225 km^2.

This Section is based on an open pit mining approach combined with processing through a sequence of crushing and screening, grinding, flotation, thickening and drying; producing a primary concentrate of graphite of various grades and flake sizes.

In respect of land tenure, the Molo Graphite Project claims were previously held in the name of Madagascar Minerals and Resources (MMR), controlled by Director Cyriaque Mamy Cheung of Antananarivo. A joint venture agreement was entered with MMR in 2007, which resulted in Uranium Star Minerals SARL (URST) owning a 75 % interest in the Molo Graphite Property.

URST, holder of the exploration permits by way of an Extraordinary General Meeting, dated 6 April 2010, approved a change of its name to Energizer. Furthermore, the change of name to Energizer Resources Inc. was officially recognized by the Registrar of Commerce and Companies in Antananarivo, Madagascar on 12 May 2010.

Of particular importance, is Mining Cadastre Permit No. 3432, the cadastral area which covers the Molo Project Area (Annexure A), which has been converted into an application for exploitation, as per Permit No. 39807 (Annexure B) and which is pending final approval and awarding.

As input into the feasibility study, this Section presents pertinent information on the required permits/ licenses to ensure legal compliance and facilitate commencement of construction and operation activities of the proposed Molo Graphite Project.

This Section also includes information on supplementary permits/ licenses for associated activities, as well as an indication as to progress on current permit / license applications, and those which will have to be commissioned should the project move into the execution phase.

1.2 Global Overview

This Section entails a legal summary of the relevant Malagasy environmental legislation that the Molo Graphite Project must adhere to, to procure it's "licence to operate". This global overview presents the required permitting requirements and the corresponding processes to obtain them.

According to the different phases of the project's development, certain permits and/ or authorisations might be required by each delocalized service and department of the state. This is to say that the list and register presented in this document may not be completely exhaustive at time of publishing.

The required permitting requirements are divided into the following aspects:

- Mining/ Exploitation;
- Environmental; and
- Other Applicable Madagascar Laws.
-

2. Mining/ Exploitation

A Mining Code [Law No 99-022 of 30 August 1999 (as amended in 2005, Law 2005-021)] (the Code), with a view to simplifying the country's mining sector and making it more transparent, governs the mining/ exploitation activities of the proposed project.

It is paramount to note that the Code regards all investors on an equal basis, irrespective of their origin or their capital ownership; which is in line with the new Constitutional provisions' aim to preserve the environment and conduct mining activities in a better socio-economic climate.

The Mining Cadastre Registry (BCMM) was established in 2000, and it established and maintains the updated public registry of mining leases. The BCMM ensures, *inter alia*, discretionary procedures and the abolishment of discrimination in the granting of mining leases. Furthermore, reasonable and progressive fees were established to discourage speculation.

The BCMM grants mineral licences based on the payment of a fixed mining administration fee, calculated on standard surface unit areas; and the submission of an environmental commitment plan.

As stated, the Project currently holds an Exploration Licence (PR) and an application has been submitted to convert the existing PR licence into a Mining Licence (PE). This process is in the approval stage. The PE licence confers on the holder the exclusive right to undertake mining, prospecting and exploration activities within the licence perimeter.

The following table provides a summary of the mining/ exploitation governance in Madagascar.

Mining Title	All mineral deposits situated on the surface, in the subsoil, as well as in underground waters on the national territory belong to the State.
Regulatory authority	• Minister in charge of Mines. • *Bureau du Cadastre Minier de Madagascar* (BCMM), the Malagasy Mining Cadastre. • Mining department of the Ministry in charge of Mines. • *Office des Mines Nationales et des Industries Stratégiques* (OMNIS), the Malagasy state entity responsible for strategic minerals.
Exploration and Mining Laws and Regulations	• *Loi n°99-022 du 19 août 1999 portant Code Minier modifiée par Loi n° 2005 - 021 du 17 octobre 2005* (Law no 99-022 dated 30 August 1999 establishing the mining code modified by Law no. 2005-021 dated 17 October 2005) (Mining Code). • *Décret n°2000-170 du 20 février 2000 fixant les conditions d'application de la Loi n° 99-022 du 19 Août 1999 portant Code minier modifiée par le Décret n°2006-910 du 19 décembre 2006* (Decree n° 2000170 dated 20 February 2000 implementing the Mining Code duly modified by Decree no. 2006-910 dated 19 December 2006) (Mining Decree). • *Arrêté n°5 470/2012 fixant le modèle de rapport d'activités pour chaque type de permis minier* (Order n°5 470/2012 setting the form of the activity report for each type of mining permit).
Validity of PE Licence	40 years, and renewable in increments of 20 years.
Transfer of PE Licence	The PE Licence is transferable without requirement for regulatory approval. However, for purpose of enforceability of the transfer against the mining authority, the transfer of the exploitation permit should be registered at the BCMM.

3. Environmental

The Constitution of the 4th Republic states that every person has the duty to protect the environment. It thereby ranks the environment as one of the first national concerns and places mankind's responsibility to ensure this on the highest level.

The most prominent Malagasy environmental legislation includes a whole range of instruments to adequately manage the environment:

- **Environment Charter No 90-033 (21st December 1990)**: The *Charte de l'Environnement* (Environment Charter) provides for, amongst others, the compilation of and Environmental and Social Impact Assessment (ESIA) by including that all public or private investment projects which may have an impact on the environment, must undertake an impact study taking into account the technical nature, scale and magnitude of the project, as well as the sensitivity of the receiving environment.
- **Decree on the Compliance of Investments with Environmental Management (MECIE) No 99-954 (15th December 1999, as amended)**: This decree governs the environmental impact study (EIE) assessment procedures, as well as the Environmental Commitment programmes (PREE), for exploration and mining activities.
- **Mines-Environment Joint Inter-Ministerial Order, No. 12032/2000 (6th November 2000)**: This decree specifies the provisions of Decree No.2000-170 of March 15, 2000, determining the rules governing the application of the Mining Code, and of the MECIE Decree, pursuant to section 10 of

the Malagasy CEM. It sets the regulation of the mining sector as far as environment protection is concerned.

NextSource is currently facilitating the required ESIA process with the competent authority. The requisite studies accompanying the ESIA are 80% complete and the estimated submission date of the ESIA and Relocation Action Plan (RAP) is early June 2017. Assessment and decision-making on the ESIA will amount to between 3 and 6 months.

The following table provides a summary of the environmental governance in Madagascar.

Applicable Laws and Regulations	• *Arrêté Interministeriel n°12032/2000 sur la réglementation du secteur minier en matière de protection de l'environnement* (Inter-Ministerial Order no 12032/ 2000 of 6 November 2000 relating to the regulation of mining areas in relation to environmental protection) (the Environmental Order). • *Décret n°99-954 DU 15 DECEMBRE 1999 modifié par le décret n° 2004-167 du 03 février 2004 relatif à la mise en compatibilité des investissements avec l'environnement (MECIE)* (Decree no 99-954 of 15 December 1999 amended by Decree no 2004-167 of 3 February 2004 relating to the compatibility of investments with the environment (MECIE)).
Environmental Impact Assessment	• An ESIA is required for an exploitation permit. This process has been commenced with.

4. Other Applicable Madagascar Laws

Other prominent Malagasy legislation includes the following:

- **Ordinance No. 62-165 dated 11st October 1962**: The permitting for the construction of buildings and allotments. The law deals with building authorisations and permissions for allotments.
- **Law No. 98-029 date 20th January 1999 – the Water Law**: The water law recognises the scarcity and importance of water as a national resource that must be conserved, improved, and managed sustainably, carefully and rationally. Surface and groundwater abstraction are covered in Articles 10 and 11. No changes to a water course may be undertaken without prior permission from the National Authority for Water and Sanitation (Autorite Nationale de L'Eau et de L'assainissement - ANDEA). Article 18 states that decrees outline the conditions under which wastes can and cannot be discharged into water, or more generally to alter the quality of surface or groundwater. Article 20 states that all companies must ensure the treatment of all waste water, and this treatment must ensure that the receiving water quality is maintained or improved. Article 21 states that all discharges into public sewers must have prior approval from the authorities. Article 22 states that all water containing industrial effluents must be kept separate from storm water runoff.
- **Decree No. 64-291 dated July 1964 - The regulations regarding the delineation, use of, conservation and policing of public property:** This decree describes the delineation, classification and alignment of public property. Possible uses of public property include temporary uses (for example during construction), which are permissible but prior approval must be obtained from the ministry in charge of public property. All requests for such a use must include a description of the activity to be undertaken and the length of time the activity will require. If the land is located near a military land, the Ministry of Defence must be consulted regarding using the land.

