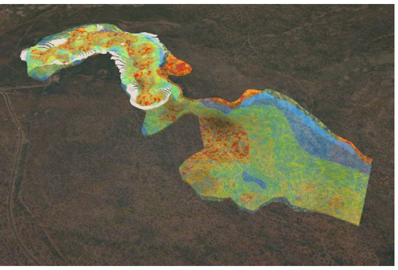
K.Hill Battery-Grade Manganese Project

National Instrument 43-101 Technical Report Feasibility Study



Effective Date: 14th November 2022

TSXV:EMM | OTC:CATPF

K.Hill Battery-Grade Manganese Project Feasibility Study

National Instrument 43-101 Technical Report

Prepared for:

Giyani Metals Corp.

Prepared by:

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Coffey Geotechnics Ltd., a Tetra Tech Company

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Effective Date:

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Signature Page

This report entitled *K.Hill Battery-Grade Manganese Project Feasibility Study, National Instrument 43-101 Technical Report*, with an effective date of 14th November 2022, was prepared on behalf of Giyani Metals Corp. by the following Qualified Persons:

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Note: Appendices for the Feasibility Study are available upon request from Giyani Metals Corp.

Abbreviations and Acronyms

AACE	Association for the Advancement of Cost Engineering
Ag	silver
Ai	Bond abrasion index
AIMS	African Mineral Standards
Al	aluminium
Al_2O_3	aluminium oxide
AM	Asian Metal
ANFO	ammonium nitrate and fuel oil
As	arsenic
Au	gold
Ba	barium
$Ba(OH)_2$	barium hydroxide
Be	beryllium
Bi	bismuth
BID	Background Information Document
BMS	Battery Management Systems
BOCRA	Botswana Communications Regulatory Authority
BOD	biological oxygen demand

BPC	Botswana Power Corporation
BR	Botswana Railways
BWi	Bond ball work index
Ca	calcium
Ca	calcium
$CaCO_3$	limestone
CAGR	compound annual growth rate
CaO	calcium oxide
CaOH	lime
Cd	cadmium
CDB	chert dolomite breccia
Ce	cerium
CF	cashflow
CFR	cost and freight
CIM	Canadian Institute of Mining, Metallurgy and Petroleum
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
Co	cobalt
COD	chemical oxygen demand
CONG	conglomerate
CPM	CPM Group LLC
Cr	chromium
Cr_2O_3	chromium oxide
CRM	certified reference material
CRT	constant rate test
Cu	copper
CWi	Bond crushability work index
D2EPHA	di-(2-ethylhexyl)phosphoric acid
DAF	dissolved air flotation
DC	direct current
DCF	discounted cash flow
DD	diamond drilling or diamond drill
DDP	delivered duty paid
DEA	Department of Environmental Affairs
DGPS	differential global positioning system
DMU	a discrete management unit
DTH	down-the-hole
E	east
EBITDA	earnings before interest, taxes, depreciation, and amortization
EIA	Environmental Impact Assessment
EMD	electrolytic manganese dioxide
EMM	electrolytic manganese metal
EMP	Environmental Management Plan
EP4	Equator Principals 4

EPCM	engineering, procurement, and construction management
ESAP	Environmental and Social Action Plan
ESG	environmental, social, and governance
ESIS	Environmental and Social Impact Statement
ESMP	Environmental and Social Management Plan
ESS	energy storage systems
EV	electric vehicle
FCA	free carrier
Fe	iron
$Fe_2(SO_4)_3$	ferric sulphate
Fe_2O_3	iron oxide
FEL	felsite
Fe-shale or FSH	iron shale
FOB	free on board
FS	Feasibility Study
g	gram
G&A	general and administrative
Ga	gallium
Ge	germanium
GEM	GEM Systems Inc.
GIIP	Good International Industry Practice
Giyani	Giyani Metals Corp.
GPS	global positioning system
GSI	geological strength index
H_2SO_3	sulphurous acid
H_2SO_4	sulphuric acid
HDPE	high-density polyethylene
HF	hydrofluoric acid
HMI	human-machine interface
HPEMM	high-purity electrolytic manganese metal
HPMSM	high-purity manganese sulphate monohydrate
HPMSS	high-purity manganese sulphate solution
HSE	health, safety, and environment
HV	high voltage
I/O	input/output
ICP-OES	inductively coupled plasma-optical emission spectroscopy
IEC	International Electrotechnical Commission
IFC	International Finance Corporation
In	indium
IP	induced polarization
IRA	inter-ramp angle
IRR	internal rate of return
IRS	intact rock strength
ISO	International Organization for Standardization

IUCN	International Union for Conservation of Nature
K	potassium
K.Hill, the K.Hill Project, or the Project	the Kgwakgwe Hill Battery-grade Manganese Project
K_2O	potassium oxide
La	lanthanum
Lab 4	Lab 4 Inc.
LFP	lithium-iron-phosphate
Li	lithium
LMO	lithium-manganese oxide
LNMO	lithium-nickel-manganese oxide
Loci Environmental	Loci Environmental (Pty) Limited
LOI	loss on ignition
LOM	life of mine
LV	low voltage
M366	Magnafloc 336
Manganese X	Manganese X Energy Corp.
MAP	Mean annual precipitation
Marble Lime	Marble Lime Associated Industries
MCC	motor control centre
MDG	Mmamokhasi Dam Group
Menzi Battery Metals	Menzi Battery Metals (Pty) Ltd.
Mg	magnesium
MgO	magnesium oxide
Mn	manganese
$Mn(OH)_2$	manganese hydroxide
Mn-clay or MCLAY	manganiferous clay
MnO	manganese oxide
Mn-shale or MSH	manganiferous shale
Mo	molybdenum
MSA	MSA Group (Pty) Ltd.
MV	medium voltage
N	north
Na	sodium
Na_2O	sodium oxide
NaHS	sodium hydrosulphide
Nb	niobium
NCA	nickel-cobalt-aluminium
NH_3	ammonia
Ni	nickel
NI 43-101	National Instrument 43-101
NMC	nickel-manganese-cobalt
NMCA	nickel-manganese-cobalt-aluminium
NMx	nickel-manganese

NPV	net present value
P	phosphorus
P_2O_5	phosphorus pentoxide
Pb	lead
PEP	Project Execution Plan
PFD	process flow diagram
PL	Prospecting Licence
PLC	programmable logic controllers
PPE	personal protective equipment
PVC	polyvinyl chloride
PwC	PricewaterhouseCoopers Associates
p-XRF	portable x-ray fluorescence
QA	quality assurance
QC	quality control
QEMSCAN	Quantitative Evaluation of Materials by Scanning Electron Microscopy
QP	Qualified Person
Rb	rubidium
RC	reverse circulation
RES	Remote Exploration Services (Pty) Ltd.
RF	revenue factor
RMR	rock mass rating
RMU	ring main unit
RO	reverse osmosis
Rocklab	Rocklab Laboratory
ROM	run of mine
Rotsrill	RotsDrill Botswana
RTD	resistance temperature detectors
RTK	real-time kinematic
S	south
S	sulphur
Sb	antimony
SCADA	supervisory control and data acquisition
Se	selenium
Se	selenium
SEP	Stakeholder Engagement Plan
SG	specific gravity
SGS Lakefield	SGS Canada Inc.
SGS Randfontein	SGS Randfontein - Natural Resources
SHL	beige-cream shale
Si	silicon
SiO_2	silicon dioxide
SMM	Shanghai Metal Markets
Sn	tin
SO_2	sulphur dioxide

SPMDD	standard Proctor maximum dry density
Sr	strontium
SRK	SRK Consulting (Kazakhstan) Ltd.
Ta	tantalum
Te	tellurium
TEM	Technical Economic Model
Tetra Tech	Coffey Geotechnics Ltd., a Tetra Tech Company
Ti	titanium
TiO_2	titanium oxide
Tl	thallium
TMF	tailings management facility
TMS	Thermal Management System
TOR	Terms of Reference
TSS	total suspended solids
TSXV	TSX Venture Exchange
UCS	uniaxial compressive strength
UPS	uninterruptable power supply
UTM	Universal Transverse Mercator
V	vanadium
V_2O_5	vanadium pentoxide
VDC	Village Development Committee
VDC	volt direct current
VHF	very-high frequency
VSD	variable speed drive
W	west
WGS	World Geodetic System
WRD	waste rock dump
WUC	Water Utilities Corporation
XRF	x-ray fluorescence
Zn	zinc
Zr	zircon

Measurements

%	percent
<	less than
>	greater than
°	degree
°C	degree Celsius
µm	micron
a	annum (year)
Bt	billion tonnes
d	day
DWT	deadweight tonnage
g/L	gram per litre
g/t	gram per tonne
Ga	billions of years
GWh	gigawatt hour
h	hour
k	kilo
kg	kilogram
kg/d	kilogram per day
kg/t	kilogram per tonne
km	kilometre
km^2	square kilometre
kN/m^3	kilonewton per cubic metre
kPa	kilopascal
kt	kilotonne
kV	kilovolt
kWh	kilowatt hour
L	litre
M	million
m	metre
m^2	square metre
m^3	cubic metre
masl	metres above sea level
mbgl	metres below ground level
mg	milligram
mg/L	milligram per litre
min	minute
mL	millilitre
mm	millimetre
mm^2	square millimetre
MPa	megapascal
Mt	million tonnes
Mt/a	million tonnes per year

mV	millivolt
MW	megawatt
MWp	megawatt peak
MWp_{dc}	megawatt peak (direct current)
NTU	nephelometric turbidity unit
P	Botswana Pula
pH	quantitative measure of acidity or alkalinity of an aqueous or other liquid solution
ppm	parts per million
R	South Africa Rand
t	tonne
t/a	tonnes per year
t/m^2	tonne per cubic metre
t/m^3	tonne per cubic metre
TWh	terawatt hour
US$	United States dollars
V	volt
W	watt
w/w	weight to weight
wk	week
Wp	watt peak

1 SUMMARY

1.1 Introduction

Giyani Metals Corp. (Giyani) intends to develop the K.Hill Battery-Grade Manganese (Mn) Project (K.Hill, the K.Hill Project, or the Project) as an integrated mining and processing operation for the manufacture of high-purity manganese sulphate monohydrate (HPMSM) on site, directly from manganese oxide (MnO) ore. HPMSM is a refined precursor material used to produce cathode powders for lithium-ion batteries deployed in electric vehicles (EVs).

As the automotive industry increases EV production as part of a global move toward decarbonisation and electrification, CPM Group LLC (CPM) reports that demand for lithium-ion batteries used in EVs is projected to grow by 25% annually between 2021 and 2031. CPM demonstrates that the resulting demand for HPMSM in lithium-ion batteries will increase nearly 30-fold between 2021 and 2036, reaching 1.8 Mt on a contained metal basis and up to 4.5 Mt by 2050. Currently, more than 90% of global HPMSM production capacity is in China, and only six non-Chinese high-purity manganese projects are forecast to come on stream in the next 5 years.

The K.Hill Project name is derived from Kgwakgwe Hill, a manganese-rich outcrop located at the southern extent of the town of Kanye in southern Botswana. This deposit can be mined using conventional open pit methods to produce the ore from which Giyani's specially developed processing facility can manufacture HPMSM to respond to the anticipated world demand for non-Chinese precursor raw material.

Giyani commissioned SRK Consulting (Kazakhstan) Ltd. (SRK) and Coffey Geotechnics Ltd., a Tetra Tech Company (Tetra Tech), in partnership with IHC Mining BV, to undertake a National Instrument 43-101 (NI 43-101) Feasibility Study (FS)-level Technical Report of this integrated scheme. This work was conducted alongside and in support of the necessary environmental and social studies and permitting for the exploration and mining phases of K.Hill by Giyani's appointed independent environmental consultancy based in Gaborone, Botswana, Loci Environmental (Pty) Limited (Loci Environmental).

Giyani has succeeded in developing a bespoke process that can produce HPMSM directly from the high-grade K.Hill manganese oxide ore. This process avoids carbon-intensive calcination and electrorefining, providing K.Hill the opportunity to develop one of the lowest carbon footprints of any such facility globally. The Project can deliver a strong return on investment over the life of mine (LOM) that exceeds 10 years as evidenced in an overview of the key project metrics presented in Table 1.1. Although the current LOM is constrained to 2 Mt of Probable Reserves, Giyani has already completed the field and laboratory work to upgrade a significant portion of the additional 3.1 Mt Inferred Resource to the Indicated Resource category. Giyani will look to incorporate the new Mineral Resource into an updated mine plan in 2023.

Table 1.1 Key project metrics

Metrics	Units	Results	
Project summary			
Type of mine	-	Conventional open pit mine	
Type of production facility	-	HPMSM hydrometallurgical processing facility	
LOM	years	11.0	
Net realised price assumption			
Average realised HPMSM price (Years 1 to 5)	US$/t	3,373	
Flat realised price HPMSM price (Years 6 to 11)	US$/t	3,918	
Production		**Annual**	**LOM**
Total ore mined	dry kt	226	2,032
ROM manganese oxide grade	% MnO	18.9	18.9
Steady-state metallurgical recovery	%	88.5	88.5
Total recovered manganese oxide	kt	31	339
Total HPMSM produced	kt	73	808
Project cash flow		**Average annual**	**LOM**
Revenue from HPMSM	US$M	272	2,993
Total operating costs (including royalties)	US$M	125	1,369
Total EBITDA	US$M	148	1,624
Initial capital cost, excluding contingency	US$M	-	249
Contingency on initial capital	US$M	-	32
Total initial capital cost, including contingency	US$M	-	281
Sustaining capital cost, including contingency	US$M	-	21
Closure costs	US$M	-	5
Total LOM capital cost, including contingency	US$M	-	307
Project economics		**Pre-tax**	**Post-tax**
NPV (8% real discount rate)	US$M	603	481
IRR	%	32.0	28.3
Payback period from the start of processing	years	3.3	3.6
Undiscounted cumulative cash flow	US$M	1,317	1,093

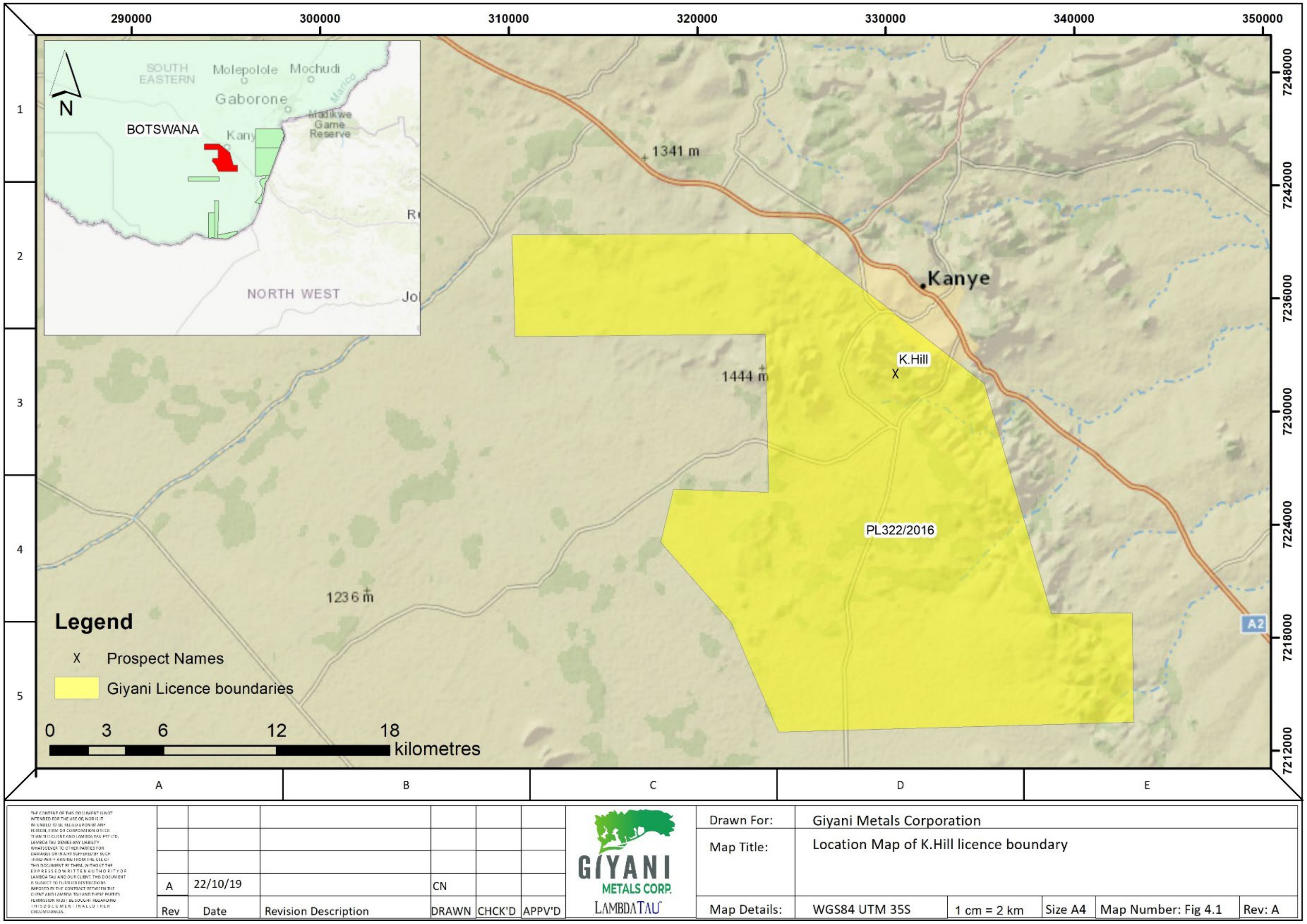
Notes: Net realised prices for HPMSM at mine gate, assuming 50% of sales to the European Union and 50% sales to North America.
ROM - run of mine
EBITDA - earnings before interest, taxes, depreciation, and amortisation
NPV - net present value
IRR - internal rate of return

1.2 Property description and location

K.Hill is located near the town of Kanye, the administrative centre of the Southern District of the Republic of Botswana. The K.Hill Project is accessible via a short section of unpaved roads and tracks from a network of paved national roads, namely the A1 and A2, with the A2 highway located just 2 km from the K.Hill Project (Figure 1.1). These highways connect the Project with export routes in Namibia to the west and South Africa to the south.

The Republic of Botswana owns the mineral rights for K.Hill. Giyani, through the Botswana-registered entity Menzi Battery Metals (Pty) Ltd. (Menzi Battery Metals), holds the exclusive right to engage in prospecting activities for "metals" within the Project area, as described in the prospecting permits issued under Section 16 of the Mines and Minerals Act of the Republic of Botswana (Government of Botswana 1999). The K.Hill Project is located within prospecting licence (PL) 322/2016 with a prospecting area of 438 km^2 within a total area of approximately 2,588 km^2 to which Menzi Battery Metals holds the prospecting rights. All PLs were renewed on 3rd August 2022 and are valid until 30th September 2024, except for PL258/2017, which was granted on 1st January 2021 and expires on 31st December 2022. These PLs also include the Otse manganese prospect and the Lobatse manganese prospect, all of which have seen historic mining activities, as well as a number of other known occurrences of manganese.

Figure 1.1 Location of the K.Hill Project



Source: Lambda Tau, 2022

1.3 History

Historical mining in the Kanye area took place from 1957 to 1971. The first company to operate at K.Hill was Marble Lime and Associated Industries (Marble Lime), which also developed the asbestos mine at Moshaneng northwest of K.Hill. Marble Lime mostly mined manganiferous shale (Mn-shale), which was beneficiated before it was sold. Marble Lime ceased mining activities around 1967 (Aldiss 1989).

In 1981, Rand London Manganese investigated the possibility of mining the Mn-shale deposits at Kgwakgwe, Otse, and Gopane (near Lobatse), together feeding a single planned processing plant at Lobatse. The additional drilling required to complete the FS was not completed, and the licence was relinquished within a year (Aldiss 1989).

In addition to formal mining and geological investigations at K.Hill, isolated artisanal mining has created a network of underground adits and galleries within the manganiferous horizons.

Little or no rehabilitation has occurred following the formal and informal mining activities, and remnants of the old operations remain.

1.4 Geology and mineralisation

The manganese mineralisation at K.Hill occurs primarily as a supergene-enriched Mn-shale present in two distinct horizons in the upper portion of a larger shale package within the Black Reef Quartzite Formation of the Transvaal Supergroup. The Mn-shale horizons are overlain by a hard chert dolomite breccia (CDB) unit. In plan, the northern part of the K.Hill deposit is approximately kidney-shaped, reflecting the pattern of outcrop along the edges of the hill, while to the south, there is outcrop expression.

The mineralised horizons have been interpreted as two main packages: the Upper Mn-shale Horizon A and the Lower Mn-shale Horizon B, both of which dip shallowly (5° to 10°) toward the NW. The current interpretation considers the horizons as continuous stratiform bodies based on outcrop (where available) and drillhole data; however, observations from a recent site visit (January 2022) indicate that the shale package as a whole has probably been deformed by post-mineralisation thrusting to form a stacked series of duplex folds and faults. A lower minor horizon (Horizon C) has also been identified with similar dips.

The Upper Mn-shale, which hosts the highest-grade manganese oxide mineralisation, varies between approximately 2 m and 15 m in thickness, with an average thickness of 4 m. Based on the existing interpretation, the Upper Mn-shale has been divided, based on grade values, into a continuous high-grade core with distinct, although slightly less continuous, lower-grade zones in the immediate footwall and hanging wall. The Lower Mn-shale horizon ranges from 1 m to 12 m in thickness with an average thickness of 3.5 m and does not show the distinct banding of grade seen in the Upper Mn-shale horizon. The two main mineralised horizons are separated by approximately 4 m of shale waste rock.

The Southern Extension Area is separated from the Northern Area of the resource by several NNW-SSE trending faults, which progressively downthrow the mineralised horizons to the south.

1.5 Drilling

Giyani has carried out drilling in five phases. The updated Mineral Resource estimate in this FS is based on the first four phases of drilling. Drilling data are stored in an electronic relational database (Datashed).

The first phase of diamond drilling (DD) was completed between April and June 2018 and consisted of a programme of 18 holes of approximately 50 m to 80 m in depth. Drillholes were located within the northern and southern portions of the deposit. Holes in the northern portion were drilled along three NW striking lines approximately 50 m and 130 m apart. The holes were drilled at approximately 100 m spacings along the lines. Holes in the southern portion of the deposit were drilled along a single N-NE striking line with holes approximately 100 m apart along the line. Of the 18 vertical DD holes drilled at K.Hill, 17 were drilled for exploration purposes, and 1 was drilled for metallurgical test work. Triple tube coring was used for drilling, and standard operating procedures were in place to guide the drilling operations. A total of 1,109 m was drilled, with 368 core samples assayed together with 57 quality control (QC) samples.

The second phase of drilling commenced in November 2020 and was completed in June 2021. The drilling was undertaken using a reverse circulation (RC) drilling rig and totalled 96 holes (including 6 redrills) for which logging, laboratory analysis, and handheld portable x-ray fluorescence (p-XRF) analysis were made available. The available data accounts for a total of 3,697 m drilled.

The third phase of 346 m of DD drilling, which occurred during the Phase 2 RC drilling programme, was completed for geotechnical purposes and to twin historical RC drillholes. Although logging data was available for use in the Mineral Resource estimate, no laboratory analysis was undertaken, as the core was submitted in full for geotechnical and comminution test work.

The fourth phase of drilling was completed in October 2021 and focused on extending and following the mineralisation to the south of northing 7233525. This phase included 2,126 m of both RC and DD drilling (28 RC and 3 DD holes).

The fifth phase of infill drilling in the K.Hill Southern Extension Area, involving 75 new holes (RC with diamond control), was completed in Q3 2022 to upgrade the area of the Mineral Resource from Inferred to Indicated. The Mineral Resource estimate will be updated in 2023 to include the results of this programme.

SRK considers that the quantity and quality of data collected during the K.Hill drilling programme are sufficient to support the reporting of a Mineral Resource in accordance with the Canadian Institute of Mining, Metallurgy and Petroleum (CIM) *Definition Standards for Mineral Resources & Mineral Reserves* (CIM 2014). Core recovery in the Phase 1 DD programme was poor, particularly within the Upper Mn-shale unit that is host to the manganese oxide mineralisation, averaging 41%. SRK notes that recoveries are much improved in the most recent Phase 3 and Phase 4 DD drilling campaigns, averaging 91% in the Mn-shales. At this stage, there is no clear relationship observed between core recovery and grade, although there is only limited data available, as the Phase 3 DD programme was undertaken for geotechnical purposes and not assayed.

DD drilling provided suitable material for density determinations; however, due to the tendency of the more friable portions of drill core to fragment when dry, the drill core sample from the Phase 1 DD programme was not oven-dried prior to completing density determinations. As no moisture content for the samples is recorded, it has not been possible to account accurately for the water content of the samples, and as such, SRK has only used data collected during the Phase 3 DD programme in determining the density for this latest study in which samples were fully dried and wax coated prior to density determination. Although this data is deemed to be more accurate, it is a significantly smaller dataset and does not have corresponding manganese oxide assays to establish a correlation between manganese oxide grade and density. The Phase 4 drilling programme only has limited density measurements taken from the three DD holes. These have a slightly lower density compared to similar horizons to the north. How representative these Southern Extension Area densities are for this area as a whole is still unsure.

Giyani has, in accordance with SRK recommendations, completed an infill drilling programme in the Southern Extension Area of the orebody as part of Phase 5 of the exploration programme. This includes drilling additional DD holes into the Southern Extension Area for the purpose of infill, obtaining additional density measurements, and continuing to undertake density measurements using the wax coating method and linking these to the assay grades.

1.6 Sample preparation, analyses and security

Sample preparation and analyses for both analysed RC and DD programmes were conducted at the SGS Randfontein - Natural Resources (SGS Randfontein) laboratory in Randfontein, South Africa.

QC samples were routinely inserted within the drillhole sample stream as part of a quality assurance (QA)/QC process. The type of QC samples used included certified reference material (CRM), blanks, and coarse duplicates. As an additional check, 40 of the samples analysed at SGS Randfontein were assayed by Intertek Genalysis laboratory in Maddington, Western Australia.

The results of the QA/QC measures applied for K.Hill do not indicate significant contamination and demonstrate a high degree of accuracy and precision. The umpire laboratory assays completed at Intertek Genalysis confirmed the primary laboratory assays within close limits. The sample preparation, security, and analytical procedures are considered to be adequate for the style of mineralisation evident at K.Hill.

1.7 Data verification

Mr. Michael John Beare, BEng, CEng, ACSM, MIMMM and Mr. James Haythornthwaite, BSc, MSc, CGeol, both of SRK, visited the Project site in December 2019 and January 2020, respectively. A follow-up visit by Mr. John Paul Hunt, MSc, FGSSA, GASA, SEG, SGA, IAGOD, GSA, of SRK, took place during the Phase 2 RC drilling programme in March 2021 to observe and validate procedures during active drilling.

Mr. Haythornthwaite conducted the following checks during the January 2020 site visit:

- inspection of mineralisation outcrops and artisanal mine workings
- check of the Giyani core storage and sampling facility
- review of the remaining drill core for holes DDKH18_002, DDKH18_005, DDKH18_008, DDKH18_0011, and DDKH18_013, including check logging

Mr. Hunt conducted the following checks during the March 2021 site visit:

- inspection of RC drilling practices
- inspection of sample storage facilities and sample dispatch

SRK completed check logging during the January 2020 site visit, which did not indicate any serious flaws in the logging completed by Giyani. SRK considers that the database is adequate for the purpose of Mineral Resource estimation.

During a follow up January 2022 site visit, Mr. Peter Gleeson, MSc, CEng, MIMMM, AIGS, of SRK, completed a review of the core for the Southern Extension Area. An update and review of the QA/QC of the latest drill sample and assay data for the Southern Extension Area also have been undertaken. SRK is confident that the nature and style of mineralisation for the Southern Extension Area is the same as that for the previously defined Mineral Resource.

1.8 Mineral processing and metallurgical testing

Using historical metallurgical test work reports and development as a starting point, Tetra Tech implemented a new test work and metallurgical development programme in order to understand and optimise the metallurgical extraction of manganese from the K.Hill deposit.

Historical documentation was available from SRK, MSA Group (Pty) Ltd. (MSA), Vietti Slurrytec, Lab 4 Inc. (Lab 4), and Dalhousie University. The available documentation covered mineralogy, chemical analysis, leach testing, and solvent extraction testing.

Test work initiated by Tetra Tech was undertaken at Mintek in Johannesburg, South Africa and included assays, specific gravity (SG), mineralogy, comminution, solid-liquid separation, leach optimisation, jarosite precipitation, iron (Fe) and aluminium (Al) precipitation, other base metal precipitation, calcium (Ca) and magnesium (Mg) precipitation, fluoride removal, crystallisation, and manganese hydroxide ($Mn[OH]_2$) precipitation.

The following summary results were obtained:

- Comminution test work indicated that the K.Hill ore displays comminution characteristics that vary from soft to hard in terms of crushability and grinding indices and were generally low in relation to abrasiveness.
- The solid-liquid testing indicated that post-leach, the Giyani material settles poorly and produces low-density thickener underflows. On this basis, the decision was made to use filtration for washing and separation rather than conventional thickening.
- The investigated leach performance indicated that a high temperature reductive leach in sulphate media produced excellent extraction results between 95% and 99%. Initial work conducted by Lab 4, using sucrose as the reductant, was replaced by using sulphur dioxide (SO_2), which provided benefits in terms of cost, practicality, and reduced acid consumption.
- Test work indicated that the stage-wise precipitation of various contaminants was effective and efficient. Manipulation of pH and addition of aqueous reagents, as well as the use of activated alumina, allowed the production of a high-purity manganese stock solution that was suitable for crystallisation of HPMSM.
- Crystallisation design was developed and the performance was confirmed based on two routes pursued for the basis of design development:
  - The use of synthetic solution produced from analytical reagents as a means for rapid and inexpensive production of crystalliser feed allowed for the development of initial process feed purity requirements and expected operational criteria.
  - The use of a fully representative stock solution made from representative ore that had been processed step-by-step through the process flow produced a significant HPMSM sample for acceptance testing and trials with customers.
- From the test work and process development, an overall recovery of 88.5% of manganese is anticipated.

1.9 Mineral Resource estimates

SRK completed an update to the October 2021 Mineral Resource estimate. The updated Mineral Resource detailed in this FS incorporates new RC and DD data, as well as additional density test work, resulting in a new set of estimation domains and an updated block model. The main differences between the October 2021 estimate and the updated model include the following:

- Phase 4 drilling results were incorporated from 28 RC and 3 DD drillholes (2,126 m of drilling).

- Fault domains were created based on offsets in the mineralised units and geophysical imagery (magnetics).
- A new geological interpretation was included for the Southern Extension Area, resulting in the definition of new mineralisation domains.

In modelling and estimating the K.Hill block model, SRK completed the following:

- A new geological domain model was constructed for the Southern Extension Area based on the key lithological units and offsets by a series of NNW-SSE trending faults. The Northern Area domains remain largely unchanged (from the October 2021 model), with only minor changes incorporated in the Northern Area models in order to integrate them into the new Southern Extension Area models.
- Four new mineralised domains were identified to the south of northing 7233525: Horizons A1, A2, B, C1, and C2; however, it should be noted that the new geological domains established for the Southern Extension Area may not be exact stratigraphical analogues of the Northern Area domains.
- Assays and density data were composited inside of the mineralisation domains to 0.5 m.
- An extended block model was created, coded, and sub-blocked by the estimation domains. The parent block size was set at 20 mX × 20 mY × 1 mZ, and the minimum sub-block size was set at 2.5 mX × 2.5 mY × 0.5 mZ.
- The block model was estimated based on the following:
  - High-grade and low-grade margin domains were estimated separately using hard boundaries.
  - No change was made to the estimation approach for the original Northern Area domains. For the Southern Extension Area domains, all variables were estimated into the domains (A1, A2, A3, B, C1, and C2) using inverse distance weighting (to the power of 2). Due to the large spacing of individual drillholes (approximately 125 m separation), it was not possible to construct robust variograms for the Southern Extension Area domains to enable a geostatistical approach to estimation. Density was assigned to blocks based on average densities derived for each geological and mineralisation unit.
  - A two-pass search strategy was used for the estimation of the high-grade Northern Area domains, with the first search range set at 120 mX × 180 mY × 10 mZ, which filled the vast majority of blocks. The second search was set to 500 mX × 500 mY × 100 mZ to fill the remaining few blocks. In the remaining lower-grade domains in the Northern Area and Southern Extension Area domains, a single large search pass was used.
  - The search ellipsoid was orientated dynamically using the corresponding domain wireframe as a guide.
  - A minimum of 4 samples and a maximum of 12 or 20 samples were used to estimate each block for the first and second search pass, with a maximum of 2 samples per drillhole:

- The estimated block grades were visually and statistically validated relative to the estimation composites.
- For the Northern Area domains A1, A2, A3, B, and C, an Indicated Mineral Resource classification was given for all blocks within 40 m of a drillhole, based on the reasonable level of geological and grade confidence and the confirmatory metallurgical test work. This remains unchanged for the Mineral Resource update except at the margins between the Northern Area and Southern Extension Area domains. For the rest of the mineralised horizons (including the Southern Extension Area domains), an Inferred Mineral Resource classification was applied up to a distance of approximately 125 m from drill sample points. Beyond this distance, where poor geological and drilling support exists, a small portion of the Northern Area and Southern Extension Area domains have not been classified. No metallurgical test work has been completed on the Southern Extension Area domains at the time of writing. However, there is nothing to suggest that the nature, style, or mineralogy of the mineralisation may be different at this stage.
- The block model was depleted using surveys of underground artisanal workings.
- In order to determine the quantities of material offering "…reasonable prospects for eventual economic extraction" (JORC 2014) through open pit mining, a pit optimisation analysis was completed on the estimated block model. This was based on reasonable mining assumptions. The Mineral Resource has been restricted to estimated blocks that fall inside of the resulting pit shell, which is based on an HPMSM price of US$1,588/t and reported above a cut-off grade of 7.3% manganese oxide. Subsequent to this optimisation study, Giyani used a revised HPMSM price of US$3,800/t but with higher processing costs. The higher price and higher mining costs basically cancel each other out; therefore, the change has resulted in only minor changes to the optimal pit. The pit shell used for the Mineral Resource statement is considered valid.

1.10 Mineral Resource statement

The Mineral Resource has been classified according to the CIM *Estimation of Mineral Resources & Mineral Reserves Best Practice Guidelines* (CIM 2019) and is reported in accordance with the 2014 *CIM Definition Standards for Mineral Resources & Mineral Reserves* (CIM 2014), which have been incorporated by reference into NI 43-101 *Standards of Disclosure for Mineral Projects* (CSA 2016). The Mineral Resources are classified into Indicated and Inferred categories (Table 1.2).

Table 1.2 K.Hill SRK Mineral Resource statement, reported within an optimised shell and at a cut-off grade of 7.3% manganese oxide, as of 22nd February 2022

Classification	Tonnes (Mt)	MnO grade (%)	MnO contained (Mt)
Indicated Mineral Resources	2.1	19.3	0.41
Inferred Mineral Resources	3.1	16.9	0.53

Notes:

(1) The Indicated and Inferred Mineral Resources are reported above a cut-off grade of 7.3% MnO.
(2) All tonnages are reported as dry.
(3) The Mineral Resource estimate is constrained within estimation domains based on geological modelling and grade and within a Lerchs-Grossman optimised pit shell based on an HPMSM price of US$1,588/t and the following technical-economic parameters:
   a. Mining cost: US$3.46/t rock
   b. Processing cost: US$213/t ROM
   c. Selling cost: 3% and a freight cost of US$60/t HPMSM
   d. General and administrative: US$20/t ROM
   e. Discount rate: 10%
   f. Processing recovery: 90.7%
   g. Mining recovery: 98%
   h. Mining dilution: 3%
   i. Geotechnical slope angle: 41°
(4) SRK notes that the long-term HPMSM price quoted is based on 2020 market data, which was available at the time of reporting the Mineral Resource. SRK understands that additional pricing information will be available for input into subsequent technical studies and this may impact the Mineral Resource reported. In light of the sensitivity of the Mineral Resource to the selling price, this is not considered to be a material risk in reporting the Mineral Resource and may present a further opportunity.
(5) All figures are rounded to reflect the relative accuracy of the estimates.
(6) Mineral Resources are not Mineral Reserves and have not demonstrated economic viability.
(7) It is uncertain if further exploration will convert Inferred Mineral Resources to higher confidence categories.

The Qualified Person (QP), in accordance with the *CIM Definition Standards for Mineral Resources & Mineral Reserves* (CIM 2014) with responsibility for the reporting of the Mineral Resource statement presented in this report, is Mr. Peter Gleeson, MSc, CEng, MIMMM, AIGS, with SRK. Dr. Tim Lucks, MAusIMM (QP), also of SRK, carried out the internal peer review for this report. Dr. Lucks role was to ensure that the highest standard of technical work was carried out.

Mineral Resources are not Mineral Reserves and have not demonstrated economic viability. SRK is not aware of any factors (environmental, permitting, legal, title, taxation, socio-economic, marketing, political, or other relevant factors) that have materially affected the Mineral Resource estimate. It is uncertain whether further exploration will convert Inferred Mineral Resources to higher confidence categories.

The Mineral Resource is presented by estimation domain in Table 1.3.

Table 1.3 K.Hill Mineral Resource, reported by estimation domain

Northern and Southern Resource domains January 2022	Resource category	Mass (Mt)	Average value MnO (%)	Metal content MnO (Mt)
Northern Horizon A1	Indicated Resource	0.31	12.2	0.04
	Inferred Resource	0.01	11.4	0.00
Northern Horizon A2	Indicated Resource	0.86	29.0	0.25
	Inferred Resource	0.08	27.1	0.20
Northern Horizon A3	Indicated Resource	0.4	11.5	0.05
	Inferred Resource	0.1	10.2	0.01
Northern Horizon B	Indicated Resource	0.39	12.0	0.05
	Inferred Resource	0.18	13.0	0.02
Northern Horizon C	Indicated Resource	0.04	10.0	0.00
	Inferred Resource	0.02	9.9	0.00
Southern Horizon A1	Indicated Resource	0.02	28.7	0.01
	Inferred Resource	0.03	28.1	0.01
Southern Horizon A2	Indicated Resource	-	-	-
	Inferred Resource	0.17	10.6	0.02
Southern Horizon A3	Indicated Resource	-	-	-
	Inferred Resource	0.02	12.3	0.00
Southern Horizon B	Indicated Resource	0.08	18.0	0.01
	Inferred Resource	2.26	18.0	0.41
Southern Horizon C1	Indicated Resource	-	-	-
	Inferred Resource	0.23	14.0	0.30
Southern Horizon C2	Indicated Resource	-	-	-
	Inferred Resource	0.03	15.5	0.00
Total	**Indicated Resource**	**2.1**	**19.3**	**0.41**
	Inferred Resource	**3.1**	**16.9**	**0.53**

1.11 Mineral Reserve estimates

The Mineral Reserve for K.Hill has been updated and is stated in Table 1.4. Indicated Mineral Resources were converted to Probable Reserves through the application of appropriate modifying factors. The Mineral Reserve statement is based on an HPMSM price of US$3,800/t and an average processing recovery of 88.5%. The QP for the Mineral Reserve is Mr. Michael John Beare, BEng, CEng, ACSM, MIMMM, who visited the K.Hill property in December 2019.

Table 1.4 Mineral Reserves for K.Hill dated 13th October 2022

	Tonnage (kt)	MnO grade (%)	MnO contained metal (kt)
Probable Reserves	2,032	18.9	384

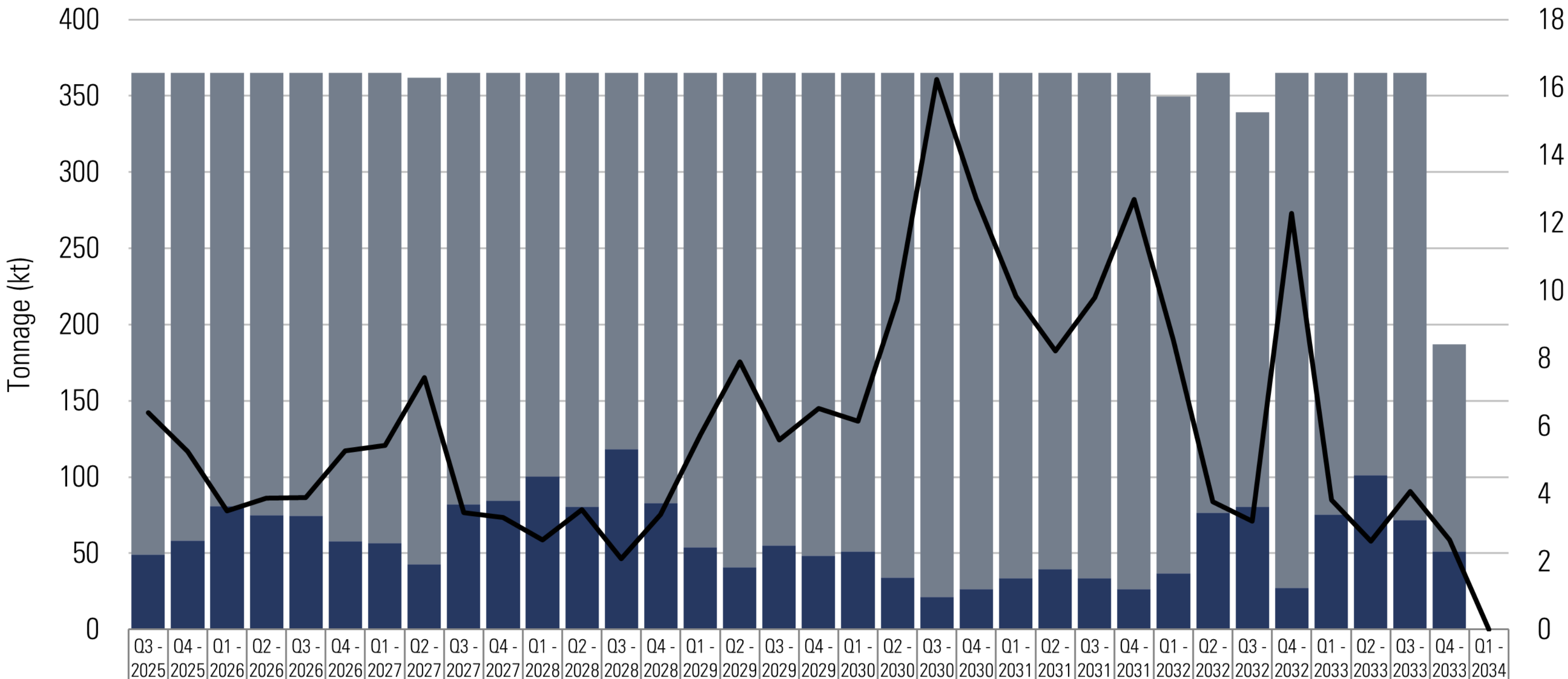
1.12 Mining methods

The Project will be developed as a small-scale open pit mining operation. Just over 2 Mt of ore will be mined at an average diluted head grade of 18.9% manganese oxide and an average strip ratio of 5.0 over a 11-year LOM. Due to the continuous nature of the deposit and the minor low-grade mineralisation that exists along much of the Mineral Reserve boundary, the impact of both dilution and ore loss is expected to be minimal to Project economics. The quarterly mining schedule for K.Hill is shown on Figure 1.2.

Mining will occur through one, 12 h day shift, using 4 m benches (divided into 2 m flitches) with a maximum slope angle of 41°. The material is generally soft in nature with some exceptions that will require hard digging; however, to ensure continuous operations with minimal downtime due to unforeseen hardness, drilling and blasting have been assumed to excavate some of the material. Two small excavators (4 m^3) will be used in combination with 30 t haul trucks. The ore will be hauled either directly to the crusher or to the stockpile located next to the processing plant, where the ore will be rehandled by a wheel loader. Waste will be transported to the waste rock dump (WRD) located to the east of the open pit, where the material will be dumped and levelled using a designated track dozer.

The mine production schedule runs over a period of 8.5 years (Figure 1.2), in which both direct and rehandled material is fed to the processing plant. The total mining rate has been capped at 375 kt per period to provide the required ore quantities over the LOM. This period is followed by 2.5 years of stockpile rehandling to fill the plant to the end of mine life, making the LOM 11 years. The processing plant's ramp-up schedule over a period of 2 years is achieved by directly feeding the required ore from the pit to the plant. The manganese oxide head grade remains relatively stable throughout years of mining and remains constant during the stockpile rehandling period. One of the key objectives for the plant feed is to ensure a relatively stable of iron oxide (Fe_2O_3)/potassium oxide (K_2O) in order to minimize the spike in reagent costs.

Figure 1.2 K.Hill quarterly mining schedule



	Q3 - 2025	Q4 - 2025	Q1 - 2026	Q2 - 2026	Q3 - 2026	Q4 - 2026	Q1 - 2027	Q2 - 2027	Q3 - 2027	Q4 - 2027	Q1 - 2028	Q2 - 2028	Q3 - 2028	Q4 - 2028	Q1 - 2029	Q2 - 2029	Q3 - 2029	Q4 - 2029	Q1 - 2030	Q2 - 2030	Q3 - 2030	Q4 - 2030	Q1 - 2031	Q2 - 2031	Q3 - 2031	Q4 - 2031	Q1 - 2032	Q2 - 2032	Q3 - 2032	Q4 - 2032	Q1 - 2033	Q2 - 2033	Q3 - 2033	Q4 - 2033	Q1 - 2034
Waste	316	307	284	290	291	307	308	319	283	280	265	285	247	282	311	324	310	317	314	331	344	338	331	325	331	338	313	288	259	338	289	264	293	136	-
Ore	49	58	81	75	74	58	57	43	82	85	100	80	118	83	54	41	55	48	51	34	21	27	34	40	34	27	37	77	81	27	76	101	72	51	-
Stripping Ratio	6.4	5.2	3.5	3.8	3.9	5.2	5.4	7.4	3.4	3.3	2.6	3.5	2.0	3.3	5.7	7.9	5.5	6.5	6.1	9.7	16.	12.	9.8	8.2	9.8	12.	8.5	3.7	3.2	12.	3.8	2.6	4.0	2.6	-

1.13 Recovery methods

The processing plant will treat 200 kt/a of run of mine (ROM) ore from the K.Hill open pit at an average grade of 18.9% manganese oxide to produce HPMSM.

The process comprises crushing and grinding the moderately hard manganese and iron shales to reduce the ROM material to a characteristic grind (P80) of 150 µm, an acid reductive leach in sulphate media at an elevated temperature using sulphur dioxide as a reductant, and a sequential purification process for the removal of metal impurities. Fluoride polishing is then undertaken to improve the purity of the solution. The purified solution then undergoes evaporative crystallisation followed by filtration and drying of the product to produce an HPMSM final product. Non-hazardous waste material from the process will be disposed of in the tailings management facility (TMF) as filter cake. Base metal sulphides will be stored as an intermediate product and will be sold to smelters in South Africa or disposed of at an appropriate facility. Any sales receipts or possible disposal costs have not been included in the Technical Economic Model (TEM) and would be insignificant in quantum. All liquors removed in the treatment of the ore will be treated for either reuse or, if non-hazardous, used for haul road dust suppression.

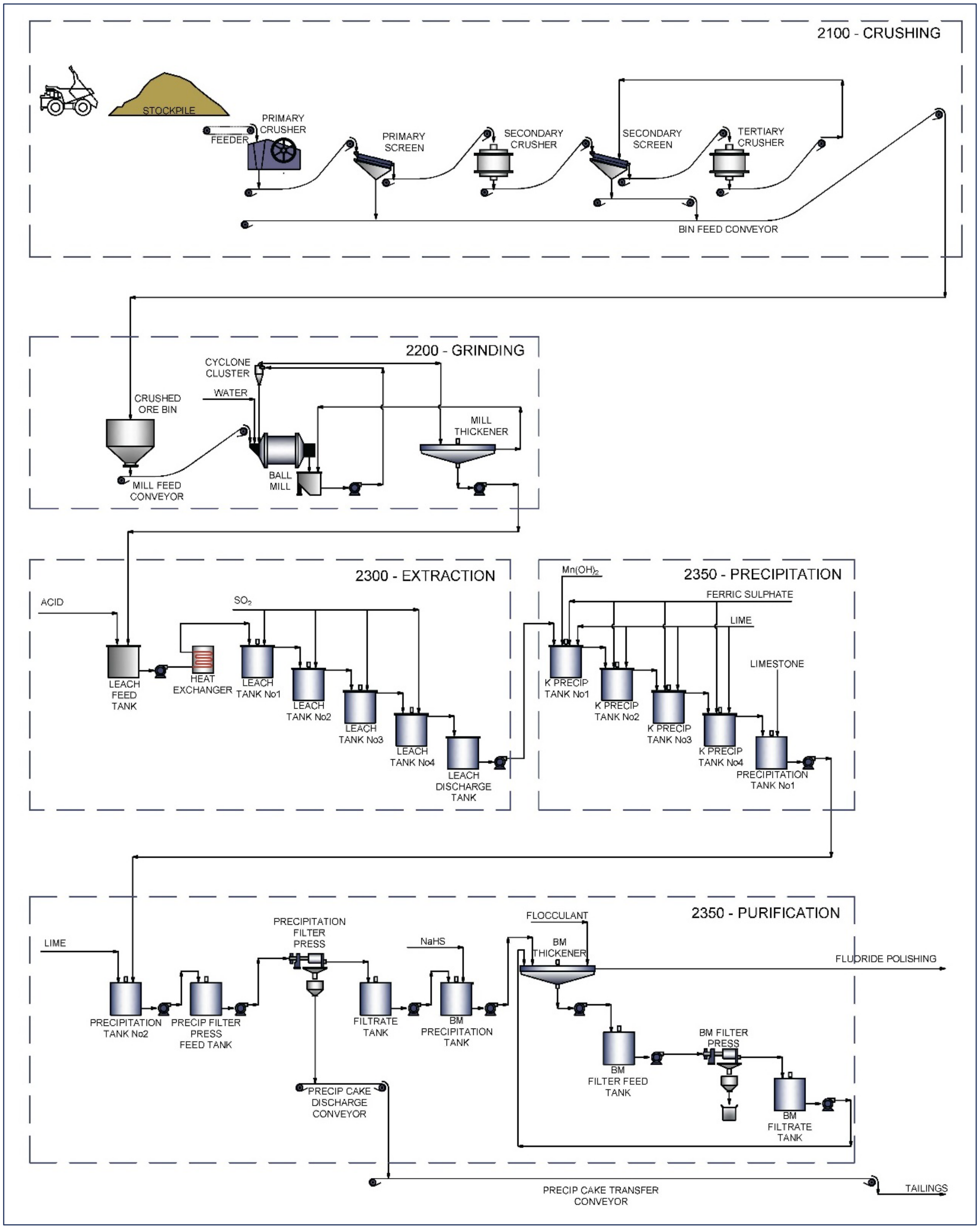
Several unit processes are used in the extraction and sequential purification of manganese. Test work was carried out on a composite sample that was selected to represent the K.Hill main orebody over the LOM to develop the process design criteria, flow sheets and equipment sizing. The inclusion of Horizon B in the Probable Reserve has decreased the overall head grade and increased the impurities to manganese ratio relative to earlier test work. However, extraction test work carried out on Horizon B samples demonstrated that this material has similar extraction characteristics to the K.Hill main orebody and can be treated successfully using the recovery methods described.

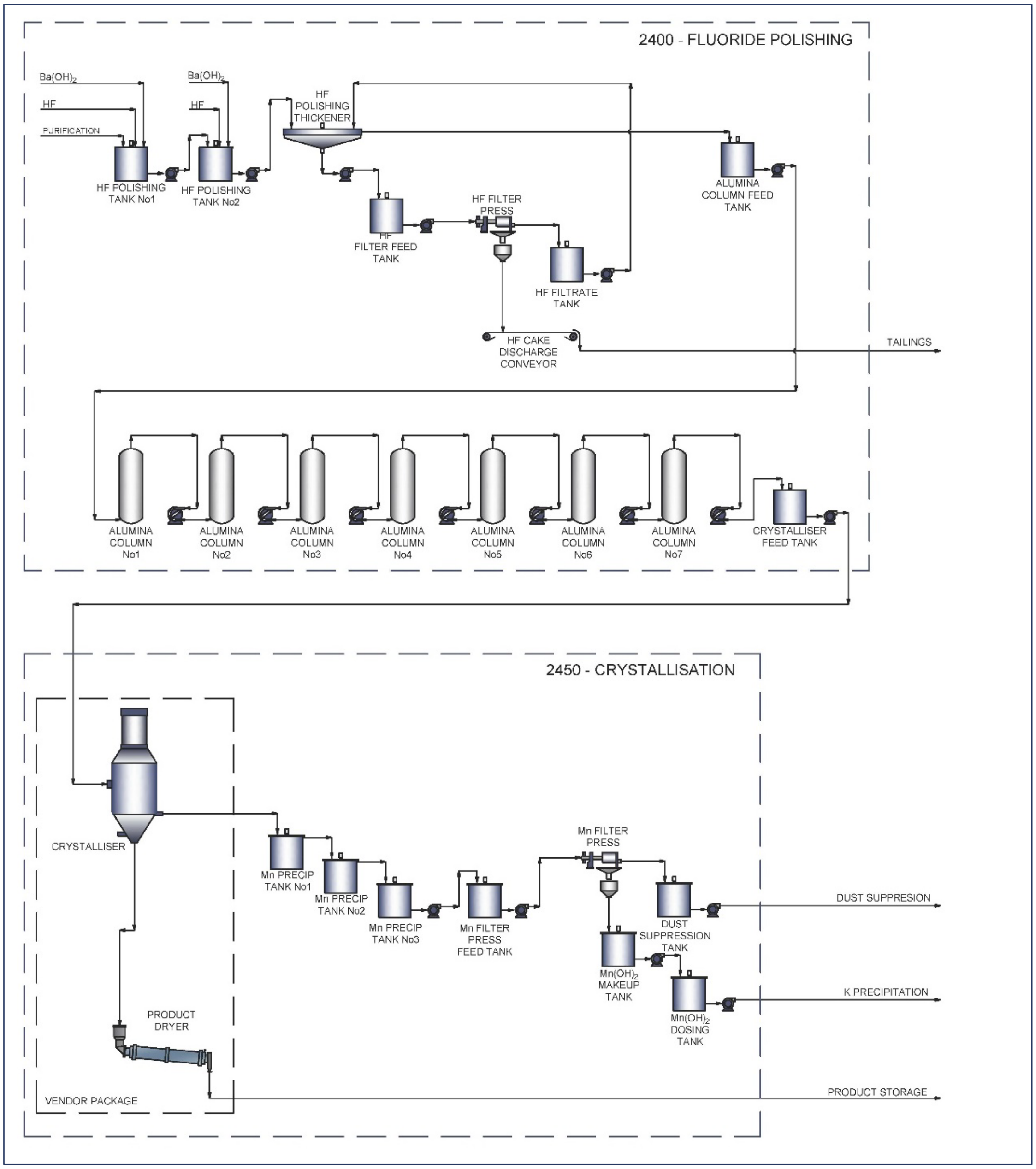
Table 1.5 and Figure 1.3 show the basis of the design and the flow sheet, respectively, for the K.Hill manganese recovery process.

Table 1.5 Basis of the process design

Item description	Units	Value
Operating hours per year - crusher	h/a	3,340
Operating hours per year - mill	h/a	7,720
Plant throughput	t/a ROM	200,000
Head grade - MnO	% w/w	18.5
Plant Recovery - Mn		
Leach extraction	%	96.8
Precipitation losses	%	0.5
Fluoride polishing precipitation losses	%	4.0
Crystallisation recovery	%	95.9
Overall plant recovery - Mn	%	88.5

Figure 1.3 Processing flow sheet





2400 - FLUORIDE POLISHING
Ba(OH)2
HF
PURIFICATION
Ba(OH)2
HF
HF POLISHING TANK No1
HF POLISHING TANK No2
HF POLISHING THICKENER
HF FILTER FEED TANK
HF FILTER PRESS
HF FILTRATE TANK
HF CAKE DISCHARGE CONVEYOR
ALUMINA COLUMN FEED TANK
TAILINGS
ALUMINA COLUMN No1
ALUMINA COLUMN No2
ALUMINA COLUMN No3
ALUMINA COLUMN No4
ALUMINA COLUMN No5
ALUMINA COLUMN No6
ALUMINA COLUMN No7
CRYSTALLISER FEED TANK
2450 - CRYSTALLISATION
CRYSTALLISER
PRODUCT DRYER
VENDOR PACKAGE
Mn PRECIP TANK No1
Mn PRECIP TANK No2
Mn PRECIP TANK No3
Mn FILTER PRESS FEED TANK
Mn FILTER PRESS
DUST SUPPRESSION TANK
Mn(OH)2 MAKEUP TANK
Mn(OH)2 DOSING TANK
DUST SUPPRESION
K PRECIPITATION
PRODUCT STORAGE

1.14 Project infrastructure

The K.Hill Project will require the development of multiple infrastructural items. The locations of Project facilities and other infrastructure items were selected to take advantage of local topography, accommodate environmental considerations, and ensure efficient and convenient operation of the mine haul fleet.

The following Project infrastructure and facilities will be included on site:

- crushing facility, including ROM pad and stockpiles, three-stage crushing plant, and a crushed ore bin
- processing area, including grinding, extraction, purification, fluoride polishing, crystallisation, product storage and handling, water treatment, reagent storage and tails handling; sulphur dioxide plant and plant infrastructure and utilities, including steam and air plants and low voltage (LV) switch rooms
- additional infrastructure, including gatehouse and weighbridge; laboratory, maintenance workshop; tyre and lube storage; administration building, including first-aid and firefighting facilities; explosives storage; and fuel farm
- water systems to supply, treat, and distribute plant water, fire water, and potable water
- site and haul roads
- electrical high voltage (HV) and medium voltage (MV) substations and power distribution to all facilities via two 11 kV feeder circuits
- communications infrastructure
- off-site infrastructure, including a solar plant and access roads
- temporary construction facilities

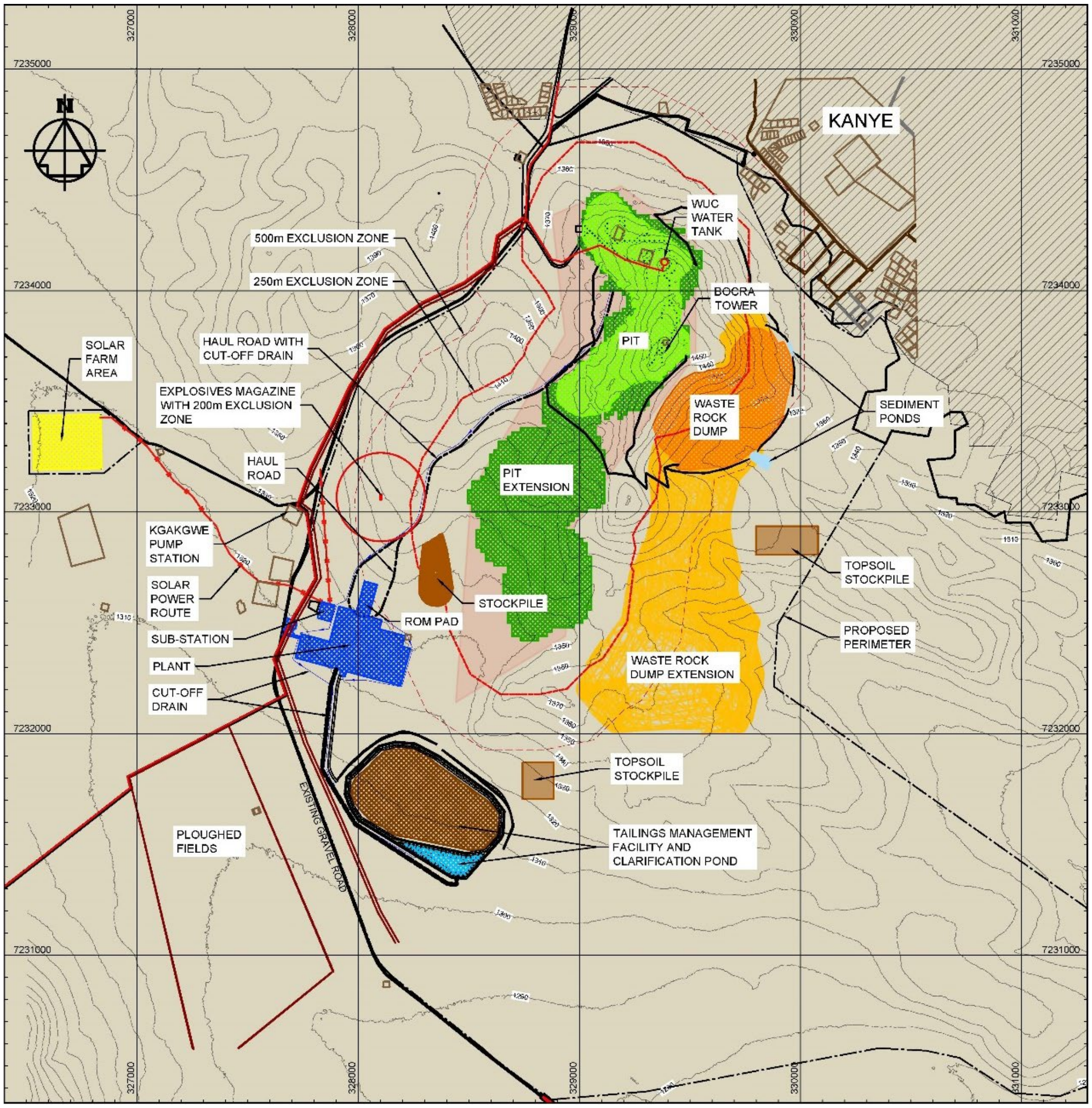
A 4.5 MWp_{dc} solar plant, covering 7.6 ha, will be constructed 1.2 km W-NW of the processing plant entrance gate. Power generation models predict excellent solar production at the K.Hill mine—greater than 74% of the theoretical maximum production; a very good value in solar generation.

Botswana Power Corporation will undertake an HV supply and will install a 33 kV HV line from the main Kanye municipal substation, north of the town, to a new HV substation next to the plant. BPC will also undertake the 33 kV HV substation, converting the incoming HV supply for 33 kV to 11 kV.

Water for ore processing will be supplied from the municipal water supply to limit the volume of impurities entering the process. The processing plant will be self-contained and a zero-runoff facility. Additional rainwater, collected in the plant bunded areas, will be pumped back into the process.

An overall site layout for the Project is shown on Figure 1.4.

Figure 1.4 K.Hill Project site layout



1.15 Environmental studies, permitting, and social or community impact

Giyani appointed Loci Environmental to carry out the necessary environmental and social studies and permitting for the exploration and mining phases of the K.Hill Project. Loci Environmental is an independent environmental consultancy based in Gaborone, Botswana registered with the Botswana Environmental Assessment Practitioners Board. Loci Environmental has a team of specialists who undertake specific studies for Environmental Impact Assessments (EIAs).

Loci Environmental is undertaking an EIA in accordance with Section 9 (1) of the Botswana Environmental Assessment Act. In 2020, Loci Environmental undertook a Scoping Report, a document that sets out the boundaries of the EIA, including the Project area, and establishes what the EIA will include and how to put the EIA together in accordance with the Terms of Reference (TOR). The TOR for the K.Hill Project was submitted to and approved by the Department of Environmental Affairs (DEA; Loci Environmental 2020). The EIA team used the approved Scoping Report and TOR to prepare Section 20 of this FS based on the EIA findings. In terms of Botswana legislation, the EIA is referred to as an Environmental and Social Impact Statement (ESIS).

The EIA is ongoing. In some cases, specialist studies are being reworked with changes to geographic study areas. The baselines and impact assessments described in this FS will be revised, as needed, for the EIA that will be submitted to the DEA in Q1 2023 for review and decision-making regarding authorisation of the Project. It should be noted that no environmental nor social red flags/fatal flaws have been identified to date, and although the study areas are expanding, preliminary visits to the new areas are indicative of a similar receiving environment (i.e., tribal lands that have been disturbed by small-scale farming).

Additional trade-off studies were carried out after the Scoping Report and TOR was approved, which resulted in changes to the Project that improve both sustainability and environmental performance (e.g., dry stack tailings vs conventional TMF; changes to processing to reduce energy consumption and decrease indirect greenhouse gas emissions; and a solar farm to reduce the amount of power taken from the national grid, which is coal-based).

The EIA is being undertaken in compliance with the national legislation of Botswana. Giyani is also committed to conforming with the requirements of the international lender community and good international industry practice (GIIP), specifically, the International Finance Corporation (IFC) *Performance Standards on Environmental and Social Sustainability* (IFC 2012) and *Equator Principles 4* (EP4; EPA 2020). Giyani will develop an Environmental and Social Action Plan (ESAP) to address gaps in the EIA with reference to, among other things, GIIP and corporate policies and procedures. A gap analysis will be undertaken post-EIA when environmental authorisation has been issued.

1.16 Market studies and contracts

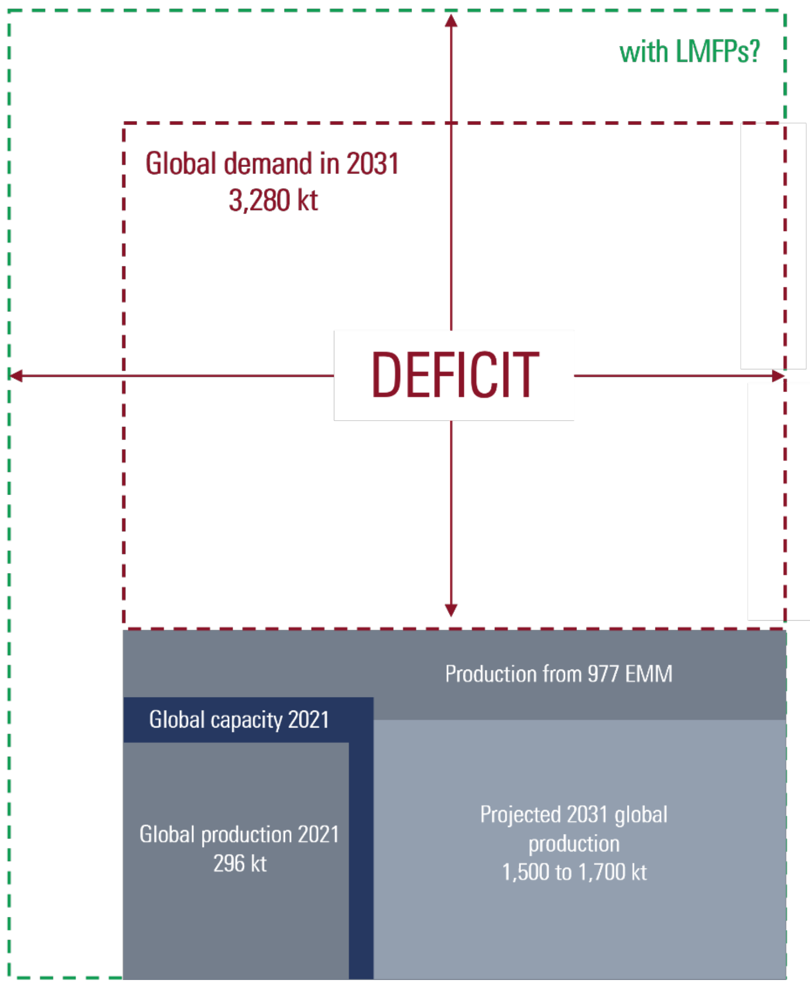
CPM, an independent research and consultancy company based in New York, completed an HPMSM products market outlook study for the FS.

The study projects demand for lithium-ion batteries used in EVs to grow by 25% annually between 2021 and 2031. Utilisation of high-purity manganese by the lithium-ion battery sector is forecast to increase in the coming years as end users seek to substitute cobalt in nickel-manganese-cobalt (NMC) cathode formulations and iron in lithium-iron-phosphate (LFP) cathodes. In 2018, the German chemical giant BASF announced new NMC 370 and NMC 271 cathodes with an expected cobalt usage of less than 5% and manganese use of 75% or more. Several companies are also working on different variations of the manganese-bearing LFP chemistry, with the addition of manganese said to improve energy density by up to 20% and lower the material cost by up to 28%.

CPM projects that the demand for HPMSM in lithium-ion batteries will grow nearly 30-fold between 2021 and 2036, reaching 1.8 Mt on a contained metal basis and may reach 4.5 Mt by 2050. With the current global HPMSM production capacity of approximately 0.1 Mt/a on a contained metal basis and the identified new project pipeline expected to contribute only an additional 0.2 Mt/a by 2031, consumers are facing a projected supply deficit of 0.7 Mt/a.

Currently, CPM forecasts that only six non-China high-purity manganese projects are reasonably likely to come on stream before 2031, producing only 0.2 Mt/a (contained metal). China may be the source of an additional 0.1 Mt/a by 2025, but there are doubts as to the purity of this material due to the use of selenium (Se) containing manganese metal as a feedstock. Figure 1.5 illustrates a projection of the 2031 supply/demand balance for HPMSM.

Figure 1.5 Supply-demand balance of HPMSM in 2031

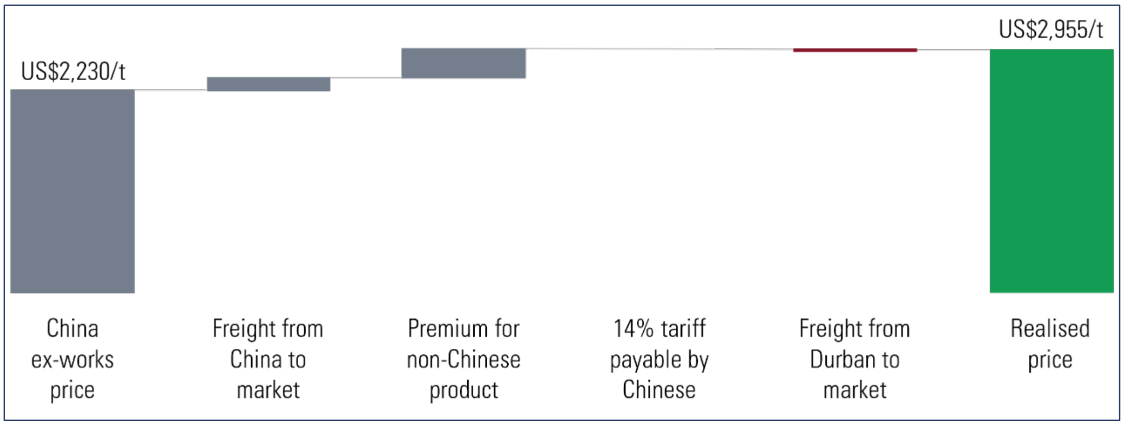


Note: Figures above are quoted in tonnes of HPMSM, not metal contained.
Source: E Source Companies LLC, International Manganese Institute, CPM, industry sources

It should be noted that the price of HPMSM is largely unrelated to the prices of other manganese products. Manganese is also the cheapest of all battery metals and accounts for only 1% to 2% of the cost of the cathode materials, making it virtually price insensitive for cathode makers.

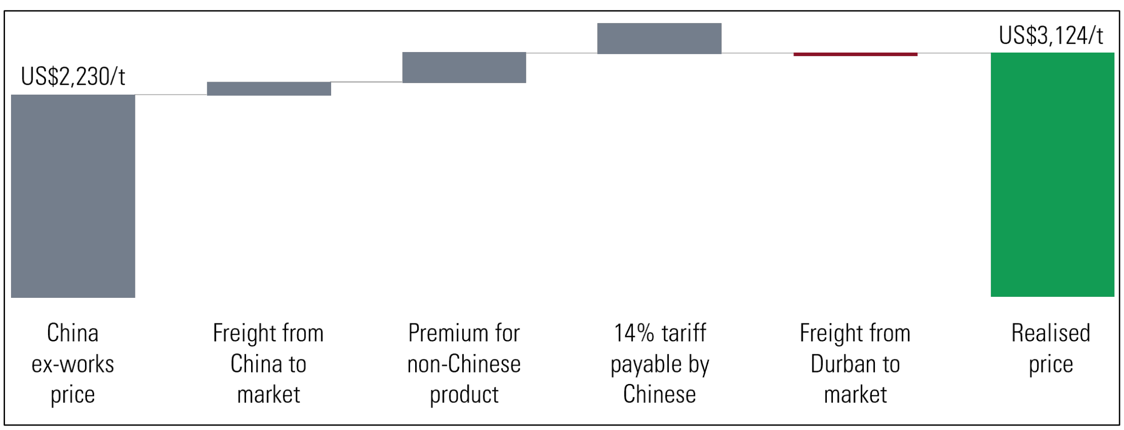
In forecasting its HPMSM prices, CPM uses ex-warehouse prices in China with freight cost, duties, and price premia added to arrive at the European and North American prices delivered duty paid in Berlin and Detroit, respectively. To calculate the price for HPMSM product received by Giyani, Giyani has assumed that its sales will be made on a free carrier (FCA) basis in Durban, South Africa; therefore, the realised price shall be the CPM forecast price in Europe or North America less the cost of freight from South Africa (Figure 1.6 and Figure 1.7).

Figure 1.6 Giyani realised HPMSM price for European sales



Source: CPM and Giyani

Figure 1.7 Giyani realised HPMSM price for US sales



Source: CPM and Giyani

1.17 Capital and operating costs

Capital costs

Capital cost estimates were prepared for initial, sustaining, and closure capital.

The total estimated initial capital cost for the design, construction, installation, and commissioning of all facilities and equipment for the K.Hill Project is US$281M, including a contingency of US$32M. This estimate includes direct field costs required to execute the Project plus indirect costs associated with design, construction, installation, and commissioning. Closure costs of US$5M have been estimated.

This estimate is a Class 3 estimate prepared in accordance with the Association for the Advancement of Cost Engineering (AACE®) International Cost Estimate Classification System. The accuracy of the estimate is -10% to +15%.

Capital costs incurred after start-up are assigned to sustaining capital and are projected to be paid out of operating cash flows. In keeping with industry practice, the annual sustaining capital allowance has been estimated as 2.5% of the hydrometallurgical plant direct capital cost over a period of 8 years, totalling US$21M (including a 15% contingency of US$3M). Table 1.6 shows the breakdown of the initial Project capital cost by area.

Table 1.6 Summary of life of mine capital expenditures by area

Area	Total (US$M)
Mining	10.5
Processing	98.1
Infrastructure and services	31.2
TMF	6.6
Offsite infrastructure	9.7
Indirect costs (including first fill and commissioning costs)	65.5
Construction overheads	21.6
Owner's costs	5.5
Total initial capital cost, excluding contingency	**248.7**
Contingency on initial capital cost	32.0
Total initial capital cost, including contingency	**280.7**
Sustaining capital, including contingency	21.4
Closure cost	5.1
Total	**307.3**

Note: The sum of costs may differ from the total due to rounding.

This estimate includes direct costs required to execute the K.Hill Project, plus indirect costs associated with design, construction, installation, and commissioning. This estimate is based on pricing as of H2 2022 with no allowances for inflation, escalation, working capital, or Project finance costs. All currency in this capital cost estimate is expressed in US dollars unless otherwise noted.

An allowance for working capital is included in the financial model.

Operating costs

The operating cost estimate for the K.Hill Project consists of mining, processing, general and administrative (G&A), and TMF costs, as summarised in Table 1.7.

The total estimated LOM average operating cost is US$672/t of ore processed. Mining accounts for 3% of the total operating cost, processing accounts for 95%, G&A accounts for 2%, and TMF accounts for less than 1%.

Table 1.7 Life of mine average operating cost summary

Area	Unit cost (US$/t processed)	Contribution to operating cost (%)
Mining	20.0	3
Processing	636.4	95
G&A	13.4	2
TMF	2.0	0.3
Total	**671.8**	**100**

Notes: Total operating costs, excluding royalties of US$2.0/t processed
The sum of costs may differ from the total due to rounding.

Metallurgical processing reagents and raw materials constitute the largest component of processing operating expenditure based on the processing plant design criteria and flow sheet to produce HPMSM, accounting for approximately 73% (US$92M annually) of the direct operating cost. However, of the total reagent cost, approximately 36% is associated with importation and freight costs of certain key reagents currently assumed to be sourced on the international markets.

During 2021 and early 2022, COVID-19-related disruptions led to an unprecedented rise in international freight rates, which elevated prices for the procurement of reagents. Since mid-2022, international freight rates have seen declines of between 50% to 75% (Freightos 2022) and are expected to continue to normalise toward pre-COVID-19 levels.

Giyani will follow the recommendations set out in Section 26 to identify opportunities to reduce operating costs by lowering consumption of certain key reagents, developing local or alternative sources of reagents to mitigate international freight costs, and pursuing a strategy of a diversified supply chain with an optimised road transport component. This work has already started.

1.18 Economic analysis

SRK prepared a TEM for the K.Hill Project. Cash inflows are based on annual production and revenue projections, while cash outflows consist of capital costs, operating costs, royalties, and taxes. The modelling period covers the LOM of 11 years, including a 2-year construction period and a 2-year ramp up to full production following plant commissioning. The net present value (NPV) is calculated by discounting back cashflow projections through the LOM to the Project's valuation date of 1st July 2023 as the start of construction and the first drawdown of capital. Key project metrics are presented in Table 1.1

1.19 Stakeholder management

Stakeholder engagement will be managed through a Stakeholder Engagement Plan (SEP) that applies to the LOM (i.e., from construction to rehabilitation and closure). The SEP will incorporate and build on the consultation associated with the EIA. Stakeholder engagement will comply with legislative and regulatory requirements and conform with international standards. The SEP will be a live document that will be updated throughout the LOM.

1.20 Project execution plan

The FS sets out a realistic Project Execution Plan (PEP) based on the scope of what will be designed, procured, built, and commissioned. The PEP includes a description of activities undertaken leading up to project execution: the execution scope, strategy, schedule, and compliance with environmental, social, and governance (ESG) and health, safety, and environment (HSE) guidelines and best practices.

The Project will be executed to achieve the following initial objectives:

- delivery of a processing plant that can achieve HPMSM production of approximately 80,000 t/a, on average, with the safest standards and in full compliance with all laws and regulations in place at the lowest operating expenditure possible
- compliance with the management and monitoring plans set out in the EIA, conditions that the DEA will apply to the environmental authorisation, and other conditions stipulated in the mining licence
- compliance with HSE management plans, monitoring plans, policies, and procedures
- on-time and on-budget Project execution

The K.Hill Project is expected to use an engineering, procurement, and construction management (EPCM) project delivery model. The appointed EPCM contractor will be responsible for most of the scope, but some work packages may also be undertaken and managed by Giyani's owner's team.

The engineering design will meet technical, regulatory, and functional requirements. Giyani will undertake a programme of value engineering before starting with basic and then detailed engineering.

Long-lead items will be specified for procurement during basic engineering, and general equipment and instrumentation specifications will be specified for procurement at the start of detailed engineering. Readily available off-the-shelf equipment will be selected, where possible, taking care to consider maintenance and spare requirements throughout the LOM.

Even though Giyani will seek to use local fabricators, it is anticipated that most of the equipment and bulk materials will be sourced from Southern African vendors and fabricators. Plant and infrastructure components will be pre-assembled as much as possible in road-transportable units to minimise erection time on site.

Procurement will be managed on behalf of Giyani by the appointed engineering firms, adhering to the principles of thorough pre-qualification, complete life-cycle procurement, and a formal tender process. Shortlisted vendors will have a demonstrated track record and the capacity to deliver and service Southern Africa.

Giyani will distribute the work over several key contracts, selected following a formal tender process. Contractors will be identified and shortlisted as per the pre-qualification process; contracting with a Botswana legal entity will be considered an advantage.

The owner's team will have a dedicated team to facilitate commissioning and handover to operations. Commissioning will be undertaken by an engineering consultant that specialises in hydrometallurgical systems and will be integrated into the owner's team and brought on board during the pre-commissioning execution phase to prepare and finalise the commissioning plan. This team will be responsible for managing the equipment vendor representatives.

Key milestone dates for the K.Hill Project used in the TEM are shown in Table 1.8. The dates provided in Table 1.8 are based on a technical execution schedule under a 100% financed basis and are not adjusted for specific commercial and funding assumptions and, therefore, do not yet represent a firm timeline for full Project development.

Table 1.8 K.Hill Technical Economic Model key milestone dates

TEM Milestone	Date
Start basic engineering	Q3 2023
Start mine pre-stripping	Q4 2024
Start plant commissioning	Q2 2025
First commercial production	Q3 2025
End of ramp up	Q3 2027

It should be noted that Environmental and Social Management Plans (ESMPs) and Giyani's policies and procedures will be applied throughout the LOM. Specific ESMPs will be developed before construction begins in readiness for implementation from the outset of construction (e.g., Emergency Preparedness and Response Plan, Water Management Plan, Alien Invasive Species Management Plan).

1.21 Post-feasibility study activities

Giyani intends to undertake a series of post-FS activities to optimise aspects of the Project, lower operating costs, develop opportunities, and mitigate residual risk. Key immediate workstreams will include the following:

- Demonstration Plant: The demonstration plant is under construction in South Africa and will be assembled in road-transportable modules with a production capacity of up to 600 kg/d of dry HPMSM crystals. The objective is to provide HPMSM samples to potential buyers for their supply chain testing and product qualification and to de-risk the commercial plant development by using the demonstration plant for optimisation of the ongoing process engineering work. The demonstration plant is currently expected to be constructed and commissioning by mid-2023 with the first samples shipped to potential buyers in H2 2023.
- Optimisation Test Work: Giyani will implement key recommendations from the FS work to optimise the processing flow sheet and identify opportunities to reduce operating costs by lowering reagent consumption or developing local sources. This activity includes material characterisation to support final equipment selection, such as solid-liquid separation and rheology tests. Many of these tests will be completed by vendors or specialist laboratories using an intermediate product produced in sufficient quantity by the demonstration plant.
- Value Engineering: Giyani will undertake a value-engineering programme as part of the final optimisation of the Project scheme prior to commencing basic engineering in anticipation of a final investment decision.

1.22 Opportunities

The FS confirms that the K.Hill Project will be able to manufacture HPMSM directly from the ore source adjacent to the processing facility. The Project delivers a post-tax NPV of US$481M at an 8% discount rate for an initial capital investment of US$281M.

The Project's economic outcome is likely to be improved with the inclusion of a portion of the 3 Mt Inferred Resource to Indicated, following the completion of the Southern Extension Area drilling in Q3 2022.

The Project's financial performance is a strong function of operating cost, the largest component of which relates to consumables supply and transport. At the time the FS was completed, prices and costs associated with these items were affected by a temporary post-COVID-19 inflation. The opportunities that have been identified to reduce operating costs comprise not only technical improvements but also optimisation of supply chains.

Opportunities to reduce capital costs also relate to the normalisation of the prices of bulk commodities, such as steel and copper, used in construction.

The TMF design presented in the FS includes a basal lining system to prevent seepage of contact water from the tailings stack to the surrounding environment and groundwater.

Such as system is potentially conservative given that acid generation is not expected. Following final confirmation of the geochemical behaviour of the details, the lining system could be simplified.

1.23 Risks

SRK and Tetra Tech maintained a risk register during the completion of the FS. Although there are no critical residual risks, two risk groups and their mitigation strategies are highlighted:

- Supply Chain Risk: Giyani will seek to source consumables from multiple suppliers and import them through multiple routes. Identifying suppliers with warehouse facilities local to the operation to shorten the short-term supply chain will be included in the vendor selection criteria.
- HPMSM Supply Risk: Giyani has invested in a demonstration plant that will be in production before the end of the basic engineering phase. Knowledge gained from this state-of-the-art facility will significantly mitigate the HPMSM production risk. In addition, the FS includes a conservative 2-year ramp up in the financial model to account for low initial plant availability.

2 INTRODUCTION

2.1 Scope of work

Giyani trades on the TSX Venture Exchange (TSXV), part of the Toronto Stock Exchange, under the stock symbol EMM, and on the Frankfurt Stock Exchange, under the stock symbol KT9: GR. Giyani's strategy is to become a responsible, low-carbon producer of battery materials for the EV industry and currently focuses on the development of manganese projects in the Republic of Botswana.

Giyani commissioned SRK and Tetra Tech to undertake an NI 43-101 FS-level Technical Report for the Project, located in the Republic of Botswana, in which Giyani holds a 100% interest.

This NI 43-101 Technical Report has been prepared to comply with disclosure and reporting requirements set forth in the TSXV *Corporate Finance Manual* (TSXV 2022); Canadian *National Instrument 43-101 Standards of Disclosure for Mineral Projects* (CSA 2016a), *Companion Policy 43-101CP* (CSA 2016b), and *Form 43-101 F1 Technical Report* (CSA 2011); and the *CIM Definition Standards for Mineral Resources & Mineral Reserves* (CIM 2014).

The QPs for this NI 43-101 Technical Report by section are (see Table 2.1 for a breakdown by section):

- Mr. Michael John Beare, BEng, CEng, ACSM, MIMMM, of SRK
- Mr. Peter Gleeson, MSc, CEng, MIMMM, AIGS, of SRK
- EUR ING Andrew Carter, BSc, CEng, MIMMM, MSAIMM, SME of Tetra Tech

Table 2.1 Qualified Persons by report section

Section no.	Section name	Consulting company	QP
1	Summary	SRK Tetra Tech	Michael John Beare/ Peter Gleeson Andrew Carter
2	Introduction	SRK	Michael John Beare
3	Reliance on other experts	SRK	Michael John Beare
4	Property description and location	SRK	Peter Gleeson
5	Accessibility, climate, local resources, infrastructure and physiography	SRK	Peter Gleeson
6	History	SRK	Peter Gleeson
7	Geological setting and mineralisation	SRK	Peter Gleeson
8	Deposit types	SRK	Peter Gleeson
9	Exploration	SRK	Peter Gleeson
10	Drilling	SRK	Peter Gleeson
11	Sample preparation, analyses and security	SRK	Peter Gleeson

Section no.	Section name	Consulting company	QP
12	Data verification	SRK	Peter Gleeson
13	Mineral processing and metallurgical testing	Tetra Tech	Andrew Carter
14	Mineral resource estimates	SRK	Peter Gleeson
15	Mineral reserve estimates	SRK	Michael John Beare
16	Mining Methods	SRK	Michael John Beare
17	Recovery methods	Tetra Tech	Andrew Carter
18	Project infrastructure	SRK Tetra Tech	Michael John Beare Andrew Carter
19	Market studies and contracts	SRK	Michael John Beare
20	Environmental studies, permitting and social or community impact	SRK	Michael John Beare
21	Capital and operating costs	SRK Tetra Tech	Michael John Beare Andrew Carter
22	Economic analysis	SRK	Michael John Beare
23	Adjacent properties	SRK	Peter Gleeson
24	Other relevant data and information	SRK Tetra Tech	Michael John Beare Andrew Carter
25	Interpretations and conclusions	SRK Tetra Tech	Michael John Beare Andrew Carter
26	Recommendations	SRK Tetra Tech	Michael John Beare Andrew Carter
27	References	SR Tetra Tech	Michael John Beare/ Peter Gleeson Andrew Carter

2.2 Principal sources of information

SRK and Tetra Tech based their technical work on information provided by Giyani, along with technical reports from consultants, government agencies, previous tenements holders, and other relevant published and unpublished data. Section 27 includes sources of information used in this FS. SRK and Tetra Tech QPs have endeavoured, by making all reasonable enquiries, to confirm the authenticity and completeness of the technical data upon which the FS is based. A final draft of the report was also provided to Giyani, along with a written request to identify any material errors or omissions prior to lodgement.

Mr. Michael John Beare, BEng, CEng, ACSM, MIMMM, of SRK, made a personal inspection of the Project between 16th and 18th December 2019, and Mr. James Haythornthwaite, BSc, MSc, CGeol, of SRK, made a personal inspection of the Project between 28thand 29th January 2020. Mr. John Paul Hunt, MSc, FGSSA, GASA, SEG, SGA, IAGOD, GSA, of SRK, conducted a follow-up site visit on 4th March 2021 to verify the drilling practices applied by Giyani during the active RC drilling. The QP in accordance with the CIM Code with responsibility for reporting the Mineral Resource statement presented in Section 14 is Mr. Peter Gleeson, MSc, CEng, MIMMM, AIGS, with SRK. Mr. Gleeson has the relevant experience in reporting Mineral

Resources on various base, precious, and ferrous metal assets globally. Mr. Gleeson inspected the property between the 17th and 21st January 2022.

The Mineral Resource estimate was prepared on information available up to and including 1st November 2021.

Unless otherwise stated, all monetary figures expressed in this report are in US dollars (US$).

2.3 Qualifications, experience, and independence

Neither SRK, Tetra Tech, nor the QPs of this report has or have had previously any material interest in Giyani or the mineral properties in which Giyani has an interest. The relationship with Giyani is solely one of professional association between client and independent consultant. This report is prepared in return for professional fees based upon agreed commercial rates, and the payment of these fees is in no way contingent on the results of this report.

3 RELIANCE ON OTHER EXPERTS

3.1 Introduction

The QPs, as authors of this report, have relied on the following sources of information in respect of previous mineral tenure, environmental matters, market information, and tax information pertaining to the K.Hill Project.

3.2 Mineral tenure

The Republic of Botswana owns the mineral rights to the Project. Giyani, through Menzi Battery Metals, holds the exclusive right to engage in prospecting activities for "metals" within the Project area through the issued prospecting permit under Section 16 of the Mines and Minerals Act of the Republic of Botswana.

The Project is located within PL322/2016. The K.Hill prospecting area covers 438 km^2 of the total area of approximately 2,000 km^2, to which Menzi Battery Metals holds prospecting rights. Seven PLs were renewed on 3rd August 2022 and are valid until 30th September 2024. A renewal application for the eighth PL, which expires on 31st December 2022, is currently under review by the Department of Mines.

Mr. Peter Gleeson, MSc, CEng, MIMMM, AIGS, of SRK, is the QP responsible for Section 4, which discusses mineral tenure. This reliance is based on the PLs in favour of Menzi Battery Metals for PLs297/2016, 298/2016, 322/2016, 336/2016, 337/2016, 338/2016, and 339/2016, dated 3rd August 2022, and PL258/2017, dated 13th November 2020, from the Department of Mines.

SRK can confirm that the mineralisation lies within the licenced areas but has not independently verified, nor is it qualified to verify, the legal status of these concessions. The present status of the tenements listed in this report is based on the mineral tenure information provided by Giyani. The report has been prepared on the assumption that the tenements will prove lawfully accessible for evaluation.

3.3 Environmental matters

In August 2018, Giyani contracted the services of Botswanan environmental consultants Loci Environmental to undertake environmental screening studies for its projects in Botswana, including K.Hill. SRK notes that no significant issues were identified during this process.

Giyani received a request from the DEA of Botswana to complete an Environmental Management Plan (EMP) for the K.Hill prospect area. Under this EMP, Giyani will have clearance to conduct exploration and evaluation work, including, but not limited to, geophysics and other non-invasive exploration techniques, drilling, and sampling.

The proposed K.Hill Mine is located in an area that has been disturbed by historical mining activities; little or no rehabilitation has been undertaken; therefore, remnants of the old operations are present (e.g., spoil heaps and tailings). In recent years, K.Hill has been used as a site to dump general waste illegally by unknown parties.

Giyani has also appointed Loci Environmental as an independent consultancy to carry out a full EIA as part of the process to authorise the Project. A Scoping Report and TOR for the EIA was completed by Loci Environmental (2020) and submitted to the DEA as per the requirements of the Environmental Assessment Act. Specialist studies for the EIA are underway, and the results will be incorporated into an ESIS and submitted to the DEA for review and decision-making on whether the K.Hill Project can proceed. Giyani plans to submit the report during Q1 2023.

Specialist studies to date have shown there are no legacy issues that could have negative economic impacts on the K.Hill Project. Similarly, neither SRK nor the QPs of this report are qualified to provide comment in detail on any environmental issues associated with the Project.

Mr. Michael John Beare, BEng, CEng, ACSM, MIMMM, of SRK, relied on Ms. Marion Thomas, MSc, CEnv, of Giyani, for information regarding environmental studies and permitting for the Project. This reliance is based on the documents listed Section 20 (Table 20.2) and referenced in Section 27.

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3.4 Market studies

Mr. Michael John Beare, BEng, CEng, ACSM, MIMMM, of SRK, relied on CPM for a market study, which is attached in Appendix F and summarised in Section 19. The CPM market study assesses the supply and demand dynamics of the HPMSM market based on projected consumption by the EV battery market versus known and estimated sources of future production to determine a long-term average price for HPMSM.

3.5 Economics and taxes

Mr. Michael John Beare, BEng, CEng, ACSM, MIMMM, of SRK relied on Mr. Liam Fitzgerald, CA, of PricewaterhouseCoopers Associates (PwC) concerning tax matters relevant to the K.Hill Project. The reliance is based on a letter from PwC entitled, *Assistance with the calculation and review of the Botswana income and mining tax portion (the "tax section") of the Feasibility Study Model (the "Model") in conjunction with the NI 43_101 Technical Report (the "Report") for the K.Hill Project ("the Project") prepared by an external consultant engaged by Giyani Metals Corp. ("Giyani" or the "Company" or the Client")* and dated 22nd September 2022 (Appendix G).

4 PROPERTY DESCRIPTION AND LOCATION

4.1 Location

K.Hill is located next to the town of Kanye, which is the administrative centre of the Southern District of the Republic of Botswana. The Project is accessible via a short section of unpaved roads and tracks from a network of paved national roads, namely the A1 and A2, with the A2 located just a few kilometres from the Project. Gaborone, the governmental and economic capital city of Botswana, is approximately 100 km by paved road from Kanye (Figure 4.1).

4.2 Project ownership

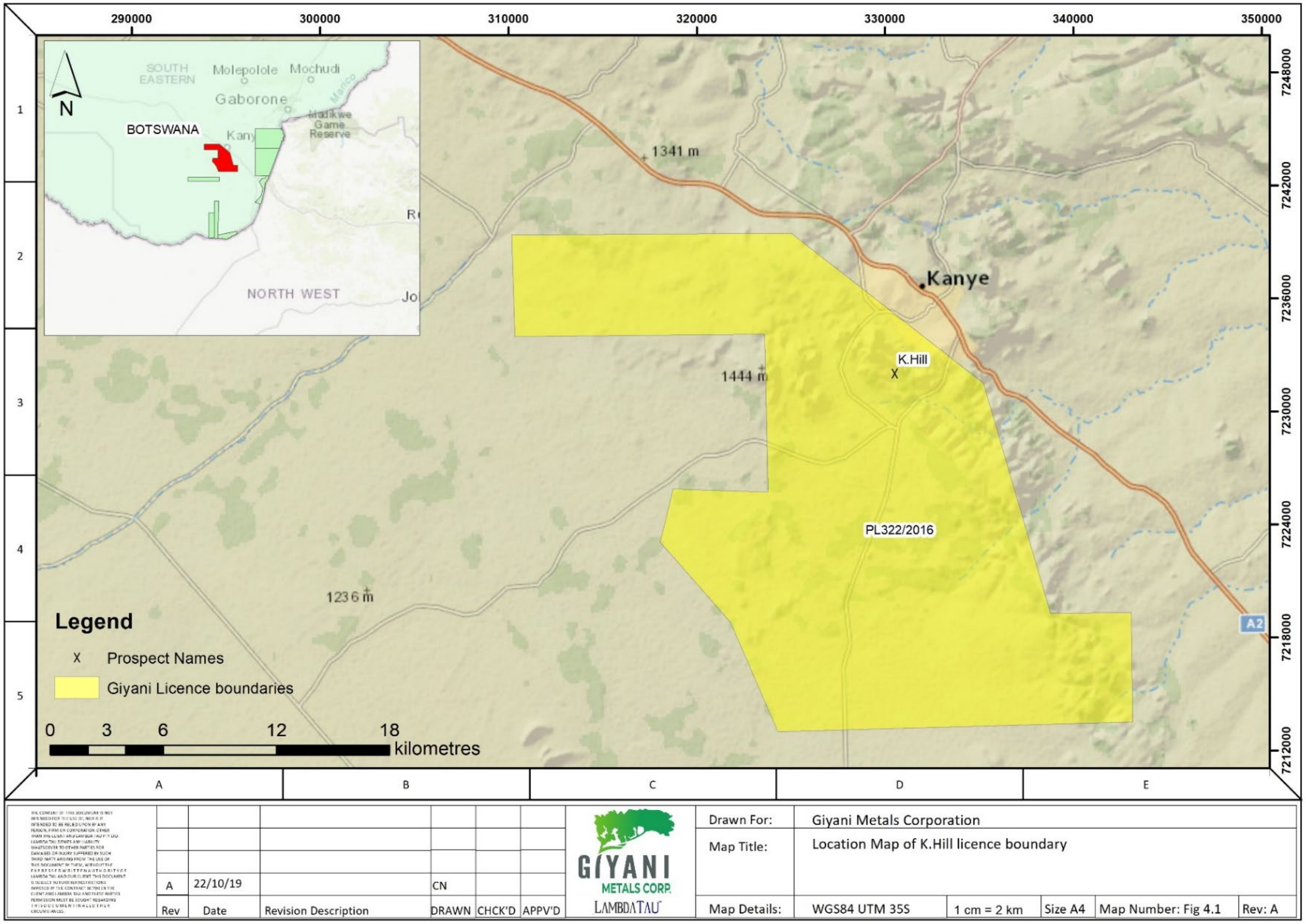
The entire Giyani project area extends over 1,960 km^2 of tenements, with the Project located in a 438 km^2 licence area, held under the Botswana-registered entity Menzi Battery Metals. Giyani is the only shareholder and owns 100% of Menzi Battery Metals.

4.3 Mineral tenure

Giyani holds the exclusive right to engage in prospecting activities for “metals” within the Project area through prospecting permits issued under of Section 16 of the Mines and Minerals Act of the Republic of Botswana. The Project is located within PL322/2016. All the Giyani PLs, through Menzi Battery Metals, were renewed on 3rd August 2022 and are valid until 30th September 2024 with the exception of PL258/2017, which was renewed on 1st January 2021 and expires on 31st December 2022 (Table 4.1). According to the Mines and Mineral Act, the holder of a PL may, at any time not later than 3 months before the expiry of such licence, apply for renewal of the PL and shall be entitled to the grant of no more than two renewals thereof, each for the period applied for, which periods shall not in either case exceed 2 years, provided that (a) the applicant is not in default and (b) the proposed programme of prospecting operations is adequate (Government of Botswana 1999).

The location of the PL322/2016 in relation to Giyani’s other PLs is shown on Figure 4.2.

Figure 4.1 Location of the K.Hill Project

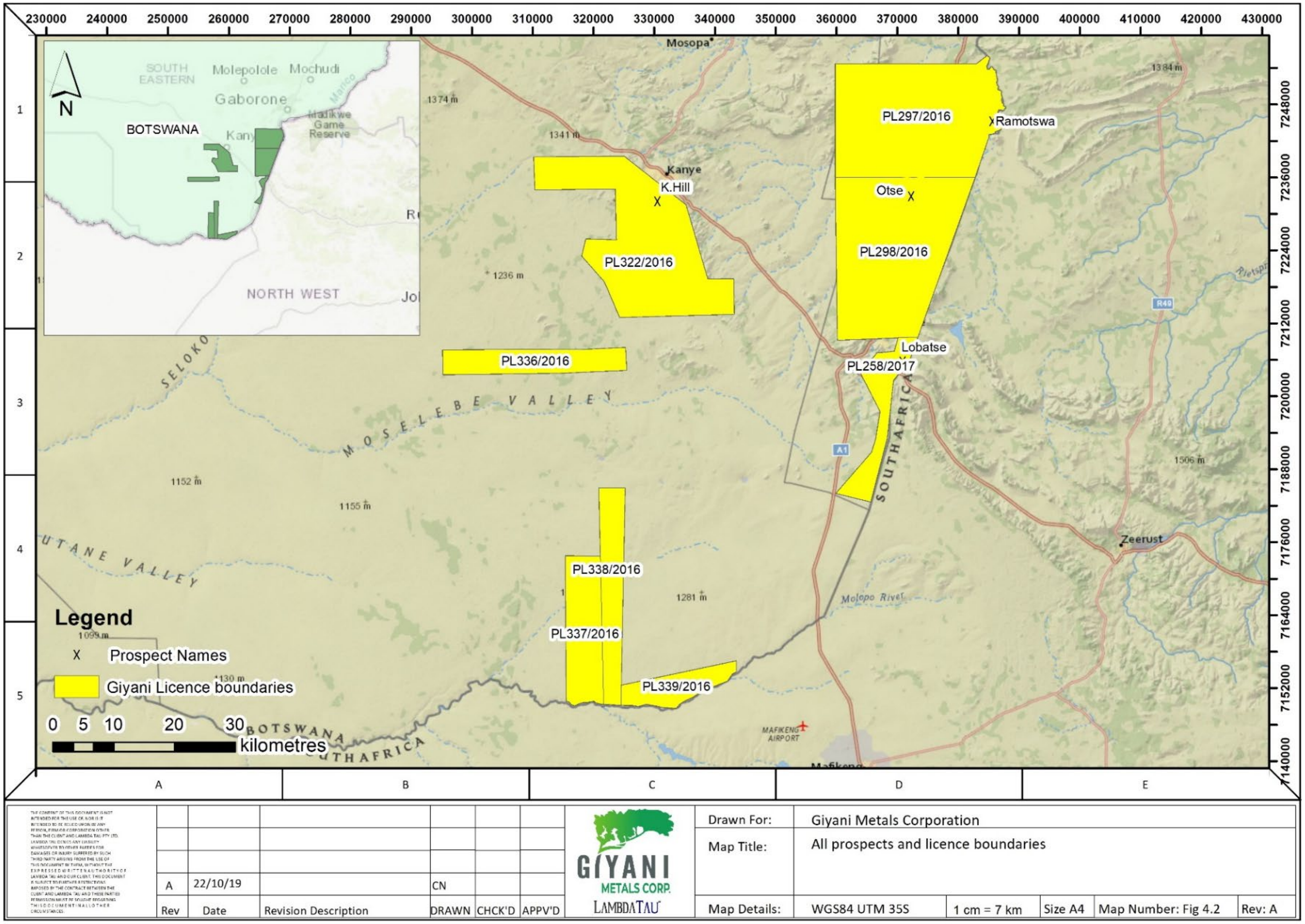


Source: Lambda Tau, 2022

Table 4.1 Summary of Giyani's prospecting licence holdings in Botswana

Licence number	Licence holder	Issue date	Licence type	Expiry date	Size (km^2)
PL297/2016	Menzi Battery Metals	01-July-2020	Prospecting	30-September-2024	482.9
PL298/2016	Menzi Battery Metals	01-July-2020	Prospecting	30-September-2024	478.4
PL322/2016	Menzi Battery Metals	01-July-2020	Prospecting	30-September-2024	437.7
PL336/2016	Menzi Battery Metals	01-July-2020	Prospecting	30-September-2024	118.1
PL337/2016	Menzi Battery Metals	01-July-2020	Prospecting	30-September-2024	144.1
PL338/2016	Menzi Battery Metals	01-July-2020	Prospecting	30-September-2024	127.1
PL339/2016	Menzi Battery Metals	01-July-2020	Prospecting	30-September-2024	76.8
PL258/2017	Menzi Battery Metals	01-January-2021	Prospecting	31-December-2022	95.0
				Total	**1,960.1**

Figure 4.2 Location of Giyani's prospecting licence holdings in Botswana



Source: Lambda Tau, 2022

4.4 Surface rights

The PL is on land that is classified as tribal and is managed by the Ngwaketse Land Board. The larger area around the Project is managed by the Ngwaketse Tribal Administration, which manage the land on behalf of the community across parts of the larger area surrounding the Project.

Water for drilling has been sourced from the Mmamokhasi Dam, which is approximately 3.4 km from the Project. Agreements were signed with the Mmamokhasi Village Development Committee (VDC) in 2018 (now expired) and 2021 (now expired), which gave Giyani permission to extract water for an agreed sum of P15,000 Botswanan Pula (P) per month. The Mmamokhasi VDC is an elected tribal authority that represents the local community in an area bordering the dam.

A third water agreement was signed in 2022 with the Mmamokhasi Dam Group (MDG); the MDG is the body that has overall responsibility for the dam. The Chief of the area in which the Mmamokhasi Dam is located, facilitated a meeting with the VDC, MDG, and Giyani representatives, and it was agreed this third agreement should be with the MDG.

4.5 Property obligations and agreements

According to Section 70 of the Mines and Minerals Act of the Republic of Botswana, the Licence Holder, at the time of issue of this licence and on each anniversary, thereafter, is required to pay to the Office of the Director of the Department of Mines an annual charge equal to P5.00, multiplied by the number of square kilometres in the licence area, subject to a minimum annual charge of P1,000. Menzi Battery Metals have fulfilled all obligations on licence expenditure.

Giyani, through Menzi Battery Metals, is expected to carry out the prospecting operations set out in PL322/2016 (Table 4.2).

Table 4.2 Programme of prospecting operations for K.Hill PL322/2016

Programme of prospecting operations	Proposed minimum expenditure (P)	Proposed minimum expenditure (US$)
Year 1: • brownfield exploration • resource expansion drilling • completion of FS study • post-FS engineering • various economical and financial analysis	2,000,000	159,617
Year 2: • mining and mineral processing optimisation • decision to mine • addition to existing Mineral Resource base	2,500,000	199,521

4.6 Environmental liabilities

In August 2018, Giyani contracted the services of Loci Environmental to undertake environmental screening studies for its projects in Botswana, including K.Hill, in August 2018. No significant issues were identified during this process.

Giyani received a request from the DEA of Botswana to complete an EMP for the K.Hill prospect area. Under this EMP, Giyani has clearance to conduct exploration and evaluation work, including, but not limited to, geophysics and other non-invasive exploration techniques, drilling, and sampling. The approval of the EMP for the K.Hill and Otse prospect areas was granted in July 2019 and was valid until 2021. The EMPs were renewed for one more year in 2021 (valid until July 2022). In September 2022, the DEA approved the EMPs for two additional years (expiring September 2024).

Giyani is required to complete a detailed EIA before any mining (which, by definition, includes construction) and/or processing can commence.

5 ACCESSIBILITY, CLIMATE, LOCAL RESOURCES, INFRASTRUCTURE AND PHYSIOGRAPHY

5.1 Accessibility

The Project area is well networked via paved national roads, namely the A1 and A2 highways. The K.Hill Project is located within a few kilometres of the A2 highway, which runs from Buitepos at the Namibian border; through Jwaneng, Kanye, and Lobatse; to the South African border at Pioneer Gate, near Zeerust, South Africa. The A2 is a major component of the Trans-Kalahari Corridor, which is a highway corridor that provides a direct route from Maputo in Mozambique via Pretoria to central Namibia, to Windhoek and the port of Walvis Bay.

The K.Hill site perimeter is accessible from the national road via paved public roads. Access on the site is mostly unpaved old mining tracks that have been opened for exploration access. Some areas remain overgrown and degraded by erosion.

Local communities own the surface areas around the K.Hill Project, and access is granted by notification only. The larger project area consists of a combination of privately-owned land and communal/tribal land.

5.2 Climate and physiography

The land surface of Botswana is mostly flat or gently undulating, with the greatest topographical relief located in the southern parts of the country. Kanye is at an elevation of approximately 1,300 masl, and Kgwakgwe Hill (after which the Project name is derived) forms a distinct topographical feature next to Kanye (Figure 5.1 and Figure 5.2), with elevations reaching approximately1,500 masl.

Various waste dumps, discards, stockpiled manganese mineralisation, and tailings occur in the K.Hill Project area, which together with cuts into the steep hillside formed from historical open pit mining, have disrupted the natural topography (Figure 5.3).

Generally, Botswana can be divided into three main physiographic regions:

- the Wetland region around the Okavango Delta to the north
- the Hardeveld region, with outcropping metamorphic geology in the southeast, in which the K.Hill Project area lies
- the Sandveld region, which comprises the central Kalahari sands

Most of southern Botswana is covered in some form of savanna. In the K.Hill Project area, common shrubs and small thorn trees exist, and no protected or scarce trees, such as the Baobab, Marula, Mopane, or Fig trees, have so far been observed at K.Hill (Lambda Tau 2017).

The climate is generally considered to be warm and arid with a summer rainfall season. Operations can continue throughout the year.

Figure 5.1 View from K.Hill toward Kanye, taken from a drilling site

Source: MSA (2018)

Figure 5.2 View of K.Hill showing historical spoil heaps

Source: MSA (2018)

Figure 5.3 Birds-eye view of the K.Hill Project area

Source: Giyani, 2018

5.3 Local resources and infrastructure

K.Hill is located just outside the town of Kanye, which has electricity supplied from the national grid. Kanye's water supply comes from the Mmamokhasi Dam, which is approximately 5 km from site. Water from this source has been used for drilling activities.

Formal mining in Botswana for copper (Cu), nickel (Ni), coal, gold (Au), and diamonds has taken place from the 1900s to present, as well as historical manganese mining in the Kanye area. Both underground and open pit mining skills are available in the country as well as skills gained from migrant labour in neighbouring South Africa. Kanye is located 70 km from Jwaneng Mine, a large open pit diamond mine. A historical tailings area is present on the site (Figure 5.3).

6 HISTORY

The discovery of manganese in the Kanye area led to mining from 1957 to 1971 (Aldiss 1989). The first of many companies operating at K.Hill was Marble Lime, which also developed the asbestos mine at Moshaneng, northwest of K.Hill. Marble Lime mostly mined the bedded-type mineralisation (described as Mn-shale during the Phase 1 mapping exercise completed by Giyani), which required beneficiation before it could be saleable (Aldiss 1989). Marble Lime ceased mining activities around 1967.

Further exploration work was carried out by Johannesburg Consolidated Investments Co. Ltd., during the late 1960s and early 1970s.

In 1981, Rand London Manganese investigated the possibility of mining the manganese shale deposits at K.Hill, Otse, and Gopane (near Lobatse), together feeding a single processing plant at Lobatse. The K.Hill deposit was considered to require further drilling for evaluation, but no further work was completed, and the licence was relinquished within a year (Aldiss 1989).

Historical production of manganese from K.Hill was reported by Baldock et al. (1977) to be 64,180 t from 1957 to 1967 and 131,563 t from 1968 to 1972 (Table 6.1). Variable prices were received for the product due to both metallurgical and high-grade battery-active products being supplied, with the latter attracting a premium at the time (Baldock et al. 1977). It is not stated how much of these tonnages were from open pit or underground mining, and these figures have not been verified by the QPs.

Table 6.1 Manganese production from the K.Hill Project

Year	Amount (t)	Value (R)
Total 1957-1967	64,180	798,678
1968	39,751	16,863
1969	16,732	290,433
1970	40,488	695,396
1971	34,387	140,655
1972	205	9,970
Total 1968-1972	131,563	-
Grand total	**195,743**	-

Notes: R - South African Rand
Source: after Baldock et al. (1977)

7 GEOLOGICAL SETTING AND MINERALISATION

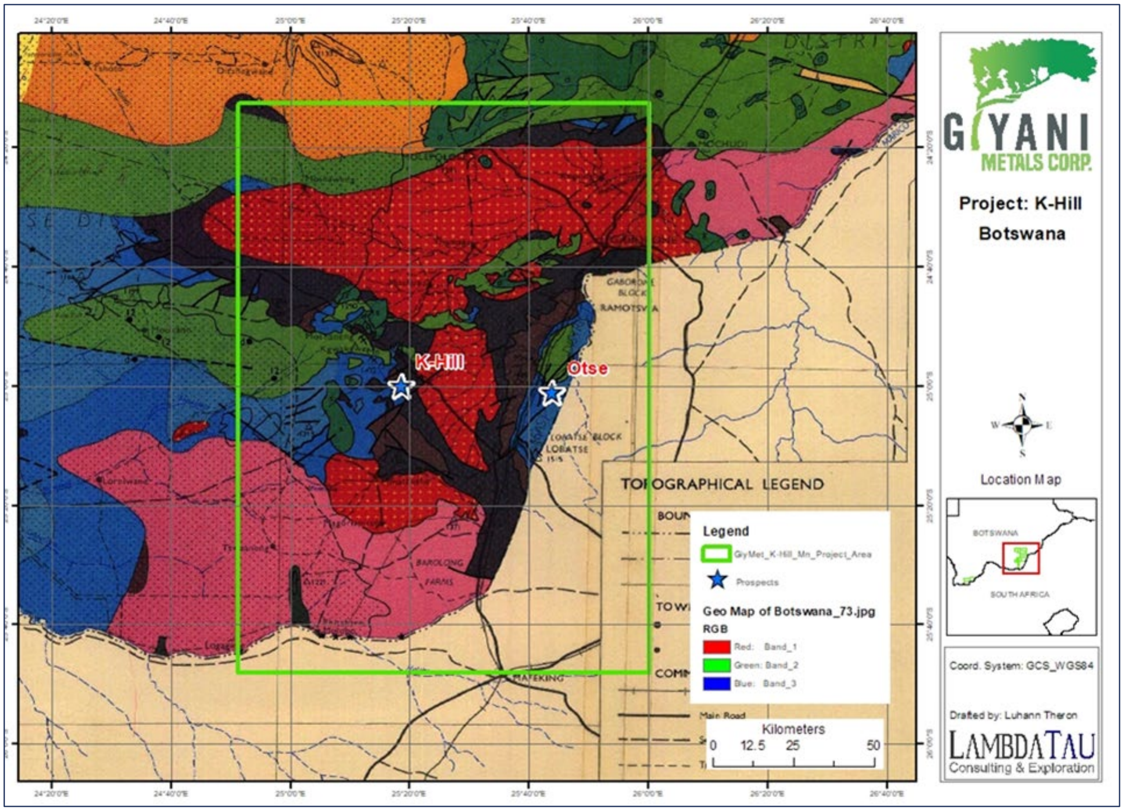
7.1 Regional geology

The stratigraphy in the K.Hill area consists predominantly of late-Archean to early- and middle-Proterozoic rocks from the Ventersdorp (meta-volcanics) and Transvaal (meta-sedimentary) supergroups, as well as the early-Precambrian Gaborone Granite (intrusives) and later Waterberg (sedimentary) Groups (Key and Ayres 2000). The location of the K.Hill prospect is shown superimposed on the 1973 regional geological map of Botswana in Figure 7.1. The Archean basement in southeast Botswana is well studied on a regional scale, and maps are generally accurate. The prospect occurs within the mapped Transvaal Supergroup sediments, consisting of shales, quartzites, limestones, and conglomerates (blue shading in Figure 7.1), and in the vicinity of the Kanye Group (part of the Ventersdorp Supergroup), consisting of a variety of extrusive lavas and subordinate siltstones and shales (purple shading in Figure 7.1).

To the east, the early-Precambrian intrusive igneous units of the Gaborone Granite suite occur (red and pink shading in Figure 7.1). The youngest succession in the K.Hill Project area is the Waterberg Group sediments (green shading in Figure 7.1). In 1998, Roger M. Key and Neil Ayres published a subsequent regional (1:1,000,000 scale) geological map of Botswana; however, most of the government regional mapping in the K.Hill area was completed prior to 1980, so for this area, the 1973 map is still accurate (Key and Ayres 2000).

The Moshaneng-Kanye area contains outcrops of a Transvaal-age sedimentary sequence, which forms part of the so-called Kanye Basin. This basin is oval in shape, with its long axis orientated NW-SE and extends over the Kgomodikae, Segwagwa, and Moshaneng areas. It is separated from the Transvaal sediments in the Lobatse area by Ventersdorp-age rocks, which comprise the Lobatse Volcanic Group, remnants of Archaean basement rocks, and the Gaborone Granite, all of which define the N-S trending Vryburg Arch between Kanye and Lobatse. At Kanye, the arch begins to swing westward through Moshaneng toward Jwaneng. Although partially separated by a veneer of Waterberg age rocks, the Transvaal Supergroup sequence around Moshaneng forms a structural continuum with that exposed around Kanye, as evidenced by the isolated ridges of chert breccia between the two. The Transvaal sediments outcrop in a poorly defined ring structure near the village of Moshaneng. The core of this structure is composed of alkaline rocks of the Moshaneng Complex.

Figure 7.1 Location of the K.Hill prospect on the regional geological map of Botswana, 1973



Source: Lambda Tau, 2021

In the Kanye area, only the lower parts of the Transvaal succession, the Black Reef Quartzite Formation, and the Taupone Dolomite Group, are present. The sediments of the Black Reef Quartzite Formation constitute a sequence that fines upwards from conglomerates at the base through arenites to shales and mudstones at the top. This suggests a progressive increase in water depth consistent with a major marine transgression. The discontinuous clast-supported conglomerates are thought to have been deposited in localised stream channels within an active tidal beach environment. This conclusion is supported by the occurrence of very mature quartz arenites overlying the conglomerates.

The Black Reef Quartzite Formation passes gradationally through an interval of bluish-grey shales and mudstones into the overlying carbonates. The carbonates are interpreted as being predominantly deposited on a tidal flat. Local sandstone lenses may occur in the upper portions of the dolomite sequence and mark the start of a regressive cycle in which terrigenous sediment was reintroduced.

The predominance of the Paupone Dolomite Group and the extensive development of chert breccias, as opposed to banded iron formation, suggests that the deposition of the Transvaal Supergroup rocks took place in a tectonically active basin. Tectonic instability is also evident during the deposition of the Black Reef Quartzite Formation, as indicated by the development of localised fault-scarp conglomerates as its base.

7.2 Local stratigraphy

7.2.1 Summary

The mineralisation at K.Hill is primarily associated with the upper shale horizon of the Black Reef Quartzite Formation. The quartzite package underlying the shales rests unconformably on Archaean felsites of the Kanye Volcanic Group. The shales in turn are overlain by the chert breccias of the Paupone Dolomite Group (Figure 7.2), which suggests non-deposition of the intervening dolomites or a massive unconformity. The Kgwakgwe Chert Breccia Formation in the Kanye area can be subdivided into two main varieties:

- a dark-brown chert breccia with milk-white angular chert fragments, cemented together by brown haematitic material
- a reddish-brown chert breccia with abundant jaspilitic fragments and a high content of jasper in the matrix

Figure 7.2 Chert breccia at K.Hill

Source: MSA (2018)

7.2.2 Lithologies

Six lithologies were consistently intersected during drilling operations. These include a chert or chert dolomite breccia unit, which occurs at the top of the stratigraphic sequence. Below that is an approximately 50 m thick package of shale identified to be part of the Black Reef Quartzite Formation, which hosts the manganese mineralisation within the shale units. Below this shale lies an iron-rich shale, which is often intruded by manganese oxide material into fractures and joints. Below the iron shale (Fe-shale) lies a lower iron shale unit, typically a beige colour with no significant manganese content. A shale-containing manganese clay is also observed within the beige shale. Between the overlying shales and the felsite footwall unit lies a conglomerate marker unit, observed in almost all the drillholes. In some holes this marker conglomerate has a gritty texture with small clasts and is also mineralised with manganese oxides.

7.2.3 Chert dolomite breccia

This unit consists of angular chert (dolomite) clasts within a haematite-rich matrix. The chert dolomite breccia (CDB) unit decreases in grain size and abundance vertically. In addition, the unit becomes laminated before transitioning into the underlying and softer Mn-shale unit. The contact is typically broken and is assumed to be sharp and erosional. Minor overburden of typically less than 1 m in thickness is also intersected at the top of the sequence.

7.2.4 Mn-shale

The Mn-shale (MSH) lithology is the primary mineralisation host. The lithology consists of massive and homogenous manganese oxide mineralisation, with a steel grey, submetallic lustre. The horizons are generally associated with higher magnetic susceptibility readings when compared to adjacent shale and CDB units, especially when manganese oxides are observed visually. The MSH lithology also has a dark black, friable shale/clay component, which makes up the bulk of the unit. These dark black sections are thought to contain manganese wad, a high-grade manganese dioxide complex. Laminae of Kaolin clay are also observed. The MSH horizons are typically 3 m to 4 m thick. Core recovery can be poor due to the friable nature.

7.2.5 Fe-shale

The Fe-shale (FSH) lithology, being rich in iron, is found above and below the MSH lithology and is, generally, the most extensive lithology in the K.Hill area. The unit hosts sporadic, vein and fissure fill mineralisation of manganese oxide and can also occur as thin 1 cm to 3 cm thick bands. Mineralisation is confined to the upper sections of the unit and grades into alternating weak to moderate non-mineralised Fe-shales downhole. Haematite and bleaching alteration often occur.

7.2.6 Beige-cream shale

The beige-cream shale (SHL) unit is a non-mineralised, homogenous unit, occurring below the FSH units. The SHL units have gradual contacts and are interspersed between a manganese clay and/or conglomerate unit.

7.2.7 Mn-clay

The manganiferous clay (Mn-clay or MCLAY) unit contains low-level mineralisation present in the form of laminations or pervasive blotches. Moderate limonite alteration is typical of this unit.

7.2.8 Conglomerate

The conglomerate (CONG) unit is the primary marker of the footwall. This unit appears to be weakly mineralised in the south of the K.Hill region. The CONG units within the north have a coarser grain size than the units in the south. The unit is characterised by a granular/sugary texture, with subhedral clasts of quartz. This unit is often interspersed by 10 cm bands of cream shale, with sharp upper and lower contacts.

7.2.9 Felsite

This felsite (FEL) unit is a fine-grained, silica-rich igneous extrusive rock forming the footwall to the shale and conglomerate units. The exact composition of the FEL unit is unknown and is referred to as felsite. The unit is not mineralised and contains pervasive-blotchy haematite alteration and localised-pervasive limonite alteration.

7.3 Property geology

The Mn-shale horizon extends at surface in outcrop in the north and to the south below surface, where its presence has been intersected in drillholes. To date, the known strike length of the horizon is 1.9 km.

The stratigraphy has been duplicated by thrusting in places, and, to the south, the mineralised horizon has been extensively downfaulted by steeply dipping E-NNE trending faults. The shales have been intensely folded and slumped in the vicinity of these dislocations, and in addition, subparallel breccia zones and quartz veining may be evident.

The entire Transvaal package is cut out against the Waterberg sediments to the west of Kgwakgwe Hill along what are thought to be northerly trending faults.

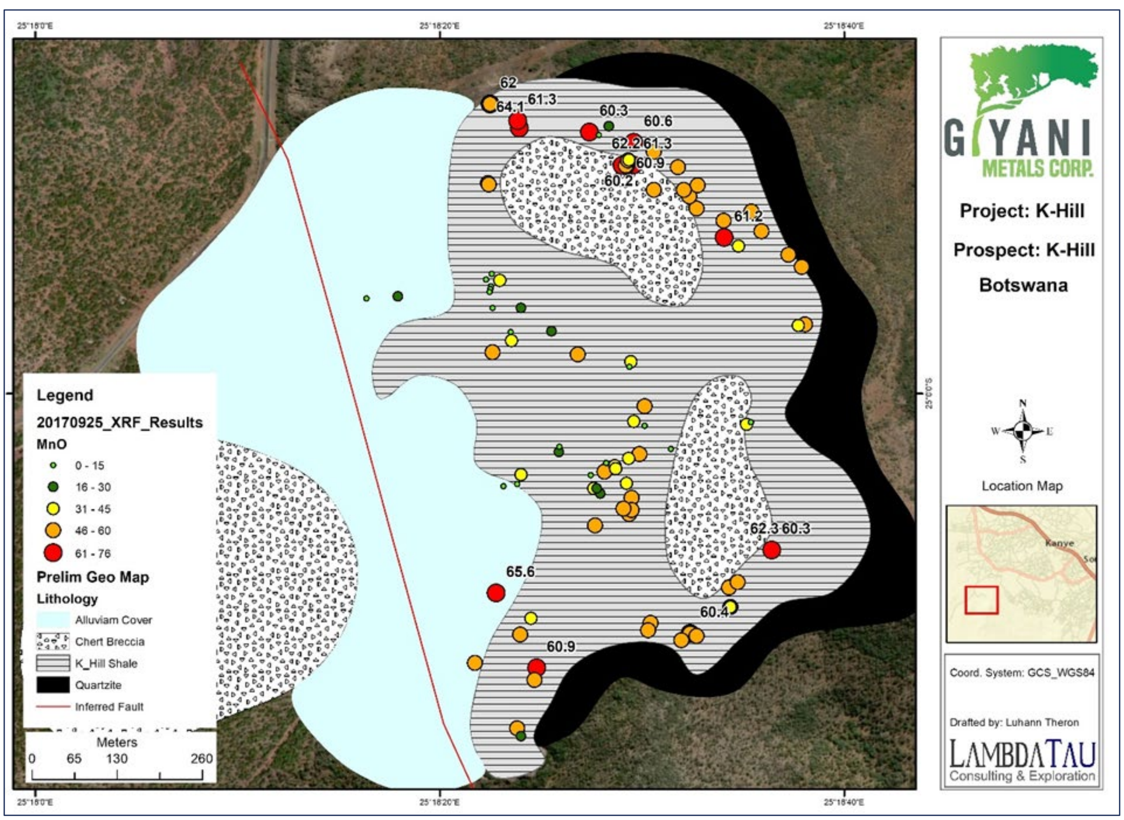
The Mn-shale outcrops along the northerly scarp slope of the Kgwakgwe Hill and dips into the hill (Figure 7.3). The strata at K.Hill dip gently toward the NW, at an average of approximately 5° to 10°, and S and Z parasitic folding is common. Numerous outcrops display parasitic folding, with local dips varying from 45° to almost subvertical. This is not consistent with the overall shallow dip of the Mn-shale and adjacent units. Where the deposit outcrops in the north, the Mn-shale unit is kidney shaped. The unit varies between approximately 2 m and 15 m thick, with an average thickness in the order of 4 m and has a delineated extent of approximately 1,900 m N-S and 350 m E-W. Some of these thicker intersections may be local fold duplications of a single horizon. In general, the Southern Extension Area shows greater thicknesses of the mineralisation than in the north.

A simplified geological map of the mineralised area, including the positions of surface grab samples of manganiferous material, is shown in Figure 7.4. The outcrop defining the limit of the Mn-shale is well defined in the east, with the areas to the west being partially covered by alluvium and/or exposed by historical surface mining into the hillside. Little or no outcrop is observed in the areas south of northing 7233525. In this southern area, the extents of mineralisation are defined by drilling only.

Figure 7.3 Mn-shale (black unit) and overlying shale (pale brown unit) exposed at the entrance to artisanal workings

Source: MSA (2018)

Figure 7.4 Simplified geological surface map of the K.Hill Project area



Source: Lambda Tau (2017)

Figure 7.5 presents an oblique view of the geological interpretation for the northern area, with a typical simplified cross section provided in Figure 7.6, showing the main Mn-shale horizons and how they have been coded for the purposes of modelling the Mineral Resource. This interpretation represents the shale horizons as broadly stratiform, shallowly dipping units (5° to 10°), where the interpretation is based on the mapped mineralisation outcrops and drillhole intercepts.

The horizons have been coded from A to C, with the highest layer coded as A, central layer as B, and lowest layer as C. In addition, A Horizon has been subdivided into the A1, A2, and A3 horizons, reflecting changes in manganese content across the layer.

Based on recent field observations (Section 7.5), it is possible that the Mn-shale horizon is not the simple, continuous, shallow dipping horizon but far more disrupted and discontinuous due to thrusting, causing local folding and faulting of the Mn-shale horizon. This alternative interpretation, which requires further investigation prior to incorporation in an updated model, is unlikely to materially impact the overall continuity of the individual horizons and, therefore, the global volumes of the horizons, but it may impact on the short-scale morphology and grade distribution of the horizons, and, in turn, may explain the variable thickness observed in the horizons.

Figure 7.5 Oblique view of the K.Hill geology model Northern Area (looking due west)

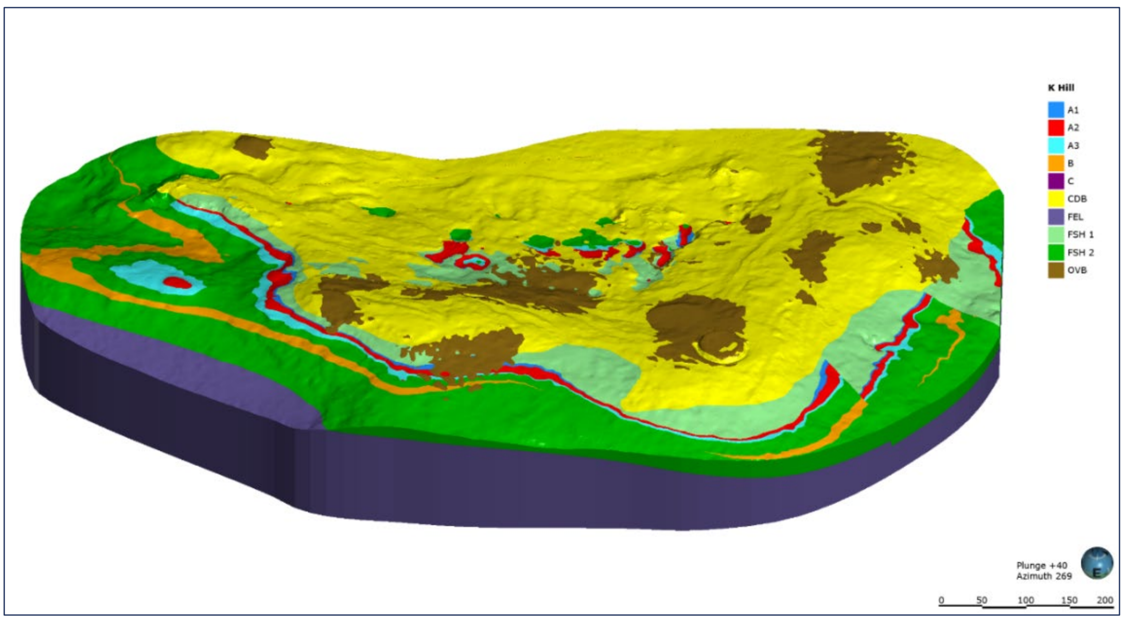
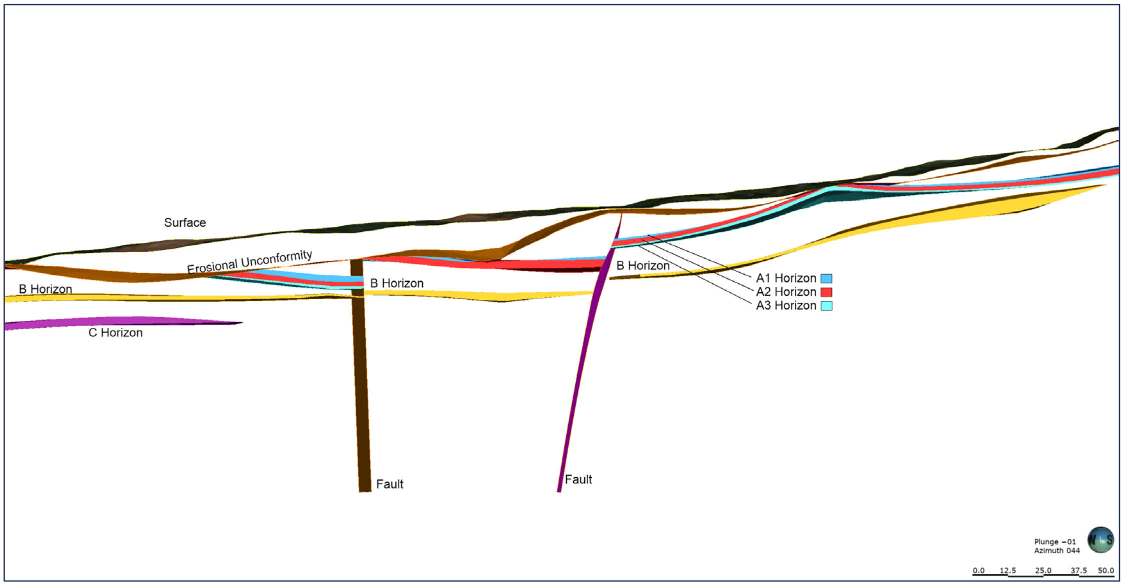


Figure 7.6 Typical cross section through the K.Hill Mn-shale horizons

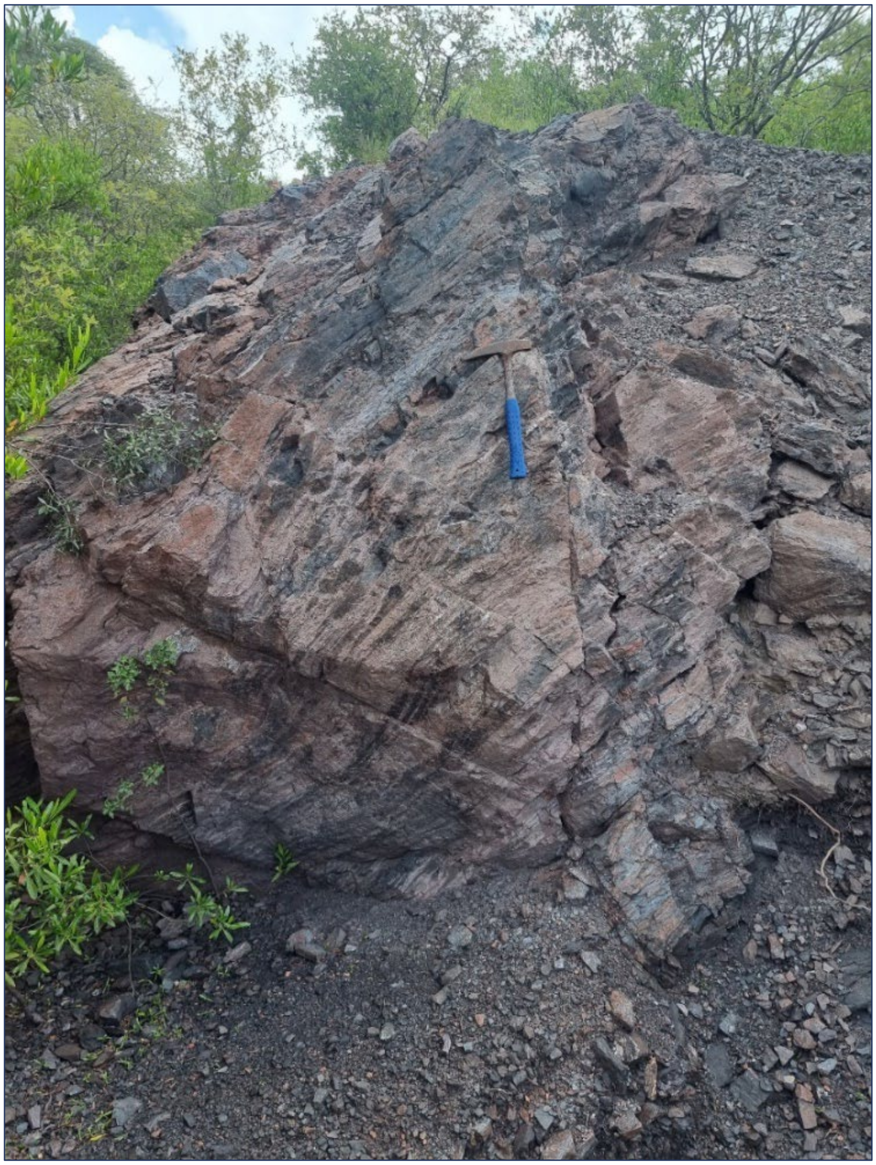


7.4 Structural geology

The mineralised horizons have been interpreted as two packages: the Upper Mn-shale A Horizon and the Lower Mn-shale B Horizon, both of which dip shallowly (5° to 10°) toward the NW. The current interpretation considers the horizons as continuous stratiform bodies based on outcrop (where available) and drillhole data.

A recent site visit in January 2022 indicates that the structural geology of K.Hill may not be as simple as originally outlined. Field observations of outcrops on the hill where the main deposit occurs show numerous examples of parasitic Z, S, and anticlinal folds. To have such folds and yet maintain such shallow uniform dips poses a problem with the spatial accommodation of the Mn-shales. The stratigraphy itself is Paleoproterozoic in age (Transvaal Supergroup, 1.2 Ga). Elsewhere in the region, stratigraphy of this age displays significant evidence of deformation. Most outcrops visited display evidence of widespread parasitic folding (Figure 7.7). Structural reading of exposed fold axial surfaces (hinges) shows strikes of between NNW-SSE to N-S, almost parallel to the overall strike of the beds with plunges of between 5° to 10°.