- **Decree No. 310 dated 2nd February 1964 - The alignment methods:** This decree states that any person wishing to construct a building or fence along a public access road is required to request a survey of the public access road prior to requesting permission for construction.
- **Decree No. 180 dated January 1964:** Any staff related housing plans must be approved by the Ministry for Public Works prior to obtaining a construction permit.
- **Law No. 99-021 dated 19th August 1999 - The management and control of industrial pollution:** This law outlines that it is the State's aim to ensure the protection of the environment and the conservation of biological ecosystems and natural resources from all causes of degradation or alteration by pollutants. Liquid wastes must be managed in accordance with the licence provided by the competent authority which will ensure that effluent discharge is limited as far as possible and that it is properly treated prior to release. Solid wastes are divided into non-hazardous wastes and hazardous (special) wastes. Non-hazardous wastes should be minimised, recovered, recycled, incinerated, buried or composted. Hazardous wastes must be dealt with in accordance with the licence provided by the competent authority.
- **Law No. 98-026 dated January 1999 - The revision of the roads charter:** This law states that all investments in roads requiring rehabilitation construction work or requiring the use of nearby materials are required to undergo an EIA in accordance with the MECIE.
- **Decree No.73 076 dated 30 March 1973:** Regulating the import, export, sale and acquisition of explosive and detonating substances (EDS).
- **Petroleum products:** In addition to Act No.96-018 defining the Petroleum Code in general, a number of other legislative texts also regulate the petroleum sector. The legislation that applies to the project is as follows:
    - Decree No.93-136 of 24/03/93 pertaining to the import system, the processing, transport, storage and distribution procedures for petroleum products, which specifies that imports and other activities related to the petroleum products, except for crude oil, premium grade petrol, petrol, diesel and kerosene (jet fuel and paraffin), are open to any operator under Malagasy law (it is therefore a liberalization of gas, fuel and lubricant-related business activities);
    - Ordinance No.5313/96 concerns the creation of a basic infrastructure management unit for petroleum products;
    - Finally, the 'Office Malagasy des Hydrocarbures (OMH)' and a fuel tax at the pump were both instituted in order to meet the environmental costs arising from oil pollution.
    - It is paramount to note that fuel will be provided, managed and licenced by a 3ed party contractor.
- **Law No.98-032 dated 20 January 1999 - The electricity sector:** The law governs the production, transport and distribution of electricity throughout the national territory. Specifically, it establishes the authorisation and concession regimes as well as the independent production regime; it includes environmental provisions specifying that the establishment and operation of power stations must comply with legislative and regulatory provisions pertaining to the protection of the environment, and in particular, those enshrined in the Charter for the Environment and subsidiary legislation.

5. Permit and Authorisation Register

The identified permits and / or authorisations for the project's development and implementation are presented in the Table overleaf. Any potential gaps or supplementary information would be subject to further analysis and documentation. Kindly note that the main authorisation procedures are attached hereto as Annexures C to F.

SUBJECT	REFERENCES	PERMIT / AUTHORISATION	COMPETENT AUTHORITY
ENVIRONMENTAL			
Global Environmental Permit (GEP) (including all project components: Mine site[1], residues, plant, RAP[2]). Possible supplementary sectoral EMPs are: - Mine - Quarry - Pre-mobilization - Unit plant - Water supply - Haul road - Port utilisations - Power transport	Decree on the Compliance of Investments with Environmental Management (MECIE) No 99-954 (15th December 1999, as amended).	Global environmental permit.	National Environment Office (ONE).
Operation and logging, slash and burn.	Decree No. 2005-849 of 13 December 2005 revising the terms and conditions of application of Law No. 97-017 of 8 August 1997 revising forest legislation.	Cutting permit.	Ministry of the Environment, Water and Forests.
Management of industrial pollution.	Law No. 99-021 of 19 August 1999 on the management policy and control of industrial pollution.	Authorisation for operation.	

1 For the Port (Ehoala) and the haul road (from Fotadrevo to Tolagnaro), sectoral EMPs may be required

2 With reference to PS5, the RAP will be a separate document

SUBJECT	REFERENCES	PERMIT / AUTHORISATION	COMPETENT AUTHORITY
Water withdrawal.	Law No. 98-029 of 20 January 1999 Carrying Water Code Decree No. 2003-793 of 15 July 2003 laying down the procedure for granting of water abstraction licenses.	Water abstraction permit. Agreement for the use of chemicals (Necessary in the context of the use of chemicals during development operations).	(Autorite Nationale de L'Eau et de L'assainissement - ANDEA)
Water discharge.	Water code. Ministerial Decree n° 2003-943 related to the direct or undirected water discharges on surface or underground water. Order n° 16248/2008 fixing royalties on uptake and discharge of water. Decree n°2003-464 dated 14 April 2003 fixing the classification of surface water and regulation of effluent liquid discharge.	Water discharge permit.	(Autorite Nationale de L'Eau et de L'assainissement - ANDEA).
MINING			
Environmental Study.	Mining Code [Law No 99-022 of 30 August 1999 (as amended in 2005, Law 2005-021)].	Environmental authorisation.	Ministry of Mines.
Exploitation.	Mining Code [Law No 99-022 of 30 August 1999 (as amended in 2005, Law 2005-021)].	Operating license "E".	Ministry of Mines.
Quarries and embankment sites (borrow pits).	Mining Code [Law No 99-022 of 30 August 1999 (as amended in 2005, Law 2005-021)].	Authorisation required for each given quarry.	Mayor of the Municipality concerned.
Quarries and embankment sites (borrow pits).	Mining Code [Law No 99-022 of 30 August 1999 (as amended in 2005, Law 2005-021)].	Authorization to exploit a given quarry.	National Environment Office (ONE), if full ESIA (screening required).

SUBJECT	REFERENCES	PERMIT / AUTHORISATION	COMPETENT AUTHORITY
	Decree No. 2006-910 dated 19 December 2006.		For a new quarry not included in the ESIA, an application is made to the Ministry of Mines (a separate EMP will be required).
Transformation of the mines products.	Mining Code [Law No 99-022 of 30 August 1999 (as amended in 2005, Law 2005-021)].	The authorisation for industrial processing of mining products.	Jointly by the Departments charged with Mining and Industry.
Marketing of the mine products.	Mining Code [Law No 99-022 of 30 August 1999 (as amended in 2005, Law 2005-021)].	Certificate of mineral export.	Mining Administration, Department of Mines.
ELECTRICITY			
Self-production of electricity.	Law No. 98-032 of 20 January 1999 on the reform of the electricity sector. Law No. 2008-038 of 18 December 2008 amending and supplementing certain provisions of Law No. 98-032 of 20 January 1999 on the reform of the electricity sector.	Declaration of self-production. Authorisation of self-production of electrical energy.	Ministry of Energy.
Use of Coal.	Law No. 98-032 of 20 January 1999 on the reform of the electricity sector.	Authorisation of self-production of electrical energy (use of coal).	Ministry of Energy.
ROADS			
Roads (surfaced and un-surfaced) and maintenance.	Law No. 98-026 dated January 1999 - The revision of the Roads Charter.	Authorization for upgrade of a National road. Decree authorizing the upgrade of roads in a given District.	Ministry of Public Works for National Roads Region/ District Municipalities for Provincial roads.

SUBJECT	REFERENCES	PERMIT / AUTHORISATION	COMPETENT AUTHORITY
		Road maintenance agreement.	
Haul trucks transport/ circulation.	Mining Code [Law No 99-022 of 30 August 1999 (as amended in 2005, Law 2005-021)].	Authorization to circulate.	Regional Department of Public Works.
Pipes crossing roads, road maintenance.	Law No. 98-026 dated January 1999 - The revision of the Roads Charter.	Authorization to cross a given National/Provincial Road.	Regional Department of Public Works.
CIVILS AND BUILT INFRASTRUCTURE			
Building permit.	Decree No. 2010-234 of 20 April 2010 amending and supplementing certain provisions of the decree No. 63-192 of 27 March 1963 laying down the code of the Urbanism and Habitat.	Building permit.	Local representative of Architecture, Urbanism and Habitat.
Waste water treatment unit.	Decree No. 2010-234 of 20 April 2010 amending and supplementing certain provisions of the decree No. 63-192 of 27 March 1963 laying down the code of the Urbanism and Habitat.	Building permit.	The Mayor at the particular Municipality.
Cutting and Logging.	Decree No. 63.192 of 03/27/63 fixing the Town Planning Code and Habitat. Decree n° 2010-234 of 20 April 2010 amending certain provisions of Decree No. 63-192 of 27 March 1963 on the Code of Urban Planning and Housing,	Pre-authorisation of work likely to jeopardize the wooded character of the land or nature of wood, not subject forests or parks in the forest system, enclosed or not, or not attached to dwellings. Authorisation cutting and felling of trees in the woods, forests and not under the forest regime parks that are classified as woodland kept by	Mayor assent of the representative of the Ministry of Public Works. President of Fokontany on a proposal from the water and forest engineer and local representative of the service of architecture, urban planning and housing.

SUBJECT	REFERENCES	PERMIT / AUTHORISATION	COMPETENT AUTHORITY
		the urban plans subject to authorisation. Authorisation to clear cutting or felling of trees.	
HYDROCARBONS			
Hydrocarbon Storage.	Decree No. 2004-669 of 29 June 2004 implementing Law No. 2004-003 of 24 June 2004.	Quality Declaration of wholesale consumer. Permission to work. Operating certificate.	Office Malgache des Hydrocarbures (Malagasy Office of Hydrocarbons).
PORTS			
Port Operations.	Law No. 2003-025 of 05/09/2003 regarding status of ports. Decree No. 2004-699 of 13/07/2004 on the implementation of Law No. 2003-025 of September 2003 status of ports.	Ports operating permit.	Port Authority.
Construction of port facilities.	Decree No. 2004-699 of 13/07/04 on the implementation of Law No. 2003-025 of 5 September 2003 status of ports.	Construction authorisation.	Agence Portuaire Maritime et Fluviale (APMF).
Loading and unloading of dangerous goods.	Decree No. 2004-699 of 13/07/04 on the implementation of Law No. 2003-025 of 5 September 2003 status of ports.	Permit for the Loading and unloading of dangerous goods.	Port officers.