Figure 7.7 Outcrop of folded, steeply dipping, Mn-shale unit at K.Hill



Based on these field observations, it appears the stratigraphy may have been duplicated by the presence of thrusting. This may well explain how the parasitic folding has been accommodated, and the overall dip of the stratigraphy remains shallow (5° to 10°) and dips to the west, whilst locally it can vary from 45° to almost vertical. The presence of a possible basal and upper thrust (now eroded) may have formed a series of detachment fold duplexes that has given rise to parasitic folding and associated faulting. Figure 7.8 shows an example of this interpretation in folded and faulted sediments from another location.

Figure 7.8 Example of localised folding and faulting similar to that seen at K.Hill

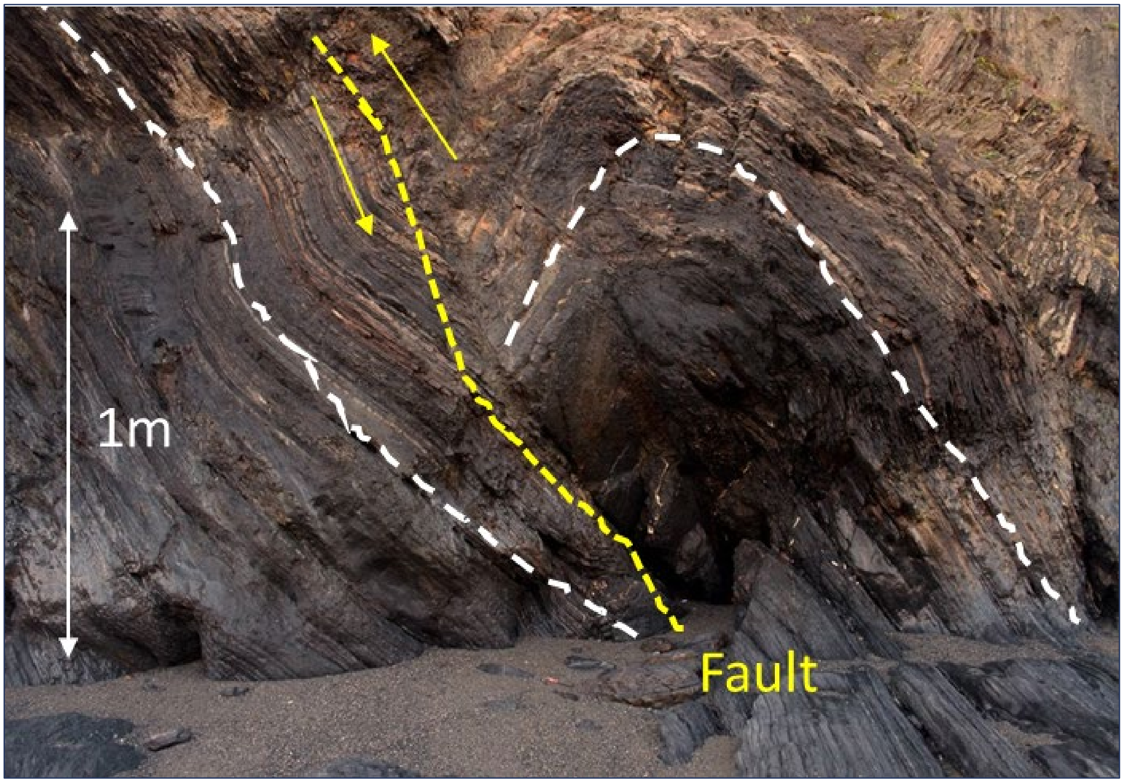
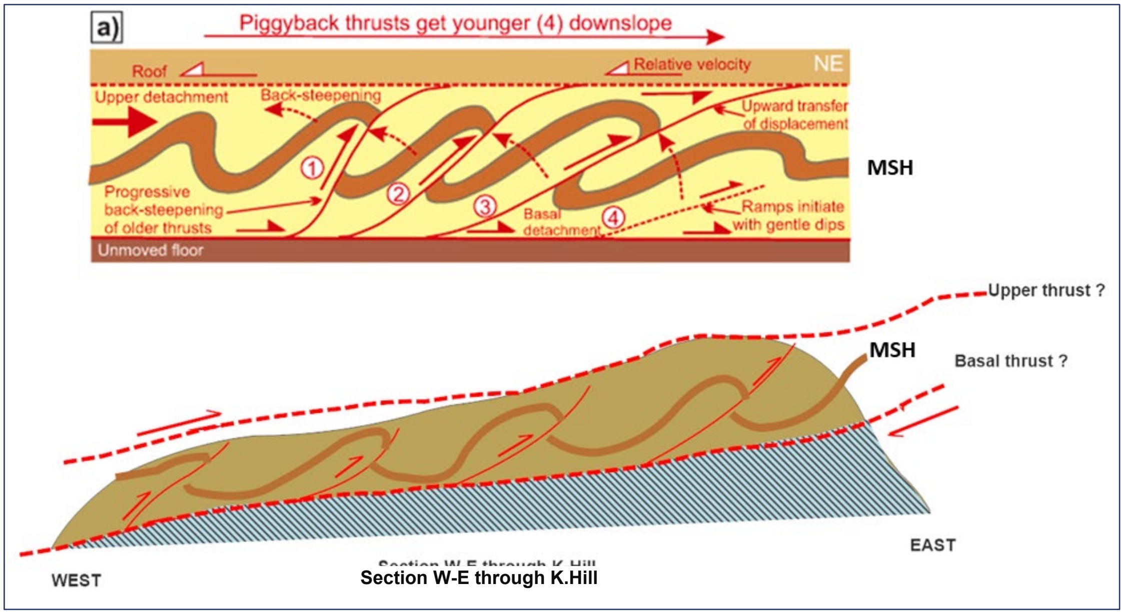


Figure 7.9 shows an idealised W-E cross section through the main K.Hill deposit at approximately northing 7233900, presenting the possible development of such structures caused by local thrusting in the footwall and hanging wall of the mineralised horizon. The development of parasitic fold duplexes caused by thrusting of the Mn-shale and associated stratigraphy may give rise to the development of localised lenses of thicker (and possibly higher grade) manganese mineralisation. It has also been noted that many of the historic workings do not follow the manganiferous mineralisation down dip to the west. It appears, based on site observations, that the historic adits may have preferential mined manganese mineralisation along fold hinges and trend in a more northerly direction.

An alternative to a sedimentary stratiform interpretation or the parasitic folding due to thrusting may be syn-sedimentary mass flow movement of material (sedimentary slumping). However, although this would account for the range of dips observed at outcrop, this is thought less likely, as no typical soft sediment deformation features have been noted (flame structures, clastic dykes, slumps).

Figure 7.9 Possible development of detachment fold duplexes associated with faulting at K.Hill



The implication for adopting a revised interpretation incorporating parasitic folding due to thrusting on mineralisation, resources, and mining at K.Hill would be:

- less continuity of mineralisation down dip than is currently envisaged and with preferential thickening of localised lenses with a dominant N-S to NNW-SSE trend
- revision of the mineralisation domain models at a local/short scale (i.e., closer than current drill spacing), where SRK would envision that globally the volumes and tonnes would be similar, but that there may be local-scale modifications to the geometry to reflect the revised interpretation and adjustments to the local-scale grade variability
- this local-scale variability may require a greater degree of grade control definition drilling to accurately define the Mineral Resource at higher levels of confidence such as Measured
- in terms of mining, a more selective approach may be required to mine mineralisation that maybe less continuous at a local scale than originally anticipated

Giyani needs to consider carrying out a detailed structural analysis of the K Hill deposit by an experienced structural geologist to determine if SRK's preliminary observations are in fact correct.

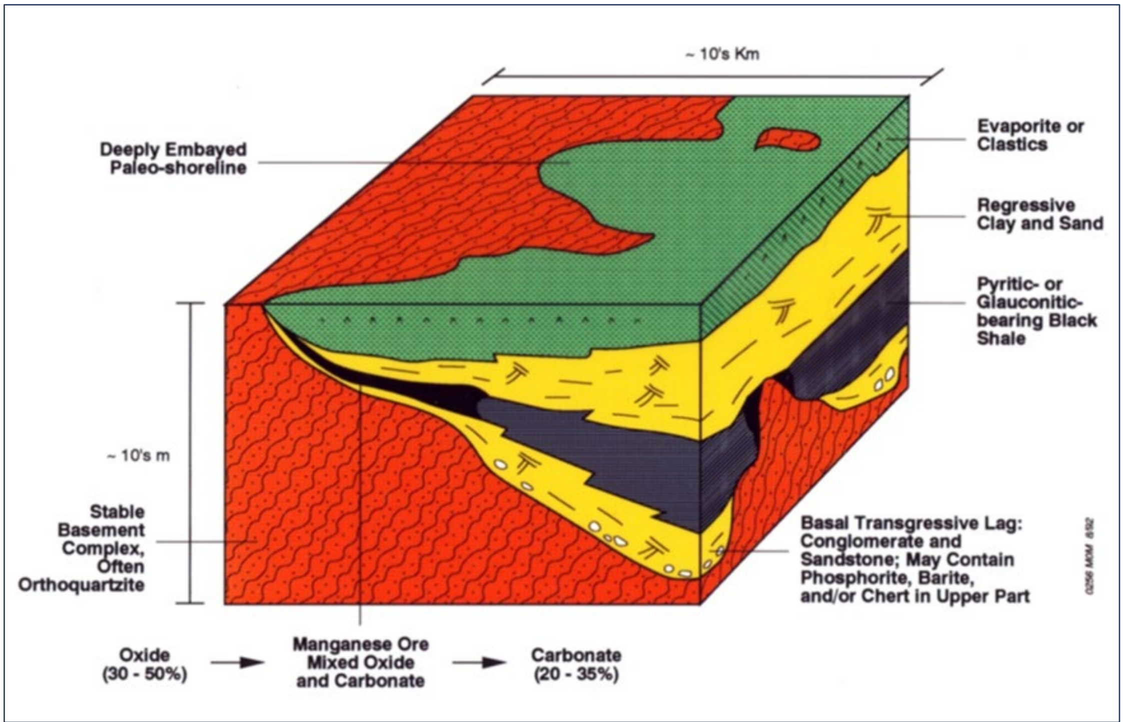
8 DEPOSIT TYPES

The manganese mineralisation occurs as a supergene-enriched shale (the Mn-shale) within the Black Reef Quartzite Formation.

The Mn-shale itself appears to represent primary manganese deposition in a shallow marine basin, as per the Canon and Force (1986) model referred to in Figure 8.1. As is typical for most manganese deposits, there is clear evidence of upgrading by means of supergene enrichment. This evidence includes the following:

- Only manganese oxide mineralogy has been noted to date.
- Observed manganese mineral textures are consistent with secondary precipitation.
- The presence of fine manganese wad and the presence of cavities and vugs are intersected in the drillholes in the Mn-shale.

Figure 8.1 Illustration of the Cannon and Force (1986) model for sedimentary manganese mineralisation



Source: Cannon and Force (1986)

There are two possible time intervals during which weathering and supergene enrichment could have occurred: the recent period of exposure as well as the ancient period of exposure associated with the unconformity at the base of the chert breccia. If supergene enrichment is only related to the current exposure, then the enrichment could be limited in extent by the current geomorphology and may only extend under the hill to the limit of weathering. If there was supergene enrichment during the period associated with the unconformity, then more extensive supergene enrichment may have occurred. The latter possibility appears to be supported by the drillhole intersections. Two mineralising processes are evident, namely an initial phase of mineralisation by precipitation and diagenesis during sedimentation (forming the Mn-shale) followed by one (and possibly two) phases of redistribution and concentration during weathering and supergene enrichment.

Interpretation of the gravity map allows the recognition of a very clear marine basin embayment paleogeography of the type typically recognised in the Cannon and Force (1986) model. The Archaean floor to the basin seems to be well described by the gravity anomalies. Interpretation of the gravity map indicates the possible presence of two shallow marine embayments with a N-S running paleo-shoreline shoaling to the east and deepening westward.

8.1 Mineralisation style

Key elements of the Canon and Force (1986) model and this mineralisation style may be summarised as follows:

- The Cannon and Force (1986) model is a depositional model for a large number of sedimentary manganese deposits that have their formation during times of high sea level stand and stratified sea columns in common. Manganese precipitation occurs at intersections of horizontal oxidation-reduction interfaces with shallow marine substrates within shallow marine embayments.
- The manganese occurs in typically thin, flat-lying stratiform and stratabound layer(s), often of enormous lateral extent. They are stratiform marine basin-margin deposits, which may be present in oxide and (or) carbonate facies, tend to be in condensed stratigraphic sequences, result from low-energy deposition, and have little clastic dilution. Characteristically, the manganese horizon is a thin but laterally extensive stratigraphic condensed sequence-type interval.
- Basin analysis has shown that these types of deposits typically occur in settings characterised by deposition in localised basins or shallow marine embayments around littoral paleo-islands, peninsulas, and shoals. It is important to delineate barrier island, embayments, and shoal settings because of the role of basin sills in isolating anoxic seas and favouring black shale formation. The relationship to the basin's basement and floor is critical. Major deposits usually formed close to the basin margin. Deposits are often less than 100 m above the basement.
- The host rocks are typically sandstone (or orthoquartzite), siltstone and claystone, shales, and black shale. Subordinate poorly consolidated limey sediments (marls) occur. Diatomaceous clays, radiolarian sediments, and shell beds are common. Black organic- and pyrite-rich shales and glauconitic sands are common in footwall rocks.

- Mineralogically, they typically include an oxide facies, an oxide-carbonate facies, and a carbonate facies. Currently there is only evidence of oxide facies in the K.Hill deposit:
  - The oxide-facies manganese mineralisation most commonly includes cryptomelane-group minerals and pyrolusite and over 40 oxide minerals. Less-oxic deposits contain manganite, braunite, and kutnohorite. Psilomelane and wad (primary and supergene iron and manganese oxide mineral intergrowths) are commonly listed in older literature. Gangue typically includes clay minerals (commonly montmorillonite), carbonate minerals, glauconite, quartz, chert, and biogenic silica.
  - If developed, the oxide-carbonate facies include psilomelane, manganite, manganoan calcite, and rhodochrosite.
  - Carbonate facies mineralisation typically includes rhodochrosite, kutnohorite, and manganoan calcite; siderite; mixed manganese and iron-carbonate minerals; pyrite; and wad. Gangue typically includes clay, calcium, and calcium-magnesium carbonate minerals; glauconite; organic matter; pyrite; quartz; and biogenic silica.
- Secondary superimposed weathering and supergene processes are common. In-situ weathering and oxidation enhance both the oxide and carbonate primary mineralisation. Manganese carbonates may weather to a brown non-descript rock. Black secondary oxides are common. Penecontemporaneous erosion, oxidation, and sedimentary reworking (tidal lag) of oxide and oxidised carbonate mineralisation can give rise to higher grades. Contacts between primary and supergene-enriched zones are typically sharp.

This mineralisation type typically presents manganese grades as follows:

- primary: 20% to 40% manganese, low iron
- secondary: 30% to 50% manganese, low iron
- iron content: host rocks are low in iron
- examples of this mineralisation type include:
  - Groote Eylandt, Australia
  - Nikopol & Bolshoi Tokmakskoe, Ukraine
  - Chiatura, Georgia
  - Obrochischte, Bulgaria

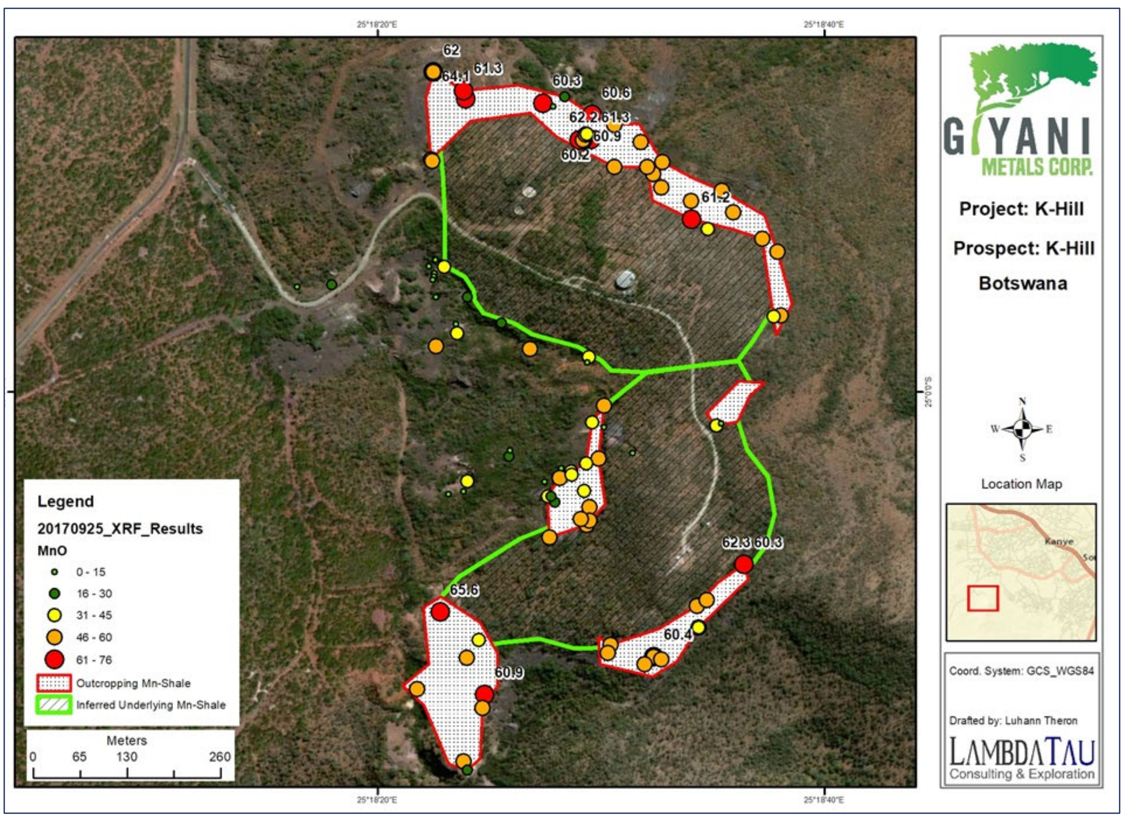
9 EXPLORATION

9.1 Mapping and sampling

Early exploration at K.Hill was designed to geologically map and geochemically sample the prospect licence area. Geologists equipped with a Garmin GPSMAP 64S global positioning system (GPS), Brunton Compro Pocket Transit compass as well as RockLogger Android software, spent 13 days mapping and sampling in and around the main prospect area.

A preliminary stratigraphic column was interpreted from the field observations. It is important to note that the Mn-shale and the K.Hill shale are not the same unit. The K.Hill shale, as shown in Figure 9.1, refers to the entire shale unit. This unit varies in composition and character but represents the same geological event. The Mn-shale refers to a specific horizon within the K.Hill shale that contains enhanced levels of manganese mineralisation.

Figure 9.1 Location of outcropping Mn-shale as well as the area of Mn-shale inferred to underly K.Hill



Source: Lambda Tau (2017)

Historical mining efforts focused toward the inner area, with unmined outcropping mineralisation toward the outer northern and north-western edges. Adits from artisanal mining around this outcropping area are common.

Outcropping mineralisation, as well as exposed mineralisation in the historical mining pits, were sampled. Various mineralisation styles were observed and sampled. Grab samples were taken from the K.Hill shale within and away from the Mn-shale outcrop. These were taken where outcrops existed, and access allowed. A total of 97 grab samples were collected from the K.Hill prospect, and additionally, 25 samples were submitted as duplicates to test variability in sampling technique and analyses. All samples were taken from surface and within old open pit faces except for two samples that were taken from artisanal adits. Sampling was focused on mineralised units, although some samples were also collected from the non-mineralised footwall and hanging wall units. Rock units sampled included Mn-shale, ferruginous shale, quartzite, chert breccia, and siliceous/silicified shale.

SGS in Randfontein, Johannesburg, South Africa analysed the grab samples using borate fusion followed by XRF.

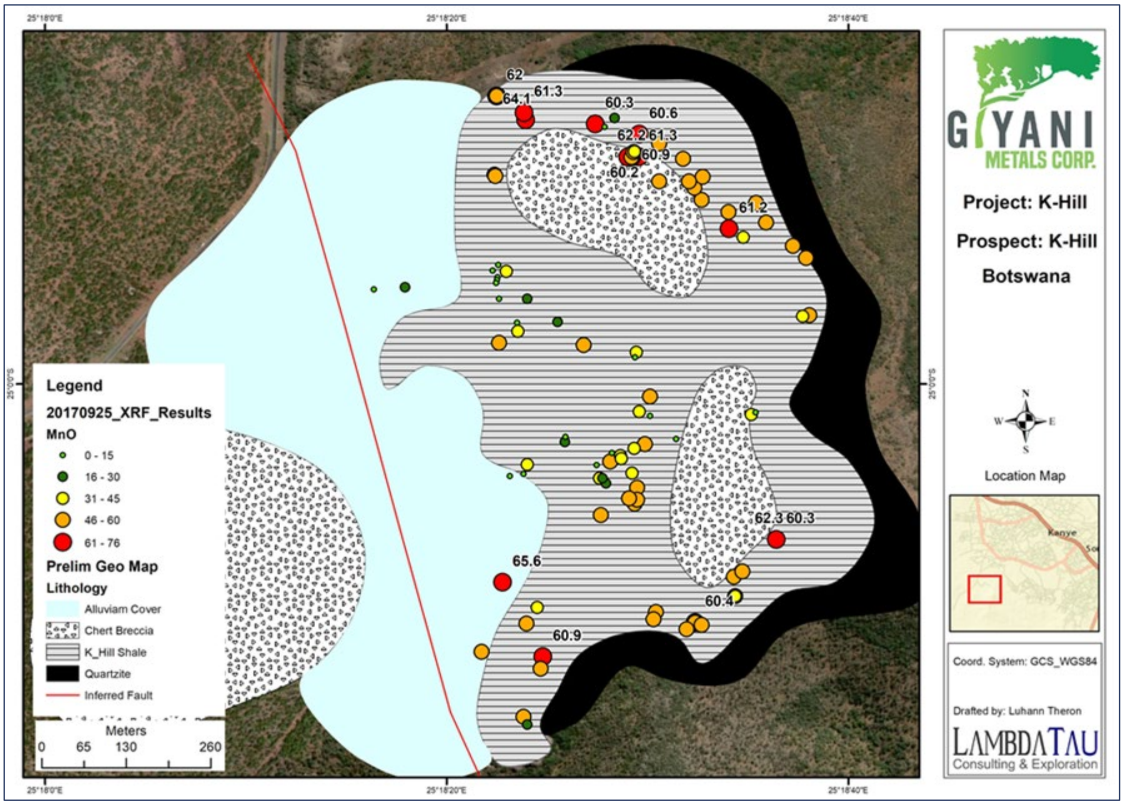
It should be noted that the sole purpose of the grab sampling was to identify the location and nature of the mineralisation. Samples of this nature are not suitable for estimating the grade of the deposit. The grab samples are not representative of the grade of the complete mineralised unit, and sampling of this nature is inherently biased, generally toward a higher grade.

Samples collected from outcropping Mn-shale units yielded the highest manganese grade, as can be expected. Lower-grade and non-mineralised footwall and hanging wall units were sampled where they were exposed by historical workings. Instances of high-grade manganese oxide (>50%) occur along the entire approximate 1.25 km of Mn-shale outcrop. Due to the biased nature of the grab sampling, this should not be misconstrued as the in-situ grade of the Mn-shale unit but does illustrate that occurrences of high-grade manganese mineralisation occur within the outcrop.

A preliminary geological map is shown in Figure 9.2. More detailed work is required to refine this surface map.

Table 9.1 summarises the average manganese oxide values of the units sampled by the grab sampling programme at the K.Hill Project. It should be noted that the figures shown in Table 9.1 are the average results of a grab sampling exercise focused on identifying the location of enhanced manganese mineralisation and the potential of different units to contain elevated levels of manganese. These figures are not intended to represent an estimate of the grade of the units.

Figure 9.2 Preliminary geological surface map of the K.Hill prospect area showing the grab sample locations and grades as ranges



Source: Lambda Tau (2017)

Table 9.1 Summary of analytical results from the K.Hill grab sampling programme

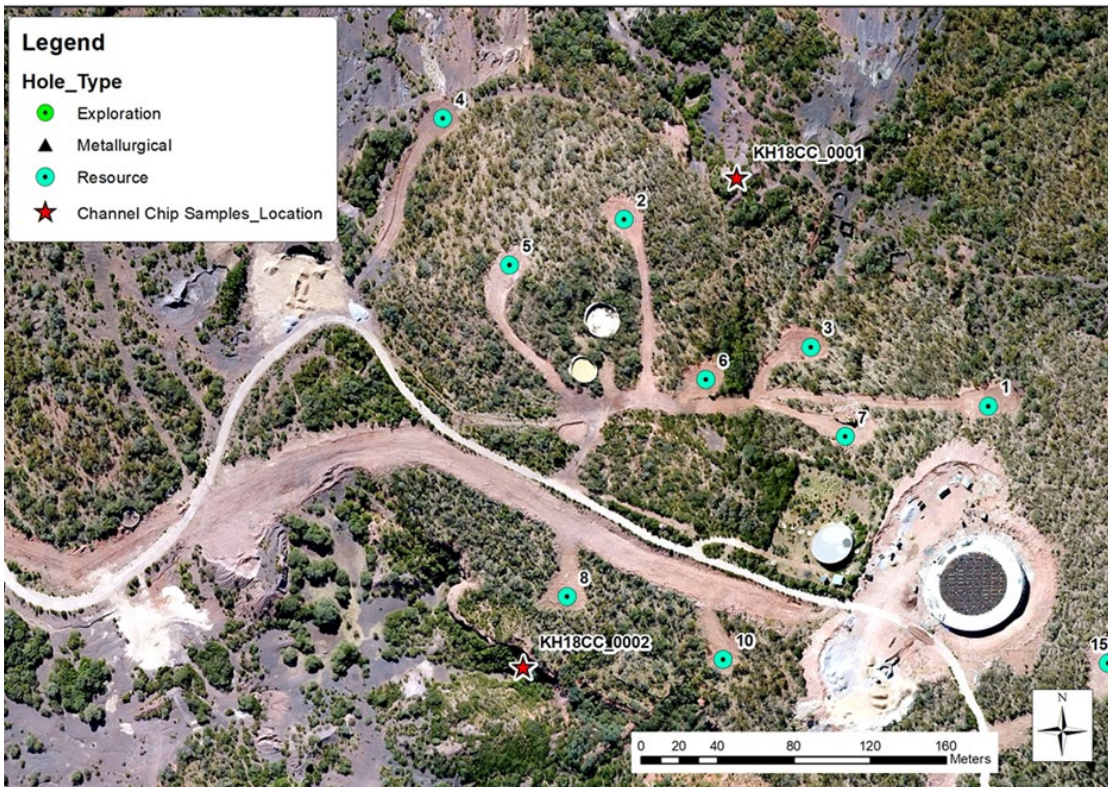
Unit	Number of samples	Maximum MnO (%)	Minimum MnO (%)	Average MnO (%)	Comments
Mn-shale	74	64.1	1.7	44.5	Main mineralised unit
Ferruginous Shale	9	0.08	0.04	0.05	-
Chert Breccia	4	0.04	0.03	0.04	Hanging wall
Silicified Shale	5	0.04	0.03	0.03	Hanging wall
Quartzite	1	32.3	32.3	32.3	Footwall: sample probably contaminated

9.2 Channel chip sampling programme

Channel chip sampling was conducted at K.Hill at two locations. The aim was to collect representative samples from the Mn-shale without any loss in material. The intended use of the samples was for future metallurgical test work.

Two outcrops were identified for sampling: KH18CC_0001 and KH18CC_0002 (Figure 9.3). Site preparation included excavation at the bottom of the face, to a depth of 1 m, to achieve a full 3 m of exposed face. The exposed face was cleaned by removing the outer 5 cm of weathered material. Sampling was conducted over a 3 m intersection of the Mn-shale unit in intervals of 1 m. A fourth sample consisting of a complete channel chip sample through the entire 3 m interval was also collected at each location.

Figure 9.3 Locations where the two channel chip samples were taken (shown as red asterixis)



Source: Lambda Tau (2017)

9.3 Geophysics (gravity, induced polarisation, and magnetics) programme

Giyani engaged Remote Exploration Services (Pty) Ltd. (RES) to complete high-resolution ground gravity and ground magnetic surveys over K.Hill. RES describes the geophysical surveys as follows (RES 2018):

- The K.Hill ground gravity grid comprised 1,987 planned gravity stations. All gravity grids were planned with 50 m × 50 m spaced stations. Ground magnetic data were collected on the same survey lines as the gravity grids along N-NE to S-SW oriented lines at K.Hill. All data were collected in continuous surveying (Walkmag) mode, which translates to a reading every 1 m to 2 m on 50 m spaced survey lines. In total, 101 km of magnetic data were collected over K Hill. Three, 1 km induced polarisation (IP)/direct current (DC) traverses were undertaken based on the results from the gravity and magnetic data.
- Ground gravity station positions were measured using a Trimble R6 real-time kinematic (RTK) differential global positioning system (DGPS). Coordinates for the beacons were provided by the Botswana Department of Surveys & Mapping in Cape LO25 format with orthometric heights. These coordinates were transformed to World Geodetic System (WGS) 84 Universal Transverse Mercator (UTM) 35S. Gravity station positions were marked and measured by walking a pattern that included approximately 5% internal repeats as well as approximately 5% external repeats. Following RTK surveying, gravity readings were taken over all stations. A Scintrex CG-5 Autograv gravity meter was used to complete the gravity survey.
- Magnetic data were collected using a GEM Systems Inc. (GEM) GSM19 Overhauser magnetometer in Walkmag at a 1 second sampling interval. A GEM proton precession magnetometer was used to monitor and correct for diurnal variations. Location data were collected with handheld GPS, which was time synchronised with both Walkmag and base station magnetometers.
- With regards to IP/DC data collection and in order to evaluate the effectiveness of IP/DC techniques, three approximately 1 km lines of IP/DC were collected. IP/DC traverses were designed to extend from felsic volcanic basement (Kanye Volcanic Formation), over the basal unit of the Transvaal quartzites (Black Reef Quartzite Formation), into Lower Transvaal shales (Kgwakgwe Shale Formation), and into Upper Transvaal chert breccia (Kgwakgwe Chert Breccia Formation). The results of the ground gravity data were used to assist with the survey design. IP/DC data were collected in dipole-dipole configuration with a = 50 m and n = 1-7. A Zonge GDP32 receiver, GGT10 10 kVA transmitter, and ZMG 7.5 kVA generator were employed.
- Various filters and processes were applied.

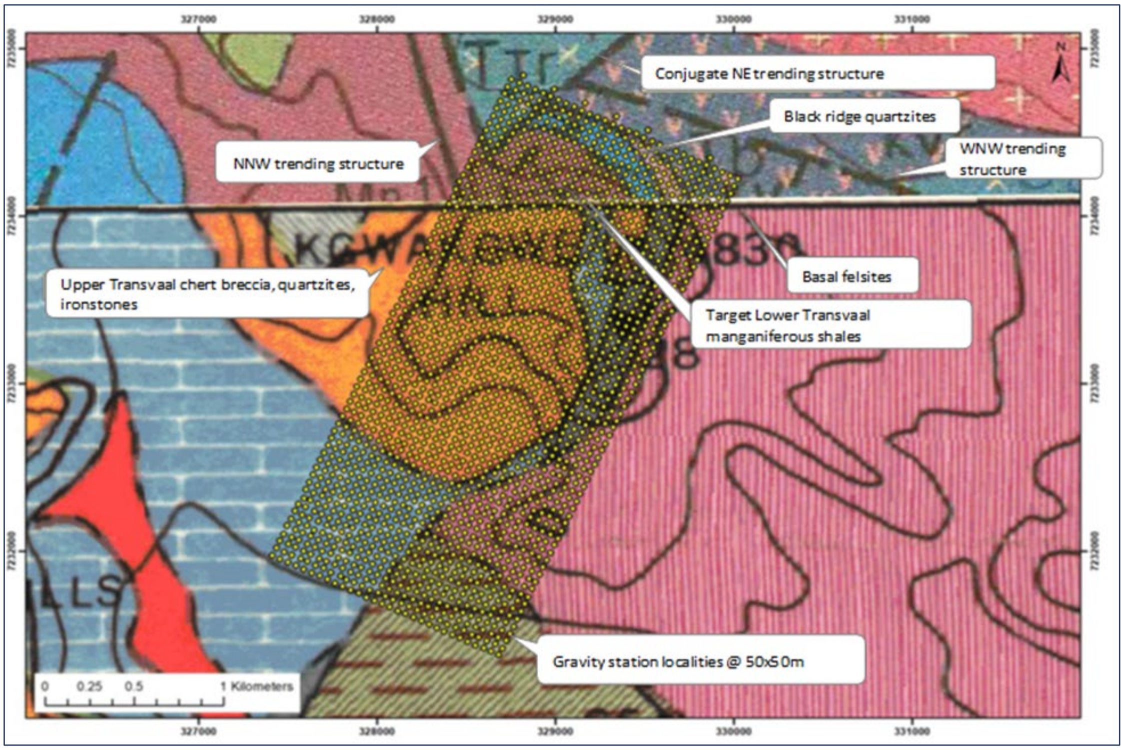
9.3.1 Interpretation of geophysical data

Bouguer anomaly and total magnetic intensity images are provided in Figure 9.4 and Figure 9.5. The following broad geophysical characteristics can be ascribed to the geological units:

- Both gravity and magnetic datasets are dominated by the response of the felsic volcanics in the northeast and eastern portion of the survey area. These units produce significant gravity and magnetic anomalies.
- The sedimentary units of the overlying Transvaal Supergroup are clearly mapped as distinct, structurally controlled, gravity lows.

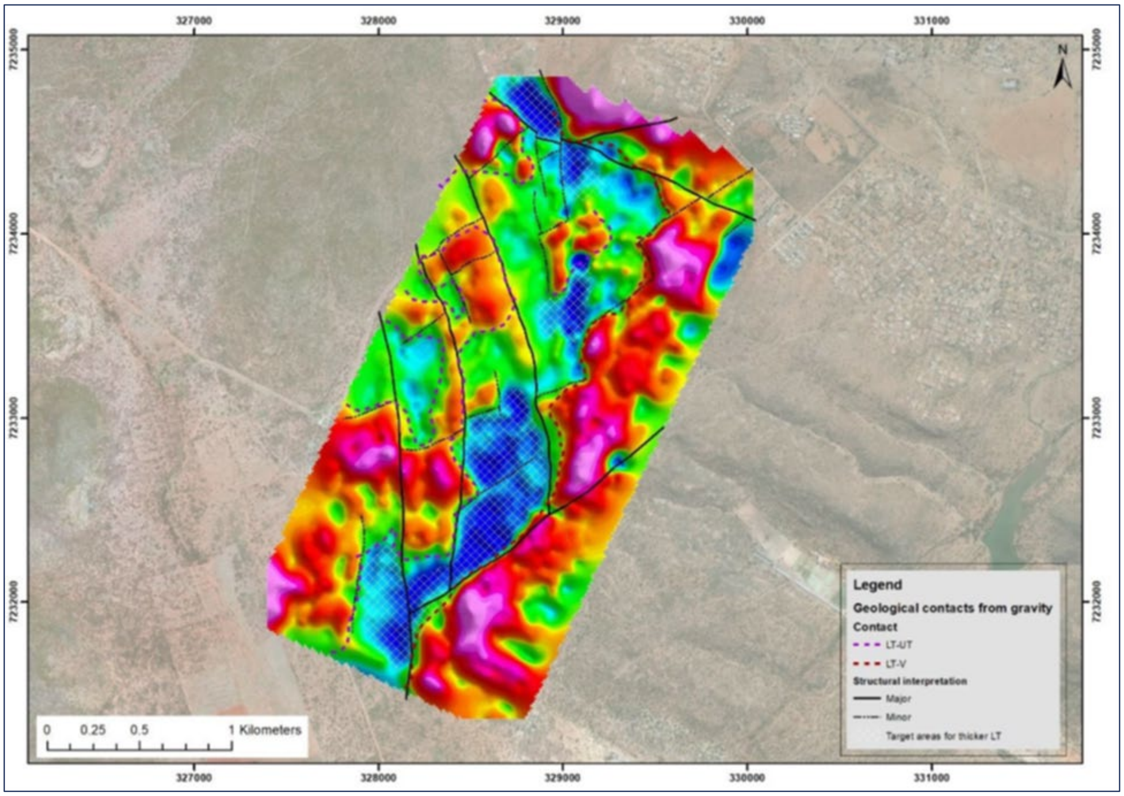
- A subtle contrast exists between the Lower and Upper Transvaal sedimentary units, with Upper Transvaal rocks appearing to be denser and producing small gravity highs.
- Thicker portions of the target Lower Transvaal units have been interpreted to correlate with more prominent associated gravity lows as a result.
- No direct gravity response appears to be associated with the manganese oxides.
- No clear magnetic contrasts have been mapped within the Transvaal sedimentary units; although, there is some evidence of subtle structure in the magnetic data.

Figure 9.4 Geology with survey stations and features of interest highlighted (1:125,000 scale)



Source: RES (2018)

Figure 9.5 Residual filtered Bouguer Anomaly image with structure, Lower Transvaal contacts, and prospective areas for thicker Lower Transvaal units highlighted



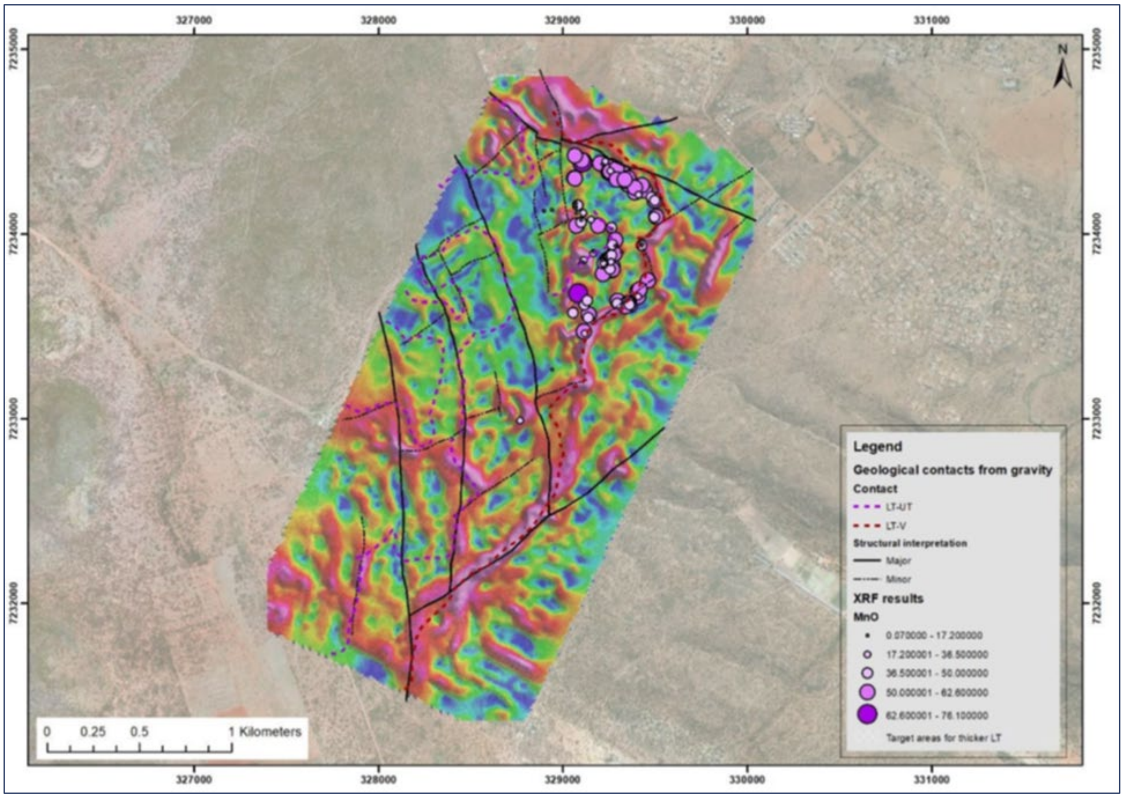
Notes: LT - Lower Transvaal, UT - Upper Transvaal, V - Ventersdorp
Hatched areas are the target areas for thicker Lower Transvaal
Source: RES (2018)

Using a number of different filter and image products, as well as depth slices through the unconstrained density volume, the relationships described above were used to map basin controlling structures, contacts with the target Lower Transvaal, and areas where the Lower Transvaal units appear to thicken. The interpreted contacts and target areas for thicker Lower Transvaal correlate well with known geology and sample results. Additional prospective target areas have been identified under recent cover.

Ground gravity surveying proved to be an effective method for mapping out the extent and possible structural controls for manganese mineralisation in the Lower Transvaal host rocks. Basement felsic volcanics are clearly delineated in both magnetic and gravity data where they are manifest as anomalous highs. IP/DC proved to be an effective means of mapping conductive Lower Transvaal host rocks over resistive Upper Transvaal and basement volcanics, as well as potentially higher chargeability manganese mineralisation (RES 2018).

The IP/DC traverse results demonstrate high correlation with the gravity inversion and interpretation. As expected, the Lower Transvaal shale units are more conductive (lower resistivity) than underlying volcanics, and overlying chert breccias correlate well with low-density portions of the inverted density volume. Distinct IP chargeability anomalies coincide with the anticipated position of Mn-shale. Significant cultural noise (small holder developments, access roads, old workings, new drill pads, etc.) in the northern IP/DC traverse across the known mineralisation has made direct comparison with the known mineralisation somewhat ambiguous (RES 2018).

Figure 9.6 Total horizontal derivative of the Bouguer Anomaly with structure, Lower Transvaal contacts and prospective areas for thicker Lower Transvaal units highlighted



Notes: LT - Lower Transvaal, UT - Upper Transvaal, V - Ventersdorp
XRF manganese oxide grab sample results are illustrated as scaled symbols
Source: RES (2018)

9.4 Topographic survey

Giyani engaged the services of PhotoSat Information Ltd. in April 2021 to acquire a 1 m stereo satellite survey and 50 cm orthophotograph for the 31 km^2 Project area. The satellite photographs were acquired on 2nd April 2021. The 1 m satellite survey and 50 cm precision orthophotograph were produced using PhotoSat's proprietary geophysical satellite processing system. PhotoSat was supplied with an additional 2,180 ground control points collected by DGPS and were able to use this data to vertically rectify the survey to an accuracy of 15 cm.

9.5 Mineralogical investigation

A mineralogical analysis was performed on the K.Hill manganese-oxide bearing rocks by Dr. Flint at the Dalhousie University Minerals Engineering Centre in Halifax, Nova Scotia, Canada (Lambda Tau 2018). Four samples were tested to determine the mineralogical composition of the manganese minerals. Haematite, other iron oxides, some pyrite along with silica, and kaolin in one horizon of the shales, are evident as well as manganese oxides. This study is described in more detail in Section 13 of this report.

10 DRILLING

10.1 Introduction

Drilling was undertaken in four programmes at K.Hill: an initial DD programme of 18 holes completed in June 2018 totalling 1,109 m, a follow-up infill programme of 96 RC holes (including 6 redrills) that commenced in November 2020 and was completed in June 2021 totalling 3,346 m, and a synchronous DD programme of 11 holes for 346 m. The 2020/2021 DD programme was primarily completed for the purposes of geotechnical analysis, and as such, this core has not been subject to sampling and assaying. That said, SRK utilised the density determinations completed on the geotechnical holes (described in Section 10.3.4) in assigning density to the Mineral Resource model. The final phase (Phase 4) of drilling to delineate the Southern Extension Area was completed in August 2021 and comprised 28 RC holes and 3 DD control holes, for a total of 2,126 m. Table 10.1 summarises the drill programmes.

Table 10.1 Summary of drill programmes

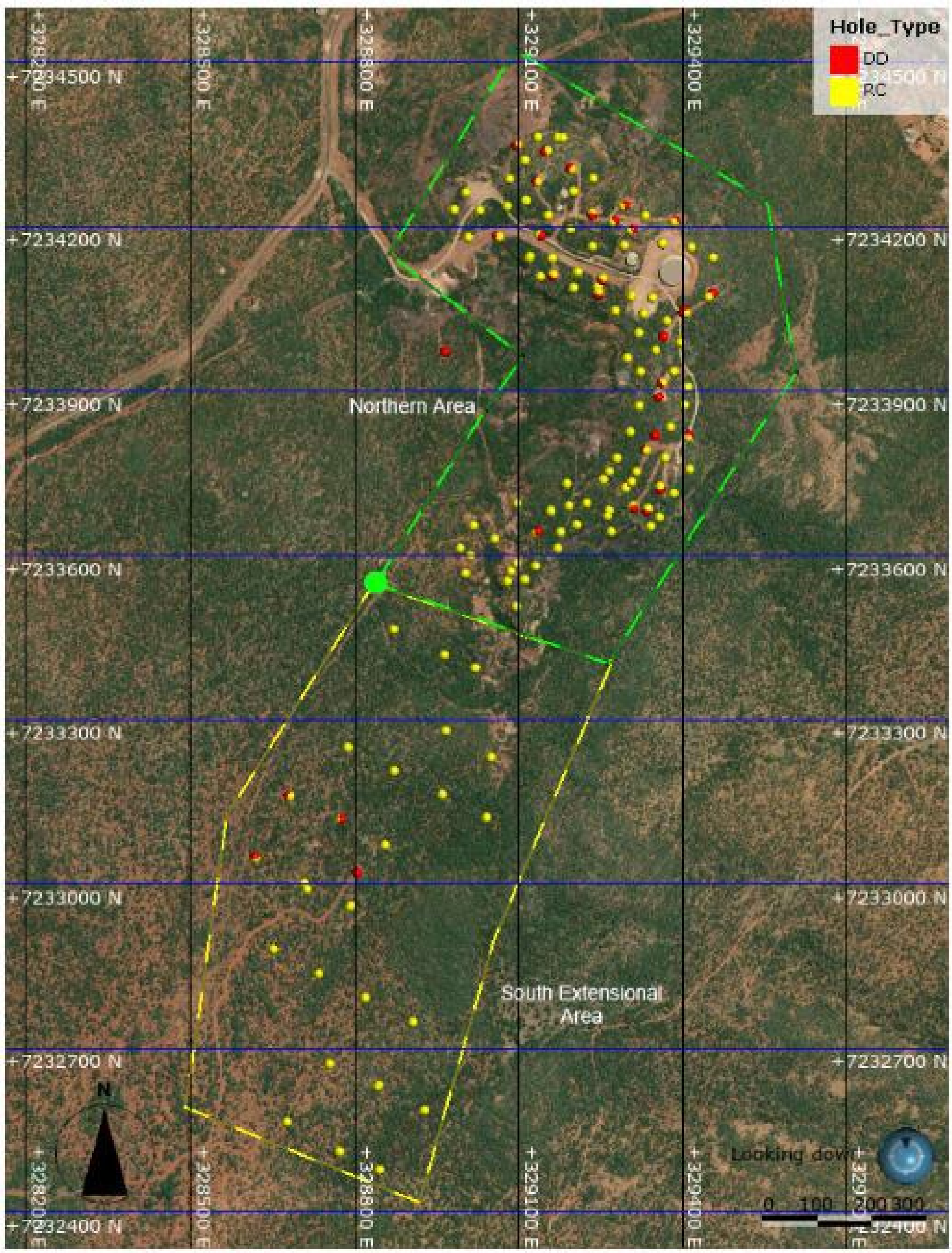
Programme	Date	No. of holes	Meterage (m)	Hole type
Phase 1	June 2018	18	1,109	DD
Phase 2	November 2020	96	3,346	RC
Phase 3	2020/2021	11	346	DD
Phase 4	August 2021	28	1,866	RC
		3	260	DD

Notes:
A fifth drilling phase was completed in May 2022. A total of 75 RC drillholes and total meterage of 6,121 m was completed as infill to the K.Hill Southern Extension Area. This drill programme brought the drillhole spacing in the area down to 75 m.
At the time of reporting, the sampling and sample analysis was still ongoing, and none of these data are used or incorporated in this estimation.

10.2 Drillhole locations

Drilling has been completed on approximately 35 m to 50 m centres in the Northern Area of the deposit and approximately 100 m to 125 m centres in the Southern Extension Area with surface outcrop mapping delineating the margins where it intersects the hill topography. A map showing all drillhole collars coloured by drilling type is presented in Figure 10.1. All drillholes were drilled vertically.

Figure 10.1 Plan view of the drillhole collars overlain on the K.Hill satellite imagery



Notes: DD holes are shown in red; RC holes are shown in yellow. Yellow outline refers to the Southern Extension Area; green outline refers to the original K.Hill Resource area (Northern Area).

10.3 Diamond drilling

The following description of the DD completed on the K.Hill Project to date is adapted and expanded upon from MSA (2018). SRK notes that the drill contractor and rig and supervision team remained unchanged for both the 2018 and the 2021 DD programmes.

All DD was undertaken by RotsDrill Botswana (RotsDrill). RotsDrill used an Atlas Copco CS14 diamond drill rig. The drilling programmes were managed by Lambda Tau. Holes were drilled using PQ core diameter and cased to depth with polyvinyl chloride casing.

The standard operating procedure provides for a geologist to be assigned to the drill rig to manage the drilling, stake collars, and align and communicate with the drilling team. The drilling supervisor reported to the geologist on the progress of drilling twice a day at the change of each shift.

The geologist is also responsible for safety and environmental matters. The drill rig and drill site preparation and setup were audited at the start and during the drilling programme. The geologist also ensured that all sites were rehabilitated according to the environmental management standards set forward by Giyani prior to the drilling team leaving the drilling site.

Casing was left in the hole once a hole was completed. This was to ensure that the hole remained intact for any future downhole geophysical surveys that might be required. A concrete plinth was constructed around the drillhole collar, such that 50 cm of casing protruded above the concrete block to permanently mark the collar. The drillhole casing was sealed at the collar and a plate was inserted with the drillhole ID (Figure 10.2).

Figure 10.2 Drillhole collar and site for drillhole DDKH18_0005

Source: MSA (2018)

10.3.1 Storage

Drilled core was placed in core trays. The trays were labelled with the drillhole ID at the top right corner of the box as well as on the side. The drilling contractor was responsible for inserting core blocks to mark the drilled depths at the end of each run. Mechanical breaks in the core were marked with two small stripes on both sides of the break to enable appropriate fitting of the core later.

The drill contractor was responsible for all the core handling at the drill site and transportation of the core to the core shed, located in Kanye. The core was transported in core boxes, stacked to a maximum of five boxes, with a lid on the top core box. The stacked boxes were strapped together using a ratchet strap and further secured to the sides of the vehicle. The delivered core was accepted at the designated core shed by the on-site geologist or manager.

10.3.2 Logging

Geotechnical and geological logging and other data were recorded at the core shed. Standard logging codes were created to ensure that logging was standardised and to reduce errors in rock identification.

10.3.3 Sampling

The cores were cut longitudinally in half using a rotating diamond saw blade. For samples that were too soft or friable to be cut with a diamond saw, the samples were longitudinally cut in half manually with a knife blade. Half-core samples were collected continually through the mineralised units at a 1 m nominal length, which was adjusted to smaller intervals in order to honour the lithological contacts. Half-core samples were collected between core blocks where the recovery was less than 50%. In some instances, this resulted in samples with drilled lengths longer than 1 m.

10.3.4 Density measurements

2020/2021

A total of 25 density measurements were carried out using the Archimedean water immersion method on pieces of core in both mineralised and waste rock. All measurements were taken from core in the K.Hill Northern Area. This method involves oven drying core samples,
then weighing the dry core in air, and then weighing the same core while immersed in water. Giyani established that, when completely dry, the core samples tend to fragment and break down more readily once placed in water, precluding straightforward density determinations. As such, samples were wax coated prior to immersion.

2018

A total of 732 core density measurements were completed on the drill core during the 2018 drill programme, again from the K.Hill Northern Area. These samples were not dried or wax coated prior to undertaking density measurements. Thus, the recorded densities were considered to be wet and not dry. SRK has not used this data in the derivation of the Mineral Resource estimate presented in Section 14 and instead has utilised the 202/2021 dataset, which, while comprising only a small number of density determinations, is considered to be more accurate. Further discussion is provided in Section 14.9.

10.3.5 Recovery

The Mn-shale is soft and weathered, within which harder layers of manganese oxide mineralisation on a centimetre scale occur. Recovery was calculated by dividing the drilled length by the recovered length. In Phase 1 (2018), poor core recoveries were observed in most of the intersections of the Mn-shale, averaging approximately 50% in the high-grade mineralisation. Improved recoveries were achieved during the second phase of DD (2020-2021), with recoveries averaging 91% in the Mn-shale horizons. For the third and fourth phases, recoveries were similar averaging 90%.

10.3.6 Other captured data

On completion of each hole, collar locations were collected using a handheld GPS. Downhole surveying was not considered necessary because both the RC and DD holes were short and vertical, with end of hole depths rarely exceeding 70 m. The following information was recorded in the database:

- hole number, with collar location, length, inclination, and direction
- drilled lengths and recovered lengths (for DD only)
- geological and mineralogical descriptions
- assay results
- QA and QC samples

Following completion of all holes, a DGPS was used to collect all collar locations to provide highly accurate locations.

10.4 Reverse circulation drilling

An extensional RC drill campaign for the Southern Extension Area was initiated in April 2021 and completed in August 2021. An approximately 100 m to 125 m spacing with an average depth of 30 m was completed. This was in addition to the earlier infill RC programme in 2020/2021 on the Northern Area of the deposit.

RC drilling was undertaken by two drill contractors: Stewardship Drilling and Master Drilling. Stewardship Drilling was responsible for the completion of the first 46 RC holes of the infill campaign, each drilled with a diameter of 127 mm. Master Drilling completed the remaining RC holes of the 2020/2021 drill campaign. Master Drilling operated two remote-controlled, GPS-enabled Atlas Copco D65 drill machines, drilling holes with a diameter of up to 140 mm. All RC drilling was managed by Lambda Tau.

The standard operating procedure provides for a geologist to be assigned to the drill rig to manage the drilling, stake collars, align the rig, and communicate with the drilling team. The drilling supervisor reports to the geologist on the progress of drilling twice a day at the change of each shift.

The geologist is also responsible for safety and environmental matters and ensured that all sites were rehabilitated according to the environmental management standards set forward by Giyani prior to the drilling team leaving the drilling site.

The completed RC holes are capped with concrete plugs with the hole names written onto them consisting of the campaign by year of drilling (e.g., RCKH20), followed by the three-digit hole number (Figure 10.3).

Figure 10.3 Concrete RC collar plugs used to close and mark completed RC holes

Source: SRK, 2021

10.4.1 Logging

Geological and alteration logging of chips were recorded at the core shed. Standard logging codes were created to ensure that logging was standardised and to reduce errors in rock identification.

10.4.2 Sampling

RC samples are collected at the rig site directly from the cyclone at 0.5 m intervals and laid out sequentially (Figure 10.4). Sample bags are pre-prepared to ensure their correct labelling. The site geologists report that the samples typically range from between 10 kg to 12 kg. The entire sample is transported to the core shed for sample preparation and analysis.

Figure 10.4 RC samples collected at 0.5 m intervals and laid out sequentially at the rig

Source: SRK, 2021

10.4.3 Density measurements

Density measurements were carried out on RC samples using a formula that combined drill sample volume, recovery, and weight of sample. Over 1,552 RC sample densities were calculated from both the Northern Area and Southern Extension Area. A comparison of RC sample densities versus those from DD core has been made (Section 13.9). A comparison of the South Extension Area RC densities with that of densities taken from diamond core using conventional Archimedean method shows comparable results for the Mn-shale. For the Northern Area, densities for the RC are marginally lower than those for the DD core samples by approximately 13%.

10.4.4 Recovery

Giyani routinely monitored RC bag weights to track sample recovery during drilling. The average bag weight per each drilled metre, after being composited to 1 m, is plotted against the prevalence of logged intervals of Mn-shale. Analysis of this data shows no systematic effects or unexpected changes in recovery downhole and no significant decrease in recovery in zones of Mn-shale.

10.4.5 Other captured data

On completion of each hole, collar surveys were completed using a handheld GPS. Downhole surveying was not necessary because the drilled holes were short and vertical with end-of-hole depths ranging from 10 m to 41 m (typically 30 m). The following information was recorded in the database:

- hole number, with collar location, length, inclination and direction
- drilled lengths and recovered lengths
- geological and mineralogical descriptions, including weathering and alteration
- assay results
- QA/QC samples

Upon completion of the drilling, all collar locations were accurately surveyed using a DGPS.

10.5 Drillhole database

Drilling information was initially captured into Microsoft® Excel spreadsheets. After entry, the data were checked by Luhann Theron of Lambda Tau, Giyani's chief geologist. As of October 2021, all digitally captured logs and other sample data were input into a professionally managed electronic relational database (Datashed) for verification, to ensure security and data integrity.

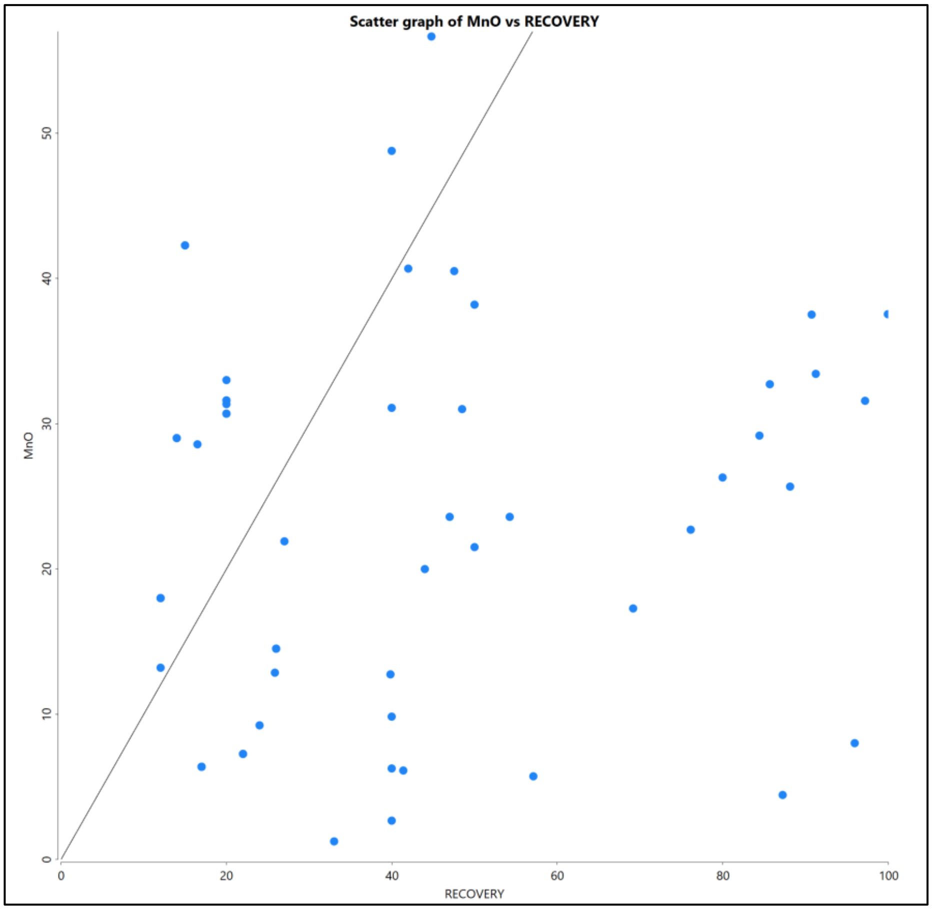
The K.Hill drillhole database consists of 163 holes (32 DD and 131 RC) with a total length of 6,928 m (excluding redrills) and 4,178 assays.

10.6 SRK comments

SRK considers that the quantity and quality of data collected in the K.Hill drilling programme is sufficient to support the reporting of a Mineral Resource estimate. That said, the following concerns are highlighted:

- Core recovery in the Phase 1 DD programme is very poor, particularly within the Upper Mn-shale unit that is host to the manganese oxide mineralisation. Specifically, average core recovery within the Upper Mn-shale unit is 41%. Recovery is less than 80% for approximately 85% of samples and less than 50% for approximately 60% of samples. Three holes have no core recovery at all at the anticipated depth of the Upper Mn-shale unit. SRK notes that recoveries are much improved in the most recent Phase 3 and Phase 4 DD campaign, averaging 91% in the Mn-shales. At this stage there is no clear relationship observed between core recovery and grade (see Figure 10.5), although there is only limited data available as the Phase 3 DD programme was undertaken for geotechnical purposes, and therefore, not assayed.

Figure 10.5 Scatterplot of Recovery (X axis) against manganese oxide percentage (Y axis) in the Mn-shale.



Notes: Data taken from the Phase 1 DD campaign only.
(X = Y line shown in black.

- As noted in Section 10.3.4, due to the tendency of the more friable portions of drill core to fragment when dry, Giyani did not oven dry the drill core from the Phase 1 DD programme prior to completing density determinations. As no moisture content for the samples is recorded, it has not been possible to accurately account for the water content of the samples, and as such, SRK has only used data collected during the Phase 3 and Phase 4 DD programme where samples were fully dried and wax coated prior to density determination. Although this data is deemed to be more accurate, it is a significantly smaller dataset and does not have corresponding manganese oxide assays to establish a correlation between manganese oxide grade and density.

SRK recommends that Giyani continue to undertake density measurements using this wax coating method where possible for diamond core. However, Giyani understands and acknowledges SRK's concerns regarding density measurements and intends to undertake work on improving obtaining reliable density measurements by possibly implementing the use of sonic core and density calliper measurements for future specific gravity work.

11 SAMPLE PREPARATION, ANALYSES AND SECURITY

11.1 Introduction

The descriptions of sample preparation, analysis, and QA/QC checks undertaken on the Phase 1 DD programme in Section 11 have been reproduced from MSA (2018). SRK has also documented sample preparation, analysis, and QA/QC checks undertaken on the RC drilling campaigns.

11.2 Diamond drill and reverse circulation sample dispatch

Samples were dispatched in batches of approximately 100 samples. The sample batches were exported by Aramex (for the DD programme) and Pinnacle Express (for the RC programme) to SGS Randfontein for geochemical analysis.

The chain-of-custody was maintained by signature at every point in which the samples changed hands, from the core shed in Kanye, where the samples were stored, to the laboratory. As part of the laboratory procedure, all samples were weighed. All the persons involved in the chain-of-custody were required to submit a copy of their receipt of handover of the samples to the project manager for record keeping on site.

11.3 Sample preparation

11.3.1 Diamond drill core sample preparation

Samples were prepared and analysed at SGS Randfontein. This is an independent commercial laboratory, which is International Organization for Standardization (ISO)17025 accredited by the South African National Accreditation System for chemical analysis. The sample preparation method code used is PRP87, which entails the following procedure:

- Samples are weighed on arrival.
- The samples are dried and then crushed using a jaw crusher to 80% passing through a 2 mm screen.
- A 500 g sub-sample is collected from a riffle splitter.
- The 500 g sub-sample is pulverised using a carbon steel ring and puck to 85% passing through a 75 µm screen.
- Pulps are logged against sample numbers and submitted for analysis.

All pulverised reject samples are stored at SGS Randfontein.

11.3.2 Reverse circulation sample preparation

Sample preparation for the RC samples follows a procedure detailed in the LT20051R standard operating procedure:

- Samples received from the drill site are weighed to record the full primary sample.
- A 3 kg to4 kg "A-sample" subset is collected from a riffle splitter, with the residual primary sample retained until the completion of the A-sample analysis or for metallurgical test work.
- Samples are washed to collect a reference chip sample and to visually identify the interval of manganese mineralisation.
- The mineralised intervals, including four bounding samples either side, are compiled with QA/QC samples to form the sample stream for laboratory analysis.
- If two or more mineralised intersections are identified, all material internal to these intervals are sampled as well.
- The A-sample mineralised stream is separated and marked for pXRF analysis.
- 10 g to 15 g of the A-sample is pulverised for a programmed time and speed (240 seconds) using an Equilab EQM-402 MixerMill, then placed into a sample cup for analysis by pXRF.

11.4 Diamond drill and reverse circulation sample analysis

All samples were assayed at SGS Randfontein by method XRF76V, which assays major element oxides by XRF using borate fusion. The oxides assayed included aluminium oxide (Al_2O_3), calcium oxide (CaO), chromium oxide (Cr_2O_3), Fe_2O_3, magnesium oxide (MgO), manganese oxide, sodium oxide (Na_2O), phosphorus pentoxide (P_2O_5), K_2O, silicon dioxide (SiO_2), titanium dioxide (TiO_2), and vanadium pentoxide (V_2O_5) reported in percent, as well as loss on ignition (LOI).

The analytical procedure involves the following:

- A pulverised sample between 0.2 g and 0.7 g is required for analysis.
- The samples are mixed with 10 g of flux, which is made up of equal amounts of lithium tetraborate-metaborate and a non-wetting agent.
- The sample is fused to create a bead.
- XRF is carried out on the fused bead.
- LOI is determined separately by roasting approximately 1 g of the pulverised sample at 1,000°C for 1 hour in a furnace.

11.5 Quality assurance/quality control

11.5.1 Introduction

The QA/QC section of the report is broken into two parts:

- QA/QC for drilling Phases 1 and 2 (i.e., pre-September 2021)
- QA/QC for the Phase 4 Southern Extension Area drilling (i.e., post-September 2021)

11.5.2 Phases 1 and 2 diamond drilling

This section describes the QC procedures undertaken for samples submitted as part of the Phase 1 DD programme. No comment is provided on the Phase 3 DD programme, as the drilling was undertaken for geotechnical purposes, and no core analysis was undertaken. These drillholes are not included in the Mineral Resource estimate reported (Section 14).

QC samples were inserted to test analytical accuracy, laboratory contamination, and repeatability on a hole-by-hole basis. CRM samples and blank samples were inserted into the sample stream with the core samples. Duplicate samples were inserted at the laboratory. Empty bags with sample labels were submitted to the sample preparation laboratory with an instruction to make a duplicate of a specified sample and insert into the sample sequence. One CRM, one blank, and one duplicate sample were inserted into the sample stream for every 20 core samples.

11.5.2.1 Blanks

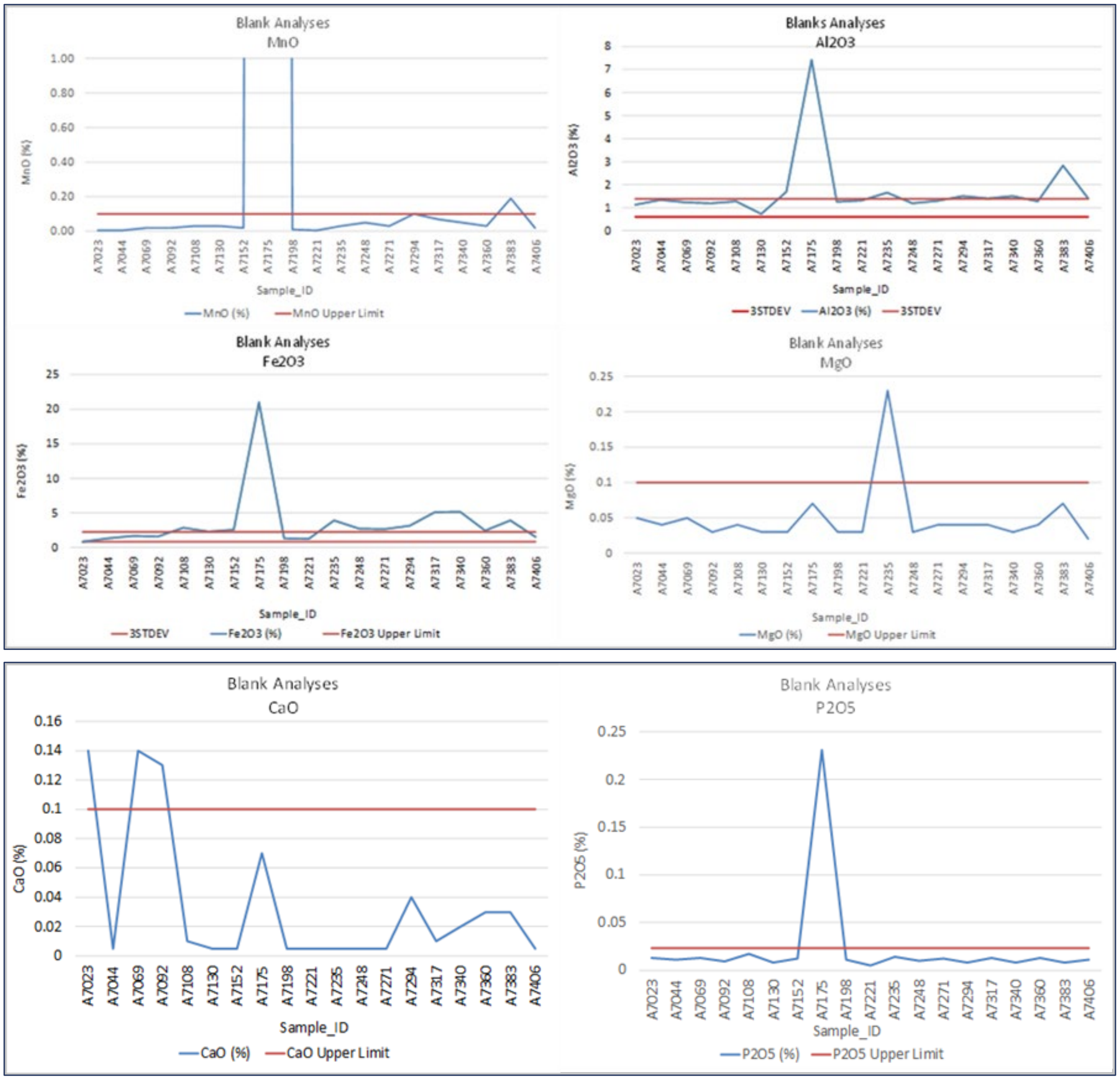
A total of 19 blank samples were inserted within the field sample stream to detect contamination, especially in the preparation stage. The number of blank samples inserted equals a 5% insertion rate, which is in line with industry practice. Giyani used blank silica chips from African Mineral Standards (AMIS) as shown in Table 11.1.

Table 11.1 AMIS0439 blank silica chips certified mean grades and two standard deviation values

Variable	Certified value (%)	Two standard deviations (%)
Al_2O_3	0.99	0.13
CaO	0.02	0.01
Cr_2O_3	0.01	0.002
Fe_2O_3	1.53	0.23
K_2O	0.21	0.04
MgO	0.03	0.01
MnO	0.01	0.01
Na_2O	0.02	0.01
P_2O_5	0.01	0.003
SiO_2	96.9	0.4
TiO_2	0.06	0.01

The graphs for all blank analyses can be seen in Figure 11.1.

Figure 11.1 Results of blank sample assays



All the manganese oxide assays of the blank samples, except two, are below the upper limit. The upper limit is the upper threshold below which the blank assays are expected to be when there is no contamination and is generally taken at ten times the lower detection limit for the method used for each analyte. The blank assays that returned values beyond the upper limit had assays of between 0.19% and 42.5% manganese oxide.

An assay of 42.5% manganese oxide is considered to be too high to result from contamination. Therefore, it is concluded that this sample was swapped with a field sample. The other blank failure, with an assayed grade of 0.19%, could have been due to contamination, as it follows a CRM, which has an assayed grade of 60.1% manganese oxide. Contamination should not have taken place during the sample preparation phase, as CRM are inserted as pulverised material, so they do not require any crushing where most contamination takes place. Overall, the blank sample assay grades for manganese oxide show that there may have been some contamination at the laboratory, but this was low and would not have any significant impact on the manganese oxide grade of the drillhole core samples (Figure 11.1).

Analyses of blank samples were also undertaken for aluminium oxide, calcium oxide, iron oxide, magnesium oxide, and phosphorus pentoxide. The aluminium oxide and iron oxide grades were judged in reference to three standard deviations of the certified values. The average assayed grade of the blank sample for aluminium oxide and iron oxide is 1.4% and 2.6%, respectively. Out of 19 samples, 1 was interpreted to be a sample swap, 11 iron oxide assays are outside three standard deviations of the certified value, and 5 aluminium oxide assays are outside three standard deviations of the certified value.

It is considered that the level of possible contamination within the Phase 1 DD samples is low. The reason for the elevated iron oxide values is uncertain, as the sample cannot be contaminated for only one analyte. This is more likely either an assay accuracy issue or inherent variability in the blank material. It is recommended that Giyani carefully monitor the accuracy of the SGS Randfontein results for iron oxide as the K.Hill Project develops.

11.5.2.2 Certified reference material

Samples of a single CRM (AMIS0403) were inserted within the K.Hill drillhole core sample stream. This CRM was made from manganese mineralisation from the Wessels Mine in the Kalahari Manganese Field in South Africa and is described in Table 11.2.

Table 11.2 Certified reference material values and two standard deviation value

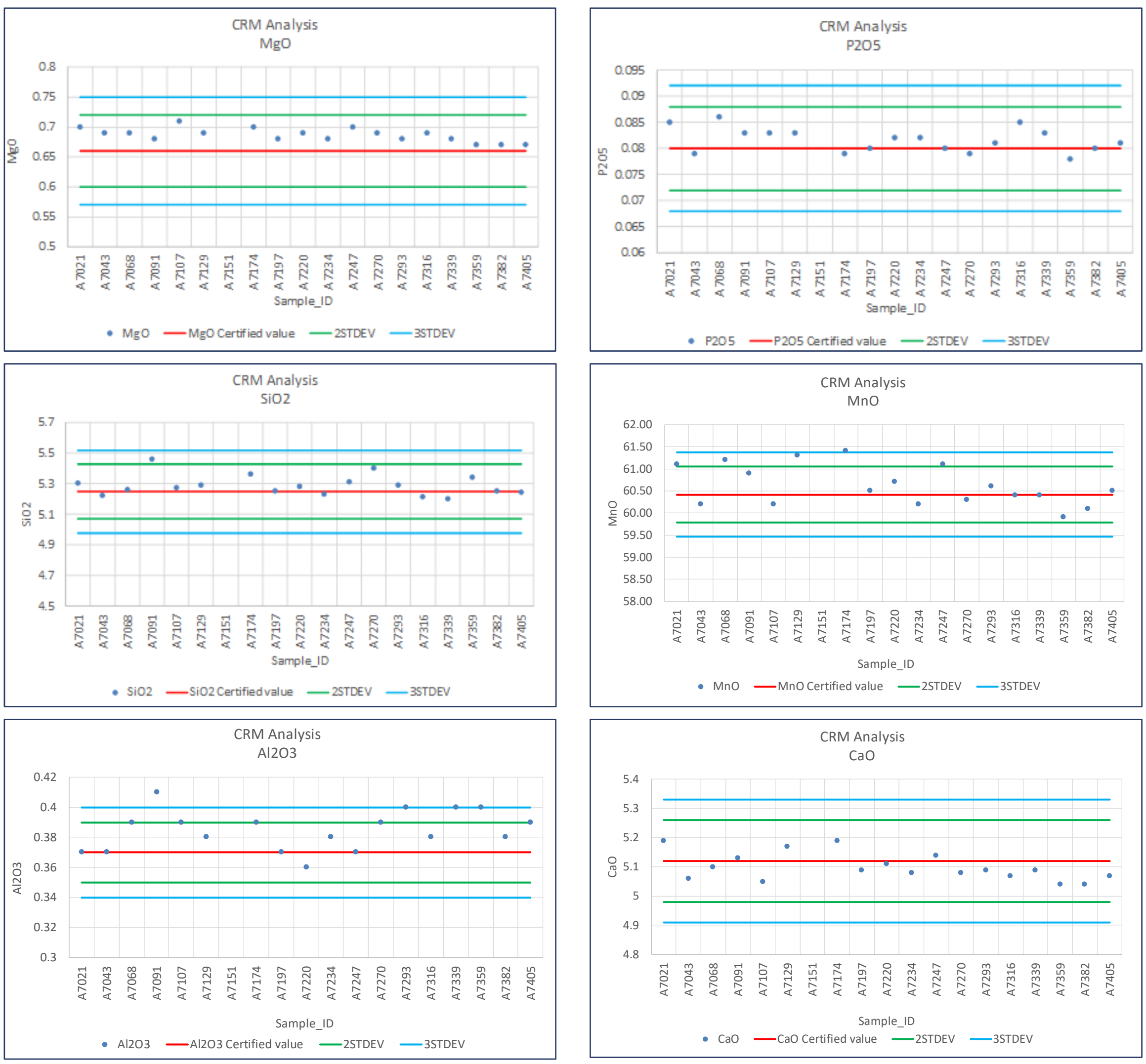
Variable	Certified value (%)	Two standard deviations (%)
MnO	60.42	0.64
Al_2O_3	0.37	0.02
CaO	5.12	0.14
Fe_2O_3	18.52	0.36
MgO	0.66	0.06
P_2O_5	0.08	0.008
SiO_2	5.25	0.18
LOI	4.27	0.48

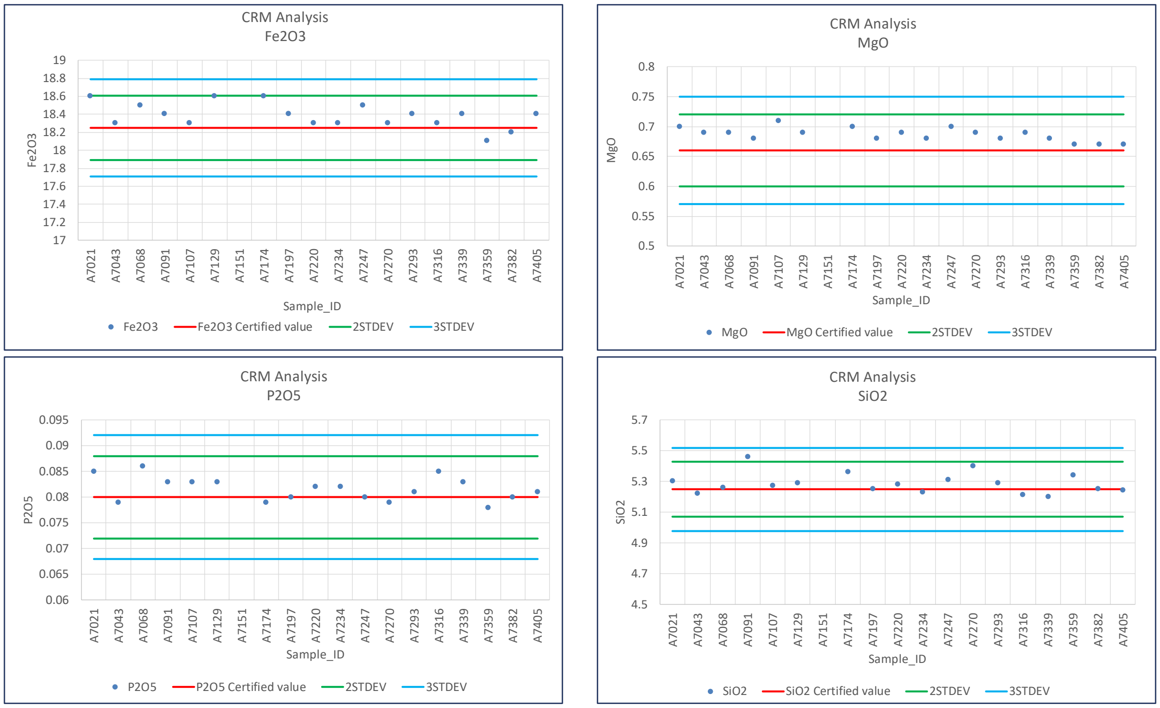
The number of CRMs inserted was 19, equating to a 5% insertion rate within the K.Hill samples, which is in line with acceptable industry practice. The manganese oxide grade of the CRM was high relative to the K.Hill samples, and more than one CRM is generally recommended.

Out of 19 samples, only 1 sample returned a value outside three standard deviations of the certified manganese oxide value. This sample had a grade of 0.02% manganese oxide and is considered to be a sample swap. The average grade of the CRM assays, excluding the sample swap, is 60.51% manganese oxide, which compares favourably with the CRM certified value of 60.42% manganese oxide (Figure 11.2).

The CRM samples were also assayed for aluminium oxide, calcium oxide, iron oxide, magnesium oxide, phosphorus pentoxide, and silicon dioxide. The CRM assays for these variables are within three standard deviations of the certified value of the respective variables, except for one aluminium oxide assay that returned a value above the limit. None of the variables showed significant bias, and none exceeded 4% relative difference from the certified values (Figure 11.2).

Figure 11.2 Results of AMIS0403 certified reference material sample assays





Source: MSA (2018)

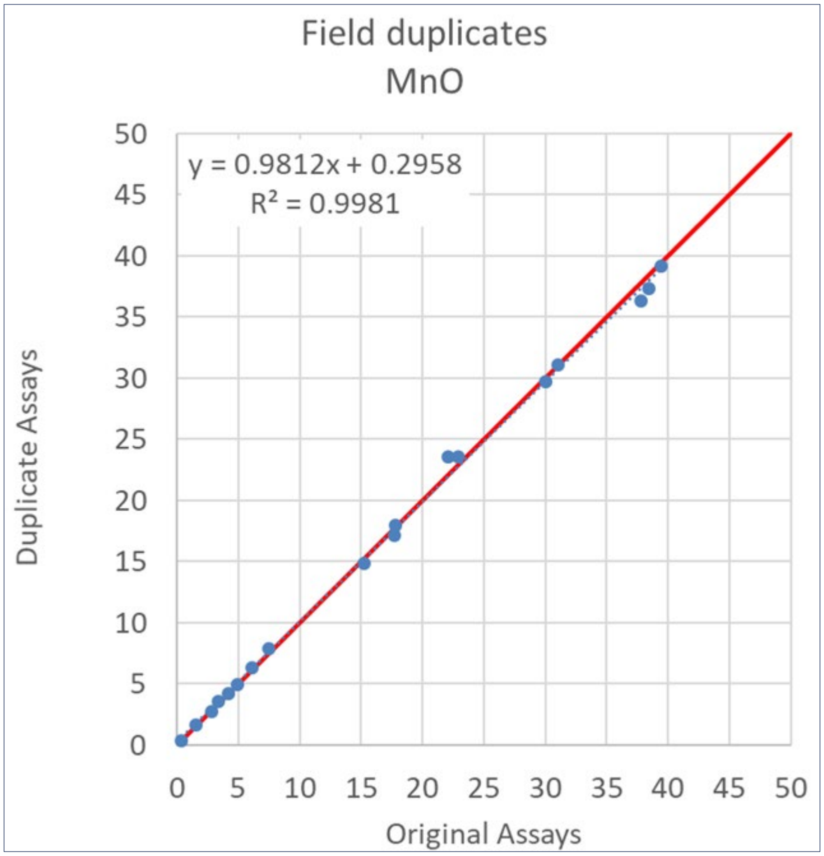
In general, the assayed grades of the Phase 1 DD CRM samples indicate acceptable analytical accuracy at the grade of the CRM. That said, the single CRM used does not fully confirm the accuracy of assays at the ranges of manganese oxide grades at K.Hill, since the K.Hill drillhole core samples have lower manganese oxide grades than the certified value of the CRM.

11.5.2.3 Coarse duplicates

Coarse duplicates were inserted to assess the adequacy of the sub-sampling process after crushing and the repeatability of the analytical process. As per the laboratory sample preparation standard operating procedure, a sub-sample of 500 g was collected using a riffle splitter after crushing. At this point, a second sub-sample was collected as a coarse duplicate and assigned a different sample number.

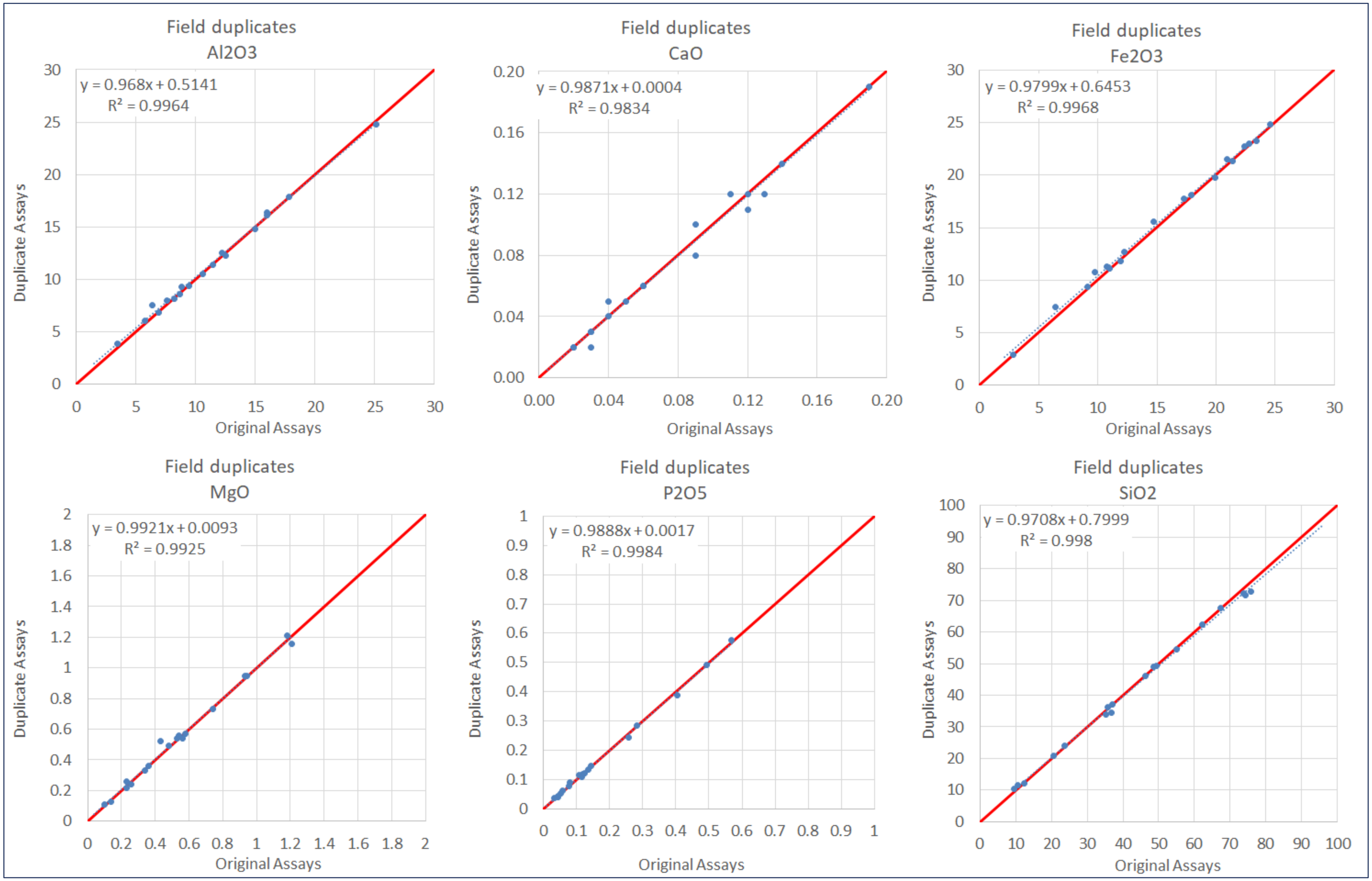
The duplicate assays of manganese oxide, aluminium oxide, calcium oxide, iron oxide, magnesium oxide, phosphorus pentoxide, and silicon dioxide show good precision (or repeatability) with linear correlation coefficients of greater than 0.9 (Figure 11.3 and Figure 11.4). This suggests that the sub-sampling process and the analytical processes are repeatable, and the results thereof are appropriate for Mineral Resource estimation.

Figure 11.3 Scatterplot of manganese oxide assay pairs (in percent) of duplicate samples



Source: MSA (2018)

Figure 11.4 Scatterplots of duplicate sample assay pairs (in percent)



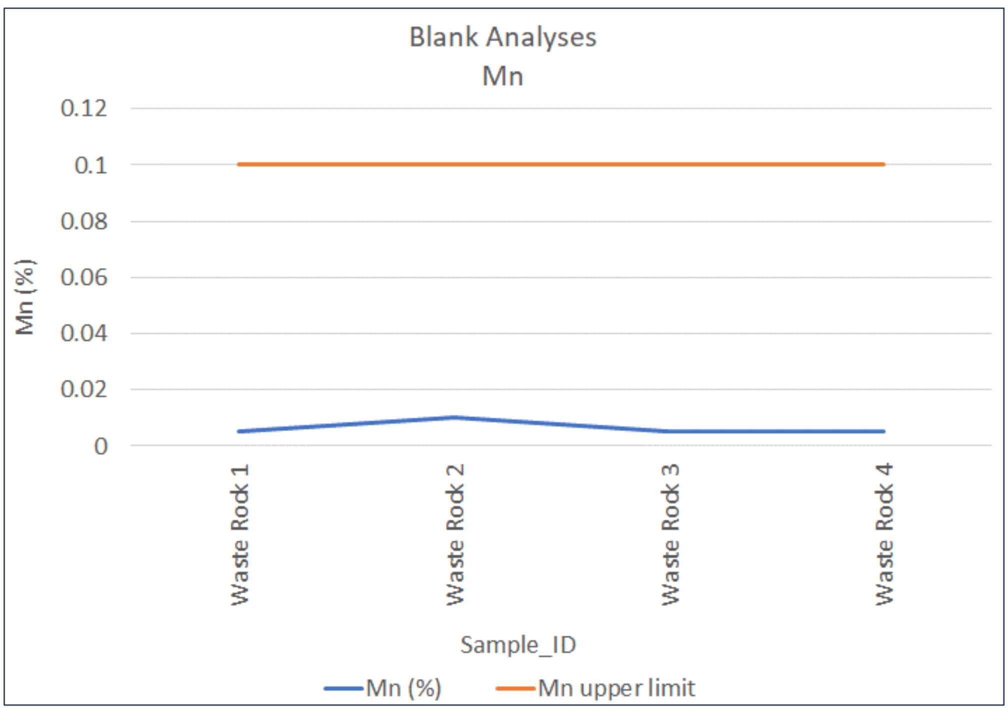
11.5.2.4 Check assays

Reject material from 40 samples that had previously been assayed by SGS Randfontein was submitted to Intertek Genalysis laboratory in Maddington, Western Australia. This is an independent commercial laboratory, which is ISO17025 accredited by the National Association of Testing Authorities, Australia for chemical testing. The duplicate samples were accompanied by four CRM and four blank samples. The assay method undertaken on these samples was XRF, similar to the primary laboratory (SGS Randfontein) assay method. The insertion rate was 10%.

The blank samples accompanying the check assays returned grades close to the detection limit for all variables, including manganese oxide (Figure 11.5). This indicates that there was limited, if any, contamination at the laboratory during the assaying of these samples.

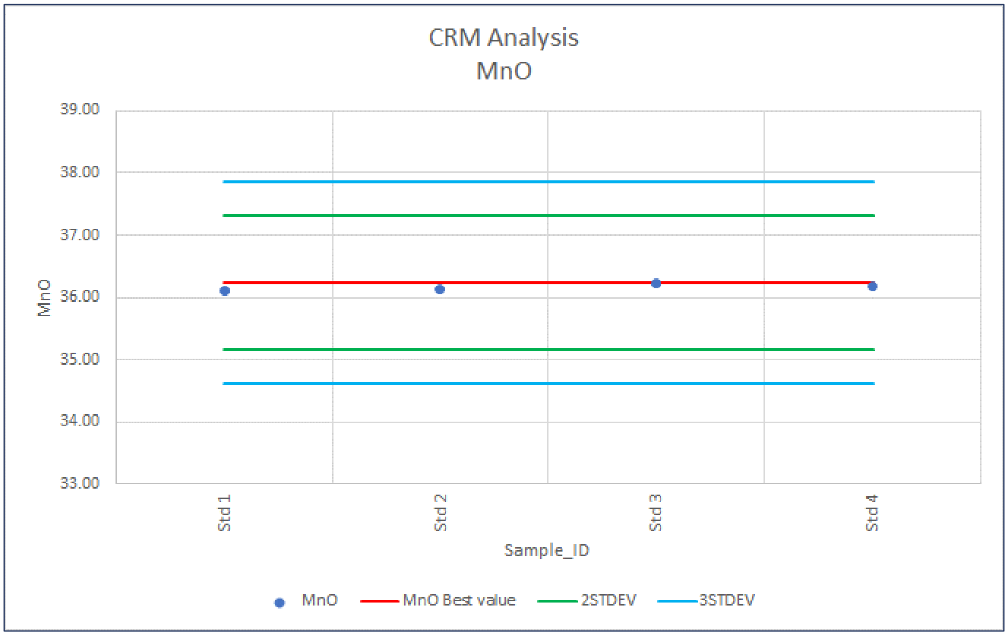
The CRM samples inserted with the check assay batch were sourced from AMIS0407. The assays that were returned are within two standard deviations of the certified manganese oxide value for this method (Figure 11.6).

Figure 11.5 Assays of manganese oxide in blank samples accompanying the check assays



Source: MSA (2018)

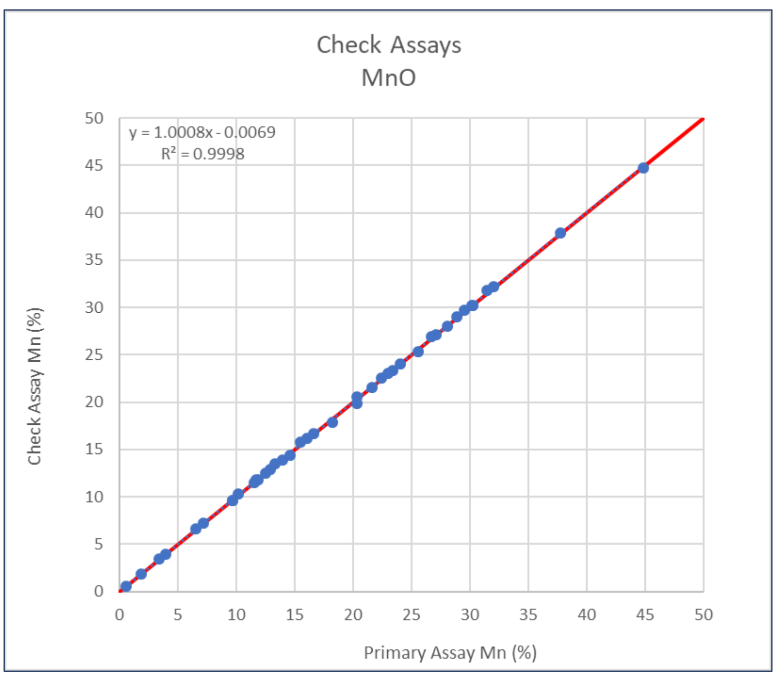
Figure 11.6 Manganese oxide assays (in percent) of AMIS0407 samples by the check laboratory



Source: MSA (2018)

A scatterplot comparing the manganese oxide assays from the primary and the secondary laboratory shows very good correlation, with a linear correlation coefficient of approximately 1 (Figure 11.7).

Figure 11.7 Scatterplot of manganese oxide assays (in percent) of the primary laboratory versus the secondary laboratory



Source: MSA (2018)

11.5.2.5 *SRK comments on phases 1 and 2 diamond drilling quality assurance/quality control*

The results of the QA/QC measures applied for K.Hill do not indicate significant contamination and demonstrate a high degree of accuracy and precision. The check laboratory assays confirm the primary laboratory assays within close limits.

SRK has not completed an independent check or visit to observe the sample preparation and analysis at SGS Randfontein. That said, the results of the QA/QC process do not highlight any significant concerns in the quality of the DD assay data used in the derivation of the K.Hill Mineral Resource estimate. It is noted that the manganese oxide grade of the CRM selected for QA/QC analysis by Giyani is not representative of the K.Hill deposit. Giyani should aim to use a combination of CRM over a range of grades that are reflective of the grade profile of the K.Hill deposit in future, rather than a single CRM.

11.5.3 Reverse circulation drilling phases 1 and 2 quality assurance/quality control

During the RC drilling campaign (96 drillholes) conducted between November 2020 and June 2021 a total of 427 QA/QC samples were inserted into the sample stream. The QA/QC samples included 121 blanks, 224 CRM, 42 field duplicates, and 40 pulp duplicates, representing an overall QA/QC sample insertion rate of approximately 13%.

11.5.3.1 *Blanks*

Giyani used “AMIS 0681” and “AMIS 0439” blank silica chips for blank material submission to the laboratory to monitor sample contamination; the results are shown in Figure 11.8 and Figure 11.9. The results show a significant proportion of samples around or exceeding the specified failure threshold (0.01% manganese oxide). Three samples returned manganese oxide (%) values greater than 0.1%, but all less than 1% manganese oxide. While noting that the results suggest minor contamination, the degree of contamination (typically less than 0.05% manganese oxide) is not considered material in the context of the average manganese oxide grades within the shale horizons.

Figure 11.8 Blank sample (AMIS 0681) control plot, 2020/21 reverse circulation drilling

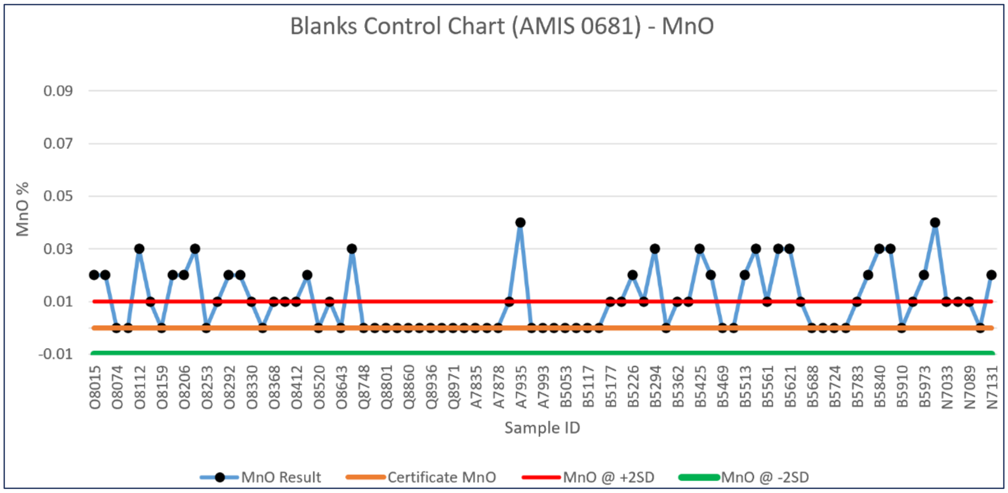
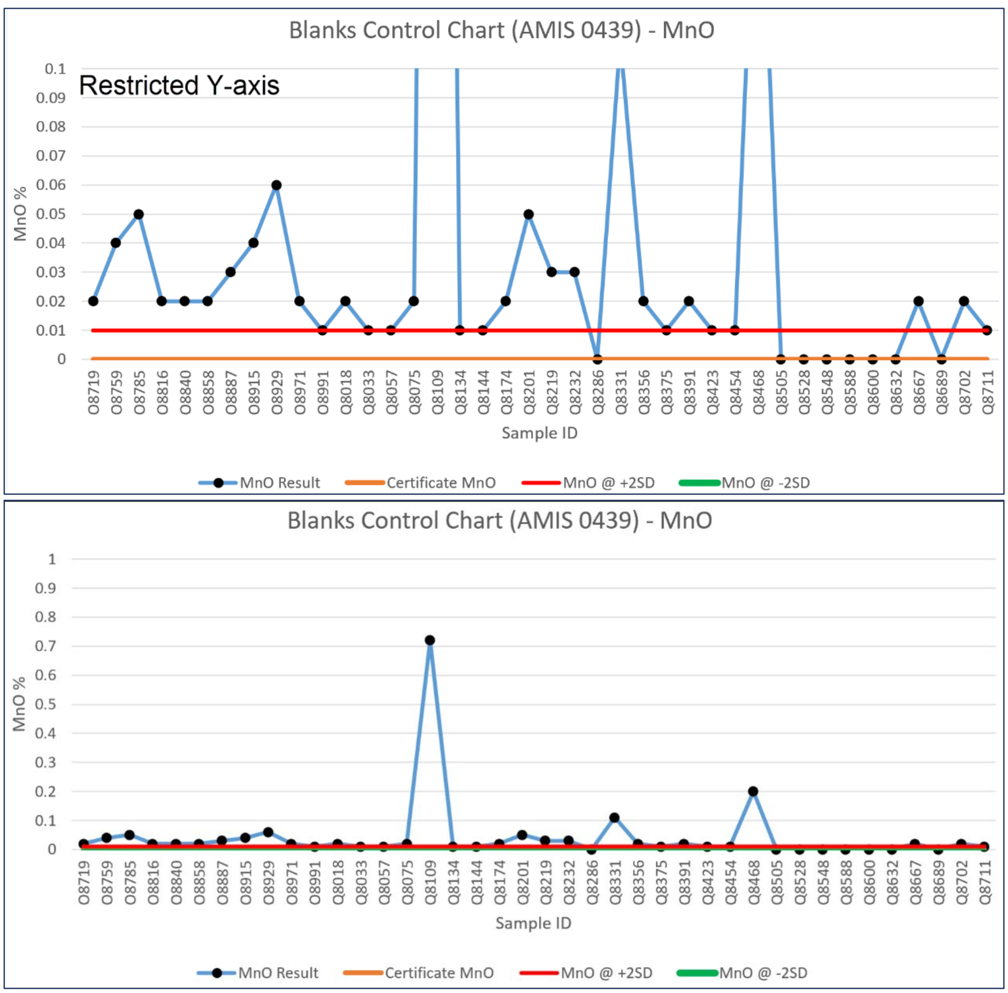


Figure 11.9 Blank sample (AMIS 0439) control plot, 2020/21 reverse circulation drilling



11.5.3.2 Certified reference material

Samples of three separate CRM (AMIS0407/533/535), covering a grade range of approximately 24% to 47% manganese oxide, were inserted into the K.Hill drillhole core sample stream. The CRM are produced by AMIS and derived from manganese mineralisation from the Sakura Ferro-Alloy (Malaysia) and the Mamatwan Mine in the Kalahari Manganese Field, South Africa. CRM grades for the main analysed elements are provided in Table 11.3. The manganese oxide grades of the CRM are appropriate to the average grade of the mineralised K.Hill samples, although inclusion of a lower grade CRM at or around the Mineral Resource reporting grade (8% to 12% manganese oxide) would be a beneficial addition.

Table 11.3 Certified reference material values for manganese oxide

CRM	Certified value (%)	Two standard deviations (%)
AMIS0407	46.81	0.740
AMIS0533	23.97	0.555
AMIS0535	26.70	0.830

The submission and failure rates of the three CRM are summarised in Table 11.4, with performance illustrated graphically in Figure 11.10 to Figure 11.12.

Table 11.4 Summary of certified reference material performance for the Phase 2 reverse circulation drilling campaign

CRM	Number of submissions	Insertion rate (%)	Number of failures	Failure rate (%)
AMIS0407	73	2.2	7	10
AMIS0533	78	2.3	2	3
AMIS0535	73	2.2	2	3
Total	**224**	**2.22**	**11**	**5**

Figure 11.10 Certified reference material control plot for certified reference material AMIS0407, 2020/21 reverse circulation drilling

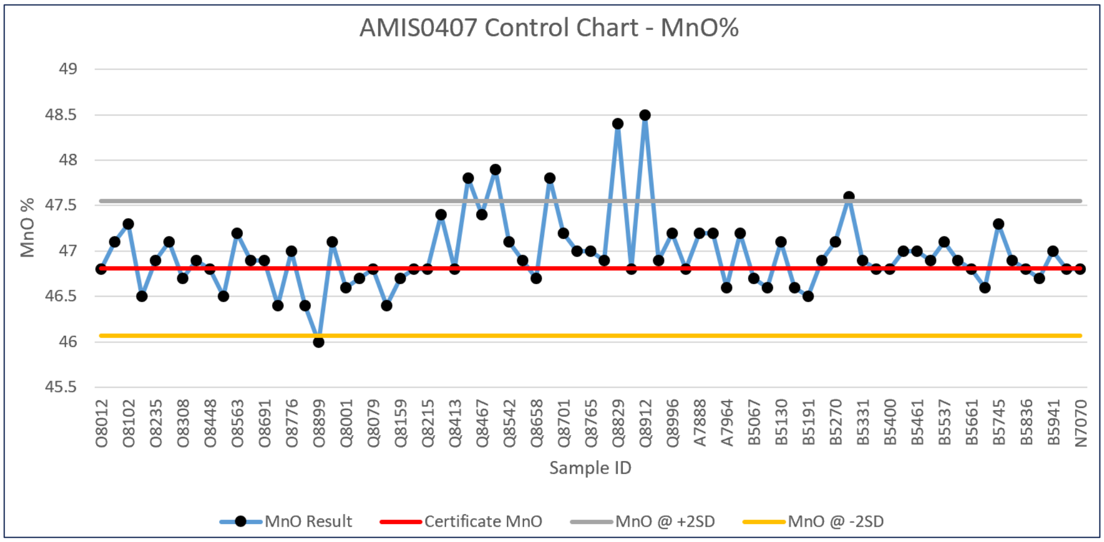


Figure 11.11 Certified reference material control plot for certified reference material AMIS0533, 2020/21 reverse circulation drilling

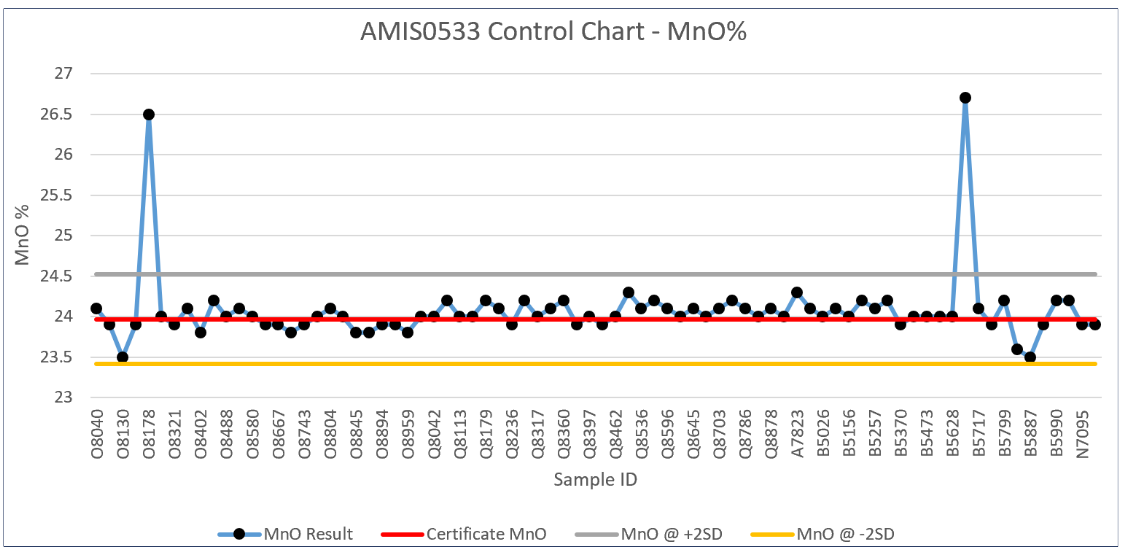
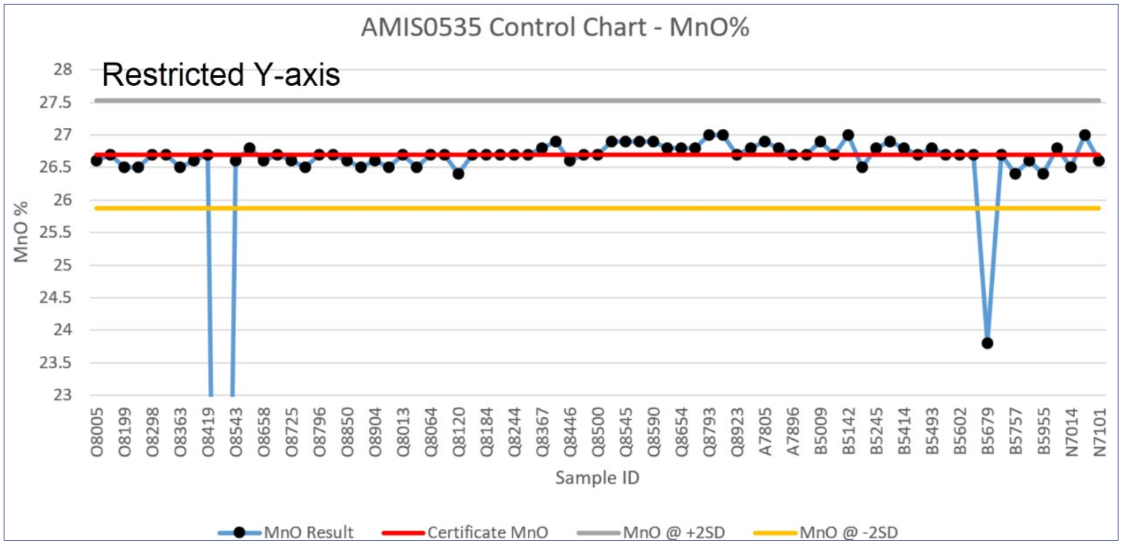
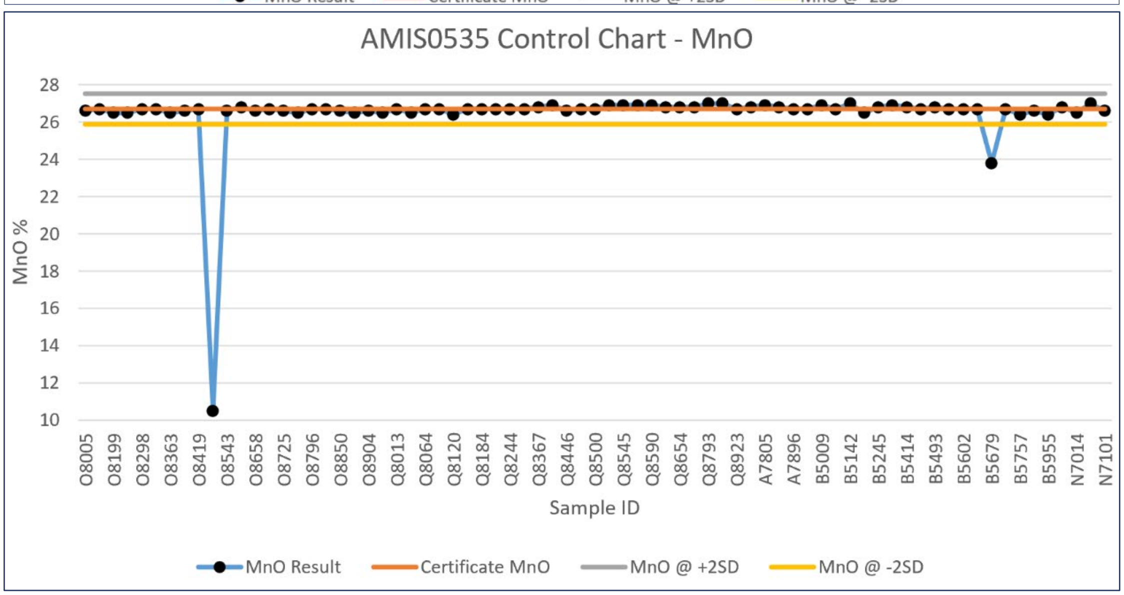


Figure 11.12 Certified reference material control plot for certified reference material AMIS0535, 2020/21 reverse circulation drilling





Overall, the two lower grade CRM (AMIS0533 and AMIS0535) perform well, with the two AMIS0533 failures likely due to sample swaps with AMIS0535 samples, and the same being true of one of the two AMIS0535 failures. The higher-grade AMIS0407 CRM shows some periods of systematic over-reporting of true grades by approximately 0.5% to 1.0% manganese oxide. However, given that the majority of samples fall within two standard deviations of the certified value for this CRM, SRK does not consider there to be a material risk to the accuracy of the sample analyses during this period.

The CRM samples were also assayed for aluminium oxide, calcium oxide, iron oxide, magnesium oxide, phosphorus pentoxide, and silicon dioxide. For brevity, SRK has not provided graphs of CRM performance of these elements. The CRM assays for these variables are all within four standard deviations of the certified value of the respective variables, except for samples previously identified as likely CRM swaps. None of the variables showed any significant, consistent bias.

11.5.3.3 Duplicates

A total of 42 field and 40 pulp duplicates were inserted into the regular sample stream during the 2020/21 RC drilling campaign, representing insertion rates of approximately 1.3% and 1.2%, respectively. Overall, both duplicate sample types show good precision (Figure 11.13 and Figure 11.14). As such, SRK considers that the sub-sampling and analytical processes show an acceptable degree of repeatability, and the precision of the assay results determined during this drilling campaign is appropriate for Mineral Resource estimation.

Figure 11.13 Field duplicate control plot, 2020/21 reverse circulation drilling

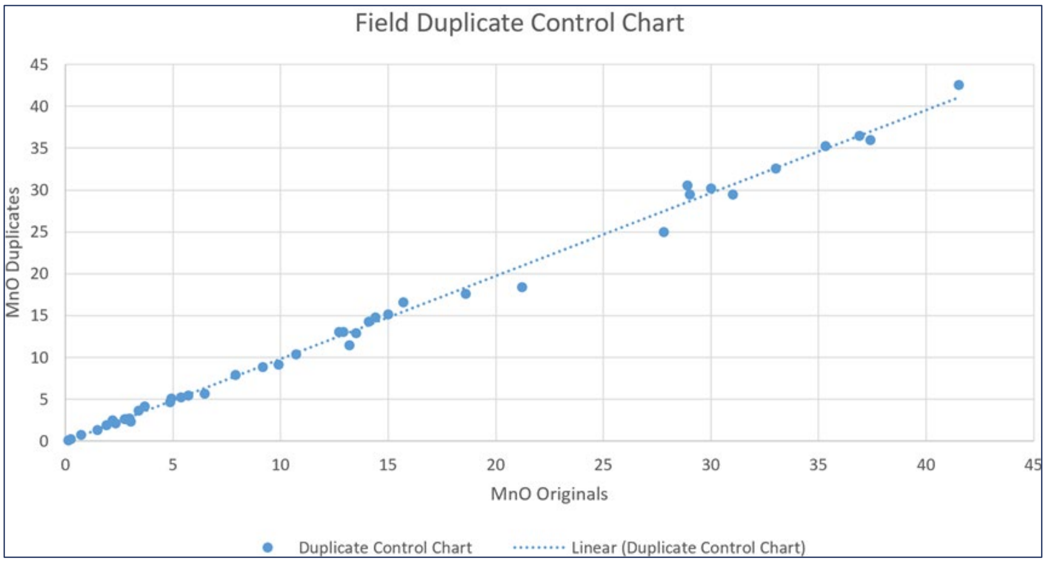
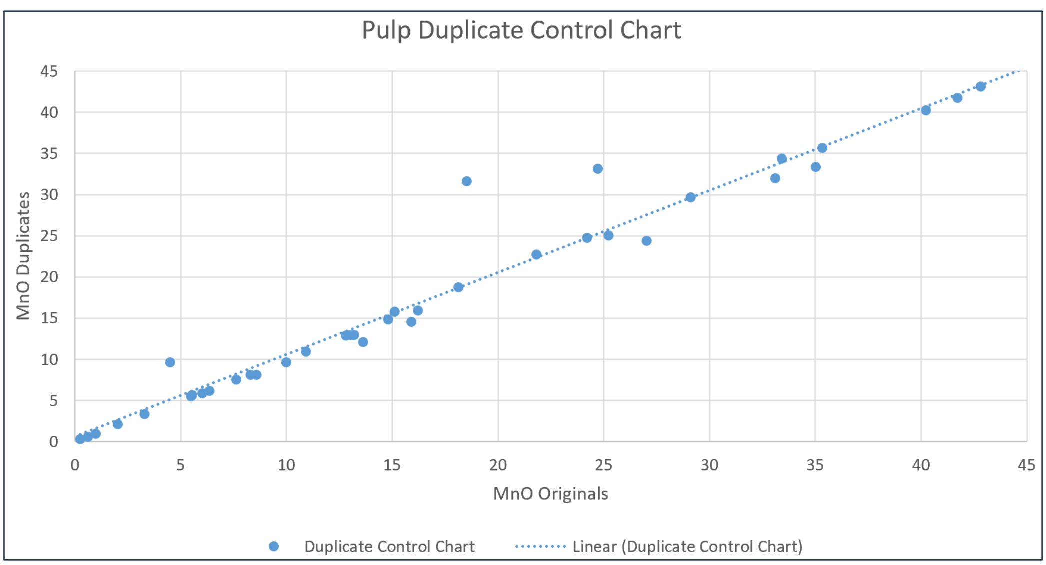


Figure 11.14 Pulp duplicate control plot, 2020/21 reverse circulation drilling



11.5.3.4 Umpire analyses

As an external control, a total of 139 duplicate samples from the 2020/21 RC drilling programme were sent to an umpire laboratory (Intertek Genalysis, Australia) for analysis. Overall, there is an excellent correlation (R2 > 0.99 for the major oxides of interest) between original (SGS Randfontein) and umpire (Intertek Genalysis) analyses for each of the elements analysed (Figure 11.15 to Figure 11.16). Based on these results, SRK does not consider there to have been a material issue with the accuracy, precision, or contamination of RC sample analyses conducted at SGS Randfontein during this period.

Figure 11.15 Umpire sample control plot for manganese oxide (%) analyses at the primary (SGS Randfontein) and Umpire (Intertek Genalysis) laboratories

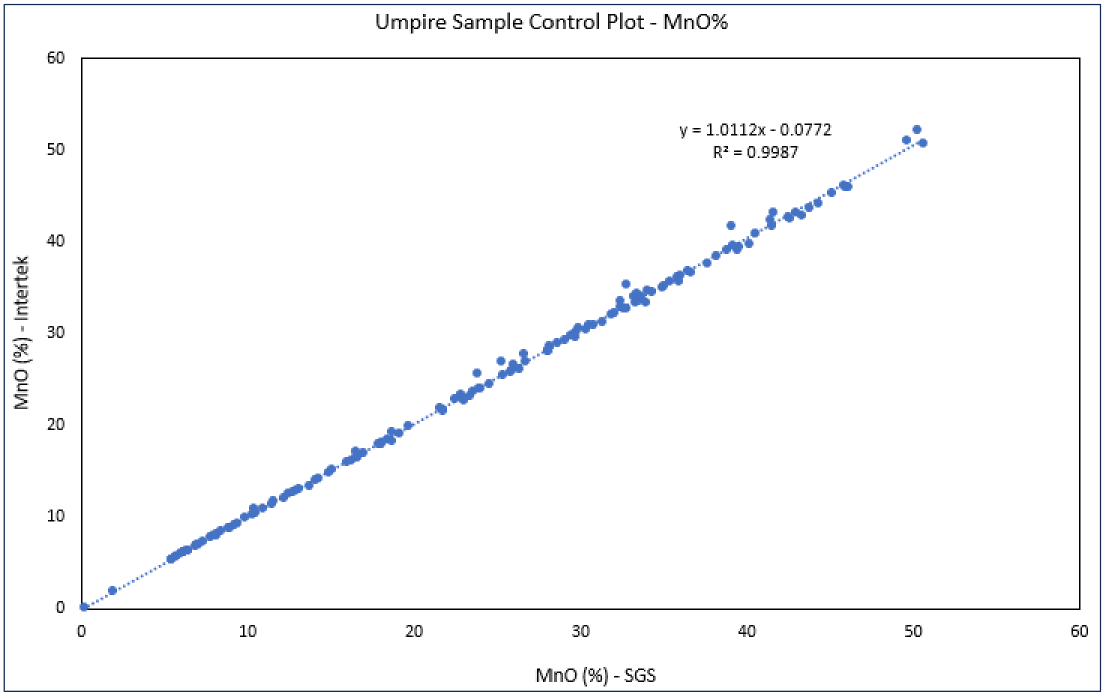
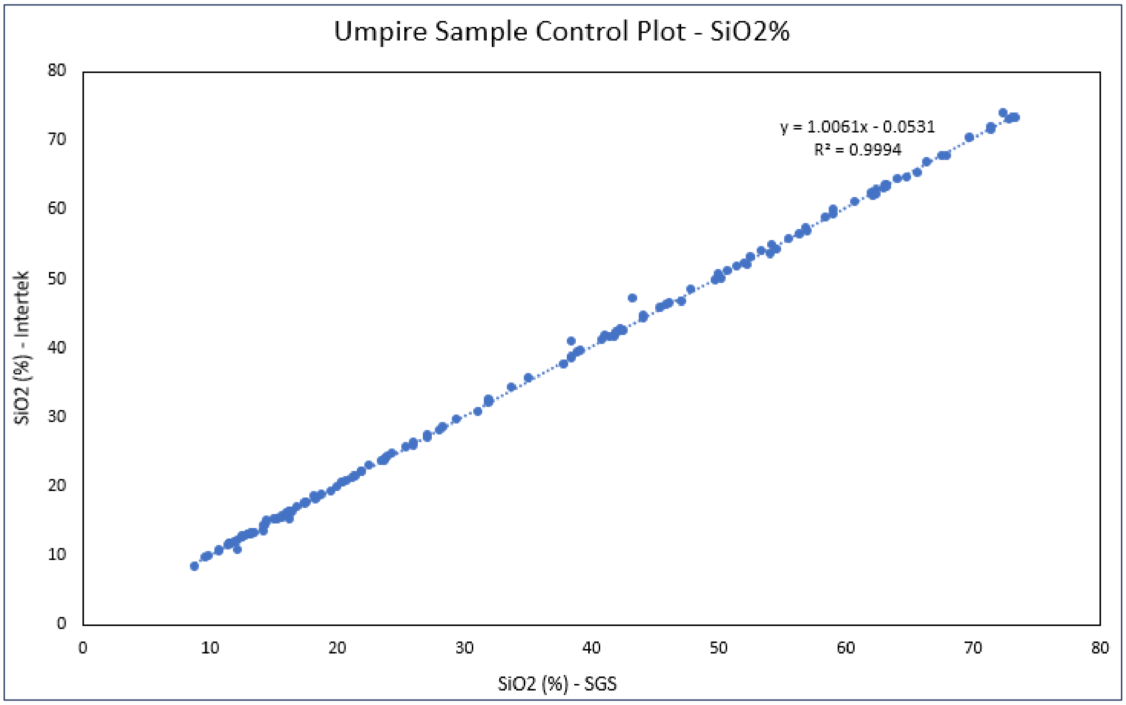


Figure 11.16 Umpire sample control plot for silicon dioxide (%) analyses at the primary (SGS Randfontein) and Umpire (Intertek Genalysis) laboratories



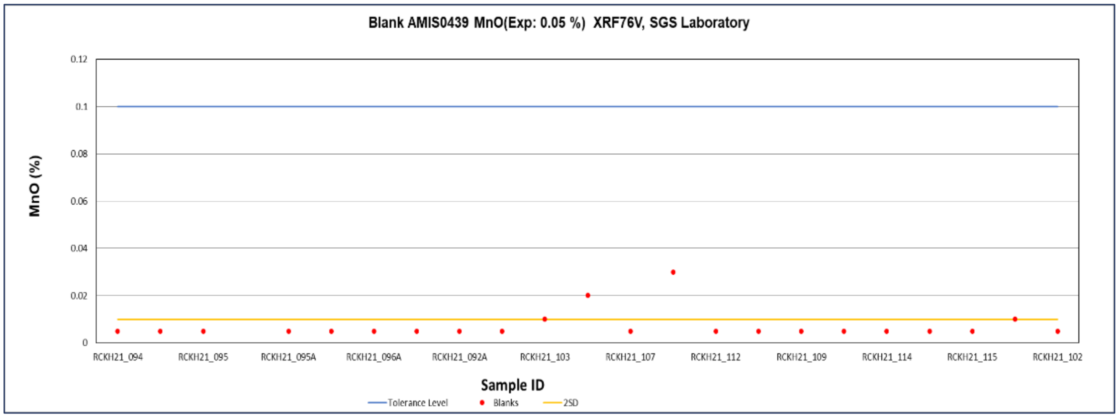
11.5.4 Reverse circulation drilling Phase 4 South Extension Area quality assurance/quality control

During the south extension drilling campaign (28 RC holes) a total of 118 QA/QC samples were inserted into the sample stream. The QA/QC samples included 21 blanks, 37 CRM, 30 field duplicates, and 30 pulp duplicates, representing an overall QA/QC sample insertion rate of 13%. SRK notes that this is below the 20% normally recommended, and SRK has recommended that Giyani address this in future RC and DD programmes.

11.5.4.1 Blanks

Giyani used AMIS0439 blank silica chips for blank material submission to the primary laboratory (SGS Randfontein) to monitor sample contamination. The results are shown in Figure 11.17 and show no blank samples exceeding the expected upper limit of 0.1% manganese oxide.

Figure 11.17 Blank sample (AMIS0439) control plot, Phase 4 reverse circulation drilling



11.5.4.2 *Certified reference material*

Samples of three separate CRM (AMIS0407/533/535), covering a grade range of approximately 24% to 47% manganese oxide, were inserted into the K.Hill southern extension drillhole core sample stream. CRM grades for the main analysed elements are provided in Table 11.5. The manganese oxide grades of the CRM are appropriate to the average grade of the mineralised K.Hill samples. As mentioned previously, inclusion of a lower-grade CRM at or around the Mineral Resource reporting grade (8% to 12% manganese oxide) would be a beneficial addition.

Table 11.5 Certified reference material values for manganese oxide

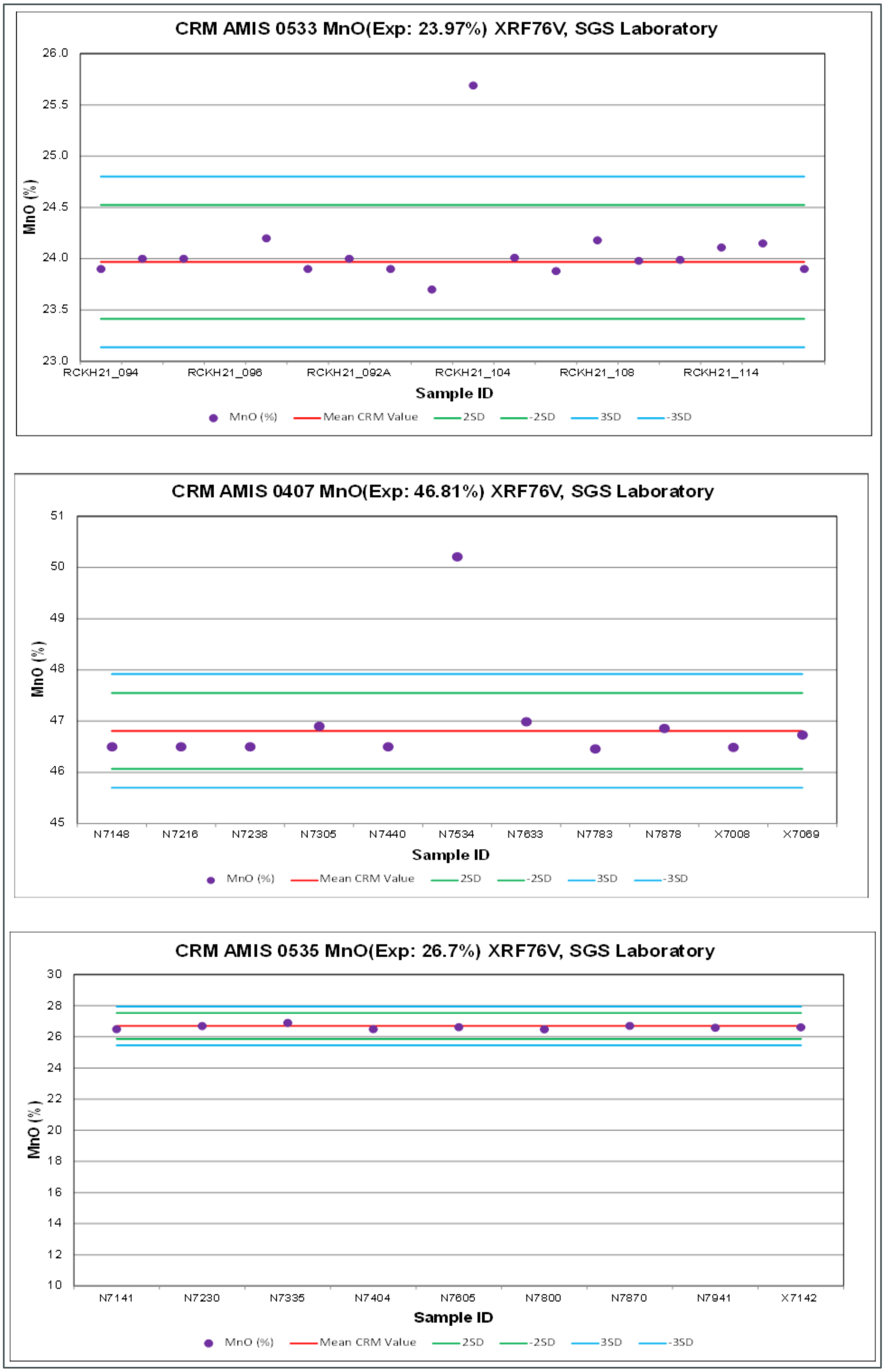
CRM	Certified value (%)	Two standard deviations (%)
AMIS0407	46.81	0.740
AMIS0533	23.97	0.555
AMIS0535	26.70	0.830

The submission and failure rates of the three CRM are summarised in Table 11.6, with performance illustrated in Figure 11.18.

Table 11.6 Summary of certified reference material performance for the Phase 4 South Extension Area reverse circulation programme

CRM	Number of submissions	Insertion rate (%)	Number of failures	Failure rate (%)
AMIS0407	11	1.2	1	9
AMIS0533	17	1.8	2	11
AMIS0535	9	1.0	0	0
Totals	**37**	**4.0**	**3**	**8**

Figure 11.18 Certified reference material control plots for certified reference material 0535, 0407, and 0533, SGS Randfontein



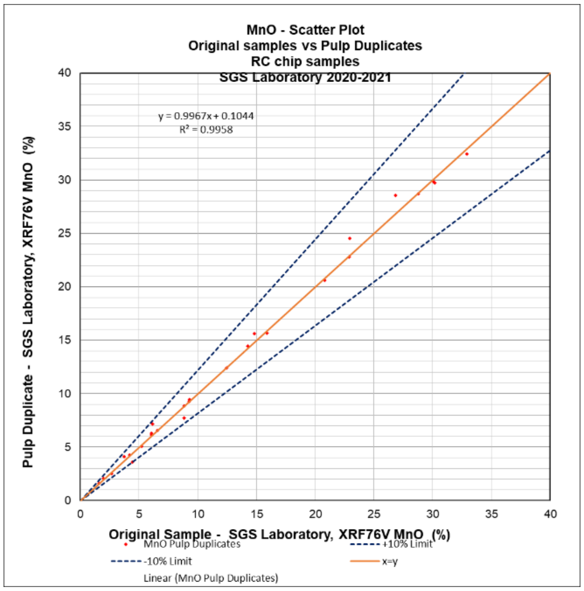
Overall, the three CRM performed moderately well, with a combined failure rate of 8% for manganese oxide. Given the majority of samples fall within two standard deviations of the certified value for this CRM, SRK does not consider there to be a material risk to the accuracy of the sample analyses for this RC drill programme.

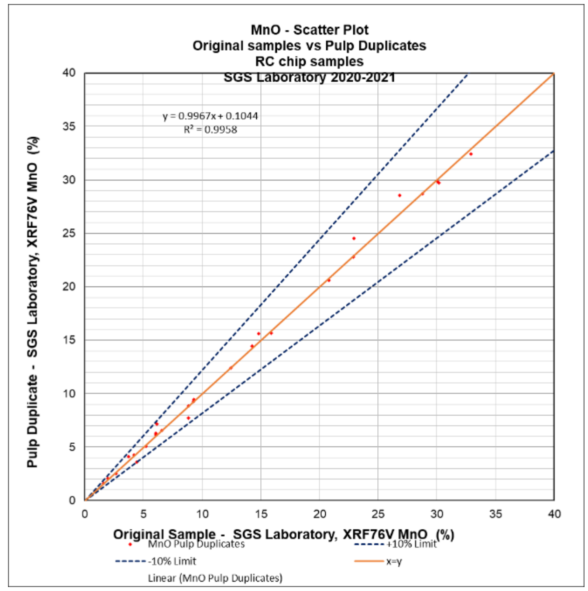
The CRM samples were also assayed for aluminium oxide, calcium oxide, iron oxide, magnesium oxide, phosphorus pentoxide, and silicon dioxide. The CRM assays for these variables are mostly within four standard deviations of the certified value of the respective variables, only a less than 2% failure rate for all elements was noted. None of the additional elements showed any significant, consistent bias.

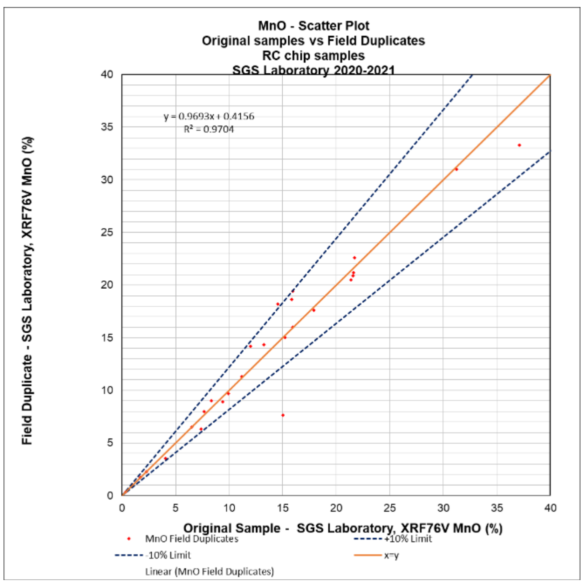
11.5.4.3 Duplicates

A total of 30 field and 30 pulp duplicates were inserted into the regular sample stream during the south extension RC drilling campaign, representing insertion rates of approximately 3.3%. Overall, both duplicate sample types show good precision Figure 11.19. As such, SRK considers that the sub-sampling and analytical processes show an acceptable degree of repeatability, and the precision of the assay results determined during this drilling campaign is appropriate for Mineral Resource estimation.

Figure 11.19 Field and pulp duplicate control charts Phase 4 reverse circulation drilling







11.5.4.4 Umpire analysis

No umpire samples were received to date as part of the south extension programme, as they were still under analysis in the umpire laboratories at the time of writing.

12 DATA VERIFICATION

12.1 Twin drillhole analysis

SRK undertook an analysis of the twin drilling completed by Giyani comparing Phase 1 DD holes against Phase 2 RC holes. Two of the RC holes twin previously completed DD holes, allowing for an analysis of the conformity of grade and logging between the DD and RC drilling to be undertaken. Twin plots showing analytical grade for manganese oxide as well as logged geology are presented in Figure 12.1 and Figure 12.2. The analysis suggests that the assays derived from RC drilling and DD show similar location, thickness, and grade across the mineralised zones, but that geological logging differs significantly between the RC drilling and DD. Consequently, when using the RC drilling to construct mineralisation wireframes, SRK has relied more heavily on the laboratory (where available) and pXRF assay data to guide the boundary locations of the wireframes, over the geological logging.