SUBJECT	REFERENCES	PERMIT / AUTHORISATION	COMPETENT AUTHORITY
Entry into the port area.	Law No.99-028 of 3 February 2000 recasting of the Maritime Code. Decree No. 2004 of 13/07/2004 on the implementation of Law No. 2003-025 of 5 September 2003 status of ports.	Security Certificate. Entry permit for the port area. Permission to perform a particular international operation in ports.	Port Authority. Director General of the APMF.

6. Stakeholder Register

The applicable stakeholders to be approached for the application of the identified permits and / or authorisations (Table 1) are recapitulated below. Stakeholders have been grouped as follows:

- Ministries;
- Region;
- District;
- Local Decentralized Municipalities;
- Attached Authorities to Ministries; and
- The local population.

Stakeholders requiring engagement prior to and during project development and implementation

HEADING	ORGANISM	MISSION	ADDRESS/OFFICE	CONTACT / INTERLOCUTOR
Environment	ONE: National Office for Environment	Prevention of environment risks in public and private investment and pollution prevention. Management of the environment information system, of monitoring and evaluation of environment status. To support environment assessment and sustainable decision making at all levels. Environmental certification	Avenue Rainilaiarivony Ananinarenina (+261) 20 22 259 99 / 641 07 / 641 11 one@pnae.mg	General Manager: RAKOTOARY Jean: 032 05 805 34 Division Chief for impact studies: Mr RAJAOMANANA Hery: 033 12 058 26
Water (uptake, discharge)	ANDEA: National Authority for water and sanitation (Autorité Nationale de l'Eau et de l'Assainissement)	Responsible for the integrated management of water resources and the rational development of the water and sanitation sector.	Rue François Vittori Ankorahotra Antananarivo 101 E-mail : andea@moov.mg Tel : 0 20 22 203 54	Mr Justin: 034 63 625 32
Electricity	ADER: Development and Rural Electrification Authority (Autorité de Développement de l'Electrification Rurale)	Management of the national fund for electricity grants. Process of applications, permits, studies, implementation and monitoring of rural electrical network. Operations control.	Lot II I 164 Ter Alarobia Antananarivo Tel : +261 20 24 245 81 ader@ader.mg www.ader.mg	Mr Mamisoa: Directeur Technique 033 23 537 95

HEADING	ORGANISM	MISSION	ADDRESS/OFFICE	CONTACT / INTERLOCUTOR
	ORE: Electricity Regulation Office (Office de Régulation de l'Electricité)	Regulate, control and monitor any activities related to the electricity sector.	Ambatoroka Antananarivo	Mr Rivo RASOLOJAONA: 032 04 815 39
	JIRAMA: Jiro sy Rano Malagasy (Malagasy Water and Electricity)	The JIRAMA, a national utility provider created by the Order n°75-024 has signed a Concession agreement with the Malagasy Government for electricity distribution. The said concession was approved by the Decree n°2001-110 dated on 16 April 2001.	149 Rue Rainandiamampandry: (Ambohijatovo ambony) Antananarivo 101 (+261) 22 200 31 (Reception phone number)	
Port activities	APMF : Maritime port authority (Autorité Portuaire Maritime et Fluviale)	Regulates the port sector in all coastal regions of Madagascar.	Immeuble Agence Portuaire, Maritime et fluvial. Routes des Hydrocarbures, Alarobia Antananarivo B.P. 581 Tel : +261 20 22 538 84 / +261 20 24 257 00 Fax : +261 20 22 539 34 GSM : +261 33 05 257 00 / +261 32 11 257 00 Website: apmf@apmf.mg	Mr Jean Germain RABARY (Direction Technique - responsable des travaux portuaires): 032 11 257 22 Mr Jean Solofoson RABARY (Direction Régulation): 032 11 257 60

HEADING	ORGANISM	MISSION	ADDRESS/OFFICE	CONTACT / INTERLOCUTOR
	EHOALA Port: Global Concessionaire of the Ehoala port	Responsible for Management of the autonomous port of Ehoala.	Liaison office: Rio Tinto at Antananarivo	General Information: seplops@stxgroup.net Transport and Shipping: nsteenbergen@stxgroup.net; sgallagher@stxgroup.net; ialyg@stxgroup.net; seploperations@stxroup.net Request for Quotation: Nathalie.Raboarinelina@riotino.com
Mines	BCMM (Bureau du Cadastre Minier de Madagascar)	Manage mining tenements in all Madagascar. Issues Research, Exploitation permit and statutory passes.	BCMM – Ministry of Mines Ampandrianomby Antananarivo (+261) 20 22 522 81 bccm@dts.mg	
	Mining Ministry		Ampandrianomby Antananarivo (+261)20 22 413 72	
Buildings	Municipality of Fotadrevo		Fotadrevo	Deputy Mayor: (+261) 33 71 713 17
Others	South Western Region		South Western Region Office Toliara	
	District of Ampanihy		Ampanihy	Deputy District Chief: 033 18 356 40
	Local population (to be consulted on any activities concerning them)		Each affected population and location is listed in the RAP report (Refer Section 12).	

7. Land Tenure

According to the Mining Code the Promoter has to negotiate with the land owner before any activities may be undertaken. The approach and methodology can be described as follows (some of these activities have already been completed):

- In addition to the desktop identification and subsequent site verification of affected people, topographic survey will be undertaken. These activities will result in the establishment of certified plot plans by a registered surveyor (or by the topographic department).
- After this, or in parallel, a detailed survey of the affected people level will be done which results in the establishment of an identification sheet for each affected plot, indicating the following:
    - The name of the owner
    - The surface area of the particular plot
    - The occupation of the owner
    - The availability of any official documents (from this process it was established that all identified plots are occupied via ancestral rights ownership and that there are not any titled properties)
- Negotiation with the owner regarding compensation for the acquisition of the land.
- Establishment of the lease agreement, resulting in finalisation of the agreed offer (negotiated) with the owner (once-off). This takes the form of a willing seller- willing buyer system, yet the seller remains the owner of the land upon the expiry of the lease (maximum 99 years).
- The same with the establishment of the lease with the domain department (for land belonging to the public domain of the State). Here the price is not negotiated; the domain department sets the cost of the lease (once-off) according to their price reference.
- Signature of the lease and certification by a notary.
- The proposed approach is that the owner has to first sign the lease, then all signed leases will be presented to the promoter for signature and will then be sent to be certified by a notary.
- Registration at domain department then occurs.
- Once the leases are signed and certified, three copies are prepared. One copy for the owner, 1 copy for the promoter and 1 copy for the domain and topographic department, for the registration in their database regarding the legal status of the concerned land.
- The promoter will then proceed with the compensation payments and is then allowed to commence with any activities on the land.