Figure 12.1 Twin plot showing logged geology and assayed manganese oxide grade for drillholes DDKH18_0014 and RCKH20_003

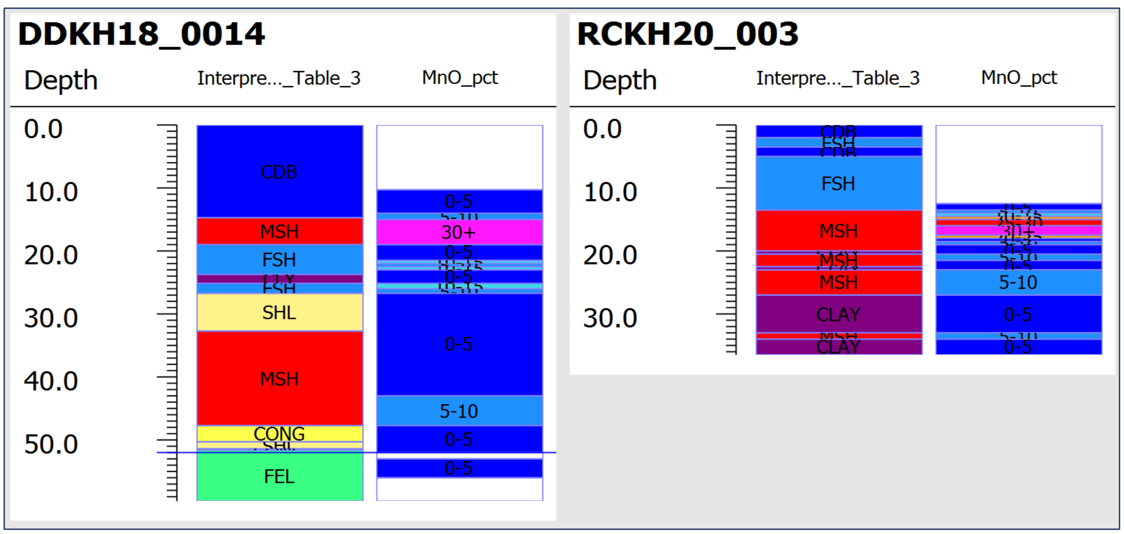
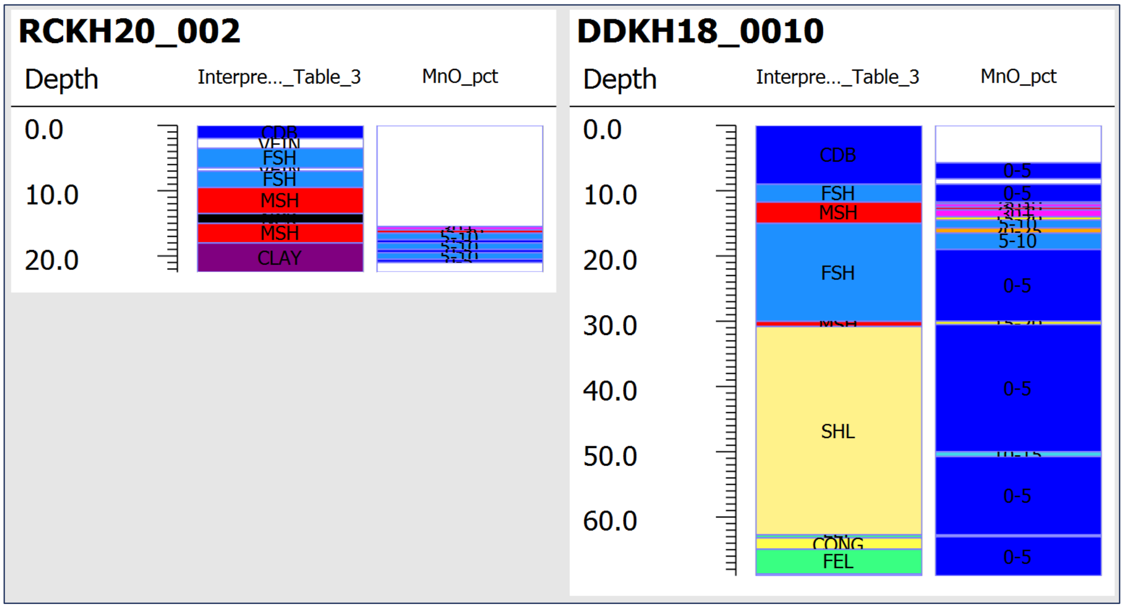


Figure 12.2 Twin plot showing logged geology and assayed manganese oxide grade for drillholes DDKH18_0010 and RCKH20_002



To date, no assay results are available for three diamond twin holes sited along adjacent RC holes in the southern extension area. These twin sets of drillholes are:

- RCKH21_114 to DDKH21_0031
- RCKH23_110 to DDKH21_0029
- RCKH21_115 to DDKH21_0030

12.2 Database validation/adjustments

SRK undertook a high-level validation process, which included the following checks:

- examining the sample assay, collar information, and geology data to ensure that the data were complete for all drillholes
- examining the de-surveyed data in 3D to check for clear spatial errors and their position relative to mineralisation
- checks for "FROM-TO" errors, to ensure that the sample data do not overlap one another or that there are no unexplained gaps in the sampling
- assays below the analytical detection limit were assigned the lower detection limit value
- intervals of core that were not sampled due to no core recovered were left absent; these intervals had a loss of core caused by the soft and friable nature of the rock

12.3 SRK site visits

Mr. Michael John Beare, BEng, CEng, ACM, MIMMM and Mr. James Haythornthwaite, BSc, MSc, CGeol, of SRK, visited the K.Hill Project site in December 2019 and January 2020, respectively. The initial site visits completed by SRK took place after Phase 1 DD was completed (and before the initiation of the Phase 2 RC drilling); therefore, active drilling activities were not observed. A follow-up site visit was undertaken by Mr. John Paul Hunt, MSc, FGSSA, GASA, SEG, SGA, IAGOD, GSA, of SRK, in March 2021 to observe and verify active drilling during RC drilling. A further site visit was made in January 2022 by Mr. Peter Gleeson, MSc, CEng, MIMMM, AIGS, of SRK, to review core, outcrop, and structure of the deposit.

During the January 2020 site visit, the following checks were undertaken by Mr. Haythornthwaite:

- inspection of mineralisation outcrops
- inspection of the underground mine workings
- check of the Giyani core storage and sampling facility
- review of the remaining drill core for drillholes DDKH18_002, DDKH18_005, DDKH18_008, DDKH18_0011, and DDKH18_013, including check logging

During the March 2021 site visit, the following checks were undertaken by Mr. Hunt:

- inspection of the RC drill sites and equipment
- check of the Giyani core storage and sampling facility

SRK commentary on the drilling procedure employed by Giyani is provided in Section 10.6. Check logging completed by SRK during the January 2020 site visit did not indicate any serious flaws in the logging completed by Giyani. SRK reviewed a number of drillholes to confirm that the interval depths of mineralised intervals, according to the assay database, correspond with visible manganese oxide mineralisation. No discrepancies between the downhole depth of the Mn-shale in drill core and the depth of mineralised intervals according to the assay database were identified.

Mr. Gleeson conducted a site visit in January 2022. As part of this site visit, Mr. Gleeson noted several aspects in relation to the geology and densities that are recommended to form part of future work programmes:

- A review of the outcrop indicates that, structurally, K.Hill maybe more complex than noted in previous reports (Section 7.5). SRK is of the opinion that detailed structural mapping of the main deposit at K.Hill is required and should be assessed during the detailed mine planning stage. This is required to assess the current resource models and may be used in future updates of the Mineral Resource estimate. However, this is not essential for the FS.

- Higher-grade portions of the Mineral Resource may follow fold hinges related to duplex fault-fold systems developed in the Mn-shale horizon.
- Observations of Mn-shale samples in both core and outcrop suggest a high degree of variability in density based on degree of weathering and manganese oxide content. SRK is of the opinion that bulk testing of the shale is required to determine accurate densities for the Mn-shale in situ.

The conclusions and results of the three site visits are included in the body of the report and any issues highlighted from the site visits have been satisfactorily addressed or are planned for in future work programmes.

12.4 Summary

SRK considers that the drilling, sampling, assaying, and QA/QC procedures utilised by Giyani have resulted in data which is of sufficient quality to support a subsequent Mineral Resource estimate. In general, Giyani have followed the recommendations on sampling made by SRK.

13 MINERAL PROCESSING AND METALLURGICAL TESTING

13.1 Summary

Tetra Tech, working closely with Giyani, used a set of historical documents, reports, and references and implemented new test work in order to understand and optimise the metallurgical extraction of manganese for the production of HPMSM from the K.Hill Project.

Historical documentation developed by Giyani and its consultants between 2018 and present was available from SRK, MSA, Vietti Slurrytec, Lab 4, and Dalhousie University. The available documentation covers mineralogy, assays, leach testing, and solvent extraction testing.

The test work initiated by Tetra Tech includes assays, specific gravity (SG), mineralogy, comminution, solid-liquid separation, leach optimisation, jarosite precipitation, iron and aluminium precipitation, other base metal precipitation, calcium and magnesium precipitation, fluoride removal, crystallisation, and manganese hydroxide precipitation. Giyani engaged an industry leading crystallisation technology company to provide a custom proprietary crystallisation process for the K.Hill Project.

In addition, samples were taken of the K.Hill Horizon B material, a separate local orebody lying just below the K.Hill LOM orebody, and leach extraction work. The intention was to understand the differences, if any, between the Horizon B material and the original LOM sample.

13.1.1 Comminution development

Comminution test work was consistent and indicated that the K.Hill ore, from both the LOM material and the Horizon B material, displays characteristics that are soft for crushing, low for abrasion, and variably soft to hard for the grinding work index.

13.1.2 Solid/liquid separation development

The solid/liquid testing consistently indicated that, post leach, the LOM leach residue material settles poorly and produces low solids-content thickener underflows. On this basis, the decision was made to use filtration for separation, rather than settling.

13.1.3 Leach development

The leach performance was investigated and consistently indicated that a high temperature (90°C) reductive leach produced excellent results (95% to 99% extraction). Initial work using sucrose as the reductant was superseded by the use of sulphur dioxide, which provided benefits of cost, practicality, and reduced acid consumption. The Horizon B material showed very similar results to the LOM material. The manganese extraction was found to be insensitive to head grade and mineralogical composition.

13.1.4 Precipitation and purification development

Test work indicated that the stage-wise precipitation of various contaminants was effective and efficient. Manipulation of pH and addition of aqueous reagents, as well as the use of activated alumina, allowed for the production of a solution that was suitable for crystallisation. The purification is sensitive to the number of impurities in the feed, as this will affect the number of reagents used, precipitates removed, and associated treatment costs.

13.1.5 Crystallisation design development

Two routes were pursued for the production of a purified stock solution that is used for the crystallisation design development:

- use of synthetic stock solution produced from analytical metal samples
- work at Mintek to produce a stock solution from representative ore that has been processed step-by-step through the intended recovery methods

The synthetic solution provides a means for rapid and inexpensive production of crystalliser feed, allowing the development of initial process feed purity requirements and expected operational criteria. The Mintek work yields a fully representative stock solution that provided the opportunity to complete the crystalliser design. The HPMSM produced by the crystalliser met the product specification and provided a significant amount of process-accurate HPMSM for acceptance testing and trials by potential battery metal clients.

13.1.6 Overall recovery

From the test work and process development, it is expected that 88.5% of manganese input into the K.Hill process will exit the plant in the form of battery-grade manganese.

13.2 Source documents

Tetra Tech had access to and reviewed the original laboratory reports from FS test work and also reviewed the following documents from historical test work.

- *Kgwakgwe Hill Manganese Project Independent Technical Report* (SRK 2020)
- *Mineral Resource Estimate for the K-Hill Manganese Project, Botswana, NI 43-101 Technical Report* (MSA 2018)
- *Metallurgical Sample Specification Memo* (Tetra Tech 2022)
- *Giyani K.Hill Process Verification* (Mintek 2022).
- *K-Hill Project Solid Liquid Separation Test Work* (Vietti Slurrytec 2021)
- MSM Crystallisation Test Work (Confidential)

All test work reported in Section 13 is taken from the information presented in these documents.

13.3 Historical test work

The historical test work was completed under the guidance of Dr. Ian Flint of Lab 4 (Canada) in two stages:

- Stage 1 included optical and electron probe work that identified both valuable and waste minerals, mineral particle size distributions, and the approximate grind sizes required for mineral phase liberation or exposure.
- Stage 2 included tests on the leaching of three samples to determine the dissolution characteristics and residence times required to extract the manganese in the primary leach stage of a hydrometallurgical process.

13.3.1 Mineralogical test work

Dalhousie University undertook a mineralogical analysis of the K.Hill mineralised material using optical and electron microscopy probes. The analysis was performed on a selection of manganese-oxide-bearing rocks taken as grab samples from the K.Hill mineralisation. Four samples were tested to determine the mineralogical composition of the manganese minerals. These samples and the resulting determinations are shown in Table 13.1.

Table 13.1 Identified and possible mineral species in K.Hill samples

Sample	Description	Mineral	Formula
KH17 MT01	Dump material	Cryptomelane	$K(Mn^{4+}{}_7Mn^{3+})O_{16}$
		Hausmannite	$Mn^{2+}Mn^{3+}{}_2O_4$
		Hollandite	$Ba(Mn^{4+}{}_6Mn^{3+}{}_2)O_{16}$
		Psilomelane	$Ba(Mn^{2+}Mn^{4+}{}_3)O_{16}(OH)_4$
		Pyrolusite	MnO_2
KH17 MT02	Altered shale	Jacobsite	$Mn^{2+}Fe^{3+}{}_2O_4$
KH17 MT03 KH17 MT05	Shale with kaolin	Coronadite	$PbMn^{4+}{}_6Mn^{3+}{}_2O_{16}$
		Cryptomelane	$K(Mn^{4+}{}_7Mn^{3+})O_{16}$
		Hausmannite	$Mn^{2+}Mn^{3+}{}_2O_4$
		Hollandite	$Ba(Mn^{4+}{}_6Mn^{3+}{}_2)O_{16}$
		Psilomelane	$Ba(Mn^{2+}Mn^{4+}{}_3)O_{16}(OH)_4$
KH17 MT04	Silicified shale	Hausmannite	$Mn^{2+}Mn^{3+}{}_2O_4$
		Psilomelane Group	$Ba(Mn^{2+}Mn^{4+}{}_3)O_{16}(OH)_4$

Dalhousie University reported that, in terms of presentation, the manganese minerals occurred in three forms:

- as staining on the silicates, iron oxides, and as themselves
- as small veins where manganese oxides have been deposited on each other, particularly within well-fissured zones

- as nodules where the manganese has built up into botryoidal masses that may contain other minerals within them
  - It was also reported that the mineralogical analysis did not specifically investigate the nodules owing to insufficient samples.

Dalhousie University also reported that the head assays of the samples were reported after converting them to the standard oxide form. The assays are shown in Table 13.2.

Table 13.2 Head assays

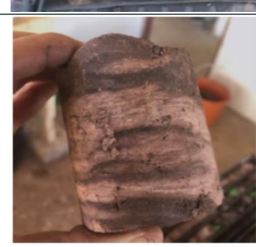
Sample	Description	FeO (%)	MnO (%)
KH17 MT01	Dump material	39.7	48.7
KH17 MT02	Altered shale	27.3	48.8
KH17 MT04	Silicified shale	4.5	4.3
KH17 MT03 KH17 MT05	Shale with kaolin	23.2	60.8

13.3.2 Metallurgical test work

Test work sample

Tetra Tech was not involved with the sample selection for the metallurgical test work completed by Dalhousie University. It is understood that three different intervals from a single drillhole were used for the metallurgical test work. The sample description and related pictures are shown in Table 13.3.

Table 13.3 Metallurgical test work samples

Sample	Description	From (m)	To (m)	Photograph
KH18 MT010	Mn-shale	23.73	27.00	
KH18 MT011	Fe-shale	27.00	30.85	

Sample	Description	From (m)	To (m)	Photograph
KH18 MT012	Manganese oxide	48.00	50.73	

Head assays

Dalhousie University reported the manganese and iron head assays for the test samples (Table 13.4). The analytical methods were not specified in the available reports.

Table 13.4 Manganese and iron head assay results for test sample

Sample	Mn (%)	Fe (%)
KTH18 MT010	24.70	13.80
KTH18 MT011	30.70	12.10
KTH18 MT012	6.85	1.99

Comminution test work

Tetra Tech understands that comminution test work was not completed owing to limited sample availability.

Leach test work

Dalhousie University conducted ROM acid leach tests, with sucrose added as a reductant. In addition, baseline leach tests were also conducted under the same conditions but without any reductant addition. The tests were conducted with 125 mL of 3.64 molar sulphuric acid (H_2SO_4) solution. Summary test conditions are shown in Table 13.5.

Table 13.5 Leach test work conditions

Description	Value
Grind size- P80 (µm)	200
Sample Mass (g)	25
Acid concentration (g/L)	260
Temperature (°C)	90
Retention time (hour)	3

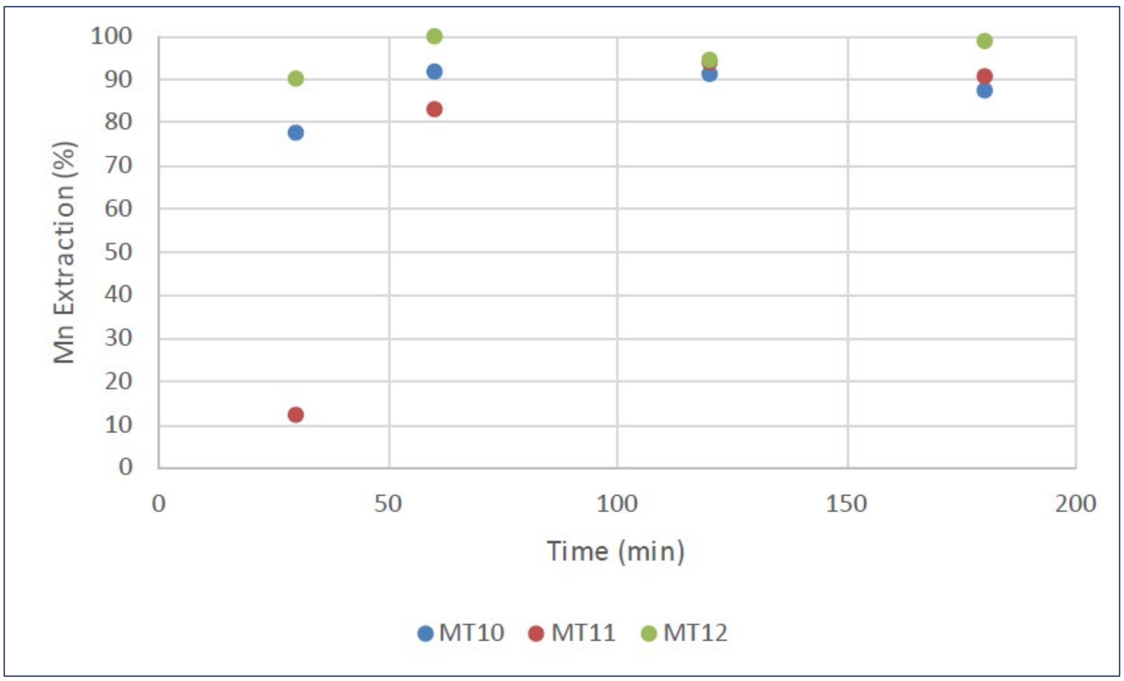
A summary of the leach results is shown in Table 13.6.

Table 13.6 Summary of leach test results

Sample	Reductant	Head assay (%)		Leach extraction (%)									
				15 min		30 min		60 min		120 min		180 min	
		Mn	Fe	Mn	Fe	Mn	Fe	Mn	Fe	Mn	Fe	Mn	Fe
MT10	Without	24.7	13.8	2.4	6.1	2.6	7.3	2.9	13.7	3.1	16.6	3.2	24.4
	With	-	-	-	-	77.5	18.6	91.7	29.1	91.4	29.4	87.7	22.4
MT11	Without	30.7	12.1	1.7	2.0	1.7	2.3	2.3	18.9	2.1	13.9	0.4	6.6
	With	-	-	-	-	12.2	34.4	83.1	58.3	93.9	78.8	90.8	74.2
MT12	Without	6.85	1.99	1.2	6.0	1.2	14.0	1.8	32.0	2.3	38.0	1.8	40.0
	With	-	-	-	-	90.3	63.0	100.5	87.0	94.6	83.3	98.9	87.0

The manganese leach kinetics for the leach with sucrose reduction and without sucrose reduction are shown in Figure 13.1.

Figure 13.1 Manganese leach kinetics (with reductant)



Source: SRK (2019)

The results indicate that the reductant has significantly improved the manganese extraction as well as the leaching kinetics. However, the test work programme did not evaluate other possible reductants such as sulphur dioxide, which is used in acidic sulphite reduction processes. This is an established process for manganese extraction and is used in several operating plants for manganese extraction. Tetra Tech identified that significant savings could be obtained by adopting the sulphur dioxide reduction process because the sulphur dioxide is used as a reductant in the process and sulphurous acid (H_2SO_3) is produced during solubilisation as an intermediate reactant. The sulphurous acid continues to take part in further chemical reactions with oxygen to make sulphuric acid, which is used as the lixiviant in the leaching process. This leads to savings as a result of reduced acid consumption.

The solution assays for various elements at the end of the leach test are shown in Table 13.7.

Table 13.7 Solution assays

Element	Assay (mg/L)	Element	Assay (mg/L)	Element	Assay (mg/L)	Element	Assay (mg/L)
Ag	1.0	Cr	1.5	Mn	26,470.0	Si	217.0
Al	938.0	Cu	29.0	Mo	0.1	Sn	1.0
As	0.1	Fe	6,589.0	Na	111.0	Sr	2.4
Ba	0.1	Ga	0.5	Nb	1.0	Ta	28.0
Be	0.3	Ge	5.0	Ni	38.0	Te	1.0
Bi	0.5	In	1.0	P	19.0	Ti	21.0
Ca	132.0	K	641.0	Pb	2.2	Tl	10.0
Cd	0.1	La	2.0	S	78,634.0	V	21.2
Ce	20.0	Li	3.1	Sb	1.0	Zn	18.0
Co	138.0	Mg	206.0	Se	7.5	Zr	1.1

The assays indicate that several metals (iron, aluminium, copper, zinc, nickel, and cobalt) are co-extracted as sulphates during leaching. The solution can be purified and the iron and aluminium sulphate removed in the form of hydroxides by precipitation with lime as indicated in the chemical reactions shown in Equations 1 and 2.

$$Fe_2(SO_4)_3 + 3Ca(OH)_2 + 6H_2O = 2Fe(OH)_3 + 3CaSO_4.2H_2O \qquad \text{Equation 1}$$

$$Al_2(SO_4)_3 + 3Ca(OH)_2 + 6H_2O = 2Al(OH)_3 + 3CaSO_4.2H_2O \qquad \text{Equation 2}$$

The solution can be further purified by removal of the base metals in the form of sulphides via precipitation with sodium hydrosulphide, as shown in Equation 3 to Equation 6.

$$CuSO_4 + NaHS = CuS + NaHSO_4 \qquad \text{Equation 3}$$

$$ZnSO_4 + NaHS = ZnS + NaHSO_4 \qquad \text{Equation 4}$$

$$NiSO_4 + NaHS = NiS + NaHSO_4 \qquad \text{Equation 5}$$

$$CoSO_4 + NaHS = CoS + NaHSO_4 \qquad \text{Equation 6}$$

Solvent extraction test work

Dalhousie University conducted solvent extraction tests on the pregnant leach solution produced from the leach tests. The solutions were tested with the organic extractant di-(2-ethylhexyl)phosphoric acid (D2EPHA). The pH conditions and results of each test are summarised in Table 13.8.

Table 13.8 Solvent extraction test results

Sample	Mn (ppm)	Mn Extraction (%)	pH
KTH18 MT010	16,908	95.8	3.0
KTH18 MT011	12,222	96.7	3.7
KTH18 MT012	7,047	92.2	3.6

The results indicate that approximately 96% of manganese could be extracted by D2EPHA into the organic phase. The loaded organic solvent could then be stripped with concentrated sulphuric acid to produce a concentrated manganese-sulphate solution. The sulphate could then be recovered by vacuum crystallisation to produce the HPMSM product.

The solvent extraction tests reported in Table 13.8 were not optimised but conducted as a standard scoping test. Thus, the 96% extraction is regarded as indicative only.

13.4 Material characterisation

13.4.1 Sample

Selection criteria

Tetra Tech specified the sample requirements and selection criteria for the metallurgical test work programme for the feasibility study. Tetra Tech's sample selection was based on the following criteria:

- There are two distinct lithological domains: Mn-shale (MSH) and Fe-shale (FSH).
- Sample sources:
  - comminution: whole PQ3 drill core
  - hydrometallurgy: RC rejects from the geological drilling programme.

Sample selection

A total mass of approximately 890 kg was selected for the test work.

Samples were packaged in waterproof sample bags with appropriate labelling, sealed, and then batched. The batches were packed into 30 L high-density polyethylene (HDPE) lock ring closure drums that were labelled, sealed, and shipped to the laboratory.

A summary of the different samples, expected sample mass, appropriate labels, and drums required for transport is shown in Table 13.9. Drums were labelled with the sample label and for variability samples either COM-VAR-seq no. or HM-VAR-seq no.

Table 13.9 Summary of sample selection

Test	Type	No of samples	Mass (kg)	Sample label	No. of drums
Comminution	Variability	11	169		4
	Composite - MSH	1	61	COM-COMP-MSH	2
	Composite - FSH	1	61	COM-COMP-FSH	2
	Composite - LOM	1	61	COM-COMP-LOM	2
Hydrometallurgy	Variability	6	60		2
	Composite - MSH	1	168	HM-COMP-MSH	4
	Composite - FSH	1	126	HM-COMP-FSH	4
	Composite - LOM	1	184	HM-COMP-LOM	5
Expected Total		**23**	**890**		**25**

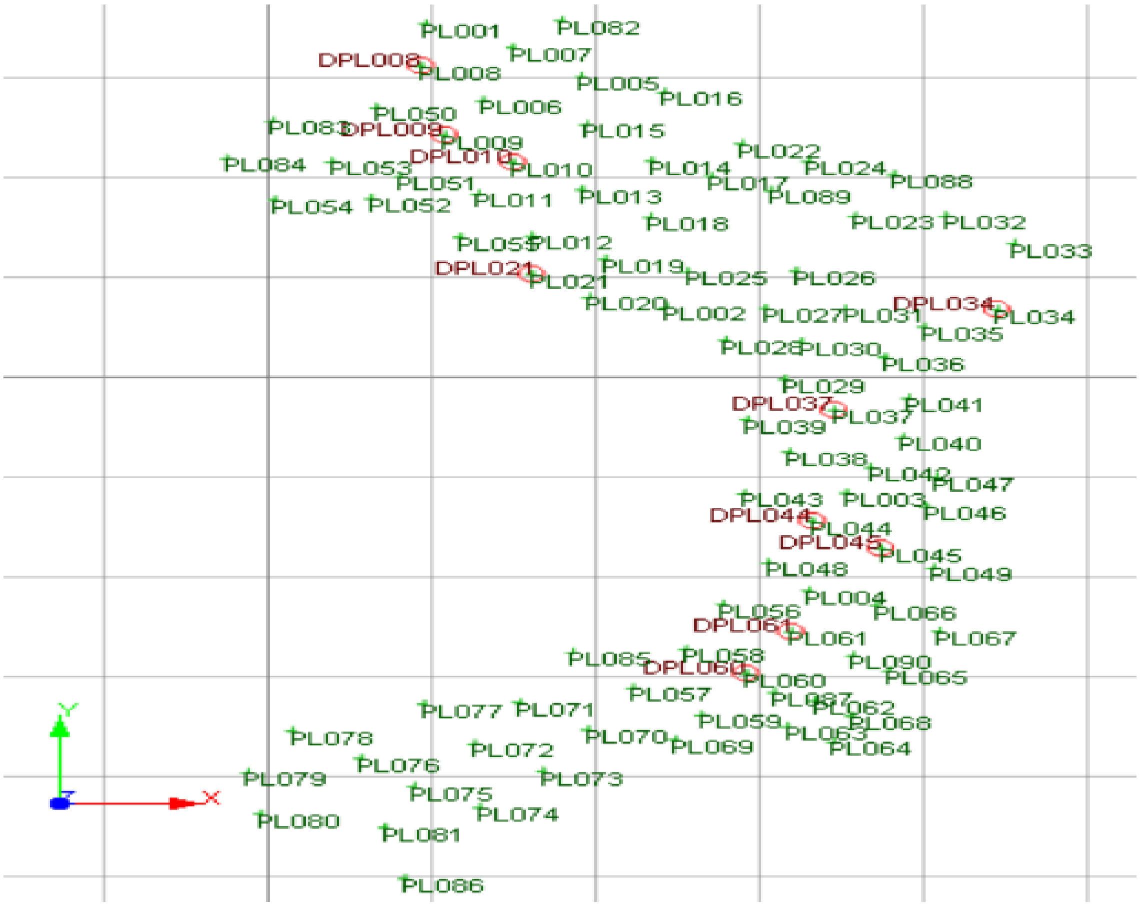
Comminution sample selection method

The comminution samples were selected from the planned PQ3 drill core, assuming the whole of the core of the selected intervals would be available for test work.

The variability samples were selected to cover the spatial variability of the ore body based on the drillhole map shown in Figure 13.2. Nine samples (five from FSH and four from MSH) were selected, and the tenth sample was taken from within the ore body where the lithology type is not known. In addition to the ten variability samples of mineralised material, an additional variability sample was selected from the host rock, since this material is likely to enter the mill as a result of dilution. The approximate length of the core and mass for each of the comminution variability samples was 1.5 m and 15 kg.

On completion of the variability sample selection, suitable intervals were identified within the leftover core to select the three composite samples, each with an approximate mass of 60 kg.

Figure 13.2 Drillhole location map indicating location of variability samples (in red)



Source: Giyani

Hydrometallurgical sample selection method

The hydrometallurgical variability samples were taken from RC drilling completed in December 2020. The primary aim of the hydrometallurgical composite sample selection was to match the sample grades of the samples that made up the LOM composite sample, which had a composite manganese oxide grade of 34%.

The aim of the variability sample selection was to compile a low-, medium-, and high-grade sample for each of the two mineralogical domains (MSH and FSH).

The lithology composite samples were selected from the completed RC drillholes. Intervals that represented the two lithologies were selected and then combined to make a composite sample.

The residual sample from the FSH domain was insufficient to achieve an equal proportion of both domains in the LOM composite that is comparable to the LOM manganese oxide grade. Thus 32% (by mass) of FSH samples and 68% of MSH samples were combined to make the LOM composite.

13.4.2 Material characterisation

Material characterisation was performed for comprehensive chemical and mineralogy analyses on three composite samples.

Sample preparation

Mintek received RC drill samples classified into three ore types. The ore types were delivered in separate 220 L plastic drums, with specific labelling for the three composites (i.e., COMP-LOM, COMP-MSH, and COMP-FSH). The samples in the drums were subdivided into multiple bags. Bags containing similar ore types were blended to obtain a representative sample of each type.

Each blend of the three ore types was crushed to -1.7 mm. Initially, only the COMP-LOM sample was milled to three different grind sizes (80% -212 µm, 80% -150 µm and 80% -106 µm) until the optimum grind size was determined from the subsequent test work. Two 200 g subsamples of each crushed sample (-1.7 mm) were taken and submitted for chemical and mineralogy analyses.

Head grade analysis

A semi-quantitative x-ray fluorescence (XRF) scan was conducted on each composite sample. Head grade analysis was conducted on each sample (pulverised) using inductively coupled plasma-optical emission spectroscopy (ICP-OES) for cobalt, copper, iron, magnesium, aluminium, silicon, calcium, titanium, vanadium, chromium, manganese, nickel, and zinc in which the detection limit was 0.05 %(m/m). The results of the XRF scan on the three composites are listed in Table 13.10; the results of the ICP-OES analysis are listed in Table 13.11.

Table 13.10 Semi-quantitative x-ray fluorescence scan on LOM, MSH, and FSH composite samples

Elements	Units	LOM	MSH	FSH
Mn	%	32.23	30.85	28.87
Al	%	5.48	5.44	6.40
Ba	%	1.22	1.32	1.31
Ce	%	nd	0.13	nd
Fe	%	19.88	22.33	19.86
K	%	1.29	1.13	1.65
Mg	%	0.07	0.11	0.19
P	%	0.07	0.11	0.07
Pb	%	1.26	2.15	1.36
Si	%	6.51	5.19	7.34
Sr	%	0.16	0.15	0.17
Ti	%	0.31	0.34	0.28
V	%	0.09	0.08	0.08
Ca	ppm	342.71	269.75	368.61
Cl	ppm	197.20	nd	425.41

Elements	Units	LOM	MSH	FSH
Co	ppm	408.89	273.75	274.98
Cu	ppm	226.07	241.11	274.52
Na	ppm	260.60	93.52	281.12
Ni	ppm	187.32	170.58	275.42
Rb	ppm	85.75	100.21	107.00
S	ppm	36.66	58.92	16.00
Zn	ppm	530.71	546.47	474.19
Zr	ppm	nd	17.71	nd

Note: nd - not detected

Table 13.11 ICP-OES head assays on LOM, MSH, and FSH composite samples

Elements	Units	LOM	MSH	FSH
Mn	%	26.6	26.4	23.9
MnO	%	34.3	34.1	30.8
Al	%	4.75	4.94	5.46
Ca	%	0.10	0.14	0.12
Co	%	<0.05	<0.05	<0.05
Cr	%	<0.05	<0.05	<0.05
Cu	%	<0.05	<0.05	<0.05
Fe	%	13.70	15.5	13.5
Mg	%	0.16	0.17	0.25
Ni	%	<0.05	<0.05	<0.05
Pb	%	0.80	1.43	0.87
Si	%	9.83	7.68	10.6
Ti	%	0.18	0.21	0.19
V	%	<0.05	<0.05	<0.05
Zn	%	0.057	0.066	0.061

The assays show high manganese grades in all the composite samples, ranging between 23.9% and 26.6%, based on ICP-OES. There is a notable difference between the ICP-OES and XRF analyses in relation to accessory elements; this is because the XRF method has a lower accuracy compared to the ICP-OES. However, the manganese assays from both techniques are in good agreement.

The major impurity elements were iron (13.5% to 15.5%), silica (7.68% to 10.60%), and aluminium (4.75% to 5.46%), based on ICP-OES. The XRF scan also detected a notable presence of lead (1.26% to 2.15%), potassium (1.13% to 1.65%), and barium (1.22% to 1.32%). The rest of the impurity elements were less than 1% or measured very low.

Specific gravity

Before 1st July 2020, a mean in-situ ore density of 2.7 t/m³ was used for resource and process estimates. Subsequently a detailed sampling programme was implemented to confirm the in-situ ore density. Following receipt and review of comprehensive K.Hill pycnometric density data from multiple core samples at various collar locations around the mine site, the mean pycnometric density increased from 2.7 t/m³ to 3.48 t/m³.

Mineralogy

The analyses were conducted on the -1.7 mm crushed samples. The head samples were screened into discrete size fractions based on particle size distribution. Representative aliquots from each of the size fractions were mounted into polished sections for analysis. Sizing of the sample produces a better result from the AutoSEM (Quantitative Evaluation of Materials by Scanning Electron Microscopy [QEMSCAN]) system. After analysis, the results from the individual size fractions were then recombined into a single result for the total sample and weighted according to the mass distributions of the size fractions. The product samples were pulverised and micronised for XRD.

The bulk modal mineralogy of head samples FSH, MSH, and LOM are presented in Table 13.12. The samples predominantly comprise manganese-bearing phases (approximately 70 mass %); cryptomelane and bixbyite are the main manganese-bearing phases, while hollandite and manganese mica are the next most significant. The manganese oxide group includes pyrolusite and hausmannite, while "other" includes sulphides such as pyrite as well as pyroxenes and carbonates. The manganese-bearing phases have been validated using XRD. The MSH and LOM samples have a slightly higher cryptomelane content, while FSH has a high manganese mica content. The gangue phases in the sample include quartz, hematite, and kaolinite.

Table 13.12 Bulk modal mineralogy for the three samples: FSH, MSH and LOM

Mineral	Ideal Formula	Mass (%)		
		FSH	MSH	LOM
Cryptomelane	$K(Mn^{4+}, Mn^{2+})_8O_{16}$	19.5	23.3	24.1
Bixbyite	$(Mn^{3+},Fe^{3+})_2O_3$	17.3	16.4	17.3
Hollandite	$Ba(Mn^{4+}{}_6Mn^{3+}{}_2)O_{16}$	8.8	11.0	8.1
Manganese oxides	-	7.2	5.9	9.6
Birnessite	$(Na,Ca,K)_x(Mn)_2O_4 \bullet 1.5(H_2O)$	2.2	1.4	1.6
Alabandite	MnS	0.2	0.6	0.3
Manganese mica	$KAl_3Si_3O_{10}(OH)_{1.8}F_{0.2}(Mn)$	14.0	10.8	9.0
Manganese silicate	$Na(Fe^{2+},Mn^{2+})_{10}(Fe,Al)_2Si_{12}O_{31}(OH)_{13}$	0.9	0.9	0.8
Hematite	Fe_2O_3	7.7	13.4	9.2
Mica	$KAl_3Si_3O_{10}(OH)_{1.8}F_{0.2}$	3.8	1.4	1.5
Quartz	SiO_2	10.8	5.7	11.4
Kaolinite	$Al_2Si_2O_5(OH)_4$	4.3	6.5	4.6
Actinolite	$Ca_2(Mg,Fe)_5Si_8O_{22}(OH)_2$	1.0	1.8	1.0
Chlorite	$(Mg,Fe^{2+})Si_3Al_2O_{10}(OH)_8$	0.9	0.3	0.1
Feldspar	$KAlSi_3O_8$	1.2	0.2	0.5

Mineral	Ideal Formula	Mass (%)		
		FSH	MSH	LOM
Ilmenite	$Fe^{2+}TiO_3$	0.1	0.0	0.1
Other(1)	-	0.2	0.4	0.8

Notes: (1) Other includes sulphides such as pyrite as well as pyroxenes and carbonates.

Assay reconciliations for magnetic separation products are presented in Table 13.13, which shows the chemical and QEMSCAN generated mineralogical assay results. The QEMSCAN generated results are calculated using the mass proportions of the mineral phases present in conjunction with theoretical chemical composition, or energy dispersive spectroscopy data, where available. The chemical and QEMSCAN assay results compare well; thus, the QEMSCAN modal results are confirmed as accurate.

Table 13.13 Chemical and QEMSCAN assays reconciliation

Element	FSH		MSH		LOM	
	Chemical Assay	QEMSCAN Assay	Chemical Assay	QEMSCAN Assay	Chemical Assay	QEMSCAN Assay
Al	5.5	5.3	5.0	4.7	4.8	4.4
Ba	1.3	1.1	1.3	1.2	1.2	0.9
Ca	0.1	0.1	0.1	0.2	0.1	0.1
Fe	13.6	13.9	15.5	16.1	13.7	14.4
Mg	0.3	0.3	0.2	0.3	0.2	0.2
Mn	23.9	23.8	26.2	26.5	26.4	27.3
Pb	0.9	0.7	1.4	1.3	0.8	1.0
Si	10.5	11.0	7.7	8.3	10.0	9.7

Elemental deportment

An elemental deportment gives the relative contribution of various mineral phases to the total elemental content of that sample; this is determined using the bulk modal mineralogy of the sample as well as the theoretical or measured chemistry of individual mineral phases.

The manganese and iron deportment of the head samples are presented in Table 13.14 and Table 13.15, respectively. The relative manganese contributions from the samples tend to be quite similar, with approximately 40% of the manganese hosted in cryptomelane, and 30% in the bixbyite; 10% to 15% of the manganese is hosted in hollandite and manganese oxides. The iron is hosted in hematite in addition to the manganese-bearing phases.

Table 13.14 Manganese deportment

Mineral	Contribution (%)		
	FSH	MSH	LOM
Cryptomelane	36.7	41.2	39.0
Bixbyite	30.4	27.0	27.8
Hollandite	13.1	15.1	10.6
Manganese oxide	14.3	10.7	17.8
Birnessite	3.7	2.1	2.4
Alabandite	0.5	1.2	0.5
Manganese mica	0.3	0.2	0.1
Manganese silicate	0.3	0.2	0.2
Hematite	0.8	2.3	1.5
Other	0.0	0.0	0.0

Table 13.15 Iron-bearing minerals

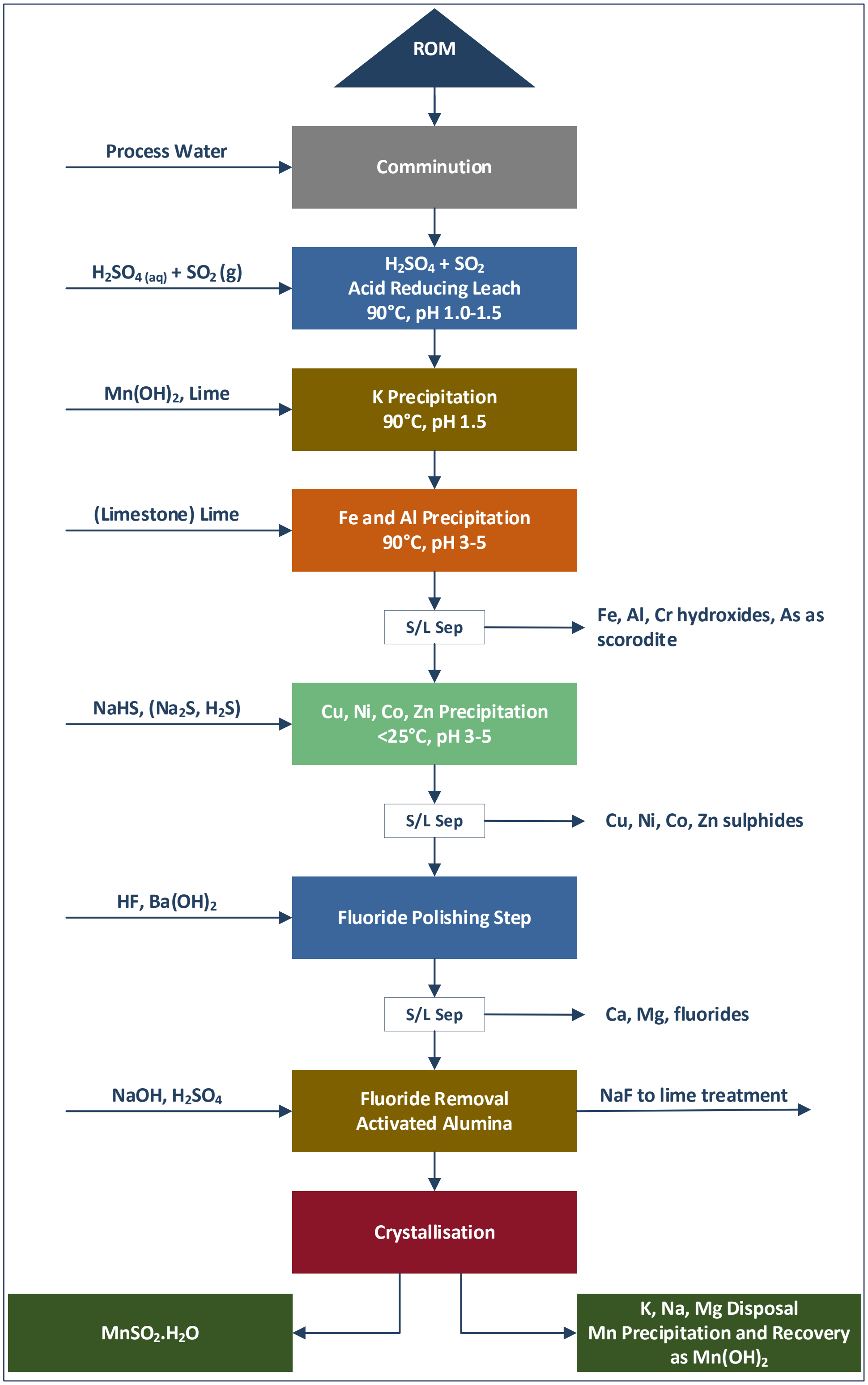
Mineral	Contribution (%)		
	FSH	MSH	LOM
Cryptomelane	24.6	22.6	26.1
Bixbyite	27.6	22.5	26.6
Hollandite	7.9	5.5	4.5
Manganese oxide	8.3	5.5	8.8
Alabandite	0.1	0.4	0.2
Manganese silicate	1.1	1.0	1.0
Hematite	28.1	40.6	31.1
Mica	0.1	0.0	0.0
Kaolinite	0.0	0.0	0.0
Actinolite	0.9	1.4	0.7
Chlorite	0.8	0.2	0.1
Ilmenite	0.3	0.1	0.2
Other	0.1	0.2	0.6

13.5 Metallurgical test work

13.5.1 Flowsheet development

The mineralised material comprises manganese and iron shales of variable hardness from soft to hard, that are amenable to reductive acid leaching in sulphate media using sulphur dioxide as a reductant. The process comprises crushing and grinding to a characteristic grind (P80) of 150 µm, an acid reductive leach in sulphate media at elevated temperature using sulphur dioxide as a reductant, and a sequential purification process for the removal of base metal impurities.

Figure 13.3 Schematic of the metallurgical flowsheet



Source: Tetra Tech

13.5.2 Comminution test work

As part of Giyani's FS for manganese recovery on the K.Hill deposit, comminution test work was conducted on various samples to get information on the ore deposit. Eleven variability samples and three composite samples were used in the investigation (Table 13.16). The following comminution tests were conducted:

- Bond crushability work index (CW_i) test
- Bond abrasion index (A_i) test
- Bond ball work index (BW_i) test

Table 13.16 Comminution test work results classification

Crusher work index (CW_i) classification		Bond abrasion index (A_i) classification		Bond ball mill work index (BW_i) classification	
CW_i (kWh/t)	Classification	A_i (g)	Classification	BW_i (kWh/t)	Classification
<10	Very Soft	<0.2	Low	7-9	Soft
10-14	Soft	0.2-0.5	Medium	10-14	Medium
14-18	Medium	0.5-0.75	Abrasive	15-20	Hard
18-22	Hard	0.75-1	Very abrasive	>20	Very Hard
>22	Very Hard	>1	Extremely		

The summary of the comminution results is presented in Table 13.17.

Table 13.17 Comminution results showing the 75th percentile

Sample no.	Sample ID	Sample type	SG (t/m^3)	CW_i(1) (kWh/t)	Ai (g)	BW_i (kWh/t)
1	COM -VAR-FSH	DDKH21-0024	2.52	6.30	0.01	3.10
2	COM -VAR-FSH	DDKH21-0024	2.64	10.30	0.09	7.70
3	COM -VAR-MSH	DDKH21-0025	3.07	4.30	0.03	8.70
4	COM -VAR-UNCLASSIFIED	DDKH21-0024	2.46	10.40	0.29	10.90
5	COM -VAR-MSH	DDKH21-0023	2.66	8.60	0.03	8.30
6	COM -VAR-MSH	DDKH21-0022	2.66	7.10	0.06	15.90
7	COM -VAR-FSH	DDKH21-0020	2.55	5.10	0.01	2.60
8	COM -VAR-MSH	DDKH21-0021	2.76	1.40	0.02	5.20
9	COM -VAR-FSH	DDKH21-0021	Not Competent		0.26	10.00
10	COM -VAR-UNCLASSIFIED	DDKH21-0024	2.58	8.40	0.02	11.20
11	COM -VAR-FSH	DDKH21-0022	2.47	7.20	0.03	3.80
12	COM-COMP -MSH		2.48	6.80	0.01	8.20
13	COM-COMP -FSH		2.53	4.30	0.02	5.60
14	COM-COMP -LOM		2.62	6.50	0.09	8.00

Notes: (1) 75th percentile results are reported.

In summation, the results represented in Table 13.17 show:

- The CW_i test results classified the samples as very soft to soft.
- The A_i test results indicate that the samples have low to medium abrasiveness.
- The BW_i test results indicate a very soft to hard deposit under ball milling.

13.5.3 Solid/liquid separation test work

Solid/liquid separation test work was carried out to generate process design data through test work for several solid/liquid separation steps in the hydrometallurgical process design. The test work that was carried out by Vietti Slurrytec can be found in Appendix A.

Cyclone overflow (pre-leach)

The cyclone overflow material exhibited a fine particle size distribution of 90% passing 150 µm and 72% passing 22 µm. Suspension of the dry milled solids in tap water (due to the unavailability of site raw water) generated a naturally coagulated (settling) slurry, which is receptive to flocculation without any requirement for further slurry conditioning prior to flocculation.

Magnafloc 336 (M366) supplied by BASF was selected as the optimum flocculant type in terms of overall settling rate and supernatant clarity. M336 is a medium anionic charge, high molecular weight flocculant. The results are presented in Table 13.18.

Table 13.18 Cyclone overflow thickening conditions and results

Thickening conditions	Units	Test 1	Test 2	Test 3
Flocculant dosing concentration	%w/w	0.025	0.025	0.025
Feed-well slurry solids concentration	%w/w	5	7.5	10
Flocculant dose rate	g/t	30	40	40
Static settling rate	m/h	59	26	19
Supernatant clarity (out of 50)	wedge no.	48	47	44

Combined leach residue and iron/aluminium precipitate

Bench-top high-density thickening (with pickets on rake) yielded a maximum underflow solids concentration of 25%w/w after a 5-hour residence time. It was for this reason that counter current decantation was removed as a step to separate the liquor from the pulp, as the number of stages and wash water requirements would have been prohibitive. The conditions and results of the pressure filtration are displayed in Table 13.19.

Table 13.19 Combined leach residue and iron/aluminium precipitate test results

Parameter	Units	Value
Feed solids concentrate	%w/w	25
Filter	type	plate and frame pressure filter
Plate size	m × m	2 m × 2 m
Active plate filter area	m × m	1.8 m × 1.8 m
Chamber area	m^2	6.5
Number of chambers per unit	-	100
Filter area per cycle	m^2	650
Number of cycles per hour	-	3
Pressure	bar	10
Cake thickness	mm	25
Cake moisture content	%w/w	36
Filter duty per unit	$t/m^2.h$	0.014

Plate and frame pressure filtration tests produced a competent hard cake, even though the moisture content was in the region of 36%m/m to 38%m/m, with a form time of 600 seconds at 10 bar pressure and a cake thickness of 22 mm to 24 mm.

Base metal sulphide precipitate

Coagulation did not make a significant difference on the clarity, and its impact could not be verified on settling rate due to the low solids content. Coagulation was therefore excluded for the rest of the tests. A preliminary flocculant dose rate of 0.3 ppm (mg/L) was determined during the static settling tests and yielded a supernatant clarity of 70 NTU. Dynamic thickening (clarification) tests showed that the flocculant dose rate had to be increased to 0.4 ppm to 0.45 ppm under dynamic conditions to maintain optimum flocculation. A hydraulic rise rate of 1 m/h produced the best overflow clarity at 65 NTU during the dynamic tests. Only a very thin slice of mud bed formed because of the low solids content and lack of available sample volume. Therefore, no underflow density, mud bed consolidation behaviour, or rheological characteristics could be determined.

As a result of the very low solids content in the feed and the size of the bench-top filter equipment, only a very thin film of "filter cake" developed, which could not be successfully isolated to have a moisture content measured. The design values used were estimated from similar material results. Solid liquid separation test work is to be carried out on the process demonstration plant. This is part of the reagent optimisation that has been planned.

Calcium and magnesium precipitation tests were not included as part of the thickening test work owing to the low solids content and limited material available. The design values used were estimated from similar material results. Solid/liquid separation test work is to be carried out on the demonstration plant. This was part of the reagent optimisation subsequently undertaken.

13.5.4 Extraction

Leach optimisation tests were carried out to establish suitable conditions for maximum recovery of manganese. The optimisation tests were carried out on the LOM material, which was considered to be a fair representation of the plant feed that comprises the Mn-shale and Fe-shale sections of the deposit.

The LOM composite sample was used to determine the optimum leaching conditions. The feed solids were pulped in deionised water, targeting a 30% m/m pulp density. The leach tests were conducted for 6 hours, and kinetic samples were only taken during the residence time optimisation test (Test 7) at hourly intervals. The redox potential was controlled at approximately 600 mV (vs. silver/silver chloride) by the addition of sulphur dioxide; the pH was controlled by the addition of 8 molar sulphuric acid. The operating conditions under which the leach optimisation tests were conducted are summarised in Table 13.20.

Table 13.20 Leach optimisation test matrix

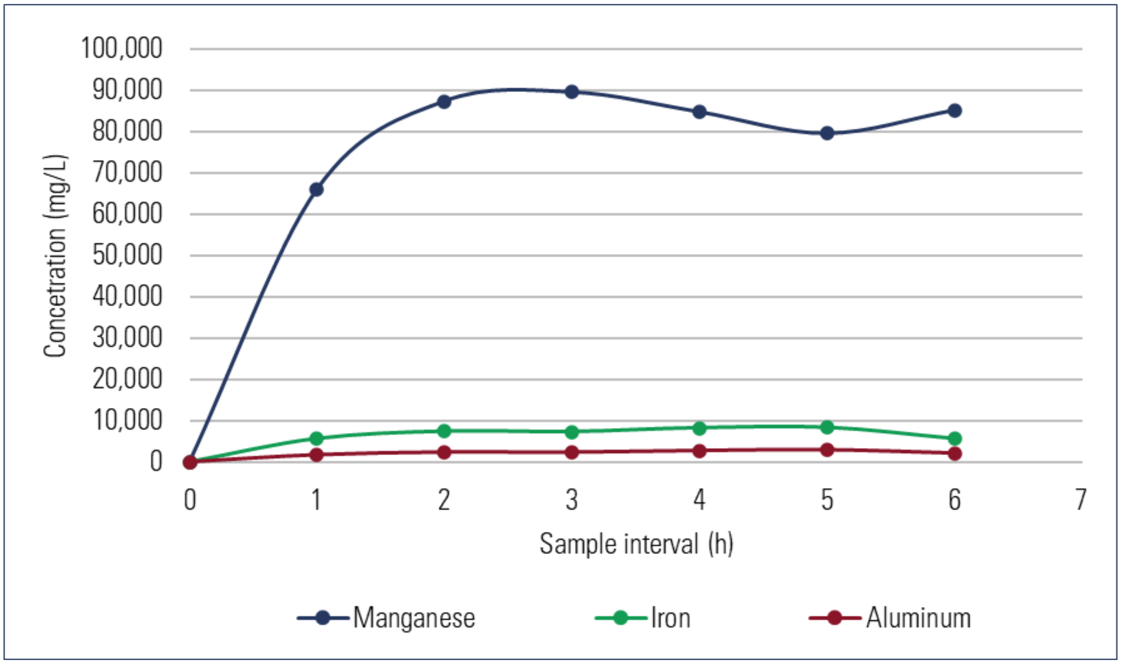
Parameter	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7
Grind size (P80)	-106 µm	-150 µm	-200 µm	-150 µm	-150 µm	-150 µm	-150 µm
Temperature (°C)	60	60	60	90	60	90	90
pH	1.5	1.5	1.5	1.5	1	1	1
Manganese extraction	81%	84%	75%	61%	80%	90%	94%

The results in Table 13.20 show that there was a small difference in manganese extractions between the three grind sizes and two pH conditions. Manganese leaching of the LOM material ranged between 75% and 84%. The P80 106 µm grind size was expected to yield the highest manganese leaching efficiencies due to higher liberation; however, the P80 150 µm performed better. The small difference in leaching efficiencies indicates that the majority of the manganese minerals were liberated in the P80 212 µm grind size, and that not much improvement was made by milling to P80 106 µm.

Extraction improved when the operating temperature was increased to 90°C and the pH set to a value of 1. Under these conditions, manganese leaching efficiency of the LOM material increased to 90%.

Figure 13.4 shows that manganese leaching was relatively fast, reaching the maximum leaching efficiency was obtained within 2 hours. Extending the leach time beyond two hours did not yield any notable improvement in the leaching efficiency of manganese.

Figure 13.4 Leach extraction profiles for manganese, iron, and aluminium at optimum conditions



Source: Tetra Tech

Variability tests

The following parameters that were established in the optimisation test work were used for the variability tests:

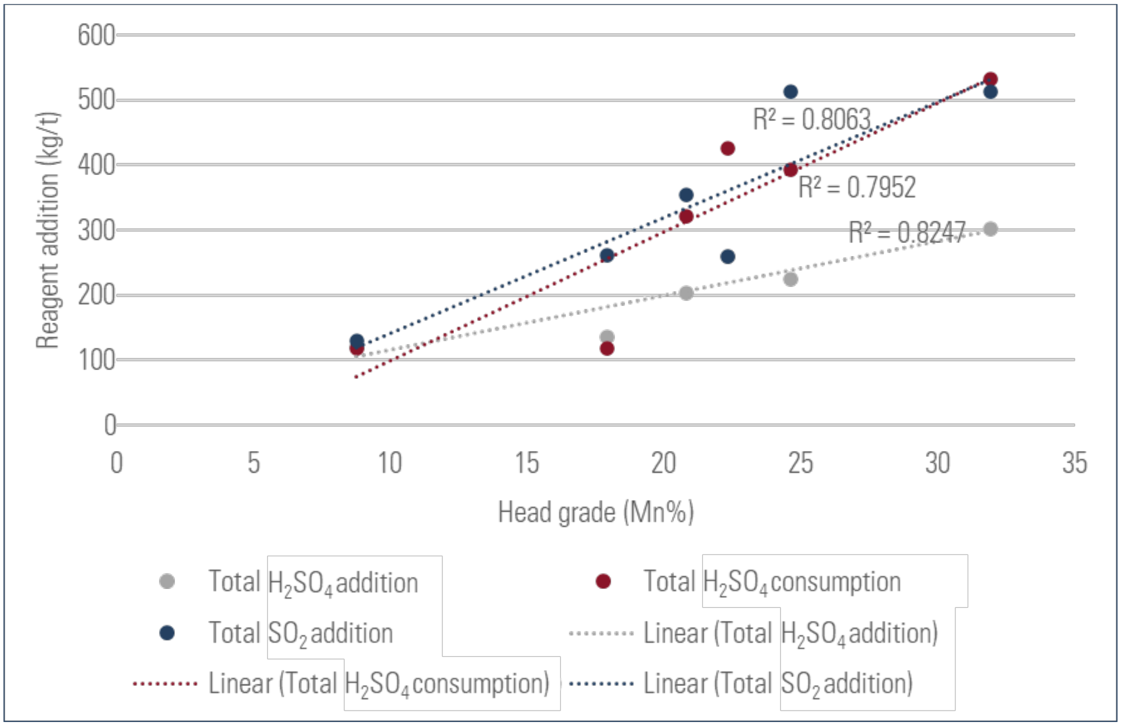
- grind size: P80 150 µm
- slurry density: 30% (m/m)
- operating temperature: 90°C
- pH: 1.0
- oxidation reduction potential: 600 mV (vs. silver/silver chloride)

The redox potential was controlled at approximately 600 mV (vs. silver/silver chloride) by the addition of sulphur dioxide; the pH was controlled by the addition of 8 molar sulphuric acid. The results of the six variability tests are shown in Table 13.21 and Figure 13.5.

Table 13.21 Leach variability test results

Parameter	Test V1	Test V2	Test V3	Test V4	Test V5	Test V6
Mn head (%)	20.8	24.6	8.76	17.9	31.9	22.3
Mn extraction (%)	97	97	96	95	99	97
Reagent Consumption						
Total H_2SO_4 addition (kg/t)	204	224	121	135	303	260
Total H_2SO_4 consumption (kg/t)	322	393	118	119	532	427
Total SO_2 addition (kg/t)	355	513	130	261	513	260

Figure 13.5 Variability test reagent addition



Source: Tetra Tech

The mean manganese extraction over the six tests was 96.7%, which was used for the design. The reagent addition showed a strong correlation with the manganese head grade between the tests. The sulphur dioxide addition was significantly higher than anticipated and was attributed to varying mineralogy, test work equipment, and measurement error. However, mineralogy data showed the mineralogy was consistent; thus, the higher than anticipated sulphur dioxide addition was attributed to equipment. This came in the form of not being able to accurately measure the sulphur dioxide added. To define the design sulphur dioxide addition, the mineralogy was used to estimate the Mn^{2+} to Mn^{3+} molar ratio. With the molar ratio of 1.38, the sulphur dioxide addition rate was at 120% of the stochiometric molar ratio.

With the increase in the Mineral Resource estimate and a decrease in the head grade, a linear regression model was used to adjust the sulphuric acid addition.

13.5.5 Purification

Jarosite precipitation

The objective of the jarosite precipitation was to remove the potassium and sodium as a precipitate.

Ferric sulphate ($Fe_2(SO_4)_3$) solution was used as a source of iron to drive the precipitation reactions.

Iron/aluminium precipitation

Scoping iron/aluminium precipitation test work was conducted to evaluate the efficacy of selective pH-based impurity rejection as a hydroxide to produce a relatively pure manganese sulphate solution. The test work comprised an initial neutralisation test to plot the precipitation extent of impurities and manganese vs. pH to identify the optimum pH value at which most impurities are precipitated while retaining the manganese in solution. Thereafter, a bulk test was conducted using the optimum pH.

Base metal precipitation

This purification step was undertaken to remove copper, cobalt, nickel, and zinc to trace levels. The initial tests were aimed at optimising pH, sodium hydrosulphide (NaHS) dosage, and residence time.

It is evident that metal sulphide precipitation is most efficient at a high pH (≥6.0); however, the optimum pH should be considered with other factors such as sodium hydrosulphide dosage and residence time. Too high a pH leads to the precipitation of metal hydroxides and the loss of manganese.

13.5.6 Fluoride polishing

Fluoride polishing describes the use of hydrofluoric acid to precipitate out the calcium and magnesium and the removal of fluoride by activated alumina. The results of the test work for these are described in the following subsections.

Calcium/magnesium precipitation

The solution was tested with three different reagents for pH adjustment to optimise the precipitation rate. The reagents were selected to limit addition of impurities to the solution. The reagents tests are listed in Table 13.22.

Table 13.22 Calcium and magnesium precipitation reagents tested

Scheme no.	Reagents used
Scheme 1	HF and NH_3
Scheme 2	HF and NH_4OH
Scheme 3	HF and $Ba(OH)_2$

Note: HF - hydrofluoric acid
NH_3 - ammonia
$Ba(OH)_2$ - barium hydroxide

The reagents specified in scheme 3 were found the be the most effective for the precipitation of calcium and magnesium.

Fluoride removal

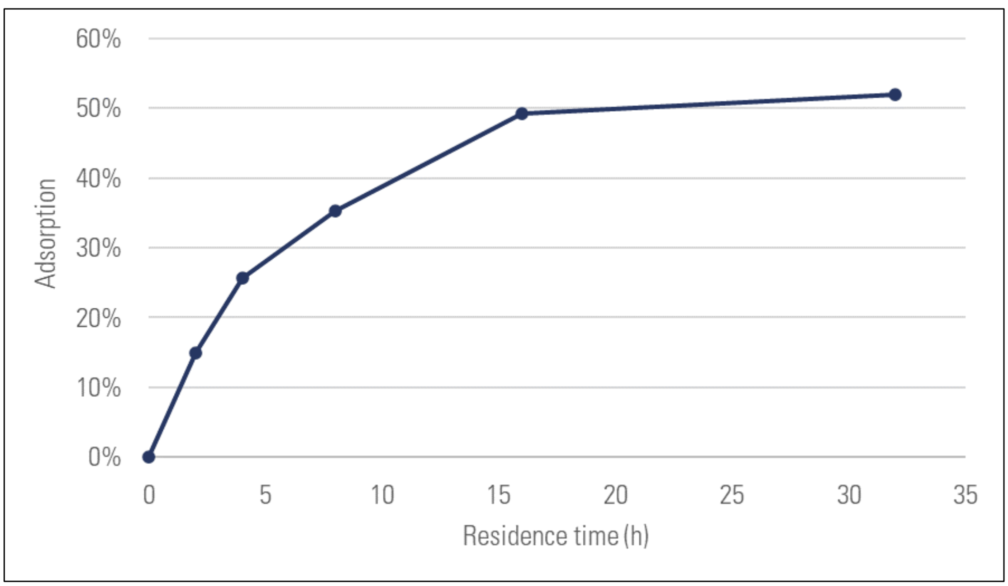
The addition of hydrofluoric acid for the removal of calcium and magnesium introduces an additional impurity to be removed. This was done using activated alumina. The first test was to do an equilibrium test; the results are shown in Figure 13.6.

Figure 13.6 Fluoride equilibrium loading on activated alumina

The results from the equilibrium test showed that equilibrium was achieved after 32 hours. A loading curve was then generated (Figure 13.7).

The results of the equilibrium curve and the adsorption isotherm were then used for sizing of the activated alumina columns. The target fluoride concentration was defined by the crystalliser feed concentration.

Figure 13.7 Fluoride adsorption isotherm



Source: Tetra Tech

13.5.7 Crystallisation design development

Two routes were pursued for the production of a purified stock solution that is used for the crystallisation design development:

- use of synthetic stock solution produced from analytical reagent samples
- work at Mintek to produce a stock solution from representative ore that has been processed step-by-step through the intended recovery methods

The synthetic stock solution provided a means for rapid and inexpensive production of crystalliser feed, allowing the development of initial process feed purity requirements and expected operational criteria.

Synthetic solution

A synthetic solution was made up based on the analysis of the stock solution and the calculated values from the mass balance. The synthetic solution was then used to test the proposed crystallisation circuit.

Stock solution

A stock solution was made using the extraction and purification steps (prior to having jarosite precipitation purification step).

A stock solution, using the LOM sample, was made by carrying out all the steps presented in the schematic metallurgical flowsheet (Figure 13.3). This work yielded a fully representative stock solution, which will provide the opportunity to complete the design of the crystalliser and provide a significant amount of process-accurate HPMSM for acceptance testing and trials by potential battery metal clients.

With the inclusion of the jarosite precipitation, there was a thousand-fold improvement in the potassium concentration in the stock solution. With the alumina optimisation, there was a 20-fold improvement in the fluoride concentration below the required 50 ppm.

Crystal product

The stock solution produced was then processed through two crystallisation steps. The first, a crude crystallisation, with the crystals produce then being redissolved and going into the second crystallisation step to produce a pure product. The final step was filtering and washing the crystal product.

The product crystals exhibited a d_{50} crystal size of 220 µm. The results indicate that the washed pure MSM meets the product specification with the result confirming the validity of the crystallisation flowsheet.

13.5.8 Manganese hydroxide precipitation

With the size of the bleed stream, and the impact on the overall recovery of manganese, the bleed stream was to be treated to recover manganese in another form and to bring this back into the process. It was for this reason that hydroxide precipitation was tested for the recovery of manganese hydroxide. The tests were carried out using synthetic solution with two different bases (sodium hydroxide and lime [calcium hydroxide]) at different pHs.

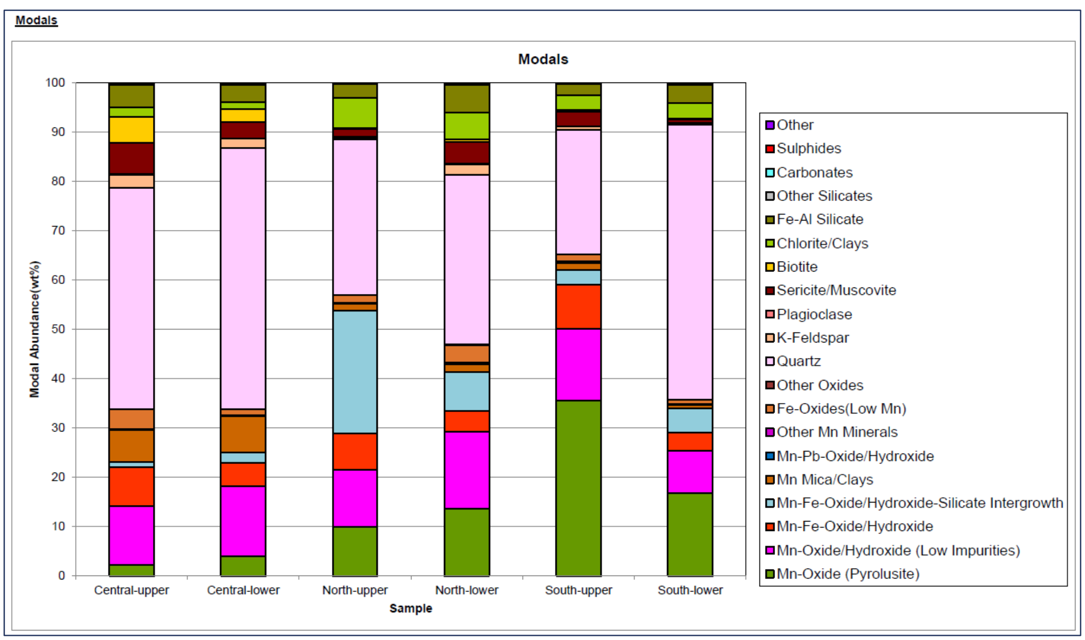
The results of the manganese precipitation using sodium hydroxide and lime were shown to be effective as a precipitating agent at a pH of 8.0 and above.

13.6 K.Hill Horizon B material

13.6.1 Mineralogy

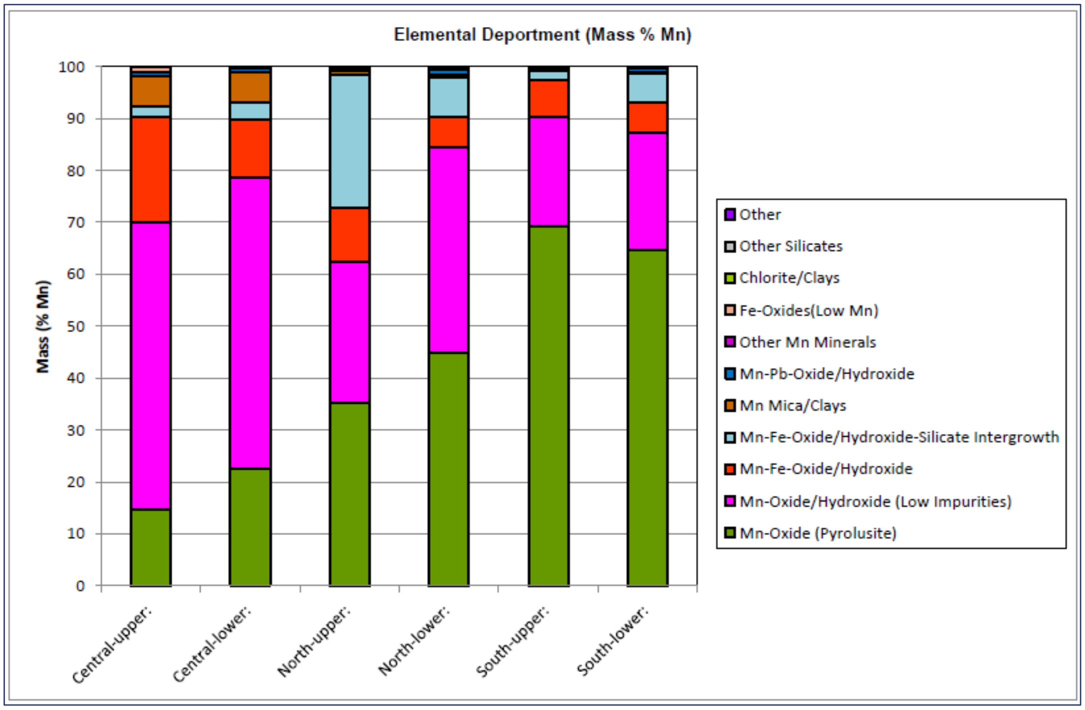
Figure 13.8 and Figure 13.9 show results from recent quantitative mineralogical work (QEMSCAN) undertaken by SGS Canada in Lakefield, Ontario (SGS Canada 2022). Figure 13.8 shows the sample's mineralogical distribution and Figure 13.9 the manganese deportment. The mineralogy indicates that the K.Hill Horizon B material is not characteristically different to that of the LOM composite sample, and the leach results are consistent with both the mineralogy and earlier leach tests.

Figure 13.8 Horizon B samples modal mineral distribution



Source: SGS Canada (2022)

Figure 13.9 Horizon B manganese distribution by mineralogical classification



Source: SGS Canada (2022)

13.6.2 K.Hill Horizon B leach variability

The K.Hill Horizon B leach variability test work was carried out under standard leach conditions to confirm extraction performance.

Summary leach extraction data from the recent Mintek K.Hill Horizon B test work programme is shown in Table 13.23.

Table 13.23 K.Hill Horizon B extraction results

Sample description	South upper	South lower	North upper	North lower	Central upper	Central lower
Head grade (%)						
Mn	27.80	14.00	13.10	17.10	10.10	9.33
Fe	6.25	4.59	9.01	8.55	9.21	6.19
Si	17.50	30.30	24.60	24.10	28.10	30.8
Al	2.38	1.45	3.34	3.10	2.97	2.02
Pb	0.15	0.09	0.08	0.08	0.08	0.13
Mg	0.29	0.22	0.31	0.28	0.42	0.26
Extraction (%)						
Mn	98	99	99	99	93	87
Fe	29	29	3	15	5	7
Si	0	0	0	1	1	0

Sample description	South upper	South lower	North upper	North lower	Central upper	Central lower
Al	12	11	8	8	6	6
Pb	11	14	17	-7	25	11
Mg	54	60	59	42	12	7
Reagent addition (kg/t)						
Total acid addition	159.9	139.6	159.9	127.0	92.5	78.4
Total SO_2 addition	272.3	145.6	200.4	180.9	122.6	91.3

The extractions were carried out on various samples selected from the ore body, as identified in the Table 13.23. The samples were subjected to a reducing sulphate leach under optimised leach conditions developed earlier for the LOM composite sample. In general, manganese leach extractions were excellent, ranging between 87% and 99%. These compare well with the results from an earlier leach variability programme in which the average manganese leach extraction was 97%. The lower-grade material approaching the manganese cut-off does not leach quite as well, probably owing to the proportion of siliceous material (Figure 13.8). Nonetheless, extractions are certainly acceptable.

Based on the foregoing, the metallurgical extraction characteristics of the Horizon B are not expected to differ significantly from those of the K.Hill main orebody. Cost may vary somewhat depending on levels of impurities, but the main difference in the material is in the proportion of siliceous material, which is inert and reports to tails.

It can be concluded that feeding Horizon B material to the proposed K.Hill processing plant is unlikely to have an appreciable impact on metallurgical extraction or plant operations in general.

13.7 SRK mine plan

A comparison of the manganese, iron, and potassium was completed between the SRK mine plan and the LOM sample that was used for the test work (Table 13.24).

Table 13.24 Comparison of the LOM sample to the SRK mine plan

Element	Test work LOM Sample (%)	Average SRK Mine Plan (%)	Difference (%)
Mn	26.45	14.60	-45
K	1.29	1.87	46
Fe	13.70	9.89	-28

Table 13.24 shows that the LOM sample used for the test work contains 45% more manganese and 28% more iron compared to the SRK mine plan, while the potassium increased by 46%. The lower manganese grade would decrease the amount of manganese produced and decrease the overall recovery, as solution losses would have a larger impact due to the smaller amount

of manganese being fed into the process. The changes in the iron and potassium would increase the amount of ferric sulphate required to remove the potassium.

Using the LOM test work programme results, Tetra Tech was able to prepare, making reasonable assumptions to adjust for grade and iron to potassium ratio, the process design criteria and mass balance for the plant to treat ore scheduled by the SRK mine plan. As part of a value engineering step, future test work on a new LOM sample based on the SRK mine plan has been planned to improve the accuracy of the process design criteria and optimise reagent use.

The process design criteria and the mass balance has been updated with the SRK mine plan numbers to ensure that the increase in the reagent costs has been included in the estimates. The changes to the downstream flows and volumes remain within the existing process design limits.

The decrease in the head grade has a big impact on the crystalliser. As this is a major cost (capital and operating) contributor to the processing plant, the feed to crystalliser was adjusted based on the output from the mass balance number.

All other equipment would either fall within the design margin or fall with the estimate envelope. Future test work has been planned to use a sample that represents the SRK mine plan to confirm the assumptions made.

14 MINERAL RESOURCE ESTIMATES

14.1 Introduction

SRK completed an update of the Mineral Resource estimate for the K.Hill Project to include the latest RC drilling and DD south of northing 7233525, known as the Southern Extension Area. Detailed herein is an overview of the work completed by SRK in constructing the model upon which the estimate is based, as well as conducting, validating, and reporting the estimate.

A comparison of the September 2021 Mineral Resource estimate and the latest February 2022 Mineral Resource estimate is given in Table 14.1 for reference.

Table 14.1 Comparison of September 2021 Mineral Resource estimate and February 2022 Mineral Resource estimate, reported on a 7.3% manganese oxide cut-off grade

Classification	Tonnes (Mt)	MnO (%)	Al_2O_3 (%)	SiO_2 (%)	Fe_2O_3 (%)	LOI (%)
September 2021						
Indicated Mineral Resources	1.6	22	10.9	35.7	16.5	7.9
Inferred Mineral Resources	1.4	13.9	9.6	51.4	13.1	6.3
February 2022						
Indicated Mineral Resources	2.1	19.3	10.56	41.17	16.66	7.37
Inferred Mineral Resources	3.1	16.9	7.6	49.7	11.5	7.46

To the best of the QP's knowledge, there are currently no title, legal, taxation, marketing, permitting, socio-economic, or other relevant issues that may materially affect the Mineral Resource, other than those described in this report.

The Mineral Resource estimate incorporates drilling data collected by Giyani from 16th April 2018 to 31st September 2021, inclusive (as described in Section 10), which, in the QP's opinion, is adequate for use in the subsequent Mineral Resource estimate.

The Mineral Resource is classified according to the CIM *Estimation of Mineral Resources & Mineral Reserves Best Practice Guidelines* (CIM 2019) and is reported in accordance with the 2014 *CIM Definition Standards for Mineral Resources & Mineral Reserves* (CIM 2014), which have been incorporated by reference into NI 43-101 *Standards of Disclosure for Mineral Projects* (CSA 2016). The Mineral Resource is classified in the Indicated and Inferred categories.

The Mineral Resource, which represents an update to the Mineral Resource reported by SRK in October 2021, is based upon an updated block model and constrained by an updated optimised pit shell. Domain modelling was undertaken in Leapfrog Geo and estimation in Leapfrog Edge software.

Mr. Peter Gleeson, AIGS, MIMMM, CEng, of SRK and the QP in accordance with the CIM Code, completed the Mineral Resource estimate. Mr. Gleeson holds the responsibility for the reporting of the Mineral Resource statement presented herein. Mr. Gleeson has the relevant experience in reporting Mineral Resources on various base, precious, and ferrous metal assets globally.

14.2 Estimation domain modelling

Estimation domains were created using all available drillhole data, as well as surface mapping and surveys of underground artisanal mining voids. DGPS collar surveys and a high-resolution satellite survey surface provided topographic constraints to the model.

The domain and lithological models are split into two areas: the original model completed in August 2021 for the Northern Area and the subsequent model completed in November 2021 for the Southern Extension Area. Only minor changes have been made to the original Northern Area models to integrate them into the new Southern Extension Area models. This is mainly around the southern limits of the original model.

In the Southern domain, the lack of diamond drill core, lower density of drilling, and the presence of several NNE-trending faults that offset the stratigraphy have made it difficult to correlate the mineralised horizons in the Northern Area to the Southern Extension Area. The domaining for the Southern Extension Area is simplified and with less geological control. Where possible, a modelling threshold of around 7% manganese oxide has been applied to define areas of mineralisation.

14.2.1 Lithology model

For the Northern and Southern Extension areas, SRK constructed wireframes of the key lithological units, based on the geological logging completed by Giyani geologists. SRK applied adjustments to the contact location of the Mn-shale horizons to snap the contacts of the wireframes to the laboratory assays for manganese oxide, to adhere to a modelling threshold of approximately 7% manganese oxide for the mineralised Mn-shale horizons. The modelling threshold was chosen as it appears to be a natural threshold between the lower-grade non-mineralised sediments and the low-grade Mn-shale margins. The following units (from hanging wall to footwall) were modelled in the Northern Area:

- overburden (OVB)
- chert dolomite breccia (CDB)
- Fe-shale (FSH 1)
- upper Mn-shale (A1, A2, and A3)
- lower Mn-shale (B)
- lower discontinuous Mn-shale (northeast only; C)
- lower iron shale (FSH 2)

- felsite (FEL)

In the Southern Extension Area, the stratigraphy was simplified due to the limited amount of data present in the lithological logging. Additionally, it was difficult to correlate the stratigraphy due to progressive down faulting of the stratigraphy to the south. The southern stratigraphy was broken down into four units:

- overburden (OVB)
- chert dolomite breccia (CDB)
- Mn-shale (MSH)
- lower stratigraphic units

In addition to modelling lithological domains, SRK constructed a total of 12 fault wireframes that break the model into independent fault blocks. The faults were interpreted from clear "steps" in the Mn-shale horizons and geophysics that show normal offsets to the mineralisation in the order of 5 to 15 m. The fault and lithology wireframes were clipped below the topography surface. Plan and oblique views of the lithology domains are presented in Figure 14.1 and Figure 14.2. A typical cross section through the deposit showing the nature of faulting is provided in Figure 14.3. The faults were modelled from polylines drawn along the traces or breaks noted in the geophysics and from offsets of the main horizons noted in the drilling. Vertical throw on some faults maybe up to 10 m. The amount of lateral offset is unknown.

All faults were modelled as vertical, as no dip information is currently available.

Figure 14.1 Oblique view of the K.Hill Project geology model Northern Area (looking due west)

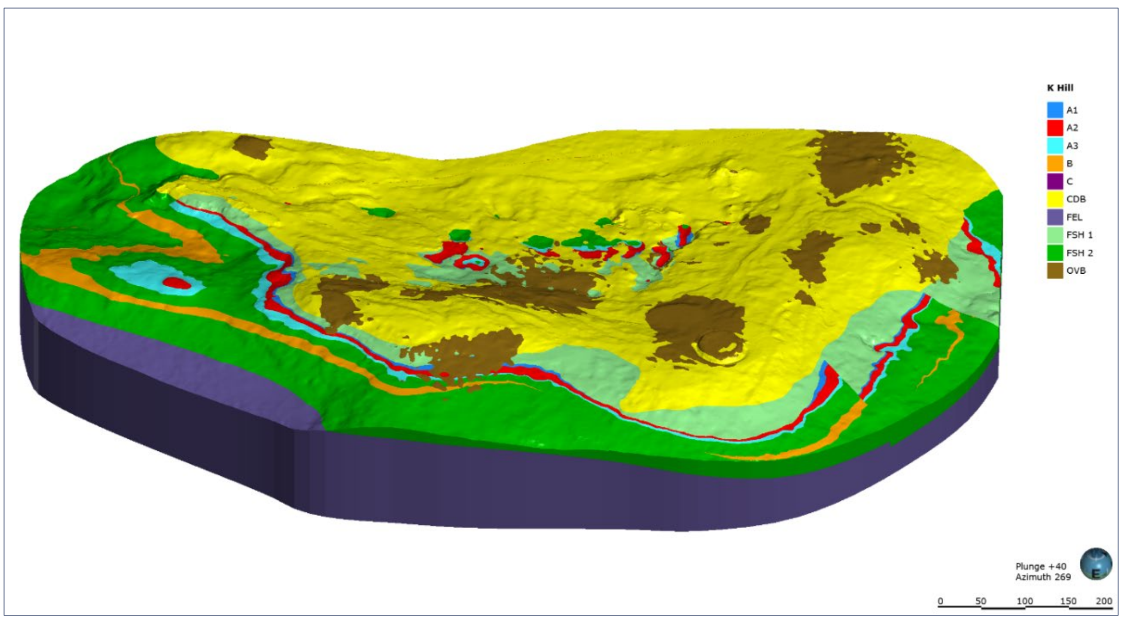
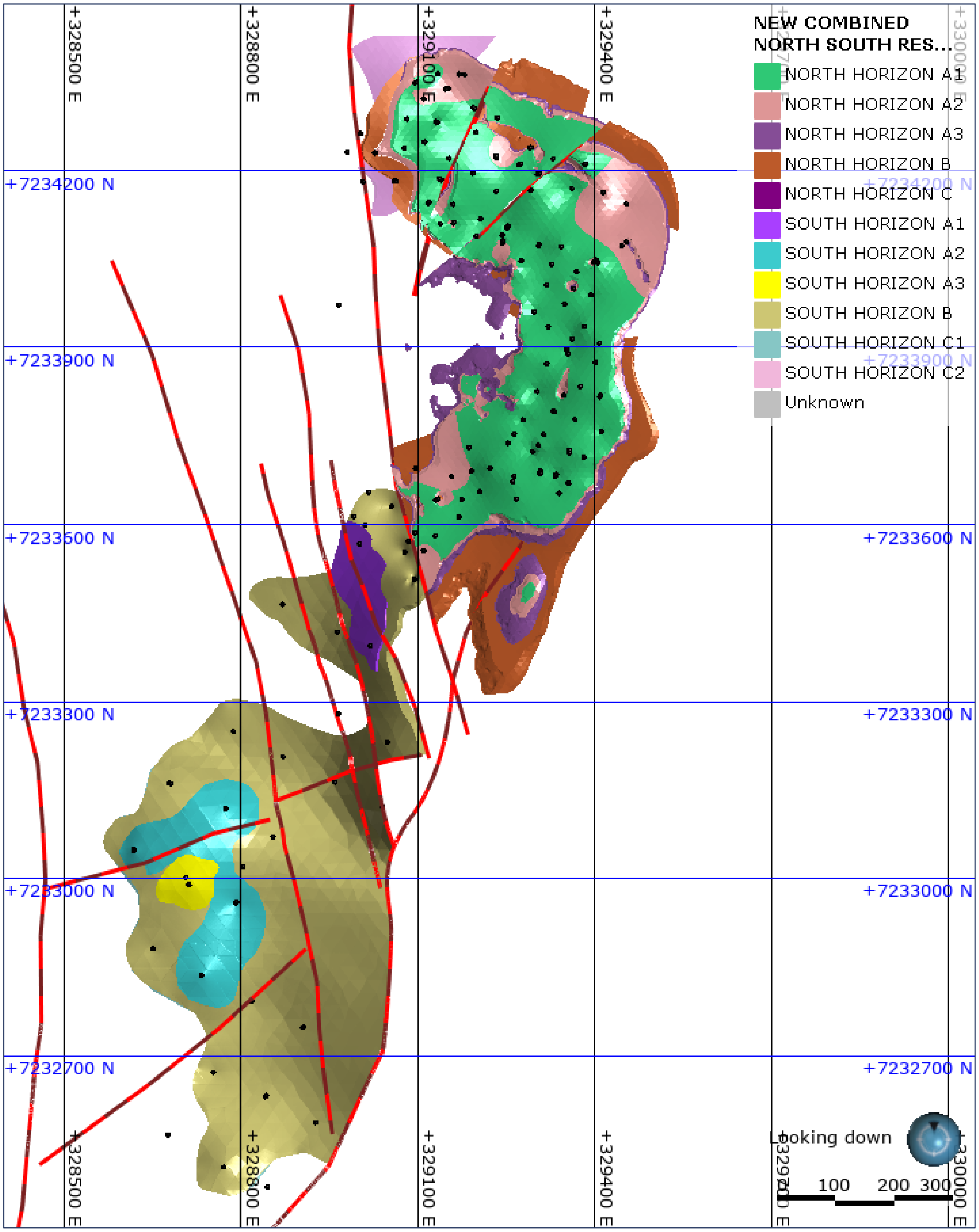
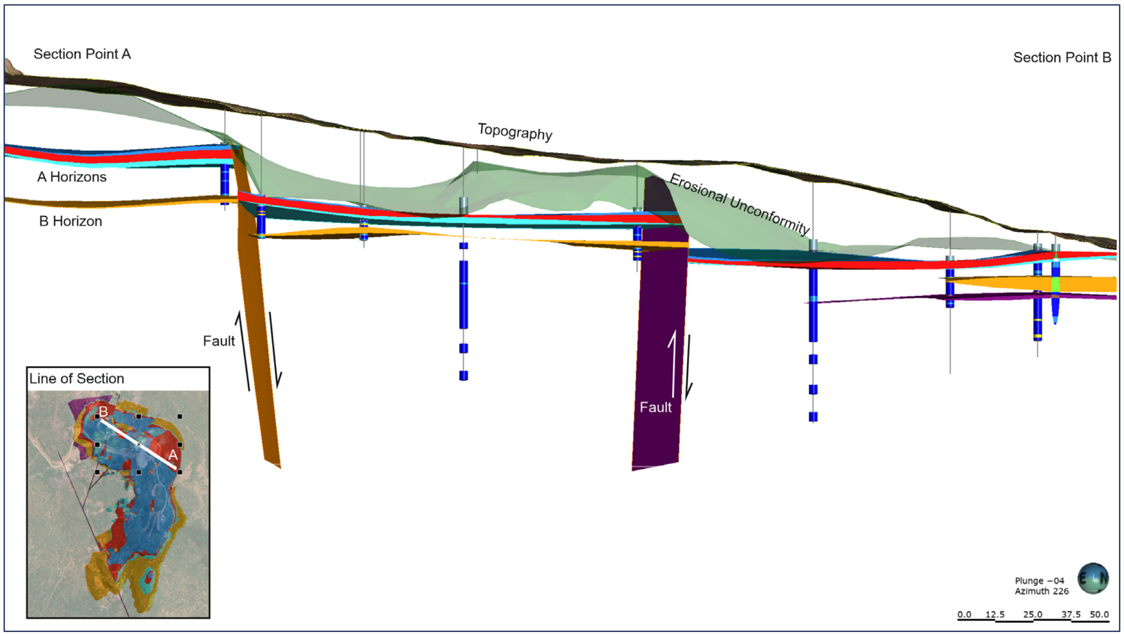


Figure 14.2 North-orientated plan view of the domains



Note: Drillhole collars are marked as black dots and interpreted faults are marked in red.

Figure 14.3 Southwest-facing cross section through the K.Hill Project geology model showing the location of faults and relative offsets of Mn-shale horizons



14.2.2 Upper Mn-shale sub-domaining

SRK conducted a statistical analysis of the manganese oxide assays within each of the lithological domains for the Northern Area. This highlighted a bimodal manganese oxide population within the upper Mn-shale domain (see Figure 14.4). After a review of the two populations in 3D and in sections, SRK decided to model low-grade horizons (A1 and A3) above and below a high-grade domain core (A2) within the upper Mn-shale domain, based on a 20% manganese oxide cut off. The high-grade core of the upper Mn-shale is generally continuous across the deposit area, with the exception of areas where it has been eroded (Section 14.2.3). The lower-grade domains are largely continuous but are absent in some areas. Figure 14.4 shows a histogram of the un-composited sample manganese oxide grade for the entire upper Mn-shale horizon, showing a clear bimodal distribution. Figure 14.5 shows the resulting histograms once the three domains have been separated.

The South Extension Area does not show this bimodality in grade. Additionally, many of the domains have insufficient samples to provide a statistically meaningful breakdown into separate populations.

Figure 14.4 Histogram of K.Hill Project un-composited sample manganese oxide grade (in percent) for the entire upper Mn-shale domain

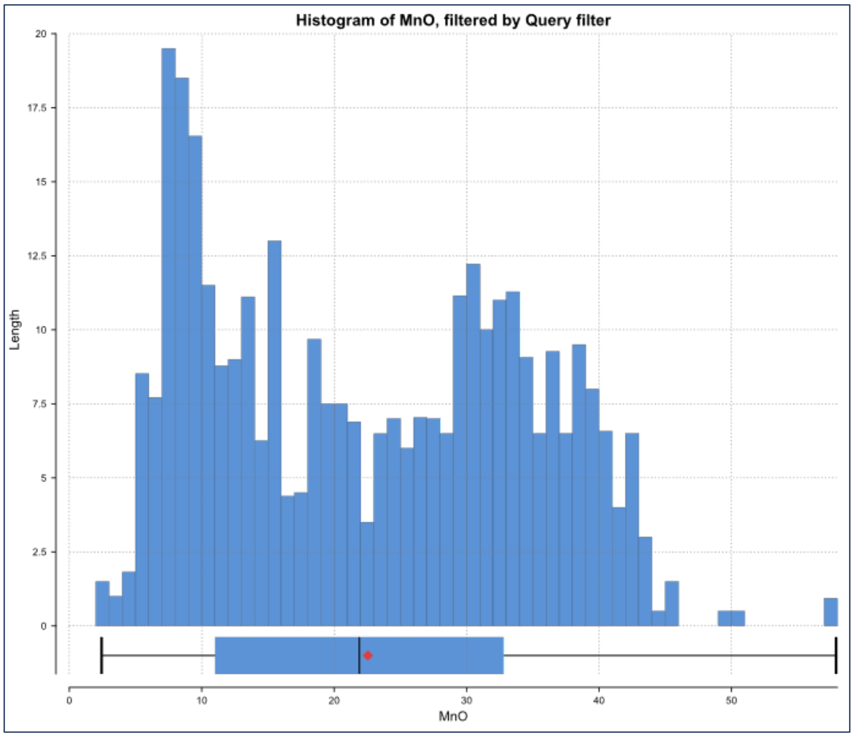
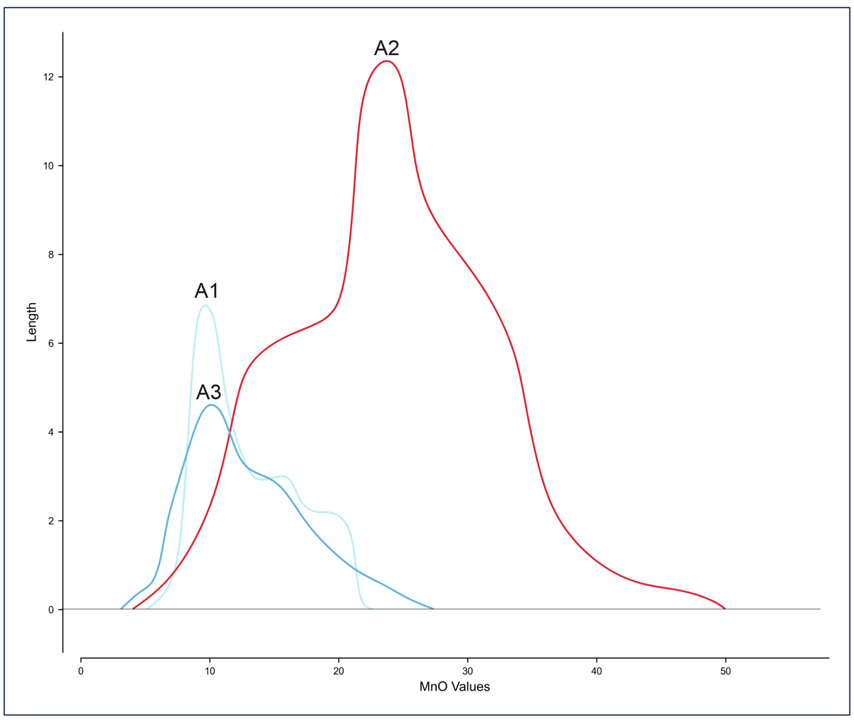


Figure 14.5 Overlaid histogram of the sub-domained A1, A2, and A3 domains showing the distinct populations



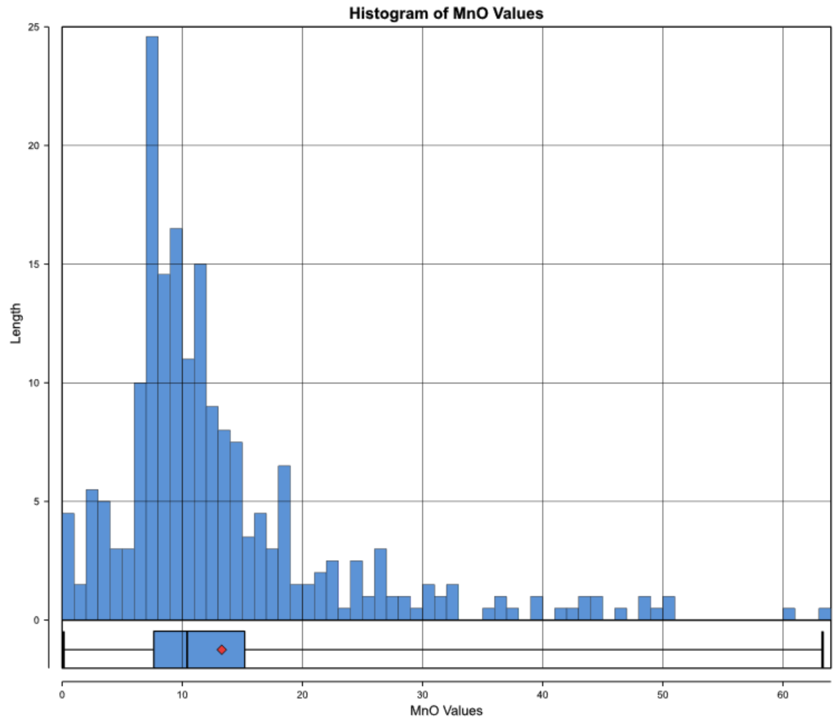
Checks on the drill core completed by SRK during the January 2020 site visit indicate a clear visual distinction between the low-grade and high-grade upper Mn-shale intersections (Figure 14.6) and a sharp transition between the two, which supports the separation of these three mineralisation horizons in the estimation domain model. Notwithstanding these observations, further investigation into the geometry and continuity of the subdivision of the A horizon may be warranted after the completion of the recommended structural study.

Figure 14.6 Core photograph for approximately 10 to 30 m in drillhole DDKH18_0005, highlighting the upper chert breccia (blue), low-grade Mn-shale (orange), high-grade Mn-shale (red), and footwall Fe-shale (yellow)

SRK concluded that the lower Mn-shale horizon (B) does not comprise multiple manganese oxide populations and, thus, did not require further sub-domaining. A histogram of manganese oxide values within the B Horizon is presented in Figure 14.7.

A similar approach was originally carried out to improve domaining for the Southern domains but proved difficult due to lack of diamond core for stratigraphic and lithological characterisation and effects of faulting.

Figure 14.7 Histogram of manganese oxide values within Horizon B showing a single population

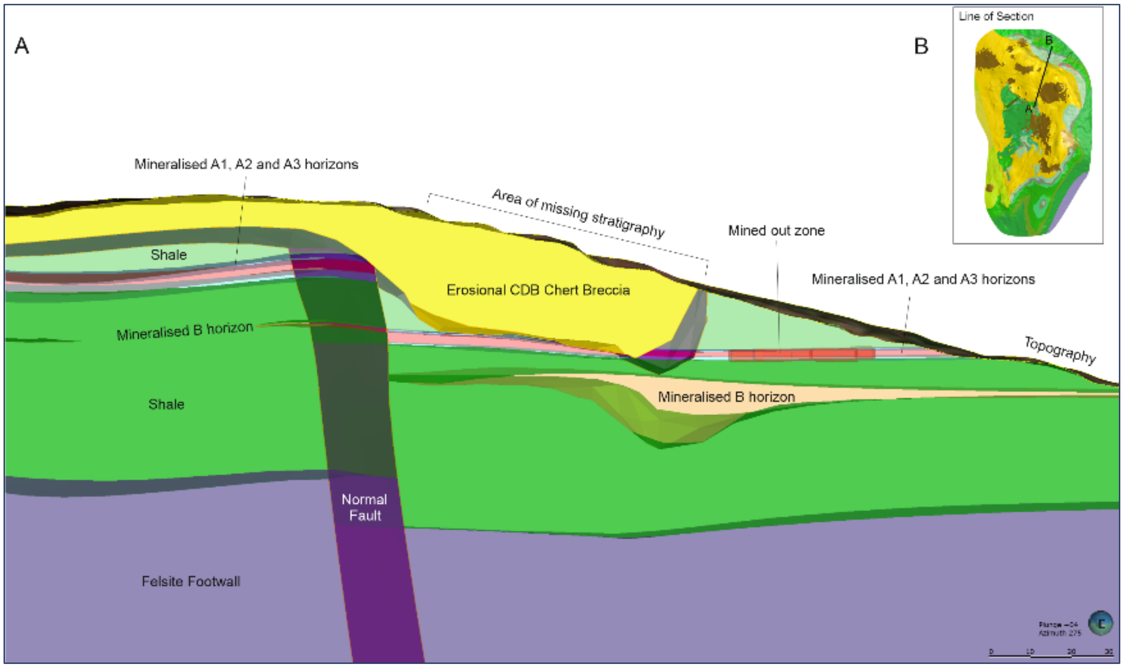


14.2.3 Erosional contact, Northern Area

In creating the geological model for the K.Hill Project, SRK identified a number of holes in the north of the deposit where a large section of the central stratigraphy, including the upper mineralised horizon, have been lost and replaced with a significantly thickened package of the overlying CDB horizon. Due to the coarse nature of the CDB unit, a sharp contact with underlying sediments, loss of stratigraphy, and the dynamic depositional/erosional environment inferred by the deposit genetic model, SRK has inferred a channelised erosional cause for the loss of the upper Mn-shale. Further drilling has allowed the extents and margins of this feature to be more clearly defined.

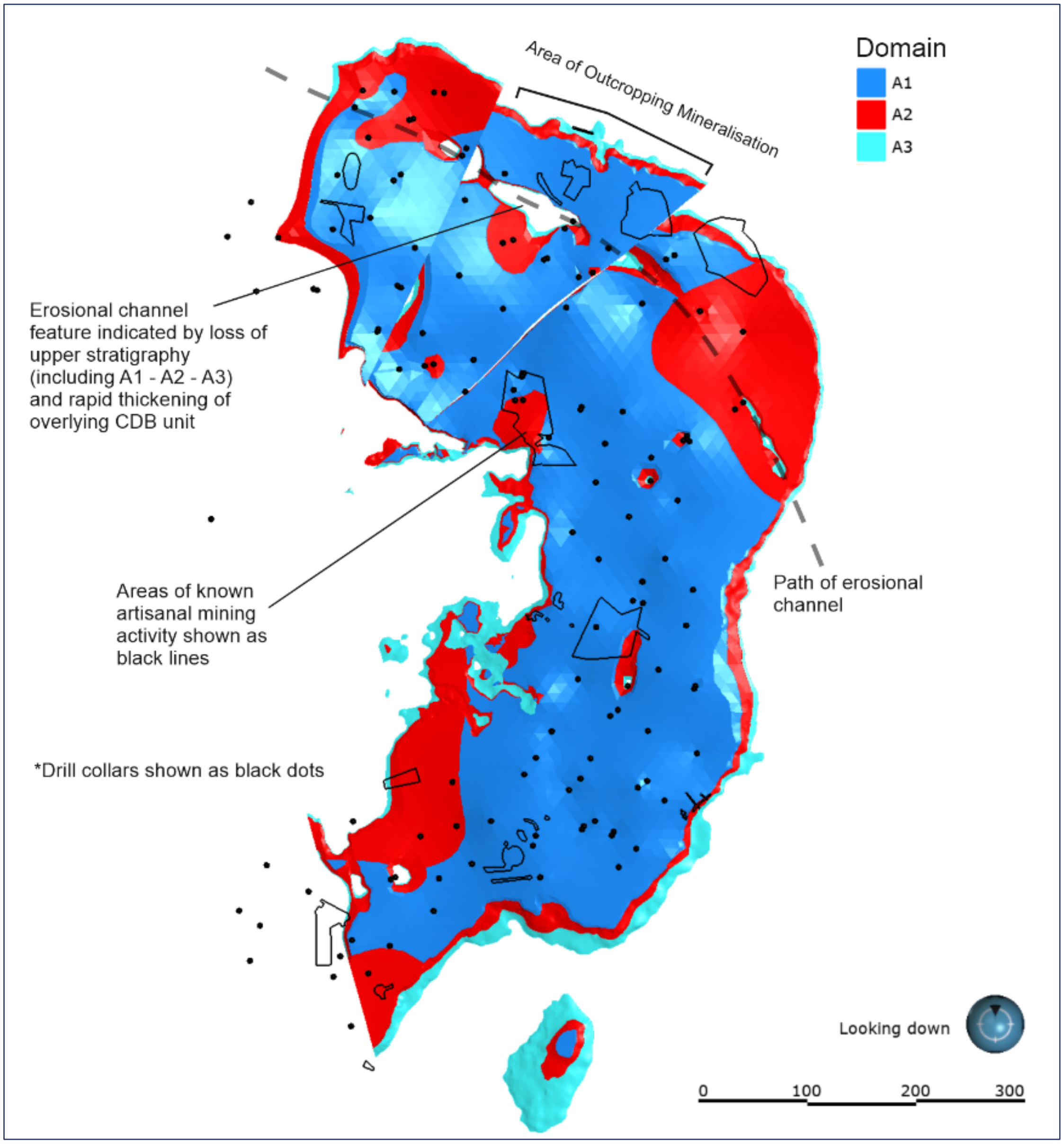
The narrow extent of the erosional feature is well constrained along its shortest axis by drilling to the southwest and outcropping mineralisation to the northeast, as well as surveyed artisanal activity, which notably abruptly stops at the edge of the modelled feature. The feature is less well constrained along its long axis and may extend as far as drillhole DDKH18_0015 to the southeast, which also intersects thickening of the CDB and loss of the upper Mn-shale horizon. The feature and possible continuation are shown in Figure 14.8 and Figure 14.9. In light of the proposed alternative potential structural interpretation (see Section 7.5), SRK considers that the nature of this contact warrants further investigation as part of the recommended structural mapping exercise.

Figure 14.8 Section looking along axis of erosional feature



Note: Scale is in metres; arrow points north.

Figure 14.9 Channel structure and erosion of upper Mn-shale unit in plan



Note: Scale is in metres; arrow points north.

14.2.4 Final estimation domains

The estimation domains and domain codes used in the original Northern Area estimate are provided in Table 14.2. Table 14.3 shows the revised estimation domain codes for the combined Northern and Southern domain models. The Mineral Resource statement presented herein comprises all modelled Mn-shale horizons, namely the Northern domains (A1, A2, A3, B, and C) and the Southern domains (A1, A2, A3, B, C1, and C2). It should be noted that the physical domains and wireframes for the Northern Area have not changed, except at the southernmost margins in order to better integrate with the Southern domains.

Table 14.2 Original estimation domains, with mineralised zones highlighted for Northern Area

Geological domain	Estimation domains
Overburden	MOD OVB
Chert dolomite breccia	MOD CDB
Fe Shale	MOD FSH 1
Low-grade Upper Mn-shale top margin	A1
High-grade Upper Mn-shale	A2
Low-grade Upper Mn-shale bottom margin	A3
Lower Mn-shale	B
Fe-shale	MOD FSH 2
Isolated Northwest Lower Mn-shale	C
Felsite	MOD FEL

Table 14.3 Final estimation domains used for combined Northern and Southern Extension Areas

Revised estimation domain Southern and Northern domains December 2021	Original estimation domain name October 2021
Northern Horizon A1	A1
Northern Horizon A2	A2
Northern Horizon A3	A3
Northern Horizon B	B
Northern Horizon C	C
Southern Horizon A1	n/a
Southern Horizon A2	n/a
Southern Horizon A3	n/a
Southern Horizon B	n/a
Southern Horizon C1	n/a
Southern Horizon C2	n/a

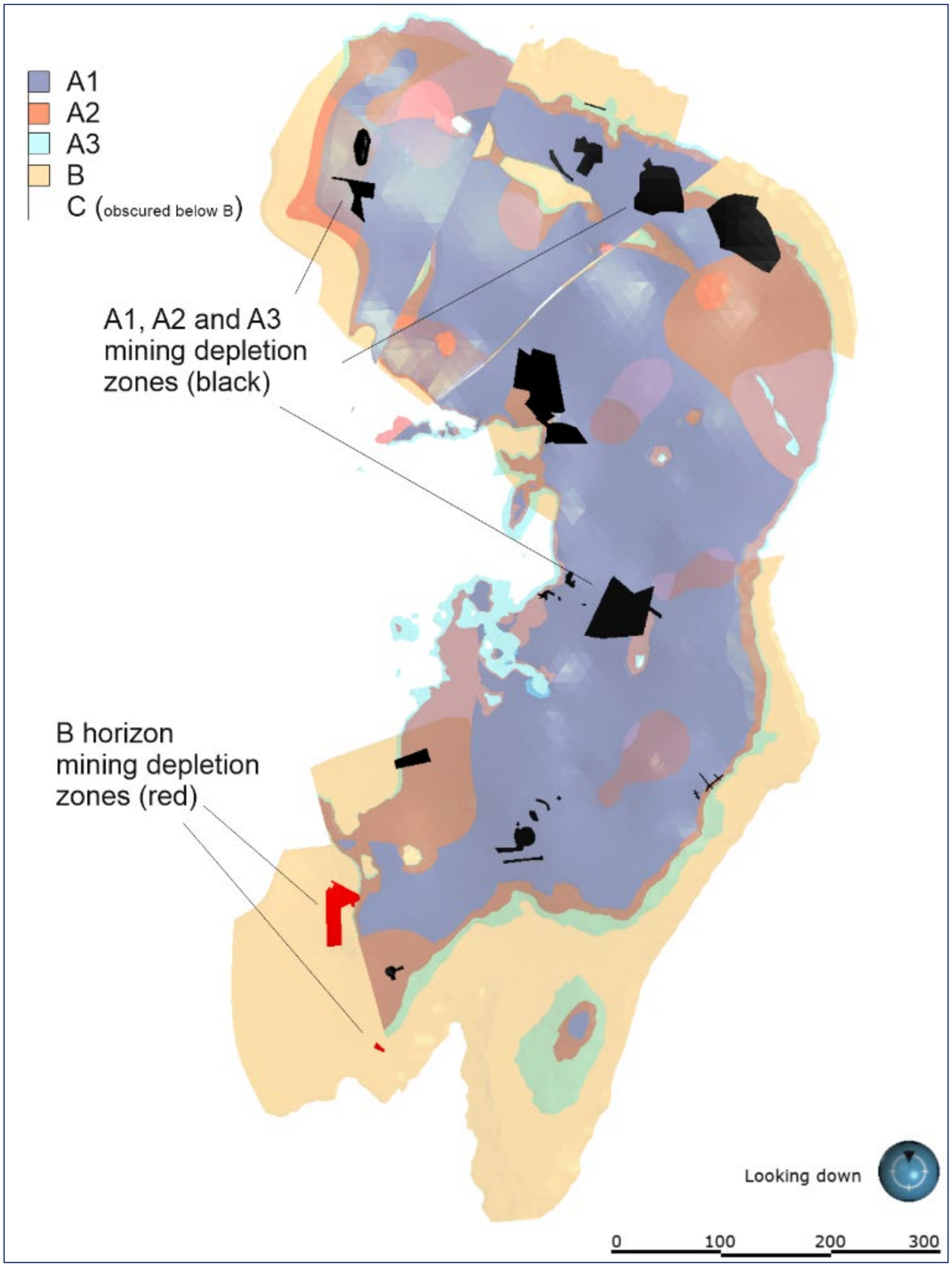
Note: n/a - not applicable

14.2.5 Artisanal mining, Northern Area

Artisanal mining activities have been documented at the K.Hill Project for a significant period of time. Giyani engaged Terravision Exploration in December 2020 to undertake a survey of the workings using ground penetrating radar and laser rangefinders. A total of 46 survey lines were made, covering a total of 5 km. Although these surveys were not exhaustive or systematic, it is considered likely that the majority of major workings will have been intercepted by these survey lines. Terravision interpreted the survey data and provided a 3D dataset outlining areas of artisanal workings, which has subsequently been applied as depletion prior to the reporting of the Mineral Resource. SRK reviewed this interpretation and it appears to be reasonable. However, SRK notes that the survey lines were not conducted in a completely systematic manner and were focused on areas of known workings. It is possible that unidentified workings with obscured accesses exist and have not yet been captured.

The workings are understood to be largely within the highest grade A1, A2, and A3 domains. However, two depletion voids were identified in the far southwest of the deposit where the A horizons do not exist, and Horizon B is found with higher grades. In this area, the artisanal mining survey has been used to deplete Horizon B in the model. No artisanal mining is recorded in the Southern Extension Area. A plan view of the artisanal mining depletion wireframes and how they have been applied is provided in Figure 14.10.

Figure 14.10 Plan view of the mineralisation domains and artisanal mining depletion wireframes



Note: Scale is in metres; arrow points north.

14.3 Estimation variables

The following variables were estimated into the 11 mineralised domains of the K.Hill Project block model:

- manganese oxide
- aluminium oxide
- silicon dioxide
- iron oxide
- potassium oxide
- phosphorus pentoxide
- sodium oxide
- LOI

14.4 Data conditioning

14.4.1 Drillholes used for domaining and estimation

As previously noted, the Mineral Resource presented herein forms an update to the previous October 2021 Mineral Resource estimate, which was conducted at the completion of the Southern Extension Area RC drilling programme completed in August 2021, and, as such, SRK used drillhole logs and laboratory assays relating to the RC drilling plus the data from the previous Phase 1 and Phase 2 drilling.

An analysis of twin drilling of DD holes by RC holes is provided in Section 11.4. SRK removed the RC twins from the estimation and modelling to limit the impact of these drillholes on the block model. SRK also notes that the Phase 3 DD holes were drilled as twins of RC holes for geotechnical purposes, and the core was not analysed. These holes have been checked against the corresponding RC hole to check that the thickness and depth of Mn-shale zones are reasonably consistent between hole types, but not used in the estimation of grades, particularly as no assaying has been completed on these DD holes.

A list of holes used for domaining and holes used for estimation is provided in Table 14.4.

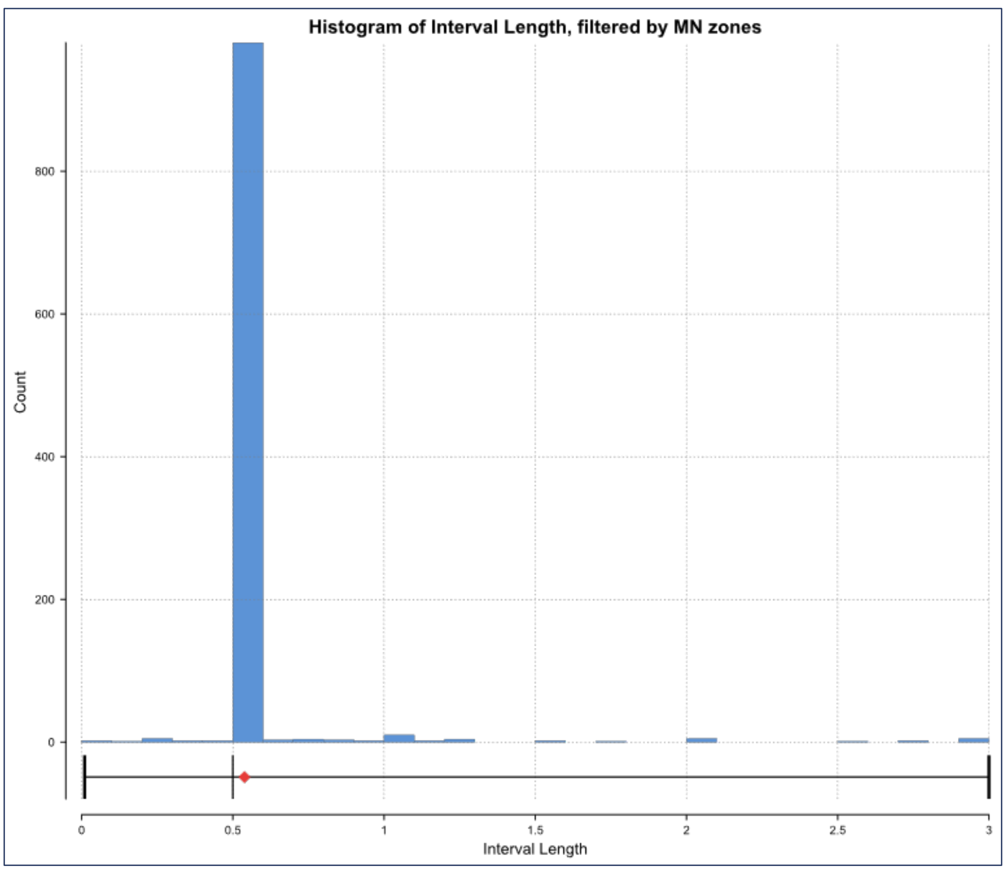
Table 14.4 List of holes used for estimation and domaining

Drillhole ID	Used for Estimation	Used for Domaining	Comment
DDKH18_0001 to DDKH18_0018	Yes	Yes	-
RCKH20_001 to RCKH20_090	Yes	Yes	-
DDKH21_0019 to DDKH21_0028	No	Yes	Geotechnical DD programme; core not assayed
DDKH21_0029 to DDKH0031	No	Yes	No assays received
RCKH21_092 to RCKH21_115	Yes	Yes	Southern Extension Area drilling

14.4.2 Compositing and data restrictions

SRK completed a sample length analysis of the raw assays used to inform the estimation domain wireframes. Sample lengths within the upper Mn-shale domain are between 0.1 and 3.00 m, with the vast majority of samples 0.5 m in length (Figure 14.11).

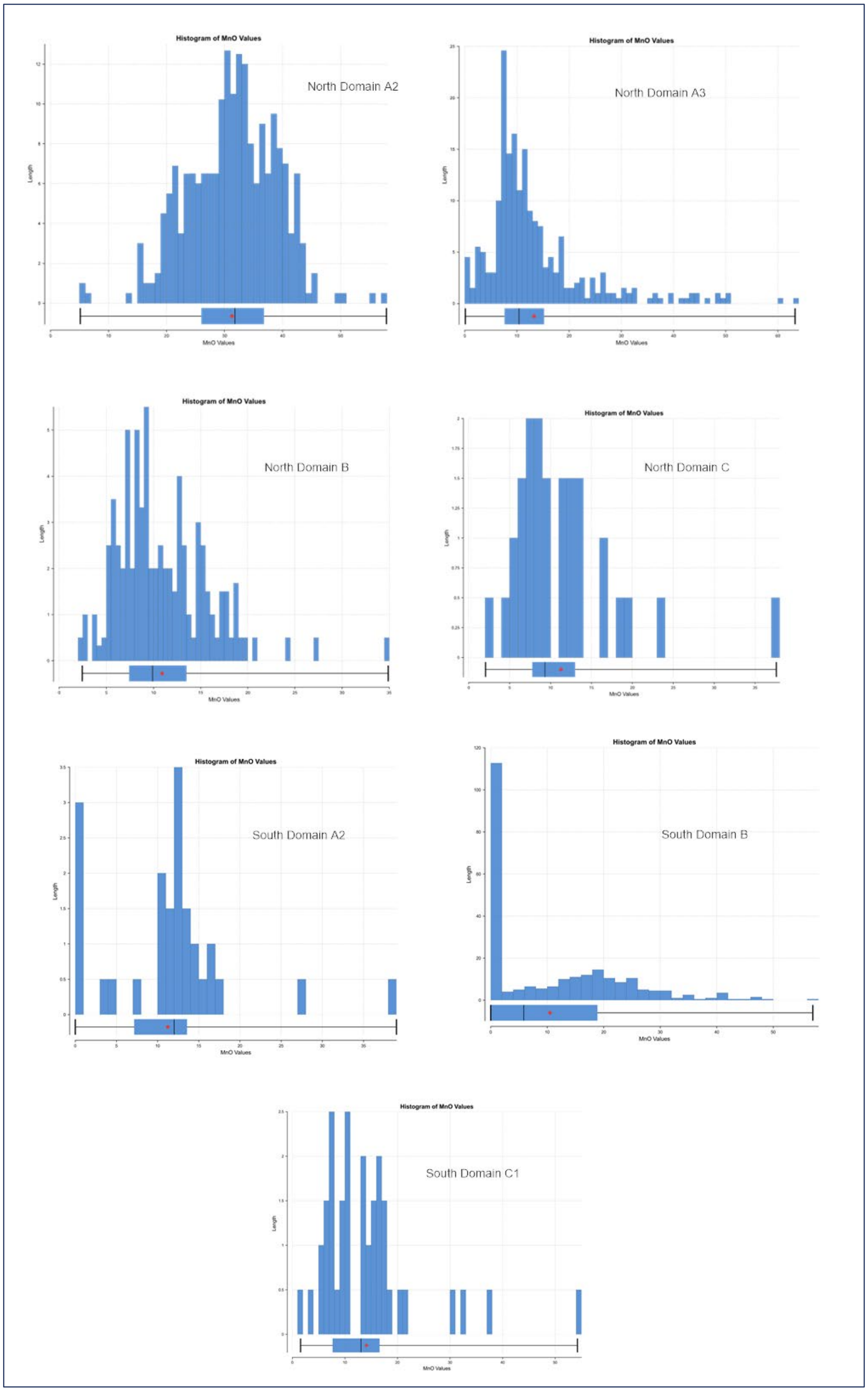
Figure 14.11 Histogram of K.Hill Project sample length (m) for Mn-shale intersections



On the basis of the sample length analysis completed, SRK composited to 0.5 m, with the estimation domain wireframes applied as compositing triggers. The minimum composite length allowed was 0.25 m, with any shorter residual intervals at the end of the intersection added to the previous composite.

Figure 14.12 shows the distribution of composited manganese oxide grades prior to capping for the capped domains (Northern domains A2, A3, B, and C and Southern domains A2, B, and C).

Figure 14.12 Histogram of composited manganese oxide values in the capped domains prior to capping applied, showing outlier high grades



The top cuts applied to each domain and for each element are shown in Table 14.5. All domains have a relatively low variability (as defined by the coefficient of variation), with few extreme outlying values; therefore, only minor grade capping has been applied, usually including the capping of one or two samples at most.

Table 14.5 Capped and uncapped composite statistics by domain

Domain	Variable	Number of composites	Uncapped mean (if capping applied)	Capped mean	Coefficient of variation
Northern A1	Al_2O_3	158	-	11.58	0.27
	Fe_2O_3	158	-	10.64	0.40
	MnO	158	-	11.53	0.33
	LOI	158	-	5.60	0.30
	SiO_2	158	-	54.82	0.20
Northern A2	Al_2O_3	393	-	9.97	0.21
	Fe_2O_3	393	-	19.25	0.22
	MnO	393	31.29	31.26	0.24
	LOI	393	-	9.99	0.18
	SiO_2	393	-	21.60	0.47
Northern A3	Al_2O_3	143	-	11.76	0.28
	Fe_2O_3	143	-	12.98	0.42
	MnO	143	10.87	10.82	0.43
	LOI	143	-	4.96	0.30
	SiO_2	143	-	53.26	0.21
Northern B	Al_2O_3	374	-	9.67	0.46
	Fe_2O_3	374	-	11.90	0.50
	MnO	374	13.29	13.24	0.73
	LOI	374	-	6.10	0.45
	SiO_2	374	-	53.56	0.26
Northern C	Al_2O_3	33	-	9.16	0.28
	Fe_2O_3	33	-	14.05	0.42
	MnO	33	11.28	10.90	0.48
	LOI	33	-	6.56	0.22
	SiO_2	33	-	54.90	0.16
Southern A1	Al_2O_3	7	-	8.03	0.43
	Fe_2O_3	7	-	8.90	2.99
	MnO	7		28.08	0.42
	LOI	7	-	8.55	0.24
	SiO_2	7	-	39.22	0.26
Southern A2	Al_2O_3	34	-	8.68	0.51
	Fe_2O_3	34	-	8.80	0.47
	MnO	34	11.23	10.74	0.61
	LOI	34	-	7.96	0.47
	SiO_2	34	-	53.06	0.35

Domain	Variable	Number of composites	Uncapped mean (if capping applied)	Capped mean	Coefficient of variation
Southern A3	Al_2O_3	14	-	6.30	0.43
	Fe_2O_3	14	-	7.70	0.47
	MnO	14		12.33	0.34
	LOI	14	-	5.73	0.48
	SiO_2	14	-	52.20	0.42
Southern B	Al_2O_3	280	-	7.36	0.51
	Fe_2O_3	280	-	10.82	0.49
	MnO	280	18.81	10.78	1.20
	LOI	280	-	7.39	0.36
	SiO_2	280	-	49.58	0.32
Southern C1	Al_2O_3	44	-	9.22	0.39
	Fe_2O_3	44	-	13.82	0.49
	MnO	44	14.11	13.79	0.67
	LOI	44	-	8.57	0.59
	SiO_2	44	-	45.98	0.31
Southern C2	Al_2O_3	8	-	7.43	0.77
	Fe_2O_3	8	-	9.15	0.67
	MnO	8		14.51	0.89
	LOI	8	-	6.13	0.56
	SiO_2	8		56.61	0.36

14.5 Geostatistical analysis

There is insufficient sample density for the application of meaningful variography for the Southern Extension Area domains. A geostatistical approach to estimation was not applied to these domains.

For the Northern domains, SRK investigated directional semi-variograms using the 0.5 m composite data. For the Northern A2 and B domains, experimental variograms were determined to be sufficiently robust, showing structures with ranges in the order of 50 to 100 m, to be used for estimation of all variables using ordinary kriging. Modelled variograms for estimated variables are provided for the Northern A2 domain in Figure 14.13 to Figure 14.17 and for the B domain in Figure 14.18 to Figure 14.22. Variograms for the Horizon A2 were modelled using a single structure; however, a two-structure variogram model was used for the Northern Horizon B semi-variograms, often showing a short range in the first structure, with a much longer range in the second structure. A table of variogram parameters is provided in Table 14.6. For the remaining Northern domains, a lack of data resulted in an inability to model robust variograms.

Figure 14.13 Manganese oxide directional variograms and 2D variogram continuity fan for the A2 domain

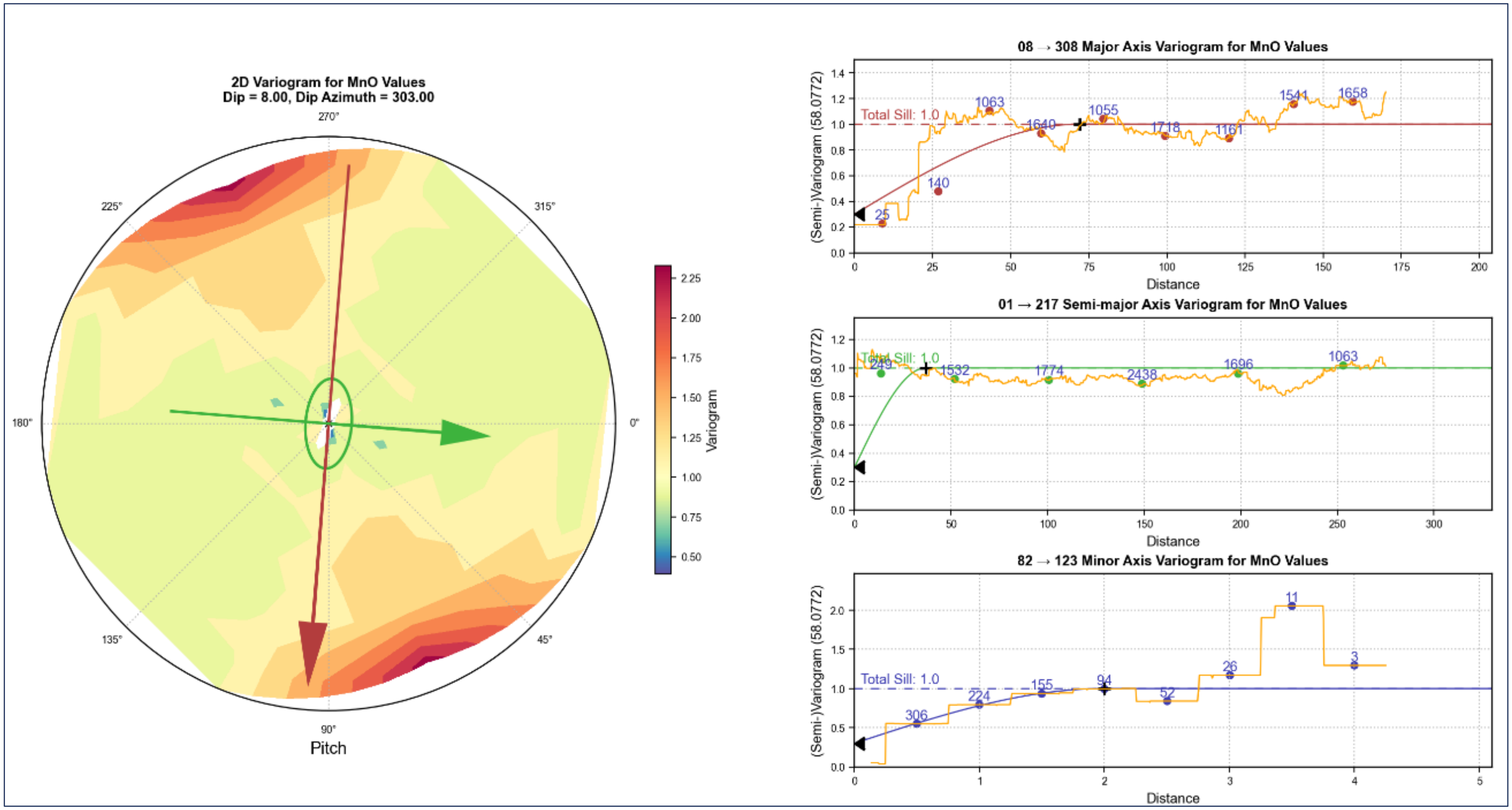


Figure 14.14 Aluminium oxide directional variograms and 2D variogram continuity fan for the A2 domain

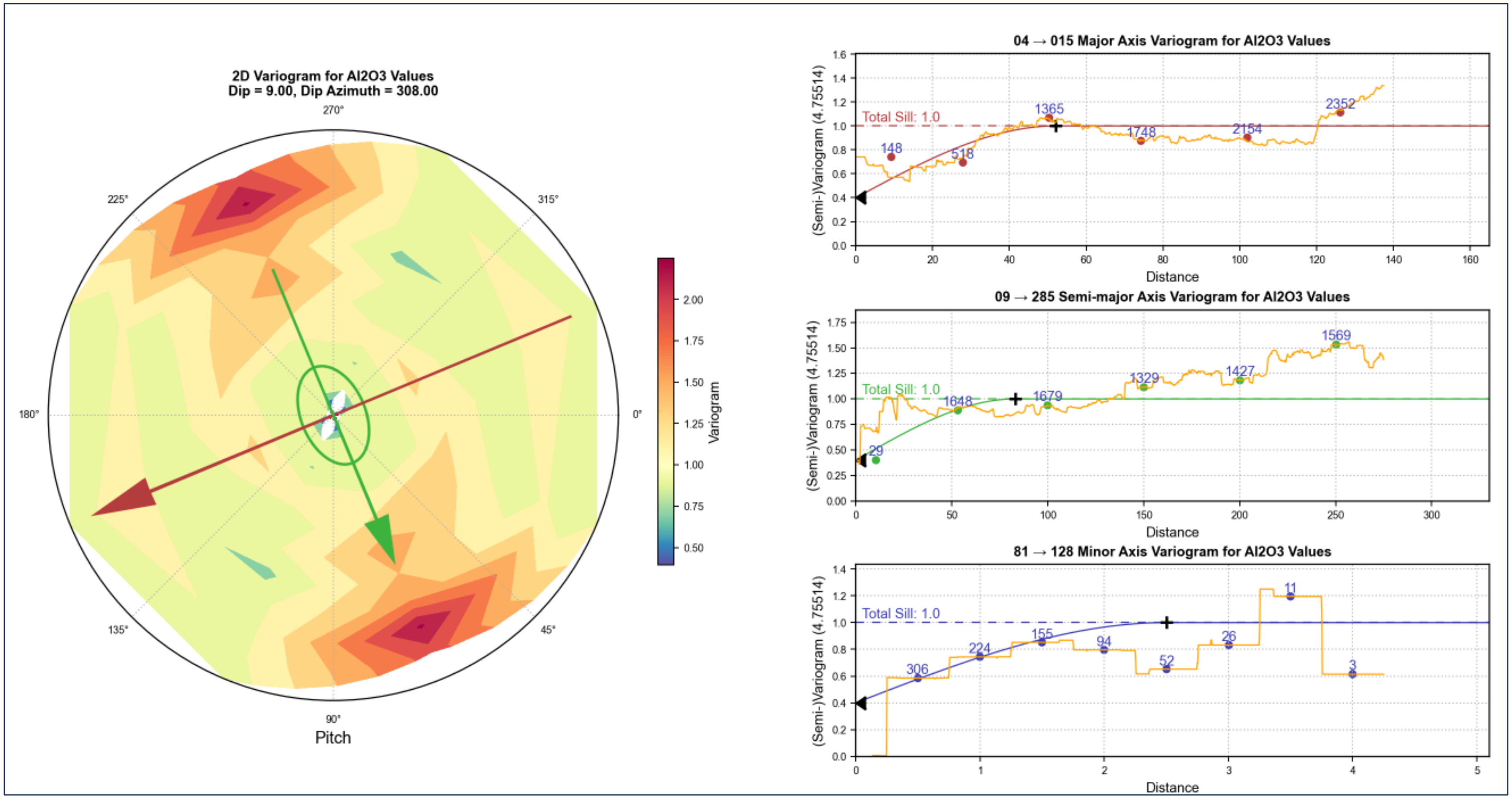


Figure 14.15 Iron oxide directional variograms and 2D variogram continuity fan for the A2 domain

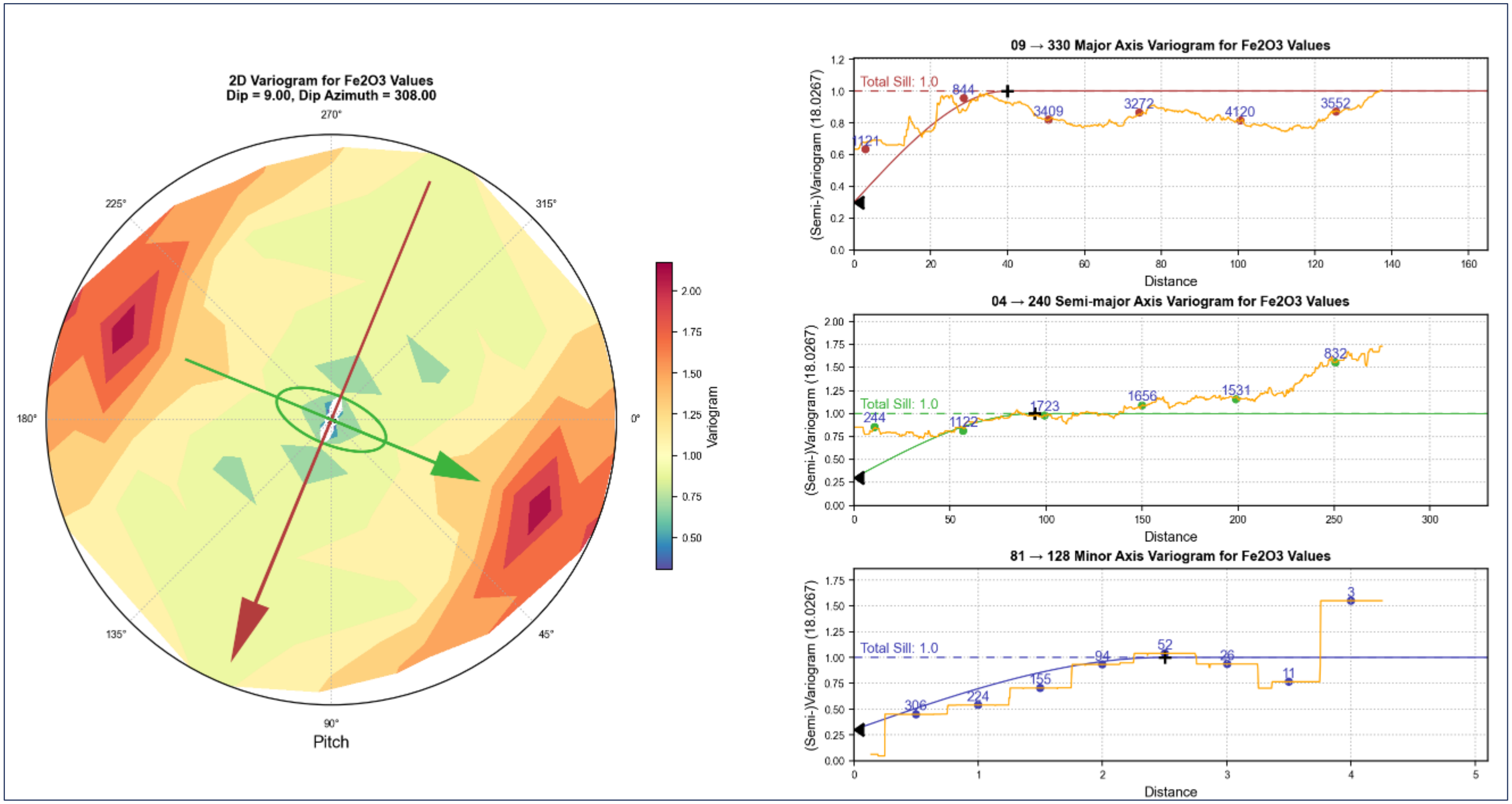


Figure 14.16 LOI directional variograms and 2D variogram continuity fan for the A2 domain

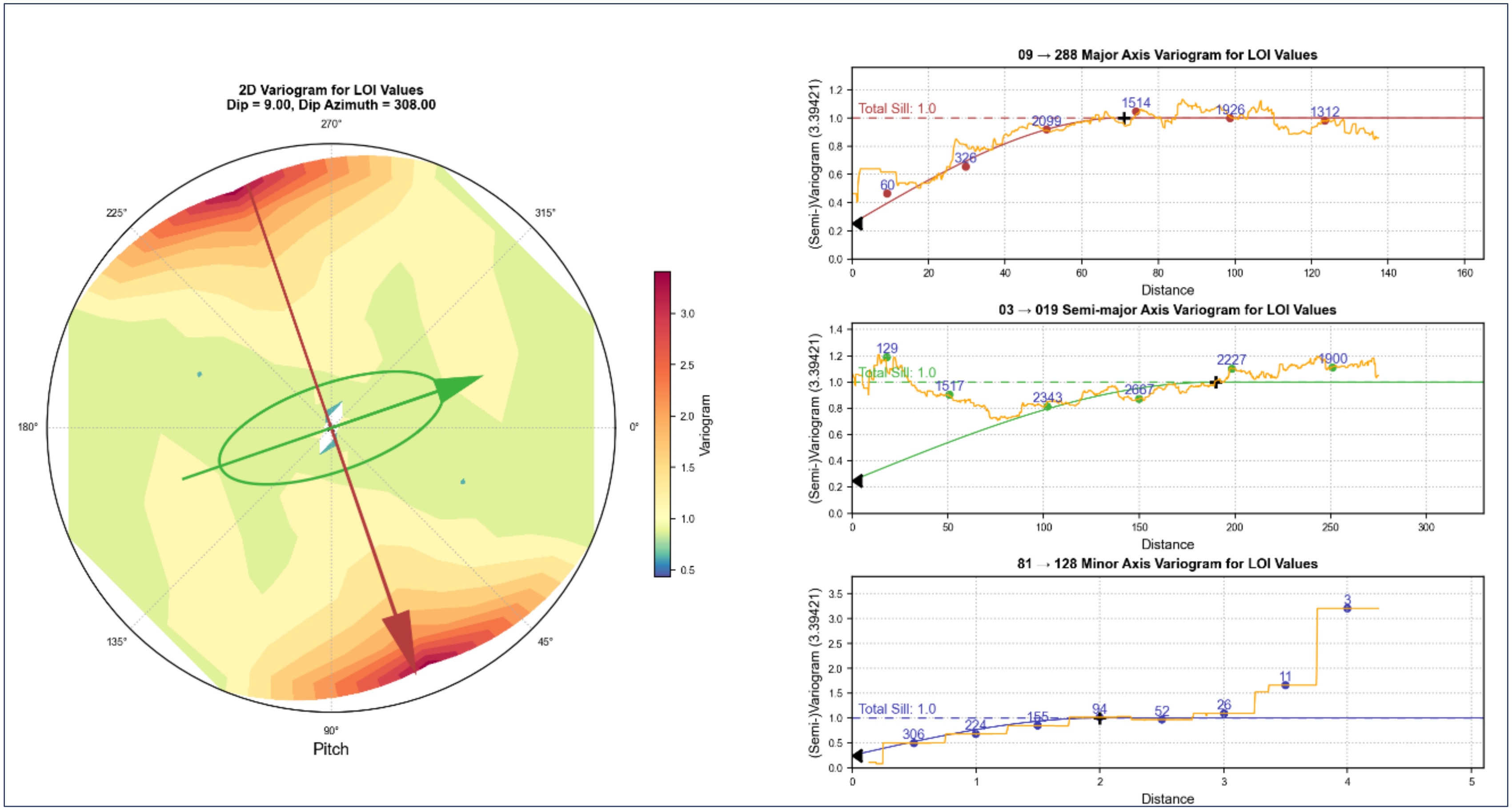


Figure 14.17 Silicon dioxide directional variograms and 2D variogram continuity fan for the A2 domain

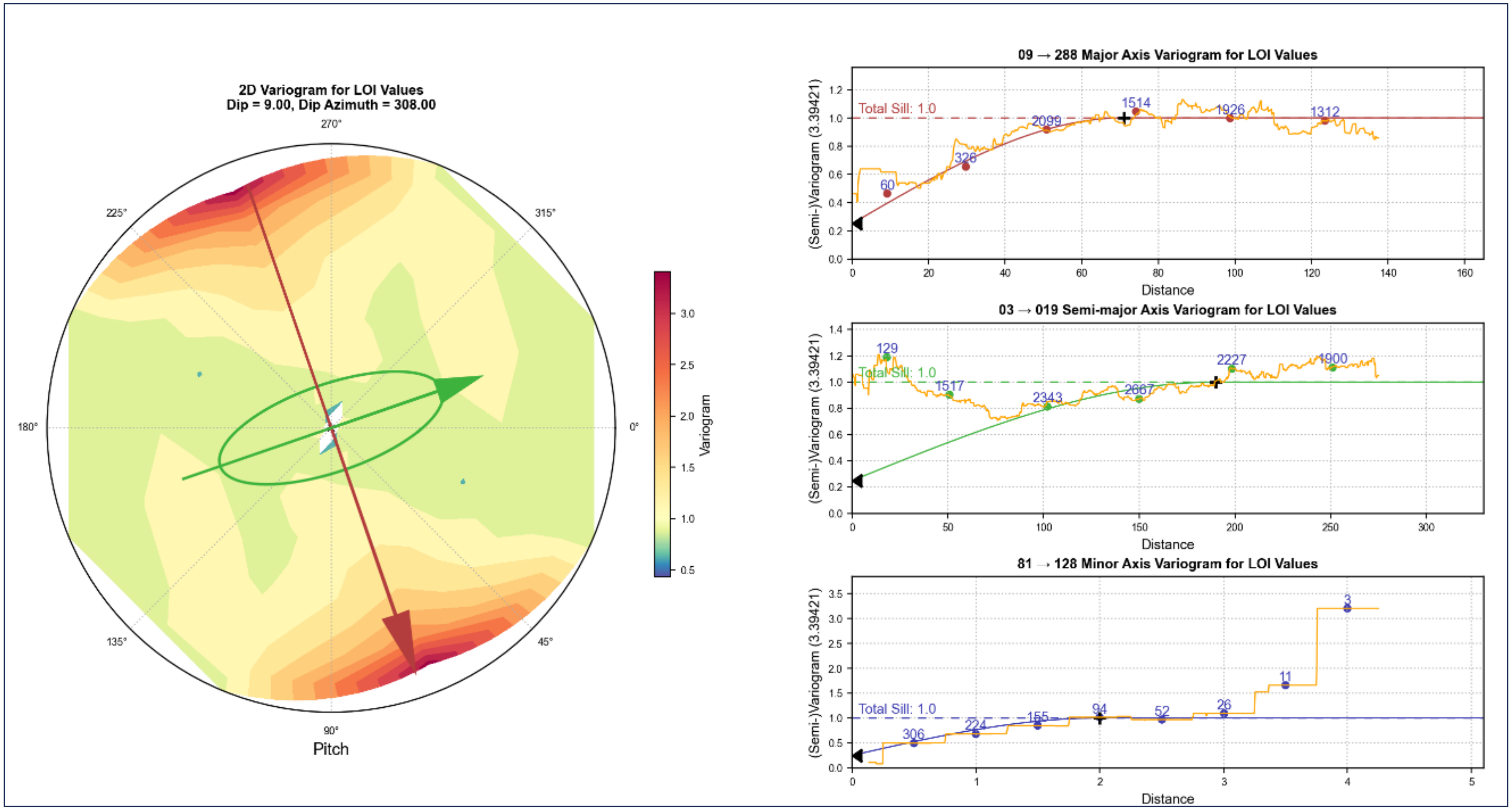


Figure 14.18 Manganese oxide directional variograms and 2D variogram continuity fan for the B domain

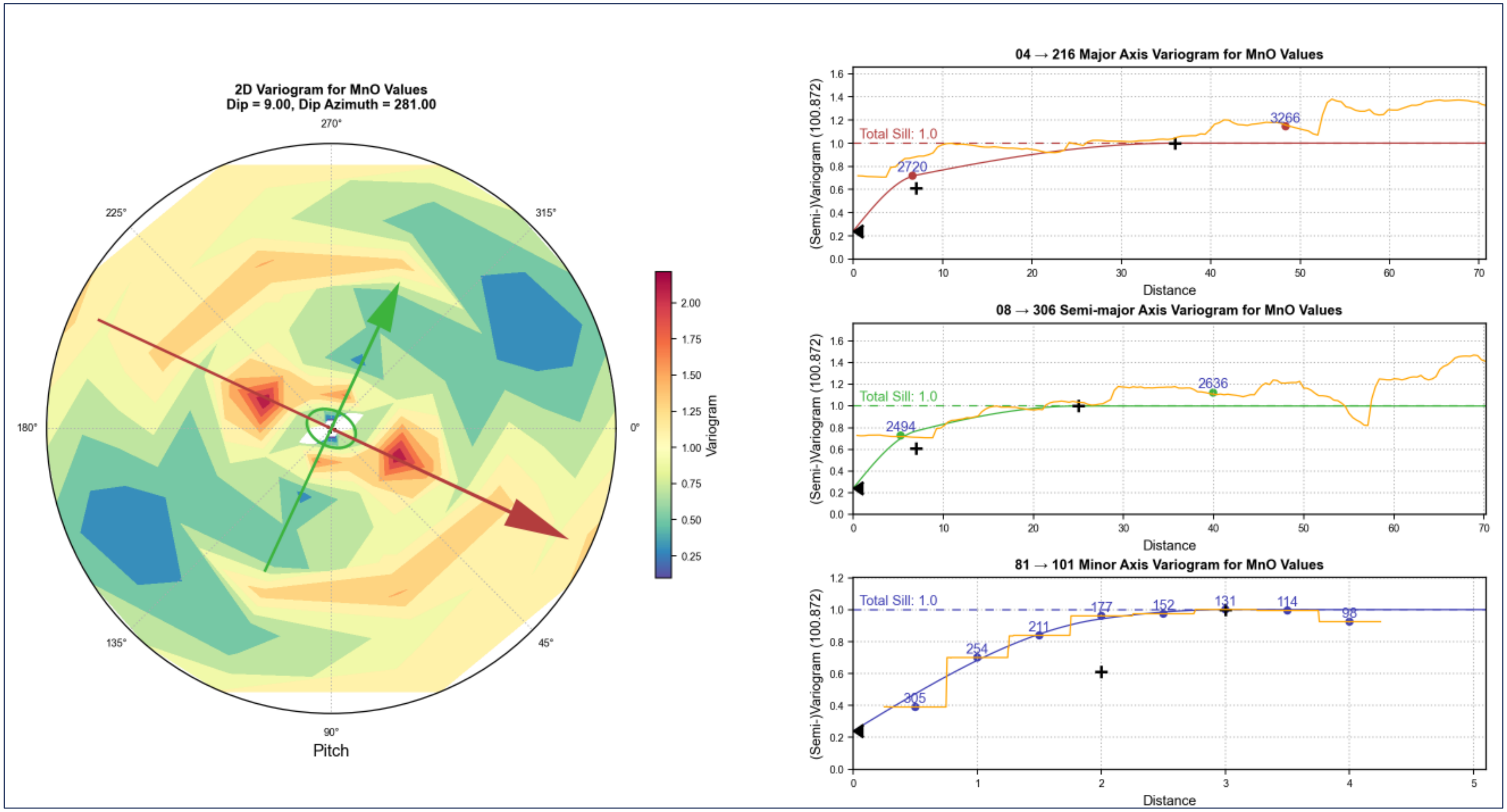


Figure 14.19 Aluminium dioxide directional variograms and 2D variogram continuity fan for the B domain

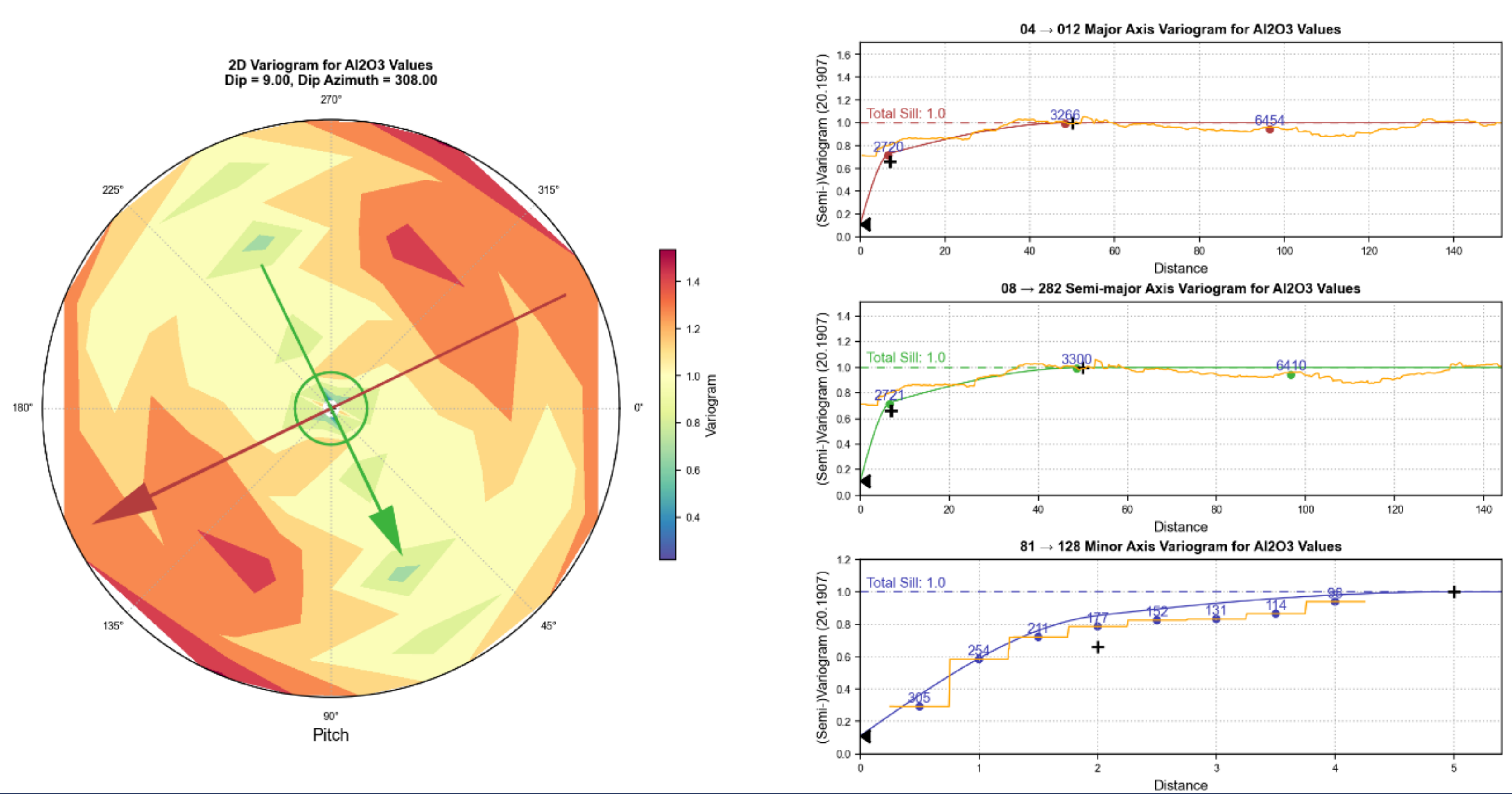


Figure 14.20 Iron oxide directional variograms and 2D variogram continuity fan for the B domain

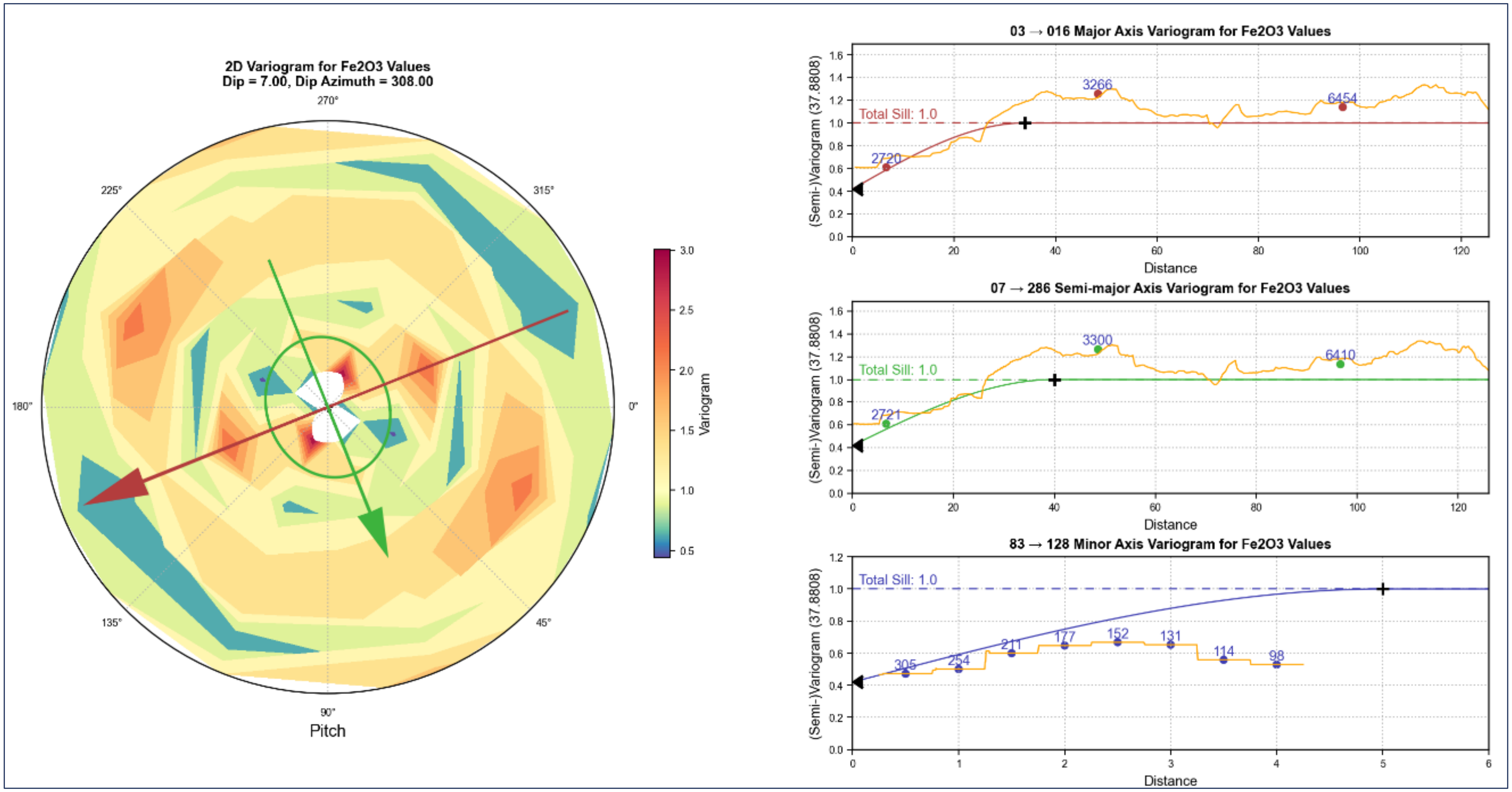


Figure 14.21 LOI directional variograms and 2D variogram continuity fan for the B domain

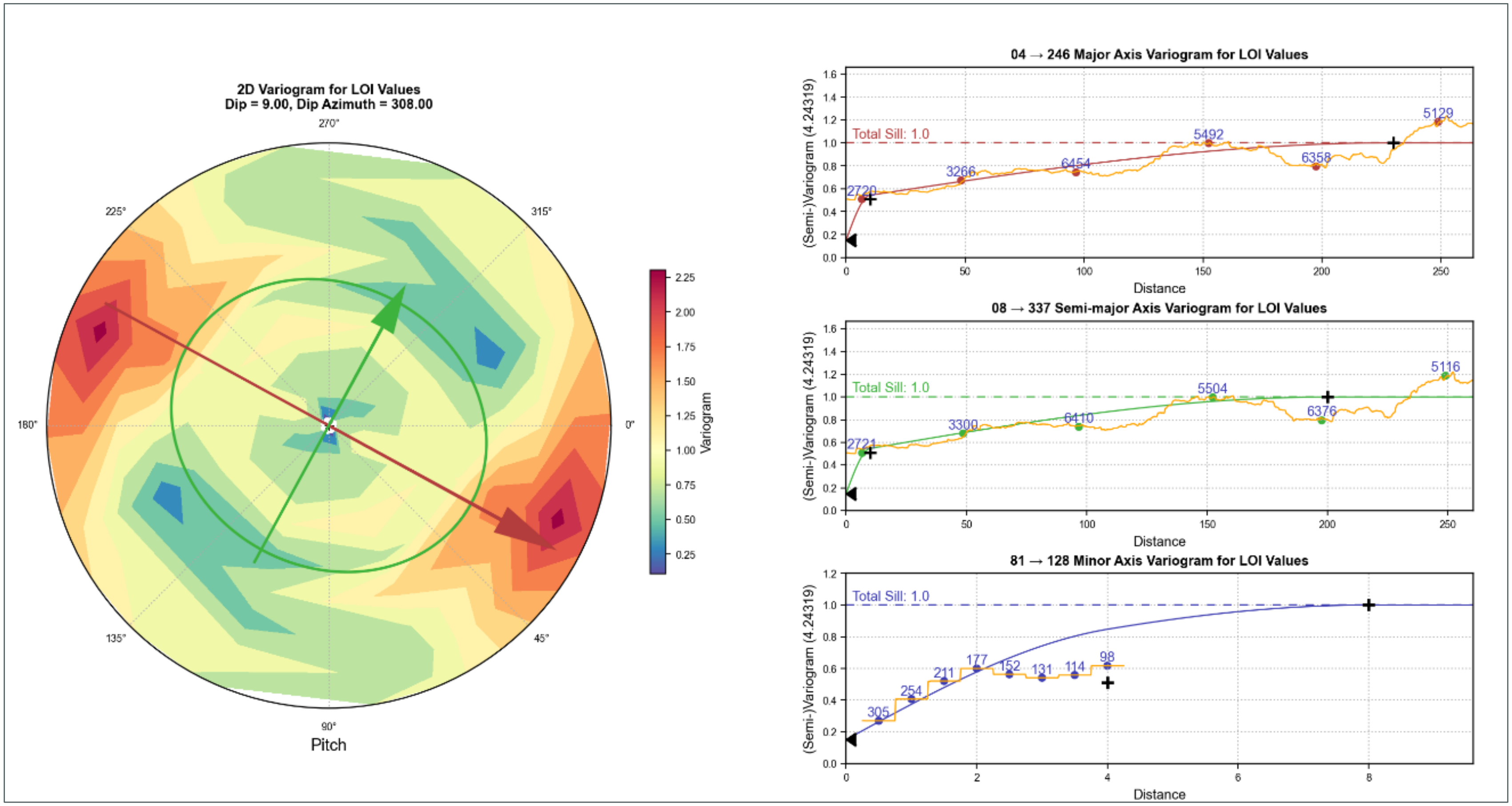


Figure 14.22 Silicon dioxide directional variograms and 2D variogram continuity fan for the B domain

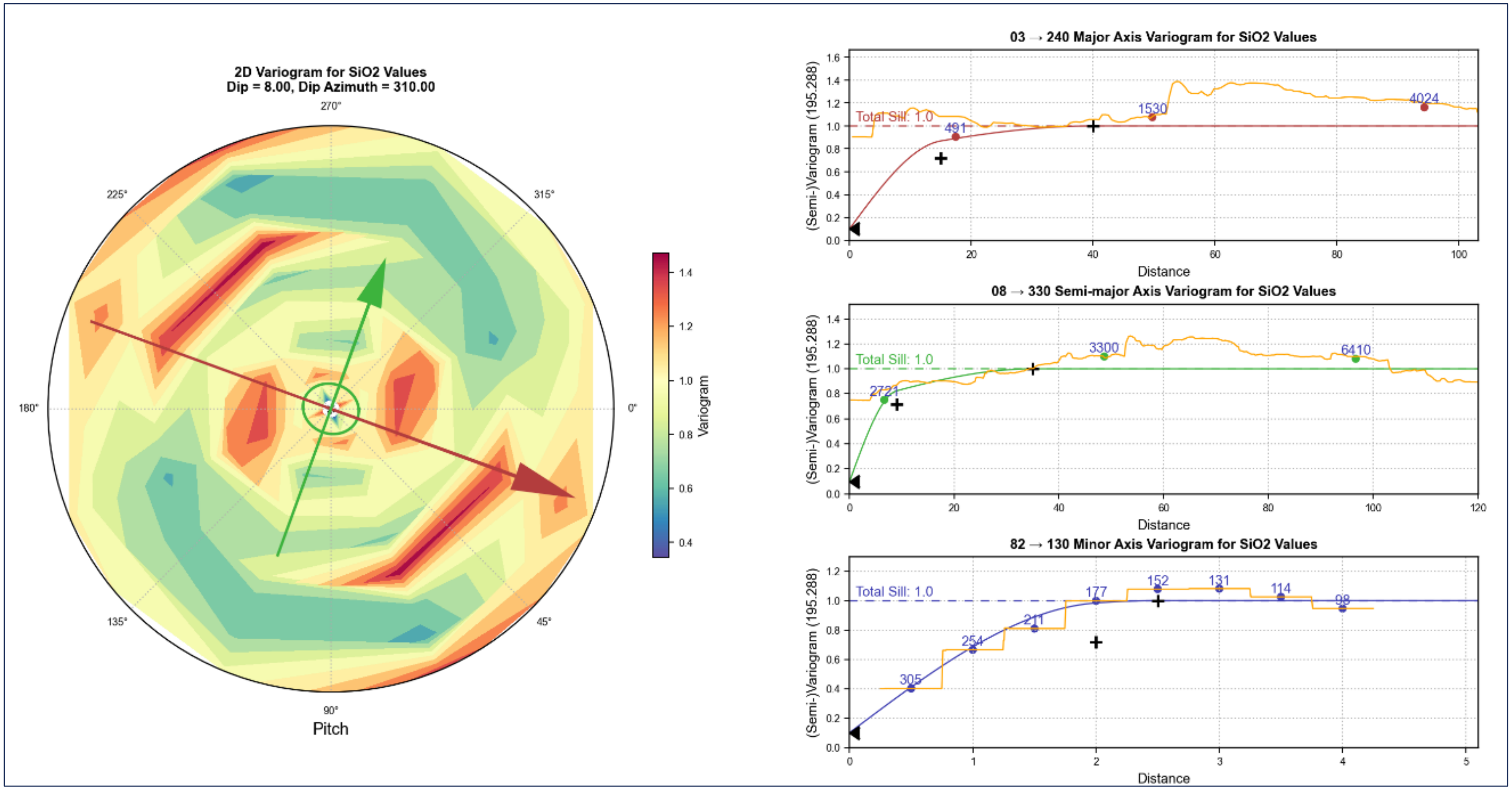


Table 14.6 Table of variogram parameters for domains estimated using ordinary kriging

Domain	Variable	Major Range (m)		Semi-major Range (m)		Minor Range (m)	
Northern A2	Al_2O_3	52		83		2.5	
	Fe_2O_3	40		94		2.5	
	MnO	72		37		2	
	LOI	71		190		2	
	SiO_2	72		200		2	
		Structure 1	Structure 2	Structure 1	Structure 2	Structure 1	Structure 2
Northern B	Al_2O_3	7	5 0	7	50	2	5
	Fe_2O_3	34	-	40	-	5	-
	MnO	7	36	7	25	2	3
	LOI	10	230	10	200	4	8
	SiO_2	15	40	9	35	2	2.5

14.6 Block model

SRK constructed a block model, with cell dimensions of 20 mX × 20 mY × 1 mZ. The block size was chosen based on approximately ½ of the average drillhole spacing of 50 m, and results in two parent blocks between drillholes (in plan) for the Northern Area. It is deemed impractical to use two block sizes for the Northern and Southern Extension Areas; therefore, a single block size was applied across the deposit. Based on the drilling extents in the southern portion of the deposit, this results in approximately four parent blocks between drillholes (in plan).

The block model was sub-blocked to a minimum sub-cell size of 5 mX × 5 mY × 0.5 mZ. The small sub-block height in the Z axis was necessary to retain the granularity of gradational change in the Z axis. Estimation domain wireframes were used as sub-blocking triggers.

14.7 Estimation

14.7.1 Estimation parameters

For the A2 and B Northern domains, where variograms could be modelled, a two-pass search strategy was used for estimation into parent blocks using ordinary kriging. The first search ellipsoid radii were set at 120 m × 180 m × 10 m. Approximately 70% of the blocks were estimated in the first pass. The second search was undertaken to estimate all the remaining blocks, using a significantly expanded search ellipsoid of 500 m × 500 m × 100 m. All other estimation parameters were unchanged from the first search pass. The search ellipsoid used a variable orientation based on the mineralisation domain wireframes aligned with the sub-horizontal layering. The minimum number of composites required to estimate a block was 4 and the maximum was restricted to 12. A maximum of two composites per drillhole was applied to the estimation of each block. The application of this restriction aimed to maintain across-strike variability in the block estimates. This approach also ensures that multiple drillholes are used to inform each block estimate. The search parameters for the A2 and B domains are summarised in Table 14.7.

Table 14.7 K.Hill Project estimation search parameters (Northern A2 and B domains)

Pass 1 search distance (m)			Number of composites		Maximum composites per drillhole	Pass 2 search distance (m)		
X	Y	Z	Minimum	Maximum		X	Y	Z
120	180	10	4	12	2	500	500	100

Since variograms could not be modelled for the remaining mineralised domains, all the assayed variables were estimated into parent blocks using inverse distance weighting (to the power of 2). The minimum number of composites required to estimate a block was 4 and the maximum was restricted to 12. A maximum of two composites per drillhole was applied to the estimation of each block. Search ellipsoid ranges were set to 600 m × 600 m × 200 m. All blocks were estimated in the first search pass. As with the high-grade domain, a variable orientation search was applied, aligned with the sub-horizontal layering.

The search parameters for the A1, A3, and C domains in the Northern Area and all domains in the Southern Extension Area are summarised in Table 14.8.

Table 14.8 K.Hill Project estimation search parameters (Northern A1, A3, and C domains and Southern A1, A2, A3, B, C1, C2 domains)

Domain	Search distance (m)			Number of composites		Maximum composites per drillhole
	X	Y	Z	Minimum	Maximum	
Northern Domain A1, A3, C	600	600	200	4	12	2
Southern Domain A1	350	350	30	4	20	2
Southern Domain A2	200	200	50	4	20	2
Southern Domain A3	100	100	10	4	20	2
Southern Domain B	300	300	50	4	20	2
Southern Domain C1	300	300	50	4	20	2
Southern Domain C2	200	200	10	1	20	2

14.8 Validation

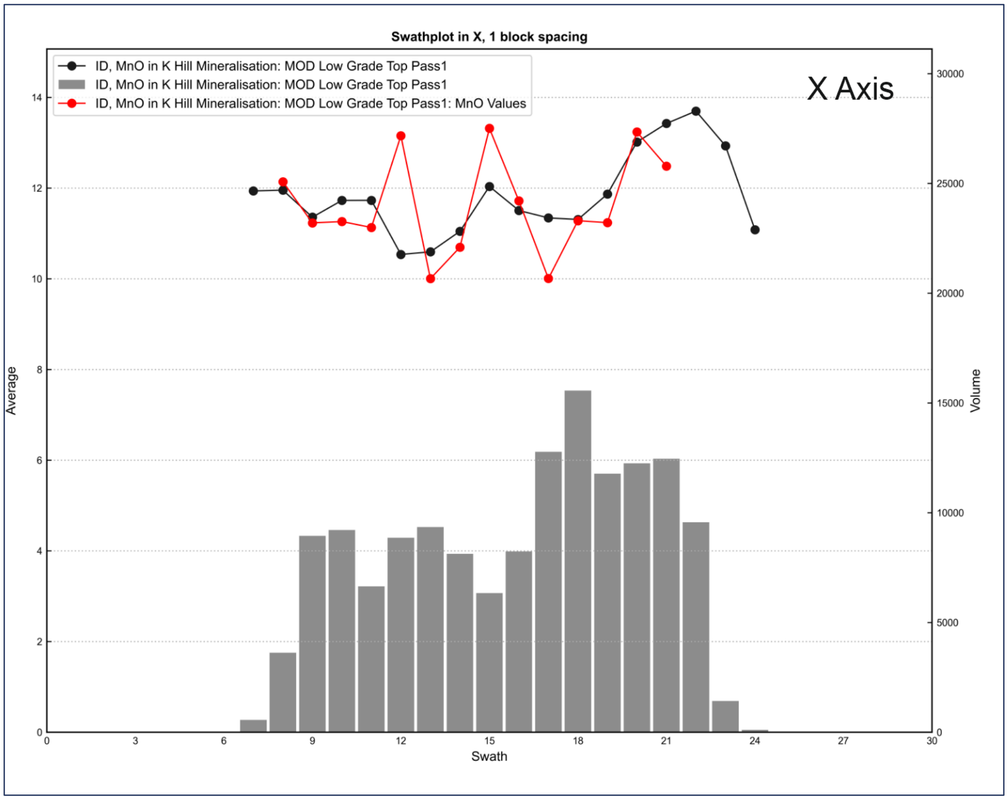
SRK undertook validation of estimated grades and densities using the following methods:

- visual examination of the input data against the block model estimates
- swath plots that compare the average grades of the block model against the input data along a number of corridors in various directions through the deposit
- comparison of the input data statistics against the model statistics

The validation checks completed by SRK suggest that the drillhole grades are well represented by the estimated block model domains, both locally and globally, and that, in general, the model validation does not highlight any material concerns in the quality of the estimation. Swath plots of manganese oxide in the five northern estimation domains are displayed in Figure 14.23 to Figure 14.27 where block grades are shown as the black line, composite sample grades in red and a histogram of sample counts as grey bars. Swath plots for the six Southern domains have not been generated due to too few samples in each domain to provide meaningful plots.

The mean composite sample grades are compared to the average model grades by estimation domain in Table 14.9. Relative differences between the model grade and input data grade for the main mineralised domains are generally less than 5%. No de-clustering was applied as all drillholes have a reasonably even spatial distribution.

Figure 14.23 Swath plots for manganese oxide in the A1 domain



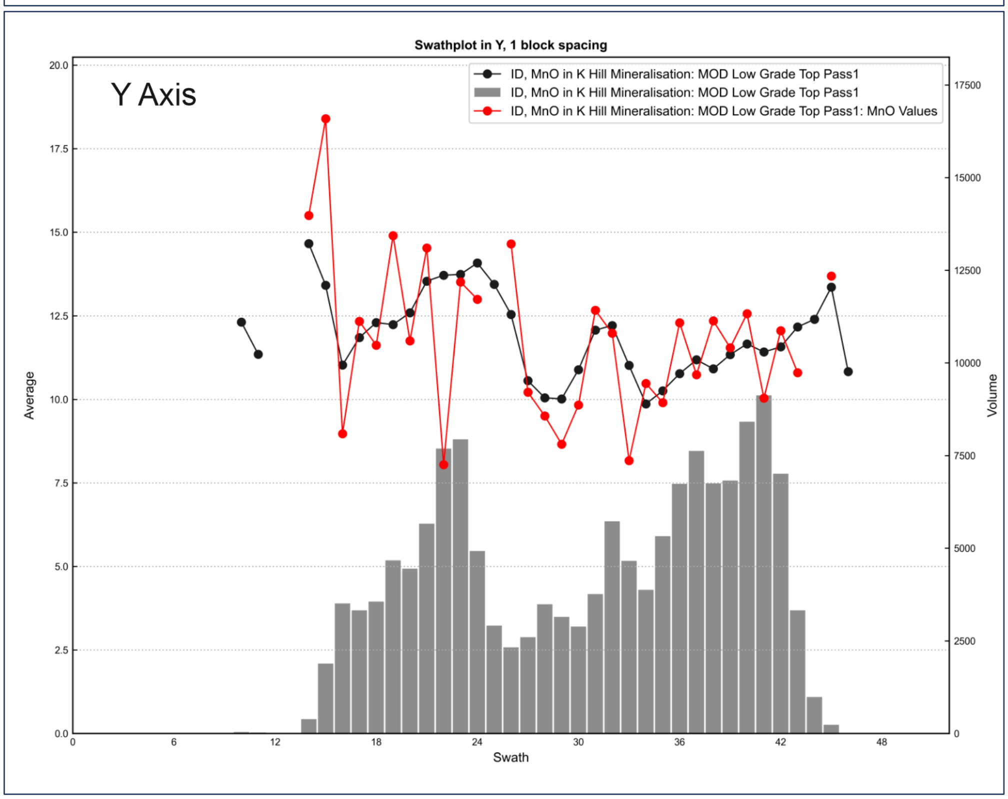
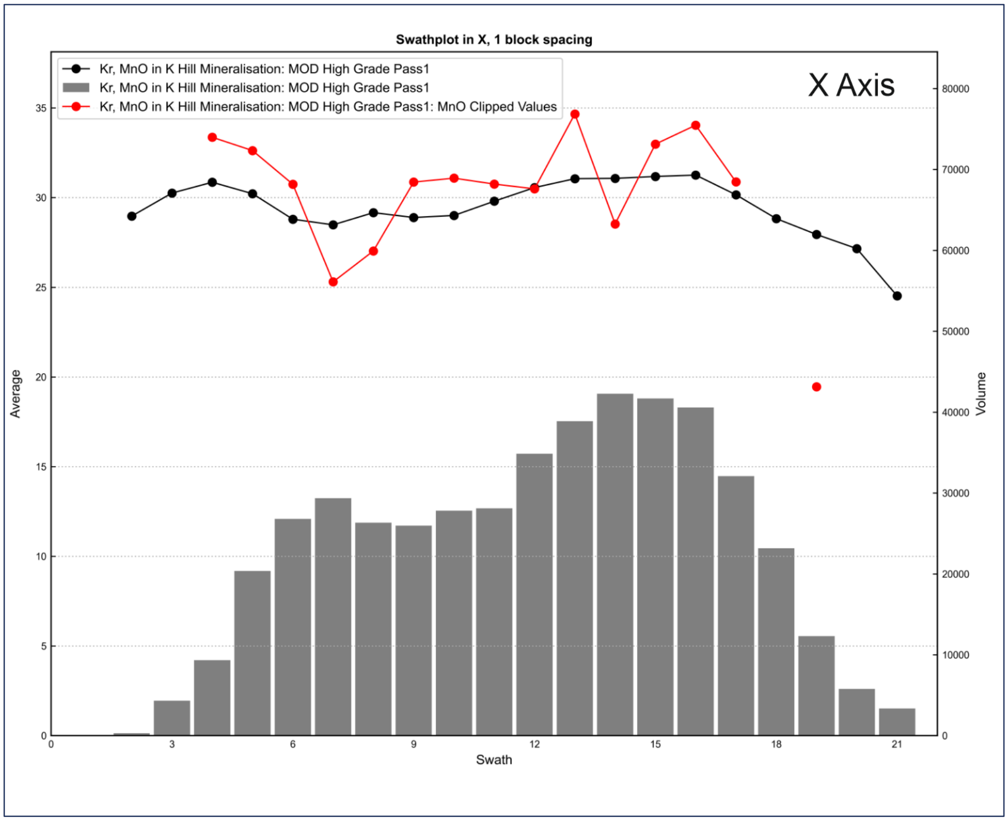


Figure 14.24 Swath plots for manganese oxide in the A2 domain



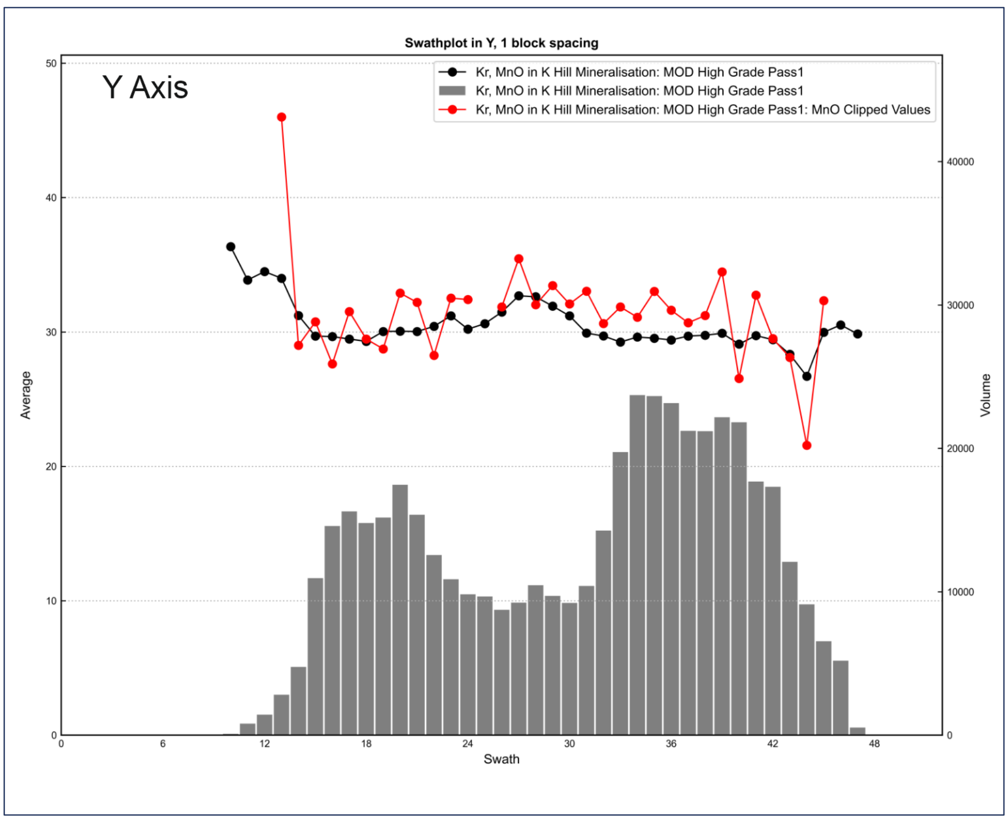
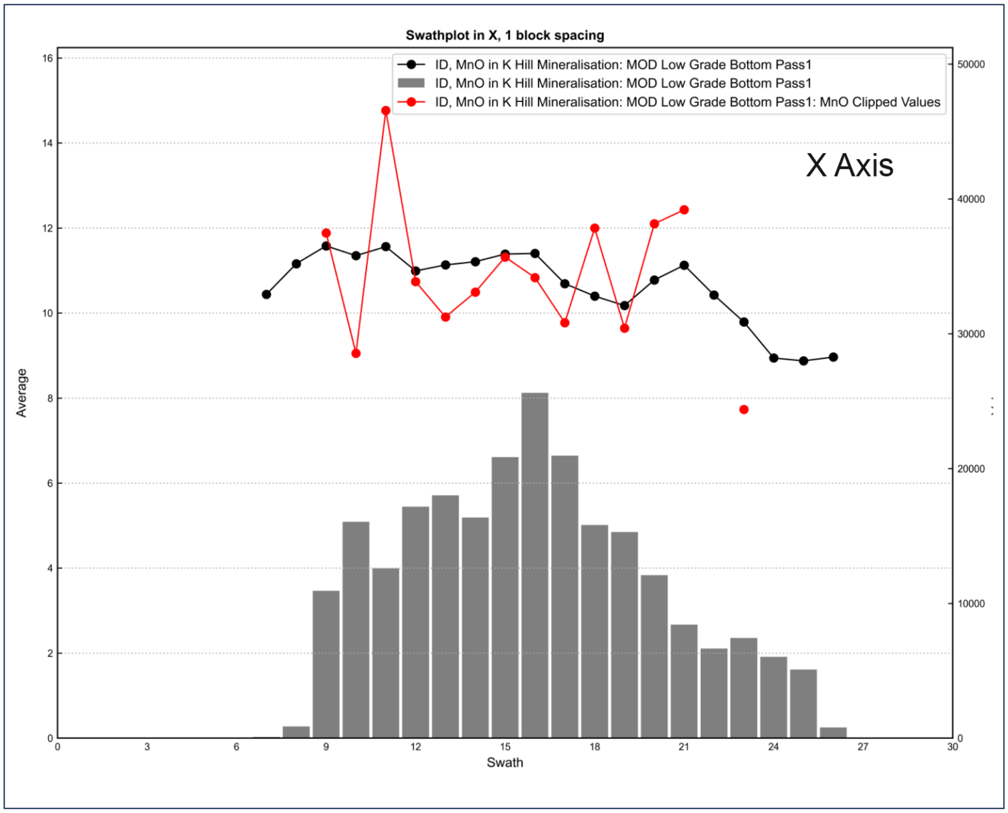


Figure 14.25 Swath plots for manganese oxide in the A3 domain



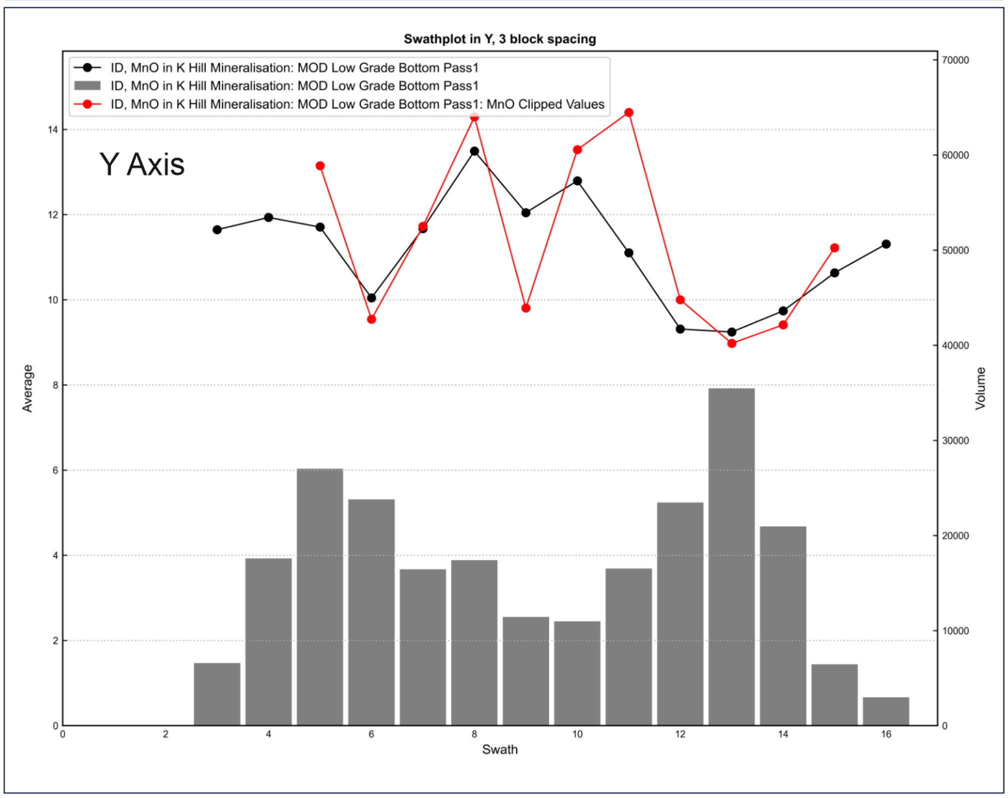
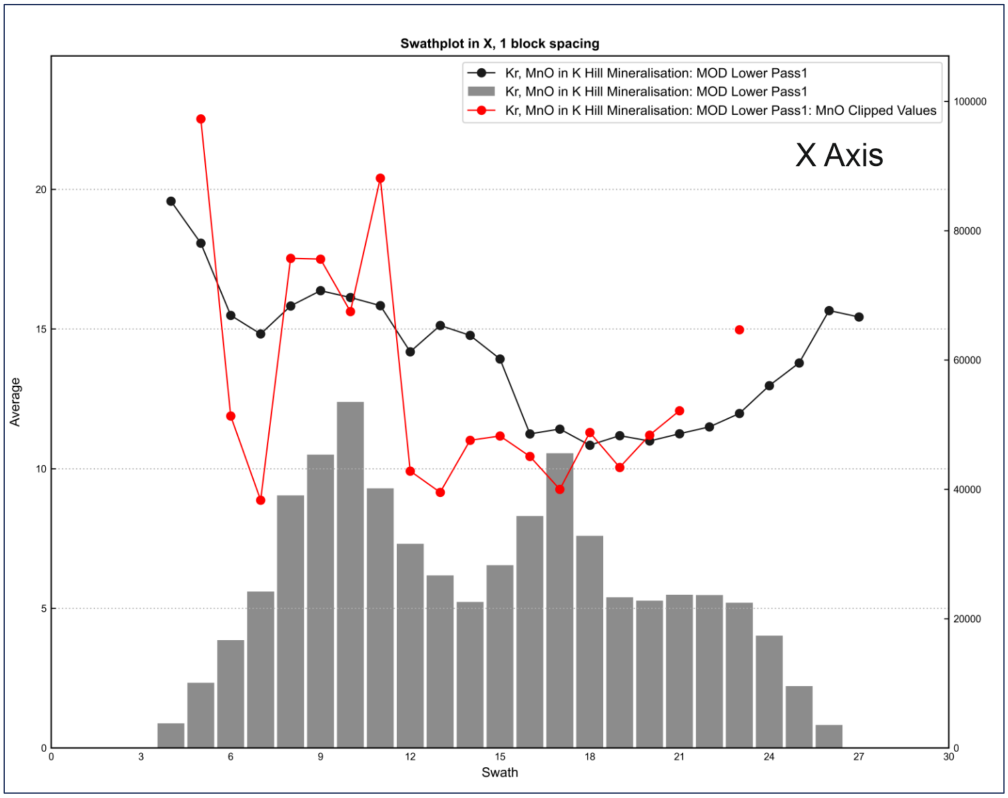


Figure 14.26 Swath plots for manganese oxide in the B domain



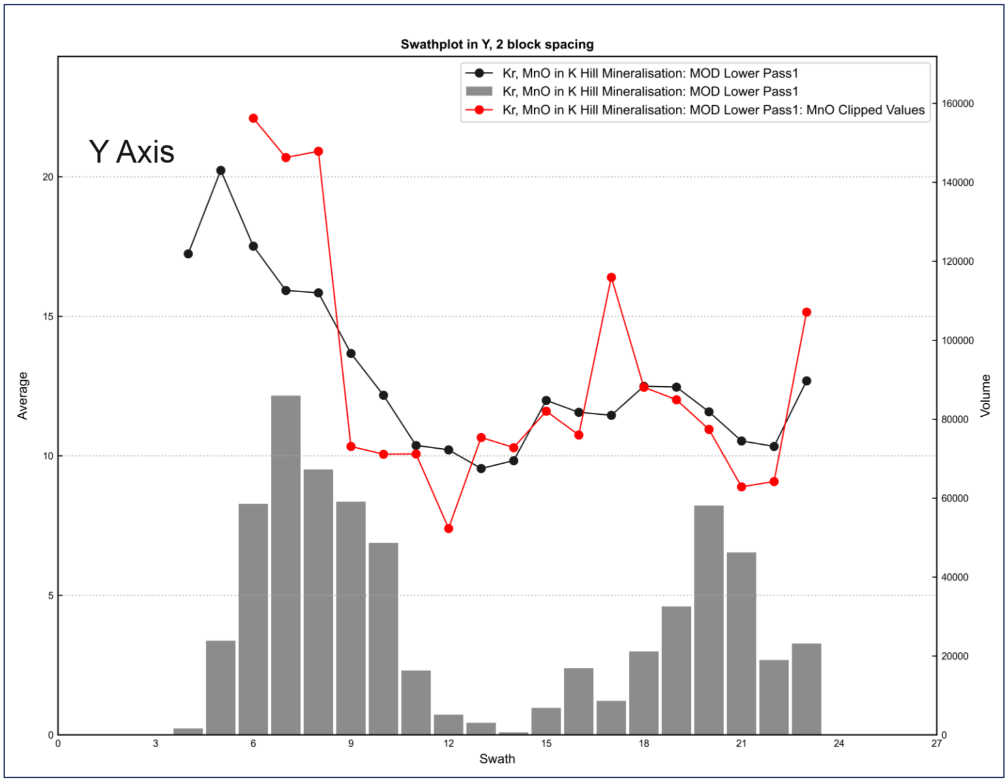


Figure 14.27 Swath plots for manganese oxide in the C domain

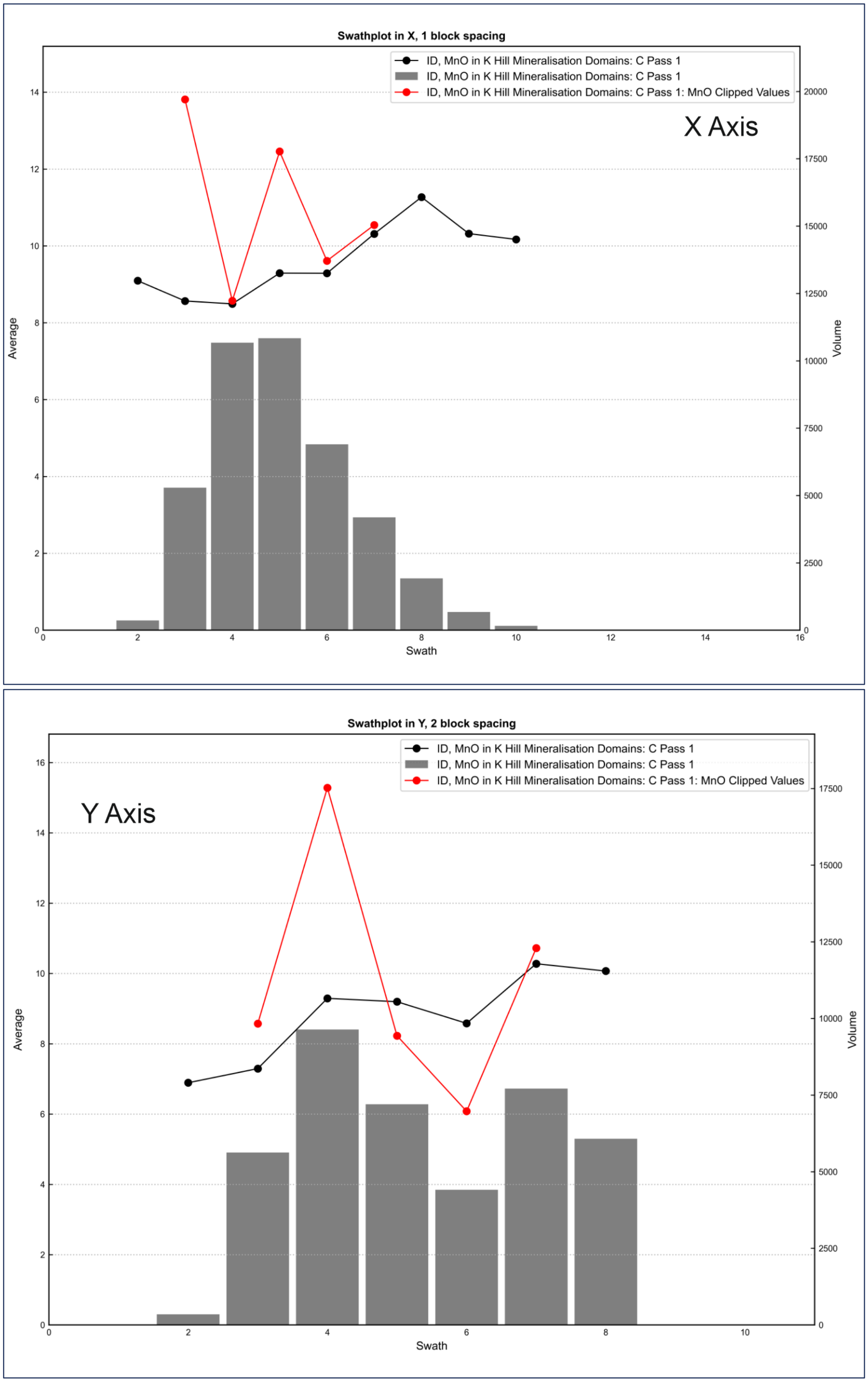


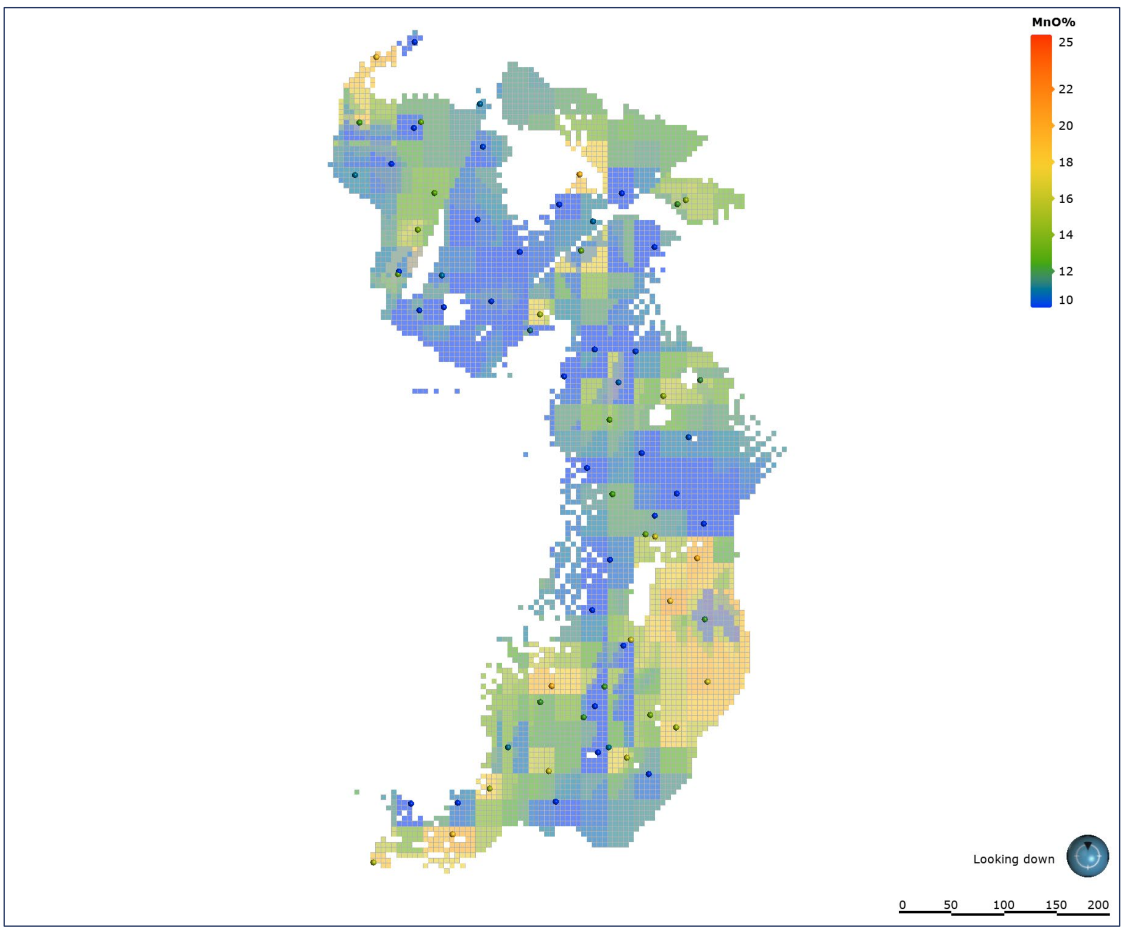
Table 14.9 Comparison of mean of the composite data with the mean of the model data

Domain	Composite mean grade (%)					Block model mean grade (%)					Percentage difference (%)				
	MnO	Al_2O_3	Fe_2O_3	LOI	SiO_2	MnO	Al_2O_3	Fe_2O_3	LOI	SiO_2	MnO	Al_2O_3	Fe_2O_3	LOI	SiO_2
Northern A1	11.55	11.56	10.65	5.62	54.83	11.85	11.81	11.24	5.82	53.35	3	2	6	4	-3
Northern A2	31.29	9.97	19.26	9.99	21.86	29.93	10.25	19.40	9.81	22.63	-4	3	1	-2	4
Northern A3	10.86	11.78	13.04	4.97	53.22	10.89	11.56	13.81	4.97	52.63	0	-2	6	0	-1
Northern B	13.23	9.68	11.93	6.11	53.55	14.32	9.01	12.66	6.56	52.03	8	-7	6	7	-3
Northern C	10.90	9.15	14.30	6.56	54.90	9.20	9.33	14.55	6.54	55.89	-16	2	2	0	2
Southern A1	28.07	8.10	8.96	8.60	39.22	28.33	8.40	8.97	8.97	36.60	1	4	0	4	-7
Southern A2	11.23	8.60	8.80	7.90	53.10	9.88	7.89	7.55	7.55	54.40	-12	-8	-14	-4	2
Southern A3	12.33	6.30	7.70	5.70	52.25	12.28	7.29	8.53	6.16	56.82	0	16	11	8	9
Southern B	18.20	7.40	10.82	7.40	49.60	17.45	7.21	10.78	7.26	51.10	-4	-3	0	-2	3
Southern C1	14.11	9.20	13.82	8.54	45.98	13.01	8.44	10.52	10.52	44.36	-8	-8	-24	23	-4
Southern C2	14.60	7.50	9.15	6.13	56.60	14.30	7.28	9.50	6.38	46.55	-2	-3	4	4	-18

The block model grades largely correspond well with the input sample data. It is noted that the block model average manganese oxide grade in Northern domain C is 16% lower than the raw composite sample mean. This is due to the presence of a single high-grade composite (18.98% manganese oxide) that is well constrained by other samples. In Southern domain A2, the manganese oxide block grade is 12% lower than the sample mean grade. Some over-smoothing may be occurring. Given the limited number of sample points in the domain, this is considered acceptable.

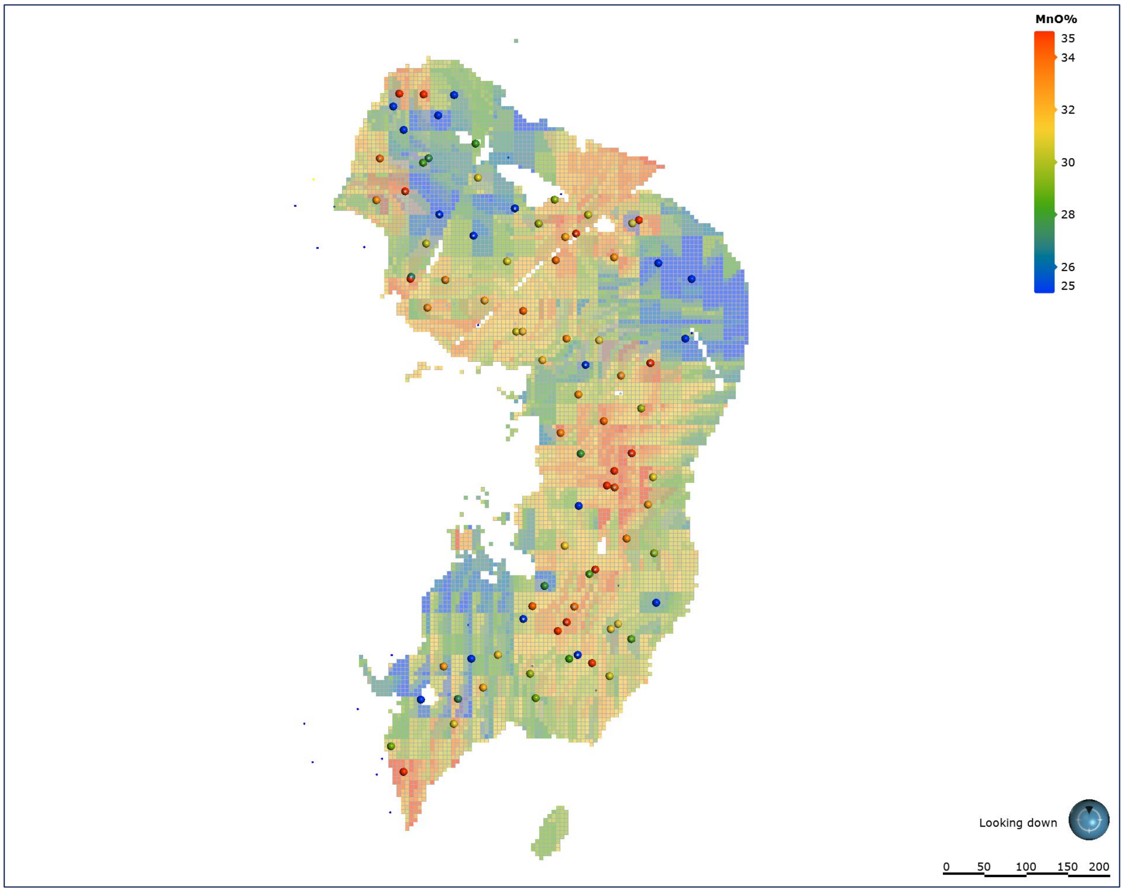
Plan view images of the Northern domain block estimates, coloured by manganese oxide grade, alongside the drillhole manganese oxide grades composited to a single composite grade per drillhole intersection, are also provided in Figure 14.28 to Figure 14.32. Figure 14.33 to Figure 14.38 show plan view images of the Northern domain block estimates, coloured by manganese oxide grade with associated drill hole grades. The plans visually confirm that the block model is representative of the composite input data. Figure 14.39 shows a plan view of the entire K.Hill Project block model manganese oxide grades for all domains.

Figure 14.28 Plan view of the A1 Northern domain block model, coloured by manganese oxide grade, shown alongside the drillhole grades (as points)



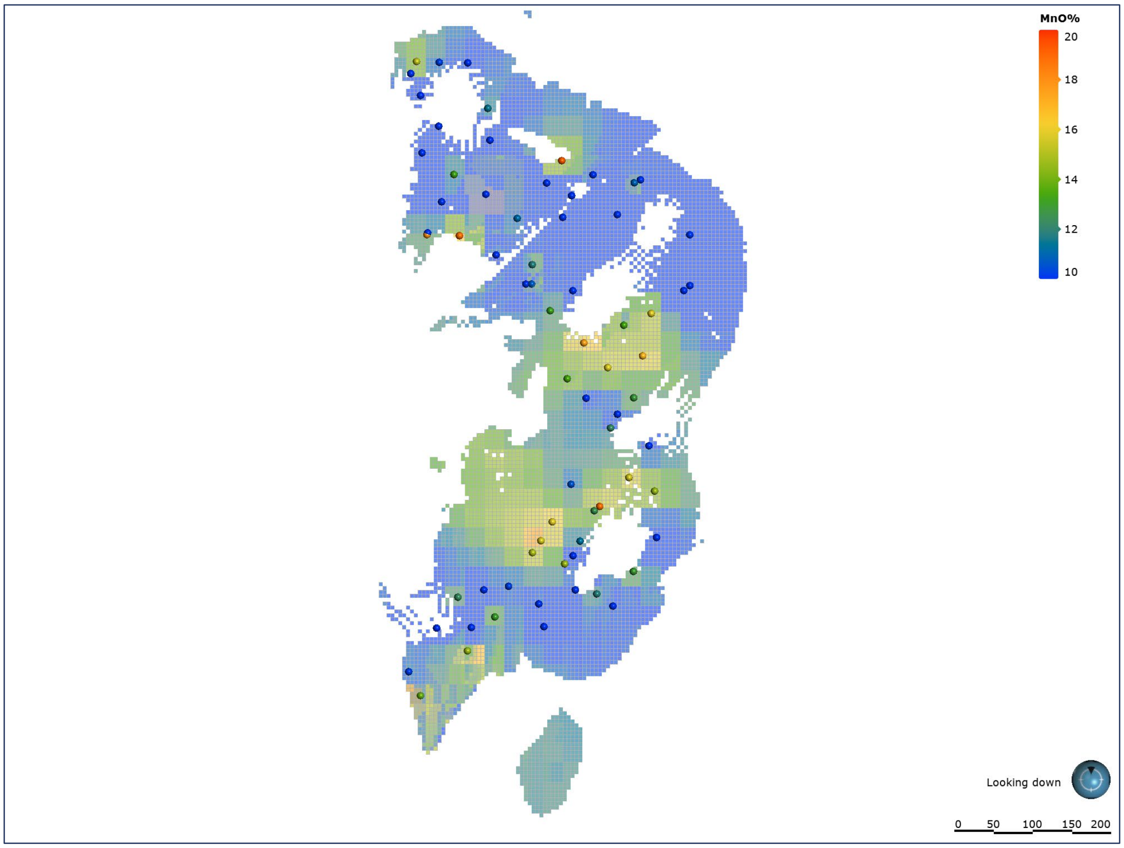
Note: Scale is in metres; arrow points north.

Figure 14.29 Plan view of the A2 Northern domain block model, coloured by manganese oxide grade, shown alongside the single composite drillhole grades (as points)



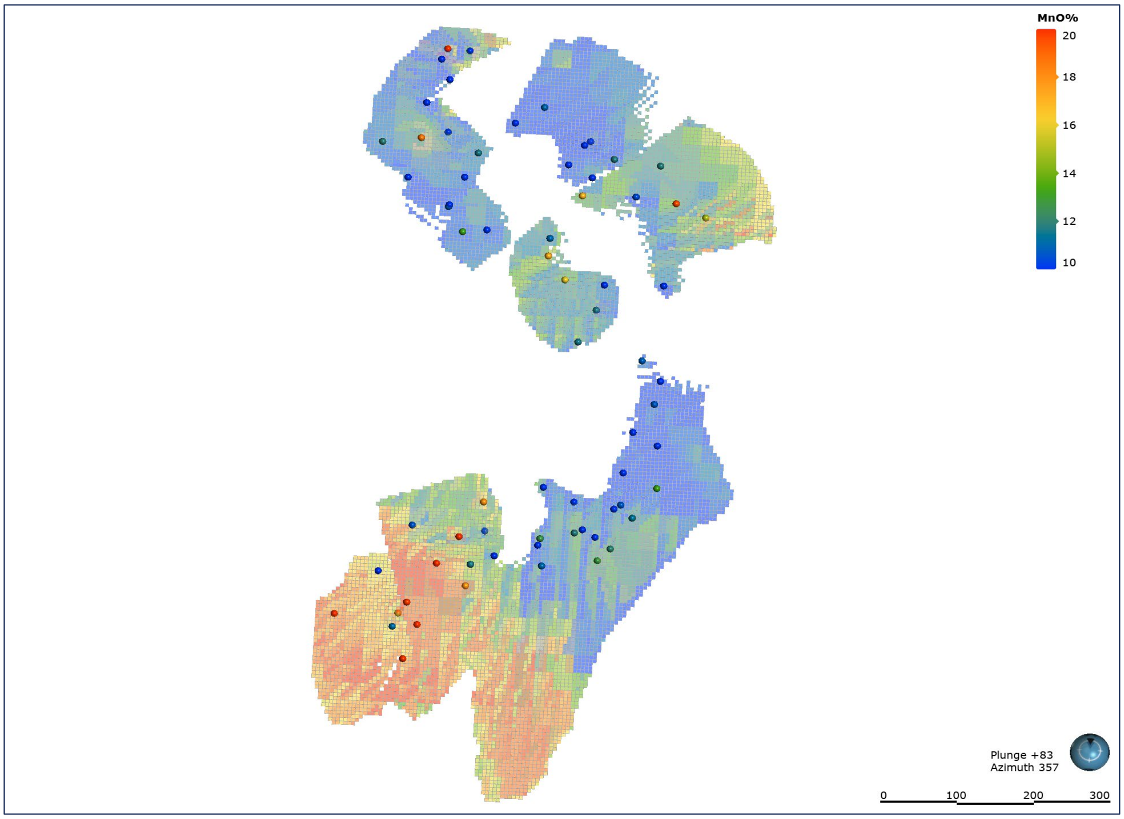
Note: Scale is in metres; arrow points north.

Figure 14.30 Plan view of the A3 Northern domain block model, coloured by manganese oxide grade, shown alongside the drillhole grades (as points)



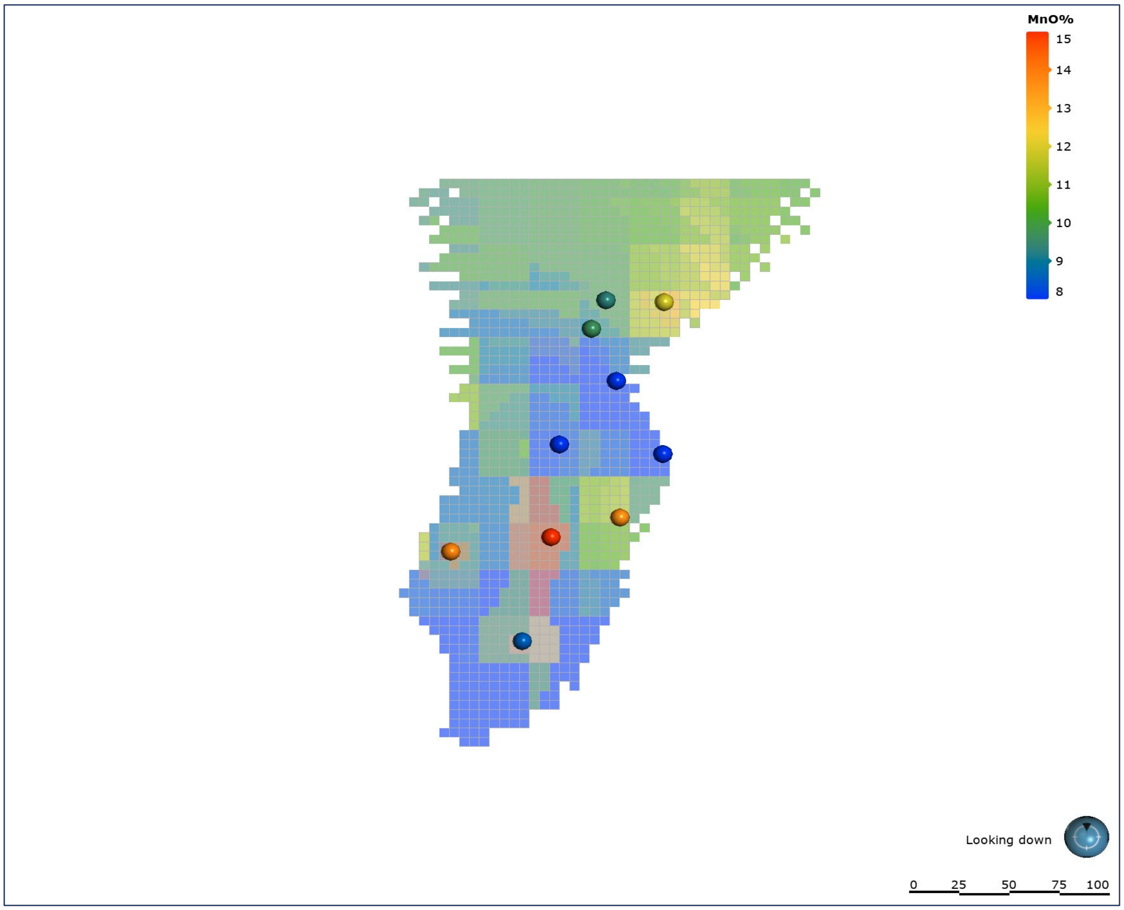
Note: Scale is in metres; arrow points north.

Figure 14.31 Plan view of the B Northern domain block model, coloured by manganese oxide grade, shown alongside the drillhole grades (as points)



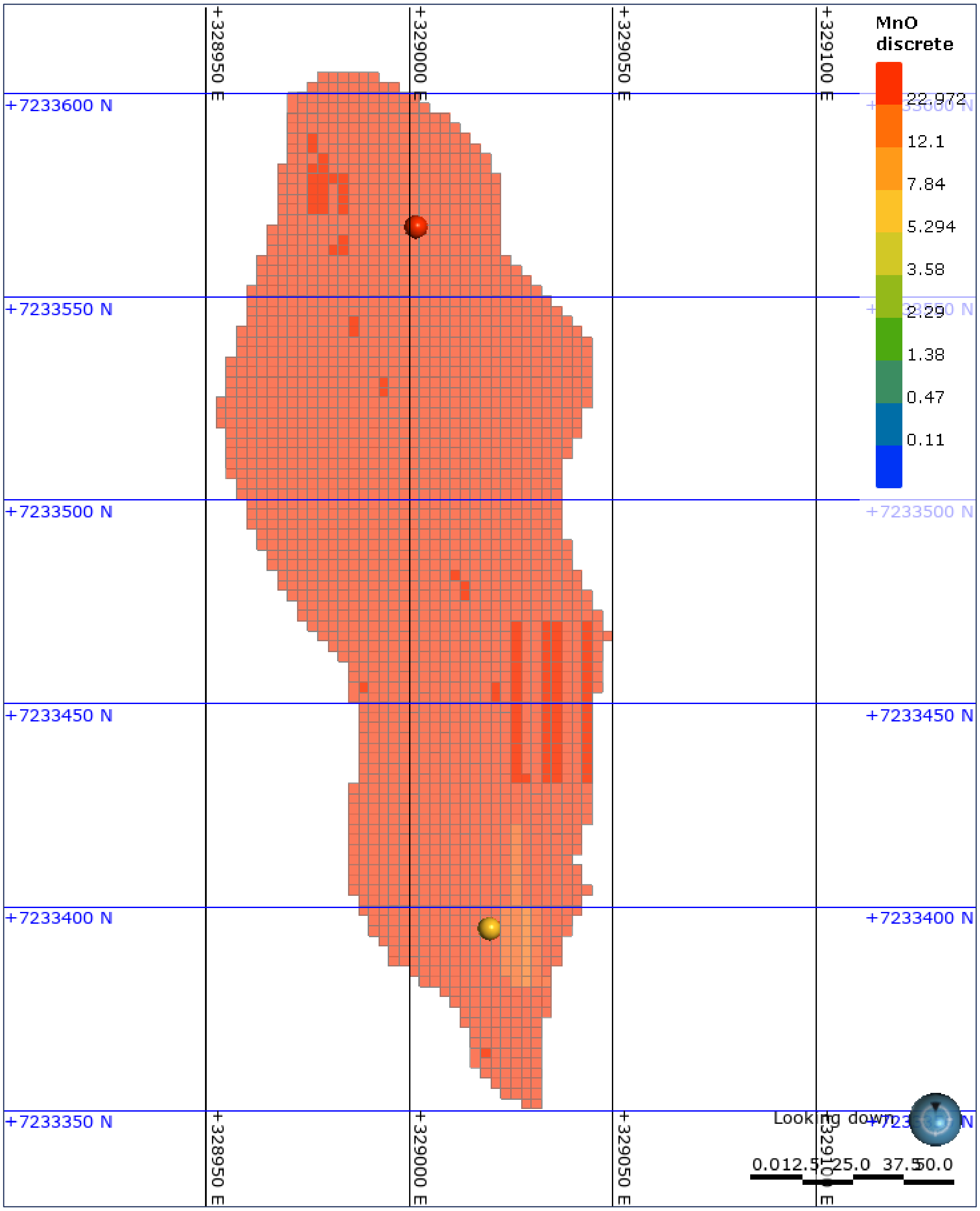
Note: Scale is in metres; arrow points north.

Figure 14.32 Plan view of the C Northern domain block model, coloured by manganese oxide grade, shown alongside the drillhole grades (as points)



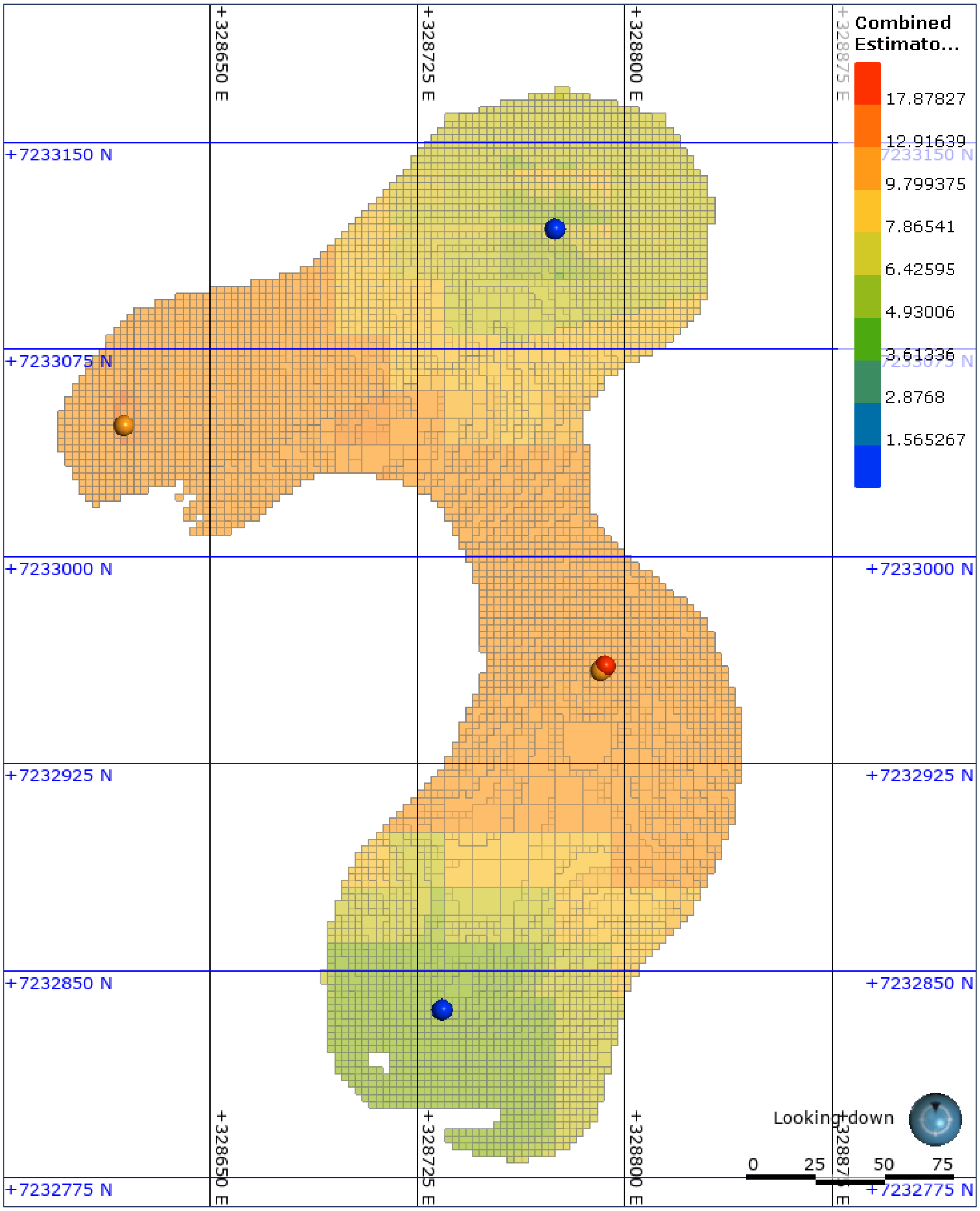
Note: Scale is in metres; arrow points north.

Figure 14.33 Plan view of the A1 Southern domain block model, coloured by manganese oxide grade, shown alongside the drillhole grades (as points)



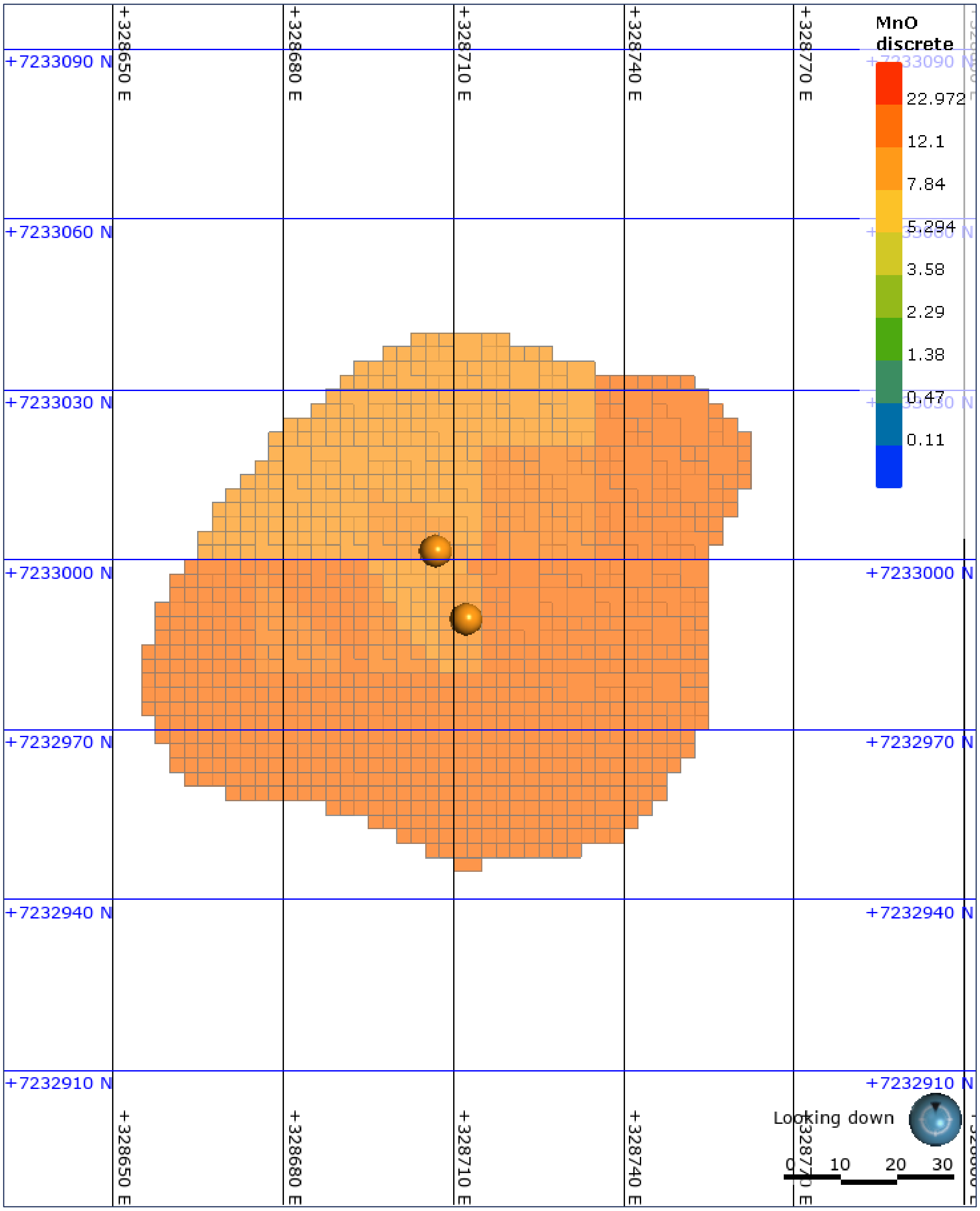
Note: Scale is in metres; arrow points north.

Figure 14.34 Plan view of the A2 Southern domain block model, coloured by manganese oxide grade, shown alongside the drillhole grades (as points)



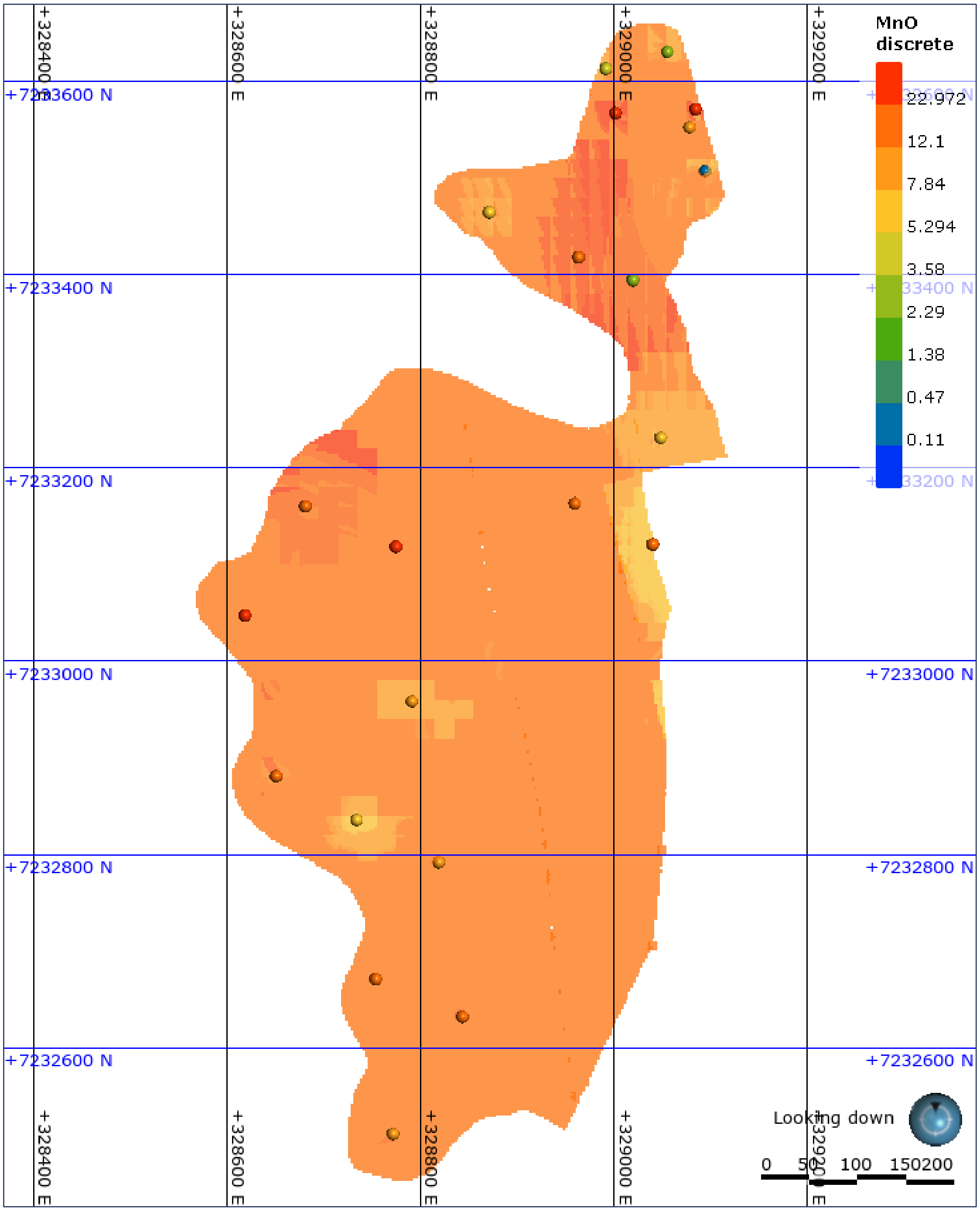
Note: Scale is in metres; arrow points north.

Figure 14.35 Plan view of the A3 Southern domain block model, coloured by manganese oxide grade, shown alongside the drillhole grades (as points)



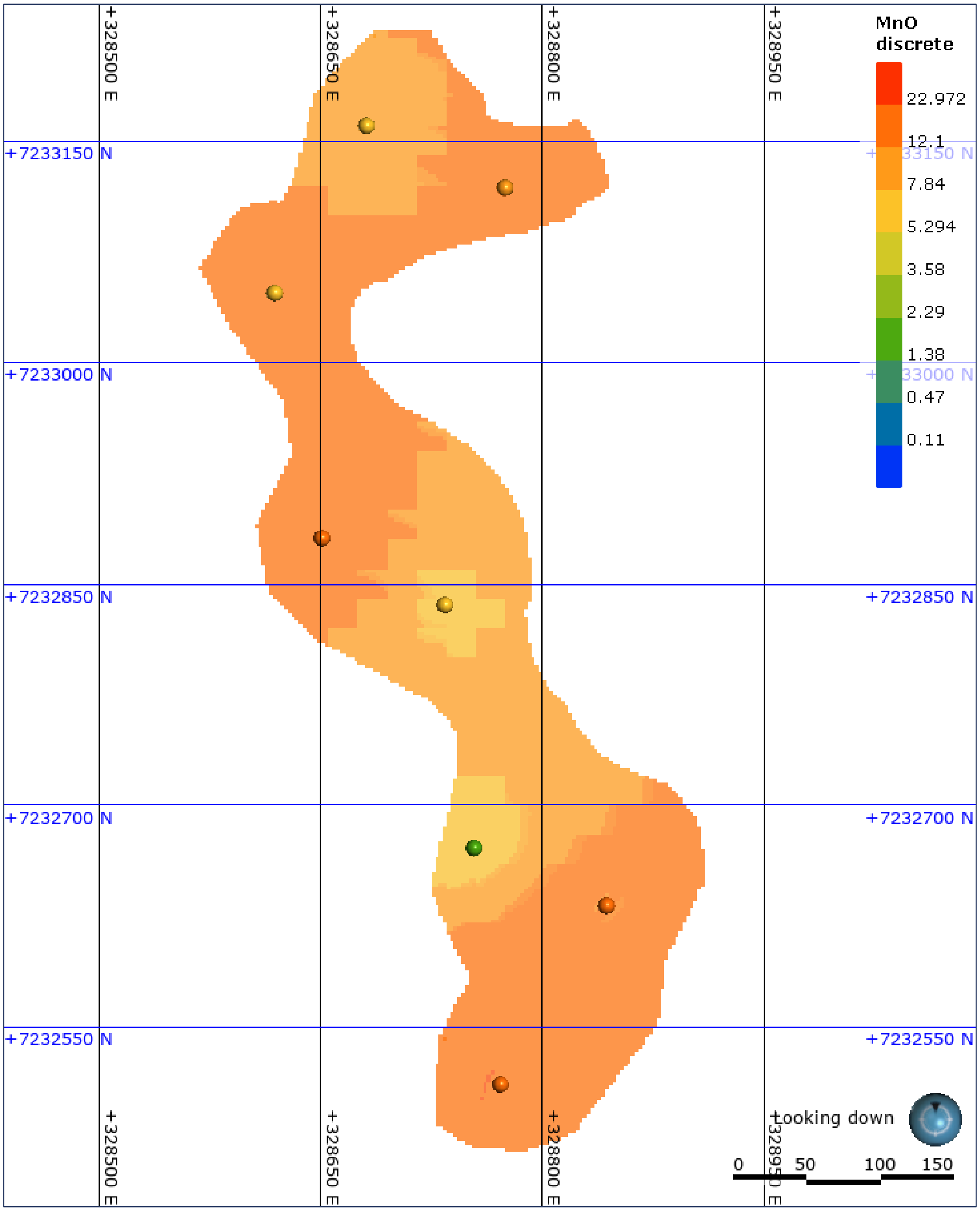
Note: Scale is in metres; arrow points north.

Figure 14.36 Plan view of the B Southern domain block model, coloured by manganese oxide grade, shown alongside the drillhole grades (as points)



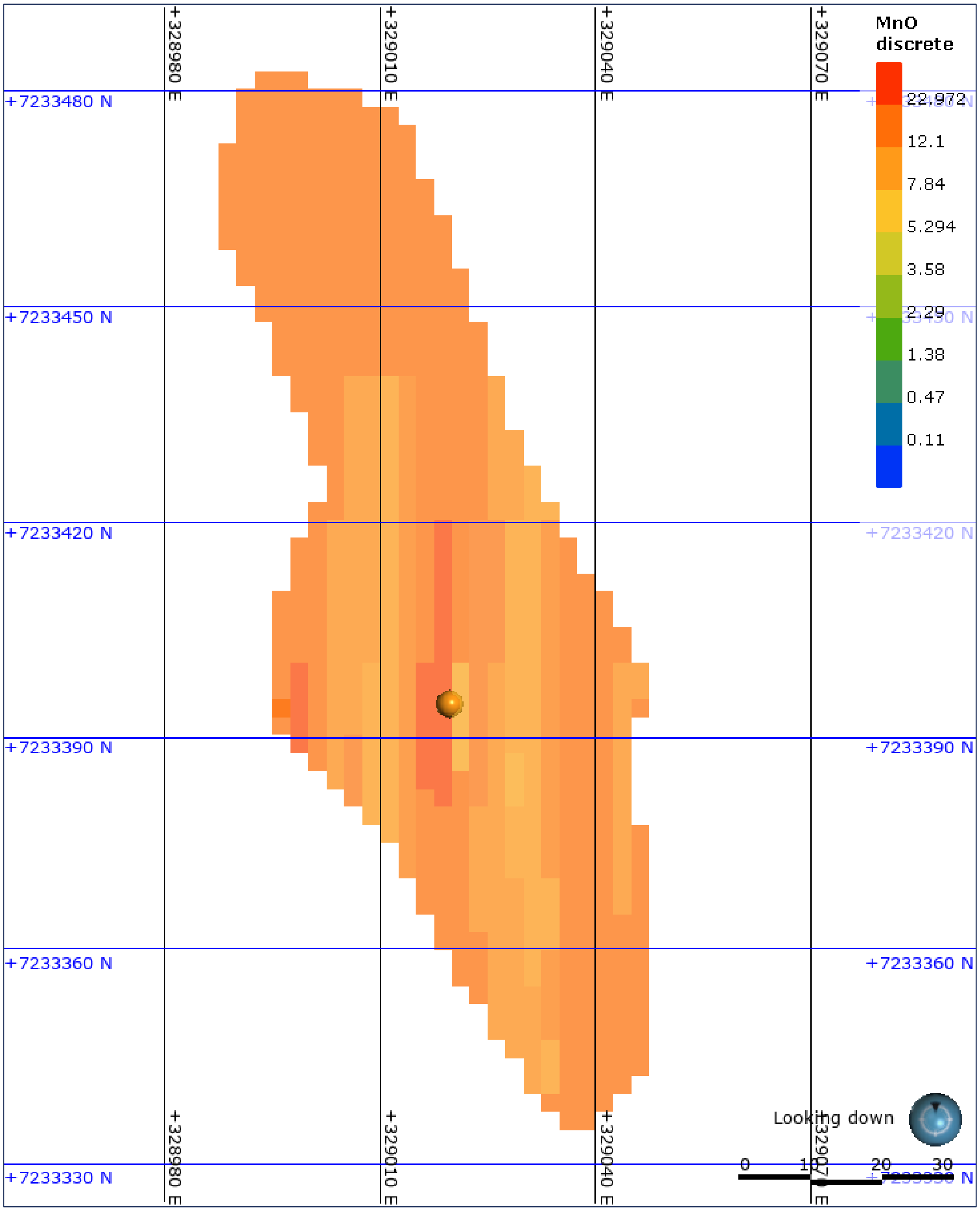
Note: Scale is in metres; arrow points north.

Figure 14.37 Plan view of the C1 Southern domain block model, coloured by manganese oxide grade, shown alongside the drillhole grades (as points)



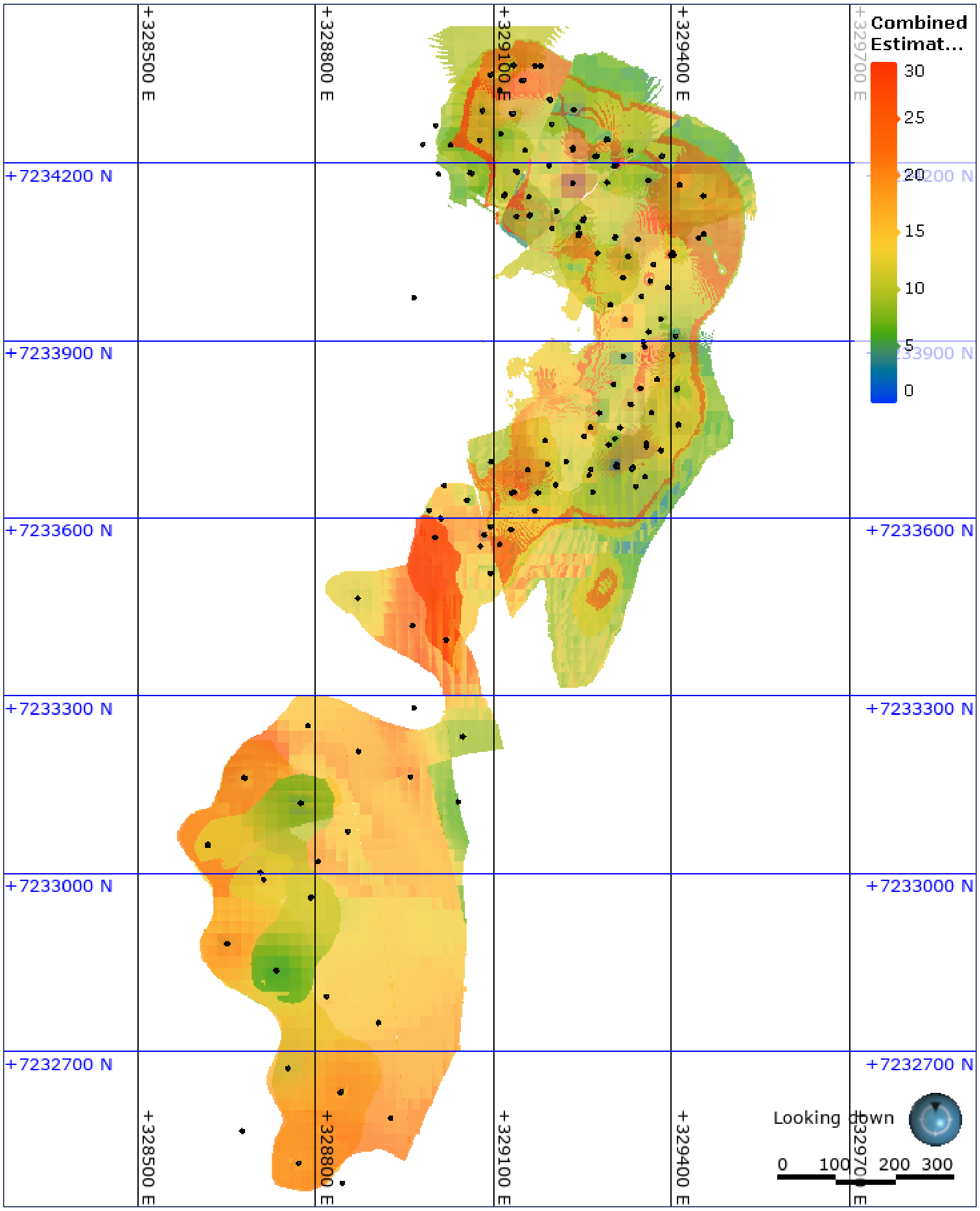
Note: Scale is in metres; arrow points north.

Figure 14.38 Plan view of the C2 Southern domain block model, coloured by manganese oxide grade, shown alongside the drillhole grades (as points)



Note: Scale is in metres; arrow points north.

Figure 14.39 Plan view of entire K.Hill Project resource block model, coloured by manganese oxide grade with drill collars shown in black



Note: Scale is in metres; arrow points north.

14.9 Assignment of density to the block model for tonnage estimation

SRK was provided with a number of different density datasets and has analysed them separately in order to decide on the best approach to assign densities to the block model. The datasets are described below:

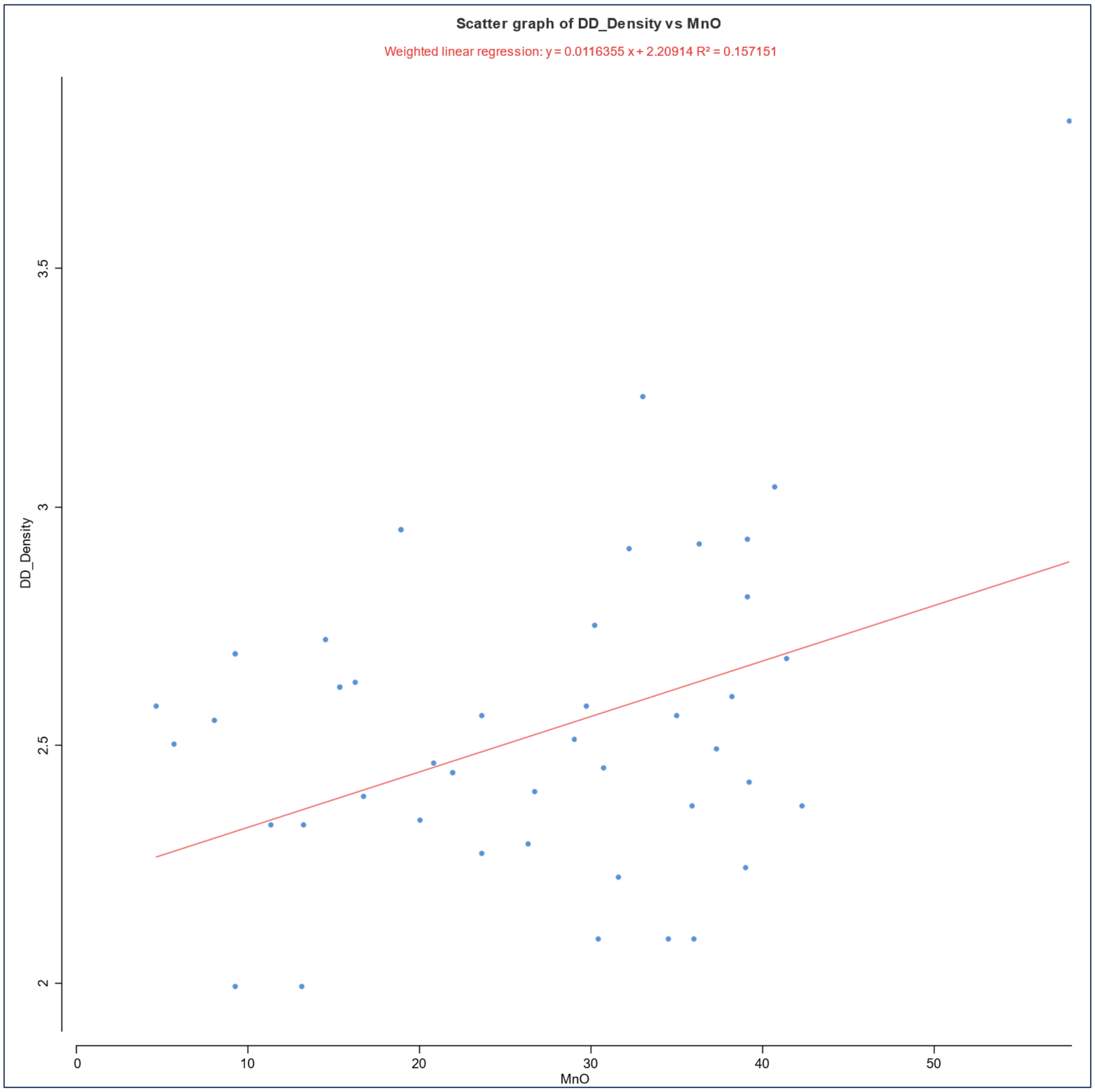
- SET 1: a dataset of 732 density samples taken from the Phase 1 DD programme and measured using the Archimedes method, of which 207 are taken within mineralisation. Core was sampled wet and not dried prior to measurement.
- SET 2: a dataset of 49 density samples taken from the Phase 2 DD programme and measured using the Archimedes method, of which 25 are taken within mineralisation. Samples were dried and wax coated prior to measurement.
- SET 3: a dataset of 30 core samples taken from outcrop using a handheld coring machine. Sample densities were calculated using the volume of the core barrel and the weight of the sample after drying rather than by the Archimedes method. All samples were taken in mineralisation.
- SET 4: a dataset of three trial pits in mineralisation where the pits were filled with water to measure volume and the excavated material was dried and weighed to calculate density. All samples were taken in mineralisation.
- SET 5: a data set of 84 samples taken from diamond core from the K.Hill Project Southern Extension Area drilling.

In the March 2021 Mineral Resource estimate, only the SET 1 dataset was available. SRK utilised this dataset and applied a 10% reduction to the density values in order to account for the assumed water content. This value was a high-level estimation and impossible to determine accurately. As a result, SRK requested that Giyani collect further density data prior to the current Mineral Resource estimate. Giyani then collected the SET 2, SET 3, and SET 4 datasets. Of these, only the SET 2 dataset provided sufficiently robust data for use in the Mineral Resource estimate. SET 3 and SET 4 datasets were disregarded after analysis, as they were taken from a single locality and showed very large variances in calculated density values. For the SET 3 dataset, this is likely due to the calculation of density based on the volume of expected material in the core barrel, and it is not possible to account for any loss of core during drilling. For the SET 4 dataset, the large variation is likely due to the fact the pits were not lined; therefore, water loss into the ground during filling is hard to account for accurately.

In deciding on an approach to assign density data to individual blocks and domains, SRK investigated the correlation between manganese oxide grade and density to create a regression. The study of the relationship between manganese oxide grade and density yielded poor results, with no clear relationship between manganese oxide grade and density identified. A scatter plot showing the relationship between the two variables is shown in Figure 14.40. SRK notes that it was only possible to conduct this analysis on the Phase 1 DD density dataset, as no assays were undertaken on core used for density determinations from the most recent Phase 3 DD programme.

SRK considers that there are insufficient samples within the SET 2 dataset to justify direct estimation of this data into the block model for the northern part of the deposit. Therefore, it was decided to apply average density values to the block model on a domain-by-domain basis. No samples are available for the thin overburden cover (OVB). As such, a standard density for soil and loose rock of 1.5 g/cm^3 was applied to this domain. Similarly, no density samples were taken within the minor Horizon C. SRK assigned an average density value from Horizon B to this domain, as both domains have a broadly similar grade profile. There are also no samples available in the SET 2 database for the FEL waste rock domain. Here, SRK used the SET 1 data, with the application of a 10% decrease in density to account for moisture content.

Figure 14.40 Scatter plot of density vs. manganese oxide grade within the three mineralised domains, taken from the Phase 1 DD programme



The Southern Extension Area domains show a significant difference in density values for the Mn-shale unit compared to the Northern domains. On average, the SG measurements for the north have a typical density of 2.1 gm/cc compared to 1.55 gm/cc for the Southern Extension Area (Figure 14.41). Whilst some 84 density samples have been obtained from 3 DD holes at the Southern Extension Area, all three holes occur in one area. A review of core from the diamond drillhole DDKKH21-030 shows highly friable, weathered material in the Mn-shale horizon, with occasional core sections that are more solid and less weathered. In addition to the diamond core there are 396 RC density measurements taken from across Mn-shale in the Southern Extension Area. Statistically, a comparison of the RC densities with that of the diamond core densities for the same horizon shows very similar average grades and with a higher variability for the RC data (Table 14.10 and Figure 14.42). This provides a level of confidence for both the RC and DD SG values. Based on these SG values for the Southern Extension Area, it is SRK's opinion that as much of the Southern Extension Area is being classified as Inferred, the use of a mean grade of 1.55 gm/cc appears reasonable. Additionally, a comparison of RC- and diamond-derived densities for the northern part of the deposit shows average values of around 2.0 gm/cc for both the DD and RC samples (1.91 RC vs. 2.3 DD).

Figure 14.41 Comparison of DD core SGs for Northern and Southern Extension Areas Mn-shale

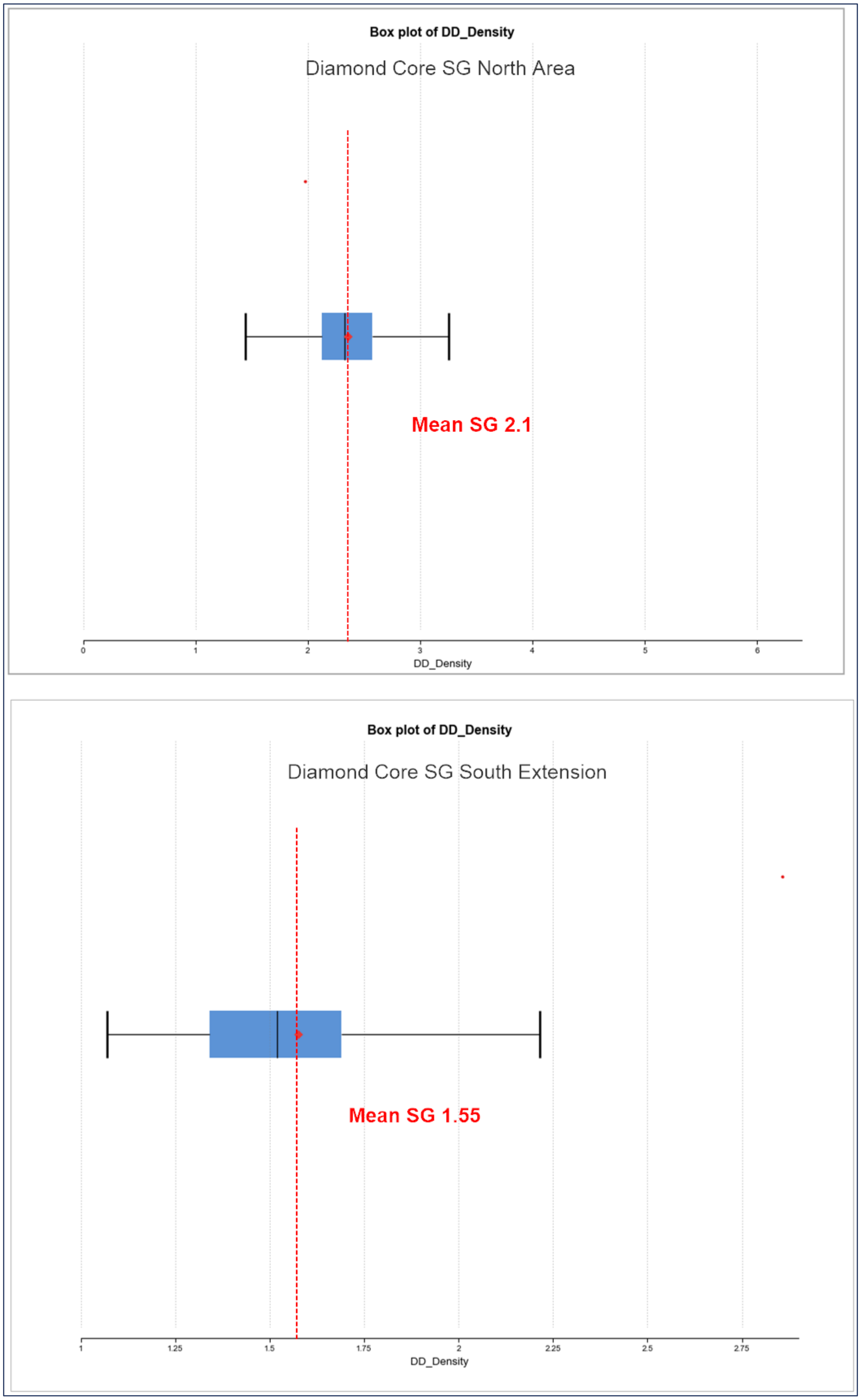


Table 14.10 Comparison of Southern Extension Area RC vs. DD densities

Statistic	RC values	DD values
Number	396	84
Mean	1.54	1.57
Coefficient of variation	0.45	0.23
Minimum	0.05	1.07
Maximum	3.92	2.83

Figure 14.42 Comparison of RC vs. DD SG measurements for the Mn-shale Southern Extension Area

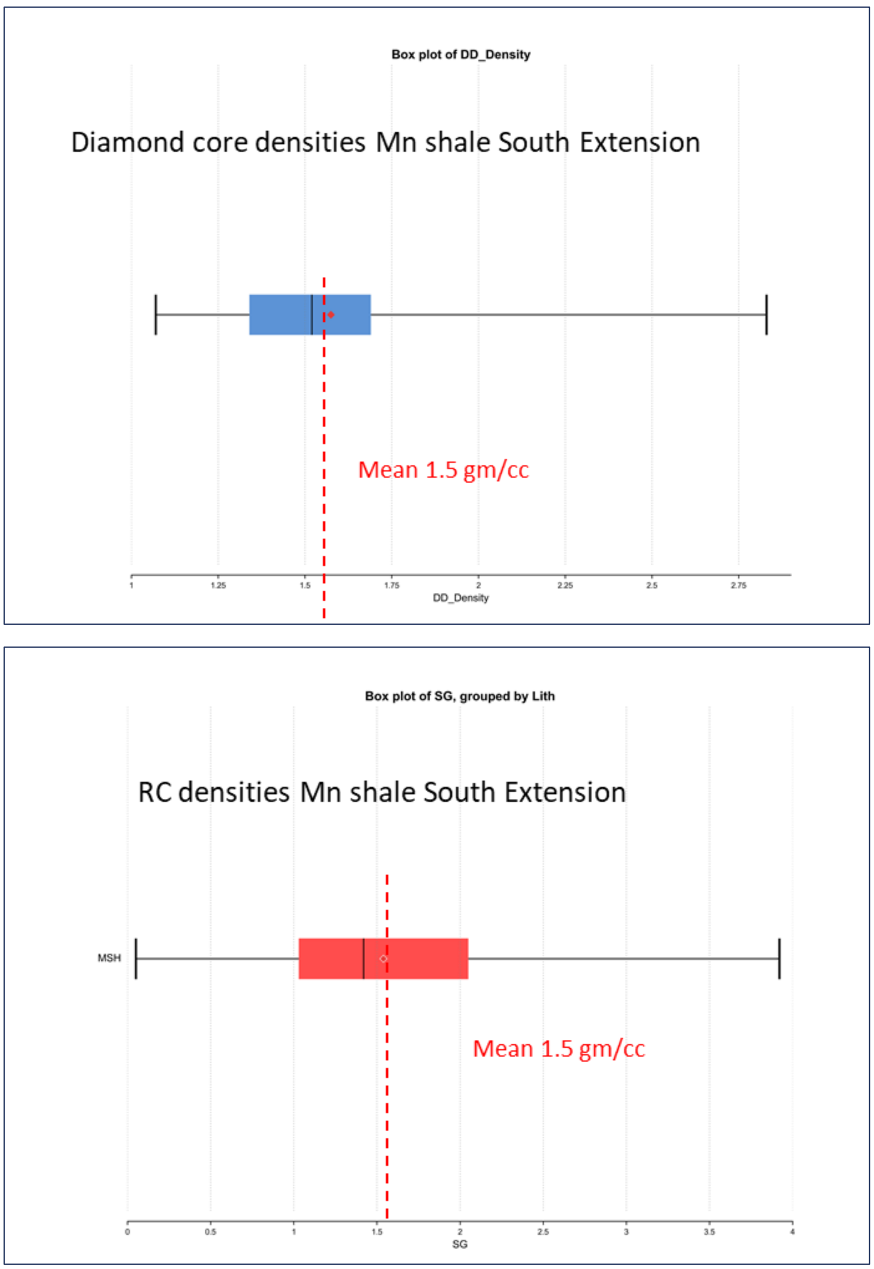


Table 14.11 provides a summary of the density and methodology used for each domain.

The allocation of accurate densities for the Mn-shale horizon is an issue. A review in the field of core and the actual samples analysed for both RC and DD core show density to be highly variable even at short distances. Observations of core and outcrop show that mineralised material can be very hard (and dense) or highly weathered and friable but still have similar grades. No bulk densities are available. Weathering of the deposit does not seem uniform and may extend up to 100 m vertically from surface. This high degree of variability both observed in the field and measured maybe directly related to weathering. Bulk sampling of the deposit is required to determine how the deposit will behave at a mining scale. Additionally, SRK recommends continued SG sampling of both RC and DD core, especially at the Southern Extension Area. This could be incorporated with downhole, geophysical, and density calliper logging of all future holes immediately following drilling. This should be done at 1 m intervals. The effect of densities on contained metal is significant.

The extent of the issue and the ability to report representative density in the Southern Extension Area requires resolution prior to considering upgrading the confidence classification as part of future Mineral Resource estimate updates.

Table 14.11 Summary of densities and methodologies applied

Domain type	Domain	Methodology	SG applied (g/cm^3)	Number of DD and RC samples
Mineralised zones	Northern A1	Average of density samples in domain from SET 2	2.18	2 DD
	Northern A2	Average of density samples in domain from SET 2	2.14	14 DD
	Northern A3	Average of density samples in domain from SET 2	2.28	5 DD
	Northern B	Average of density samples in domain from SET 2	2.32	4 DD
	Northern C	Average of samples from the B domain used from SET 2	2.32	0
	Southern A1	Average of density samples in Southern domain B from SET 5	1.55	0 DD 5 RC
	Southern A2	Average set of samples from the samples in Southern domain B from SET 5	1.55	0 DD RC 19
	Southern A3	Average set of samples from the samples in Southern domain B from SET 5	1.55	0
	Southern B	Average set of samples from the samples in domain from SET 5	1.55	30 DD RC 176
	Southern C1	Average set of samples from the samples in domain from SET 5	1.55	0 DD RC 19
	Southern C2	Average density for Southern domain B	1.55	DD RC 2

Domain type	Domain	Methodology	SG applied (g/cm³)	Number of DD and RC samples
Waste rock	OVB	Soil density applied	1.5	n/a
	CDB	Average of density samples in domain from SET 2	2.48	7 DD
	FSH 1	Average of density samples in both FSH domains from SET 2	2.01	17 DD
	FSH 2	Average of density samples in both FSH domains from SET 2	2.01	17 DD
	FEL	Average taken from SET 1 dataset, with 10% reduction applied	2.38	22 DD

14.10 Classification

The K.Hill Project Mineral Resource has been classified based on confidence in the data, confidence in the geological model, grade continuity and variability, and the frequency of the drilling data. The main considerations in the classification of the Mineral Resource are as follows:

- There is confidence in the accuracy and precision of the assay data, which is considered appropriately robust for the reporting of a Mineral Resource.
- There is variability in the manganese oxide grade within the Upper Mn-shale domains.
- The extent of the mineralisation is based on mapped outcrops and geological confidence in the extent of the mineralisation horizons, but there is recognition that the local-scale variability in terms of thickness/morphology and grade requires further investigation.
- The drilling recoveries in the Phase 1 DD programme are very poor due to the friable nature of the near surface material; however, significant improvements in drilling technique have been made, allowing for much higher recoveries in the later Phase 3 DD campaign. RC recoveries are hard to assess but do not show any systematic biases.
- Reliable density is limited, despite Giyani's best efforts to explore numerous methods of collecting density data. The reliance on a small but high-quality dataset of wax-coated dry density measurements is the most significant risk identified. SRK notes that the average values derived from the smaller wax coated density dataset correlate well with the average values derived from the much larger "wet density" dataset used in the previous Mineral Resource estimate, once the 10% reduction in density has been applied to account for the presence of water. In the Southern Extension Area this problem still persists, with core providing poor density values in terms of reliability due to weathering of the core, whilst a review of the RC data shows a consistency in measured SGs with that of the core, albeit with significantly more samples across a broader area.
- The topographic survey used to limit the vertical extent of the geological interpretation and block model is considered to have a high degree of accuracy.
- The extent of underground workings is reasonably well understood. SRK notes that there is a potential risk that additional underground workings of significance may exist which have not been currently identified.

- The drillhole collars were measured using a DGPS; thus, the X and Y collar locations have a high degree of accuracy and precision.
- Direct metallurgical test work has been undertaken on material from the A, B, and C horizons in the north but not south. At this stage, it is unclear whether the material in the Southern domains will have the same comminution and processing characteristics as the tested material from the Northern horizons. Until detailed test work on the Southern domains has been completed, the processing characteristics of these six horizons remain an unknown, and this has been considered in the classification of the updated Mineral Resource

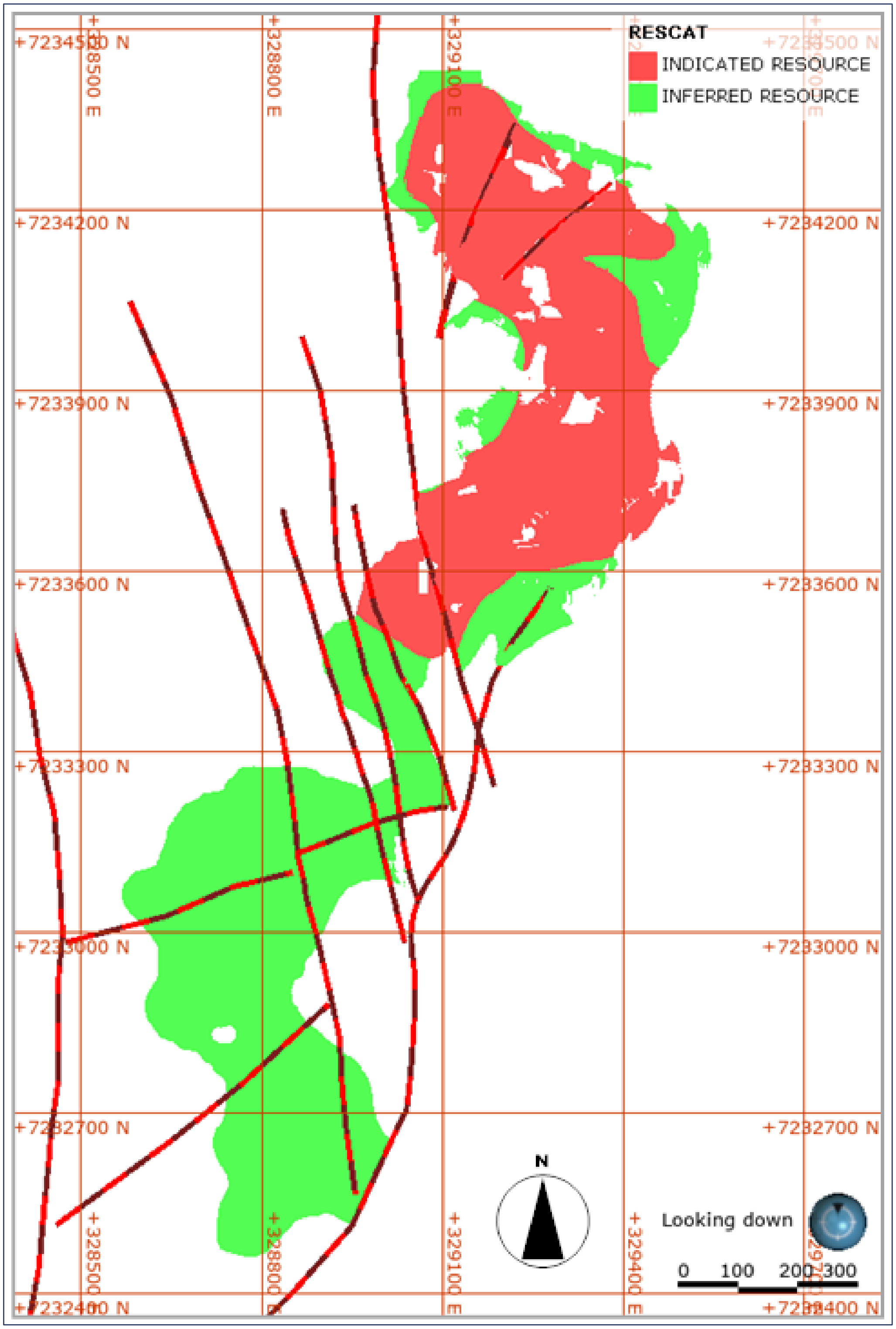
Given the above-noted considerations, SRK has classified the Northern A1, A2, A3, and B domains as Indicated Mineral Resources for all blocks within 40 m of a drillhole and Inferred Mineral Resources for areas with adequate geological support and informed by a drilling greater than 40 m spacing. A small portion of the Northern A1, A2, and A3 horizons have not been classified at the margins where poor geological and drilling support exists. SRK has classified the Northern Horizon C as Inferred Mineral Resources due to the reasonable level of geological and grade confidence, but current lack of appropriate metallurgical test work, which is ongoing. As with the A horizons, a small portion of the B and C horizons have not been classified at the margins where poor geological and drilling support exists.

The entirety of the Southern domains (A1, A2, A3, B, C1, and C2) have been classified as Inferred Mineral Resources, with some material at the margins of the resource unclassified. At this stage, the geological understanding of the Southern Extension Area is poor due to the limited drilling and structural complexity (faulting). The drill sample spacing (approximately 125 m × 125 m), geological complexity, and grade continuity in SRK's opinion is only sufficient in part to provide an Inferred level of classification. No metallurgical test work has been completed in this area. SRK considers it is reasonable to assume that the metallurgical characteristics of the Southern Horizon B will be similar to that for the Northern Horizon B at this stage of the study.

Plan views of the classified domains are provided in Figure 14.43. All other estimation domains, as well as the areas impacted by artisanal mining, are not considered as part of the Mineral Resource.

SRK has provided a series of recommendations (Section 26) on steps required to improve confidence in the data quality, geological and grade continuity, and grade/tonnage estimation.

Figure 14.43 Plan of K.Hill Project coloured by classification (A, B, and C horizons combined)



Notes: Drill collars used to estimate the Mineral Resource are displayed as points; scale is in metres; red lines are main interpreted faults.

14.11 Reasonable prospects for eventual economic extraction

In order to assess the quantities of material offering "reasonable prospects for eventual economic extraction," have been applied according to Australasian Joint Ore Reserves Committee (JORC; 2012). SRK has completed a pit optimisation study based on economic and mining assumptions to evaluate the proportions of the block model that could be "reasonably expected" to be mined from an open pit.

The open pit optimisation was undertaken using NPV Scheduler software. NPV Scheduler uses the Lerchs-Grossmann algorithm for determining the shape of an optimal pit using a set of input parameters. The Project assumes the production of an HPMSM product. For the purposes of the pit optimisation study, SRK has applied a long-term price for HPMSM of US$1,588/t cost and freight (CFR) Japan/Korea, based on market data supplied by a third-party marketing consultant acting on behalf of Giyani (this price was applied prior to receiving the CPM market study report outlined in Section 19).

SRK notes that the long-term HPMSM price quoted is based on 2020 market data, which was available at the time of reporting the Mineral Resource. SRK understands that additional pricing information will be available for input into subsequent technical studies, and this may impact on the Mineral Resource reported. In light of the lack of sensitivity of the Mineral Resource to the selling price, this is not considered to be a material risk in reporting the Mineral Resource and may present a further opportunity.

The pit optimisation parameters are outlined in detail in Table 14.12 and include consideration for the relevant operating costs, selling costs (incorporation of freight charges to reflect free on board [FOB] pricing and royalties).

Table 14.12 Pit optimisation parameters

Parameters	Units	Base case
Production		
Production rate - ROM	t/a	200,000
Geotechnical	-	-
Overall slope angle	degrees	41
Mining factors		
Dilution	%	3
Recovery	%	98
Processing	-	-
Total process recovery MnO	%	90.7
Operating costs	-	-
Mining cost	US$/t rock	3.46
Processing	US$/t ROM	213.0
Selling cost Mn	%	3.0
	US$/t MnO	114.0
G&A	US$/a	3,500,000
	US$/t ROM	20.0

Parameters	Units	Base case
Metal price		
MnO	US$/t	3,784
HPMSM	US$/t	1,588
Other		
Discount rate	%	10
Cut-off grade		
Marginal	% MnO	7.3

SRK notes that the pit optimisation and the pit selected is relatively insensitive to changes in product pricing above a HPMSM price of approximately US$1,000/t (approximate 9% reduction in reported metal using a pit at this price).

In addition to the application of a pit shell for reporting, the Mineral Resource is reported above a marginal cut-off grade of 7.3% manganese oxide, calculated based on the parameters outlined in Table 14.12.

14.12 Mineral resource statement

The Mineral Resource statement reported herein has been restricted to all classified material falling within the optimised pit shells described in Section 14.11 representing an HPMSM price of US$1,588/t and through the application of the parameters outlined in Table 14.12. Additionally, the Mineral Resource is reported above a cut-off grade of 7.3% manganese oxide. This represents the material that SRK considers has reasonable prospects for eventual economic extraction.

The Mineral Resource has been classified according to the CIM *Estimation of Mineral Resources & Mineral Reserves Best Practice Guidelines* (CIM 2019) and is reported in accordance with the 2014 *CIM Definition Standards for Mineral Resources & Mineral Reserves* (CIM 2014), which have been incorporated by reference into NI 43-101 *Standards of Disclosure for Mineral Projects* (CSA 2016). The Mineral Resource is classified into the Indicated and Inferred Mineral Resource categories as shown in Table 14.13.

The QP, in accordance with the CIM Code, with responsibility for the reporting of the Mineral Resource statement presented herein, is Mr. Peter Gleeson, MSc, CEng, MIMMM, AIGS, Mr. Gleeson has the relevant experience in reporting Mineral Resources on various base, precious, and ferrous metal assets globally. The internal peer review for this report was carried out by Dr. Tim Lucks, MAusIMM (CP), who is an employee of SRK. The role of Dr. Lucks is to ensure that the highest standard of technical work is carried out.

Mineral Resources are not Mineral Reserves and have not demonstrated economic viability. SRK is not aware of any factors (environmental, permitting, legal, title, taxation, socio-economic, marketing, political, or other relevant factors) that have materially affected the Mineral Resource estimate. It is uncertain if further exploration will convert Inferred and Indicated Mineral Resources to higher confidence categories.

Table 14.13 K.Hill Project Mineral Resource statement, reported within an optimised shell and at a cut-off grade of 7.3% manganese oxide, as of 16th February 2022

Classification	Tonnes (Mt)	MnO (%)	Al_2O_3 (%)	SiO_2 (%)	Fe_2O_3 (%)	LOI (%)
Indicated Mineral Resources	2.1	19.3	10.56	41.17	16.66	7.37
Inferred Mineral Resources	3.1	16.9	7.6	49.70	11.50	7.46

Notes:

(1) The Indicated and Inferred Mineral Resources are reported above a cut-off grade of 7.3% MnO.

(2) All tonnages are reported as dry.

(3) The Mineral Resource estimate is constrained within estimation domains based on geological modelling and grade and within a Lerchs-Grossman optimised pit shell based on an HPMSM price of US$1,588/t and the following technical-economic parameters:

  a. Mining Cost: US$3.46/t rock
  b. Processing Cost: US$213/t ROM
  c. Selling Cost: 3% and a freight cost of US$60/t HPMSM
  d. G&A: US$20/t ROM
  e. Discount Rate: 10%
  f. Processing Recovery: 90.7%
  g. Mining Recovery: 98%
  h. Mining Dilution: 3%
  i. Geotechnical Slope Angle: 41°

(4) SRK notes that the long-term HPMSM price quoted is based on 2020 market data, which was available at the time of reporting the Mineral Resource. SRK understands that additional pricing information will be available for input into subsequent technical studies and this may impact on the Mineral Resource reported. In light of the sensitivity of the Mineral Resource to the selling price, this is not considered to be a material risk in reporting the Mineral Resource and may present a further opportunity.

(5) All figures are rounded to reflect the relative accuracy of the estimates.

(6) Mineral Resources are not Mineral Reserves and have not demonstrated economic viability.

(7) It is uncertain if further exploration will convert Inferred Mineral Resources to higher confidence categories.