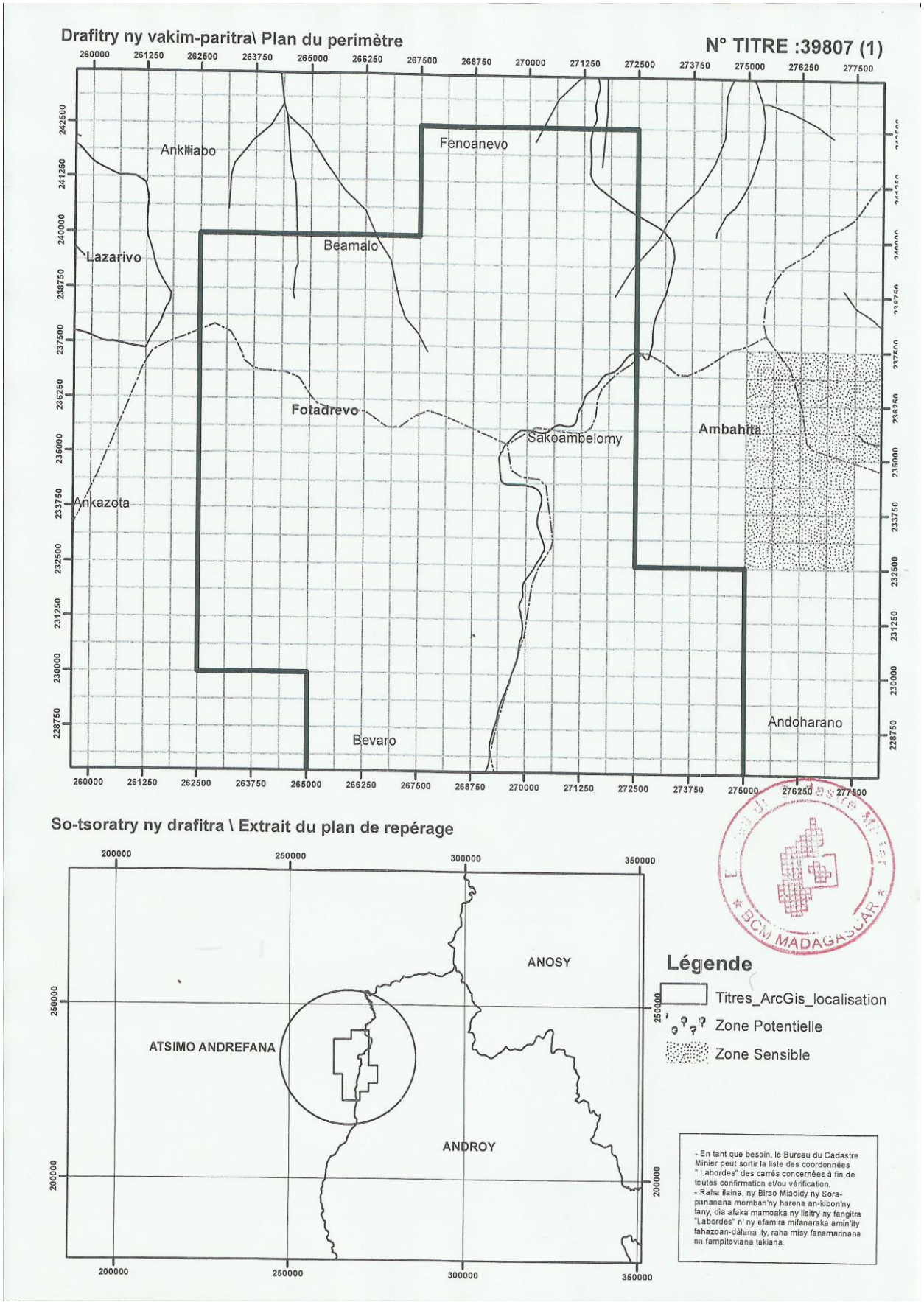
In respect of the abovementioned process, NextSource has made the following progress:

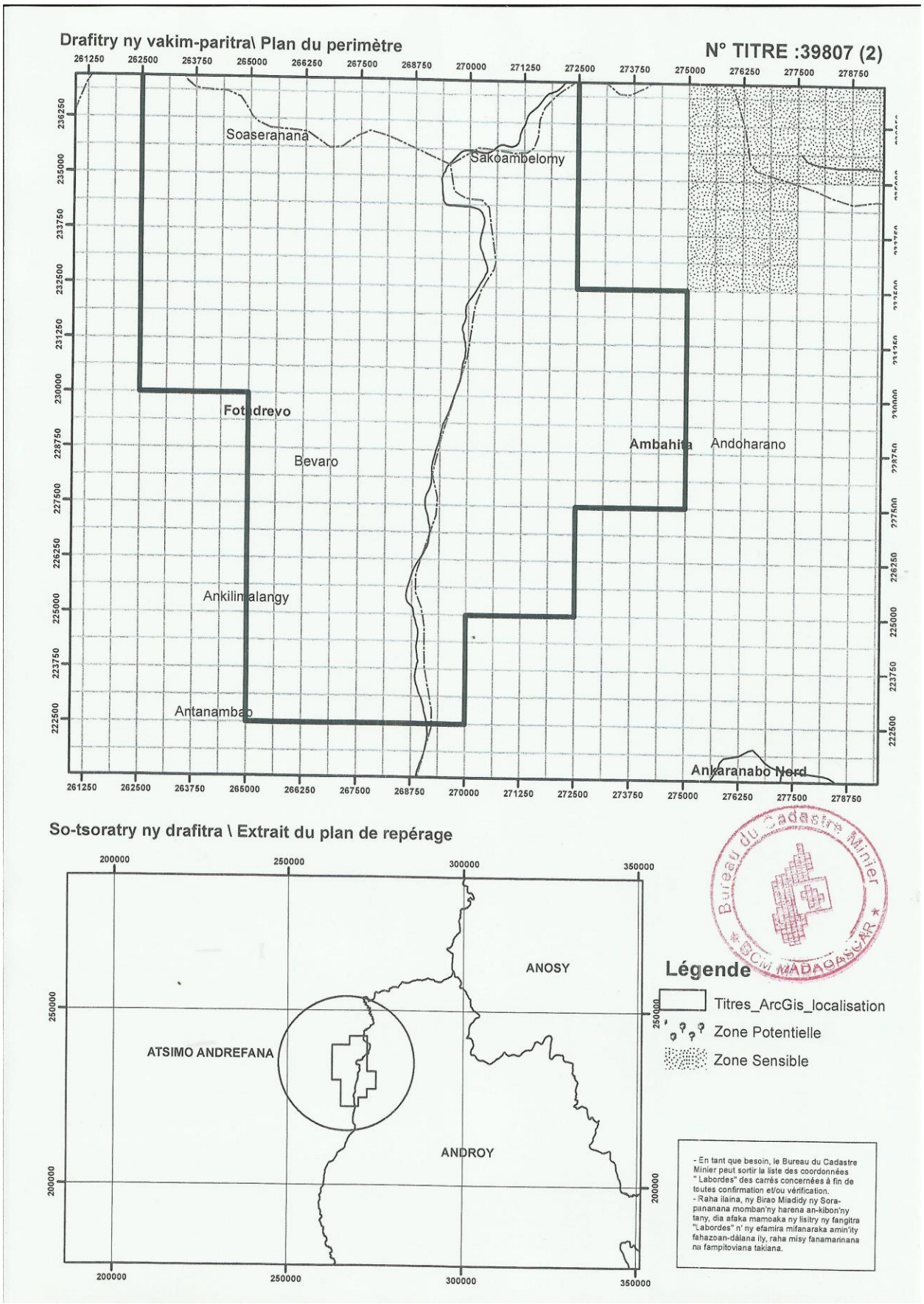
- The application processes have been identified and defined with local specialist input;
- Identification of relevant government officials are in progress;
- The exact area of influence has been defined; and
- Community engagement will commence imminently, once plot plan has been finalized.

Initial indications are, based on the 240kt area of influence, that only crops and fields would require compensation and relocation, and that no dwellings or communities would require relocation at this stage. This will, however, be confirmed once stakeholder engagement commences.

The estimated timeline for completion is approximately 9 months from date of formal commencement with the process.

Annexure A: Mining Cadastre Permit No. 3432




Drafitry ny vakim-paritra\ Plan du perimètre
N° TITRE :39807 (2)
261250 262500 263750 265000 266250 267500 268750 270000 271250 272500 273750 275000 276250 277500 278750
236250 235000 233750 232500 231250 230000 228750 227500 226250 225000 223750 222500
Soaseranana
Sakoambelomy
Fotadrevo
Bevaro
Ambahita
Andoharano
Ankilimalangy
Antanambao
Ankaranabo Nord
So-tsoratry ny drafitra \ Extrait du plan de repérage
200000 250000 300000 350000
ANOSY
ATSIMO ANDREFANA
ANDROY
Légende
Titres_ArcGis_localisation
Zone Potentielle
Zone Sensible
Bureau du Cadastre Minier
BCM MADAGASCAR
- En tant que besoin, le Bureau du Cadastre Minier peut sortir la liste des coordonnées " Labordes" des carrés concernées à fin de toutes confirmation et/ou vérification.
- Raha ilaina, ny Birao Miadidy ny Sora-pananana momban'ny harena an-kibon'ny tany, dia afaka mamoaka ny lisitry ny fangitra "Labordes" n' ny efamira mifanaraka amin'ity fahazoan-dàlana ity, raha misy fanamarinana na fampitoviana takiana.

Annexure B: Permit No. 39807

REPUBLIQUE DE MADAGASCAR
« Fitiavana – Tanindrazana – Fandrosoana »
MINISTERE AUPRES DE LA PRESIDENCE CHARGE DES MINES ET DU PETROLE

BCMM
BUREAU DU CADASTRE MINIER DE MADAGASCAR

CERTIFICAT D'ENREGISTREMENT

Délivré sur la demande de Monsieur/Madame:
ROLAND FOK SEUNG
Le Gérant de la Société ERG MADAGASCAR S.A.R.L.U.

---------- oOo ----------

Le Bureau du Cadastre Minier de Madagascar dénommé (BCMM), sis Ampandrianomby, Antananarivo, suivant les informations enregistrées dans sa base de données,
Certifie par le présent que :
Nom: MADA-AUST *Prénoms/Statut:* S.A.R.L.
Adresse: Batiment L Ex-Cité BRGM Ampandrianomby, Rue Farafaty ANTANANARIVO 101
est titulaire de permis minier ayant les informations ci-après: Permis N° 39807 *renouvelé le* 21/09/2015 *sous l'arrêté/décision N°* 29551/2015 *pour une durée de* 03 *ans qui couvre(nt) le(s) substance(s) suivante(s):* Cuivre, Nickel, Cobalt, Labradorite, Chrome, Fer, Manganèse, Platine, Palladium, Rhodium, Or, Argent, Vanadium, Bentonite, Fluorspar, Kaolin, Marbre, Phosphate, Staurotide, Lithium, Vermiculite, Granite, Kyanite, Mica, Potash, Zéolite, Alunite, Carbonatite, Graphite, Argile, Olivine, Pumice, Barite, Corindon, Gypse, Dolomite, Perlite, Quartz

Type	*Nb Cr*	*Commune*	*Province*
R	320	Fotadrevo	TOLIARA
R	128	Ambahita	TOLIARA

portant **448** *carré(s), sous réserve du paiement des frais d'administration minière annuels ,*

""En tant que de besoin, le Bureau du Cadastre Minier peut sortir la liste des coordonnées « Labordes » des carrés concernées aux fins de toutes confirmations et/ou vérifications.""