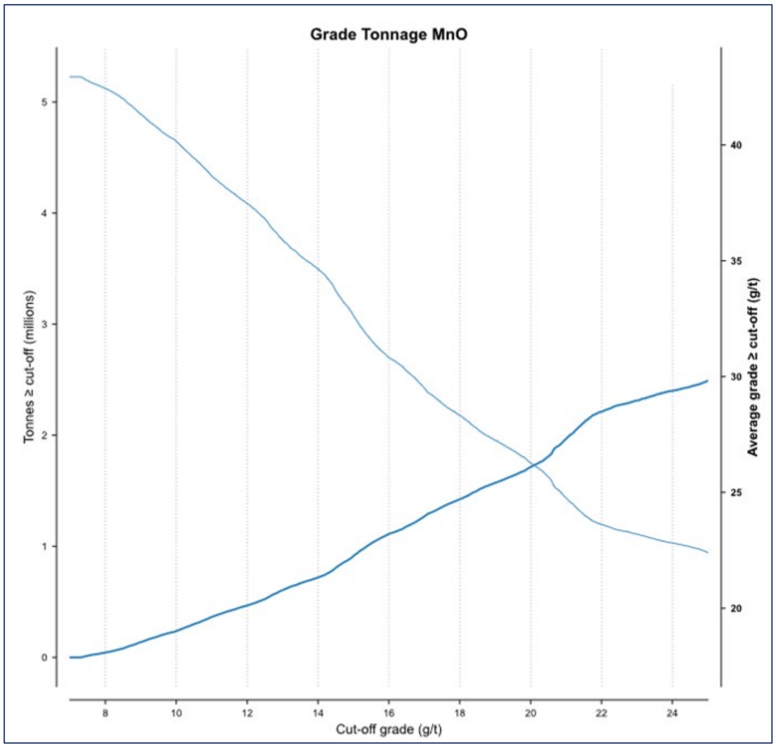
Table 14.14 K.Hill Project Mineral Resource, reported by estimation domain

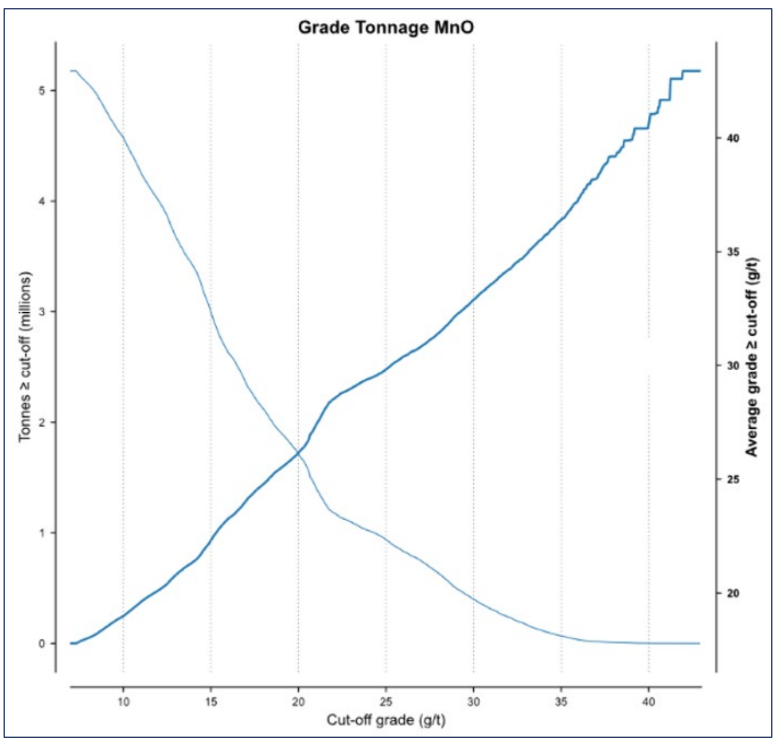
Northern and Southern Resource domains January 2022	Resource Category	Mass (Mt)	Average value MnO (%)	Metal content MnO (Mt)
Northern Horizon A1	Indicated Resource	0.31	12.2	0.04
	Inferred Resource	0.01	11.4	0.00
Northern Horizon A2	Indicated Resource	0.86	29.0	0.25
	Inferred Resource	0.08	27.1	0.20
Northern Horizon A3	Indicated Resource	0.4	11.5	0.05
	Inferred Resource	0.1	10.2	0.01
Northern Horizon B	Indicated Resource	0.39	12.0	0.05
	Inferred Resource	0.18	13.0	0.02
Northern Horizon C	Indicated Resource	0.04	10.0	0.00
	Inferred Resource	0.02	9.9	0.00
Southern Horizon A1	Indicated Resource	0.02	28.7	0.01
	Inferred Resource	0.03	28.1	0.01
Southern Horizon A2	Indicated Resource	-	-	-
	Inferred Resource	0.17	10.6	0.02
Southern Horizon A3	Indicated Resource	-	-	-
	Inferred Resource	0.02	12.3	0.00
Southern Horizon B	Indicated Resource	0.08	18.0	0.01
	Inferred Resource	2.26	18.0	0.41
Southern Horizon C1	Indicated Resource	-	-	-
	Inferred Resource	0.23	14.0	0.30
Southern Horizon C2	Indicated Resource	-	-	-
	Inferred Resource	0.03	15.5	0.00
Total	**Indicated Resource**	**2.1**	**19.3**	**0.41**
	Inferred Resource	**3.1**	**16.9**	**0.53**

14.13 Grade/tonnage curves

Figure 14.44 shows the manganese oxide grade/tonnage curve for all Indicated and Inferred blocks that fall inside the optimised pit shell. The grade and tonnage estimates are relatively insensitive up to the applied cut-off grade, i.e., up to approximately 7% manganese oxide. At increasing cut-off grades, there is a steep reduction in tonnage and increase in grade.

Figure 14.44 Manganese oxide grade/tonnage curve for all Indicated and Inferred blocks above the optimised pit shell. Notes: thick blue line shows manganese oxide percentage; thin blue line shows tonnage (Mt). Upper image is zoomed in on lower cut-off grades.





14.14 Comparison to previous Mineral Resource estimates

SRK previously reported a Mineral Resource estimate for the K.Hill Project in September 2021. The Indicated Mineral Resource totalled 1.6 Mt at 22.0% manganese oxide, with a further 1.4 Mt at 13.9% manganese oxide in Inferred (Table 14.15 shows a comparison of the September 2021 Resource and current February 2022 Resource). The reported Mineral Resource was based on the northern mineralised domains only.

Table 14.15 Comparison of SRK March 2021 Mineral Resources, as reported by SRK 2nd September 2021 at a cut-off grade of 7.3% manganese oxide with the current February 2022 Mineral Resources (reported at same cut-off)

Classification	Tonnes (Mt)	MnO (%)	Al_2O_3 (%)	SiO_2 (%)	Fe_2O_3 (%)	LOI (%)
September 2021						
Indicated Mineral Resources	1.6	22	10.9	35.7	16.5	7.9
Inferred Mineral Resources	1.4	13.9	9.6	51.4	13.1	6.3
February 2022						
Indicated Mineral Resources	2.1	19.3	10.56	41.17	16.66	7.37
Inferred Mineral Resources	3.1	16.9	7.6	49.7	11.5	7.46

The current Mineral Resource, as reported herein, represents an updated interpretation and estimate. The updated model includes additional RC and DD data drilled in the Southern Extension Area, as well as updated density test work and a new high-resolution topographic model to allow the construction of an updated geological model. Regarding the available data and approach taken, the Mineral Resource differs from the September 2021 Mineral Resources in the following specific ways:

- An updated block model and set of estimation domains were created, based on a significantly updated drillhole database. The previous Mineral Resource estimate relied on data from an additional 28 RC holes and 3 DD holes, of which only the RC holes had laboratory analysis data that was used in the estimation of block grades. The updated database for the Mineral Resource presented herein includes 29 assayed DD holes and 131 assayed RC holes that effectively define the recently identified Southern Extension Area.
- The Northern Horizon B was re-classified as an Indicated Mineral Resource, based on the review of updated metallurgical test work, which is now complete and shows little difference in terms of metallurgy to that of the Horizon A.
- An updated density dataset was used, as described in Section 13.9. The updated data consists of including data from an additional three diamond core holes and the results of 28 RC holes. Whilst of limited coverage, the updated diamond density data is considered to be of improved accuracy relative to the density database used in the assignment of density to previous resource models, which was considered as "wet" density data and required the application of a 10% tonnage reduction factor to account for moisture content in the samples upon which determinations were completed. The RC data covers most of the Southern Extension Area.

The updated Mineral Resource estimate, as presented in Table 14.15, represents a 72% increase in total reported tonnage and a similar manganese oxide grade (17.9%), compared to the September 2021 Mineral Resource estimate. The difference in tonnage can largely be attributed to the inclusion of the Southern Extension Area mineralisation.

15 MINERAL RESERVE ESTIMATES

15.1 Introduction

The Mineral Reserve for the K.Hill Project is a subset of the Indicated Resource, as part of the Mineral Resource described in Section 14 and is supported by the engineering work described in Section 16.

Considering the absence of Measured Resources, Probable Mineral Reserves have been modified from Indicated Resources only. Inferred Resources have been set as waste. Mineral Reserves have been estimated in accordance with the CIM *Estimation of Mineral Resources & Mineral Reserves Best Practice Guidelines* (CIM 2019) and classified according to the definitions presented in *CIM Definition Standards for Mineral Resources & Mineral Reserves* (CIM 2014).

15.2 Mineral Reserve statement

As of 13th October 2022, SRK notes that the K.Hill Project has Mineral Reserves reported at a cut-off grade of 7.3% manganese oxide, consisting of 2,032 kt of ore with 18.9% manganese oxide. Modifying factors for dilution and recovery have been applied at the rate of 3% dilution at zero grade and 98% recovery applied on the Mineral Resource block model. The Mineral Reserve statement is based on an HPMSM price of US$3,800/t and an average recovery of 88.5%. The Mineral Reserve estimate is shown in Table 15.1.

Table 15.1 Mineral Reserve estimate for the K.Hill Project as of 13th October 2022

	Tonnage (kt)	MnO grade (%)	MnO contained metal (kt)
Probable Reserves	2,032	18.9	384

The QP is Mr. Michael Beare, BEng, CEng, ACSM, MIMMM, who visited the site between 16th and 18th December 2019.

SRK notes that the K.Hill Project is economic based on the Mineral Reserves stated in Table 15.1.

SRK notes that changes in the modifying factors underlying the Mineral Reserve estimate may affect the total Probable Reserves.

16 MINING METHODS

16.1 Introduction

The previously considered conventional truck-and-shovel mining method, as presented in the April 2021 Preliminary Economic Assessment (SRK 2021), has been re-evaluated and developed further for this FS. This section provides a summary of the detailed mining study report, as presented in Appendix B.

The following work has been undertaken as part of the mining study:

- pit optimisation and final pit shell selection
- strategic cutback selection and strategic mine scheduling
- pit, WRD, and stockpile design, including surface roads
- detailed mine scheduling
- haul cycle and equipment productivity estimation
- equipment and labour requirements and equipment scheduling
- development of a mining cost model based on budget pricing and an appropriately selected equipment class size
- discussion and recommendations for key operating strategies
- discussion and recommendations for pit and WRD closure strategies

16.2 Geological model

SRK developed a geological model for use in the Mineral Resource and inventory estimate (see Section 14). The block model used for the Mineral Resource and inventory estimation is called "K Hill MRE Combined North South Mineralisation FEB 2022_SUBBLOCKED MODEL.dm."

The block model extents and global inventory by material type are shown in Table 16.1 and Table 16.2, respectively.

The block model includes the main orebody situated within the hill southwest of Kanye, and extends further south than previous block models used for the K.Hill deposit.

Table 16.1 Mineral Resource block model extents

	Unit	X	Y	Z
Minimum coordinates	m	328,355	7,232,400	1,205
Maximum coordinates	m	329,715	7,234,500	1,490
Parent block size	m	20	20	1
Number of blocks	-	68	105	285

Table 16.2 Mineral Resource block model global inventory, not constrained within pit shell and no cut-off applied

	Tonnage (kt)	MnO (kt)	MnO (%)	Dry density (t/m^3)
Waste	1,193,454	0	0	2.35
Low-grade Indicated + Inferred (MnO% 7.3 to 11)	1,100	102	9.24	2.08
High-grade Indicated + Inferred (MnO% ≥11)	4,446	868	19.51	1.74

Note: Inventory includes the following material classifications: Indicated, Inferred, and waste (including unclassified material). The inventory has been depleted of all the mined-out voids specified through the block model field "MINING = 1" by implementing a zero density.

16.3 Pit optimisation

SRK ran several pit optimisations during the study with the updated input parameters and produced a mine design and a LOM plan accordingly. The latest pit optimisation parameters and results are presented in this section and assessed in the final TEM to adequately assess the financial outcome of the K.Hill Project.

16.3.1 Pit optimisation parameters

SRK ran several pit optimisations using the input parameters updated during the study. A summary of the input parameters used in the latest pit optimisation is provided in Table 16.3.

Table 16.3 Pit optimisation parameters

Parameters	Units	Reserve	Basis
Production			
Production rate	t/a	200,000	Giyani
Geotechnical			
Overall slope angle	degrees	41	SRK estimate
Mining factors			
Dilution	%	3	SRK estimate
Recovery	%	98	SRK estimate
Processing			
MnO recovery	%	88.5	Tetra Tech
Operating costs			
Mining cost	US$/t rock	3.46	SRK estimate
Processing	US$/t ore	702	Tetra Tech
Royalty	% MnO	3.0	Giyani
	US$/t MnO	78	Giyani
Product transport cost	US$/t HPMSM	47	Giyani
	US$/t MnO	112	Calculation
G&A	US$/a	3,000,000	Giyani
	US$/t ore	15	Calculation

Parameters	Units	Reserve	Basis
Metal price			
HPMSM	US$/t	3,800	Giyani
MnO	US$/t	9,055	Calculation
Other			
Discount rate	%	10	SRK estimate
Resource cut-off grade			
Marginal operating costs	US$/t ore	717	Calculation
Marginal cut-off grade	% MnO	9.14	Calculation

16.3.2 Pit optimisation geotechnical parameters

A global overall slope angle of 41° was applied for the pit optimisation, which was supported by a geotechnical assessment of the rock types within the pit, where results indicated a relatively uniform rock mass characterisation throughout. These results are shared in the geotechnical analysis provided in Section 24.1.

16.3.3 Pit optimisation results

In accordance with CIM, the Mineral Reserve classification can only contain material from the Measured and Indicated Resource categories. Therefore, the Mineral Resource shell includes both the Inferred and Indicated material, whereas the Mineral Reserve shell only includes the Indicated material (no material as yet has been classified as Measured for the K.Hill deposit).

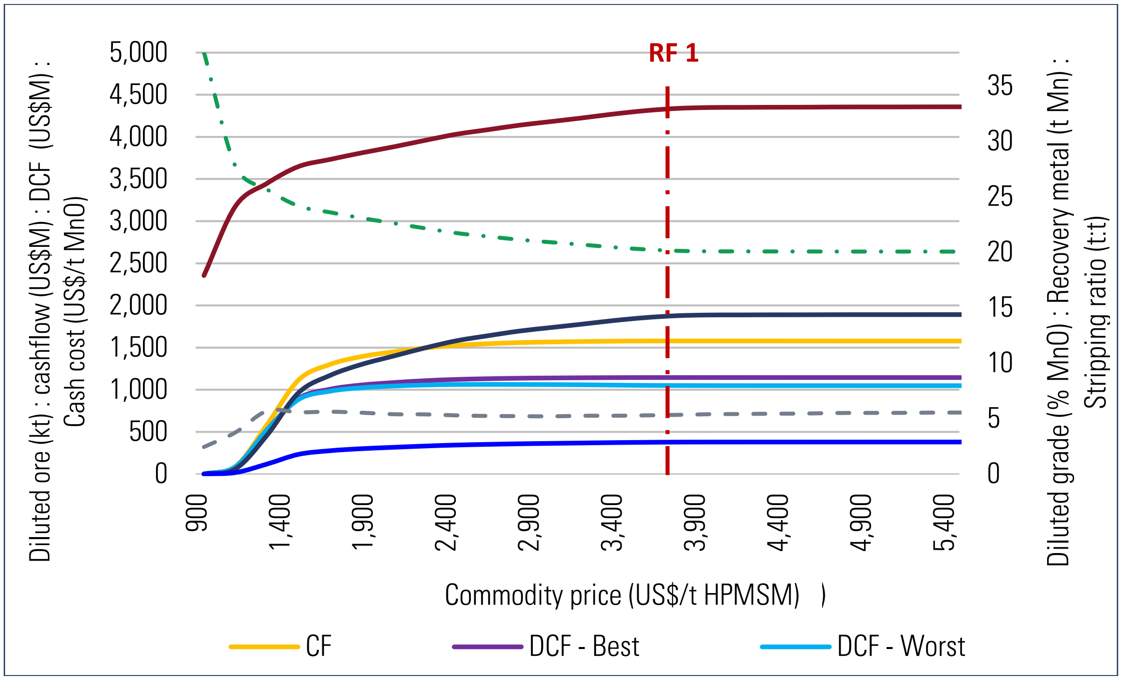
A series of nested pit shells were assessed to provide an understanding of the deposit's sensitivity to various metal prices given the same input parameters and with the base case metal price set at US$3,800/t HPMSM. The key objective during the shell selection was to maximise mineralised inventory while achieving a healthy discounted cash flow (DCF).

Figure 16.1 shows the metal price sensitivity analysis results from the pit optimisation and Table 16.4 shows the pit optimisation results.

Optimisation results show that the maximum undiscounted cash flow is reached for the revenue factor (RF 1.0), which has an average DCF of US$1,097 M (pre-capital).

The US$3,800/t HPMSM pit shell (RF 1.0) was selected as the ultimate pit limit, which was used as the basis for the final pit design. The selected pit shell has an in-situ inventory of 11.9 Mt of rock with 1.86 Mt of ore with a grade of 20.7% manganese oxide at a cut-off of 9.14% manganese oxide.

Figure 16.1 Metal price sensitivity



Notes: CF - cash flow, DCF - discounted cash flow

Table 16.4 Pit optimisation results

Optimisation results	Units	HPMSM price				
		US$950/t	US$1,900/t	US$2,850/t	US$3,420/t	US$3,800/t
Revenue factor		0.25	0.50	0.75	0.90	1.00
Modifying factors						
Mining dilution	%	3	3	3	3	3
Mining recovery	%	98	98	98	98	98
Processing recovery	%	88.5	88.5	88.5	88.5	88.5
Ore						
Inventory	t	109	1,300,747	1,695,957	1,821,060	1,878,239
	% MnO	38.04	23.08	21.13	20.44	20.13
	t MnO	41	300,212	358,366	372,301	378,036
Quantities						
Total rock	t	373	8,394,226	10,426,125	11,225,567	11,705,031
Ore	t	109	1,300,747	1,695,957	1,821,060	1,878,239
Waste	t	264	7,093,479	8,730,168	9,404,507	9,826,792
Stripping ratio	t:t	2.43	5.53	5.22	5.25	5.33
Operating expenditures						
Mining	US$/t mined	3.46	3.46	3.46	3.46	3.46
	US$/t ore	11.84	22.55	21.48	21.60	21.87
Processing + G&A	US$/t ore	717	717	717	717	717
Selling cost	US$/t MnO	190.40	190.40	190.40	190.40	190.40
Total cash cost	US$/t MnO	2,355	3,811	4,139	4,273	4,338
Product						
Recovered metal	t MnO	37	265,688	317,154	329,487	334,562
Recovered metal	t HPMSM	87	633,135	755,778	785,168	797,261
Economic summary						
Metal price (MnO)	US$/t	2,264	4,528	6,792	8,150	9,055
Revenue	US$M	0.33	2,406	2,872	2,984	3,030
Mining costs	US$M	0.001	29.33	36.43	39.34	41.08
Processing costs	US$M	0.08	933	1,216	1,306	1,347

Optimisation results	Units	HPMSM price				
		US$950/t	US$1,900/t	US$2,850/t	US$3,420/t	US$3,800/t
Selling costs	US$M	0.01	51	60	63	64
Cashflow	US$M	0.25	1,393	1,559	1,576	1,578
Discount rate	%	10.0	10.0	10.0	10.0	10.0
Mill rate	t/a	200,000	200,000	200,000	200,000	200,000
DCF - best case	US$M	0.25	1,056	1,136	1,143	1,144
DCF - worst case	US$M	0.25	1,023	1,062	1,055	1,050
LOM	years	0.00	7	8	9	9
Cut-off grade						
Marginal cut-off costs	US$/t ore	717	717	717	717	717
Marginal cut-off grade	% MnO	39.07	18.68	12.27	10.18	9.14

16.4 Mine plan

Based on Giyani's mine production targets, the FS ore processing target has been set at 200 kt/a of mill feed beginning in Q3 2025. This target was set to ensure a LOM of 8 to 10 years having a positive effect on the K.Hill Project economics. The schedule will start with a 2-year ramp-up period for full commissioning of the processing plant. It is assumed that technical optimisation, grade control drilling, and training will be completed prior to this period.

16.4.1 Cut-off grade strategy

SRK has implemented a cut-off grade based on the input parameters that were available in April 2022. The marginal cut-off grade was estimated at 7.3% manganese oxide. SRK notes that the marginal cut-off grade is slightly higher at 9.14% manganese oxide when applying the latest product pricing, processing cost, and metallurgical recoveries. However, the difference in total inventory for both cut-off grades is negligible. Therefore, SRK supports using a slightly lower cut-off grade in defining the mineral inventory for the LOM plan, and it is deemed appropriate considering the likelihood of further reductions in process operating costs in the future.

The cut-off grade strategy used in the FS mine plan is shown in Table 16.5 and described further in this section.

Table 16.5 Mine plan cut-off strategy

Material	Cut-off (% MnO)	Destination
Waste	<7.3	WRD
Ore	≥7.3	Direct mill feed/stockpile

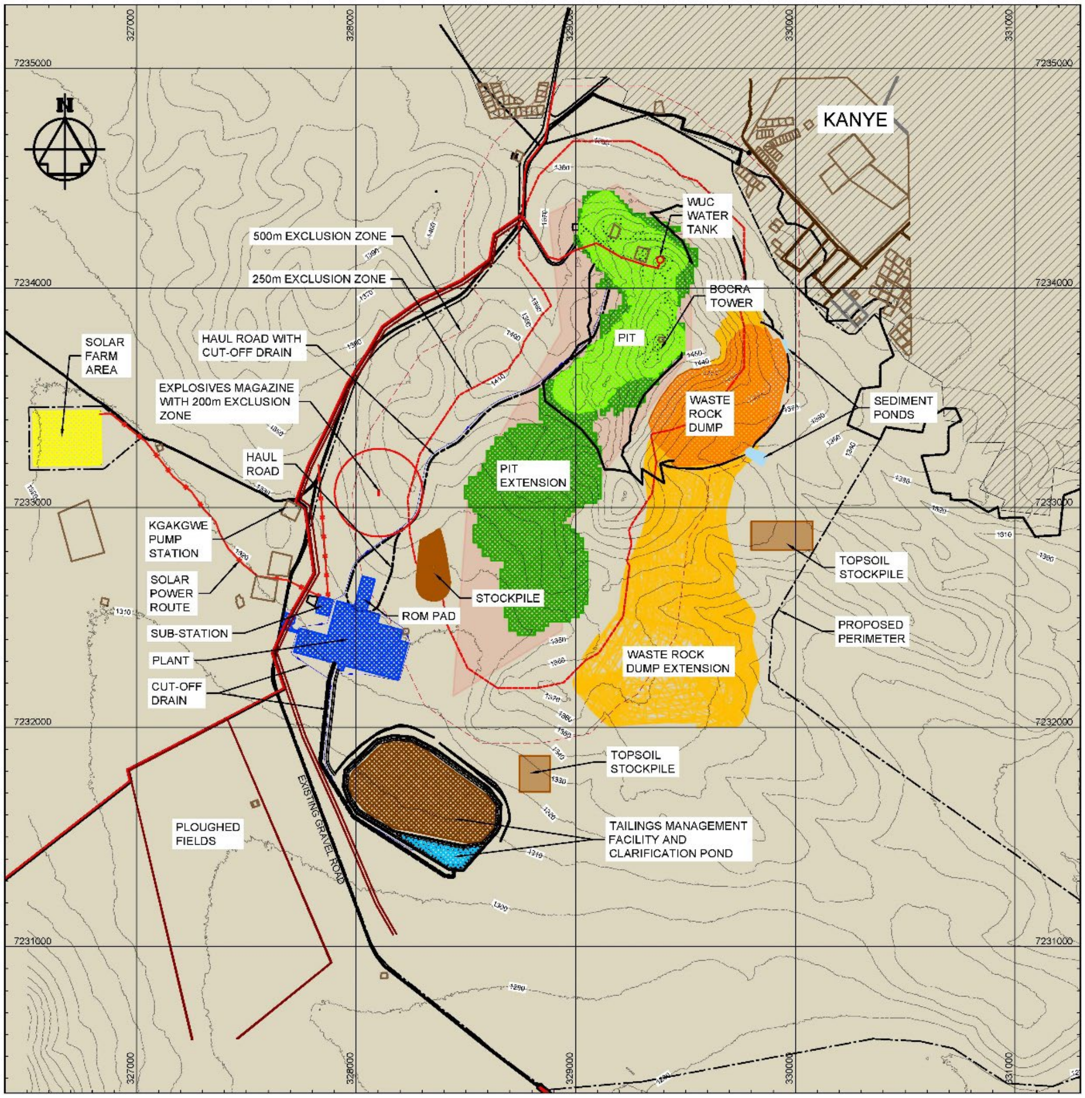
The mineral inventory uses a marginal cut-off of 7.3% manganese oxide. In addition to revenue being driven by the manganese oxide grade, additional deleterious elements were proven to be detrimental to the process operating costs due to the additional reagent requirements and, therefore, play a critical role in the production scheduling of the mineralised material.

The following cut-off approach was used for the FS mine plan:

- Plant feed material is defined as Indicated mineralisation above 7.3% manganese oxide and has been kept to one material bin, which is scheduled to meet the blending targets through the implementation of an operating stockpile.
- Depending on the deleterious element feed, the ore will be sent either directly to the plant or stockpiled on a designated stockpile in close proximity to the plant to allow for blending.
- Waste material will be sent to a dedicated WRD located in close proximity to the pit and an adequate distance away from Kanye.

The location of both the WRD and the stockpile is shown in the overall site layout (Figure 16.2).

Figure 16.2 Simplified site layout showing the designed pit, waste rock dump, stockpile, and haul roads



A stockpiling strategy has been applied predominantly to stabilise the iron oxide to potassium oxide ratio while ensuring a smooth total material movement and feed grade while production targets are being met throughout the LOM. This stockpile strategy will be achieved through extensive grade control of the stockpiles to prevent any major unwanted spikes of deleterious elements within the plant feed. Additionally, a ROM stockpile will be in place to allow for contingencies if needed.

16.4.2 Cutback sequencing

SRK developed a cutback strategy within the selected ultimate pit shell based on targeting the preferred areas of the deposit while also considering topographical constraints. The selection of the cutback sequencing was guided by a strategic scheduling assessment completed in

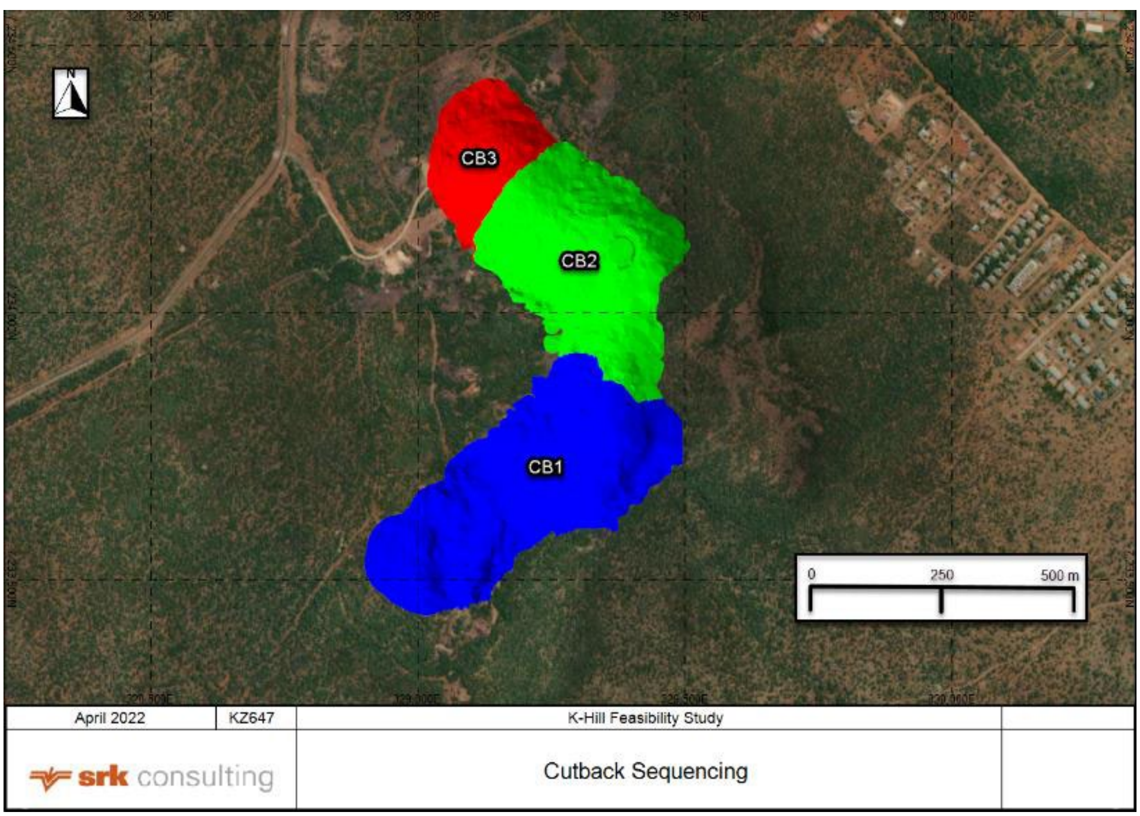
Studio NPVS software, where the optimum extraction sequence was determined. Due to the topographical location of the deposit situated on a hill, the optimum and practical mining sequence indicated a downward progressing series of horizontal slices of the topography. Subsequently, typical open pit pushbacks, normally used to gain access to certain areas of the pit, are not required; however, mining zones, which are referred to as cutbacks, have been selected to allow for enhanced control of the ore grades during the detailed lateral scheduling part of the mining plan.

The cutback sequence is shown in Figure 16.3 and described here:

- Cutback 1 (CB1) - Starter Pit: this cutback targets the southern region of the planned pit and provides initial ore at the start of the mine schedule from higher elevations.
- Cutback 2 (CB2) - Upper Section Northern Flank: this cutback targets both ore and waste material and will be mined out alongside the southern flank once an even elevation is reached.
- Cutback 3 (CB3) - Lower Section Northern Flank: this cutback targets material situated at lower parts of the northern flank. This section will be mined out once similar elevations are reached relative to Cutback 2, but through a separate access road.

All the waste material from each cutback will be excavated and hauled through a truck-and-shovel operation.

Figure 16.3 Cutback sequencing



16.5 Mine design

SRK developed an ultimate pit design based on the selected final pit shell and interim cutback designs for the phased development of the open pit. The ramp locations have been selected based on easy access to the WRD and the processing plant. The ramp locations also provide access to cutbacks and flexibility in haulage destination for mining with trucks and shovels.

16.5.1 Open pit design parameters

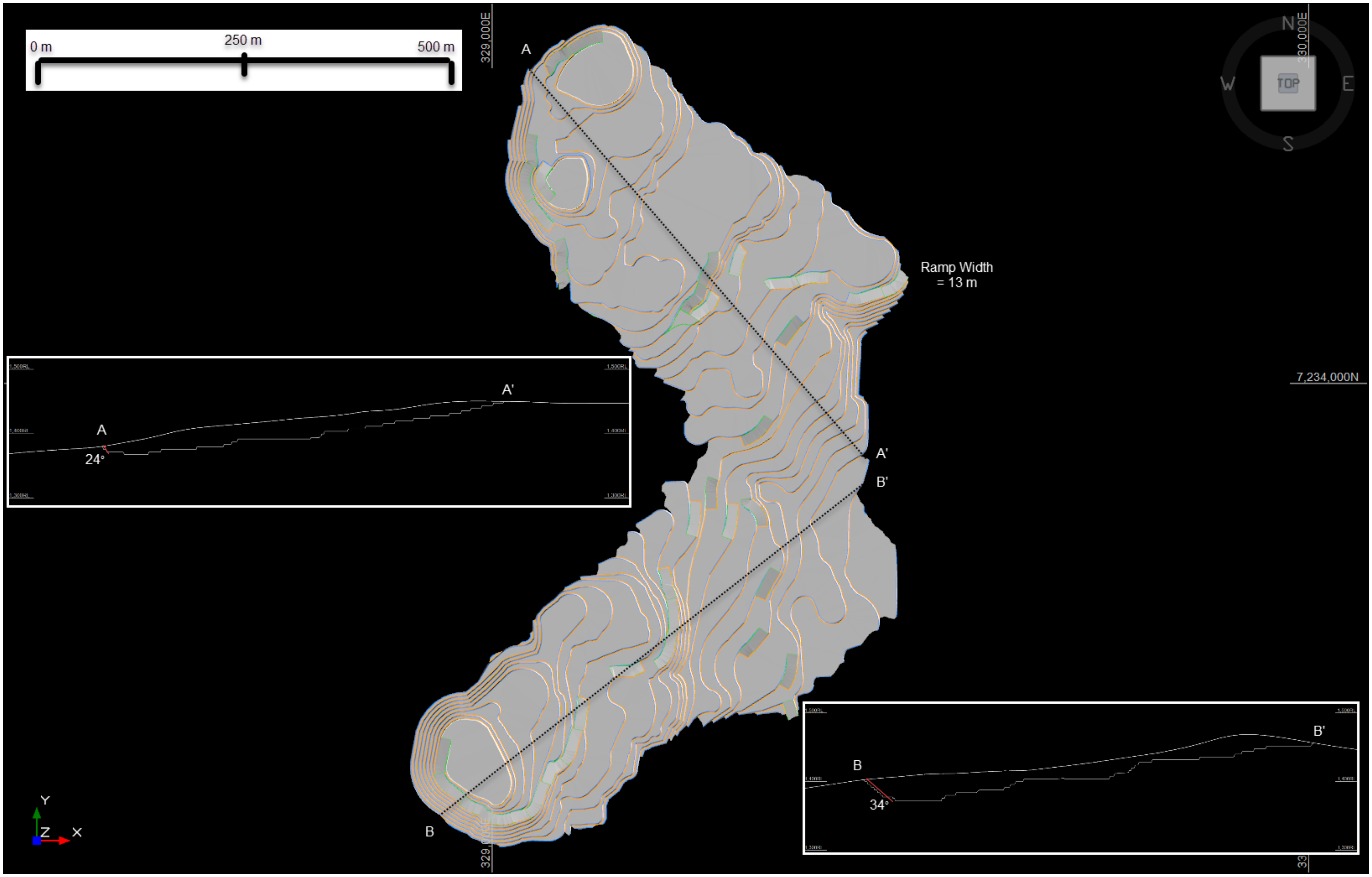
Based on the results of SRK's geotechnical analysis and modelling work (Section 24.1), the following design parameters have been deemed appropriate for use:

- bench height: 4 m
- face angles: 70°
- berm width: 3.2 m
- inter-ramp angle: 41°

A ramp width of 13 m has been used in the pit design, which is in line with industry-standard ramp widths for the considered haul truck class. This ramp width was estimated based on 3.5 × truck width (3 m) = 10.5 m, which was increased to 13 m considering the required drainage and safety bund walls.

The engineered pit design is shown in Figure 16.4.

Figure 16.4 Engineered pit design



16.5.2 Engineered pit design

The pit design contains a total ROM inventory (excluding Inferred material) of 2,032 kt grading 18.9% manganese oxide above an in-situ cut-off of 7.3% manganese oxide. The overall strip ratio is 5.0 t:t (waste:ore). Considering the location of the pit on a hill, the highest elevation difference relative to the pit crest on the east and pit bottom on the west is roughly 95 m.

The final pit layout is shown in Figure 16.2 (site layout), and the pit design inventory is shown in Table 16.6.

Table 16.6 Pit design inventory

	Unit	Total
Total mined	kt	12,188
Waste	kt	10,156
Ore	kt	2,032
MnO	%	18.9
Contained MnO	kt	384
High-grade (MnO >11%)	kt	1,521
MnO	%	22.15
Contained MnO	kt	337
Low-grade (7.3%<MnO<11%)	kt	511
MnO	%	9.20
Contained MnO	kt	47
Stripping ratio	t:t	5.00

16.6 Waste rock dump and stockpile design

SRK developed a WRD and stockpile design to determine the surface area requirements of storing waste and long-term stockpiled material. A key strategic challenge for the operation will be the rehandling of the stockpile during mine operations and, therefore, requires extensive grade control.

16.6.1 Waste rock dump design parameters

The WRD design has a total height of 74 m due to the elevation differences of the underlying topography. The maximum elevation from the foot of the WRD to the crest is 60 m and comprises several slopes designed with batter angles of 31° with 10 m wide berms. The future WRD overall slope is planned to be 20° (based on preliminary slope configurations) and range from 1,356 masl to 1,430 masl in height. The designs presented in this report are considered detailed slope configurations for operational WRD construction planning while taking progressive closure planning into consideration. However, it is recommended to assess the compaction factor during further detailed engineering stages to confirm the design parameters. WRD geotechnical design parameters are summarised in Table 16.7.

Table 16.7 WRD geotechnical design parameters

	Unit	
Lift height	m	20
Batter angle	degree	31
Berm width	m	10
Ramp width	m	26
Maximum dump height	m	74
Overall slope angle (crest to toe)	degree	20

16.6.2 Waste rock dump and stockpile design

Figure 16.2 shows the planned final WRD and stockpile that have been developed with the potential future pit expansion in mind by being located outside of the exploration areas and designed to provide sufficient storage capacity for the current LOM plan.

The WRD and stockpile design capacity are provided in Table 16.8, which shows that the designs have a contingency volumetric allowance of 13% and 3% for waste and ore, respectively. Over the LOM, approximately 941 kt of ore is planned to be sent to the stockpile, with a cumulative peak of 484 kt to be stockpiled and 10.1 Mt of waste to be dumped.

Table 16.8 Waste rock and stockpile capacity

	Units	Total	Waste	Stockpile
Requirements (From open pit)	Mm^3	5.92	5.7	0.28
	Mt	10.45	10.1	0.48
Capacity	Mm^3	-	6.5	0.28
	Mt	-	11.4	0.5
Contingency	Mm^3	-	0.7	0.001
	Mt	-	1.3	0.014
	%	-	13	2.9

The WRD slope configuration was designed at an overall slope angle of 20°, which is appropriate for rehabilitation and closure.

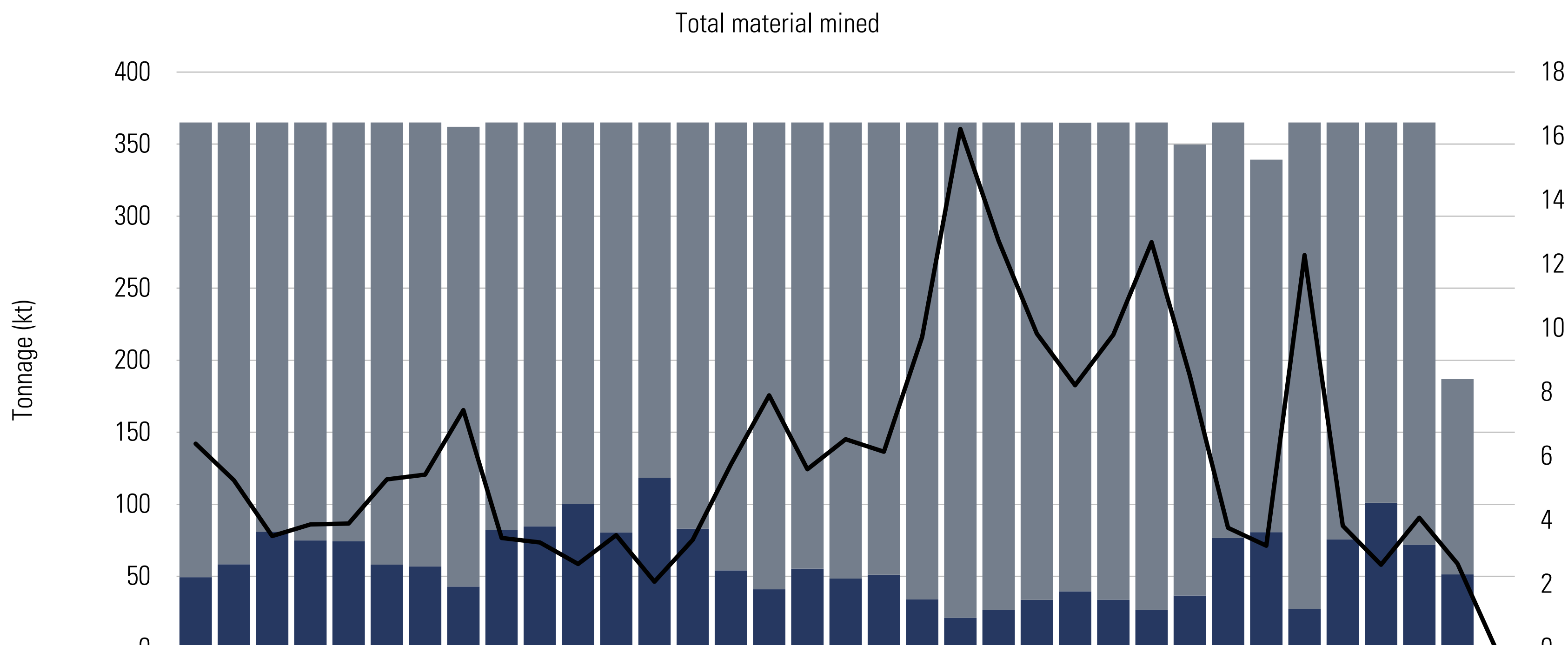
16.7 Mine schedule

SRK developed a detailed schedule over the LOM based on a conventional backhoe and haul truck equipment combination and includes detailed excavation, haulage productivity, and cycle time calculations. This material handling solution will provide more flexibility for a plausible future expansion of the mine. Mine development is considered conventional, considering the size of the deposit and its location on top of a hill. The hill will be mined out through a series of benches from the top and gradually down to the bottom, where all the material, depending on the composition, will be sent to either the process plant, a WRD, or a stockpile. The mine production schedule is summarized as follows:

- Inferred material was excluded from the mine schedule.
- The schedule includes a LOM of 8.5 years of direct ore feed, supplemented with rehandled stockpiled ore, followed by 2.5 years of only stockpile rehandling.
- Mining begins in July 2025 on the upper section of the southern flank of the pit.
- A maximum mining rate of 1.46 Mt/a was assumed.
- A total of 10.1 Mt of waste will be stored on the WRD located east of the pit.
- Roughly 315 kt of waste is required to be stripped in Q3 2025.
- Considering the relatively slow processing plant ramp-up schedule, sufficient ore will be available starting from Q3 2025, where 10.4 kt of ore will be directly fed to the plant. This will be followed by a gradual direct ore feed over a 2-year period to finally achieve 50 kt of ore feed during Q1 2027. Effectively, no pre-stripping is required due to the shallow nature of the deposit relative to the topography. However, some waste may have to be mined out earlier than initially scheduled for use as construction material of the TMF.
- A total of 200 kt/a mill feed will consist of a blend of all the mineralised material above the cut-off grade of 7.3% manganese oxide in order to stabilise the head grade and deleterious elements to the plant.
- An operating stockpile strategy will be adopted to allow for a smooth total material movement and to assist with blending throughout the years.
- A total of 994 kt of ore will be transited through the stockpile, with a total cumulative peak of 484 kt of ore throughout the LOM.

The quarterly mining and processing schedules are included on Figure 16.5 and Figure 16.7, respectively, and the stockpile capacity over the LOM is included on Figure 16.7.

Figure 16.5 K.Hill mining quarterly schedule



	Q3 - 2025	Q4 - 2025	Q1 - 2026	Q2 - 2026	Q3 - 2026	Q4 - 2026	Q1 - 2027	Q2 - 2027	Q3 - 2027	Q4 - 2027	Q1 - 2028	Q2 - 2028	Q3 - 2028	Q4 - 2028	Q1 - 2029	Q2 - 2029	Q3 - 2029	Q4 - 2029	Q1 - 2030	Q2 - 2030	Q3 - 2030	Q4 - 2030	Q1 - 2031	Q2 - 2031	Q3 - 2031	Q4 - 2031	Q1 - 2032	Q2 - 2032	Q3 - 2032	Q4 - 2032	Q1 - 2033	Q2 - 2033	Q3 - 2033	Q4 - 2033	Q1 - 2034
Waste	316	307	284	290	291	307	308	319	283	280	265	285	247	282	311	324	310	317	314	331	344	338	331	325	331	338	313	288	259	338	289	264	293	136	-
Ore	49	58	81	75	74	58	57	43	82	85	100	80	118	83	54	41	55	48	51	34	21	27	34	40	34	27	37	77	81	27	76	101	72	51	-
Stripping Ratio	6.40	5.25	3.51	3.87	3.90	5.28	5.43	7.44	3.45	3.31	2.64	3.54	2.08	3.39	5.75	7.91	5.59	6.53	6.14	9.72	16.2	12.7	9.83	8.22	9.80	12.6	8.52	3.76	3.20	12.2	3.83	2.61	4.08	2.64	-

Ore Waste Stripping ratio

Figure 16.6 K.Hill processing quarterly schedule

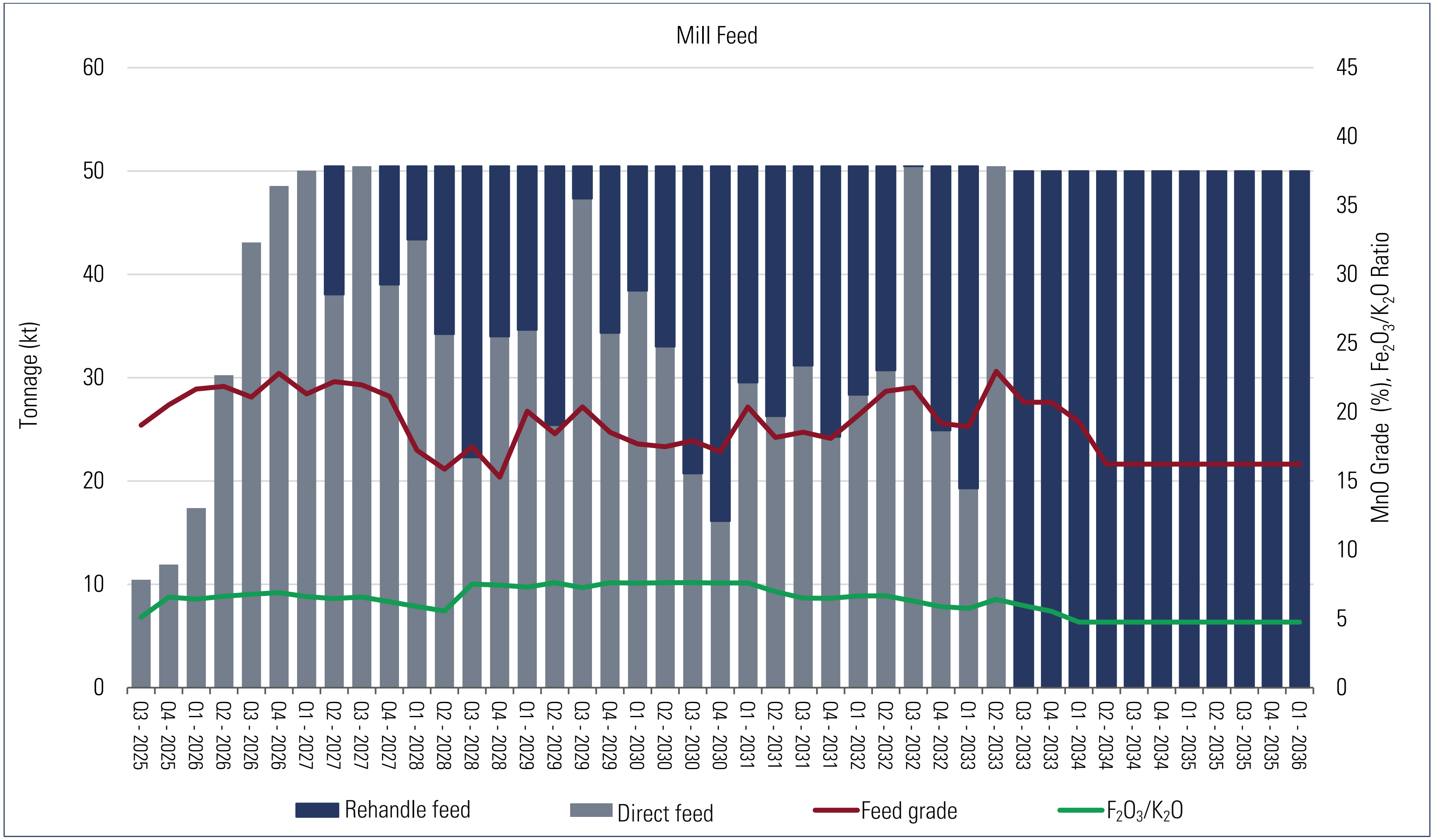
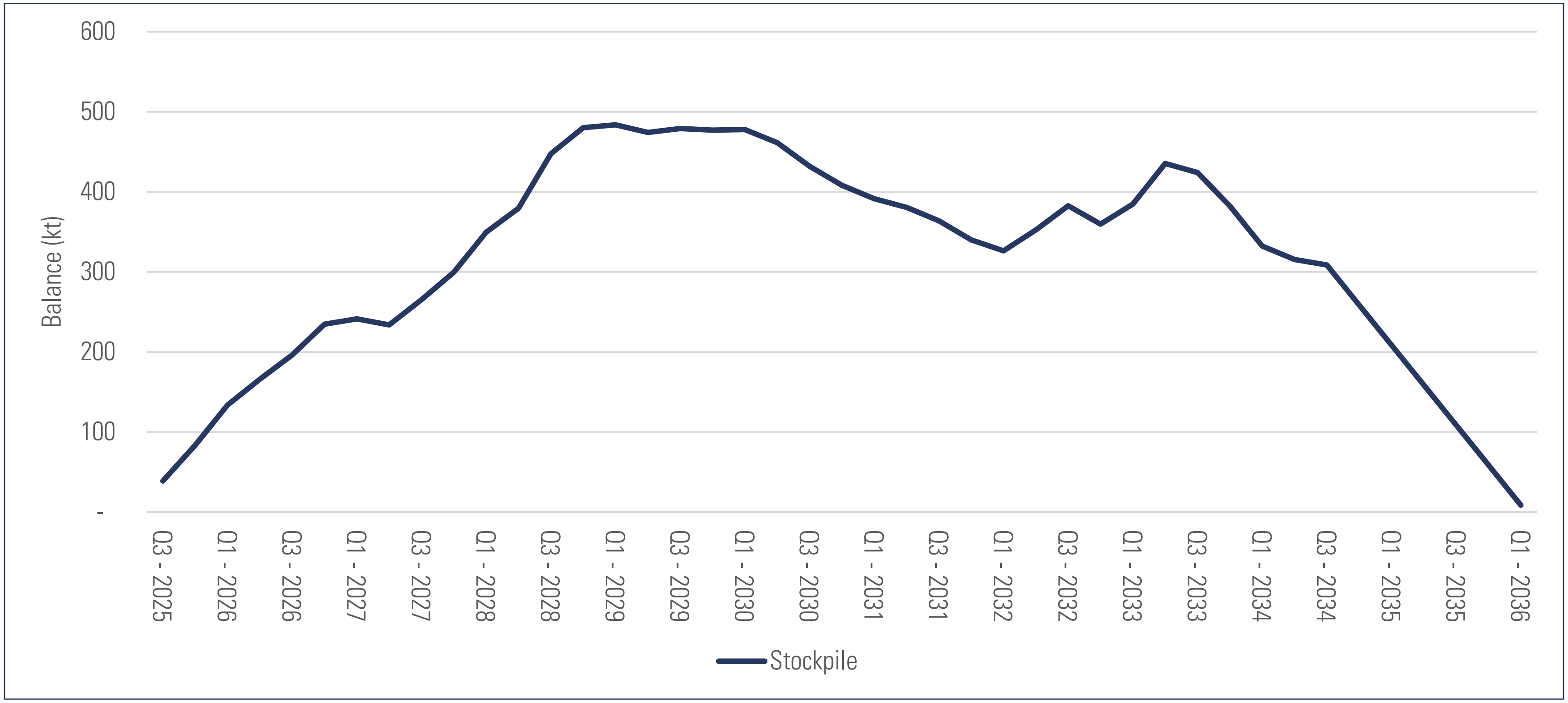


Figure 16.7 K.Hill stockpile capacity over life of mine



16.8 Mining equipment and labour

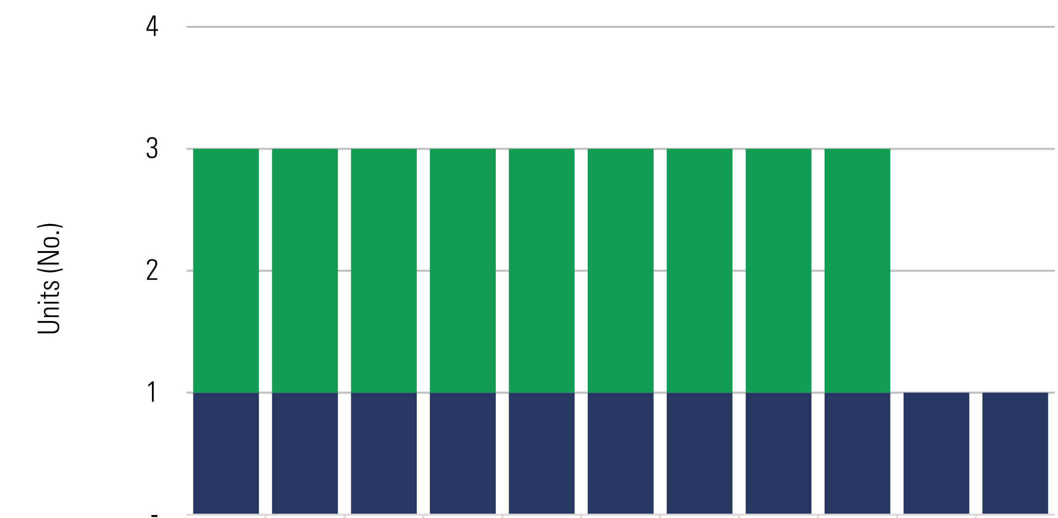
A mining equipment and labour schedule was developed based on an owner-operated scenario for all the primary earth moving, ancillary fleet, production drilling, grade control drilling, and sample collection. The equipment requirements were developed based on planned site conditions, ex-pit material movements, rehandle requirements, haulage travel times, and haul distances, all set to support the mining operations for 365 d/a with one 12-hour shift per day.

Two 4.0 m^3 bucket excavators are planned for the ROM and waste loading (Figure 16.8). Both ROM and waste material will be loaded into 30 t payload class trucks. The number of haul trucks increases over the schedule to a maximum of eight units by 2029 due to increased haul cycles and material movement rates (Figure 16.9). The fleet will not have to be replaced over the LOM, considering the relatively short direct operating hours.

One 2.5 m^3 bucket front-end loader will be used at the stockpiles and ROM pad to feed the crusher.

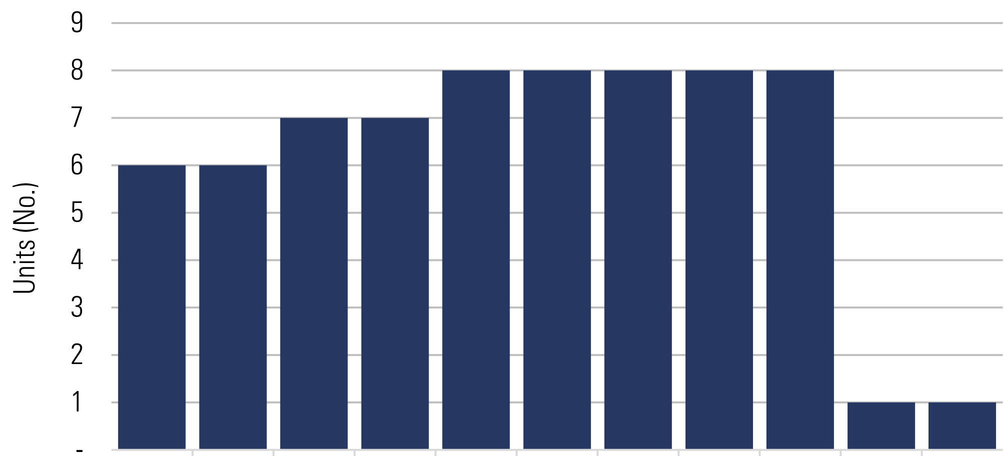
Essentially, no drilling and blasting are deemed necessary, and all material is considered suitable for free digging with some ripping requirements. However, in order to ensure continuous operations with minimum downtime as a result of unforeseen hardness, drilling and blasting have been assumed for some of the material. The drilling fleet will consist of one primary drill rig for the production drilling, which will be assigned to 50% of the in-pit material. Furthermore, one RC drill rig has been included for the grade control drilling and is considered as owner-operator, which might change through further discussions with potential contractors (Figure 16.10).

Figure 16.8 Loading fleet requirements



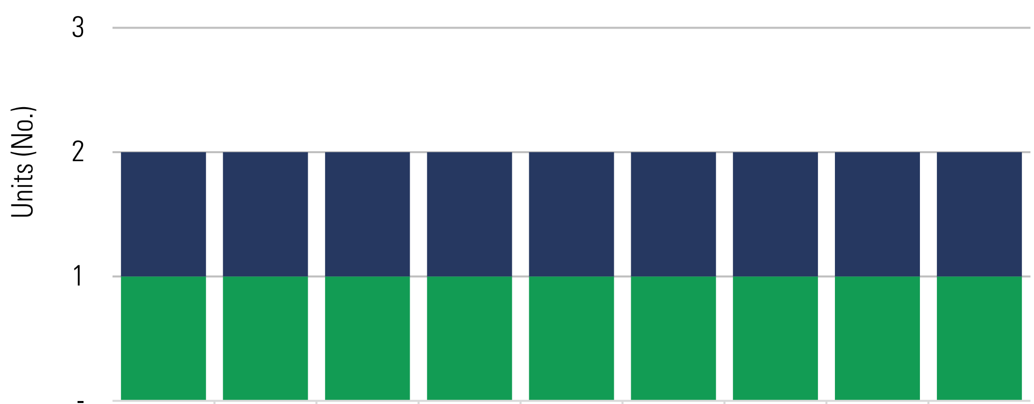
	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Excavator	2	2	2	2	2	2	2	2	2	-	-
Stock Loader	1	1	1	1	1	1	1	1	1	1	1

Figure 16.9 Truck fleet requirements



	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Primary truck	6	6	7	7	8	8	8	8	8	1	1

Figure 16.10 Drill fleet requirements



	2025	2026	2027	2028	2029	2030	2031	2032	2033
Infill drill	1	1	1	1	1	1	1	1	1
Primary drill	1	1	1	1	1	1	1	1	1

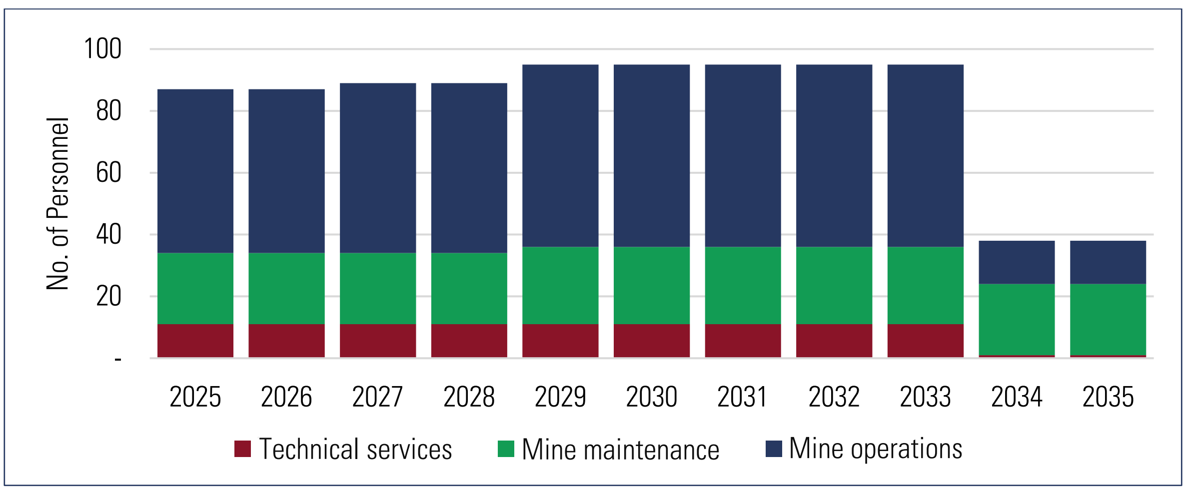
An appropriate ancillary fleet has been planned to include track dozers, a motor grader, a water truck, a service and fuel truck, a blast truck, a rock breaker, a tyre handler, light vehicles, lighting plants, and a crew bus. The TMF will be constructed with the help of a compactor and a designated track dozer.

Table 16.9 Ancillary fleet requirements

Equipment	Max.	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Excavator	2	2	2	2	2	2	2	2	2	2	-	-
Tyre handler	1	1	1	1	1	1	1	1	1	1	1	1
Stock loader	1	1	1	1	1	1	1	1	1	1	1	1
Primary truck	8	6	6	7	7	8	8	8	8	8	1	1
Primary track dozer	2	2	2	2	2	2	2	2	2	2	-	-
Wheel loader	1	1	1	1	1	1	1	1	1	1	-	-
Primary motor grader	1	1	1	1	1	1	1	1	1	1	1	1
Rockbreaker	1	1	1	1	1	1	1	1	1	1	-	-
Water truck	1	1	1	1	1	1	1	1	1	1	-	-
Fuel/lube truck	1	1	1	1	1	1	1	1	1	1	1	1
Maintenance service truck	1	1	1	1	1	1	1	1	1	1	1	1
Blast truck	1	1	1	1	1	1	1	1	1	1	-	-
Lighting plant	4	4	4	4	4	4	4	4	4	4	2	2
Light vehicle	8	8	8	8	8	8	8	8	8	8	7	7
Crew bus	1	1	1	1	1	1	1	1	1	1	1	1

The mine labour requirements have been estimated for mine operations, mine maintenance, and technical services. The maximum mining labour requirement will be 95 employees: 59 in owner operations, 25 in owner maintenance, and 11 in technical services (Figure 16.11).

Figure 16.11 Mining labour requirements



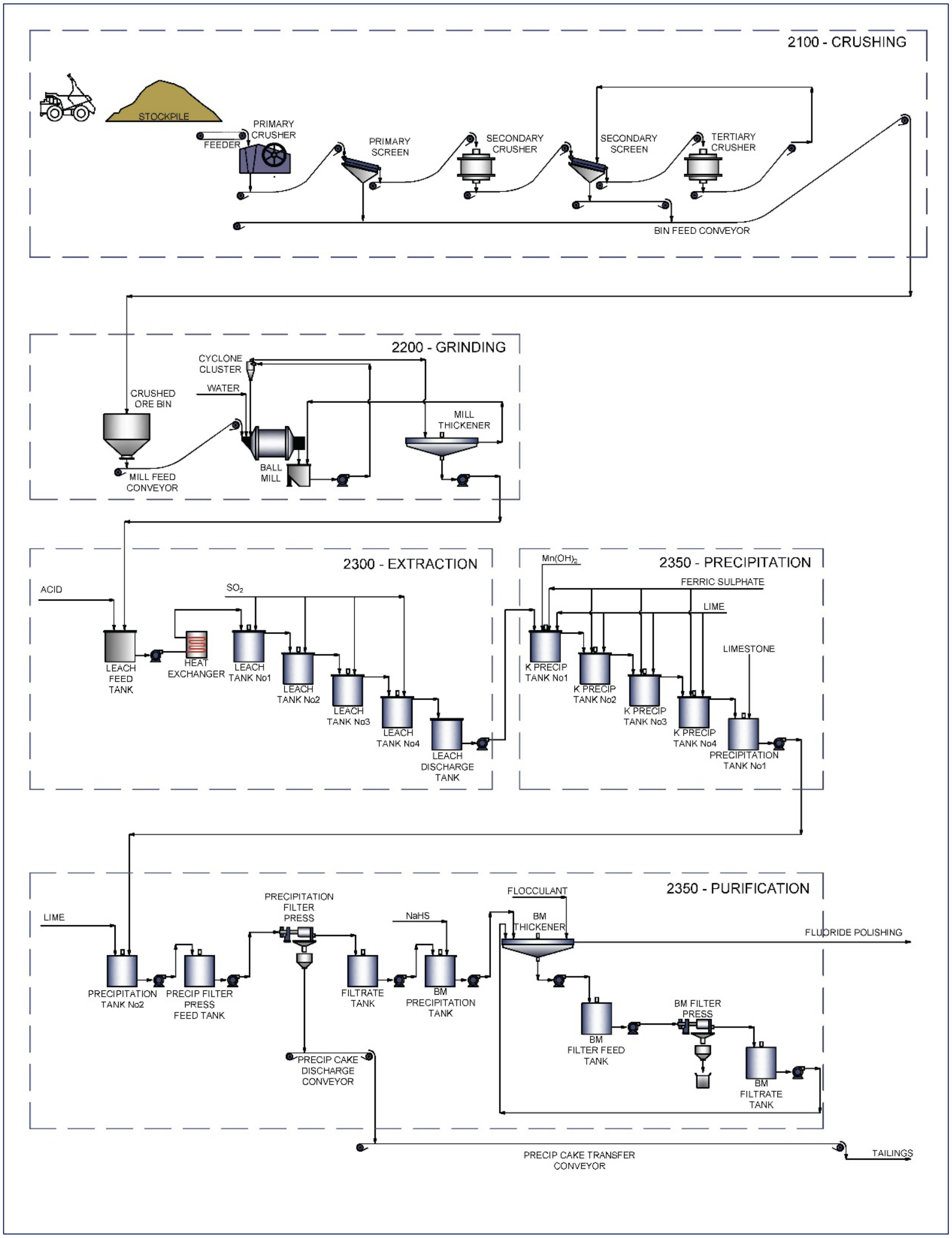
17 RECOVERY METHODS

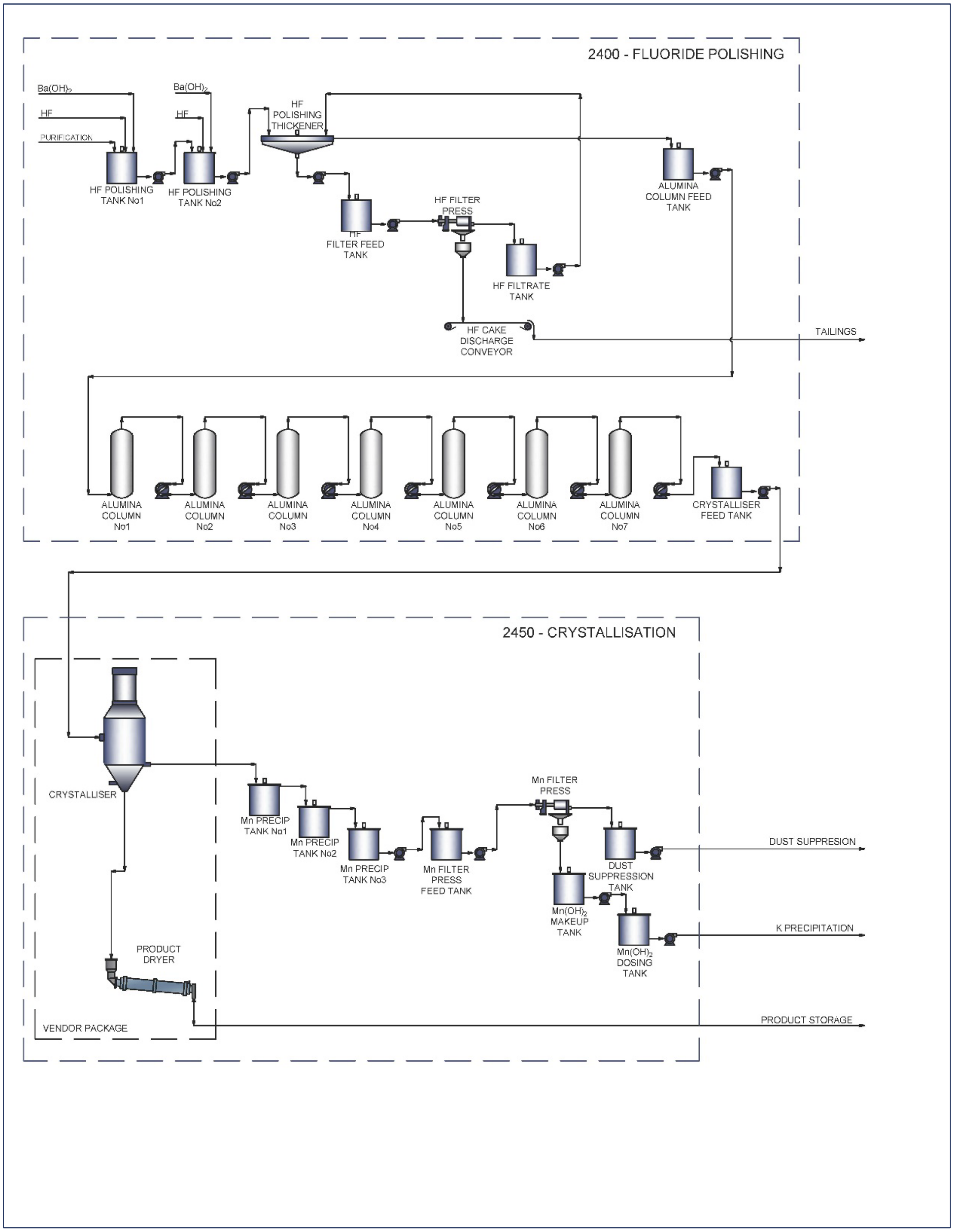
17.1 Introduction

The processing plant will treat 200 kt/a of ROM ore from the K.Hill manganese open pit, at an average grade of 19% manganese oxide, to produce HPMSM (>31.5% Mn). The mineralised material comprises manganese and iron shales, is moderately hard and amenable to reductive acid leaching in sulphate media using sulphur dioxide as a reductant. The process comprises crushing and grinding to reduce the ROM material to a characteristic grind (P80) of 150 µm, an acid reductive leach in sulphate media at elevated temperature using sulphur dioxide as a reductant, and a sequential purification process for the removal of metal impurities. Fluoride polishing is undertaken to further improve the purity of the solution. The purified solution then undergoes evaporative crystallisation, followed by filtration and drying of the product, to produce an HPMSM final product. The solids removed during sequential purification and fluoride polishing are either disposed of in the TMF or are stored as an intermediate product. All liquors removed in the treatment of the ore are either treated for reuse or used for haul road dust suppression.

A simplified process flow diagram (PFD) is presented as a schematic in Figure 17.1. The full block flow diagram (03357AA-2000-BFD-Z-001) is available in Appendix C.

Figure 17.1 Schematic of the manganese recovery process





17.2 Basis of design

Table 17.1 shows the basis of the design of the manganese recovery process.

Table 17.1 Basis of the process design

Item description	Units	Value/comment
Operating time		
Days per annum	d/a	365
Statutory holidays	d/a	0
Operating days available	d/a	365
Operating hours per day - crusher	h/d	16
Operating hours per day - mill	h/d	24
Operating hours per year - crusher	h/a	3,340
Operating hours per year - mill	h/a	7,720
Throughput (dry basis)		
Plant throughout	t/a ROM	200,000
Head grade - MnO	% w/w	18.9%
Overall plant recovery - Mn	%	88.5
Leach dissolution	%	96.8
Precipitation losses	%	0.5
Fluoride polishing precipitation losses	%	4.0
Crystallisation recovery	%	89.6
Mn precipitation recovery	%	97.0

For more detailed information, the process design criteria are given at Appendix C.

A number of unit processes are used for achieving the overall recovery of 88.5%. Each of these processes are described further in the sections that follow. The PFDs in Appendix C should be reviewed in conjunction with each of the areas described, to obtain an understanding of each of the processing steps.

Test work was carried out on composite samples that were selected to represent the K.Hill main orebody over the life of the mine, as well as material selected from the Horizon B. Test results from these samples were used to develop the process design criteria, flowsheets, and equipment sizing. As per Section 13, extraction test work carried out on Horizon B samples demonstrated that this material has similar extraction characteristics to K.Hill main orebody. With the introduction of Horizon B material, there has been a decrease in the overall head grade and an increase in the impurities relative to earlier test work. However, this does not change the recovery methods described in this section.

17.3 Area 2100 - Crushing

The crushing circuit will comprise three stages of crushing with interstage screening to reduce the ROM ore size to the required size for the grinding section (see PFD 03357AA-2100-PFD-Z-001 in Appendix C).

17.3.1 ROM feed and primary crushing

The ROM ore is fed by a dump truck to a ROM stockpile. The stockpile will comprise several smaller stockpiles (typically as fingers) that will allow the plant to manage feed grade and impurity levels. Material is collected by a front-end loader and fed onto the primary crusher feeder. The feeder discharges onto the primary grizzly feeder. The oversize material from the grizzly feeder is fed into the primary crusher. The product from the primary crusher and undersize from grizzly reports to the primary crusher discharge conveyor. The conveyor has an electromagnet at the discharge end of the belt that removes the tramp iron.

17.3.2 Secondary crushing

The ore discharged from the primary crusher discharge conveyor passes over a primary vibrating screen. The oversize material from the screen feeds into the secondary cone crusher using the secondary crusher feed conveyor.

17.3.3 Tertiary crushing

The tertiary cone crusher is operated in a closed circuit with the secondary vibrating screen. The secondary crusher discharge conveyor is a combination of the product of the secondary cone crusher and the product from the tertiary cone crusher. This material is fed onto the secondary vibrating screen. The oversize from the secondary vibrating screen is fed onto the tertiary crusher feed conveyor, which discharges into the tertiary cone crusher. The product from the tertiary cone crusher discharges onto the tertiary crusher discharge conveyor, which feeds onto the secondary crusher discharge conveyor. The undersize material from the secondary vibrating screen discharges onto the secondary vibrating screen discharge conveyor.

The mill bin feed conveyor is fed from the undersize material from the primary vibrating screen and the discharge from the secondary vibrating screen discharge conveyor. The mill bin feed conveyor feeds the ball mill feed bin.

17.4 Area 2200 - Grinding

The grinding circuit consists of a ball mill in a closed circuit with cyclones. The overflow from the cyclone cluster feeds into the mill thickener. The purpose of this area is to reduce the material size to a P80 less than 150 µm and to ensure that the slurry fed to the extraction area is at the required slurry density (see PFD 03357AA-2200-PFD-Z-001 in Appendix C).

17.4.1 Milling

The mill bin feed conveyor is fed with the undersize material from the primary vibrating screen and the discharge from the secondary vibrating screen discharge conveyor. The mill bin feed conveyor feeds the ball mill feed bin. The material in the ball mill bin is removed by the ball mill feed bin feeder and discharged onto the ball mill feed conveyor. The ball mill feed conveyor has a weightometer to measure the feed rate going into the ball mill. After the weightometer, steel balls are added to the ball mill feed conveyor. The material on the ball mill feed conveyor, cyclone cluster underflow, and dilution water are fed into the ball mill for size reduction.

17.4.2 Classification and solid liquid separation

The pulp discharges from the ball mill via a trommel and gravitates into the cyclone feed pump box. The oversize material discharged by the ball mill trommel falls by gravity into a scats bunker.

The mill discharge slurry that is fed into the cyclone feed pump box is diluted with process water to achieve the correct density for the cyclones and pumped to the cyclone cluster. The cyclone cluster underflow gravitates to the ball mill for further size reduction. The cyclone cluster overflow reports to the mill thickener feed box. The feed box is fed from the overflow from the cyclone cluster and flocculant to aid in the settling of the solids.

As part of the requirement to minimise water usage, the overflow from the mill thickener is pumped to the cyclone feed pump box.

17.5 Area 2300 - Extraction

The manganese is associated with higher oxides of manganese such as cryptomelane, hollandite, and bixbyite, in which the manganese occurs as either manganese (III) or manganese (IV). In extraction, the manganese must be reduced to manganese (II) to be extracted as a soluble sulphate. This is achieved in an acidic sulphate medium at a pH of 1.0 to 1.5, an elevated temperature of 90°C, and using sulphur dioxide as a reductant, e.g., extraction of manganese from the mineral cryptomelane:

$$2KMn_8O_{16} + 15SO_2 + 2H_2SO_4 = 16MnSO_4 + K_2SO_4 + 2H_2O$$

At the same time, other base metals, such as iron, aluminium, zinc, vanadium, nickel, copper, cobalt, chromium, and arsenic, are partially co-extracted as sulphates during leaching (see PFD 03357AA-2300-PFD-Z-001 in Appendix C).

17.5.1 Leaching

The underflow from the mill thickener is pumped to a leach feed tank. The leach feed tank acts as a surge tank to smooth out the amount of feed variability coming from the mill thickener to the leach tanks. Sulphuric acid is added to the leach feed tank and the slurry is heated to 90°C. The slurry is then pumped to the first of four leach tanks. Each of the leach tanks has sulphur dioxide gas injected into the slurry to maintain the redox potential (E_h) of the slurry at 600 mV, to ensure the reduction and leaching of the manganese in the ore. The slurry flows by gravity, cascading through each of the leach tanks. The discharge from the fourth leach tank flows by gravity into the leach discharge pump box and is pumped to the first potassium precipitation tank in the purification area.

17.6 Area 2350 - Purification

Purification will be undertaken in several stages. The first will be a jarosite precipitation process in which potassium and sodium impurities are removed at an elevated temperature (90°C) and a low pH of 1.0 to 1.5 by ferric iron in solution, together with supplementary ferric iron as required, generally:

$$3Fe^{3+} + M^{+} + 2SO_4^{2-} + 6H_2O \rightarrow MFe_3(SO_4)_2(OH)_6 + 6H^{+}$$

Where:
M is a monovalent cation such as potassium or sodium.

The second stage will be neutralisation, where other metals such as residual iron and aluminium are precipitated out at higher pH levels. The leach residue slurry is neutralised in two stages using limestone ($CaCO_3$) and lime (CaOH); first to a pH of about four using limestone then to a pH of five to 5.5 using lime, in which iron and aluminium are precipitated as the hydroxides and other base metals partially co-precipitated as hydroxides, e.g.:

$$Fe_2(SO_4)_3 + 3CaCO_3 + 9H_2O = 2Fe(OH)_3 + 3CaSO_4.2H_2O + 3CO_2$$

$$Al_2(SO_4)_3 + 3Ca(OH)_2 + 6H_2O = 2Al(OH)_3 + 3CaSO_4.2H_2O$$

The residue is a mixed precipitate comprising primarily ferric and aluminium hydroxides, gypsum, Epsom salt, and insoluble minerals such as silica and micas. Arsenic is removed as scorodite. The solids in the slurry are then removed, and the solution moves to the base metal precipitation section within the purification area. The precipitate is filtered and washed; the solids residue constitutes the tails product, and the solution moves downstream to the next purification step. Residual base metals in solution are removed by sulphide precipitation using sodium hydrosulphide, e.g.:

$$ZnSO_4 + NaHS = ZnS + NaHSO_4$$

The mixed sulphide by-product is filtered and washed, and the solution proceeds to the next purification step (see proceed flow diagrams 03357AA-2350-PFD-Z-001, -002, and -003 in Appendix C).

17.6.1 Jarosite precipitation

The leached slurry is pumped from the extraction area into the first potassium precipitation tank. In the first potassium precipitation tank, ferric sulphate ($Fe_2[SO_4]_3$) is added for the jarosite precipitation reaction. A low pH in the jarosite precipitation tanks is maintained using manganese hydroxide returned from the crystallisation area and lime. The discharge from the fourth potassium precipitation tank flows by gravity into the first precipitation tank.

17.6.2 Iron and aluminium precipitation

The discharge from the fourth potassium precipitation tank flows by gravity into the first precipitation tank in the purification area, along with the material from the scrubber in the plant infrastructure area and limestone, to increase the pH in the first precipitation tank. The carbon dioxide produced from the neutralisation reaction is vented off. The slurry is then pumped to the second precipitation tank where lime and air are added to increase the pH further and oxidise the remaining ferrous iron and precipitate iron and aluminium to their insoluble hydroxides. The slurry is then pumped into the filter press feed tank. The filter press feed tank acts as a buffer for batch filtration using plate and frame filter presses. The slurry is pumped into the plate and frame filter presses, which remove the solids from the slurry, leaving a filter cake that is conveyed to tailings handling. The filtrate is collected in the filtrate tank before being pumped to the base metal precipitation tank.

17.6.3 Base metal precipitation

Sodium hydrosulphide is also added to the base metal precipitation tank to drive the precipitation of the base metals. The slurry is then pumped to the base metal thickener for solids concentration. The thickened underflow slurry from the base metal thickener is then pumped into the base metal filter press feed tank. The base metal filter press feed tank acts as a buffer for batch filtration using a plate and frame base metal filter press. The slurry is pumped into the plate and frame base metal filter press, which removes the solids from the slurry, leaving a filter cake that is conveyed to a bulk bag for storage. The filtrate is collected in the base metal filtrate tank before being pumped back into the base metal thickener. The overflow from the base metal thickener flows by gravity into the first hydrofluoric acid polishing tank.

17.7 Area 2400 - Fluoride polishing

Calcium and magnesium are removed by fluoride polishing using hydrofluoric acid and barium hydroxide for pH adjustment. Calcium is almost completely removed and the magnesium is substantially removed as insoluble fluorides, the barium used in pH adjustment is precipitated as an insoluble sulphate:

$$CaSO_4 + 2HF + Ba(OH)_2 = CaF_2 + BaSO_4 + 2H_2O$$

The precipitate is concentrated and removed by filtration, and the solution is transferred to fluoride removal. Residual fluoride is removed conventionally using activated alumina in columns. The columns are operated as a carousel, with one of the columns having the alumina stripped of fluoride and regenerated. This is described in further detail using the method outlined in the following sections (see PFDs 03357AA-2400-PFD-Z-001, -002, -003, -004, -005, -006, -007, -008, -009, and -010 in Appendix C).

17.7.1 Calcium and magnesium precipitation

The overflow from the base metal thickener flows by gravity into the first hydrofluoric polishing tank, along with slurry seed material from the hydrofluoric polishing thickener underflow, where hydrofluoric acid and barium hydroxide are added to facilitate the precipitation of the calcium and magnesium. The slurry flows by gravity from the first hydrofluoric polishing tank into the second hydrofluoric polishing tank. The slurry is then pumped from the second hydrofluoric polishing tank into the hydrofluoric polishing thickener together with the filtrate from the hydrofluoric polishing filtrate tank. The overflow from the hydrofluoric polishing thickener flows by gravity into the alumina column feed tank. The underflow from the hydrofluoric polishing thickener is pumped to a slurry stream and is split between returning to the first hydrofluoric polishing tank and the hydrofluoric polishing filter feed tank. The hydrofluoric polishing filter press feed tank acts as a buffer for the batch filtration using plate and frame hydrofluoric polishing filter press. The slurry is pumped into the plate and frame hydrofluoric polishing filter press, which removes the solids from the slurry, leaving a filter cake that is conveyed to tails handling. The filtrate discharges into the hydrofluoric polishing filtrate tank. The filtrate collected in the hydrofluoric polishing filtrate tank is pumped back into the hydrofluoric polishing thickener.

17.7.2 Fluoride removal

The alumina column feed tank acts as a buffer for the batch removal of fluoride in the alumina adsorption columns. Seven alumina columns operate as a carousel. Six operate in series with the seventh column used for stripping of fluoride and regeneration of the alumina. The solution that has been contacted with the activated alumina is then pumped into the crystalliser feed tank.

After feeding the solution through the six columns for 4 h, the feed arrangement then changes. The column that was being regenerated becomes the first column in the sequence; what was the first column now is the second, the second becomes the third in the series, and so on. The last column in the sequence starts the regeneration sequence for the column that was number six in the sequence.

The regeneration sequence starts by draining the column and pumping the solution back into the alumina column feed tank. Then the alumina is washed with a caustic solution to strip the fluoride from the alumina. Then the alumina is washed to remove any residual caustic solution and then the solution is contacted with a dilute sulphuric acid solution to complete the regeneration step. The spent solution is pumped to the water treatment area for treatment.

The dilute acid is made up by adding demineralised water to the dilute acid tank and then adding the required concentrated sulphuric acid to the tank. Similarly, the diluted caustic solution is made up in the regenerant tank by adding demineralised water to the regenerant tank and adding the concentrated caustic solution to the tank.

17.8 Area 2450 - Crystallisation

The preceding purification scheme results in a high-purity stock solution of manganese sulphate; however, it still contains some minor impurities, notably, potassium, sodium, manganese, and residual fluoride. These constituents will be further removed during crystallisation, resulting in a HPMSM. The bleed stream from the crude crystalliser is fed into the manganese hydroxide precipitation for the recovery of the manganese from the bleed stream (see PFDs 03357AA-2450-PFD-Z-001 and -002 in Appendix C).

The manganese hydroxide precipitation is undertaken at an elevated pH of 8.0 to precipitate the manganese as a hydroxide, e.g.:

$$MnSO_4 + Ca(OH)_2 + 2H_2O = Mn(OH)_2 + CaSO_4.2H_2O$$

The precipitate is then separated and repulped using demineralised water, with the transfer of the pulp back into the process. Section 17.8.1 is the description of the vendor-supplied crystallisation package and the manganese hydroxide precipitation.

17.8.1 Crystallisation (vendor package)

The description in this section is the anticipated process and may not be the final description. Some of the process detail has been omitted as the underlying process is proprietary,

Pre-concentrator

The pumped feed is preheated with hot export process condensate before being introduced under level control into a forced circulation evaporator.

Crude manganese sulphate monohydrate crystallisation and filtration

Forced circulation crystallisation is employed to facilitate good crystal growth and minimise unwanted deposits forming on the walls of the main heaters.

Washed and dewatered crude manganese sulphate monohydrate cake is dissolved into hot water in a stirred tank making up the feed to the next crystalliser step; this process breaks all crystal structures, essentially redissolving everything into a solution for a subsequent purification recrystallisation step.

Pure manganese sulphate monohydrate crystallisation and filtration

This is the same process as the previous crude crystallisation but with moderately smaller hydraulic and evaporative loads, with the washed and dewatered cake being discharged to a dryer.

Water - hot/seal/washings

A seal water system, including standby pumps for the double mechanical seals, is allowed for reticulating around the plant. A dump tank system is allowed for to accommodate regular boil-outs of equipment. Lastly, a sump and integral sump pump allows any spillage and rain contamination to be stored and managed.

Slurry filtration and slurry dewatering

The crystallised slurry is pumped into the filter feed tank. The filter press operates on a batch cycle and is initially fed from the filter feed tank, filling the press with the filtrate initially being recycled to the feed tank and then flowing directly into the crystalliser feed tank (the filtrate tank). The cake is then "flash washed" using clean hot condensate in a specially designed vessel, where the mass of wash water is pre-measured and high-pressure air blows the water through the cake and then follows with an air blow to displace the washings.

17.8.2 Manganese precipitation

The bleed stream from the crude crystalliser is fed into the first manganese precipitation tank together with lime to increase the pH to drive the precipitation of manganese hydroxide. The solution flows by gravity into the second and third manganese precipitation tank where lime is added to maintain the pH. The slurry is then pumped on to the manganese filter feed tank. The filter press feed tank acts as a buffer for batch filtration using plate and frame filter presses. The slurry is pumped into the plate and frame filter presses, which remove the solids from the slurry, leaving a filter cake that is conveyed to the manganese hydroxide make-up tank. The filtrate is collected in the dust suppression tank along with bleed from the water treatment, blowdown from the cooling water, and the waste stream from the scrubber. The solution in the dust suppression tank is then pumped to haul road dust suppression or tailings and removed from the process.

The manganese hydroxide make-up tank is fed with filter cake from the manganese hydroxide filter press and diluted down to be able to pump the slurry back into the process. The slurry from the manganese hydroxide make-up is pumped into the manganese hydroxide dosing tank, which acts as a buffer to remove the variation due to the batch nature of the filter press. The manganese hydroxide dosing pumps pump the slurry to the jarosite precipitation to be used for pH adjustment and return the manganese into the process.

17.9 Area 2500 - Product handling

The product handling area consists of a rotary drier to remove moisture from the product and packaging plant (see PFD 03357AA-2500-PFD-Z-001 in Appendix C). This is part of the crystalliser vendor package. The description in this section is the anticipated process and may not be the final description. Refer to the vendor equipment process description for further details.

17.9.1 Drying and packaging (vendor package)

Material from the crystallisation plant is fed into the product rotary drier using the product enclosed screw conveyor, to ensure that there is no external contamination, e.g., dust, and to ensure that very little product is lost off the conveyor. The product rotary drier heats the product, driving off the entrained water.

The dry product is stored in a product silo is removed from t to fill lined bulk bags. The bulk bags are sealed and then moved to the enclosed storage area for storage.

17.10 Area 2600 - Lime preparation

The lime preparation consists of two lime preparation sections: limestone and slaked lime. The limestone undergoes size reduction to produce a product size of 80% less than 75 µm and dewatering to ensure that the minimum amount of water is added when adding limestone to the process (see PFDs 03357AA-2600-PFD-Z-001 and -002 in Appendix C).

The burnt lime undergoes hydration, an exothermic reaction, in the lime slaker before being used in the process. The hydration reaction is as follows:

$$2CaO + H_2O = 2Ca(OH)_2$$

17.10.1 Limestone preparation (vendor package)

The description in this section is the anticipated process and may not be the final description. Refer to the vendor equipment process description for further details.

Limestone is delivered by truck and offloaded into the limestone bunker. The limestone bunker uses a limestone bunker discharge gate to discharge the limestone onto the limestone discharge conveyor, which then feeds onto the limestone feed conveyor. The limestone feed conveyor feeds the lime ball mill with fresh limestone. The lime ball mill is fed fresh limestone from the limestone feed conveyor, the underflow from the limestone cyclone, water from the process water tank, and steel balls from the lime ball mill ball charger, when required. The discharge from the lime ball mill discharges into the limestone cyclone feed pump box where it is diluted with return water from the limestone dewatering cyclone and additional dilution water from the process water tank to meet the required limestone cyclone feed density. The limestone slurry is then pumped to the limestone cyclone for size classification, where the oversized limestone returns to the lime ball mill via the limestone cyclone underflow. The overflow from the limestone cyclone flows by gravity into the limestone dewatering pump box. The limestone slurry is then pumped to the limestone dewatering cyclone for dewatering. The thickened limestone dewatering cyclone underflow feeds into the limestone stock tank, and the overflow flows back into the limestone cyclone feed pump box. The limestone slurry in the limestone stock tank is then pumped to the dosing points required in the plant, with the ring main returning to the limestone stock tank.

17.10.2 Slaked lime preparation (vendor package)

The description in this section is the anticipated process and may not be the final description. Refer to the vendor equipment process description for further details.

Burnt or quick lime is delivered by the lime truck and offloaded using the lime unloading blower to transfer the lime to the lime storage silo. The lime is drawn down from the lime storage silo using the lime screw conveyor to dose lime into the agitated lime slaker tank. The lime slaker tank is fed with treated water from the water treatment area and burnt lime from the lime screw conveyor to achieve the required mixing concentration. After the required hydration time the slaked lime slurry is ready for transfer to the slaked lime storage tank. The slurry is agitated to maintain the suspension of the slaked lime particles. The slaked lime storage tank then pumps the slurry to the dosing points in the plant, with the ring main returning the slaked slurry that is not used back to the slaked lime storage tank.

17.11 Area 2700 - Water treatment

The water treatment area supplies water services throughout the processing plant. The water services include potable water, fire suppression, raw water distribution, process water distribution, and a demineralised water treatment plant (see PFDs 03357AA-2700-PFD-Z-001 and -002).

The plant is a net consumer of water. Water enters the system through the following inputs:

- ROM ore in-situ moisture
- water generated in chemical reactions
- potable water
- water used for steam, cooling water, and scrub liquor make-up
- raw water used to balance the water demand

Water leaves the plant by the following routes:

- water contained in the deposited tailings
- sewage discharge
- remainder of the returned water from various streams is used on the site and mine roads for dust suppression

Water loss from venting and evaporation has not been accounted for.

For further details refer to Appendix C and Section 18.

17.11.1 Potable water

Potable water is supplied from the municipal water supply at a rate of 4.5 m^3/d into the potable water tank. The potable water tank ensures that if there is an interruption in the water supply from the municipality there is potable water available for the users. Water from the potable water tank is pumped into the safety shower ring main for the supply of water to the safety showers and eyewash stations distributed at strategic positions throughout the plant. From the ring main there are take-off points for drinking water points and ablutions.

17.11.2 Raw and fire water

Raw water, supplied from the boreholes and local dams, is fed into the raw water tank. The raw water tank has sufficient capacity for the firewater requirements and the plant requirements. The plant raw water requirements are supplied by the raw water pumps, with the take-off nozzle above the firewater volume requirement.

Three pumps are used for the supply of firewater. The firewater jockey pump is a smaller electrical pump that maintains the pressure in the firewater distribution. The firewater pump is another electrical pump that will start if required. The third pump is the firewater diesel pump that will start if there is no electrical supply and is required.

17.11.3 Process water

The process water tank is filled with raw water from the raw water tank and condensate from crystallisation. Process water is then distributed throughout the processing plant.

17.11.4 Water treatment plant (vendor package)

The description in this section is of the anticipated process and may not be the final description. Refer to the vendor equipment process description for further details.

The vendor package is fed from the process water distribution tank and spent solution from activated alumina regeneration. The solution proceeds to dissolved air flotation where chemical reagents are introduced, and fine particulates are removed and transferred to the TMF. The clean solution then proceeds to the first stage of reverse osmosis (RO) where anti-scalent is added and the pH adjusted with acid. The solution is then subjected to a first stage of RO for the removal of dissolved salts. The solution is then subjected to a further two stages of RO. The clean water (permeate) from each stage is collected in a permeate storage tank before being returned to the process. The solids residue slurry (centrate) from each stage is returned to the tailings filtration feed.

17.12 Area 2800 - Reagents

The plant uses reagents to undertake different parts of the purification process. This section describes the offloading, mixing, and dosing description of each of the reagents used (see PFDs 03357AA-2800-PFD-Z-001, -002, -003, -004, -005, -006, and -007 in Appendix C). The reagents described in the reagent section are:

- sodium hydrosulphide (NaHS)
- hydrofluoric acid (HF)
- barium hydroxide ($Ba[OH]_2$)
- sulphuric acid (H_2SO_4)
- sulphur dioxide (SO_2) gas
- caustic/sodium hydroxide (NaOH)
- flocculant
- ferric sulphate ($Fe_2[SO_4]_3$)

17.12.1 Sodium hydrosulphide makeup and dosing

Sodium hydrosulphide is used in the purification area for the precipitation of base metals.

A bulk bag of sodium hydrosulphide is lowered onto a sodium hydrosulphide bag splitter to empty the sodium hydrosulphide into the sodium hydrosulphide mixing tank. Demineralised water is added to the sodium hydrosulphide mixing tank to achieve the required concentration, and the tank is agitated to ensure dissolution. When ready for transfer, the reagent is pumped into the sodium hydrosulphide dosing tank, where it is then pumped to the purification section for addition.

17.12.2 Hydrofluoric acid storage and dosing

Hydrofluoric acid is used in the fluoride polishing area for the precipitation of calcium and magnesium from the solution.

ISO containers containing the hydrofluoric acid are unloaded using the hydrogen fluoride unloading pump to pump the acid into the hydrogen fluoride storage tank. When required, the acid is pumped into the hydrogen fluoride dosing tank. From the hydrogen fluoride dosing tank, the acid is then pumped to the fluoride polishing area for addition.

17.12.3 Barium hydroxide makeup and dosing

Barium hydroxide is used in the fluoride polishing area for control of pH during the precipitation of calcium and magnesium from the solution.

A bulk bag of barium hydroxide is lowered onto a barium hydroxide bag splitter to empty the barium hydroxide into the barium hydroxide mixing tank. Demineralised water is added to the barium hydroxide mixing tank to achieve the required concentration, and the tank is agitated to ensure suspension of the solids. When ready for transfer, the reagent is pumped into the agitated barium hydroxide dosing tank.

The barium hydroxide slurry in the barium hydroxide dosing tank is then pumped to the dosing point in the purification section for addition, with the ring main returning to the barium hydroxide dosing tank.

17.12.4 Sulphuric acid storage and dosing

Sulphuric acid is used for the extraction of metals from the ore in the extraction area.

Sulphuric acid is delivered by a tanker and offloaded by pumping the acid into any of the four acid storage tanks. One of the four acid feed pumps is then used for the dosing of sulphuric acid into the leach tank and the dilute acid tank.

17.12.5 Sulphur dioxide (vendor package)

The description in this section is the anticipated process and may not be the final description. Refer to the vendor equipment process description for further details.

Sulphur dioxide is used as a reducing agent to reduce the manganese to soluble manganese (II) in the extraction area.

Sulphur is conveyed from the stockpile into the sulphur melting tank. The liquid sulphur is then filtered to remove any solids. The molten sulphur is then pumped into the sulphur burner along with clean dry air to produce sulphur dioxide gas. The gas is cooled using demineralised steam, which is then used in the plant, and the cooled sulphur dioxide gas is then stored in a receiver for use in the leach area as required.

17.12.6 Sodium hydroxide makeup and dosing

Caustic/sodium hydroxide is used in the fluoride polishing area for the regeneration of the activated alumina.

A bulk bag of sodium hydroxide is lowered onto a caustic bag splitter to empty the sodium hydroxide into the caustic mixing tank. Demineralised water is added to the caustic mixing tank to achieve the required concentration, and the tank is agitated to ensure the mixing and dissolution of the sodium hydroxide. When ready for transfer, the reagent is pumped into the caustic dosing tank.

The sodium hydroxide solution in the caustic dosing tank is then pumped to the fluoride polishing section for addition to the regenerant tank.

17.12.7 Flocculant makeup and dosing (vendor package)

The description in this section is the anticipated process and may not be the final description. Refer to the vendor equipment process description for further details.

Flocculant is used to increase the size of the particles in the slurry by joining them together. This improves the solid-liquid separation and decreases the required equipment size.

Flocculant bags and demineralised water are added to the flocculant mixing tank. The flocculant is hydrated and then pumped into the storage tank. The flocculant solution is then pumped into the equipment that needs the reagent.

17.12.8 Ferric sulphate makeup and dosing

Ferric sulphate is used in the purification area for the precipitation of jarosite.

A bulk bag of ferric sulphate is lowered onto a ferric sulphate bag splitter to empty the ferric sulphate into the ferric sulphate mixing tank. Demineralised water is added to the ferric sulphate mixing tank to achieve the required concentration, and the tank is agitated to ensure the mixing and dissolution of the ferric sulphate. When ready for transfer, the reagent is pumped into the ferric sulphate dosing tank.

The ferric sulphate solution in the ferric sulphate dosing tank is then pumped to the purification area section for addition to the potassium precipitation tanks.

17.13 Area 2900 - Plant infrastructure and utilities

The area plant infrastructure and utilities comprise a scrubber, to ensure that the gases released comply with the emission standards, and the plant utilities such as steam, which is used for slurry heating duty, cooling water, and plant and instrument air. Each of these is vendor-supplied equipment to deliver the required utility (steam, cooling water, or compressed air). Each of these is distributed throughout the plant to where they are required (see PFDs 03357AA-2900-PFD-Z-001, 03357AA-2910-PFD-Z-001, 03357AA-2920-PFD-Z-001, and 03357AA-2930-PFD-Z-001 in Appendix C).

17.14 Control philosophy

The plant is intended to run fully automated. Minimal operator supervision will be required to ensure production requirements; to manage the interaction between the production plant, utility, and reagent areas; and in the event of equipment breakdown. For further details on the control philosophy refer to the control philosophy document in Appendix C.

The plant will generally be controlled in the direction of flow between unit operations.

Control will be described as “PUSH” or “PULL” based.

PUSH control is defined as source nodes determining outflow to receiving nodes. An example could include a tank level being controlled by the variation of drive speed on the discharge pump. Fluid is moved downstream without direct influence from the downstream system.

PULL control is defined as receiving nodes determining inflow from source nodes. An example could include reagent addition to a tank, where the flow of reagent is controlled at the receiving tank, and reagent supplies must be maintained upstream to meet demand.

18 PROJECT INFRASTRUCTURE

18.1 Overview

The K.Hill Project will require the development of several infrastructure components:

- mining infrastructure, including a truck shop, explosives facilities, and stockpiles
- processing plant, including a processing plant facility and associated infrastructure
- general infrastructure and services, including water treatment, haul roads, administration offices, workshops, warehouses, a fuel farm, a gatehouse, and power supply
- TMF with stormwater pond and a return water pumping system
- solar plant
- temporary construction facilities

The locations of the Project facilities and other infrastructure items were selected to take advantage of local topography and environmental conditions and to ensure efficient and appropriate operations.

18.2 Site location and layout

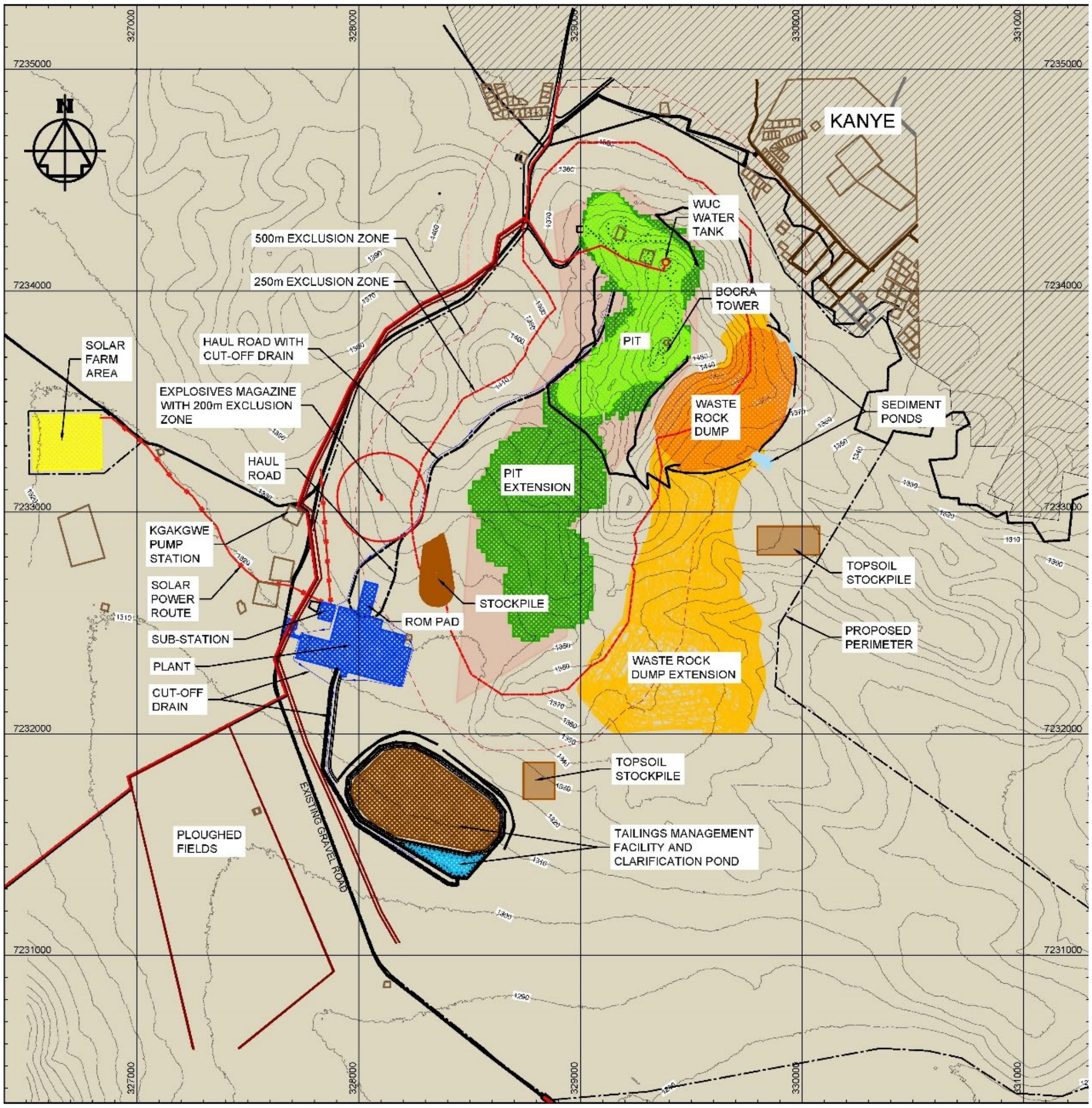
The processing plant, infrastructure, and TMF will be located SW of the open pit, approximately 2 km away from the suburbs of Kanye, on relatively flat ground, close to the existing road, and downwind of Kanye. Figure 18.1 shows the overall site layout with the open pit, WRDs, processing plant, TMF, and proposed solar farm. The solar farm will be located on relatively flat ground, west of the processing plant, along an existing road.

The design philosophy is to keep the mine site as compact as practicable to minimise environmental and social impacts, to keep haul and pumping distances as short as possible, and to minimise the amount of surface water that would have to be managed because of infrastructure interference.

The mine site layout design is constrained by the following:

- the extent of the orebody, depth, and development areas
- the property licence area, specifically the northern boundary with its proximity to the suburbs of Kanye
- existing public roads, including the tarmac road running north to south on the western side of the open pit and the dirt road running east to west on the southern side of the TMF

Figure 18.1 Overall site layout



18.3 Site access

Botswana's transport sector is of great importance to the country's development, and the major modes of transportation are road, air, and rail. As Botswana is landlocked, marine transport, while important in terms of transporting goods to European, Asian, and North American markets, is not directly under the control of the Government of Botswana in terms of transport policy interventions.

In 2000, Botswana had close to 20,000 km of highway, of which 8,761 km are sealed. The total of unpaved and gravelled road surfaces is approximately 11,200 km. There are 12 airports with paved runways and approximately 80 airstrips with unpaved runways. Of the 12 airports, Air Botswana uses 5 in their regular operations. Three of the five airports regularly serve international transport needs.

The main transportation routes in Botswana are shown on Figure 18.2.

Figure 18.2 Main transportation routes

Notes: RBCT - Richards Bay Coal Terminal
Source: Research Gate

18.3.1 Ports

The coasts of South Africa lie on the southern end of the continent's landmass, and the country meets the Indian Ocean on its east coast and the South Atlantic Ocean on its west coast. Therefore, vessels of all sizes have three-way access to the 2,780 km South African coastline.

The Port of Durban has the highest vessel traffic in Africa and is the largest port facility in South Africa. The facility occupies Durban Bay, extending over 18.5 km^2 with 8.9 km^2 of high-tide waterfront. Over 58 berths handle container, dry bulk, and liquid cargo throughout the year. The facility operates vessels of up to 230,000 DWT. Additionally, its massive outer anchorage allows cargo lightening for vessels with heavier DWT. Ore carriers with a 300 m+ length and a beam of 35 m+ can easily ply alongside the facility.

The Richards Bay facility has 2.76 km^2 of land area and six berths for sea-going vessels of all sizes. The facility accommodates large vessels with channel draughts varying between 17.5 m to 19.5 m.

The Port of Walvis Bay is Namibia's largest commercial port. It is a natural gateway for international trade and is strategically situated in the central coastal region of Namibia, to offer direct access to principal shipping routes. It receives between 1,500 and 2,500 vessel calls each year and handles about 5 million tonnes of cargo. The existing infrastructure accommodates container ground slots for 3,875 containers per annum and with the provision for 424 reefer containers.

18.3.2 Access roads

The K.Hill Project area is well-networked via the A1 and A2 national highways. K.Hill is located within a few kilometres of the A2 highway, which runs from Buitepos at the Namibian border through Jwaneng, Kanye, and Lobatse, Botswana, to the South African border at Pioneer Gate near Zeerust, South Africa. The A2 is a major component of the Trans-Kalahari Corridor, which is a highway corridor providing a direct route from Maputo, Mozambique, through Pretoria, South Africa, to Windhoek in central Namibia, and endings at the Port of Walvis Bay.

The site is accessible from the A2 via a few kilometres of unpaved roads from Kanye. Old mining tracks are largely overgrown and degraded by erosion, and access to some areas is by foot or four-wheel drive vehicle.

18.3.3 Rail

Botswana Railways (BR) has four dry ports with container terminals located in Gaborone (GABCON), Francistown (FRANCON), Palapye (PALCON), and the Walvis Bay dry port in Namibia. Established to increase BR's traffic share, these dry port facilities have reduced the turnaround time and costs of containerised cargo deliveries, giving locally based importers and exporters a safe, faster, and cheaper alternative to road transport.

18.3.4 Air

International air transport in Botswana is a duopoly currently operated by Air Botswana and South African Airways. The government regulates cargo service rates on domestic routes, and the practice is for Air Botswana to file charges for cargo service with the International Air Transport Association. The airline has a dedicated cargo service that was boosted by the airline's cargo service operations agreement, which allows Air Botswana to carry cargo for DHL, a worldwide courier company.

Sir Seretse Khama International Airport (FBSK) is located approximately 10 km north of Gaborone, a 1-hour flight from Johannesburg, South Africa and a 2-hour flight from Harare, Zimbabwe. This airport was opened in 1984, offers a large capacity to handle regional and international traffic, and has the largest passenger movement in the country.

Johannesburg O.R. Tambo International Airport (FAOR) is the busiest airport in Africa. It is situated in the Kempton Park district of Johannesburg, South Africa, 23 km northwest of the city centre and 46 km south of Pretoria city centre.

18.4 Scope

The K.Hill Project area breakdown structure is presented in Table 18.1.

Table 18.1 Area breakdown structure

Area number	Area description
1000	**Mining**
1100	Pit
1200	Haul roads
1300	ROM pad
1400	WRD
1500	Heavy vehicle workshops
1600	Heavy mobile plant
1700	Explosive magazine
2000	**Processing**
2100	Crushing
2200	Grinding
2300	Extraction
2350	Purification
2400	Fluoride polishing
2450	Crystallisation
2500	Product handling
2550	Intermediate product handling
2600	Lime preparation
2700	Water treatment
2750	Tailings
2800	Reagents
2900	Plant infrastructure
3000	**Internal infrastructure and services**
3100	Water management
3200	Internal roads
3300	Buildings
3500	Waste management
3600	Electrical supply
3700	Fuel farm
3800	Laboratory
3900	Light mobile plant
4000	**Tailings general**
4100	TMF
4200	Seepage pond
4300	Drain pumping
8000	**External infrastructure and services**
8100	Solar farm
8200	HV supply

Area number	Area description
8300	Raw water supply
9000	**Construction**

18.5 Design basis

The principles of safe design were applied to all design elements, components, and systems for the mine site. The six principles of safe design are:

- consider all the phases in the life cycle of an item of plant from manufacture through use to dismantling and disposal
- design for safe erection and installation
- design to facilitate safe use by considering, for example, the physical characteristics of users, the maximum number of tasks an operator can be expected to perform at any one time, and the layout of the workstation or environment in which the plant may be used
- consider intended use and reasonably foreseeable misuse
- consider the difficulties workers may face when maintaining or repairing the plant
- consider types of failure or malfunction and design the plant to fail in a safe manner

The design philosophy for the site infrastructure is to use local materials and designs appropriate for the location and climate.

18.5.1 Site conditions

A weather station is located in Kanye. The Köppen Climate Classification subtype for the climate in this area is "Bsh" (Mid-Latitude Steppe and Desert Climate).

18.5.1.1 Design temperatures

The average annual temperature in Kanye is 19.4°C. The warmest month is January, with an average temperature of 24.4°C. The coolest month is June, with an average temperature of 12.3°C (Table 18.2).

Table 18.2 Monthly temperature (°C)

	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average	24.4	23.3	2.2	19.0	15.6	12.3	12.4	15.4	18.9	21.7	23.2	24.1
Minimum	16.9	16.2	14.4	10.8	6.6	3.5	3.2	5.5	9.4	13.9	15.5	16.4
Maximum	30.4	29.1	28.0	25.9	24.0	21.1	21.1	23.8	27.1	29.8	29.6	30.3

Source: www.weatherbase.com

18.5.1.2 Rainfall

The average annual precipitation in Kanye is 19.9 inches (506.2 mm). January has the most precipitation, with an average of 4.1 inches (105 mm), and June has the least precipitation, with an average of 0.1 inches (3 mm; Table 18.3). Kanye has 63.3 d of average annual precipitation, with the most precipitation occurring in January (11 d) and the least occurring in July (0.5 d).

Table 18.3 Monthly precipitation (mm)

	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average	105	82	63	47	10	3	1	4	16	42	64	72
Annual	506.2											

Source: www.weatherbase.com

18.5.1.3 Humidity

The recorded monthly average relative humidity for the Kanye region ranges between 48% in September and 69% in April (Table 18.4).

Table 18.4 Average relative humidity (%)

	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average	62	66	67	69	66	64	60	54	48	50	56	58

Source: www.weatherbase.com

18.5.1.4 Wind

The prevailing wind most often moves from NNE for the entire year. The annual average wind speed is 6.2 km/h (1.7 m/s), with the highest speed recorded in November and the lowest recorded in May and June (Table 18.5).

Table 18.5 Average monthly speed (km/h)

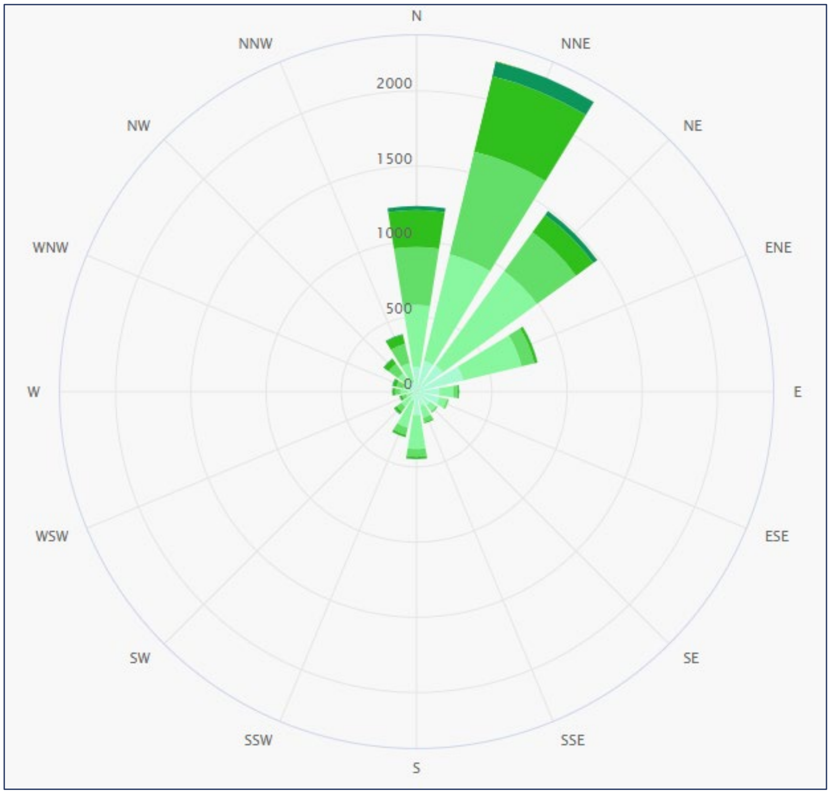
	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average	6.8	5.8	5.4	5.0	4.7	4.7	5.0	6.1	7.2	8.3	7.9	7.2
Maximum	13.1	12.8	12.2	12.0	11.9	12.0	12.6	13.8	16.0	16.2	16.3	14.1

Source: www.weatherbase.com

18.5.2 Layout

A practical approach to the site facilities layout was taken, primarily driven by site topography, proximity to Kanye, access to local road structures, and prevailing wind direction (Figure 18.3).

Figure 18.3 Wind rose



The overall processing plant and infrastructure layout aim to maximise operability, maintainability, and safety. As presented in Figure 18.3, the prevailing wind direction is from the NNE, which will blow any residual gases and vapours from the processing plant away from Kanye. Special design attention was given to the positioning of processing and other equipment in the processing plant layout to ensure a direct and efficient flow of material from the ROM feed point through the production facility to product storage and despatch while minimising conveyor lengths and piping runs.

18.5.3 Buildings

In keeping with the (PEP; Section 24), modularised building construction was specified to be used, where possible, to maximise offsite fabrication. Fully fitted, modular portacabin-style buildings will be used for the administration area with a separate ablution block and a covered outside seating area. All buildings will be erected on simple concrete foundations, and all parking and outdoor storage facilities will be installed on compacted hard stands.

Light steel structures used for buildings, such as warehouses and workshops, will use a portal frame construction complete with overhead gantry cranes. These buildings will be clad with simple corrugated sheeting with large roller doors for major access and conventional doors for personnel access. These entry points have been orientated on opposite sides of the buildings to allow for ventilation during the higher ambient temperatures in summer.

In areas where liquids will be stored or handled, a sloped bund will be constructed as an integral part of the building, complete with sumps.

Specific architectural features will include the following:

- Modular steel-framed buildings will be provided for all maintenance buildings and storage warehouses.
- The explosives and detonator stores will be located within bunkered and modular steel-framed buildings.
- Roll-over metal doors suitable for vehicle entry will be provided for the maintenance buildings and storage warehouses.
- External personnel access doors will be provided, as appropriate, as well as internal partitions.
- Liquid storage will be provided by using sloping bunds complete with sumps.
- Local building materials will be used where possible.

18.5.4 Geotechnical considerations

The site geotechnical profile was determined based on studies conducted during the site investigation. SRK designed the geotechnical site investigation programme and follow-up site and laboratory activities. Material Testing Services (Pty) Ltd. conducted the geotechnical site investigation work.

The ground investigation indicates that a coarse material with low fines content underlies the topsoil across the site. This material composes mostly coarse gravels and sands, boulders, or cobbles of chert breccia, and, to a lesser amount, fine sand. The geotechnical parameters of the soil foundation were estimated according to field measurements, laboratory test results, and internationally used correlations.

The geotechnical profile was defined in accordance with borehole logs, lithological profiling of test pits, and laboratory tests. Table 18.6 shows the geological units present underneath the mine site footprint and the most relevant soil features. The geotechnical parameters were determined based on laboratory tests, trial pits, borehole procedures and standard penetration tests. Foundations were designed taking into consideration the most adverse scenario within the processing plant zone.

The ultimate bearing capacity of shallow foundations was determined according to the Brinch-Hansen formulation for foundations of different dimensions, assuming two different foundation levels: 1.0 m and 1.5 m. Additionally, Schmertmann´s (1978) procedure determined the maximum allowable load, which limits settlements to a maximum of 25 mm. The minimum value between safety limit (by resistance) and service limit (by settlement) must be determined for foundation design.

Table 18.6 General geotechnical profile

Description	Depth (m)	P#200 (%)	Natural moisture content	Plasticity index
Organic topsoil	0.0-0.4	7.0-9.0	0.3-2.0	<4
Loose- to medium-dense sandy gravel with cobbles and boulders	0.4-15.0	5.0-20.0	0.1-5.1	<12
Bedrock (progressively weathered rock transitioning to fresh rock at depth)	-	-	-	-

Note: P#200 is the percentage of material finer than a no. 200 (0.075 mm) sieve.

From the data collected during the field campaign, SRK's analysis recommends an allowable bearing pressure no higher than 150 kPa with a minimum foundation depth of 1.0 m and an allowable bearing pressure no higher than 250 kPa with a minimum foundation depth of 1.5 m.

An expert geotechnical engineer will supervise excavations to set foundations for the processing plant and its facilities to identify if the calculation hypothesis and the observations presented in this report are supported.

18.5.5 Earthworks

18.5.5.1 Bearing capacity

Typical allowable bearing capacities of various sizes for square pad foundations are provided in Table 18.7. The bearing capacities have been calculated based on the Brinch Hansen (1970) equation for shallow foundations. A factor of safety of 3 has been applied to the ultimate bearing resistance calculated from the Brinch Hansen (1970) equation to limit likely settlement below the foundation.

Table 18.7 Typical allowable bearing pressure on pad foundations

Pad size	Allowable bearing pressure(1) (kPa)
1 × 1	271
2 × 2	275
3 × 3	297
4 × 4	324
5 × 5	352

Note: (1) pads are to be founded at least 1 m below the surrounding ground level.

Strain softening (or loosening) of the soils owing to earthquake loading has been allowed in the calculation by selecting reduced effective stress parameters. A preliminary assessment of the information indicates that liquefaction due to earthquake loading is unlikely to be an issue at this site. However, a more detailed assessment is required at the detailed design stage.

The allowable bearing pressure on pad foundations detailed in Table 18.7 assumes that the pads are located on horizontal ground. This assumption remains valid where the pad foundations are located at least twice the width of the pad foundation away from the edge of a slope, for example, a 2 m × 2 m pad foundation located at least 4 m away from the crest of the sloping ground. Where this is not possible, a more detailed bearing capacity assessment will be required at the detailed design stage.

18.5.5.2 Cut-and-fill slopes

Cut-and-fill slopes are expected to be stable in the long term at slopes of 1V:1.5H (vertical:horizontal). Construction of fill slopes should be conducted according to good earthworks practices, as outlined in the earthworks specification. Unused fill will be set aside for use in site rehabilitation. A detailed seismic stability assessment of cut-and-fill slopes was not undertaken as part of the FS.

18.5.5.3 Site roads

All site roads will be graded roads suitable for the intended vehicles and will conform to the road design criteria.

Site roads have been designed according to the general criteria that consider road use, vehicle type, and speed limit. Road-specific criteria are outlined in Table 18.8.

Table 18.8 Road design criteria

Item	Unit	Site roads	Access roads
Maximum design speed	km/h	30	60
Minimum sight distance	m	150	150
Minimum width for single-lane roads	-	2.5 × width of the largest vehicle	-
Minimum width for two-lane roads	-	3.5 × width of the largest vehicle	2.5 × width of the largest vehicle
Minimum safety berm height	-	2/3 diameter of the largest wheel	3.5 × width of the largest vehicle
Maximum safety berm slope	-	1V:1H	1V:1H
Roads widening on curves	-	1.18×	1.18×
Drainage ditch location	-	either side of the road	either side of the road
Drainage ditch minimum depth	m	0.6	0.6
Drainage ditch maximum side slope adjacent to the carriageway	-	1V:2H	1V:2H
Drainage ditch maximum side slope on the external side	-	1V:1H	1V:1H

Item	Unit	Site roads	Access roads
Road maximum gradient haul trucks	%	10	10
Road maximum gradient light vehicles	%	20	20
Road maximum gradient on curves	%	4	4
Road maximum gradient on corners	%	0	0
Minimum camber (cross-fall)	%	3	3
Maximum cut-and-fill slopes	-	1V:1.5H	1V:1.5H

18.5.6 Civil

Aggressiveness testing did not reveal values that indicate medium or high aggressiveness; therefore, concrete of ordinary Portland cement with no additives can be used.

The main parameters that control the design slab foundations for the K.Hill Project are the minimum and maximum temperatures experienced on site. These temperatures have the potential to both degrade concrete once poured and disrupt pouring schedules since there is an optimal temperature range for pouring concrete. Outside this range, various remedial measures must be taken.

Concrete quantities were estimated and classified from the 3D AutoCAD® mine site model and by expert engineering judgment. For estimating purposes, designers provided concrete quantities per the following breakdown:

- foundations (building, equipment, grade beam, slab-on-grade, pedestals, trench, and ductwork)
- elevated concrete (slabs, beams, walls, and any other elevated concrete)
- precast concrete
- grout under base plates
- structural excavation
- structural backfill

A typical reinforced concrete structure was measured and priced, including reinforced steel, concrete, smooth and rough formwork to foundations, columns, suspended slabs, plinths, basic cast-in items such as heavy-duty bolts and joints, and an allowance for the possible use of permanent formwork such as QC decking. Further costing details are provided in Section 21.

18.5.7 Mechanical

18.5.7.1 Processing plant equipment

All processing plant equipment design flow rates are based on the processing plant design feed rates, as stated in the process design criteria and the PFDs (Appendix C). All equipment has been selected for compatibility with the process for which they are designed or selected. Equipment material has been selected, where possible, to eliminate corrosion, clogging, film build-up, etc., owing to the processing fluids.

The equipment has been arranged according to current and approved PFDs.

The design criteria for the equipment layout are as follows:

- Gravity and natural properties of material flow have been utilised to the maximum extent possible to reduce energy inputs.
- Arrangements have been designed to provide a smooth process flow and to allow for merging with other process flow streams.
- All material transfer points have been designed to minimise spillage.
- Adequate accessibility and clearance around equipment have been provided for installation, operation, and maintenance.
- Optimal use of the structures and available space within the structures have been implemented.
- Floors have been suitably sloped, and drains/sumps will be provided and positioned at the lowest point to collect spillage and wash-down water.

The equipment selected is robust and fit for heavy-duty applications typically found in a mining environment. All equipment has been conservatively rated and sized to allow for capacity changes owing to process upsets and variations.

All equipment has been selected to meet site conditions, such as altitude, ambient temperatures, seismic, wind, rain, humidity, and any locally corrosive atmosphere. The equipment has been selected to meet or exceed the Project-specified production requirements for the expected LOM operation.

Wherever possible, standard “off the shelf” equipment and components have been selected. All equipment has been designed and selected according to the processing requirements and site conditions.

As far as possible, equipment has been selected to have a transport weight of less than 10 t per axle or with the capacity to be broken down into subcomponents weighing less than 10 t per axle to meet the transportation requirements to site. Equipment has also been selected to have maximum dimensions of 12 m (long) × 3 m (wide) × 2.6 m (high) or be able to be broken down into subcomponents of less 12 m × 3 m × 2.6 m.

18.5.8 Piping

Piping material has been selected to be reasonable and economical. Piping materials have been selected based on application, operating conditions, climate conditions, and industry-accepted practice. Typically, HDPE pipe will be used for most solution systems, and stainless-steel pipes will be used in corrosive reagent systems.

All pipe sizes have been expressed in Diameter Nominal (DN) using the International System of Units (SI; metric). Piping has been sized for design flow rates and conditions shown on the PFD. Non-standard DNs (32, 65, 90, 125, 175, 225, 325, 550, 800 and 850 mm) have not been used except where required to connect to equipment.

All piping has been designed to be self-draining. Drain and vent connections will be provided at low and high points of the piping system to facilitate maintenance and hydro testing as well as processing requirements.

Generally, all major piping systems have been designed as a "looped" system when possible and practicable, so the solution in the pipe continuously moves to reduce the risk of blockages.

Fire water will be supplied by a combined fresh/fire water tank. The tank will include segregated fire water storage and will be fed by the fresh-water pumps. Fire water will be transferred into two distribution systems: processing plant fire water and crushing plant fire water.

Fire pump types and quantities will be installed per applicable fire protection codes and standards. A jockey pump will keep the fire water ring under pressure.

Fire water supply and pump flow will be provided per applicable fire protection codes and standards, and the pump head will be calculated based on the maximum pressure requirements for the farthest hydrant/user.

18.5.9 Structural

Structural steel shall be modularised, as much as possible, so that construction work on site is minimised. To this end, the use of pre-engineered buildings shall be maximised to obtain cost-effective optimal designs. It is envisaged that all steelwork structural connections will be bolted.

Design for operational serviceability and any accidental load cases will be to a consistent set of design codes such as Eurocodes or ISO codes where different. These codes dictate the recommended loadings and load combinations, plus consequential allowable stresses and deflection limits.

Typical primary steel shall be grade S355 or similar with metric bolts of grade 8.8 or higher.

Typical standard live loads will vary by location from 5 kPa to 15 kPa, with more extreme values considered within the area of the crushers (a minimum of 20 kPa).

Typically, allowable deflections as a function of member length will vary between 1/90 and 1/800, depending on the application.

18.5.10 Electrical

18.5.10.1 Power supply

Electrical power for the K.Hill Project will be provided by an HV (33 kV) line from the main Kanye substation located north of the town, running around the town and down along the western access road to the main plant substation. BPC will provide the HV line and the main plant substation.

The step-up transformers and an 11 kV distribution switchgear will be used for interface to the rest of the facility. The electrical loads are summarised in Table 18.9.

Table 18.9 Electrical loads

	Average load (kWe)	Peak load (kWe)	Emergency load (kWe)
Phase 1	9,875	12,250	7,310

18.5.10.2 Power distribution

Power distribution around the site will be at 11 kV. Cables will run in trenches, and trays will deliver power to the processing plant, including the mills. Overhead lines with a drop to loads along the line will deliver power to areas outside of the processing plant. Electrical rooms will be located close to loads to limit voltage drops to within acceptable tolerances.

The electrical system shall be designed using the voltage levels, frequency, and earthing listed in Table 18.10.

Table 18.10 Electrical system voltages

Application	Criteria
MV level	11 kV, 3 Phase, 50 Hz, high resistance grounded
LV level	400 V, 3+N, 50 Hz high resistance grounded
Lighting and small power	220 V, 1+N, 50 Hz
LV motor contactors	220 V, 1+N, 50 Hz
Equipment heaters	220 V, 1+N, 50 Hz
MCC control circuits	24 VDC
Plant control system hardware	24 VDC
Electrical field controls	24 VDC
Instrumentation	24 VDC

Notes:
MCC - motor control centre
VDC - volt direct current

18.5.11 Control and instrumentation

The control system shall be capable of fully automated integrated process control and incorporate proportional, integral, and derivative (PID) loops and sequence logic control; this is to improve on setpoint control. Improved set point control reduces the number and amplitude of processing upset conditions. It also decreases reagent consumption while not compromising the processing requirements. A fully automated system can decrease maintenance downtime and increases throughput.

18.6 Mining infrastructure

18.6.1 Heavy vehicle workshop

The heavy vehicle workshop will be located within the administration area and consist of a truck wash, a tyre store, two maintenance bays, a spares warehouse, an office, a washroom, and a truck parking area.

18.6.2 Stockpile

The operating stockpile will be located approximately 200 m NE of the processing plant. Preparation for the stockpile will consist of clearing and grubbing; topsoil removal; unsuitable soil removal; low-permeable soil placement; and ripping, moisture conditioning, and compacting. Once all organic material, topsoil, and unsuitable material have been removed, and any low points have been filled with low-permeability material, the foundation will be shaped to promote adequate drainage. Water surrounding the stockpile will flow to the south, as indicated in the water management report (Appendix D) and be diverted around the TMF through the planned diversion channels. Minor diversion ditches around the stockpile should be designed once exact locations and operational strategy are confirmed, considering the dynamic nature of the stockpile.

Design parameters of the stockpile are included in the mining report (Appendix B), where the boundaries are illustrated in the site layout.

The stockpile will be easily accessible, as it is located next to the haul road leading to the processing plant. The ore will be reclaimed using a wheel loader. Finally, the area will be rehabilitated by recovering the area with the topsoil using the wheel loader and levelled using a track dozer once all the material has been reclaimed.

18.6.3 Waste rock dump

The WRD will be located approximately east next to the main pit. All waste generated from open pit operations will be stored in an environmentally sound, safe, and secure manner in permanent storage facilities. The WRD has been designed to accommodate waste rock according to the production and mining schedule. The preparation for the WRD will consist of clearing and grubbing, topsoil removal, unsuitable soil removal, low-permeable soil placement in low-lying areas, and ripping and compacting to create a firm and dense platform to dump the waste rock.

Design parameters of the WRD are included in the mining report (Appendix B), where the boundaries are illustrated in the site layout.

The operational and rehabilitation strategy is covered but mainly involves two access roads from the north and south. The WRD will be gradually rehabilitated, and topsoil will be added back once completed.

It is assumed that the WRD runoff (and seepage) will follow the topography of the existing terrain, draining in an east-to-southeast direction. Collection channels will intercept the drained water along the southern and eastern boundaries of the WRD. This water will be channelled to the low topographic points south and east of the WRD, where a sedimentation pond in each location is proposed to control the settling of suspended solids and water quality.

18.6.4 Explosive magazine

The mine will use ammonium nitrate and fuel oil (ANFO) explosives in controlled blasts to mine heavily consolidated parts of the orebody. Bagged ammonium nitrate will be stored in a secure, bunkered facility near the open pit; detonators will be stored separately at the same facility. The ANFO will be prepared on an explosives truck.

The explosives store will be contained behind a high-security fence within an exclusion zone and will be accessible via a boom gate at the entrance that will be manned by security guards. Only authorised personnel will be permitted to enter the facility. A maintained graded road will connect the components of the storage area.

18.7 Processing

The processing plant will treat 200 kt/a of ROM ore from the open pit at an average grade of 18.9% manganese oxide to produce HPMSM. The mineralised material comprises Mn-shale and Fe-shale, is moderately hard, and is amenable to reductive acid leaching in sulphate media using sulphur dioxide as a reductant.

The process comprises crushing and grinding to reduce the ROM material to a characteristic grind (P_{80}) of 150 µm, an acid reductive leach in sulphate media at an elevated temperature using sulphur dioxide as a reductant, and a sequential purification process for the removal of metal impurities. Fluoride polishing will be carried out to further improve the purity of the solution. The purified solution will undergo evaporative crystallisation followed by filtration and drying to produce the HPMSM as a final product. The solids removed in the sequential purification and fluoride polishing will be either disposed of in the TMF or stored in an intermediate product storage facility. All liquors removed in the treatment of the ore will be either treated in the water treatment plant or used for haul road dust suppression

18.7.1 Plant area layout

The overall processing plant layout is based on the concepts of maximised operability, maintainability, and general safety. Special design attention was given to the position of processing and other equipment in the processing plant layout to ensure a direct and efficient flow of material from the ROM feed point through to the crystalliser, minimising conveyor lengths and piping runs.

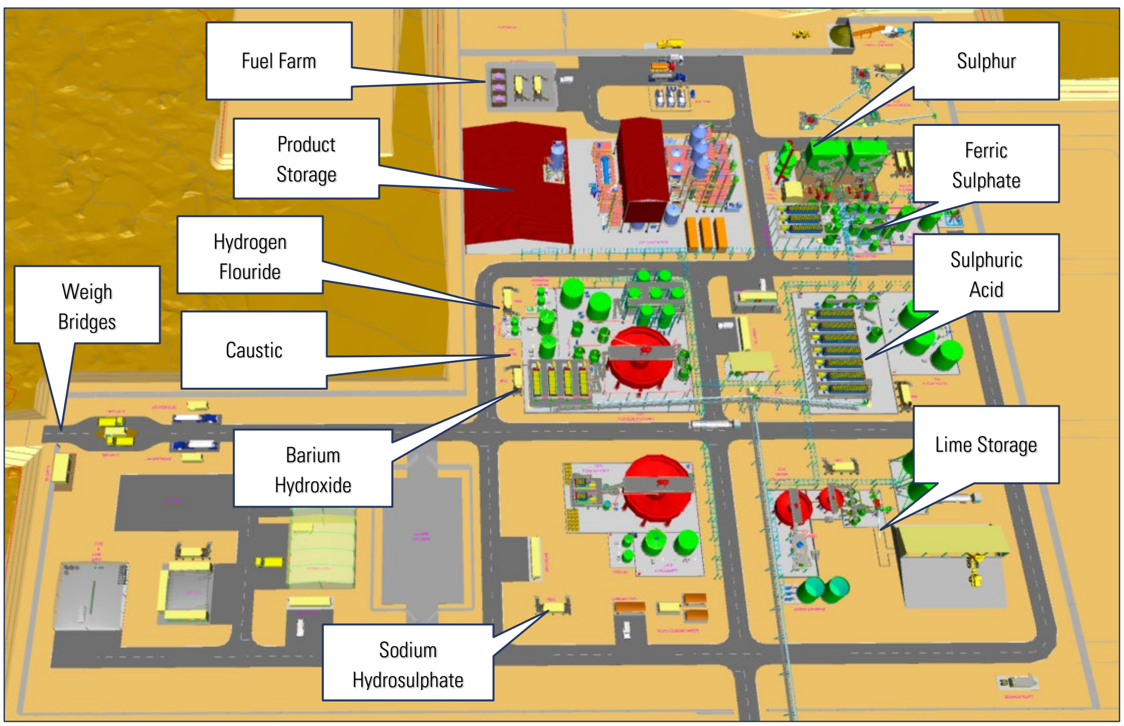
The processing plant layout includes provision for a possible future production capacity increase through an additional processing stream east of the currently planned installation.

18.7.2 Transport movements

The overall plant road layout was developed to provide ready access to all processing plant areas. Most of the traffic will be logistical in nature, with reagent deliveries comprising the major vehicle flow. On average between 11 and 12 trucks per day will deliver reagents.

As shown on Figure 18.4, the truck route from the incoming weighbridge to offloading and the outgoing weighbridge allows for a single direction of travel without reversing or the use of turnabouts. Sufficient parking space has been allowed for ten trucks to park outside the gatehouse to avoid congestion of heavy vehicle traffic inside the plant area. The weighbridges will be manned 24 h/d, 7 d/wk.

Figure 18.4 Principal materials and unloading points



Non-logistical traffic, such as staff vehicles, will be largely confined to the office and administration area at the entrance to the site. This is intended to minimise the interaction between light and heavy vehicles. For the same reason, heavy vehicle traffic travelling to the tyre and lube workshop area will enter the plant area from the south gate, which is off-limits for light vehicle use. Similarly, heavy vehicles using the fuel filling station will be isolated from other traffic by the processing plant boundary fence.

18.7.3 Run-of-mine pad

The ROM pad and stockpile area will provide temporary storage to balance the processing plant feed rate with mine production and a facility for blending material of different grades and quality before being fed to the processing plant. Material will be trucked from multiple stockpiles and dumped on the ROM pad, where it will be blended and stacked by a front-end loader. The ROM pad operation will be integrated into mine stockpiling activities, the mining schedule, and mine operations. ROM stockpiling activities will be designed to keep potential feed contaminants within specified ranges. Blending will be achieved by stacking in layers and recovering in vertical "slices." Material recovery will be undertaken by an front-end loader that will deliver feed material to the mobile crusher feed hopper.

18.7.4 Crushing

Ore will be delivered either by mine haul truck directly from the open pit or with an front-end loader and dumped onto a ROM feeder that will control the ore discharge into a skid-mounted mobile jaw crusher. The integrated unit is equipped with a vibrating grizzly feeder that separates the fines from the feed to reduce the load on the crusher. The undersize and jaw crusher product will be conveyed to a two-stage cone crushing circuit.

The crushed rock will be screened by the single-deck primary vibrating screen. Oversize will be conveyed to the secondary cone crusher and undersize combined with the final crushed product. Secondary crushed product will be conveyed to a tertiary cone crusher in a closed circuit with a single deck secondary vibrating screen. The combined underflows of the secondary and tertiary screens (with a P80 of 13 mm) will be conveyed to the mill feed bin.

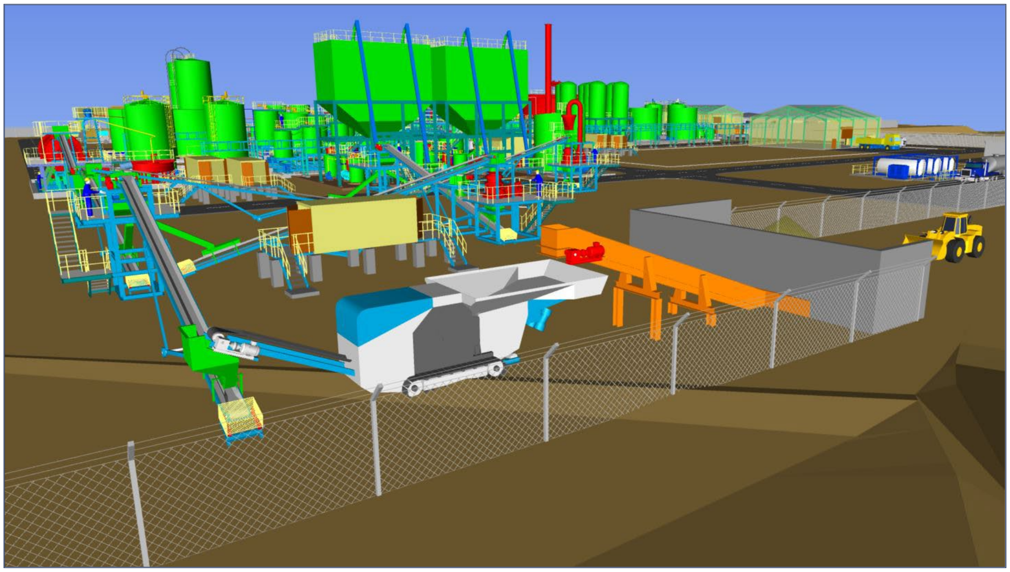
The screen undersize from the secondary crushing circuit will be conveyed to a crushed material bin, where it will be reclaimed and fed to the processing plant as required. The crushed material bin has been designed with enough surge capacity to provide an uninterrupted feed supply to the mill during crusher shutdown periods.

A summary of the major crushing equipment is shown in Table 18.11, and a sketch of the crushing plant is shown in Figure 18.5.

Table 18.11 Crushing - major equipment

Equipment number	Equipment description	Nominal rate/ capacity (m^3/h)	Motor size (kW)
2100-FE-001	Primary crusher feeder	35.1	37.5
2100-XM-001	Primary crusher	35.1	55.0
2100-SC-001	Primary vibrating screen	20.8	5.5
2100-CR-002	Secondary cone crusher	15.6	75.0
2100-SC-002	Secondary vibrating screen	46.8	5.5
2100-CR-003	Tertiary cone crusher	31.2	75.0

Figure 18.5 Crushing plant



18.7.5 Grinding

The crushed ore will be extracted from the mill feed bin using vibrating feeders to control the rate measured by the weightometer on the mill feed conveyor. Balls will be added to the feed from time to time.

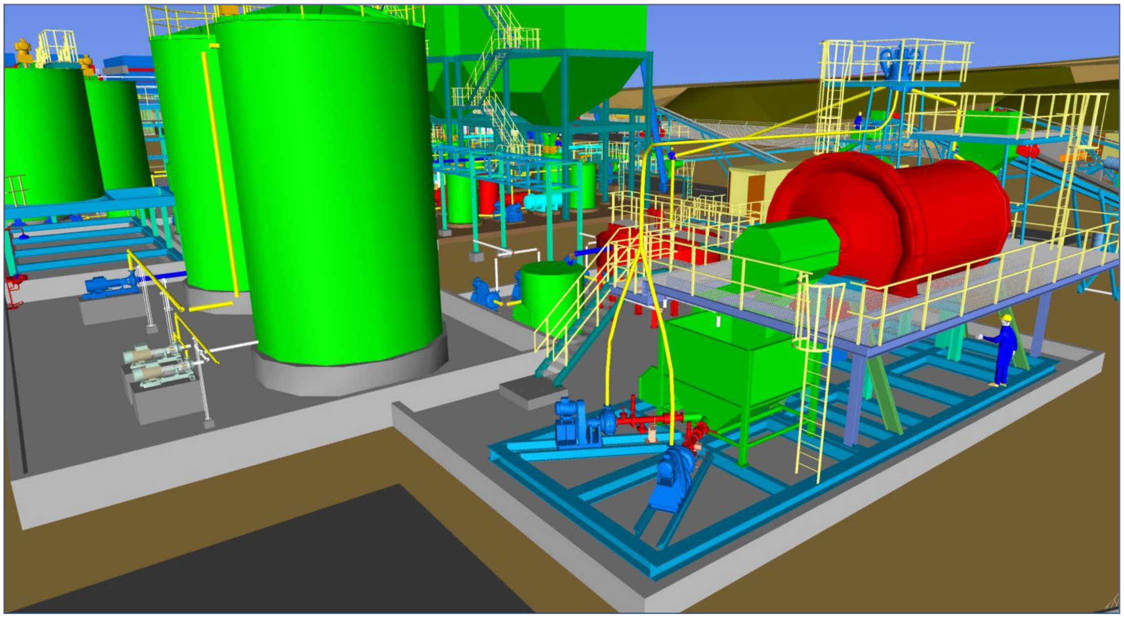
A closed-circuit mill will reduce the 13 mm feed to a P80 of less than 150 µm. The conventional pinion-driven overflow ball mill will discharge via trommel into a pump box and the milled slurry will be pumped into a cyclone cluster. Cyclone overflow will launder to the mill thickener to control leach feed density. Thickener overflow will be recycled in the mill circuit and topped up with process water into the feed spout and mill discharge pump box.

The major grinding equipment is shown in Table 18.12, and a sketch of the grinding plant is shown on Figure 18.6.

Table 18.12 Grinding - major equipment

Equipment number	Equipment description	Normal rate/ capacity (m^3/h)	Dimensions	Motor size (kW)
2200-BN-001	Ball mill feed bin	15.2	-	-
2200-FE-001	Ball mill feed bin feeder	15.2	-	5.5
2200-ML-001	Ball mill	56.4	-	450.0
2200-CY-001	Cyclone cluster	129.0	-	-
2200-TH-001	Mill thickener	85.7	5 m Ø	5.5

Figure 18.6 Grinding plant



18.7.6 Extraction

Manganese will be extracted as a sulphate in a reductive sulphuric acid leach at a pH of between 1.0 to 1.5 at 90°C using sulphur dioxide as a reductant.

Mill thickener underflow will be pumped to a sealed agitated leach feed tank to control the feed rate and pH of the leach feed. Sulphuric acid will be added to this conditioning and surge tank while elevating the temperature. The acidic slurry will then be pumped via a heat exchanger to the first of four agitated overflow leach tanks. Sulphur dioxide gas will be sparged into each tank to maintain a redox potential (EH) of 600 mV. The discharge from the fourth leach tank will flow by gravity into the leach discharge pump box and will be pumped to the first potassium precipitation tank in the purification area.

All tanks in this area will be made from 904L stainless steel with nitrile rubber liner agitators. Pump casings will be mild steel with nitrile rubber-lined liners and casings.

The major extraction equipment is shown in Table 18.13.

Table 18.13 Extraction - major equipment

Equipment number	Equipment description	Nominal rate /capacity (m³/h)	Dimensions	Motor size (kW)
2300-HX-001	Leach heat exchanger	79.9	-	-
2300-TK-002	Leach tank no. 1	53.9	3 m Ø × 5 m	-
2300-TK-003	Leach tank no. 2	53.9	3 m Ø × 5 m	-
2300-TK-004	Leach tank no. 3	53.9	3 m Ø × 5 m	-
2300-TK-005	Leach tank no. 4	53.9	3 m Ø × 5 m	-

18.7.7 Purification

The first stage of purification is jarosite precipitation, in which potassium and sodium impurities will be removed at an elevated temperature and at a low pH by ferric iron in a series of agitated tanks.

The second stage is neutralisation. The leach residue slurry will be neutralised in two stages using limestone and lime, first to a pH of approximately 4 using limestone and then to a pH of 5 to 5.5 using lime, in which iron and aluminium are precipitated as hydroxides, and other base metals are partially co-precipitated.

Major purification equipment is shown in Table 18.14.

Table 18.14 Purification - major equipment

Equipment number	Equipment description	Normal rate/ capacity (m³/h)	Dimensions	Motor size (kW)
2350-TK-001	Potassium precipitation tank no. 1	95.3	4.4 m Ø × 7.1 m	-
2350-TK-002	Potassium precipitation tank no. 2	95.3	4.4 m Ø × 7.1 m	-
2350-TK-003	Potassium precipitation tank no. 3	95.3	4.4 m Ø × 7.1 m	-
2350-TK-004	Potassium precipitation tank no. 4	95.3	4.4 m Ø × 7.1 m	-
2350-FP-001	Filter press no. 1	90.5	2 m × 2 m × 80 Chambers	37.5
2350-FP-101	Filter press no. 2	90.5	2 m × 2 m × 80 Chambers	37.5
2350-FP-201	Filter press no. 3	90.5	2 m × 2 m × 80 Chambers	37.5
2350-FP-301	Filter press no. 4	90.5	2 m × 2 m × 80 Chambers	37.5
2350-FP-401	Filter press no. 5	90.5	2 m × 2 m × 80 Chambers	37.5
2350-FP-501	Filter press no. 6	90.5	2 m × 2 m × 80 Chambers	37.5
2350-FP-601	Filter press no. 7	90.5	2 m × 2 m × 80 Chambers	37.5
2350-TH-001	Base metal thickener	91.2	22 m Ø	18.5
2350-FP-002	Base metal filter press no. 1	1.0	2 m x 2 m x 20 Chambers	18.5
2350-FP-102	Base metal filter press no. 2	1.0	2 m x 2 m x 20 Chambers	18.5

The slurry will be pumped from the extraction area into the first potassium precipitation tank. In the first precipitation tank, ferric sulphate will be added for the jarosite precipitation reaction. The pH of 1.5 in the jarosite precipitation tanks will be maintained using manganese hydroxide returned from the crystallisation area as well as lime.

The discharge from the fourth potassium precipitation tank will flow by gravity into the first limestone precipitation tank in the purification area, along with the material from the scrubber in the processing plant infrastructure area and limestone to increase the pH. The carbon dioxide produced from the neutralisation reaction will be vented off. The slurry will then be pumped to a second precipitation tank where lime and air will be added to further increase the pH and oxidise the remaining ferrous iron, precipitate iron, and aluminium as their insoluble hydroxides. The slurry will then be pumped into the filter press feed tank. The filter press feed tank acts as a buffer for batch filtration, which employs plate and frame filter presses. The slurry will then be pumped into the plate and frame filter presses, which will remove the solids from the slurry, leaving a filter cake that will be conveyed to tailings handling. The filtrate will be collected in the filtrate tank before being pumped to the base metal precipitation tank.

Sodium hydrosulphide will be dosed to the base metal precipitation tank to precipitate the base metals. The slurry will then be pumped to the base metal thickener for solids concentration. The thickened underflow slurry from the base metal thickener will then be pumped into the base metal filter press feed tank. The base metal filter press feed tank will act as a buffer for batch filtration using a plate and frame base metal filter press. The slurry will then be pumped into the plate and frame base metal filter press, which will remove the solids from the slurry, leaving a filter cake that will be conveyed to a bulk bagging and storage area. The filtrate will then be collected in the base metal filtrate tank before being pumped back into the base metal thickener. The overflow from the base metal thickener will then flow by gravity into the first hydrofluoric acid polishing tank.

18.7.8 Fluoride polishing

Calcium and magnesium will be removed through fluoride polishing, using hydrofluoric acid and barium hydroxide for pH adjustment. The calcium will be almost completely removed, and magnesium will be substantially removed both as insoluble fluorides, and the barium used in pH adjustment will be precipitated as an insoluble sulphate.

Major equipment for fluoride polishing is shown in Table 18.15.

Table 18.15 Fluoride polishing - major equipment

Equipment number	Equipment description	Normal rate /capacity (m^3/h)	Dimensions	Motor size (kW)
2400-TH-001	HF polishing thickener	132.2	24 m Ø	18.5
2400-FP-001	HF polishing filter press no. 1	14.9	2 m × 2 m × 70 Chambers	18.5
2400-FP-101	HF polishing filter press no. 2	14.9	2 m × 2 m × 70 Chambers	18.5
2400-FP-201	HF polishing filter press no. 3	14.9	2 m × 2 m × 70 Chambers	18.5

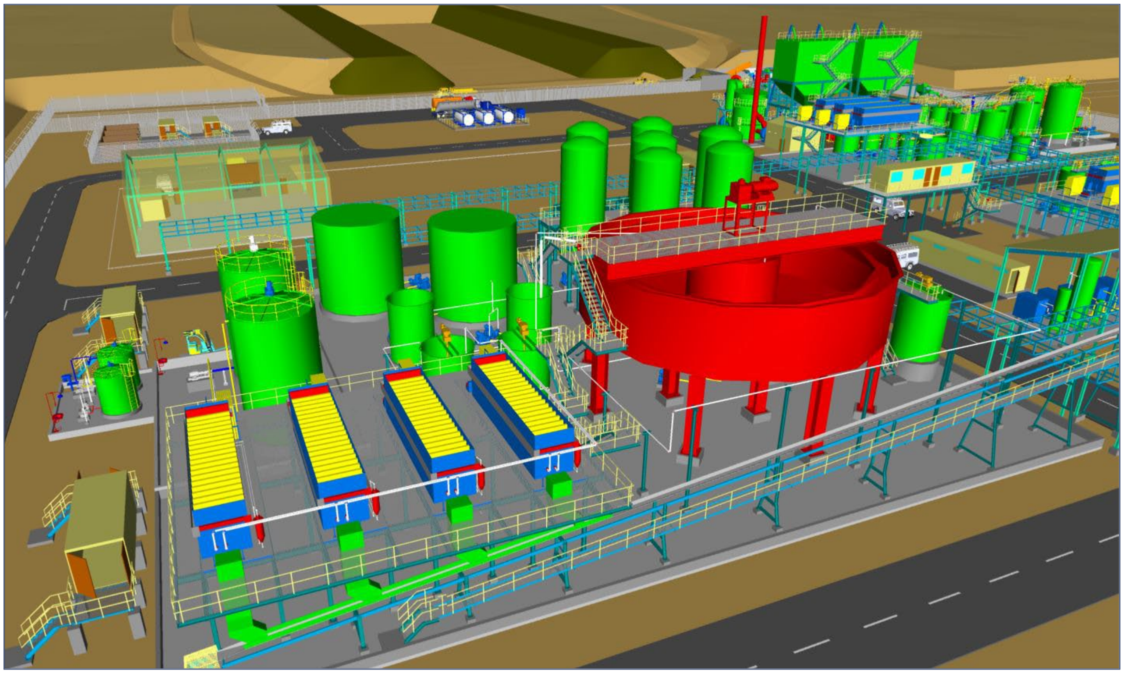
Equipment number	Equipment description	Normal rate /capacity (m^3/h)	Dimensions	Motor size (kW)
2400-FP-301	HF polishing filter press no. 4	14.9	2 m × 2 m × 70 Chambers	18.5
2400-TK-004	HF polishing filtrate tank	12.6	1.9 m Ø × 2.2 m	-
2400-CL-001	Alumina adsorption column no. 1	111.3	4 m Ø × 10.3 m	-
2400-CL-002	Alumina adsorption column no. 2	111.3	4 m Ø × 10.3 m	-
2400-CL-003	Alumina adsorption column no. 3	111.3	4 m Ø × 10.3 m	-
2400-CL-004	Alumina adsorption column no. 4	111.3	4 m Ø × 10.3 m	-
2400-CL-005	Alumina adsorption column no. 5	111.3	4 m Ø × 10.3 m	-
2400-CL-006	Alumina adsorption column no. 6	111.3	4 m Ø × 10.3 m	-
2400-CL-007	Alumina adsorption column no. 7	111.3	4 m Ø × 10.3 m	-

The precipitate will be concentrated and removed by filtration, and the solution will be transferred to fluoride removal. Residual fluoride will be removed conventionally using activated alumina in columns. The columns will be operated as a carousel, with one of the columns having the alumina stripped of fluoride and regenerated cyclically. This is described in further detail using the following method.

The overflow from the base metal thickener will flow by gravity into the first hydrofluoric acid polishing tank, along with slurry seed material from the hydrofluoric acid polishing thickener underflow, where hydrofluoric acid and barium hydroxide are added to facilitate the precipitation of the calcium and magnesium. The slurry will then flow by gravity from the first hydrofluoric acid polishing tank into the second hydrofluoric acid polishing tank. The slurry will then be pumped from the second hydrofluoric acid polishing tank into the hydrofluoric acid polishing thickener together with the filtrate from the hydrofluoric acid polishing filtrate tank. The overflow from the hydrofluoric acid polishing thickener will then flow by gravity into the alumina column feed tank. The underflow from the hydrofluoric acid polishing thickener will be pumped and split between the first hydrofluoric acid polishing tank and the hydrofluoric acid polishing filter feed tank. The hydrofluoric acid polishing filter press feed tank will act as a buffer for the batch filtration using a plate and frame hydrofluoric acid polishing filter press. The slurry will then be pumped into the plate and frame hydrofluoric acid polishing filter press, which will remove the solids from the slurry, leaving a filter cake that will be conveyed to tails handling. The filtrate will then discharge into the hydrofluoric acid polishing filtrate tank. The filtrate collected in the hydrofluoric acid polishing filtrate tank will then be pumped back into the hydrofluoric acid polishing thickener.

A sketch of the fluoride polishing plant is shown in Figure 18.7.

Figure 18.7 Fluoride polishing plant



The alumina column feed tank will act as a buffer for the batch removal of fluoride in the alumina adsorption columns. Seven alumina columns will operate as a carousel. Six columns will operate in series, with the seventh column used for stripping of fluoride and regeneration of the alumina. The solution that has been contacted with the activated alumina will then be pumped into the crystalliser feed tank.

After feeding the solution through the six columns for four hours, the feed arrangement will then change. The column that was being regenerated will become the first column in the sequence, what was the first column will become the second, the second will become the third in the series, and so on. The last column in the sequence will start the regeneration sequence for the column that was number six in the sequence.

The regeneration sequence will start by draining the column and pumping the solution back into the alumina column feed tank. The alumina will then be washed with a caustic solution to strip the fluoride from the alumina. The alumina will then be washed to remove any residual caustic solution, and then the solution will be contacted with a dilute sulphuric acid solution to complete the regeneration step. The spent solution will then be pumped to the water treatment area for treatment.

The dilute acid will be developed by adding demineralised water to the dilute acid tank and then adding the required concentrated sulphuric acid to the tank. Similarly, the diluted caustic solution will be developed in the regenerant tank by adding demineralised water to the regenerant tank and adding the concentrated caustic solution to the tank.

18.7.9 Crystallisation

High-purity stock solution will be pumped to a bespoke designed multistage crystalliser that will produce a dried crystalline HPMSM product as well as a bleed stream that will prevent a build-up of dissolved solids in the crystalliser. The bleed stream contains sufficient manganese to warrant secondary recovery as a manganese hydroxide precipitate which will be separated and repulped using demineralised water. The pulp will be pumped back into the manganese hydroxide dosing tank, which will act as a buffer, allowing for variations in flow owing to the batch nature of the filter press. The manganese hydroxide dosing pumps will control the resulting slurry feed to the jarosite precipitation to be used for pH adjustment and return the manganese into the process. The major equipment for the crystallisation process is shown in Table 18.16.

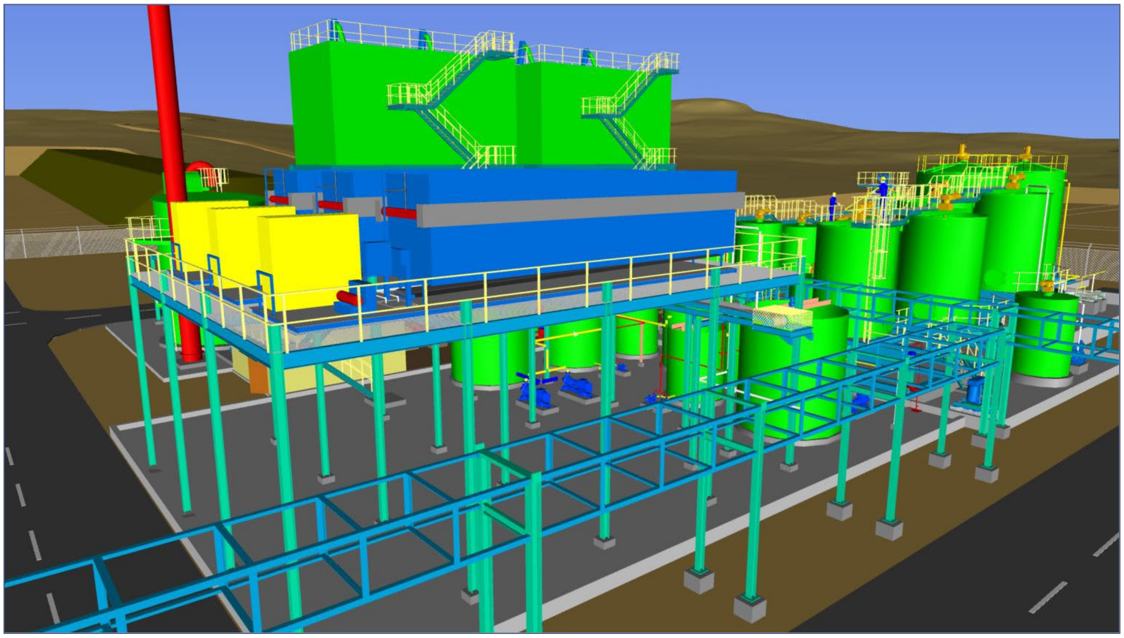
Table 18.16 Crystallisation - major equipment

Equipment no.	Equipment description	Normal rate/ capacity (m^3/h)	Dimensions	Motor size (kW)
2450-CN-001	Crystalliser pre-concentrator	100.2	-	500.0
2450-BL-001	Crystalliser crude fan	-	-	2,200.0
2450-BL-002	Crystalliser pure fan	-	-	2,200.0
2450-AN-001	Crystalliser ancillaries	-	-	2,000.0
2450-DR-001	Crystalliser dryer	-	-	2,200.0
2450-TK-001	Manganese precipitation tank no. 1	10.7	2.4 m Ø × 2.9 m	-
2450-TK-002	Manganese precipitation tank no. 2	10.7	2.4 m Ø × 2.9 m	-
2450-TK-003	Manganese precipitation tank no. 3	10.7	2.4 m Ø × 2.9 m	-
2450-FP-001	Manganese filter press no. 1	10.7	2 m × 2 m × 60 Chambers	18.5
2450-FP-101	Manganese filter press no. 2	10.7	2 m × 2 m × 60 Chambers	18.5
2450-FP-201	Manganese filter press no. 3	10.7	2 m × 2 m × 60 Chambers	18.5

A semi-automated bulk bag bagging machine will be used to package the HPMSM crystals ready for shipping. The systems will use looped bulk bags that are placed onto the bag-holding frame by the operator. After the operator places the bags, the bagging machine system will fill the bag to a pre-set weight or value. Once the required pre-set value has been reached, the bag will be lowered on to a roller conveyor, where it will be transported by truck lift to the storage area.

A sketch of the manganese precipitation plant is shown in Figure 18.8.

Figure 18.8 Manganese precipitation plant



18.7.10 Reagents

The processing plant will use reagents for different parts of the purification process. This section describes the offloading, mixing, and dosing description of each of the reagents to be used:

- sodium hydrosulphide
- hydrofluoric acid
- barium hydroxide
- sulphuric acid
- sulphur dioxide gas
- caustic/sodium hydroxide
- flocculant
- ferric sulphate

The storage parameters for each of the reagents are shown in Table 18.17.

Table 18.17 Storage parameters for on-site primary commodities

Commodity	Rate (m^3/h)	Storage (days)	Storage quantity	Tankage details
Sodium hydrosulphide	0.02	28	20 t	20 bulk bags
Hydrofluoric acid	0.24	14	100 m^3	5 × ISO tank
Barium hydroxide	0.88	14	350 m^3	1 silo
Sulphuric acid	6.17	12	2,000 m^3	4 of 8 × 12 m tanks
Sodium hydroxide	0.43	14	300 t	300 bulk bags
Flocculant	0.02	28	15 t	15 bulk bags
Ferric sulphate	0.97	14	350 m^3	1 silo
Elemental sulphur	2.89	14	1,000 m^3	2 silos
Activated alumina	0.06	28	40 t	50 bulk bags
Lime	4.45	5	600 m^3	2 silos
Limestone	2.61	14	1,000 m^3	Bunker

18.7.10.1 Sodium hydrosulphide makeup and dosing

Sodium hydrosulphide will be used in the purification area for the precipitation of base metals.

A bulk bag of sodium hydrosulphide will be lowered onto a sodium hydrosulphide bag splitter to empty it into the sodium hydrosulphide mixing tank. Demineralised water will be added to the sodium hydrosulphide mixing tank to achieve the required concentration, and the tank will be agitated to ensure dissolution. When ready for transfer, the reagent will be pumped into the sodium hydrosulphide dosing tank and then pumped to the purification section for addition.

18.7.10.2 Hydrofluoric acid storage and dosing

Hydrofluoric acid will be used in the fluoride polishing area for the precipitation of calcium and magnesium from the solution.

ISO containers of hydrofluoric acid will be unloaded using the hydrofluoric acid unloading pump to pump the acid into the hydrofluoric acid storage tank. When required, the acid will be pumped into the hydrofluoric acid dosing tank. From the hydrofluoric acid dosing tank, the acid will then be pumped to the fluoride polishing area for addition.

18.7.10.3 Barium hydroxide makeup and dosing

Barium hydroxide will be used in the fluoride polishing area for control of pH during the precipitation of calcium and magnesium from the solution.

A bulk bag of barium hydroxide will be lowered onto a barium hydroxide bag splitter to empty it into the barium hydroxide mixing tank. Demineralised water will be added to the barium hydroxide mixing tank to achieve the required concentration, and the tank will be agitated to ensure suspension of the solids. When ready for transfer, the reagent will be pumped into the agitated barium hydroxide dosing tank.

The barium hydroxide slurry in the barium hydroxide dosing tank will then be pumped to the dosing point in the purification section for addition with the ring main, returning to the barium hydroxide dosing tank.

18.7.10.4 Sulphuric acid storage and dosing

Sulphuric acid will be used for the extraction of metals from the ore in the extraction area.

Sulphuric acid will be delivered by a tanker and offloaded by pumping the acid into any of the four acid storage tanks. One of the four acid feed pumps will be used for the dosing of sulphuric acid into the leach tank and the dilute acid tank.

18.7.10.5 Sulphur dioxide (vendor-supplied)

The sulphur dioxide plant will be supplied as a vendor package. Sulphur will be conveyed from the sulphur stockpile into the sulphur melting tank. The liquid sulphur will be filtered to remove any solids, and the molten sulphur will be pumped into the sulphur burner along with clean, dry air to produce sulphur dioxide gas. The gas will be cooled using demineralised water. The generated steam will be used in the plant for slurry heating duty, and the cooled sulphur dioxide gas will be stored in a receiver for use in the leach area as required.

18.7.10.6 Caustic/sodium hydroxide makeup and dosing

Caustic (sodium hydroxide) will be used in the fluoride polishing area for the regeneration of the activated alumina.

A bulk bag of sodium hydroxide will be lowered onto a caustic bag splitter to empty into the caustic mixing tank. Demineralised water will be added to the caustic mixing tank to achieve the required concentration. The tank will be agitated to ensure the mixing and dissolution of the sodium hydroxide. When ready for transfer, the reagent will be pumped into the caustic dosing tank.

The sodium hydroxide solution in the caustic dosing tank will be pumped to the fluoride polishing section for addition to the regenerant tank.

18.7.10.7 Flocculant makeup and dosing (vendor-supplied)

A vendor-supplied unit will provide flocculant to the plant. Flocculant will be used to flocculate fine, low concentration particulate material. This will improve the solid-liquid separation characteristics of the slurry and decrease the required equipment size.

Flocculant bags and demineralised water will be added to the flocculant mixing tank. The flocculant will be hydrated and pumped into the storage tank. The flocculant solution will be pumped into the various separation equipment as required.

18.7.10.8 Ferric sulphate makeup and dosing

Ferric sulphate will be used in the purification area for the precipitation of jarosite.

Bulk bags of ferric sulphate will be lowered onto a ferric sulphate bag splitter to empty into the ferric sulphate mixing tank. Demineralised water will be added to the ferric sulphate mixing tank to achieve the required concentration, and the tank will be agitated to ensure the mixing and dissolution of the ferric sulphate. When ready for transfer, the reagent will be pumped into the ferric sulphate dosing tank.

The ferric sulphate solution in the ferric sulphate dosing tank will then be pumped to the purification area section to be added to the potassium precipitation tanks.

18.7.11 Plant utilities

The following utility streams will be managed in the processing plant:

- raw water provided by the Water Utilities Corporation WUC into the plant raw water tank at 30.6 m^3/h
- process water reclaimed from the TMF clarification pond
- excess water reclaimed from process water and water treatment effluent used for dust suppression
- soft water produced on site for steam production
- demineralised water produced on site for high-purity process uses
- medium-pressure steam, approximately 6 bar(g), generated on site in dedicated boiler units at the sulphur burning plant
- compressed air divided into two uses, each with their own line and receivers:
    - plant air: 7.5 bar(g) for general use
    - instrument air: 7.5 bar(g) dried and filtered

Processing plant infrastructure includes:

- off-gas scrubber to remove pollutants and appropriate for discharge to the atmosphere (clean gas will be discharged via a stack)
- plant control room
- laboratory
- product stores

18.7.12 Control and instrumentation

18.7.12.1 Control

Tetra Tech has designed a control architecture that will consist of distributed programmable logic controllers (PLCs) with personal computer-based supervisory control and data acquisition (SCADA) stations located in the processing plant and the crystalliser control rooms, respectively.

Site-wide infrastructure (i.e., telephone, Internet, security, fire alarm and control system, and a fibre optic backbone) will be installed throughout the processing plant site. Electronic instrumentation and the process control system, with locally mounted input/output (I/O) panels or local PLCs, will be connected to a fibre optic redundant control network so that all controls for the facilities at the processing plant site can communicate on this network.

Vendor control systems provided with equipment packages will have local operator control stations, human-machine interface (HMI), or SCADA workstations. These control packages will interface with the main plant control system via a digital communication gateway (Ethernet or equivalent) to the central fibre optic control network. Digital signals from the central control system to external control systems will be fail-safe volt-free contact closures.

A control room located with the crystalliser vendor package will be provided with a single SCADA workstation. Control and monitoring of the crystalliser and product handling areas will be conducted from this location. Control and monitoring functions for instrumentation will include the vendors' instrumentation packages.

The PLC, in conjunction with the SCADA system, will perform all equipment and process interlocking, control, alarming, trending, event logging, and report generation. PLC I/O cabinets will be located in electrical rooms throughout the plant and interconnected via a plant-wide fibre optic network. The control system will be capable of integrated process control, PID loops, and sequential logic control. Programming will adhere to the International Electrotechnical Commission (IEC) 61131/3 control systems programming standard.

Analogue I/O cards will be Profibus DP protocol capable. The control system will be capable of communicating via various industrial protocols, including DeviceNet, Foundation Field Bus, Profibus DP, Ethernet IP, and Modbus TCP/IP.

Intelligent-type MCCs will be located in the electrical rooms throughout the plant. MCC remote operation and monitoring will use a Profibus DP, or another approved industrial communications protocol interfaced with the PLC system.

As a safety measure and for increased plant availability, the control system will have redundancies on controllers, operator consoles, power supplies, communications modules, and critical plant I/O cards. In addition, an uninterruptable power supply (UPS) will be installed to power the control system and field instruments in the event of a power outage. All interlock systems will be designed to be "fail safe". Upon device failure, loss of power, or loss of instrument air, the outputs that control process streams will fail to a pre-defined safe state (e.g., output contacts fail open, solenoid valves fail de-energised, control valves fail to close, motors fail stopped).

A continuous historian server with backup facilities will collect process data that will be accessible via the control system SCADA stations.

A summary of the control system architecture is presented in Table 18.18.

Table 18.18 Control system architecture

System	Specification	
Programming software	WINCC	
SCADA software	Siemens PCS 7	
Historian software	OSIsoft PI Historian	
Central site control point	Central control room in processing plant	
Local/remote SCADA	Employ local and remote control and monitoring	
Level of operators	Semi-skilled	
Distributed controllers	Yes, I/O Extension: Siemens Simatic ET200M	
PLC	Preferred PLC: Siemens S7-300 & 400 (Consider new S7-1500)	
Communications protocol	Ethernet for PLC to SCADA; Profibus for variable speed drive	
Communication links	Optic fibre ground wire some overhead lines (preferred)	
UPS	Yes, 30 minutes.	
Enclosures	Inside IP52, outside IP66	
If radio	Frequency band	D-link radio (2.4 GHz)

18.7.12.2 Instrumentation

Field instrumentation will consist of microprocessor-based “smart” type devices. Instruments will be grouped into processing areas and wired to local field instrument junction boxes located within those areas. Signal trunk cables will connect the field instrument junction boxes to PLC I/O cabinets.

Flow measurement

In general, Tetra Tech specified magnetic-type flow meters for remote flow monitoring. For slurry applications or installations in non-conducting pipes, the magnetic flow tubes will be supplied with liner protection/grounding rings. Rotameters will be used for local flow indication of air or clean fluids. Vortex flow meters will be used for remote flow measurement of air or clean fluids. Mass flow will be calculated in the plant control using a separate density measurement and the volumetric flow. Water flow switches will be thermal type; mechanical-type flow switches will not be used.

Level measurement

Conductivity-type level switches were specified for point liquid level measurements in sumps, tanks, or pump boxes, and ultrasonic level transmitters for continuous liquid level measurements. For continuous level measurement in environments that are misty or for applications that may involve a liquid interface, the use of radar-level-type transmitters will be investigated during detailed design.

Tetra Tech specified capacitance plate-type switches for conveyor discharge chutes, and ultrasonic level transmitters and target floats for continuous liquid level measurement in leach cells. Continuous level measurement of outdoor ponds will use submersible (pressure-type) level transmitters.

Pressure measurement

Generally, local pressure indication will be measured by bourdon-type element process pressure gauges. Where processing service conditions dictate, gauges will be supplied with an integral diaphragm seal to protect gauge internals. For continuous remote pressure measurement of air, water, or other clean services, standard process-type pressure transmitters will be used. For pressure measurements of corrosive or erosive services, pressure transmitters with diaphragm seals will be used. For single-point pressure sensing, snap action-type switches will be used with adjustable dead bands.

Temperature measurement

Generally, temperature sensors will be platinum-type resistance temperature detectors (RTDs). The RTDs will be installed in thermowells and wired to integral connection heads. RTD signals will be wired to remotely mounted temperature transmitters. Thermowell materials will meet all Project piping specifications of the line in which they are installed.

Modulating valves

Tetra Tech selected electro-pneumatic positioner, spring-opposed actuator, and air set modulating control valves, all pre-tubed and mounted to the valve prior to shipment to site. For clean service, an eccentric disc, plug-type, or v-ball-type valve will be used. Control valves will not be used for slurry flow control. Rubber pinch valves will be used for slurry applications in reagents only. Knife gates will be used in slurry applications greater than 100 mm.

Open/close valves

Open/close valve types will follow the Project piping specification. Valves that are 100 mm (4 inches) or larger will be supplied with a double-acting pneumatic actuator, limit switches, and a remotely mounted pneumatic hand switch. A spring-opposed actuator and solenoid valve will be supplied with open/close valves requiring actuation to a failsafe position on loss of power or loss of air. Inline solenoid valves will be used for isolation of non-slurry lines of 50 mm or less.

Discrete inputs

All discrete switch-type field instruments will be dry form “C” contacts, with a preferred rating of 24 VDC.

18.8 Tailings management facility

A summary of the detailed findings associated with the planned TMF is presented in this section. The full TMF report can be found is Appendix E.

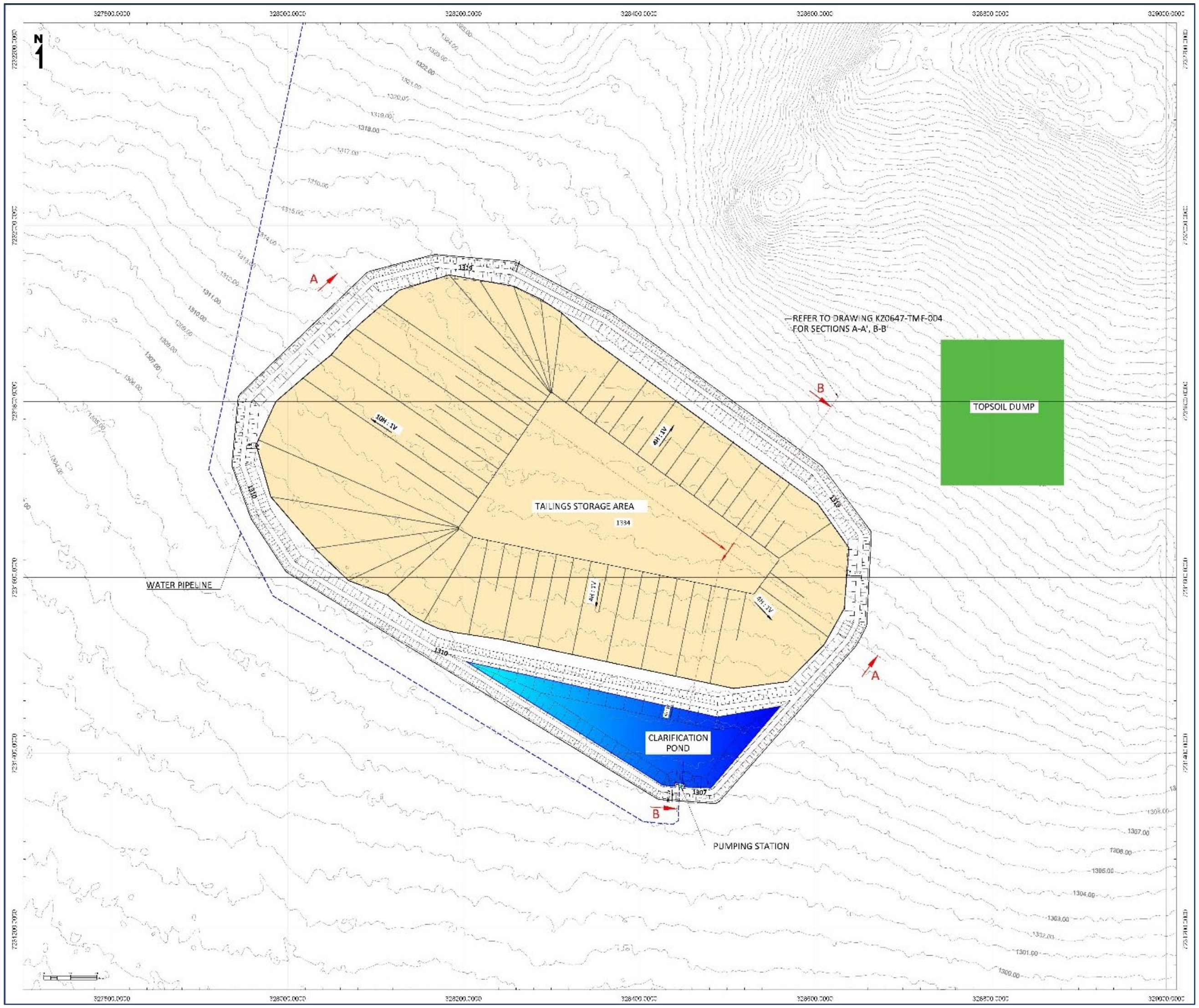
The TMF has been designed as a fully lined facility; there will be zero discharge of process-affected fluids. To achieve zero discharge, the facility will consist of a fully lined filtered tailings storage area and a clarification pond in which any runoff and seepage water will be collected.

The TMF will be located southeast of the processing plant. Tailings material will leave the processing plant in the form of filter cake from solid-liquid separation stages using pressure filtration combined with a small amount of water treatment effluent and will be stored as a dry stack in the TMF. The design criteria for the TMF are included in Table 18.19, and a TMF plan view is included on Figure 18.9.

Table 18.19 Tailings management facility design criteria

Design Criteria	Value	Source/comment
LOM	11 years	SRK mine production schedule
Tailings deposition type	Filter Press dewatered tailings or "filter cake"	Tetra Tech PFD
Total tailings produced for the LOM	3,387 kt	Based on mass ratio (feed:tailings) of 0.6 provided by Tetra Tech
Tailings deposited dry density	1.437 t/m^3	TMF report (Appendix E)
Embankment geometry - tailings dry stack		
Maximum height Maximum external slope gradient	24.0 m 4H:1V	Per SRK design
Clarification pond (excavated)		
Maximum depth Storage requirement	4.4 m 55,000 m^3	Calculated using a rainfall intensity for a 100-year return period
Minimum embankment freeboard for clarification pond	0.5 m	Australian National Committee on Large Dams guidelines
Stability factor of safety design criteria		
Static (long-term) Static (short-term) Pseudo-static	1.5 1.3 1.0	Canadian Dam Association guidelines

Figure 18.9 Tailings management facility plan view



Note: not for construction purposes.
Source: SRK

The filtered tailings storage area will be separated from the clarification pond by a filtration berm constructed to a maximum height of 3 m. In the final construction configuration, tailings will be stacked to a maximum height of 24 m above the existing ground level.

The perimeter berm will vary in height (a maximum height of 3 m above natural ground level), and its function will be to separate the clean surface water (runoff water from the surrounding topography) from the process-affected water (runoff water from the dry cake storage area). The perimeter berm can be constructed of granular materials found on site and waste rock and will require screening prior to use.

The TMF will be a “zero release” structure, and the design incorporates a fully lined basal section to prevent the release of seepage into the environment. All contact water will be collected and returned to the processing plant for treatment before discharge.

18.8.1 Operating methodology

Tailings will be delivered to the tailings storage area in the form of “dry cake” using a single 30 t articulated dump truck, similar to the ones to be used by the mining fleet. Tailings will be loaded onto the truck from the stockpile outside the processing plant. Upon deposit in the tailings storage area, tailings will be spread and compacted by a dozer. After the tailings have been spread, an 11 t (or heavier) sheepsfoot roller will be used to consolidate the material to a degree of compaction of at least 92% SPMDD (standard Proctor maximum dry density).

Since the tailings will be delivered with a high moisture content (36% to 39%), they should be deposited in thin layers and left to dry for a few days to reach a moisture content close to the optimum (25% to 30%). Since the moisture content after compaction will also be relatively high, it is not expected that dust will be generated on the surface before the next layer is placed. Therefore, during construction, no dust-related problems are foreseen. However, for the closure of the structure, some dust control measures will be necessary.

In case a problem with dust is expected, SRK suggests using a water truck for dust control within the TMF during the driest months and in locations where the evaporation rate is at its highest.

18.8.2 Water return infrastructure

The clarification pond will have a total volume of 55,000 m^3 and 0.5 m of freeboard under operational conditions. In the event of a 1:100-year flood, the clarification pond will need to be rapidly drained of the volume of water. To rapidly drain the pond, a pump and return line to the processing plant were designed to drain and empty the clarification pond in 48 h.

The water return infrastructure will consist of a static pump system installed at the southern dike of the clarification pond, drawing directly from the pond via a 5 m-long suction line. The return line is assumed to be a straight pipeline to the processing plant, where it will be accepted and integrated into the process flow.

18.8.3 Closure planning

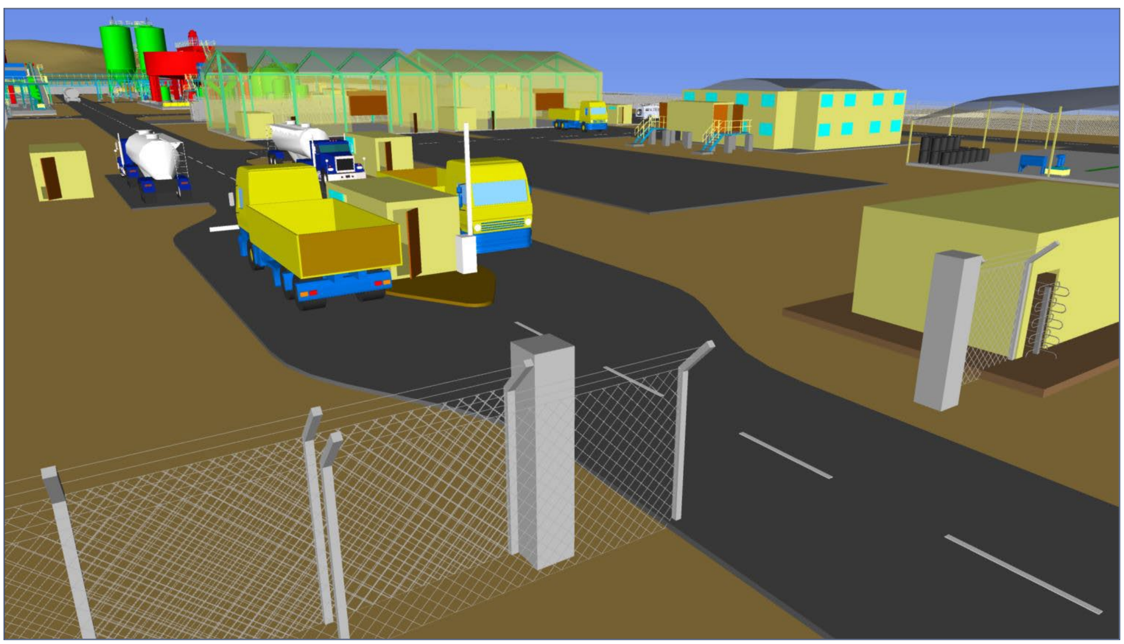
The dry stack will be closed progressively by covering the surface with vegetation to minimise water ingress and erosion of faces while decreasing the potential for dust generation. Due to the absence of ponded water, tailings dewatering will not be considered, as it is assumed the stack will be free draining. The closure plan is designed to be a "walk away" solution.

18.9 Infrastructure and services

18.9.1 Site gatehouse

Vehicular access to the site will be controlled to provide security for personnel and property and to manage the risk to the mining and processing operations. The gatehouse will consist of a four-bay truck parking area, a guard house, two weighbridges, and a control room and a site gate (Figure 18.10).

Figure 18.10 Gatehouse



18.9.2 Site roads

The haul roads will link the open pit to the ROM pad. The tailings road will link the tailings stockpile, located outside the processing plant, to the TMF. The location of the road has been selected to minimise the associated cut-and-fill earthworks, within reason, noting the variable topography. The main haul road design criteria are presented in Table 18.20.

Table 18.20 Main haul road-specific design criteria

Largest Vehicle	Volvo A60H (or similar)
Number of traffic lanes	2
Minimum road width	13.42 m
Minimum safety berm height	1.335 m

The site access roads will be mainly traversed by delivery vehicles, light vehicles (i.e., 4 × 4 Toyota Hilux or similar), and personnel buses. Access to this area will be relatively frequent; therefore, a two-lane road will be required. The site access road design criteria are presented in Table 18.21.

Table 18.21 Site access road-specific design criteria

Largest Vehicle	Mercedes-Benz Actros (or similar)
Number of traffic lanes	2
Minimum road width	8.715 m
Minimum safety berm height	0.75 m

The access roads to the processing plant and product warehouse will require access for delivery vehicles, light vehicles (i.e., 4 × 4 Toyota Hilux or similar), and personnel buses. Access to this area will be relatively frequent; therefore, a two-lane road will be required. The processing plant road design criteria are presented in Table 18.22.

Table 18.22 Processing plant road-specific design criteria

Largest Vehicle	Mercedes-Benz Actros (or similar)
Number of traffic lanes	2
Minimum road width	8.715 m
Minimum safety berm height	0.75 m

18.9.3 Site vehicles

It is expected that there will be three general categories of vehicles on the mine site:

- Mine Vehicles: The mine vehicles will include all vehicles required to operate the pit and haul operation; this includes, but is not limited to, haul trucks; excavators; wheel loader; dozers; graders; compactors; drilling machines; lorry-mounted crane trucks; forklift trucks; maintenance, water, and fuel trucks; low bed trailers and tractor units; and 4 × 4 pickups.
- Plant Vehicles: The plant vehicles will all be provided by the owner and will include all vehicles required to operate the plant (both crushing and processing). Vehicles will include

1.5 t forklifts trucks, 35 t mobile crane, flatbed truck, reach stacker container handler, skid steer mini excavators, tele-handlers, and 4 × 4 pickups.

- Site-wide Vehicles: The site-wide vehicles will all be provided by the owner and will include all vehicles required to operate the site-wide services. Vehicles will include 22-seater buses for personnel transport, vacuum tanker truck (honey sucker), fuel tanker trucks, and 4 × 4 pickups.

All vehicles on site will, as a minimum, have an orange repeater beacon, two-way radio, off-road tyres, emergency medical kit, roll over cage, 2 m whip-pole with LED light, and flag.

All vehicles and facilities will have the ability to communicate via two-way radio and in all conditions. Site to incorporate appropriate repeater stations.

18.9.4 Access roads

The main access road will run from the Kanye-Mmathethe Road at the air strip to the mine site; this is an existing dirt track road that requires upgrading for use to transport materials and personnel to the site. The road design takes into consideration every aspect of highway engineering, including minimum slope inclines, properly banked curves, minimum sight distance, and horizontal and vertical alignment, to ensure safe and efficient roads for quick and economical movement to the site. Good road design improves safety and helps reduce costs associated with truck and equipment maintenance because of wear and tear on vehicles and their components.

The roads have been designed in accordance with the following general criteria that considers road use, vehicle type, and speed limit. Road-specific criteria include:

- maximum design speed: 60 km/h
- minimum sight distance: 150 m
- minimum road width for two-lane roads: three and a half times the width of the largest vehicle using the road
- minimum safety berm height: two thirds of the diameter of the largest wheel using the road with slopes of 1V:1H
- roads to be widened by 1.18 times on curves
- drainage ditches to be provided on either side of the road, with a minimum depth of 0.6 m, maximum side slope of 1V:2H adjacent to the carriageway, and 1V:1H on the external side
- a maximum gradient of 10% where haul trucks will use the roads and up to 20% where light vehicles will use the roads
- a maximum gradient of 4% on curves and 0% on switch back corners
- a minimum camber (cross-fall) of 3%
- cut-and-fill slopes, with a maximum slope of 1V:1.5H.

18.9.5 Warehouses and workshop

The mechanical and electrical workshop will be equipped to undertake routine maintenance. Large scale refurbishment will be outsourced. The workshop will be housed in a portal frame building with a light electric overhead crane. Integral to the workshop will be a prefab office for the maintenance superintendent and maintenance planner, a store, light tool shed and toilet facilities.

The main warehouse will be a light steel portal frame building with corrugated cladding. The warehouse will house spares, maintenance consumables and hydrocarbons. A large roller door will provide access for truck deliveries and forklift access. A laydown area outside will house large spares, and waste materials for recycling. The building will include an office and toilet facilities.

18.9.6 Emergency services

Kanye offers firefighting and emergency medical services close to the mine site. A fire station on site, consisting of an office, storage facility for all firefighting equipment, and designated unimpeded parking space for the fire truck, will act as first response. A paramedical facility, consisting of a reception area, a consulting room, an emergency room, storage facility for medical equipment and waste, will offer emergency response medical care from where a patient can either be sent to Kanye hospital or immediately sent to Gaborone, depending on the severity of their condition. The ambulance will have a designed parking space with unimpeded access in all directions.

18.9.7 Site administration

The site administration building will be located at the southern end of the site in the processing plant. The building will be sized to accommodate on-site administration requirements and will provide offices, a meeting room, and clerical space for the site based general and administrative staff. The building will be constructed from repurposed 40-foot shipping containers and will be insulated and airconditioned to provide a comfortable working environment. The toilet facilities for the processing plant will be in the administration building. A septic tank will be buried next to the building and will be emptied as necessary by mobile bowser to take sewage and wastewater to the sewage plant at the camp for treatment.

The building will be a double height, insulated container structure with an insulated steel truss roof. Offices will occupy the first floor, and the lower floor will be meeting rooms, a boardroom, toilets, a kitchenette, and some offices. The open space between the containers will be used as an open plan office space and meeting room.

18.9.8 Communications

Site-wide data and voice telecommunications for the Project will be provided by a cellular network provider.

The LAN network will include all cabling, equipment, and infrastructure for connection to each operational building within the processing plant area, crushing plant, site offices, and gatehouses. The cellular mast and transmission equipment will be installed and maintained by the cellular network provider.

Communications for all other site areas (mining, trucking, etc.) will be covered by very-high frequency (VHF) radio.

18.9.9 Power distribution

The electrical users were functionally grouped into motor control centre (MCC) nodes according to the PFDs and considering the geographical location of the consumers. The MCC nodes will be connected to the 11 kV supply network either as 11 kV loads or as 400 V loads connected though 11 kV/400 V stepdown transformers.

A main 11 kV consumer substation will be established adjacent to the site, earmarked for the BPC supply. MCC nodes will be serviced at an 11 kV level through local ring main units (RMUs).

The RMUs will be serviced in turn through ring fed supplies from the main 11 kV consumer substation. Cables will be installed above ground via cable racks and, where possible, via cable racking along overhead pipe bridges.

The substation concept is indicative for planning purposes but is representative of proven substation design in the region. The infrastructure at each MCC node will consist of an RMU servicing a freestanding step-down transformer. The RMUs will require raised platforms, and the transformers will require bunded areas enclosed by fire walls on three sides and access gates on one side.

The electrical design does not include the mechanical requirements of high-level road crossings. Where possible, pipe bridges will be used for cable transits. Cable support structures at ground level are not yet detailed. Such cable runs are set out to allow reasonable pedestrian movement without requiring cross-over bridges. Vehicle access to the respective RMUs and transformers has been considered and each location and equipment orientation accommodates vehicle access.

Redundancy at the 11 kV level is provided for at each MCC node through ring feeds and RMUs. RMUs at each node location will provide for isolation of the local infrastructure and will also allow for alternate supply switching and/or isolation of cable sections in case of emergency. Eleven-kilovolt cables will be routed along sperate routes, where possible, to allow for maximum availability of an alternate supply.

18.9.9.1 Motor control centres

The low-voltage MCCs and distribution boards will be fully installed in air-conditioned containerised buildings prior to shipment to site. Each room will be maintained at temperatures in the range of 5°C (winter) to 30°C (summer) with suitable air conditioning and heating. The containerised buildings for the MCCs and low-voltage distribution boards will be mounted 1,500 mm from the finished ground level to allow bottom entry access for all cabling.

Low-voltage variable speed drives (VSDs) and soft starters will be supplied as part of the low-voltage MCC package. All VSDs supplied will eliminate low-order harmonics using either an active rectifier or a mains passive filter.

18.9.9.2 Earthing

The earthing system will be a "TN-C-S" system as defined in IEC60364.

The main earthing electrode system will comprise localised earth grids and electrodes around the generators and main switch room, tied by means of polyvinyl chloride (PVC)-insulated 120 mm^2 copper cables to the switch room main earth bar.

The underground earth grid will be installed around and below the generators to prevent dangerous step and touch potentials developing under fault conditions.

Rods will be driven in sufficient numbers and to sufficient depth to achieve less than 1 ohm for substation/MCC rooms and less than 10 ohms at connection points for lightning protection.

A neutral earthing resistor will be installed at the power station to protect against and limit fault current scenarios.

18.9.9.3 Cables

Cables will be sized and selected according to IEC60364. Cables will be installed on a heavy-duty, galvanised cable ladder mounted on building and support structures. All cables will have steel wire armour protection.

18.9.9.4 Lighting and small power

Roadway and plant lighting will be installed at the wet and dry processing plant areas suitable for 24-hour operation.

Small power outlets will be provided throughout the plant. Lighting and small power distribution boards will be located in electrical rooms and plant areas, and these will distribute power at three-phase and single-phase voltage as required.

18.9.9.5 Vendor packages

The plant will include several vendor packages. In general, vendor packages will be supplied with electrical equipment such as motors and heaters pre-installed. The electrical interface with each package will be designated during detailed design.

18.9.10 High voltage supply

The HV supply will be undertaken by BPC, who will install a 33 kV HV line from the main Kanye municipal substation, north of the town, around the west edge of Kanye, mainly following the road infrastructure to the HV substation next to the plant.

The 33 kV HV substation again will be undertaken by BPC, converting the incoming HV supply for 33 kV to 11 kV. The negative busbar on the MV (11 kV) side will be the battery limit between the BPC scope and the Project scope.

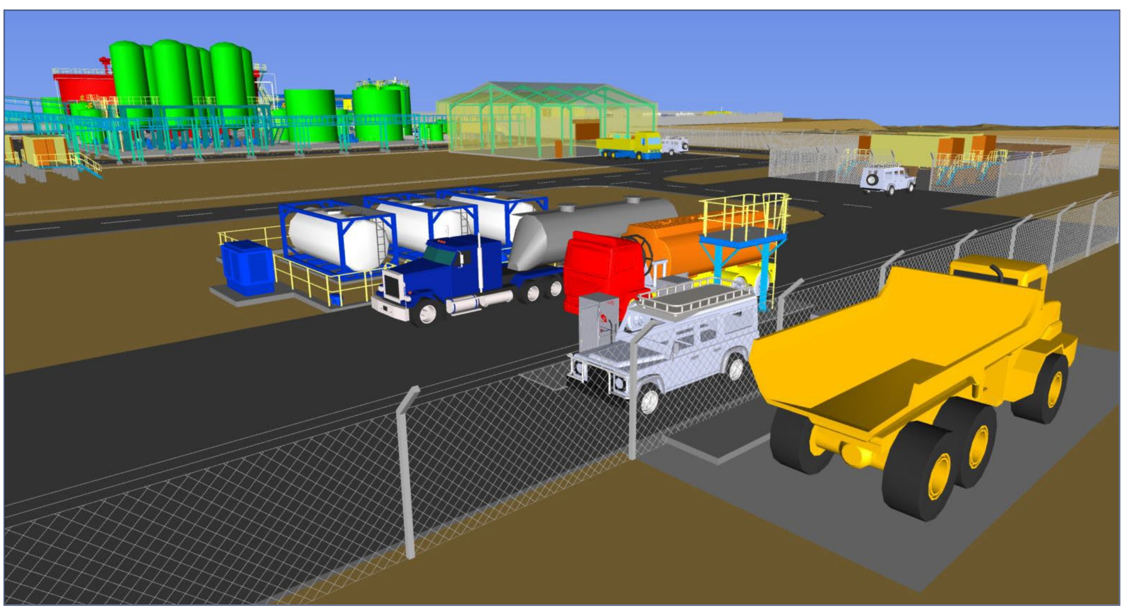
Giyani has liaised with BPC to undertake this processing and will charge Giyani for usage accordingly.

18.9.11 Fuel farm

The fuel farm will be made up of a tank farm holding a total of 75,000 L of diesel, located on a bunded concrete pad. The bund will be designed to take 110% of the volume of the largest tank on the pad. The tank farm will be made up of three, 20-foot ISO container tanks.

Fuel will be delivered by tanker to a receiving pump station adjacent to the fuel farm, where the fuel will be pumped up into the fuel farm. Alongside the pumping station will be a facility to fuel site vehicles.

Figure 18.11 Fuel farm



18.9.12 Plant water management

The processing plant will receive raw water makeup from the local WUC pump station, discharged at atmospheric pressure into the 250 m³ raw water makeup tank. The tank will be split into two sections through placement of the suction nozzles for each system it will feed. The upper section will be for raw water and the lower section for fire water.

Raw and fire water will be distributed via two independent ring mains using centrifugal pumps. An electric fire water pump, a diesel fire water pump, and a jockey pump make up the fire water pump arrangement. The fire water pumps will draw water from the lowest section of the raw water tank and will distribute the water through a fire water ring main that will run through the processing plant, reagent mixing area, and crystalliser. Stringers for fire hoses will be installed throughout the ring main.

18.10 External infrastructure and services

18.10.1 Water Utilities Corporation water reservoir and Botswana Communications Regulatory Authority tower

In close cooperation with WUC and the local Kanye authorities, Giyani will engage a local Botswana contractor to relocate the water reservoir and associated piping. The new facility will be installed and commissioned before the existing infrastructure is removed. Similarly, Giyani will appoint a local firm to relocate the Botswana Communications Regulatory Authority (BOCRA) spectrum monitoring tower.

18.10.2 Solar farm

A 4.5 MWp_{dc} solar plant, covering 7.6 ha, will be constructed 1.2 km west-northwest of the Kayne municipal borehole. The space makes provision for an interconnection corridor along the southern edge of the plant, with provision for the central inverter option, alternating current and HV switchgears, communications and weather station, step up transformer, 11 kV feeder pole interconnection, and clearance path for incoming HV feeders from eventual future expansions, allowing those expansion blocks to share the initial interconnection step-up transformer and main feeder to the mine’s 11 kV main bus.

This location was selected to take advantage of the relatively flat topography west of the mine and to position the solar plant outside of any dust plume coming from K.Hill mine, for which dominant wind direction and speeds were accounted. The site is well served by existing roads.

Power generation models predict excellent solar production at the K.Hill mine—greater than 74% of the theoretical maximum production. A very good value in solar generation. The largest losses are associated with hot operation of the solar array (generally unavoidable), module degradation (reduced through the purchase of high-quality solar panels), and mismatch loss (reduced through having few strings connected to an inverter).

In general, all components, as well as the general design principles of the plant, will adhere to IEC standards, which are applicable to each component and functions, inclusive of those applicable to communications and data exchange.

The specified key characteristics of the proposed equipment and components respond to the considerations of site, soil, location, logistics, constructability, grid integration and eventual expansion.

Tetra Tech specified the Jinko 450M 78V as an exemplary solar panel to predict the K.Hill mine solar plant performance. JinkoSolar is the largest solar panel manufacturer globally and provides reliable solar panels with industry leading manufacturing and performance warranties. This panel generates 450 W with an efficiency of 20% using 156 mono-crystalline cells.

Tetra Tech conducted two separate feasibility assessments: one on a central inverter-based plant and another on a string inverter-based plant. When selecting inverter to use in the FS, the key selection criteria, listed below, pivot on identifying a manufacturer with in-country technical service personnel and a product catalogue that contained both central and string inverters. For the two feasibility assessments, Tetra Tech used the SMA Sunny Tripower 60-10 string inverter and SMA Central 4400 UP central inverter. SMA is a German inverter manufacturer commonly found in Africa with an excellent reputation.

Given the observed soil conditions on the site, high resistance is expected. The grounding system must achieve a resistance below 10 ohm to allow for the intended operation of plant's protections, neutral and ground. Interconnecting the grounding ring around the step-up transformer, the low volt ring around the eventual switchgear enclosure, and wider ring around the solar array is proposed to achieve the required resistance to ground values. The advised grounding topology is Tetra Tech. This recommendation may change once the pre-construction geotechnical study has been completed.

The solar plant's connection point, just after the mine's point of connection to BPC, allows for the energy generated from the solar system to be distributed across all power systems of the mine facilities, reducing the power supplied from the grid.

18.11 Site water management

Management of water, within the boundaries of the Project's site surface infrastructure footprint, is based around current industry best management practices to:

- control surface water runoff to prevent pollution of clean or non-impacted water resources
- control erosion of the site to limit sediment runoff that may impact receiving waters.

Water is collected at various points on the mine site and classified based on the infrastructure or surface from which it has made contact. All contact water, with the exception of the WRD water, will be diverted via ditches to the collection pond at the TMF, that will, in turn, be pumped to the water treatment plant at the processing plant facility. The average annual evaporation is estimated to 1,345 mm, indicating a significant deficit between rainfall and evaporation losses all year around.

Total precipitation at the site were derived from regional stations captured from US National Oceanic and Atmospheric Administration database and compared with the satellite information available from ERA5-Land Model. The average annual precipitation at the site amounts to around 520 mm. Over a 24-hour duration the 2-year return period storm is estimated to be 64 mm. However, for a 100-year return period, the rainfall depth is estimated to reach 260 mm over 24-hour duration

Rainfall data for the period from 1990 to 2020, considered the most representative for the site, are used in the frequency analysis to represent the future conditions for the LOM. The monthly precipitation distribution boxplot for the site rainfall for the period of records from 1990 to 2020 is presented in Figure 24.14 (Section 24). It shows strong seasonal aspect of rainfall trends, with median rainfall value of almost 0 mm for months from May to September.

The World Meteorological Organisation suggests applying an adjustment for fixed observational time intervals applying a correction factor (WMO 2009). Daily precipitation depths were corrected by factor for 1.13 to obtain 24-h rainfall. Estimated rainfall depths are provided in Table 18.23.

Table 18.23 Maximum 24, 48, and 72 h precipitation based on ERA5-Land Model and Kanye weather station for return periods from 2- to 100-years

Return period (years)	Precipitation depth (mm)		
	24 h	48 h	72 h
2	67	82	88
5	97	135	153
10	127	175	205
20	161	215	259
25	173	228	276
50	214	269	331
100	260	310	386

Based on the review, the 24-hour storm/rainfall depth associated with the 100-year return period is estimated to be 260 mm, which is almost 50% of mean annual precipitation.

Sub-daily precipitation depth has not been estimated owing to the lack of hourly data.

18.11.1 Pit water

Design of open pit passive dewatering infrastructure (pump capacity and sump size) is usually dependent on the amounts of surface water runoff and groundwater inflows that drain into the mine sump. Since the pit is located above the phreatic surface, groundwater inflow into the pit is predicted to be negligible. Therefore, the mine water management should focus on the surface water component only.

Considering the arid climate of the region, as described in the climate analysis section of this report, surface water inflows into the mine will likely be limited to storm events which usually occur for short durations. However, the storm runoff can generate high inflows into the pit in case of rare storm events such as 50 or 100-year return period events.

The water runoff volumes generated by storm events do not have to be pumped out at the same rate that they flow in as they can be stored in the pit base up to the capacity of the pit sump and then pumped out over a period by pumps dedicated to pumping such short-term inflows (the “standby” pumping infrastructure). In the first year of mining, recurrent storms generating 4,000 m^3 (roughly 170 m^3/h) of water per day are expected to occur every 2 years. In the same first year of mining, a total volume of about 16,000 m^3 (roughly around 670 m^3/h) of water should be expected to drain into the pit sump in 24h if a 100-year return period storm event occurs. Toward the end of mine life when the pit extent is at its maximum, a 24-hour duration 100-year return storm would generate as much as 54,500 m^3 of water (roughly equivalent to 2,270 m^3/h). Pump capacity therefore needs to be sized accordingly.

Instead of sizing the pit dewatering system (pump station and pipelines) based on exceptional storm events, the mine should adopt a flexible approach to the dewatering of the pit during such storm events. Halting of the mining operation at the lowest benches could be considered.

Accordingly, making provision for a dewatering system capable of evacuating the 10-year return period storm runoff of 8,000 m^3 per day would be appropriate. Such system should consist of one operating pump of 4,000 m^3/d capacity for day-to-day operation, and a similar pump on standby.

In addition to the use for dust suppression, the pumped mine water should be used for the plant water supply to reduce water demand and the associated impact on other users where applicable. Enough water storage capacity should be installed at the plant site to effectively manage storm water and reduce the risk of water shortage for the plant in case of breakdown/issue in the water supply system.

18.11.2 Waste rock dump water

Regular water sampling and analysis of water quality at an accredited laboratory is recommended to decide an appropriate water management approach.

Management of water accumulated in the proposed WRD drainage ponds will depend on the quality of the water:

- If the water is not contaminated and fulfil local environmental requirement, it can be released into the natural watercourse
- However, if water is contaminated, it will require treatment (or use if possible) to avoid the impact on downstream environment. The appropriate water management approach (and related infrastructure) should be envisaged based on the findings of the EIA study, which should consider waste rock geochemistry and related risk of acid rock drainage and metal leaching.

18.11.3 Tailings management facility water

The 1:100-year return period 24-hour storm event has been considered to estimate the peak flow of surface runoff from contributing catchments and size the diversion structures required at this facility.

The preliminary design parameters used for TMF diversion are as follows:

- design storm event: 100-year return storm of 24-hour duration
- rainfall intensity: 260 mm/d (equivalent to 10.83 mm/h)
- runoff coefficient: 0.55, which means 55% of rainfall is converted into direct surface runoff and the rest is lost as infiltration, soil moisture, interception, or evaporation
- Q_{100yr} = 1.7 $m^3/s/km^2$
- Q_{5yr} = 0.63 $m^3/s/km^2$

Owing to the flat topography at the north-western corner of the proposed TMF site, two options of stream diversion could be envisaged at this location.

All contact water diverted into the collection pond will be pumped to the water treatment plant at the processing facility and added into the plant water system for general processing.

18.11.4 Processing plant water

Water for ore processing will be supplied from the municipal water supply to limit the volume of impurities entering the process. The processing plant will be self-contained and a zero-runoff facility. Additional rainwater, collected in the plant bunded areas, will be pumped back into the process.

Runoff from the ore stockpile and the plant site will be directed into ditches from where it will drainage to the collection pond at the TMF. Water collected in areas outside of the processing plant (where it may have come into contact with contaminants such as hydrocarbons and industrial chemicals) will again be diverted to the collection pond at the TMF.

The overall plant water balance is shown in Table 18.24.

Table 18.24 Overall processing plant water balance

Area	Value (t/h)	Source/comment
Water Inputs		
Run-of-mine ore	1.4	Process mass balance - 2112
Raw water makeup	27.1	Process mass balance - 2701
Reaction water	21.2	Calculated (OUT less IN)
Potable water	0.2	Process mass balance - 2706
Total Water Input	**49.9**	**Calculated (sum IN values)**

Area	Value (t/h)	Source/comment
Water Outputs		
Tailings water content	20.2	Process mass balance - 2751, 2363
Sewage	0.2	Process mass balance - 2706
Total dust suppression	29.5	Process mass balance - 2459 (less dissolved solids)
Total Water Output	**49.9**	**Calculated (sum OUT values)**

The processing plant water treatment has not allowed for any return water from the collection pond at the TMF. The treatment of the impurities could not be estimated reliably. This creates the opportunity to treat this water to reduce the overall water consumption.

18.12 Temporary construction facilities

To provide productive space for Project operations staff, temporary site offices will be provided.

Also, to cater for the daily practical requirements of the workforce, a general field canteen and ablution block will be included.

All final fabrication, assembly, repairs, modifications, and such will need to be performed on site. To provide for this requirement, as well delivery space for large equipment, a temporary contractors' fabrication and storage area will be constructed.

18.12.1 Site offices

A temporary, furnished and air-conditioned container office area with:

- main project meeting room
- EPCM management and engineer's offices
- site secretary and administration office
- contractors' management offices
- basic kitchen to provide refrigeration, tea, coffee, microwave
- toilet units

18.12.2 Workforce catering

The following will be provided:

- containerised field kitchen to prepare meals for labourers
- temporary pole barn to act as canteen with table and bench seating
- temporary/containerised toilet and wash facilities at suitable locations

18.12.3 Contractor fabrication camps

Temporary construction facilities will be supplied by the civils construction contractor(s) and shall comprise a temporary accommodation camp, laydown area, construction power, construction water, mobile equipment, and possibly a batch plant at a later stage by the structural construction contractor.

Upon site establishment, the first activity the civil contractor will have to execute will be to prepare a basic road network to connect the camp and prepare an area for a laydown area and batch plant.

It is recommended that the locations of the laydown area and batch plant be close to the processing area where initial works will be carried out and will also be out of the way of construction operations for rest of the site, but this can be reviewed during basic engineering and confirmed with a site visit.

Construction power will include power for the camp as well as lighting as required. Any crushing and/or screening requirements for construction will be by diesel-powered mobile plant. All diesel is to be supplied by the construction contractors and will likely be trucked in and stored in temporary tanks on site.

Construction water will be available from the municipal water supply. Construction water can be drawn and transported via bowser to temporary tanks also supplied by the contractor(s) and placed strategically as required.

The batch plant will be required for concrete supply on site for foundations for structures and mechanical equipment, as well as slabs, bunds and mass concrete as required. The batch plant will be supplied and erected by the structural contractor if it is deemed more cost effective than to truck ready-mix concrete in by truck. It will be powered by its own independent diesel power supply.

A construction laydown area will be prepared by the civils contractor and shared by all the contractors. There will not be a fence around the laydown area, but the contractors may supply security personnel to safeguard their plant and materials if deemed necessary.

The fabrication area will be separated into a number of camps to provide storage space for the main equipment, as well as work areas for all on-site contractors during construction.

Each contractor fabrication camp will be equipped with:

- fully fenced perimeter
- hard standing area for laydown and storage
- covered shed, incorporating:
  - lighting
  - power: 400 V, three phase

- power: 220 V, single phase
- potable water connection

Contractors will be expected to furnish the provided facilities fully, including tools, work benches, storage lockers, etc.

18.12.4 General requirements

To serve the general area of the offices, canteen area, and fabrication camps, the following will be provided:

- secured access points
- main parking area suitable for light vehicles
- bus parking and pedestrian walkways for bus users

19 MARKET STUDIES AND CONTRACTS

CPM completed a HPMSM products market outlook study for Giyani in support of the K.Hill Project FS. CPM is an independent research and consultancy company based in New York and has advised clients on precious and speciality metals markets since 1986. Andrew Zemek of CPM, with inputs from other members of the CPM team and selected external consultants, prepared the market outlook study (Appendix F).

The study concludes the following:

- The demand for lithium-ion batteries used in EVs is expected to grow by 25% annually between 2021 and 2031 and at a slightly slower rate, around 10% annually, between 2031 and 2041.
- The demand for high-purity manganese (HPMSM and high-purity electrolytic manganese metal [HPEMM]) from the battery sector will grow nearly 30 times between 2021 and 2036, reaching 1.8 Mt on a contained metal basis and may reach 4.5 Mt by 2050.
- Current global high-purity manganese production capacity is approximately 127 kt/a, and the identified new project pipeline is expected to contribute only an additional 221 kt/a by 2031[1], resulting in a projected supply deficit of 726 kt/a over this period.
- Presently, 92.5% of demand from batteries is satisfied by HPMSM produced directly from ore, rather than via refinement of electrolytic manganese meta (EMM).
- Between 2023 and 2035, the realised price of HPMSM for the K.Hill Project is expected to range from US$2,993 to US$5,499/t (FCA Durban).

19.1 High-purity manganese sulphate monohydrate demand

19.1.1 Battery technology

Manganese is used in the production of batteries in the form of high-purity manganese sulphate solution (HPMSS). Most cathode makers buy HPMSM as a dry crystalline powder and dissolve it to make HPMSS, but some produce it in-house through the metal route by purchasing HPEMM. The latter is almost exclusively practised in Japan, but some European cathode makers are said to be considering it too. Suppliers of HPMSM can either make it directly from ore or via the HPEMM route.

Presently, there are two groups of lithium-ion battery chemistries that use high-purity manganese (either HPMSM or HPEMM) to produce their cathodes: NMC and lithium-nickel-manganese oxide (LNMO).

[1] Does not include potential 300 kt/a of HPMSM produced from selenium-containing 997 EMM not meeting the specification of Tier 1 cathode producers.

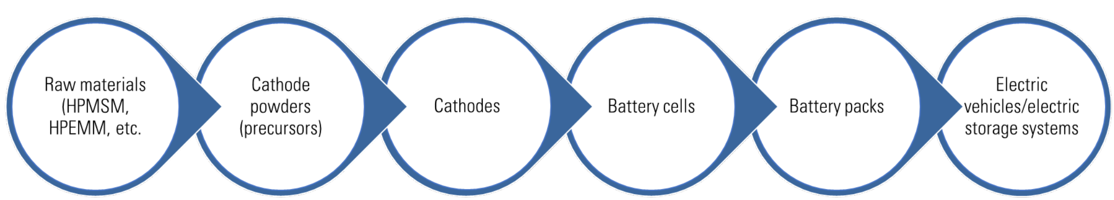
- Lithium-manganese oxide (LMO) is a legacy battery chemistry accounting for only 0.25% of all rechargeable batteries on the market today and is expected to be phased out by 2025. This chemistry uses electrolytic manganese dioxide (EMD) as its manganese feedstock.
- LNMO is a variation of the LMO chemistry that uses HPMSM as its source of manganese. Its use in battery manufacturing is expected to grow rapidly—about 30 times between 2021 and 2031—although it would still account for less than 1% of all manganese-using batteries. LNMO battery chemistry is one of the most manganese-intensive battery chemistries, requiring over 1 kg of manganese per kilowatt hour of battery capacity.
- NMC is the dominant lithium-ion battery chemistry, currently claiming approximately 44% of the rechargeable battery market, and is likely to remain the dominant technology, contributing about 47% to 50% to the market by 2031 and beyond. NMC chemistry is further subdivided into categories named after the proportion of the three metals used in the cathode:
  - Until recently, the dominant chemistry was NMC-111, in which nickel, manganese, and cobalt were used in equal parts (by weight).
  - The current mainstream NMC chemistries are NMC-622 and NMC-532.
  - NMC-811, nicknamed "the battery of the future," still needs some perfecting, although it is already produced on a commercial scale by some Chinese and European companies. NMC-811 batteries promise longer-range EVs (+500 km on a single charge) but, at the same time, present many problems yet to be resolved (thermal instability and short cycle life, among others).

19.1.2 Battery supply chain

The umbrella term "battery factories" is often used in a broad sense and can refer to manufacturers of cathode materials, battery cells, and battery packs. The capacity of batteries is the amount of energy it stores measured in kilowatt hours. Subsequently, the production capacities of battery factories are measured in megawatt hours, gigawatt hours, or terawatt hours.

The lithium-ion battery industry has its own structure and supply chain with many specialised manufacturers. HPMSM can be sold to different manufacturers, depending on the level of supply chain integration by the various battery and EV manufacturers; some make just cathode powders or cathodes and others (e.g., Tesla) have many stages of battery production within their manufacturing operations. The ultimate product is a battery pack sold to or assembled by an EV manufacturer (Figure 19.1).

Figure 19.1 Lithium-ion battery supply chain



19.1.3 Cobalt replacement

Depending on the stage of the price cycle, cobalt contained in the NMC-111 batteries can account for up to 80% of the cost of materials needed to make a cathode, despite being only one-third of its weight. Between 65% and 70% of cobalt metal (and a large part of current reserves and resources), comes from the Democratic Republic of Congo. This reliance on a supply from a socio-politically unstable region, coupled with cobalt's significant contribution to cost and its high price volatility, presents a risk to battery manufacturers that they have actively sought to mitigate by engineering cobalt out of batteries or, at least, significantly reducing its use. The new designs now in the mainstream, like NMC-622, NMC-532, or NMC-811, partially realise this goal.

In 2018, the German chemical giant BASF announced both battery types NMC-370 and NMC-271 with an expected cobalt usage of less than 5% and manganese use of 75% or more. Chinese cell producers like SVOLT Energy Technology Co. Ltd. have also developed cobalt-free batteries known as NMx (nickel-manganese). The first commercially available EV with such a battery (Great Wall Ora Cherry Cat) was revealed in 2021. Its battery gave the vehicle a range of 600 km and did not contain any cobalt; instead, it needed 95 kg of manganese in its cathode.

19.1.4 Iron replacement

There is growing evidence that manganese may also be used to replace 40% to 65% of iron in LFP batteries. The LFP chemistry is the second most common lithium-ion battery chemistry after NMC and is expected to account for 32% of all batteries produced by 2030. Several companies are working on different variations of the manganese-bearing LFP chemistry known collectively as LMFP. The addition of manganese is said to improve the energy density of such batteries by up to 20% and lower the material cost by up to 28%; however, no LMFP variation has yet emerged as the "mainstream," and it is difficult to say what percentage of future LFPs will become LMFPs. In CPM's assessment (Appendix F), LMFPs might add 35% to 70% of new demand to the high-purity manganese requirements of the battery industry presented in this study.

19.1.5 Battery passports and environmental, social, and governance issues

The future demand for batteries and the materials used for their production are likely to be strongly influenced by factors other than just the supply and demand situation or technological changes. The European Union has very strong views on the traceability of batteries and their materials; the ESG aspects of their production; and their carbon footprint. All these concerns are to be enshrined in law in the form of battery passports.

A European consortium of 11 carmakers and battery producers, funded by the German government, is developing the concept of such passports, and now the initiative has also been adopted by the Global Battery Alliance (GBA 2020). This will likely result in a wider adoption of such passports beyond Europe and most certainly in North America.

The consortium, including BMW, Umicore, and BASF, has received €8.2M in government funding to develop common classification and standards for gathering and disclosing data on batteries. The initiative aligns with new battery regulations currently being prepared by the European Union.

EV batteries will be the first to come under scrutiny. A European Commission proposal, due to be discussed later in 2022, states that rechargeable EVs and light transport and industrial batteries sold in Europe must disclose their carbon footprint from 2024 to comply with carbon dioxide emission limits from 2027. The raw materials within the batteries—and whether they are recycled or not—*must also be disclosed*. Additionally, there are directives for battery makers to use a minimum of recycled cobalt, lithium, nickel, and lead from 2030 onwards.

These administrative restrictions are likely to make access to European and North American battery and EV markets more difficult for the non-compliant exporters and push prices for compliant products higher.

19.1.6 Demand for batteries

CPM focused its high-purity manganese sulphate market analysis on its use in the cathodes of rechargeable (secondary) batteries; non-rechargeable (primary) batteries were not considered.

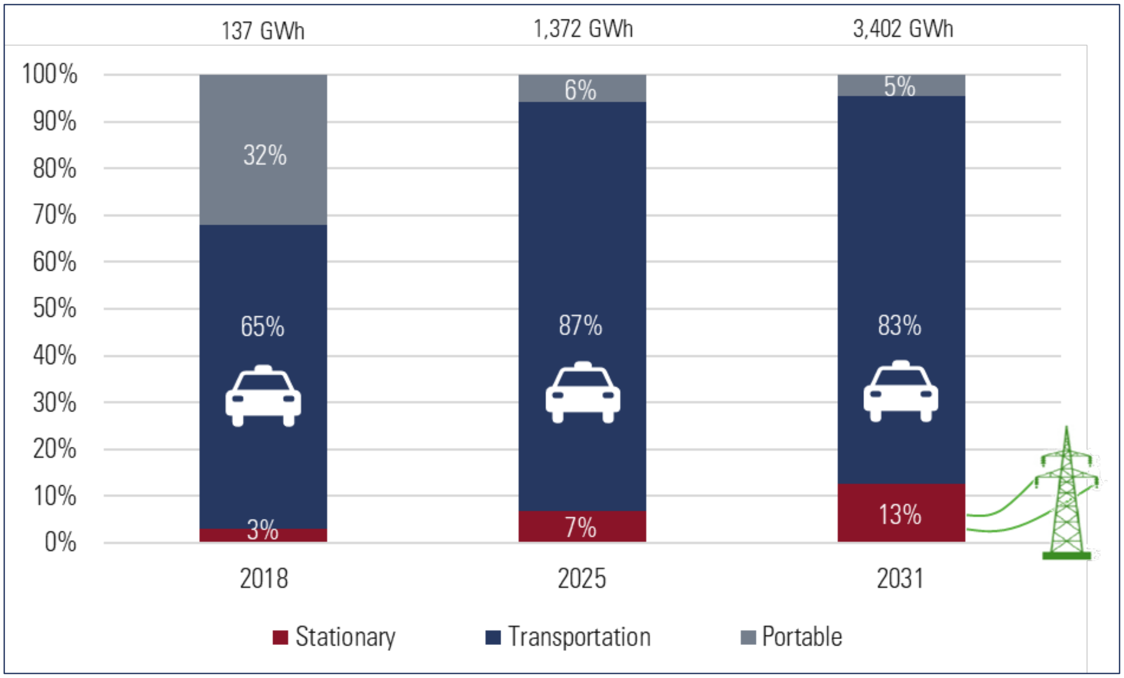
Rechargeable battery demand stems mainly from EVs, energy storage systems (ESSs), and consumer electronics. Each application requires specific battery chemistries and configurations.

The battery chemistry of choice for ESS in 2022 is the LFP, which contains no manganese. It is expected that by 2031 NMC chemistries will account for only 10% of the ESS battery demand. New technologies better suited to the scale often required for ESS, such as redox flow batteries, are likely to acquire a larger portion of the market. Therefore, CPM does not see ESS as a key driver for high-purity manganese demand.

In contrast, the demand for batteries used in EVs is expected to grow at a compound annual growth rate (CAGR) of 25% between 2021 and 2031 and at a slightly slower rate (around 10% CAGR) between 2031 and 2041 (Figure 19.2).

The penetration rate of EVs (sales of EVs as a percentage of total new vehicle sales each year) has increased in China from 11% in 2020 to 16% in 2021 (reaching 20% in December 2021), and in Europe it reached 17% for the year 2021. European monthly sales were highest in the last quarter of 2021, when electric car sales reached a 27% market share and surpassed diesel vehicles for the first time. While the high penetration rates of countries like Norway (86%) and Iceland (72%) could be dismissed because of the small size of their markets, the double-digit rates in China (16%), Germany (25%), or France (19%) testify to the growing maturity of the EV markets in these countries. EV penetration rates in the United States (4.5% in 2021) remained much lower than in China and Europe but increased two-fold compared to 2020. The demand from batteries for EVs is likely to dominate the battery market and is expected to claim approximately 87% market share by 2025.

Figure 19.2 Lithium-ion batteries by end use (2018, 2025, 2031)



Source: E Source, CPM

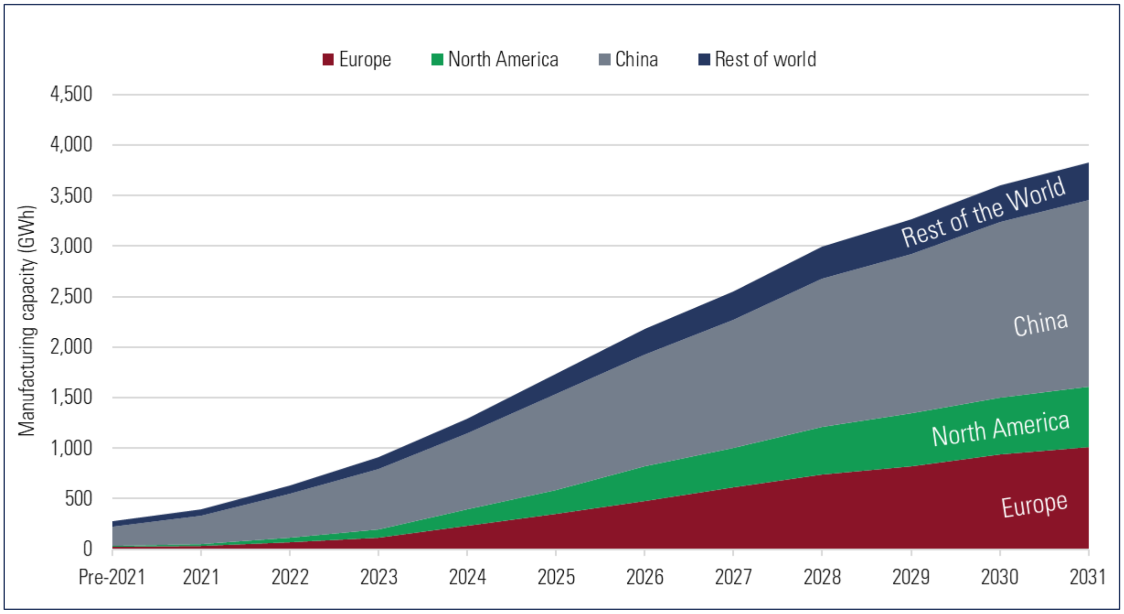
Another method of calculating the demand for battery raw materials is to add up the capacity of the present and future (announced) battery factories who are the clients for the cathode active materials producers. Some forecasters, like Benchmark Mineral Intelligence, put the total capacity of all lithium-ion factories in 2031 at more than 6 TWh, while others, like E Source, apply their own "build probability factors" to come up with lower figures: just under 4 TWh in the case of E Source (Figure 19.3)

CPM's high-purity manganese demand forecast is based on E Source's battery demand forecast figure of 3.4 TWh in 2031 and, in the context of battery factory capacity, can be considered conservative.

Most chemistries using manganese for secondary battery production require HPMSM as the feedstock. A very small proportion (the LMO chemistry and less than 1% of the battery market) needs manganese in the form of the EMD, but these are likely to be discontinued after 2025.

Consumer electronics demand continues to grow but at a much slower pace.

Figure 19.3 Battery factories: cumulative effective manufacturing capacity by region to 2031



Source: E Source, CPM

19.1.7 Demand for manganese in lithium-ion batteries

The trend in recent years has been for battery manufacturers to buy a ready-made HPMSM, 92.5% of which has been produced directly from ore. In 2021, only 7.5% of HPMSM required by battery makers was made using HPEMM as an intermediate product.

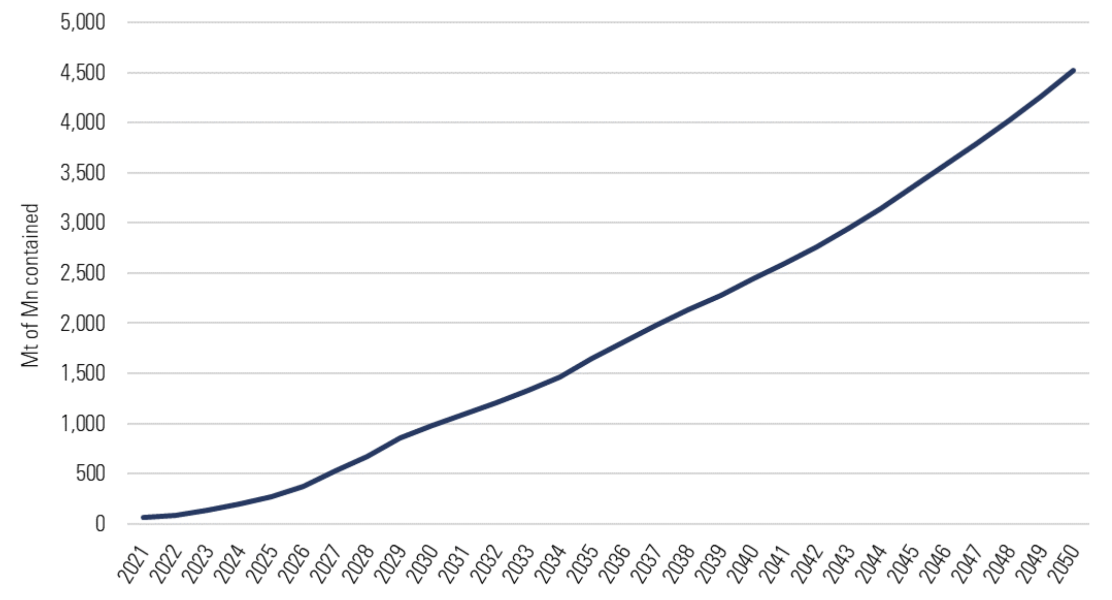
Manganese-based chemistries are likely to dominate the rechargeable battery market over the next 10 to 20 years, partly owing to cobalt supply chain problems and partly because of the technical merits of manganese as a battery metal. CPM, and many battery experts like E Source, expect the demand for high-purity manganese from the battery sector to grow nearly 30 times between 2021 and 2036, reaching 1.8 Mt. The global production would need to rise 15 times to satisfy this demand.

If the battery chemistry mix remains unchanged after 2035 and the demand for batteries grows between 6% and 11% per year, by 2050 the total demand for high-purity manganese from the battery industry could reach 4.5 Mt, compared to 0.13 Mt in 2021 (Figure 19.4).

The use of manganese in LFP batteries can potentially boost the demand for high-purity manganese by an additional 35% to 70%, according to CPM's calculations.

In 2020 and 2021, many major original equipment manufacturers like Tesla, Volkswagen, Stellantis, Nissan-Mitsubishi-Renault, and others, made announcements about developing their electrification strategies around manganese-based batteries. At the time of writing, there are about 30 battery chemistry variations in production or development, which are using between 30% (Tesla) to 80% (BASF) manganese in their cathodes. The current average manganese intensity of batteries in production (measured in kilograms of manganese per kilowatt hour of battery capacity) is expected to grow 83% by 2031.

Figure 19.4 Manganese demand from nickel-manganese-cobalt and lithium nickel-manganese oxide batteries to 2050 (kt)



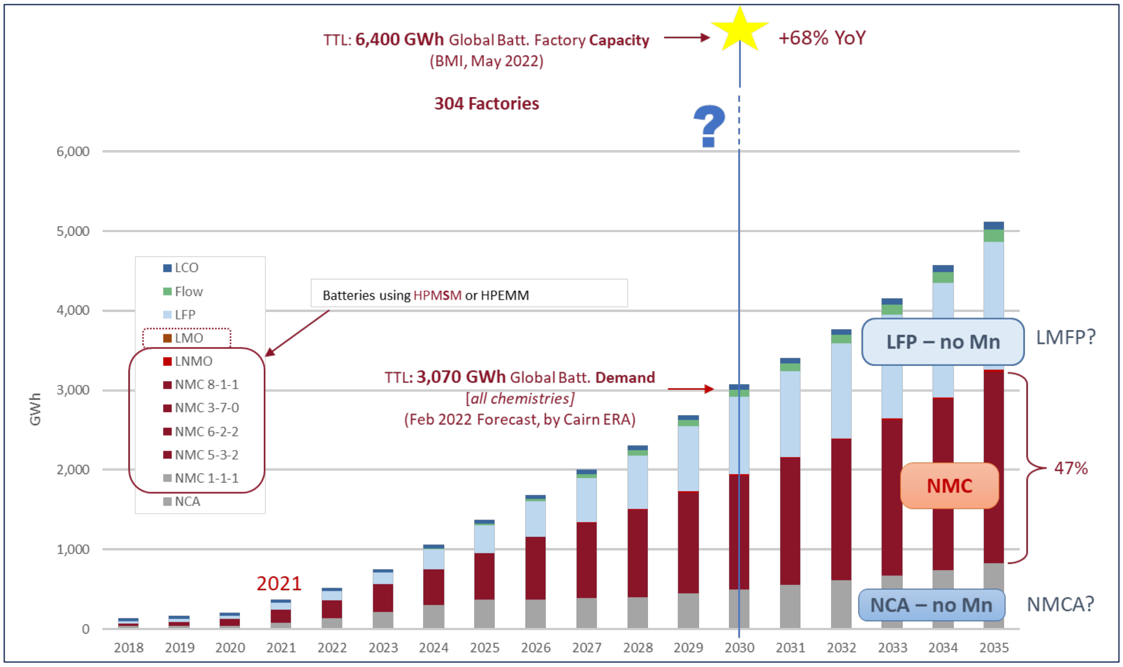
Notes: Thousand tonnes; NMC and LNMO battery chemistries only.
Chemistry mix shares frozen after 2031; stipulated growth beyond 2031 assumed at 11% to 6% per year.
Source: E Source, CPM

The United Sates currently has five lithium-ion battery factories. Tesla's Gigafactory 1, at 30 GWh capacity, accounts for 82% share of the North American market. According to the industry announcements, by 2031 there could be 26 gigafactories in the United States, with an overall installed capacity of more than 700 GWh, shrinking Tesla's share to just 7% of North American battery output, despite their continued expansion. At present, the Panasonic nickel-cobalt-aluminium (NCA) batteries (no manganese) will be produced in the Tesla factory. Beginning in 2023, Tesla will start using manganese-based batteries as well, most likely nickel-manganese-cobalt-aluminium (NMCA).

E Source predicts that by 2031, 67% of batteries produced in the United States will be NMCs (i.e., using manganese). Another American consultancy, LMC Automotive, goes much further, reporting that batteries that contain manganese could take more than 90% market share by 2028.

Comparing different forecasts, some calculating regional North American battery demand and others counting the announced battery factory capacities, CPM concludes that by 2031 North America might need between 233 and 400 kt of high-purity manganese (metal units) annually.

Figure 19.5 Global battery demand to 2035 by chemistry (GWh)



Source: E Source, CPM

19.2 High-purity manganese sulphate monohydrate supply

Manganese is the twelfth most abundant element in the earth's crust and the fifth most mined metal by tonnage, with current annual production around 21,600 kt. However, the vast majority (90%) is used to produce ferroalloys: silicomanganese and ferromanganese for the steel industry; less than 0.5% of manganese ore mined is processed into HPMSM. In 2021, the total global production of HPMSM was only 99 kt on a metal-contained basis.

Most cathode makers buy HPMSM as a dry crystalline powder and dissolve it to make HPMSS, but some produce it in-house by purchasing HPEMM and dissolving it in acid. The disadvantage of this route is the high cost of electricity required for electrowinning of HPEMM—up to 10,000 kWh/t of HPEMM. Producers using this route need to make the sulphate solution twice: 1) by leaching the ore to prepare the pregnant solution for electrowinning, and 2) by dissolving EMM to prepare another sulphate solution prior to its precipitation to HPMSM crystals. In practice, this means having two plants: an EMM plant and an HPMSM plant. Production of the sulphate directly from the ore is much cheaper than "going through metal," but may require additional processes to remove impurities, hence the importance of quality feedstock.

The United States Geological Survey estimates global manganese resources at over 17.3 Bt (metal contained; Schulz et al. 2017). These resources could be mined at the current extraction rates for more than 300 years. This secure supply of metal underpins the choice to include more manganese in future battery cathode chemistries. Manganese is also the cheapest battery metal: up to six times cheaper than nickel and 10 to 30 times cheaper than cobalt.

Despite the apparent abundance of manganese ore, the sustainable production of battery-grade feedstock in the form of HPMSM, based on the currently known expansions and new projects, does not come anywhere near to satisfying the demand. It is acknowledged that the EV market is a nascent industry, and that technologies may change to less or more manganese-intensive cathode chemistries, but this is unlikely in the next 10 to 15 years, as automotive and battery companies will want the return on their capital and are unlikely to make radical changes to their plants and technologies lightly.

High-purity manganese (HPMSM and HPEMM) demand by 2031 may be satisfied from the following sources:

- current operations
- projects with a demonstrated path to execution
- existing projects that are either not announced or have stalled in their development
- recycling of spent batteries

At the beginning of 2019, Chinese producers announced that their HPMSM capacity would reach 920 kt/a in the near future. Three years later, at the beginning of 2022, the self-declared Chinese capacity stands at 356 kt/a of HPMSM and actual production at 270 kt. An underwhelming result compared to the 920 kt/a forecast.

Some Chinese producers intend to use 99.7% manganese "standard quality" EMM as a feedstock, resulting in 50 to 80 ppm of selenium in the sulphate. Environmental and health and safety issues aside, such a product cannot be called "high-purity sulphate" under the battery-grade specifications of the Chinese standard HG-T 4823-2015 and will not be accepted by majority of western battery makers.

Chinese domestic carbonate ores grade only 13% on average, and their purification to HPMSM comes at a great environmental and financial cost. Importing higher-grade ore will increase production costs and may need additional production steps such as calcination of imported oxide ores.

CPM's assessment of the global high-purity manganese industry indicates that there are only a few large-capacity high-purity manganese projects planned. Currently, there are six non-Chinese high-purity manganese projects likely to come on stream before 2031, producing 221 kt/a of new supply of high-purity manganese. An additional 100 kt/a (metal units) may be coming from China by 2025, but there are doubts about the purity of this material because of the use of selenium-containing EMM as a feedstock (discussed previously).

In North America, only Vibrantz in Mexico and Manganese X Energy Corp. (Manganese X) in Canada have reasonably clear (though long) paths to production. In May 2022, Manganese X announced the preliminary economic assessment results of its Battery Hill Project, revealing its intention to produce 68 kt/a of HPMSM, equivalent to only 10% of the North American gigafactories' capacity by 2031. For the foreseeable future, American battery cell factories are likely to rely mostly on imports. CPM believes it is likely that the 14% import duty for Chinese goods will remain in place, providing a 14% price premium on non-Chinese materials.

In addition to the projects with a demonstrated route to production, CPM has considered several projects less likely to achieve production before 2031 and, giving them the benefit of the doubt, included their potential output in the supply-demand balance calculations.

CPM also considered new high-purity manganese supply from the recycling of spent EV batteries. Assuming a 50% recycling rate and 100% manganese recovery (unlikely), this supply stream could satisfy up to 6% of 2031 high-purity manganese demand.

19.3 High-purity manganese sulphate monohydrate supply-demand balance

CPM estimates that the known project pipeline will add up to 221 kt/a of new supply of high-purity manganese. Combined with the current declared (but not fully utilised) production capacity of up to 180 kt/a, the total capacity available in 2031 will be 401 kt/a of metal contained. Meanwhile, 2031 projected high-purity manganese demand from the battery sector alone stands at 1,094 kt/a (1,127 kt/a when metallurgical uses are included). This creates a supply deficit of 726 kt. Correcting for nascent projects and recycling, the 2031 deficit comes down from 726 kt to 475 kt.

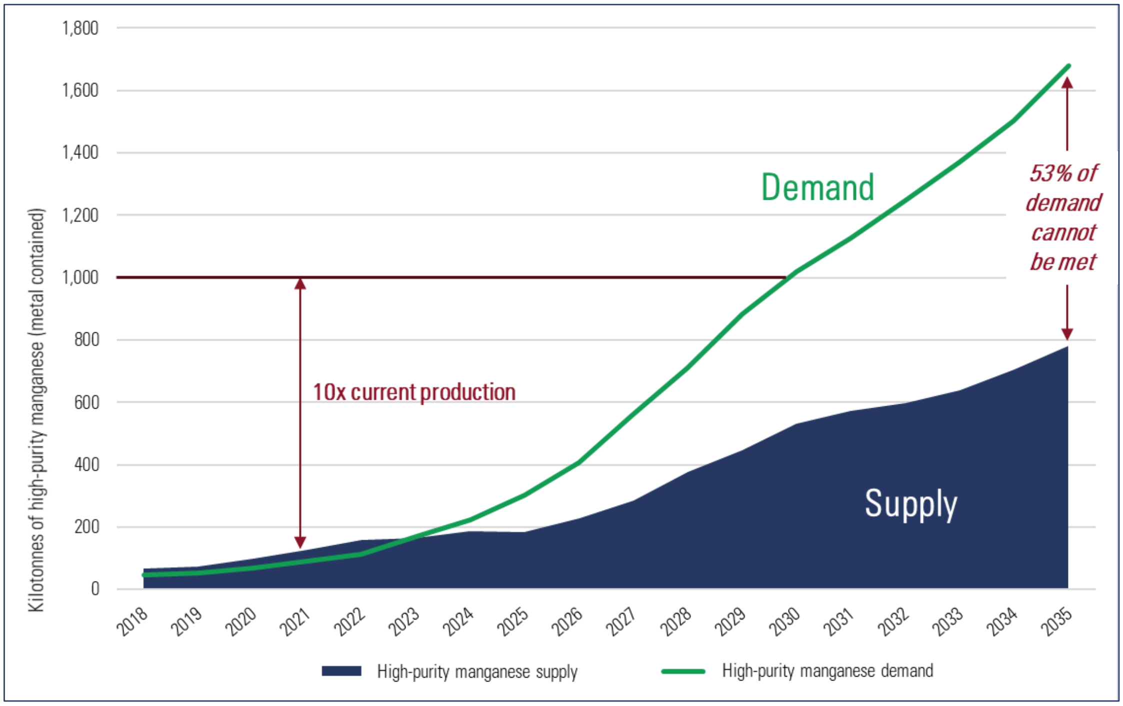
If battery demand continues to grow as expected and no new projects come to the market, the deficit will increase to 1 Mt by 2037. If this deficit is to be reduced to zero, the high-purity manganese industry would have to increase its capacity elevenfold (and produce at a close-to-100% utilisation rate).

The global supply-demand balance as projected by CPM is shown in Figure 19.6.

Many countries are planning to implement bans on sales of new internal combustion engine vehicles starting in 2035, leading to a surge in demand for batteries. Even assuming a moderate demand growth of 6% to 10% per year by 2040, the high-purity manganese demand could reach between 2.5 Mt and 4.5 Mt by 2050 (assuming no major changes in the battery chemistries mix after 2031).

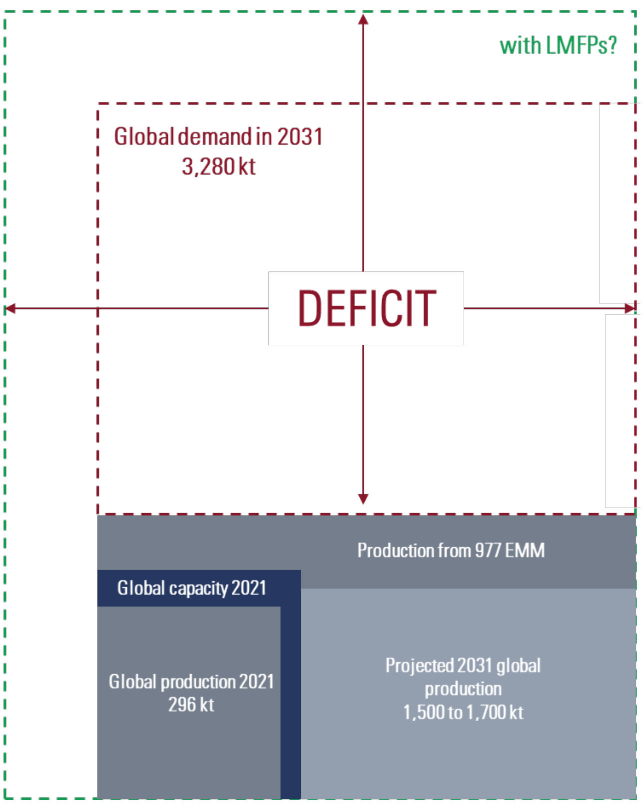
Presently, the key manganese feedstock for cathode powder production is HPMSM. Future technologies, like the M2CAM from Nano One Materials Corp., may increase the use of HPEMM, but sulphate is likely to remain the main tradeable product even then. The area chart in Figure 19.7 is a visual representation of the supply and demand situation in the HPMSM market in 2031. The chart also shows a potential new additional demand coming from the use of manganese in LMFP batteries. Because there is currently no large-scale commercial production of LMFPs, and it is still unclear which of the manganese variations of LFP chemistry could become mainstream, this portion of the demand was not considered in the report (Appendix F). Such a significant deficit is very likely to have a serious impact on the prices of battery-grade, high-purity manganese products.

Figure 19.6 High-purity manganese demand to 2035



Note: In metal units, included HPEMM and HPMSM
Source: E Source, CPM

Figure 19.7 Supply-demand balance of high-purity manganese sulphate monohydrate in 2031

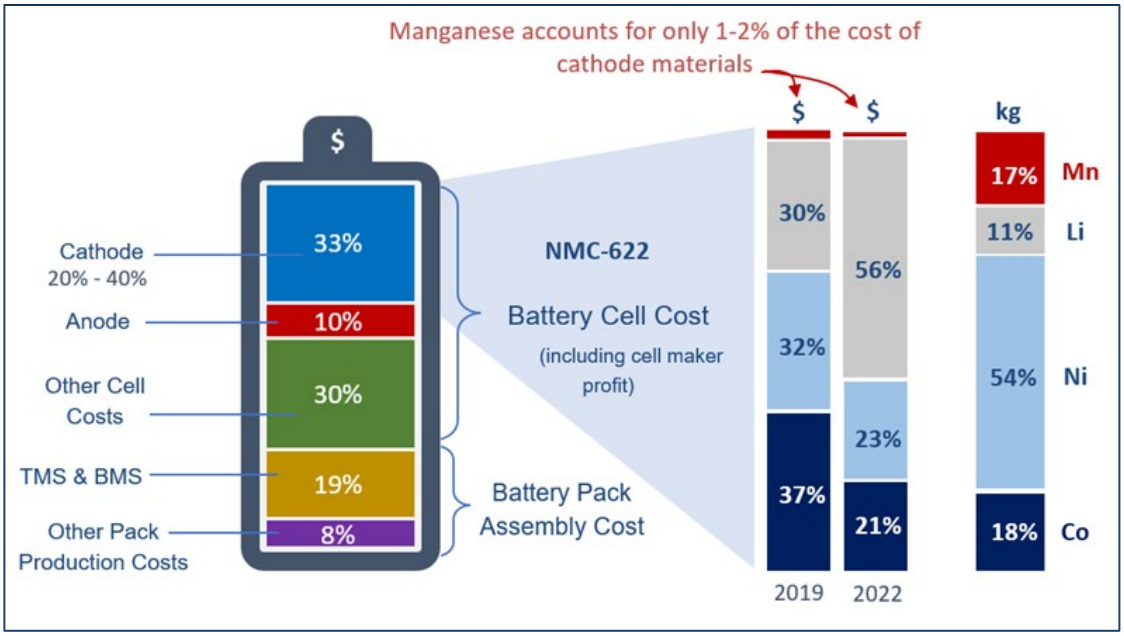


19.4 High-purity manganese sulphate monohydrate pricing

Prices set in bilateral agreements between the sellers and the buyers of HPMSM are, to a large extent, divorced from prices of other manganese products. While manganese ferroalloys and 997 EMM follow the behaviour of metal markets (steel market in particular), the HPMSM market behaves more like chemical markets, where purity matters more than the underlying metal price.

Manganese is the cheapest of all battery metals and, despite having an equal weight (in kilograms) to cobalt (in the example shown in Figure 19.8), it accounts for only 1% to 2% of the cost of the cathode materials. This makes manganese virtually price insensitive for cathode makers; they will buy it even if the price doubles or triples, as long as they can secure the right purity (Figure 19.8).

Figure 19.8 Cost and weight of cathode materials in NMC-622 battery pack (2019, 2022)



Notes: Prices used (per kilogram of battery-grade material, metal contained):
January 2019: lithium = $85, nickel = $18, manganese = $3.2, cobalt = $62
May 2022: lithium = $386, nickel = $31, manganese = $3.5, cobalt = $84
TMS - Thermal Management System (cooling)
BMS - Battery Management Systems (electronics)

Source: E Source, American Manganese Inc., Bloomberg, CPM

19.4.1 CPM price projection assumptions

CPM used ex-warehouse prices in China as a basis for their price forecasting. Freight cost, duties, and price premia were added to arrive at the European and North American prices. The European price is assumed to be delivered duty paid (DDP) Berlin because of its proxy to numerous Central and Eastern European battery factories. Similarly, the North American price is DDP Detroit as a hub for battery factories.

CPM notes the following price basis:

- HPMSM prices will remain high because of the developing deficit. The recent dip in HPMSM prices in China is a short-term symptom of COVID-19-related lockdowns in the battery-producing areas, leading to the build-up of domestic inventories.
- CPM anticipates a global recession around 2024-2025, when demand and prices may dip. The previous economic downturn caused by the COVID-19 epidemic was weathered well by the battery industry, and it is expected that the 2025 recession will have a smaller impact on EVs and batteries than on other sectors.
- Many countries in key automotive markets have announced their intentions to ban sales of new internal combustion engine vehicles around 2035. If these policies are implemented, CPM anticipates a spike in battery stock demand from the car makers, resulting in a spike in battery metals prices (including HPMSM) around 2035.
- Only six non-Chinese HPMSM projects have a chance to come on stream before 2031. With all their production considered, CPM still sees a significant supply gap, even assuming a 300% increase in Chinese production.
- CPM projects a flat price between 2035 and 2040 at the 2035 level, declining after 2040. This is to account for new producers who might appear in the market attracted by high price levels and profit margins. CPM assumes that their production will bring more balance to the market and that the prices will stop growing as rapidly as before, despite continuing growing demand, and may start falling after 2040.
- CPM believes that the position of manganese-based batteries is secure for the next 10 to 15 years, followed by higher uncertainty afterwards. The uncertainty does not necessarily mean lower demand for manganese; we may see an increase in demand if manganese-rich chemistries continue to be commercialised and if manganese finds its way to other chemistries, like LFP, which are currently manganese free.
- CPM's price forecast reflects the impending significant supply deficit in the HPMSM market and the differentiation between Chinese, European, and North American prices.

19.4.2 High-purity manganese sulphate monohydrate prices in China

Asian Metal (AM) and Shanghai Metal Markets (SMM) report HPMSM prices ex-works China. More recently, London-based Argus Media also started reporting prices of so-called battery-grade manganese sulphate. These HPMSM prices are reference prices in the broad understanding of this term; they refer to a mix of products of different specifications, sometimes not even reaching the 32% manganese declared in the description of the price data series.

19.4.3 High-purity manganese sulphate monohydrate prices in Europe

Although HPMSM prices paid by European buyers remain private, in the near term, China will remain the main HPMSM supplier to Europe and, therefore, it is reasonable to use the price of Chinese materials landed in Europe as a starting point for a calculation of any European price.

European and Chinese HPMSM prices may differ significantly because of the cost of transportation, import duties, a different supply-demand balance in the local market, as well as a strong corporate and European Union ESG requirement.

CPM calculated the theoretical European HPMSM price for the material imported from China by adding the following correction to the ex-works China price:

- cost of internal land transport in China and cost of customs clearance
- sea freight to the European port and costs of customs clearance
- cost of inland transport in Europe (to the cathode factory gate)
- European Union import duty (5%, currently suspended till the end of 2023)
- Europe-specific additional premia for:
  - purity better than Chinese Class I
  - non-Chinese origin
  - green credentials
  - recycled content
  - European Union border carbon tax

The cost of transport in the projection is based on the recent quotes for transporting a 20-foot sea container from the Changsha in China (the "capital" of the HPMSM production in the Hunan Province) to Berlin (a proxy for numerous battery factories in Central Europe). In the first quarter of 2022, this freight cost added $665 (or 44%) per tonne of HPMSM. CPM notes these excessive container shipping costs are likely to stabilise to pre-COVID-19 levels, and that the calculation above is also based on a small consignment of up to ten containers only. Larger consignments will attract lower prices. As such, CPM has applied a variable shipping cost between $500/t (near term) and $200/t in the later years.

The Europe-specific premia are estimated in aggregate based on anecdotal evidence from industry insiders. CPM's conservative estimate puts these premia at 15% to 25% or more of the ex-works China warehouse price.

CPM's European HPMSM price estimate assumes tariff-free access for Chinese HPMSM imports. It is likely the tariff of 5% for Chinese goods will remain suspended or abolished until Europe has enough internal capacity to satisfy the needs of its battery industry.

19.4.4 High-purity manganese sulphate monohydrate prices in North America

There is currently no HPMSM production in North America. Once converted, Vibrantz's Tampico plant in Mexico will be the first North American producer of HPMSM. Even when their second phase is implemented, they will meet only 10% of the American battery industry demand for HPMSM in 2030, which means that for the foreseeable future most of the HPMSM needed will be imported, predominantly from China. The price for Chinese material landed in the USA will form the basis of the North American HPMSM price estimate

CPM's American price projection includes freight cost from Changsha in China to the battery factories cluster near Detroit, as well as the 14% import duty and a likely premium for the "non-Chinese origin" and "better than Chinese product specification." Due to the limited metallurgical test work by aspiring future North American producers and the lack of current local suppliers, it is hard to say if American buyers would be willing to pay the extra premium for "better than Chinese" quality and what tonnage of such quality from local production will be available to them.

19.4.5 High-purity manganese sulphate monohydrate prices for the K.Hill Project

To calculate the price for its HPMSM product received by Giyani, Giyani has assumed that its sales will be made on a FCA basis in Durban, South Africa; therefore, the realised price shall be the prevailing benchmark price in Europe or North America, as estimated by CPM, less the cost of freight from South Africa and any applicable import tariffs. As Giyani is currently in discussions with potential off takers in both Europe and North America, it has been assumed that 100% of its production will be split equally between customers in these two markets.

Table 19.1 illustrates the net realised prices for HPMSM shipped from K.Hill to the ports of Rotterdam and Baltimore in Europe or North America, respectively. The freight costs include one-way containerised trucking from K.Hill to Durban based on quotes received from an established international freight company and forecast sea freight rates from Durban using 2022 spot prices and CPM data. At present, there are no tariffs applicable to imports from Botswana in either Europe or North America.

Table 19.1 Net realised high-purity manganese sulphate monohydrate (32% manganese) price projections

Year	Net realised price FCA Durban (US$/t of HPMSM)
2026	2,993
2027	3,250
2028	3,517
2029	3,775
2030	3,918
2031	4,147
2032	4,427
2033	4,729
2034	5,053
2035	5,499
Average 2026-35	4,131

Notes: Projected annual average prices in US$/t of HPMSM.
Net realised prices at K. Hill Project's gate assuming 50% of sales to the European Union (Berlin) and 50% sales to the USA (Detroit).
Real price base: 2021.

Source: CPM's calculations based on supply-demand assessment and historical prices reported by Bloomberg, AM, Argus, SMM, and industry sources.

20 ENVIRONMENTAL STUDIES, PERMITTING AND SOCIAL OR COMMUNITY IMPACT

20.1 Introduction

Giyani appointed Loci Environmental to carry out the necessary environmental and social studies and permitting for the exploration and mining phases of the K.Hill Project. Loci Environmental is an independent environmental consultancy based in Gaborone, Botswana and is owned and operated by five practitioners registered with the Botswana Environmental Assessment Practitioners Board. Loci Environmental has a team of specialists who undertake specific studies for EIAs.

Loci Environmental is undertaking the K.Hill EIA in accordance with Section 9 (1) of the Environmental Assessment Act. In 2020, Loci Environmental prepared a Scoping Report and TOR for the K.Hill Project, which was submitted to and approved by the DEA (Loci Environmental 2020). The EIA team used the approved Scoping Report and TOR to prepare Section 20 of the FS based on the EIA findings to date. In terms of Botswana legislation, the EIA is referred to as an ESIS.

The EIA is ongoing and, in some cases, additional specialist studies are being conducted due to modifications of the Project Description, including:

- a study on the solar plant, which was not in the initial Project Description
- a study on the water supply coming from aquifers outside of the PL area
- a traffic impact assessment (increased traffic volumes)

The baselines and impact assessments described in this section will be revised and updated as the results of these additional studies become available.

It should be noted that no environmental or social red flags/fatal flaws have been identified to date. Although the study areas are expanding, preliminary visits to the new areas indicate a similar receiving environment (i.e., tribal lands disturbed by small-scale farming in places). As the studies progress, the study areas will be defined in each of the specialist studies.

The engineering teams conducted trade-off studies after the DEA approved the Scoping Report and ToR, which resulted in changes to the Project that improved both sustainability and environmental performance (e.g., dry stack tailings vs conventional tailings, changes to processing to reduce energy consumption, and a solar farm to reduce the amount of power taken from the national grid, which is coal-based and to minimise contributions of greenhouse gases through Scope 2 [indirect emissions]).

20.2 Limitations

At the time of writing Section 20, only draft reports were available for reference, as listed in Table 20.2. These reports were drafted during 2020 and Q1 2021, with life cycle carbon and climate change and adaptation reports completed in 2022. After Giyani reviewed the draft reports, changes to the Project meant that the environmental studies were placed on hold until the Project Description was finalised. Hence, some information, such as population data, is out of date but will be updated with information from the Botswana census of 2022.

The study areas have not been defined in the draft reports but will be defined for each specialist study with terms that have been adopted by Loci Environmental (e.g., local study area, area of influence, footprint).

20.3 Legislative review

The EIA is being conducted in compliance with the national legislation of Botswana. Giyani is also committed to conforming with the requirements of the international lender community and GIIP, specifically, the IFC *Performance Standards on Environmental and Social Sustainability* (IFC 2012) and EP4 (2020).

Giyani will develop an ESAP to address gaps in the EIA with reference to, amongst other things, GIIP and corporate policies and procedures. The gap analysis will be conducted when the environmental authorisation has been issued.

The following subsections outline the pertinent legislation related to land, water, mining, and energy.

20.3.1 Land-related legislation

Botswana has three principal land tenure systems:

- Freehold is estimated to account for approximately 5% of all land; freehold land can be bought and sold on the open market.
- Tribal is estimated to account for 72% of all land; tribal lands are governed by traditional systems and the Botswanan Land Boards. The K.Hill Project is located entirely on tribal land.
- State is estimated to account for 23% of all land; state land includes national parks and much of what is defined as urban land.

20.3.2 Environmental legislation

Environmental legislation pertinent to the Project includes:

- Environmental Assessment Act
- Monuments and Relics Act

- Tribal Land Act
- Wildlife Conservation and National Parks Act (which enacts the Convention on International Trade in Endangered Species of Wild Flora and Fauna)
- Conveyance of Dead Bodies Act
- Waste Management Act
- Atmospheric Pollution (Prevention) Act
- Factories Act
- Radiation Protection Act
- Public Health Act
- Employment Act
- Workers Compensation
- Agricultural Resource Conservation Act

20.3.3 Water legislation

Water legislation pertinent to the Project includes:

- Boreholes Act
- Water Act
- Water Utilities Act
- Waterworks Act

In May 2009, the Government of Botswana initiated the first of a series of water sector reforms, which included consolidating all water and wastewater operations under the WUC umbrella.

20.3.4 Mining and energy legislation

Mining and energy legislation pertinent to the Project includes:

- Mines and Minerals Act
- Mines, Quarries and Works and Machinery Act
- Explosives Act
- Electricity Supply Act

20.4 Policies and standards

The policies and standards adopted for the holistic development of Botswana include:

- Vision 2036 (2016-2036)

- National Settlement Policy (2004)
- National Policy on Land Tenure (1983)
- Botswana Land Policy (2015)
- National Policy on Resource Conservation and Development (1990)
- National Policy on Gender and Development (2015)
- National Mainstreaming Strategy for Botswana: Framework for Mainstreaming in Development (2012)
- Botswana Bureau of Standards: Water Standards
- Ambient Air Quality - Limits for Common Pollutants (BOS 498:2012)
- Maximum Permissible Limits for Environmental Noise (BOS 575:2013)
- National Policy on HIV/AIDS (2012)
- The Second Botswana National Strategic Framework for HIV and AIDS (2010-2016)
- Disability Policy (1996)
- National Youth Policy (2010) and the National Action for Youth (2001)
- National Policy on Culture (2001)
- National Gender Policy (1995)
- National Policy for Wastewater and Sanitation Management (2001)
- Guidelines for Waste Recycling (2013)

20.4.1 International conventions

Botswana is a signatory to several international treaties and conventions, including:

- the Basel Convention of the Control of Transboundary Movements of Hazardous Wastes and Their Disposal (1992)
- the Paris Agreement (2016) and the Right to Organise and Collective Bargaining Convention (1949)
- United Nations Framework Convention on Climate Change
- Kyoto Protocol (1997)
- the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) (1975)

Other conventions relevant to the Project will be referenced in the EIA.

20.5 Permitting requirements

Permitting requirements for exploration and mining (mining begins when the first sod of earth is turned) are listed in Table 20.1; the list will be verified through consultation with the relevant Government of Botswana departments and parastatal departments.

20.5.1 Authorisation for the exploration phase

Giyani, through its wholly owned subsidiary Menzi Battery Metals, holds PLs for K.Hill and adjacent areas (Section 4). Loci Environmental submitted an EMP, which was authorised by the DEA on 24th July 2019 with an expiry date of July 2021. The EMP was renewed in July 2021 for 1 year, with the option to renew the EMP again.

Prior to submitting a renewal for the EMP in 2022, Menzi Battery Metals made an application for renewal of the Kanye PL322/2016, which was due to expire in June 2022; an EMP authorisation will only be granted for the period that a PL is valid. Per Section 16 of the Mines and Minerals Act, the Department of Mines renewed the PL for 2 years (ending 30th September 2024)

The DEA undertook a site visit to K.Hill before renewing the EMP authorisation. In a letter dated 31st August 2022, the DEA renewed the authorisation for 2 years to October 2024 (per Section 14 of the Environmental Assessment Act). Thus, all exploration activities on K.Hill comply with Botswana legislation.

Table 20.1 Permits and authorisations for K.Hill Project

Name of permit/ authorisation	Authority	Supporting documentation/ information required	Relevant legislation	Required timeline
Mining Licence	Department of Mines	EIA approved by DEA; letter of authorisation from DEA; parent company guarantee; certificate of incorporation; company documents of directors and shareholding; FS report; proposed rehabilitation programme; letter of surface rights; letter of authorisation from the Department of National Museum and Monuments; copy of prospecting licence	Mines and Minerals Act	Before Project construction start
EIA approval	DEA	Draft EIA report (which is termed an ESIS); specialist reports will be attached as appendices	Environmental Assessment Act	Before the application for the mining licence
Archaeological planning permission	Department of National Museum and Monuments	Specialist study report with plans of the area	Monuments and Relics Act	Before EIA approval; already approved for the proposed mine licence area but with Project Description changes, new areas will be subject to specialist studies and an application for archaeological planning permission
Water borehole registration	Department of Water and Sanitation	Coordinates of the borehole; plans; report on drilling and pump tests; capping of holes	Boreholes Act	Five groundwater boreholes have been drilled and are registered with the Department of Water and Sanitation
Water rights	Department of Water and Sanitation	Borehole information – test results of pump tests	Water Act	Before Project construction starts (before water abstraction), application through Water Apportionment Board
Working conditions - construction	Department of Labour, Department of Mines, Department of Health and Safety	Ongoing inspections by the departments regarding safety and sanitary conditions	Factories Act, Mines, Quarries, Works and Machinery Act	Before Project construction starts

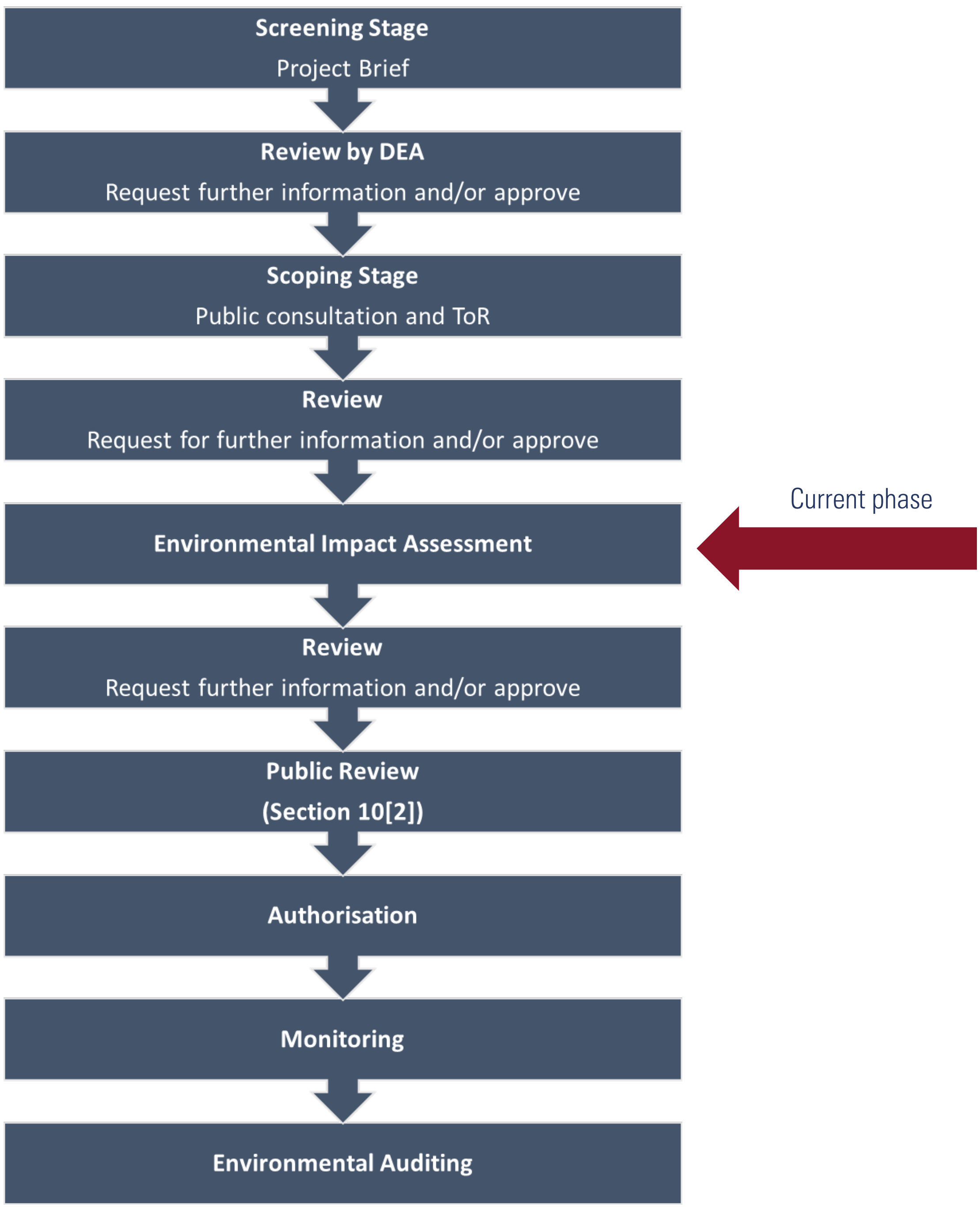
Name of permit/ authorisation	Authority	Supporting documentation/ information required	Relevant legislation	Required timeline
Working conditions - operation	Department of Labour, Department of Mines, Department of Health and Safety	The Departments conduct ongoing inspections to check that work permits are valid; sanitary and safety conditions	Employment Act, Mines, Quarries, Works and Machinery Act	Before Project operations start
Work permits and residence permits	Department of Labour Affairs	Valid job offer; curriculum vitae (CV); certified copies of birth, marriage and education certificates; medical report; passport; jobs to be advertised within Botswana first	Employment Act	As and when needed
Storage of explosives	Department of Mines	Approved plans; application letter; conditions regarding lightning conductor; magazine plans; magazine fence	Explosives Act	Before blasting activities
Application to import and possess explosives	Department of Mines (Chief Inspector of Explosives)	Copies of company certificate of incorporation; trading licences; directors' declaration forms; and company share certificate	Explosives Act	Before blasting activities; the application takes 5 days
Obtain surface rights/change of land use	Land Board	EIA and plan of the area	Tribal Land Act	Before the application for the mining licence
Resettlement - WUC tank; BOCRA spectrum monitoring tower; fields and land users (cattle posts); use of airstrip road	DEA/Land Board	EIA and plans showing land use/ lease areas	Tribal Land Act	Before construction begins; BOCRA and WUC have agreed that their infrastructure will be relocated, and new sites have been identified. Owners of cattle posts and Solomon's Temple have indicated they are willing to relocate; the Land Board will identify new areas as part of the relocation process

Name of permit/ authorisation	Authority	Supporting documentation/ information required	Relevant legislation	Required timeline
Permission to generate power for own use by gen-sets and solar	Department of Energy Botswana Energy Regulatory Authority	Applicant name and address; description of activity that requires a licence; location; technical and financial capabilities; and land ownership/rights (e.g., lease agreement, deeds)	Electricity Supply Act Botswana Energy Regulatory Authority Act	Before the construction of power supply facilities
Waste permit	Department of Waste Management & Pollution Control	Site plan; EIA report or EMP; operation plan; certificate of incorporation; lease agreement; environmental health report; authorisation from local authorities; record keeping procedures; and closure plan	Waste Management Act	Before construction begins
Permission to connect access roads to existing roads	District Council, Roads Department	Plans with coordinates; discussions with either Council for regional/local roads or Department of Roads for national roads	Road Traffic Act	Before access road construction
Licences (mining and EIA approval) for borrow pits	Department of Mines, DEA	Site plans and description of Project; submit Project Brief to DEA	Mines and Minerals Act, Environmental Assessment Act	Before the excavation of any materials for construction
PL renewals	Department of Mines	Letter with request for renewal; reports on work completed to date with expenditure; application form with maps and coordinates; Company extract from the Companies and Intellectual Property Authority; commitment letter from Giyani; Board resolution to confirm the application for renewal; police clearance for local members of the Board; bank account statements for last three months; annual financial statement; and CVs of the exploration team	Mines and Minerals Act	Before the PL expires (current renewal expires October 2024)
Renewal of EMP for exploration	DEA	Valid prospecting licence and EMP monitoring report	Environmental Assessment Act	Before EMP expires; current EMP authorisation expires October 2024
Approval of mine design	Department of Mines	Project FS; environmental authorisation	Mines and Minerals Act, Section 39 (1)	Before construction begins

20.5.2 Authorisation for the mining phase (construction through to operations and closure)

The Botswana EIA process guides the environmental authorisation process and is summarised in Figure 20.1.

Figure 20.1 The environmental assessment process in Botswana guided by the Environmental Assessment Act



The process for obtaining an environmental authorisation begins with submitting a Project Brief to the DEA, which is a screening tool that gives a high-level description of a proposed project and the receiving environment. The Project Brief must be sufficiently detailed for the DEA to decide which level of study should be undertaken (i.e., a basic EMP or full EIA). The K.Hill Project Brief was submitted in January 2020, and a letter was received from the DEA on 7th February 2020 (DEA reference no. DEA/BOD/EXTR/ MINE 127 [2]).

The letter stipulated the following:

- Under Section 9 (1) of the Environmental Assessment Act, implementation of the proposed activity (i.e., the Project) requires a detailed EIA.
- The proposed Project is a listed activity for which an EIA is mandatory as per Schedule 1, Regulation 3 of the Environmental Assessment Regulations (2012).
- Public consultation should be undertaken in accordance with Section 7 (2) of the Environmental Assessment Act as part of the scoping exercise to identify the salient issues to be addressed by the EIA study.
- Pursuant to Section 10 (2) of the Environmental Assessment Act, the Project will also be subject to public review.
- A Scoping Report and TOR should be submitted to the DEA for review and approval before proceeding with the detailed assessment.
- A practitioner who has been duly certified by the Botswana Environmental Assessment Practitioners Association must be engaged to undertake the study.
- No construction/activity should take place until the authorisation of the EIA is granted, per Section 9 (3) of the Environmental Assessment Act.
- The study should, at a minimum, contain the following specialist studies: social impact assessment, geotechnical studies, hydrogeological impact assessment, and occupational health and safety studies.
- Upon submission, the reports must be accompanied by a fee of P1,500 for review, as prescribed in Schedule 3, Regulation 4 of the Environmental Assessment Regulations (2012).
- Seven hard copies and one soft copy of the draft Scoping Report and TOR should be submitted to the DEA for review.