FAM:	2001	*Date de Paiement:*	05/07/2001	*OV N°:*	01/202	*QUIT. N°:* 0141660D
FAM:	2002	*Date de Paiement:*	26/03/2002	*OV N°:*	C066/02	*QUIT. N°:* 801453D
FAM:	2003	*Date de Paiement:*	11/03/2003	*OV N°:*	C489/03	*QUIT. N°:* 125037E
FAM:	2004	*Date de Paiement:*	22/03/2004	*OV N°:*	C1063/04	*QUIT. N°:* 418283C
FAM:	2005	*Date de Paiement:*	24/03/2005	*OV N°:*	C1175/05	*QUIT. N°:* 0A
FAM:	2006	*Date de Paiement:*	28/03/2006	*OV N°:*	C1164/06	*QUIT. N°:* 988179B
FAM:	2007	*Date de Paiement:*	28/03/2007	*OV N°:*	C952/07	*QUIT. N°:* 67532D
FAM:	2008	*Date de Paiement:*	28/03/2008	*OV N°:*	C927/08	*QUIT. N°:* 431918C
FAM:	2009	*Date de Paiement:*	30/03/2009	*OV N°:*	C582/09	*QUIT. N°:* 493728D
FAM:	2010	*Date de Paiement:*	29/06/2010	*OV N°:*	C1150/10	*QUIT. N°:* 429826A
FAM:	2011	*Date de Paiement:*	31/03/2011	*OV N°:*	C195/11	*QUIT. N°:* 432052A
FAM:	2012	*Date de Paiement:*	28/03/2012	*OV N°:*	C162/12	*QUIT. N°:* 432499A
FAM:	2013	*Date de Paiement:*	28/03/2013	*OV N°:*	C161/13	*QUIT. N°:* 432765A
FAM:	2014	*Date de Paiement:*	14/08/2014	*OV N°:*	C715/14	*QUIT. N°:* 835295DR
FAM:	2015	*Date de Paiement:*	15/12/2015	*OV N°:*	C723/15	*QUIT. N°:* 951899DR
FAM:	2016	*Date de Paiement:*	25/04/2016	*OV N°:*	C514	*QUIT. N°:* 843371DR 3/4
FAM:	2016	*Date de Paiement:*	14/04/2016	*OV N°:*	C501/16	*QUIT. N°:* 843365DR

Mouvement(s) du permis enregistré(s) au Bureau du Cadastre

Demande N°	*Type Acte*	*Type*	*En date du*	*Date Signature*	*N° Acte*
3432-1	TRANSFORMATION / EXTENSION	R	19/07/2002	20/11/2002	7123/2002
4332-3	CESSION	R	22/06/2005	20/07/2005	10172/2005
3432-2	TRANSFORMATION PARTIELLE	R	24/01/2006	10/03/2006	3435/2006
3432-4	TRANSFORMATION PARTIELLE	R	29/11/2006	18/01/2007	2036/2007
3432	TRANSFORMATION EN CARRE DE 625m	R	12/10/2007	26/10/2007	19353/2007
3432-5	EXTENSION DE SUBSTANCE(S)	R	18/01/2008	13/03/2008	-
3432-6	AMODIATION	R	01/10/2008	01/10/2008	3432
3432-7	RENONCIATION PARTIELLE	R	03/12/2008	19/01/2009	3432
3432-8	RENOUVELLEMENT	R	17/08/2011	21/09/2015	29551/2015
3432-9	EXTENSION SUBSTANCES / AMODIATION	R	11/02/2014	19/10/2015	-
3432-10	RENONCIATION PARTIELLE	R	16/12/2014	19/10/2015	
3432-11	RENONCIATION PARTIELLE	R	11/12/2015		
3432-12	CESSION PARTIELLE	R	14/04/2016		
3432-13	CESSION PARTIELLE / TRANSFORMATION	E	14/04/2016		

et, ce permis minier fait l'objet d'une procédure de CESSION PARTIELLE et TRANSFORMATION enregistrée au profit de:
Nom: ERG MADAGASCAR *Prénoms/Statut:* S.A.R.L.U.
Adresse: Près Lot 001 A BIS Andranomena Antehiroka - 101

Conformément aux dispositions de l'article 205 du Code Minier, ce(s) permis minier(s) garde(ent) leur période de validité jusqu'à l'échéance initialement prévue, nonobstant un changement ultérieur des régimes miniers, qui peut intervenir par application d'une loi nouvelle.

Cette disposition ne dispense pas, toutefois, le titulaire des obligations qui peuvent être requises par ladite loi nouvelle.
La validité de ce certificat est de trois (03) mois après sa signature.
En foi de quoi, ce certificat lui est délivré pour servir et valoir ce que de droit .

Antananarivo le 28 AVR 2016

Bureau du Cadastre Minier BCM MADAGASCAR

Chef Service Juridique
BCM MADAGASCAR

Bureau du Cadastre Minier de Madagascar : Tel: 22 522 81 FAX : 22 522 26 E-mail: bccm@moov.mg

Annexure C: Global Environmental Permit Process

The MECIE Decree lays down the rules and procedures to be followed to:

- ensure the compatibility of investments with the environment; and
- specify the nature, respective attributions and the degree of authority of the institutions or organizations entitled for thi s purpose.

STEP	COMMENTS	OUTPUT	WBANK PROCEDURES
(1) Screening	Fill in a form available at ONE office	A letter from O.N.E indicating the category of study to be undertaken: (1) Small projects: nothing required (2) Medium projects and reversible impacts: an environmental commitment plan is required (3) Full EIA: Projects with significant adverse environmental impacts that are sensitive, diverse, or unprecedented.	(i) Category C (ii) Category B (iii) Category A
(2) Signature of a protocol of collaboration with ONE	Such protocol de fines a few aspects: - Payment of the fees (see below) - Monitoring of the studies - Tentative timetable until environmental permit delivery	Optional but recommended	
(3) Submission and subsequent approval of terms of reference (ToR) of the study	O.N.E. may organize public consultations on the ToR (depending on the project)	Optional but recommended	

STEP	COMMENTS	OUTPUT	WBANK PROCEDURES
(4) Environmental and social studies	As appropriate, intermediate meetings with O.N.E are possible during the studies		
(5) Certification of the total investment amount	Will enable ONE to fix the contribution fees on step (6)		
(6) Payment of the contribution fees pertaining to review and follow-up costs to O.N.E according to the above-mentioned protocol	• 0,5% of the amount of the material investment if the latter is less than 2 billion Ar • 2 million Ar + 0,4% of the amount of the material investment if the latter is between 2 billion and 5 billion Ar • 7 million Ar + 0,3% of the amount of the material investment if the latter is between 5 billion and 25 billion Ar • 32 million Ar + 0,2% of the amount of the material investment if the latter is between 25 billion and 50 billion Ar • 82 million Ar + 0,1% of the amount of the material investment if the latter is higher than 50 billion FMG		

STEP	COMMENTS	OUTPUT	WBANK PROCEDURES
(7) Submission of environmental and social impact reports (ESIA) to ONE			
(8) Analysis of admissibility by ONE	A letter of admissibility will be sent by O.N.E and the assessment period runs from that day		
(9) Constitution of the technical review Committee (CTE) by ONE	Representatives of departments and communities concerned		
(10) Review by O.N.E (including on-site evaluation by the committee)	There will be public consultations for public hearings (free entrance in the sessions by any interested person)		
(11) Public consultations	For category A projects: - Public audiences - Placement in public places accessible to the affected groups of Malagasy and French summaries	Feedback from affected communities	Information disclosure process
(12) Modification of the provisional reports on the basis of comment of the ONE and transmission of the final reports to ONE	Submission of the final document to ONE		
(13) Preparation of the draft CCE by ONE	The CCE lists also the specific EMPs (environmental management plans) to be prepared prior to construction and operation (along		

STEP	COMMENTS	OUTPUT	WBANK PROCEDURES
	the way, it is possible that an additional list is provided)		
(14) Comments on the draft CCE by the promoter	The promoter is allowed to suggest more realistic measures than the committee does		
(15) Issuance of Environmental Permit and related CCE	The EMPs (included in the CCE) should be implemented in an adequate way		
(16) Integration of the envisaged measures in the call for tenders	Environmental and social costs taken into account		
(17) Placement of the final reports in public places accessible to the affected groups by ONE	Information disclosure	The affected communities and NGOs can be able to alert the authorities in case of failure by the project promoter	Information disclosure

Annexure D: Quarries and Borrow Pits

According the Art 26, 28, 51, 54, 270, 276, 314,315 of the Mining Code, the opening of a borrow pit must be authorised by the Municipality. The deliverance of this authorization may take 2 weeks and the corresponding administration fees of its application differ from one Municipality to another one. This is generally symbolic.