Scoping was completed and included stakeholder engagement, in line with the Environmental Assessment Regulations (2012). A Scoping Report and TOR for the full EIA was compiled and submitted to the DEA (25th August 2020).

20.6 Environmental and social studies

20.6.1 Methodology

To meet the requirements for environmental authorisation for K.Hill, an EIA will be submitted to the DEA. A series of specialist studies have been undertaken; however, they are currently under revision to account for Project changes that have occurred since the agreement with Loci Environmental was first signed in 2020. The objective of the studies is to describe and characterise the receiving biophysical and socio-economic environments (i.e., to establish the baseline) against which the Project's potential impacts will be assessed and to define appropriate mitigation measures to reduce negative and enhance positive impacts.

In parallel with the specialist studies, a stakeholder engagement programme was developed and implemented. Stakeholders comprise authorities (at national, local, and tribal levels), local communities, and those that may be directly or indirectly affected by the Project. The population of Kanye is the largest group of stakeholders and closest to the Project.

The specialist reports and EIA will provide the basis for monitoring and mitigation that will be implemented for the construction, operation, rehabilitation and closure, and post-closure phases of the Project. It should be noted that the transitions from one phase to another (e.g., construction to operations) are significant changes that will require monitoring and management plans to be reviewed and revised. Specific management plans will be developed in readiness for construction and subsequent phases, all of which will be informed by the EIA and the results of monitoring programmes.

Specialist reports that have been drafted to date are summarised in Table 20.2.

Table 20.2 Specialist environmental and social reports

Title	Date	Status	Scope
K.Hill climate change and adaptation summary	March 2022	Final	Technical memo on climate change and physical risks to the Project under future emissions scenarios.
K.Hill life cycle assessment study technical memo V2	March 2021	Draft; for internal purposes	An initial benchmark of the global warming potential per kilogram of product was established using a life cycle assessment approach. Scenario analysis to determine the change in global warming potential associated with a change in power source (national grid and solar).
Streamlined prospective life cycle assessment study of the HPMSM production at the K.Hill Project	September 2022	Final	The draft technical memo (V2 March 2021) was updated and incorporated into a final report that determined the significant project and process parameters contributing to the global warming potential of HPMSM at K.Hill.
Rehabilitation and closure	February 2021	Draft; being revised to incorporate additional mine components	General rehabilitation and closure requirements regarding Project components; estimated closure costs.
Occupational health risk assessment and health impact assessment	August 2020	Draft	Presents an overview of country-wide health and Project-specific risks with recommendations to manage them; occupational health; legislative requirements; health policies; community health; international conventions; COVID-19; medical emergency response plan; disaster management; available primary healthcare; occupational health surveillance; public health and hygiene; exposure to potentially hazardous materials; potential impacts and mitigation.
Hydrogeological assessment K.Hill	July 2020	Draft; progress report	Preliminary aquifer characterisation and groundwater modelling. The groundwater study will be subject to extensive revision following the provision of data from groundwater boreholes drilled by Giyani in late 2021 and June 2022.
Biodiversity study	January 2021	Draft; being revised to incorporate additional mine components	Identifies biodiversity features; species of conservation concern; and invasive alien species. Informs ecosystem services; natural, modified, and critical habitat assessment; invasive alien species management plan. Identify risks and impacts associated with the Project and provide a mitigation/biodiversity monitoring programme. Informs biodiversity impact and net gain strategy.

Title	Date	Status	Scope
Archaeology and cultural heritage impact assessment	September 2020	Draft; being revised to incorporate additional mine components	Accredited archaeologists drafted the report; identifies potential sites of archaeological, cultural, and historic significance; assesses potential impacts on such resources; and provides mitigation; recommendations to promote overall conservation and protection of natural and cultural resources in the Ngwaketse Sub-district (within which the Project is located). Scope was carried out with reference to heritage legislation; planning permission was issued by the Department of National Museums and Monuments for the study area.
Social impact assessment report	February 2021	Draft; being revised to incorporate additional mine components	Presents the socio-economic setting in the site-specific, local, and regional study areas. Identifies infrastructure; sacred/religious places; access routes; land use; residential and civic uses; services; demographics (quantitative surveys of 76 households in the Mmamokhasi Ward [closest ward to the site]); economics and land zoning. Impact assessment with ratings, proposed mitigation; residual impacts (i.e., impacts after mitigation has been applied).
Hydrology assessment	June 2020	Draft	Describes the hydrological setting of the Project; rainfall and hydrometeorology; evaporation; return floods. There are no perennial watercourses in or near the Project footprint. The focus of surface water is stormwater management which is incorporated into engineering designs (e.g., TMF; WRD; open pit; processing plant); water will be collected in settling ponds and recycled for use in the processing plant or for dust suppression.
Traffic study report	November 2020	Draft; to be revised using latest transport information	Traffic surveys to determine baseline traffic and forecasted traffic associated with K.Hill; counts at 11 intersections around Kanye network; baseline average daily traffic, road capacity analysis and projected future traffic; assessment of route options; potential traffic impacts and mitigation.
Waste impact assessment	February 2021	Draft	Waste management for all phases of the Project; analysis of waste streams (qualitative); available waste facilities in the nearby area; hazardous waste management and disposal; waste management hierarchy.
Landscape and visual assessment	March 2021	Draft; to be revised incorporating revised layout and components	Describes the existing aesthetic; landscape character and visual amenity; potential visual impacts on the character of the are study area; with mitigation.

20.7 Existing (baseline) environment

The K.Hill Project is located 5 km from Kanye, the administrative centre of the Southern District of Botswana. Kgwakgwe Hill (named after the historical mine) is a significant landscape and visual feature that forms a prominent landmark (approximately 1,412 masl). The Project is in a brownfield site, which has been disturbed by previous exploration/mining projects and the construction and operation of two water supply reservoirs and a communication tower with associated infrastructure. Currently, the lower parts of the hill are used for illegally dumping waste (e.g., packaging, plastics, clothing, utensils, and disposable nappies).

20.7.1 Social baseline

The social study areas comprise the following zones:

- The primary zone (Zone A) is the directly affected area or areas located within the footprint of the Project.
- The secondary zone (Zone B) comprises the adjacent areas indirectly affected by the Project activities due to their proximity to the Project.
- The tertiary zone (Zone C) covers the greater study area, including Kanye and neighbouring areas.

Kanye is the nearest urban centre, with a population of approximately 48,000. Census data shows that the population has increased from approximately 10,000 in 1970 to 45,196 in 2011 and is continuing to grow. A national census was undertaken in 2022; however, data was unavailable at the time of writing Section 20 but will be included in the ESIS. Kanye is the ninth-largest urban area in Botswana and one of the oldest settlements, with records indicating it was established around 1798 by Kgosi Makaba of the Ngwaketse tribe. The Ngwaketse had settled on the hill but were attacked by the Rolong and Griquas and resettled to the present-day location of Kanye.

Authorised and unauthorised spiritual groups visit the wider area of Kgwakgwe Hill. On the Project site, spiritual rituals have taken place in abandoned mine adits. Local legends refer to a spiritual creature that protects and guards the hills. Some respondents, during key informant interviews, reported that it is believed the spirit was unhappy with the previous miners and chased them away. However, the common consensus is that the spirit may allow new mining activity if all is done with consultation and respect, it being a sacred place. A church, known as Solomon Temple, is approximately 180 m from the proposed mining area. It is an informal structure built on ruins of housing from previous mining operations.

K.Hill is on tribal land, as is most of the surrounding land. There is limited farming activity. Two commercial farms are more than 2 km to the SW and SE of the Project. An abandoned cattle post is approximately 1.4 km from the Project boundary and had been used for small-stock farming. Household surveys of 76 households in Zone B recorded 28 cows, 20 goats, and 79 chickens.

There are approximately 100 residential areas (houses; the nearest being 0.5 km NE of the site) and ten civic facilities such as rural schools (e.g., Ngwaketse Community Junior Secondary School is approximately 0.7 km from site).

Social surveys were conducted during numerous site visits that began on 14th July 2020 (the Scoping Study phase), which adopted methods including public and key informant interviews. Secondary data was collected from publicly available documents and data. Where gaps existed, data was collected from key informants at national, district, and local levels (e.g., tribal administration; Kanye legislators, planners, and district administrators; health officials - district health team; Table 20.3).

Table 20.3 Key informants; local, district and national levels

Level of organisation	Key informants
Local	• Tribal administration: Paramount chief, senior representatives, headmen of arbitrations, headmen of records • Kanye legislators, planners, and district administrators • Village leaders - Kgosi (tribal leader), councillors, school heads, local entrepreneurs
District	• District council official (social worker), district commissioner, Sejelo Police Station, district health management team
National	• Department of Animal Production • Department of Agricultural Research • Department of Tourism • Department of AIDS Prevention and Care • Department of Public Health • Department of Clinical Services • Department of Gender Affairs • Department of Labour and Social Security • Department of Lands • Department of Land Boards Services • Deeds Registry • Department of Mines • Department of Water Affairs • Department of Youth • Department of Culture

Quantitative surveys of randomly selected households, and all those directly affected by the Project (representative sample), were carried out to determine baseline characteristics (e.g., skills, demographics, socio-economic conditions). Two enumerators were employed in Kanye to assist with surveys; 257 people were interviewed.

Southern District education facilities comprise pre-schools and primary and secondary schools. The literacy rate for Botswana is 90%, but 80.8% for the Southern District, which may be attributed to a lack of capacity in schools.

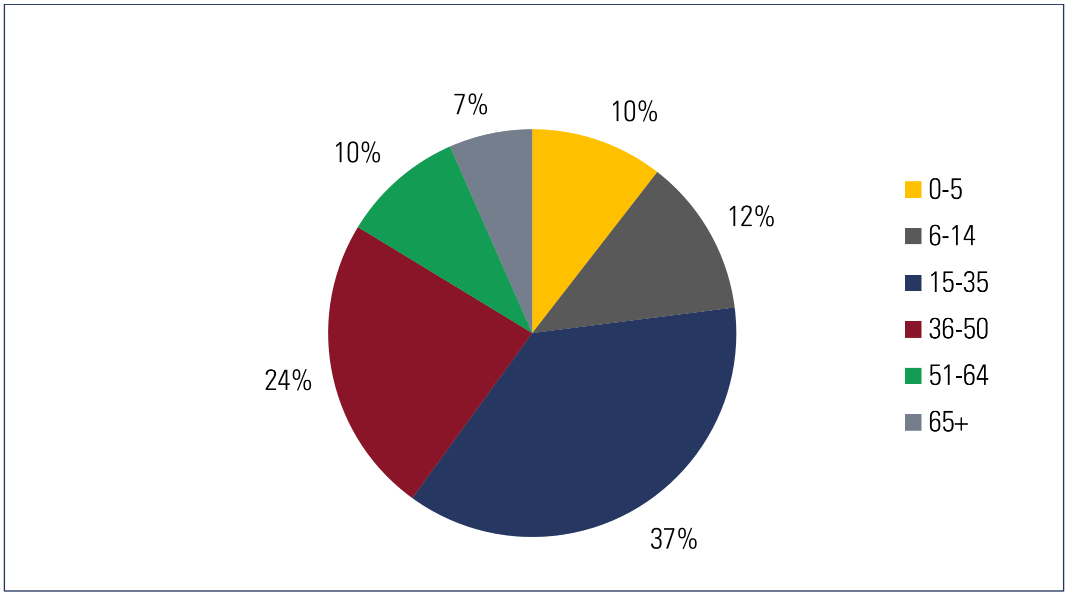
Botswana provides universal healthcare for its citizens through primary, district, and referral hospitals. Southern District has 53 health posts and 15 clinics (13 more clinics are needed to keep up with population growth).

Forty-three percent of households use electricity for lighting, while 39% use paraffin, 11% use candles, and firewood accounts for <5%.

All ethnic groups are known collectively as Batswana (people of Botswana). Tswana-speaking people are 79% of the population; Kalanga 11%; and Basarwa (Bushmen) 3%. Other ethnic groups account for 7% of the national population.

Age distribution from the household surveys is illustrated in Figure 20.2. Approximately 70% reported having construction skills, while only four households have mining-related skills. The unemployment rate for those seeking work is 15.6% (14.6% are unemployed but not seeking work).

Figure 20.2 Age distribution of Project affected area



Archaeology and cultural heritage

Botswana legislation was referenced for planning and implementing the baseline archaeology and cultural baseline study (i.e., the Monument and Relics Act). The eligibility criteria of sites in state regulations relate only to history, architecture, and archaeology; culture and intangible cultural heritage are omitted but implied. However, the Department of National Museums and Monuments has supported several efforts to integrate culture into preservation. The Department of National Museum and Monuments' site register and site maps were referenced for information on the archaeological sites already known in and around the Project area. This preliminary research was intended to provide the study with background information on the area that would act as a guide in the next phases of the study. This survey was conducted with the help of persons familiar with the Project area and the history of its surroundings. The "local guides" were helpful in guiding the survey team to the known archaeological/cultural sites and other places of particular interest.

The Kgwakgwe Area is rich in archaeological resources; however, no archaeologically significant materials were observed in the areas proposed for mining activities and supplementary development. Though no cultural material was found, the site remains a potential archaeological interest due to its location, associated sites, and settlement history. Moreover, the site has been utilised by the local community and trans-local visitors as a sacred place.

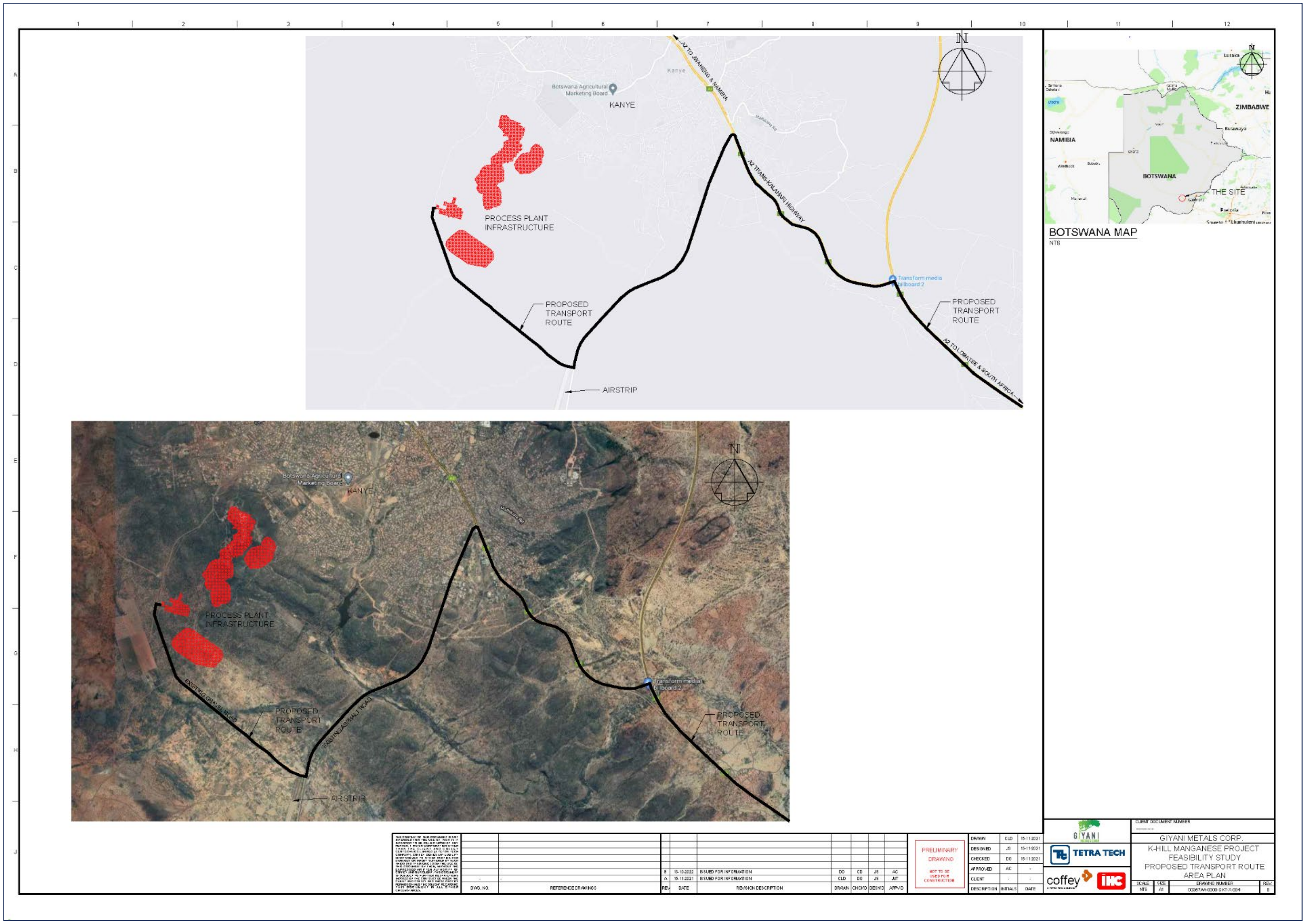
It is important to note that this was a surface survey, and archaeological materials may be hidden under the surface, which could be exposed during further earth-moving activities. A chance-find procedure will be implemented, and all contractors involved with excavation will receive training during induction.

Traffic

Traffic counts were undertaken at 11 road intersections in the Kanye road network over 3 days; results were analysed to establish average daily traffic movements. Notable findings included no defined traffic patterns with no significant distinction between morning, afternoon, evening, and off-peak periods. Most traffic in Kanye is local, with few leaving the village during usual commuting hours. Analysis of types of traffic will be presented in the ESIS.

Giyani's preferred option at this juncture is to use public roads that avoid the urban areas of Kanye (Figure 20.3).

Figure 20.3 Preferred road option for Giyani traffic



20.8 Biodiversity

Field surveys were undertaken during May, June, and December 2020 so that representative seasonal data could be collected. Species were identified through direct observation or, for fauna, through evidence such as scats, nests, burrows, and footprints. Ecosystem services were identified through consultation with possible beneficiaries and professional opinion. No permanent waterbodies or watercourses exist on site; therefore, an aquatic survey was unnecessary.

20.8.1 Vegetation

The Project area is located within the Southern African Bushveld ecoregion, which is one of Botswana's seven ecoregions. The Southern African Bushveld eco-region is vulnerable due to the direct and indirect impacts of increasing human and livestock populations (DEA 2016). The Project is located within the Savanna biome, which is broadly classified as Vachellia/ Senegalia-Colophospermum-Terminalia Kalahari bushveld vegetation, and the vegetation sub-type around Kanye is Arid Sweet Bushveld.

Five vegetation communities were identified in the Project footprint:

- Hill top *Croton gratissimus* - *Combretum apiculatum* thicket
- Hill slope *Dichrostachys cinerea* shrubland
- Hill foot *Vachellia tortillis* - *Dichrostachys cinerea* shrubland
- Hill foot *Combretum apiculatum* thicket
- Drainage line *Croton gratissimus* - *Cmobretum apiculatum* thicket

A total of 53 flora species were recorded at the site comprising 25 tree species, 16 grass species, and 12 herbaceous (flowering plant). None of these species are of conservation concern in accordance with the Botswana Red Data Book or International Union for Conservation of Nature (IUCN). One species, *Grewia flava*, is endemic to Southern Africa. Only one invasive species was identified within the site: *Verbesina encelioides*.

Various veld products were identified (these serve as ecosystem services) from the flora species recorded (see Section 20.7.3).

20.8.2 Fauna

The range distribution of 62 mammal species falls within the Project footprint, the majority of which are medium to small species. During the site survey, only two mammals and evidence of the passage of two other species were observed. Sixteen mammal species that may occur in the area are of conservation concern; however, none were found to be resident at the site.

The Project footprint overlaps with the range distribution of 44 reptile species. The majority of these species are considered highly likely to occur within the Project footprint; however, none were recorded during the site survey. Five species are of conservation concern.

The Project area falls within the range distribution of c.285 bird species. Seventy of these species are protected under Botswana law, 20 are listed on the IUCN Red Data Lists, and 47 are listed in the Convention on International Trade in Endangered Species of Wild Flora and Fauna Appendices. The number of bird species actually occurring at site is expected to be significantly lower due to the disturbed state of the environment. During the survey of the Project footprint, 24 species were recorded. Of interest are the water birds that frequent the dams surrounding K.Hill (the nearest of which is 7 km from site). Here, 31 species have been recorded during bird counts carried out by BirdLife Botswana. Of the species recorded at site or the dams, 11 are protected in Botswana, and 1 is listed in CITES Appendix II.

20.8.3 Ecosystem services

Ecosystem services that K.Hill provides to the nearby communities fall into four categories: provisioning, regulating, supporting, and cultural. The majority of the ecosystem services are provisioning ecosystem services (e.g., trees used for making canoe, traditional medicine, edible fruit, grasses and sedges used for thatching, weaving baskets and mats, grazing resources, and fuel wood). Cultural services are critical ecosystem services, as K.Hill is associated with spiritual icons. Regulating services include erosion control and soil fertility. The supporting ecosystem services identified were biodiversity and nutrient recycling.

20.8.4 Critical habitat

The Critical Habitat Assessment was carried out in a discrete management unit (DMU), encompassing the Project area of influence. For the assessment, the area of influence comprises the area that will be disturbed by the Project and dams within 7 km of K.Hill where waterbirds occur. The DMU consists of both natural and modified habitats. All species considered for this assessment were avi-faunal species. No other species that potentially meet the criteria for critical habitat were found to be present within the DMU. Four avi-faunal species within the DMU were assessed for Criterion 1 (Critically Endangered or Endangered species). None of these species met the requirement of 10% of the global population present within the DMU. Congregatory water bird species were identified within dams within the DMU; however, the minimum threshold (10% of the global population) was not met. No species triggered an assessment for Criterion 2 (endemic or range-restricted species). Criterion 4 (threatened or unique ecosystems) and Criterion 5 (key evolutionary processes) were not triggered for assessment. Thus, the current state of the DMU does not qualify the area as a critical habitat.

20.9 Physical environment

20.9.1 Surface water

There are no permanent watercourses within the Project footprint. Stormwater runoff drains from Kgwakgwe Hill to the east and west into local streams.

Runoff from the western slopes of Kgwakgwe Hill flows approximately 3 km into the Nneneke River. The river has confluences with the Mathlhapise River, the Mokape River (near the

Lobatse Road), and flows into the Masinyetse River. Thirty kilometres west at Mogobane village, the Masinyetse River flows into the Taung River, then into the Notwane River, which flows 150 km north into the Limpopo River; the Limpopo discharges into the Indian Ocean.

The Matlhapise River, 2 km east of the mining area, drains the southern slopes of Kanye into the Mmamokhasi Dam. Theungauged Matlhapise River probably discharges an average of 400,000 m^3/a into the dam, and the flow rate can vary from zero to about 50 m^3/s during a storm. The Mmamokhasi Dam has a capacity of approximately 250,000 m^3 of water; it is classified as an agricultural dam, and the MDG is responsible for managing it. The MDG comprises locally appointed representatives who manage it on behalf of the community. The dam water is used for livestock and irrigation for small-scale farming.

20.9.2 Groundwater

Groundwater data were obtained from the Southern African Development Community information portal (2010), the Botswana Water and Sanitation Department, and the WUC. Approximately 48 borehole sites were identified within an 8 km radius of K.Hill. During July 2020, geological exploration boreholes for the K.Hill Project were visited to undertake a hydro-census. A total of 26 boreholes comprising existing water boreholes and Giyani exploration boreholes were visited, but water levels could only be measured in three of them; many of the water boreholes were blocked or vandalised. Water levels in the three exploration holes were 45.4 mbgl, 12.2 mbgl, and 43.1 mbgl.

The aquifer in the vicinity of K.Hill comprises low permeability fractured rock systems associated with shales. South and west fissured aquifers are dolomitic; dolomites are associated with higher yields of water. A moderate correlation exists between groundwater level data and topography for shallow boreholes (an average of 54 mbgl), good correlation for medium-depth boreholes (77 mbgl), and poor correlation for deep boreholes.

The WUC informed Giyani that boreholes on K.Hill could not be used for the Project water supply as they are resting and recovering. The WUC has adopted a strategy of having multiple water sources to reduce the risk of interruptions to water supply to communities. The K.Hill aquifers supply water to Kanye and surrounding communities; farmers that are not connected to the WUC supply network drill boreholes of their own. A significant contributor to the Kanye water supply is the North-South Carrier pipeline that brings water from the north of Botswana to Gaborone and southern areas. Thus, the Kanye water supply comes from various wellfields managed by the WUC and reservoirs on K.Hill fed by the North-South Carrier.

Giyani has been working with the WUC to identify target areas to drill for water. Giyani has now completed a drilling programme in two areas where five boreholes have been drilled; two holes were dry, and three had water strikes (Figure 20.4). Pump tests have been completed, and at the time of writing, results are under analysis, and a report is being compiled. Early indications are that Giyani has secured more than enough water for the Project (i.e., 50 m^3/h/24 h/d). Seventy-two-hour constant rate tests on two boreholes were pumped at 65 m^3/h with 96% recovery; the third borehole had a net yield of 13 m^3/h.

Figure 20.4 Groundwater pump test set up

20.9.3 Air quality

The Project footprint is located in a rural setting with no permanent residential houses or point sources of pollution (such as factories or industrial developments). The only structures of significance are the WUC water reservoirs and the BOCRA communication tower, from which there are negligible air emissions. A concrete access path was constructed between the gravel access road at the base of Kgwakgwe Hill and the peak where the BOCRA tower is located to allow all-weather access for maintenance crews. This path also serves the WUC reservoirs but is only used periodically, and vehicle emissions are also considered negligible.

The terrain is quite well covered with vegetation, but dust may be raised during windy periods in areas where vegetation is scant (e.g., around old mine workings).

Overall, air quality is good and typical of rural airsheds.

20.9.4 Noise

There are no sources of constant noise due to the absence of development; occasional vehicle traffic uses the access road to the WUC water reservoirs and BOCRA tower. The background noise is typical of rural areas.

20.10 Waste management

20.10.1 Mine waste

Mining waste comprises waste rock and tailings. SRK designed a WRD and TMF located within the proposed mining licence footprint. Various standards were referenced for the design of the TMF (e.g., Global Industry Standard on Tailings Management [2020]; Canadian Dam Association *Application of Dam Safety Guidelines to Mining Dams* [2014]). The design criteria are presented in Appendix E.

A trade-off study was completed comparing conventional and dry stack tailings. The preferred option is dry stack, which has several advantages (e.g., stability, water conservation [water extracted from the tailings can be recycled through the plant, which reduces the amount taken from local sources] and safety [a dam wall is not holding back slurry]). The TMF has been designed as a fully lined (HDPE) facility with zero discharge; this will prevent seepage into the environment. Preliminary indications are that acid drainage will not occur.

A perimeter berm of up to 3 m will separate clean stormwater runoff from dirty water (process-affected water). A clarification pond will collect runoff and any seepage from the tailings; this will be returned to the plant or used for dust suppression as a measure to reduce the amount of make-up water being used in the Project.

A filtration berm will separate the clarification pond from the filtered tailings storage area. The filtration berm will allow fluid to pass through while retaining fine tailings; it will be constructed of sand and gravel with <10% fines, with a fine-woven geotextile to minimise fines crossing into the clarification pond. The clarification pond will be excavated to a depth of approximately 4.4 mbgl, with the berm located approximately 3.0 magl. It will be HDPE lined with geotextile above and below the liner. The storage capacity is approximately 55,000 m^3, which would accommodate a 1:100-year storm event.

One WRD has been designed, which will be located to the east of the open pit with two access roads. A total of 10.1 Mt of rock will be stored in the WRD. The maximum height of the WRD from foot to crest will be 60 m and have slopes with batter angles of 31° with 10 m wide berms. The future WRD overall slope will be 20° (based on preliminary slope configurations) and range from 1,356 masl to 1,430 masl in height. The design incorporated the overall slope (20°) to be appropriate for rehabilitation and closure. Tracked dozers will progressively rehabilitate the WRD during the LOM using ancillary equipment as part of normal duties.

20.10.2 Non-mining waste

Non-mining waste comprises packaging; green (biomass) waste; rubber tyres; and general waste, including small quantities of food waste. Hazardous waste will include oil, grease, oil filters, batteries, electric and electronic waste, fluorescent tubes, health waste (from the first-aid post), and sewage waste.

General waste will be removed from site to the Southern District Council, which also accepts used motor oil. Botswana does not have a hazardous waste disposal site; therefore, such waste has to be transported to Holfontein (Springs) in South Africa (approximately 300 km from K.Hill) until a site in Francistown is developed; the Chamber of Mines is undertaking studies for a site in Francistown. There is a double chamber health care waste incinerator at the Kanye landfill site, which is suitable for the small amounts of medical waste the Project will generate.

Private contractors will be appointed to transport waste from K.Hill to the Kanye landfill site, but the quantities are not deemed significant and the costs will not be material.

20.11 Stakeholder engagement

Stakeholder engagement comprises that which is carried out for the EIA and is managed by the independent consultant, in this case Loci Environmental, and that which applies to the life of the Project and continues on after the EIA consultation.

For the EIA, stakeholder engagement was initiated during the scoping phase. Stakeholders were identified so that each group could be engaged appropriately, and tools and materials could be determined to suit each group/individual. Table 20.4 provides a list of stakeholders identified to date; however, this list will grow as consultation continues throughout the EIA and a SEP is developed and implemented for the LOM.

20.11.1 Disclosure of Project information

A Background Information Document (BID) was developed and forwarded (both printed and electronically) to Project stakeholders. The BID will be updated to reflect any changes to the Project as the EIA progresses.

20.11.2 Public meetings

Discussions were held with the Kanye tribal administration, and it was agreed that a public consultation meeting would be held with the residents of Kanye on 25th March 2020. This date was publicised in the Mmegi newspaper on 28th February 2020. However, this meeting could not be held, as a lockdown was imposed during this period due to the COVID-19 pandemic. Due to continued restrictions and requirements for social distancing, a meeting was later held with the Dikgosi and the VDC on 19th August 2020 at the Kanye main kgotla (meeting place).

Sarah Maswabi and Victor Lelaka (Loci Environmental) facilitated the public participation meeting, with input from the Giyani's representative, Kneipe Setlhare. During the comments and response sessions, appropriate answers were given by either Loci Environmental or Giyani, depending on the question (e.g., Loci Environmental responded to questions about the environment, such as impacts on water, and Giyani answered questions about company policy, such as employment).

Key issues raised were about water quality and potential pollution; the relocation of the WUC reservoirs should not interrupt water supply to Kanye; land use within the mine lease area should be mapped and affected parties should be consulted; influx of jobseekers; employment should be for local people; health issues and facilities; noise may disturb local communities;

health and safety; air pollution; and clearance from the Department of National Museums and Monuments.

20.12 Potential environmental and social impacts, mitigation and management plans

Table 20.5 presents a summary of potential impacts and mitigation; this table will be completed when the specialist studies have been updated. At this juncture, the list of impacts is preliminary but it will be updated in the EIA.

Table 20.4 Stakeholders

Name of stakeholder organisation, group or individual	Type of stakeholder	Stakeholder description	Role in the Project	Comments
Local Level Groups				
Leaders of the communities located near the Project site	Local	These are leaders of the affected communities and residential areas nearest to the Project. The Chiefs are responsible for promoting and upholding cultural values of their communities and in particular to promote sound family values. In cooperation with the VDC, the local Chiefs facilitate socio-economic development of the affected village.	Community leaders represent the interests of the communities. Therefore, they need to understand the proposed Project in detail to give feedback or comments to their community.	Consulted as part of the EIA stakeholder consultations. Giyani has held formal and informal meetings with local Chiefs, Paramount Chief, local leaders, and VDCs (e.g., meeting Chairs of the 17 VDCs in the Kanye area).
District and National Key Informants				
Kanye Administrative Authority	District	Local authority mandated with provision of socio-economic services and infrastructure within the surrounding areas.	Management of environmental and public health issues related to the Project activities.	Consultation meetings with the Kanye Administrative Authority were held regarding Giyani's community development plan; the Kanye Administrative Authority facilitated meetings with the 17 Chairs of the VDC.
WUC	National/District	The organisation responsible for providing potable water and wastewater management services to the Botswana population.	Directly affected party as WUC has two reservoirs on K.Hill that will be relocated before construction begins. WUC has worked in cooperation to identify water supply sources (groundwater)	Well informed due to close working relationship with Giyani regarding infrastructure and water supply.

Name of stakeholder organisation, group or individual	Type of stakeholder	Stakeholder description	Role in the Project	Comments
Department of Waste Management and Pollution Control	National/District	Government department mandated to prevent and control pollution resulting from inappropriate and inadequate waste management practices.	Oversight of management waste generated by the Project as per the Waste Management Act.	Consulted as part of the stakeholder consultations undertaken.
DEA	National	Government department responsible for management of environmental issues, including authorisation of environmental reports.	Environmental authorisation for the EIA study will be dealt with by this department.	Engaged with DEA from the outset to discuss the Project and authorisation process through the Project Brief (already submitted) and meetings.
Department of Mines	National	Government department responsible for management and licensing of prospecting and mining activities.	Mining licence will be applied for at this department.	To be consulted throughout the detailed EIA and authorisation process.
Department of National Museums and Monuments	National	This department is mandated in the preservation of archaeological sites and monuments as per the Monuments and Relics Act of Botswana.	Protection of artefacts and sites during mining activities. Responsible for giving planning permission prior to Project implementation	This department has been informed about the Project through archaeological impact assessment consultations; a permit was issued by the department.

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Table 20.5 Environmental and social potential impacts and mitigation (table to be completed on finalisation of specialist studies)

Parameter	Description of impacts and phase to which impact applies	Significance (profound, significant, moderate, low, negligible)	Scale of change			Description of mitigation measures	Significance after mitigation applied (profound, significant, moderate, low, negligible)
			Positive, neutral, negative	Permanent, long-term, medium-term, short-term	Direct/ indirect		
Ecology (flora)	Loss of vegetation and disturbance of plant communities due to bush clearing. Phase: construction	Significant	Negative, permanent, direct			All areas to be cleared of vegetation should be demarcated. Bush clearing should only be carried out within the designated areas.	Moderate
	Increased risk of invasive or encroacher flora species establishing due to bush clearing, areas devoid of vegetation and soil disturbance. Phase: all phases	Moderate	Negative, permanent, indirect			Potential invasive flora species should be identified, and action to be taken to clear these species.	Negligible
Ecology (fauna)	Disturbance and alteration of faunal and avifauna habitats. Phase: construction, operations	Low	Negative, medium-term, direct			Any fauna directly threatened by operation activities should be relocated in accordance with Fauna Management Plan.	Negligible
	Risk of fauna fatalities due to collisions with moving equipment. Phase: construction, operations	Low	Negative, medium-term, direct			Drivers to be aware of the danger that traffic poses to the local fauna. Speed limits must be enforced and strictly adhered to.	Low

Parameter	Description of impacts and phase to which impact applies	Significance (profound, significant, moderate, low, negligible)	Scale of change			Description of mitigation measures	Significance after mitigation applied (profound, significant, moderate, low, negligible)
			Positive, neutral, negative	Permanent, long-term, medium-term, short-term	Direct/ indirect		
Air quality	Decline in air quality from the production of dust from use of heavy mining equipment, materials handling, unpaved haul roads, stockpiles, crushing, and conveyors. Potential for dust generation will vary with season and level of activity. Impacts on health. Phase: Construction Operations Rehabilitation and Closure	Moderate - significant	Negative, medium-term, direct			Develop and implement procedure for monitoring dust as part of air quality management plan Monitor roads for dust generation Spray roads with water (using recycled water); experiment with road treatment products (binders) for specific areas such as at transfer points Personal protection equipment (PPE) – to protect workers Access roads that are used by communities and nearby to houses, to be monitored and managed to minimise dust generation	Low to moderate

Parameter	Description of impacts and phase to which impact applies	Significance (profound, significant, moderate, low, negligible)	Scale of change			Description of mitigation measures	Significance after mitigation applied (profound, significant, moderate, low, negligible)
			Positive, neutral, negative	Permanent, long-term, medium-term, short-term	Direct/ indirect		
Groundwater Impacts	Quantity - change of groundwater levels (cone of depression) due to pumping. Phase: Operations	Moderate	Negative, medium- long term, direct			Develop management/ monitoring plan for water supply so that over-pumping is avoided Planning water supply to rest boreholes (and equipment) as part of the management plan Monitor abstraction volumes and water levels (monthly)referring to groundwater model to verify if predicted changes to water level are accurate N.B., groundwater modelling has yet to be completed as water borehole drilling and pump tests have just been completed (July 2022) Monthly water level measurements Annual update of the groundwater flow model	Moderate
	Quality - risk of contamination of groundwater in the vicinity of K.Hill and Giyani's borehole sites. Phase: Operations	Low	Negative, medium/long term			Water management and monitoring plan to be developed and implemented before work begins Geochemical sampling and testing; samples submitted to certified laboratory Routine environmental inspections of sites as part of monitoring programme TMF is fully lined to mitigate potential impacts from infiltration	Negligible

Parameter	Description of impacts and phase to which impact applies	Significance (profound, significant, moderate, low, negligible)	Scale of change			Description of mitigation measures	Significance after mitigation applied (profound, significant, moderate, low, negligible)
			Positive, neutral, negative	Permanent, long-term, medium-term, short-term	Direct/ indirect		
Noise	Increased noise levels impacting workforce and other receptors. Phases: Construction Operations Rehabilitation and Closure	Moderate	Negative, local, medium term, direct			Receptors have been mapped – noise modelling to be completed (for ESIA) Develop and implement management and monitoring plans for environmental aspects and occupational health and safety Schedule of auditing will be included in management plans Maintenance of equipment, machinery, vehicles and roads so operating at optimum conditions Workforce and visitors to wear appropriate PPE	Low
Storage of reagents and chemicals on site	Potential impacts to land, groundwater, and workforce. Phases: Construction Operations	Moderate	Negative, short-term, direct			All reagents and chemicals to be stored in designated areas which are secure, ventilated, covered with roof; impermeable floor with sump Material safety data sheets to be displayed in close proximity to each type of material All workers to be trained in handling, storage and management of materials All workers to be equipped with PPE	Low - moderate

Parameter	Description of impacts and phase to which impact applies	Significance (profound, significant, moderate, low, negligible)	Scale of change			Description of mitigation measures	Significance after mitigation applied (profound, significant, moderate, low, negligible)
			Positive, neutral, negative	Permanent, long-term, medium-term, short-term	Direct/ indirect		
Traffic	Increased number of road traffic accidents. Phases: Construction Operations Rehabilitation and Closure		Negative, long term, direct			Suppliers delivering materials to and from site will be professionally qualified; assessing qualifications and experience of drivers, and all aspects of vehicles (e.g., types and maintenance records) will be part of contract evaluation Traffic management plan and driver training to be included as part of induction; this will focus on specific requirements of the K.Hill Project and will address stakeholder concerns (e.g., speed restrictions within the mine licence area and access roads).	Low
	Risk to pedestrians and livestock (that wander freely along public and access roads). Phases: Construction Operations Rehabilitation and Closure		Negative, long term, direct			Undertake road safety awareness campaigns in the community and for the workforce (e.g., high vis and carry torches at night) Driver training for dealing with incidents	

Parameter	Description of impacts and phase to which impact applies	Significance (profound, significant, moderate, low, negligible)	Scale of change			Description of mitigation measures	Significance after mitigation applied (profound, significant, moderate, low, negligible)
			Positive, neutral, negative	Permanent, long-term, medium-term, short-term	Direct/ indirect		
Waste	Risk of land pollution due to waste. Phases: Construction Operations		Negative, medium term, direct			Waste to be stored in designated areas and receptacles before being removed from site Waste to be removed to licensed sites on weekly basis Waste management to be part of induction and training	Low
	Hazardous waste; medical waste in very small quantities as only a first-aid post on site; treatment for more than first aid will be carried out at designated clinic/hospital. Phases: Construction Operations		Negative, medium term, direct			Segregation of medical waste and stored in medical containers such as sharps box Removed to Kanye disposal site for incineration	Low
	Used oils, greases, and lubricants. Phases: Construction Operations		Negative, medium term, direct			Store in sealed containers on site in locked storage area; bunded on hardstanding with sump to contain spills and leaks	Low

Parameter	Description of impacts and phase to which impact applies	Significance (profound, significant, moderate, low, negligible)	Scale of change			Description of mitigation measures	Significance after mitigation applied (profound, significant, moderate, low, negligible)
			Positive, neutral, negative	Permanent, long-term, medium-term, short-term	Direct/ indirect		
Archaeology	Risk of loss or damage of archaeological materials and cultural heritage resources. Phases: construction	Low	Negative, permanent, direct			Archaeological monitoring during clearance and excavation. Train all contractors and those involved in excavating land about identifying potential artefacts and the steps to be followed as described in the chance-find procedure All chance -finds must be reported to site and environmental manager and then the authority Qualified person on site during excavation activities	Negligible
Occupational Health and Safety	Increased instances of HIV/AIDS and STI infections; increased occurrence of tuberculosis and malaria. Phases: all phases	Significant	Negative, permanent, indirect			Development and implementation of an HIV/AIDS, STI and tuberculosis procedure. Subject for induction, training and toolbox talks	

Parameter	Description of impacts and phase to which impact applies	Significance (profound, significant, moderate, low, negligible)	Scale of change			Description of mitigation measures	Significance after mitigation applied (profound, significant, moderate, low, negligible)
			Positive, neutral, negative	Permanent, long-term, medium-term, short-term	Direct/ indirect		
Socio-economic	Creation of employment with the Project and through entrepreneurs setting up independent support services (e.g., shops serving workforce). Phases: construction, operations	Significant	Positive, long term, direct and indirect			Employment policy giving priority to local people Roles will be advertised locally and communicated through community leaders. No hiring at the gate/ site. Establishing local and regional recruitment centres	
	Regional economic development; payment of royalties and taxes. Phases: construction, operations	Significant	Positive, long term, direct and indirect			Utilise any existing local business database to identify local small, medium and micro enterprises. Establish linkages with other key stakeholders in the area involved in skills and small, medium and micro enterprise development	Significant
	Skills transfer and development; part of Giyani's strategy for sustainable development. Phases: construction, operations	Significant	Positive, long term, direct			Liaison with vocational training centres and schools to promote skills development On the job training, apprenticeships, CSR programmes should be designed in consultation with community.	Significant
	Public safety; risk of injury to members of the public through Project activities. Phases: all phases	Low - significant	Negative, long terms, direct			Develop and implement a community health and safety plan	Low - moderate

20.13 Rehabilitation and closure

A Framework Rehabilitation and Closure Plan has been drafted and presents the basis for planning for closure from the Project outset. Both the WRD and TMF were designed with closure in mind. The design philosophy of the mine structures revolves around pre-fabrication and modular systems, which will be relatively easy to dismantle and remove. However, all will require hard-standings, bases, and foundations, which will be broken up and removed from site; some may be disposed of on the WRD, depending on capacity at the time of demolition.

A key aspect of rehabilitation and closure is to determine post-closure land use at a very early stage of the Project, in consultation with the authorities and nearby communities. Restrictions will be applied to potential uses for certain components (e.g., the TMF) but these will be identified through consultation with the authorities. It is envisaged that, as part of the ongoing stakeholder engagement, communities will be involved in workshops to discuss ideas and options for post-closure land use. Some of the infrastructure will have value and will be handed over to third parties, who will then take responsibility for care and maintenance (e.g., solar farm, boreholes, and access roads). Other facilities, such as offices and workshops, may have uses for communities (e.g., as meeting places and training facilities).

The overall WRD slope angle of 20° and lift heights of 20 m facilitate contouring and topsoil placement. Closure activities will comprise dozing crests to create smooth slopes covered with topsoil to a depth of 30 cm where possible; topsoil will be stockpiled on site following site clearance. Thirty articulated dump trucks will transport rock to the WRD. Tracked dozers will be used to flatten benches as part of normal duties.

The dry stack TMF will be subject to progressive rehabilitation and is designed to be a walkaway solution. Progressive rehabilitation will comprise covering with vegetation to minimise dust generation, erosion of the faces, and minimise water ingress. The slopes will be protected by a layer of waste rock, then topsoil to enable vegetation to be established. Soil will be sourced from stockpiles that are established when the footprint of the TMF is cleared and the diversion ditch and clarification pond are constructed.

A powerline will be installed from a substation approximately 15 km from the proposed mine. The electrical supply and equipment, although funded by Giyani, remains the property of the BPC. BPC is currently formulating a policy for dealing with the dismantling and removal of redundant or abandoned infrastructure.

Botswana legislation refers to what is required for rehabilitation but omits reference to costs. Giyani will likely follow a mechanism similar to that proposed by the Botswana Chamber of Mines, which is used by other mining companies in Botswana:

- Each company will establish its own rehabilitation and closure fund, in line with its own operational requirements.
- The fund should be ring-fenced and not accessed apart from to fund rehabilitation/closure activities.
- A board of trustees should be appointed to monitor the fund.

- The movement of funds into and out of the account should be reported to the Department of Mines.

Elements of the closure works are summarised in Table 20.6. For the purposes of costing, the assumption is that all the elements will be dismantled and removed. Options for selling or handing over to third parties will be assessed during post-mining land use and revisions of the closure plan.

Table 20.6 Summary of closure works

Element	Closure work
Open pit	• Securing the pit: ✦ Construct a high security fence and access point. ✦ Construct a berm and channel to direct stormwater away from the pit. (This will be constructed during mining operations but will have to be serviced as part of mine closure.) ✦ Drainage channels within the pit to mitigate against erosion.
WRD	• Complete the levelling to acceptable slopes and compaction of the WRD. A lot of this will be done during the course of mining operations. • Provision of drainage. • Spreading topsoil on the exposed portions. Topsoil would have been stockpiled at the start of mining operations.
Processing plant	• The processing plant has a number of elements: ✦ ore stockpile ✦ comminution (crushing and grinding) ✦ processing (separation of the manganese from the prepared ore) ✦ product stockpile ✦ general and reagent store • Dismantling the plant elements has been taken as approximately 35% of the installation costs.
TMF	• The TMF will be closed as per the engineering design, which has provided for ongoing rehabilitation and walkaway closure plan.
Workshops	• The workshops will be prefabricated structures. • These can be sold off or handed over to third parties such as communities. • Hardstanding is to be ripped up and the rubble disposed of on the WRD or in the mine pit and covered.
Laboratory and offices	• Prefabricated construction will be dismantled and disposed of or sold. • Hardstanding is to be ripped up and the rubble disposed of on the WRD or in the mine pit and covered.
Material storage areas	• Stockpile areas are to be levelled and topsoiled. • Hardstanding is to be ripped up and the rubble disposed of on the WRD or in the mine pit and covered.
Electrical substation and powerline	• Transformers and switch gear to be returned to BPC. • Power line transferred back to BPC and incorporated into the Kanye infrastructure.

Element	Closure work
Fuel storage for mine equipment and backup power	• Bulk storage tanks will be drained and sold. • Any spillage of other contamination to be treated as per recommendations. • Hardstanding is to be ripped up and the rubble disposed of on the WRD or in the mine pit and covered.
Water boreholes and raw water dams	• Pumps and piping to be salvaged. • Borehole to be capped and sealed for possible future use. • Dams to be left for possible livestock watering points or breached so as not to pose a hazard. Input from the DEA to be sought at the time.
Water treatment plant	• This would be a vendor package unit and could be sold or reused on other projects. • Pipe work to be left in the ground.
Sewage	• Septic tanks or conservancy tanks to be pumped out and back filled.
Waste holding facilities	• Stockpile areas are to be levelled and top soiled.
Product storage area and loading facilities	• Containment structures to be demolished. Assumed to be concrete floor with containment walls. • Stockpile areas are to be levelled and top soiled. • Hardstanding is to be ripped up and the rubble disposed of on the WRD or in the mine pit and covered.
Security and fencing	• All fencing to be serviced and made good. • Perimeter fence surrounding the whole site. • Fencing around the tailings dam. • High-level security fencing around the open-caste pit.
Roads and general areas	• Gravel roads no longer required for access to be ripped to encourage and re-establish vegetation. • All disturbed areas not covered elsewhere to be restored. • Adits remaining from previous mining activity or exposed during the proposed mining activities to be sealed.
Post-closure requirements	• Quality of groundwater to be monitored bi-annually for 5 years after closure. (Monitoring boreholes installed with establishment of the mine.) • Site to be inspected bi-annually for 5 years after mine closure completed and accepted.

The cost of rehabilitation and closure has been estimated based on the Project described in this FS. The cost estimate is based on information available at the time of writing and on current market rates and conditions. Closure costs will be updated on an annual basis; therefore, costs are realistic and the closure fund is adequate. At this time closure costs are estimated to be P73,725,000.

20.14 Resettlement

The permanent structures within the mine footprint are two WUC concrete water reservoirs and a BOCRA communication tower. The WUC reservoirs and pipelines are part of the water reticulation for Kanye. Giyani has been in consultation with both entities to discuss relocating the structures. Before construction of the mine begins, the BOCRA tower will have to be relocated and a new reservoir constructed on a nearby hill (Dinake Hill, also known as D.Hill). ensuring no interruption of water supply to Kanye.

There are a few cattle posts in the vicinity of the Project. Should any of these need to be relocated, due process will be followed and the Land Board (custodians of tribal land) will be involved, as is usual practice in Botswana.

No permanent residences or assets, other than those described above, are present within the Project footprint.

20.15 Environmental and social management

At the time of writing, the EIA has not been completed; therefore, the impacts and mitigation presented in Table 20.7 are preliminary and will be updated as work progresses. The Project design and development is ongoing, so additional mitigation and monitoring will be considered to minimise negative impacts and enhance positive ones.

Prior to construction, specific environmental and social management/monitoring plans will be developed (e.g., emergency preparedness and response; water management plan; community security, health and safety; waste management; occupational health and safety). All mitigation will be specific, measurable, achievable, reasonable, and time-bound (i.e., SMART), which will allow Giyani to track the efficacy of plans and adjust them as necessary. All plans will be living documents. The rehabilitation and closure plan will be reviewed annually and the closure costs updated to reflect the current funding requirements.

Giyani has developed a framework Environmental and Social Management System (ESMS), based on ISO 14001:2015, which consists of six main elements: leadership and commitment, policy, planning, implementation, checking, and management review (Table 20.7).

Table 20.7 The six elements of the ESMS

ESMS element		ESMS Manual paragraph	
5.1	Leadership and commitment	5.1.1	Leadership & Responsibilities
5.2	Policy	5.2.1	HSE Policy
5.3	Planning	5.3.1	Risk Management
		5.3.2	Legal Obligations
		5.3.4	Planning
		5.3.5	Document Management

ESMS element		ESMS Manual paragraph	
5.4	Implementation	5.4.1	Operational Control
		5.4.2	Training & Competency
		5.4.3	Emergency Management
		5.4.4	Contractor Management
		5.4.5	Inspections & Behaviour Based Observations
		5.4.6	Consultation & Communication
5.5	Checking	5.5.1	Measuring & Monitoring
		5.5.2	Incident & Injury Management
		5.5.3	Action Management
		5.5.4	Reporting
		5.5.5	Audits
5.6	Management review	5.6.1	Management Review

Giyani is also developing policies and procedures as part of its sustainability planning (Table 20.8). A community development policy is being reviewed at the time of writing; however, Giyani has set up a fund to provide support for community projects and events (Figure 20.5).

Figure 20.5 Giyani supported and attended a disability event in Kanye

Table 20.8 Policies and procedures

Policy/action	Public (on website)	WIP/ draft	Final	Outstanding
Company value and ethics	✓		✓	
Grievance procedures		✓		
Harassment policy	✓		✓	
Anti-bribery and corruption plan			✓	
Cyber security management plan			✓	
Management quality and experience	✓		✓	
E&S embedded in contractor documentation				✓
Whistle-blower	✓		✓	
Transparency	✓		✓	
Board independence	✓			
Shareholder democracy	✓			
Executive compensation	✓			
Equal opportunity	✓			
Compliance		✓		
Health and safety and statistics		✓		
Community development plan and implementation		✓		
Security policies and plans			✓	
Supply chain policy		✓		
Diversity and inclusion	✓		✓	
Human rights	✓		✓	
Labour Standards				
Child Labour	✓			
Freedom of association				
Climate change		✓	✓	
ESMS		Framework		
Greenhouse gas emissions reporting		✓		
Energy efficiency		✓		
Biodiversity - action plans and net gain		✓		
Water management		✓		
Waste management		✓		
Air quality		✓		
Rehabilitation		✓		

21 CAPITAL AND OPERATING COSTS

21.1 Capital costs

21.1.1 Summary

Capital cost estimates were prepared for initial, sustaining, and closure capital.

The total estimated initial capital cost for the design, construction, installation, and commissioning of all facilities and equipment for the K.Hill Project is US$281M, including a contingency of US$32M. This estimate includes direct field costs required to execute the Project plus indirect costs associated with design, construction, installation, and commissioning. Closure costs of US$5M have been estimated.

This estimate is a Class 3 estimate prepared in accordance with the AACE® International Cost Estimate Classification System. The accuracy of the estimate is -10% to +15%.

Table 21.1 shows the capital cost summary for the LOM.

Table 21.1 Life of mine capital cost summary

Area	Total (US$M)
Mining	10.5
Processing	98.1
Infrastructure and services	31.2
TMF	6.6
Offsite infrastructure	9.7
Indirect costs (including first-fill and commissioning costs)	65.5
Construction overheads	21.6
Owner’s costs	5.5
Total initial capital cost, excluding contingency	**248.7**
Contingency on initial capital cost	32.0
Total initial capital cost, including contingency	**280.7**
Sustaining capital, including contingency	21.4
Closure cost	5.1
Total	**307.3**

Note: The sum of costs may differ from the total due to rounding.

Capital costs incurred after start-up are assigned to sustaining capital and are projected to be paid out of operating cash flows. In keeping with industry practice, the estimated annual sustaining capital allowance is 2.5% of the hydrometallurgical plant's direct capital cost over a period of 8 years, totalling US$21M (including a 15% contingency of US$3M).

This estimate is based on pricing as of H2 2022 with no allowances for inflation, escalation, working capital or project finance costs. All currency in this capital cost estimate is expressed in US dollars unless otherwise noted.

An allowance for working capital is included in the financial model.

21.1.2 Basis of capital estimate

Responsibilities

SRK and Tetra Tech compiled the project estimates, with SRK as the lead consultant. Subsequently, the capital cost estimate was developed by a team of engineers, procurement specialists, and cost estimators. Areas of responsibility for the capital cost estimate listed by company are shown in Table 21.2.

Table 21.2 Estimate responsibilities matrix

Area	Company
Mining	SRK
Processing	Tetra Tech
Infrastructure	Tetra Tech
TMF	SRK
Construction overheads	Tetra Tech
Indirect costs	Tetra Tech
Owner’s costs	SRK
Contingency	SRK

Validity and scope

This estimate was prepared with a base date of H2 2022. The equipment quotations used in this FS estimate were obtained in H2 2022 and have a validity period of 90 days.

There is no provision in the estimate for escalation beyond Q4 2023. There is no allowance provided for foreign exchange fluctuations.

The following items are excluded from the estimate:

- schedule delays and associated costs, such as those caused by:
  - large-scale unexpected ground conditions
  - extraordinary climate events
  - labour disputes
  - receipt of information beyond the control of the EPCM team
- schedule recovery or acceleration

- taxes (except as supplied by the owner)
- sunk costs associated with activities up to project execution, such as research and exploration drilling costs
- force majeure

Approach

SRK and Tetra Tech developed a capital cost model of the processing plant and infrastructure presented in Section 18. The model recorded the capital cost estimate elements using the following classification:

- Direct costs are directly attributable to and associated with infrastructure. These include the fabrication, supply, construction, and installation of equipment, structural steel, cables, concrete, foundations, etc. and costs associated with the physical manifestation of the infrastructure.
- Indirect costs are not directly attributable to and associated with the infrastructure. These include engineering and management, first-fills and spares, commissioning, operational readiness, and transport and logistics.
- Construction overheads are preliminary and general costs associated with the major construction contracts.
- Owner's costs support the execution of the Project, including the owner's project team, licences, insurance, and G&A.

The contingency allowance was assessed per project area and suitably accumulated to determine the total allowance.

The estimate is based on package quotations for equipment; unit rates for construction, installation, and supply of materials; and rates and prices from SRK and Tetra Tech's in-house database for items of lesser value, in some cases applied in conjunction with quotation prices for a more accurate estimate. Suppliers responded well to requests for quotations; however, a few declined to provide quotations.

Costs were determined through a combination of actual quotations from reputable suppliers, as well as construction and installation contractors who are active and experienced in the region. Information from these quotations was considered along with consultant experience in construction costs globally.

Foreign exchange rates

The capital cost estimate and operating cost estimate are expressed in US dollars. Costs submitted in other currencies were converted to US dollars based on the foreign exchange rates listed in Table 21.3 (base date Q3 2022).

Table 21.3 Foreign exchange rates

Base currency		Foreign currency	
US$1.00	USD	£0.8439	GPB
		€0.9936	EUR
		R17.02	ZAR
		P12.53	BWP

Mechanical equipment

Tetra Tech has provided a detailed equipment list with the description, size, and unit cost for each piece in accordance with the PFDs and equipment lists. Quotations were obtained for all the major items based on preliminary specifications (Table 21.4). In total, 31 procurement packages were prepared and executed as part of the mechanical equipment cost estimate.

Major equipment costs are based on current market prices. Costs were obtained based on one vendor for packages with an expected total value of less than US$250,000 or three vendors with an expected total value of more than US$250,000. Vendors selected from an approved vendor list were asked to provide equipment prices, spare costs, delivery lead times, and freight costs to a designated marshalling yard for each major equipment package. The quotations provided are budgetary and non-binding.

Exceptions to the three-vendor approach in any equipment and material costs are included as free carrier manufacturer plant Incoterms 2010. Other costs, such as spares, taxes, duties, freight, and packaging, are covered in the indirect costs section of the estimate.

Table 21.4 Mechanical equipment procurement packages

Package description	Vendors
Primary jaw crusher	Metso Outotec
	Weir
	NMS AFRICA
Cone crushers	Metso Outotec
	Weir
	Ersel Agir Makina Sanayi ve Ticaret
Mills	Manhattan Mining Equipment
	MechProTech
	Metso Outotec
Water treatment plant	PCI Africa
	SGS Industrial Services
	DRA Global
	Pura Plant
	Veolia
Steam plant	Energy Partners Steam
	Steam Generation Africa (Pty) Ltd

Package description	Vendors
Thickeners and clarifiers	FLSmidth (Pty) Ltd
	TAKRAF Botswana (Pty) Ltd
	Metso Outotec
Crystalliser	Confidential
Alumina columns	Proxa
	Turnmill
	MIP-Process
Sulphur burner (SO_2) plant	Desmet Balestra
	East China Engineering Science and Technology Co.
	Sinopect Nanjing Engineering
	Metso Outotec (RSA) (Pty) Ltd
	INEOS Calabrian
	Desmet Ballestra
	NORAM
	LUNDBERG
Screens and sieve bends	Vibramech (Pty) Ltd
Feeders	Weir
	Metso
	Kwatani
	Mclanahan
Belt conveyors	Senet
	NEPEAN
	FLSmidth (Pty) Ltd
Filters	FLSmidth (Pty) Ltd
	Savannah/Vietti
	Metso
Limestone mill	Carmaky Engineering
Heat exchangers	Protherm Systems
	STEGEL
	Confidential
	Turnmill Proquip
	Alfa Laval
Air plant	AIR systems
Scrubber and stack	Polimatrix SA cc
	SG Plastics
	Confidential
	Multotec (Pty) Ltd
	Turnmill Proquip Engineering (Pty) Ltd.
Lime plant	Bulk Technik
Agitators	Mixtec
	Afromix

Package description	Vendors
Cyclones	Multotec
	Weir Minerals Africa
	FISmidth
Pumps - dosing	HIPPO
	Tufekcioglu Kaucuk ve Makina Sanayi
	Amakosi Fire
	Grundfos
	Tapflo
Pumps - centrifugal	HIPPO
	Weir
	SAM Engineering
	Grundfos
	Verder Pumps
	FLSmidth
	Tapflo
Pumps - peristaltic	Grundfos
	Verder Pumps
	FLSmidth
	Tapflo
Pumps - sump	HIPPO/Hazletonpumps
	FLSmidth
	Weir Minerals Africa (Pty) Ltd.
	FLSmidth
Pumps - fire	HIPPO
	Amakosi Fire
	Davron Equipment
Weighbridges	SASCO Africa
Tramp metal magnet	Eriez (RSA)
Weightometer	Famdra Industrial Weighing
	Process Automation
Ball chargers and kibbles	Metso Outotec (RSA) (Pty) Ltd.
	Carmaky Engineering (Pty) Ltd.
Fuel farm	Orca Fuel Solutions
	FAMS
Bulk handling valves	RotoLok

Electrical and control and instrumentation installation

The cost for electrical infrastructure and distribution consists of the following main elements:

- substations
- switch rooms (facilities and switchgear), for which preliminary quotations were compared with costs for similar installations and provisions allowed accordingly

- MV ring main system
- LV power distribution and lighting and small power supply to the processing and facilities areas

All cabling support quantities between the main station, substations, and control room are based on the plant design (3D model). For estimation purposes, engineers provided designs (sketches) with support quantities specifying:

- type, size, and total length of the cable trays
- profile types, lengths, and total weight of the supports
- profile types, lengths, and total weight of the road crossings

Piping

All-inclusive linear rates for pipe lengths, connections, support, fittings, and finishes were applied to the piping lengths. All piping quantities, if not included in the equipment itself (vendor package), inner areas, as well as piping between areas, are based on the PFDs, piping line list, the plant design (3D model), and the equipment specifications. For estimation purposes, designers provided designs (sketches) with piping quantities specifying:

- piping lengths, sizes, and weights
- number of flanges, elbows, and tees
- number, type, and size of brackets
- profile types, lengths, and total weight of additional support

All piping support quantities between the areas are based on the plant design (3D model), the piping line list, and the PFDs. For estimation purposes, engineers provided designs (sketches) with support quantities specifying:

- profile types, lengths, and total weight of the supports
- profile types, lengths, and total weight of the road crossings

Platework, tanks, and liners

An estimate was made of the quantities for all platework and liners for tanks, launders, pump boxes, and chutes, which fall outside of the lump sum packages. The cost of items outside the packages was estimated based on quantities multiplied by unit rates.

Buildings

Budget quotes were obtained from vendors for pre-engineered and modular buildings. Architectural components for the product warehouse and maintenance workshops were estimated separately.

Structural steel

All structural steel quantities, if not included in the equipment itself, are based on the plant design (3D model), PFDs, and equipment specifications and dimensions (equipment list and/or suppliers specs). For estimation purposes, designers provided designs (sketches) with steel quantities specifying:

- profile types, lengths, and total weight
- square meters grating
- meter lengths of handrails

A typical structural steel rate was determined by considering the cost of supply and fabrication, detailing, painting, transport, and erection. The costs associated with each item are based on the information available in the estimator's database and information supplied by contractors active in Southern Africa.

Bulk earthworks and concrete

Earthworks and concrete quantities were estimated and classified from the 3D AutoCAD® model of the mine site and by using expert engineering judgement. For estimating purposes, designers provided concrete quantities per the following breakdown:

- excavations and grading
- foundations (building, equipment, grade beam, slab-on-grade, pedestals, trench, and ductwork)
- elevated concrete (slabs, beams, walls, and any other elevated concrete)
- precast concrete
- grout under base plates
- structural excavation
- structural backfill

Construction and installation

Instead of relying on budget tenders from contractors, which are often based on a contractor's opinion of costs rather than a considered opinion of what the likely costs will be, construction and installation costs were determined by applying unit rate costs to quantities.

Tetra Tech developed rates using a bottom-up approach that relied on an in-house cost database and considered the particular commercial environment in the region as well as the K.Hill Project structure. Included in the calculation are specific overhead costs (referred to as "preliminary" and "general") usually associated with the activity for which the rate was calculated. Each rate was compared with current Southern African contractual rates to confirm validity.

Rates were obtained from contractors who operate businesses in Southern Africa and have local knowledge of climate, conditions, legislation, and government restrictions.

In developing the capital cost estimate, Tetra Tech made the following assumptions:

- Concrete aggregate and suitable backfill material will be locally available.
- Construction activities will be continuous, except with respect to the TMF.
- Bulk materials, such as cement, reinforcing steel, structural steel and plate, cable, cable tray, and piping, will be available when required.

Quantities

All quantities were developed from general arrangement drawings, process design criteria, PFDs, pipe and instrumentation diagrams, and equipment lists. Details on the respective discipline quantities are described in the following sections.

Table 21.5 shows the key quantities for each major procurement package derived as part of the FS design, which provides an indication as to the scale of the K.Hill Project. The actual values may be slightly different following detailed design and procurement in the months following the completion of the FS. The effect of these changes has been discounted in the capital estimate following a review of the K.Hill Project records. The key quantities exclude quantities included in facilities provided as packages and priced as lump sums by the supplier.

Table 21.5 Key quantities

Description	Unit	Quantity
Earthworks	m^3	469,910
Concrete	m^3	9,865
Structural steel	t	932
Platework	t	332
Piping	m	13,990
Electrical and earthing cables	m	55,618

21.1.3 Mining

SRK developed a mining cost model to assess the mining capital and operating costs expected for the proposed K.Hill mine operation, based on an owner operation for the primary earth moving, drilling, and blasting for production drilling, grade control drilling, and ancillary fleet. A single equipment class case is presented in this FS, as no trade-offs were undertaken. The equipment class sizes were selected based on operating practicability, considering the size of the operation.

Dewatering costs involve a small amount associated with the surface water and dewatering of the pit. It is assumed that this water will be used for dust suppression. Further details are given in Section 24.2, and the cost of dewatering is summarised in Section 22.

SRK developed the mining cost estimate based on equipment supplier budget pricing provided by Giyani and supplemented by SRK's internal cost database and the 2020-2021 InfoMine cost database (Infomine 2022).

Although specific makes and models of equipment were used to develop operating costs, SRK does not recommend one manufacturer or equipment model over any other. Where specific equipment models or manufacturers have been referred, it is merely to acknowledge where information has been derived or to provide the reader with an example of the type of equipment being discussed. The description of the equipment selected and used in the cost estimate, as well as the purchase costs per unit, are shown in Table 21.6.

Table 21.6 Mining equipment description and purchase costs

Equipment	Make	Model	Description	Cost (US$)
Excavator	Liebherr	R966	Backhoe (4 m^3)	695,530
Tyre handler	Liebherr	L538	Modified FEL	167,996
Loader	Liebherr	L538	FEL (2.5 m^3)	167,996
Primary truck	BELL	B30E	Dump truck (30 t)	359,831
Primary track dozer	Liebherr	PR744	Track dozer (3.7 m wide, 7 m^3)	413,045
Wheel loader	Liebherr	L538	FEL (2.5 m^3)	167,996
Primary motor grader	Case	865B	Motor grader (4 m blade)	244,286
Rock breaker	Kobelco	SK300LC	Excavator with hammer	259,556
Water truck	BELL	B25E	Water tanker bell B25E	362,204
Fuel/lube truck	Benchmark	Generic	Mobile in-pit fuel truck	184,000
Blast truck	Benchmark	Generic	ANFO loader	237,885
Production drill rig	Benchmark	Generic	Percussion drill (DTH)	739,900
Grade control drill rig	Benchmark	Generic	RC drilling	1,574,800
Maintenance service truck	Benchmark	Generic	Mobile in-pit service truck	222,700
Lighting plant	Benchmark	Generic	Lightning plant	15,500
Light vehicle	Benchmark	Generic 4 × 4	In-pit light vehicle	53,000
Crew bus	Benchmark	Generic	Personnel carrier	61,000

Notes: DTH - down-the-hole

The cost of pumps for dewatering is not included in the mining cost model but is referred to in the hydrogeological section of this report (Section 24.2). These costs are summarised in the SRK financial model and discussed in Section 22.

A miscellaneous cost of US$0.5M is included for the purchase and installation of survey equipment and software for the technical services team, together with radio systems displacing the dispatch system requirements. An allowance for 15% of the initial capital cost as sustaining capital cost is included as miscellaneous operating costs for the maintenance of survey and mining software.

Equipment replacement costs were not applicable due to the short LOM and direct operating hours of the selected equipment.

A summary of the total mining equipment capital costs for the mine plan is provided in Table 21.7. Further details of the capital cost schedule and contingency are presented as part of Section 21.1.11.

The total estimated LOM unit capital cost for mining equipment is US$0.86/t of rock mined (including initial purchase costs). This is deemed reasonable and is in line with expected Project capital costs based on SRK's experience.

Table 21.7 Mining capital cost estimate

Area	Cost (US$M)
Equipment capital	9.97
Equipment replace/rebuild	-
Miscellaneous	0.56
Total	**10.53**

Notes: The sum of costs may differ from the total due to rounding.

Closure costs for the WRD were accounted for in the mining operating cost estimate by allowing the assigned fleet to take on an additional workload by conducting progressive mine closure throughout the LOM.

21.1.4 Processing

Table 21.8 provides a summary of the processing capital cost estimate by system. Equipment transport is captured in the K.Hill Project indirect costs.

Table 21.8 Processing capital cost estimate

Area	Cost (US$M)
Crushing	1.02
Crystallisation	46.80
Extraction	0.37
Fluoride polishing	5.32
Grinding	4.78
Lime preparation	0.87
Plant infrastructure	1.64
Product handling	0.36
Product handling intermediate	0.00
Purification	14.93
Reagents	7.30
Tailings	0.00

Area	Cost (US$M)
Water treatment	13.63
Lime slaking	1.05
Total	**98.07**

Notes: The sum of costs may differ from the total due to rounding.

21.1.5 Infrastructure and services

Site infrastructure and services include bulk earthworks, roads, communications, ancillary buildings, electrical equipment, mobile equipment, laboratory, and fuel (Table 21.9).

Table 21.9 Site infrastructure capital cost estimate

Area	Cost (US$M)
Control and instrumentation	6.83
Facilities	3.49
Fuel farm	0.04
Laboratory	1.26
Mobile equipment	1.54
Plant infrastructure	1.20
Platform	5.10
Roads and access	1.47
Site shaping	1.15
Stormwater management	0.02
Weighbridge	0.44
Cable racking	0.09
Electrical	4.95
Fencing	0.49
Paving	0.03
Electrical cable	0.20
Fittings	0.17
Grating	0.03
Stairs	0.01
Railing	0.01
Pipe supports	0.18
Instrumentation cable	0.20
Structural steel	0.09
Total	**29.00**

Notes: The sum of costs may differ from the total due to rounding.

Tetra Tech prepared a cost estimate for the proposed 4.5 MWp solar plant, reflective of June 2022 indicative prices. Following industry practice, Tetra Tech itemised the main components and aggregated small components and labour with a generic item called "balance of plant," which includes items such as cables, protections and switchgears, reclosers, ring main unit, labour, freight, logistics, custom duties, labour, and the large scope of small elements needed to assemble and install the components conforming a power block. A summary of the initial capital cost estimate is presented in Table 21.10.

Table 21.10 Solar plant capital cost estimate

Component	Unit	Quantity	Unit Cost (US$)	Total (US$M)
Solar panels (>410 Wp)	kWp	4,500	230	1.04
Inverters (4,400 kW)	kW	4,400	65	0.29
Mounting structure	kW	4,500	30	0.14
Balance of plant	kW	4,500	130	0.69
Transformer 0.4 to 11 kV/10 MVA	MVA	10	600	0.01
Cable AL 95 20 kV	m	1,500	11	0.02
Feeder poles, concrete	unit	18	280	0.01
Balance of feeder and HV switchgear	unit	18	178	0.003
Total	-	-	-	**2.20**

Note: The sum of the costs may differ from the total due to rounding.

Table 21.11 Site infrastructure capital cost estimate

Area	Cost (US$M)
Site infrastructure	29.00
Solar plant	2.20
Total	**31.20**

Notes: The sum of costs may differ from the total due to rounding.

21.1.6 Tailings management facility

SRK prepared material take-offs to allow for the development of a cost estimate for all capital, sustaining capital, and operational cost items associated with the construction of the TMF and clarification pond.

Typical cost items include:

- site clearance
- mass excavation (removal of topsoil and unsuitable foundation material)
- restricted excavation (sub-excavation beneath the main embankments and clarification pond)

- embankment construction (mass rockfill)
- diversion ditch excavation
- geotextile and geomembrane liners

Allowances for engineering and contractor costs include:

- detailed design engineering: 2% of direct costs
- contractor mobilisation/demobilisation: 5% of direct costs
- construction QA/QC: 2% of direct costs
- contingency: 15% of direct costs

The following construction requirements that have not been addressed in this section of the FS include:

- recruiting and training costs
- site communications
- accommodation and messing
- human resources and safety resources and equipment
- environmental monitoring
- office, stores, workshops, refuelling facilities, servicing facilities and maintenance facilities
- utilities for fixed infrastructure: power, water, sewerage, communications, etc.

SRK utilised equipment from the mining and processing areas, wherever possible, to optimise the cost. The material take-offs that summarise the TMF items noted previously are included in Table 21.12.

Table 21.12 Tailings management facility capital cost estimate

Area	Cost (US$M)
Foundation preparation storage area	2.88
Foundation preparation clarification pond	0.75
Perimeter berm and filtration berm construction	0.42
Diversion ditch (option 2)	0.11
Closure cover system	0.52
Equipment	1.20
Detailed engineering and contractor costs	0.74
Total	**6.60**

Notes: The sum of costs may differ from the total due to rounding.

21.1.7 Offsite infrastructure

Tetra Tech has included the following offsite infrastructure items:

- fibre optic communication connection to site
- relocation of the BOCRA communications tower
- relocation of reservoirs from Kgwakgwe Hill and the associated infrastructure

The estimate presented in Table 21.13 is based on quotes from in-country contractors and suppliers.

Table 21.13 Offsite infrastructure capital cost estimate

Area	Cost (US$M)
Fibre connection	0.10
BOCRA tower	0.05
WUC reservoirs	9.58
Total	**9.73**

Note: The sum of the costs may differ from the total due to rounding.

21.1.8 Indirect costs

Indirect capital costs include:

- **Commissioning** includes vendor support at US$2.6M, plant operational costs at US$10.7M, and commissioning spares at US$2.0M. Note that engineering support is included in the engineering and management estimate item.
- **Engineering and management** include basic and detailed engineering, procurement, construction management, specialist consultants, and an allowance for value engineering.
- **First-fill and spares** include provision for the initial stocking of stores with consumables and general spares and represent approximately 2 weeks of inventory.
- **Operational readiness** includes the overhead of an operational team as well as training four months in advance of the start of production.
- **Transport and logistics** include the cost of logistics of major equipment. Estimated transport costs of US$4.2M are based on quotations, where possible.

Table 21.14 shows the summary of the K.Hill Project's indirect costs.

Table 21.14 Indirect capital cost estimate

Area	Cost (US$M)
Commissioning	15.32
Engineering and management	37.43
First-fill and spares	7.20
Operational readiness	1.43
Transport and logistics	4.17
Total	**65.54**

Notes: The sum of costs may differ from the total due to rounding.

21.1.9 Construction overheads

The construction overhead cost is for the preliminary and general costs of contractors to operate on site and execute their work, but that are not directly associated with the quantity of material (e.g., cubic metres of concrete or tonnes of steel).

Table 21.15 shows a summary of construction overhead costs.

Table 21.15 Construction overheads capital cost estimate

Area	Cost (US$M)
Civil and building	8.80
Mechanical equipment	4.50
Platework	1.10
Structural steel	2.90
Piping and valves	1.70
Electrical	1.80
Instrumentation and control	0.70
Total	**21.60**

Note: The sum of the costs may differ from the total due to rounding.

21.1.10 Owner's costs

The owner's costs include a provision for the following items:

- cost of the owner's project team during execution
  - The team will comprise both full-time Giyani personnel and part-time external consultants (Figure 21.1).
- cost of the application for licences and permits
- an allowance for insurance
- an allowance for owner's G&A

A summary of the owner's costs is presented in Table 21.16.

Figure 21.1 Owner's team

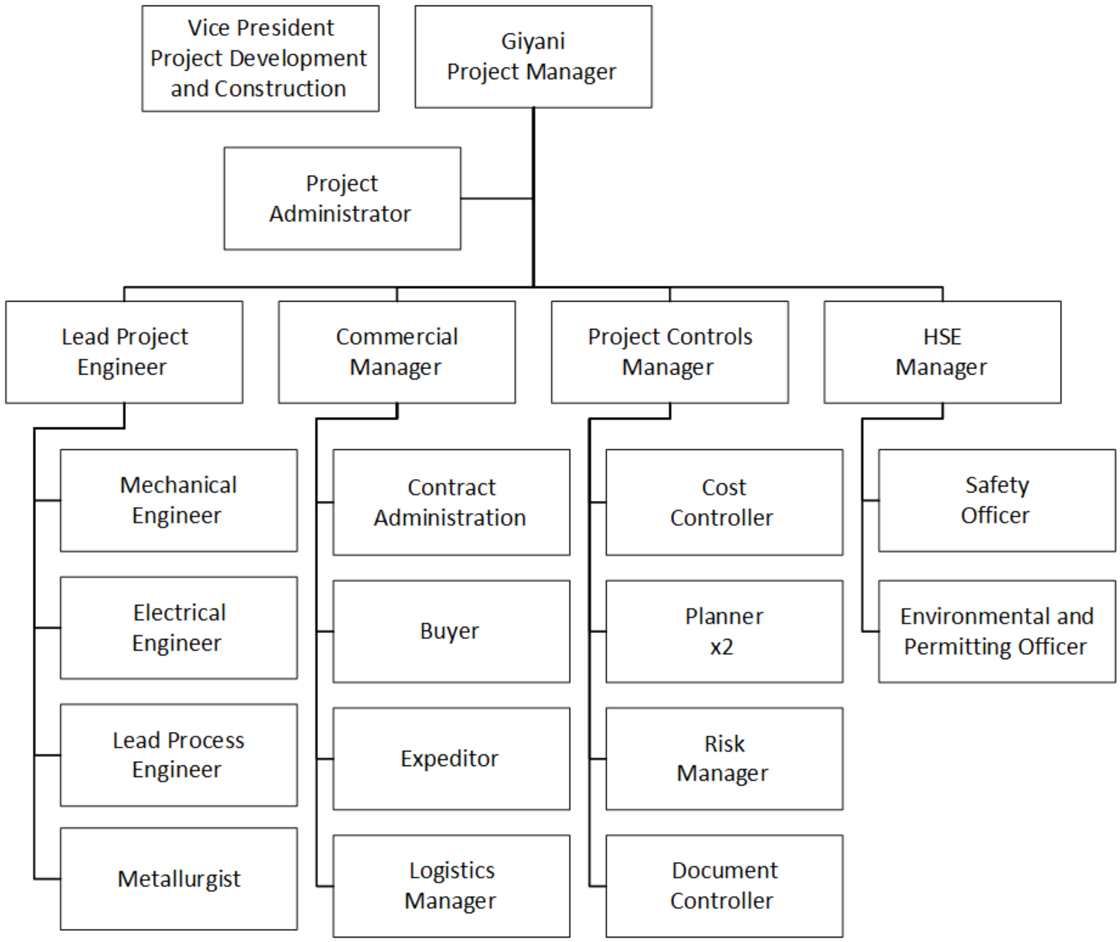


Table 21.16 Owner's costs

Area	Cost (US$M)
Owner's team	2.53
Licences	0.50
Insurance	2.00
Owner's G&A	0.50
Total	**5.53**

Notes: The sum of costs may differ from the total due to rounding.

21.1.11 Contingency

A contingency based on the total direct and indirect costs is included as an allowance for items, conditions, or events for which the state, occurrence, or effect is uncertain, which experience shows will likely result in aggregate in additional cost. Therefore, the contingency allowance is an integral part of the estimate. The contingency allowance is not to be considered a compensating factor for estimating inaccuracy, nor is it intended to cover such items as any potential labour disputes, currency fluctuations, escalation, force majeure, or other uncontrolled risk factors. It should be assumed that the contingency amount is spent over the engineering and construction period.

The contingency percentage for each discipline is individually assessed on the accuracy of quantity measurement, type and scope of work, and price information. These allowances are based on in-house data from previous similar projects and adjusted based on the engineering confidence and quality of pricing information received for each component of the capital cost estimate.

The proposed contingency percentage allowance is outlined in Table 21.17.

Table 21.17 Contingency

Area	Total Costs (%)
Mining	10.0
Processing	13.0
Infrastructure and services	13.0
Solar plant	13.0
Offsite infrastructure	13.0
Indirect costs	13.0
Construction overheads	13.0
TMF	13.3
Owner's cost	15.0
Weighted average	**12.9**

21.1.12 Sustaining capital

An allowance for plant maintenance and spares is included in the operating costs. From time-to-time, equipment and facilities will have to be refurbished to their original working conditions to provide a safe and reliable operation. This expense will be capitalised. Typical refurbishments will include:

- replacement of whole pump sets on approximately 80% of pumps on a 10,000-hour operating cycle
- refurbishment of the acid-proofing in bunded areas every 2 years
- replace approximately 10% of piping per year
- replace instrumentation and control components every 5 years
- replace the equivalent of the whole valve set every 2 years
- refurbish general infrastructure from time to time, including road maintenance

In keeping with industry practice, the estimated annual sustaining capital allowance is 2.5% of the hydrometallurgical plant's direct capital cost over a period of 8 years, totalling US$21.3M (including a 15% contingency).

21.2 Operating costs

21.2.1 Summary

The operating cost estimate for the K.Hill Project consists of mining, processing, G&A., and TMF costs, as summarised in Table 21.18.

The total estimated LOM average operating cost is US$672/t of ore processed. Mining accounts for 3% of the total operating cost, processing accounts for 95%, G&A accounts for 2%, and TMF accounts for less than 1%.

Table 21.18 LOM average operating cost summary

Area	Unit cost (US$/t processed)	Contribution to operating cost (%)
Mining	20.0	3
Processing	636.4	95
G&A	13.4	2
TMF	2.0	0.3
Total	**671.8**	**100**

Notes: Total operating costs, excluding royalties of US$2.0/t processed.
The sum of costs may differ from the total due to rounding.

Metallurgical processing reagents and raw materials constitute the largest component of processing operating cost based on the plant design criteria and flow sheet to produce HPMSM, accounting for approximately 73% (US$92M annually) of the direct operating cost. However, of the total reagent cost, approximately 36% is associated with importation and freight costs of certain key reagents currently assumed to be sourced on the international markets.

During 2021 and early 2022, COVID-19-related disruptions led to an unprecedented rise in international freight rates, which elevated prices for the procurement of reagents. Since mid-2022, international freight rates have seen declines of between 50% to 75% (Freightos 2022) and are expected to continue to normalize toward pre-COVID-19 levels.

Giyani will follow the recommendations set out in Section 26 to identify opportunities to reduce operating costs by lowering consumption of certain key reagents, developing local or alternative sources of reagents to mitigate international freight costs and pursuing a strategy of a diversified supply chain with an optimised road transport component. This work has already started.

21.2.2 Basis of operating cost estimate

Labour rates

Labour rates for the operating cost estimate are based on the Tsa Badiri Consultancy (Pty) Ltd. (Tsa Badiri) report commissioned by Giyani for the Project. The rates, presented in Botswana Pula, include:

- base rate and overtime rate
- an allowance to attract and retain labour
- vacation and statutory holiday pay
- fringe benefits and payroll burdens
- overtime and shift premiums
- small tools
- consumables
- personal protection equipment
- contractors' overhead and profit
- on-cost

SRK and Tetra Tech selected the 50th percentile (P_{50}) data set and made use of the presented Paterson grading system to allocate salary cost per person. A summary of the salary rates is presented in Table 21.19.

Table 21.19 Salary rates

Paterson equivalent	Position	Salaries	
		P_{50} (P)	P_{50} (US$)
E2 (Lower E)	General manager	1,754,028	154,404
D3 (Lower D)	Senior mining engineer, senior geologist, chief surveyor	980,050	86,272
D2 (Lower D)	Production superintendent, maintenance superintendent, mining engineer, mine supervisor	773,465	68,087
D1 (Lower D)	Surveyor, geologist	647,238	56,975
B4 (Upper B)	Mechanics, tyre fitters, articulated truck driver	184,223	16,217
B2 (Lower B)	Clerk, excavator operator, backhoe operator, dozer operator, grader operator, drill rig operator, bowser driver, FEL loader operator	122,922	10,821
B1 (Lower B)	Assistant	117,983	10,386

Note: The exchange rate applied at the time was P11.36 per US dollar

Fuel price

Diesel and petrol will be supplied at the mine site by one of the three main suppliers in Botswana: Oryx, Total, or Shell. The fuel price will include the initial and sustaining capital and operating cost of freight logistics, storage, treatment, maintenance, and operation. The fuel costs used in this FS are summarised in Table 21.20; however, the authors note that there has been significant volatility in fuel prices over the last 12 months, and this may continue in the future.

Table 21.20 Fuel cost summary

Type	Operation (P/L)	Operation US$/L
Diesel	8.09	0.65
Petrol	9.03	0.72

Power cost

Electric power will be supplied by BPC, the national power utility. The estimated power cost used in this study is US$0.12/kWh based on the standard tariff structure of the utility company.

21.2.3 Mining

SRK developed an operating cost estimate for the mine plan using a first-principles approach with the following components:

- the mine plan tonnages for each destination
- equipment productivity and hourly equipment operating costs
- estimated labour requirements and salaries
- fuel and lubricant costs from Giyani and equipment suppliers
- estimated explosive consumables

Mine equipment costs

Most of the equipment unit operating costs are based on equipment supplier budget pricing. The 2020-2021 InfoMine (InfoMine 2022) cost database was used where data was unavailable from equipment suppliers.

The cost estimate uses budget fuel pricing and lubricant costs provided by Giyani.

Mine operating costs

The total estimated unit operating cost per tonne of ex-pit material movement for the mining fleet is US$3.46/t mined (Table 21.21).

Table 21.21 Average mining operating unit costs per tonne mined

Category	Unit cost (US$/t)	Activity	Unit cost (US$/t)
Labour	1.31	Management	0.41
Maintenance	0.62	Loading	0.39
Fuel	1.00	Hauling	0.83
Power	0.00	Ancillary	1.11
Lubricants	0.11	Drilling	0.12
Tires	0.07	Blasting	0.39
Wear parts	0.00	Water management	0.00
Explosives	0.18	Grade control	0.04
Sampling	0.00	Crushing	0.00
Miscellaneous	0.05	Miscellaneous	0.05
Contingency	0.00	Contingency	0.00
Total	**3.33**	**Total**	**3.33**

Notes: The sum of costs may differ from the total due to rounding.

It is important to note that both drilling and blasting and grade control costs were added to the total mining cost, assuming it will be completed by the owner. This implies that the required equipment, labour, maintenance, and miscellaneous costs have been accounted for in terms of both capital and operating costs. These costs may turn out slightly different when actual quotes are provided by the supplier. However, these potential differences are not expected to be material.

The estimated quantities of fuel are shown in Table 21.22.

The total mining operating cost decreases during the years of only stockpile rehandling by roughly a factor of two.

The total weighted average mining cost of US$3.46/t mined, which is similar to the average mining cost resulting from the pit optimisation.

Table 21.23 shows a breakdown of the mining equipment operating cost per tonne of rock mined. The unit operating cost during the year 2034 is shown to be zero since that period only includes some stockpile rehandling material movement activities. The total included costs can be seen as a total annual operating cost.

Table 21.22 Mining fleet fuel consumption

	Units	Total	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036
Fuel requirements	(ML)	13.1	0.7	1.4	1.4	1.5	1.5	1.5	1.5	1.5	1.4	0.4	0.3	0.3

Table 21.23 Mining equipment operating cost estimate per tonne of rock mined

Parameter	Units	Total	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036
Operating costs - category	**(US$M)**	**40.6**	**2.2**	**4.3**	**4.4**	**4.5**	**4.48**	**4.65**	**4.61**	**4.52**	**4.41**	**1.16**	**1.14**	**0.33**
Labour	(US$M)	16.0	0.8	1.7	1.7	1.7	1.7	1.8	1.8	1.8	1.7	0.6	0.6	0.2
Maintenance	(US$M)	7.6	0.4	0.8	0.8	0.9	0.9	0.9	0.9	0.9	0.8	0.1	0.1	0.0
Explosives	(US$M)	2.2	0.1	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.0	0.0	0.0
Fuel	(US$M)	12.1	0.6	1.3	1.3	1.3	1.3	1.4	1.4	1.3	1.3	0.4	0.4	0.1
Power	(US$M)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lubricants	(US$M)	1.4	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0
Tires	(US$M)	0.9	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0
Miscellaneous	(US$M)	0.6	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.0	0.0	0.0
Contingency	(US$M)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Operating costs	**(US$/t)**	**3.33**	**2.95**	**2.96**	**3.01**	**3.07**	**3.07**	**3.19**	**3.16**	**3.19**	**3.44**	**0.00**	**0.00**	**0.00**
Labour	(US$/t)	1.31	1.13	1.14	1.16	1.16	1.18	1.23	1.23	1.25	1.35	0.0	0.0	0.0
Maintenance	(US$/t)	0.62	0.56	0.56	0.58	0.60	0.59	0.61	0.60	0.62	0.66	0.0	0.0	0.0
Fuel	(US$/t)	1.00	0.87	0.87	0.88	0.92	0.90	0.94	0.93	0.95	1.01	0.0	0.0	0.0
Power	(US$/t)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.0	0.0
Lubricants	(US$/t)	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.0	0.0	0.0
Tires	(US$/t)	0.07	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.0	0.0	0.0
Explosives	(US$/t)	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.0	0.0	0.0
Miscellaneous	(US$/t)	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.03	0.05	0.0	0.0	0.0
Contingency	(US$/t)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Operating costs - activity	**(US$M)**	**40.6**	**2.2**	**4.3**	**4.4**	**4.5**	**4.48**	**4.65**	**4.61**	**4.52**	**4.41**	**1.16**	**1.14**	**0.33**
Management	(US$M)	5.0	0.3	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.1	0.1	0.0
Loading	(US$M)	4.8	0.3	0.6	0.5	0.6	0.6	0.6	0.6	0.6	0.5	0.0	0.0	0.0
Hauling	(US$M)	10.1	0.5	1.0	1.1	1.2	1.2	1.3	1.3	1.2	1.2	0.1	0.1	0.0
Ancillary	(US$M)	13.5	0.7	1.3	1.3	1.3	1.3	1.4	1.4	1.3	1.3	0.9	1.0	0.3

Parameter	Units	Total	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036
Drilling	(US$M)	1.5	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.0	0.0	0.0
Blasting	(US$M)	4.8	0.3	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.5	0.0	0.0	0.0
Grade control	(US$M)	0.4	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0
Miscellaneous	(US$M)	0.6	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.0	0.0	0.0
Contingency	(US$M)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.0	0.0
Operating costs	**(US$/t)**	**3.33**	**2.95**	**2.96**	**3.01**	**3.07**	**3.07**	**3.19**	**3.16**	**3.19**	**3.44**	**0.00**	**0.00**	**0.00**
Management	(US$/t)	0.41	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.40	0.44	0.0	0.0	0.0
Loading	(US$/t)	0.39	0.38	0.38	0.38	0.38	0.39	0.39	0.39	0.39	0.41	0.0	0.0	0.0
Hauling	(US$/t)	0.83	0.68	0.69	0.74	0.80	0.79	0.89	0.86	0.87	0.91	0.0	0.0	0.0
Ancillary	(US$/t)	1.11	0.91	0.90	0.90	0.90	0.91	0.93	0.93	0.95	1.04	0.0	0.0	0.0
Drilling	(US$/t)	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.13	0.0	0.0	0.0
Blasting	(US$/t)	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.42	0.0	0.0	0.0
Grade control	(US$/t)	0.04	0.03	0.04	0.04	0.04	0.03	0.03	0.03	0.04	0.04	0.0	0.0	0.0
Miscellaneous	(US$/t)	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.03	0.05	0.0	0.0	0.0
Contingency	(US$/t)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

21.2.4 Processing

The nominal processing plant operating cost estimate is presented in Table 21.24.

Approximately 21% of the processing cost is considered fixed, which means 79% of the cost varies with the production rate. Note that these unit processing costs shown in Table 21.24 are calculated for a nominal 200,000 t/a throughput rate. When the plant production rate is turned down, as it would be during the ramp-up period in the first two years of operation, the unit processing rate will increase. The costs shown in Table 21.18 are average LOM values as calculated in the TEM.

Table 21.24 Summary of processing operating costs

Area	Costs (US$/t processed)
Energy	60.34
Labour	9.84
Laboratory and QC	0.73
Water treatment	18.73
Maintenance spares	75.22
Raw materials	460.38
Tailings production and disposal	1.83
Solar plant	0.09
Total	**627.16**

The sum of costs may differ from the total due to rounding.

Energy

Estimated energy costs, calculated based on an estimate of absorbed power requirements at standard BPC power supply rates, is US$0.12/kWh on average. Tetra Tech calculated that the 6.2 GWh of solar power that will offset the grid supply cost would result in a net saving of US$3.75/t, resulting in a net unit energy cost of US$60.34/t.

Labour

Giyani's philosophy of employing mostly Botswana nationals is reflected in the estimated labour cost. The labour cost for the processing plant and tailings operation is US$9.84/t milled. Table 21.25 shows the processing plant organisational structure labour cost.

Table 21.25 Plant organisational structure and cost

Role	Level	Type of shift	No. on shift	No. employed	Total unit cost (P/a)	Total cost (P/a)	Total cost (US$/a)
General/plant manager	E2	Manager	1	1	1,296,000	1,296,000	103,432
Plant superintendent	D3	Day shift	1	1	410,400	410,400	32,753
Metallurgists	D2	Day shift	4	4	324,000	1,296,000	103,432
Metallurgical clerk	C1	Day shift	2	2	135,000	270,000	21,548
Laboratory clerk	C1	Day shift	1	1	135,000	135,000	10,774
Assayer	C2	Day shift	1	1	199,800	199,800	15,946
Laboratory technicians	B2	Day shift	2	2	64,800	129,600	10,343
Laboratory general hand	A1	Day shift	2	2	43,200	86,400	6,895
Services foreman	C2	Day shift	1	1	199,800	199,800	15,946
Services operator	B2	Day shift	3	4	64,800	259,200	20,686
Services general hand	A1	Day shift	3	3	43,200	129,600	10,343
Shift boss extraction	C1	Shift	1	4	135,000	540,000	43,097
Plant foreman	C2	Day shift	1	1	199,800	199,800	15,945
Shift boss comminution	C1	Shift	1	2	135,000	270,000	21,548
Shift boss leach	C1	Shift	1	4	135,000	540,000	43,097
Shift boss services	C1	Shift	1	4	135,000	540,000	43,097
Operators	B2	Shift	3	12	64,800	777,600	62,059
Operator general hand	A1	Shift	3	12	43,200	518,400	41,373
Warehouse/logistics manager	C2	Day shift	1	1	199,800	199,800	15,946
Warehouse clerk	B1	Shift	2	8	54,000	432,000	34,477
Resident engineer	D3	Day shift	1	1	410,400	410,400	32,753
Maintenance foreman	C2	Day shift	1	1	199,800	199,800	15,946
Maintenance clerk	C1	Day shift	1	1	135,000	135,000	10,774
Electrician	C1	Day shift	2	2	135,000	27,0000	21,548
Control and instrumentation technician	C2	Day shift	2	2	199,800	399,600	31,891
Fitter	C1	Day shift	2	2	135,000	270,000	21,548
Boilermaker	C1	Day shift	1	1	135,000	135,000	10,774
Assistant	B1	Day shift	5	5	54,000	270,000	21,548

Role	Level	Type of shift	No. on shift	No. employed	Total unit cost (P/a)	Total cost (P/a)	Total cost (US$/a)
General hand	A1	Day shift	5	5	43,200	216,000	17,239
Tailings superintendent	D3	Day shift	1	1	410,400	410,400	32,753
Tailings foreman	C2	Day shift	1	1	199,800	199,800	15,946
Tailings operator	B2	Shift	1	4	64,800	259,200	20,686
Tailings general hand	A1	Shift	2	8	43,200	345,600	27,582
Total	-	-	**60**	**104**	**6,183,000**	**11,950,200**	**953,727**

Notes: The sum of costs may differ from the total due to rounding.

Laboratory and quality control

The estimated laboratory and QC cost for the processing plant and tailings operation is US$0.66/t milled. The breakdown of the estimated laboratory costs is shown in Table 21.26.

Table 21.26 Summary of estimated annual laboratory and quality control costs

Analysis Type	Cost per analysis (R)	No. of samples	Annual cost (R)	Annual cost (US$)
Processing				
Particle size distribution - sieve	15.7	12,545	196,957	11,572
pH	0.1	15,440	1,544	91
Oxidation-reduction potential	0.1	1,930	193	11
Percentage solids (%m/m)	0.5	9,650	4,825	283
Metal (sol) assay	100.0	16,405	1,640,500	96,387
Full assay	200.0	1,930	386,000	22,679
Total dissolved solids	0.1	643	64	4
Bacterial	5.0	52	260	15
Confirmation sample - metal assay	100.0	5	500	29
Confirmation sample - full assay	200.0	5	1,000	59
Tailings operation				
pH	0.1	322	32	2
Percentage solids (%m/m)	0.5	322	161	9
Metal (sol) assay	100.0	52	5,200	306
Total	-	-	-	**131,447**

Notes: The sum of costs may differ from the total due to rounding.

Water treatment

The water treatment plant comprises dissolved air flotation (DAF), chemical treatment, two stages of reverse osmosis, and solids separation and disposal. A summary of costs is provided in Table 21.27.

Table 21.27 Summary of water treatment costs

Area	Annual cost (US$/a)
Reagents	2,376,216
Labour	420,000
Maintenance	950,000
Total	**3,746,216**

Notes: The sum of costs may differ from the total due to rounding.

Maintenance

Tetra Tech provided annual maintenance spares costs as 7% of the cost of the mechanical equipment, an increase from the more conventional 5% allowance to account for the heavy chemical duty of the hydrometallurgical plant.

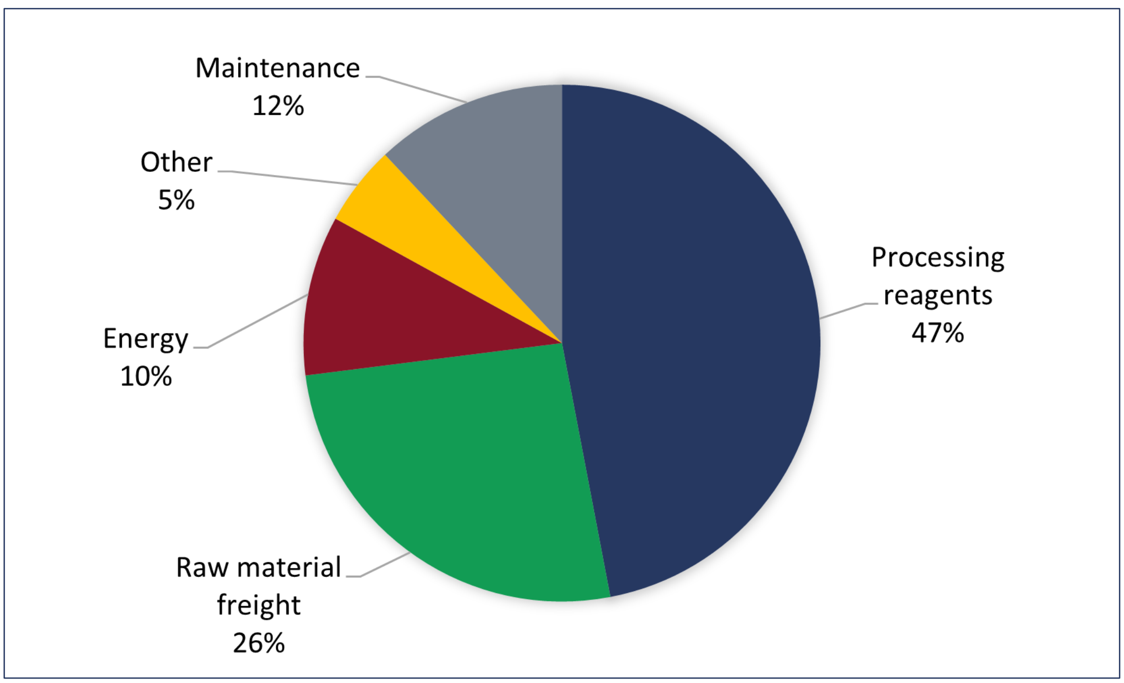
Raw materials

Raw materials constitute the largest component of processing operating cost based on the process design criteria and mass balance (Section 17), reagent consumption forecasts based on the head grade analysis included in the mine schedule (Section 16.7), and supply and supply chain costs. Unit costs were estimated from the following sources:

- formal analyst-based studies, such as the CRU Sulphuric Acid Market Outlook (February 2022) study report
- formal supply cost enquiries from specialist chemical supply companies, including AfriGrown, ChemQuest Africa (Pty) Ltd (SNF Chemquest), Kemcore Botswana (Pty) Ltd, Magotteaux (Pty) Ltd, Protea Mining Chemicals and Setchem (Pty) Ltd
- formal transport cost enquiries from freight forwarding companies, including Ceva Logistics (Manica Botswana (Pty) Ltd), Namibia Logistics (Pty) Ltd Trading as Namlog, SYNERGY Worldwide Logistics (Pty) Ltd, and Unitrans

Figure 21.2 shows that processing reagents and raw material supply and freight constitute 47% and 26%, respectively, of the processing operating cost. Energy, maintenance, and miscellaneous items make up just more than a quarter of the cost.

Figure 21.2 Breakdown of the direct raw materials processing costs



The total estimated direct processing operating cost is US$92M/a for a plant capacity of 200,000 t/a, for a cost of US$460/t of ROM feed.

The breakdown of the average direct processing operating annual costs is shown in Table 21.28.

Table 21.28 Summary of the annual raw materials cost

Commodity	Annual cost (US$M/a)
Leach reagents	15.96
Polishing reagents	24.44
Purification reagents	50.91
Miscellaneous	0.76
Total	**92.07**

Notes: The sum of costs may differ from the total due to rounding.

Tailings production and disposal

The estimated tailings operating cost is US$1.83/t to produce and deliver the dewatered tailings material to the TMF (excluding the TMF operation).

Solar plant

The estimated cost to operate the solar plant operation US$0.09/t.

21.2.5 General and administrative

The G&A cost estimate basis includes the following:

- The personnel rates (labour) are derived from the remuneration information report dated 16th November 2021, prepared by Tsa Badiri for Giyani.
- Equipment costs are estimated using assumed long-term rental costs as the basis.
- The facilities costs are based on self-operation for the accommodation in Kanye by renting houses and employing staff to maintain, clean, and prepare meals, as well as the cost of groceries, including food, but assuming outsourcing of the services for on-site mess and medical facilities.
- The laboratory services account for the average external geological assays required, including the associated transport costs. This excludes any mining or processing operational laboratory cost, which are included in the operating cost estimates.

The total estimated annual G&A cost is US$2.5M or US$12.61/t processed, shown in Table 21.29.

Table 21.29 General and administrative expense breakdown

Area	Annual cost (US$/a)
Labour	698,486
Equipment	60,449
Facilities	227,373
Utilities	42,545
Services	155,091
Botswana corporate (Menzi Battery Metals)	667,248
Overheads	343,142
Laboratory services	58,036
Contingency	270,285
Total	**2,522,656**

Notes: The sum of costs may differ from the total due to rounding.

21.2.6 Tailings management facility

The estimated TMF operating cost for the LOM is US$1.06M, ranging from US$0.30/t to US$2.50/t, with a nominal value of US$2.00/t.

Costs for annual operation have excluded all costs associated with pumping, lighting, analysis, and transportation, which are included in the processing operating cost.

22 ECONOMIC ANALYSIS

22.1 Introduction

SRK prepared a TEM for the K.Hill Project. Cash inflows are based on annual production and revenue projections, while cash outflows consist of capital costs, operating costs, royalties, and taxes. The modelling period covers the LOM of 11 years, including a 2-year construction period and a 2-year ramp up to full production following plant commissioning. The NPV is calculated by discounting back cashflow projections through the LOM to the K.Hill Project's valuation date of 1st July 2023, which is the start date of construction and the first drawdown of capital. Key project metrics are presented in Table 22.1.

Table 22.1 Key Project metrics

Metrics	Units	Results	
Net realized price assumption			
Average realized HPMSM price (Years 1 to 5)	US$/t	3,373	
Net realized price HPMSM price (Years 6 to 11)	US$/t	3,918	
Production		Annual	LOM
Total ore mined	dry kt	226	2,032
ROM manganese oxide grade	% MnO	18.9	18.9
Steady-state metallurgical recovery	%	88.5	88.5
Total recovered manganese oxide	kt MnO	31	339
Total HPMSM produced	kt	73	808
Project cash flow		Average annual	LOM
Revenue from HPMSM	US$M	272	2,993
Total operating costs (including royalties)	US$M	125	1,369
Total EBITDA	US$M	148	1,624
Initial capital cost, excluding contingency	US$M	-	249
Contingency on initial capital	US$M	-	32
Total initial capital cost, including contingency	US$M	-	281
Sustaining capital cost, including contingency	US$M	-	21
Closure costs	US$M	-	5
Total LOM capital cost, including contingency	US$M	-	307
Project economics		Pre-tax	Post-tax
NPV (8% real discount rate)	US$M	603	481
IRR	%	32.0	28.3
Payback period from the start of processing	years	3.3	3.6
Undiscounted cumulative cash flow	US$M	1,317	1,093

Notes: Net realized prices for HPMSM at mine gate, assuming 50% of sales to Europe and 50% sales to North America.

22.2 Pre-tax model

SRK prepared a 100% equity TEM in real terms based on the mine schedule presented in Section 16, the processing inputs presented in Section 17, and the capital and operating costs presented in Section 21 (repeated in Table 22.2 and Table 22.3 for convenience).

Table 22.2 Summary of life of mine capital costs

Area	Cost (US$M)
Mining	10.5
Processing	98.1
Infrastructure and services	31.2
TMF	6.6
Offsite infrastructure	9.7
Indirect costs (including first fill and commissioning costs)	65.5
Construction overheads	21.6
Owner's costs	5.5
Total initial capital cost, excluding contingency	248.7
Contingency on initial capital cost	32.0
Total initial capital cost, including contingency	280.7
Sustaining capital, including contingency	21.3
Closure cost	5.1
Total	**307.3**

Note: The sum of costs may differ from the total due to rounding.

Table 22.3 Life of mine average operating cost summary

Area	Unit cost (US$/t processed)	Contribution to operating cost (%)
Mining	20.00	3.0
Processing	636.40	95.0
G&A	13.40	2.0
TMF	2.04	0.3
Total	**671.84**	**100.0**

Note: Total operating costs, excluding royalties of US$2.00/t processed
The sum of costs may differ from the total due to rounding.

Initial capital costs will be expended over the first 2 years of the TEM. All revenue and costs were modelled quarterly to match the mining schedule. The TEM uses HPMSM forecast prices provided by CPM for Giyani's key markets of Europe and North America but adjusted to run a flat price from Year 6 of the production period. The CPM market outlook report for high-purity manganese products is summarised in Section 19, and the full report can be found in Appendix F.

22.2.1 Working capital

An allowance for working capital is included in the TEM and reflected in the cash flow with the following delays assumed:

- Debtors: 90 days
- Creditors: 60 days
- Stores: 30 to 60 days

22.2.2 Commissioning and ramp up

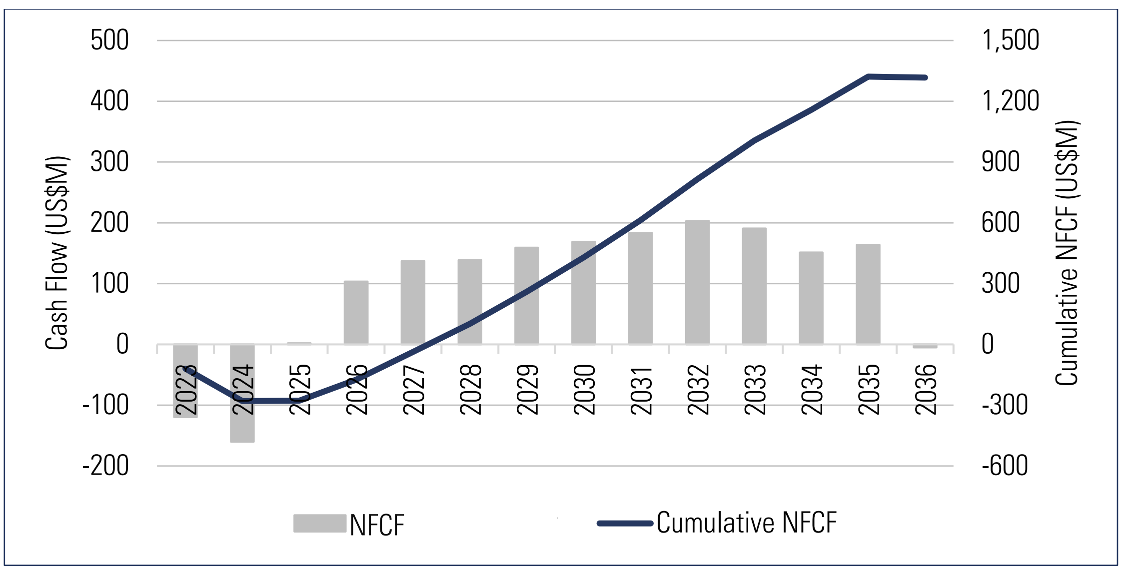
The TEM assumes plant commissioning over two quarters, followed by an S-curve ramp-up schedule to reflect the sophisticated nature of the K.Hill processing plant. Ramp up has been staged over a conservative eight-quarter period, and metallurgical recoveries are assumed to start at 75.0% and rise to 88.5% by completion.

During the ramp-up period, processing costs have been treated as 20% fixed and 80% variable, except for labour costs, which are treated as 100% fixed.

Due to the nature of the orebody, access to ore will be rapid, and as such, mining production will exceed planned plant capacity during the ramp-up period. As mining only accounts for 3% of overall costs and processing accounts for 95% of costs, being treated as 20% fixed/80% variable, sufficient ore will be processed to generate revenue to more than offset the operating costs during the ramp-up period.

A summary of the LOM pre-tax net free cash flow (NFCF) is presented in Figure 22.1.

Figure 22.1 Net free cash flow (pre-tax)



NPV (calculated from the first drawn down of capital) is presented in Table 22.4 for discount rates ranging from 0% to 15%.

Table 22.4 Net present value summary, pre-tax pre-finance

	Unit	Discount Rate					
		0%	5%	8%	10%	12%	15%
NPV	US$M	1,317	808	603	495	404	295

Table 22.5 Cash flow summary

	Unit	Total/ Average	Year													
			Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14
Open pit production																
Waste mined	kt	10,156	0	0	1,196	1,225	1,112	1,163	1,271	1,339	1,271	1,149	429	0	0	0
ROM mined	kt	2,032	0	0	264	232	348	297	189	121	174	285	123	0	0	0
Total Ex-pit	kt	12,188	0	0	1,460	1,457	1,460	1,460	1,460	1,460	1,445	1,434	552	0	0	0
Stripping ratio	tw:to*	5.00	0.00	0.00	4.54	5.27	3.20	3.92	6.73	11.06	7.31	4.04	3.48	0.00	0.00	0.00
Rehandled	kt	841	0	0	28	14	35	86	49	109	87	57	155	202	21	0
Total material moved	kt	12,188	0	0	1,460	1,457	1,460	1,460	1,460	1,460	1,445	1,434	552	0	0	0
Processing																
Ore processed	kt	2,032	0	0	70	192	202	202	202	202	202	202	200	200	159	0
MnO grade processed	%	18.89	0.00	0.00	21.17	21.88	19.06	17.81	18.52	18.40	19.48	20.72	19.25	16.27	16.27	0.00
MnO content	kt	383.8	0.0	0.0	14.8	42.0	38.5	36.0	37.4	37.1	39.3	41.8	38.5	32.5	25.8	0.0
MnO process recovery	%	87.7	0.0	0.0	84.1	88.5	88.5	88.5	88.5	88.5	88.5	88.5	88.5	88.5	88.5	0.0
MnO recovered	kt	339.0	0.0	0.0	12.5	37.2	34.0	31.8	33.1	32.9	34.8	37.0	34.1	28.8	22.8	0.0
HPMSM tonnes produced	kt	807.8	0.0	0.0	29.7	88.6	81.1	75.8	78.9	78.3	82.9	88.2	81.2	68.6	54.4	0.0
Macro economics																
HPMSM product price	US$/t	3,705	0	0	2,873	3,126	3,366	3,656	3,843	3,918	3,918	3,918	3,918	3,918	3,918	0
Revenue																
Total revenue	US$M	2,993.2	0.0	0.0	85.2	277.1	273.0	277.2	303.0	306.8	324.9	345.6	318.1	268.9	213.2	0.0
Operating costs																
Mining	US$M	40.6	0.0	0.0	4.3	4.3	4.4	4.5	4.6	4.6	4.6	4.5	2.7	1.2	0.9	0.0
Processing	US$M	1,293.2	0.0	0.0	61.7	121.6	126.6	126.6	126.6	126.6	126.6	126.6	125.4	125.4	99.4	0.0
TMF cost	US$M	4.1	0.0	0.0	0.1	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.0
G&A	US$M	27.2	0.0	0.0	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.0	0.0
Mining royalties	US$M	4.0	0.0	0.0	0.5	0.5	0.7	0.5	0.4	0.3	0.4	0.6	0.2	0.0	0.0	0.0
Total operating costs	US$M	1,369.2	0.0	0.0	69.2	129.3	134.7	134.5	134.5	134.4	134.5	134.7	131.2	129.5	102.7	0.0
Capital costs																
Mining	US$M	10.5	0.0	9.5	0.2	0.4	0.0	0.0	0.4	0.0	0.2	0.0	0.0	0.0	0.0	0.0
Processing	US$M	98.1	44.8	53.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Infrastructure and services	US$M	31.2	12.6	18.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Offsite infrastructure	US$M	9.7	7.3	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Indirect costs	US$M	65.5	24.3	41.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

	Unit	Total/ Average	Year													
			Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14
Construction overheads	US$M	21.6	10.8	10.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Owner's costs	US$M	5.5	2.8	2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tailings	US$M	6.6	3.3	3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sustaining capital	US$M	18.5	0.0	0.0	0.0	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	0.0	0.0	0.0
Subtotal capital	US$M	267.3	105.9	141.8	0.2	2.7	2.3	2.3	2.7	2.3	2.5	2.3	2.3	0.0	0.0	0.0
Contingency - capital	US$M	35.0	13.8	18.2	0.0	0.4	0.3	0.3	0.4	0.3	0.4	0.3	0.3	0.0	0.0	0.0
Overall contingency rate	%	13.1	13.1	12.9	10.0	14.3	15.0	15.0	14.3	15.0	14.7	15.0	15.0	0.0	0.0	0.0
Closure costs	US$M	5.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.1
Total project capital	**US$M**	**307.3**	**119.7**	**160.0**	**0.2**	**3.1**	**2.7**	**2.7**	**3.1**	**2.7**	**2.8**	**2.7**	**2.7**	**0.0**	**0.0**	**5.1**
Economics																
Sales revenue	US$M	2,993	0.0	0.0	85.2	277.1	273.0	277.2	303.0	306.8	324.9	345.6	318.1	268.9	213.2	0.0
Operating costs	US$M	1,369	0.0	0.0	69.2	129.3	134.7	134.5	134.5	134.4	134.5	134.7	131.2	129.5	102.7	0.0
Operating profit - EBITDA	US$M	1,624	0.0	0.0	16.1	147.8	138.4	142.7	168.5	172.4	190.4	210.9	186.9	139.4	110.5	0.0
Capital cost	US$M	307	119.7	160.0	0.2	3.1	2.7	2.7	3.1	2.7	2.8	2.7	2.7	0.0	0.0	5.1
Working capital	US$M	0	0.0	0.0	14.1	41.4	-1.7	1.2	6.4	0.9	4.3	5.3	-6.4	-12.0	-53.4	0.0
Net free cash flow pre-tax	**US$M**	**1,317**	**-119.7**	**-160.0**	**1.8**	**103.3**	**137.4**	**138.9**	**159.1**	**168.8**	**183.3**	**202.9**	**190.7**	**151.3**	**163.9**	**-5.1**
Tax liability	US$M	224	0.0	0.0	0.6	12.7	23.1	20.9	22.6	22.2	26.0	32.7	25.9	20.8	16.5	0.0
Net free cash flow post-tax	**US$M**	**1,093**	**-119.7**	**-160.0**	**1.2**	**90.6**	**114.3**	**118.0**	**136.5**	**146.6**	**157.3**	**170.2**	**164.8**	**130.6**	**147.5**	**-5.1**

Note: *tonnes of waste to tonnes of ore

SRK notes that at an 8% discount rate, the pre-tax NPV for the K.Hill Project is US$603 M. The Project IRR is 32.0% with a 3.3-year payback (Table 22.6).

Table 22.6 Pre-tax financial performance

Project economics	Unit	Value
NPV (8% real discount rate)	US$M	602.7
IRR	%	32.0
Payback period, from the start of processing	years	3.3

22.3 Sensitivity analysis

Figure 22.2 to Figure 22.3 show the NPV, IRR, and payback period sensitivity charts for the K.Hill Project operating costs, capital costs, and commodity prices.

The K.Hill Project's NPV, IRR, and payback period are most sensitive to commodity price, which can also be a proxy for grade and recovery, as illustrated by the blue lines. The K.Hill Project has a lower sensitivity to operating costs and is least sensitive to capital costs, as indicated by the green and red lines, respectively.

Figure 22.2 Net present value sensitivity

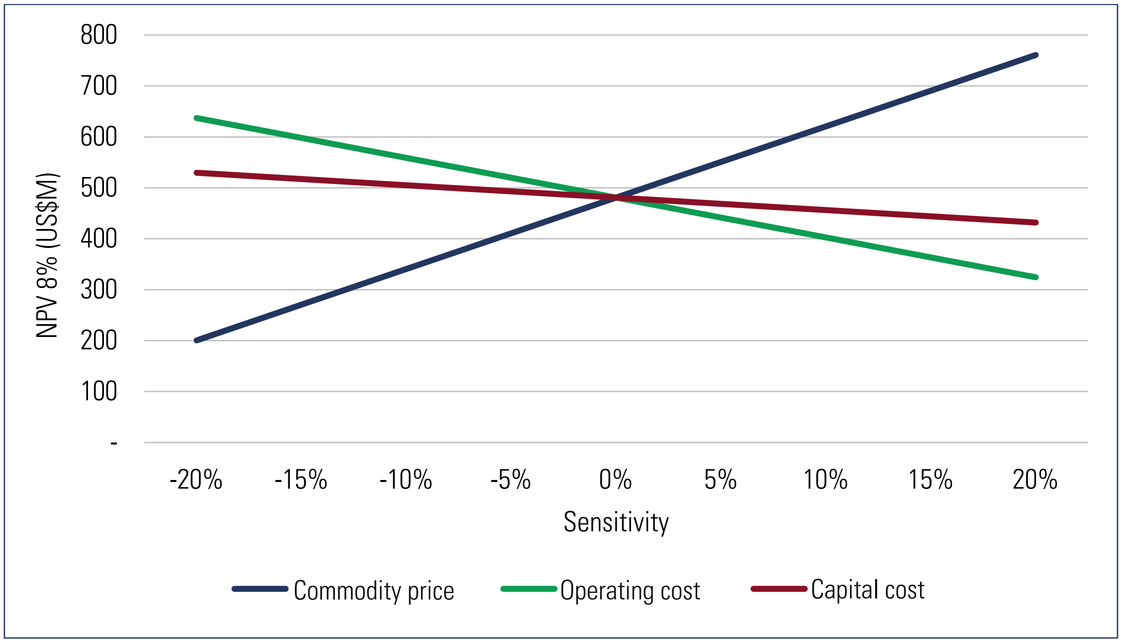
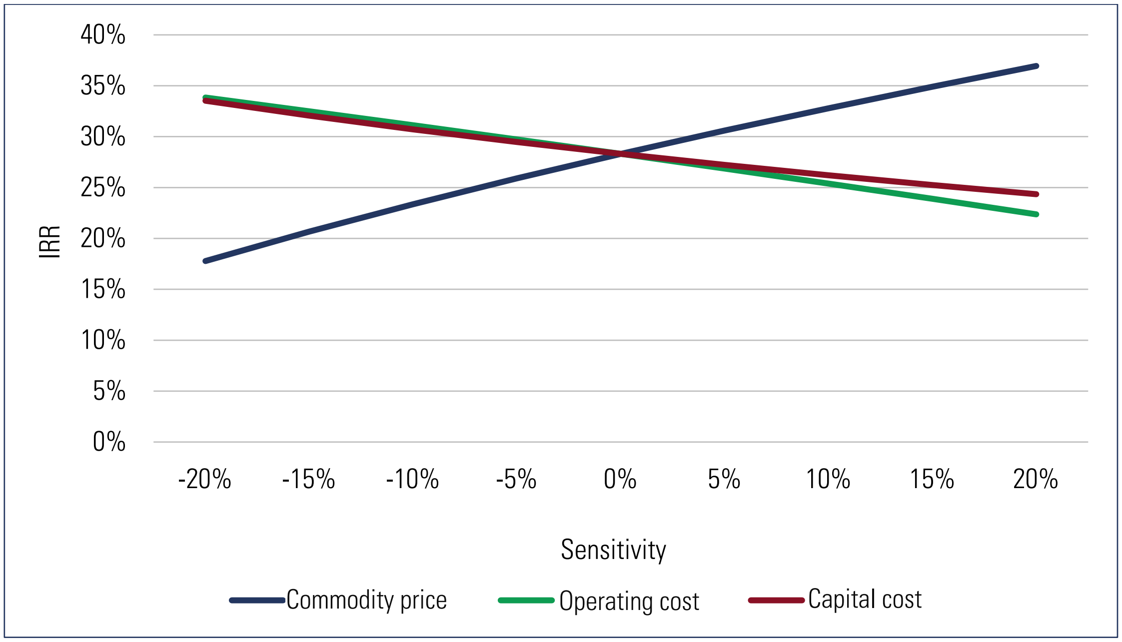


Figure 22.3 Internal rate of return sensitivity



22.3.1 Upside pricing scenario

The assumed prices are based on the CPM market outlook report (Section 19; Appendix F).

Table 22.7 Pre-tax financial performance using the uncapped CPM pricing

Parameter	Unit	Value
Average HPMSM price	US$/t	4,416
Revenue	US$M	3,349
Operating cost	US$M	1,369
Operating profit	US$M	1,980
Cash flow (undiscounted)	US$M	1,673
NPV (8% discount rate)	US$M	756
IRR	%	34.0
Payback period, from the start of processing	years	3.3

22.4 Post-tax analysis

Following a review of the Botswana tax regime and discussions with local stakeholders, Giyani intends to split the K.Hill operation into two business units: mining and manufacturing. The mining operation will sell ore to the manufacturing operation at an assumed long-term manganese ore price, as forecast in the consensus market forecast subscribed to by SRK.

The mining unit will be taxed according to the Botswana mining company tax formula, or a minimum of 22%, on the sale of manganese ore to the manufacturing unit. The mining tax formula is as follows:

$$70 - \{1{,}500 \div [(taxible\ income \div gross\ income) \times 100]\}$$

A mining royalty of 3% will be applied to the revenue on the sale of the manganese ore to the manufacturing unit. For the mining unit, capital investments will depreciate immediately, and unredeemed capital will be carried forward indefinitely, as allowed for mining projects in Botswana.

The manufacturing unit will be taxed on the manufacturing tax rate, assuming a manufacturing development order will be received, resulting in a tax rate of 15%. For the manufacturing unit, initial capital investments will depreciate at 10% per year on a straight-line basis and sustaining capital will depreciate at 20% per year.

Giyani received a post-tax analysis from PwC in support of this tax arrangement. The full analysis is included in Appendix G. These arrangements will require approval from the Ministry of Finance and Economic Development, the Director of Mines, and the Commissioner General of the Botswana Unified Revenue Services.

In preparing the tax structure and calculations, SRK fully relied on the direction and guidance from Giyani and the supporting review by PwC.

Table 22.8 presents the post-tax analysis results.

Table 22.8 Post-tax financial performance

Parameter	Unit	Value
Revenue	US$M	2,993
Operating cost	US$M	1,369
Operating profit	US$M	1,624
Tax liability	US$M	224
Capital cost	US$M	307
Cash flow	US$M	1,093
Post-tax NPV @ 8% discount	US$M	481
IRR	%	28.3
Payback period, from the start of processing	years	3.6

Table 22.9 presents the post-tax NPV at discount rates ranging from 0% to 15%.

Table 22.9 Net present value summary, post-tax pre-finance

	Unit	Discount Rate					
		0%	5%	8%	10%	12%	15%
NPV	(US$M)	1,093	656	481	388	311	219

23 ADJACENT PROPERTIES

There are no adjacent properties.

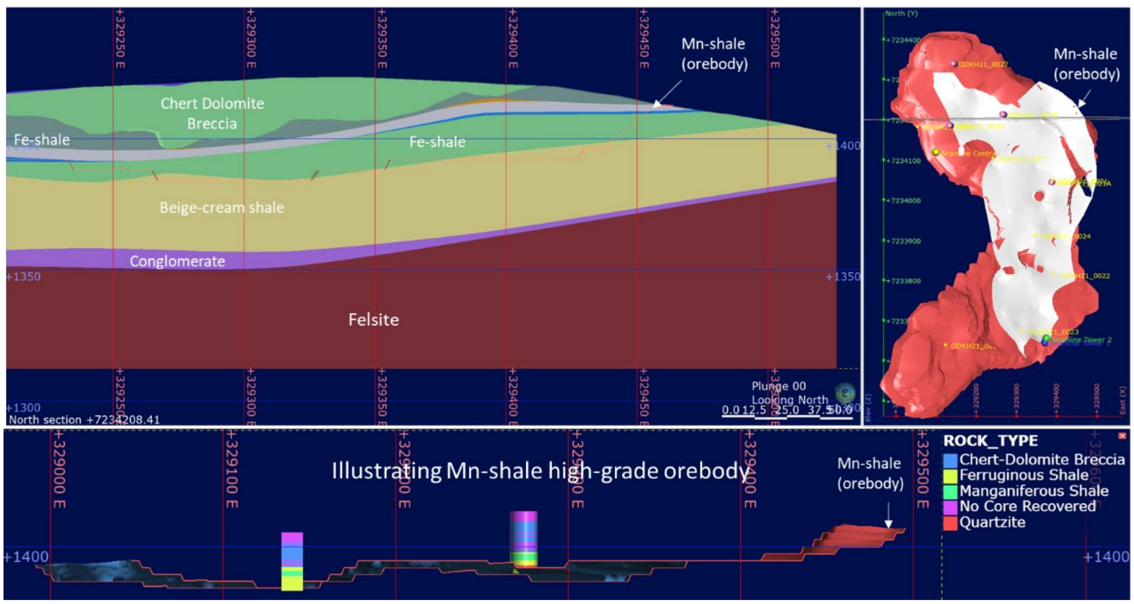
24 OTHER RELEVANT DATA AND INFORMATION

24.1 Geotechnical assessment

24.1.1 Introduction

The geology of the K.Hill Project comprises a supergene-enriched Mn-shale interbedded within Fe-shale, which is overlain by a chert dolomite breccia unit (Figure 24.1). The ore-bearing Upper Mn-shale unit varies from approximately 2 m to 12 m, with an average thickness of 4 m, and dips at approximately 5° to 10° to the NW.

Figure 24.1 Geological model



24.1.2 Geotechnical programme

SRK undertook an analysis based on data collected as part of the FS ground investigation to develop FS-level geotechnical criteria for the engineered open pit design. Eleven vertical DD holes were drilled, geotechnically logged, and sampled for laboratory testing. Two areas of exposed outcrop were mapped to provide structural data.

Geotechnical drilling

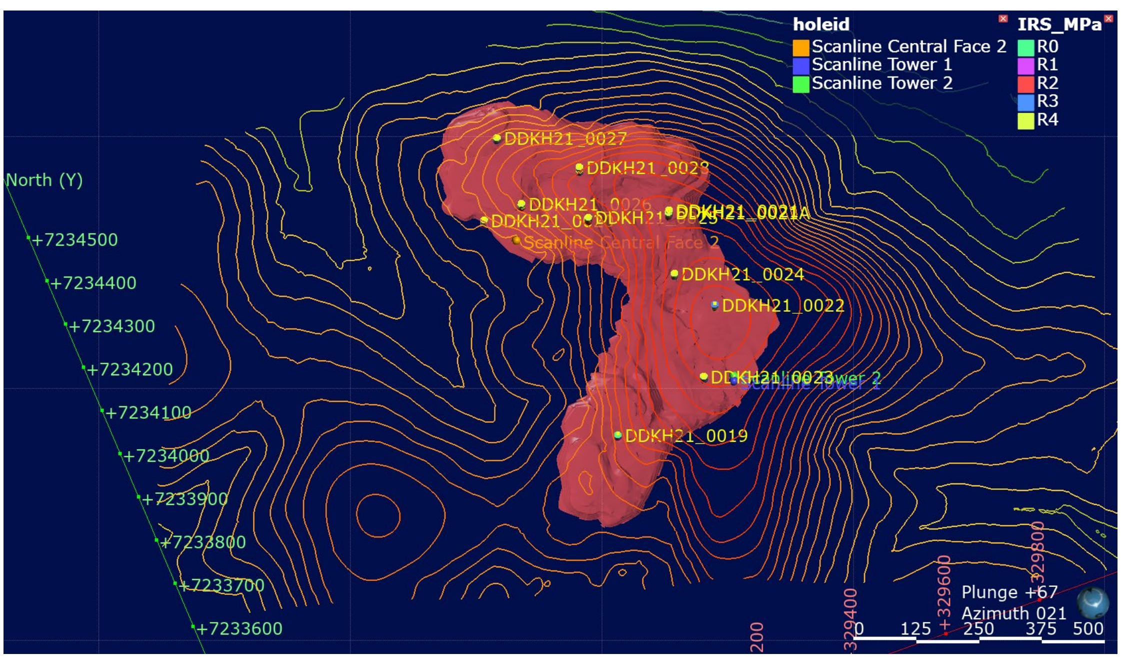
Eleven vertical DD holes were drilled between 25th April 2021 and 22nd June 2021, totalling 322.55 m. One of these drillholes (DDKH20_0021A) was a redrill of DDKH20_0021 due to poor core recovery (Table 24.1).

Table 24.1 As-drilled geotechnical drillhole details

Drillhole ID	Easting	Northing	Elevation	As-drilled depth (m)
DDKH21_023	329333	7233682	1,466.5	31.20
DDKH21_022	329410	7233819	1,464.6	37.20
DDKH21_024	329361	7233915	1,454.5	31.15
DDKH21_021A	329399	7234044	1,447.7	30.00
DDKH21_021	329402	7234049	1,447.8	34.00
DDKH21_025	329251	7234103	1,422.2	30.00
DDKH21_028	329274	7234211	1,420.5	30.00
DDKH21_026	329140	7234184	1,408.4	30.00
DDKH21_027	329148	7234338	1,398.5	34.00
DDKH21_020	329060	7234183	1,395.5	22.15
DDKH21_019	329135	7233644	1,422.2	36.00

Onsite geologists logged all drillholes using a rock mass rating (RMR) 89 logging spreadsheet provided by SRK. SRK provided remote assistance due to COVID-19 quarantine restrictions; therefore, no site visit was conducted to provide personal training to the logging geologists. Drillhole locations are presented on Figure 24.2.

Figure 24.2 Geotechnical boreholes displaying logged rock strength, current final open pit design, and 5 m topographic contours



24.1.3 Laboratory testing

Rocklab Laboratory (Rocklab), located in South Africa, conducted laboratory testing. Rocklab issued results on 15th October 2021, and SRK received the results on 18th October 2021.

Uniaxial compressive strength with elastic modulus and Poisson ratio

A total of 35 samples were submitted for uniaxial compressive strength (UCS) testing, including elastic modulus and Poisson ratio. Thirteen of these samples could not be prepared for testing due to either the softness of the material or existing fractures within the sample. The deformation measurements were unsuccessful for one sample.

Discontinuity direct shear testing

Thirteen discontinuity direct shear tests were conducted with peak and residual values reported. Validation of the direct shear test results with a Barton-Bandis shear strength envelope derived from logged data was not conducted due to the kinematic analysis not identifying any significant potential structural failure modes (as discussed in Section 24.1.6).

Brazilian tensile strength testing

Fifteen samples underwent Brazilian tensile strength testing. Fourteen of these samples were within the shale lithologies, and one was within the chert dolomite breccia. All samples were reported to have failed on an existing fracture or joint.

24.1.4 Scan line mapping

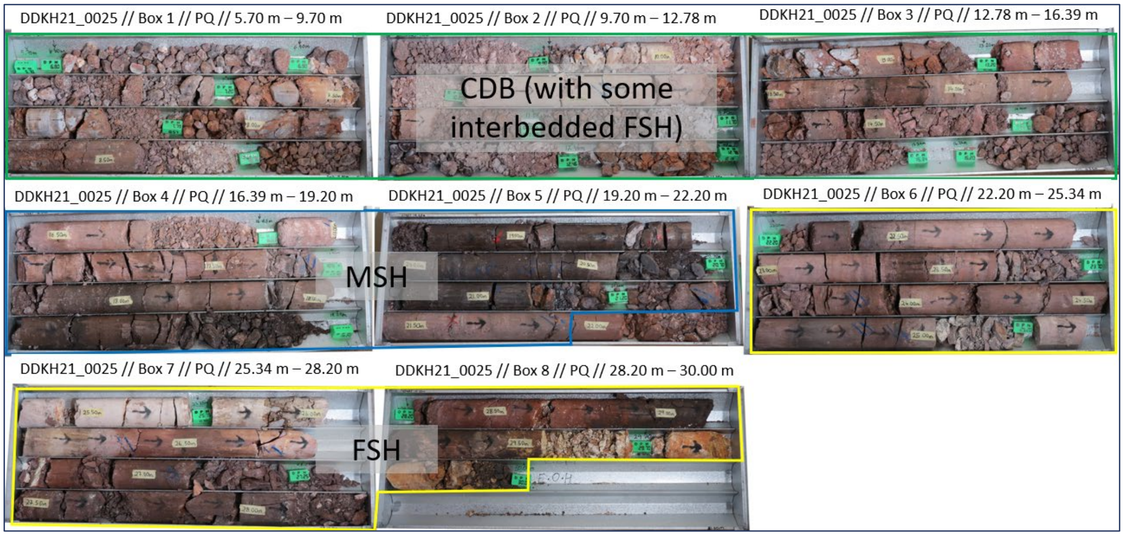
Geotechnical structural mapping of four areas of exposed rock outcrop was completed totalling 86 m and recording 261 structures. The scan line locations are presented on Figure 24.2.