Annexure E: Building Permit Process

PHASE	ESTIMATED PERIOD	OUTPUTS	OUTCOMES	COMPETENT AUTHORITY	INFORMATION, NECESSARY DOCUMENTS AND LEVEL OF DETAIL, ADMINISTRATION REQUIREMENTS
1. Alignment application					
Step1: study of admission of the dossier	10 days	• Alignment authorization • Alignment sketch • Planning prescription • Payment notice datasheet • 01 official plan of the site with its Laborde coordinates • 01 legal certificate of registration and legal status less than 3 months	Issuance of the alignment authorization	Municipality	Official plan of the land with Laborde Coordinates (2 copies) from topographic department legal certificate of registration and legal status less than 3 months (2copies) from domain department For the applicant: • Certified copy of the National Identity Card (1 copy) • Stamped envelopes with address (2 copies) • Forms to be signed (1 copy)
Step 2: Legal land technical studies				Municipality	

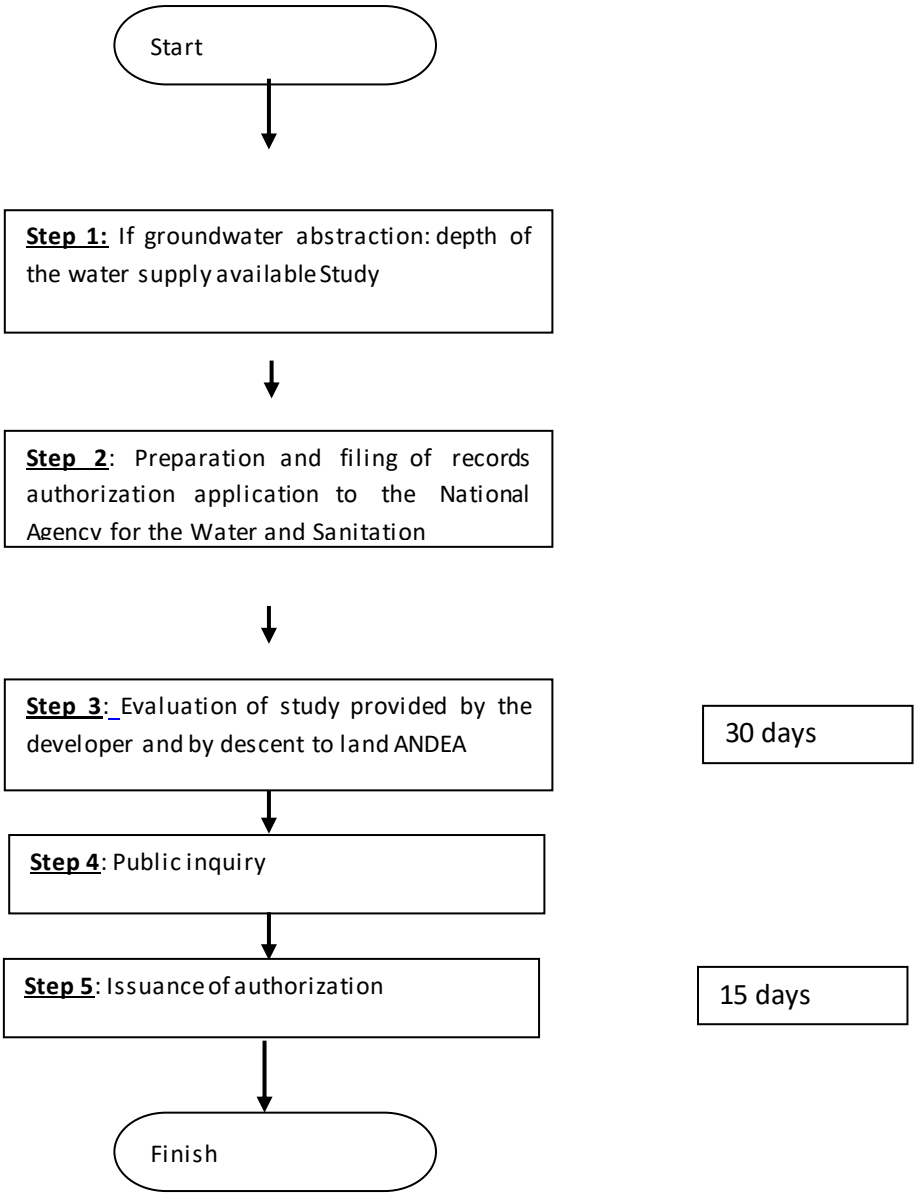
PHASE	ESTIMATED PERIOD	OUTPUTS	OUTCOMES	COMPETENT AUTHORITY	INFORMATION, NECESSARY DOCUMENTS AND LEVEL OF DETAIL, ADMINISTRATION REQUIREMENTS
Step 3: On site visit after appointment				Municipality	
Step 4: Payment of fees Withrawal of dossier dealt			Payment	Promoter Municipal treasury Municipality	
2. Prescription on town planning (SRAT: Regional service for Town planning)					
Step 5: On site visit Withdrawal of dossier dealt at SRAT	10 to 15 days	Alignment authorization with town planning prescription overleaf	Prescriptions issued	SRAT	Documents delivered after alignment: Official plan of the land with Laborde Coordinates (1 copy) certificate of legal status less than 3 months (1copy) Demand for prescription (1 copy) Alignment Authorization (issued by the Municipality) Alignment sketch (issued by the Municipality)

PHASE	ESTIMATED PERIOD	OUTPUTS	OUTCOMES	COMPETENT AUTHORITY	INFORMATION, NECESSARY DOCUMENTS AND LEVEL OF DETAIL, ADMINISTRATION REQUIREMENTS
3. Application for Building permit					
Step 6: Application submission **Step 7**: On site visit **Step 8**: technical and legal study **Step 9:** Payment of fees **Step 10**: Withdrawal of dossier dealt	30 days	Payment notice Municipal Order authorizing the construction (01) Project plan set (01)	Building authorization	Municipality Promoter	Alignement Dossier délivered by the SRAT: • Official plan of the land with Laborde Coordinates (1 copy) • certificate of legal status less than 3 months (1copy) • Demand for prescription (1 copy) • Alignment Authorization For the applicant: • Technical form filled and signed (1 copy), • Certified copy of the National Identification Card (1 copy), • Stamped envelopes with address (2 copies), • Photos of the sites and its surroundings, • Project plan set duly signed: Site Plan with sanitation infrastructures

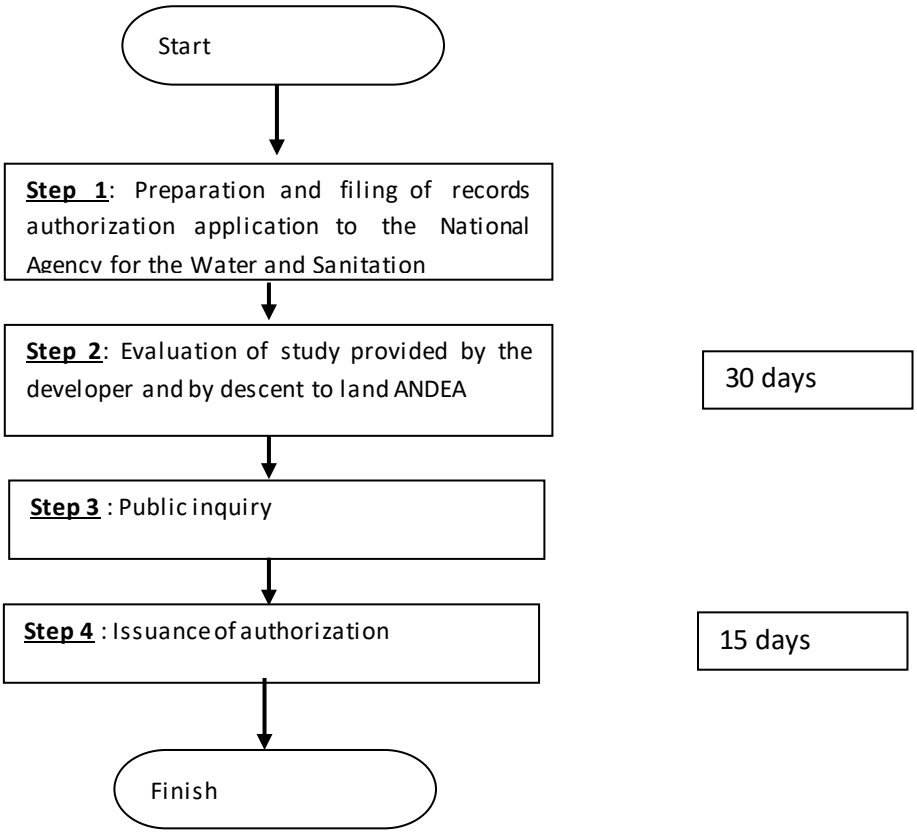
PHASE	ESTIMATED PERIOD	OUTPUTS	OUTCOMES	COMPETENT AUTHORITY	INFORMATION, NECESSARY DOCUMENTS AND LEVEL OF DETAIL, ADMINISTRATION REQUIREMENTS
					- Sectional plan, roofing, detailed plan of the building and related infrastructures: boundary wall, retaining wall.