24.1.5 Rock mass characterisation and model

Geotechnical domaining

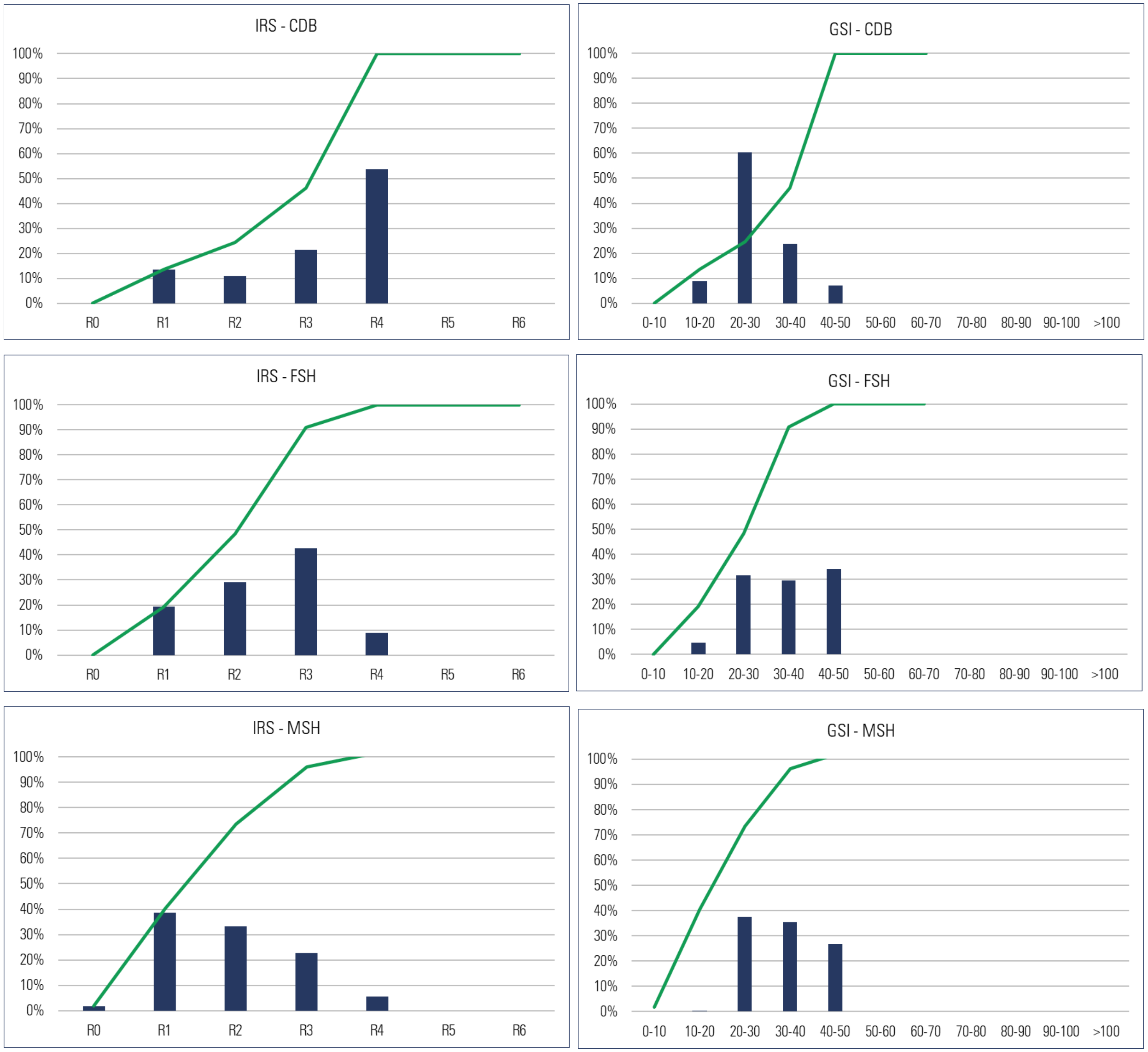
Statistical analysis of the geotechnical logging data was conducted by identifying three separate geotechnical design domains plus overburden. The primary geotechnical domains are based on lithology and comprise chert dolomite breccia (CDB), Fe-shale (FSH), and Mn-shale (MSH). Figure 24.3 presents drillhole DDKH21_0025 with the geotechnical domains labelled.

Figure 24.3 Drillhole DDKH21_0025 illustrating the geotechnical domains



The intact rock strength (IRS) and geological strength index (GSI) distributions of the logging data are displayed on Figure 24.4.

Figure 24.4 Geotechnical domain intact rock strength and geological strength index statistics



	IRS	GSI
Mean	3.4	25.4
Median	4.0	21.7
Mode	4.0	20.4
Maximum	4.0	48.0
Minimum	1.0	11.0
Count	137	137
Length (m)	118.7	118.7

	IRS	GSI
Mean	2.5	32.2
Median	3.0	31.9
Mode	3.0	26.4
Maximum	4.0	48.0
Minimum	1.0	11.0
Count	111	111
Length (m)	129.7	129.7

	IRS	GSI
Mean	1.9	32.8
Median	2.0	33.3
Mode	1.0	26.1
Maximum	4.0	47.8
Minimum	0.0	18.7
Count	41	41
Length (m)	52.9	53.9

The data shows that the MSH domain is slightly weaker than the FSH domain with a mean IRS of R2. Although the SHL unit material properties are sufficiently similar to allow them to form a single geotechnical domain, they have been modelled separately to allow investigation into the effect of a weaker MSH unit.

Universal compressive strength vs logged intact rock strength

To confirm that the estimated field strengths recorded in the geotechnical logging data were sufficiently accurate to utilise as domain material properties, each laboratory UCS test result was plotted against the representative logged estimated field strength (Figure 24.5).

Figure 24.5 Laboratory universal compressive strength vs logged estimated field strength

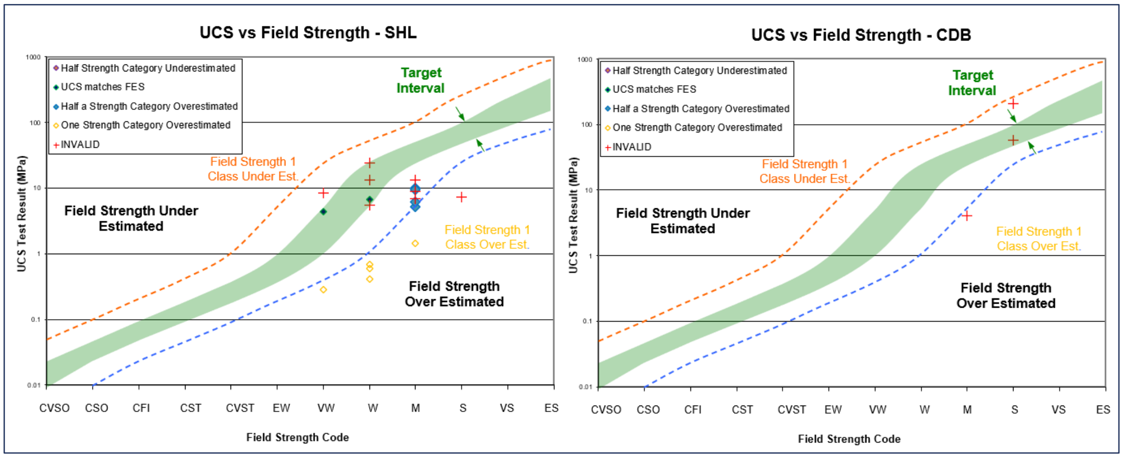


Figure 24.5 shows that all three laboratory UCS tests conducted on the CDB unit were deemed to be invalid due to the laboratory-recorded length to diameter ratios of <2.5:1. The comparison with the logged estimated field strengths for the CDB geotechnical domain are relatively accurate, although the lower than standard length to diameter ratio indicates potentially higher results than would be received if the proportions were within the standard International Society for Rock Mechanics' guidelines. From the available data, it is considered sufficient to utilise the field estimated strength to compile the design material strength for analysis.

Forty-two percent of the SHL samples tested were deemed to be invalid. Approximately 80% of the valid samples tested in the SHL domain were logged as either half or one strength category stronger than UCS testing indicates. For this reason, it is considered appropriate to use the lower bound of the logged field estimated strength as the SHL material design strength.

Geotechnical domain design material properties

From the data interpretation, the geotechnical domain design material properties and likely parameter ranges are presented in Table 24.2. Design unit weights were taken as the average of the unit weights from the UCS testing.

Table 24.2 Design geotechnical domain material properties

Geotechnical domain	UCS (MPa)	RMR89	GSI	mi	Unit weight (kN/m^3)
CDB	75 (50-100)	30 (25-55)	25 (20-50)	9	25.2
FSH	5 (5-50)	37 (25-55)	32 (20-50)	6	22.8
MSH	5 (1-50)	38 (25-55)	33 (20-50)	6	22.8

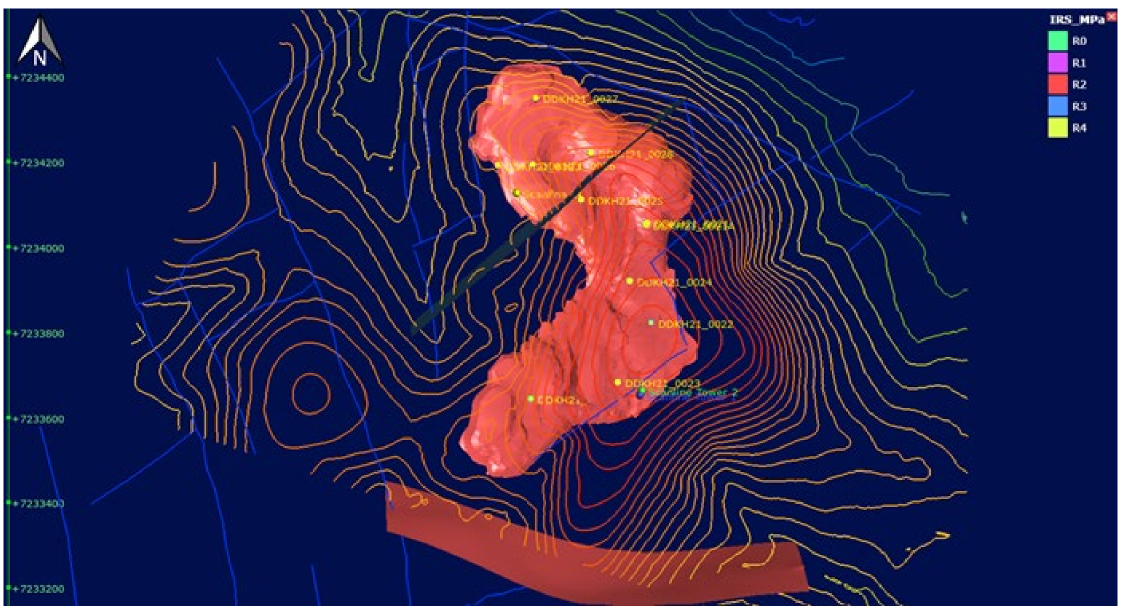
The rock mass at the Project site is determined to be poor to fair quality rock, with intact rock strengths ranging from weak (5 Mpa to 25 Mpa) to strong rock (50 Mpa to 100 Mpa). Therefore, SRK considers that the rock mass properties, in particular the low GSI, will have the largest influence on the slope design and resulting performance. Notwithstanding this, the structural data available from the completed scan line mapping was interrogated for potential kinematic failure modes.

24.1.6 Structural characterisation and model

Structural assessment

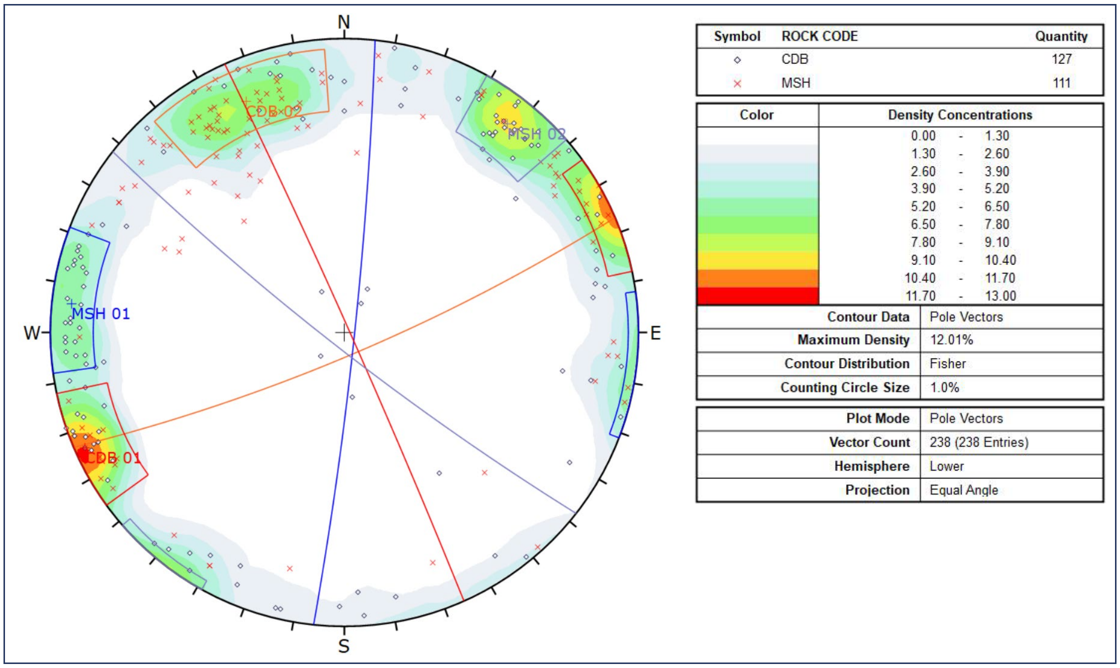
An assessment of the large-scale fault structures was made in relation to the pit geometry, and it was determined that they will be inconsequential to the geotechnical design. Traces of the known large-scale structures are presented on Figure 24.6.

Figure 24.6 Known large-scale structures



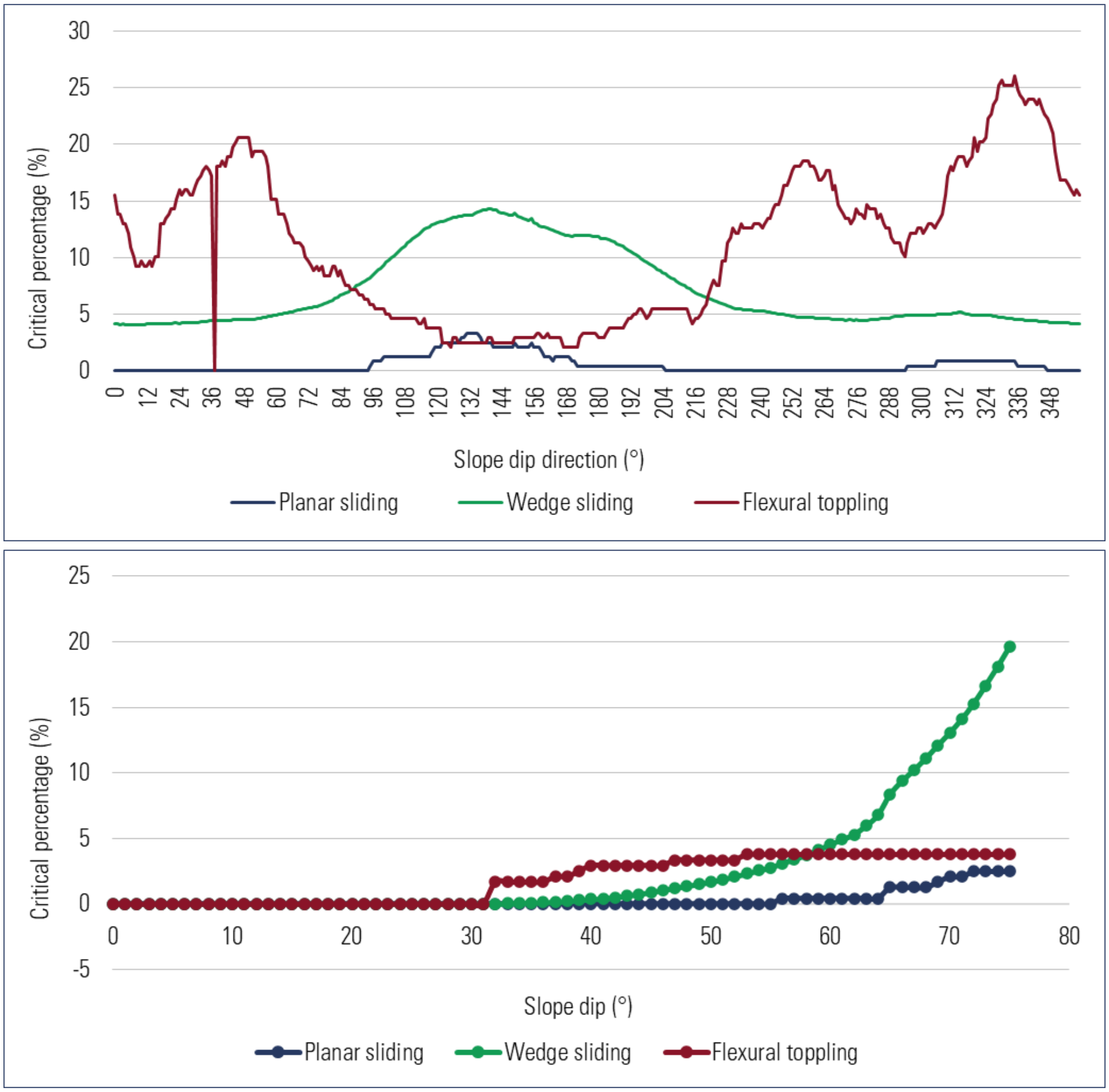
A small-scale structural assessment was completed based on the structural data obtained from scan line mapping of four areas of exposed outcrop. The structures identified were predominantly subvertical with two identified sets for each domain. The identified sets within the CDB unit dip steeply to the ESE and WSW, and the sets within the MSH unit dip steeply to the SSE and ENE (Figure 24.7).

Figure 24.7 Scan line data presenting identified structural sets



Probabilistic kinematics for planar sliding, wedge sliding, and flexural toppling indicate only batter-scale kinematic instability occurs in low percentages (Figure 24.8). It is considered that any structural failure modes can be managed through routine mining processes.

Figure 24.8 Kinematic sensitivity analyses



24.1.7 Slope stability analysis

Limit equilibrium analysis

Two-dimensional limit equilibrium analysis was conducted using industry standard RocScience Inc. software, Slide2; the material properties are presented in Table 24.3.

Table 24.3 Design material properties

Geotechnical Domain	UCS (Mpa)	GSI	mi	Unit weight (kN/m^3)
CDB	75	25	9	25.2
FSH	5	32	6	22.8
MSH	5	33	6	22.8

Due to the shallow nature of the designed wall angles and the simplicity of the proposed pit, only the critical slope sector was modelled. The critical slope was identified as the highest and steepest slope within the SHL geotechnical domain. The identified section is a stack of seven, 4 m high benches totalling 28 m with an inter-ramp angle (IRA) of 41°. Figure 24.9 illustrates the modelled cross section.

The results of the stability modelling indicate that the critical slope sector is sufficiently stable (factor of safety of >1.3) when dry and when partially saturated (Table 24.4).

Table 24.4 Limit equilibrium method design material properties

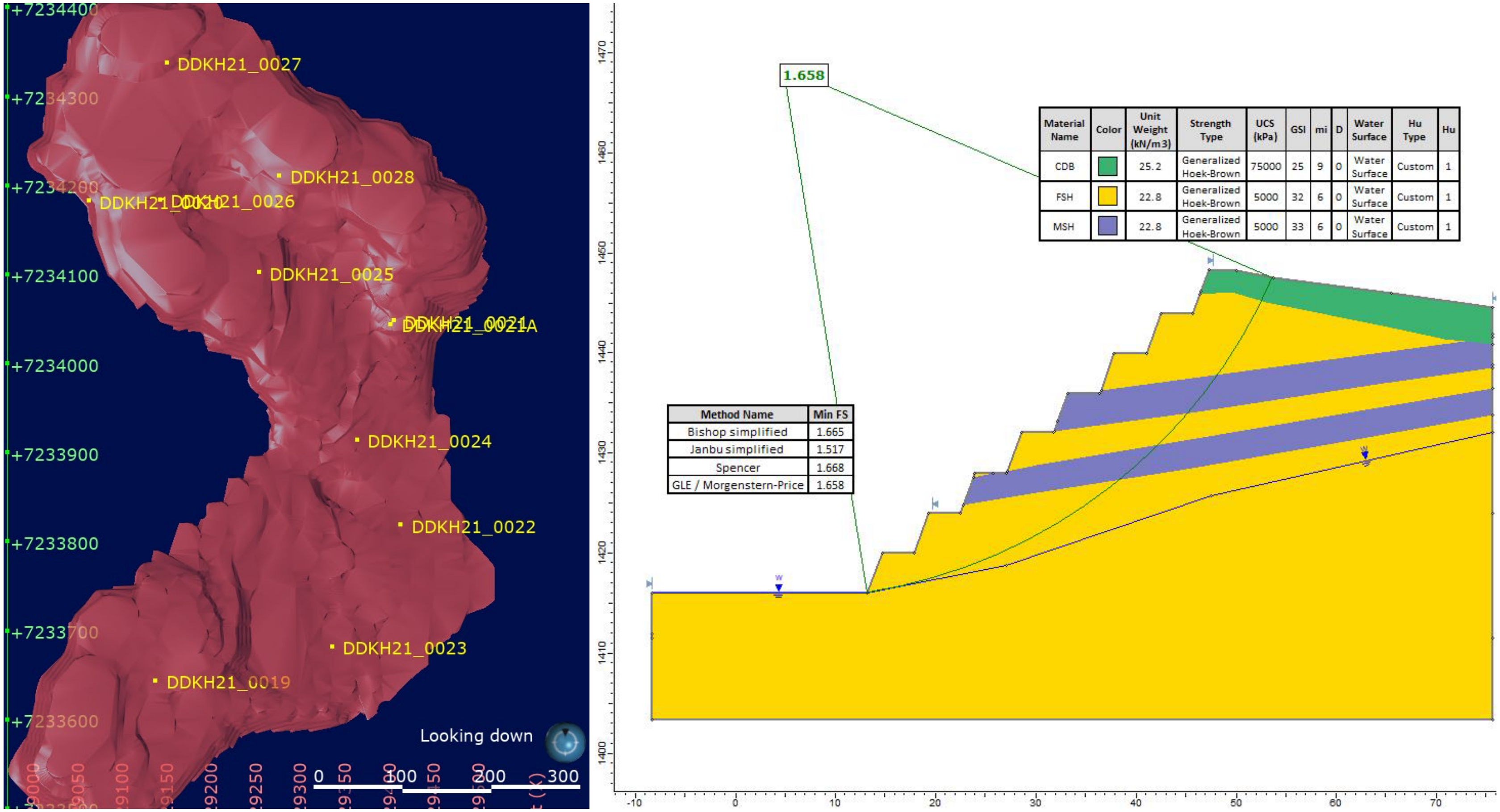
	Bishop Simplified	Janbu Simplified	Spencer	GLE Morgenstern -Price
Dry	1.66	1.55	1.67	1.66
Partially saturated	1.66	1.51	1.67	1.66
Weak layer	1.14	1.11	1.15	1.14

Notes: GLE - general limit equilibrium

Modelling indicates that small-scale batter instability can be expected, particularly in the weaker MSH unit; however, it is expected that this can be managed through routine mining activities.

The possibility of a low-strength layer being present at the base of the MSH was also investigated. Core photographs and geological and geotechnical logging does not indicate the presence of such a layer (Figure 24.10). However, to determine the effect that such a low-strength layer would have on stability, a weak layer was applied to the model within Slide2 at the base of the main MSH unit.

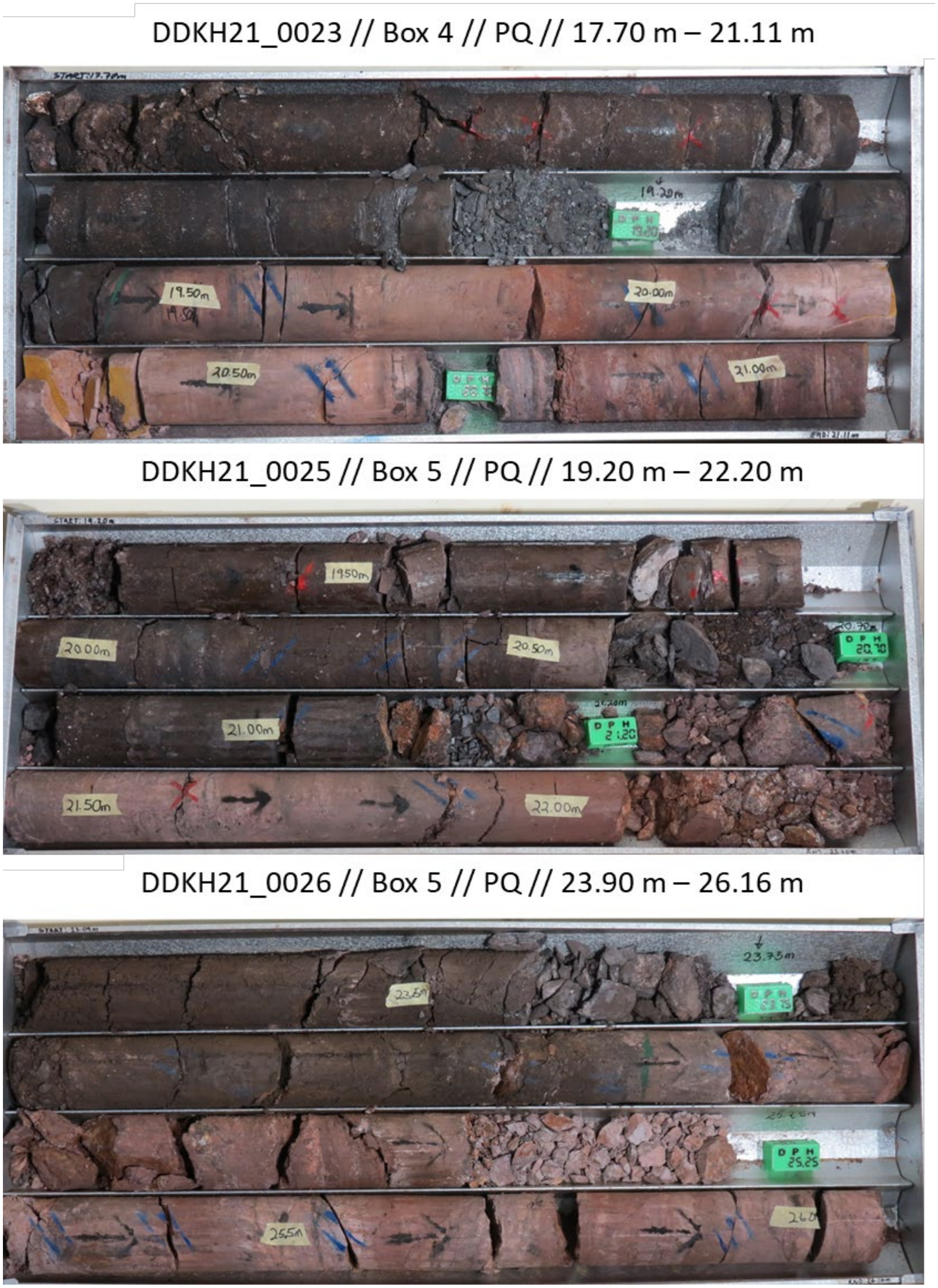
Figure 24.9 Two-dimensional limit equilibrium method analysis of the critical slope sector



Material Name	Color	Unit Weight (kN/m3)	Strength Type	UCS (kPa)	GSI	mi	D	Water Surface	Hu Type	Hu
CDB		25.2	Generalized Hoek-Brown	75000	25	9	0	Water Surface	Custom	1
FSH		22.8	Generalized Hoek-Brown	5000	32	6	0	Water Surface	Custom	1
MSH		22.8	Generalized Hoek-Brown	5000	33	6	0	Water Surface	Custom	1

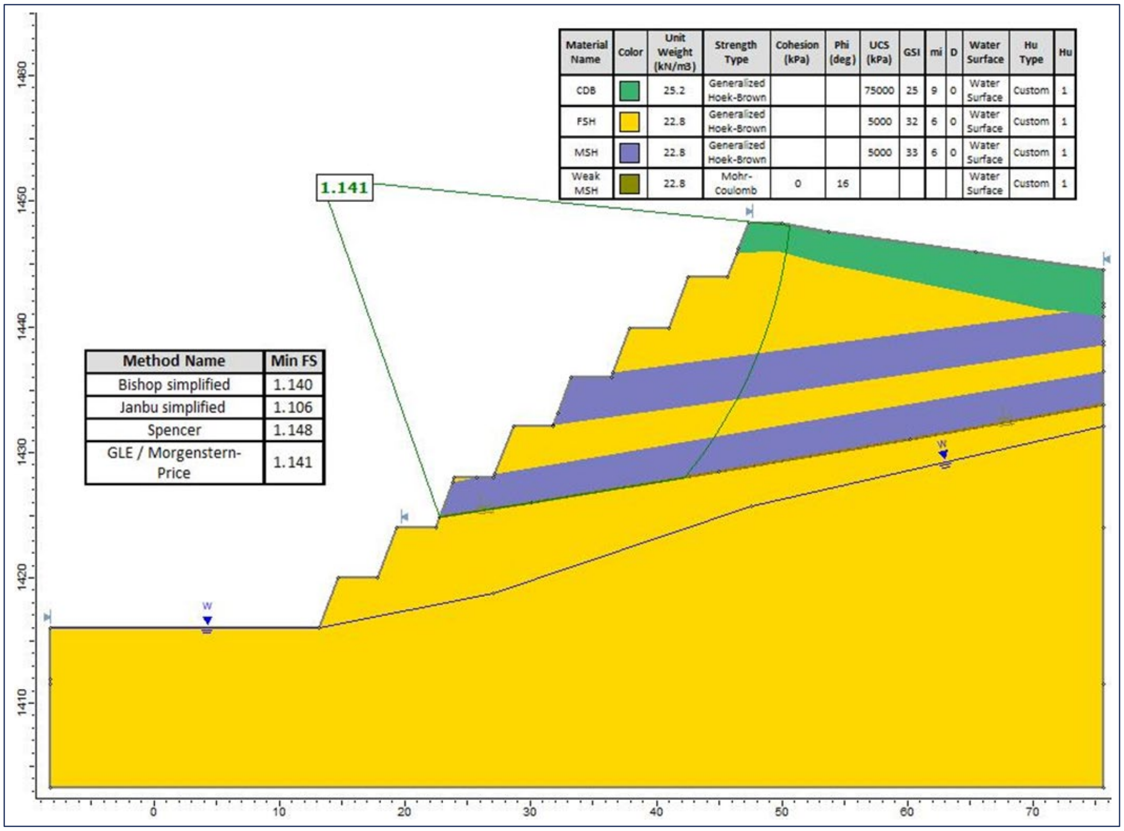
Method Name	Min FS
Bishop simplified	1.665
Janbu simplified	1.517
Spencer	1.668
GLE / Morgenstern-Price	1.658

Figure 24.10 Core photographs of three boreholes illustrating no low-strength layer at the base of MSH



Modelling results show that the slope remains stable but below the design factor of safety, even when unrealistically low parameters (Cohesion = 0 kPA, Phi = 16°) are utilised (Figure 24.11)

Figure 24.11 Two-dimensional limit equilibrium method worst case analysis



24.1.8 Excavatability assessment

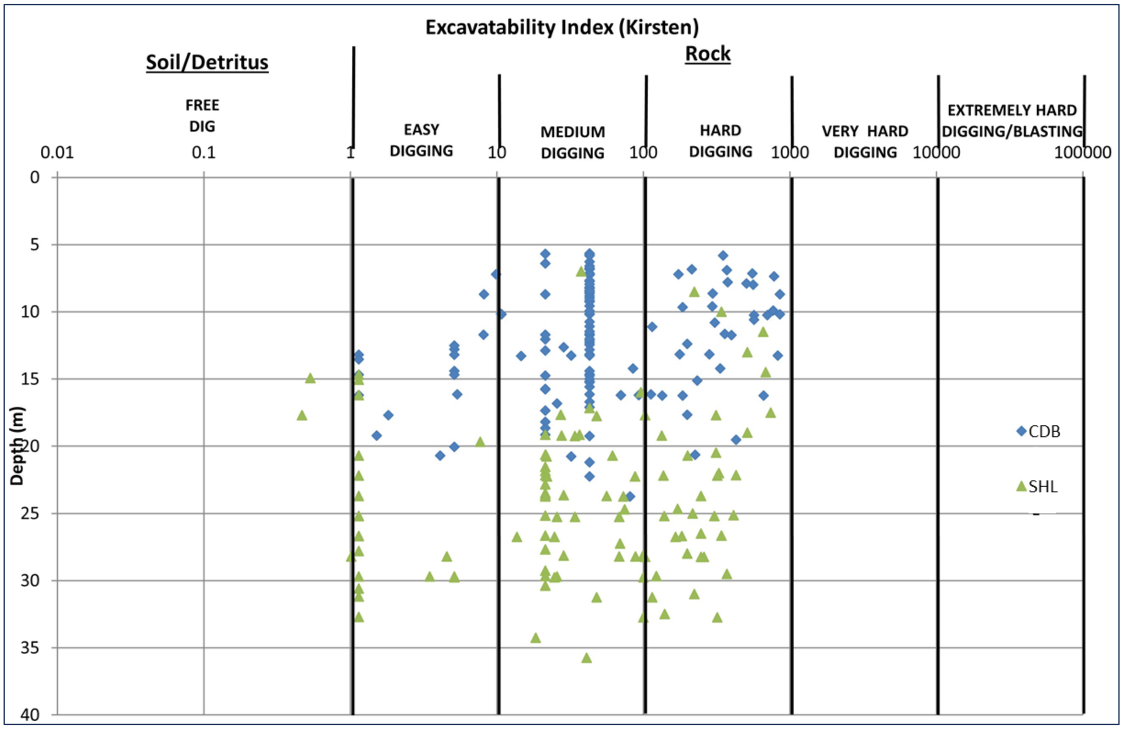
Excavatability analysis

An analysis of the excavatability of the materials encountered during the investigation was conducted utilising the method of Kirsten (1982). A reassessment of the digging classification categories was made with regard to currently available machinery and results have been reported in terms of ease of digging with an excavator, rather than ripping by bulldozer.

All core logging data was utilised to define Kirsten's (1982) excavatability index. The results were then plotted by depth and geotechnical domain (Figure 24.12). Due to the data available, some assumptions have been applied:

- Lower bound shale IRSs were utilised, as discussed in Section 24.1.5.
- Two joint sets were applied, as identified from scan line mapping and discussed in Section 24.1.6.

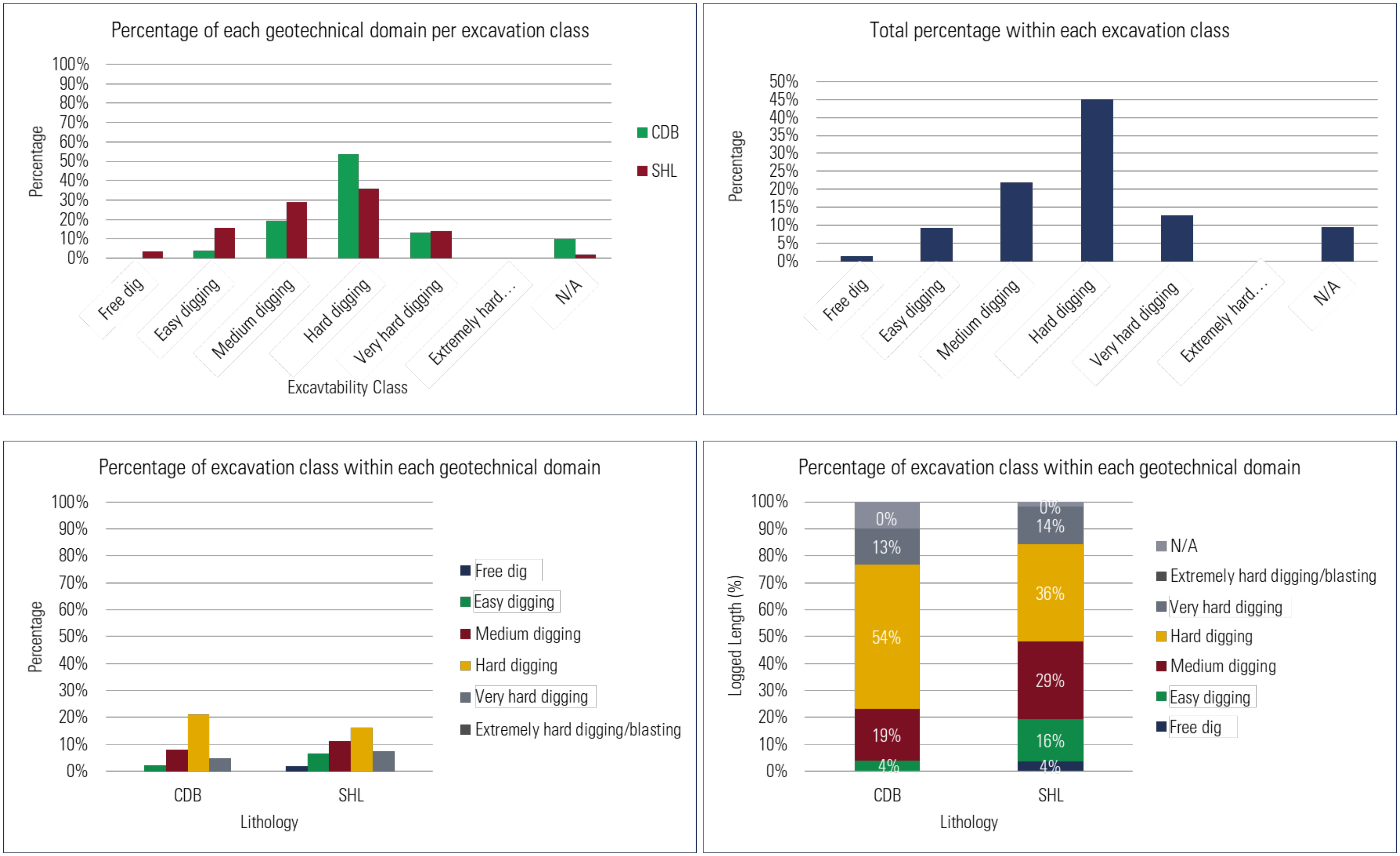
Figure 24.12 Excavatability index vs depth



The analysis indicates that the maximum excavatability indexes (and therefore hardest digging) was found to be in the CDB domain between a 7 m and 13 m depth. Additional charting in Figure 24.13 illustrates a detailed breakdown of the percentages of each excavation class per domain.

The data shows that a total of 45% of the material has been classified as hard digging; 54% of CDB and 36% of SHL fall into this category. Twelve percent of the total material has been classified as very hard digging, including 5% of CDB and 7% of SHL. The assigned Liebherr PR744 crawler tractor will be capable of ripping most of the material in case the excavator has difficulty loosening some of the material. Additionally, it is expected that due to the likely variance in material strength of CDB, small-scale blasting will be undertaken. This will allow for a smooth ongoing operation with minimal downtime and reduced wear on machine tools when very hard or extremely hard digging material is encountered.

Figure 24.13 Percentages of excavation class per geotechnical domain



24.1.9 Recommended bench-berm configuration

Based on the analysis completed, the recommended preliminary bench-berm configuration is to form 4 m high benches at a 70° bench face angle and with a 3.2 m wide berm. This results in an IRA of 41°.

Kinematic analysis indicates that planar-sliding-type, batter-scale instability is more prevalent for slope azimuths of 095° to 205° and 295° to 347°, wedge sliding from 095° to 215°, and flexural toppling from 017°to 075° and 220° to 005°. Batter-scale instability is expected to occur as combined structural/rock-mass-type failure and is expected to be easily managed by routine mining activities.

24.1.10 Limitations and constraints

The preliminary geotechnical slope criteria presented in this section are based on a high-level analysis (due to data and time constraints) and have limitations. Limited small-scale structural information is available. As such, kinematic analyses are of low confidence. However, due to the relatively poor rock mass quality, structural instability modes are not expected to be critical for design.

24.2 Water management

24.2.1 Scope of work

This water management study addresses the following aspects of the FS:

- reviewing climate parameters and estimating storm depth and frequency
- estimating surface water runoff into the pit, sizing of drainage ditches around the WRD, and diversion channel around the TMF
- reviewing site hydrology and hydrogeology and pit dewatering requirements
- providing guidance and review of the processing plant water supply study prepared by a third party

24.2.2 Site physical characteristics

24.2.2.1 Climate review

Data sources

Data are available for the Kanye meteorological station from 1925 to 1985, with gaps in the record for Kanye in 1951, 1952, and 1965. There are no observations recorded for the last 30 years. To cover the gaps in the records and to improve the length of time series for statistical analysis, the precipitation information was complemented with records from the ERA5-Land Climatic Gridded Model[1] (1951-2020) and adjusted with a bias correction technique.

Total precipitation

The information from the ERA5-Land Model was bias-corrected based on the Kanye meteorological station data. Kanye data were then extended to cover a continuous period from 1926 (when records began at the station) to 2021.

Assuming that the historical trend from 1926 holds for recent samples of precipitation from 1990-2020, this would have been shown statistically as well. However, the analysis suggests that although monthly averages are extremely similar, as shown in Table 24.5, statistical parameters relevant for rainfall frequency analysis, particularly for rare and extreme events, indicate slightly higher values in the last 30 years.

Mean annual precipitation (MAP), when calculated for the period of 1926-2020, is 514 mm, whereas the MAP in the past 30 years is 4% higher or 524 mm. Therefore, instead of using the full record, only the period from 1990-2020 was treated as representative of the current period and used for the frequency analysis. The results of the frequency analysis are presented in Table 24.6.

Table 24.5 Site-representative monthly average precipitation (mm) for the complete period of record (1926-2020) and for the last 30 years of records (1990-2020)

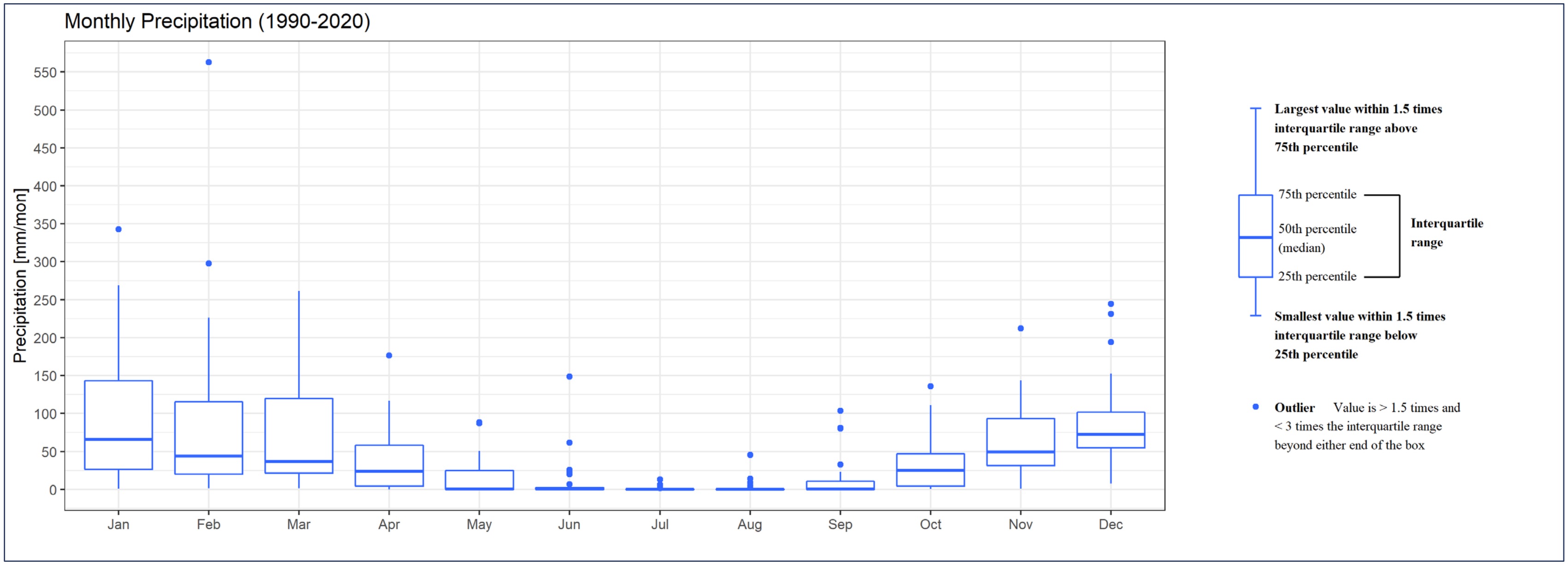
Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1926-2020	96.8	88.8	69.1	36.9	12.8	7.7	2.4	3.2	13.4	38.4	64.0	80.1	514.0
1990-2020	96.9	92.5	69.9	37.0	16.3	10.3	1.0	2.6	12.5	33.2	64.3	87.0	524.0

The monthly precipitation distribution boxplot[2] for K.Hill rainfall for the period of record from 1990-2020 is presented on Figure 24.14. It shows strong seasonal aspect of rainfall trends, with a median rainfall value of almost 0 mm for the months from May to September.

[1] The ERA5-Land Model is a re-analysis dataset providing a consistent view of the evolution of land variables over several decades. The ERA5-Land Model has been produced by replaying the land component of the ECMWF ERA5 climate re-analysis. Re-analysis combines model data with observations from across the world into a globally complete and consistent dataset using the laws of physics. Re-analysis produces data that goes several decades back in time, providing an accurate description of the climate of the past.

[2] The boxplot is a statistical method for graphically depicting groups of numerical data through their quartiles. Boxplots may also have lines extending from the boxes (whiskers) indicating variability outside the upper and lower quartiles, hence the terms box-and-whisker plot and box-and-whisker diagram. Boxplots display variation in samples of a statistical population without making any assumptions of the underlying statistical distribution. The spacings between the different parts of the box indicate the degree of dispersion (spread) and skewness in the data and show outliers.

Figure 24.14 Boxplot showing variation in monthly precipitation for the period 1990-2020



Extreme rainfall analysis

A long-duration precipitation frequency analysis was carried out for the Project site to estimate rainfall depths for different return periods for 24, 48, and 72 h duration storm events.

Daily precipitation depths were corrected by a factor of 1.13 to obtain the 24 h rainfall depth.

Transforming maximum daily rainfall amounts for a single fixed observational interval of 1 h to 24 h by 1.13 yields values close to those to be obtained from an analysis of true maxima, (WMO 2009)

Estimated rainfall depths are provided in Table 24.6.

Table 24.6 Maximum 24, 48, and 72 h precipitation based on the ERA5-Land Model and Kanye weather station for return periods from 2 to 100 years

Return period (years)	Precipitation depth (mm)		
	24 h	48 h	72 h
2	67	82	88
5	97	135	153
10	127	175	205
20	161	215	259
25	173	228	276
50	214	269	331
100	260	310	386

The 24 h rainfall storm associated with the 100-year return period is estimated to be 260 mm, which is almost 50% of the MAP. Sub-daily precipitation depth, or rainfall events lasting for less than 24 h, was not estimated due to the lack of hourly data.

Potential evaporation

Daily potential evaporation was estimated from site latitude and daily mean temperature using the method developed by Oudin (2005). Mean monthly values are presented in Table 24.7.

Table 24.7 Mean monthly potential evaporation at the K.Hill (1951-2020)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Potential evaporation (mm)	167	140	130	93	69	50	54	76	106	140	152	167	1,345

Hydrography

The K.Hill Project is located along a hydrological catchment divide. The site drains into seasonal streams that flow into the Taung River, which is a tributary of the Ngotwane River that feeds and flows through the Gaborone Reservoir just south of the capital city of Gaborone.

Hydrogeology

Aquifer system and groundwater flow direction

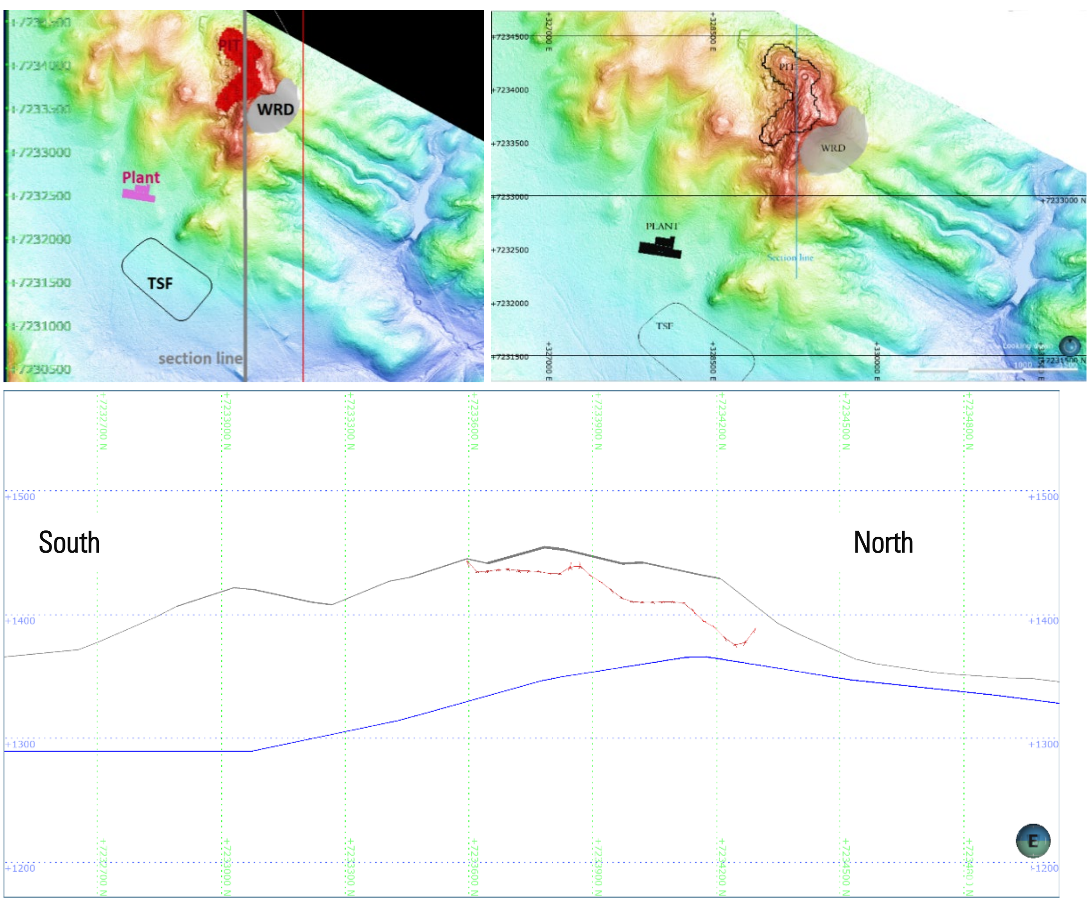
The GCS (2020) hydrogeological report describes the aquifer systems around K.Hill as mainly a low-permeability fractured rock system associated with shales. However, the area further WNW consists of fissured aquifer systems associated with dolomites.

Groundwater level data were obtained from GSC (2020) and suggest that the site is located at a hydrogeological divide, and groundwater underlying the proposed mine site seem to flow mainly SSE. The data suggest the presence of cones of depressions around water supply wellfields operated by WUC.

Position of the proposed pit in respect of the phreatic surface

Using Leapfrog software, SRK combined the final design open pit surface, topography, and phreatic surface in 3D to check the position of the open pit with regard to the water table in order to determine if groundwater management will be required during mine development. The N-S cross section is shown on Figure 24.15 to illustrate the pit position with regard to the water table.

Figure 24.15 North-south cross section of the pit and water table (3x vertical exaggeration)



The cross section shown on Figure 24.15 illustrates that the final open pit position will be located above the water table; therefore, no active groundwater flow management is required for the development of the proposed K.Hill Mine. Surface water runoff will be the main water inflow to be managed at the mine, which is addressed in Section 24.3.2.

While no groundwater inflow is expected into the mine, monitoring of the groundwater level and quality is required to inform any impact on local water resources.

24.2.3 Surface water management

Approach

SRK estimated surface water runoff for the pit, WRD, and stream diversion around the TMF. The Rational Method was used in the estimation of peak flows, as this method makes use of drainage catchment and runoff coefficient.

The open pit area and potential contributing catchments were calculated from the pit shell files provided by the mine design team. The following runoff conditions were considered in the estimation to provide a range of potential inflows into the pit:

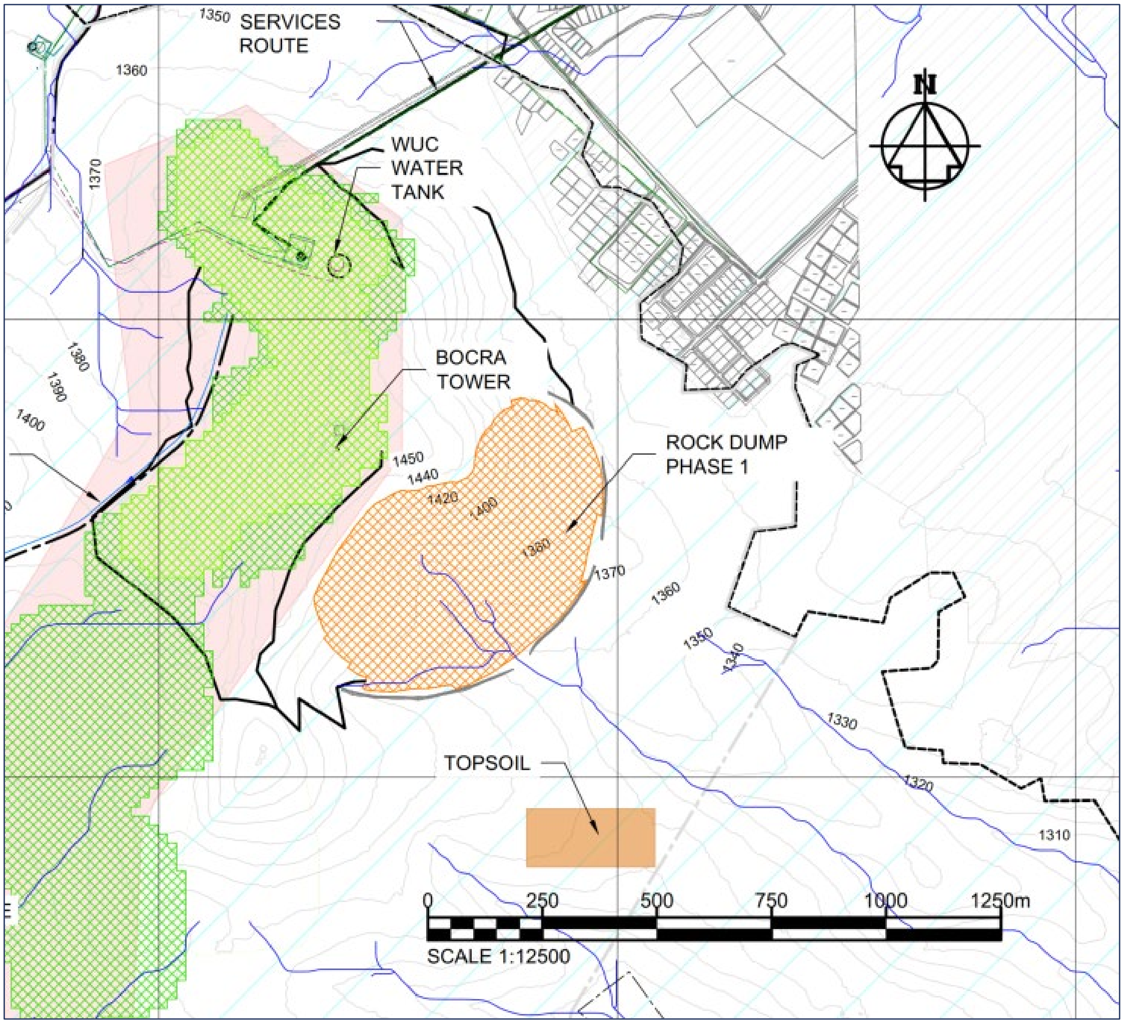
- 70% runoff coefficient on the pit wall
- 24 h, 48 h, and 72 h runoff rates after extreme storm event rainfall

For the WRD catchments and the diversion around the TMF, the same simple Rational Method was used for runoff estimation. The return periods chosen to size the diversion ditches around the WRD and the diversion channel around the TMF are 50 years and 100 years, respectively.

Pit surface water runoff estimation

The final design open pit and WRD footprints are shown on Figure 24.16. The open pit is located in the uppermost part of the catchment, which implies that pit inflow will consist of direct runoff into the pit only and that inflow from the surrounding area should not have to be collected and diverted.

Figure 24.16 Open pit and waste rock dump drainage network



The estimated surface water inflow volumes to the open pit throughout the LOM are summarised in Table 24.8 for 2-year, 10-year, and 100-year return periods and 24 h, 48 h, and 72 h storm durations.

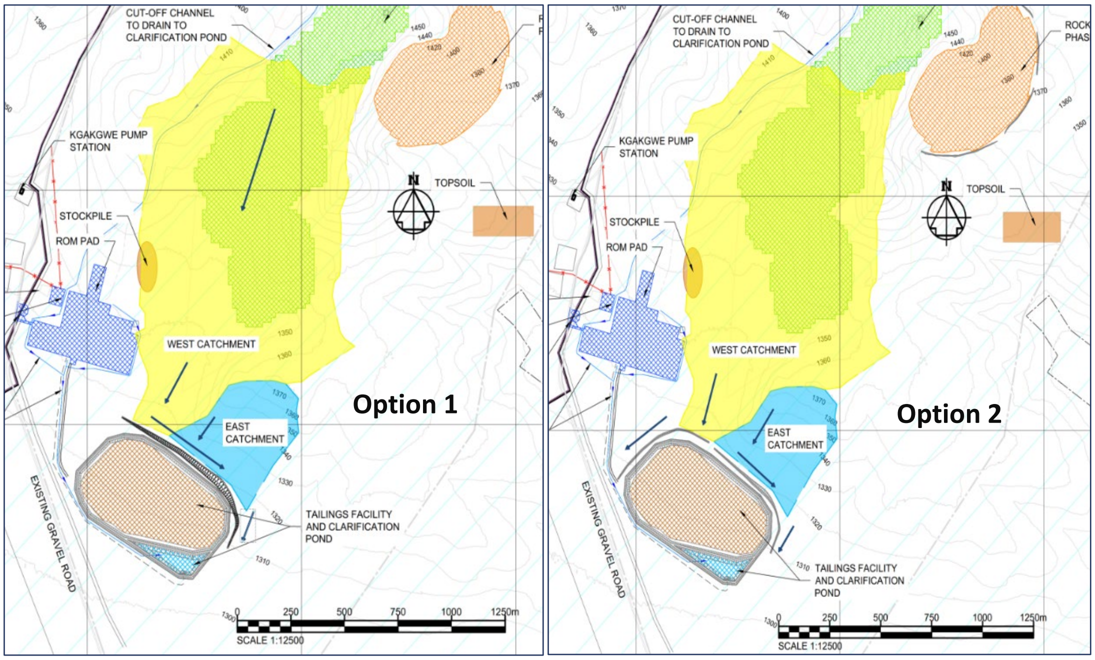
Table 24.8 Estimated surface water inflow volumes to the pit throughout the life of mine

Pit shell year	Surface water inflow volumes (m^3)		
	Storm event duration		
	24 h	48 h	72 h
2-year return period			
Year 1	3,808	4,879	5,236
Year 2	6,039	7,738	8,304
Year 3	8,387	10,745	11,532
Year 4	10,524	13,483	14,470
Year 5	11,558	14,809	15,893
Year 6	12,616	16,164	17,347
Year 7	13,395	17,163	18,418
Year 8	13,395	17,163	18,418
10-year return period			
Year 1	7,557	10,413	12,198
Year 2	11,984	16,513	19,344
Year 3	16,642	22,932	26,863
Year 4	20,883	28,775	33,708
Year 5	22,936	31,605	37,023
Year 6	25,034	34,496	40,410
Year 7	26,581	36,628	42,907
Year 8	26,581	36,628	42,907
50-year return period			
Year 1	12,733	16,006	19,695
Year 2	20,193	25,383	31,233
Year 3	28,043	35,250	43,374
Year 4	35,188	44,232	54,426
Year 5	38,648	48,581	59,779
Year 6	42,184	53,025	65,247
Year 7	44,790	56,302	69,278
Year 8	44,790	56,302	69,278
100-year return period			
Year 1	15,470	18,445	22,967
Year 2	24,534	29,252	36,423
Year 3	34,070	40,622	50,581
Year 4	42,752	50,973	63,470
Year 5	46,956	55,986	69,712
Year 6	51,251	61,107	76,088
Year 7	54,418	64,883	80,790
Year 8	54,418	64,883	80,790

Tailings management facility catchment diversion channels

Due to the flat topography at the NW corner of the proposed TMF site, two options of stream diversion are possible at this location, as illustrated in Figure 24.17.

Figure 24.17 Tailings management facility upstream catchment areas and drainage channel options



In order to assess the feasibility of both options, including cut-and-fill analysis, the preliminary design of the channel was prepared in Autodesk Civil 3D® software. Key findings from cut-and-fill tables and longitudinal sections presented in drawings are summarised in Table 24.9.

Table 24.9 Channel options comparison

Options	Cut (m^3)	Maximum trench depth (m)
Option 1 (two channels)	9,794	1.7
Option 2 (one channel)	36,777	3.0

Option 1, with two channels, will require less trench depth and almost four times less earth cut. Therefore, Option 1 with two collection channels is recommended for the next design stage.

Waste rock dump runoff and seepage assessment

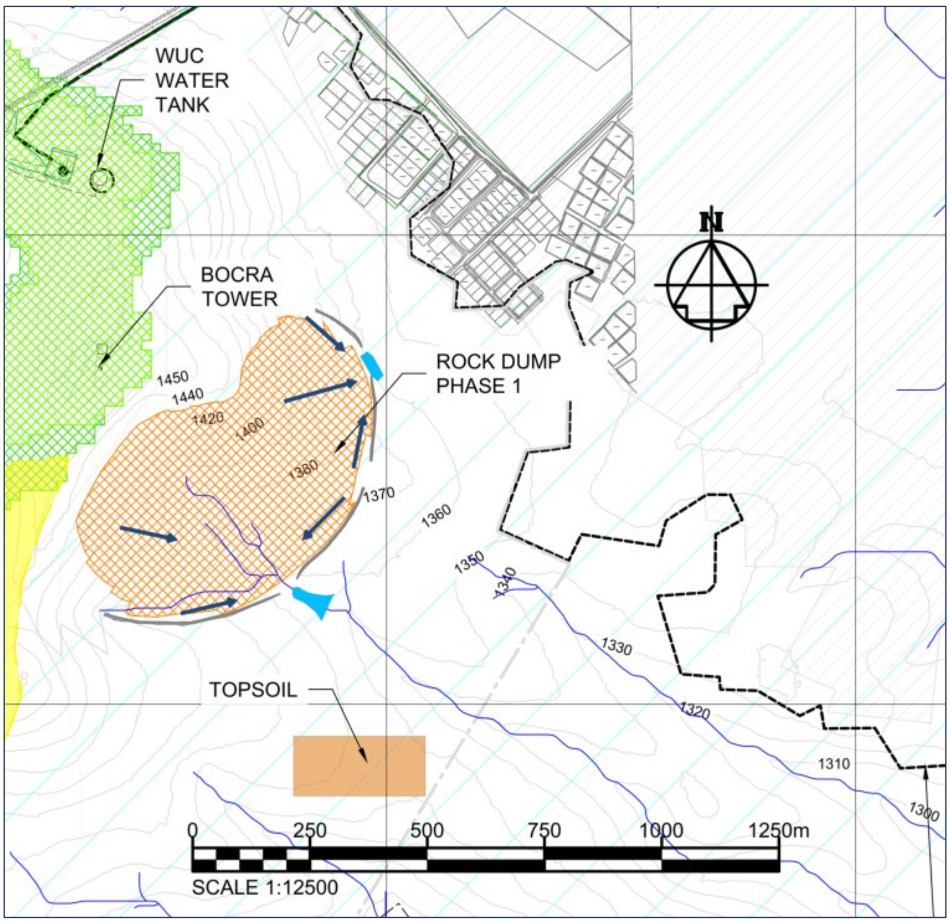
It is assumed that the WRD runoff (and seepage) will follow the topography of the existing terrain, draining in an E-SE direction, as depicted on Figure 24.18.

WRD water management has to account for two potential inflows:

- surface water runoff
- lateral seepage

The drained water will be intercepted by collection channels along the southern and eastern boundaries of the WRD. This water will be channelled to the low topographic points south and east of the WRD, where a sedimentation pond in each location is proposed to control settling of suspended solids and water quality.

Figure 24.18 Schematic of the waste rock dump seepage and collection system



For channel sizing, the WRD runoff was estimated using a 35% runoff coefficient, and two design storms of 24 h duration: 10-year and 50-year return periods, as shown in Table 24.10.

Table 24.10 Estimated diversion channel runoff

Runoff area	Area (m^2)	Return period (L/s)	
		50-year	10-year
North	72,900	63.20	37.50
South	199,240	172.72	102.50

24.2.4 Project water supply

SRK specified the scope of work and provided technical guidance to Rotsdrill Explorations to complete a field programme to find water. The work was very successful and met all targets.

The water demand is 49 m^3/h for ore processing. It is understood that the site work force will be located in Kanye, which has its own domestic and potable water supply system. Workers will be provided with bottled water for drinking at the site.

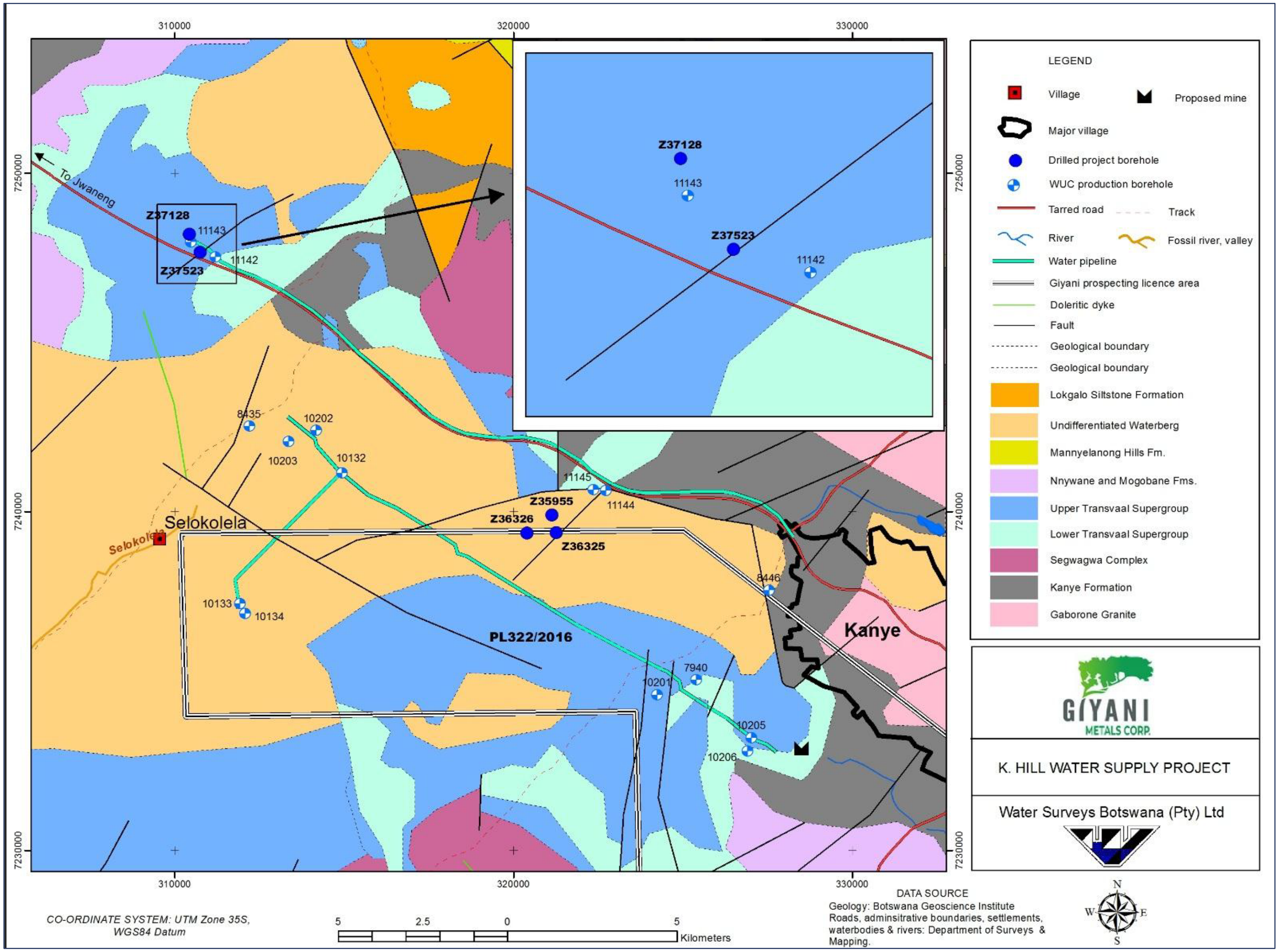
Few options for plant water supply have been envisaged as part of the FS. An option of using water supply from local reservoirs has been envisaged in project team discussions during the early stage of the study. However, it appears that water from the two reservoirs near Kanye is limited and such option was discarded. Catchment delineation using Shuttle Radar Topography Mission data shows that the area of the catchment of the reservoir south of Kanye is around 32 km^2.

The possibility to obtain water from the supply network of WUC was discussed between Giyani and WUC. The latter supplies water to the town of Kanye and confirmed it will provide only 20 m^3/h to the Project. An additional 40 m^3/h supply should be sourced from elsewhere. SRK suggested the option of treated water from the Kanye town sewage treatment plant; however, the option was considered difficult.

The final option, considering the limited amount of water required for the Project, is to use pumping wells to supply groundwater to the facilities. A surface geophysical survey was carried out by a local company, and the location of two groundwater exploration boreholes was identified in an area NW of the mine, adjacent to the proposed mining licence area. The location of the groundwater exploration area (including geophysical profiles) with respect to existing water wells and the pipeline of WUC is shown on Figure 24.19 on a geological background map, with the five wells drilled as a part of this Project shown as blue dots. The provisional locations of the five boreholes, drilled to an approximate 200 m depth, are depicted with green dots on satellite imagery on Figure 24.20.

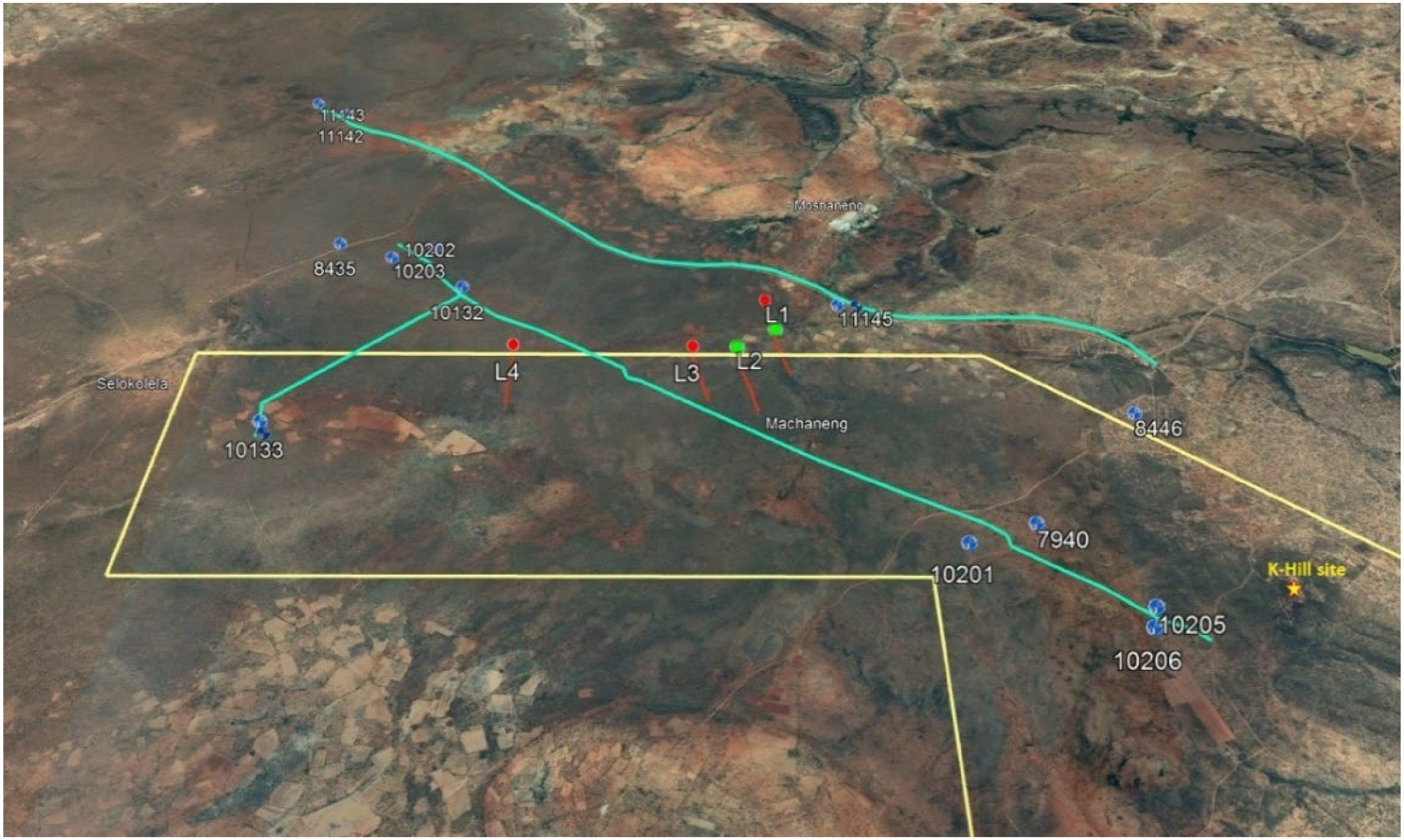
Giyani was able to demonstrate that the boreholes they drilled could supplement the WUC water supply sufficiently to secure the 49 m^3/h of water from WUC at a point adjacent to the processing plant.

Figure 24.19 Location of the groundwater exploration area with respect to the K.Hill site, existing water utility water supply wells and pipelines, and geology



Note: Boreholes drilled for the K.Hill Project water supply are shown as blue dots.

Figure 24.20 Location of the two groundwater exploration boreholes (green dots) with respect to the K.Hill site and the existing water utility water supply wells and pipelines



Source: Giyani and WUC

Drilling and hydraulic testing

Rotsdrill Exploration conducted drilling at three locations during Phase 1 within the Waterberg Formation (Sites, S1 [Z35955], S2 [Z36326], and S3 [Z36325]), and in two locations during Phase 2 within the Transvaal-Supergroup dolomites (Sites S6 [Z37128] and S7 [Z37523]), These locations were chosen based on the results of the geophysical survey conducted at the K.Hill site. Two of the boreholes within the Waterberg Formation (S1 and S3) did not encounter any major water strikes and only minor water seepage was seen; therefore, these boreholes were excluded from hydraulic testing. A comprehensive summary of borehole construction, lithology, water strikes encountered, and hydraulic testing results can be found in Appendix D.

The following hydraulic tests were carried out at boreholes S2, S6, and S7:

- calibration test: 5 × 15 min steps
- step test: 5 × 60 min steps
- 72 h constant rate test (CRT)
- recovery monitoring: 95% of static level or up to 24 h

Step-test data were analysed using the Hantush-Bierschenk method within DWA Test Curve 9.5 software, and CRT test data was analysed using the Theis recovery method. Owing to equipment availability, boreholes S6 and S7 were under pumped (i.e., the maximum pumping rate applied during hydraulic testing [55 to 65 m^3/h] did not produce a significant drawdown of the water table). A summary of the hydraulic testing results is shown in Table 24.11.

Table 24.11 Hydraulic testing results

BH ID	BH depth (m)	Dev. yield (m^3/h)	Pump intake depth (m)	Rest water level (mbmp)	Available drawdown to pump intake (mbgl)	Calibration test			Step test			CRT			Recovery	
						Step	Yield (m^3/h)	Drawdown (m)	Step	Yield (m^3/h)	Drawdown (m)	Duration (h)	Yield (m^3/h)	Drawdown (m)	Duration (h)	Residual drawdown (m)
Z36326 (S2)	205	25	156	57.29	100???	1	6	7.54	1	5	7.82	72	20	53.99	9	2.62
						2	12	13.8S	2	10	15.62	-	-	-	-	-
						3	16	22.46	3	15	30.22	-	-	-	-	-
						4	24	45.31	4	20	45.48	-	-	-	-	-
						5	28	60.27	5	25	64.14	-	-	-	-	-
						6	31	72.59	-	-	-	-	-	-	-	-
Z37128 (S6)	97	29	67.99	50.54	10	1	5	0	Not undertaken			72	55	0.19	12	0.03
						2	15	0.02				-	-	-	-	-
						3	25	0.04				-	-	-	-	-
						4	35	0.06				-	-	-	-	-
						5	55	0.12				-	-	-	-	-
Z37523 (S7)	115	97.9	96.24	48.18	-	Not undertaken			1	13	0.05	72	65	1.28	12	0.04
									2	26	0.37	-	-	-	-	-
									3	39	0.64	-	-	-	-	-
									4	52	0.9	-	-	-	-	-
									5	65	1.2	-	-	-	-	-

Recommended abstraction rates

The sustainable borehole yield for borehole S2 was interpreted using DWA Test Curve 9.5 software, whereas boreholes S6 and S7 were not interpreted due to the low drawdowns encountered during CRT testing due to under pumping. The magnitude of the water strikes encountered and data obtained from CRT testing do not, however, indicate that a pumping rate of 50 m^3/h during a 12 h pumping day would be sustainable over the next 10 years for these two boreholes. Based on the analysis of borehole S2, a pumping rate of 20 m^3/h during a 16 h pumping day over a 10-year period is deemed sustainable.

Figure 24.21 Water strike at 66 mbgl at borehole S7

Water quality

Laboratory testing of water samples from the five water supply boreholes were taken and analysed for major anions and cations as well as total suspended solids (TSS) and biological oxygen demand (BOD) and chemical oxygen demand (COD), important factors in ore processing at K.Hill. These data were then compared to BOS 32:2015 local Botswana drinking water standards.

Of all the water samples taken, all eight were above the recommended manganese limit, and four of the eight were above the recommended iron limit. All other ions analysed fell within BOS 32:2015 standards. This should not have any impact on ore processing. TSS, BOD, and COD levels were all within acceptable limits.

24.3 Project execution plan

The PEP sets out the way the scope presented in this report will be designed, procured, built, and commissioned. The PEP includes a description of activities to be undertaken leading up to project execution, execution scope, strategy, schedule, project governance, and the approach to be taken to comply with HSE guidelines and best practices.

24.3.1 Post-feasibility study activities

Giyani will undertake the following post-FS activities to continue to optimise aspects of the Project, develop opportunities, and mitigate residual risk. Key work streams will include the following:

- Demonstration Plant: The demonstration plant is under construction in South Africa and will be assembled in road transportable modules. The objective is to transport the demonstration plant to Botswana after producing sufficient product sample for off takers, where it will be used for training the operations team and testing ore from other deposits.
- Optimisation Test work: Following completion of the FS metallurgical test work described in Section 13, Giyani will implement some of Tetra Tech/IHC's key recommendations. This includes material characterisation to support final equipment selection, such as solid-liquid separation and rheology tests. Many of these tests will be completed by vendors or specialist laboratories using intermediate product produced in sufficient quantity by the demonstration plant.
- Value Engineering: Giyani will undertake a value engineering programme as part of the final optimisation of the Project scheme prior to commencing basic engineering. Value engineering will include:
  - optimising the selection of dewatering equipment
  - optimising crystalliser and hydrometallurgical plant configuration to optimise net revenue as a function of manganese recovery and operating cost

24.3.2 Project scope

The scope of the Project execution, after receipt of all necessary permits and approvals from authorities, will include the following areas:

- Mine: All vegetation will be cleared and any topsoil removed from the open pit area, WRD, and ore stockpile sites. Production with an owner-operated fleet can then start immediately.
- Processing Plant: All vegetation will be cleared and the pads prepared for plant construction. The plant will be constructed as described in Section 18, including all foundations, concrete, steel, equipment, electrical, and instrumentation and access.
- TMF: Site clearing and grubbing and removal of 0.5 m of topsoil will take place. Foundation will be prepared, perimeter drains constructed, and installation of geomembrane. The pond

will be constructed and return water pump and return pipeline will be installed along the tailings haul road.

- On-site Infrastructure: All vegetation will be cleared and pads prepared for building erection. Components of infrastructure will be constructed, as described in Section 18, including all foundations, concrete, steel, equipment, and power supply. Key components include:
  - perimeter fence, gatehouse, and weighbridge
  - administration, warehouse, and workshop buildings
  - wastewater treatment plant
  - site roads, parking, and laydown areas
  - main substation and power distribution to switch rooms
  - explosive storage facility
  - fuel farm
- Off-site Infrastructure:
  - main access road from the B202 highway to the main gate
  - water boreholes and connecting pipeline to feed into the WUC water network and water pipeline to extract water via the WUC pump station to a termination point at the gate
  - solar plant
  - HV power supply to be provided by BPC
- Existing Infrastructure Relocation: K.Hill is a brownfield site that is disturbed by old workings, a communications tower (BOCRA), WUC water reservoirs, concrete strip roads, lots of tracks, and evidence of waste dumping. Giyani will work with the owners and local authorities to relocate the following existing infrastructure from the site:
  - Two water reservoirs that are part of WUC's water supply system to Kanye. A site has been identified for construction of the new reservoirs. The reservoirs will be built and commissioned before the existing reservoirs are demolished.
  - A BOCRA spectrum monitoring tower on top of the hill will be dismantled and relocated to a site north of Kanye.
  - Two active LV three-phase power lines cross the site and will have to be rerouted.

24.3.3 Project execution strategy

Project objectives

The K.Hill Project will be executed to achieve the following Project objectives:

- compliance with the management and monitoring plans set out in the ESIS, conditions that the DEA will apply to the environmental authorisation, and other conditions stipulated in the mine permit
- compliance with HSE management plans, monitoring plans, policies, and procedures
- on-time and on-budget Project execution

Project delivery model

The K.Hill Project will be delivered in an EPCM project delivery whereby the Project scope will be divided into a number of work packages. The engineering consultant firm that is selected as the EPCM contractor will be responsible for providing all aspects of EPCM for certain work packages, but some work packages may also be self-performed and managed by the owner's project team.

Stakeholders

Stakeholder engagement will be managed through an SEP that applies to the K.Hill LOM (i.e., from construction to rehabilitation and closure). The SEP will incorporate and build on the consultation associated with the ESIS. Stakeholder engagement will comply with legislative and regulatory requirements and conform with international standards. Stakeholders are classified as directly and indirectly affected parties and are grouped as follows:

- authorities at local, regional, and national levels:
  - national level: ministries, government departments, government agencies for economic development, tax authorities, and other regulatory oversight
    - key departments include the Departments of Mines, Environmental Affairs, Water and Sanitation; and National Roads
  - local authorities: Kanye Administrative Authority, District Council, Paramount Chief and other Chiefs, VDCs, and land boards
- communities and land users: these are mostly directly affected parties including the population of Kanye, the communities represented by the 17 VDCs, farmers, those using access routes across or adjacent to the K.Hill Project, and residents/businesses along access routes
- the K.Hill Project workforce: employees and contractors
- national utility companies: power company (BPC), water and sewage company (WUC), and telecommunications company (BOCRA)
- service providers: fire department, police, traffic police, emergency response/ambulance (public and private), and hospitals and clinics (public and private)
- suppliers of materials and goods such as fuel, building materials, and reagents
- off-takers and customers

Engineering

The engineering design will meet technical, regulatory, and functional requirements. After completing the FS and undertaking value engineering, the design for the K.Hill Project will move into basic and then detailed engineering.

Long-lead items will be specified for procurement during basic engineering, and general equipment and instrumentation specification will be specified for procurement at the start of detailed engineering. Readily available off-the-shelf equipment will be selected where possible, taking care to consider maintenance and spare requirements throughout the LOM.

Even though Giyani will seek to use local fabricators, it is anticipated that most of the equipment and bulk materials will be sourced from Southern African vendors and fabricators or imported via South Africa. Plant and infrastructure components will be preassembled as much as possible in road transportable units to minimise erection time on site.

Various engineering firms will be employed to design each of the major speciality areas:

- mine
- plant and general infrastructure
- TMF
- solar plant
- external infrastructure

Procurement

Procurement will be managed on behalf of Giyani by each of the engineering firms. The following general principles will be applied:

- Pre-qualification: Engineers, consultants, suppliers, and contractors will be pre-qualified following HSE, legal, and financial due diligence. Shortlisted vendors will have a demonstrated track record and the capacity to deliver and service Southern Africa.
- Complete Life-cycle Procurement: Equipment and spares will be sourced from vendors that can continue to provide parts and services throughout the LOM. Local component distribution warehouses will alleviate the site inventory and associated working capital. Rationalisation of the vendor list to encourage commonality in spares and more effective supply chains will be supported by a standardised criteria in the engineering phase. The latter will require the identification of key vendors during basic engineering, as these suppliers will become partners in the engineering process. Partnership opportunities include:
    - pumps and valves
    - instrumentation
    - filters

- Tender Process: A request to tender will be sent to a minimum of three shortlisted companies. The tender procedure will be fair and transparent with every step documented and auditable.
- Specialist Vendor Packages: The crystallisation and effluent treatment plants are examples of bespoke packages designed by specialist vendors. To secure their services and finalise the process design during basic engineering, these procurement packages will be advanced at the outset.

Contracting strategy

Giyani will distribute the works over several key contracts selected following a formal tender process. Contractors will be identified and shortlisted as per the pre-qualification process; contracting with a Botswana legal entity will be considered an advantage.

Commissioning

The owner's EPCM team will have a dedicated team to facilitate commissioning and handover to operations. Commissioning will be undertaken by a specialist consultant on hydro-metallurgical systems who will be integrated into the owner's EPCM team and brought on board during the pre-commissioning execution phase to prepare and finalise the commissioning plan. This team will be responsible for managing the equipment vendor representatives.

A four-stage commissioning schedule will be prepared.

Stage 1: Dry commissioning

Under dry commissioning the processing plant is run under manual control and then under automatic control without water or ore flow. During this period, plant equipment will be adjusted with controls systems and interlocks proven protection tested.

Stage 2: Wet commissioning

During wet commissioning the plant will run under manual and then under automatic control with only water. Instrumentation and automation can be tested, and additional adjustments can be made. Before continuing to the next stage in commissioning, all critical punch-list items related to the safe intended use of the plant need to be closed out. At this stage, the quality control system and standard operating procedures for hazardous reagents will need to be in place.

Stage 3: Load commissioning

The objective during load commissioning is to make the first commercial product to specification. The processing plant will first receive low-grade ore, and reagents will gradually be introduced into the process. After adjustments, ore to specification will be introduced. Once there is first commercial product, the hand over from the commissioning team to Giyani's operations team will commence section by section. Both teams remain on the Project as responsibilities are exchanged.

By this time, the construction management team has closed out all punch-list items and handed over any remaining documentation. Contractors will be fully demobilised from site. From this point, any remaining punch-list items are now managed by Giyani's operations team.

Stage 4: Ramp up

The objective of the ramp up is to bring production to full design capacity and delivery on the recovery rates and operational costs; this is the responsibility of Giyani's operations team. The commissioning team will gradually be demobilised.

External utilities such as water and grid and solar power supply will be undertaken by the appropriate contractor for these works.

Stage 5: Handover

Project handover will include several smaller handovers by area. The project team, represented by the project manager, will handover to the operations team, represented by the plant manager. Once an area of the K.Hill Project has been handed over, the operations team takes on full responsibility (e.g., for maintenance, paying utility bills, etc.); the project team will continue to use items handed over (e.g., power, roads, water, etc.).

24.3.4 Project execution schedule

Sequence

The Project will undergo the design and construction of major components, for example the plant and TMF. Construction in each of these areas will go through typical phases of engineering, procurement, delivery, fabrication, and construction. These phases are sequential but can partly overlap to compress the schedule. The start of every phase is represented by a milestone in the Project execution schedule, which serves as a decision gate to ensure the risk assessment for the Project is updated and that conditions are met to commence with the next phase.

A basic sequence of major activities underpins the Project execution schedule. These activities include, in approximate chronological order:

- finalising the Project Description and basic engineering scope of work following the completion of value engineering
- completing a tender enquiry and subsequent appointment of the key technology partners for the design and supply of specialist vendor packages
- completing a tender enquiry and appointing the EPCM contractor
- completing a tender enquiry and appointing the contractors to relocate the existing site infrastructure, including the water reservoirs and the high-voltage power supply

- specifying and completing the final material characterisation test work
- completing the plant basic engineering phase to produce the following typical deliverables:
  - process design package, including PFD's, mass balance, PDC, and control philosophy
  - Project specifications, including general, mechanical, structural, civil and earthworks, electrical, control and instrumentation, and site conditions
  - discipline design criteria
  - mechanical equipment list
  - long-lead item specifications and associated procurement packages
  - general arrangements
  - AACE Class 2 capital cost estimate and subsequent control budget
- finalising construction contracts
- commencing with the specification and procurement of equipment
- commencing detailed engineering
- mobilising contractors to site and commence site preparation
- commencing construction
- commissioning

Schedule

Key milestone dates for the K.Hill Project are shown in Table 24.12 and a summarised schedule is shown in Figure 24.22.

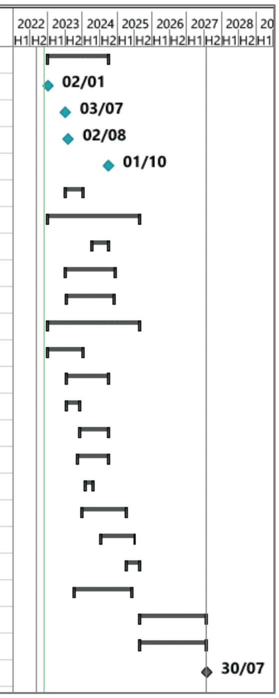
Table 24.12 K.Hill Project key milestone dates

Milestone	Date
Start basic engineering	Q3 2023
Start mine pre-stripping	Q4 2024
Start plant commissioning	Q2 2025
First commercial production	Q3 2025
End of ramp up	Q3 2027

It should be noted that ESMPs and Giyani's policies and procedures will be applied throughout the LOM. Specific ESMPs will be developed before construction begins in readiness for implementation from the outset of construction (e.g., Emergency Preparedness and Response Plan; Water Management Plan; Alien and Invader Species Management Plan).

Figure 24.22 K.Hill Project summarized schedule

ID	Task Name	Duration
1	**Milestones**	**456 days**
2	Start EPCM contracting	0 days
3	Start of Project	0 days
4	Demonstration plant operational	0 days
5	Start mining	0 days
6	**Value Engineering**	**140 days**
10	**K.Hill Project Phase**	**680 days**
11	**Mine**	**120 days**
14	**External infrastructure**	**380 days**
36	**Infrastructure**	**360 days**
53	**Process Plant**	**680 days**
54	**Phase 0 - Early works**	**270 days**
64	**Phase 1 – Basic, Detailed Engineering & Procurement**	**320 days**
65	**Basic Engineering**	**100 days**
72	**Detailed Engineering**	**220 days**
77	**Procurement**	**240 days**
83	**Phase 2 – Site Preparation & External Utilities**	**60 days**
86	**Phase 3 – Equipment Delivery & Fabrication**	**320 days**
91	**Phase 4 – Construction**	**240 days**
94	**Phase 5 – Testing & Commissioning**	**100 days**
98	**Tailings Management Facility**	**420 days**
113	**K.Hill Operational phase**	**480 days**
114	**Ramp-up**	**480 days**
118	Full production	0 days



24.3.5 Project governance

Steering committee

The K.Hill Project execution will be overseen by a steering committee that will consist of senor members of Giyani's management team and designated consultants. A combination of internal and external technical specialists will provide ad hoc support. The steering committee will have regular meetings and adjust their meeting frequency to suit.

Owner's project team

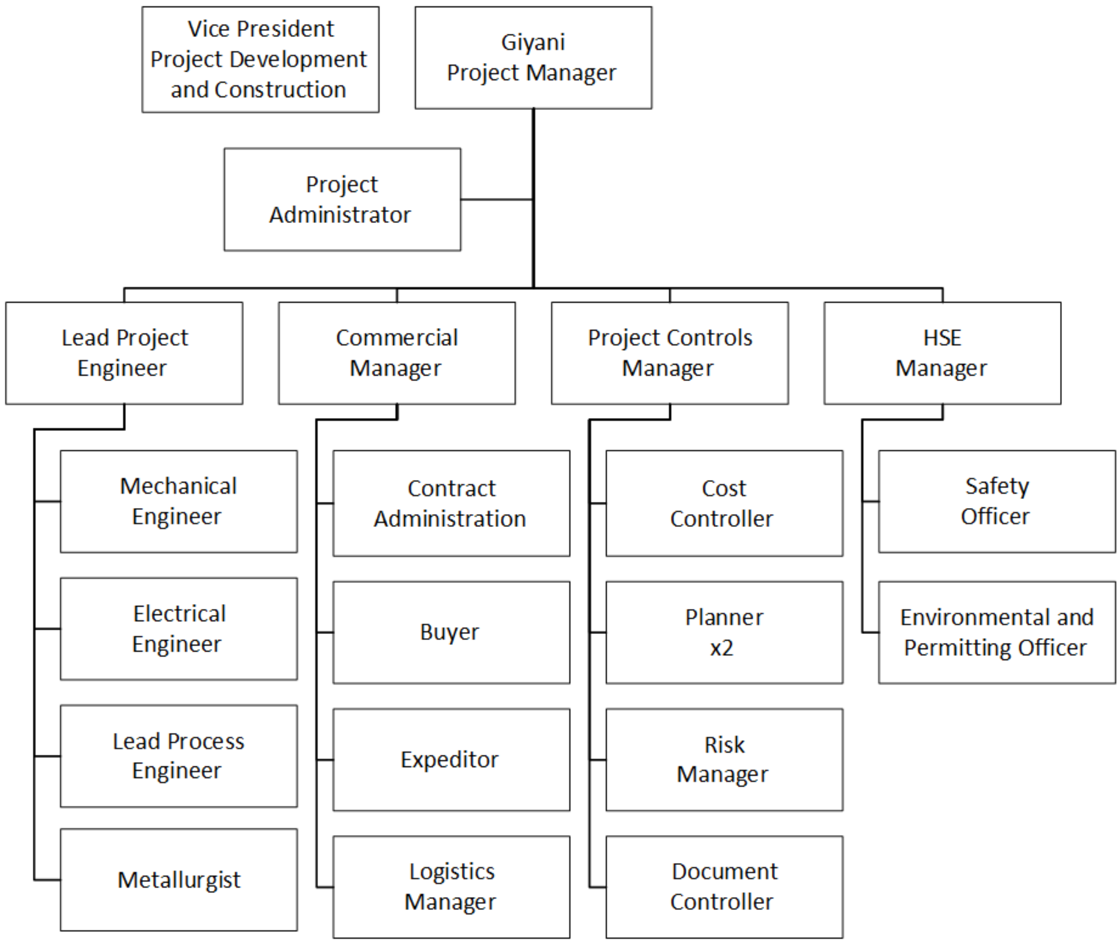
A dedicated owner's project team, comprising engineering and construction professionals, will be established under the leadership of an owner's project manager. Once the Project is handed over, the project team is demobilised.

The owner's project team will be integrated with several functions of the operations team such as tax, finance, legal, information technology, environmental, health and safety, sales, and production. Project participants of these functions report to department heads inside the operations team. Some members of the Giyani operations team may be seconded to the project team.

The project team will prepare a PEP and submit it to the steering committee for approval. In general, the project team operates autonomously within the agreed plan. All major decisions required to deliver the Project, as well as deviations from the approved plan, will be presented to the steering committee for review and approval. The status of the Project will be communicated formally in a monthly report and on an ad hoc basis for major upset conditions.

The proposed owner's project team is shown in Figure 24.23 and comprises Giyani project staff supplemented with external consultants.

Figure 24.23 Owner's project team



Project controls

Project controls will gather data oversight in the following main areas of project performance:

- Scope Control: Project scope will be managed through a formal change management procedure.
- Cost Control: The project control budget will be carried out in US dollars. A key deliverable from the basic engineering phase will be a cost breakdown structure that emulates the work breakdown structure. The cost controller will manage commitments, payments, forecasting (estimate to complete), and cost reporting against the baseline budget. Care will be taken to manage the impact of foreign exchange rate fluctuations.

- Schedule: The EPCM contractor will be tasked with maintaining a master schedule that collates the inputs from contractor and supplier schedules. Contractors will be expected to maintain a Level 4 schedule and report on Level 3. Suppliers will maintain and report on a Level 3 schedule. The master schedule will be maintained at Level 3, with reporting to the steering committee at Level 2 and to the board of directors at Level 1. Project controls will provide oversight and maintain an overarching high-level project schedule.
- Earned Value: The progress of the project will be tracked in terms of the planned work completed at a planned cost at a given time.
- Risks and Opportunities: A formal register will be maintained recording the likelihood and impact of each event, assigning an owner, and identifying possible mitigation.
- Reporting: Weekly dashboard style reports will be completed that include an update on design deliverables, procurement packages status, safety on site, environmental performance, budget vs actual, and earned value.

24.3.6 Health, safety and environment

HSE management plans, monitoring plans, policies, and procedures are fundamental for delivering the Project. Management and monitoring plans will be included in the ESIS, and implementation by Giyani will be a condition of environmental authorisation, as will the right for the authorities to undertake site visits and audits. Undertaking audits (internal, third party and those undertaken by the authorities) will be important.

A safety induction will be mandatory for anybody who visits or works on the construction site. The construction site will comprise three zones, and the level of induction and required personal protective equipment (PPE) will be geared to each of them:

- green: the visitor area with meeting rooms, which is freely accessible
- orange: the access-controlled area with construction camp, laydown areas
- red: the construction site itself

Health and safety

Contract conditions imposed by Giyani will require that all contractors be required to provide ESMPs, method statements, and standard operating procedures for all works for which they are responsible; these plans will cover the period from mobilisation through to demobilisation. The documents will describe the scope of work, mitigation and management, number of workers and skills, safety measures, equipment, and risk assessment. All documents will need to be approved by the steering committee prior to mobilisation.

Statistics on safety performance will be displayed prominently on-site signboards. The construction site will be equipped with safety systems such as access control, an alarm system, demarcated walkways, evacuation routes, muster points, traffic calming measures, speed signs, parking bays, fire-fighting equipment, emergency showers, and eyewash stations. Specific security zones will be equipped with closed-circuit television and additional access control. Every construction vehicle will be inspected by security when entering and leaving site.

Conditions of employment will be included in each worker's contract, which will include responsibilities with reference to health, safety, and the environment. There will be a zero-tolerance policy toward alcohol and drug abuse. Subject to the law and company procedures and policies, workers who are under the influence of drugs or alcohol will have to leave site immediately and face dismissal.

Before work begins, the construction and safety manager will hold a work and safety coordination meeting to discuss the day's work activities, associated risks, and other contractors' activities that will take place in the same working area. Toolbox talks will be arranged by the safety manager to highlight specific topics (e.g., evacuation plans, handling hazardous materials, and PPE).

The site will employ a safety work permit system. No works will be allowed to take place on site without a safety work permit that describes the works, the names of the workers, the supervisor, and equipment involved. Work permits will be issued the day before by the contractor and will need to be approved by the safety manager. Certain activities will require an additional work permit: excavation works, hot works like welding, works in confined spaces like tanks, works at heights, and works involving hazardous substances. For electrical works, tag-out and lock-out procedures will be followed. Works with special permits will be inspected first to verify that all rules are being followed and measures are in place.

All equipment including cranes, compressors, generators, small tools, pulleys, excavators, and extension leads will be in good order and will be inspected. Equipment without applicable certification will not be used on site; the options are the contractor gets certificates or it will be removed from site.

Environment and community

It is a standard condition of environmental authorisation that the ESMPs presented in the ESIS are implemented for each phase of the Project (construction, operations, rehabilitation and closure, and post-closure monitoring). Giyani will develop other ESMPs and procedures before construction begins to manage all aspects of the overall environment including, but not limited to:

- surface and groundwater monitoring
- air and noise monitoring
- waste (non-mining and mining waste)
- materials management procedure, including fuels and hazardous materials (chemical register, transport, handling, usage, storage, disposal, spillage)
- topsoil management (stripping, maintenance of quality, contaminated soil)
- emergency preparedness and response plan

- SEP
- grievance procedure
- community security, health and safety
- cultural heritage and restricted areas
- legal obligations (legal registers, auditing)

All ESMPs and procedures will be reviewed annually, at a minimum, when there are changes to the Project or in response to non-conformances. As the Project transitions from one phase to another, significant changes will occur and will warrant document revisions and updates.

Third-party workshops

Works undertaken at third-party workshops remain the direct responsibility of the supplier or contractor. As part of the procurement process, Giyani will visit workshops of contractors to verify capabilities. The safety standards of contractors will be verified as part of the procurement process and, where minimum standards are not met, Giyani will apply additional requirements. Safety statistics from third-party workshops will not be included in the overall statistics of the K.Hill Project.

25 INTERPRETATIONS AND CONCLUSIONS

25.1 Geology

The manganese mineralisation of the K.Hill deposit occurs primarily in two supergene-enriched Mn-shales (the Upper Mn-shale and the Lower Mn-shale), occurring in the upper portion of a larger shale package within the Black Reef Quartzite Formation of the Transvaal Supergroup. The Mn-shale is overlain by and, in places, eroded away by a hard CDB unit.

In plan, the K.Hill deposit is approximately kidney shaped. In the north, it forms a gently sloping hill, and to the south, the mineralised unit is not exposed at surface. The Upper and Lower Mn-shales, which host the mineralisation, vary between approximately 2 m and 15 m thick, with an average thickness of 4 m. The unit dips shallowly (5° to 10°) toward the NW and has a delineated extent of approximately 1,900 m N-S and 350 m E-W.

The upper Mn-shale can be divided into a continuous high-grade portion with discontinuous lower-grade margins in the immediate hanging wall and footwall.

Observations from a site visit in January 2022 point to the possible presence of duplex faults and folding. The global grade and tonnage estimate stands; however, these possible local structural complexities warrant a tight infill drilling pattern, such as one would expect during grade control, as part of operational mine planning.

To date, a total of 163 drillholes (32 DD and 131 RC) have been drilled at K.Hill. The latest drill programme consisted of 3 DD and 28 RC holes all sited on the K.Hill Southern Extension Area. All of the holes have geological logging and laboratory analytical data available to support a future Mineral Resource estimate update.

Densities of Mn-shales appear to vary depending on the degree of weathering and manganese grade. Giyani has followed all the practical field recommendations made by SRK to obtain reliable density data. The density data is considered acceptable for the purpose of the quoted Mineral Resource. Continued implementation of these techniques will improve Giyani's understanding of density distribution.

A survey of artisanal mining workings by Terravision in 2020 allowed the block model to be updated to allow for known and historical underground workings.

25.2 Mineral Resource estimate

SRK considers that the quantity and quality of data collected in the K.Hill drilling programmes are sufficient to support the reporting of a Mineral Resource estimate. That said, some concerns have been identified, most notably the limited quantity of reliable density data.

The current updated Mineral Resource estimate totals 2.1 Mt of Indicated Resource at 19.3% manganese oxide and 3.1 Mt of Inferred Resources at 16.9% manganese oxide. This represents an overall 73% increase in tonnage at a similar average grade of 17.9% manganese oxide relative to the September 2021 Mineral Resource estimate (Table 25.1).

Table 25.1 K.Hill SRK Mineral Resource statement, reported within an optimised shell and at a cut-off grade of 7.3% manganese oxide, as of 22nd February 2022

Classification	Tonnes (Mt)	MnO grade (%)	MnO contained (Mt)
Indicated Mineral Resources	2.1	19.3	0.41
Inferred Mineral Resources	3.1	16.9	0.53

Notes:

(1) The Indicated and Inferred Mineral Resources are reported above a cut-off grade of 7.3% MnO.

(2) All tonnages are reported as dry.

(3) The Mineral Resource estimate is constrained within estimation domains based on geological modelling and grade and within a Lerchs Grossman optimised pit shell based on an HPMSM price of US$1,588/t and the following techno-economic parameters:

a. Mining cost: US$3.46/t rock
b. Processing cost: US$213/t ROM
c. Selling cost: 3% and a freight cost of US$60/t HPMSM
d. General and administrative: US$20/t ROM
e. Discount rate: 10%
f. Processing recovery: 90.7%
g. Mining recovery: 98%
h. Mining dilution: 3%
i. Geotechnical slope angle: 41˚

(4) SRK notes that the long-term HPMSM price quoted is based on 2020 market data, which was available at the time of reporting the Mineral Resource. SRK understands that additional pricing information will be available for input into subsequent technical studies, and this may impact the Mineral Resource reported. In light of the sensitivity of the Mineral Resource to the selling price, this is not considered to be a material risk in reporting the Mineral Resource and may present a further opportunity.

(5) All figures are rounded to reflect the relative accuracy of the estimates.

(6) Mineral Resources are not Mineral Reserves and have not demonstrated economic viability.

(7) It is uncertain if further exploration will convert Inferred Mineral Resources to higher confidence categories.

Changes to the geological model can be attributed to a significant increase in the quantity of assayed drillhole intervals in the Southern Extension Area and the addition of the lower-grade northern Lower Mn-shale horizon (B) into the Indicated.

Average densities for each domain in the block model were taken from a small database of densities calculated from wax-coated core samples. Although of high quality, the quantity of data presents a risk to the K.Hill Project. SRK notes the close correlation with the much larger density database of “wet” density readings (with the 10% reduction factor applied), where the samples were not dried prior to measurements being taken. The wet density values have not been used in the Mineral Resource estimate included in this FS due to uncertainties about the moisture content. Low confidence in density data, or a small set of density data points, will result in SRK classifying the Mineral Resource at the lower Inferred classification level, as is the case for the Southern Extension Area of the deposit. In this area, only limited density samples were taken from the Phase 3 DD holes. These may not be entirely representative of the mineralised units in this area.

Channel structures interpreted in the base of the overlying CDB unit that erodes the Upper Mn-shale horizon have been observed. These structures have been modelled where they intersect, and any similar structures that may exist are expected to be smaller than the approximately 50 m drill spacing achieved at the K.Hill main area. Similar structures may still exist in the Southern Extension Area, where the drill spacing used for the purposes of this FS is still at approximately 100 m, and these structures may influence the interpretation and the estimation in this area. These channel structures, together with the lower confidence in the density data of the Southern Extension Area, were considered for the classification of the Inferred Mineral Resource for this portion of the deposit.

SRK notes that further in-fill drilling has now been completed in the Southern Extension Area, but this has not been included in this FS.

25.3 Mineral processing and metallurgical testing

The mineralogical investigations indicate that most of the manganese is associated with the minerals cryptomelane and bixbyite. The metallurgical investigations also confirm the mineralogical study findings, where the optimal grind size is estimated to be a P80 of 150 µm, yielding a manganese extraction in sulphate media of 96.8% when subjected to a reducing leach using sulphur dioxide. The manganese losses during the purification process were found to be 0.5% during the precipitation stage, 4.0% in the fluoride polishing stage, and 3.8% during crystallisation, giving an overall manganese recovery of 88.5% net of manganese recycle streams.

25.4 Mineral Reserve estimate

The K.Hill Project hosts a Probably Mineral Reserve of 2 Mt of ROM ore at 18.9% manganese oxide (excluding Inferred material) above a marginal cut-off grade of 7.3% manganese oxide. This includes a total contained manganese oxide metal quantity of 384 kt.

The mine will use a fixed cut-off grade policy. Material will be fed to the mill as scheduled, which is in line with a cut-off grade of 7.3% manganese oxide. Stockpiled material may be blended with ROM ore in order to stabilise the feed of deleterious elements to the plant.

25.5 Mining methods

The K.Hill Project will be developed as a small-scale, open pit mining operation. Over 2.0 Mt of ore will be mined at a strip ratio of 5.0 over a 11-year LOM. Small excavators with a 4 m^3 bucket size will be used in combination with 30 t haul trucks to transport ore directly to the ROM pad or stockpile next to the processing plant or transport waste to the WRD located east of the open pit. Mining operations will be supported by the necessary ancillary fleet to ensure a continuous operation. This FS assumes the use of an owner-operated fleet.

25.6 Geotechnical assessment

SRK has concluded that, given the deposit geometry and local topography, the slope heights of the final open pit will be low.

There is limited small-scale structural information available, and as such, kinematic analyses are of low confidence. However, due to the relatively poor rock mass quality, these structural instability modes are not expected to be critical for open pit design.

The standing water level in the proposed open pit area is approximately 43 m below ground level, which means that the final open pit will be above the groundwater level. As a worst-case scenario, SRK has utilised an idealised worst-case partially saturated water surface, with the modelled water surface at the base of the proposed pit, in consultation with the SRK principal hydrogeologist. This is likely conservative.

25.7 Site water management

The analysis and mapping of the available groundwater level data in the open pit footprint show that the final elevation of the proposed open pit floor is above the water table; therefore, no active groundwater flow management will be required for the development of the mine.

There are no perennial watercourses in the K.Hill Project catchment area. Open pit inflow will consist only of surface water runoff in the open pit catchment. In the early years of mining, storms generating 4,000 m^3/d of water (roughly 170 m^3/h) are expected to occur at least once every 2 years. In the first year of mining, a 100-year return period storm event will result in the accumulation of an estimated 16,000 m^3 of water in 24 h in the open pit sump (approximately 670 m^3/h). Water pumped from the mine will be used for dust suppression and as preferential processing plant raw water makeup to reduce water demand and the associated impact.

Using estimated runoff volume from a 1:100-year return period 24 h storm, SRK estimated the size of diversion structures required around the TMF. However, the water collection ditches around the WRD were designed using a 1:50-year return period storm. Approximately 9,794 m^3 to 36,777 m^3 of cut (earthworks) with a maximum trench depth of 1.7 m to 3.0 m will be required for the installation of the diversion channel.

Five exploration water supply boreholes were drilled across two primary locations based on the results of geophysical surveys. Three of the boreholes had water strikes and underwent hydraulic testing. Two of the five boreholes (both within the Waterberg Formation target area) were found to show limited seepage. The remaining three boreholes (one within the Waterberg Formation and two within the Transvaal Supergroup dolomites) all encountered major water strikes. Limited equipment availability meant that the two boreholes within the Transvaal Supergroup dolomites (S6 and S7) were under-pumped. Despite this, a yield of 50 m^3/h per borehole during a 12 h pumping day is believed to be sustainable over the next 10 years.

Analysis of the one borehole within the Waterberg Formation (S2) produced a sustainable yield of 20 m^3/h during a 16 h pumping day over the next 10 years.

25.8 Recovery methods

The process recovery method is based on the extraction of manganese in sulphate media using sulphur dioxide gas as a reductant followed by sequential removal of impurities to produce a pure manganese sulphate solution suitable to produce an HPMSM by vacuum crystallisation.

The process is based on established chemistry and has been demonstrated in the laboratory, where it has been carried out on bulk samples of mineralogical materials from the K.Hill deposit. Further, laboratory testing, as well as advanced crystallisation modelling and testing, has demonstrated that it is possible to produce an HPMSM product suitable for sale to the battery market.

Design and construction of a proof-of-concept demonstration plant is being undertaken by MET63 in Johannesburg, South Africa. The demonstration plan will produce up to 600 kg/d of HPMSM from K.Hill material and is due to be commissioned in 2023. Upon completion of initial trials and an operating period where product can be produced and supplied to potential customers for suitability and pre-approval, the demonstration plant may be transported to site, where it will be used for further Project and process development.

Recent supplementary test work in relation to alternative purification routes has indicated the potential for savings in both operating and capital costs, as well as improvement in product quality; these preliminary results will be further verified during additional test work planned in the short term.

The process is under continued development, and further process improvements, as well as reductions in costs, are anticipated as the K.Hill Project moves toward implementation.

25.9 Project infrastructure

The K.Hill Project will require the development of several infrastructure components:

- mining infrastructure, including a truck shop, explosives facilities, and stockpiles
- processing plant, including a processing plant facility and associated infrastructure
- general infrastructure and services, including water treatment, haul roads, administration offices, workshops, warehouses, fuel farm, gatehouse, and power supply
- TMF with stormwater pond and a return water pumping system
- solar plant
- temporary construction facilities

The locations of facilities and other infrastructure items were selected to take advantage of local topography and environmental conditions and to ensure efficient and appropriate operations. The mine site layout design philosophy is to keep the mine site as compact as practicable to minimise environmental and social impacts, to keep haul and pumping distances as short as possible, and to minimise the amount of surface water that would have to be managed because of infrastructure interference.

The K.Hill Project area is well-networked via the A1 and A2 national highways. K.Hill is located within a few kilometres of the A2 highway, which runs from Buitepos at the Namibian border through Jwaneng, Kanye and Lobatse, Botswana, to the South African border at Pioneer Gate near Zeerust, South Africa. The A2 is a major component of the Trans-Kalahari Corridor, which is a highway corridor that provides a direct route from Maputo, Mozambique, through Pretoria, South Africa, to Windhoek in central Namibia and ends at the port of Walvis Bay. This road network provides excellent access to South African ports in the south and the Namibian port, Walvis Bay, in the west.

Water requirements will be met by WUC via a local pumping station adjacent to the processing plant. Giyani has successfully drilled for water and will be able to partially offset this raw water make-up from these boreholes in compliance with their arrangement with WUC.

BPC will undertake the HV supply and will install a 33 kV HV line from the main Kanye municipal substation, north of the town, around the west edge of Kanye, mainly following the road infrastructure to the HV substation next to the processing plant. BPC will also undertake the 33 kV HV substation, converting the incoming HV supply from 33 kV to 11 kV. Giyani has liaised with BPC to undertake this process and will charge Giyani for usage accordingly.

25.10 Tailings management

Tailings material will leave the plant as filter cake from solid-liquid separation stages using pressure filtration combined with a small amount of water treatment effluent and will be stored as a dry stack in the TMF. Tetra Tech and SRK selected the dewatering methodology to minimise potential impacts on the environment and simplify material handling.

The facility has been designed as a "zero release" structure, which includes a fully lined basal system and a clarification pond to retain all process-affected fluids throughout operations. This water will be returned to the processing plant by means of a pumping system.

The perimeter berm of the TMF will vary in height (maximum height above natural ground of 3.0 m), and its function will be to separate the clean surface water (runoff water from the surrounding topography) from the process-affected water (runoff water from the dry cake storage area). The perimeter berm can be constructed of local granular materials and waste rock and will require screening prior to use.

An assessment of embankment slope stability was conducted as part of the FS design to ensure that the TMF external slopes, as designed, meet the accepted criteria set out in international guidelines.

The dry stack will be closed progressively by covering the surface with vegetation to minimise water ingress and erosion of faces while decreasing the potential for dust generation. Due to the absence of ponded water, tailings dewatering will not be considered, as it is assumed that the stack will be free draining.

25.11 Market studies and contracts

According to CPM, commissioned to undertake a market review for the FS, the demand for lithium-ion batteries used in EVs is expected to grow by 25% annually between 2021 and 2031 and at a slightly slower rate, around 10% annually, for the period between 2031 and 2041.

CPM further believes that the demand for high-purity manganese (HPMSM and HPEMM) from the battery sector will grow nearly 30-fold between 2021 and 2036, reaching 1.8 Mt on a contained metal basis and may reach 4.5 Mt by 2050.

Current global high-purity manganese production capacity is approximately 127 kt/a, and the identified new project pipeline is expected to contribute only an additional 221 kt/a by 2031, resulting in a projected supply deficit of 726 kt/a over this period.

Presently, 92.5% of demand from batteries is satisfied by HPMSM produced directly from ore rather than via refinement of EMM.

25.12 Environmental studies, permitting and social or community impact

The K.Hill Project is a brownfield site that occupies land that has been subject to a history of mining. The prospecting licence for K.Hill is situated on tribal land, which is governed by traditional systems and managed by the Land Board. Giyani will apply for land acquisition to the Land Board once an environmental authorisation is granted.

An EIA (known as an ESIS in Botswana) is currently being completed by Loci Environmental, a local environmental consultant, in compliance with Botswana legislation and international standards. The EIA will be submitted to the DEA for review and environmental authorisation; a public review is a regulatory requirement of the environmental authorisation process and affords stakeholders a final opportunity to comment on the K.Hill Project. Permitting/authorisation requirements have been reviewed, and a list of these requirements, with reference to the responsible authorities, legislation, requirements, and timeframes has been compiled to guide project development.

Thirteen specialist studies have been and are being carried out as part of the EIA, and to date, no red flag issues have been identified. Currently, some study areas are being revised, as the K.Hill Project has undergone changes since the draft specialist studies were produced between 2021-2022 (e.g., a solar farm has been included, and water supply is coming from boreholes approximately 23 km from the processing plant using existing WUC infrastructure). The social studies identified directly and indirectly affected communities and key informants at local, district, and national levels.

Stakeholder engagement was initiated during the scoping phase and is ongoing. Printed and electronic versions of a background information document were made available to stakeholders, and this information will be updated as the EIA continues. Key issues raised during meetings and interviews with stakeholders included water quality and potential pollution, land use, the influx of job seekers, employment, health issues, noise, health and safety, air pollution, and clearance from the Department of National Museums and Monuments. Some resettlements will be required (WUC reservoirs, BOCRA communications tower, and relocation of cattle post farmers). These parties are aware of the need for resettlement, and there have been no significant objections. Meetings have taken place with the farmers, local Chiefs, and the Land Board.

The village of Kanye has a population of approximately 45,000, per the 2011 census. Literacy rates in Botswana are 90% but 80% in Kanye, which may be attributed to the lack of capacity in schools. Healthcare in Botswana is provided through health posts, clinics, and hospitals. In terms of cultural heritage, planning permission has been granted by the Department of National Museums and Monuments for the area that was surveyed in 2020. However, another application has been submitted to deal with the areas covering the revised Project.

The completed traffic study comprised counts at 11 intersections over 3 days; the preferred option is to use public routes that avoid urban areas of Kanye. Air quality and noise levels are typical or rural areas. Dust will likely be raised during windy conditions in areas such as the open pit and TMF, and mitigation measures will need to be put in place.

Five vegetation communities were identified at K.Hill, and 53 flora species were recorded, none of which are of conservation concern. A distribution of 62 mammals, 44 reptile species, and up to 53 bird species occur over the Project area. The number of birds that actually occur is expected to be considerably lower due to the disturbed nature of the environment.

No perennial watercourses or water bodies are located within the prospecting licence area. Surface water management during the LOM will comprise stormwater management; recycling water from the open pit and preventing contaminated runoff from escaping the site will be key focus areas. Water supply will come from the municipal water supply from the WUC (20 m^3/h/d) and from boreholes drilled by Giyani, located approximately 23 km from the processing plant.

Tailings will be disposed of in a dry stack TMF, which has been designed as a zero-discharge facility, and rock excavated from the open pit will be disposed of in a WRD. Both the TMF and WRD have been designed to be rehabilitated during the LOM to minimise the final rehabilitation activities during the closure phase.

No rehabilitation was completed when the previous mining companies abandoned the site. The proposed mine plan will incorporate old workings, spoil heaps and tailings, and, ultimately, the rehabilitation and closure plans developed by Giyani will result in improvements compared to the existing landscape. A framework rehabilitation and closure plan (with cost estimate) has been drafted; this will be revised throughout the LOM so that planned and unplanned closures can be managed. A preliminary list of potential impacts and mitigation measures has been drafted, and this will be completed when the EIA is finalised.

25.13 Capital and operating costs

The total estimated initial capital cost for the design, construction, installation, and commissioning for all facilities and equipment for the K.Hill Project is US$281M, including a contingency of US$32M. This estimate includes direct field costs required to execute the Project plus indirect costs associated with design, construction, installation, and commissioning. Closure costs of US$5M have been estimated.

The total operating cost has been estimated based on the mining rate, process design work, and the reagent consumption has been estimated based on the FS test work results. The estimated processing plant operating cost is US$671.8/t processed.

25.14 Economic analysis

A TEM, prepared by SRK on a 100% equity basis, demonstrates that K.Hill provides a robust post-tax NPV at an 8% discount rate of US$481M and a post-tax IRR of 28% in real terms. The TEM uses HPMSM forecast prices provided by CPM for Giyani's key markets of Europe and North America but adjusted to run a flat price from Year 6 of the production period.

Free cash flow over the LOM is estimated at US$1,093 M, equivalent to US$99M per year. Payback of initial capital expenditure is estimated to be approximately 3.6 years from the start of production (Table 25.2).

Table 25.2 Valuation metrics

Metric	Unit	Pre-tax	Post-tax
NPV 5%	US$M	808	656
NPV 8%	**US$M**	**603**	**481**
NPV 10%	US$M	495	388
Payback period, from the start of processing	years	3.3	3.6

The K.Hill Project NPV, IRR, and payback period are most sensitive to commodity price (which is also a proxy for grade and recovery). The K.Hill Project has a lower sensitivity to operating costs and is least sensitive to capital costs.

For the purposes of the TEM, following a review of the Botswana tax regime and discussions with local stakeholders, it has been assumed that the K.Hill Project will be subdivided into two business units with discrete tax treatment: mining and manufacturing.

The mining operation will sell ore to the manufacturing operation and be taxed according to the Botswana mining company tax formula (minimum of 22% on operating income). A mining royalty of 3% will be applied to the revenue on the sale of the manganese ore to the manufacturing unit. Capital investments on the mining unit can be depreciated in the year incurred, and unredeemed capital will be carried forward indefinitely.

Income from the manufacturing unit will be taxed at the Botswana manufacturing tax rate of 15%, assuming a manufacturing development order will be received from the Botswana authorities. For the manufacturing unit, initial capital investments will depreciate at 10% per year on a straight-line basis and sustaining capital will depreciate at 20% per year.

25.15 Risks and opportunities

Opportunities

The K.Hill Project financial performance is a strong function of operating cost, the largest component of which relates to consumables supply and transport. At the time the FS was completed, prices and costs associated with these items were affected by temporary post-COVID inflation. The opportunities that have been identified to reduce operating costs comprise not only technical improvements but also optimisation of supply chains.

- The iron used to remove potassium and sodium from the leachate is a combination of iron leached from the ore and reagent addition. Tetra Tech has identified an opportunity to improve the iron extraction from the ore to reduce the amount of supplemental ferric required.
- Improvements in the use of recycle streams to displace the use of reagents have shown promise in initial test work results.
- Improvements to adsorption reactor performance through the selection of optimum adsorption media and improvements to the adsorption kinetics following more detailed test work will likely reduce capital and operating costs.
- The ferric iron reagent should be produced locally in either Botswana or South Africa using readily available technology.
- Improving the fluoride polishing kinetics through the manipulation of reagent dosing will lower the calcium and magnesium in solution, decreasing the recycle stream and increasing overall recovery.
- Lower prices should be locked in by negotiating long-term supply contracts.
- Existing freight routes should be exploited to negotiate lower land transport using empty trucks on return legs. Namibia is a net importer in terms of road transport, which offers substantial opportunities for supply from Walvis Bay using the return leg of transport routes.
- Warehouse facilities could be established at the port to mitigate supply chain risk and procure at a lower rate.

Opportunities to reduce capital costs also relate to the normalisation of the prices of bulk commodities, such as steel and copper, used in construction. In addition, the following technical and commercial opportunities to reduce capital costs have been identified:

- A mining contractor could be employed to reduce the capital cost of the fleet, truck shop, and explosives facilities.
- Investigate a two-stage crushing circuit on the basis that the ore has been proven to be medium hard and friable.
- Test work should be completed to optimise the fluoride removal reactors. An optimised design will reduce the number and size of the reactors, associated pumping system, and downstream effluent treatment requirements.

The design presented in the FS includes a basal lining system to prevent seepage of contact water from the tailings stack to the surrounding environment and groundwater. Such a system is potentially conservative, given that acid generation is not expected. Following a final confirmation of the geochemical behaviour of the details, the lining system could be simplified.

Risks

SRK and Tetra Tech maintained a risk register throughout the completion of the FS, as presented in Appendix H. Table 25.3 presents a summary of the high-level risks that may hinder Giyani's ability to achieve its stated technical and economic objectives.

Table 25.3 Summary of risks

Item	Risk	Mitigation
1	• Metallurgical recovery of the processing plant achieved during the start-up period is different from the value assumed for the FS.	• Metallurgical recovery has been calculated based on the laboratory test work results, with appropriate allowances for processing plant design conditions. An allowance was made for a recovery ramp up in the first year. • Implementation of a full automation system on the demonstration plant will allow the full-scale control system to be de-risked and optimised by the time the full-scale processing plant starts up.
2	• Reagent consumption was sometimes higher than predicted by metallurgical test work (which was based on a blended ore sample) because of a change in feed mineralogy, leading to higher operating costs.	• Changes in feed conditions could lead to both an increase and decrease in reagent consumption. Reagent consumption should be modelled as a function of feed composition to predict and plan for variations in processing performance in advance. • During detailed engineering, provide a sufficient operating envelope in the design criteria for reagent handling. • Use the demonstration plant to test the performance of lithologies.
3	• The solid-liquid separation is less efficient than anticipated, leading to reduced throughput to maintain the specified wash efficiency.	• Complete specialist solid-liquid test work on the intermediate stream generated by the demonstration plant. Allow for spare plates in the filter presses, sufficient design factors in the thickener sizing, and free space for expansion in the layout.
4	• The actual rock density of a given domain varies from the estimated value, leading to a higher or lower actual tonnage mined. The resulting uncertainty complicates mine planning and metal accounting.	• Continue to use the specified density measurement techniques throughout exploration to increase the size of the density database on which the Mineral Resource is based.
5	• Extended disruption to the supply chain may lead to a delay in consumable delivery and unplanned production downtime.	• Source consumables from multiple ports to mitigate against external threats to the supply chain. • Identify suppliers with warehouse facilities local to the operation to shorten the short-term supply chain. • Source consumables from multiple suppliers.

26 RECOMMENDATIONS

26.1 Geology and Mineral Resource estimate

SRK recommends the following activities associated with two pieces of work: upgrading the portion of the deposit currently classified as Inferred Resource to the Indicated Resource category and further exploration to delineate the full extent of the K.Hill deposit.

26.1.1 Mineral Resource estimate

The following recommendations are provided to assist in progressing the upgrade of the K.Hill Inferred Resource to the Indicated Resource category:

- Giyani should complete an infill drilling programme, which will decrease the current drill spacing of 100 m to approximately 75 m. The infill drilling can be RC drilling, with DD drilling acting as confirmation. At the time of writing, Giyani had completed the fieldwork for 6,166 m of RC drilling and 217 m of DD drilling and submitted a total of 2,161 RC samples and 172 DD samples for assays. The geological and geochemical database for this work has been shared with SRK, but this information was not processed or considered as part of this feasibility study.
- In SRK's opinion, detailed structural mapping (by an expert structural geologist) should be completed prior to further Mineral Resource updates to determine if the recent observations on the structural geology of the deposit are correct.
- SRK acknowledges Giyani's efforts to record density using wax-coated core and recommends that this practice continues during the next phase of exploration. In addition to further densities being taken from the diamond core, SRK recommends that the use of downhole geophysical density calliper logging be undertaken for all RC and DD holes immediately after the holes are completed. Bulk sampling of the mineralised horizon is recommended to determine bulk densities for the mineralised shale horizon.
- Considering that the fieldwork for this programme has already been completed, the cost of re-evaluating the geological model and re-estimating and re-classifying the Mineral Resource estimate is estimated to be US$150,000. SRK suggests that further mineralogical and metallurgical test work be completed to ensure that the ore from the Southern Extension Area of the K.Hill orebody will respond similarly in the process flow designed for the K.Hill main orebody. The cost for this work is estimated to be US$100,000.

26.1.2 Exploration

Current exploration to define extensions to the known deposits should continue to fully define the area's potential. The areas south of the current Southern Extension Area may contain further manganiferous horizons. Geophysical gravity maps suggest the host basin may continue to the south of the current limit of RC drilling in the south. The total expected cost, including all ancillary work, including access clearing, data collection, and incorporation of data into the geological and block models, is expected to be approximately US$1,000,000.

26.2 Mineral processing and metallurgical testing

Tetra Tech recommends that Giyani undertake a value-engineering study prior to confirming the control budget to exploit possible areas for improvement and cost savings. Specific areas include:

- additional metallurgical tests to optimise and evaluate alternative methods to fluoride polishing for solution purification to reduce capital and operating costs
- investigate alternative sources or methods for the supply of ferric iron to the process, which is required for potassium removal by jarosite precipitation
- review the solid-liquid separation method described in the base metal precipitation area, targeting reduced solids concentration and filtration residence time after precipitation to reduce precipitate re-dissolution
- review of the crushing circuit equipment selection; the conservative crushing circuit selected is a three-stage crushing circuit; with additional information on the feed particle size distribution, Tetra Tech recommends a two-stage crushing circuit be considered to reduce capital and operational costs
- evaluation of thermal crystallisation as an alternative to vacuum evaporation to save on crystallisation energy costs

It is recommended that more extensive metallurgical variability sampling in line with the mine plan be undertaken and test work completed on the samples to confirm:

- ore extraction data and solution purification requirements
- detailed engineering design criteria, such as mill design parameters, bulk material handling requirements, slurry rheology, dissolution, and precipitation extents

The sampling for this metallurgical test work could be done during the 2023 exploration activities. A comprehensive metallurgical variability testing scheme can be expected to cost between US$75,000 and US$150,000.

Tetra Tech recommends that Giyani establish a QA/QC programme for the supply of consumables and reagents to allow the characterisation of these materials; this includes, but is not limited to, grinding media, lime, and sulphur. All process inputs are potential sources of impurity, which can adversely affect the production of battery-grade HPMSM. The cost of QA/QC programme is included in the operational readiness component of the capital cost estimate (Section 21).

26.3 Mining methods

The mine design presented in the FS is based on a cost and product price at a point in time. SRK recommends that Giyani revisit the pit optimisation prior to detailed design and during the operational phase when any of the fundamental cut-off grade parameters change materially. These parameters include forecasted metal prices, metallurgical recoveries, operating costs, as well as the latest Mineral Resource model and geotechnical design inputs.

If the outcome is materially different than the ultimate pit shell, the final pit design should be updated.

The mine production schedule, which is ultimately the basis of the K.Hill Mineral Reserves, has focused on a stable feed of deleterious elements to minimise the fluctuating reagent requirements, which affects the processing operating cost significantly. It is recommended to revisit the development and application of the cut-off grade policy to determine if further value can be obtained. The mine schedule will require updating if the final pit design is updated.

Furthermore, it is recommended to refine the materials handling strategy of the waste rock dump and stockpile sequence during detailed engineering.

26.4 Geotechnical

The following recommendations have been derived from the geotechnical study and constitute operational recommendations to be conducted during the development of the K.Hill mine:

- start implementing the planned slope configuration
- implement an ongoing programme of scan line geotechnical mapping as bench faces are exposed in order to improve confidence in the small-scale structural model
- review the achieved bench angles in the short term to determine if the planned future slope angles can be met, in particular within the MSH unit

The cost of these recommendations is included in the capital and operating cost estimates presented in this study (Section 21).

26.5 Site water management

SRK makes the following recommendations regarding water management for the K.Hill Project:

- Owing to water scarcity in the region and the potential impact on the K.Hill Project on downstream water resources, it is recommended to opt for zero water discharge from the K.Hill site. Water runoff within the Project footprint should be collected and either treated, if necessary, and/or used to reduce the site water demand and minimise the potential impact on the environment.
- No hydrogeological investigation was carried out because the base of the open pit will not intersect groundwater, and no groundwater management (dewatering) is required. SRK recommends that Giyani use any existing or new drillholes to collect hydrogeological information within the mine area (e.g., water quality).
- As part of the water management control at the mine site, SRK recommends installing a network of at least ten groundwater monitoring drillholes around the open pit and waste sites (four around the pit, two downstream of the WRD, and four around the TMF). The drillholes should be drilled to 20 m below static groundwater level and fitted with cement/grout seal and locked cap to protect from vandalism and surface water ingress.

- Water samples should be collected from the monitoring boreholes per the water management plan (at least quarterly) and sent to an accredited laboratory for chemical analysis to verify compliance with regulations; should a non-compliance be detected, corrective measures will be developed.

The cost of these recommendations is included in the capital and operating cost estimates presented in this study (Section 21).

26.6 Project infrastructure

In terms of future project infrastructure development, consideration should be given to the following:

- Engineering Contract Structure and Type: An EPCM contract structure would provide Giyani greater control over site development than, for example, an EPC-type contract.
- Planning and Development: A significant amount of infrastructure must be in place before construction can commence roads, utilities, security fencing, site access control, construction camp etc. The PEP should take note of these requirements.
- Geotechnical Survey: A detailed site geotechnical survey should be carried out.
- Regulator Review: A detailed regulatory and compliance review should be conducted pre- and post-construction.
- Logistics: A detailed site logistics, transport, and operational review should be completed.
- Infrastructure Reuse: Post-construction and post-mine closure uses of infrastructure should be evaluated in relation to the local community, particularly in relation to the solar power plant, water supply, site buildings, and facilities.

26.7 Tailings management

The TMF presented in this study has been designed conservatively. SRK recommends a number of actions to optimise the design prior to Project execution and during detailed engineering.

- Optimisation:
  - Investigate the technical and economic viability of reducing the moisture content of tailings cake material coming out of the plant from over 36% to near 26.7% optimum moisture content (3% less or 1% more) at the plant to avoid difficulties in transport and compaction of tailings to and at the TMF. A provision has been made for the temporary storage of tailings to naturally dewater before permanent placement. SRK notes that Giyani has included this activity in its demonstration plant works programme.
  - Further materials test work should be completed on representative tailings samples generated from the operation of Giyani's demonstration plant. This test work will allow the compaction characteristics of the material to be more thoroughly understood so that the deposition method within the TMF can be reappraised and optimised prior to commissioning.

- The design presented in this FS includes a basal lining system to prevent seepage of contact water from the tailings stack to the surrounding environment and groundwater. Such as system is potentially conservative given that the tailings are filtered and, therefore, the volume of interstitial pore water that can be released is low; the geographic site location means that total rainfall is low; and acid generation is not expected (full environmental characterisation work has not been completed). Geochemical testing of tailings should be undertaken to determine potential contaminants and evaluate other possible solutions to prevent seepage through the embankment. This work is included in the current EIA programme.
- In order to properly assess the volume of precipitation water, a weather station should be installed to collect data including, but not limited to, evaporation, rainfall, temperature, and humidity.

- Detailed engineering:
  - Direct shear testing of the geomembrane with sand bedding material on one side and tailings on the other should be performed prior to detailed design.
  - SRK recommends that vibrating wire piezometers are specified in the detailed design phase so that water-pore pressure distribution within the tailings cake can be understood during the operational phase.

26.8 Environmental studies, permitting and social or community impact

- The EIA has yet to be completed. It is recommended that Giyani continue to engage with the authorities and other stakeholders, so that it is prepared to submit the draft EIA report.
- Giyani should continue and complete the EIA in compliance with Botswana legislation and international standards as per schedule so that upon receipt of environmental authorisation, applications can be made for land acquisition, change of land use, and the mining licence.
- A gap analysis should be undertaken when the EIA has been completed to identify areas and any shortcomings regarding international standards.
- The study areas for the specialists should be defined (local study area and regional study area) for each of the specialist studies, so it is clear which areas are directly and indirectly affected by the K.Hill Project.
- Stakeholder engagement should continue throughout the EIA and then be continued by the operations team as the K.Hill Project progresses into construction and operations.
- Groundwater and air quality modelling should be completed in agreement with stakeholders (e.g., WUC). The models will be used to develop monitoring and management plans.
- The framework rehabilitation and closure pan should be revised as the K.Hill Project designs are developed and finalised.

- An abbreviated Resettlement Action Plan should be drafted to demonstrate that due process has been followed. In Botswana, the Land Board is involved in this process and responsible for identifying new land for farmers.
- Prior to construction, the ESMP proposed in the EIA should be further developed (e.g., an Emergency Preparedness and Response Plan; Community Security, Health, and Safety Plan; Water Management Plan).

26.9 Capital and operating costs

Tetra Tech recommends that Giyani revisit the capital and operating cost estimate prior to finalising the control budgets, as it is expected that prices affected by an upheaval in the market following the COVID-19 pandemic will normalise during the first half of 2023, providing better long-term planning data that is likely to indicate a downward cost trend.

Tetra Tech also recommends that Giyani investigate the manufacturing of some of the reagents locally to avoid being exposed to foreign supply markets and the high cost of transport. It is estimated that the cost of a trade-off study will range between US$10,000 and US$15,000 and, should it show potential, the cost of including it in a FS update will range between US$50,000 and US$100,000.

26.10 Economic analysis

Based on the work carried out for this FS, SRK recommends that Giyani ensure early and proactive engagement with relevant authorities to realise the necessary approvals regarding tax and royalty structuring.

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