Annexure F: Water Uptake and Water Discharge Authorization Process

APPLICATION PROCESS FOR WATER UPTAKE AUTHORIZATION



APPLICATION PROCESS FOR INDUSTRIAL WASTEWATER DISCHARGE AUTHORIZATION



Appendix G

HAZID – Graphite Dust

Globesight

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Molo Graphite Project: Research observations pertaining to Health Risk from Graphite Dust Exposure - 2017

Report Date – 23 May 2017

Globesight (Pty) Ltd— PostNet Suite #25, Private Bag X06, Helderkruin, 1733

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Configuration

Document Name:	Molo Graphite Project: Research observations pertaining to Health Risk from Graphite Dust Exposure - 2017	Status:	Draft for client review - Rev A
Report Reference:	DSS_2016_ARP	Issue Date:	2017/05/25
Author(s):	Leandré Ehlers Ferdi Pieterse	Revision:	Rev A
Approved:		Approval Date:	

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1.2 Common Graphite uses 3
2. Context 3
2.1 Graphite Dust and Graphitosis 3
2.2 Workplace Exposure 3
3. Risk Analysis 4
3.1 What is the Risk 4
4. Conclusion 5
5. References 6

1. Introduction

1.1 Graphite

Graphite is a naturally-occurring form of crystalline carbon. It is a native element mineral found in metamorphic and igneous rocks. Graphite is a mineral of extremes. It is extremely soft, cleaves with very light pressure, and has a very low specific gravity. In contrast, it is extremely resistant to heat and nearly inert in contact with almost any other material. These extreme properties give it a wide range of uses in metallurgy and manufacturing (geology.com).

1.2 Common Graphite uses

Graphite's unique collective mineral properties make it invaluable to industry. Natural graphite is in demand, not only for conventional applications such as refractories, lubricants, crucibles, coatings, gaskets, consumer electronics, pencils and advanced polymer systems, but with the emerging applications and green initiatives in nuclear energy, fuel cell and Li-ion battery technologies, the future will require a much higher supply of this unique mineral (canadacarbon.com).

2. Context

2.1 Graphite Dust and Graphitosis

Excessive exposure to graphite dust over extended periods of time can cause a chronic and more serious condition known as Graphitosis, which is a form of pneumoconiosis. This condition arises when inhaled particles of graphite are retained in the lungs and bronchi. Hazards such as Graphitosis have typically been associated with natural graphite, but have been associated with synthetic graphite in extremely rare instances. Natural graphite contains crystalline silica that precipitates Graphitosis. This is not found in synthetic graphite or any dust produced by machining synthetic graphite. Long-term inhalation studies in rodents have not shown graphite dust to have serious health effects; however, air quality samples should be taken on a regular basis to monitor the concentration of airborne graphite dust (Mercer, 2012).

Graphite pneumoconiosis, called also graphitosis and graphite fibrosis, and silicosis due to inhalation of graphite dust, which often contains up to 10 per cent silica, are illnesses associated with graphite dust exposure (Medical Dictionary, 2011).

2.2 Workplace Exposure

The current OSHA (Occupational Safety and Health Administration) standard for natural graphite is 424 752 particles of natural graphite per cubic metre of air, averaged over an eight-hour work shift. (OSHA, U.S. Department of Labour, Occupational Health Guideline for Natural Graphite, September 1978).

As identified by the American Conference of Governmental Industrial Hygienists (ACGIH), the exposure guideline for time-weighted average (TWA) for graphite dust over an 8-hour period is 10 mg/m³ total. At this concentration, the graphite dust would be thick enough to hinder visibility. Having a concentration of this magnitude in a manufacturing environment is unlikely, especially if some type of dust collection system is in use (Mercer, 2012).

3. Risk Analysis

The Washington Post has published an article about the impact of lithium-ion batteries, which includes a view on the full life cycle of said product. The paper reports on the pollution that is being caused by graphite in China. While many associate graphite with pencils, the substance has become essential for lithium-ion batteries as well, accounting for ten to fifteen percent of the total production cost of such a battery. The production of natural graphite has a significant impact on the communities that are located close to factory sites (Whoriskey, 2016).

The Washington Post heard similar stories from people in different villages: local waters and crops are being polluted, and community members worry about the health risks of eating food and breathing in air that contains graphite particles (goodelectronics.org).

3.1 What is the Risk

Despite the name, only a small portion of a lithium-ion battery consists of lithium. Graphite is used to make the negative electrode and represents about 10 to 15 percent of the cost of a typical lithium-ion battery, according to analysts (Whoriskey, 2016).

The demand for graphite has risen in parallel with the demand for more-powerful laptops, tablets and phones. Without proper controls, mining and refining can cause pollution in two ways – by air and by water. Graphite powder can quickly become airborne dust, drifting for miles. Without systems of tarps and fans to keep it under control, the resulting fine-particle pollution can cause an array of breathing difficulties, such as aggravating lung disease or reducing lung function, and has been linked to heart attacks in people with heart disease, according to the U.S. Environmental Protection Agency (Whoriskey, 2016).

Graphite operations can also lead to pollution because their chemicals leak into local waters. According to industry sources, the purifying process, especially in China, is commonly done with acids, often hydrofluoric acid, a highly toxic substance. This method is cheaper than the one used in other countries, where the graphite is purified by "baking," — that is, heating it up. Riddle, of Asbury Carbons, said refining graphite that way is better for the environment but adds about 15 percent to the price (Whoriskey, 2016).

4. Conclusion

Globesight / the author of this report is of the opinion that there is a definite indication of health and environmental risk pertaining from graphite dust exposure. However, we believe there is not enough substantial data to support a proper risk analysis since the majority of data and sources available are outdated and not recent enough to justify a concrete opinion.

It is recommended that a detailed study be undertaken by a specialist to fully assess the potential impact of graphite mining operations and its exposure on the environment and society at large.

5. References

The following sources were consulted in the preparation of this report:

http://geology.com/minerals/graphite.shtml

https://www.canadacarbon.com/what-is-graphite

http://www.moldmakingtechnology.com/articles/how-to-deal-with-graphite-dust-part-1

http://medicine.academic.ru/151869/graphite_pneumoconiosis

https://www.washingtonpost.com/graphics/business/batteries/graphite-mining-pollution-in-china/

https://goodelectronics.org/news-en/traces-of-graphite

Appendix H

HAZID – Silica Dust

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Molo Graphite Project: Research observations pertaining to potential Health Risk from Silica Dust Exposure - 2017

Report Date – 23 May 2017

Globesight (Pty) Ltd— PostNet Suite #25, Private Bag X06, Helderkruin, 1733

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Configuration

Document Name:	Molo Graphite Project: Research observations pertaining to potential Health Risk from Silica Dust Exposure – 2017.	Status:	Draft for client review - Rev A
Report Reference:	DSS_2016_ARP	Issue Date:	2017/05/25
Author(s):	Leandré Ehlers Ferdi Pieterse	Revision:	Rev A
Approved:		Approval Date:	

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1. Introduction

1.1 Silica

Silica is a natural substance found in varying amounts in most rocks, sand and clay. Silica is also a major constituent of construction materials such as brick, tiles, concrete and mortar and the second most common mineral in the earth's crust, making it one of the most common naturally occurring elements on the planet (HSE, 2017 and UCONN, 2017);

Silica, the mineral compound silicon dioxide (SiO_2), is found in two forms, crystalline or noncrystalline (also referred to as amorphous). It is the scientific name for a group of minerals containing silicon and oxygen. Sand and quartz are common examples of crystalline silica (Silica-Safe.org, 2017).

2. Context

2.1 Silica Dust and RCS (Respirable Crystalline Silica)

Dust is generated from these materials during many common construction tasks. These include cutting, drilling, grinding and polishing. Some of this dust is fine enough to get deep into your lungs. The fine dust is known as respirable crystalline silica (RCS) and is too fine to see with normal lighting. RCS is commonly called silica or silica dust (HSE, 2017).

Materials that contain crystalline silica are not hazardous unless they are disturbed, generating small-sized particles that can get in your lungs (RCS). For example, blasting, cutting, chipping, drilling and grinding materials that contain silica can result in silica dust that is hazardous for construction workers and others to breathe (Silica-safe.org, 2017).

2.2 Quartz

Quartz is the most common form of crystalline silica. Cristobalite and tridymite are two other forms of crystalline silica. All three forms may become respirable size particles when workers chip, cut, drill or grind objects that contain crystalline silica. (OSHA, 2002).

Quartz is abundant in most rocks, sands, and soils (IARC, 1997). The extensive natural occurrence of quartz and the wide uses of the materials that contain quartz are directly related to potential occupational exposures to quartz for workers in many industries and occupations. Virtually any process that involves movement of earth (e.g., mining, farming, construction), disturbance of silica-containing products such as masonry and concrete, or use of sand and other silica-containing products (e.g., foundry processes) may potentially expose a worker to quartz (IARC, 1997).

Environmental exposures to quartz can occur when ambient quartz is emitted into the air as a component of particulate emissions produced by natural, industrial and farming activities (US EPA, 1996). These activities include construction and demolition, quarrying and mining, dust from travel on paved and unpaved roads, electrical power generation, agricultural tilling, forest fires, volcanic eruptions and wind erosion (US EPA, 1996; IARC, 1997).

2.3 Workplace Exposure Limits

The Workplace Exposure Limit (WEL) value is expressed as a time weighted average (TWA) and there are two variations, the Long Term Exposure Limit (LTEL), which is the maximum exposure permitted over an 8-hour period and the Short Term Exposure Limit (STEL), which is the maximum exposure permitted over a 15-minute reference period. The LTEL is designed to protect the workforce from concentrations of contaminant, which over a large period of time could cause long-term chronic ill health effects, whereas the STEL exposure limit relates to peak exposure incidents and is designed to protect against immediate acute ill-health effects (Envirocare , 2014).

The Occupational Safety and Health Administration (OSHA) of the United States Department of Labor has issued a final rule to curb diseases associated from prolonged exposure to RCS by reducing the permissible exposure limit (PEL) for RCS to 50 micrograms per cubic meter of air, averaged over an 8-hour shift. Currently the UK and the US share the same 0.1mg/m^3 workplace exposure standard for RCS (OSHA, 2017).

At the moment, only five EU countries – Austria, Hungary, Luxembourg, Poland and Slovenia – have a weaker standard than the UK's, and three – Finland, Italy and Portugal – already have standards at or more stringent than the proposed US standard of 0.05mg/m^3. Several Canadian jurisdictions have, like Portugal, a respirable crystalline silica standard of 0.025mg/m^3. Germany goes further, regulating silica as a carcinogen, meaning all exposures should be avoided (Hazards.org, 2014).

Excerpt from Developing a silica exposure control plan, WorkSafe BC, British Columbia, Canada.

> ***If they can do it in Canada…***
>
> *"Worker exposure measurements The Occupational Health and Safety Regulation lists an occupational exposure limit (OEL) for respirable crystalline silica (including quartz) of 0.025 milligrams per cubic metre (mg/m³). This is a concentration to which nearly all workers could be exposed for eight hours a day, five days a week, without adverse health effects. However, as a suspected carcinogen, crystalline silica is also an ALARA (as low as reasonably achievable) substance, and exposures must be reduced to levels as low as reasonably achievable below the OEL."*

According to a Public Health Guidance Note (Silica and your Health, March 2002), the exposure standards only refer to particles of crystalline silica in the respirable size range i.e. particles with diameters less than approximately 7 micrometers (1 micrometer is 1 millionth of a meter (Queensland Department of Health, 2002).

3. Risk Analysis

3.1 What is the Risk

According to information from www.silica-safe.org, a worker's chance of becoming ill from exposure to silica dust depends on the tasks performed, the amount of dust they are exposed to, and the frequency of the exposures. Each exposure to silica adds into the total load of silica in the lungs – in other words, each exposure adds to the lung damage. Health professionals express the total silica dose one person accumulates over time as "mg/m^3 years," usually calculated as an average exposure each year in mg/m^3 multiplied by the number of years with that exposure, or by an estimated average for each year. As the total dose increases, so does the likelihood, or the risk, for developing silicosis, lung cancer, or chronic obstructive pulmonary disease (COPD). Some workers become ill after many years of low exposure levels, while other workers who perform less frequent but high exposure tasks can become ill with a lower cumulative exposure.

Researchers have developed estimates of the total dose likely to cause disease. For example:

- Among granite workers in the U.S. the rate of death from silicosis doubled at a cumulative exposure of less than 1 mg/m^3.
- A recent study of pottery workers found high rates of silicosis, up to 20%, among workers with an average exposure of 0.2 mg/m^3 over many years.

The likelihood of getting lung cancer from silica exposure follows a similar pattern, with a significant risk at levels around 0.2 mg/m^3 over many years, or higher exposures in a shorter period of time.

There is less information available to estimate the risk for COPD, but there is documentation showing that about 25% of cement masons, bricklayers, and plasterers have COPD after many years of work in the trade. These very general estimates do not take into account individual susceptibility or other exposures at work that add onto the injury caused by silica and lead to disease at an earlier age.

It is important to remember that repeated exposures to silica add up to a total dose that can cause serious lung disease. The kinds of exposures we see in high exposure tasks, such as sandblasting and tuckpointing, over time can give a worker enough exposure to put him or her at serious risk for a silica-related illness.

Silica is the biggest risk to construction workers after asbestos. Heavy and prolonged exposure to RCS can cause lung cancer and other serious respiratory diseases. HSE (Health and Safety Executive, the UK official workplace safety regulator, the Health and Safety Executive) commissioned estimates it was responsible for the death of over 500 construction workers in 2005. In addition to the risks from lung cancer, silica is also linked to other serious lung diseases, according to the HSE:

- Silicosis can cause severe breathing problems and increases the risk of lung infections. Silicosis usually follows exposure to RCS over many years, but extremely high exposures can cause acute silicosis more quickly.
- Chronic obstructive pulmonary disease (COPD) is a group of lung diseases including bronchitis and emphysema. It results in severe breathlessness, prolonged coughing and chronic disability. It can be very disabling and is a leading cause of death. Around 4000 deaths are estimated annually due to COPD resulting from past workplace exposures in the past. Construction workers are a significant at risk group within this.

Other common diseases associated from prolonged exposure to RCS include pulmonary tuberculosis, autoimmune diseases such as rheumatoid arthritis, systemic lupus erythematosus (SLE), scleroderma, sarcoidosis, renal disease and some connective tissue disorders.

4. Risk Mitigation

The OSHA advises the following action to be taken to protect against silica exposure:

- **Silica Substitutes:** Reducing RCS exposure is achievable by making use of silica substitutes by using a different, safer material in place of the silica-containing substance where possible. Where silica products must be used, the OSHA requires that engineering controls be used wherever possible.
- **Engineering Controls:** Some of these controls may be very simple such as installing a water hose to wet down the dust at the point of generation and installing dust collection systems onto machines or equipment that generates dust, amongst other measures.
- **Work Practices:** Informing workers about what to do to reduce silica intake and understanding the severity of its health hazard is an important and empowering measure that is easy to implement and uphold as a work practice.
- **Personal Protective Equipment:** A good option as a temporary control is wearing Personal Protective Equipment (PPE) against silica exposure, which includes respirators and masks.

Additional control measures to mitigate the risk of and lowering RCS exposure can further include the following[1]:

- Reduce the permissible exposure limit (PEL) / workplace exposure limit (WEL) for RCS to at least 50 micrograms per cubic metre of air, averaged over an 8-hour shift;
- Make use of common dust control methods, such as wetting down work operations to keep silica-containing dust from getting into the air;
- Enclosing an operation ("process isolation");
- Using a vacuum to collect dust at the point where it is created before workers can inhale it;
- Require employers to:
    - Use engineering controls (such as water or ventilation) to limit worker exposure to the PEL;
    - Provide respirators when engineering controls cannot adequately limit exposure;
    - Limit worker access to high exposure areas;
    - Develop a written exposure control plan;
    - Offer medical exams to highly exposed workers and give them information about their lung health;
    - Train workers on silica risks and silica-related hazards and how to limit exposure.
- Replace crystalline silica materials with safer substitutes, whenever possible (OSHA Fact Sheet, 2002);
- Where disposable or washable work clothes and shower if facilities area available. Vacuum the dust from clothes and / or change into clean clothing before leaving the work site (OSHA Fact Sheet, 2002);

[1] https://www.osha.gov/OshDoc/data_General_Facts/crystalline-factsheet.pdf
https://www.osha.gov/silica/factsheets/OSHA_FS-3683_Silica_Overview.html
https://www.osha.gov/silica/index.html

- Provide and / or participate in training, exposure monitoring and health screening and surveillance programmes to monitor any adverse health effects caused by crystalline silica exposures (OSHA Fact Sheet, 2002);
- Be aware of the operation and job tasks creating crystalline silica exposures in the workplace environment and know how to protect yourself (OSHA Fact Sheet, 2002);
- Be aware of the health hazards related to exposures to crystalline silica. Smoking adds to the lung damage caused by silica exposures (OSHA Fact Sheet, 2002);
- Do not eat, drink, smoke or apply cosmetics in areas where crystalline silica dust is present. Wash your hands and face outside of dusty areas before performing any of these activities (OSHA Fact Sheet, 2002).

5. Conclusion

Following from the information presented in this report Globesight advises that an acceptable exposure standard is selected which will ensure sufficient limitation of exposure in order to mitigate or negate any potential human health risks due to the presence of silica dust (if applicable). As stated in the report, several Canadian jurisdictions have a respirable crystalline silica standard of 0.025mg/m^3, which is more stringent than the current UK and US standards of 0.1mg/m^3.

Sufficient knowledge about effective control measures are available and can easily be implemented in order to limit exposure to RCS and to ensure work place exposure falls within acceptable standards that are environmentally safe.

6. References

The following sources were consulted in the preparation of this report:

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